final report

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Enhancing pasture stability and profitability for producers in Poplar Box and Silver-leaved Ironbark woodlands

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Abstract

Over 7 years, this project collected data about the pasture, tree and soil surface dynamics of two major *Aristida/Bothriochloa* pasture types within the eucalypt woodlands of central Queensland. Six different grazing management scenarios were compared ecologically and economically, along with the effects of spring burns and tree killing.

Heavy stocking (3-4 ha per adult equivalent) produced the greatest short-term financial return from healthy pastures but was not a sustainable practice and long-term cash returns were no better than those from moderate stocking. The environmental benefits of moderate grazing over heavy grazing were very clear. Light stocking produced better environmental outcomes compared to moderate stocking but was clearly inferior with respect to economic returns.

Killing silver-leaved ironbark trees near Rubyvale produced no measurable improvement in pasture growth or quality for at least 6 years whereas at Injune the same treatment of poplar box trees resulted in an immediate and large enhancement in pasture production and carrying capacity. The gritty red duplex soil at Rubyvale was much more erodible than the grey solodic at Injune although the latter becomes very erodible if the stable surface soil is breached.

Good seasonal rainfall produced faster changes in pasture composition than extremes of grazing management. The perennial grasses were easier to recruit than to eliminate by grazing management changes.

Executive Summary

The project was undertaken primarily because no research had been done in these extensive eucalypt woodlands that were clearly in a sensitive region and land type. These woodlands are also potential sources of sediments to coastal regions and the Great Barrier Reef.

Project Objectives:

I. Describe the productivity and ecological dynamics of 2 major subtypes of the *Aristida / Bothriochloa* (A/B) pasture type, with particular reference to the impact of climate and common management practices such as grazing pressure, clearing and fire.

II. Develop practical grazing management packages which are economically viable and ecologically sustainable for *Aristida / Bothriochloa* pastures in central Queensland.

III. Communicate evolving and existing native pasture management knowledge to primary producers, resource managers and the general community.

What was achieved

Over 7 years, this project collected data about the pasture, tree and soil surface dynamics of two major land types within the A/B pasture woodlands of central Queensland. Six different grazing management scenarios were compared ecologically and economically, along with the effects of spring burns and tree killing. We studied a silver-leaved ironbark community on a gritty red soil near Rubyvale and a poplar box woodland on a silty, grey solodic near Injune.

The project has produced a huge amount of data about pasture dynamics and potential animal production under quite a wide range of seasonal conditions between 1994 and 2002. Prior to 1993 there was virtually no such data from A/B communities. However, the real value of the data is that it was all collected at the same time so that crucial linkages between pasture, soil, animal and rainfall have been made. That will add value to other more detailed or specialised studies in the future, once the data has been fully analysed and archived.

We have documented a case where killing trees has not resulted in any change in pasture growth for at least 5 years at Rubyvale. This is very unusual and we cannot adequately explain why at present, but it highlights that care needs to be taken when predicting the outcome of land management changes where there is inadequate prior study of that landscape. A lack of early tree regrowth at both sites was also unexpected but highlights the episodic nature of plant recruitment in the region. Equally notable was that removal of grazing for 7 years had no effect on the organic matter levels of the surface soil at Injune. Killing the trees with herbicide also showed no consistent impact on organic matter of the surface soil.

We have shown that, economically, producers can be just as successful running steers at a moderate grazing pressure as at high stocking rates, thus avoiding all the known risks and negative effects from overgrazing. We have demonstrated that short term spelling of pastures in fair condition during a good season can result in a very rapid return to good pasture condition. We have confirmed how critical green feed is to animal production, to the extent that low grazing pressure was ineffectual in negating the lack of green feed where there was sufficient pasture bulk to ensure gut fill of animals. The study has confirmed that 40% ground cover is critical to protect against serious soil loss and that such a level is easy to maintain under moderate grazing pressure. The benefits of moderate grazing pressure for sustainable livestock production also translate across into good nature conservation and biodiversity outcomes in grazed woodlands.

The use of spring fires to reduce wiregrass densities was not very successful at either site. Heavy grazing pressure did not result in a rapid build-up of wiregrasses in the pasture nor a rapid change in perennial grass abundance during our trials. Good seasonal rains were very influential

in changing pasture composition, far more than prolonged very light stocking. Complete exclusion of grazing and fire did lead to a rapid improvement in the infiltration capacity of the Rubyvale soil.

When and how industry can benefit from the work

The cattle industry and others managing eucalypt woodlands in central Queensland can use our information immediately. There have been a number of field days held in both districts to present our results and to discuss the best practical ways to implement the basic research results. The Grazier Guide to managing semiarid woodlands was published and distributed to all producers with A/B country in the region in 2000. The practical implications of our trial results were also included in the Emerald (April 1998) and Roma (July 2001) Meat Profit Days. A preliminary economic analysis was presented at the closing field day at Rubyvale in July 2001.

All research results have to be interpreted by the individual producer in the context of their particular property and production system. Our detailed final report provides them, landscape process modellers and extension and information providers with all the detailed data to supplement the many local presentations that the project team has made as part of the project's communication package. Importantly, these results provide critical information and data for customisation of the MLA Grazing Land Management education package, in both the Fitzroy and the Murray-Darling Basins.

Who can benefit from the results

The results benefit all landholders in the central Queensland Eucalypt woodlands, all rural agencies responsible for sustainable management of these resources and also conservation groups who now have objective data on which to base submissions. Regional groups charged with managing national action plans and developing investment strategies for future natural resource management now have high quality data about plants, animals and soils that is linked to climate, and collected repeatedly over a 5 to 7 year period. The MLA also benefits from its foresight by having such information available now when issues of land tenure, catchment management, environmental standards etc are such important political issues.

Future information needs

There is a need to study the interaction between spring burning and the time of return of livestock afterwards. Currently there is conflicting information about the effects of fire on wiregrasses in different regions where different post-fire grazing management was used. Our project was unable to include a study of the interaction of fire and grazing. That confusion will rapidly extend to other major perennial grasses once the limited data available is closely scrutinised.

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1 Project Background

1.1 The land resource

Native pastures in Northern Australia have been grouped into 27 major types and 151 LPUs (Local Pasture Units) by Tothill and Gillies (1992). These are based on a combination of vegetation structures (eg. woodlands, shrublands and grasslands) together with soil type (based on the soil series of the Atlas of Australian Soils). In central inland Queensland, a variety of eucalypt woodlands grow on non-agricultural soils and have no obvious dominant pasture grass or grasses. They were classified by Weston *et al*. (1981) as *Aristida/Bothriochloa* pastures because species of these two genera are common. The lands in higher rainfall areas to the east are regarded as black speargrass pastures although *Bothriochloa ewartiana* and *B. bladhii* are dominant components in some places (Ash *et al*. 2001 and Orr *et al.* 1997). Mitchell grass or mulga pastures dominate native vegetation to the west. All of these have been extensively researched in the past, a marked contrast at that time to the *Aristida/Bothriochloa* (A/B) pasture of Central Queensland.

Weston *et al*. measured over 10 million ha of A/B pasture country in central Queensland in the area shown in Map 1 which is the area we believe our research is valid for. This is about 53% of the total land surface in that region and these pastures are intermingled with a similar area of brigalow country and smaller areas of State Forests (Silcock *et al.* 1996). The brigalow country is much more fertile and can be cropped on low slopes or sown to improved pastures. Most properties have a mixture of brigalow land and A/B pastures beneath open eucalypt woodlands.

Table 1.1 Assessed percentage of land in each condition status for the 3 main LPUs within the Central Qld A/B community (ex. Tothill & Gillies Table 3).

Local pasture unit	**A Condition** (Minimal degradation at present)	**B Condition** (Not degraded beyond easy repair by good grazing management)	**C Condition** (Degraded beyond repair by grazing management alone)
50	20	50	30
51	25	50	25
53	25	55	20

Tothill and Gillies continued Weston's naming system and identified 15 sub units (LPU 41 to 55) of which 7 occur in Central Queensland (Units 47-53). The survey of 108 sites in central Qld done in the first phase the project (1992–94) did not identify any clearer grouping of land types based on pasture composition. However, poplar box communities separated somewhat from silverleaf ironbark, based on pasture composition, and from another group which included cypress pine and narrowleaf ironbark. In the Tothill & Gillies report, the main LPUs in the project area were assessed for pasture condition by consensus of knowledgeable people in about 1991. Results for the 3 main ones in our project area are summarised in Table 1.1 which shows 2030% were considered to be in poor land condition at that time.

1.2 The goals and industry context

Very few sheep are now raised in A/B country north of the Dalby to Charleville railway line and much of the land is excellent for cattle breeding. With interspersed brigalow country providing options for fattening and grain cropping, most properties have the potential for a balanced land use based on cattle. However in the early 1990s there was no useable pasture management data based on quantitative research for A/B pastures. The Meat Research Corporation (now the MLA) assessed this undulating to steeply sloping country on potentially very erodible duplex soils as being at risk in the long term and instigated research to redress that knowledge deficiency.

The project was part of a broader industry push to improve the productivity of the northern beef herd (Walker 1997). This was thought possible via 2 main areas, increased fertility and improved annual growth rates of young animals. However, if achieved, these improvements could come at the expense of the forage resource if it was not used in a sustainable manner. The project we are reporting on, Project NAP3.208, came within the 'Improving Resource Management' subprogram of NAP3 (1996–2001) which itself was an extension of an R&D thrust begun by MLA (then AMLRDC) in 1986 as the North Australia Program Phase 1 (NAP1) (Walker 1997).

Fortunately in an earlier project, we found that Class C land was probably less prevalent than the Tothill & Gillies survey results suggested. However, we picked up no clear indications of pasture species or species groups that would reliably correlate with a subjective assessment of site condition. Ground cover was possibly a better indicator but drought conditions prevailed for much of the survey period so we could not settle upon a confident pasture composition on which to split country into condition class A, B or C. Only with such a quantitative basis can research really help industry to achieve its dual objectives of profitable production and sustainable land use.

1.3 Project Objectives

I. Describe the productivity and ecological dynamics of 2 major subtypes of the *Aristida / Bothriochloa* pasture type by February 2001, with particular reference to the impact of climate and common management practices such as grazing pressure, clearing and fire.

II. Develop practical grazing management packages by June 2001 which are economically viable and ecologically sustainable for *Aristida / Bothriochloa* pastures in central Queensland.

III. Communicate evolving and existing native pasture management knowledge to primary producers, resource managers and the general community according to the time schedule outlined under the project milestone schedule.

1.4 Project Participants

1.4.1 Main participants

Mr Charlie & Mrs Jacqui Hawkins, "Keilambete" Rubyvale (1994-2000)
Mr John & Mrs Maree Chandler, "Glentulloch" Injune (1994-2002)
Mr Cameron & Mrs Jude Hicks, "Keilambete" Rubyvale (2000-01)

Ms Jill Aisthorpe, QDPI Roma (1998-2000)
Mr Greg Bortolussi, QDPI Emerald (1999 –2000)
Mr Scott Brady, QDPI Roma (1998-2000)
Ms Melinda Cox, QDPI Emerald (1998)
Mr Joff Douglas (Van der Meulen) QDPI Roma (1994-2000)
Mr Russell Drysdale, DNR&M Emerald (1997 –99)
Dr Piet Filet, QDPI Emerald (1994-96)
Ms Cass Finlay, QDPI Toowoomba (1994-97)
Mr Grant Fraser, DNR&M Indooroopilly (2000-02)
Mr Stephen Ginns, QDPI Emerald (1999)
Mr Trevor Hall, QDPI Roma (1994-2002)
Mr Paul Jones, QDPI Emerald (1997 – 2002)

Mr Peter Knights, QDPI Roma (1994-2001)
Mr Brett Kuskopf, DNR&M Emerald (1996 –97)
Mr David Osten, QDPI Emerald (1994-97)
Mr Steve Riches, DNR&M Emerald (2000-01)
Mr Bryan Robertson, QDPI Roma (1994-96)
Dr Richard Silcock, QDPI Toowoomba (1994-2002)
Ms Anne Sullivan, QDPI Emerald (2000-01)
Mr Evan Thomas, QDPI Roma & Emerald (1994-96)
Mr Ross Warren, QDPI Emerald (1998 –99)
Mr David Waters, QDPI & DNRM Emerald (1997-2000)

1.4.2 Other participants

Ms Kerry Bell, QDPI Toowoomba (Statistics)
Mr Cyril Ciesiolka, QDPI & DNR&M Toowoomba (Runoff & erosion)
Mr Paul Greenwood, QDPI Rockhampton (Pasture ecology)
Mr Len Mikkleson, QDPI Rockhampton (Pasture ecology)
Mr Don Myles, QDPI Rockhampton (Pasture ecology)
Mr Gavin Peck, QDPI Emerald (Grazing systems)
Ms Christine Playford, QDPI Rockhampton (Statistics)
Mr Laurie Tait, QDPI, Rockhampton (Pasture ecology)

1.4.3 Other contributors

Ms Vanessa Alsemgeest, Univ of Qld
Mr Andrew Biggs, DNR&M Toowoomba
Mr Ernie Brazier, Injune
Dr David Coates, CSIRO Townsville
Mr Ken Day, DNR&M Indooroopilly
Mr Ben Harms, DNR&M Indooroopilly
Ms Madonna Hoffmann, QDPI Rockhampton
Mr Michael Yee, QDPI Rockhampton
Mr Paul Back, QDPI Rockhampton
Mr Steven Bray, QDPI Rockhampton
Mr Keith Chandler, Injune
Mr David Cobon, QDPI Toowoomba
Mr Matthew Hall, Roma
Mr Tony Holmes, Roma
Mr Brian Slater, QDPI Toowoomba

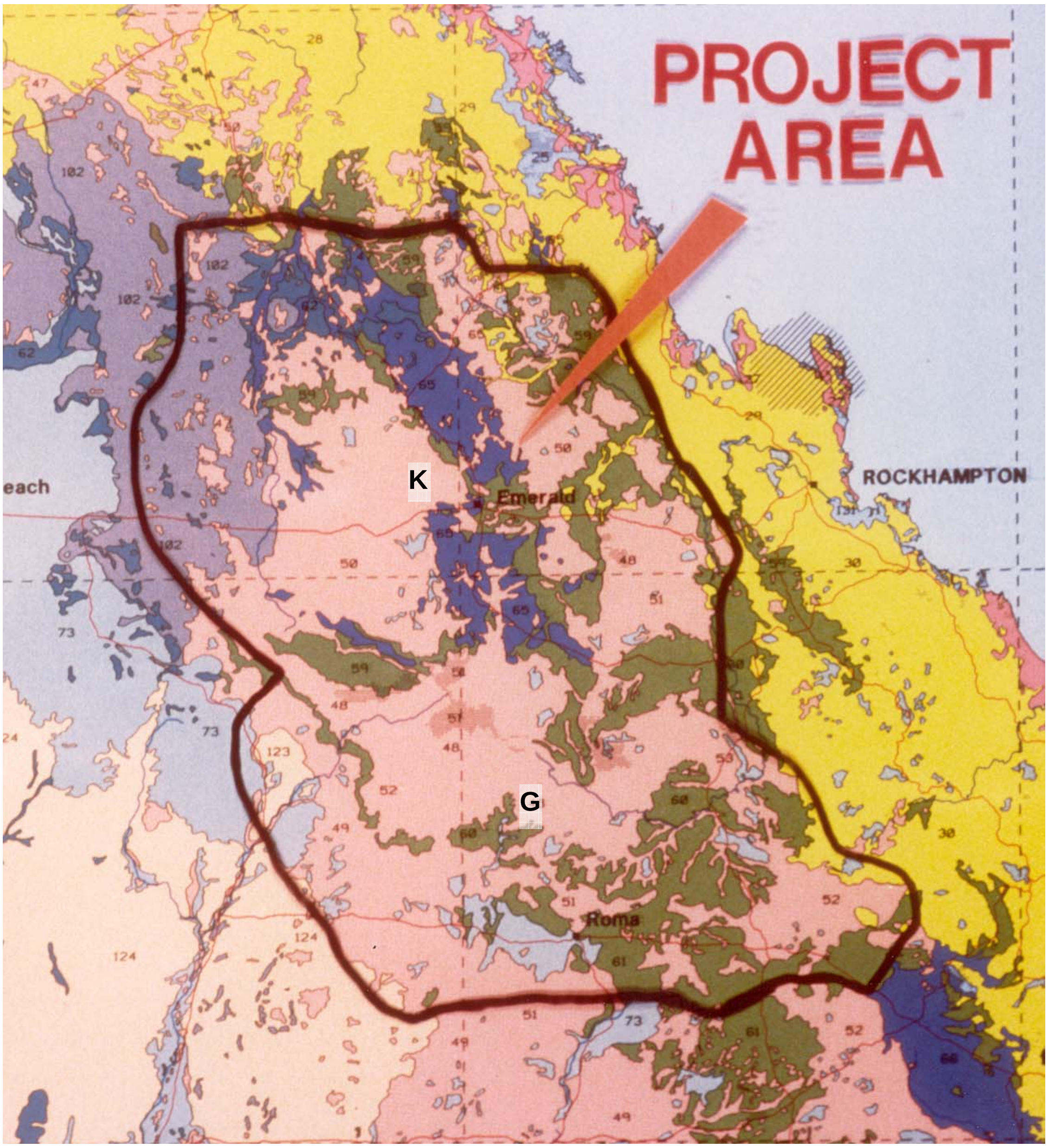
1.4.4 Main funders

Meat and Livestock Australia (formerly Meat Research Corporation)
Qld Dept Primary Industries
Qld Dept Natural Resources & Mines

1.5 Project core study area

1.5.1 **Pasture Communities**

Aristida/Bothriochloa (47-53)	Pink	Qld Bluegrass (65)	Dark blue
Black speargrass (28,30)	Yellow	Brigalow (59-61)	Olive green
Mitchell grass (72,73)	Light blue	Spinifex (102)	Purple
Mulga (123-124)	Fawn		



Map 1. Pasture communities of east central Qld with study sites and area relevant to the research overlayed.

Core Sites
K **=** *"Keilambete"*
G **=** *"Glentulloch"*

2 Methodology

2.1 Methodology outline

The three main objectives of this project were tackled as follows —

I. Describe the productivity and ecological dynamics of A/B pastures.

To do this we extended the detailed research being conducted at two core sites, 'Keilambete' and 'Glentulloch'.

Key components of the core site research were:

A. Studying the reaction of key species and pasture yield to management inputs and major climatic events, specifically

   grazing pressure - this can vary greatly from year to year and, unless well managed, can destabilise a pasture system

   timber management - eucalypt woodlands if cleared correctly often offer benefits in pasture growth

   fire - this is a simple tool for maintaining stable woodland tree populations

B. Key species studies in the field to ascertain how persistent seedbanks are, how long individual plants normally persist and how readily seedling recruitment occurs in the field, including for trees and shrubs.

C. Measurement of cattle growth rates under the differing grazing regimes over a range of seasons. This work has also linked, via regular faecal sampling, to NIRS (Near Infrared Reflectance Spectroscopy) dietary studies being undertaken by Mr David Coates, CSIRO Townsville.

D. Quantify the effects of cover and pasture condition on runoff and erosion and thus potential plant available water storage in the soil. This data is then used to validate existing models such as PERFECT (for erosion predictions) and an expanded GRASP (for pasture production predictions) to improve long-term risk predictions.

II. **Develop practical, sustainable management packages** in consultation with producer groups.

Towards the end of the project, some ideas on management strategies should be testable on properties of interested producers. All ideas would have to be adapted to the individual property situation but broad principles should apply everywhere, eg. setting future winter stocking rates on available autumn feed. Members of the project Consultative Groups would be the most likely to try such ideas.

The project team has also been continually developing its ideas on what the results mean for practical land management in the region and discussing those ideas with a broad range of people with an interest in the topic. This has involved workshops, field days, technical reviews and informal discussions, many of which were instigated and primarily funded by other groups or agencies such as the Natural Heritage Trust.

III. Communicate our results and ideas to producers, agency staff and policy makers.

We undertook to conduct field days and contribute to Landcare and Property Management Planning (PMP) group activities about recognition of key native pasture species and the management options by which each species is most affected. At each core site, **a producer group** was established as part of the "team" tackling the problems. Close liaison/interaction/consultation was maintained with these groups throughout, including **field**

days to upgrade their skills in key species recognition and management. Producers need to have this knowledge before they can manage their native pastures well.

We would provide technical input to a Grazier Guide to be produced by Mr Ian Partridge. That guide was to be distributed free to all producers with A/B country in the region between Charters Towers and the NSW border. We put on displays of our research at MLA Meat Profit Days held in the region at Emerald and Roma.

The project would also assist the extension of general principles for woodland management to producers in districts where woodland management projects had not hitherto reached directly.

2.2 General framework of the research trials

2.2.1 Activity Summary

- Conducted 2 grazing trials and associated manipulation studies
- Maintained instrumented runoff and erosion monitoring sites at core sites
- Monitored cattle liveweight change at regular intervals
- Monitored pasture composition and basal cover each autumn.
- Measured pasture growth for incorporation into the GRASP model
- Charted crowns of key species in fixed quadrats experiencing different management
- Determined soil seed loads at core sites each spring
- Conducted controlled spring burns when seasons permitted
- Surveyed tree and shrub populations in all treatments
- Undertook ancillary measurements to allow broader extrapolation of results

2.2.2 Core grazing management sites

Two specific eucalypt woodland communities were chosen to be studied in detail:

1. Silver-leaved ironbark woodland (*Eucalyptus melanophloia*) - frequently found in the mid-slope part of the landscape and most common in the Central Highlands district.
2. Poplar box woodland (*E. populnea*) - frequently found in the lower part of the landscape and common throughout the region, but is the more typical component in the Maranoa.

The study of both communities was based on identical grazing management comparisons which aimed to –

- document the pasture and animal productivity of each community under a range of grazing pressures, and
- identify the key ecological processes which either change or maintain the condition / state of the pasture, and
- Correlate measured runoff and soil movement on selected plots with pasture condition.

The sites chosen were:

1. “Keilambete” - (*E. melanophloia* site) 60 km WNW of Emerald near Rubyvale
2. “Glentulloch” - (*E. populnea* site) 20 km west of Injune

As major experimental sites, these locations also provided a district focus for discussion and exchange of information with graziers and students, as well as for visits by researchers and land managers from other agencies.

2.2.3 Key treatments and methodology

At each core site, three major grazing management options are compared in two separate studies. They were –

Tree killing in conjunction with either -
(a) 3 different levels of grazing pressure
or (b) fire, specifically spring fires, without any grazing.

Differences and similarities amongst the responses to these options provide a measure of the sensitivity of the various processes that are critical to a grazed woodland. Monitoring, based on a systems framework, measured the following key processes:

- pasture growth
- animal production
- pasture population dynamics
- woody overstorey and understorey population dynamics
- soil erosion and hydrology

2.2.3.1 *The main Grazing x Tree killing investigation*

This study examined the impact of timber development at three grazing pressures, namely –

- **low *'L'*** - aim for stock to eat 25% of the standing autumn pasture over the next 12 months
- **medium *'M'*** - aim for stock to eat 50% of the standing autumn pasture over the next 12 months
- **high *'H'*** - aim for stock to eat 75% of the standing autumn pasture over the next 12 months

Trees at both sites were poisoned by herbicide in 1994. At Keilambete, the trees, mainly ironbarks, were stem injected in March 1994 with Velpar®, except along waterways, and most small seedlings were given a herbicide squirt on the soil at the base of the stem. At Glentulloch, the trees, mostly poplar box, were stem injected with Tordon 50D® in June-July 1994. Big myalls (*Acacia pendula*) here were ringbarked because they are tolerant of Tordon. Each treatment was replicated twice, resulting in twelve grazed paddocks, half of which were not treated with herbicide. Weaner steers (usually 3) continuously grazed each paddock, which differed in size to provide the comparative grazing pressures (Table 2.1).

Table 2.1 Paddock sizes (ha) of the 6 main treatments at the 2 grazing management sites.

Grazing Management Treatment	Treatment Code	Keilambete paddock size (ha)	Glentulloch paddock size (ha)
Treeless - Low grazing pressure	CL	11	12
Treeless - Medium grazing pressure	CM	5.5	6
Treeless - High grazing pressure	CH	3.5	4
Treed - Low grazing pressure	TL	21.5	18
Treed - Medium grazing pressure	TM	11	9
Treed - High grazing pressure	TH	7	6

Assumptions used initially for deriving paddock sizes to meet the utilization targets were:

1. Use weaners, av. LWt 200 kg in May.
2. Possible mean (/normal) pasture DM production on these soils in a treeless situation – 2,000 kg/ha.
3. Reduction in pasture yield due to trees 50%.
4. A 200 kg weaner eats 1 800 kg DM in the next year if it averages 93 kg LWt gain during the year. (This assumes gains of 0.7 kg/day on growing mid-summer pastures and losses of 0.3 kg/day in spring before the first storms.)
5. Replace weaners each year but adjust animal size if necessary to reflect the past summer growth [ie. larger av. LWt if > 2000 kg/ha on offer and smaller av. LWt if < 1500 kg/ha on offer].
6. In drought years, one animal could be removed from overgrazed paddocks. In very wet years, extra animals could be used to keep grazing pressure in the desired range and with consistent relativity.
7. Grazing pressure set on the basis of standing autumn feed must retain the same relative differences between treatments but can vary slightly with seasonal conditions, ie.

   A nominal 75% could range between 65 & 85%,
   50% could range between 40 & 60%, and
   25% could range between 15 & 35%

As an adjunct to each grazing trial and as a link to predictive models, an area of about 50 hectares was fenced-off beside the main trial. This was called the ‘Commercial’ treatment (COMM). At Glentulloch, about 15 weaners, new each year, grazed in a paddock which was stocked according to the moderate grazing pressure guidelines in the main trial. At Keilambete, weaner numbers were kept at 15 each year but patches of rank dry pasture were burnt in spring 1998. These animals, plus the others, were weighed every 2 -3 months to link reliable animal performance data to pasture data at the same site. At Keilambete, this COMM paddock was timbered (5m^2 tree basal area/hectare) while at Glentulloch it was cleared but had some regrowth which had to be re-poisoned with Tordon.

After the first 2 years, it became obvious that the anticipated pasture response from some paddocks, particularly the timbered ones at Keilambete, was not as initially expected. Hence we slightly altered the way in which animal intake was calculated to take into consideration the measured rates of liveweight gain that each site had demonstrated. The method for making those calculations is detailed in Appendix T, but it basically used a sinusoidal fluctuation in LWG/day over a year with a peak in mid-summer and a trough that was at its lowest in August. The extremes to which those peaks and troughs reached were slightly different for each utilisation level and for each site, based on our experience. Thus the formulae are smoothed approximations of what actually happens during growing seasons where moisture and greenness fluctuate regularly. Non-lactating animals tend to smooth out those changes via an average LWG, so we calculated likely intake and growth over 10day periods. The basis for the intake rates is Minson and McDonald (1987) and animal weights were incremented every 10 days throughout a year, based on the calculated gains over that prior 10 days.

The formula used for daily intake was $I = (1.185 + 0.00454L - 0.0000026L^2 + 0.315G)^2$

where L = LWt of a beast at day X
G = LWt gain/day for that day
$X = \pi * [(\text{days since 30 April})/365]$

Liveweight gain on a particular day was calculated by the formula $G = a + b \sin X$

Table 2.2 Variables used to calculate the date-dependent LWG parameter G for each treatment when calculating probable animal intakes over the ensuing year at different grazing pressures.

Grazing pressure	Constant (a)	Change rate (b)
Keilambete		
Low	0	1.0
Moderate	- 0.3	1.1
High	- 0.5	1.2
Glentulloch		
Low	0	1.1
Moderate	- 0.2	1.1
High	- 0.4	1.1

The values for parameters a and b for each grazing pressure at both sites are given in Table 2.2. Those values were used to set stock numbers each year after 1996 for the remainder of the project.

2.2.3.1.1 Other notes about animal management

The first mob of weaners went into the Keilambete paddocks on 4 November 1994 while at Glentulloch this occurred on 30 November 1994. For operational reasons, one mob of steers was retained for a second season at both sites. Hence their performance is not strictly comparable with that of the weaners every other year. At times, 1 or more animals had to be removed from some high grazing pressure paddocks into adjacent laneways when feed became scarce. Also at Keilambete, 2 animals grazed 2 adjoining high grazing pressure paddocks in 1 summer to allow grazing when pasture was too scarce to carry 2 in either paddock.

At Glentulloch, new mobs initially went into paddocks about early summer but this was changed to early winter late in the trial. This was done to address concerns of modellers about compensatory weight gains in summer, which their current models do not consider.

2.2.3.2 *The fire investigations*

This study examined the effects of fire on treeless and wooded pastures. These treatments were not grazed, as the additional area and effort required to monitor such a treatment set was not feasible. An annual spring burn was planned for each spring but was not always possible when wet, green conditions occurred. For each ***Treeless*** and ***Treed*** treatment that was **Burnt**, there was a corresponding treatment set **Unburnt**, giving a set of four treatments. Each treatment was replicated three times, resulting in twelve (1 hectare) exclosures at each site. At Glentulloch they were all in 1 block situated about 800m from the grazing trial while at Keilambete the plots were scattered around the grazed paddocks.

The accompanying maps in Appendix A and Section 3 detail the location of treatment paddocks at each site. The area labelled Stock paddock at Keilambete and Commercial paddock at Glentulloch are the medium grazing pressure COMM treatment with 15 weaner steers. Those paddocks also allowed demonstrations of various commercial options, eg. spear traps and how to operate a monitoring site (Grasscheck method). The location of the runoff and erosion monitoring sites is also shown on the maps.

2.2.4 Measurements taken regularly

A wide range of similar measurements was taken at both sites using identical techniques to cover tree, pasture, soil and animal topics. They are summarised in Table 2.3. Full details of the methods used are given at the start of each section as it reports the findings on a particular topic.

Extra measurements were taken by other researchers or ourselves at individual sites, to complement the basic set, often due to the availability our infrastructure and treatments to answer pressing questions. They will be described in more detail in the sections most closely aligned to the topic, eg. NIRS on cattle faeces or refoliation of ironbarks after fire or landscape function in Section 9. At Glentulloch, a one year project extension into 2002 was used to collect some extra data about soil salinity potential.

Table 2.3 Grazing and burning trial sampling parameters and the methods used.

Attribute Measured	Technique	Key Sampling Details
A. Tree and Shrub Component		
A(I) Tree Basal Area	Bitterlich Stick	• 50m x 50m grid per paddock • start of trial only
A(II) Tree Population Dynamics	TRAPS monitoring	• fixed 450m x 4m belt transect • sampling every 2 years • details collected include species, height, basal area and location
B. Pasture Component		
B(I) Pasture Growth	Swiftsynd - Exclosure from grazing	• plant yield and soil moisture sampled • to 5 sampling's per growing season • growth partitioned for key species (infrequent after year 3)
B(II) Species Composition	Botanal survey	• species frequency, cover and yield are measured • 25 samples per hectare • April-May annual sampling • quadrat size $0.25m^2$
B(III) Basal Area	Point frame (pins 25cm apart)	• 450m fixed sampling line per pdk • Autumn or spring annual sampling
B(IV) Plant Population Dynamics	Permanent quadrat charting	• 9 x $1.5m^2$ quadrats charted per pdk • charting of 6 key species only • measure persistence and plant size
B(V) Soil Seed Reserves	Field sampling followed by pot germination	• 9 composite cores collected per pdk • sampling depth 5cm • field sampling in late winter • pot germination in early summer, with ample moisture
C. Cattle Component		
Animal Growth	Weighing and Fat Scoring	• stock weighed 4 to 6 times per year • weaner mobs changed each winter
D. Runoff and Soil Loss		
D(I) Runoff	Tipping buckets and height recorders	• events are logged by data recorders • manual count device as backup • ground cover monitored
D(II) Soil Loss	Trough collection and sediment sampling	• bedload soil is trapped in troughs at the bottom of each catchment bay • suspended soil loads are sub-sampled from the runoff as it passes though each installation
E. Burning Experiment		
All the above tree and pasture components	Identical techniques to above	• Burn in late winter or early spring (Every year, if possible) • 200m of transects for trees • 1 composite sample/plot for soil seeds

2.2.4.1 *Photographic records*

A photographic record was also kept of each paddock at both trials. See Appendix L.

2.2.4.1.1 Photographic system

- permanent reference sites were located in each paddock
- each site was the northern post of the main TRAPS transect recording lines.
- each photo was taken facing south, toward the next steel post
- field of view minimised the amount of sky with the centre of field approximately 20 metres away
- Photos are stored in an album and most are also scanned to an electronic file

2.2.4.1.2 Recording frequency

At least one set was taken after the peak of the growing season, generally in April or May. Additional sets, at a series of treeless and treed locations, showing major seasonal differences were also taken.

2.3 Grazing management packages

2.3.1 Methods used to develop packages

A number of techniques were employed to achieve this objective. Firstly we used the Consultative Group members in onsite discussions about how we might extrapolate our results into practical management initiatives. This happened on several occasions at both sites and the exchange of ideas was most valuable, eg. about how many animals and paddocks can practically be handled through a set of yards in a day when using only the normal property labour force of 2-3 people.

With financial assistance from the Natural Heritage Trust Fund (Project 972737) we ran 3 workshops at Emerald to explore practical options for incorporating our research findings into sustainable grazing land management packages. Invited people from diverse backgrounds such as the Great Barrier Reef Marine Park Authority, the Central Qld Indigenous Liaison Office, local tourism boards, forestry and wildlife officers attended these facilitated one day workshops. The main themes from these workshops, about the need for more integrated planning and co-ordination between the numerous agencies and greater access to baseline data, was fed back into the Consultative Group discussions. Those Group discussions then focussed more on the details of implementing our findings locally.

Peer Review meetings arranged by MLA during the project also helped to generate discussion with other researchers, MLA Program Co-ordinators and invited producers. These talks alerted us to any inconsistencies in our approach and provided ideas that we were able to incorporate, eg. NIRS faecal sampling, fat scoring while weighing the cattle, and the installation of a tree-covered Gerlach trough in an exclosure at Glentulloch.

Scientific review of our contribution to the Grazier Guide for Semiarid Woodlands also helped develop our ideas, eg. from forestry specialists about the use and timing of fire for tree versus pasture control. Another peer review of our summary project booklet ensured that we did not gloss over the importance of climate variability in our risk management strategies.

Feedback at many forums where our work was displayed inevitably produced better-considered initiatives or ways to implement basic concepts, eg. how we practically deal with biodiversity issues. These have been included in later reports and publications (See Section 14) and presented at meetings and field days.

2.4 Communication methods

The project team always had **an extension specialist** in its early years and, with staff resident in the community around each core research site, there was a regular interchange of information and ideas with producers and other agency staff. We were **'on call' to any local Property Management Planning, Landcare or Catchment group** to assist them in their capacity building work.

Our main formal system of communication was via the **Consultative Group attached to each core site** and via the **NAP3 Peer Review process**. At least one meeting was held each year with the Consultative groups. We participated in and reported in some detail to the Peer Review Workshops which were held annually up to 2000.

We contributed regular items to **local newspapers and rural newsletters** such as the Maranoa Rural News and the Central Highlands Newsletter. Broader coverage was received via State and national radio and press such as Country Life. These are reported upon in detail later in Section 14. Full copies of most items are included on the CD of project results, available from the authors and MLA, Sydney.

We gave talks and had displays of our work at **Beef Industry Forums** such as Meat Profit Days and Beef2000.

We ran the three facilitated workshops discussed previously in Section 2.3.

Project staff presented interim findings to specialist local, national and international **Conferences and Workshops**. They also sat on **discussion panels and planning groups** involved in developing the Regional investment strategies for the federal National Action Plan for Salinity & Water Quality, the Regional Vegetation Management Plans and the Cypress Pine Industry.

The project has also acted as a valuable conduit for cross-agency information exchange between the three big rural community agencies, Environmental Protection Agency (EPA), Dept Natural Resources & Mines (DNR&M) and Qld Dept Primary Industries (QDPI).

Details of most of the communication activities with which we were involved are presented in Section 14.

3 Trial Site Descriptions

3.1 The Silver-leaved ironbark site

3.1.1 Location

The ironbark site on 'Keilambete' was located 10 km NW of Rubyvale, a sapphire mining town 50 km WNW of Emerald. The trial site, centred on 23° 22' 30" S, 147° 35' 15" E at 325m elevation, is typical of the Peak Vale land system – undulating country with silver-leaved ironbark (*Eucalyptus melanophloia*) and texture contrast soils on granite exposed below the Tertiary weathered zone (Gunn *et al.* 1967). This land systems covers 185,000 hectares between Rubyvale and Clermont and is also coded as Regional Ecosystem (RE) 11.12.2 by Sattler and Williams (1999). As such it is not an RE of concern at present because over 30% of its original extent remains uncleared and regarded as remnant vegetation.

The site has a gentle undulation between each drainage line, with 2 branches of a significant waterway joining just beyond the trial site near Middle bore which supplied the stock water. There were no semi-permanent ponds because the country drains so well. Ghost gums (*Corymbia papuana*) are common along waterways. The soil type was very even across the whole site. The highest points were in the SW corner (paddock TL2) and the low point at the northern end of the 'Commercial' paddock (Figure 3.1). Some small rock outcrops occurred along the main ridgelines but were not a significant feature of the landscape. The main water tank was at the southern end of the central laneway beside TM2 and the yards where animals were weighed were at the opposite end near TH1 (See Figure 3.1).

3.1.2 Soil type

The soil is a gritty red duplex derived from granite. A limited survey was made of the site and profile descriptions from 11 mapped locations around the site are found in Appendix B. The soils have been classified under 3 different systems that have been widely used in Australia –

Duplex Non-calcic brown	(Great Soil Group classification)
Red duplex - Dr2.12	(Northcote classification)
Chromosol/ Red/ Eutrophic/ Haplic	(Isbell Australian classification)

The few profiles that are different from the general Dr2.12 type are mostly either near waterways (sites 4,10 & 11) or on small basalt outliers (site 6).

The silver-leaved ironbark was completely dominant at the site, with only a scattering of other species such as prickly pine (*Bursaria incana*) and variable-barked bloodwood (*Corymbia erythrophobia*) away from watercourses. Along small waterways, ghost gums, currantbush (*Carissa ovata*), dead finish (*Archidendropsis basaltica*) and quinine bush (*Petalostigma pubescens*) are found regularly. It was relatively open in comparison to other eucalypt woodland types in the district (e.g. poplar box and narrow-leaved ironbark) and it had small areas of thick regrowth (tree densities of 1,000 stems/ha or greater).

The trees in the 'Treeless' paddocks were treated in March 1994 by stem injection with Velpar. Subsequent to this treatment, it was observed that over 12 months there were 3 circulations of the poison in the trees that resulted in yellowing of the leaves. All tree species have been killed by the application, except for prickly pine, which has shown resistance. Trees were left untreated along the narrow drainage lines.

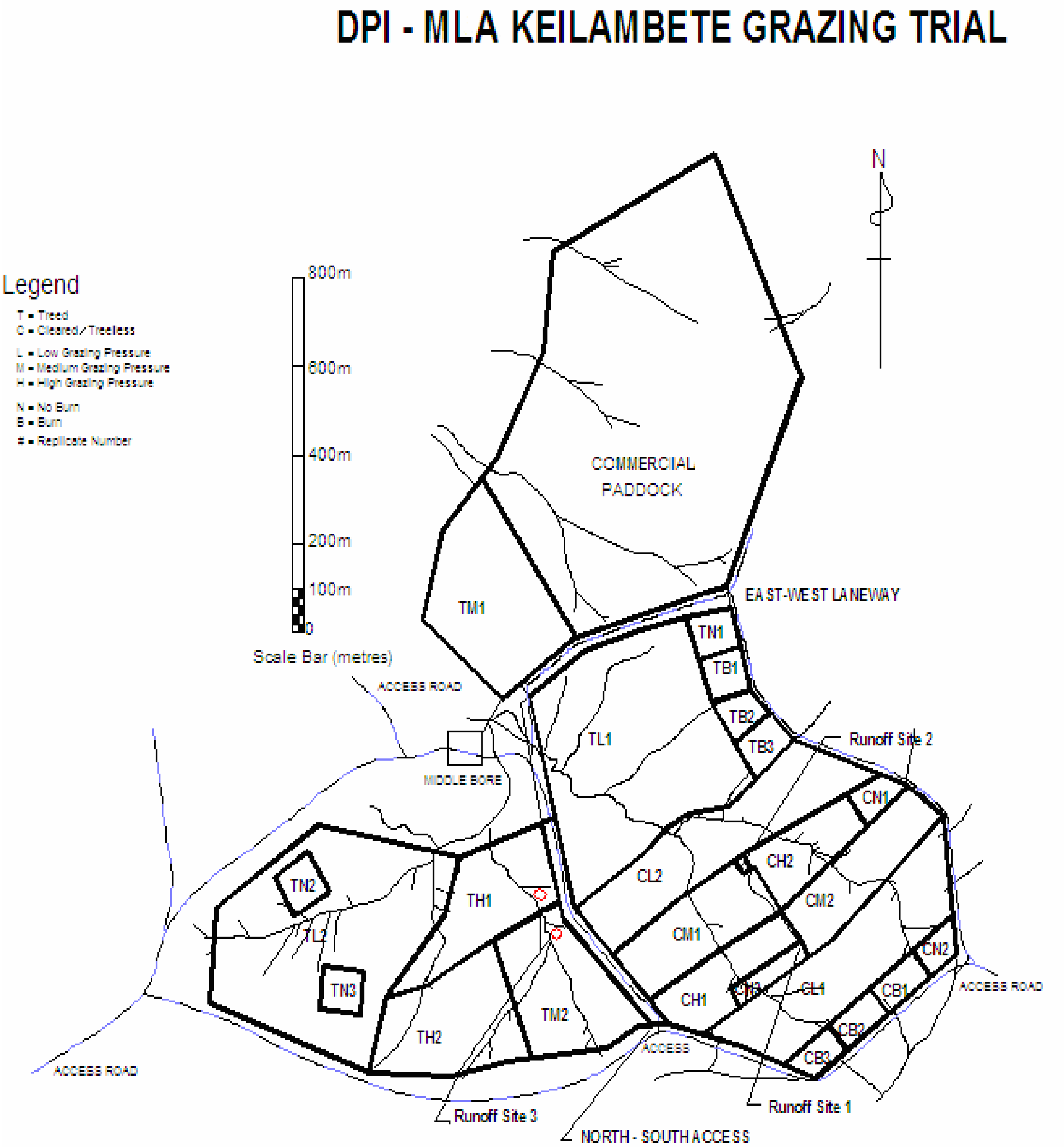


Figure 3.1 Layout of the Keilambete site showing major infrastructure, sampling sites and drainage lines.

3.1.3 Climate at the Ironbark site

The Central Highlands area has a sub-tropical climate and the rainfall is highly variable. The main period of potential pasture growth is from October to March when temperatures are optimal and 75% of the annual rainfall occurs in this period (see Table 3.1). Most of the rain from September to December is from thunderstorms while January and February have the highest monthly rainfall and heaviest daily falls (Bourne and Tuck, 1993). Only 14% of daily totals are 25 mm or more (Spackman and Garside, 1995). Average storm intensity at Emerald is 35 mm/hr, so only a minor proportion of annual rainfall events are likely to contribute to pasture growth (Willcocks, 1993).

Table 3.1 Monthly average climate data relevant to Keilambete.

Month	Mean Rainfall[a] (mm)	Median Rainfall[a] (mm)	Pan Evaporation[b] (mm/day)	Mean Maximum Temperature[b] (^oC)	Mean Minimum Temperature[b] (^oC)
January	108	84	8.9	34.1	21.5
February	110	76	7.7	33.2	21.3
March	68	48	6.7	31.9	19.7
April	36	23	5.5	29.5	16.5
May	36	25	4.1	25.7	12.5
June	33	20	3.6	22.7	8.9
July	27	9	4.1	22.4	7.6
August	23	10	4.9	24.6	9.0
September	21	8	6.7	28.3	12.3
October	43	27	8.4	31.8	16.5
November	59	49	9.6	33.7	19.4
December	88	66	9.8	34.5	20.9
Year	652	616	6.6	29.4	15.5

[a] = data from Anakie Railway Station (20km southeast of the site)
[b] = data from Emerald Post Office

3.1.3.1 *Rainfall during the project*

Table 3.2 Rainfall at Keilambete.

Year[1]	1993[2]	1994	1995	1996	1997	1998	1999	2000	2001
Rainfall (mm)	260	525	472	460	828	482	852	632	745
Decile Range	1	3	3	2	8	3	9	6	7

Project duration was July 1994 to June 2001. Values are means of 8 raingauges spread around the site.
[1] = Year is from prior July to June of year listed [2] = 1993 data from homestead, 4km away.

Rainfall during the project has been very variable. The interaction of rainfall variability and treatments applied has had a large affect on pasture yield, 3P (perennial, productive, palatable) grass dynamics, runoff, soil loss and animal production. Summer and yearly rainfall totals were very low during the two years prior to the trial resulting in large-scale regional destocking and urea molasses feeding. Rainfall during the establishment year of the trial was also low (decile 3), however good growth conditions prevailed. A picture of how typical the trial period rainfall was compared to the long term record is shown in Figure 3.2 below, derived from Rainman (Clewett *et al.* 2003).

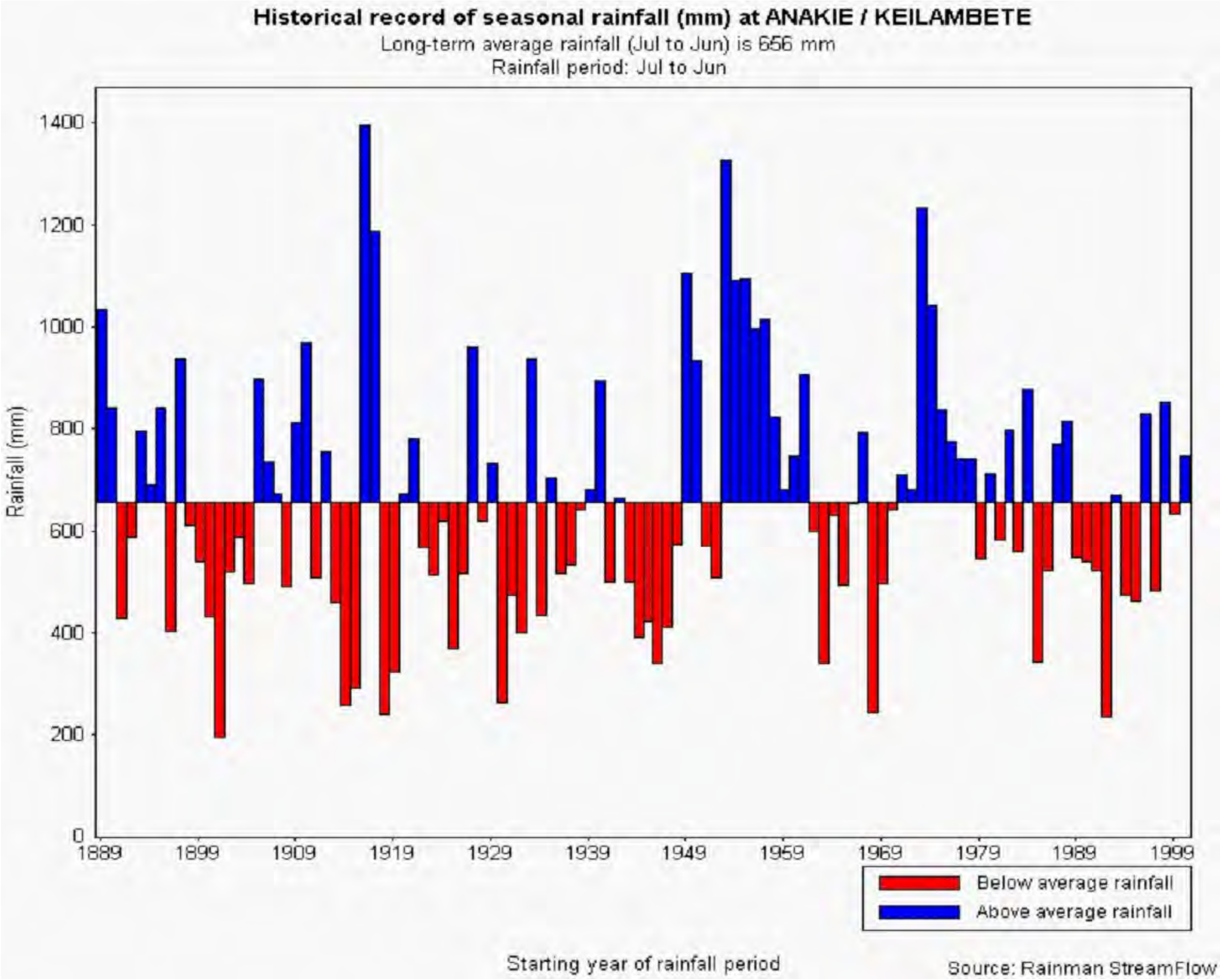


Figure 3.2 Deviation about the long term mean annual rainfall for July to June at Anakie, with the actual Keilambete data appended from 1994 to 2001.

A smoothed figure based on 5-year moving averages is shown in Appendix C. This clearly illustrates that the trial period was in the latter part of a protracted dry era, which is somewhat masked by individual above average years such as 1997.

3.1.3.2 *Recent Drought Periods around Anakie*

The DPI's AUSTRALIAN RAINMAN is an integrated package of rainfall information to assist management of climate variability (Clewett *et al.* 2003). Rainman classes periods of rainfall deficit as moderate or severe drought and allocates those of the driest 5% of periods as severe drought while those falling between there and the 10% of driest years are called moderate droughts. The minimum test periods used for such 'drought' assessments are 6, 12 and 24 months for what are described as seasonal, major and extended droughts respectively.

Severe seasonal (6 month) droughts (driest 5% of time for any contiguous 6 month period) have a frequency of 21 times in 112 years for the region. Severe seasonal drought occurred for 33% of the period from September 1992 to July 1993. January 1993 to July 1993 was also a severe drought at Anakie.

A major (12 month) drought is defined as the driest 5% of years for any 12 month period and has a historical frequency of 19 times in 112 years. A severe major drought occurred for 36% of the period January 1992 to January 1994. Severe drought conditions persisted at Keilambete at the start of the trial, for the majority of the period April 1994 to January 1995.

Extended (24 month) droughts are the driest 5% of times for any 24 month period and have a frequency of 7 times in 112 years. Severe drought occurred for 11% of the period from January 1992 to March 1996. January 1992 to February 1994 was a severe drought at Anakie.

Thus the period leading into the start of the Keilambete trial was extremely dry for an extended period and relatively dry conditions continued into 1996. In contrast there had been no extended wet periods for over a decade before the trial and during the trial, but there were some shorter (6 month) wet periods identified during the trial, from mid-1998 and again from mid-2000.

3.2 The Poplar box site

3.2.1 Location

The Poplar box site was located on "Glentulloch", about 18km NW of Injune – lat. 25^{o} 45' 23" S, long. 148^{o} 24' 56" E and about 480m elevation. The country is undulating and was originally well timbered but after several cycles of axe-thinning is now a mixture of natural bushland, cleared woodland, sown buffel grass pastures and tree regrowth adjacent to Hutton Creek.

The country is part of the Montana Land System described in the Dawson – Fitzroy Land Research Series (Perry 1968) and is equivalent to the Bymount Land Resource Area in the Roma Land Management Manual (Macnish 1987). Hence, though it is physically in the Fitzroy River Basin, it has the same features as Land Units 10 and 11 of the Balonne-Maranoa Land Resources Survey (Galloway *et al.* 1974). Those units occur in the headwaters of the Murray-Darling System. The sites are just to the east of Hutton Creek which runs ENE into the Dawson River north of Injune. It fits into Regional Ecosystem 11.9.7 of the Sattler & Williams (1999) classification, and as such the RE is rated as "of concern" because less than 30% of its original extent remains uncleared.

These lands, which cover thousands of square kilometres, are broadly described in the map legend (CSIRO 1968) as "Undulating plains to low hills. Grey and brown clays with some texture contrast soils. Poplar box and silver leaved ironbark woodland." The 120ha site begins on the flat crest of a hill and runs down the long 4-8% slope to a minor drainage line and then up over a smaller gentle rise adjacent to Hutton Ck (Figure 3.3). The grazing trial site is about 1km further SW along the Creek than the burning trial site which is in the lower part of the general landscape. The country is at the better end of the productivity scale for poplar box woodlands but is very important because the labile sediments beneath are susceptible to erosion and salinity inputs to the downstream rivers.

3.2.1.1 *Specific features of the site*

The site lies in undulating lands 3 km north of the Injune to Womblebank road on the eastern side of Hutton Creek. The geology of the area sees rock strata at quite a steep angle to the horizontal so that soils developed from the various beds can vary quiet a deal in a short distance, - from Cypress pine on sands to eucalypt woodland on duplex solodic soils to brigalow scrubs on cracking brown clays with dry vine scrubs on rocky caps of basalt. The fertile brigalow country has been cleared and sown very successfully to buffel grass for five decades now but the buffel has generally not invaded into the adjacent solodic soils.

The country has a long history of cattle grazing with several cycles of ringbarking (about every 50 years) as regrowth became too thick and reduced pasture yields. The trial site in Swamp Paddock, was being prepared for re-thinning when arrangement were made to lease the trial site for this project. Hence the trees present in 1994 represented fairly mature poplar box regrowth prior to the use of herbicide to clear half the area. The owner went ahead with the killing of trees on much of the surrounds of the trial in line with the original intention and under an approved tree clearing permit.

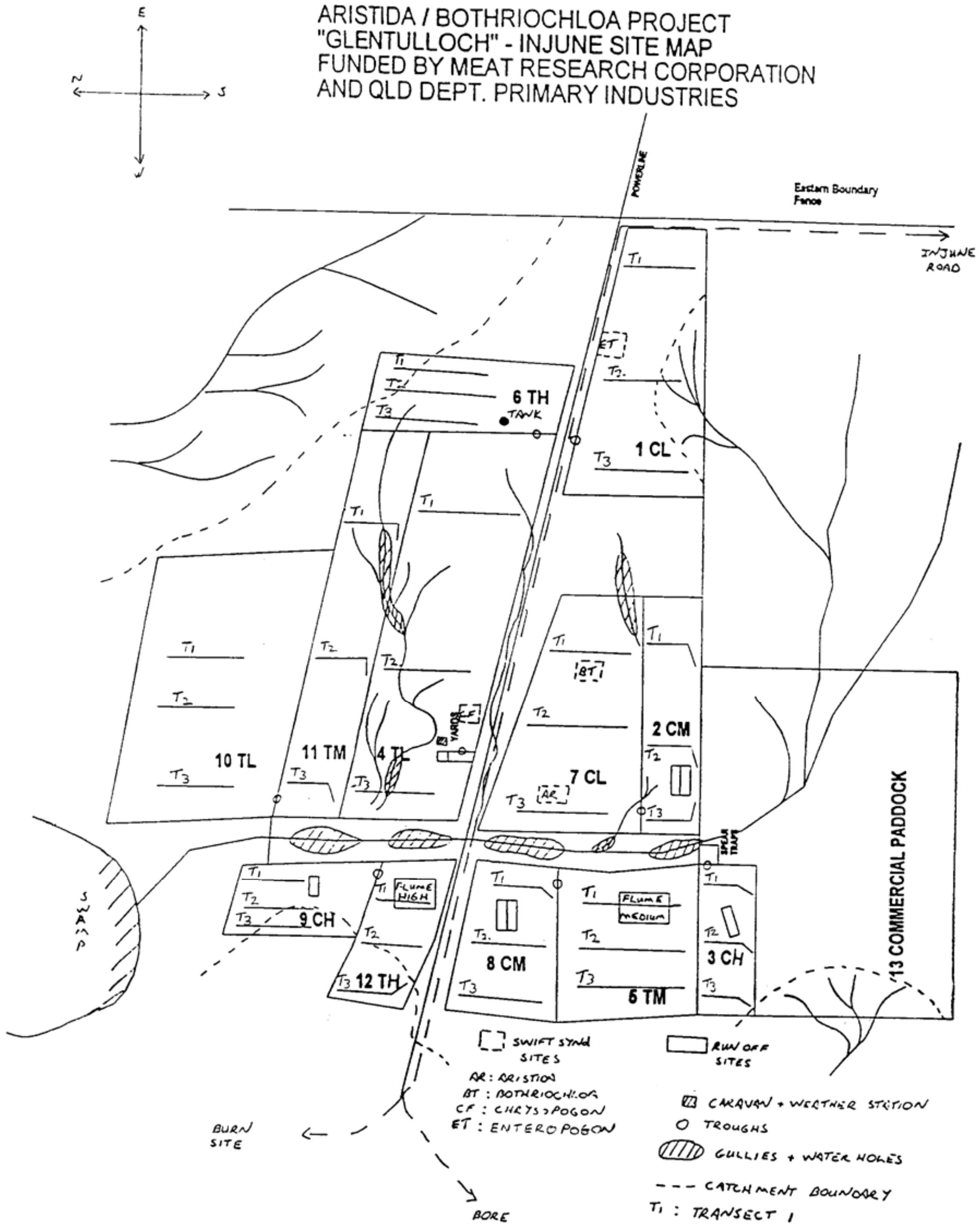


Figure 3.3 Map of the poplar box Grazing Trial Site at 'Glentulloch', Injune showing the location of the main sampling transects, runoff sites and infrastructure.

The SE corner of paddock CL1 of the actual trial site runs into brigalow country (Figure 3.3) while much of paddock 6 (TH1) is on the stony ridge that forms the NE edge of the trial area. This ridge has a significant number of bulloak (*Allocasuarina luehmannii*) and silver-leaved ironbark trees amongst the poplar box, plus a variable understorey of yellow-berry bush (*Maytenus cunninghamii*) and hopbush (*Dodonaea* spp.). In the SW corner of paddock 1, on the lower western slopes of the site and the Hutton Creek levee banks, myall (*Acacia pendula*) is common on silty soils and some of these trees were left as shade trees in several paddocks eg. CH2 and CL1.

The small N-S watercourse through the centre of the grazing trial area (mapped on 1:250.000 topographic maps) had stands of very dense purple wiregrass (*Aristida ramosa*) on the deep alluvium beside it and that wiregrass had an impact on grazing patterns in paddocks 2 (CM1), 4 (TL1) and 7 (CL2). Heavier clay patches were significant in paddock 1 (CL1) and parts of paddocks 3 (CH1) and 8 (CM2). Mean tree density across the grazing site before the trial was 377 trees/ha while at the burning trial it was 348 trees/ha (Section 4.2) although the trunk diameter of the individual trees was much greater at the burn site.

The burning trial site was approximately 1 km north from the central lane of the grazing trial on a gently sloping, solodic soil that was almost free of stone. Poplar box was virtually the only tree species there and there was negligible shrub in the understorey. All plots were in one block and the surrounding trees were killed by the property manager during the course of the project. There were no drainage lines and the soil type was very consistent except for a more clayey spot in the SW corner, in plots CB2 and CN2.

3.2.2 Soil Type

The main soil type is a texture contrast soil with shallow loamy surface overlying heavy clay subsoil. A full description follows below (Section 3.2.2.1) that was done by Mr Brian Slater and Mr Ben Harms for a field day booklet in 1998 (Anon 1998).

The surface is generally hard setting, slightly acid but quickly changes to a blocky alkaline, saline-sodic clay over 1 metre deep. Those near the main crest are probably Luxor family, the midslopes Retro (Perry 1968) with alluvium on the drainage floor of paddocks 2,4 and 7. The major soil profiles and types identified from sampling 55 profiles around the site are Sodosols and Dermosols (Isbell 1996) with Principal Profile Forms Db1.13, Db1.33, Dy2.33 and Dy2.43 (Northcote *et al.* 1975). That means the A horizon is generally hard-setting, there is a varying degree of A2 horizon bleaching (due to lateral water flow above the B horizon) and a consistent alkaline reaction trend with increasing soil depth. Smaller areas of grey earths (Gn3.9), cracking clay (Ug5.2 with linear gilgais) and red subsoil duplex (Dr) soils were recorded.

The soil at the centre of paddock 7 (CL2) was examined in detail by Harms and a description from Anon (1998) is provided below. The booklet also gave a summary of the environmental and agricultural significance of those soil characteristics and that is copied here also. Other soil and landform examinations were conducted by Brian Slater and Andrew Biggs (DNR&M Toowoomba) to provide data to their departmental soils database called SALI (NR&M 2003).

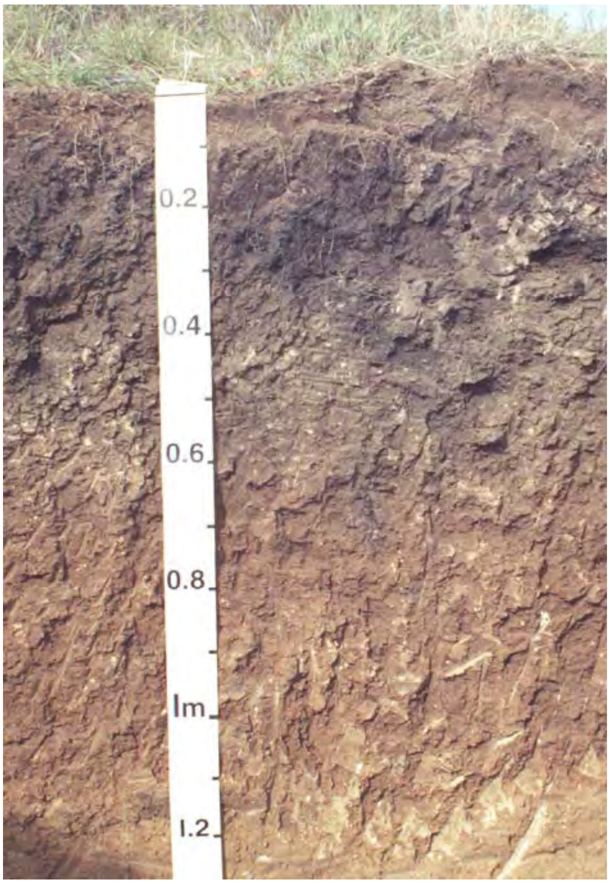
3.2.2.1 *Detailed soils data from Glentulloch*

SITE DESCRIPTION

Brief soil description:	Texture contrast soil with shallow loamy surface soil overlying heavy clay subsoil.
Landform and geology:	Undulating rises (slope 4%). Fine grained sedimentary rock ('unresistant' weathered rock).
Vegetation:	Open woodland of poplar box (cleared). Pitted & forest bluegrass, *Aristida* spp. (wiregrass), barbwire grass, curly windmill grass.

SOIL DESCRIPTION

	Depth	Description
A_1	0-8 cm	dark greyish brown clay loam (fine sandy); massive (or very weak) structure; pH 6.0; clear change to -
A_{2j}	8-10 cm	light grey clay loam (sandy); weakly bleached, massive structure; abrupt change to -
B_{21t}	10-30 cm	black medium heavy clay; moderate angular blocky structure (medium size); pH 8.5; gradual change to -
B_{22t}	30-65 cm	dark greyish brown medium heavy clay; strong angular blocky structure (medium size); a few calcium carbonate nodules; pH 9.5; gradual change to -
B_{23t}	65-115 cm	brown medium heavy clay; moderate angular blocky (medium size); a few calcium carbonate nodules; pH 9.5; gradual change to -
BC	115-150 cm	brownish yellow fine sandy light medium clay; massive structure; a few calcium carbonate and manganese nodules (clay mixed with weathered rock)
Surface condition:		hard setting, a few medium pebbles.



INTERPRETING THE SOIL DATA

Surface soil (0-10 cm)

hard setting surface reduces infiltration and may hinder seedling establishment.

pH approx. 7.0 neutral, within the preferred range for most plants. Will not impair the availability of major plant nutrients.

organic carbon 1.2% low - especially for a pasture soil. [This soil therefore has a reduced ability to supply mineral nitrogen and mineral sulfur for plant growth.]

nitrate nitrogen (NO_3-N) 3 mg/kg. Very low.

available phosphorus (P) 13 mg/kg. Rating depends on type of enterprise:
- adequate for native pasture
- marginal for improved pasture.

sulfate sulfur (SO_4-S) 5 mg/kg. Low level - could be reducing the productivity of the pasture.

trace elements all adequate except for zinc (Zn) which is low

Subsoil

pH Strongly alkaline (approx. 9.0) throughout - may reduce availability of some micronutrients.

cation exchange capacity (CEC) approx. 35 in the subsoil, which is moderate. This reflects the type of clay and its moderate ability to hold nutrients for plant growth.

exchangeable sodium percentage (ESP) > 18% below the surface: soil is strongly sodic. Sodic soil may disperse (which clogs pore spaces, reduces drainage and root penetration, increases risk of gully erosion). The dispersion ratio of about 0.8 throughout the profile indicates high tendency of this soil to disperse.

effective rooting depth: Theory of water and salt movement suggests an accumulation of salt occurs at the bottom of the root zone, since water recharge and drainage following plant water use should flush salts from the active root zone. Soil chloride (Cl) is high from about 40 cm (see graph) and very few plant roots were observed below 45 cm which may indicate the effective rooting depth is about 45 cm.

plant available water content estimated to be 55 mm to a depth of 45 cm (from laboratory particle size and wilting point moisture content). This is very low for cropping, low to moderate for sown pastures.

salts, as measured by EC and Cl% are medium at 20-30 cm and high below that. Only tolerant plants will do well in highly salty soils such as this. Many native pasture and tree species have a high level of tolerance, but introduced species would need to be checked first. For example, buffel is tolerant, as are wheat and sorghum.

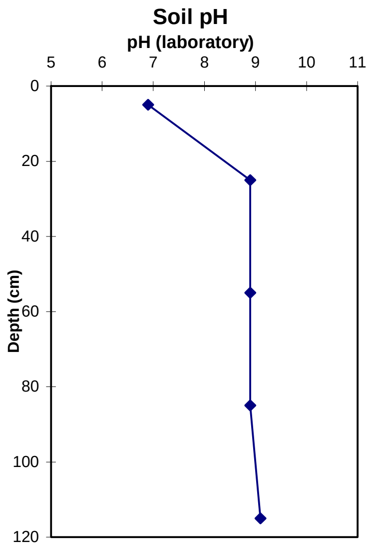
Excerpt from Anon (1998)

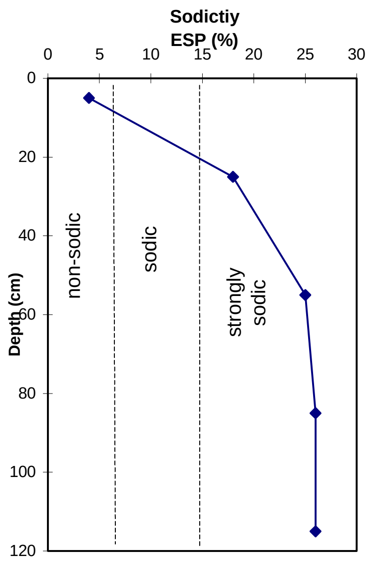
SURFACE FERTILITY (Bulked surface sample, 0–10 cm)

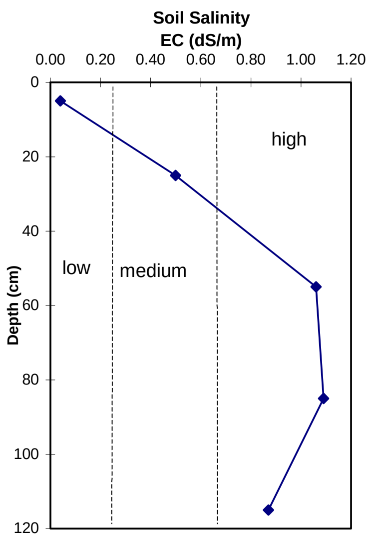
pH (lab.)	Org.C %	Total N %	Avail. P (bicarb) (mg/kg)	Avail. K (meq %)	SO4 - S (mg/kg)	NO3-N (mg/kg)	DTPA extractable trace elements (mg/kg) Fe	Mn	Cu	Zn
7.1	1.2	0.08	13	0.55	5	3	33	30	1.5	0.57

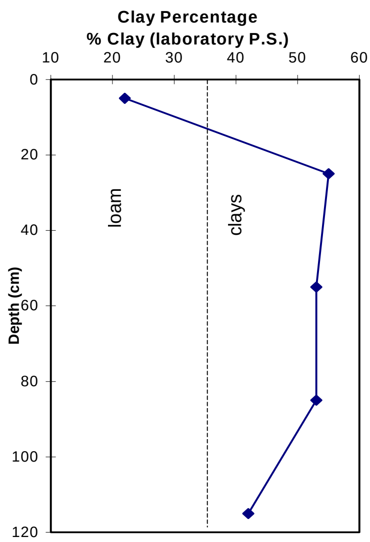
SOIL PROFILE CHEMISTRY DATA

Depth (cm)	Particle size (%) @ 105 °C				pH H_2O	EC dS/m	Cl mg/kg	Exchangeable cations (m.eq/100g)					Total element %			NO_3-N	moist WP % @ 105	Disp ratio	ES P %
	CS	FS	SIL	CLA				CEC	Ca	Mg	Na	K	P	K	S	mg/kg			
0-10	24	39	16	22	6.9	0.04	13	12	7.5	3.2	0.5	0.65	0.03	0.93	0.02	2	9	0.79	4
20-30	12	19	14	55	8.9	0.50	348	36	18	11	6.4	0.29	0.02	0.93	0.03	1	24	0.79	18
50-60	13	19	17	53	8.9	1.06	1163	36	16	11	9.0	0.30	0.02	0.80	0.04	1	23	0.77	25
80-90	12	22	15	53	8.9	1.09	1216	34	15	9.8	8.7	0.36	0.02	0.94	0.03	2	22	0.87	26
110-120	20	29	11	42	9.1	0.87	836	25	11	7.5	6.6	0.31	0.02	1.05	0.03	2			26









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3.2.3 Relationship to other eucalypt woodlands

To put the site in context with other country across the broad region of eastern Australia where poplar box grows, we now include some data from other researchers who used our site to calibrate tree growth and carbon sequestration models (Burrows *et al.* 2000). The data (from Mr Paul Back and Ms Madonna Hoffman of QDPI Rockhampton) show that our site is typical of the eucalypt woodlands of eastern Australia, especially poplar box woodlands (Figure 3.4).

3.2.3.1 *Glentulloch tree data [Pdk 5]*

- Aboveground Biomass[A] : 64.08 ± 8.93 t/ha {[A] = from Wandobah allometric regressions}
- Fine Root Biomass : 12.80 ± 1.2 t/ha
- Coarse Root Biomass[A] : 6.00 ± 0.9 t/ha
- Total Belowground Biomass[B] : 18.8 t/ha {[B] = Coarse Root Biomass + Fine Root Biomass}
- Root:shoot Ratio : 0.29

Table 3.3 Distribution of tree roots under poplar box woodland of Pdk 5.

Soil depth interval	Fine root weight (t/ha)
0 – 15 cm	2.8 ± 0.2
15 – 30 cm	6.4 ± 0.9
30 – 50 cm	3.1 ± 0.01
50 – 100 cm	0.6 ± 0.01

* Obtained by coring and included only roots <15mm diam

3.2.3.2 *Glentulloch tree data [Burn site 2003]*

The graph below shows that our poplar box site was structurally typical of others that are widely dispersed over eastern Australia.

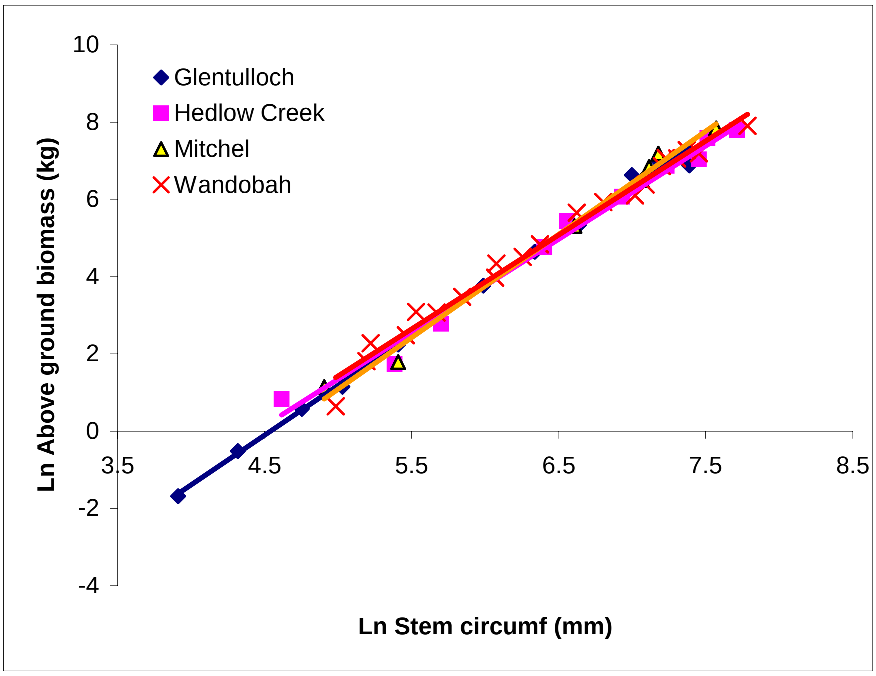


Figure 3.4 Glentulloch poplar box tree above-ground biomass compared to other sites.

3.2.4 Climate at the poplar box site

The Maranoa district, 250km to the south of Anakie, also experiences highly variable rainfall, with 70% of the annual rain falling during the 6 months from October to March. This pattern is a reflection of the monsoonal influences the area receives from the north during summer, and the low pressure influence from the south during winter. This area is actually on the extremity of both these influences, which causes the reliability of these influences to be very poor (estimated to be around 70% deviation around the median). The area is prone to heatwaves between October and March, along with frosts between May and September, with both type of event impacting negatively on pastures and cattle production. Table 3.4 shows average climate data for the Glentulloch district.

Table 3.4 Monthly average climate data relevant to Glentulloch.

Month	Mean Rainfall[a] (mm)	Median Rainfall[a] (mm)	Pan Evaporation[b] (mm/day)	Mean Maximum Temperature[b] (°C)	Mean Minimum Temperature[b] (°C)
January	94	72	9.6	33.6	19.2
February	85	65	7.9	32.2	18.8
March	64	42	7.0	30.7	16.3
April	38	27	5.4	27.6	12
May	35	23	3.6	23.1	8
June	32	21	3.1	19.9	4
July	31	16	3.4	19.6	3
August	22	16	4.5	21.9	4.2
September	26	18	6.1	25.6	7.4
October	47	43	7.7	29.4	12.5
November	62	50	9.2	31.3	15.3
December	85	74	10.0	33.5	17.7
Year	623	608	6.4	27.4	11.5

[a] = data from Westgrove rainfall station [b] = data from Injune Post Office

3.2.4.1 *Rainfall during the Project*

Table 3.5 Rainfall at Glentulloch, in sequential years1. (Mean of 5 rain gauges).

Year	1993[2]	1994[3]	1995	1996	1997	1998	1999	2000	2001	2002
Rainfall (mm)	362	557	392	571	654	706	844	391	568	456
Decile	1	4	2	5	7	7	9	2	5	3

[1] Year is from prior July to June of year listed
[2] Data from Westgrove approx 20kms North of the trial site
[3] Rainfall was from Glentulloch homestead, 1km away

Glentulloch has also seen some very dry and one very wet seasons over the trial period (see Figure 3.5 for seasonal rainfall). Compared to the long term rainfall sequences for the district, the trial period was generally dry, especially at either end of the period.

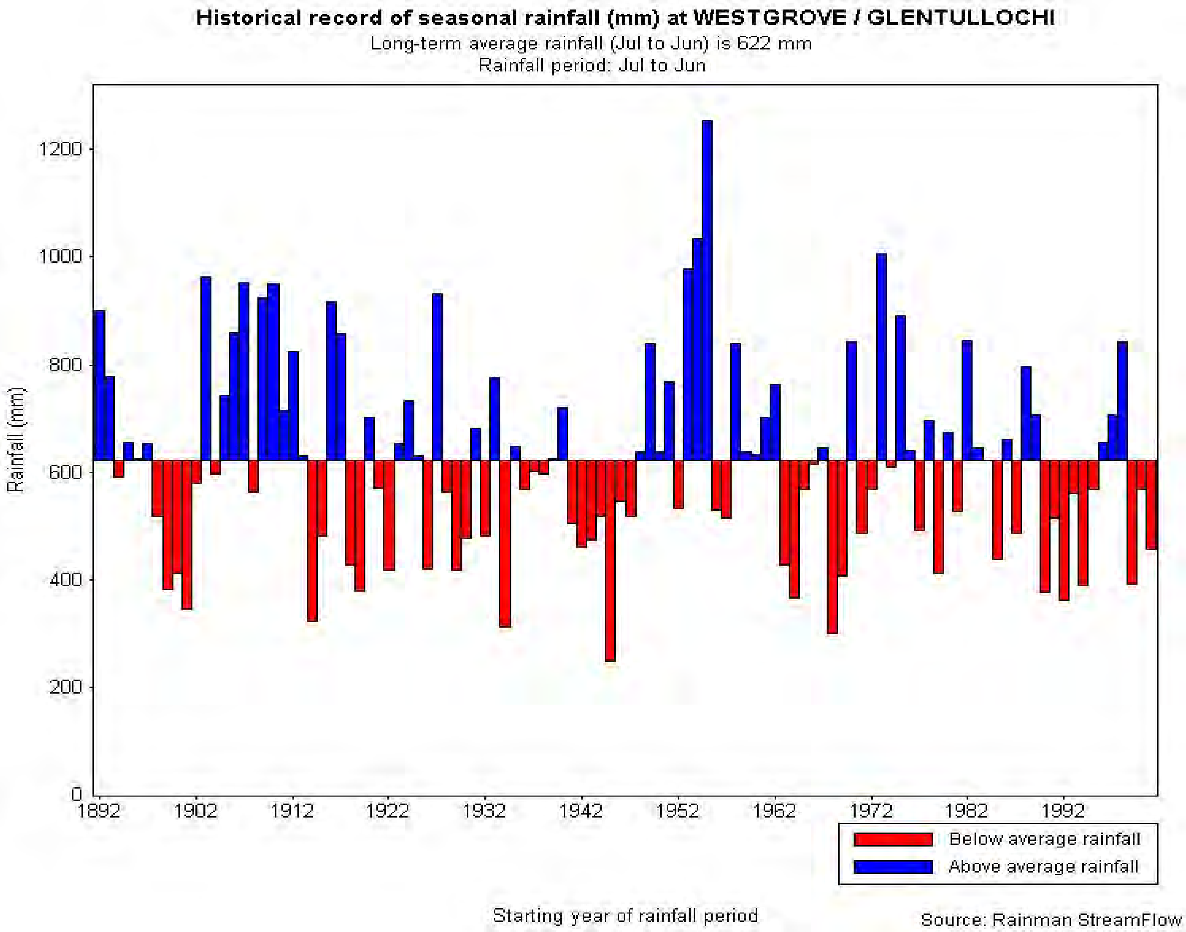


Figure 3.5 Deviation about the long term mean annual rainfall for July to June at Westgrove, with the actual Glentulloch data appended from 1994 to 2002.

3.2.4.2 ***Recent Drought Periods at Glentulloch***

Seasonal (6 month) droughts have a frequency of 22 in 87 years, yet severe drought occurred prior to the trial between August 1991 and January 1992 and again from October 1992 to May 1993. A major (12 month) drought has a historical frequency of 18 in 87 years around Injune. An extended (24 month) drought has a frequency of only 7 in 87 years yet severe drought occurred for 40% of the time between the period of March 1991 to June 1993.

Hence, like Keilambete, the period leading into the start of the trial at Glentulloch was extremely dry by historical standards.

4 Climate

Climatic conditions during the trials were not unusual, with winter frosts and short summer heatwaves. Conditions did not lead to serious outbreaks of pests or diseases. There were no cyclones or tornados of note and the only bushfire was a small one at Glentulloch which skirted the southern edge of the trial site on 17 November 1999. This fire burnt out much of paddock 8 (cleared, moderate grazing pressure rep 2) but rain fell soon after and the pasture recovered rapidly. The cattle were only moved out for a few days. Hence the major climatic information to study is the rainfall received and its seasonal distribution.

4.1 Southern Oscillation Index (SOI)

During our trials, the Southern Oscillation Index (Partridge 1994) which has some influence on regional rainfall in Queensland, varied greatly (Figure 4.1). It was below –5 each month (indicating a high probability of below average summer rainfall) for much of 1994/95, below –10 in 1997/98, and strongly positive in mid-1998 to 1999 when good autumn rains fell. It then fell steadily until below –5 again in late 2001 and remained low for all 2002 until the end of the trial. When smoothed out to moving 3-monthly means the short term jumps are removed to show this pattern more clearly (Figure 4.2).

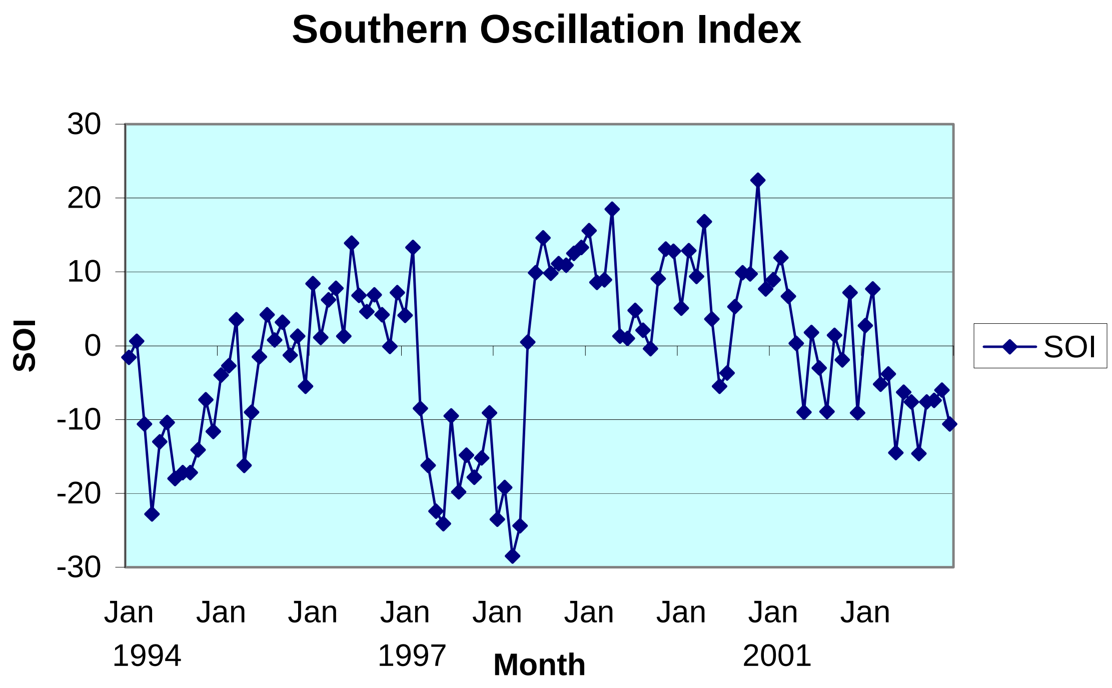


Figure 4.1 Variation between 1994 and 2002 in the monthly average SOI.

Rainman v4.3 also shows (Figure 4.3) that our current ability to predict in advance next summer's rainfall (Nov-Mar), when next year's grazing pressures were being determined in advance in autumn (May-Jun), was not reliable at Anakie, as eventual rainfall at our sites showed. Historically, confident prediction can only be had when the SOI is consistently positive, indicating good rains next summer, or falling rapidly which foretells of poor rains next summer at Anakie. During our trials, the SOI was never consistently positive in autumn but did fall rapidly sometimes, particularly during the drought prior to the start of the trials. At Glentulloch there is no skill gained by using SOI phases at any time in autumn to predict next summer's rain according to Rainman.

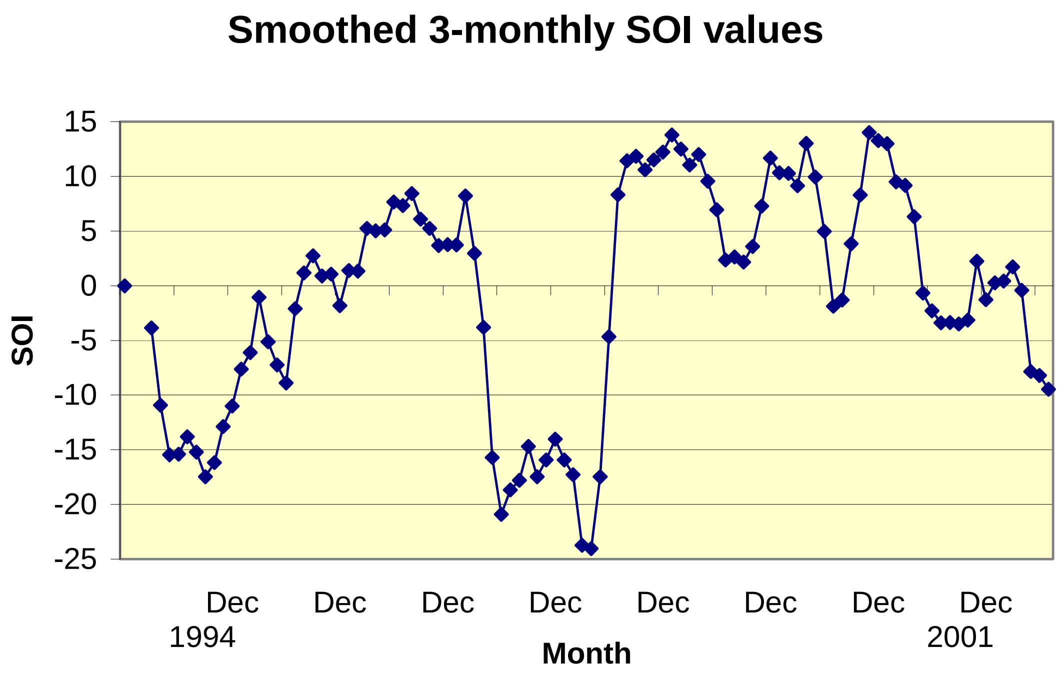


Figure 4.2 Smoothed 3-month running mean of the SOI from 1994 to 2002.

Chance of rainfall at ANAKIE / KEILAMBETE
Analysis of historical data (1889 to 2001) using SOI Phases: May to Jun Leadtime of 4 months
The SOI phases/rainfall relationship for this season is statistically doubtful because KW test is above 0.9 but Skill Score (-1.2) is below 7.6 (p = 0.44).
Chance result or real skill ? Help

Rainfall period: Nov to Mar	SOI falling	SOI negative	SOI neutral	SOI rising	SOI positive	All years
% yrs with at least 803 mm	0	0	0	10	14	5
600 mm	4	19	15	29	27	20
500 mm	13	31	25	52	50	36
400 mm	48	44	55	52	73	54
300 mm	57	69	80	68	86	71
200 mm	78	75	100	87	95	88
150 mm	91	94	100	97	95	96
% yrs above median 421 mm	39	38	45	52	73	50
KS/KW probability tests	KS=0.95	KS=0.26	KS=0.49	KS=0.85	KS=0.92	KW=0.91
Significance level	*	Not significant	Not significant	Not significant	#	
Years in historical record	23	16	20	31	22	112
Highest recorded (mm)	618	746	775	1,095	1,129	1,129
Lowest recorded (mm)	116	123	208	60	122	60
Median rainfall (mm)	345	349	406	504	498	421
Average rainfall (mm)	345	402	431	466	528	438

Figure 4.3 Output capture from RAINMAN ver. 4.3 showing that statistical confidence from using SOI phase data in late autumn (May-June) to predict next summer's rain at Anakie is generally poor.

The greyed central columns lack an adequate degree of confidence. Only when the SOI is consistently positive (>+5) or falling rapidly (a drop of 7 units to below at least –3) over 2 consecutive months is the measure significant.

Hence, from an historical perspective, our seasons should have tended to be drier than the long term pattern of rain, and they generally were. It certainly was not an abnormally wet run of years and so the results would not be biased by better than normal seasons.

4.2 Rainfall

4.2.1 Ironbark site

Details of the monthly rainfall prior to and during the trial are given on the next page (Table 4.1) and compared to long term records from nearby Anakie. Figure 4.4 shows that mid-summer rain (January–March) was well above the median only in 1997 but was well below in 1996 and 1998, after a dry summer prior to the trial starting. The trial here ran from mid-1994 to mid-2001 and did not experience the extended dry conditions that have occurred in 1992 to late 1994.

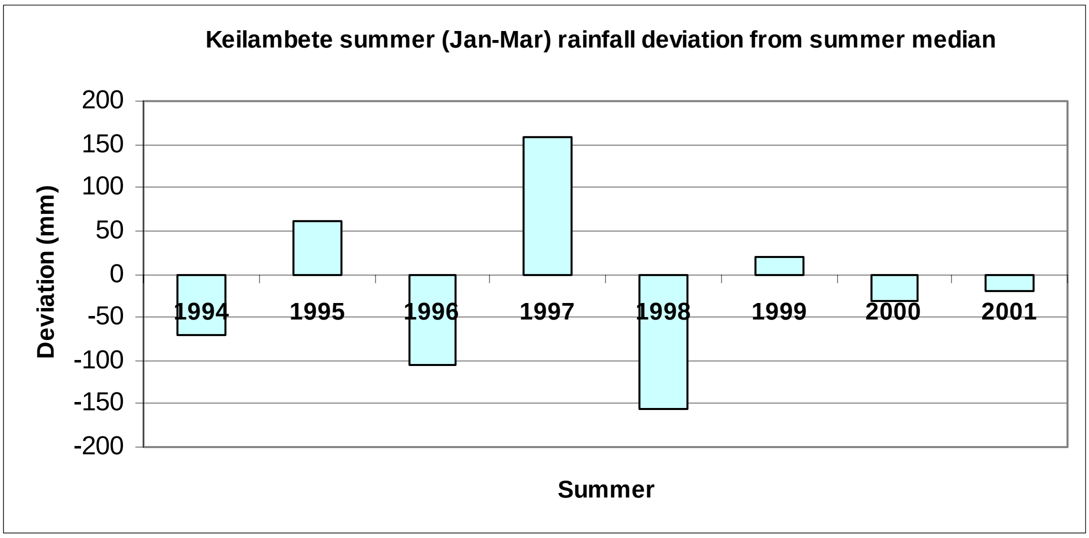


Figure 4.4 Summer rainfall deviation from median at the Keilambete grazing trial site.

Over the trial period we have seen some very wet and some very dry seasons (see Figure 4.5 for seasonal rainfall). Some events of significance are:

- For November 2000, the monthly rainfall was in decile 10 – over 250mm of rain fell.
- A dry winter at Keilambete during 1999 saw all cattle lose weight irrespective of grazing pressure.
- Winter of 1998 was the complete opposite – green feed was present all year round (May rainfall was decile 9, September was decile 10).
- Summer 1998 was very dry (February rainfall was in decile 3, March was decile 1).
- 1997 summer was very wet at Keilambete.
- Rainfall to the 12 months to June 1997 was in decile 9 at Keilambete (774mm).
- During the 1996 / 1997 summer there was a storm at Keilambete that approached the 100 year return period for both 6 (276mm/hr) and 30 minute (154mm/hr) events.
- The period leading into the start of the trial was extremely dry for an extended period.

Table 4.1 Monthly rainfall details for Keilambete (mean of 8 rain gauges).

(A) Keilambete site - rainfall summary

(Data in millimetres) * = from homestead

Year	*July*	*Aug*	*Sept*	*Oct*	*Nov*	*Dec*	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*June*	*Annual*
1993-94	19*	90	60	20	136	5	20	25	146	0	0	5	526*
1994-95	0	0	0	17.8	3.5	34.6	128.7	192.9	0	53.9	40.1	0.4	471.9
1995-96	1	30.2	2.7	69.9	60.5	35.6	136.7	9.5	8.5	48.6	52.7	4.3	460.2
1996-97	0.6	29	20.9	100.8	67.4	128.7	58.2	181	181.1	3.3	56.1	1.4	828.5
1997-98	0	17.4	17	16.2	85.8	88.2	73.6	31.6	0.4	86.8	19	46.4	482.4
1998-99	9.7	184.1	30.2	92.6	127.3	100.3	141.8	79.9	59.9	9.6	10.5	6.4	852.3
1999-00	11.3	5.3	3.9	33.5	105.8	28.3	77.4	150.5	2.2	100.2	56.4	57.6	632.4
2000-01	7.6	40.2	0.5	52.3	261.6	114.8	73.9	106.3	60.8	27.4	0	0	745.4

(B) Seasonal rainfall

Year	Winter (Jy-Se)	decile	Spring (Oc-De)	decile	Summer (Ja-Mr)	decile	Autumn (Ap-Ju)	decile	Year	decile
1993-94	169	9	161	5	191	4	5	1	526.0	3
1994-95	0	1	55.9	1	321.6	7	94.4	6	471.9	3
1995-96	33.9	4	166	5	154.7	2	105.6	6	460.2	**2**
1996-97	50.5	5	296.9	9	420.3	9	60.8	4	828.5	8
1997-98	34.4	4	190.2	6	105.6	2	152.2	8	482.4	3
1998-99	224	10	320.2	8	281.6	6	26.5	2	852.3	**9**
1999-00	20.5	3	167.6	5	230.1	5	214.2	9	632.4	6
2000-01	48.3	4	428.7	9	241	4	27.4	1	745.4	7
Long term mean	72		191		288		105		658	

(C) Anakie Decile values

Month	**Lowest**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Highest**
July	0	0	0	2	6	10	18	29	43	75	299
Aug	0	0	0	2	5	10	15	22	40	65	198
Sept	0	0	0	0	5	8	15	25	44	62	123
Oct	0	1	6	16	22	27	38	57	72	97	239
Nov	0	7	16	29	37	44	53	69	85	133	311
Dec	0	12	28	40	54	66	85	108	135	192	533
Jan	0	18	37	55	68	85	107	139	168	214	547
Feb	0	13	30	41	61	76	100	123	188	257	712
Mar	0	4	14	21	33	48	61	81	121	192	283
Apr	0	0	0	5	15	23	35	49	62	95	228
May	0	3	3	6	14	23	30	44	63	98	216
June	0	2	2	4	10	20	29	42	55	91	270
YEAR	**218**	**399**	**445**	**509**	**561**	**612**	**649**	**724**	**810**	**979**	**1690**

(D) Anakie 111yrs records **Seasonal Deciles** ex Rainman 3.3 Sep '00

Season	Lowest	1	2	3	4	**5**	6	7	8	9	Highest
Jy-Se	0	5	13	24	37	53	66	88	124	175	462
Oc-De	13	79	101	121	145	173	193	222	263	339	671
Ja-Mr	53	101	143	177	206	261	289	338	416	541	1013
Ap-Ju	1	24	36	51	65	86	103	128	169	229	514

"Will it rain" (Partridge 1994) says "Deciles divide a set of recorded rainfalls (monthly, seasonal or annual) into 10 groups. The lowest 10% of falls belong to decile range 1, the next lowest to decile range 2 and so on, up to the highest 10% of recorded falls, which belong to decile range 10.
The top of decile range 5 is the median."

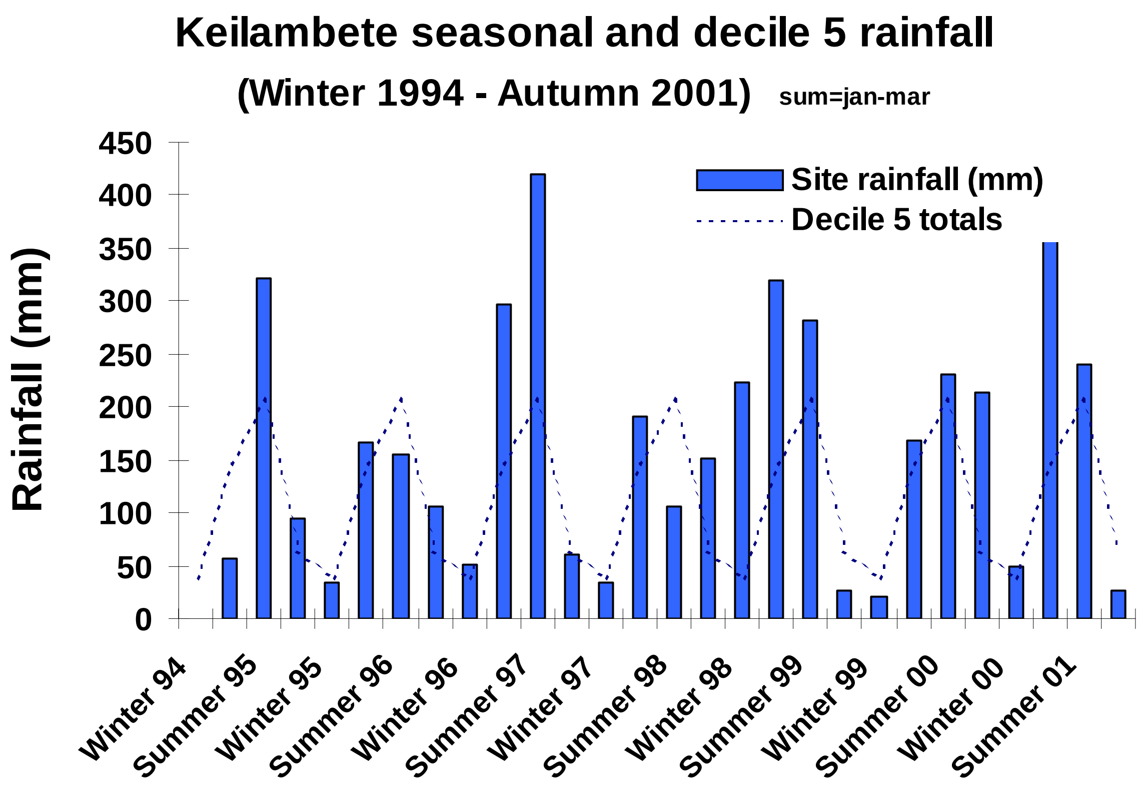


Figure 4.5 Seasonal and median (decile 5) rainfall at Keilambete. (NB Summer = January–March).

4.2.2 **Poplar box site**

As at Keilambete, summer rainfall drives the pasture growth here and during the 8 years of research at this site, only the last one in 2001/02 was notably dry. The summer of 1999 was significantly wetter than average (Figure 4.6).

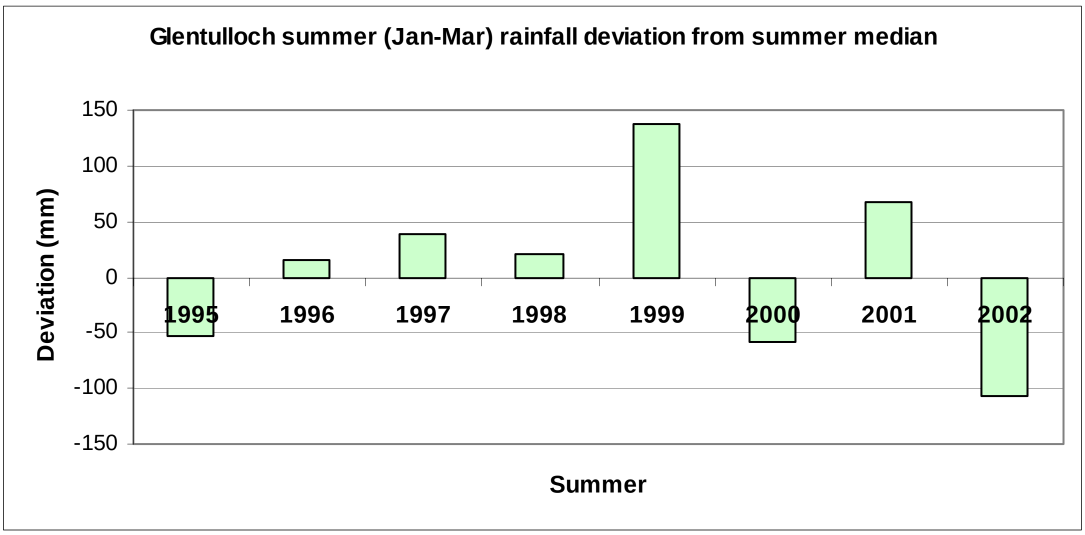


Figure 4.6 Mid-summer rainfall deviations from the long term median at Glentulloch during the trial.

Details of the monthly rain and long term decile values are shown next page (Table 4.2).

Table 4.2 Monthly rainfall details for Glentulloch (mean of 7 rain gauges).

(A) **Glentulloch site - rainfall summary** avge of 9 gauges
(Data in millimetres) * = homestead

Year	*July*	*Aug*	*Sept*	*Oct*	*Nov*	*Dec*	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*June*	*Annual*
1993-94	29*	8	95	20	77	71	27	106	113	2	0	9	557*
1994-95	0	0	5	72.9	42.1	26.3	75.9	81	16.2	29.1	30.2	12.9	391.6
1995-96	3.4	0	26	74	67.4	56.9	184.1	32.8	24.3	39.5	50.8	11.5	570.7
1996-97	24.5	57.5	33.7	101	50.7	57.7	99.6	99.1	66.8	25.6	37.6	0	653.8
1997-98	0.9	0	11.4	71.8	89.5	97.7	145.5	65.3	36.1	109.3	46.4	32.6	706.5
1998-99	42.0	27.0	144.7	46.4	49.4	66.9	173.6	99.1	91.3	31.4	27.1	44.8	843.7
1999-00	11.3	5.7	1.5	42.8	18.9	59.7	66.6	95.1	5.2	42.2	29.8	12.6	391.4
2000-01	0	54	0	84.5	98.9	24.3	165.8	103.7	23.3	14	0	0	568.5
2001-02	77.8	0	0	31.3	101.7	18.1	26	92.7	0	47.9	11.9	48.9	456.3

(B) **Seasonal rainfall**

Year	Winter (Jy-Se)	decile	Spring (Oc-De)	decile	Summer (Ja-Mr)	decile	Autumn (Ap-Ju)	decile	Year	decile
1993-94	132	9	168	4	246	6	11	1	557.0	4
1994-95	5	1	141.3	3	173.1	4	72.2	5	391.6	2
1995-96	29.4	2	198.3	6	241.2	6	101.8	7	570.7	5
1996-97	115.7	9	209.4	7	265.5	7	63.2	4	653.8	7
1997-98	12.3	4	259	9	246.9	3	188.3	9	706.5	7
1998-99	213.7	10	162.7	4	364	9	103.3	7	843.7	**9**
1999-00	18.5	2	121.4	2	166.9	6	84.6	7	391.4	2
2000-01	54	5	207.7	7	292.8	7	14	1	568.5	5
2001-02	77.8	6	151.1	3	118.7	2	108.7	7	456.3	3
Long term mean	80		196		249		109		634	

(C) **Westgrove** Upper Decile values

Month	**Lowest**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Highest**
July	0	0	3	8	13	17	31	36	47	79	206
Aug	0	0	0	5	10	15	20	27	38	52	123
Sept	0	0	1	5	12	18	20	33	46	61	172
Oct	0	7	18	23	30	39	48	59	72	96	226
Nov	0	14	20	27	37	47	62	78	108	132	208
Dec	0	20	39	53	62	78	88	100	125	148	326
Jan	0	21	32	45	58	67	88	108	140	214	354
Feb	0	15	27	35	51	62	84	107	135	192	383
Mar	0	4	15	23	37	43	54	78	110	188	412
Apr	0	0	0	6	13	27	37	46	63	98	304
May	0	0	3	8	16	22	32	37	56	80	277
June	0	0	3	7	13	21	30	39	71	82	306
YEAR	**232**	**390**	**437**	**496**	**567**	**616**	**691**	**719**	**789**	**889**	**1384**

(D) **Westgrove** 110 yrs of records **Seasonal Deciles**

	Lowest	1	2	3	4	**5**	6	7	8	9	Highest
Jy-Se	0	19	32	40	51	64	79	95	106	180	308
Oc-De	45	97	126	153	176	191	202	232	253	294	512
Ja-Mr	43	89	127	172	204	226	262	298	333	420	762
Ap-Ju	0	23	40	54	66	86	101	135	152	237	491

Some events of significance during the project at Glentulloch were:

- The rainfall in the months of August and October in 2000 was in the Decile 10 range.
- Winter and spring of 1999 was dry (well below median rainfall) following a wet summer and autumn.
- Summers of 1999-2000 and 2001-02 were very dry (Figure 4.7).
- Spring 1996 and summer 1997 yielded good falls with above average rainfall.
- Rainfall for the 12 months to June 1997 was rated as decile 8 (649mm).
- Of the 26 3-month seasons, 6 have been in decile 9 or 10 (very wet years), across all seasons, while 4 seasons were rated as in decile 1 or 2 (very dry years).
- The 1996-97 season experienced a high intensity event that approached the 10 year return period for 6 minutes (132mm/hr) and a 30 year return period for 30minutes (154mm/hr).
- The trial generally ended on a very dry trend after a generally improved situation over the first 4 years.

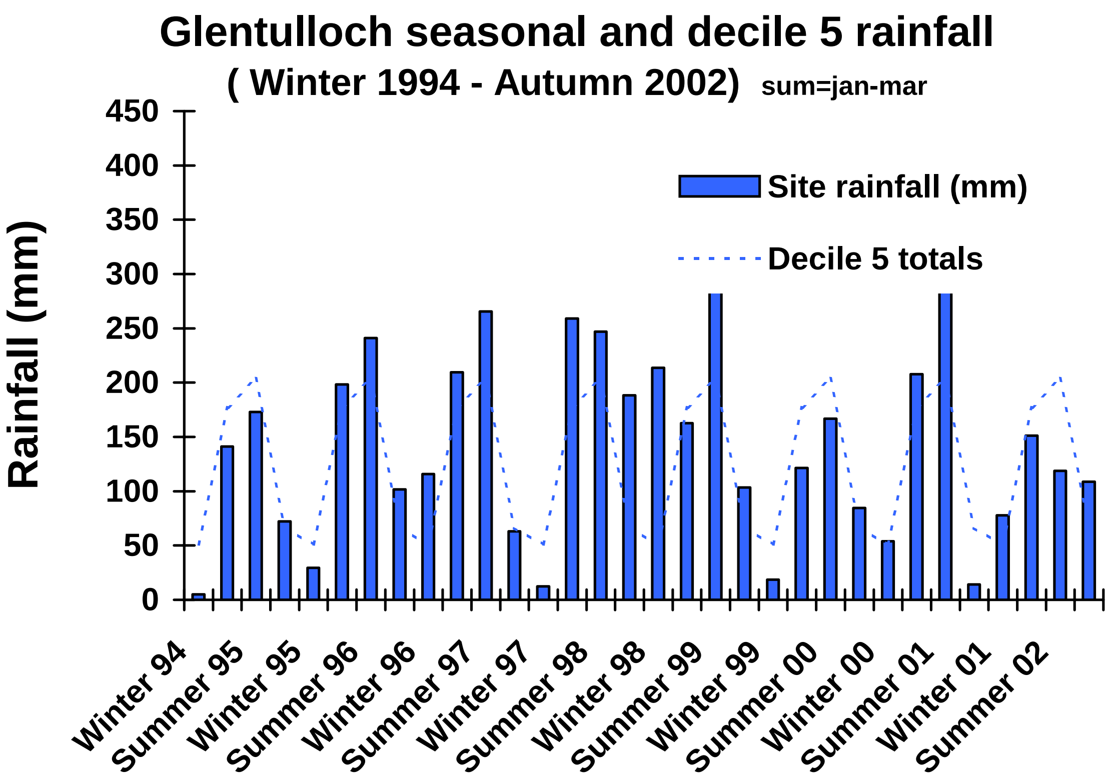


Figure 4.7 Seasonal and median (decile 5) rainfall at Glentulloch. (NB. Summer = January–March).

Like Keilambete, the period leading into the start of the trial at Glentulloch was extremely dry. The annual disparities between the two sites in the rainfall that each experienced are graphically illustrated in Figure 4.8. The Glentulloch site tends to have a lower total annual rainfall than Keilambete and falls during the trials were generally like that except in 1995/96 and 1997/98 when summer rains at Keilambete were much lower than average (Figure 4.4).

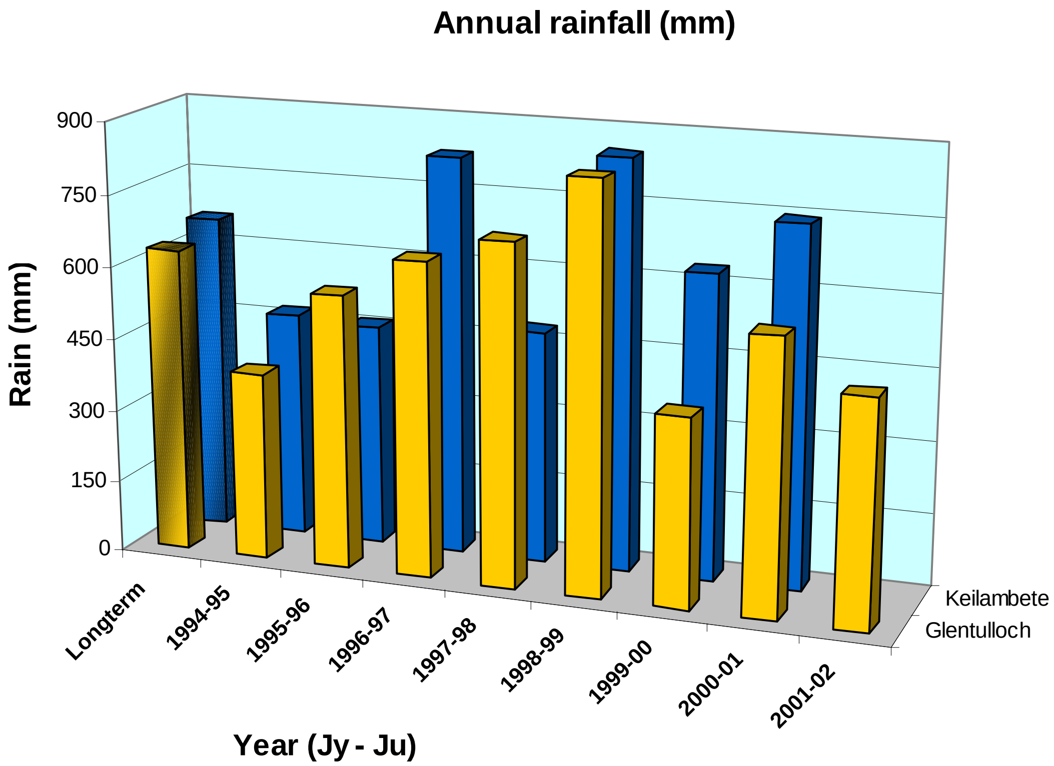


Figure 4.8 Annual rainfall totals (Jul-Jun) for both trial sites compared to the long term average for nearby official stations, Anakie (back row) and Westgrove (front row).

5 Tree and shrub dynamics

5.1 Ironbark site

5.1.1 Grazing trial

5.1.1.1 *Abstract*

Tree basal area and density decreased slightly in the treed plots from 1995 to 1999. From 1995 to 1997 the decrease was most likely due to poor seasonal conditions. Grazing pressure had no effect on tree basal area or density in the treed or treeless plots. Use of Velpar for tree killing in 1994 continued to cause a small but significant reduction in tree basal area and density from 1995 to 1999. The expected pasture growth response from the killing of trees did not occur.

5.1.1.2 *Background*

Tree and shrub monitoring was conducted to gain an understanding of woodland regeneration and dynamics under treed and chemically induced treeless pastures when exposed to different grazing pressure. This was an important aim of the project. Additionally, tree and shrub dynamics are a major factor affecting pasture ecology and needs to be understood for that purpose also. Tree clearing has not been a common practice in Ironbark country around Rubyvale but is increasing nowadays.

5.1.1.3 *Methods*

The initial size and density of the trees and shrubs in all the trial paddocks was assessed using the Bitterlich stick technique (Forge & Pelger 1997). That provided an estimate of the stem basal area of all trees for each paddock. Later, a formalised system of regular recordings was undertaken about every 2 years using the TRAPS band transect methodology (Back *et al.* 1997). Details are given in Appendix D and Section 2. TRAPS recordings at the Ironbark site were eventually done on July 1995, October 1997 and September 1999. TRAPS is a detailed recording system which relies on the ability to relocate previously recorded plants. The method only aims to sample a small portion of the paddock population. Adequate sample numbers are based on having at least 30 individuals in each particular species and size class.

Details of the method used at this site are:

- sampling was undertaken along permanent transect lines, which total 450m in length per paddock in the grazing trial
- the recording width was 2m either side of the central line and each segment is 50 long.

Details recorded for each plant were:

- species
- location,
- stem number (greater than 8 is recorded as 9 and means multiple)
- stem circumference measured at 30cm from the base of the plant
- plant height
- any specific notes

The data is stored in a database, analysed by proprietary software, and edited in the file during each subsequent recording visit.

5.1.1.4 *Results*

5.1.1.4.1 Original woodland structure

Silver-leaved ironbark (*Eucalyptus melanophloia*) is by far the main species at the Ironbark site with a scattering of bloodwood (*Corymbia erythrophloia* syn. *E. erythrophloia*) and prickly pine (*Bursaria incana*). Ghost gums (*C. papuana*) are found in the main waterways. There are few other understorey shrubs. Apart from waterway trees, all trees and shrubs in the paddocks to be treeless were stem injected with Velpar® in March 1994. Small seedlings were hit with a squirt of Velpar on the ground beside them.

Tree and shrub recordings were done in July 1995, October 1997 and September 1999 using the TRAPS methodology. For data analysis, plants were grouped into seven height classes, namely <0.5, 0.5-1.5, 1.5-4, 4.1-7, 7.1-10, 10.1-15 and > 15 m tall.

E. melanophloia is a medium-sized tree up to 20 m tall with a short trunk and a deep crown. Regrowth from butt suckers occurs following mechanical clearing, particularly on the light soil types. Regrowth from seed occurs when isolated 'seed' trees are left after clearing, and again the problem is greater on light soils (Anderson 1993). Anecdotal evidence shows that there have been very few establishments of silverleaf ironbark in central Queensland over the last 15 years. Experience would suggest that not only the dry conditions but a lack of seed and a lack of disturbance has been responsible. There were obviously large scale establishments in the 1950's and some in the 70's. This came about probably due to a large seed set and continuing wet conditions. Seeds are set irregularly and it is thought that it is only the current season's seeds which make up the seed bank. However the seed rain can be up to 0.5 million viable seeds/ha (Burrows and Burrows 1992).

C. erythrophloia is a small to medium tree up to 12 m tall with a short trunk and spreading crown. It is one of the few *Corymbias* (bloodwoods) to root sucker when the tree is damaged (Anderson 1993). Seed ecology is thought to be similar to *E. melanophloia*.

B. incana is a loosely growing shrub or erect small tree up to 6 m tall (Milson 1995). Regrowth occurs from butt suckers following damage to the tree. It is moderately palatable and cattle often break down branches to browse the leaves. It seeds readily.

5.1.1.4.2 Grazing effects on treed areas

Grazing pressure had no effect on tree and shrub density or basal area

5.1.1.4.2.1 All trees and shrubs

- total density and structure mirrored that of *E. melanophloia*
- total density and basal area decreased slightly from 1995 to 1999
- from 1995 to 97 plant density reduced by 8% and basal area reduced by 15%
- grazing pressure had no significant effect on total density or basal area
- there was an establishment of 145 plants/ha of which 64 were *E. melanophloia*

In 1995, 1997 and 1999, total density and structure mirrored that of *E. melanophloia* (see Table 5.2). The majority of plants (58%) were less than 0.5 m tall, and plant density decreased as height class increased. Basal area had the largest proportion (74%) for plants in the height class 4-15 m tall (see Appendix D).

Table 5.1 Total density and basal area for the treed treatments in 1995, 1997 and 1999.

Treed	Density (plants/ha)			Basal area (m^2/ha)		
Grazing pressure	**1995**	**1997**	**1999**	**1995**	**1997**	**1999**
Low	2135	1872	1931	5.82	6.44	5.71
Medium	2410	2456	2189	8.99	7.43	7.07
High	1710	1663	1584	8.18	4.53	5.53
Average	2085	1997	1901	7.67	6.13	6.10

In 1997 plant density reduced by 8% and basal area reduced by 15% due to the decrease in *E. melanophloia*. The density decrease occurred in plants less than 0.5 m tall, while the basal area decrease occurred across all height classes except 4-7 m tall. Deaths occurred across all height classes, with the majority (204 plants/ha) occurring in plants less than 0.2 m tall. Grazing pressure had no significant effect on total density or basal area. There was an establishment of 145 plants/ha of which 64 were *E. melanophloia*. Maintenance of density and basal area from 1997 to 1999 is a result of improving seasonal conditions.

5.1.1.4.2.2 Eucalyptus melanophloia

- *E. melanophloia* is the main species at the site by density (1406/ha in 1999) and basal area (4.61 m^2/ha) (Table 5.2)
- 50% of the plants present are less than 0.5 m tall
- 10% of the plants present (those 4-15 m tall) contribute 75% of the total basal area
- from 1995 to '97 density reduced by 9% due mainly to deaths of plants <0.2 m tall,
- from 1995 to '97, 64 new ironbark plants/ha established
- from 1995 to '97 basal area reduced by 27% due to deaths of plants >7 m tall
- changes in *E. melanophloia* density and basal area mirror changes in total density and basal area at the site
- wide height class range of *E. melanophloia* ensures that conventional clearing encourages regrowth
- potential exists for basal area increase at the trial site
- grazing pressure had no effect on density or basal area

E. melanophloia is the main species at the site accounting for 81% of the total density and 81.7% of the total basal area in 1995. Variation between replicates was high with the percentage of total density varying from 47.8-94.3% and the percentage of total basal area varying from 65.6-98.0%. In 1997, *E. melanophloia* accounted for 78.8% of the total density (range 42.8-93.8), and 77.2% of the total basal area (range 65.6-98.0). There was a small reduction in density and basal area between the two recording dates due to below average rainfall in years 94/95 and 95/96, with near drought for much of 94/95. The high grazing pressure treatment had a 51% decrease in basal area from 1995 -97 due largely to deaths in plants 7.0-10 m tall. However, there was no statistically significant relationship with grazing pressure. Maintenance of density and basal area from 1997 to 1999 is a result of improving seasonal conditions.

Table 5.2 Density and basal area of *E. melanophloia* for the treed treatments in 1995, 1997 and 1999.

Treed	Density (plants/ha)			Basal area (m^2/ha)		
Grazing pressure	**1995**	**1997**	**1999**	**1995**	**1997**	**1999**
Low	1786	1556	1564	4.71	5.01	3.70
Medium	1453	1373	1295	7.68	5.76	5.74
High	1502	1390	1358	7.20	3.55	4.39
Average	1580	1439	1406	6.53	4.77	4.61

The largest proportion of *E. melanophloia* plants (57%) were less than 0.5 metres tall, with the numbers of plants decreasing as height class increased (see Appendix D). In 1995, 79% of the plants were less than 1.5 m tall yet the small percentage of plants in the height range 10-15 m tall had 29% of the basal area (the largest proportion of any height class). Plants between 4 and 15 m tall had 71% of the total basal area while only accounting for 9.4% of the total density. Grazing treatment means also followed the same trend for density and basal area (see Appendix D).

The total density across all height classes had reduced by 9% from 1995 to 97. In 1997 only 46% of *E. melanophloia* plants were less than 0.5 m tall. The death rate in this height class was 16% (247 plants/ha) of the 1995 population. Deaths occurred across all height classes less than 15 m tall, but the majority (162 plants/ha) was from those less than 0.2 m tall. Death rate decreased as height class increased. Increasing numbers in height classes 0.5-1.5 m and 1.5-4 m was due to growth of existing plants, placing them in the bigger height class. However, the proportion of plants less than 1.5 m tall (78%) is no different to those in 1995 (79%). An apparent establishment of 64 plants/ha maintained the numbers of smaller plants although this was due to only 4 plants per 150m transect.

Basal area in 1997 for a height class was greatest in the height range 4-7 m (25%). Plants between 4 and 15 m tall provided 72% of the total basal area while being 8.5% of the total density. Total basal area reduced by 27% from 1995 to 1997. This reduction occurred in the plants greater than 7 m tall and is explained by the death rates occurring there. The increase in numbers of plants which are 0.5-4 m tall was accompanied by a small decrease in basal area. Basal area and density stayed relatively constant from 1997 to 1999. Management implications are discussed later.

5.1.1.4.2.3 Bursaria incana

- *B. incana* was the next most common woody species after *E. melanophloia*
- 72% of the plants present (178/ha) are less than 0.5 m tall
- 5% of the plants present (4-10 m tall) contribute 58% of the total basal area
- from 1995 to 97 density reduced by 5% due mainly to deaths of plants <0.2 m tall,
- from 1995 to 97, 13 plants/ha established
- from 1995 to 99 total basal area remained constant
- in 1995, 65% of the basal area was contributed by the height class 7-10 m tall
- in 1997, 58% of the basal area was contributed by the height class 4-10 m tall
- *B. incana* was stable through dry conditions compared to *E. melanophloia.*

Table 5.3 Density and basal area of *B. incana* for the treed treatments in 1995, 1997 and 1999.

Treed	Density (plants/ha)			Basal area (m^2/ha)		
Grazing pressure	**1995**	**1997**	**1999**	**1995**	**1997**	**1999**
Low	208	192	222	0.22	0.30	0.26
Medium	175	181	158	0.01	0.01	0.00
High	73	63	64	0.27	0.21	0.23
Average	152	145	148	0.16	0.17	0.16

B. incana is a major species at the site, accounting for 8.9% of the total density and 4.7% of the total basal area in 1995. It was stable across the four years of monitoring (see Table 5.3) and accounted for 9.4% of the total plant density and 5.6% of the basal area in 1997. The dry conditions did not affect *B. incana* to the same extent as *E. melanophloia*. Grazing pressure had no significant effect on the density of *B. incana.* The medium grazing pressure treatments had a low basal area because there were no large plants.

In 1995, the largest proportion of *B. incana* plants (72%) was in the less than 0.5 m tall class with the numbers of plants per class decreasing as height increases (see Appendix D). Basal area had the largest class proportion (65%) for those plants in the height range 7-10 m tall, which only accounted for 6% of the total plant numbers. Grazing treatment means also followed the same trend for density and basal area.

In 1997 only 61% of *B. incana* plants were less than 0.5 m tall while the total density had remained constant. There were deaths of 15 plants/ha in this height class and an establishment of 13 plants/ha. Some plants in each class up to 7 m tall grew into the next height class. Plants in the height class 7-10 m tall had a death rate of 20%, and 41% of the plants reduced in height to less than 7 m tall. This reduced the basal area in this height class by 45%, and increased basal area for plants in the height class 1.5-7 m tall by 374%. Plants in the height class 4-10 m tall now contribute 58% of the total basal area. However, plants in this height class only accounted for 5% of the total plant numbers.

5.1.1.4.2.4 Corymbia erythrophloia

- *C. erythrophloia* has the highest basal area after *E. melanophloia*
- plant density is evenly distributed through height classes up to 7 m tall
- 40% of the plants present (4-15 m tall) contribute 88% of the total basal area
- from 1995 to '97 density reduced by 9% due mainly to deaths of plants <0.2 m tall,
- from 1995 to '97, 2 plants/ha established
- from 1995 to '97 total basal area increased by 26%
- *C. erythrophloia* was stable through dry conditions compared to *E. melanophloia.*

C. erythrophloia is a significant species at the site accounting for 4.5% of the total density and 10.1% of the total basal area in 1995. It was stable across the four years of monitoring (see Table 5.4) and accounted for 4.4% of the total density and 14% of the total basal area in 1997. There was a small reduction in density and a small increase in basal area since 1995.

Table 5.4 Density and basal area of *C. erythrophloia* for the treed treatments in 1995, 1997 and 1999.

Treed	Density (plants/ha)			Basal area (m^2/ha)		
Grazing pressure	1995	1997	1999	1995	1997	1999
Low	71	60	70	0.89	1.13	1.75
Medium	149	160	142	1.01	1.37	1.03
High	49	51	45	0.59	0.65	0.70
Average	99	90	85	0.83	1.05	1.16

C. erythrophloia is more consistent than *E. melanophloia* and *B. incana* in the density distribution across height classes for plants less than 7 m tall. Plants greater than 7 m tall decrease in density as height class increases. In 1995, 86% of plants were evenly spread through the height classes <0.5, 0.5 -1.5, 1.5-4 and 4-7 m tall. The majority of basal area (88%), which is from plants 4-15 m tall (see Appendix D), is provided by 39% of the total plants.

In 1997 plant numbers reduced in all height classes less than 1.5 m tall. There were deaths of 10 plants/ha of which 5 were less than 0.2 m tall, and an establishment of 2 plants/ha. There was a slight decrease in density and a small increase in basal area over the four years of monitoring, however the proportion of basal area in each height class remained constant.

5.1.1.4.3 Grazing effects on treeless (Velpared) areas

5.1.1.4.3.1 All trees and shrubs

- structure and changes mirror that of *E. melanophloia*
- there was a death rate of 44% mainly due to residual Velpar applied near small plants
- growth of surviving plants maintained basal area.

In 1995 and 1997, total density, basal area and structure mirrored that of *E. melanophloia*, as occurred in the treed plots (see Table 5.9). In 1995, the majority of plants (79%) were less than 0.5 m tall and plant density decreased as height class increased (see Appendix D). Amongst the 7 height classes, plants 4 to 7 m tall had the largest proportion (29%) of the basal area. Plants between 1.5 and 15 m tall accounted for 88% of the total tree basal area.

Table 5.5 Total density and basal area for the treeless plots in 1995, 1997 and 1999.

Treeless	Density (plants/ha)			Basal area (m^2/ha)		
Grazing pressure	**1995**	**1997**	**1999**	**1995**	**1997**	**1999**
Low	544	280	681	0.43	0.33	0.40
Medium	665	319	484	1.27	1.13	1.12
High	760	258	506	1.69	2.17	2.44
Average	656	286	557	1.13	1.21	1.32

By 1997 plant density fell by 56% due to deaths of plants less than 0.5 m tall (which were mainly *E. melanophloia*). Residual Velpar is thought to be responsible for most of the deaths. Basal area had a slight increase. Basal area did not decrease in line with density because of growth of the surviving plants. The surviving plants were usually close to watercourses where Velpar was not applied. Growth of the surviving plants in this height class ensured that their basal area only had a small decrease (12%). The recruitment in 1997 is from lignotubers and the lack of seedling regeneration is probably due to a limiting seedbank. Total density and basal area were not significantly affected by grazing pressure although basal area steadily increased at high grazing pressure. An increase in density and basal area from 1997 onwards is most likely due to improving seasonal conditions and reduced residuality of the arboricide.

5.1.1.4.3.2 Eucalyptus melanophloia

- *E. melanophloia* is the main species accounting for most of the density and basal area
- the majority of plants are less than 0.5 m tall
- there was a 53% death rate due to residual Velpar and below average rainfall killing plants <0.5 m tall from 1995 to 1997
- density increased from 1997 to 1999
- basal area gradually increased from 1995 to 1999
- potential exist for basal area increase
- Velpar application has been very effective, and residuality has increased the longevity of the treatment.

E. melanophloia is again the main species at the site accounting for 53% of the total density and 50% of the total basal area in 1995. In 1997 it accounted for 54% of the total density and 57% of the total basal area. There was a big reduction (44%) in *E. melanophloia* density in the <0.5 m class due to residual Velpar activity and below average rainfall killing plants (see Table 5.6). However there was an increase in basal area (8%) which occurred in the plants 10-15 m tall.

Table 5.6 Density and basal area of *E. melanophloia* for the treeless plots under different grazing pressure in 1995, 1997 and 1999.

Treeless	Density (plants/ha)			Basal area (m^2/ha)		
Grazing pressure	**1995**	**1997**	**1999**	**1995**	**1997**	**1999**
Low	395	162	472	0.05	0.06	0.18
Medium	356	190	281	0.65	0.36	0.36
High	218	103	158	1.45	1.93	1.98
Average	323	151	304	0.72	0.78	0.84

In 1995 the largest proportion of *E. melanophloia* plants (85%) were less than 0.5 m tall with the numbers of plants decreasing as height class increases (see Appendix D). The largest proportion (41%) by basal area was for plants in the height range 4-7 m tall. This was from a few large trees that were left along watercourses for shade and landscape stability and which the recording transects crossed in several paddocks.

In 1997, 70% of *E. melanophloia* plants were less than 0.5 m tall, while 52% of the basal area was accounted for by plants 10-15 m tall. The density changes are explained by the residual Velpar activity. The original Velpar application gave a 69% kill which was recorded in the 1995 data. The residual Velpar probably went on to kill a further 36% of the 1995 population (below average rainfall is possibly responsible for a death rate of 12%). The total death rate from 1995 to ‘97 equals 44%. Nearly all of this death occurred in plants less than 0.5 m tall. Basal area increased by 8% from 1995 to 97 and is due to growth of trees in the height class 10-15 m tall. An increase in density and basal area from 1997 onwards is most likely due to improving seasonal conditions and reduced residual toxicity of the arboricide.

5.1.1.4.3.3 Bursaria incana

- *B. incana* has the highest density after *E. melanophloia*
- from 1995 to 97 there was a 45% death due mainly to residual Velpar
- there was a 22% decrease in basal area from 1995 to 1997
- the majority of plants are less than 0.5 m tall
- density increased from 1997 to 1999
- basal area was relatively constant throughout the trial.

Table 5.7 Density and basal area of *B. incana* for the treeless plots in 1995, 1997 and 1999.

Treeless	Density (plants/ha)			Basal area (m^2/ha)		
Grazing pressure	**1995**	**1997**	**1999**	**1995**	**1997**	**1999**
Low	104	48	75	0.37	0.25	0.17
Medium	229	101	158	0.09	0.10	0.09
High	148	114	136	0.07	0.07	0.18
Average	160	88	123	0.18	0.14	0.15

B. incana is a significant species in the treeless plots accounting for 23% of the total density and 18% of the total basal area in 1995. In 1997 it still accounted for 27% of the total density and 23% of the total basal area. From 1995 to 97 there was a 34% death rate (see Table 5.7) due to residual Velpar, occurring mainly in plants less than 0.5 m tall. There was a 22% increase in basal area occurring in plants in the height classes less than 0.5 m tall, and 1.5 to 4 m tall.

In 1995 the largest proportion of *B. incana* plants (67%) were less than 0.5 m tall with the number of plants decreasing as height class increases (see Appendix D). 46% of the basal area was found for plants in the height class 7-10 m tall. Grazing treatment means also followed the same trend.

In 1997, only 37% of *B. incana* plants were now less than 0.5 m tall, due to deaths of plants in this height class. This death is thought to be due to residual Velpar because there was negligible death (3%) in the treed treatments. An increase in density and basal area from 1997 onwards is most likely due to improving seasonal conditions and reduced residuality of the arboricide.

5.1.1.4.3.4 Corymbia erythrophloia

- *C. erythrophloia* has the highest basal area after *E. melanophloia*
- from 1995 to 97 there was a 70% death rate due to residual Velpar activity
- deaths occurred only in plants less than 7 m tall.

C. erythrophloia is a common species in the treeless plots accounting for 5% of the total density and 31% of the total basal area in 1995. In 1997 it still accounted for 3% of the total density and 18% of the total basal area. From 1995 to 97 there was a 70% death rate (see Table 5.8) due to residual Velpar, occurring mainly in plants less than 4 m tall, however, basal area was relatively constant.

Table 5.8 Density and basal area of *C. erythrophloia* for the treeless plots in 1995, 1997 and 1999.

Treeless	Density (plants/ha)			Basal area (m^2/ha)		
Grazing pressure	**1995**	**1997**	**1999**	**1995**	**1997**	**1999**
Low	12	6	17	0.00	0.00	0.00
Medium	54	17	25	0.53	0.68	0.67
High	28	3	6	0.10	0.11	0.09
Average	31	9	16	0.21	0.26	0.25

In 1995, the largest numbers of plants (47%) were in the class less than 0.5 m tall with the density of plants decreasing as height class increases (see Appendix D). The bulk of the basal area (55%) was in plants in the height class 1.5-4 m tall. Grazing treatment means also followed the same trend.

By 1997, all deaths that had occurred were from plants less than 7 m tall in 1995 and, of those, 70% were of plants <4m tall. This death is thought to be due to residual Velpar because there was negligible death in the treed treatment. An increase in density and basal area from 1997 onwards is most likely due to improving seasonal conditions and reduced residuality of the arboricide.

5.1.1.4.4 Tree killing effect on all trees and shrubs

Tree killing significantly reduced tree density ($P<0.001$) and basal area ($P<0.01$) in 1995, 1997 and 1999. The original treatment was very effective and the residual Velpar activity ensured that regrowth did not begin to occur until 1999. The treed plots had a gradual decline in density and basal area (Table 5.9). The treeless plots showed a gradual increase in basal area. Density declined markedly in the treeless plots in 1997 because many silver-leaved ironbarks appeared to be dead and were not recorded. However, the lignotubers were still alive and resprouted by 1999. Seasonal conditions did not appear to affect the initial mortality induced by the arboricide (Velpar). In the herbicide-treated plots, an increase in density and basal area from 1997 onwards is most likely due to improving seasonal conditions and reduced residual toxicity (=residuality) of the arboricide.

Table 5.9 Total tree density and basal area in 1995, 1997 and 1999.

	Density (plants/ha)			Basal area (m^2/ha)		
	1995	**1997**	**1999**	**1995**	**1997**	**1999**
Treeless	656	286	557	1.13	1.21	1.32
Treed	2085	1997	1901	7.67	6.13	6.10

5.1.1.5 *Tree/pasture relationship*

The TRAPS data fitted well with our previous experience with tree regrowth but during the early years of the trial, the expected pasture growth response from the killing of the trees did not occur. The classical relationship between tree basal area (a measure of competition, especially for soil moisture) and pasture biomass is one of a declining curvilinear shape (Scanlan & Burrows 1990). To investigate this inconsistency, Paul Back carried out a simple sampling of the Ironbark site property in late November 1997 after a very good spring season. He measured pasture biomass and the accompanying tree basal area for 12 sites (about 1 hectare area) with a range of tree densities on the same land type as our trials.

The samples were taken in commercially grazed paddocks, so the peak pasture yield of about 5000 kg/ha is very good for that district and would indicate that full expression of the pasture's growth potential was there at sampling time. The results are shown in Figure 5.1 and they show a surprisingly shallow slope and a nearly linear relationship with tree basal area.

The small decline in pasture growth due to tree competition was much less than would be expected for a soil type that is comparatively infertile and not very deep (See Appendix B). The relationship is more akin to that from a fertile clay soil near the coast. It still shows some decline in pasture production where the tree basal area was 5-7 square metres per hectare, which was the initial tree density for our site (Table 5.1). That density reduced pasture yield by about 35% (5500kg/ha down to 3500 kg/ha) in Back's samples yet our trial site showed no reduction at all initially (See Figure 5.3 in Section 5). Also of interest was the very small further reduction in pasture yield that occurred as the tree competition doubled from 6 to 12 sq m per hectare.

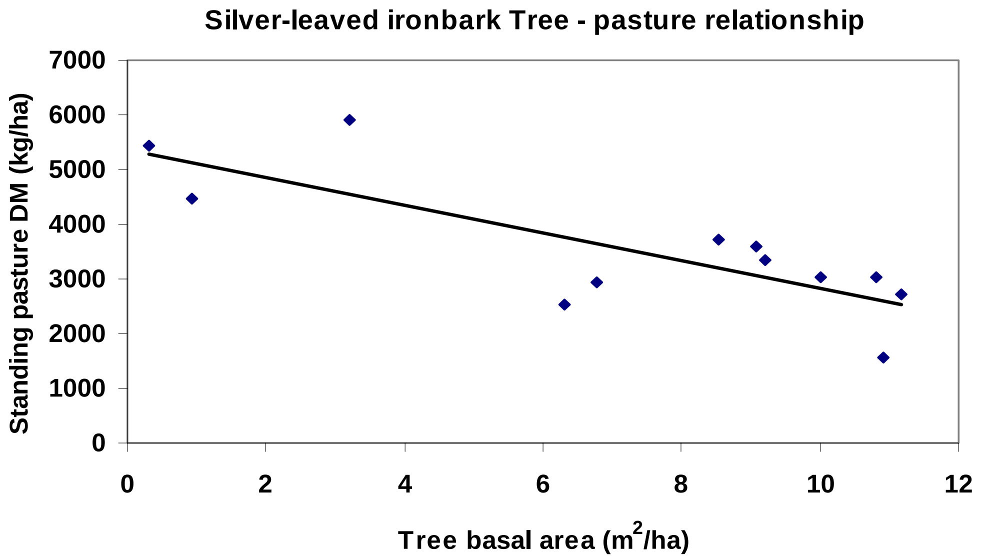


Figure 5.1 Relationship at the Ironbark site between tree competition and pasture biomass in late November 1997.

5.1.1.6 *Discussion*

5.1.1.6.1 Treed plots

There was a small decrease in total basal area and density of *E. melanophloia* over the first three years of monitoring, probably due to dry conditions. This is not consistent with the views of Burrows *et al.* (1998, 2002) or anecdotal evidence that suggests woody plant thickening has occurred. However there was an establishment of 145 plants/ha which is surprising given the strong grass and tree competition which can often prevent recruitment (McIvor 2004). These changes were a reflection of the changes occurring in *E. melanophloia* due to its dominance at the site. *B. incana* and *C. erythrophloia* were quite stable through dry conditions. *E. melanophloia* contributed the majority of the basal area (3.14 m^2/ha) through the plants which are between 4 and 15 m tall. However the majority of plant numbers (1252/ha) are less than 1.5 m tall. Total woody plant density and basal area were unaffected by grazing pressure. While heavy grazing pressure can reduce sucker numbers it is considered an unsustainable practise. Increasing grazing pressure can also contribute to woody thickening by reducing the competitive effect of grass (McIvor 2004).

The understanding of structure has major implications for management. Chemical and mechanical clearing operations target the trees with the majority of basal area, which is those greater than 2 m tall. Trees and shrubs less than this height are either not treated (with chemical control), or barely affected (with mechanical control). While the majority of basal area is reduced, large numbers of shrubs are primed to regrow. Competition for moisture from the taller trees is reduced and the shrubs and small tree seedlings rapidly regrow. While mechanical or chemical clearing is often a cost effective operation, the need for future regrowth management has to be considered when planning the development.

The total basal area (6.10 m^2/ha in 1999) is not as large as reported from other monitoring sites on similar land types in central Queensland (Burrows *et al.* 1997). Burrows *et al.* (1997) have also estimated an annual stem increment of 0.210 m^2/ha/yr for eucalypt woodlands in central Queensland. Quite possibly then, the treed plots would have increased further in basal area prior to the trial's termination in 2001.

5.1.1.6.2 Treeless plots

Similar to the treed plots, *E. melanophloia* accounts for most of the density and basal area, with *B. incana* having the next highest density and *C. erythrophloia* having the next highest basal area. Deaths (mean 56%) occurred in all species from 1995 to 97 and were mainly due to residual Velpar. The majority of deaths occurred in plants less than 0.5 m tall, and were mainly of *E. melanophloia.* Total basal area (1.32 m^2/ha) was maintained from 1995 to 1999 due to growth of surviving plants. Total density and basal area were unaffected by grazing pressure.

The herbicide treatment was very effective in reducing basal area by killing the taller trees. Shrubs also had a high death rate because of the Velpar applied on the ground. The residual potency of squirts to the ground beside tree seedlings increased the longevity of treatment response until 1997. The recruitment in 1997 was from lignotubers and the lack of seedling regeneration is probably due to a limiting seedbank. The seed source had been removed, the seedbank is short-lived, the seed has poor transport mechanisms and external sources are limited by infrequent flowering and seeding. Additionally, lack of seedling recruitment may be due to strong grass competition (McIvor 2004). Seasonal conditions did not appear to affect the initial mortality induced by the arboricide. In the treeless plots, an increase in density and basal area from 1997 onwards is most likely due to improving seasonal conditions and reduced residuality of the arboricide.

5.1.2 Burning trial

5.1.2.1 *Abstract*

Burn severity decreased as foliage height increased. Trees in the 10-15 m tall height class had only 70% of their foliage browned by the fire. Within 5 months of the burn most trees and shrubs had regained their pre-fire foliage. Total tree density and basal area declined significantly between 1995 and 1999 in the plots that had been subjected to herbicide in 1994. Regular burning had no effect on density or basal area in total, or at the species level.

5.1.2.2 *Background*

Burning is a useful management tool and is commonly used in *Aristida-Bothriochloa* communities to:

- manage tree densities;
- improve animal production by increasing pasture palatability;
- remove low quality senescent herbage;
- manage the distribution of grazing animals and so even out long-term grazing pressure;
- reduce the risk of wildfires; and
- facilitate pasture establishment.

District fire frequencies are estimated at once every 3-7 years (Grice and Slatter 1996).

Tree and shrub monitoring was conducted to gain an understanding of the effects of regular spring burning on the woodland dynamics and structure under treed and treeless pastures without any grazing interaction. Additionally, tree and shrub competition is a major factor affecting pasture ecology and it needs to be understood for this purpose. We were particularly interested on the effect on young trees and pasture.

5.1.2.3 *Methods*

There was a low fuel load (<1000kg/ha) in the 1994 spring and very dry conditions, so a controlled burn was too difficult to arrange that year. The first burn, in spring 1995 was a disappointing trickling burn which did little damage to small woody plants and missed many grass tussocks as well. That burn resulted in a reduction of 1300 kg DM/ha standing pasture compared to the unburnt plots in April 1996 (Silcock *et al.* 1996).

Spring 1996 was relatively cool and moist and it was impossible to arrange a fire after August 1996. The August 1997 burn was conducted as a mild burn for safety reasons because of the high fuel loads. It was the first burn to significantly affect the trees. Thus we were interested in how rapidly and well the burnt foliage of trees regrew, as well as the pasture recovery. In October a defoliation rating was done after the fire and again in February 1998, a refoliation rating and canopy scorch assessment was done at the Ironbark site.

A formalised system of regular tree and shrub recordings about every 2 years was instigated using the TRAPS methodology (Back *et al.* 1997). Details are given in Appendix D and Section 2. TRAPS recordings at the Ironbark burn site were done in July 1995, October 1997 and September 1999. TRAPS is a detailed recording system which relies on the ability to relocate previously recorded plants as described in section 5.1.1.3.

The TRAPS methodology includes a defoliation and refoliation rating. The **defoliation rating** assessed burn severity by rating the degree of leaf scorch as follows:

0 No visible fire effect
1 All leaves 'browned out' with no evidence of charring or burning
2 All leaves consumed but stems intact
3 All the plant consumed by the fire

The **refoliation rating** assessed to what extent the shrub or tree has regained it's pre-fire foliage by resprouting, and was recorded as follows:

0 100% foliage return
1 50% foliage return
2 All leaves gone, stems intact and no foliage return
3 All the plant gone and no foliage return

These ratings were conducted for the August 1997 burn. The defoliation rating was conducted in October 1997 and the refoliation rating was conducted in February 1998.

5.1.2.4 ***Results***

5.1.2.4.1 Fire effects on tree foliage

5.1.2.4.1.1 Defoliation

The average defoliation rating per plant across the site equalled 1.6, and showed that the fire gave an effective leaf scorch (see Table 5.10) despite the mild burn conditions described earlier. All leaves were browned with 60% of leaves being consumed by the burn. Burn severity was higher for smaller plants. Most leaves were consumed in those plants less than 0.5 m tall. Burn severity decreased as height increased. Plants in the height class 10-15 m tall had 70% of their foliage browned by the fire. Very few plants were burnt off at ground level and then only those that were less than 0.5 m tall.

Table 5.10 Mean defoliation rating per plant from burning in the treed treatments.

	Height class (m)								
Species	**<0.5**	**0.5-1.5**	**1.5-4.0**	**4.0-7.0**	**7.0-10.0**	**10.0-15.0**	**>15.0**	***n* =**	**Average**
B. incana	2.1	1.9	0.7	1.0	1.0	-	-	81	1.8
C. erythrophloia	1.0	2.0	0.5	1.4	2.0	-	-	16	1.5
E. melanophloia	1.8	1.6	1.4	1.3	0.7	0.7	-	478	1.6
Average	1.9	1.6	1.4	1.3	1.1	0.7	-	575	1.6

Burn severity was similar for *E. melanophloia* and *B. incana,* however *C. erythrophloia* had an erratic burn severity for different height classes.

5.1.2.4.1.2 Refoliation

Refoliation occurred rapidly (within 5 months of the burn), with the taller plants showing a greater refoliation. Plants larger than 7.0 m tall had regained their pre-fire foliage, while those 4.0 -7.0 m tall showed only a small burn effect (see Table 5.11).

Table 5.11 Mean refoliation rating per plant, after burning in the treed treatments.

	Height class (m)								
	<0.5	**0.5-1.5**	**1.5-4.0**	**4.0-7.0**	**7.0-10.0**	**10.0-15.0**	**>15.0**	***n* =**	**Average**
B. incana	1.2	1.4	1.0	0.0	0.0	-	-	81	1.2
C. erythrophloia	0.0	0.0	0.5	0.0	0.0	-	-	16	0.1
E. melanophloia	0.4	0.3	0.6	0.3	0.0	0.0	-	478	0.4
Average	0.5	0.4	0.7	0.2	0.0	0.0	-	575	0.4

B. incana refoliated more quickly as height class increased but was generally the slowest to refoliate. *E. melanophloia* was quicker to refoliate, while *C. erythrophloia* showed very little effect of the burn after 5 months.

5.1.2.4.2 Fire effects on tree and shrub dynamics

5.1.2.4.2.1 Tree killing and burning

The use of Velpar herbicide significantly reduced total density of woody plants in 1995 ($P<0.001$), 1997 ($P<0.001$) and 1999 ($P<0.01$). Total living basal area was also significantly reduced by tree killing in 1995, 1997 and 1999 ($P<0.01$). Burning had no effect on density or basal area (Table 5.12). The treed plots gradually reduced in density and basal area. While the plots with trees killed also gradually reduced in basal area, the density reduced markedly from 1995 to 1997 because many *E. melanophloia* plants appeared dead in 1997 and were not recorded. However, the lignotubers were still alive and resprouted by 1999 in the plots with trees killed that were not burnt (Table 5.13). Burning had no affect on either the size or density of existing woody plants.

Table 5.12 Total woody plant density and basal area under differing management without grazing.

	Density (plants/ha)			Basal area (m^2/ha)		
Management	**1995**	**1997**	**1999**	**1995**	**1997**	**1999**
Treeless	584	410	604	0.42	0.25	0.15
Treed	1904	1675	1652	4.92	4.60	4.04
Burnt	1368	1154	1085	2.67	2.34	1.93
Unburnt	1120	932	1171	2.67	2.51	2.26

Table 5.13 Effect of fire on suppressing tree and shrub regrowth in the absence of grazing.

	Density (plants/ha)			Basal area (m^2/ha)		
Management	**1995**	**1997**	**1999**	**1995**	**1997**	**1999**
Treeless and burnt	477	389	367	0.08	0.10	0.04
Treeless and unburnt	690	432	842	0.75	0.41	0.25
Treed and burnt	2259	1918	1804	5.26	4.59	3.81
Treed and unburnt	1549	1433	1500	4.58	4.61	4.28

Tree killing significantly reduced *E. melanophloia* density in 1995, 1997 and 1999 (P<0.001). Basal area was also significantly reduced by tree killing in 1995 (P<0.01), 1997 (P<0.01) and 1999 (P<0.05). *B. incana* and *C. erythrophloia* were not significantly affected by tree killing although the loss of bloodwood plants was noticeable. Burning did not significantly affect density or basal area of *E. melanophloia, B. incana* or *C. erythrophloia* in any year (Table 5.14).

Table 5.14 *E. melanophloia, B. incana* and *C. erythrophloia* density and basal area under differing management.

	Density (plants/ha)			Basal area (m^2/ha)		
Management	**1995**	**1997**	**1999**	**1995**	**1997**	**1999**
E. melanophloia						
Treeless	338	226	333	0.05	0.05	0.02
Treed	1587	1362	1329	4.02	3.67	3.14
Burnt	1066	876	819	2.26	1.90	1.53
Unburnt	859	712	844	1.81	1.82	1.63
B. incana						
Treeless	122	99	167	0.10	0.20	0.13
Treed	203	199	206	0.42	0.43	0.46
Burnt	159	155	146	0.15	0.22	0.21
Unburnt	166	142	227	0.33	0.40	0.38
C. erythrophloia						
Treeless	25	13	13	0.26	0.00	0.00
Treed	78	72	83	0.44	0.45	0.44
Burnt	32	32	33	0.18	0.18	0.19
Unburnt	72	53	63	0.52	0.27	0.25

5.1.2.5 *Discussion*

The trial burn reflected local practice on properties in the vicinity of the trial site when there was a good fuel load and plant available water in the soil. However, producers often burn for 'green pick' and graze the country immediately afterwards. This practice has been reported elsewhere for much of the *Aristida/ Bothriochloa* community (Grice and Slatter 1996). Producers burn in early spring for the purpose of encouraging young green grass shoots and enhancing animal production by providing stock with palatable and nutritious grass, and removing low quality senescent grass. In the 1997 spring, pastures were reshooting within several days of the burn on the plant available water. Producers believe that animal production benefited from this management. Unfortunately, a subsequent below average summer rainfall meant that the burnt areas are still very low in pasture yield and ground cover by summer's end. The areas are still being patch grazed in autumn with each small fall of rain and green shoot being grazed down to the crown.

In our trial there was no grazing after the burn and pasture regrowth was good by the end of the 1997-98 summer. The possibility for detrimental effects on perennial grass establishment by combining burning with immediate grazing has been demonstrated by Orr and Paton (1997). They significantly reduced wiregrass populations quite quickly by this tactic in speargrass country. Winston Trollope, *pers. comm.* has also denounced this form of management as "an invalid use of fire" due to the extra pressure brought on to perennial grasses.

The trial burn had negligible effect on the tree and shrub competitive effects on the pasture. McIvor (2004) has stated that intense fires are necessary to induce high mortalities in eucalypts. The trees and shrubs were quick to refoliate, and intuitively then, retaining their maximum competitive effect. The taller trees (>4.0 m) were less affected by the burn and also refoliated more quickly. Additionally, these trees contribute the majority of the basal area and competitive effect. Only for the first half of the summer could there have been a benefit to the pasture. In the burnt plots, over 4000 kg/ha of pasture dry matter was sacrificed for a negligible effect on tree and shrub competition.

Early spring burns could well lead to a seedling storm of *E. melanophloia* if there is a viable seed bank and moist conditions prevail. Early spring burns are beneficial to tree establishment because grass competition is reduced for a while and soil fungi, which can affect tree seedlings, are also removed by the fire. Additionally, control of *E. melanophloia* seedlings is thought possible by burns in the establishment year, before the seedlings have gained resprouting ability. This is less likely where a very early spring burn has occurred. In our trial, tree seed set has not been observed for several years beforehand, and because eucalypt seed remains viable in the field for only about for six months (P.V. Back, *pers. comm*.), negligible establishment was likely from our 1997 burn.

A later spring burn conducted under drier, hotter and windier conditions would have inflicted more damage on the trees and shrubs. A more severe effect on the taller shrubs would be beneficial for pasture because of their competitive effect, and increasing the period of refoliation. Where an *E. melanophloia* seed set is observed burning should be held over in case of an establishment. The burn can then be used to induce a high mortality for those tree seedlings. The cumulative effect of lack of burning was starting to show by 2001 in ungrazed plots. There was obvious regrowth in some areas that points to what will happen in the future without the use of controlled fires for tree seedling suppression (Figure 5.2).

Figure 5.2 Silverleaf ironbark seedling &/or sucker regrowth in an unburnt, ungrazed plot (midground) 7 years after the original trees were poisoned at the Ironbark site. Note the smaller ones in the grazed paddock in the foreground.

5.2 Tree and shrub dynamics – Poplar box site

5.2.1 Background

Clearing of thick timber has been a common practice in the Roma/Injune district, a proven means of improving grazing land production and for greater ease of stock mustering. There are large tracts of commercial cypress pine forest in the region, so fire management is an important issue for foresters and graziers alike. The dingo barrier fence runs east-west near Injune, so cattle have been the sole domestic stock run north of Injune. South of the barrier fence sheep used to hold sway but the industry emphasis has shifted in recent decades from sheep to cattle. There has also been an increase in opportunity cropping on fertile clay soils of brigalow or Mitchell grass downs origins as well as forage oats and sorghums on the best poplar box and myall flats.

Brigalow scrubs dominate heavy clay soils around Injune and they have normally been developed by clear-felling with chains and then ploughing plus cropping to control suckering. In the eucalypt woodlands, tree clearing was not widespread where fire could be used to periodically control understorey regrowth, especially by cypress pine. Hence, producers have for decades used strategic burning and tree clearing (originally by ringbarking) to manage their grazing land. Our research aimed to quantify the size of the economic response from removing the trees as well as better defining the role that spring burning can have in land management, especially for wiregrass control.

5.2.2 Grazing trial site dynamics

5.2.2.1 *Abstract*

Only a little seedling recruitment of any woody species was detected in the grazing trial site after 7 years. That change was not significantly discouraged by high grazing pressure and may have been enhanced by very light grazing pressure. Lack of large numbers of new recruits (seedlings or root suckers) and spatial variability around the site and within the larger paddocks precluded statistically significant differences in recruitment or growth rate being detected due to tree killing or grazing pressure.

5.2.2.2 *Original poplar box tree size*

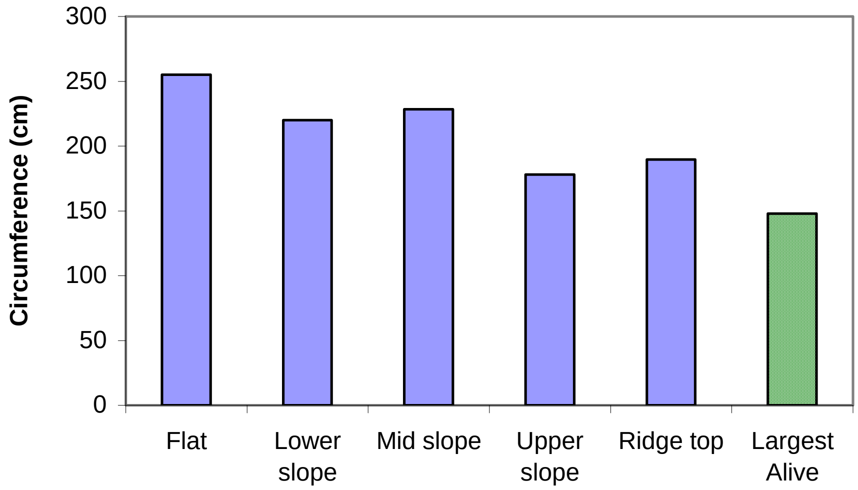


Figure 5.3 Original poplar box tree circumference related to slope position and the largest live tree at the poplar box site.

The size of the original poplar box trees at the Glentulloch site before the first ringbarking in the 1920's was much larger than the current size of older trees. Figure 5.3 shows the trunk circumference at 1.2 m of the killed, ring-barked trees at various positions up the slope compared with the largest live tree currently at the site, which was on a creek flat.

5.2.2.3 *Methods*

Tree and shrub dynamics were recorded within the main grazing trial, the design of which was described in general terms in Section 2. Recordings were made in each of the 12 paddocks in 1995, 1996, 1997, 1999 and 2002. Thus data relates to the effects of tree competition and to three different levels of grazing pressure.

Woody plants, both trees and shrubs, were measured using the 'Transect Recording and Processing System' (TRAPS) methodology (Back *et al.* 1997). In each paddock of the grazing trial there were 3 permanent transects 150 m long by 4 m wide. The transects were located in upper, middle and lower slope positions and ran in a north to south direction. The total recording area was 1800 m^2 for each of the 12 treatment paddocks.

Tree basal area was calculated from the stem diameter of small trees and the stem circumference of larger trees, using the circle formula. The canopy area was calculated using the mean canopy diameter in the formula for a circular area.

5.2.2.4 *Results*

5.2.2.4.1 Current tree and shrub populations

The population of trees and shrubs in this poplar box community is diverse with some 61 species, 15 trees and 46 shrubs, recorded (Appendix E). Poplar box was dominant, with 42.2 % of the total woody plants recorded (377 /ha) at the grazing trial in 1995. There were patches of shrubs at the grazing trial site while few shrubs were present at the burning trial site. The grazing and burning treatments had commenced in spring of 1994 after domestic stock grazed the whole area right up to the start of the trails.

After poplar box, the next most common species in the grazing trial were myall (*Acacia pendula*) 9%, yellow-berry bush (*Maytenus cunninghamii*) 8.9%, sticky hopbush (*Dodonaea viscosa*) 6.6%, whitewood (*Atalaya hemiglauca*) 4.8%, beefwood (*Grevillea striata*) 4%, bull oak (*Allocasuarina luehmannii*) 3.9% and silver-leaved ironbark (*Eucalyptus melanophloia*) 3.8%. Silver-leaved ironbark was the only other common eucalypt, and occurred mainly on the upper slopes and ridge tops. Most species were not widespread and occurred on small areas of stony soils near hill tops or near watercourses. The prickly pear species (*Opuntia* spp.), which were widespread across the site, were included with the 'woody' plants and they had the most dynamic population, with the effects of Cactoblastis damage causing a rapid population turnover. The commonness of the main smaller woody plants around the 12 grazing trial paddocks is summarised in Table 5.15, eg. prickly pear was found in 8 paddocks and whitewood in 4.

At the burning trial *E. populnea* was 86.8% of the total species (348 /ha), with false sandalwood (*Eremophila mitchellii*) 4.5% and wilga (*Geijera parviflora*) 3.3%.

For all transect analysis, plants were grouped into nine height classes: < 0.5, 0.5–1.5, 1.5-4.0, 4-7, 7-10, 10-15, 15–20, 20–25, and 25-30 m tall. The data presented is mostly for the sum of all height classes. Initially there were an equal number of woody plants <50cm tall in both the treed paddocks and the paddocks where the large trees had been killed by Tordon. By 1999 that number was slightly increased in the treeless paddocks but had increased by 33% in the treed ones.

Table 5.15 Number of poplar box grazing trial paddocks (out of 12) in which small-statured (<3 m tall) woody shrubs and young trees were recorded along the T.R.A.P.S. transects in the early years of the trial, plus total numbers recorded of the main woody species in all paddocks in 1995 & 1997.

Common Name	Species	Nbr of pdks with this species	TRAPS Year 1995	TRAPS Year 1997
Pretty wattle	Acacia decora	3	9	9
Ironwood	Acacia excelsa	1	1	1
Mimosa	Acacia farnesiana	3	12	12
Brigalow	Acacia harpophylla	1	1	1
Sydney golden wattle	Acacia longifolia	1	2	2
Myall	Acacia pendula	5	62	61
A wattle species	Acacia sp.	3	10	13
Bitterbark	Alstonia constricta	1	23	23
Bulloak	Allocasuarina luehmannii	5	6	7
Whitewood	Atalaya hemiglauca	4	21	33
	BITTE	1	1	1
Kurrajong	Brachychiton populneus	1	1	1
Nipan	Capparis lasiantha	1	14	13
Currantbush	Carrisa ovata	1	5	5
	Cassia sp.	1	1	1
A hopbush species	Dodonaea sp.	1	1	2
Sticky hopbush	Dodonaea viscosa	5	21	41
Limebush	Eremocitrus glauca	2	26	26
False sandalwood / Budda	Eremophila mitchellii	7	17	18
	Eremophila sp.	1	11	12
Silver-leaved ironbark	Eucalyptus melanophloia	6	7	11
Poplar box	Eucalyptus populnea	12	112	112
Unidentified eucalypt	Eucalyptus sp.	1	1	1
Wilga	Geijera parviflora	2	2	4
Grewia species	Grewia sp.	1	1	0
Beefwood	Grevillea striata	4	26	28
Yellowberry bush	Maytenus cunninghamii	1	36	57
Ellangowan bush	Myoporum deserti	1	1	1
Prickly pear	Opuntia stricta	8	11	31
Emuapple	Owenia acidula	1	2	2
	SEENO	1	2	2
	Sp A	1	2	2
	Spec. A	1	2	2
	SUCK	1	1	1
	UNID	1	3	4

5.2.2.4.2 Woody plant numbers

The population of live woody plants in the treeless and treed treatments of the grazing trial is shown in Table 5.16. The treeless treatments had a higher population of small shrubs, such as *Carissa* and *Capparis* species, while the treed treatments were dominated by *Eucalyptus* trees. There was an increase in woody plants in the both treatments between 1999 and 2002.

Table 5.16 Live woody plant populations (no. ha^{-1}) for plants of all sizes in the Tordoned and treed treatments of the grazing trial from 1995 to 2002.

TREE effect	1995	1996	1997	1999	2002
Treeless	211	208	207	217	292
Treed	438	421	456	453	527

The live woody plant populations at the 3 grazing pressures over the grazing period (Table 5.17) shows a similar population in the low and high treatments and a lower population in the medium treatment. This is from the treeless and medium grazing pressure paddocks having a relatively lower starting population.

Table 5.17 Changes in mean live woody plant populations (no. ha^{-1}) at three pasture grazing pressures from 1995 to 2002.

Grazing pressure	1995	1996	1997	1999	2002
Low	353	340	364	390	499
Medium	249	249	265	249	292
High	372	356	367	365	439

The change in total live woody plant populations between recording times (Table 5.18) shows and increase in all treatments with the greatest increase in the low grazing pressure treatment. This increase occurred in both treeless and treed treatments and the largest increase occurred between 1999 and 2002. A significant contributing species to the increase was prickly pear which had greater increases as grazing pressure increased and also beneath trees than in the open. Three sandalwood seedlings were recorded in the intensively charted quadrats of paddock CL1 after the wet 1998 winter. This is a very rare achievement amongst scientific research to date, partly because seedset rarely occurs after flowering.

Table 5.18 Mean woody plant population change (no. ha^{-1}) between recording times in the main treatments of the grazing trial.

	1995-96	1995-97	1995-99	1995-02
Tree effect				
Treeless	-2.8	-3.7	5.6	81.5
Treed	-16.7	18.5	14.8	88.9
Grazing pressure				
Low	-12.5	11.1	37.5	145.8
Medium	0.0	16.7	0.0	43.1
High	-16.7	-5.6	-6.9	66.7
Site	-9.72	7.41	10.19	85.19

Low grazing pressure did not curtail woody plant regeneration

The mean population of poplar box trees, suckers and seedlings over the grazing trial site (Table 19) increased by 9 % between 1995 and 2002 in the treed treatments while there was a 35 % decrease in the treeless treatments.

Table 5.19 Mean population of poplar box plants (no. ha^{-1}) in treeless and treed treatments of the grazing trial.

Trees mean	1995	1996	1997	1999	2002	% Change 1995 - 02
Treeless	26	25	21	19	17	-35
Treed	208	209	211	213	227	+9

There was a marginal increase in poplar box populations in the medium and high grazing pressure treatments but no change at low grazing pressure (Table 5.20).

Table 5.20 Mean population of poplar box plants (no. ha^{-1}) at three grazing pressures at the grazing trial.

Grazing pressure	1995	1996	1997	1999	2002	% change 95-02
Low	93	93	94	93	92	-1
Medium	169	169	164	167	178	+5
High	89	89	90	89	96	+8

5.2.2.4.3 Stem basal area

The tree basal area in the treed paddocks, measured by the Bitterlich method, showed higher levels in 3 paddocks; 5, 6 and 10 (Figure 5.4). The tree basal area in paddock 5 was almost entirely from poplar box, while paddocks 6 and 10, although dominated by poplar box, had a higher proportion of silver leaved ironbark, bulloak and shrub species on the upper slopes. The basal area of paddock 6 was reduced at the start of the trial by the selective stem injection killing of some ironbark and bulloak trees to produce a basal area more similar to that of the other treed treatments.

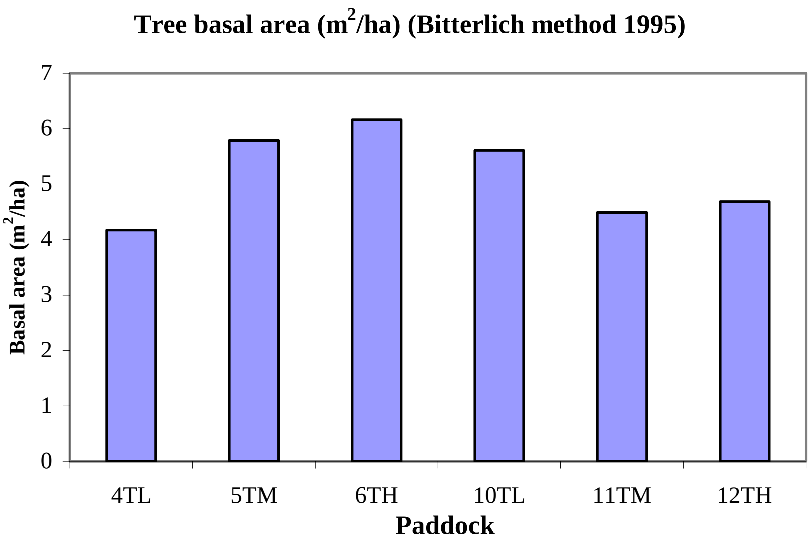


Figure 5.4 Tree basal area (m^2 ha^{-1}) in the treed paddocks at the poplar box site.

The woody plant basal area in treeless and treed treatments increased over the grazing trial period (Table 5.21). The higher basal area in the treed treatment in 1995 was before the silver-leaved ironbark trees were thinned out in paddock 6 to give it a tree cover nearer to that of the other paddocks (treed and high grazing pressure, replicate 1). The 1996 basal area of 6.56 m^2 ha^{-1} represents the starting basal area after the tree thinning exercise aimed at bringing this paddock to a more similar tree competition level as the remainder of the trial site. The treeless treatments had the largest increase in basal area between 1999 and 2002, while the treed treatments had a steady increase between each recording period, from 1997 to 2002.

Table 5.21 Woody plant basal area (m^2 ha^{-1}) in herbicide treated and treed treatments each recording date between 1995 and 2002.

TREE effect	1995	1996	1997	1999	2002	Incr. 96-02	% increase
Treeless	0.8	0.8	0.9	0.8	1.5	0.7	90
Treed	7.7*	6.6	6.5	7.2	7.6	1.0	16

* basal area before thinning *E. melanophloia* in treatment Treed, High grazing pressure, replicate 1.

There was an increase in woody plant basal area at the 3 grazing pressures between 1995 and 2002 (Table 5.22). Note the high grazing pressure treatment was thinned (paddock 6) before the 1996 recording.

Table 5.22 Woody plant basal area (m^2 ha^{-1}) in the three grazing pressure treatments between 1995 and 2002.

Grazing pressure	1995	1996	1997	1999	2002	Incr. 96-02	% increase
Low	3.5	3.0	3.3	4.1	4.5	1.6	53
Medium	4.0	4.1	4.1	4.5	4.8	0.6	16
High	5.3*	3.9	3.6	3.5	4.4	0.4	11

* basal area before thinning *E. melanophloia* in treatment Treed, High grazing pressure, Rep 1.

The mean basal area of the poplar box population, including live and killed trees, in treatments over all years in the grazing trial (Table 5.23) shows there was higher basal area in the Treed, High Grazing pressure treatments and a lower basal area in the Tordoned treatments. The first measure was a summer after the trees were killed in the Tordoned treatments.

Table 5.23 Mean basal area of poplar box in treatments over all years in the grazing trial plus percentage of woody plants due to poplar box.

Treatment means	Poplar box %	Poplar box $m^2\ ha^{-1}$	Total woody $m^2\ ha^{-1}$
Treeless Low	56	0.0	1.3
Treeless Medium	84	0.04	0.3
Treeless High	56	0.01	1.3
Treed Low	80	4.7	6.1
Treed Medium	89	7.5	8.3
Treed High	57	3.0	7.0

The year means of poplar box basal area (Table 5.24) show a marginal increase over the grazing trial period, although the percentage contribution to total basal area declined marginally over this period, indicating a greater rate of increase in basal area from other woody species.

Table 5.24 Mean basal area of poplar box within years over all treatments in the grazing trial.

Year means	Poplar box %	Poplar box $m^2\ ha^{-1}$	All woody plants $m^2\ ha^{-1}$
1995	72	4.1	6.3
1996	72	3.8	5.9
1997	72	3.9	6.3
1999	69	4.1	6.8
2002	66	4.4	7.5

The change in basal area of woody plants between sampling times (Table 5.25) shows a small increase in the treeless treatments, mainly between 1999 and 2002. The basal area of the treed treatments increased after 1996 (after the thinning of paddock 6). There was an increase in basal area of 1.1 $m^2\ ha^{-1}$ in the low grazing pressure treatments, with a lower increase at the two higher grazing pressures. This steady increase in basal area will eventually contribute to an increase in competition with the pasture.

Table 5.25 Change in woody plant basal area ($m^2\ ha^{-1}$) between recording times in the main treatments of the grazing trial.

	1995-96	1995-97	1995-99	1995-02 (SD)#
Tree effect				
Treeless	0.01	0.14	-0.02	0.73 (1.21)
Treed	-1.16*	-1.25	-0.48	-0.12 (3.29)
Grazing pressure				
Low	-0.51	-0.14	0.58	1.06 (1.24)
Medium	0.11	0.11	0.48	0.75 (0.92)
High	-1.34*	-1.64	-1.83	-0.91 (3.98)
Site	-0.58	-0.55	-0.25	0.30

* change from thinning paddock 6. # Std Deviation of mean

5.2.2.4.4 Estimated crown area of woody plants

The estimated crown area of woody plants in the treeless and treed treatments (Table 5.26) remained consistent over the grazing period and was 10 times greater level in the treed treatments. The crown cover in the treeless treatments was mainly from low bushy shrubs and seedling myall trees.

Table 5.26 Tree crown area (m^2 ha^{-1}) in Tordoned and treed treatments between 1995 and 2002.

TREE effect	1995	1996	1997	1999	2002	Av % of ground
Treeless	389	368	385	434	442	4.0
Treed	3356*	3312	3309	3329	3385	33.4

* before thinning paddock 6.

The tree canopy cover ranged from 22.5% in paddock 4CL to 29.9% in paddock 10TL in July 1999 (Figure 5.5). There was an annual fall of tree leaf from the poplar box trees with the quantity of dry tree leaf on the ground reaching 600-1000 kg/ha in paddock 5TM. There appeared to be a greater fall of leaf in dry winter periods following short summer rainfall seasons, effectively reducing the total tree canopy area.

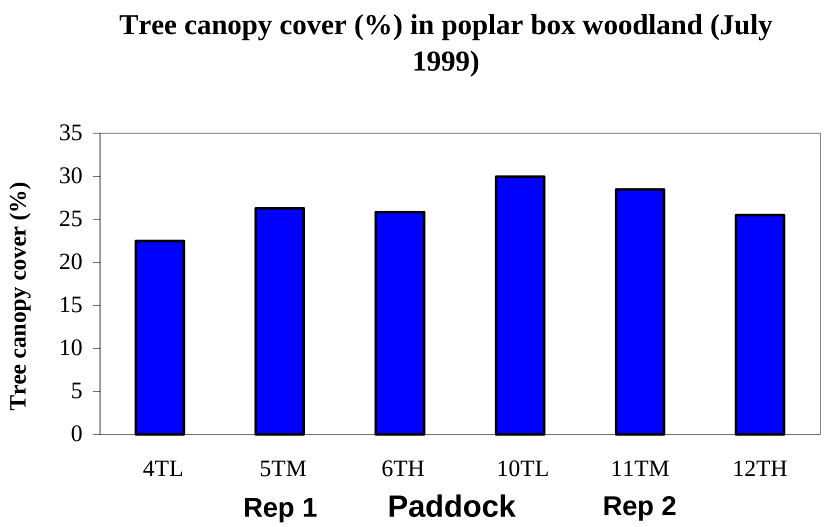


Figure 5.5 Total tree canopy cover (%) in the 6 treed paddocks at the poplar box grazing trial.

The species contribution to total tree canopy cover (Figure 5.6) shows the dominance of poplar box in all paddocks, except for Pdk 6 where silver leaved ironbark was common. Bull oak was another common species in patches in paddocks 4, 6, 10 and 11.

Amongst the grazing pressure treatments, the medium rate had a marginally greater crown area than the low and high treatments (Table 5.27). The trends were for the crown area to increase at low grazing pressure and to remain constant at medium and high grazing pressures.

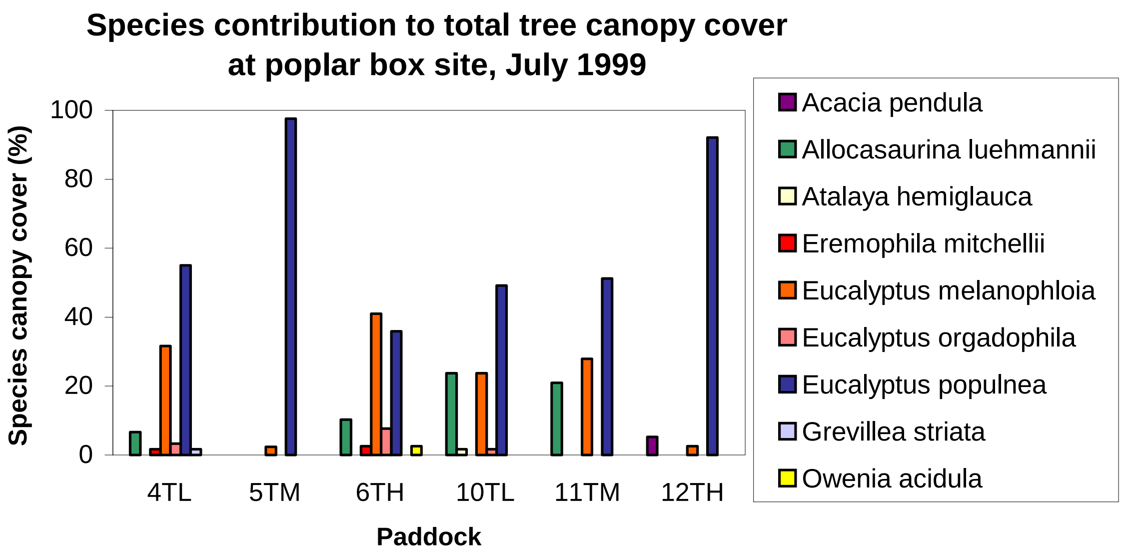


Figure 5.6 Species contribution to total tree canopy cover (%) in the 6 treed paddocks at the poplar box site.

Table 5.27 Mean woody plant crown area (m^2 ha^{-1}) in the three grazing pressure treatments between 1995 and 2002.

Grazing pressure	1995	1996	1997	1999	2002	change 96-02
Low	1530	1659	1663	1718	1821	+162
Medium	2274	2432	2346	2364	2209	-223
High	1814*	1431	1532	1562	1493	+62

* before thinning paddock 6.

There was inconsistent change in mean crown area within the treeless and treed treatments over the grazing trial period, however there may be trends with grazing pressure (Table 5.28). At low grazing pressure, the crown area was increasing marginally over time, while at the high and moderate rates, the trend seemed to reflect seasonal rainfall changes more than grazing pressure. These data could also simply reflect the lack of accuracy or skill in calculating this parameter by the method used.

Table 5.28 Change in estimated crown cover (m^2 ha^{-1}) of woody plants between recording times in grazing trial main treatments.

Change over years	1995-96	1995-97	1995-99	1995-02
Treeless	-21	-4	45	-92
Treed	-43	-46	-27	29
Low	129	134	188	291
Medium	158	72	90	-64
High	-383*	-282	-252	-321

* before thinning paddock 6.

5.2.2.5 ***Discussion***

Poplar box was the dominant tree with localised stands of silver-leaved ironbark, myall and bulloak. Over the 7 years of recording, about 30 woody species were found along the transects out of 54 recorded for the site (Appendix E4). Many were found only in isolated patches, eg. hopbushes. The most widespread ones, apart from poplar box, were false sandalwood and prickly pear (Table 5.15). The density of poplar box in treed paddocks averaged $5m^2 ha^{-1}$ (Figure 5.4) which is a moderate density for the region.

Low grazing pressure did not suppress woody plant regeneration and may even have enhanced it (Table 5.18). The presence of mature trees did not alter the degree to which new woody plants recruited under grazing conditions (Table 5.18).

Changes in woody plant stem basal area were modest but, on a percentage basis, were greatest at low grazing pressure (50% compared to 11% at high grazing pressure – Table 5.22). There is a hint that high grazing pressure restricted total woody plant growth (Tables 5.18, 5.22 and 5.25) but also that the opposite applied to poplar box (Table 5.20). This may relate to the relative palatability of some species such as myall, limebush and beefwood, compared to poplar box.

Lack of any major recruitment event of woody species or seedset by them ensured that the TRAPS methodology was not sensitive enough to detect significant differences between the main treatments over 7 years. Our scientific highlight was to document seedling recruits of false sandalwood in Pdk 1, a very rare feat despite the apparent frequency with which it seems to occur based on anecdotal evidence. Viable seed of false sandalwood is very difficult to collect (Burrows, pers. comm.; Silcock, pers. comm.; and Alchin, pers. comm.).

5.2.3 **Burning trial dynamics**

5.2.3.1 ***Abstract***

Tree growth rates were typical of eucalypt woodlands in Central Queensland, stem basal area increasing on average $0.26m^2 ha^{-1} yr^{-1}$. This equates to a doubling of tree stem area every 33 years. Regular spring fires did not reduce the rate of poplar box stem or canopy growth but did reduce the degree of recruitment of new woody plants generally. The localised presence of trees did not affect the extent of seedling recruitment of woody plants.

5.2.3.2 ***Background***

This component of the project investigated the impact of regular spring burning on tree and shrub dynamics on both existing, semi-mature poplar box woodland and poplar box woodland newly retreated with Tordon 50-D. In this way we hoped to see how well fires could control the anticipated seedling and sucker regeneration after killing the mature trees as well as how minor understorey shrubs such as cypress pine and false sandalwood reacted. The burning study was done in the absence of grazing for operational simplicity.

5.2.3.3 ***Methods***

The general design of this trial site was described in Section 2. It was fenced in June 1994 to exclude cattle and marsupials. There were 12 plots each of 1 hectare area, half of which had been treated with herbicide in July 1994. Each plot had a cleared border and there was a double-width cleared firebreak around the 6 adjacent burning treatment plots (Figure 5.7). The first fire across the 6 burning treatment plots was in October 1994. In each plot, there were 2 transects 100 m long by 4 m wide, across the diagonal of the square plots, giving a recording area of 800 m^2. Each treatment was replicated 3 times.

The main treatments were regular spring burning after 25 mm rain or no burning, both with treeless and treed treatments, making 4 combinations of treatments and there were 3 replications. Details of the burning regime, fire types and environmental conditions are shown in Table 5.29. There was no grazing to avoid confounding the pasture responses with the usual selective grazing of fresh regrowth after a fire.

The 12 plots were in a single block 300 m by 400 m and the 6 burnt plots were adjacent to improve fire management and containment with cleared breaks. A treatment plan with basal area and TRAPS sampling transects is shown (Figure 5.7).

Differences and similarities amongst the responses to these interactions of burning and tree competition provide a measure of the sensitivity of the various processes that are critical in this woodland. Monitoring, based on a systems framework, measured the following key processes:

- pasture yield, cover and greenness in autumn,
- pasture population dynamics, by species frequency, yield composition and basal area,
- woody overstorey and understorey population dynamics,
- soil surface condition indicating erosion, hydrology and nutrient cycling.

More details of the sampling methods are given in Section 5.1.1.3.

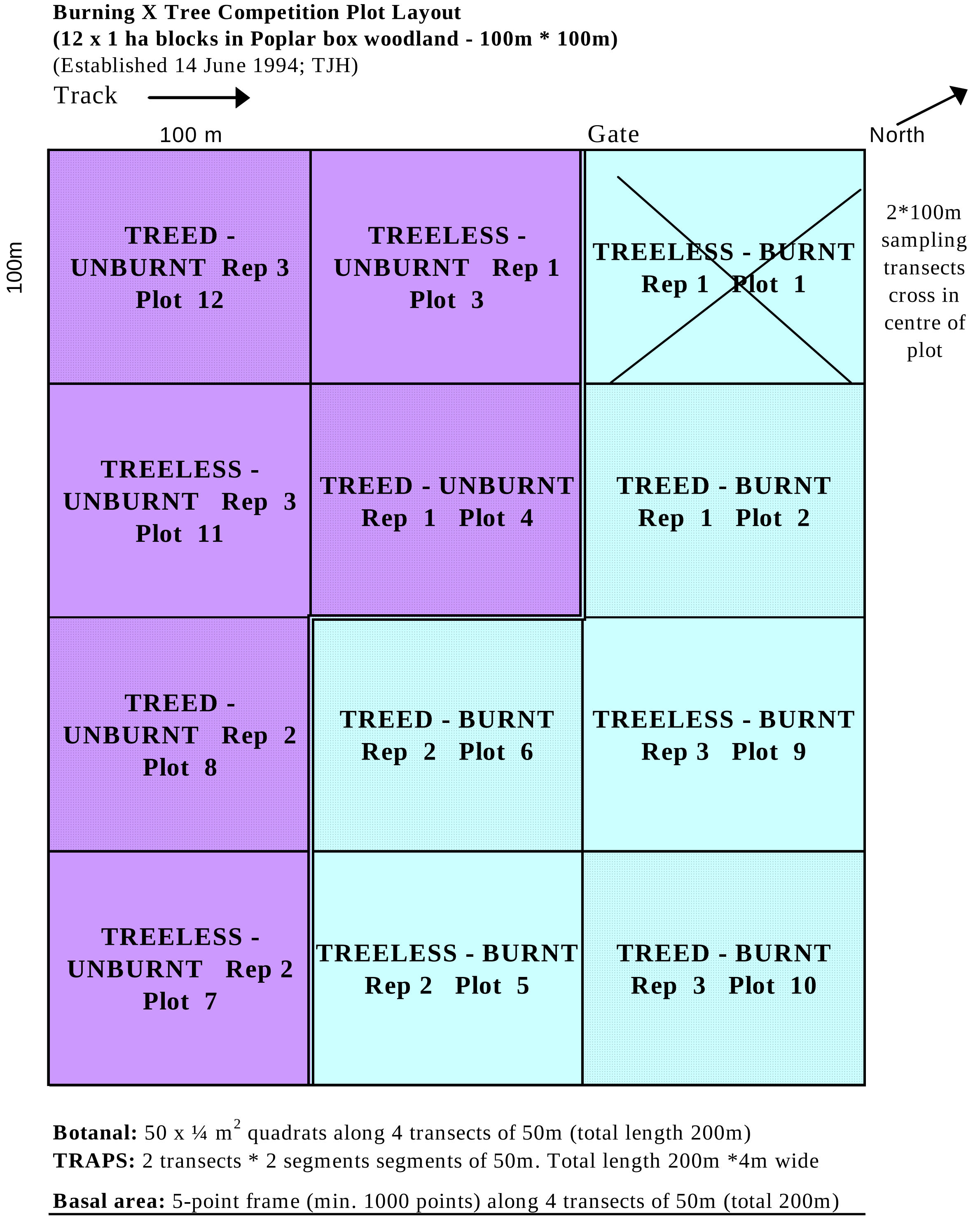


Figure 5.7 Field plot layout of 12 plots of 1 ha of the poplar box burning trial.

Table 5.29 Burning times and fire details of the 6 plots of 1 ha in poplar box woodland burning trial (3 plots treeless and 3 plots treed).

Fire Parameter	1994	1995	1996	1997
Fire No.	**1**	**2** (plots 1 and 9 only)	**3**	**4**
Date	3/11/1994	5/10/1995	19/09/1996	14/10/1997
Time of Day	12-3.00 pm	12-4.00 pm		12-2.00 pm
Grass Condition	Dry and short	Green in Grass	Dry	Dry to Green tinges
Wind Speed (km/hr)	0 (nil)	0 (nil)	Gusty	5-10 km/hr gusty
Wind Direction	-	-	West - North West	North West
Air Temperature	Warm	Cool	Warm	Warm
Relative Humidity				
Rate of Spread	Very Slow	Slow - Nil	Good	5 km/hr and gusty
Danger Index	Low	Low	Moderate to high	Moderate to high - wide breaks
Flame height (m)	2 m in cleared	Low	4 m in cleared	4 m in cleared
Fuel Load - Treed	Low; estm 600 kg/ha	see Botanal DM yields	see Botanal DM yields	see Botanal DM yields
- Treeless	Low; extra tree leaf litter			
Litter	Tree leaf significant cover	Negligible	Negligible	Some in Cleared
Fire assistance	Fuel fire lighter Bug	Fuel fire lighter	Fuel lighter in trees mainly	Fuel lighter in trees mainly
Ease of Burn - Treed	Constant assistance	Constant assistance; abandoned	Patchy to good fire in trees;	Patchy to good fire in trees;
- Treeless	Frequent assistance	Frequent assistance	Very good fire in cleared	Very good fire in cleared
Type of Fire	Cool; slow Very difficult to burn Walked back & forth over whole site using fire dripper, Tree litter carried between tussocks	Very Cool; slow Couldn't get a burn in trees Only burnt plots 1(CB1) & 9(CB3) mostly by hand dripper	Warm Slow burn under trees	Warm Slow burn under trees Good burn across cleared with gusts of wind

Table 5.29 (cont.) Burning dates and fire conditions at the poplar box woodland site for spring 1998, 1999, 2000 and 2001.

Fire Parameter	1998	1999	2000	2001
Fire No.	No Burn	**5**	**6**	**7**
Date	wet winter/spring	24/08/1999 (early)	26/10/2000 (after rain); followed by 50 mm	16/10/2001 (after light rain and rain predicted)
Time of Day	fire wouldn't carry	12-1 pm	11-1 pm	10-3 pm
Grass Condition	Green grass and Calotis	Dry, insignificant green	Dry, small amount green at base	Dry, small green tinge at base some tussocks
Wind Speed (km/hr)		NE 25 km/hr	NE to 20 km/hr	N - NW to 30 km/hr
Wind Direction		NE	NW - NE; gusts from SW	N - NW; strong gusty
Air Temperature		Cool Max 23^{o}C	Cool breeze, Max 30^{o}C	Max 28^{o}C (constant wind)
Relative Humidity	high	Low	High - heavy clouds, 88 mm last week	High; clouds leading a rain front from west
Rate of Spread	nil	Good	Good all Treeless; drippers in strips in trees	Fast north half CB1; slow backburn other plots
Danger Index	nil	Moderate to high	Moderate to high - good wide breaks	High - strong gusty wind towards unburnt plots
Flame height (m)	no fire	4 m in Treeless, <1 m Treed	5m in CB1, to 4m Treeless, 0.30 -1 m Treed	5m in CB1, to 4m Treeless, <1.5m in Treed
Fuel Load - Treed	1405/3435 kg/ha	1720 kg/ha	1010 kg/ha; Spaced tussocks, cover of leaves	1330 kg/ha; Spaced tussocks, tree leaves
- Treeless	additional green growth	4565 kg/ha	2560 kg/ha; Good, dry grass	3180 kg/ha; Good, dry grass
Litter		Moderate, excellent in Treeless	Moderate, tree leaf almost carpet in Treed	Moderate, tree leaf only; wind blown leaf strips
Fire assistance		Fuel fire Bug	Fuel Fire Bug, strips in trees	Fire Bug, strips in trees, backburn against wind
Ease of Burn - Treed		Patchy	Patchy to poor strips	Patchy due to back burn for safety
- Treeless		Excellent	Excellent	Excellent back burn Bark of Tordoned trees burning; falling over
Type of Fire	nil	Cool, quick; initially backburn Slow burn under trees Excellent in Treeless Better fire with wind gusts Burnt around edges	Cool, quick in Treeless, slow in Treed Slow burn under trees Excellent in Treeless Better fire with wind gusts Burnt around edges (initially back burn)	Slow; quick patches in Treeless; slow in Treed Slow back burn under trees, small patches left Excellent in cleared Better fire with wind gusts Back burnt from south, some strips across site

5.2.3.4 *Results*

In general, the tree population here was fewer than at the grazing trial – 344 stems ha^{-1} compared to 377 initially. However, they were of greater size, 13.5m^2 ha^{-1} compared to 7.7 m^2 ha^{-1} at the grazing site.

5.2.3.4.1 Populations

The population of live woody plants in the treeless and treed treatments of the burning trial (Table 5.30) show a small increase in populations over the trial period. The treeless, unburnt treatments had a higher population of small shrubs, such as *Eremophila* and *Jasminum* species, while the treed treatments remained dominated by poplar box trees.

Table 5.30 Mean woody plant populations (no. ha^{-1}) in the main treatments of the ungrazed burning trial from 1995 to 2002.

	1995	1997	1999	2002	Change 95-02 (SD)	% change
Plant mean ha^{-1}						
Treeless	21	29	46	60	39 (31.0)	+88
Treed	344	344	387	379	35 (34.8)	+ 6
Plant mean ha^{-1}						
Burnt	154	158	165	183	29 (20.4)	+ 7
Unburnt	210	215	269	256	46 (39.3)	+13

The rate of increase in woody plant numbers over time was greater in the Tordoned plots than in the untreated plots (Table 5.30) but very similar when burnt and unburnt means were compared.

Poplar box tree populations increased slowly from seedlings and suckers during the trial period after clearing, but there was no change in the treed treatments (Table 5.31). Hence either the seasonal conditions experienced during the trial were not conducive to seedling establishment or the mature trees may have suppressed seedling establishment. There were no differences between the burning treatments. There was a decline in proportion of poplar box over the trial as shrubs established, mainly in the unburnt treatments.

Table 5.31 Live poplar box populations (no. ha^{-1}) in the main treatments of the ungrazed burning trial between 1995 and 2002.

Treatments	1995	1997	1999	2002	Change 95-02	% change
Trees (mean ha^{-1})						
Treeless	8	17	13	25	+17	+213
Treed	308	306	302	300	- 8	- 3
Burning (mean ha^{-1})						
Burnt	142	146	140	150	+ 8	+ 6
Unburnt	175	177	175	175	0	0
Site mean	158	161	157	163	+ 5	+ 3
% of Total live woody	87	87	73	74	- 13	- 15

The change in live poplar box plant populations between recording times (Table 5.32) fluctuated between an increase and a decrease and showed a small increase after 7 years in Tordoned (17 plants ha^{-1}) and burnt treatments, with a small reduction in the treed plots. There was no change in the unburnt treatment. The largest increases occurred between 1999 and 2002, following the wet winter period in 1998 but this is based on very small numbers of actual new plants (2-4 in 4800m^2). Hence the changes are not statistically significant.

Table 5.32 Change in poplar box populations (no. ha^{-1}) between years.

Treatments	1995-97	1997-99	1999-02	1995-2002
Trees (mean ha^{-1})				
Treeless	8	-4	13	17
Treed	-2	-4	-2	-8
Burning (mean ha^{-1})				
Burnt	4	-6	10	8
Unburnt	2	-2	0	0

5.2.3.4.2 Stem basal area

The average tree basal area in the burning trial was higher than the mean across the grazing trial. At the end of the burning trial, after 8 years of exclosure from grazing, the mean tree basal area in the unburnt treatments was marginally higher than in the burn treatments (Figure 5.8).

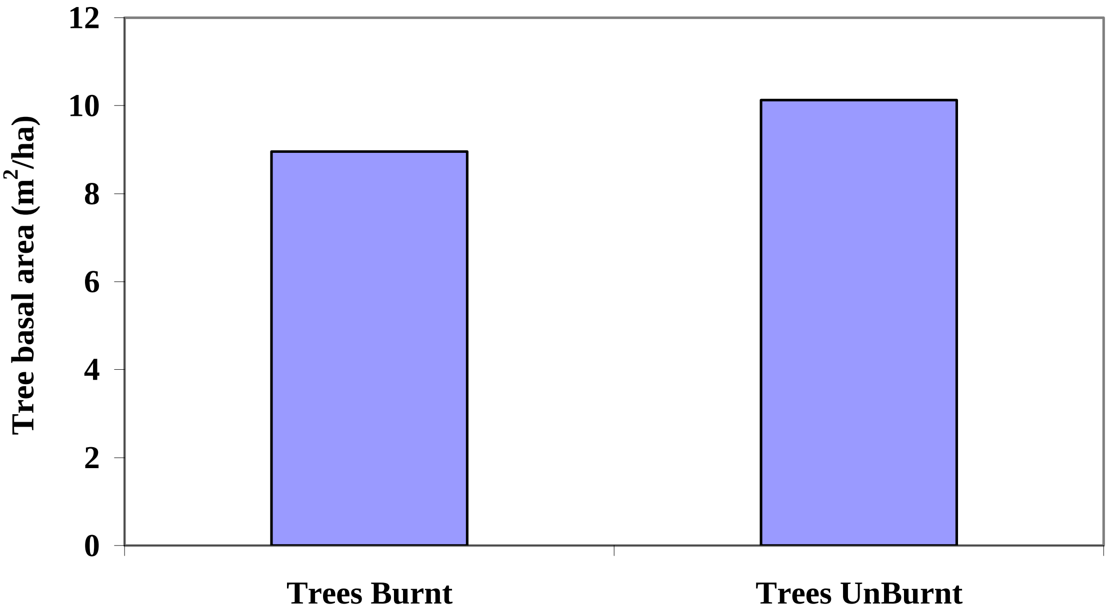


Figure 5.8 Poplar box tree basal area in the burning trial in 2002.

There was no big change in woody plant basal area in the treeless treatments. However, there was an increase of 1.8 m^2 ha^{-1} in the treed treatments between 1995 and 2002 (Table 5.33). In both burning treatments, there was an increase in basal area of near 1 m^2 ha^{-1} over the same period, which is nearly 20%. Some of this increase is due to prickly pear (*Opuntia* spp.). Some of the 'noise' in the results is also caused by the fluctuating presence of prickly pear in the burnt trial areas. These plants were recorded with the 'woody' species because they are not herbaceous and are an obvious component of woodland dynamics in Qld. Their plant density ranged from 0 to 11 in individual plot sample areas and they were more common where unburnt and also under trees compared to in treeless plots.

Table 5.33 Basal area (m^2 ha^{-1}) of all woody plants in tree and burning main treatments, 1995-2002.

Treatments	1995	1997	1999	2002	Change 95-02 (SD)	% change
Trees (mean ha-1)						
Treeless	0.01	0.0	0.06	0.07	0.05 (0.10)	+650
Treed	10.4	10.4	11.5	12.2	1.8 (0.63)	+17
Burning (mean ha-1)						
Burnt	4.4	4.4	5.1	5.4	1.0 (1.13)	+23
Unburnt	6.0	6.0	6.4	6.8	0.8 (0.99)	+14

SD = Std Deviation

Regular spring fires did not slow the growth of existing poplar box trees

There was no increase in basal area of poplar box in the treeless treatments, although their trunks in the treed plots increased by 1.72 m^2 ha^{-1} during the trial period (Table 5.34). There were increases of less than 1 m^2 ha^{-1} in basal area of box trees in both burnt and unburnt treatments. This demonstrates that 6 fires in 8 years were ineffective in controlling the established box trees.

Table 5.34 Poplar box tree basal area (m^2 ha^{-1}) in treed and burning main treatments of Tordoned and treed plots, between 1995 and 2002.

Treatment	1995	1997	1999	2002	Change 95-02	% change
Trees mean						
Treeless	0.01	0.00	0.00	0.00	-0.01	0
Treed	10.2	10.2	11.2	11.9	+1.7	+17
Burn mean						
Burnt	4.3	4.3	5.0	5.3	1.0	+23
Unburnt	5.9	5.9	6.3	6.6	0.7	+12
Burnt+Treed						
Burnt	8.6	8.7	10.0	10.6	2.0	+23
Unburnt	11.8	11.8	12.5	13.3	1.5	+13

The proportion of poplar box contribution to woody plant basal area remained constant around 97%, although the basal area of the box trees increased by 1.7 m^2 ha^{-1} during the trial (Table 5.34).

Existing poplar box trees would double their stem area in 33 years

The increase in poplar box basal area between 1995 and 2002, though small proportionally, shows its competitive ability to the pasture in this community in the absence of grazing, even with a burning regime. A rate of 15% over 7 years equates to a doubling of poplar box trunk area every 33 years in regrowth stands. Our data also shows that the rate is not slowed by regular burning (Table 5.34). Note also that the biggest increase in stem basal area was between 1997 and 1999 when we had a wet winter and above average rainfall.

5.2.3.4.3 Estimated Crown Cover

There was a small increase in estimated crown cover of all woody plants in all treatments (Table 5.35). There was no difference in the increase between the burnt and unburnt treatments (110 m^2 ha^{-1}). Across the site, mean crown area increased by 110 m^2 ha^{-1} during the trial but the figure was a 185m^2 increase where the trees were not poisoned. The burnt plots averaged a crown area spread about 60% greater than occurred on the unburnt ones.

Table 5.35 Crown area (m^2 ha^{-1}) in treeless and burnt treatments during the trial and change, 1995-2002.

Treatments	1995	1997	1999	2002	Change 1995-02	% change
Trees (mean ha^{-1})						
Treeless	6	5	22	42	36	+600
Treed	4473	4564	4590	4658	185	+ 4
Burning (mean ha^{-1})						
Burnt	1718	1737	1752	1828	110	+ 6
Unburnt	2761	2833	2860	2872	111	+ 4
Site mean	2240	2285	2306	2350	110	+ 5

Some of the tabulated data in this section is presented in graphical form in Appendix D.

5.2.3.5 *Discussion*

This site showed a consistent increase in woody stem basal area over time. Fifteen percent increase over 7 years equates to a doubling every 33 years by this semi-mature regenerating woodland in the absence of grazing. The rate of increase of 1.8m^2 ha^{-1} over 7 years is equivalent to 0.26 m^2 ha^{-1} yr^{-1} which matches the results of Burrows *et al.* (2002) for central Queensland eucalypt woodlands generally. So our trial site results are typical of what the industry might expect over a normal run of good and poor seasons.

The increase in tree size, almost all from existing trees, occurred irrespective of regular spring fires (6 fires in 7 years, Table 5.33). So spring burning cannot help to control competition from existing trees unless they are burnt out from within after developing hollows. As our trees were 40-60 years old at most, regeneration from previous ringbarking, they had not yet developed hollows in their trunks and so were not susceptible to being burnt down by mild to moderate spring fires.

Regular spring burning did slow the rate of recruitment of new woody plants but that was mainly by species other than poplar box (Table 5.30). This means that burning can assist in making mustering easier in woodlands and it will suppress fire-sensitive species such as cypress pine. Rate of recruitment was similar in both treed plots and those where trees had been recently poisoned (Table 5.30) but numbers were still low, 37 per hectare after 7 years. This included the favourable recruitment period during the wet winter of 1998.

Poplar box recruited better in the treed plots and recruitment was generally better where spring fires were eliminated (Table 5.30). However, it did not have any major seedling germination events during our trial, so the ability of spring burns to kill its seedlings was not really tested.

Recruitment rates of 37 ha^{-1} were lower than in the grazing trial (85 ha^{-1}). Thus there is no apparent link between this and grazing management because greater recruitment occurred at the lowest grazing pressure in the grazing trial.

5.3 Comparisons between sites

The woodland trees and shrubs at the ironbark site were completely different from those at the poplar box site. Yet at both sites, the arboricide used was very effective at killing the dominant eucalypt species but not for some of the minor woodland components such as prickly pine and myall.

Woodland regeneration at both sites was unusually low but, by the end of 7 years, evidence of tree regrowth was clear at both sites in the ungrazed plots. At the box site, this was a steady growth increment, but at the ironbark site the residual effect of the Velpar caused a prolonged loss of plants for several years after application. Thus a fall in woody plant numbers and stem area was general between 1995 and 1997 but then a complete or partial recovery was common by 1999 (Tables 5.1 and 5.5). There were also indications that the trees there were still suffering ill-thrift after the severe 1992-94 drought and having possible continued deaths as a consequence. Unfortunately no final tree recordings were done at the ironbark site in 2001 to see if the recovery in 1999 was continued while above average seasons prevailed around 2000. However, the picture in Figure 5.2 would suggest that the recovery continued strongly.

Spring fires were not helpful in reducing the growth of established eucalypts at either site. However recruitment of woody plants was reduced by regular fires at both sites. Removal of existing trees by arboricide had minimal impact on the initial rate of recruitment of woody species.

Grazing pressure at both sites had little impact on woody species regeneration but there was a suggestion that low grazing pressure tended to favour woody plant recruitment and for high grazing pressure to discourage it (Tables 5.5 and 5.17), in the absence of fire. This trend was largely driven by the relative abundance of plants that are more palatable than the dominant eucalypts, plants such as prickly pine at Rubyvale and myall at Injune.

Use of a squirt gun to put herbicide (Velpar) into the ground adjacent to small, multi-stemmed ironbark plants confounded the interpretation of the results at the ironbark site. Plants continued to die for several years up to 1997 but then some apparently dead ones resprouted by 1999 (Tables 5.5 and 5.12). At the poplar box site, use of Tordon as the arboricide meant a similar option to treat small trees was not feasible because of Tordon's differing chemistry in soil.

6 Pasture dynamics

6.1 Ironbark site

6.1.1 Grazing trial

6.1.1.1 *Abstract*

The dynamics of native pastures over seven consecutive years in response to tree removal, three grazing pressures and their interaction were studied in a Rubyvale silver-leaved ironbark community from 1994 to 2001. The pasture is dominated by a healthy stand of the palatable, productive perennial (3P) grasses *B. ewartiana, H. contortus* and *C. fallax.* *B. ewartiana* generally had the highest yield and basal area. Minor grasses, *T. triandra*, forbs and native legumes contributed individually less than 5% to pasture yield. The dominant treatment effects were decreasing ground cover, pasture yields, basal area and lifecycles resultant from increasing grazing pressure. However, increasing grazing pressure caused higher rates of recruitment and mortality, and reduced survival for both *B. ewartiana* and *H. contortus*.

Grazing pressure affects the population dynamics of *H. contortus* far more strongly than occurs with the other two main grasses. *T. triandra* frequency is a good indicator of increasing grazing pressure as it was reduced by increasing grazing pressure in most years of the trial. *T. australianus* frequency was improved with increasing grazing pressure in most years of the trial. Tree killing resulted in small increases in ground cover and pasture yield. The years when the size of the seedbanks of *B. ewartiana* and *H. contortus* was high generally followed above average rainfall in the previous summer. However, in all years of the trial there appears to have been adequate rainfall to generate seedbanks sufficient for recruitment. The seedbanks of other species were not affected by treatment. The woody species seedbank was virtually non-existent.

6.1.1.2 *Background*

Studies into the ecology and production potential of grazed native pastures provide a sound base for the development of good grazing land management. Measuring the persistence, recruitment and mortality of key species and determining their lifespans under differing management gives a good understanding of their dynamics. Ground cover, yield, composition, basal area and seedbank measurements assist with determining the functions involved when a landscape process is changed as a result of management and/or climatic interactions.

6.1.1.3 *Methods*

6.1.1.3.1 Ground cover, pasture yield and species composition

The Botanal technique (Tothill *et al.* 1992) was used to describe ground cover, species frequency, yield and composition within each paddock. All operators had an ability to visually rank pasture yield, an ability to identify the base set of pasture species recorded at each site and an ability to visually rank ground cover. Other sampling details -

- quadrat size 0.5 metre by 0.5 metre (size $0.25m^2$)
- yield ranking 00 to 100 - the Botanal input program ignores the decimal place

- number of species ranked for yield 3
- species frequency all species present in quadrat
- cover class codes 1= 0-5%, 2=5-15%, 3=15-35%, 4=35-50%, 5=50-90%, 6=90-100%
- 15 ranked quadrats were cut, dried and weighed to develop the regression equations to convert the Botanal yield ratings to species and pasture dry matter yields in kg/ha

The paddocks were sampled each year on a grid pattern along the same marked transects.

Annual sampling was generally in April or May when species identification was easiest. Both the grazing trial and burning trial used the same technique but with differing sample sizes. There were up to 520 quadrats recorded in paddocks in the grazing trial.

A Forall header program was generated to calculate plot means. The header program also calculated frequencies of genus groups where identification to species was not possible (Appendix E1). Treatment means were calculated in Excel Pivot tables.

6.1.1.3.2 Perennial grass basal area

Basal area was measured using the point frame method. Pasture basal area is sensitive to marked changes in grazing pressure and climatic conditions. Absolute values in semi-arid native pastures are low, often < 5%. Hence to ensure that error due to operational factors was minimised the following procedures were necessary:

- sampling was done along the fixed TRAPS transect lines. Steel posts 50 metres apart marked the start and finish of each sector.
- total transect length in each grazed paddock was 450 metres, subdivided as 3 lengths of 150 metres. In small and narrow paddocks subdivision into lengths of 100 and 50 metres was necessary.
- 3000 pin strikes were observed for each paddock in the grazing trial. Using a 0.75 metre long frame, with a distance of 25 cm between pins, this equates to 600 “end to end positionings” of the frame.
- at each pin strike either bare or plant base is recorded. If a strike occurred on a plant base, the species or plant group was recorded.
- definition of plant base is critical to the reliability of this method. The pin must strike from directly above the rooted base of the plant. If the plant was shorn to ground level, any pin that would miss the plant base is deemed “bare”. At any one sampling the same operator should observe all strikes and where possible the same operator should be used for consecutive samplings.

Annual sampling was generally in June and July. Both the grazing trial and burning trial used the same technique but with differing sample sizes.

6.1.1.3.3 Grass population dynamics

These measurements were taken to determine the persistence, recruitment and mortality of key perennial grass species and to estimate their life spans under different grazing management. The life history of plants was monitored by charting plants of key species in permanent quadrats. Quadrats were distribution in each paddock in clusters located near a steel post on the fixed transect lines.

A data recording sheet, identical to the quadrat grid configuration allowed the location of each key species plant to be mapped to scale by hand in pencil. Only the base of a plant was drawn and its species code was put alongside. Any new recruits were drawn on the grid and notes were also entered on the sheet. Plants on the edge of the quadrats were mapped and included in the population calculations because they often migrated further within over time. Sampling was done annually at end of growing season, from May onwards.

The actual shape of the quadrats used differed between the sites as did the method of recording plant co-ordinates during data entry into a database. Both the grazing trial and burning trial at the same site used the same technique but with differing sample sizes. The grazing trial used 15 quadrats per plot. See Appendix Q for more details.

The key species recorded at the ironbark site were – *Bothriochloa ewartiana* (forest Mitchell), *Chrysopogon fallax* (golden-beard grass) and *Heteropogon contortus* (black speargrass).

6.1.1.3.4 Soil seed reserves

These measurements were taken to see how large the pool of seeds of all species was each spring and how much they varied amongst years. Such reserves can have a big bearing on how strongly a damaged pasture recovers and how susceptible a pasture is to active invasion by existing weedy plants.

Field collection details:

- it was critical that sampling was complete prior to the onset of spring rains, to ensure that no seed germination occurred prior to sampling, ie. it was done in August to September.
- a soil corer with sampling dimensions of 5.3cm diameter (area of 22cm^2) and able to sample to 5cm depth was used. The bulk of soil seeds are located in the top 2cm of soil.
- 4 cores were bulked into one bag to form a single sample from one location
- cores were taken from around the permanent quadrats used to record the grass population dynamics

Sampling was done annually at end of winter. Both the grazing trial and burning trial used the same technique but with differing sample sizes.

After sampling, the soil was air-dried in paper bags and then carefully sieved to remove large stones and litter, without losing any soil or seeds in small litter. In early summer the soil was spread about 2 cm deep over the surface of pots nearly filled with washed sand in a glasshouse. The pots were then regularly sprayed with water to induce germination of all germinable seeds.

Germinated seeds were counted and removed as soon as they were identifiable to a species level. Regular watering was discontinued after 4 to 6 weeks, by which time the vast majority of germinable seeds had emerged but moss and algal cover was still acceptably low. Watering continued intermittently for many further weeks to keep existing, unidentified plants growing until they could be named. Sometimes this required the addition of some nitrogenous fertiliser to keep plants growing in the 15cm pots. See Appendix I for more information.

6.1.1.4 *Results*

6.1.1.4.1 Ground cover

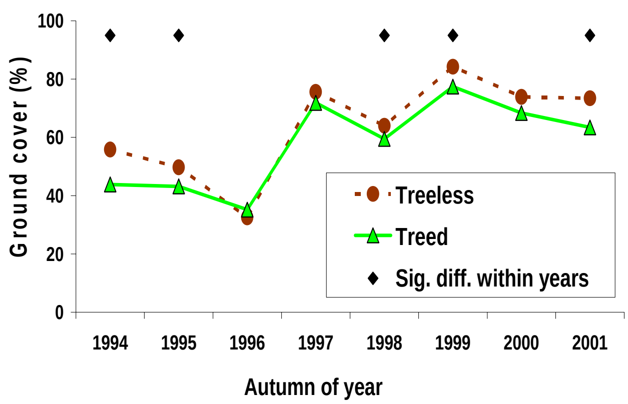
The ironbark site trials aimed to quantify the effect of interactions between tree killing and burning, and the interactions of tree killing and grazing pressure on ground cover and hence better understand the landscape processes that operate in that land system. Ground cover is important for reducing runoff and soil loss by intercepting and absorbing the energy of falling rain drops, impeding the flow of runoff water, increasing infiltration and resisting the erosive force of flowing water

(Osborn 1952, Thurow 1993 and Holechek *et al.* 1989). McIvor *et al.* (1995) found that, for small rainfall events, runoff and soil loss decreased rapidly as ground cover increased. However for large rainfall events (total > 100mm and intensity >45mm/hour) ground cover had no effect on runoff but it did reduce soil movement.

Tree killing

Throughout the trial, tree killing via arboricide only resulted in a minor increase in ground cover which is not surprising given that pasture yield was largely unaffected by tree killing. Tree killing was associated with a very significant increase in ground cover in the autumn of 1994 and 2001 (P<0.001, Figure 6.1). Stem injection treatment was applied in March 1994 so that the early increase in ground cover could only have been a result of leaf drop from dying trees. There was a weak improvement in ground cover due to tree killing in 1995, 1998 and 1999 (P<0.05). The increase in ground cover due to tree killing in 2001 was associated with a higher pasture yield in the treeless plots (4840 vs 3083 kg/ha), the only year in eight when tree killing significantly increased pasture growth. Neither annual nor summer rainfall affected the influence of tree killing on ground cover.

Mean autumn ground cover in the large COMM paddock which had its trees left intact and was grazed at a moderate grazing pressure according to local best practice, was always high from 1998 through to 2001. It ranged from a low of only 82% in 1999 to a high of 90% in 2001.

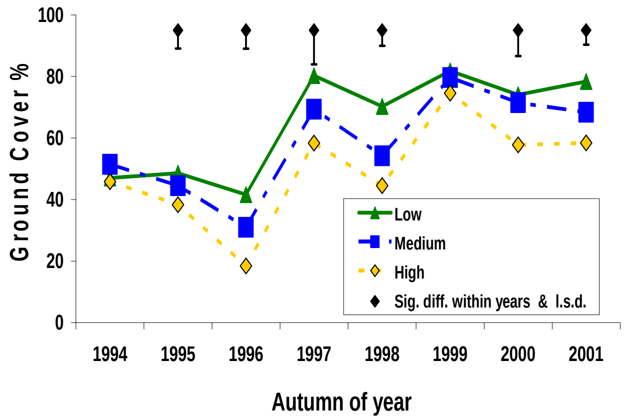


Tree killing caused a minor increase in ground cover in some years

Figure 6.1 Tree killing impact on ground cover (%), ironbark site.

Grazing pressure

Increasing grazing pressure resulted in a significantly decreased ground cover in 6 out of the 8 years of recordings (Figure 6.2). Mean level of autumn cover at the site tended to reflect total and annual rainfall from the previous year (See Figure 4.5). The low ground cover levels in 1996 were associated with high levels of runoff and erosion during the 1996/97 summer (described in Section 10). Runoff and erosion were considerably increased as ground cover was decreased by increasing grazing pressure. Grazing pressure did not significantly affect ground cover in the autumn of 1999. This was due to a low annual stocking rate set in autumn 1998 to achieve high grazing pressure of the available forage being overtaken by a well above average summer rainfall in the 1998/99 summer. Detailed statistical analysis is presented in Appendix N1.



Low grazing pressure provides more ground cover

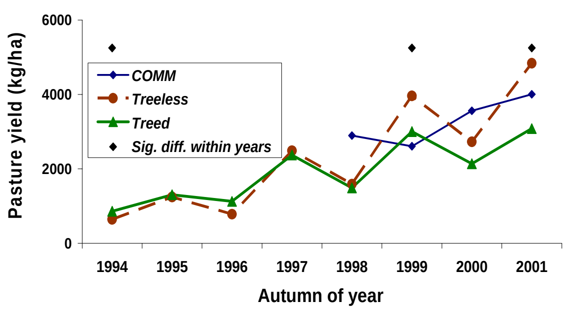
Figure 6.2 Grazing pressure impact on ground cover (%), ironbark site.

6.1.1.4.2 Community yield and composition

6.1.1.4.2.1 Total pasture yield (kg/ha)

Tree killing

Tree killing had minimal effect on total pasture yields (kg/ha – kgs of standing dry matter per ha), in the first four years of the succeeding 7 years of the grazing trial (Figure 6.3). There was a trend towards an ever increasing benefit from tree killing as the trial progressed from a slightly poorer yield initially to a steadily increasing differential in favour of tree killing by the end of 8 years. Tree killing resulted in significantly increased pasture yields in 2001 ($P<0.01$) and 1999 ($P<0.001$). In 1999, the increase in pasture yield due to tree killing was enhanced at reduced grazing pressure ($P<0.05$).



Tree killing had minimal impact on pasture yield initially

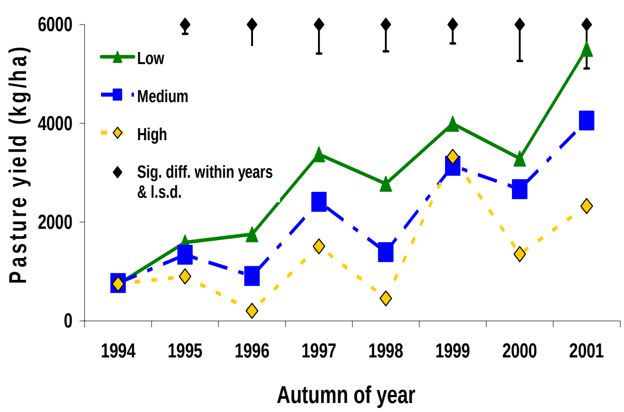
Figure 6.3 Tree killing impact on total pasture yield (kg/ha) in the grazing trial, ironbark site; compared to the large COMM paddock.

Grazing pressure

Pasture yields at the start of the trial in 1994 reflected the low rainfall in the previous two years. Greater grazing pressure resulted in a decreased pasture yield in all years of recordings barring 1994 when cattle were first introduced (Figure 6.4). Enduring recovery of the pasture under low grazing pressure indicates previous grazing practises had not stilled the capacity of the pasture to recover if well managed. The low pasture yields in 1996 were associated with relatively high levels of runoff and erosion during the 1996/97 summer (described in Section 10). Runoff and erosion were considerably increased as pasture yield was decreased by increasing grazing pressure. Pasture yield increased abnormally in the high grazing pressure treatments in the autumn of 1999.

This was due to the low annual stocking rate set in the previous autumn to achieve high grazing pressure of the pasture then present then being overtaken by a well above-average summer rainfall in the 1998/99 summer. The recovery of the pasture, shown by the pasture yield and basal area (Section 6.1.1.4.2) is quite significant over one good wet season. High pasture yields (>2500 kg/ha) in the autumn of 1997, 1999 and 2001 under medium grazing pressure followed above average summer rainfall (Section 4.2.1). Low grazing pressure ensured the highest pasture yields in all years of the trial. Detailed statistical analysis is presented in Appendix N1. Under low grazing pressure there is less pasture grazed by stock, there is more carryover standing dead material and there is probably more pasture grown from the same amount of rainfall due to a better pasture condition.

In the large COMM paddock, standing pasture yield similarly increased over time (Figure 6.3) but was often higher than the equivalent moderate grazing pressure, treed pastures which had their stocking rate adjusted every year to reflect seasonal conditions. However, the major component species followed the season-induced trends of all paddocks, with a noticeable increase in *T. triandra* over time, a steady yield of *B. ewartiana* each year and a fluctuating contribution from *H. contortus* (Appendix H1, Table H1e). Note that pasture composition in the COMM paddock was not assessed in the early years of the trial, but we are confident that it was as typical of all the other paddocks then as it proved to be in later years when full data was collected.



Low grazing pressure increased autumn pasture yields

Figure 6.4 Grazing pressure impact on total pasture yield (kg/ha) each autumn at the ironbark site.

6.1.1.4.2.2 Pasture component yields

Visually the main components of the pasture at a paddock scale are *B. ewartiana*, *H. contortus*, and *C. fallax*. Their respective proportions fluctuate each year but together they contributed between 60 and 70% of the total pasture yield on offer. All other grasses, the forbs and the native legumes group contributed, individually, less than 5% of total pasture yield. The main species and species groups and their frequency at the ironbark site are described in Appendix E.

Major perennial grasses

Tree killing

The yields of most components of the pasture were correlated with tree killing or tree retention at some time during the trial. In general, the main grasses grew increasingly better as the trial progressed where the trees had been killed (Figure 6.5). *H. contortus* yields were much higher in treeless paddocks in 2001 (P<0.001) and this effect was relatively greater at a lower grazing pressure (P<0.05) (Appendix H). There was a weak benefit of tree killing (P<0.05) on *H. contortus* and *B ewartiana* yields in 1999, and on *T. triandra* in 1995. Trees had a weak positive benefit on

C. fallax but only in 1998 was it significant (P<0.05). Tree killing in 1994 also had a strong positive association (P<0.001) with *T. triandra* yields in 2000 and 2001. Increasing grazing pressure decreased the positive effect of tree killing on *T. triandra* in 2000 (P<0.05).

Tree killing increased the yields of major perennial grasses

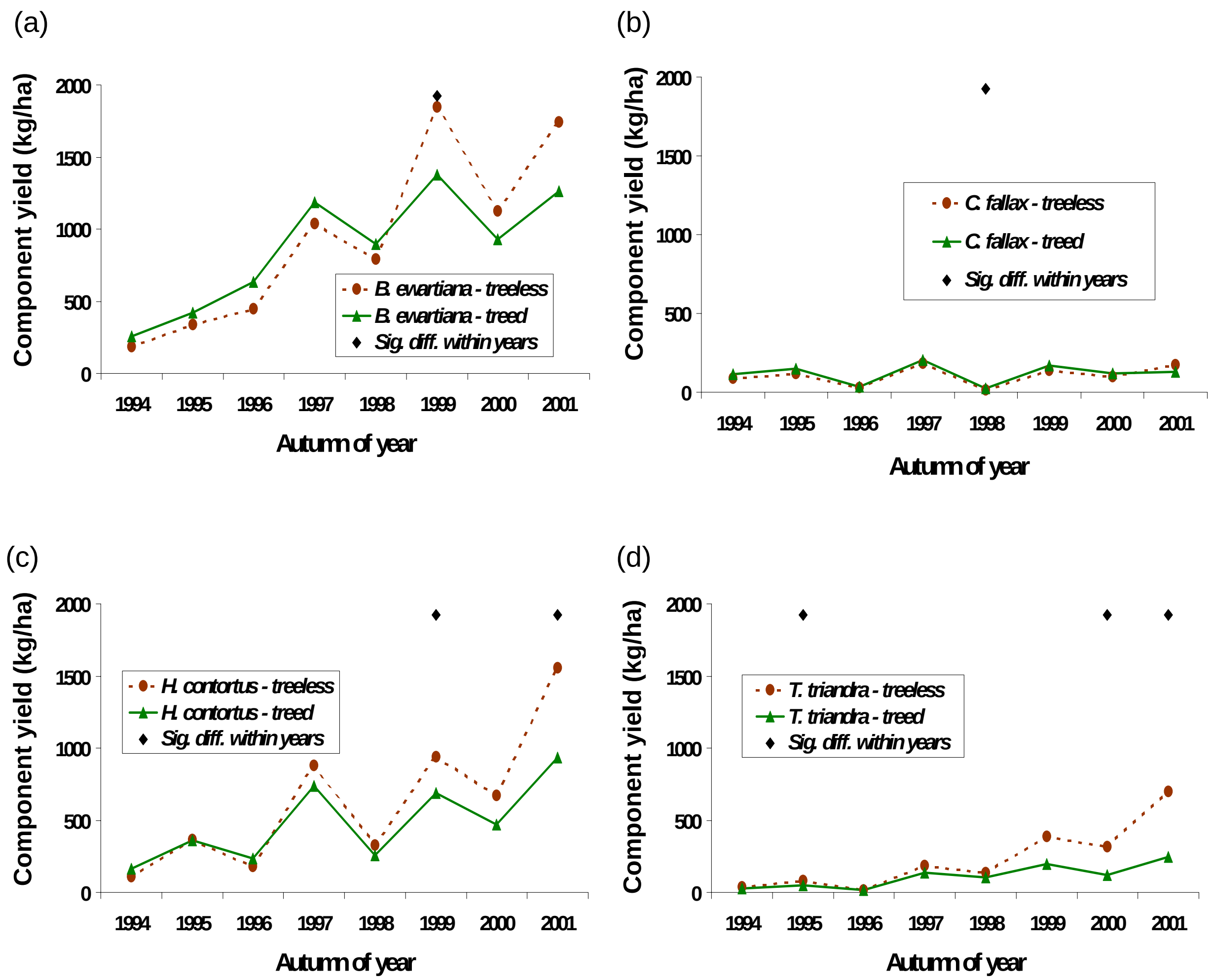


Figure 6.5 Tree killing impact on the yield of (a) *B. ewartiana*, (b) *C. fallax*, (c) *H. contortus*, and (d) *T. triandra* at the ironbark site from 1994 to 2001.

Grazing pressure

Increasing grazing pressure decreased the measured yield of all the major perennial grasses in most years (Figure 6.6). Increasing yields of *H. contortus*, *B. ewartiana* and *T. triandra* over the period of the trial is evident under low and medium grazing pressure, and in response to the improving seasonal conditions. *B. ewartiana* generally had the highest yields under low and medium grazing pressure. It had the highest standing crop in the autumn of 1997, 1999 and 2001 following above average summer rainfall in 1996/97, 1998/99 and 2000/01. Yields of *B. ewartiana* were also the highest for all species following the extended dry conditions preceding the trial, and the dry summers of 1997/98 and 1999/00. This consistently higher yield was associated with a consistently higher basal area of *B. ewartiana* than *H. contortus* and *C. fallax* (Section 6.1.1.4.2) throughout the trial.

B. ewartiana yields were not significantly affected by grazing pressure in the autumn of 1997 and 1999 following good summer growing conditions. This could indicate a lower grazing preference for this plant while other species are freely available. The lack of a significant grazing pressure effect on all the major perennial grass yields in the autumn of 1999 was due to a low annual stocking rate set in autumn of 1998 as explained in Section 6.1.1.4.1. Detailed statistical analysis is presented in Appendix N1.

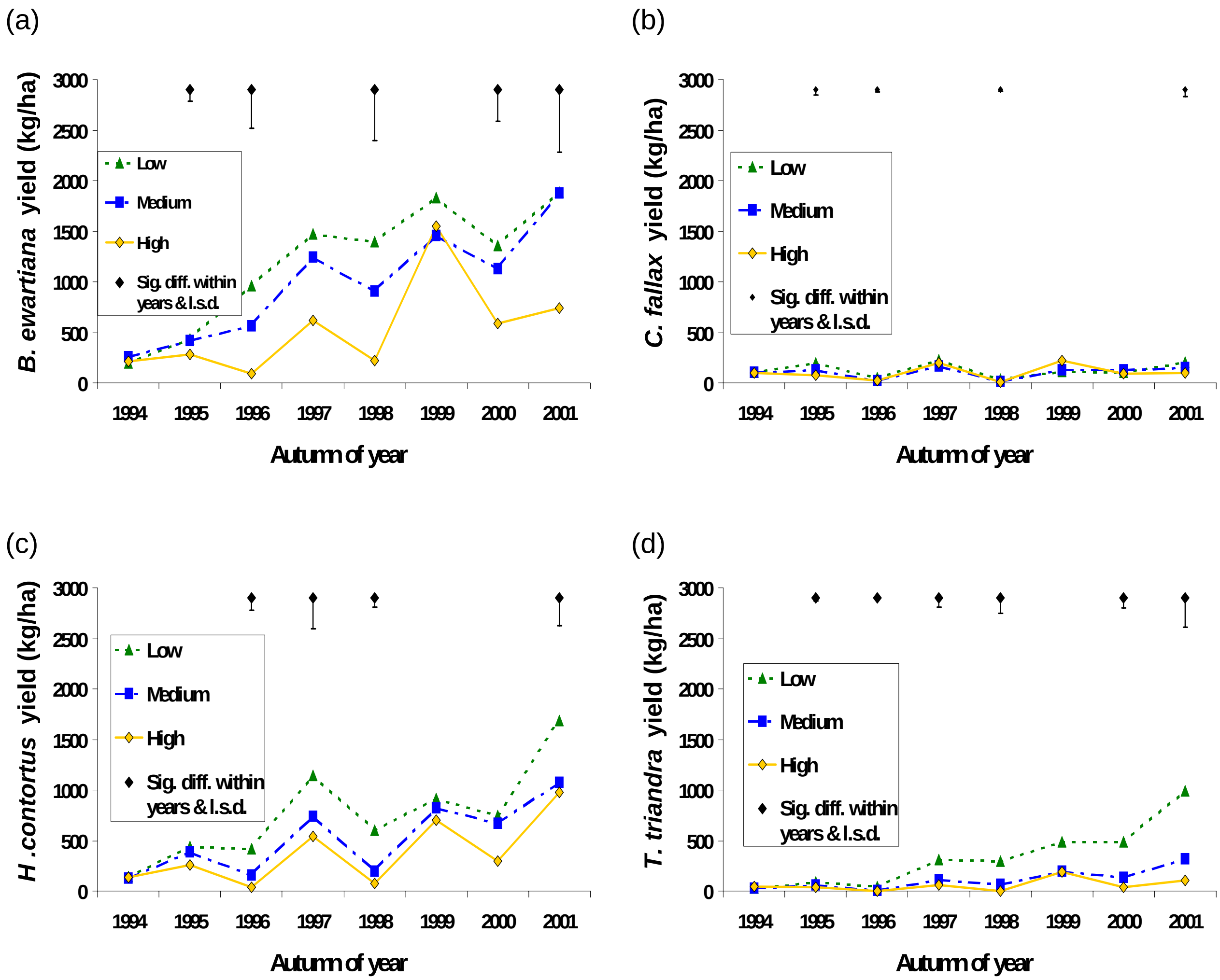


Figure 6.6 Grazing pressure impact on the yield of (a) *B. ewartiana*, (b) *C. fallax*, (c) *H. contortus* and (d) *T. triandra* over 8 years at the ironbark site.

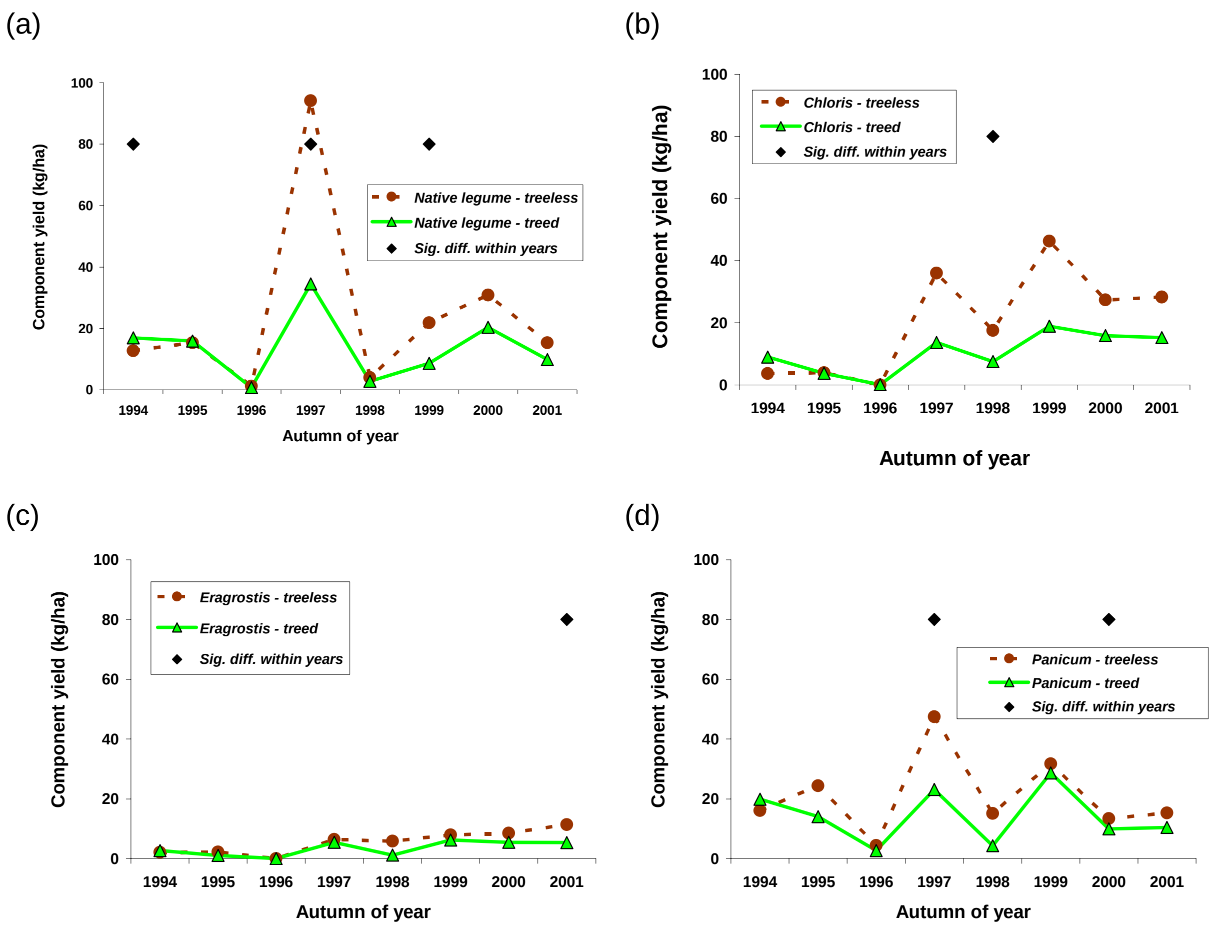
Low grazing pressure increased the yield of the major perennial grasses, especially *B. ewartiana*

Minor pasture components

Tree killing

Tree killing often enhanced the yield of minor species and it strongly benefited the yield of native legumes in 1997 (P<0.001). The effect in that year was even stronger at higher grazing pressure (P<0.01). In 1999, the tree-killing stimulus on native legume yield was again significant (P<0.05). Tree killing was also associated with a small increase (P<0.05) in the yield of *Chloris* spp. in 1998, *Eragrostis* spp. in 2001, and *Panicum* spp. in 1997 and 2000. Tree killing resulted in an increased (P<0.001) yield of forbs in 2001. Tree retention had a weak benefit (P<0.05) to sedges in 2000 and to *T. australianus* yield in 1996. The benefit of tree retention to *T. australianus* was increased with increasing grazing pressure (P<0.01) (Figure 6.7). Overall these results demonstrate the fluctuating presence of particular minor pasture components in individual years while the dominant ones are consistently relatively productive every year.

Tree killing increased the yield of most of the minor pasture components



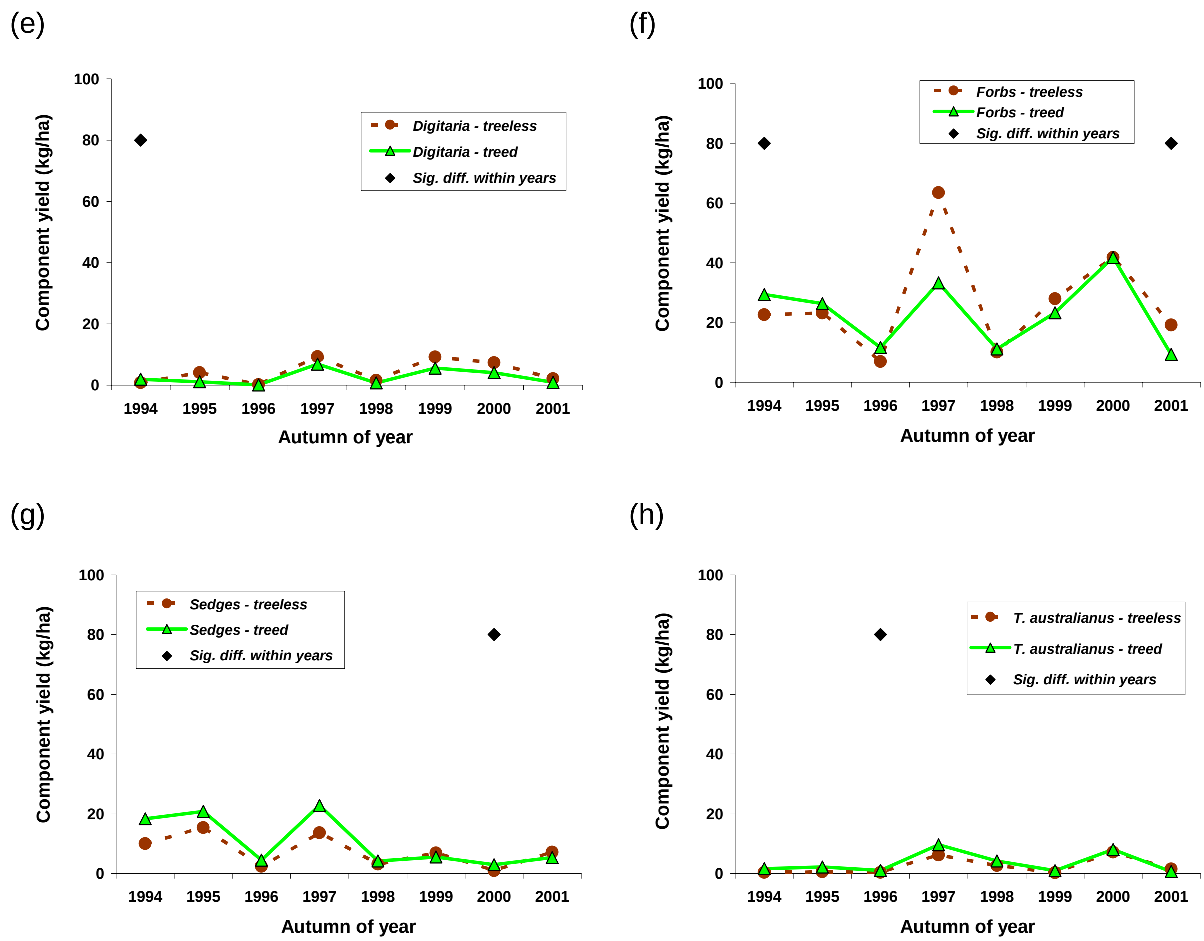
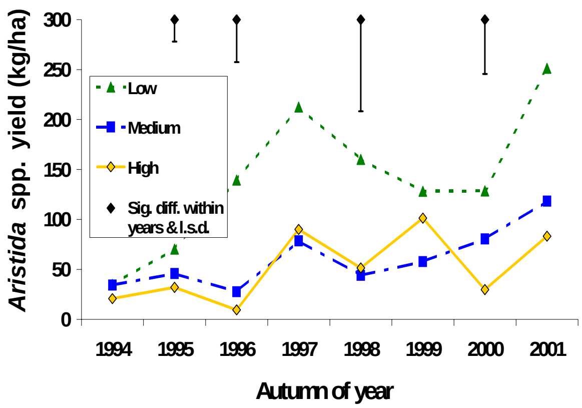


Figure 6.7 Tree killing impact on the yield of (a) Native legumes, (b) *Chloris* spp., (c) *Eragrostis* spp., (d) *Panicum* spp., (e) *Digitaria* spp., (f) forbs, (g) sedges , and (h) *T. australianus* at the ironbark site.

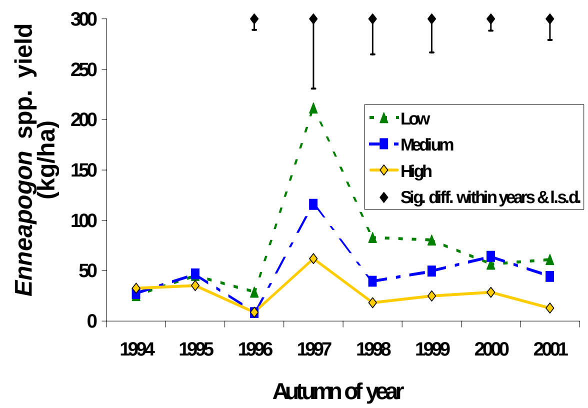
Grazing pressure

Increasing grazing pressure decreased the autumn yields of *Aristida* and *Enneapogon* spp. in most years of the trial. Nonetheless, at low grazing pressure, *Aristida* spp. grew well in response to above average rainfall conditions in the 1996/97 and 2000/01 summer, while *Enneapogon* spp. only had a large growth response at low grazing pressure following the 1996/97 summer (Figure 6.8). Detailed statistical analysis is presented in Appendix N1. The decreaser response is surprising given that both species have previously been regarded as increasers. In contrast, *T. australianus* had an increased yield under increasing grazing pressure during most years of the trial. All three species are relatively low value grasses but on the infertile ironbark soils their palatability may be relatively enhanced. It should also be noted that several of the *Aristida* species are fine-stemmed types such as *A. schultzii*, *A. gracilipes*, *A. ingrata* and *A. perniciosa*. These have been noted as more palatable than *A. calycina*.

(a)



(b)



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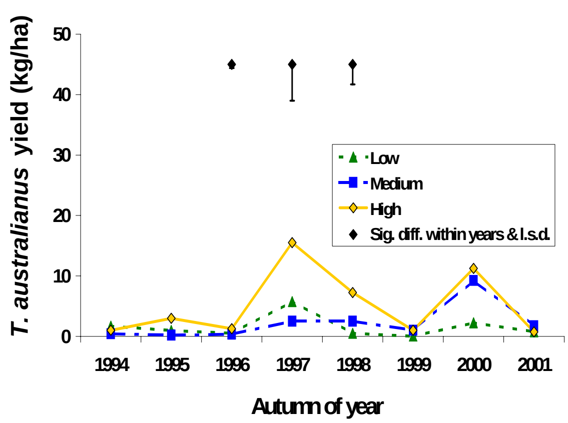


Aristida and Enneapogon spp. behaved as decreasers, while T. australianus behaved as an increaser

Figure 6.8 Grazing pressure impact on the autumn yield of (a) *Aristida* spp., (b) *Enneapogon* spp., and (c) *T. australianus* at the ironbark site.

6.1.1.4.2.3 Pasture component frequencies (%)

Frequency of individual species in the pasture was measured by recording presence or absence of up to nine taxa in 0.5m x 0.5m quadrats evenly spaced over each paddock, and is interpreted as a measure of plant density (Brown, 1954). The technique is sensitive to sameness and to change. Frequency change was also used as an indicator of trends due to different seasonal conditions and/or treatments. The small-statured, minor components of a pasture, such as legumes, often had a high frequency of occurrence in each sample area (quadrat), disproportionate to their ground cover and biomass.

Tree killing had minimal impact on pasture composition

Major perennial grasses

Tree killing

Tree killing increased the frequency of *T. triandra*, a bulky species sensitive to grazing management, in 1995 ($P<0.01$) and 2000 ($P<0.05$) but its frequency remained below 21% in all years. Tree killing did not significantly affect the frequency of *B. ewartiana, H. contortus* or *C. fallax* in any year (Figure 6.9). Their respective frequencies averaged 49, 39 and 34% respectively over the 8 years.

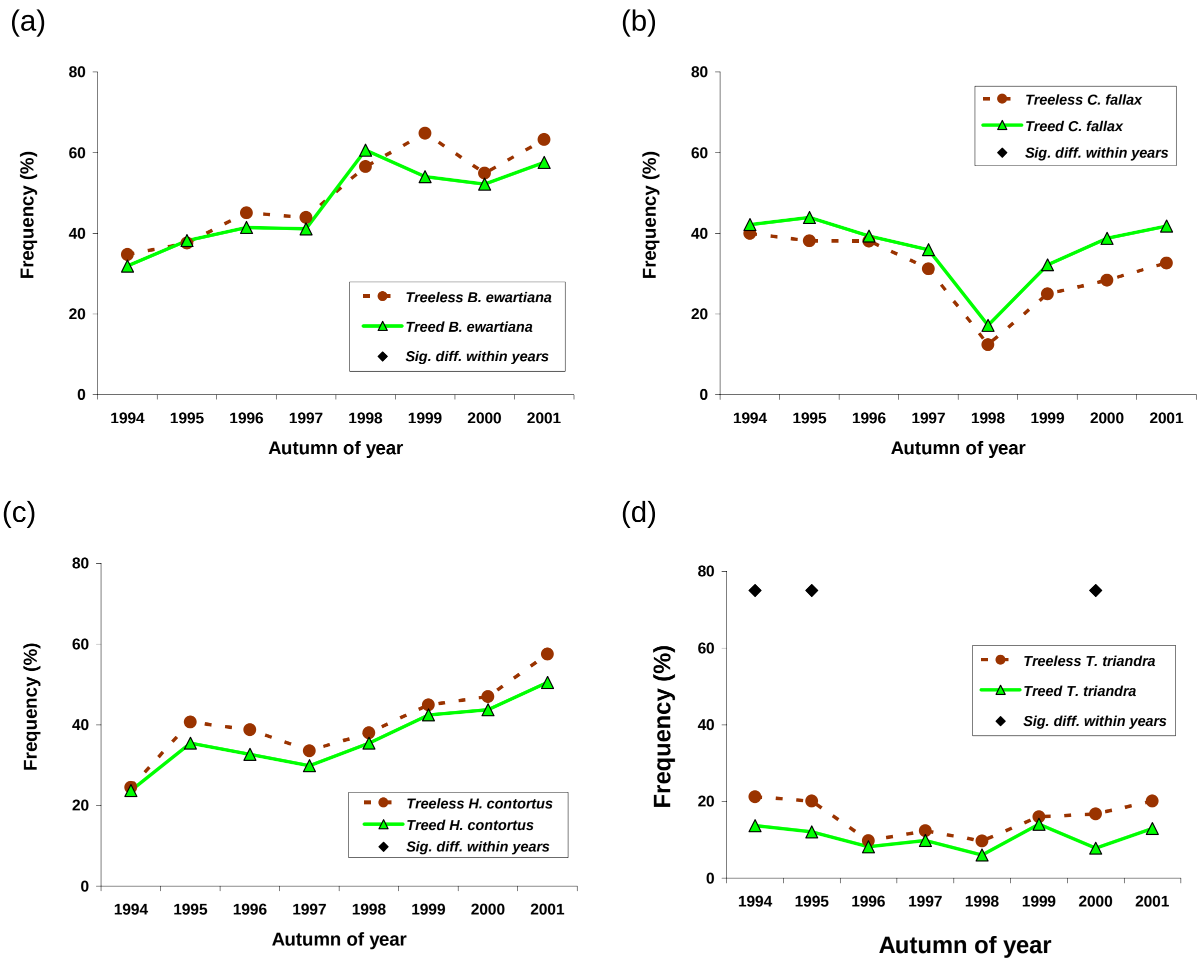


Figure 6.9 Tree killing impact on the frequency of (a) *B. ewartiana*, (b) *C. fallax*, (c) *H. contortus* and (d). *T. triandra* at the ironbark site.

Grazing pressure

Grazing pressure had no significant effect on the frequency of *B. ewartiana, C. fallax* or *H. contortus*. Section 6.1.1.4.3 discusses how the density of these grasses has been maintained. The frequency of *T. triandra* was considerably reduced by medium and high grazing pressure in most years of the trial (Figure 6.10). The sensitivity of *T. triandra* to high grazing pressure became evident after one year and is probably due its growth habit and the seasons. The simultaneous emergence of the buds of tillers with spring growth and the relatively high location on the plant crown renders *T. triandra* very susceptible to heavy grazing pressure in dry summers with resulting mortalities.

This is most evident in the summers ending in 1995, 1996, 1998 and 2000. Detailed statistical analysis is presented in Appendix N1.

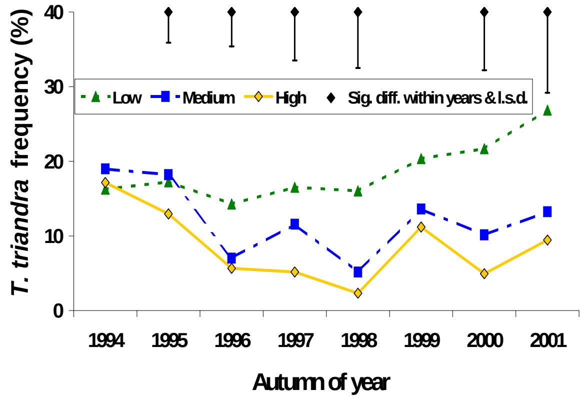


Figure 6.10 Grazing pressure impact on *T. triandra* frequency % at the ironbark site.

High and medium grazing pressure significantly reduced the frequency of *T. triandra*, but it did not affect the other major perennial grasses

Minor pasture components

Tree killing

Tree killing had minimal effect on the occurrence of most minor species but some were affected in some years. *Enneapogon* spp., *T. australianus* and *T. loliiformis* had a reduced frequency in the treeless paddocks in the autumn of 1999 (P<0.01) (Figure 6.11). Tree killing was associated with a much increased frequency of *Digitaria* spp. in the autumn of 1999 and 2000 (P<0.01) and of the native legumes group in the autumn of 1996 (P<0.001) and 1997 (P<0.01). Tree killing increased the frequency of *Chloris* spp. slightly in the autumn of 1996, 1997 and 1998 (P<0.05). The huge fluctuations in recorded legume frequencies are related to the dryness of the pastures at sampling time. Under temporary dry autumn conditions, perennial legumes often drop many leaves, cease flowering or are preferentially grazed so that they are far less obvious to recorders.

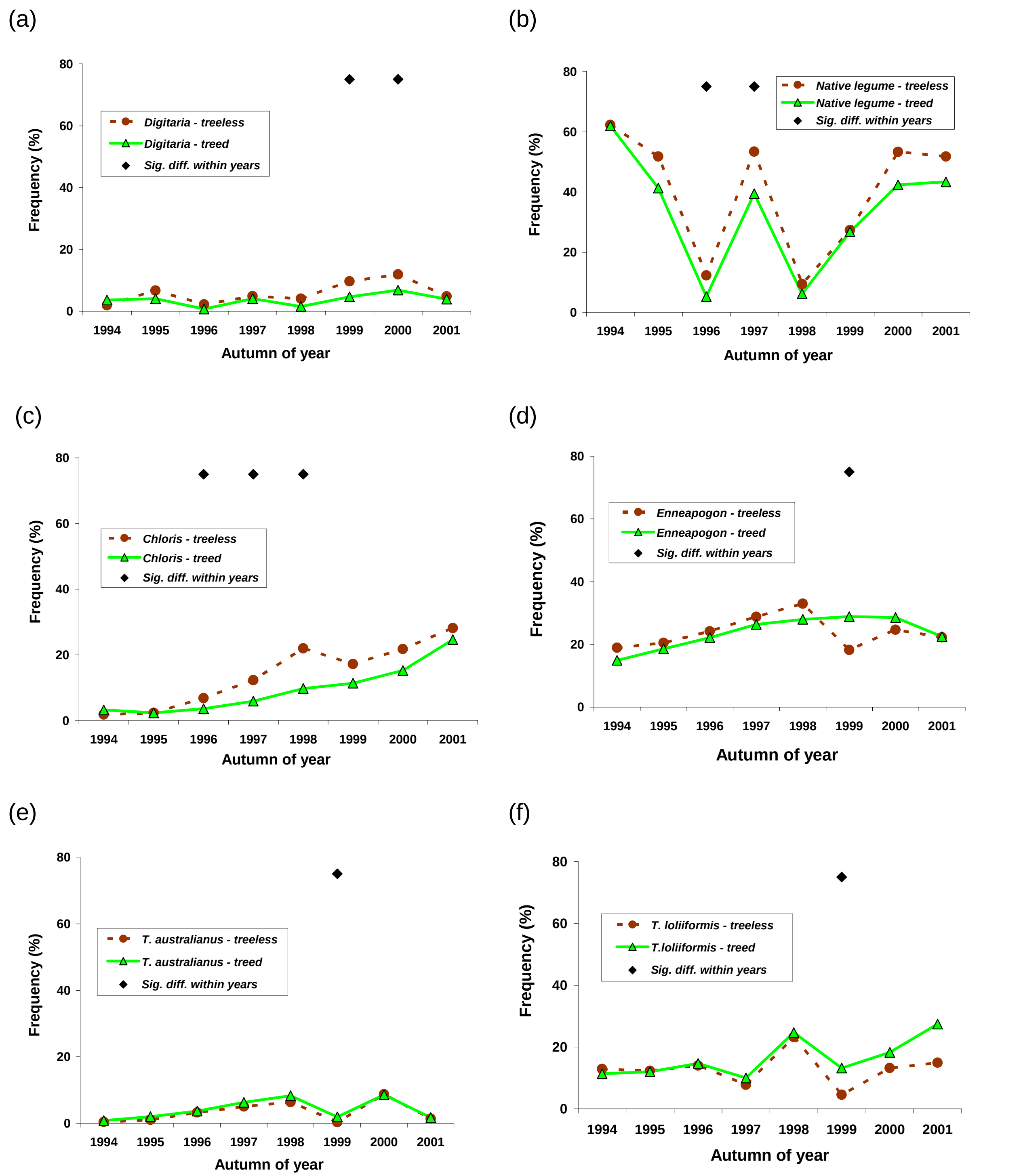


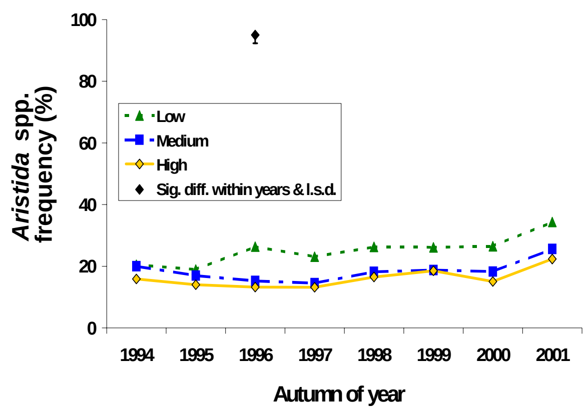
Figure 6.11 Tree killing impact on the frequency of (a) *Digitaria* spp., (b) native legumes, (c) *Chloris* spp., (d) *Enneapogon* spp., (e) *T. australianus* and (f) *T. loliiformis* under grazing at the ironbark site.

Grazing pressure

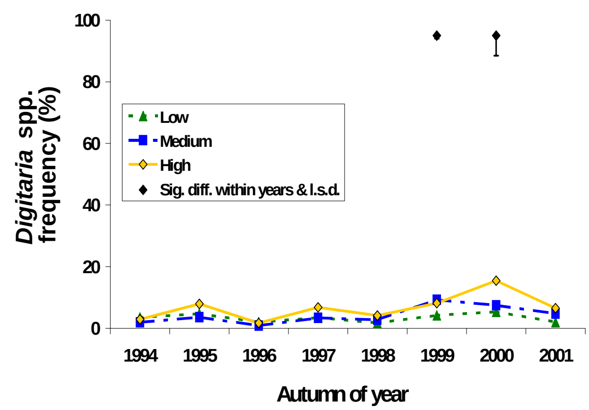
Increasing grazing pressure increased the frequency of *T. australianus* in most years (Figure 6.12). In 1999 and 2001 the autumn frequency of *T. australianus* declined substantially under all grazing pressures despite good summer rainfall in the previous summer and a trend of increasing total pasture yields. Pasture yield of *T. australianus* also declined in 1999 and 2001 and this is probably the result of strong competition and shading inhibiting the spring germination of *T. australianus* seeds or the subsequent seedling growth.

Grazing pressure had minimal recorded effect on the other minor pasture components. *Aristida* and *Enneapogon* spp. demonstrated a significantly decreased frequency with increasing grazing pressure in 1996 and 1999 respectively. *Digitaria* spp generally had an increased frequency with increasing grazing pressure and such differences reached significant levels (P<0.05) in 1999 and 2000.

(a)



(b)



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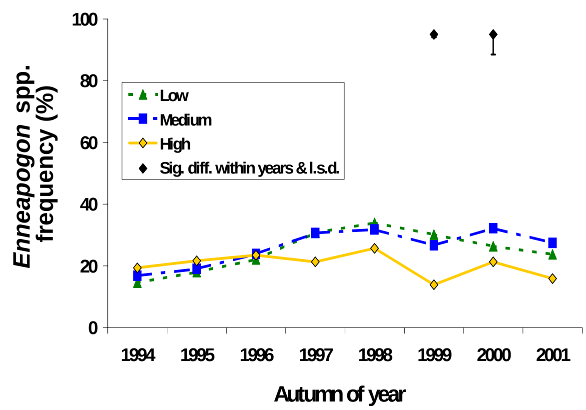

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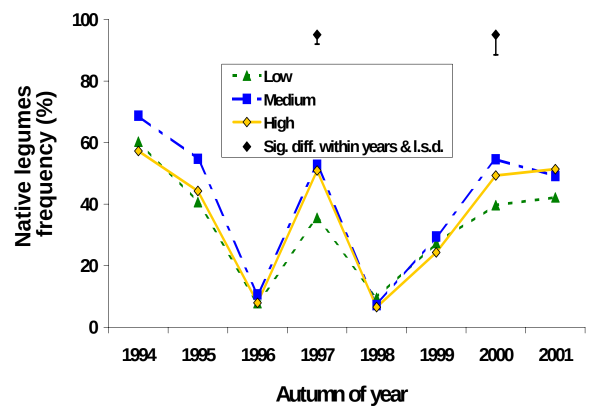

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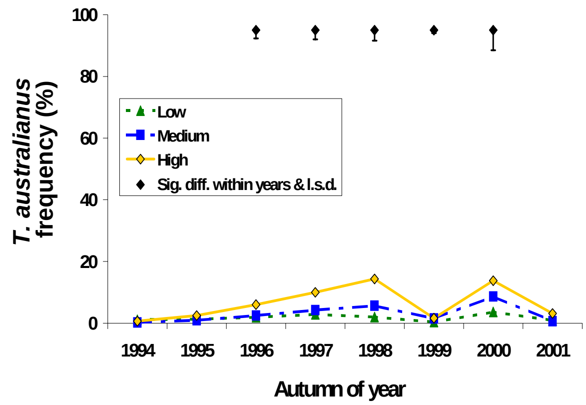


Increasing grazing pressure increased the frequency of *T. australianus*

Figure 6.12 Grazing pressure impact on frequency of (a) *Aristida* spp., (b) *Digitaria* spp., (c) *Enneapogon* spp., (d) Native legumes and (e) *T. australianus* at the ironbark site.

Plant frequencies from the large COMM paddock were similar to those of the moderate grazing pressure treed paddocks that it most closely emulated (Appendix H Table H1d). Between 1998 and 2001 the commonest grasses were *H. contortus* (mean 65% frequency), *B. ewartiana* (60%), *C. fallax* (43%), *Enneapogon* and *Aristida* spp. (22%) and *T. triandra* (15%). During that time *T. triandra* increased its frequency noticeably, like that of the low grazing pressure paddocks (Figure 6.10), and *H. contortus* also increased from 51% to 80% frequency.

6.1.1.4.2.4 Pasture biomass proportions (% composition)

Major perennial grasses

Tree killing

Tree killing had minimal effect on the proportion of pasture biomass (% composition) contributed by most of the pasture components. *T. triandra* was increased in 1997 by the prior tree killing (P<0.001) and increasing grazing pressure strongly enhanced the effect of tree killing (P<0.01). However, in 1995, 2000 and 2001 the *T. triandra* contribution was little affected by tree killing (P<0.05). Retention of trees had a small positive effect initially on the % contribution of *B. ewartiana* in 1995 (P<0.05) and of *C. fallax* in 1998 and 1999 (P<0.05) (Figure 6.13).

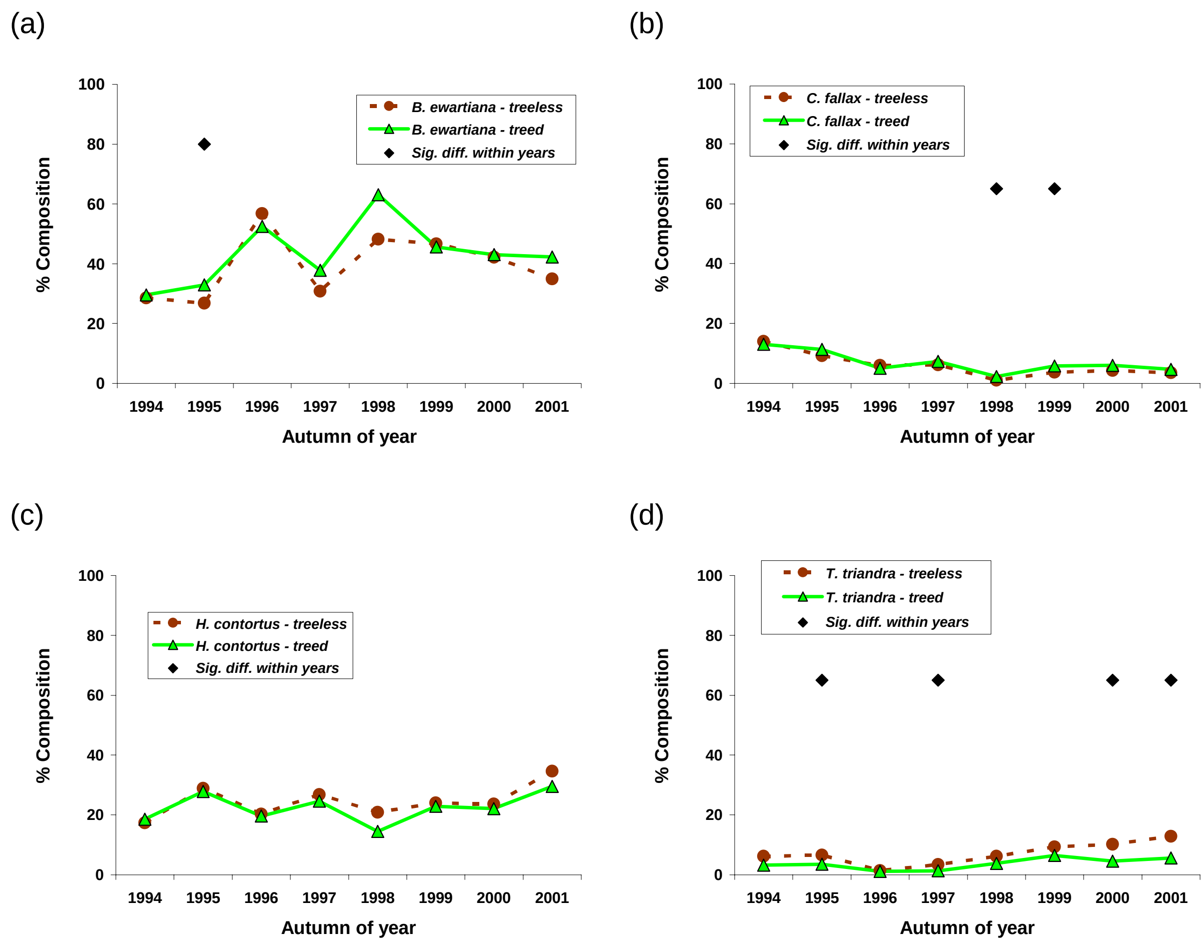


Figure 6.13 Tree killing impact on pasture biomass proportions of (a) *B ewartiana*, (b) *C. fallax*, (c) *H. contortus* and (d) *T. triandra* at the ironbark site.

Tree killing had minimal impact on pasture biomass proportions

Grazing pressure

Grazing pressure had minimal impact on the pasture biomass proportions of the major perennial grasses and the minor pasture components. Detailed statistical analysis is presented in Appendix N1.

Minor pasture components

Tree killing

Tree retention had an inconsistent effect on the % contribution of *Enneapogon* spp. (significant only in 1999, P<0.05), a positive effect on sedges in 1996 (P<0.05) and on *T. australianus* in 1996 and 1999 (P<0.05). Tree killing had a small positive effect on the proportion of *Chloris* spp. in the wet year of 1998 (P<0.05) (Figure 6.14) and on *T. australianus* in 1996 and 1999 (P<0.05).

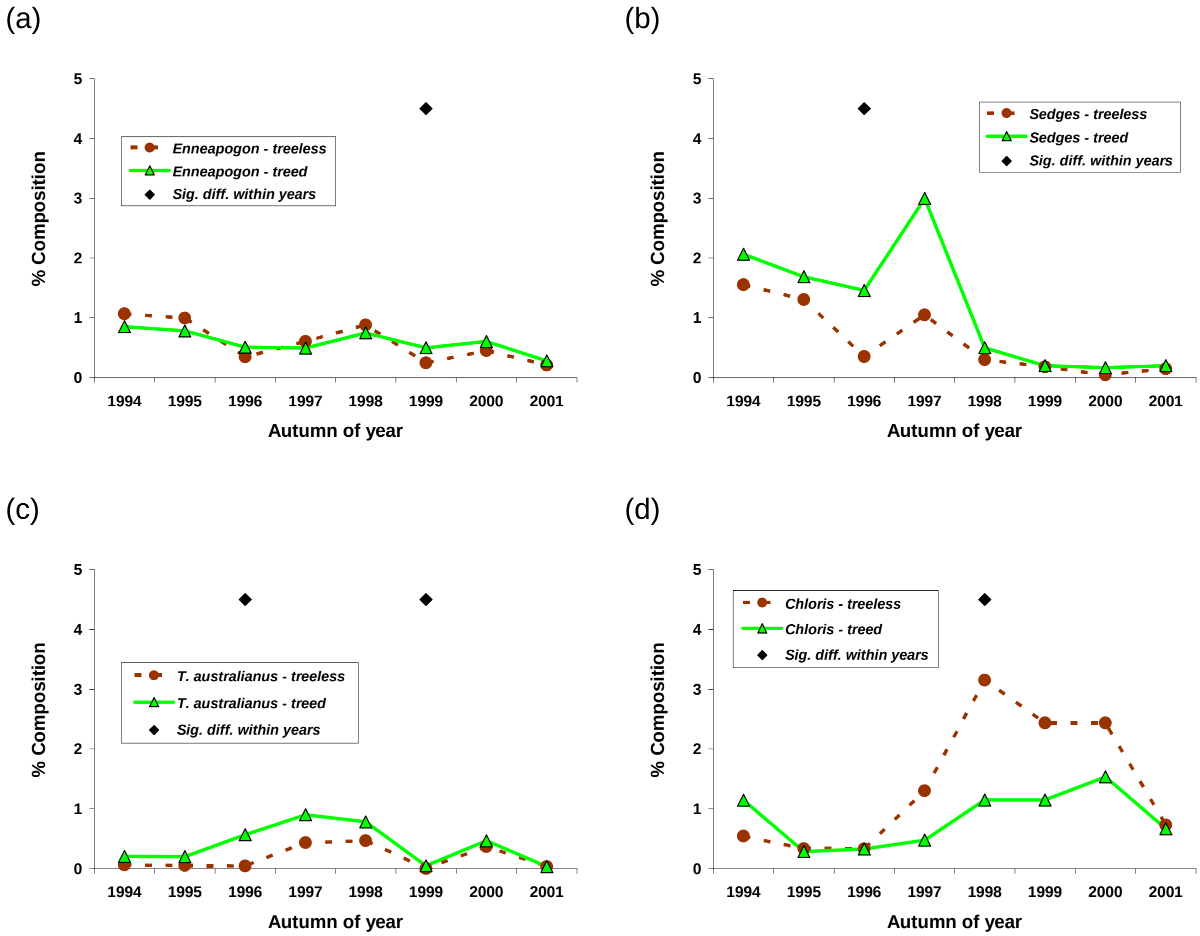
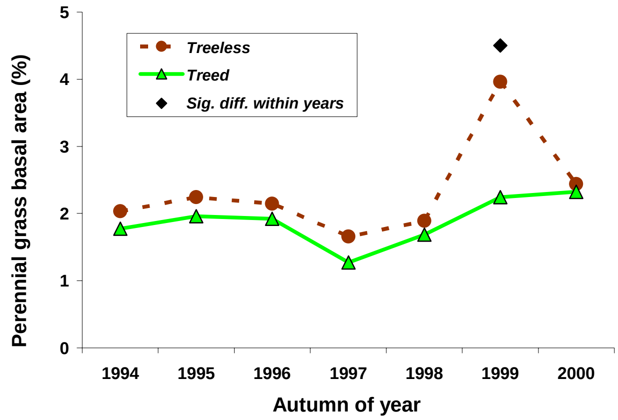


Figure 6.14 Tree killing impact on % contribution to autumn pasture biomass of (a) *Enneapogon* spp., (b) Sedges, (c) *T. australianus* and (d) *Chloris* spp. over 8 years under grazing at the ironbark site.

6.1.1.4.2.5 Perennial grass basal area

Tree killing

Tree killing resulted in a noticeably increased perennial grass basal area in 1999 only (P<0.01) (Figure 6.15). The lack of response of basal area to tree killing was in keeping with the lack of effect of tree killing on pasture yield. The increase in basal area due to tree killing in 1999 coincides with a strong effect of tree killing on pasture yield and ground cover in 1999. The increase is discussed in Section 11.

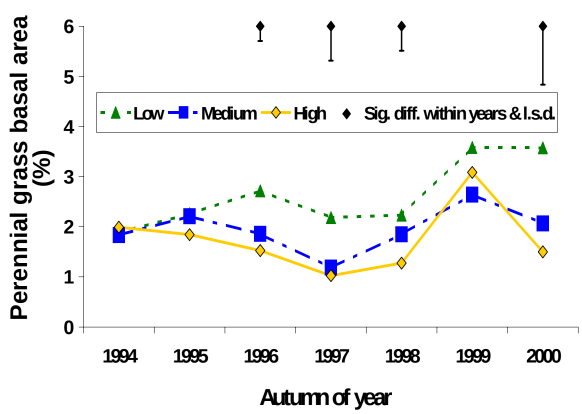


Tree killing had minimal impact on total perennial grass basal area

Figure 6.15 Tree killing impact on perennial grass basal area (%), ironbark site.

Grazing pressure

Increasing grazing pressure significantly reduced perennial grass basal area in the 4 later years of the trial (Figure 6.16). However, there was a trend towards increasing basal area under low grazing pressure and improving seasonal conditions. Two years of high grazing pressure elapsed before the reduction of basal area was significant despite pasture yield being significantly reduced by only one year of high grazing pressure. Detailed statistical analysis is presented in Appendix N1. Recordings were done by different operators in the 1994 to 1996 period compared to the 1997 to 2000 period. This may account for a decline in basal area in all treatments in 1997 when an increase would be expected to be consistent with pasture yields. Treatment differences are still valid however. Basal area increased in the high grazing pressure treatments in the autumn of 1999, again due to the method used to set grazing pressure (See Section 6.1.1.4.1). The recovery of the pasture, shown by the pasture yield and basal area is quite significant for one good wet season with an early summer start.



High grazing pressure reduces perennial grass basal area

Figure 6.16 Grazing pressure impact on perennial grass basal area (%), ironbark site.

6.1.1.4.3 Plant population studies

6.1.1.4.3.1 Summary of results

Density recordings demonstrate the stable nature of *C. fallax,* that *B. ewartiana* is more dynamic while *H. contortus* populations undergo a large number of recruitments and mortalities regularly. Increasing grazing pressure increased recruitment and mortality, and decreased survival rates and lifetimes of *B. ewartiana* and *H. contortus.* *B. ewartiana* and *C. fallax* had twice the survival and expected longevity of *H. contortus*. In the grazing trial, total crown area and crown area per plant was smaller than that in the ungrazed, burning trial (Figure 6.17). The former is partly confounded with original quadrat locations and is higher than the paddock averages derived by the point frame method and presented in Section 6.1.1.4.2. *B. ewartiana* and *H. contortus* contributed most to total crown area and this improved as the trial progressed and seasonal growing conditions improved.

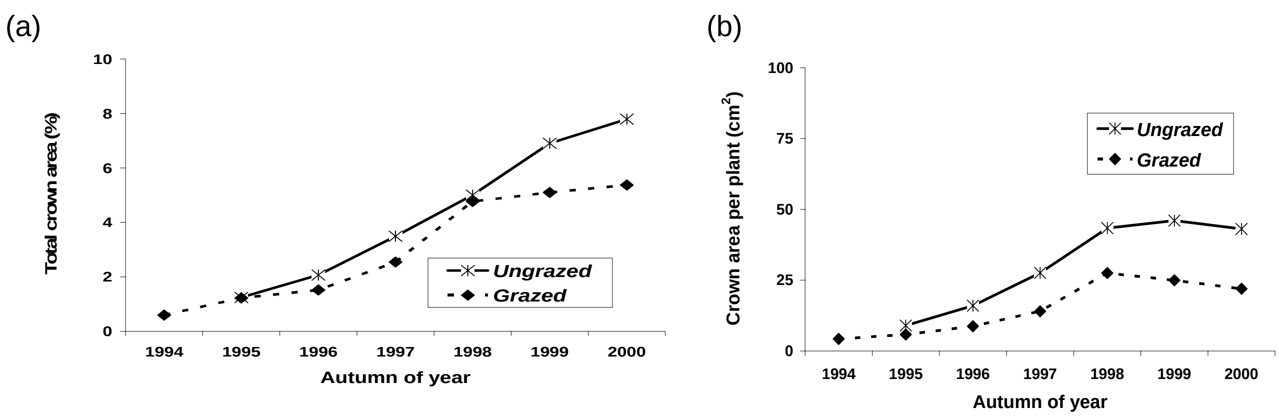


Figure 6.17 (a) Total crown area (%) and (b) Crown area per plant (cm2) for all ungrazed and grazed treatments during the trial at the ironbark site.

Total crown area is dependant on the number and size of plants. *H. contortus* had a higher density but smaller size per plant than *B. ewartiana* in our quadrats. *C. fallax* showed a small increase in total crown area over time due to an increase in the size of existing plants while its density was stable throughout the trial. The persistence of the 1995 seedling cohort showed that both *H. contortus* and *B. ewartiana* followed a Type 3 Deevey survivorship (Orr 2000) with mortality greatest in young individuals. The size of the plants which died throughout the trial was generally small. Seedbanks were not significantly affected by grazing pressure. Recruitments were affected by the presence of a seedbank, summer rainfall and grazing pressure.

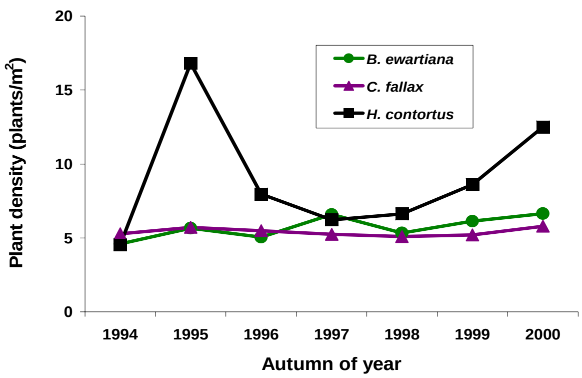
6.1.1.4.3.2 General

Understanding changes in botanical composition and structure in a paddock benefits from following the life history of individual plants. In all treatments permanent quadrats were established and the persistence, recruitment, mortality and migration of key species was monitored annually. The effects of season and grazing management are also assessed via changes of plant size. The focus was on three key perennial grasses (*B. ewartiana, C. fallax* and *H. contortus*). Each of the species had a high frequency throughout the site, was a major component of the total pasture growth and was important across the *A-B* region. Monitoring of these quadrats continued throughout the trial despite no major changes in pasture composition resulting from tree killing and/or grazing pressure, as assessed by Botanal sampling on a paddock scale.

H. contortus reproduces sexually although there are some reports of vegetative spread via ageing tussocks breaking up into segments (Orr 1998). *B. ewartiana* reproduces mainly sexually although there is some clonal reproduction from layering along prostrate stems in good seasons. *C. fallax* appears to reproduce almost entirely clonally from rhizomes. Recruitments reported for *C. fallax* are those believed to be from seedlings, however the lack of any significant seedbank would suggest that any recruitment is clonal.

6.1.1.4.3.3 Plant density

Density recordings demonstrate the stable nature of *C. fallax* presence in the pasture, that *B. ewartiana* is more dynamic than *C. fallax,* and that *H. contortus* populations undergo a large number of recruitments and mortalities over a few years (Figure 6.18). The density recorded annually is a nett result of survival and recruitment which is described in the next 2 sections. *C. fallax* density has changed very little over 6 years and this is due to a high survival rate unaffected by grazing pressure, and a low rate of recruitment. *B. ewartiana* has a similar high rate of survival to *C. fallax*, however it has a higher number of recruits, but also high mortalities of new recruits. *B. ewartiana* survival is reduced with increasing grazing pressure, but the number of recruits is increased with increasing grazing pressure (Figure 6.26a). *H. contortus* numbers have fluctuated markedly (Figure 6.18). Orr (2002 unpubl.) reported similar levels of fluctuation in *H. contortus* density from research in south-east Queensland during below average rainfall conditions, however densities were double that reported here. It has a large number of recruits and a lower survival rate, both of which are strongly affected by grazing pressure (Figure 6.26c).



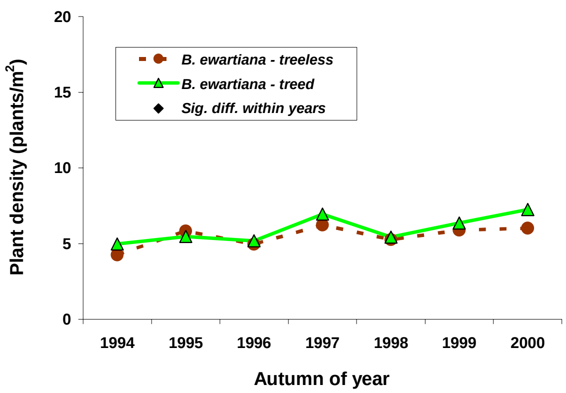
C. fallax populations are very stable

Figure 6.18 Density of *B. ewartiana, C. fallax* and *H. contortus* over time under grazing at the ironbark site.

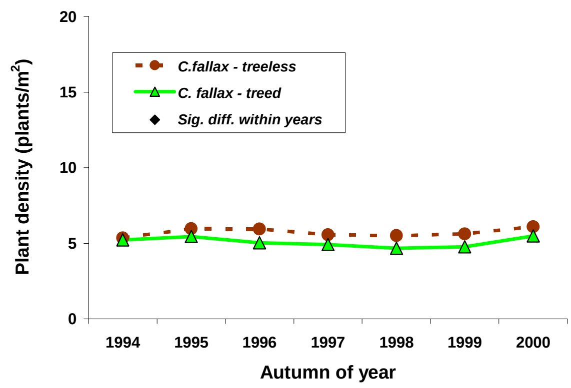
Tree killing

Density of all three species was largely unaffected by tree killing (Figure 6.19) and only marginally by grazing pressure (Figure 6.20). *H. contortus* density was significantly greater in the tree killing and high grazing pressure treatments in 2000 at the end of a consistent trend towards this outcome. Detailed statistical analysis is presented in Appendix N1. The benefit of tree killing to *H. contortus* density was consistent across all years. This pattern is in agreement with the frequency recordings presented in Section 6.1.1.4.2.

(a)



(b)



(c)

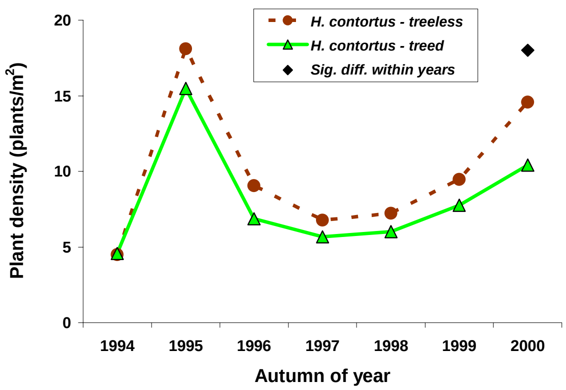


Figure 6.19 Tree killing effect over time on density of (a) *B. ewartiana,* (b) *C. fallax* and (c) *H. contortus* at the ironbark site under grazing.

Grazing pressure

High and medium grazing pressure increased the plant density of *B. ewartiana* noticeably in 1997 and 2000 and that of *H. contortus* in 1995 and 2000 (Figure 6.20). The medium and high grazing pressure created an appropriate space in the pasture for possible seedling recruitment. That recruitment was not limited by seedbank or summer rainfall for these latter species. However, grazing pressure clearly affects the population dynamics of *H. contortus* far more strongly than occurs with the other two main grasses. These differences in plant density are due to different rates of recruitment and survival.

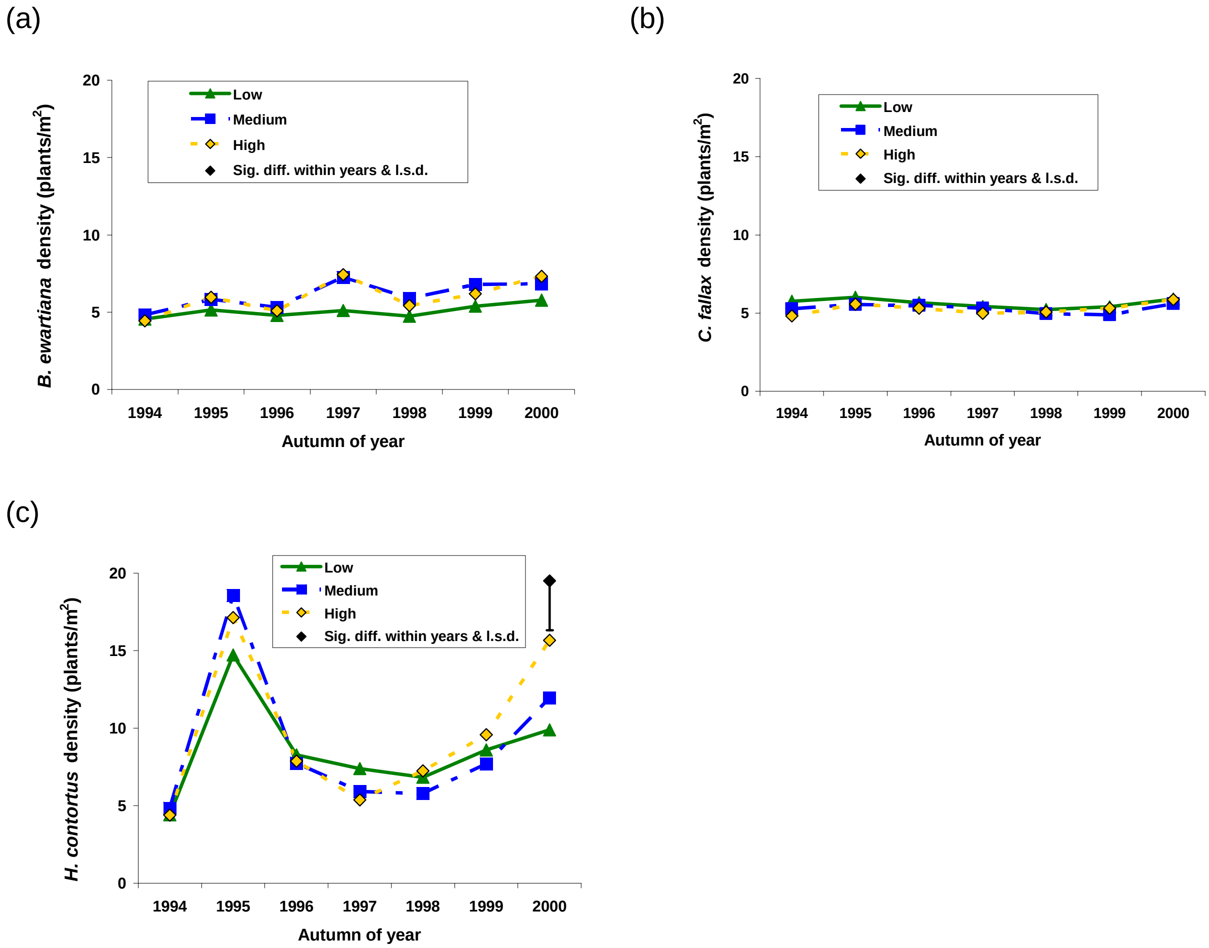


Figure 6.20 Grazing pressure effect on density of (a) *B. ewartiana,* (b) *C. fallax* and (c) *H. contortus* at the ironbark site from 1994 to 2000.

6.1.1.4.3.4 Recruitment

H. contortus usually had the highest number of recruitments and in 1995 (13.2/m^2) and 2000 (6.4/m^2) this was substantially more than by the other main grasses (Figure 6.25). Orr (2002 unpubl.) reported similar levels of recruitment and survival for *H. contortus* in south-east Queensland during below-average rainfall conditions. Most of the 1995 recruits died in their first year. *B. ewartiana* recruitments were less in number in 1995 (1.7/m^2), however the majority of these plants survived throughout the trial (Figure 6.21). *C. fallax* had recruitments in all years (0.2 to 1.6/m^2) despite having no recorded seedbank in the majority of years. This suggests that all recorded recruitments for this grass have been clonal via short rhizomes. In all years of the trial, there appears to have been adequate rainfall to generate seedbanks and recruitment for *B. ewartiana* and *H. contortus*.

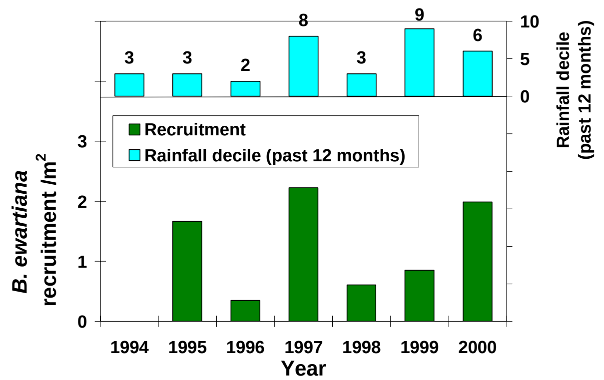


Figure 6.21 Recruitment each year of *B. ewartiana* at the ironbark site under grazing

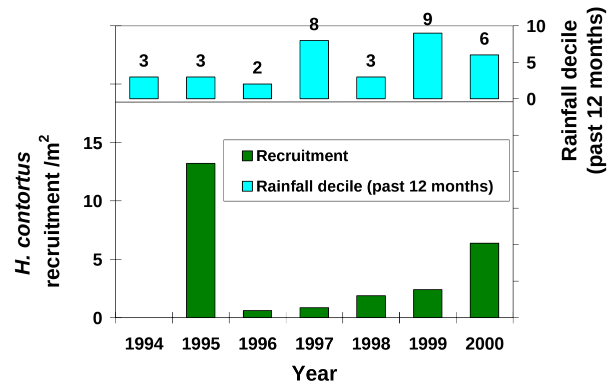


Figure 6.22 Recruitment of *H. contortus* at the ironbark site under grazing

(note different scale from other Figures)

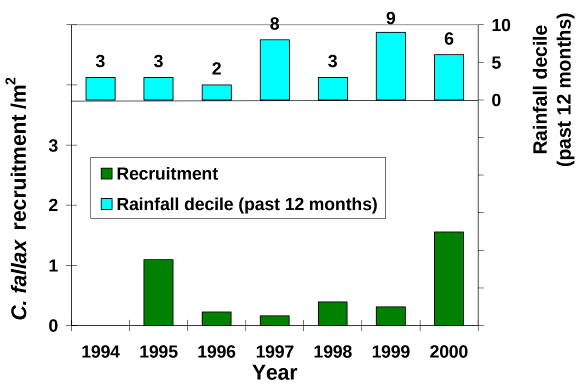


Figure 6.23 Recruitment each year of *C. fallax* at the ironbark site under grazing.

Increasing grazing pressure caused higher rates of recruitment and mortality of both *H. contortus* and *B. ewartiana*

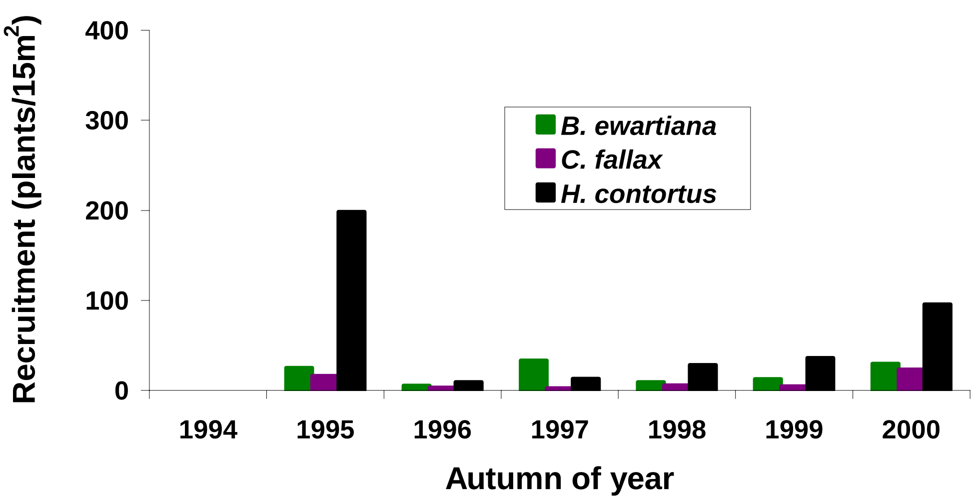
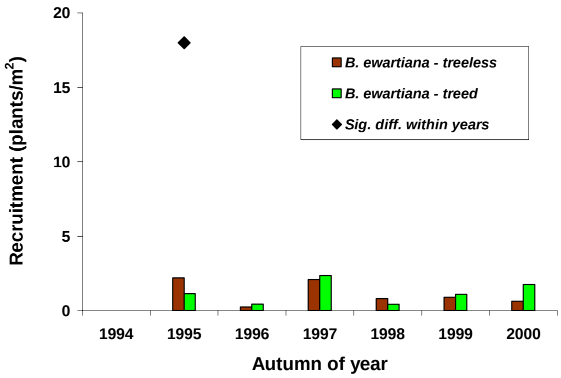


Figure 6.24 Year by year recruitment of *B. ewartiana, C. fallax* and *H. contortus* at the ironbark site under grazing

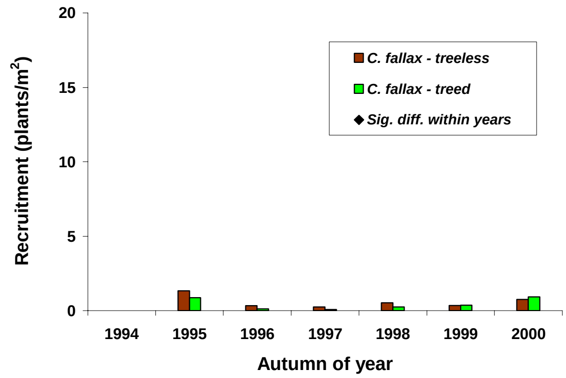
Tree killing

Tree killing had no consistent effect on the recruitment of new *B. ewartiana* and *C. fallax* plants but numbers were consistently greater for *H. contortus* in the absence of trees (Figures 6.21–6.24). There was a trend for *H. contortus* recruitment to increase steadily each year from 1996 to 2000, from a low value after a big flush in 1995.

(a)



(b)



(c)

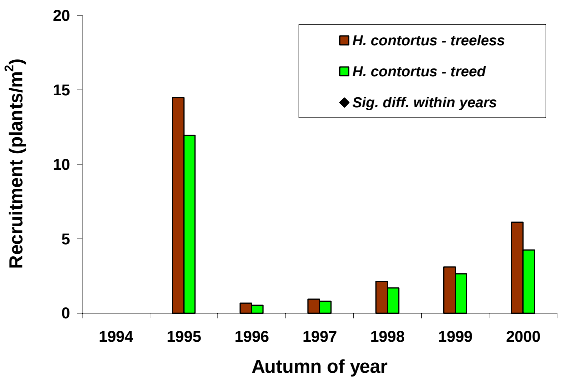


Figure 6.25 Annual recruitment under grazing over 6 years of (a) *B. ewartiana,* (b) *C. fallax* and (c) *H. contortus* plants in the presence or absence of trees at the ironbark site.

Grazing pressure

Recruitment for *B. ewartiana* and *H. contortus* increased with increasing grazing pressure for most years (Figure 6.26). Where there is an adequate, viable seedbank (>10/m^2) and summer rainfall, the high and medium grazing pressure encouraged seedlings to establish, probably by providing an appropriate space in the pasture. *B. ewartiana* had the highest recruitment in 1994/5, 1996/7 and 1999/00 summers under high and medium grazing pressure but average summer rainfall only occurred in the 1996/7 and 1998/9 summers. *H. contortus* had its highest recruitments in 1994/5 and 1999/00. *H. contortus* recruitments did not appear to be enhanced by above average summer rainfall. Good recruitment in 1995, 1998 and 2000 followed below average summer rainfall (Figure 6.22), but average to above average in the prior summer when most of the germinating seed was probably set. Recruitments in 1999 did reflect above average rainfall and was similar at all grazing pressures. The small recruitment in 1996/7 is surprising given the well above average summer rainfall and may have been due to a limiting seedbank (See Section 6.1.1.4.4).

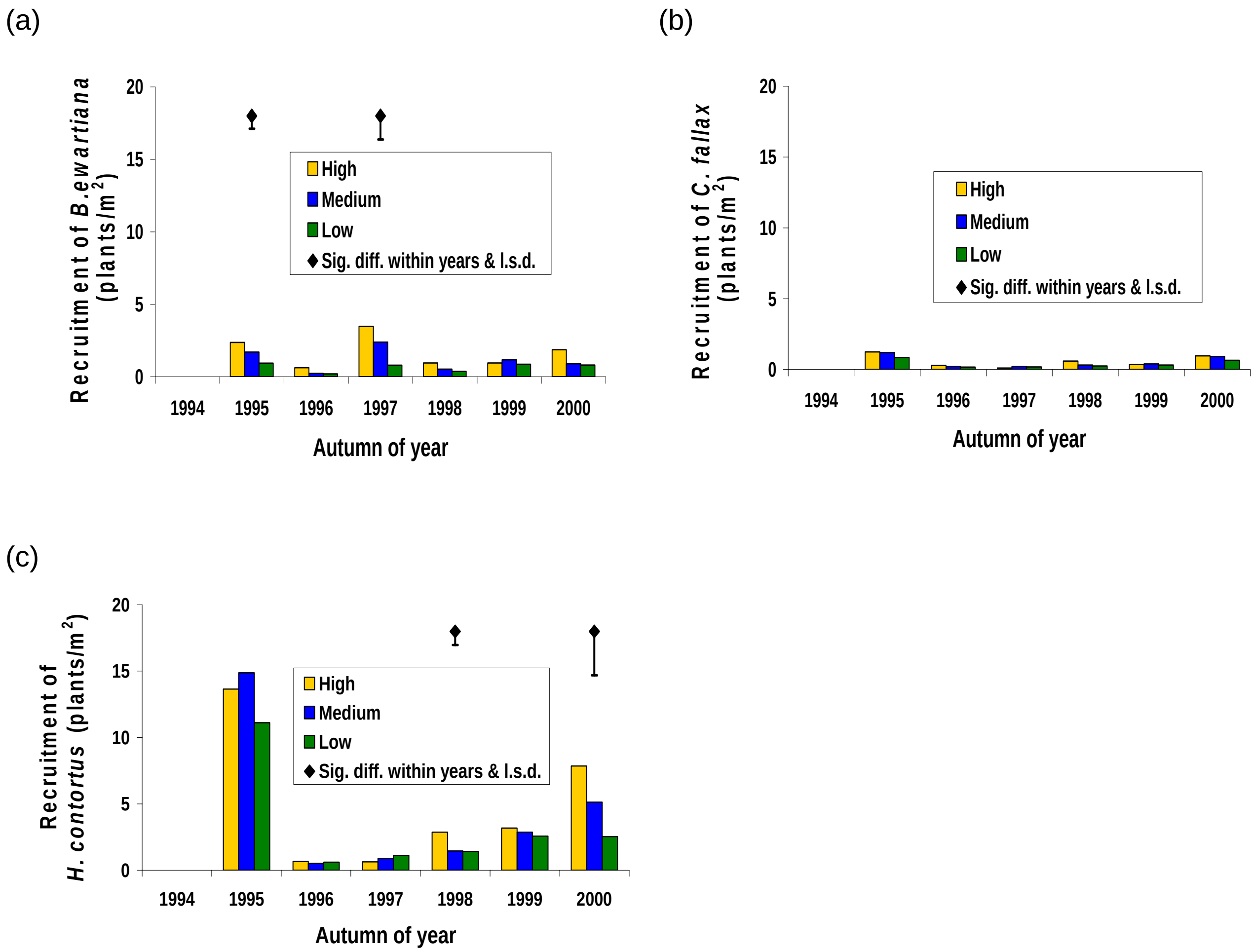


Figure 6.26 Grazing pressure effect on recruitment of (a) *B. ewartiana,* (b) *C. fallax* and (c) *H. contortus* plants at the ironbark site.

6.1.1.4.3.5 Death / Survival

B. ewartiana and *C. fallax* had similar levels of survival for the original plants in the charted quadrats (66 and 67% Table 6.1 and Figure 6.27 a). Numbers in Table 6.1 (a) and (b) refer to the total population (mature plants and seedlings) of the 3 species. *C. fallax* had a low rate of mortality and a very low rate of recruitment, resulting in very little change in plant density. *B. ewartiana* had a similar low rate of mortality of original plants. However it had higher mean recruitment rates resulting in a higher plant flux (41% - item k in Table 6.1), compared to *C. fallax* with 30% (Table 6.1, item k – calculations based on the method of Sarukhan and Harper, 1973). *H. contortus* only had 33% survival of original plants after 6 years and maintained a stable density by having a high recruitment rate to counteract the lower survival rate. It had the highest rate of plant flux at 56%. *B. ewartiana* and *C. fallax* had similar mean calculated lifespan at 20 years. At the ironbark site, *H. contortus* had only 10 years average expected lifespan for original plants to die, based on the conditions experienced (item i). The plants dying were generally small with a median size of 2.6 cm^2 (range 0.03 to 38.3 cm^2).

Tree killing and grazing pressure

Tree killing had no significant overall effect on individual species nor on their population dynamic characteristics, while grazing pressure had varying influences. Tree killing did significantly increase the survival of *H. contortus* ($P<0.001$) from 1999 to 2000. Increasing grazing pressure increased the total number of recruits in all three species. Decreasing grazing pressure improved the survival of plants and the expected time before death for *B. ewartiana* and *H. contortus* but had no effect on *C. fallax* mortality (Item h, Table 6.1). By examining two consecutive years for survival, varying treatment effects were recorded. Increasing grazing pressure decreased the survival of *B. ewartiana* in the periods 1994-95 ($P<0.05$), 1995-96 ($P<0.01$) and 1997-98. These periods correspond with the below average rainfall in the previous 12 months. Increasing grazing pressure also decreased the survival of *C. fallax* ($P<0.05$) in 1999-2000. A survival – hazard analysis was conducted for the plants originally recorded in 1994, the recruits in 1995 and the recruits in 1997. High grazing pressure significantly decreased the survival of plants of *B. ewartiana* ($P<0.001$) and *H. contortus* ($P<0.01$) from 1994 to 2000 (Appendix N1.5i). The survival of *B. ewartiana* plants recruited in 1995 and recorded until 2000 was significantly reduced ($P<0.01$) by high grazing pressure.

Increasing grazing pressure reduced survival rates and lifetimes of *H. contortus* and *B. ewartiana*

The survival of the 1995 cohort of *B. ewartiana* and *H. contortus* followed a Type 3 Deevey survivorship (Figure 6.27 b) (Deevey 1947). The mortality was greatest in the first year after recruitment. Orr (2002 unpubl.) reported similar levels of survival of *H. contortus* in the first year after recruitment during below average rainfall conditions such as existed in the 1994 to 1996 period.

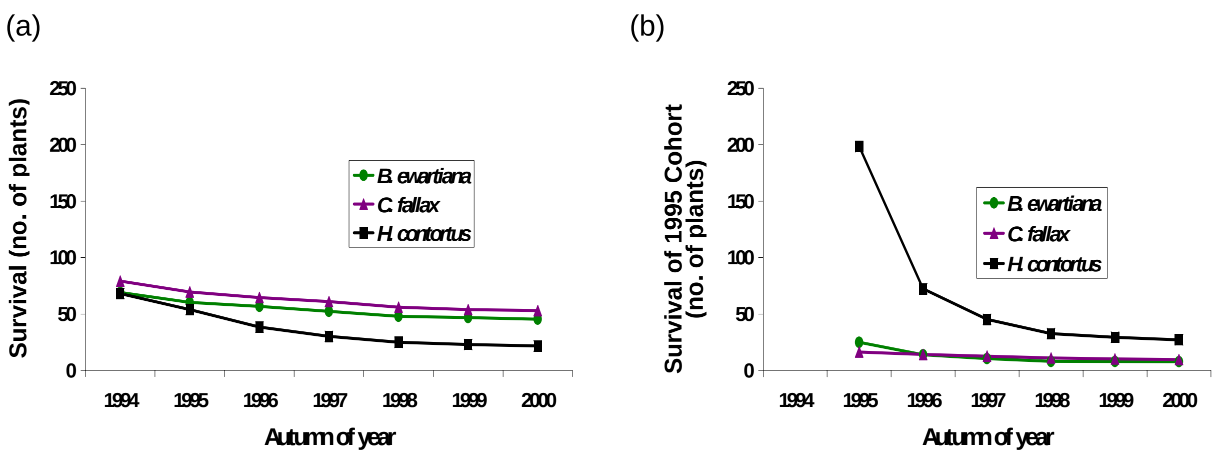


Figure 6.27 Survival of (a) original plants, and, (b) 1995 cohort at the ironbark site.

Table 6.1 Plant flux calculations for (a) *B. ewartiana*, (b) *C. fallax* and (c) *H. contortus* at the ironbark site under grazing (from 15m² of charted quadrats).

B. ewartiana				
	High	**Medium**	**Low**	**Mean**
(a) Average No. of plants in 1994	67	73	68	69
(b) Average No. of plants in 2000	110	103	87	100
(c) Average Net change (b-a)	43	30	18	31
(d) Average rate of increase (b/a)	1.64	1.41	1.27	1.44
(e) Average No. of plants recruited between 1994 and 2000	154	104	60	106
(f) Average No. of plants lost between 1994 and 2000	109	73	41	74
(g) Average No. of Plants present in 1994 and alive in 2000	35	50	51	45
(h) Average percent survival of original plants (g/aX100)	53	69	75	66
(i) Average time for original plants to die (years) (no. yrs/(100-h))X100	13	20	25	20
(j) Total plants recorded (a+e)	220	176	128	175
(k) Average plant flux - % annual mortality of all individuals (f/jX100)	51	41	31	41
C. fallax				
	High	**Medium**	**Low**	**Mean**
(a) Average No. of plants in 1994	72	79	86	79
(b) Average No. of plants in 2000	88	84	89	87
(c) Average Net change (b-a)	16	5	2	8
(d) Average rate of increase (b/a)	1.21	1.06	1.02	1.10
(e) Average No. of plants recruited between 1994 and 2000	54	49	36	46
(f) Average No. of plants lost between 1994 and 2000	37	42	33	37
(g) Average No. of Plants present in 1994 and alive in 2000	51	49	60	53
(h) Average percent survival of original plants (g/aX100)	69	62	69	67
(i) Average time for original plants to die (years) (no. yrs/(100-h))X100	21	16	22	20
(j) Total plants recorded (a+e)	126	128	122	125
(k) Average plant flux - % annual mortality of all individuals (f/jX100)	30	33	26	30
H. contortus				
	High	**Medium**	**Low**	**Mean**
(a) Average No. of plants in 1994	66	73	66	68
(b) Average No. of plants in 2000	235	179	148	188
(c) Average Net change (b-a)	169	107	82	119
(d) Average rate of increase (b/a)	3.70	2.50	2.27	2.82
(e) Average No. of plants recruited between 1994 and 2000	433	386	291	370
(f) Average No. of plants lost between 1994 and 2000	262	278	207	249
(g) Average No. of Plants present in 1994 and alive in 2000	16	20	29	22
(h) Average percent survival of original plants (g/aX100)	25	29	45	33
(i) Average time for original plants to die (years) (no. yrs/(100-h))X100	8	9	12	10
(j) Total plants recorded (a+e)	499	459	357	438
(k) Average plant flux - % annual mortality of all individuals (f/jX100)	53	59	57	56

B. ewartiana* and *C. fallax* had twice the survival rate of *H. contortus

6.1.1.4.3.6 Crown area of major perennial grasses

Total crown area under grazing increased steadily throughout the trial and this was mainly due to increases in the crown area of *B. ewartiana*, and *H. contortus* (Figure 6.28). While treatment responses reported in Section 6.1.1.4.2 are valid, the data presented in the current section is a better representation of the changes over time. The permanent quadrat method of studying plant lifecycles is less prone to discrepancies between operators but does give a generally higher figure than the point method. The increasing total crown area is primarily due to above average rainfall in some years. Total crown area was abnormally low at the beginning of the trial due to the preceding severe drought. Similar responses are reported in the ungrazed, burning trial (Section 6.1.2.4.2).

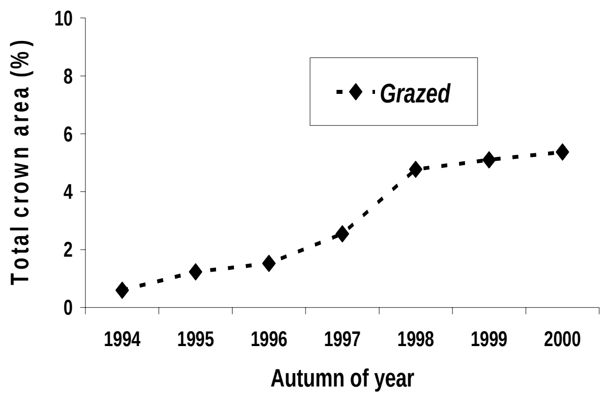


Figure 6.28 Total crown area (%) changes under grazing at the ironbark site.

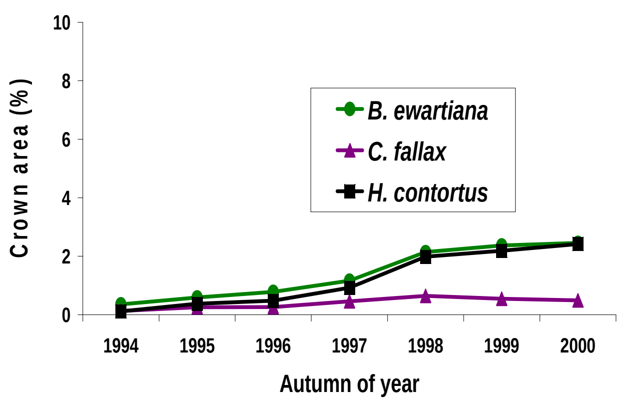


Figure 6.29 Crown area (%) of *B. ewartiana*, *C. fallax* and *H. contortus* over time at the ironbark site.

6.1.1.4.3.7 Size of major perennial grasses

Generally the size of individual plants of the major perennial grasses increased over the first half of the trial. As total crown area increased (Figure 6.29), the average size of *H. contortus* decreased (Figure 6.30) due to an increasing total number of plants from 1997 to 2000. The average size of *B. ewartiana* and *C. fallax* was stable after 1998 due a stable density (Figure 6.20). The plants dying were generally small with a median size of 2.6 cm^2 (range 0.03 to 38.3 cm^2).

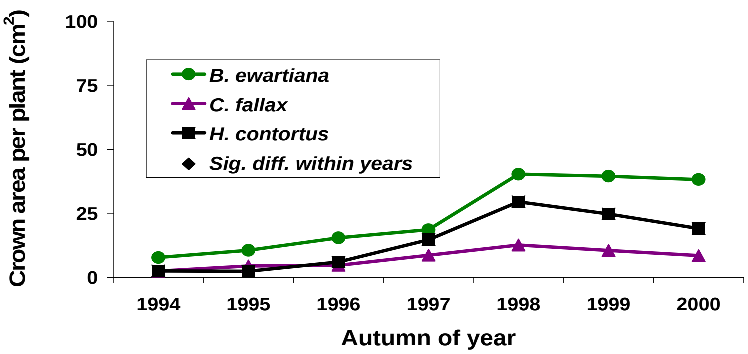


Figure 6.30 Mean size of major perennial grasses (cm^2 per plant) under grazing, the ironbark site.

Tree killing

Tree killing had no initial effect on the size of the major perennial grasses (Figure 6.31) but was tending to result in larger plants late in the trial. The 1994, 1995 and 1997 recruitment cohorts of the major perennial grasses were also analysed for treatment effects. For the 1994 cohort, the size of *H. contortus* plants was increased in the absence of trees in 1998 ($P<0.05$), 1999 ($P<0.01$) and 2000 ($P<0.001$). The 1997 cohort of *B. ewartiana* was significantly affected by the interaction of tree killing and grazing pressure in 2000. In the plots with trees killed, increased grazing pressure decreased the size of *B. ewartiana* plants ($P<0.05$). In the treed plots, increased grazing pressure increased the mean size of *B. ewartiana* plants ($P<0.05$) in 2000.

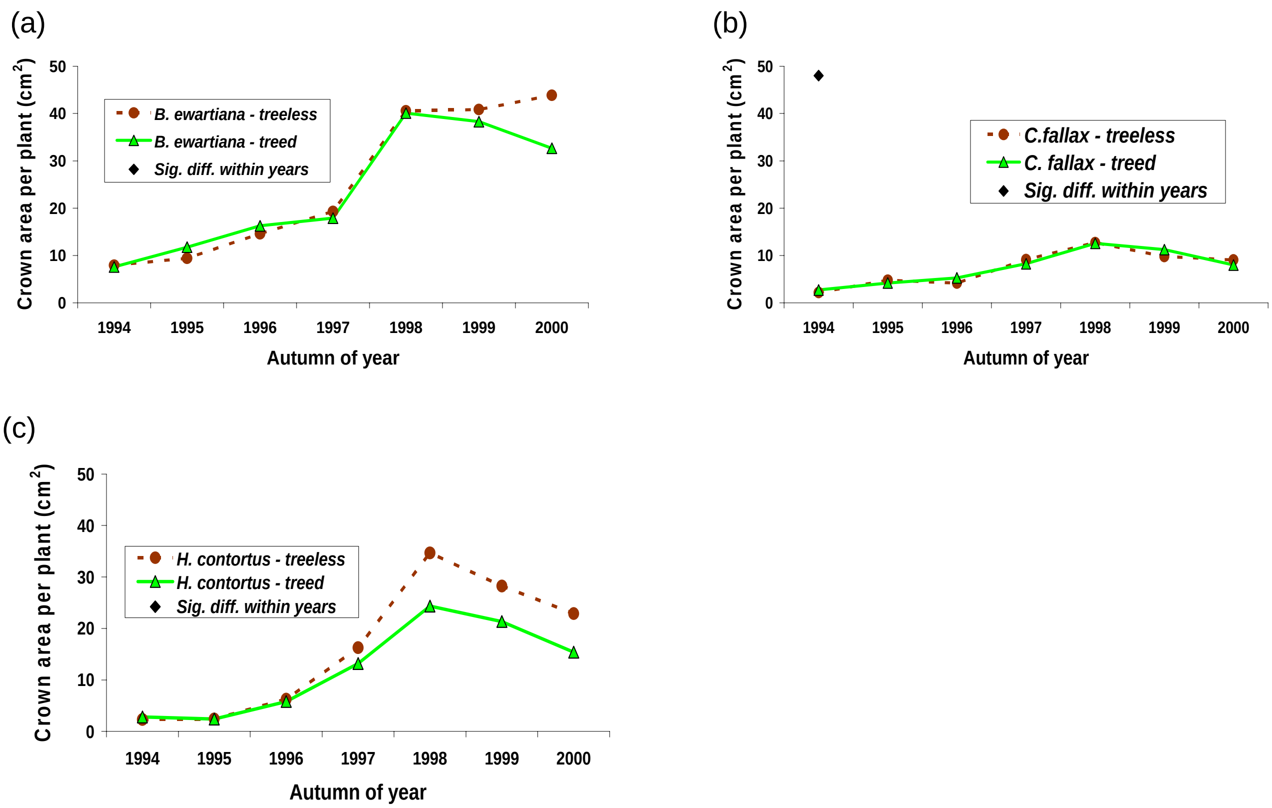
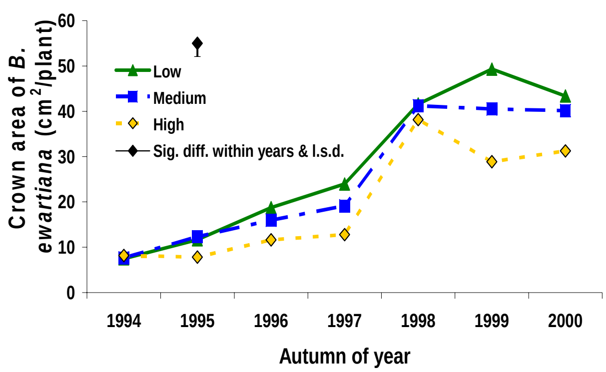


Figure 6.31 Tree killing effect on mean size (cm^2 per plant) of (a) *B. ewartiana,* (b) *C. fallax* and (c) *H. contortus* plants under grazing at the ironbark site.

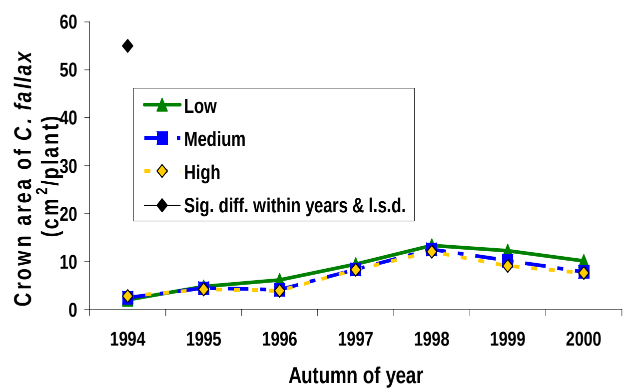
Grazing pressure

Grazing pressure had no consistent overall effect on the size of the major perennial grasses recorded in each year (Figure 6.32) although it often appeared to for *B. ewartiana*. The 1994, 1995 and 1997 recruitment cohorts of major perennial grasses were also analysed for treatment effects. For the 1995 cohort, the size of *H. contortus* plants was increased by high grazing pressure in 1998 ($P<0.05$). The 1997 cohort of *B. ewartiana* was significantly affected by the interaction of trees and grazing pressure in 2000. In plots without trees, increased grazing pressure decreased the size of *B. ewartiana* plants ($P<0.05$), while in treed plots grazing pressure increased the size of *B. ewartiana* plants ($P<0.05$). See Appendix N1 for more details of statistical analysis outcomes. These 'significant' results may be 'false positives' induced by the limited sample sizes from small cohorts.

(a)



(b)



(c)

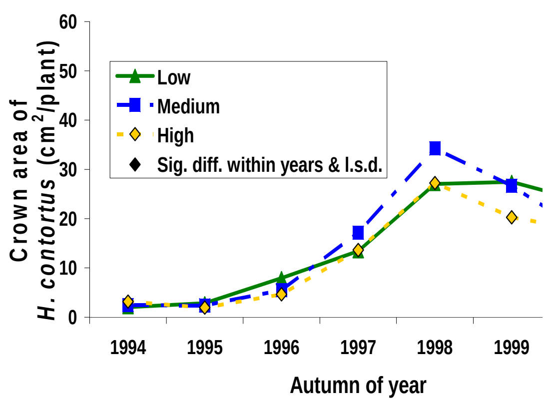


Figure 6.32 Grazing pressure effect on plant size (cm^2 per plant) of (a) *B. ewartiana,* (b) *C. fallax* and (c) *H. contortus* at the ironbark site.

6.1.1.4.3.8 Lifecycles

The plant population studies have lead to generalizations about the lifecycles. *C. fallax* is quite stable, *B. ewartiana* is more dynamic and *H. contortus* populations regularly undergo a large number of recruitments and mortalities. Increasing grazing pressure increased recruitment and mortality, and decreased survival rates and lifetimes of *B. ewartiana* and *H. contortus*. High grazing pressure decreased the nett survival of *B. ewartiana* and *H. contortus* over the life of the trial. However, survival of *B. ewartiana* was significantly affected by increasing grazing pressure following the years of below average rainfall. The survival of *H. contortus* plants recruited in 1995 was not significantly reduced by high grazing pressure largely because of the high mortality across all treatments in the first year after recruitment, which was a below average rainfall year. *B. ewartiana* and *C. fallax* had twice the survival and mean expected longevity (20 years), compared to that of *H. contortus* (10 years).

6.1.1.4.4 Soil seed banks

6.1.1.4.4.1 Major perennial grasses

Studies of the soil seed bank provide an insight into the potential for subsequent seedling recruitment and help to understand the lifecycle studies which provide details of a species response to grazing management at a paddock scale. The seedbank levels reported (Figure 6.33) are designated to the spring of the year in which the soil cores were sampled. Therefore, the 1994 seedbank is responsible for the 1995 recruitment data. While heavy grazing was expected to reduce soil seed banks and subsequent seedling recruitment and even threaten the existence of some species, in this study, seedbanks are more affected by rainfall than management. The years when seedbanks were high generally followed above average rainfall in the previous summer. However in all years of the trial, there appears to have been adequate rainfall to generate seedbanks sufficient for recruitment (Figure 6.33, 34 and 35 and Section 4.2.1).

Data for *C. fallax* is often not presented due to the lack of any significant seedbank although plants did regenerate from rhizome fragments in a few core samples. High levels of *H. contortus* recruitments in 1995 and 2000 occurred when there was a large soil seed bank recorded in 1994 and 1999 and good growing conditions. While *H. contortus* seedbanks were high in 1997, low recruitment levels occurred in 1998 due to below average rainfall. *B. ewartiana* also had high levels of recruitment following good growing conditions and a high seedbank level in 1994 and 1996. In 2000, *B. ewartiana* had a fair level of recruitment despite a small seedbank (12.2 seeds/m^2).

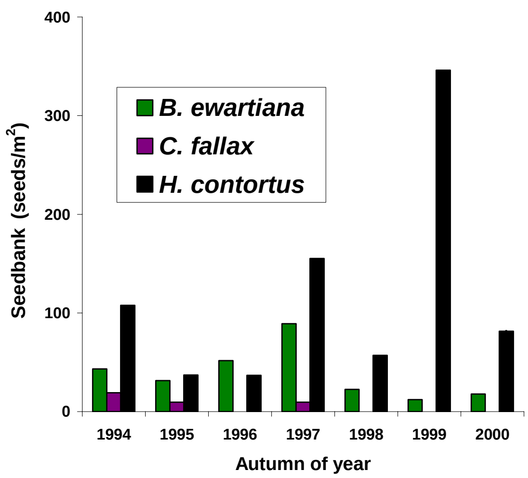


Figure 6.33 Seedbank of *B. ewartiana, C. fallax* and *H. contortus* at the ironbark site each spring.

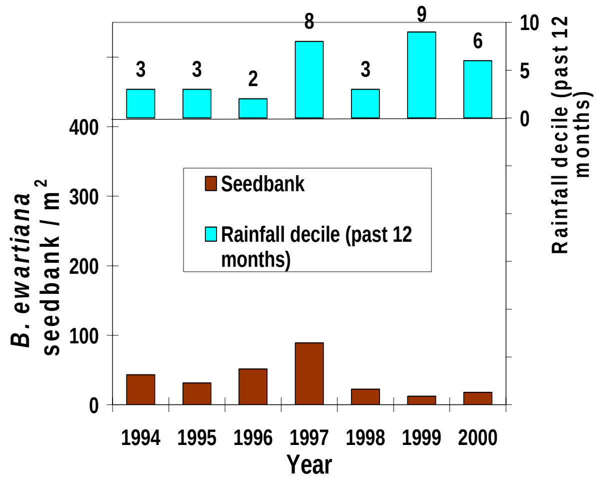


Figure 6.34 Seedbank of *B. ewartiana,* and rainfall decile for the past 12 months at the ironbark site.

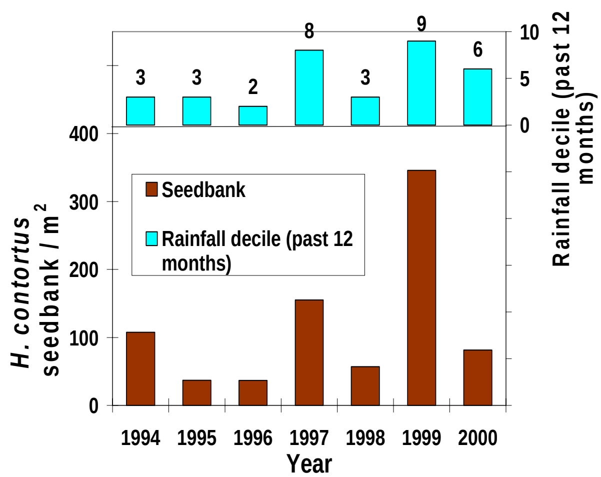


Figure 6.35 Seedbank of *H. contortus,* and rainfall decile for the past 12 months at the ironbark site.

Tree killing and grazing pressure

An absence of trees only increased the seedbank significantly once, that of *B. ewartiana* in 2000 (P<0.05) (Figure 6.36). Low grazing pressure only resulted in an increased seedbank of *H. contortus* in 1996 (P<0.05), (Figure 6.37).

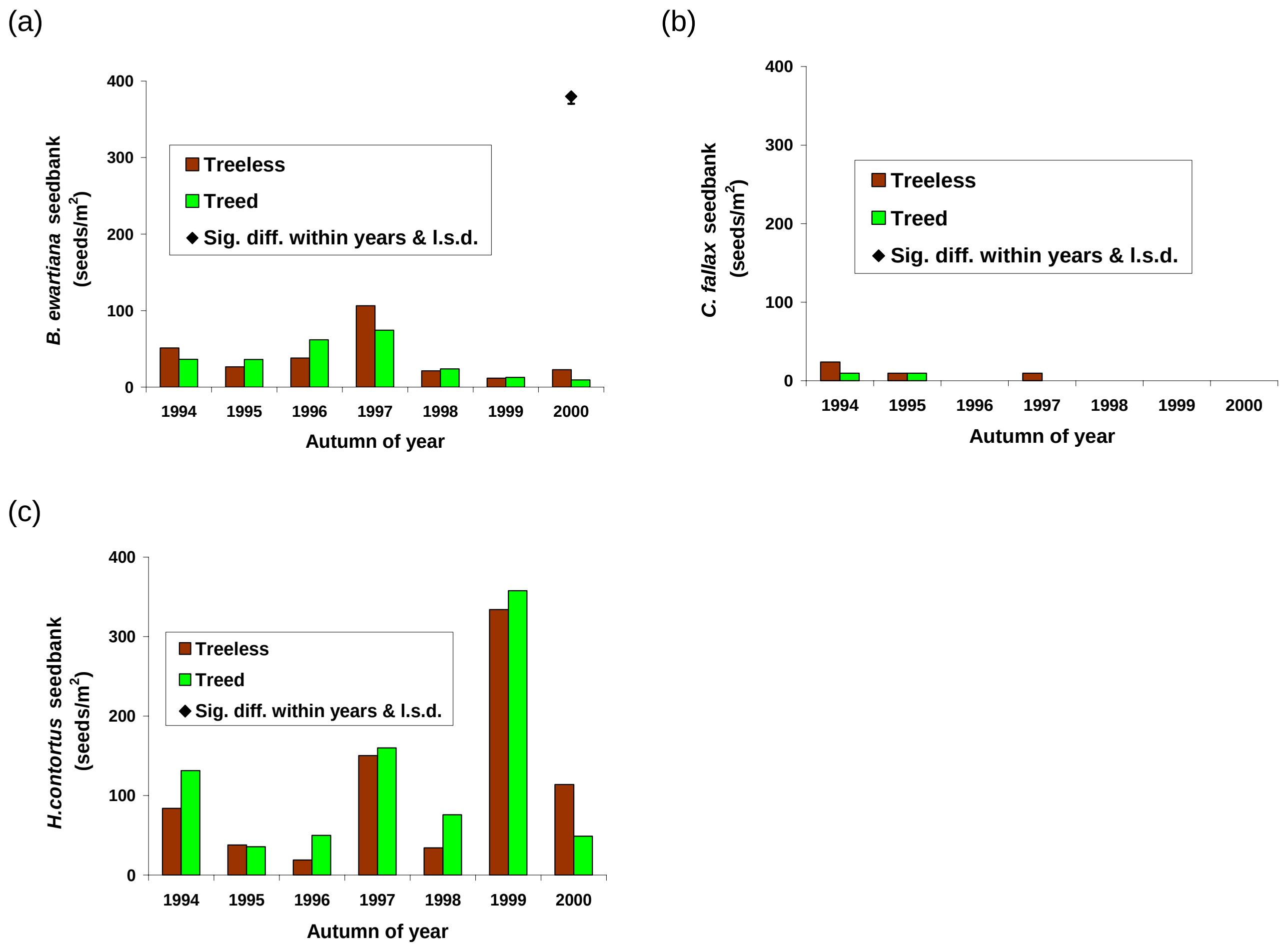
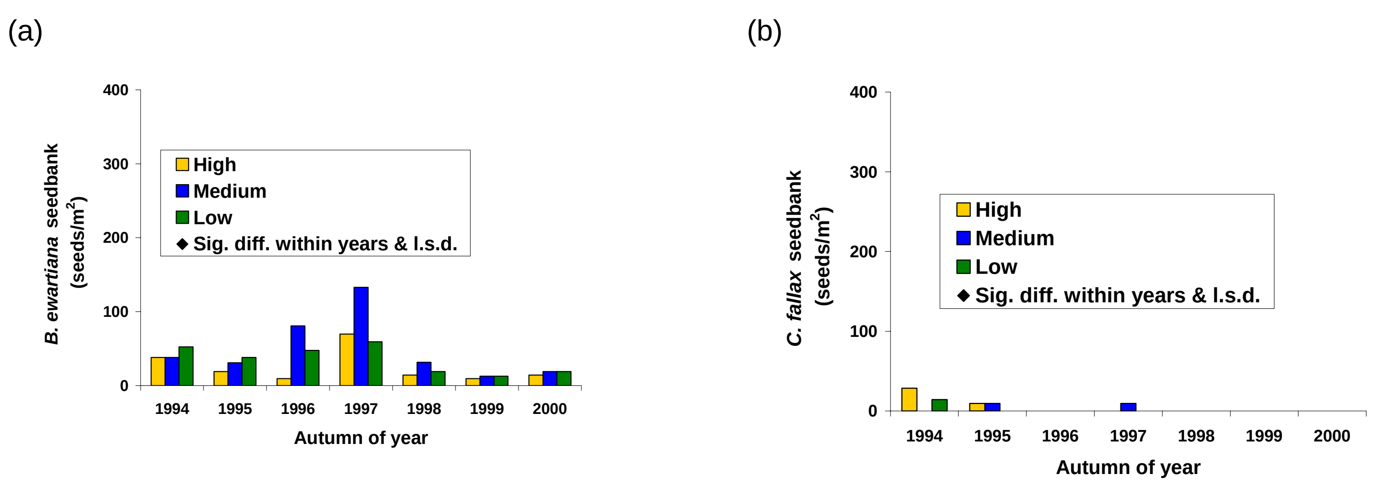


Figure 6.36 Tree killing effect over time on the seedbanks of (a) *B. ewartiana,* (b) *C. fallax* and (c) *H. contortus* at the ironbark site.



(c)

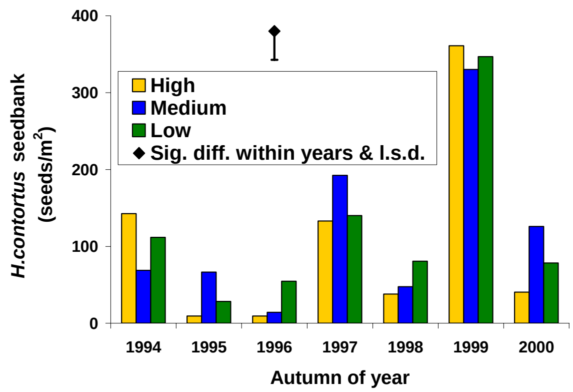


Figure 6.37 Grazing pressure effect over time on the seedbanks of (a) *B. ewartiana,* (b) *C. fallax* and (c) *H. contortus* plants at the ironbark site.

Table 6.2 Main species to germinate (plants / sq metre) from grazing trial spring soil samples.

	Year									
Species group	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	Mean	%age	Years
Wahlenbergia spp.	11	131	177	337	388	542	468	293.5	28.26	7
Heteropogon contortus	108	28	21	155	52	346	82	113.1	10.89	7
Chloris divaricata	10	7	11	255		46	85	59.1	5.70	6
Hybanthus spp.	123	51	58	6	64	22	85	58.4	5.62	7
Indigofera spp.	10	14	8	69	25	125	54	43.4	4.18	7
Sonchus spp.		2		27	132	78	21	37.2	3.58	5
Bothriochloa ewartiana	40	26	30	82	15	7	12	30.2	2.91	7
Tripogon loliiformis	9	15	6	69	2	59	43	29.0	2.79	7
Fimbristylus spp.	10	3		47	21	29	60	24.2	2.33	6
Digitaria spp.	17	3	2	30	2	59	40	22.2	2.13	7
Cheilanthes spp.				2			134	19.3	1.86	2
Eragrostis spp.	9	8	7	31	19	24	37	19.2	1.85	7
Spermacoce spp.	24	13	6	42	8	21	17	18.8	1.81	7
Echinochloa colona						90	39	18.4	1.78	2
Pterocaulon spp.	10	10	6	11	13	30	49	18.3	1.76	7
Euphorbia spp.	17	39	18	4	18	9	14	17.1	1.64	7
Enneapogon spp.	22	23	13	43		9	3	16.2	1.56	6
Cyperus spp.	16	31	13	33	1	10		14.8	1.43	6
Portulaca spp.	2	13	18	31	6	28	5	14.6	1.40	7
Zornia spp.	3	3	1	25	2	46	19	14.1	1.36	7
Cheilanthes distans						93		13.3	1.28	1
Phyllanthus spp.	14	20	3	17	13	9	6	11.9	1.14	7
Aristida spp.	9	8	2	29		22	4	10.6	1.02	6
Sporobolus australasicus	9	8	18	2	32	2	1	10.2	0.98	7

Grazing management did not much affect which were the commonest emerging species, nor their frequency. Very similar mean numbers of the main perennial grasses were germinated from both trials (Tables 6.2 & 6.3). Under grazing, short-lived forbs and annual grasses were more common, notably *Chloris divaricata*, *Digitaria* spp., *Eragrostis* spp. and *Indigofera* spp. The only reverse examples were the bluebells and possibly the wiregrasses (Table 6.3).

The differences were not often statistically significant (Appendix N1) because of the small numbers involved and year-to-year variation in presence. The greater number of species recorded from the grazing trial (See Appendix I) is probably due to the more extensive sampling of that trial area.

Table 6.3 Main species to germinate from spring soil samples from the ungrazed burning trial. Data is expressed as plants per sq metre of surface soil sampled.

	Year								
Species group	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	Mean	%age	Years
Wahlenbergia spp.	*200*	*98*	*538*	*887*	*1165*	*760*	*521.1*	*51.57*	*6*
Heteropogon contortus	82	89	209	105	291	29	114.9	11.37	6
Fimbristylus spp.			41	54	51	139	40.7	4.03	4
Bothriochloa ewartiana	57	108	35	13	10	13	33.5	3.31	6
Tripogon loliiformis	*13*	*13*	*117*		*44*	*6*	*27.6*	*2.73*	*5*
Hybanthus spp.	25	41	10	54		48	25.3	2.51	5
Enneapogon spp.	32	79	35			3	21.3	2.10	4
Aristida spp.	32	32	19		16	16	16.3	1.61	5
Chloris spp.	6	3	67		16	22	16.3	1.61	5
Pterocaulon spp.	6		3	13	60	22	14.9	1.48	5
Cyperus spp.	48	25	29				14.5	1.43	3
Portulaca spp.	25	38	10	6	16		13.6	1.34	5
Sonchus spp.	3			54	19	16	13.1	1.30	4
Spermacoce spp.	13	19	22	10	13	10	12.2	1.21	6
Euphorbia spp.	19	44	6	3			10.4	1.03	4
Indigofera spp.	3	22	10	3	13	10	8.6	0.85	6
Digitaria spp.	19		10		10	13	7.2	0.72	4

Other points of note are –

- Usually 20-30 species groups were recorded each sampling run
- *Aristida* spp. were absent in the 1998 spring after a wet autumn/winter
- In spring 2000 many more seeds emerged from the treeless plots
- Sedges were a common germinating group in almost every year
- *Themeda* seeds only germinated in a few years
- Legumes were common but never in large numbers
- Buffel grass was a rare emergee but more common than *Sehima nervosum*
- 3P grasses were always a relatively low proportion (12-14%) of the total seedbank
- Tree and shrub seedlings were virtually non-existent

Of the species that had large seedbanks, *C. divaricata* was always more common under high grazing pressure while wiregrasses were generally most common at low grazing pressure in the grazing trial and more common in the ungrazed burn trial. *Enneapogon* spp. seed bank numbers also decreased as grazing pressure increased (mean of 665 / sq m at high, 418 at medium and 275 at low grazing pressure over 7 years). There was no pattern of numbers with grazing pressure for *Hybanthus* spp., *S. australasicus*, *T. loliiformis* and *Wahlenbergia* spp. (See Appendix I).

6.1.1.5 *Discussion*

The main features of land condition deterioration in the *A-B* region are an increase in less desirable grasses, regrowth from the dominant *Eucalyptus* spp. and soil erosion (Hall *et al.* 1994). While these may be long term results, they did not occur during the seven years of the grazing trial. The main treatment effects from increasing grazing pressure were similar to most grazing trials reported. A decrease in pasture yield, perennial grass basal area, ground cover and plant lifespan from increasing grazing pressure resulted in accelerated soil erosion and decreased animal production. This was a valid justification for the safe utilisation level of around 25% to calculate a safe carrying capacity and demonstrated the importance of stocking rate as a determinant of land condition and animal production. The resilience of the pasture was also demonstrated by the maintenance of pasture composition while under stress. Densities of major perennial grasses were maintained by increasing recruitment levels as grazing pressure increased.

Seedbanks of the major perennial grasses were not affected by grazing pressure. These processes may not have occurred if there had been consecutive below average rainfall years during the trial. This is in contrast to the work of Orr (2004) where drought had the overriding effect on *H. contortus* lifecycles. The similarity in these studies is that the *H. contortus* population is maintained by seedling recruitment. This shows the importance of a seedbank to ensure the persistence of this species. Both studies also demonstrated the increase in basal area as seasonal conditions improved. This highlights the importance of maintaining populations so that plants can respond to grass-growing rains. Additionally there were no germinating seeds of trees or shrubs recorded. This may have been due to the lack of favourable episodic events which contribute to a big pulse of seed. *Aristida* spp. did not increase under increasing grazing pressure as would be expected. Yields of *Aristida* spp. were actually increased at low grazing pressure. There are varying responses reported for *Aristida* spp. in relation to grazing pressure and drought. While *Aristida* spp. were a very small component of the pasture in this trial, the responses were probably due to the particular taxonomic units present at this site.

In contrast to other studies, there was a minimal increase in pasture production from tree clearing. The grazier consultative group attached to the Ironbark site strongly recommended that tree clearing was not worthwhile in this land type because there is usually a serious regrowth problem, buffel grass could not be established and the improvements in stocking rates were not significant. While our result is not fully understood, work by (Day pers. comm.) indicates that the projected foliage area of the dominant *E. melanophloia* was considerably lower than *E. populnea* for communities with the same tree basal area. This may be an indicator of competitive effect with pastures for communities with similar tree basal areas. The apparent co-existence of grasses and trees may be due to the two layer soil hypothesis. Grasses were superior competitors for soil moisture in the upper layer while only trees could access soil moisture in the lower layer. This was certainly demonstrated by the soil moisture data in Section 6.1.4 where soil moisture fluctuated in the 0-10 cm surface layer, and was more stable at lower levels. Soil moisture levels at depth also appeared to be higher in the treeless areas. With the higher clay content of the B horizon a high proportion of rainfall may not move to deeper soil layers. This may explain the excellent grass growth under *E. melanophloia* trees compared with the “ill-thrift” appearance of those trees due to the poor foliage area. The high sparse canopy with a low leaf biomass compared to other tree species would indicate less potential for tree transpiration and therefore less potential for grass competition. Scanlan (2002) has also demonstrated how the spatial variability of patches of trees may have contributed to higher than expected pasture yields at high tree basal areas. The paddock scale recordings may have captured this response in contrast to the small plot results in Section 5.1.1.5.

6.1.2 **Burning trial**

6.1.2.1 ***Abstract***

The dynamics over 7 consecutive years (1994–2001) of native pasture in response to removal of tree competition or the use of regular spring fires, and their interaction, were studied in detail in ungrazed silver-leaved ironbark country near Rubyvale. The pasture was initially dominated by a healthy stand of the palatable, productive perennial (3P) grasses *B. ewartiana, H. contortus* and *C. fallax. B. ewartiana* generally had the highest yield and basal area. *T. triandra*, minor grasses, forbs and native legumes individually contributed less than 5% to pasture yield at all times.

In the absence of grazing, tree killing had no significant effect on ground cover, pasture yields and pasture basal area. Regular spring burning caused a significant reduction of ground cover and pasture yield with or without the presence of trees. Tree retention increased *C. fallax* density and also the recruitment of *H. contortus*. However, overall the density of the key species was only marginally affected by the treatments.

Individually, the yields of the main grasses were not affected by tree killing. Regular burning decreased the standing autumn yield of *B. ewartiana* and *T. triandra*. Tree killing resulted in higher yields of forbs, *Enneapogon* spp. and native legumes. Regular burning resulted in a consistently increased yield of *Enneapogon* spp., usually double.

Seedbanks in the ungrazed plots were similar to those in the grazing trial. Regular burning seemed to reduce total seedbank levels, however they were quickly replenished where there was one spring without burning.

Contrasts in the behaviour of the key species over time are apparent. While *C. fallax* presence is quite stable, *B. ewartiana* is more dynamic and *H. contortus* has an even larger number of recruitments and mortalities. *B. ewartiana* had a higher plant mortality rate under burning than where unburnt.

6.1.2.2 ***Background***

Studies into the ecology and production potential of native pastures provide a sound base for the development of good grazing land management. Measuring the persistence, recruitment and mortality of key species and determining their lifespans under differing management gives a good understanding of their inherent dynamics. Ground cover, yield, species composition, basal area and seedbank measurements, when used in combination, assist with determining the most sensitive factors involved when a landscape process is changed as a result of management and/or climatic interactions. In this study the impact of regular spring burning was our primary focus.

6.1.2.3 ***Methods***

Ground cover, pasture yield and species composition.

The Botanal technique (Tothill *et al.* 1992) was used to describe ground cover, species frequency, yield and composition within each paddock. All operators had an ability to visually rank pasture yield, an ability to identify the base set of pasture species recorded at each site and an ability to visually rank ground cover. Other sampling details -

- quadrat size 0.5 metre by 0.5 metre (size $0.25m^2$)
- yield ranking 00 to 100 - the Botanal input program ignores the decimal place

- number of species ranked for yield 3
- species frequency all species present in quadrat
- cover class codes 1= 0-5%, 2=5-15%, 3=15-35%, 4=35-50%, 5=50-90%, 6=90-100%
- 15 ranked quadrats were cut, dried and weighed to develop the regression equations to convert the Botanal yield ratings to species and pasture dry matter yields in kg/ha

The paddocks were sampled each year on a grid pattern along the same marked transects.

Annual sampling was generally in April or May when species identification was easiest. Both the grazing trial and burning trial used the same technique but with differing sample sizes. There were up to 40 quadrats recorded in paddocks in the burning trial.

A Forall header program was generated to calculate plot means. The header program also calculated frequencies of genus groups where identification to species was not possible (Appendix E1). Treatment means were calculated in Excel Pivot tables.

Perennial grass basal area

Basal area was measured using the point frame method. Pasture basal area is sensitive to marked changes in grazing pressure and climatic conditions. Absolute values in semi-arid native pastures are low, often < 5%. Hence to ensure that error due to operational factors was minimised the following procedures were necessary:

- sampling was done along the fixed TRAPS transect lines. Steel posts 50 metres apart marked the start and finish of each sector.
- total transect length in each grazed paddock was 200 metres, subdivided as 2 lengths of 200 metres.
- 1333 pin strikes were observed for each paddock in the burning trial. Using a 0.75 metre long frame, with a distance of 0.15 metres between pins, this equates to 267 "end to end positionings" of the frame.
- at each pin strike either bare or plant base is recorded. If a strike occurred on a plant base, the species or plant group was recorded.
- definition of plant base is critical to the reliability of this method. The pin must strike from directly above the rooted base of the plant. If the plant was shorn to ground level, any pin that would miss the plant base is deemed "bare". At any one sampling the same operator should observe all strikes and where possible the same operator should be used for consecutive samplings.

Annual sampling was generally in June and July. Both the grazing trial and burning trial used the same technique but with differing sample sizes.

Grass population dynamics

These measurements were taken to determine the persistence, recruitment and mortality of key perennial grass species and to estimate their life spans under different grazing management. The life history of plants was monitored by charting plants of key species in permanent quadrats. Quadrats were distribution in each paddock in clusters located near a steel post on the fixed transect lines.

A data recording sheet, identical to the quadrat grid configuration allowed the location of each key species plant to be mapped to scale by hand in pencil. Only the base of a plant was drawn and its species code was put alongside. Any new recruits were drawn on the grid and notes were also entered on the sheet. Plants on the edge of the quadrats were mapped and included in the population calculations because they often migrated further within over time.

Sampling was done annually at end of growing season, from May onwards.
The actual shape of the quadrats used differed between the sites as did the method of recording plant co-ordinates during data entry into a database. Both the grazing trial and burning trial at the same site used the same technique but with differing sample sizes. The burning trial used 3 quadrats per plot. See Appendix Q for more details.

The key species recorded at Keilambete were *Bothriochloa ewartiana* (forest Mitchell), *Chrysopogon fallax* (golden-beard grass) and *Heteropogon contortus* (black speargrass).

Soil seed reserves

These measurements were taken to see how large the pool of seeds of all species was each spring and how much they varied amongst years. Such reserves can have a big bearing on how strongly a damaged pasture recovers and how susceptible a pasture is to active invasion by existing weedy plants.

Field collection details:

- it was critical that sampling was complete prior to the onset of spring rains, to ensure that no seed germination occurred prior to sampling, ie. it was done in August to September.
- a soil corer with sampling dimensions of 5.3cm diameter (area of 22 cm^2) and able to sample to 5cm depth was used. The bulk of soil seeds are located in the top 2cm of soil.
- 4 cores were bulked into one bag to form a single sample from one location
- cores were taken from around the permanent quadrats used to record the grass population dynamics

Sampling was done annually at end of winter. Both the grazing trial and burning trial used the same technique but with differing sample sizes.

After sampling, the soil was air-dried in paper bags and then carefully sieved to remove large stones and litter, without losing any soil or seeds in small litter. In early summer the soil was spread about 2 cm deep over the surface of pots nearly filled with washed sand in a glasshouse. The pots were then regularly sprayed with water to induce germination of all germinable seeds.

Germinated seeds were counted and removed as soon as they were identifiable to a species level. Regular watering was discontinued after 4 to 6 weeks, by which time the vast majority of germinable seeds had emerged but moss and algal cover was still acceptably low. Watering continued intermittently for many further weeks to keep existing, unidentified plants growing until they could be named. Sometimes this required the addition of some nitrogenous fertiliser to keep plants growing in the 15 cm

6.1.2.4 *Results*

Burning regime

Despite the absence of grazing on this site, burning was not possible every year due to wet conditions preventing adequate pasture curing for ignition to occur. Burning was achieved in the springs of 1995, 1997, 1998 and 1999. The first burn, in spring 1995 was a disappointing trickling burn which did little damage to small woody plants and missed many grass tussocks. The 1997 burn was conducted as a mild burn for safety reasons because of the high fuel loads. In 1998, all plots (including controls) were burnt because of the high accumulated fuel loads. The burnt treatment plots were burnt with a slow trickling burn and had to constantly be relit. In 1999, the burnt treatment plots were burnt with a headfire and flame height estimated at 3 metres.

6.1.2.4.1 Ground cover

6.1.2.4.1.1 Effect of Tree killing

Ground cover was not affected by tree killing or tree retention in ungrazed pasture. The significantly greater ground cover in 1994 (P<0.01, Figure 6.38a) could not be attributed to a treatment effect because tree killing by arboricide was only done in March 1994 and no further rain fell before this data was collected. The lack of treatment effect on ground cover is not surprising given that pasture yield was largely unaffected by tree killing. Detailed statistical analysis is presented in Appendix N1.

Tree killing did not affect autumn ground cover under regular burning, or when unburnt

6.1.2.4.1.2 Effect of regular spring burning

Ground cover was significantly decreased by burning in the autumn of 1996 (P<0.01), 1998 (P<0.001), 2000 (P<0.001) and 2001 (P<0.001) (Figure 6.38b). This result is similar to the burning effect on pasture yield (Section 6.2.2) where burning reduced pasture yield in the years 1995, 1996, 1998, 2000 and 2001. Ground cover was generally reduced in the autumn following the spring burn when summer rainfall was below average. In the autumn of 1999, ground cover in the burnt and unburnt plots was similar (87.8 versus 86.2%) following the burning of all of these plots in the previous spring.

Regular burning decreases autumn ground cover with or without the presence of trees

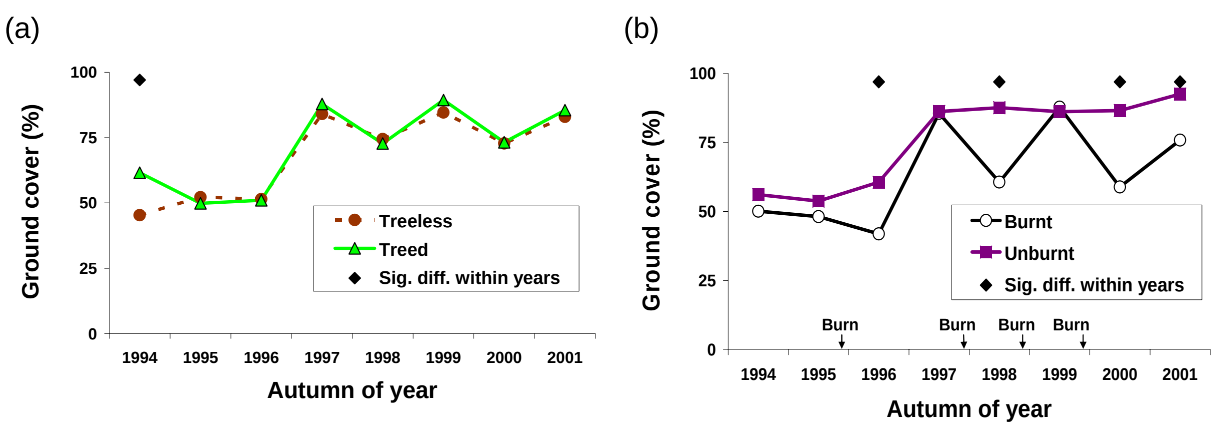


Figure 6.38 The impact of (a) Tree killing, and (b) Regular burning on autumn ground cover (%) on ungrazed plots at the ironbark site.

6.1.2.4.2 Community yield and composition

6.1.2.4.2.1 Total pasture yield (kg/ha)

Tree killing

Tree killing had a minimal effect on total pasture yields in the succeeding 8 years of the trial and this was not influenced by burning. However, regular burning reduced pasture yield regardless of tree treatment (Figure 6.39). Tree killing resulted in a small but significantly increased pasture yield in 1995 ($P<0.05$) and decreased pasture yield in 2000 ($P<0.05$, Figure 6.39). In contrast to the grazing trial, tree killing did not benefit pasture yield as the trial progressed. Perhaps this was because regular burning of half the plots continued to set back the trees trying to recover from the damage suffered in the 1992 drought while the high pasture competition where ungrazed exacerbated all other effects more than what occurred in the grazing trial. Detailed statistical analysis is presented in Appendix N1. The lower yields in autumn 1999 result from burning all plots in spring 1998 to remove a huge bulk of old dead pasture that had accumulated over 4 years in the absence of grazing. However the 1998/99 season quickly replaced that material and even more accumulated in the following 2 years. Nearly 4000 kg/ha grew in one good season which is more than we would normally expect on this site. The accumulation of up to 8000 kg/ha by autumn 2001 in the absence of grazing may signify the large fuel loads that historically would have been potentially available in the region.

Tree killing did not benefit pasture yield under regular burning, or when unburnt

Burning the previous spring significantly reduced total pasture yields in the autumn of 1996 ($P<0.01$), 1998 ($P<0.001$) and 2000 ($P<0.001$), and the effect was maintained into 2001 ($P<0.01$) without another spring burn (Figure 6.39). In the autumn of 2000, the effect of the reduction in yield due to burning, was significantly enhanced by the retention of trees ($P<0.01$). Pasture yield was generally reduced in the autumn following the spring burn when summer rainfall was below average. In the autumn of 1999, pasture yield in the burnt and unburnt plots was similar, following an average summer after the burning of all of these plots. Detailed statistical analysis is presented in Appendix N1.

Regular burning decreases pasture yield with or without tree killing

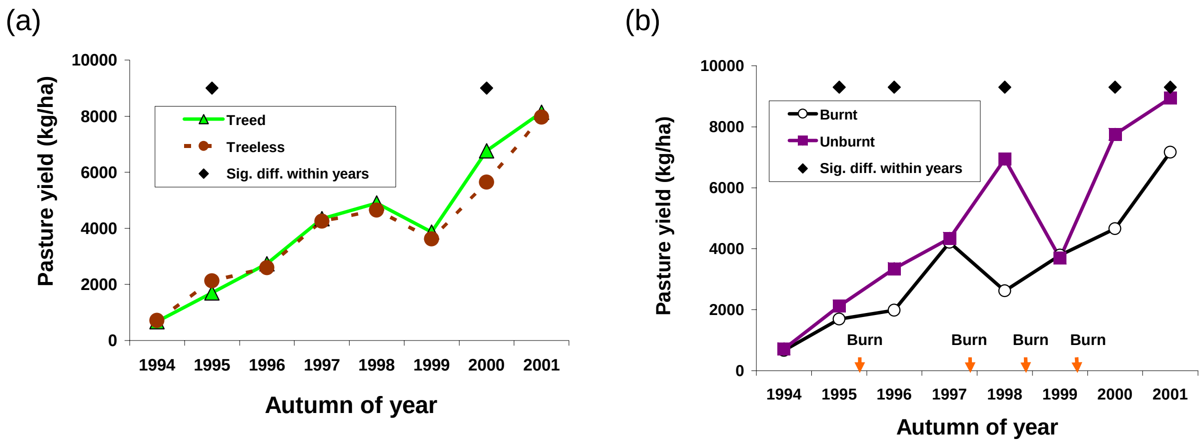


Figure 6.39 The impact of (a) Tree killing, and (b) Regular burning on total pasture yield on ungrazed plots at the ironbark site.

6.1.2.4.2.2 Pasture component yields

Major perennial grasses

Tree killing

Tree killing in the absence of grazing had minimal effect on yields of the main grasses although it was associated with a statistically significant decrease in yield of *C. fallax* in 1999 (P<0.01, Figure 6.40). The statistically greater yield of *B. ewartiana* (P<0.01) in 1994 cannot convincingly be attributed to a treatment effect because tree killing by arboricide was only applied in March 1994 and no further rain fell before yields were measured in the early winter. Detailed statistical analysis is presented in Appendix N1.

Tree killing had minimal effect on the yields of the major perennial grasses

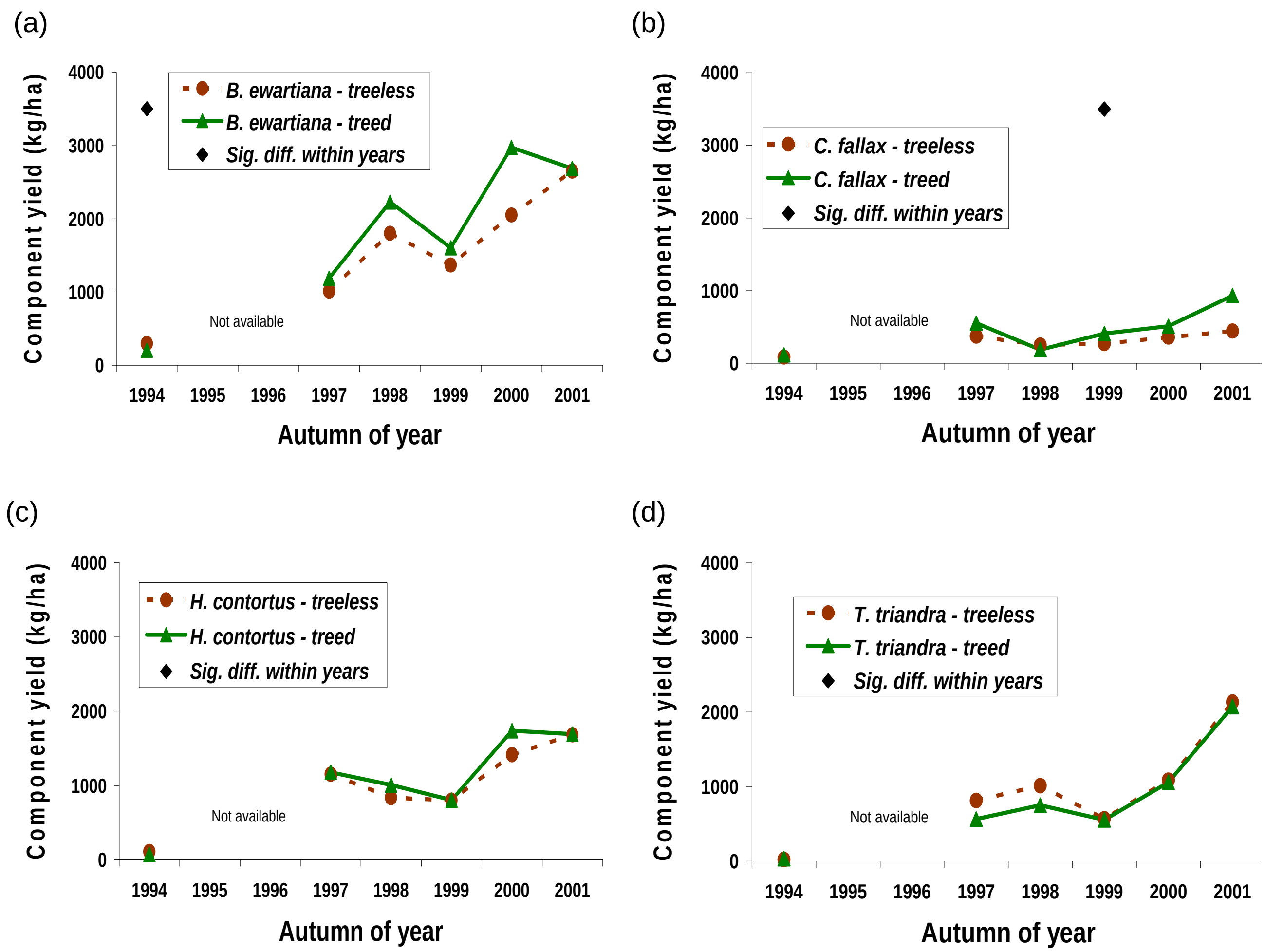


Figure 6.40 Tree killing impact on the yield of (a) *B. ewartiana*, (b) *C. fallax*, (c) *H. contortus* and (d) *T. triandra* on ungrazed plots at the ironbark site.

Regular burning decreased the yield of *B. ewartiana* significantly in 1997 ($P<0.01$), 1998 ($P<0.01$) and 2000 ($P<0.001$), and *T. triandra* in 1998 ($P<0.05$) and 2000 ($P<0.05$) (Figure 6.41). The reduction of *B. ewartiana* yield had a major influence on total pasture yield. Note how low the yield of *C. fallax* was where there was no grazing and thus strong competition from the other more bulky grasses. Also burning in the absence of grazing did not stimulate the growth of *H. contortus* (Figure 6.41(c)) as might be predicted from other studies in the Burnett region (Orr *et al*. 1997).

Regular burning decreases pasture yield of *B. ewartiana* and *T. triandra*

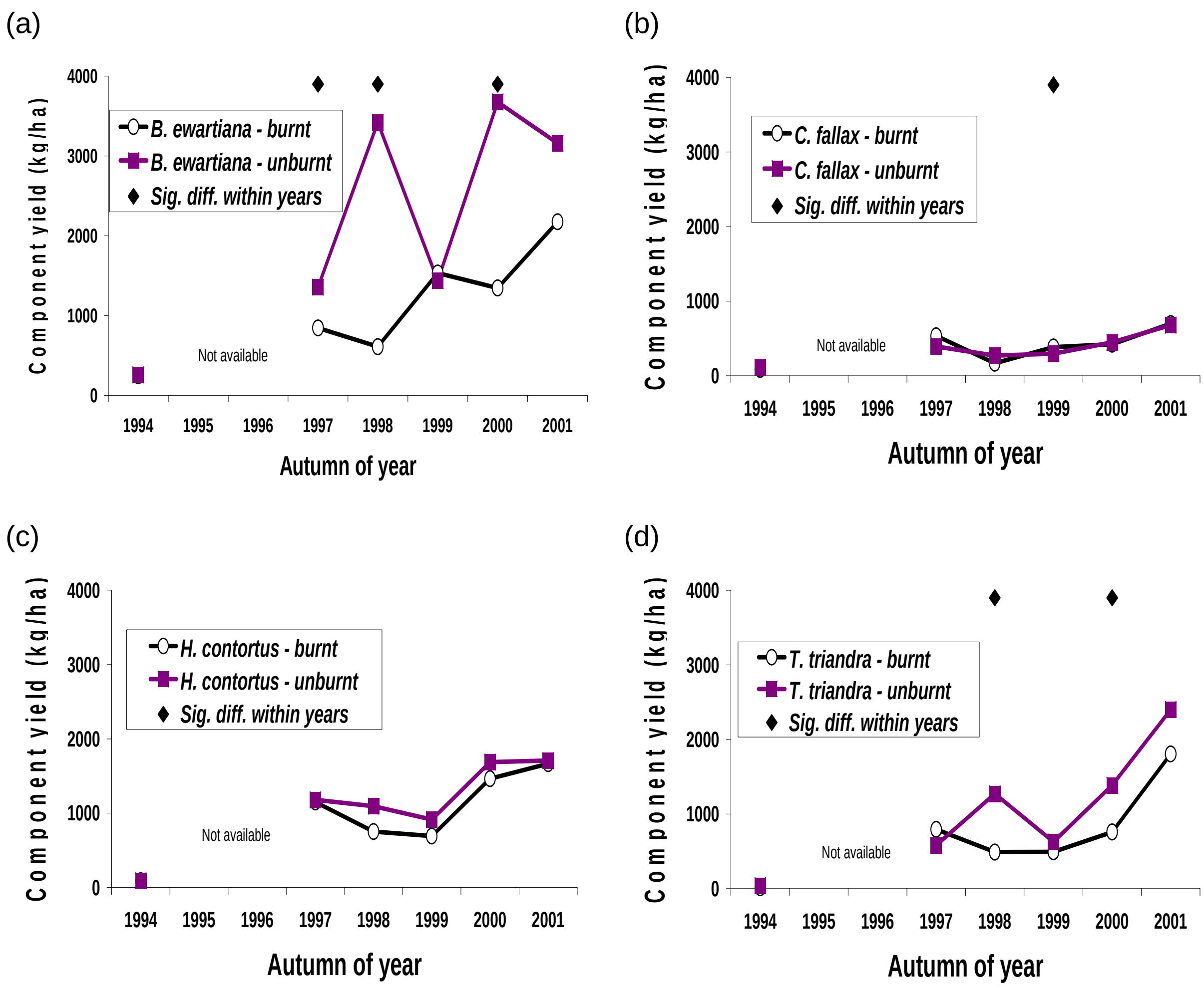


Figure 6.41 The impact of regular burning on the yield of (a) *B. ewartiana*, (b) *C. fallax*, (c) *H. contortus* and (d) *T. triandra* on ungrazed plots at the ironbark site.

Minor pasture components

Tree killing

The yield of forbs in 1999 (P<0.01) and 2000 (P<0.05) was greater in the treeless plots, as was the yield of *Enneapogon* spp. in 1999 (P<0.05) and native legumes in 2000 (P<0.05). However, the contribution of these plants is an order of magnitude less than that of the major perennial grasses (Figure 6.42). Detailed statistical analysis is presented in Appendix N1.

Yields of some minor pasture components increased when trees were killed

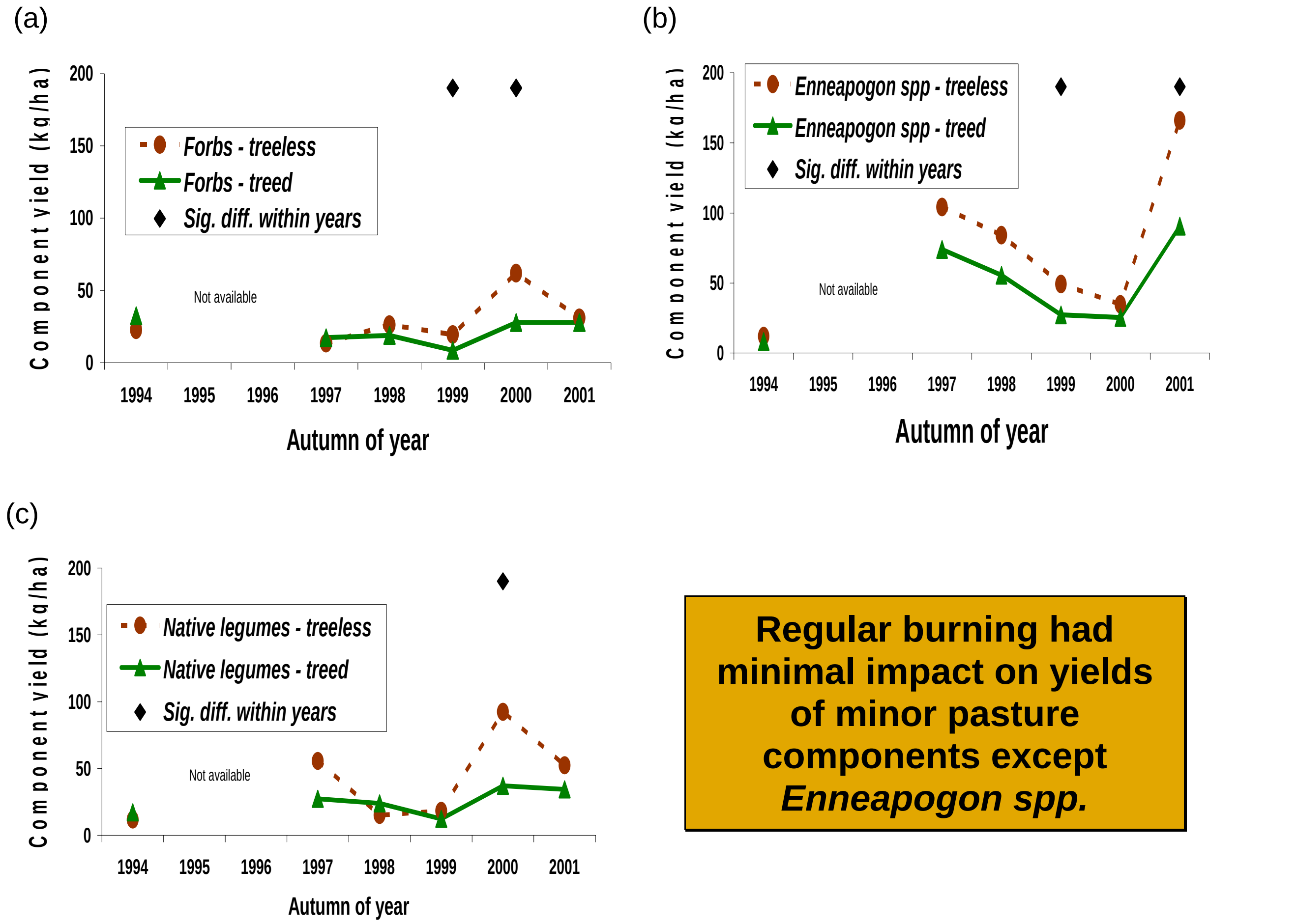


Figure 6.42 Tree killing impact on the yield of (a) Forbs, (b) *Enneapogon* spp., and (c) Native legumes on ungrazed plots at the ironbark site.

Regular burning had a minimal impact on the minor components of the pasture except bottlewasher grasses. Regular burning resulted in a consistently increased yield of *Enneapogon* spp. in 1999 (P<0.01), 2000 (P<0.05) and 2001 (P<0.001). In contrast, native legume yields were decreased but only significantly in 2000 (P<0.01) (Figure 6.43). The reduction of bottlewasher grasses by burning is not unexpected as their fluffy seeds would be burnt if unburied and their crowns do not appear to be very robust or protected from fire.

(a) (b)

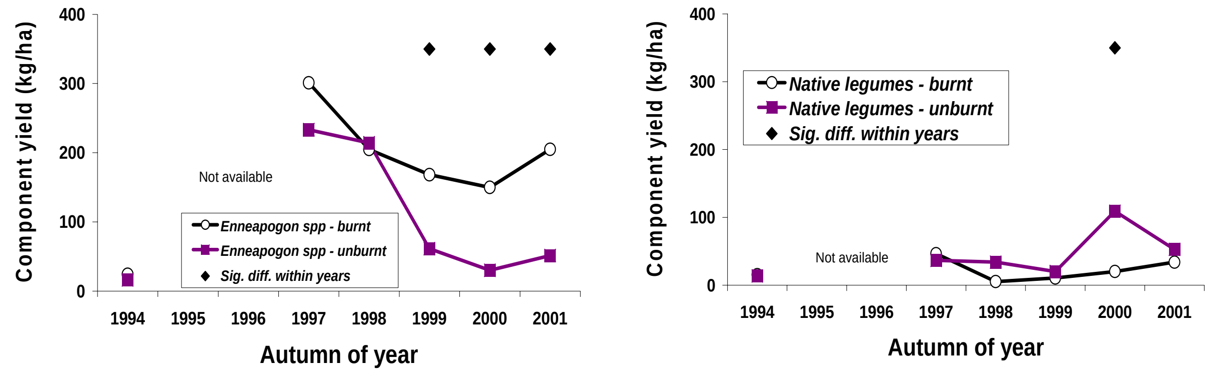


Figure 6.43 The impact of regular burning on the yield of (a) *Enneapogon* spp., and (b) Native legumes on ungrazed plots at the ironbark site.

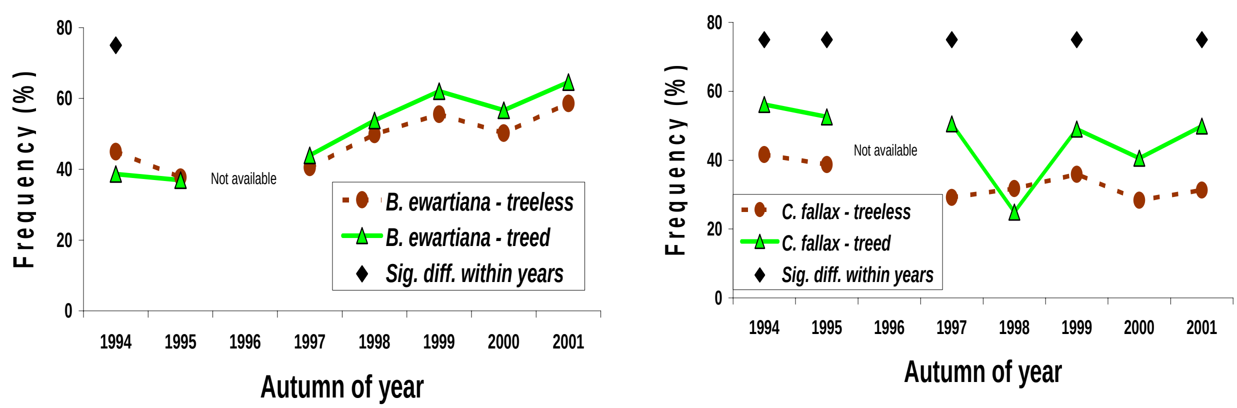
6.1.2.4.2.3 Pasture component frequencies (%)

Major perennial grasses

Tree killing

Neither tree killing nor tree retention affected the frequency of *T. triandra* or *H. contortus* in the burning trial. Tree retention increased the frequency of *C. fallax* in most years with a strong effect (P<0.001) in the autumn of 1997 and 1999, and a weaker effect (P<0.05) in the autumn of 1995. The frequency of *C. fallax* was significantly lower in the treeless plots from the start of the experiment and a 15% difference was maintained each year except for autumn 1998. There seemed to be a slight downward trend in *C. fallax* frequency as the length of time without grazing increased. We have no explanation for the large drop in frequency in 1998 in the treed plots. A weak effect (P<0.05) of tree killing on the frequency of *B. ewartiana* in 1994 could not be attributed to a treatment effect because tree killing by arboricide was only done in March 1994. Over time the frequency of *B. ewartiana, H. contortus* and *T. triandra* trended upwards in the absence of grazing (Figure 6.44). Detailed statistical analysis is presented in Appendix N1.

(a) (b)



(c) (d)

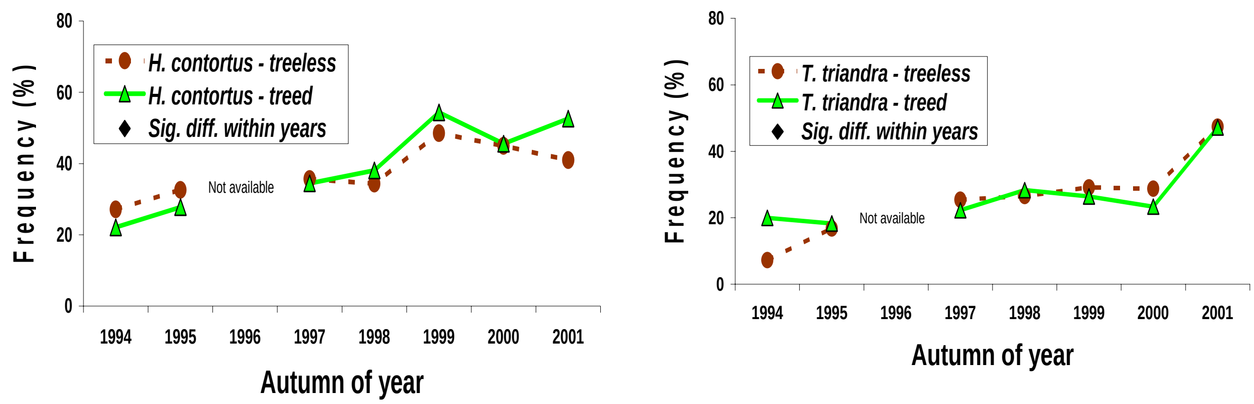
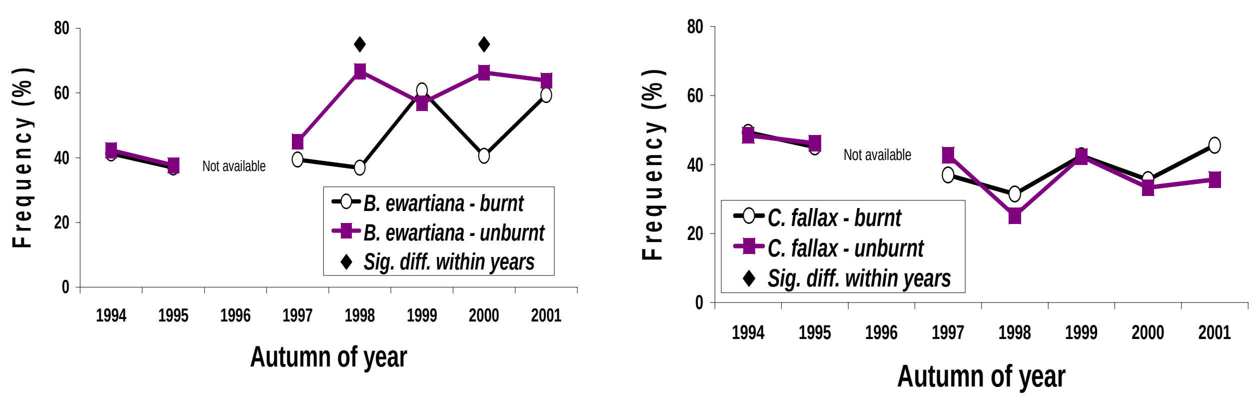


Figure 6.44 Tree killing impact on the frequency of (a) *B. ewartiana*, (b) *C. fallax*, (c) *H. contortus* and (d) *T. triandra* on ungrazed plots at the ironbark site.

Regular burning had minimal impact on the frequency of major perennial grasses (Figure 6.45). Burning decreased the frequency of *B. ewartiana* in the autumn of 1998 (P<0.01) and 2000 (P<0.05). All plots were burnt in the spring of 1998 so that the decrease in *H. contortus* frequency in the autumn of 1999 could not be attributed to the burning treatment. Regular burning had no effect on the frequency of *C. fallax* or *T. triandra*.

Regular burning had minimal impact on the frequency of the major perennial grasses

(a) (b)



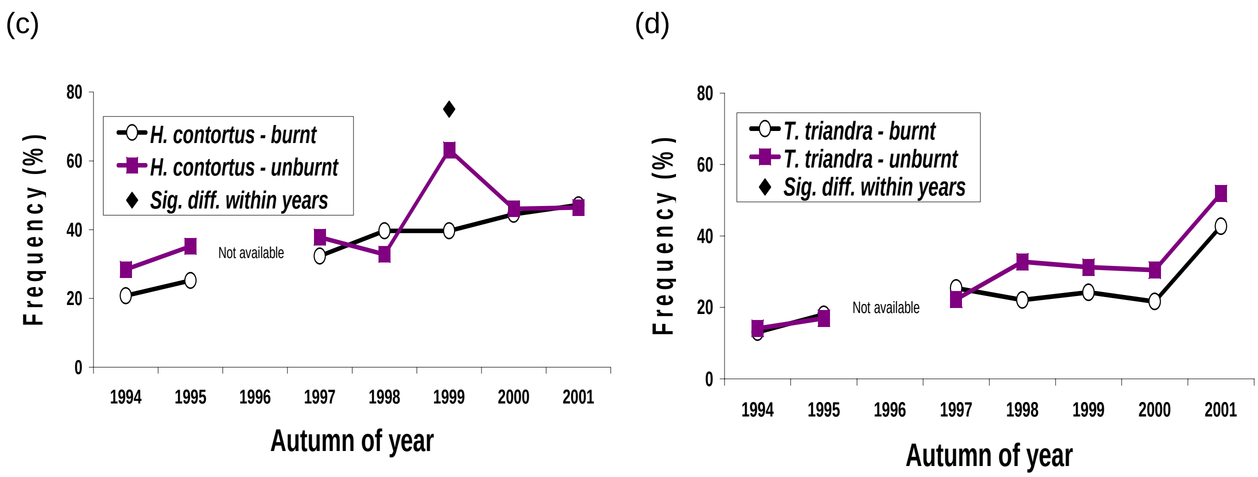


Figure 6.45 The impact of regular burning on the frequency of (a) *B. ewartiana*, (b) *C. fallax*, (c) *H. contortus* and (d) *T. triandra* on ungrazed plots at the ironbark site.

Minor pasture components

Tree killing

Tree killing increased the frequency of some of the minor pasture components while disadvantaging others. The effect was statistically significant for the enhanced frequency of *Chloris* spp. in 1998, ($P<0.05$), *Enneapogon* spp. in 1997 and 2000 ($P<0.05$), forbs in 1998 ($P<0.01$) and native legumes in 1995 and 1997 ($P<0.05$). Tree retention favoured an increase in the frequency of *Panicum* spp. in 1998 and 1999 ($P<0.05$). The frequency of *Aristida* spp. was enhanced in 1995 by tree retention ($P<0.05$), but it was also significantly increased in 1999 by prior tree killing ($P<0.05$, Figure 6.46). Generally, treed plots had a lower frequency of *Enneapogon* spp. and native legumes in all years

Tree killing increased the frequency of some minor components of ungrazed pasture

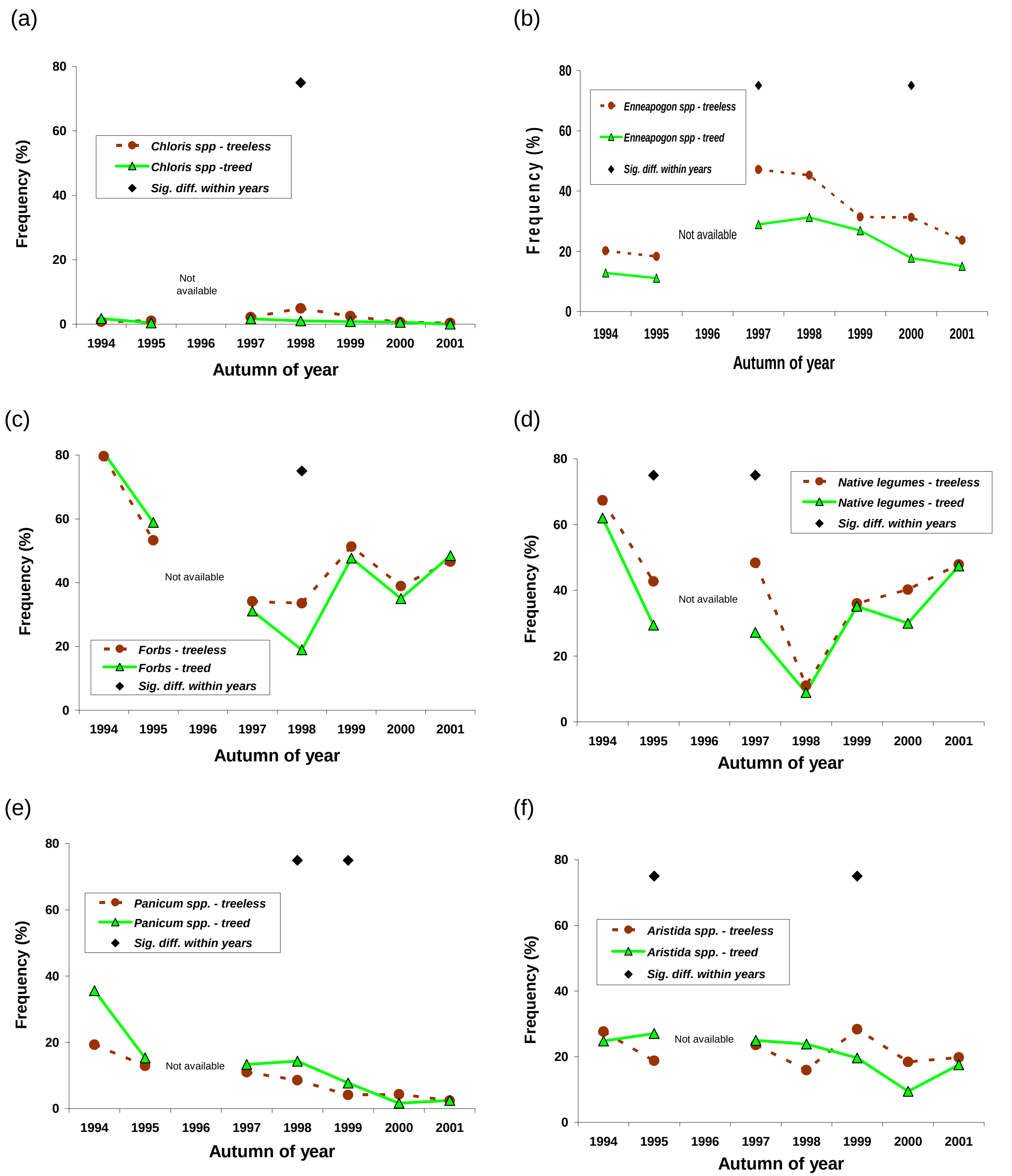


Figure 6.46 Tree killing impact on the frequency of (a) *Chloris* spp., (b) *Enneapogon* spp., (c) Forbs, (d) Native legumes, (e) *Panicum* spp. and (f) *Aristida* spp. on ungrazed plots at the ironbark site.

Regular burning had minimal impact on the frequency of most minor pasture components (Figure 6.47). However, burning consistently increased the frequency of *Enneapogon* spp. in the years 1997 ($P<0.05$), 1998 ($P<0.05$), 1999 ($P<0.01$), 2000 ($P<0.01$) and 2001 ($P<0.01$). Conversely, burning decreased the frequency of native legumes in the years 1999 ($P<0.01$), 2000 ($P<0.01$) and 2001 ($P<0.05$).

Regular burning had minimal impact on the frequency of minor pasture components

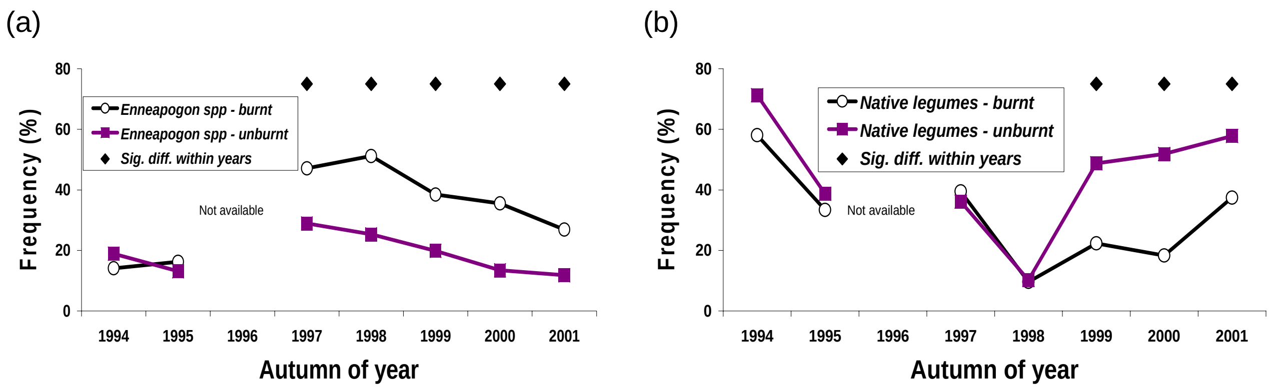


Figure 6.47 The impact of regular burning on the frequency of (a) *Enneapogon* spp. and (b) native legumes on ungrazed plots at the ironbark site.

6.1.2.4.2.4 Pasture biomass proportions (% composition)

Major perennial grasses

Tree killing

Tree killing had minimal impact on the % contribution of the major perennial grasses to pasture yield. Tree retention slightly improved the % contribution of *C. fallax* in 1999 ($P<0.05$, Figure 6.48). The increased yield of *B. ewartiana* ($P<0.01$) in 1994 could not be attributed to a treatment effect because tree killing by arboricide was only applied in March 1994.

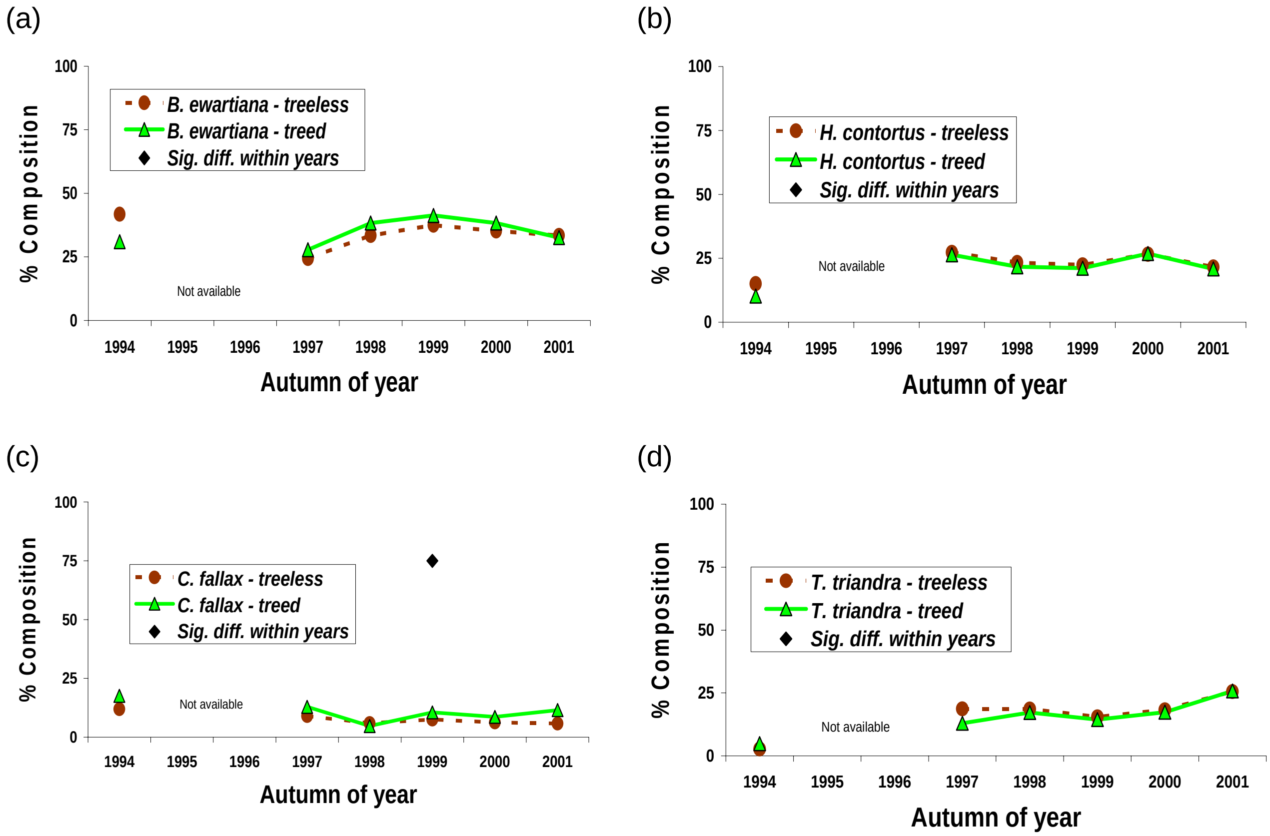


Figure 6.48 Tree killing impact on the % contribution of (a) *B. ewartiana*, (b) *H. contortus*, (c) *C. fallax* and (d) *T. triandra*, to ungrazed pasture yields at the ironbark site.

Tree killing had minimal impact on pasture biomass proportions

Regular burning decreased the biomass proportion of *B. ewartiana* in 1997 (P<0.05), 1998 (P<0.05) and 2000 (P<0.05) (Figure 6.49) while increasing the biomass proportions of *H. contortus* in 1998 (P<0.05) and *C. fallax* in 1999 (P<0.05). Detailed statistical analysis is presented in Appendix N1.

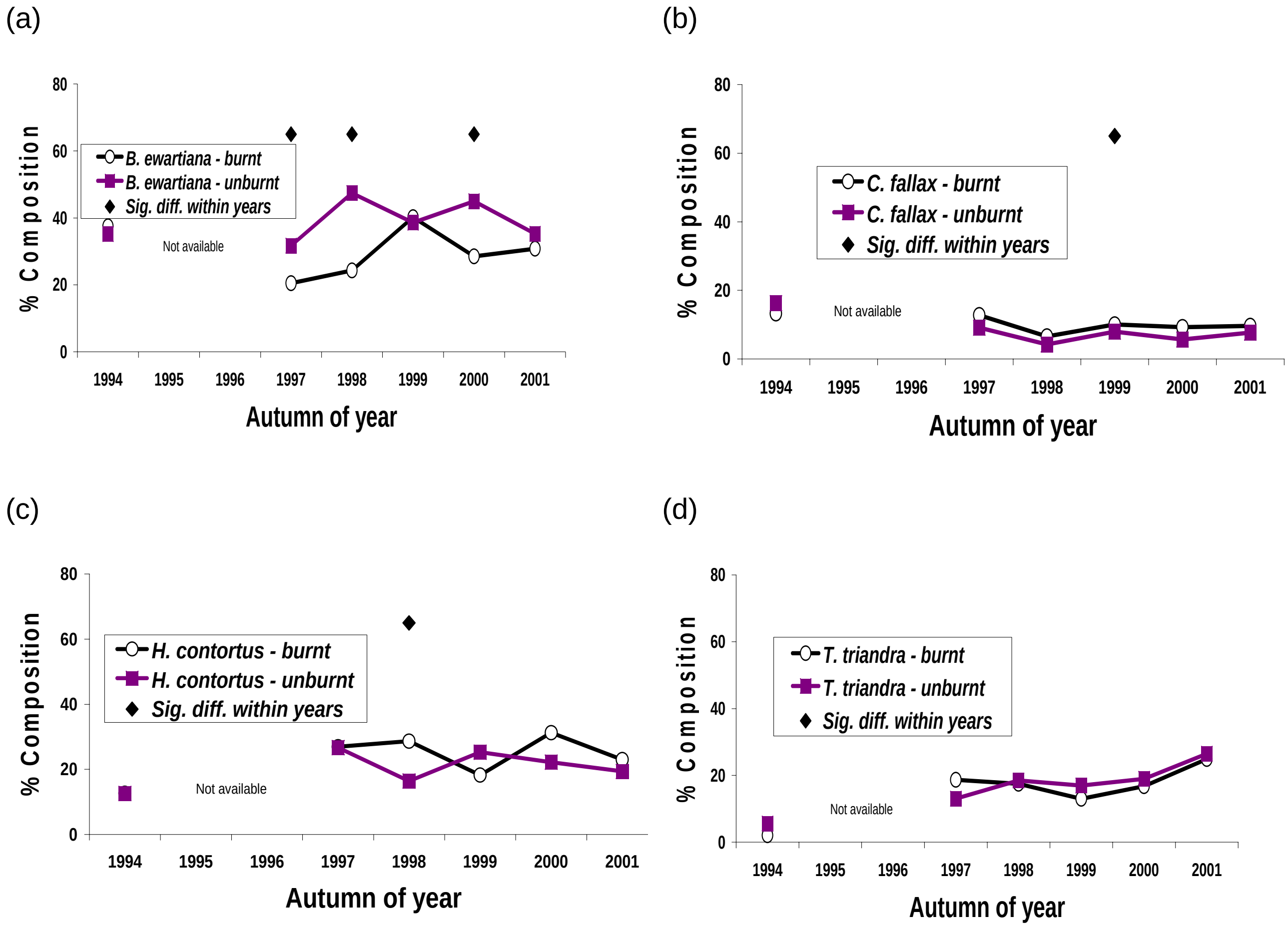


Figure 6.49 The impact of regular burning on the % contribution of (a) *B. ewartiana*, (b) *C. fallax*, (c) *H. contortus* and (d) *T. triandra* to ungrazed pasture yields at the ironbark site.

Regular burning decreased the proportion of *B. ewartiana* in the pasture biomass

Minor pasture components

Tree killing

Tree killing was associated with a slightly increased % contribution of forbs in 1999 and 2000 ($P<0.05$), *Enneapogon* spp. in 1999 ($P<0.01$), and native legumes in 2000 ($P<0.01$, Figure 6.50). Tree retention increased the % contribution of *Panicum* spp. in 1997 ($P<0.05$) although this may be an artefact induced by a higher initial presence in that treatment from before the trial began (Figure 6.50d). Detailed statistical analysis is presented in Appendix N1.

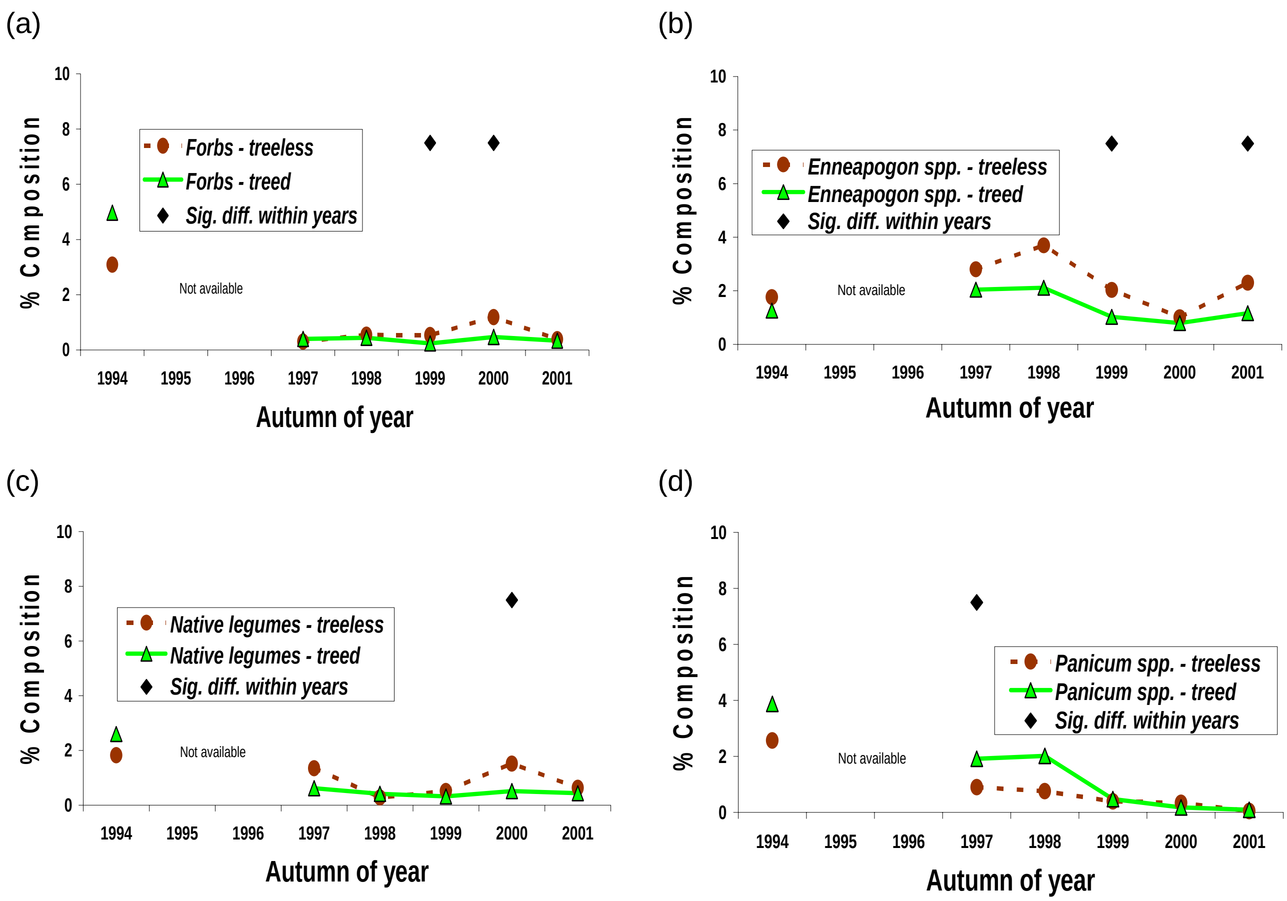


Figure 6.50 Tree killing impact on the % composition of (a) forbs, (b) *Enneapogon* spp., (c) native legumes and (d) *Panicum* spp. on ungrazed plots at the ironbark site.

Regular burning decreased *Enneapogon* spp. in 1998 (P<0.05) 1999 (P<0.001), 2000 (P<0.01) and 2001 (P<0.001) while it increased native legumes in 1999 (P<0.05) and 2000 (P<0.01) (Figure 6.51).

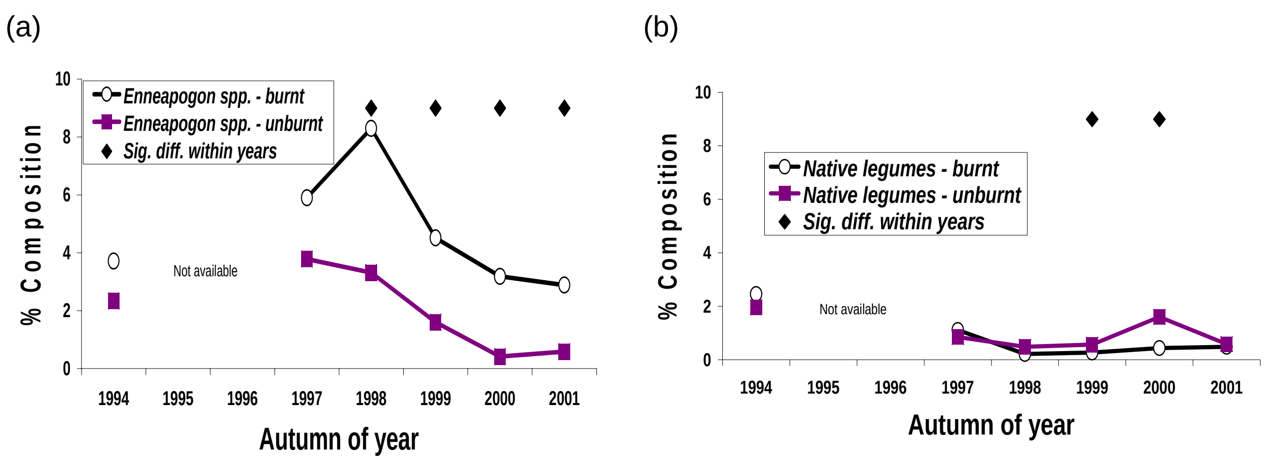


Figure 6.51 The impact of regular burning on the % contribution of (a) *Enneapogon* spp., and (b) native legumes to pasture yield on ungrazed plots at the ironbark site.

6.1.2.4.2.5 Perennial grass basal area

Tree killing

Tree killing had no effect on perennial grass basal area in the years it was recorded (1995, 1997, 1998, 1999 and 2000, Figure 6.52). This is consistent with the minimal effect of tree killing on total pasture yield. The gradual increase in perennial grass basal area is consistent with the trend in the grazing trial where there was a trend towards increasing basal area under low grazing pressure and improving seasonal conditions. Burning was associated with a significantly increased (P<0.001) perennial grass basal area in 2000, 4.5% compared to 2%. This is possibly due to an increase in the size and density of *H. contortus*. Detailed statistical analysis is presented in Appendix N1.

(a) (b)

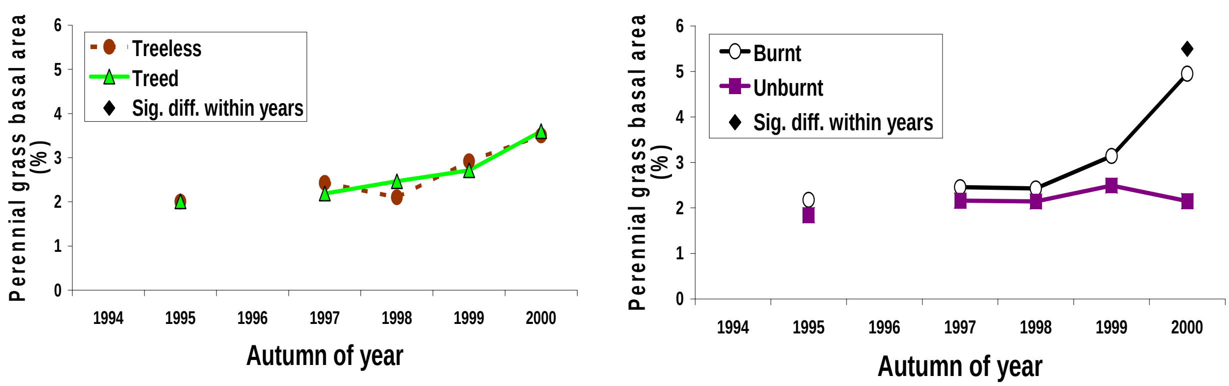


Figure 6.52 The impact of (a) tree killing and (b) regular burning on perennial grass basal area (%) on ungrazed plots at the ironbark site.

6.1.2.4.3 Plant population studies

6.1.2.4.3.1 General

B. ewartiana and *H. contortus* contributed most to total crown area which improved as growing conditions improved and the trial progressed (Figure 6.53). Total crown area was calculated from crown dimensions within fixed quadrats, not from vertical interception of pinpoints across a whole paddock as applied in the previous section. It is dependant on the number and mean size of plants. Total crown area and mean size per plant increased throughout the trial for *B. ewartiana* and *C. fallax*. *H. contortus* had a dramatic density increase in 1999 and 2000 and an associated decrease of the average size per plant. However, compared to *H. contortus*, *B. ewartiana* and *C. fallax* density was very stable throughout the trial, with total crown area increasing as a result of an increase in size of existing plants.

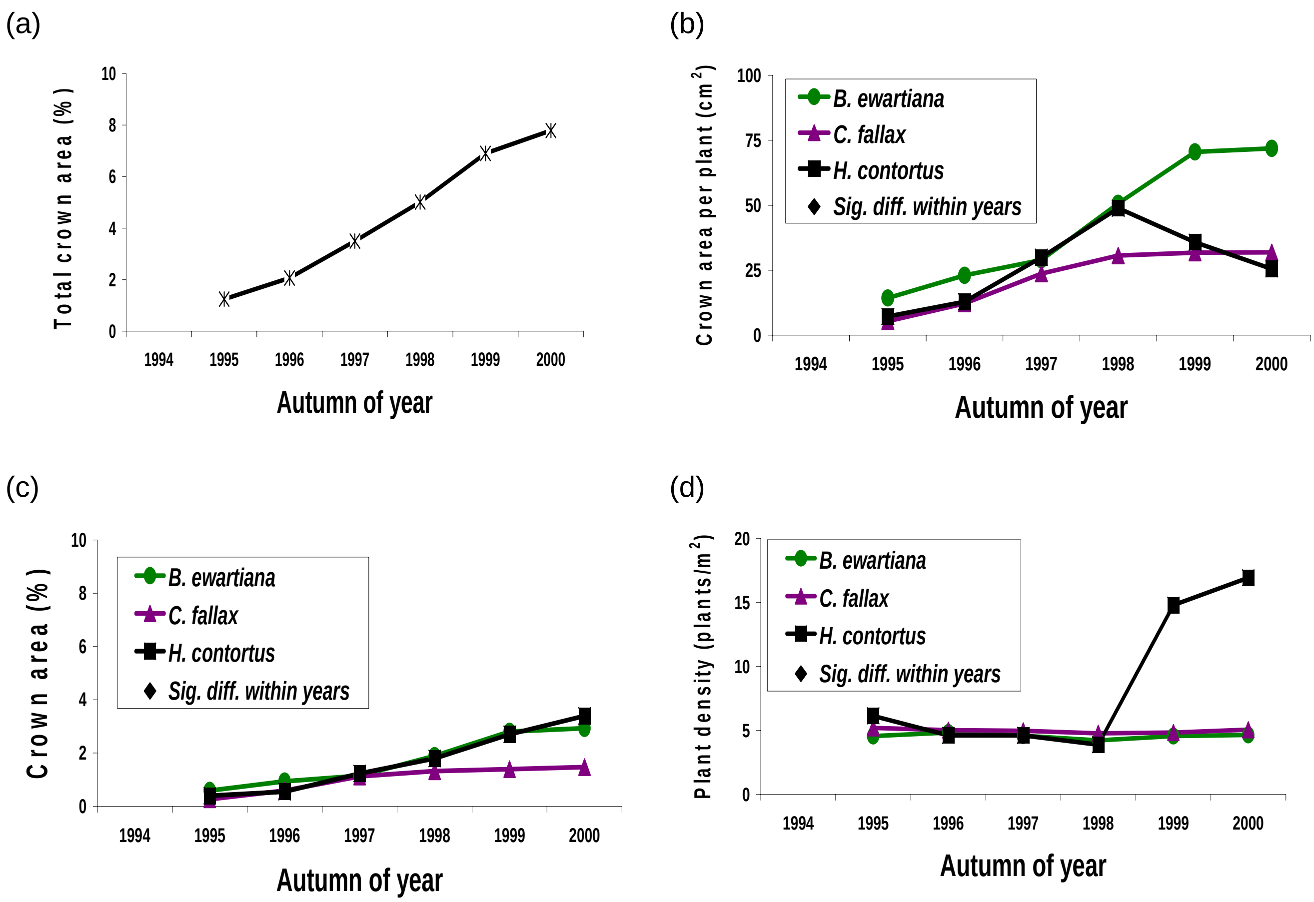


Figure 6.53 Key species (a) Total crown area, (b) Crown area per plant, (c) Crown area % and (d) Plant density on the charted ungrazed quadrats at the ironbark site. Values are meaned over tree management and annual burning treatments.

Note that the total crown area in the charted areas was noticeably higher by 2000 than the paddock means reported earlier. This occurs partly because the quadrats were deliberately placed where a good density of the key grasses existed so that adequate numbers were recorded using a minimal number of quadrats. Additionally, the technique for recording crown area in the quadrats involved two diameter measurements which does not account for spaces within where there is no living material at ground level. However, both sets of sites began at or below 2% in 1995, so the final difference may be related to grazing intensity as well.

Contrasts in the behaviour of the key species over time are apparent, reflecting the differing individual characteristics of these plants. Figure 6.54 shows the persistence, average number of recruitments and mortalities for the key species across the burning trial. The stable nature of *C. fallax* is apparent. *B. ewartiana* is more dynamic and *H. contortus* has an even larger number of recruitments and mortalities. The large number of *H. contortus* plants in 1995 would have included numerous ones which established after the early 1990's drought broke in 1994. As in the grazing trial, there were surprisingly few new recruits after the excellent 1996/97 summer due to a small seedbank. The plants dying were generally small with a median size of 3.14 cm^2 (range 0.01 to 81.28 cm^2).

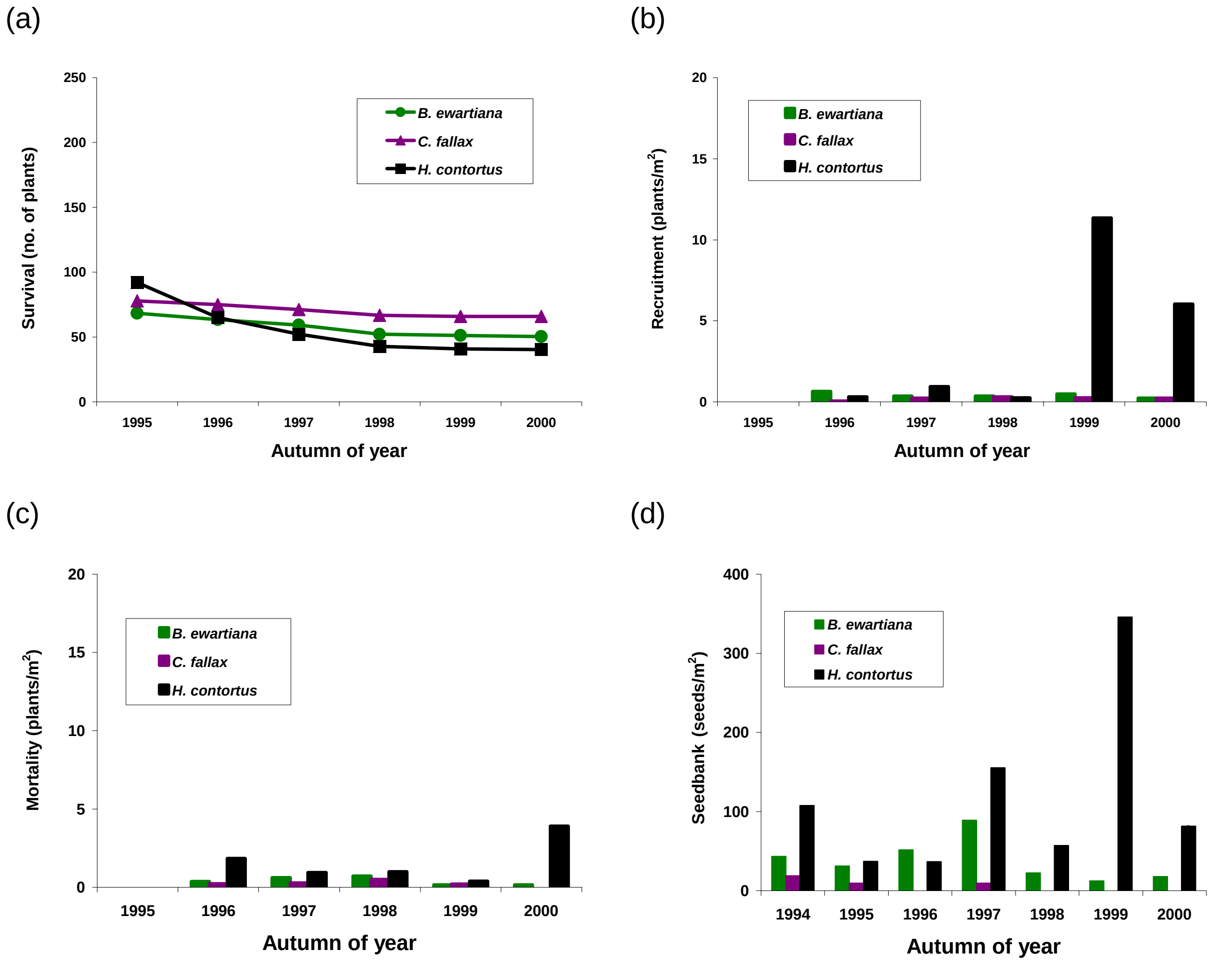


Figure 6.54 ***B. ewartiana*, *C. fallax* and *H. contortus* (a) Survival of original 1995 plants, (b) Recruitments, (c) Mortality, and (d) Seedbank, of all recorded plants in the ungrazed plots at the ironbark site.**

Density of the key species was only marginally affected by the treatments. Tree retention increased *C. fallax* density in 1996, 1998, 1999 and 2000 (P<0.05), while *H. contortus* density was increased in the unburnt plots in 1999 (P<0.05). The recruitment of *H. contortus* was increased by tree retention in 2000 (P<0.05) and also by the absence of burning in 1999 (P<0.05), resulting in the increased density. Mortality of *H. contortus* plants was also increased in the unburnt plots in 2000 (P<0.05, Figure 6.55 a, b, c, d and e).

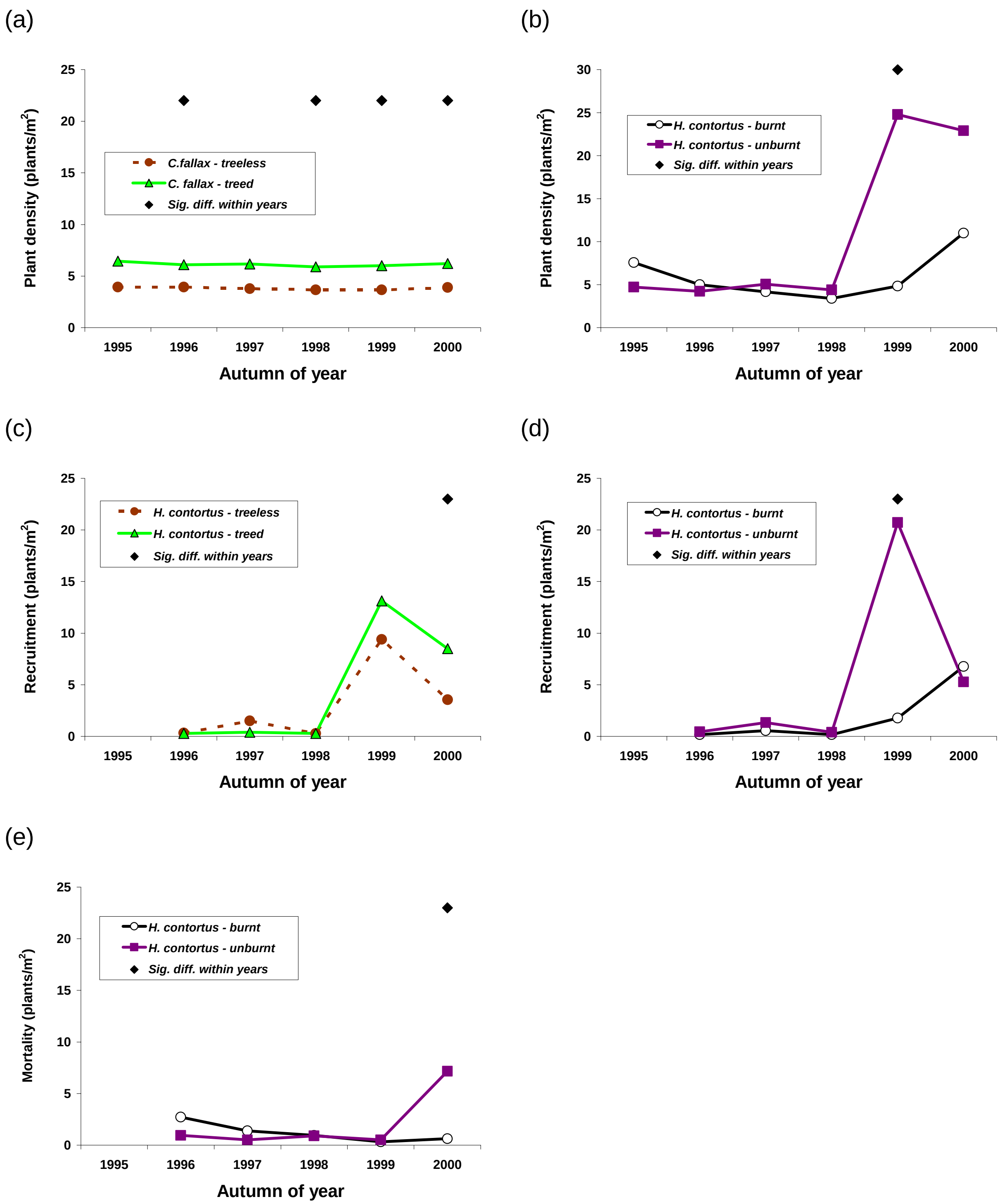


Figure 6.55 (a) Tree killing effect on *C. fallax* density (b) Burning effect on *H. contortus* density (c) Tree killing effect on *H. contortus* recruitment (d) Burning effect on *H. contortus* recruitment (e) Burning effect on *H. contortus* mortality, in the ungrazed plots at the ironbark site.

6.1.2.4.3.2 Population flux

Plant flux was calculated based on the method of Sarukhan and Harper (1973). Similar to the grazing trial, *C. fallax* has a low rate of mortality and a very low rate of recruitment, resulting in very little change in plant density. *B. ewartiana* had a similar low rate of mortality of original plants, however it had higher recruitment rates resulting in a higher plant flux (25% - item k in Table 6.4), compared to *C. fallax* with 15% (Table 6.4, item k). *H. contortus* only had 49% survival of original plants after 5 years and maintained a stable density by having a high recruitment rate to counteract the lower survival rate. It had the highest rate of plant flux at 35%.

Table 6.4 Plant flux calculations for (a) *B. ewartiana,* (b) *C. fallax* and (c) *H. contortus* at the ironbark site (from 3m^2 of charted quadrats, ungrazed)

B. ewartiana	**Treeless**	**Treed**	**Burnt**	**Unburnt**	**Mean**
(a) Average No. of plants in 1995	13	15	15	13	14
(b) Average No. of plants in 2000	13	15	15	13	14
(c) Average Net change (b-a)	0	0	0	1	0
(d) Average rate of increase (b/a)	1	1	1	1	1
(e) Average No. of plants recruited between 1995 and 2000	7	5	8	5	6
(f) Average No. of plants lost between 1995 and 2000	7	5	8	4	6
(g) Average No. of plants present in 1994 and alive in 2000	10	11	11	9	10
(h) Average percent survival of original plants (g/aX100)	79	71	72	78	75
(i) Average time for original plants to die (years) (no. yrs/(100-h))X100	n.r.d	20	21	n.r.d	n.r.d
(j) Total plants recorded (a+e)	20	20	23	17	20
(k) Average plant flux - % annual mortality of all individuals (f/jX100)	25	25	30	20	25
C. fallax	**Treeless**	**Treed**	**Burnt**	**Unburnt**	**Mean**
(a) Average No. of plants in 1995	12	19	17	15	16
(b) Average No. of plants in 2000	12	19	16	15	15
(c) Average Net change (b-a)	0	-1	-1	0	0
(d) Average rate of increase (b/a)	1	1	1	1	1
(e) Average No. of plants recruited between 1995 and 2000	2	3	2	3	2
(f) Average No. of plants lost between 1995 and 2000	2	4	3	3	3
(g) Average No. of plants present in 1995 and alive in 2000	10	16	14	12	13
(h) Average percent survival of original plants (g/aX100)	85	83	86	82	84
(i) Average time for original plants to die (years) (no. yrs/(100-h))X100	n.r.d	n.r.d	n.r.d	n.r.d	n.r.d
(j) Total plants recorded (a+e)	13	23	18	18	18
(k) Average plant flux - % annual mortality of all individuals (f/jX100)	13	17	13	17	15
H. contortus	**Treeless**	**Treed**	**Burnt**	**Unburnt**	**Mean**
(a) Average No. of plants in 1995	17	20	23	14	18
(b) Average No. of plants in 2000	39	63	33	69	51
(c) Average Net change (b-a)	21	44	10	55	32
(d) Average rate of increase (b/a)	2	4	2	5	3
(e) Average No. of plants recruited between 1995 and 2000	45	68	28	85	56
(f) Average No. of plants lost between 1995 and 2000	24	24	18	30	24
(g) Average No. of plants present in 1995 and alive in 2000	8	8	8	8	8
(h) Average percent survival of original plants (g/aX100)	51	47	38	60	49
(i) Average time for original plants to die (years) (no. yrs/(100-h))X100	12	10	9	13	11
(j) Total plants recorded (a+e)	62	87	51	99	75
(k) Average plant flux - % annual mortality of all individuals (f/jX100)	42	28	37	33	35

n.r.d = no result because no recorded deaths

B. ewartiana had a substantially high plant flux mortality under burning compared to unburnt plots (30 vs. 20), due to a higher number of plants recruiting and dying. Tree killing resulted in a higher plant flux for *H. contortus*. Mean plant flux was considerably lower for the ungrazed plots than the grazing trial. In the grazing trial, *C. fallax* had twice the mean plant flux, while *B. ewartiana* and *H. contortus* had 1.6 times the mean plant flux compared to the ungrazed plots. Individual treatment effects (treeless, treed, burnt or unburnt) resulted in a mean plant flux lower than that recorded under low grazing pressure for *B. ewartiana, C. fallax* and *H. contortus*. The ungrazed plots also had higher survival rates than the grazing trial for *B. ewartiana, C. fallax* and *H. contortus*.

Average expected lifespan for original plants to die, could only be calculated for *H. contortus* because some of the plots did not have any mortalities of the individual major perennial grasses (item i). This is probably indicative that the period of monitoring is not long enough to make assumptions about expected life spans.

6.1.2.4.4 Soil seed banks in exclosures

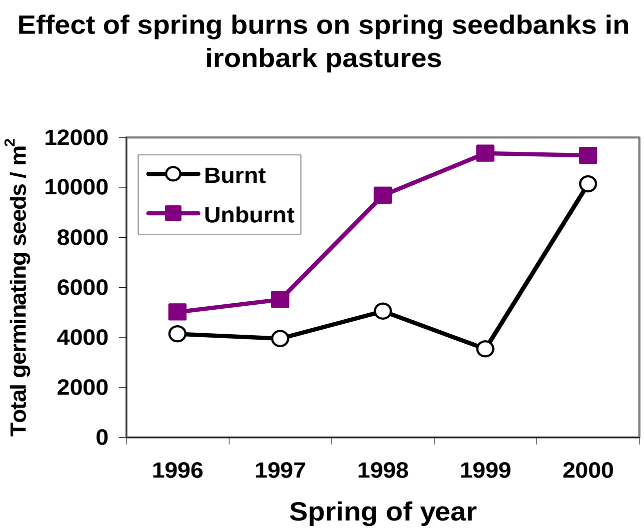


Figure 6.56 Effect of regular spring burns on total soil seedbanks over time.

Seed banks in the burnt and ungrazed exclosures reflected those in the grazing trial, except for small grasses and forbs that did not gain sufficient openings to establish or germinate.

Bluebells made up well over 20% of the emerging seedlings while blackspear grass was about 8.5% on average under both conditions. Germination was quite sporadic for many minor species, so statistically meaningful differences for individual species are rare. A few examples are given to illustrate examples of clear effects of treatment.

Burning seemed to reduce seed loads if conducted regularly but that effect was lost if not burn had occurred recently. There was no burn in the spring of 1996 or 2000 (Figure 6.56). The overall result strongly reflects the bluebell results because they were such a large proportion of the total numbers emerging (Figure 6.57).

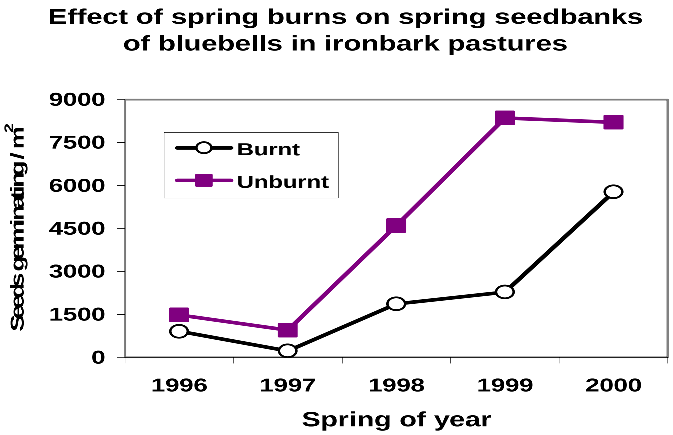


Figure 6.57 Effect over time of regular spring burns on soil seed loads of *Wahlenbergia* spp.

More details of individual species and treatments are given in Appendix I.

6.1.2.5 *Discussion*

The burning did not effect composition of any pasture component. Orr *et al.* (2004) reported that spring burning in combination with reduced grazing pressure had no effect on the density of *H. contortus* or *Aristida* spp. when they experienced extreme drought conditions. The taxonomic groupings within the *Aristida* spp. also favoured this response by not allowing individual species responses to be detected.

In contrast to other studies (Walker *et al.* 1972; Scanlan & Burrows 1990), there was a minimal increase in pasture production from tree clearing. The grazier consultative group attached to the Ironbark site strongly recommended that tree clearing was not worthwhile in this land type because of, firstly the regrowth problem, secondly buffel grass could not be established and the improvements in stocking rates were not significant. While this is not fully understood, work by (Ken Day pers. comm.) indicates that the projected foliage area of the dominant *E. melanophloia* is considerably lower than *E. populnea* for communities with the same tree basal area. This has effects that were discussed before in Section 6.1.1.5.

6.1.3 Comparison between studies

Ground cover, total pasture yield and component yields all increased in the ungrazed plots compared with the grazing trial. The frequency of *T. triandra* was consistently lower in the grazing trial compared with the ungrazed plots. The minor pasture components had similar frequencies but *Enneapogon* spp. were often significantly affected by tree competition in the absence of grazing but not in grazed pastures. These short-lived perennials seemed sensitive to both grazing pressure (Figure 6.8) and spring fires (Figure 6.43) while the response of other minor pasture species to grazing management was not clear, eg. native legumes.

Total perennial grass basal area was higher in the ungrazed plots in the last two years of the trial. *B. ewartiana* and *C. fallax* density were similar in both trials, however *H. contortus* density varied dependant on the number of seedlings present. In the grazing trial, total crown area and crown area per plant was consistently smaller than that of grass plants in the ungrazed, burning trial (Figure 6.58).

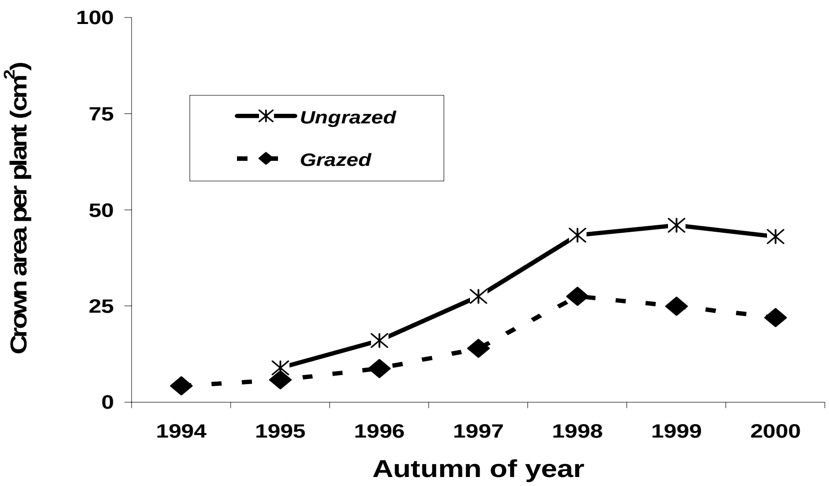


Figure 6.58 Mean crown area of individual grass plants over time at the grazed and ungrazed plots.

Mean plant flux was considerably lower for the ungrazed plots than the grazing trial. Individual treatment effects (treeless, treed, burnt or unburnt) resulted in a mean plant flux lower than those recorded under low grazing pressure for *B. ewartiana*, *C. fallax* and *H. contortus*. The ungrazed plots also had higher survival rates than the grazing trial.

6.1.4 Primary production measurements (Swiftsynd)

6.1.4.1 *Abstract*

For two consecutive years there was no suppression of pasture growth by silver-leaved ironbark trees with about 6 m^2 ha^{-1} of stems. Pasture dry matter yield in relatively dry years (decile 2-3) averaged about 1800 kg/ha. Perennial C_4 grasses dominated the yields but golden-beard grass was unusual by having low above-ground biomass (200 kg/ha) and very little stem.

6.1.4.2 *Background*

A measure of pasture growth is required in the absence of grazing to describe total biomass productivity. The association of the project with colleagues with interest in the GRASP model lead to the adoption of the Swiftsynd technique as the means to measure pasture growth. Data collected in this format can be used in calibrating the GRASP model for this location and thus extrapolation to other climatic scenarios.

6.1.4.3 *Methods*

Enclosed sites were established in 1994 in treed and treeless areas and the Swiftsynd methodology used (Day and Philp 1997). Basically pastures are cut or burnt to ground level before the start of the growing season, soil moisture content determined for various layers in the underlying profile, and then plant growth weighed at various times thereafter. Soil profile moisture is sampled at each subsequent pasture growth sampling date.

Closer examination the treeless site after summer 1995 showed some minor signs of scalding and it was abandoned after the 1994/95 season. A new exclosed site was set up nearby for these measurements.

Changes in phenology (leaf, stem and seedhead development rates) and growth rates of key species were also measured by this technique.

6.1.4.4 *Results*

Despite differences in the amount and distribution of rainfall in the first 2 seasons, similar total pasture growth yields were recorded (Table 6.5). The absence of any increase pasture yield due to tree removal is very surprising. In 1994/95, the treeless site had a pasture basal area of 2.6%, whilst the treed site had a basal area of 3.1%. In the 1995/96 season after establishing a new pair of sites, there was again no observed difference in the pasture yield estimates. Basal area comparisons were 3.2% in the treeless site and 2.5% in the treed site.

Table 6.5 Total pasture growth (kg DM/ha/year) in Swiftsynd exclosures.

Year	Treeless	Treed
1994/95	1680	2000
1995/96	1890	1850

Table 6.6 Species yields (kg DM/ha) and plant proportions (%) at maximum yields, in Swiftsynd exclosures at the silver-leaved ironbark site.

	1994/95		1995/96	
Pasture yield	**Treeless**	**Treed**	**Treeless**	**Treed**
B. ewartiana	652	565	789	433
H. contortus	449	779	501	799
C. fallax	73	354	207	205
Other grasses	359	252	340	346
Forbs	147	52	52	68
Plant parts (%)				
B. ewartiana				
Green leaf	25	15	26	11
Dead leaf	36	35	32	10
Green stem	32	31	27	19
Dead stem	6	19	3	1
Seed head	1	0	3	2
H. contortus				
Green leaf	50	53	20	25
Dead leaf	15	26	59	29
Green stem	32	16	11	13
Dead stem	1	trace	4	0
Seed head	3	5	12	11
C. fallax				
Green leaf		43	48	38
Dead leaf		48	53	20
Green stem		2	5	5
Dead stem		4	0	7
Seed head		3	0	3

Table 6.6 compares these attributes at the date of maximum yields in each of the two years. *Bothriochloa ewartiana* and *Heteropogon contortus* were the major components of total growth, whilst *Chrysopogon fallax* recorded lower growth rates. This contrast was also observed in the pasture yields in paddock surveys (Section 6.1.1). Contrasts in phenology portray *B. ewartiana* with a greater stem proportion than *H. contortus*, which tends to be a much leafier plant. Different to both is *C. fallax*, which has little stem at all and is a leafy, base-growing plant in this environment. In the monsoon areas of north Australia, *C. fallax* has a lot more stem and is frequently avoided by stock, but in this environment cattle actively seek *C. fallax.* Further details on growth and phenology at all harvest dates are presented in Appendix H.

Soil moisture is an important determinant of pasture growth. As modelling inputs, the relationships between rainfall, soil moisture and pasture growth derived from these Swiftsynd sites are a critical requirement for any extrapolation or simulation exercises proposed from this project. At this site, soil moisture levels are typified by fluctuations in the surface layer (0-10cm) and generally stable lower levels (Figure 6.59). Given that the majority of pasture plant roots are in the 0-10cm layer, management practices need to minimise the amount of moisture that is lost from this layer.

6.1.4.5 ***Discussion***

A contrast that appears to be associated with treatment differences is the higher soil moisture levels at depth in the treeless areas (Figure 6.59). Confirmation of this observation requires some further soil moisture sampling across a larger area of treeless and wooded areas. A similar contrast in profile moisture holding capacity was also found between the two main runoff study sites. So such spatial variability around this visually even site may complicate modelling exercises in future (see Section 12). Soil moisture data for each 10cm layer at each harvest is presented in Appendix H3.

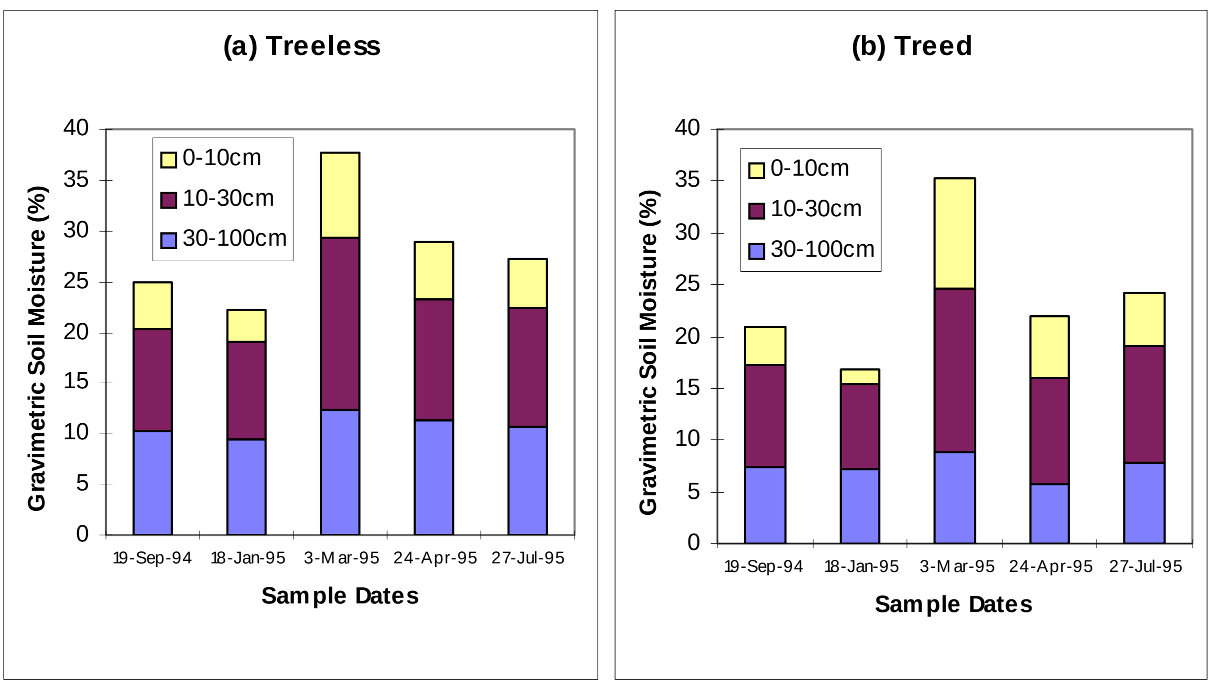


Figure 6.59 Gravimetric soil moisture (%) in (a) Treeless and (b) Treed Swiftysnd exclosures during the 1994/95 growing season.

6.2 Poplar box

6.2.1 Grazing trial

6.2.1.1 *Abstract*

Interactions between 3 grazing pressures (adjusted annually as low, medium or high consumption rates) and 2 tree competition rates (treeless and treed) were measured in poplar box woodland near Injune in southern inland Queensland between 1994 and 2002. This chapter reports on the effects on the pastures. There is a rich flora, with 173 herbaceous species recorded at the start of the grazing period and the number of both the grass and forb taxa was increased by the low grazing pressure during the trial, although tree competition had no effect on the numbers of either grasses or forb species.

Ground cover was inversely related to grazing pressure, with the highest cover at the low grazing pressure. There was also a consistent reduction in ground cover, mean of 28%, caused by tree competition every year. The site mean cover increased in response to high summer rainfall years.

Total pasture dry matter yield responded to both reducing grazing pressure and to absence of tree competition. The low grazing pressure had the highest yields, while the high grazing pressure had the lowest yields every year. Similarly there was an advantage of between 1000 kg/ha and 2000 kg/ha in pasture yield from a lack of tree competition for the 8 years of the trial. There was a consistent advantage of 1000 kg/ha of treeless over treed paddocks for the last 4 years.

Species composition was affected by both grazing pressure and tree competition. After 8 years, the desirable 3P grass, *Dichanthium sericeum*, was ranked 3rd in species contribution to total pasture yield at low grazing pressure, but was 11th at high grazing pressure. The most frequent bluegrass, *Bothriochloa decipiens*, increased in yield at low grazing pressure, but was not affected by tree competition. After grouping the grasses into the desirable decreasers, as a functional group for composition analysis, their yield was consistently highest in the low grazing pressure and treeless paddocks. The native palatable legumes and sedges had higher autumn yields in the treed paddocks. *D. sericeum* yield increased with no tree competition, while *Aristida calycina* and *Chrysopogon fallax* had higher yields in treed paddocks.

The frequency of *D. sericeum* was increased by lower grazing pressure and a lack of tree competition, while frequency of *Tripogon loliiformis*, a short-lived grass indicative of deteriorating perennial grass competition, was increased at high grazing pressure. *Brunoniella australis* and *Verbena tenuisecta* were the most common forb species that were well grazed. *Calotis lappulacea* was the most common forb at high grazing pressure.

6.2.1.2 *Background*

6.2.1.2.1 Poplar box site

Managing the woody vegetation in eucalypt woodlands, especially in poplar box country, has been a constant land management issue for livestock producers. In southern inland Queensland, the dominant *Eucalyptus* trees, poplar box, are known to reduce grass production, but the extent of any competition and effects on livestock production had not been measured. An awareness of tree competition with the pasture in these woodlands by producers is demonstrated by the historical management of the woody vegetation. Most poplar box country has been treated by ring-barking and/or herbicide stem injection, usually with Tordon®, over the last 85 years. Some eucalypt woodlands have been treated twice or three times during this period. In the poplar box Grazing Trial at Injune, all trees and shrubs were killed ('Treeless treatment') by Tordon stem injection. Tree killing and differing grazing pressures were the main experimental treatments imposed on the pastures.

The initial detailed botanical survey of the poplar box grazing experiment site was conducted in January 1995 using the BOTANAL dry weight rank technique (Tothill *et al.* 1992). All observed species were identified, with 173 grass and forb species being recorded then (See Appendix E). This initial recording followed several years of drought (since 1992-93) and exclusion from regular grazing between July 1994 and November 1994, when the first draft on steers were introduced. Only 16mm of rain fell between April and September 1994 and the first decent rain came on 22 October, 5 weeks before the animals first went into the treatment paddocks. Thus the paddocks had been grazed for two months over summer before the first comprehensive botanical survey.

The dynamics of the pasture and tree vegetation over the next 8 years of imposed grazing treatments were recorded. All pasture and tree data has been analysed to identify the main tree effect (Trees killed/Treeless vs Treed), the grazing pressure effects, and the tree interaction with grazing pressure.

6.2.1.3 *Methods*

The poplar box grazing trial design was 2 tree competition rates * 3 grazing pressures (consumption rates) * 2 replications. The paddock areas for the 6 treatments are shown in Table 6.7. There was also a single paddock of 30 ha (Commercial paddock) which was developed and managed as a larger version of the medium grazing pressure - treeless treatment.

Table 6.7 Areas (ha) of treatment paddocks in poplar box grazing trial.

Grazing Pressure (Consumption rate)	Trees Present (Treed)	Trees + Tordon (Treeless)
Low (L)	18	12
Medium (M)	9	6
Heavy (H)	6	4
Commercial (COMM)	-	30

Tordon stem injection was used to kill all trees with the exception of shade trees in the 'cleared' treeless treatments after the paddocks were fenced in June and July 1994. Initially all mature and seedling trees were left in the 6 treed treatments. In 1996, some trees were thinned using Tordon stem injection in one paddock (no. 6 – high grazing pressure) to reduce the tree basal area to a similar level to the other treed paddocks.

The poplar box grazing trial field layout is shown in Figure 6.60. Watercourses, sampling transects for pastures and trees, and species growth modelling sites were shown in Figure 3.2.

6.2.1.3.1 Sampling techniques

Pastures were sampled on various scales from whole paddock, using Botanal for botanical composition, pasture dry matter yield, cover % and greenness %, to fixed transect lines for pasture basal area, to fixed quadrats for charting individual species dynamics. There were also 6 Swiftsynd sites (see Day and Philp 1997 for explanation) where annual growth and associated water use of the main perennial grass species were measured.

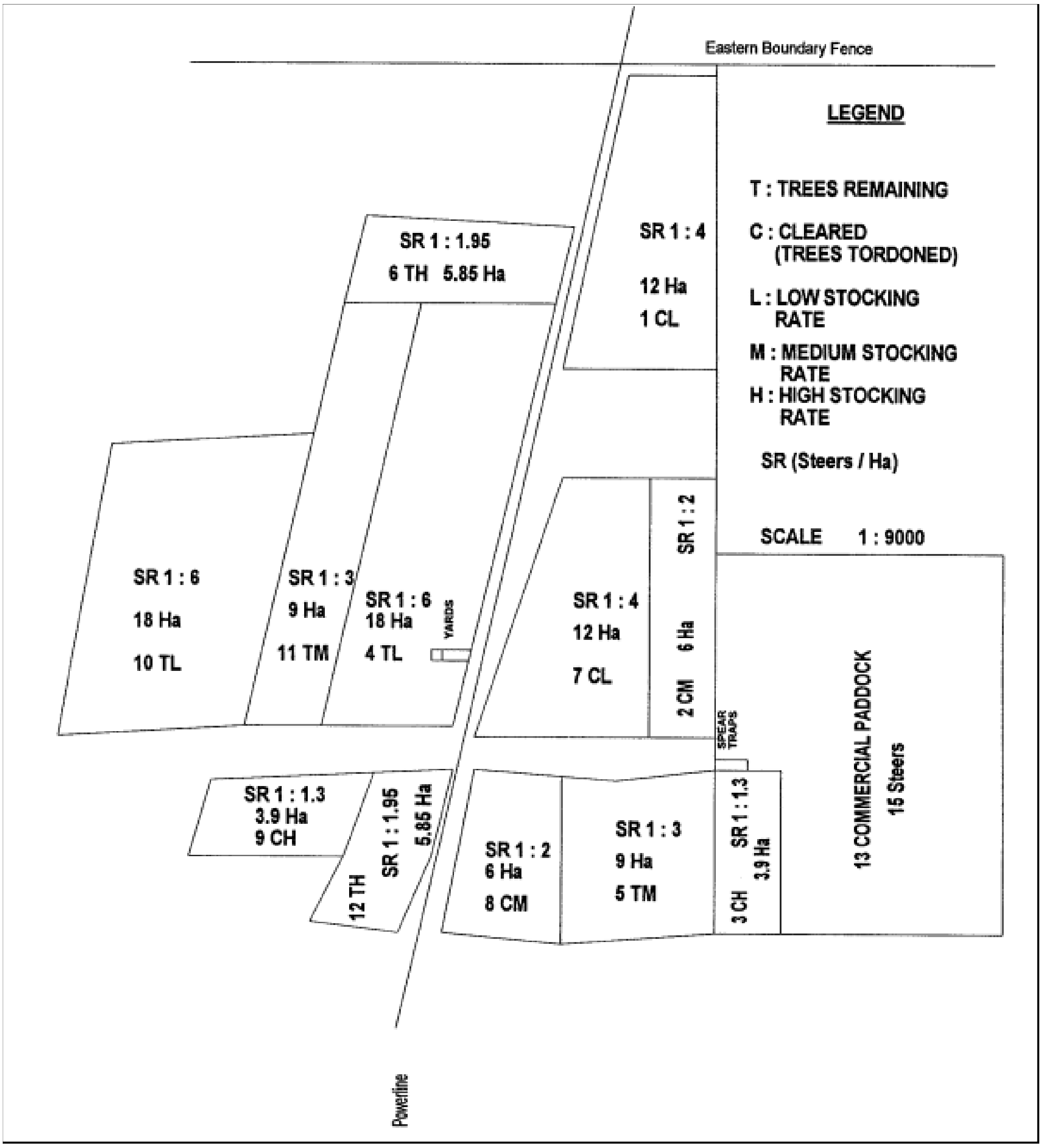


Figure 6.60 Field plan layout of the 13 treatment paddocks in the poplar box grazing trial.

6.2.1.3.2 Pasture yield, species composition, cover, basal area and greenness

At the poplar box site, all herbaceous species were recorded in the first year (173 species, Appendix E). Only a few more were added during later years of the trial. Species were subsequently assigned to 75 individual species or species groups for data analysis (Appendix E6). This set of 75 taxa was used in all annual recordings for the following 7 years. Data was analysed for the years 1995 to 2002 using the 75 sets, as well as combining these species into 7 functional groups for a broader analysis of treatment effects.

The **Botanal** technique was used as the species recording method to describe species frequency, yield and composition within each paddock. Pasture cover estimates were also included in each survey and percentage green pasture in most years. All operators had an ability to visually rank pasture yield, an ability to identify the base set of pasture species recorded at each site and an ability to visually rank pasture cover. The paddocks were sampled each year on a grid pattern. Other sampling details -

- quadrat size 0.5 metre by 0.5 metre (size $0.25m^2$)
- yield ranking 00 to 70 – (the Botanal input program ignores the decimal place)
- number of species ranked for yield top 5
- total number of species recorded 6
- species frequency all species present in quadrat (usually to a maximum of 6)
- cover estimated as a percentage and converted into classes for analysis with codes 1=0-5%, 2=5-15%, 3=15-35%, 4=35-50%, 5=50-90%, 6=90-100%

During each sampling, 15 ranked quadrats were cut, dried and weighed to develop the regression equations to convert the Botanal yield ratings to species and pasture dry matter yields in kg/ha. A Forall header program was developed within the BOTANAL package to analyse the pasture data into: paddock, treatment, treed/treeless, and low/medium/high grazing pressure (consumption) means. A separate header program was developed to analyse the burning trial data into plot, burnt/unburnt and treed/treeless treatments. The analysis calculates: -

- species frequency as % of quadrats ($0.25\ m^2$) recorded,
- species composition as a percentage contribution to yield,
- species dry matter yield,
- paddock dry matter yield (kg/ha),
- cover (%), and
- pasture greenness (%).

6.2.1.3.3 Frequency of sampling

Annual sampling was in April or May at the end of the growing season when species still had seed heads for easier identification. Both the grazing trial and burning trial used the same technique, but with differing sample sizes. There were up to 300 quadrats recorded in paddocks of the grazing trial and 50 quadrats were recorded in each plot of the burning trial.

6.2.1.3.4 Grass root biomass

Towards the end of the trial (Dec 2000), some core samples were taken to 60cm depth to estimate the amount of root that existed to support the main pasture grasses in their growth and resistance to heavy defoliation. Sampling intensity was not high but it was felt to be adequate to give a reasonable picture of what a more detailed sampling would reveal. Cores were taken through the crowns of typical plants and midway between crowns at the northern end of each tree and basal area sampling transect. Hence the root mass is only a relative comparison amongst species growing in close proximity to each other in the main treatments.

6.2.1.4 *Results*

6.2.1.4.1 Pasture species groups

From the 75 herbaceous taxa recorded each year, there were a total of 40 grasses, 29 herbs (broad leaves, non-grass) and 6 ferns, sedges or rushes. The 75 ‘species groups’ were grouped into 7 functional groups for some analyses and to provide a more broad interpretation of treatment effects. The functional group definitions are shown in Table 6.8.

Table 6.8 Pasture species functional group definitions.

Group No.	Functional group name	Characteristics
1	Decreaser grass	Desirable perennial species (3P grasses)
2	Intermediate grass	Useful grasses, not particular indicators
3	Increaser grass	Undesirable perennial species
4	Annual/short-lived grasses	Invaders of open spaces
5	Legumes	Palatable species only included
6	Forbs	Palatable and unpalatable, broadleaves
7	Sedges, Ferns, Lilies, Rushes	Not in grasses or broadleaf groups

6.2.1.4.2 Pasture diversity

Each year, the number of grasses and forbs (all non-grasses) occurring in the Botanal quadrats in each paddock were counted as a measure of pasture species diversity. The number of grass species per paddock in the grazing trial between 1995 and 2002 ranged between 16 and 32 of those taxa, forb numbers between 9 and 25, while total species present ranged from 25 to 55. The mean numbers for both grasses and forbs was very similar in the treeless and treed paddocks for the 8 years of recording (Figure 6.61).

Figure 6.61 Effect of tree cover on the mean numbers of grass and forb species recorded in Botanal quadrats in the poplar box grazing trial (1995–2002).

Poplar box communities have a rich herbaceous and tree species diversity when well managed

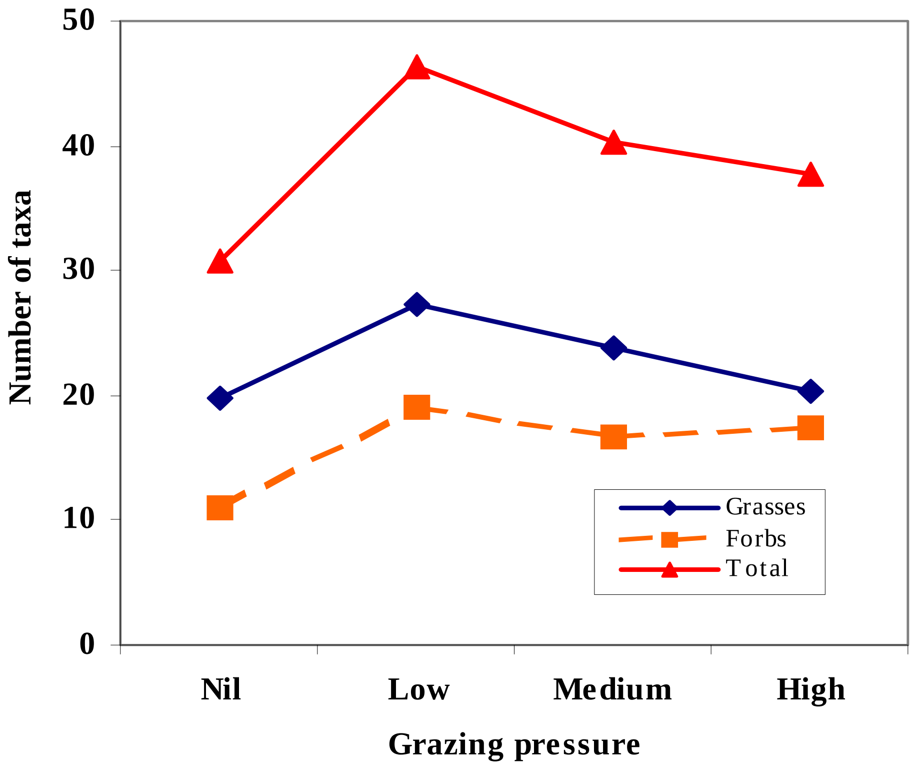


Figure 6.62 Mean autumn numbers of grasses and forbs at 4 grazing pressures in poplar box pastures (mean 1995-2002).

When taxa numbers were compared across grazing pressures, the ungrazed pastures had the lowest forb diversity, while the low grazing pressure ones had the most grasses and forbs (Figure 6.62). There was a steady decline in numbers of grasses as the grazing pressure increased with less of an effect of grazing pressure on forb numbers.

Grass and forb species diversity is increased at low grazing pressures

The main differences between the poplar box pastures and those from silverleaf ironbark country are discussed in more detail later, e.g. differing importance of wiregrasses and black speargrass.

6.2.1.4.3 Ground cover

Ground cover % was estimated visually in each 0.25 m2 quadrat recorded at Botanal sampling in autumn at the end of each growing season across all treatments and in the runoff plots. After the first year, there was a higher cover in the treeless treatments than in the treed treatments every year, and this increased cover has been significant in most years (Figure 6.63). The ground cover showed similar trends to that of pasture yields. There was reduced cover at the high grazing pressure every year after 1996 and a similar cover between the low and medium rates, except in 1998 when cover was 7.5 % less at the medium rate than at the low rate. The decline in cover in the last 2 years follows the declining rainfall during this period. The mean ground cover over the trial period in the treed paddocks was 72% of that in the treeless paddocks.

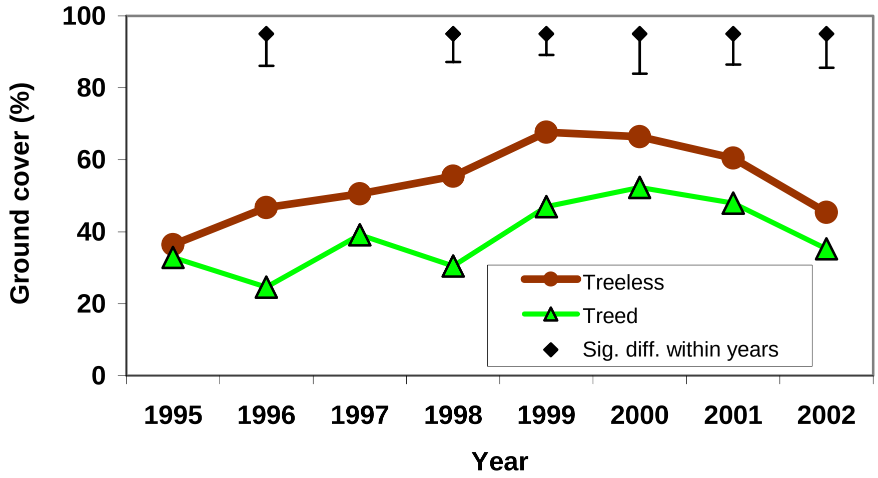


Figure 6.63 Ground cover in treeless and treed poplar box paddocks from 1995 to 2002. Bars at the top show significant difference at P=0.05.

The mean site difference due to tree cover, averaged across all grazing pressures for all years, was about 20% actual and a 40% increase over treed plots (Figure 6.64).

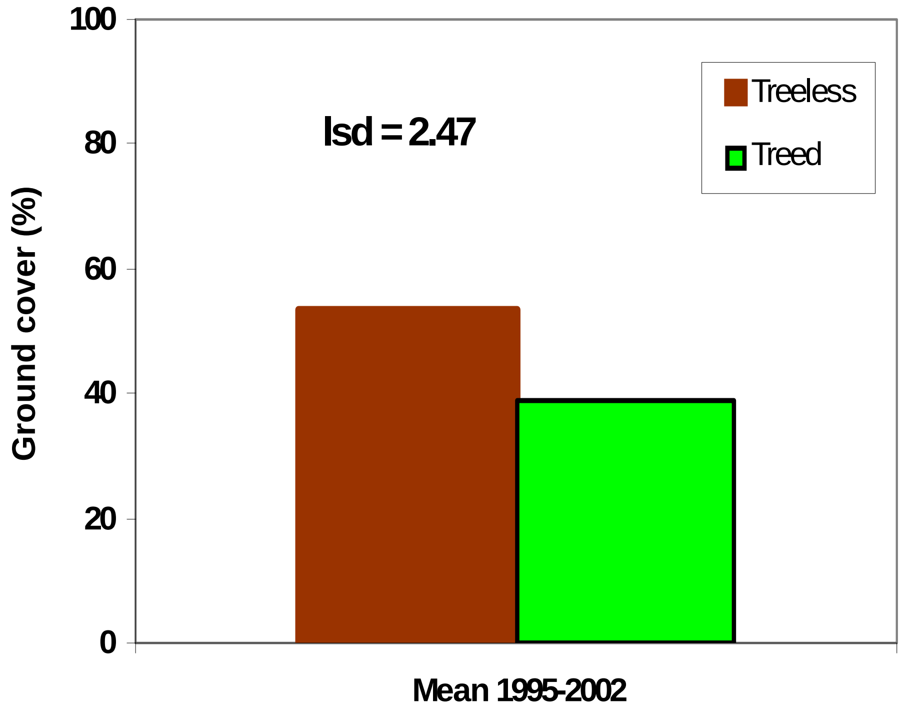


Figure 6.64 Ground cover (%) in treeless and treed plots (mean of all years from 1995 to 2002).

Between years in the grazing trial, there were significant changes in mean pasture cover across the site (Figure 6.65). There was a steady increase following the drought of 1992-94 and then a decline going into the drought of 2002-03. Tree retention always reduced the percentage of ground cover in autumn (Table 6.9). The mean pasture ground cover was higher in the 3 treeless treatments than in any treed treatments and there was a trend of decreasing cover as grazing pressure increased (Table 6.9).

Tree competition reduces ground cover

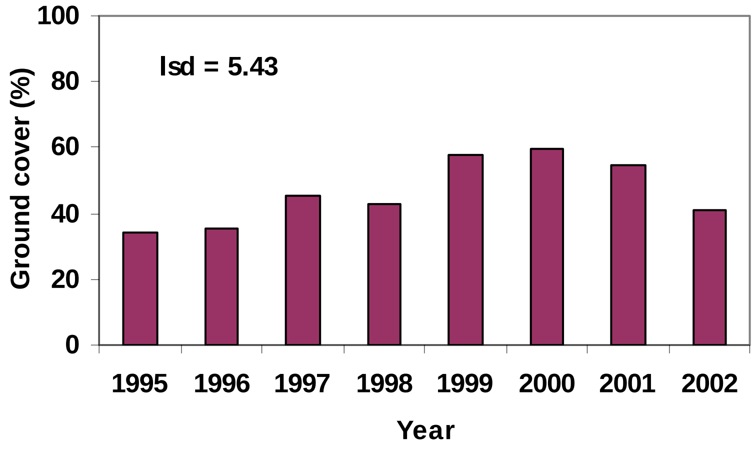


Figure 6.65 Mean pasture ground cover at the end of summer in the grazing trial in poplar box woodland.

Table 6.9 Ground cover in the six main treatments of the poplar box grazing trial each autumn, plus that of the large COMM paddock that was equivalent to Treeless Moderate grazing pressure.

	Cover %								
Treat.	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**Mean**
C L	45	54	54	63	74	73	69	54	60.8
C M	30	47	64	57	70	66	59	47	55.0
C H	34	39	34	45	59	60	54	36	45.1
T L	41	30	45	37	51	55	48	39	43.3
T M	22	25	41	28	49	50	47	33	36.9
T H	35	19	32	27	41	52	48	34	36.0
COMM	34	36	45	43	58	60	54	41	46.3

C = Chemically cleared, treeless,   T = Treed,   L = Low grazing pressure, etc.

There were consistent trends in ground cover between the 3 grazing pressures, with low grazing pressure maintaining the highest cover and the high grazing pressure a consistently lower cover after the first year (Figure 6.66). There were no significant differences between low and medium grazing pressure, although the low grazing pressure maintained a marginally higher cover every year except 1997. The mean ground cover from 1995 to 2002 (Figure 6.67) shows the trend of decreasing cover as grazing pressure increases. The large, cleared COMM paddock with about 15 head in it usually had cover in the mid to high grazing treatment's range and higher than any treed paddock each year (Figure 6.68).

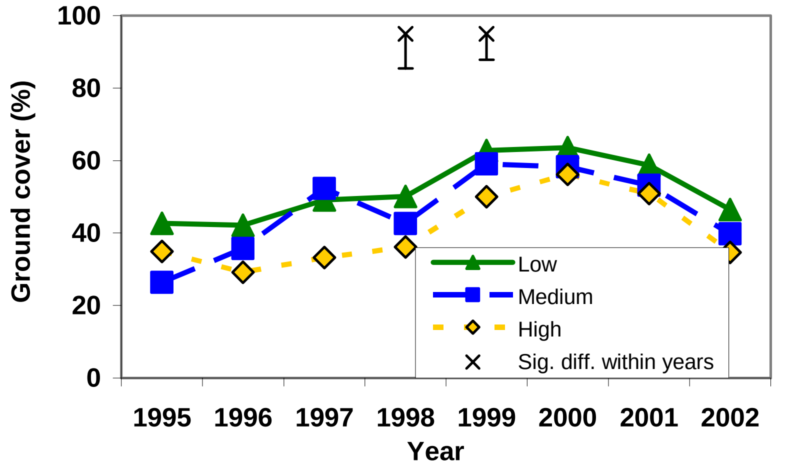


Figure 6.66 Yearly autumn mean ground cover percentage in the three grazing pressure treatments in a poplar box woodland.

Increasing grazing pressure reduces ground cover

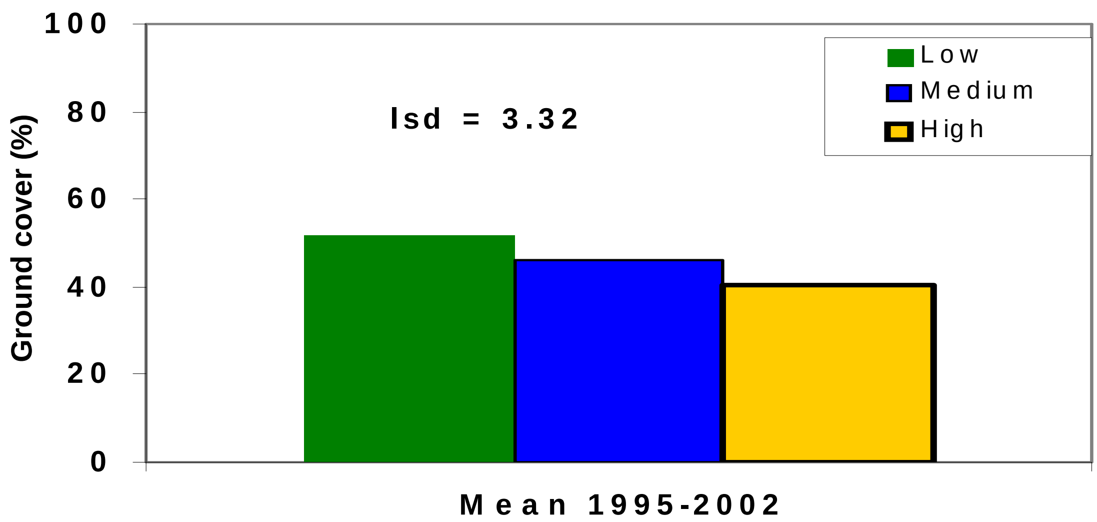


Figure 6.67 Mean (1995-2002) ground cover percentage in the three grazing pressure treatments in poplar box woodland.

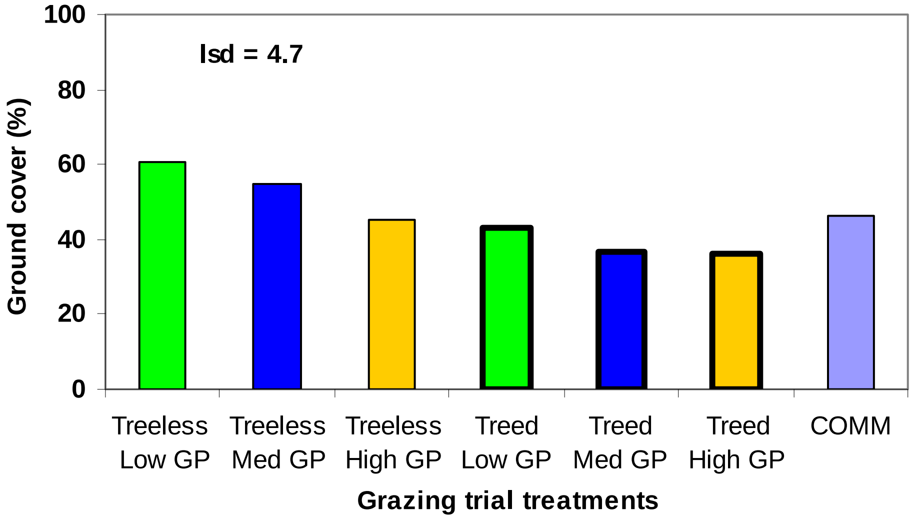


Figure 6.68 Ground cover percentage in six grazing management treatments (mean of years 1995 to 2002), plus that of the large COMM paddock.

There was a consistent contribution to ground cover by fallen tree leaves in the treed poplar box paddocks. In autumn 2002, separate estimates were made of the total ground cover and of the contribution made by standing pasture only (Figure 6.69). A mean 37% of the total ground cover was not from the standing pasture. In the treeless paddocks, grass litter provided most of the extra cover, of 38%, towards total ground cover, while it was tree leaf fall that made up almost all the extra cover in the treed paddocks. There were consistently lower levels of both pasture cover and total ground cover as grazing pressure increased in poplar box woodland (Figure 6.70).

Figure 6.69 Pasture only and total ground cover percentage in autumn in treeless and treed paddocks in poplar box woodland (mean of years 2001 and 2002).

There were consistently lower trends in both pasture cover and total ground cover percent as grazing pressure increased in poplar box woodland (Figure 6.70).

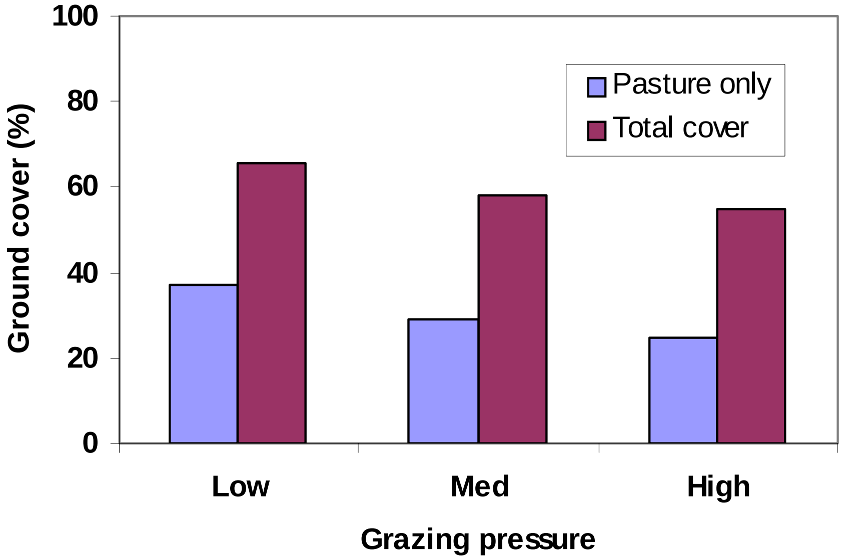


Figure 6.70 Pasture only and total ground cover percentage in autumn at three grazing pressures in poplar box (mean of years 2001 and 2002).

6.2.1.4.4 Total pasture yield

There were no differences in initial pasture yield in mid-summer of the first year (January 1995) following the first summer rain in November 1994 after a 2-year drought. However, in subsequent years, there was a consistently higher yield from the treeless treatments (Figure 6.71). Good rainfall fell during first 3 summers even though the seasons finished early and there was little winter rain. There were consistent trends in treatment yields. The treeless treatment produced higher yields than the treed treatment, and there was a declining trend in yield from the low to the medium to the high grazing pressure (Figure 6.72). Highest pasture yields were always in the treeless low grazing pressure treatment and the lowest yields were in the treed, high grazing pressure treatment. The large, treeless COMM paddock tended to have yields nearer to the low mean than the high (Figure 6.72).

The mean pasture yield difference across the 3 grazing pressures due to trees increased for the first 4 years to an advantage of 2000 kg/ha. It then stabilised over the last 4 years, with a constant advantage of around 1000 kg/ha due to the elimination of trees. Killing the trees resulted in about a doubling in pasture yield throughout the trial.

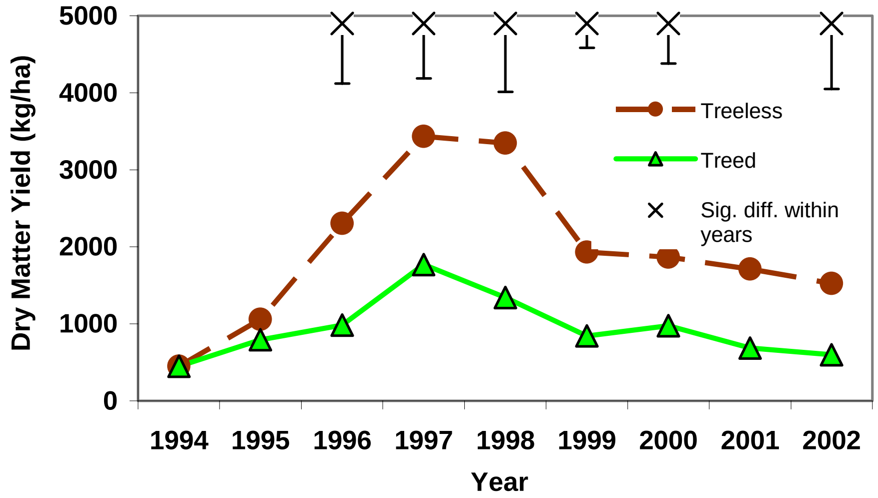


Figure 6.71 Tree effects on autumn pasture dry matter yield (kg/ha) during the grazing trial in poplar box country. Bars indicate lsd (P <0.05) for each year.

Killing poplar box trees can double pasture production and effects last at least 8 years

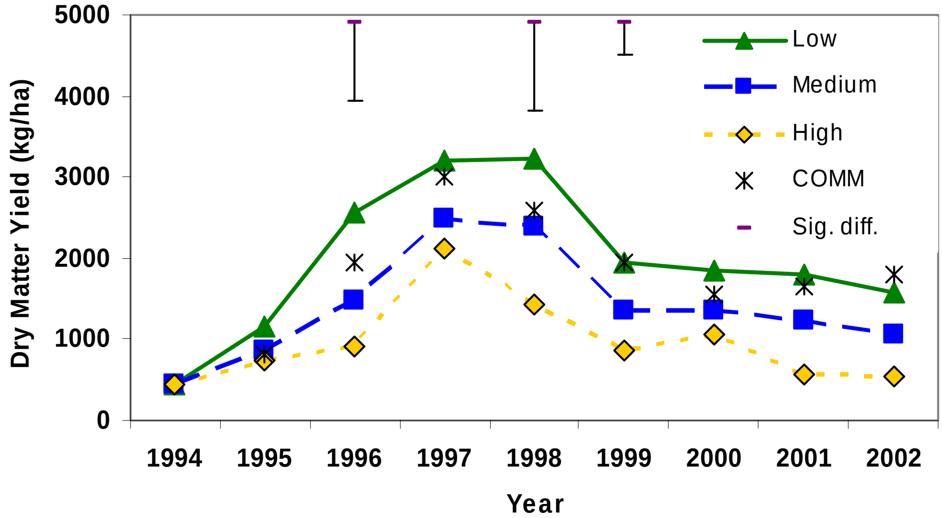


Figure 6.72 Grazing pressure effect on autumn pasture dry matter yield (kg/ha) during the grazing trial at the poplar box site, including the COMM paddock. Bars indicate lsd (P <0.05) for each year.

There was a rapid, annual increase in site mean pasture yield for the first 3 years (1995 to 1997) after establishing the grazing trial (Figure 6.73) and an equally rapid decline for 2 years before stabilising in 1999.

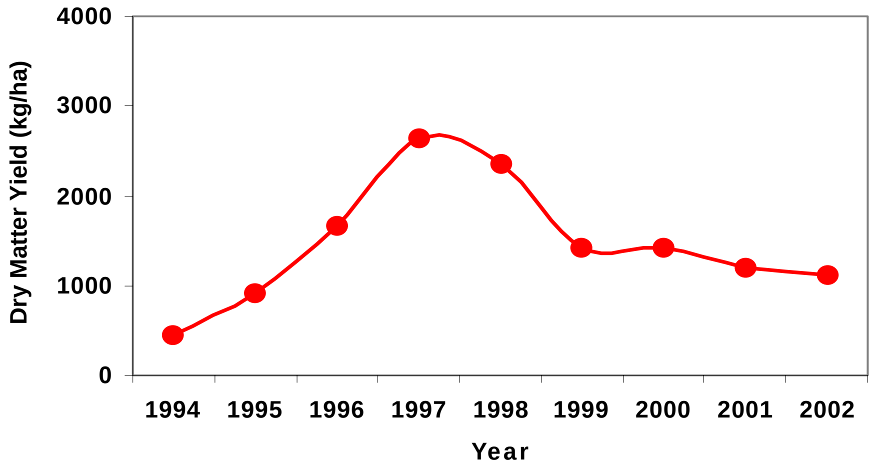


Figure 6.73 Mean autumn pasture dry matter yield (kg/ha) for each year at the grazing trial in poplar box country.

6.2.1.4.5 Species proportions

There were differences between the three grazing pressures in the ranking for species dominance. Higher yields and a greater percentage contribution to total pasture yield came from more desirable 3P grasses, such as *D. sericeum* and *Bothriochloa bladhii*, at the low grazing pressure (Table 6.10). As grazing pressure increased, less desirable perennial grasses such as *Tripogon loliiformis* (five minute grass) and *Eragrostis molybdea* (granite lovegrass), made a greater contribution to yield. The invasive, short-lived perennial grass, *Chloris divaricata* (slender chloris), increased its contribution to total yield as the grazing pressure increased. However, it made a valuable contribution to pasture stability, by colonising some heavily grazed areas, and helped maintain cattle performance in these more heavily grazed paddocks. *T. loliiformis* played a similar role to slender chloris and increased in areas that were continuously heavily grazed, and was also more abundant in the cleared paddocks.

Autumn yields of the bluegrasses, *Chloris, Enteropogon* and *Enneapogon* species in the treeless treatments were regularly more then double that of these species growing in the treed paddocks (Table 6.12). The notable exception is in *Chrysopogon fallax* yield, which was not affected by the tree killing treatment. Though autumn standing yields give a good estimate of pasture growth during the growing season, they are the net result of the consumption rate of the growing pasture. Hence the dominant yielding species are probably not the most palatable summer species even if well grazed over a full year, e.g. *E. ramous* and *D. sericeum* are not heavily grazed in mid-summer.

Grazing pressure affects species dry matter yield contribution

Table 6.10 Mean species dry matter yield ranking at low, medium and high grazing pressure over the trial period (1995–2002).

Low grazing pressure	Medium grazing pressure	High grazing pressure
Enteropogon ramosus	*Aristida ramosa*	*Enteropogon ramosus*
Aristida ramosa	*Bothriochloa decipiens*	*Bothriochloa decipiens*
Dichanthium sericeum	*Dichanthium sericeum*	*Enneapogon* spp.
Bothriochloa decipiens	*Enneapogon* spp.	*Chloris divaricata*
Enneapogon spp.	*Chloris divaricata*	*Aristida ramosa*
Chloris divaricata	*Enteropogon ramosus*	*Sclerolaena birchii*
Aristida spp.	*Aristida* spp.	*Dichanthium sericeum*
Bothriochloa bladhii	*Chrysopogon fallax*	*Tripogon loliiformis*
Aristida leptopoda	*Aristida calycina*	*Aristida* spp.
Chrysopogon fallax	*Bothriochloa bladhii*	*Calotis* spp.
Aristida latifolia	*Tripogon loliiformis*	*Eragrostis molybdea*
Aristida calycina	*Eragrostis molybdea*	Forb - small
Eragrostis spp.	*Aristida latifolia*	*Sida subspicatum*
Eragrostis molybdea	Forb - small	*Chrysopogon fallax*
Forb - small	*Eragrostis* spp.	*Aristida calycina*
Cenchrus ciliaris	*Calotis* spp.	*Eragrostis* spp.
Malvastrum americanum	*Sclerolaena birchii*	*Tragus australianus*
Tripogon loliiformis	*Verbena tenuisecta*	*Malvastrum americanum*
Sporobolus (small)	*Brunoniella australis*	*Aristida leptopoda*

Yield of most grasses was reduced by high grazing pressure, with the exception of *Tripogon* and *Enteropogon*, even though the latter normally unpalatable grass had the tops hedge-grazed to less than 50 % of its ungrazed height. The very unpalatable, weed-type forbs, such as *Sida* spp. have their highest yields in the high utilisation treatment.

For the first three years, the gap in the autumn pasture yield between the three grazing treatments increased steadily. Cattle were forced to graze the less palatable species at the high utilisation rates. Three of the first four summers received around average rainfall, and there were good pasture growth periods during every year. These wet periods would have moderated the effects of the tree and grazing pressure treatments on species survival. By the end of the trial in mid-2002, the dominant pasture plants had not changed but grazing pressure influenced the amount of the more palatable species that were still present in autumn 2002 (Table 6.11). Very little Qld bluegrass or blue trumpet (*B. australis*) was left under high grazing pressure while *C. fallax* ranking was unaffected.

Table 6.11 Main species dry matter yield ranking at low, medium and high grazing pressure in the final year 2002, after 8 years of grazing treatments.

Low grazing pressure	Medium grazing pressure	High grazing pressure
Aristida ramosa	*Aristida ramosa*	*Enteropogon ramosus*
Enteropogon ramosus	*Bothriochloa decipiens*	*Bothriochloa decipiens*
Dichanthium sericeum	*Dichanthium sericeum*	*Aristida ramosa*
Bothriochloa decipiens	*Enneapogon* spp.	*Enneapogon* spp.
Enneapogon spp.	*Enteropogon ramosus*	*Chloris divaricata*
Bothriochloa bladhii	*Chrysopogon fallax*	*Aristida calycina*
Aristida leptopoda	*Chloris divaricata*	*Tripogon loliiformis*
Chloris divaricata	*Aristida calycina*	*Sida subspicatum*
Aristida calycina	*Eragrostis molybdea*	*Sclerolaena birchii*
Aristida latifolia	*Cyperus* spp.	*Chrysopogon fallax*
Chrysopogon fallax	*Malvastrum americanum*	*Dichanthium sericeum*
Malvastrum americanum	*Tripogon loliiformis*	*Sporobolus* - small
Cyperus spp.	Forb - small	*Malvastrum americanum*
Eragrostis molybdea	*Aristida* spp.	*Eragrostis molybdea*
Brunoniella australis	*Brunoniella australis*	*Sida* spp.
Cenchrus ciliaris	*Sida subspicatum*	*Fimbristylis dichotoma*
Aristida spp.	Legume - palatable	*Cyperus* spp.

The effect of tree competition on the mean yield of individual species over the grazing period 1995 to 2002 shows both desirable species such as *D. sericeum* and some undesirable species such as *Aristida ramosa* were both higher in treeless treatments (Table 6.12). Treed paddocks only had 14% of the yield of *D. sericeum* compared with the mean of the treeless paddocks. There was no tree effect on the yield of *B. decipiens*, the unidentified *Aristida* group or *Chrysopogon fallax*. *Aristida calycina* yield was highest under trees.

After 8 years of grazing treatments, useful grasses such as *D. sericeum, Bothriochloa bladhii, Cymbopogon* spp. and *Heteropogon contortus* were all higher yielding without tree competition, while *A. calycina* and *C. fallax* were higher yielding, 205% and 161% respectively, in the treed paddocks than in the treeless ones (Table 6.13).

Table 6.12 Mean species dry matter yield (in treeless rank order) in treeless and treed paddocks over the grazing trial period (1995–2002).

	Mean 1995-2002		
Species	**Treeless**	**Treed**	**% of Treeless**
Aristida ramosa	310	149	47.9
Enteropogon ramosus	308	97	31.6
Dichanthium sericeum	242	33	13.8
Bothriochloa decipiens	210	203	96.9
Enneapogon spp.	192	60	31.5
Chloris divaricata	140	29	20.5
Aristida spp.	61	62	101.6
Bothriochloa bladhii	57	21	37.4
Sporobolus (ratstail)	43	11	26.4
Chrysopogon fallax	41	39	94.6
Aristida leptopoda	38	2	5.0
Cymbopogon spp.	33	11	33.3
Sclerolaena birchii	29	18	61.0
Aristida latifolia	27	7	26.7
Tripogon loliiformis	27	21	78.9
Aristida calycina	26	30	114.9
Eragrostis molybdea	26	10	40.2
Chloris spp.	25	16	62.5
Heteropogon contortus	24	18	77.0
Themeda triandra	23	4	16.2
Eragrostis spp.	19	12	60.7
Forb - small	18	14	77.6
Calotis spp.	18	10	56.6
Eriochloa pseudoacrotricha	17	2	14.8

Table 6.13 Main species dry matter yield, in rank order, in treeless and treed treatments in the final year 2002, after 8 years of grazing treatments.

	2002		
Species	**Treeless**	**Treed**	**% of Treeless**
Aristida ramosa	456	180	39
Enteropogon ramosus	196	55	28
Dichanthium sericeum	136	16	12
Bothriochloa decipiens	120	125	104
Enneapogon spp.	75	30	40
Cymbopogon spp.	69	5	7
Chloris divaricata	58	17	28
Sporobolus (ratstail)	48	2	5
Aristida leptopoda	41	1	1
Heteropogon contortus	41	9	22
Bothriochloa bladhii	41	3	6
Aristida latifolia	20	4	18
Aristida calycina	17	34	205
Chrysopogon fallax	16	26	161

6.2.1.4.6 Dry matter yield of functional groups

The treeless paddocks had consistently higher dry matter yields of the major pasture functional groups of decreaser (Figure 6.74), intermediate and increaser grasses, while usually having higher yields of the annual grasses and forbs (Figure 6.75). There was negligible difference between tree treatments in palatable legumes, and sedges were usually greater in the treed paddocks.

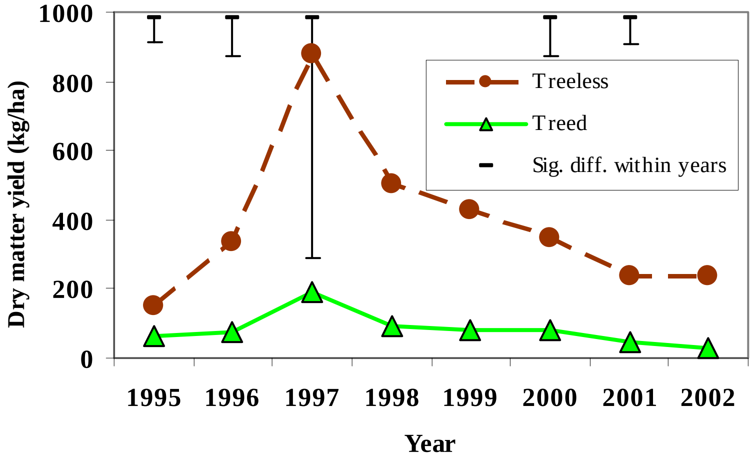
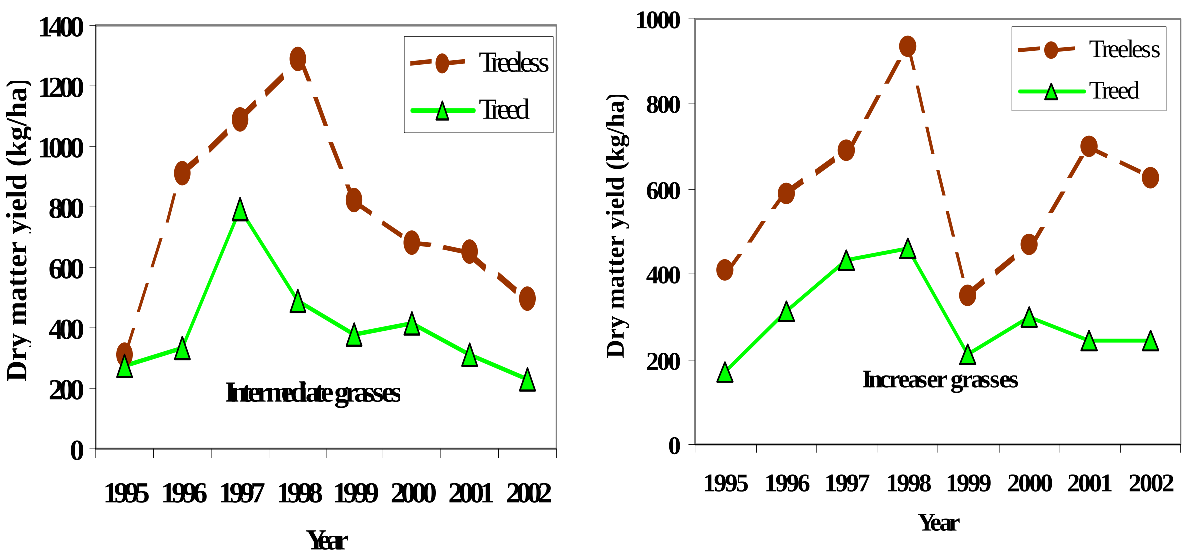


Figure 6.74 Tree competition effect on decreaser grass dry matter yield (kg/ha) each autumn, meaned over grazing pressures. Bars show lsd's for individual years.

Tree competition reduces total pasture dry matter production



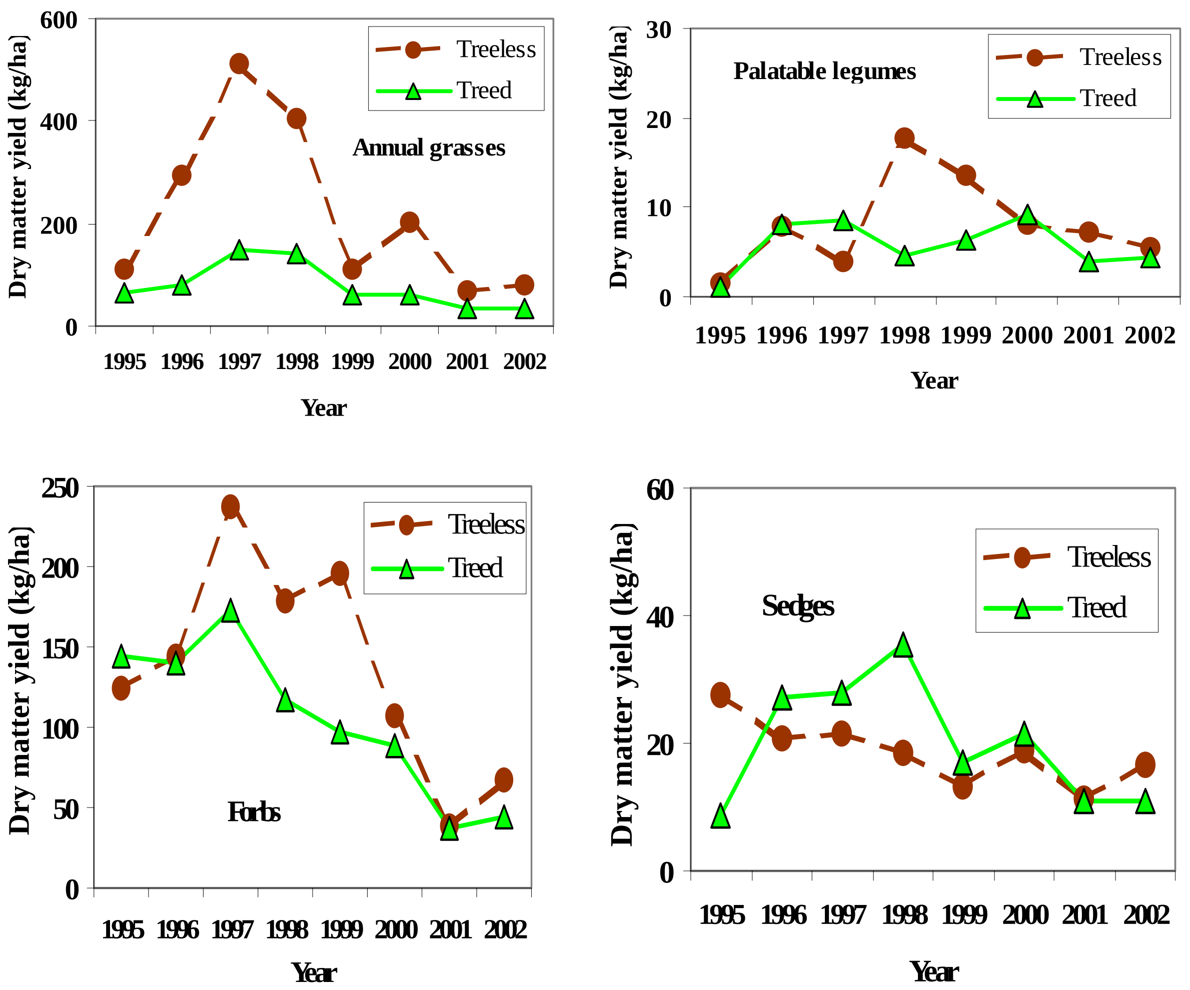


Figure 6.75 Tree competition effect on dry matter yield (kg/ha) of six plant functional groups; - Intermediate grasses, Increaser grasses, Annual grasses, Palatable legumes, Forbs and Sedges.

The annual comparison of dry matter yield of species functional groups showed the big benefit of tree removal over treed treatments on the yield of desirable grasses of the decreaser group (Figure 6.74). There was an initial rapid increase in decreaser grasses, predominantly *Dichanthium sericeum,* for 3 years after clearing. This species composition improvement lasted for the length of the trial, although the difference was gradually declining. The initial increase in the desirable species after clearing may have been promoted by the additional nutrients released into the system from killing the trees, from leaf fall, bark litter and root decomposition, as well as from the improved water relations with reduced water competition.

The intermediate and increaser grasses also responded to tree killing with higher yields for the 8 years of the study (Figure 6.75). The annual grasses and forbs responded to clearing in the early years, but not in later years. There was no consistent trend in palatable legume or sedge yields between treeless and treed areas although sedges seemed to yield more under trees. The general decline in yields in 2001–2002 can be attributed to the developing drought conditions.

Tree competition affects the contribution of species functional groups to pasture production

The % contribution to total annual pasture yield of the functional groups shows the treeless plots always had almost double the contribution from the desirable grasses, the decreasers, than did the tree paddocks. There were no strong trends with increaser grass contribution %, while the treed paddocks consistently had a higher contribution % from the forb and sedge components (Figure 6.76).

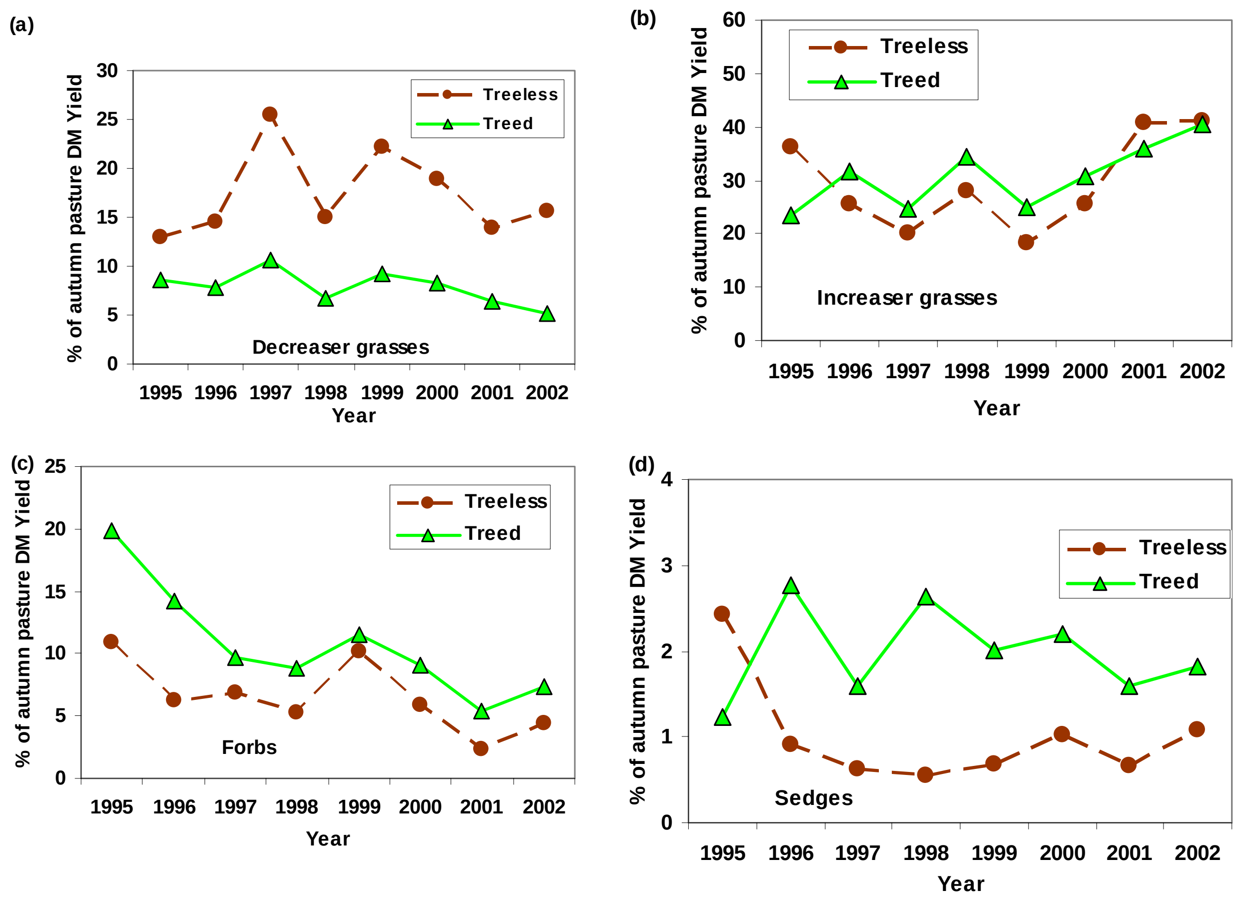


Figure 6.76 Plant functional groups, decreaser grasses, increaser grasses, forbs and sedges, contribution (%) to total annual pasture dry matter yield in grazed poplar box woodland.

Desirable grasses are more productive in treeless pastures, while forbs and sedges are more productive in treed pastures

Dichanthium sericeum (Queensland bluegrass) was the key perennial grass species (a decreaser) whose dry matter yield was most strongly influenced by tree competition (Figure 6.77) and grazing pressure across years (Figure 6.78). There was the clear effect that increased grazing pressure on reduced yield and the strong early response to clearing in the first 3 years after the drought. It was never competitive in the treed treatments. The sedge, *Fimbristylis dichotoma* was more productive under the trees than in the treeless paddocks. High grazing pressure had a consistent depressing effect on Queensland bluegrass, while the less desirable pitted bluegrass was most productive at medium grazing pressure.

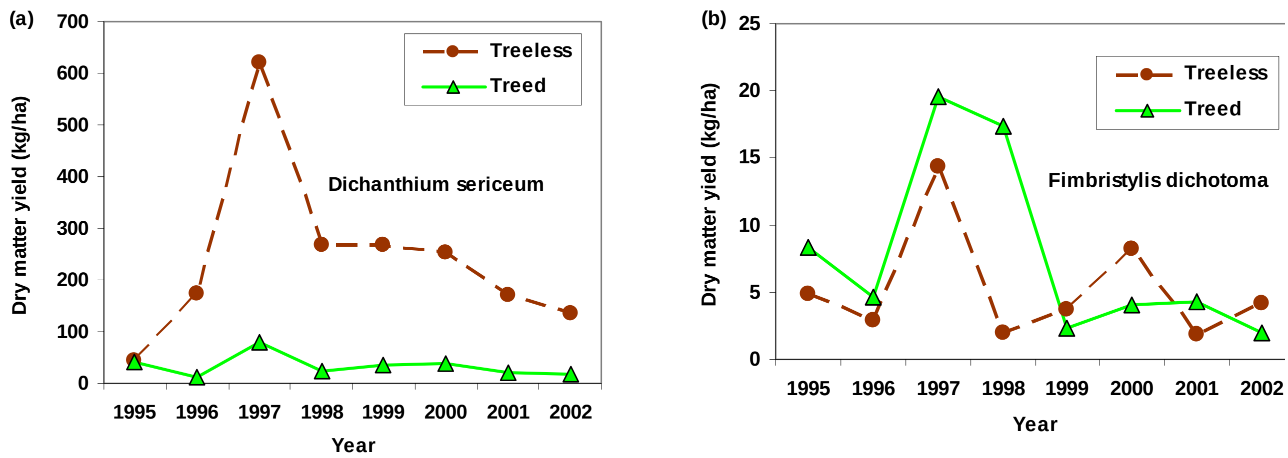


Figure 6.77 Effect of trees on autumn dry matter yield of the key perennial grass Qld Bluegrass (*D. sericeum*) and the sedge, (*F. dichotoma*) throughout the poplar box grazing trial.

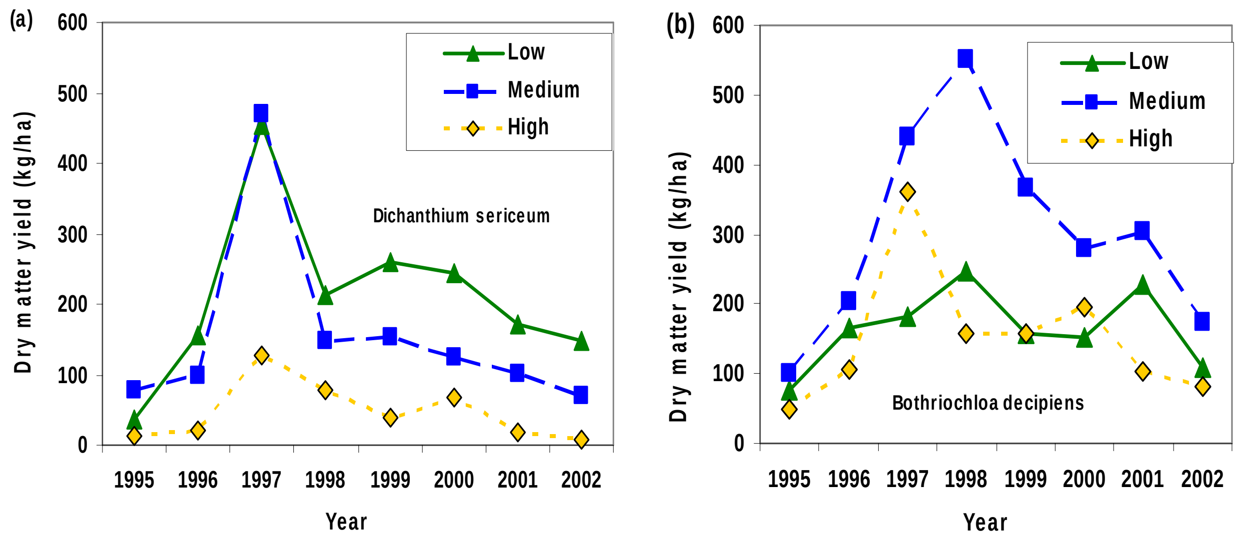


Figure 6.78 Effect of grazing pressure on autumn dry matter yield of the key perennial grasses Qld Bluegrass (*D. sericeum*) and pitted bluegrass (*B. decipiens*) throughout the box grazing trial.

Pasture production of 3P grasses responds to lower grazing pressures

6.2.1.4.7 Pasture component frequencies (%)

A list of the 75 taxa that were routinely recorded is given in Appendix E. A summary of the relative importance of the main species based on frequency percent in the treed/treeless treatments and in the high/medium/low utilisation treatments is shown in Table 6.14 and Table 6.15. There were fluctuations in frequency of both desirable and undesirable species, although there were no dramatic weed species invasions caused by the treatments. Compared to other pasture types such as black speargrass country, some species of note that differ in their importance or underwent changes include:

- *Aristida* species have increased marginally in the treed treatments,

- *Tragus australianus* (small burrgrass) has declined 22% since the drought ended,
- *Chloris divaricata* has increased across the site over time, particularly where there were no trees
- *Brunoniella australis* (blue trumpet) is the most significant forb and occurs across the whole site, but has declined noticeably everywhere
- *Calotis* spp., predominantly *C. lappulacea* (yellow daisy burr), has fluctuated in all treatments,
- There was a greater increase in *D. sericeum*, the most desirable 3P species, in the treeless treatments (28%) than in the treed paddocks (10%),
- The most desirable bluegrasses in the poplar box woodlands, *Bothriochloa bladhii* and *D. sericeum,* have both declined at the high utilisation rate.
- Some forb species, which are generally regarded as weeds, such as *Malvastrum americanum, Portulaca* spp. (pigweeds), *Sclerolaena birchii* (galvanised burr) and *Sida* spp., have all increased over time at the high utilisation rate.

Table 6.14 Frequency (%) of the main species in the treeless and treed treatments of the grazing trial, plus the difference between these main effects and the COMM paddock mean. The list is sorted in decreasing order of the difference between treeless and treed treatments.

	Mean 1995-2002		Difference	Large
Main species	**Treeless**	**Treed**	**Treeless - Treed**	**COMM paddock**
Chloris divaricata	36.8	14.3	22.4	41.7
Enneapogon spp.	52.2	30.3	21.8	44.3
Dichanthium sericeum	28.5	10.5	18.0	26.2
Tragus australianus	12.8	6.0	6.8	15.8
Sporobolus - small	8.9	4.4	4.5	7.6
Aristida leptopoda	4.6	0.6	4.0	6.5
Eragrostis molybdea	9.0	5.7	3.3	6.9
Enteropogon ramosus	16.0	12.7	3.3	6.8
Tripogon loliiformis	24.1	21.2	2.8	13.1
Aristida latifolia	3.6	1.1	2.4	3.6
Malvastrum americanum	6.5	4.1	2.4	4.2
Cenchrus ciliaris	2.8	0.7	2.1	5.0
Portulaca spp.	2.4	0.8	1.6	6.6
Bothriochloa bladhii	5.8	4.8	1.0	5.0
Sclerolaena birchii	7.1	6.9	0.2	3.5
Solanum spp.	3.4	3.7	-0.3	3.5
Sida spp.	8.1	8.9	-0.8	5.7
Vittadinia spp.	4.1	5.4	-1.3	5.3
Brunoniella australis	19.3	20.9	-1.6	24.4
Eragrostis spp.	5.4	7.1	-1.7	7.3
Verbena tenuisecta	9.3	11.2	-1.9	14.8
Heteropogon contortus	2.2	4.6	-2.4	2.3
Fimbristylis dichotoma	7.4	10.0	-2.6	4.4
Sida subspicatum	1.5	4.7	-3.2	3.3
Forb - small	25.6	29.9	-4.3	18.8
Calotis spp.	10.9	15.3	-4.4	
Cyperus spp.	6.3	12.3	-5.9	5.6
Legume - palatable	9.3	15.3	-6.0	12.6
Aristida calycina	3.5	9.5	-6.0	3.7
Aristida spp.	6.0	13.0	-7.0	11.3
Chrysopogon fallax	18.6	27.9	-9.3	19.6
Aristida ramosa	15.6	25.7	-10.1	18.8
Bothriochloa decipiens	19.3	41.3	-22.0	23.3

Tree competition reduces frequency of *Dichanthium sericeum*, the most important 3P grass

C. divaricata had a significantly smaller recruitment in the treed treatments. It is an increaser species at this site, although it has the desirable characteristics of rapid growth response to spring rain and an ability to tolerate heavy grazing. It increased in the patch grazed areas in the cleared treatments. Buffel grass was the only sown pasture species to make an obvious contribution to these native pastures but only in isolated microsites. Buffel colonised some disturbed areas such as roadsides, but did not spread into the grazed or burnt pastures.

B. decipiens and most *Aristida* spp. were always more frequent in the treed treatments. There were pre-existing areas of dense *Aristida ramosa* on the flats of the treed and cleared paddocks that were not influenced by the clearing treatment.

Tree competition affects species frequency

Table 6.15 Mean frequency (%) over 7 years of the main species in each of the three grazing pressure treatments, sorted on Low grazing pressure rank order.

		Mean 1995 - 2002	
Main species	**Low**	**Medium**	**High**
Enneapogon spp.	40.8	41.0	41.7
Chloris divaricata	25.6	22.0	27.0
Dichanthium sericeum *	24.5	23.1	10.9
Bothriochloa decipiens	22.7	35.3	32.8
Chrysopogon fallax *	22.7	33.0	14.2
Brunoniella australis	22.3	23.9	14.0
Aristida ramosa	20.1	18.5	12.8
Forb - small	19.8	22.4	22.3
Aristida spp.	15.1	13.2	11.4
Enteropogon ramosus *	14.5	5.6	16.9
Tripogon loliiformis *	12.5	21.2	28.0
Legume - palatable *	12.0	17.6	8.2
Verbena tenuisecta *	10.6	13.1	6.2
Cyperus spp.	9.9	8.6	8.4
Calotis spp.	9.2	11.7	17.0
Fimbristylis dichotoma	8.4	7.7	10.0
Tragus australianus	7.8	9.0	11.4
Bothriochloa bladhii *	6.7	6.7	0.9
Eragrostis spp.	6.2	7.6	6.9
Aristida calycina	6.0	7.2	4.3
Sporobolus (small)	5.4	4.9	7.1
Sida spp. *	5.3	7.6	10.8
Eragrostis molybdea	5.3	7.7	6.5
Malvastrum americanum	4.8	4.3	7.0
Aristida leptopoda	4.7	1.9	2.3
Aristida latifolia	4.0	2.3	0.8
Solanum spp.	3.4	3.3	3.5
Sclerolaena birchii *	2.8	3.5	11.7
Portulaca spp.	2.8	2.4	5.8
Cenchrus ciliaris	2.7	1.5	1.1
Sida subspicatum	2.6	1.5	5.2
Vittadinia spp. *	2.5	4.6	6.7

(* = Species with obvious differences due to grazing pressure or inherent paddock contrasts).

Increasing grazing pressure reduces *Dichanthium sericeum* and increases *Tripogon loliiformis* frequency

The most frequent species across the grazing trial was *Enneapogon* spp. with a similar frequency of 41% at the 3 grazing pressures (Table 6.15), although it was more frequent in the treeless paddocks than in treed paddocks (Table 6.14). *C. divaricata* was next most common species and had a marginally higher frequency at high grazing pressure (27%). The high grazing pressure had the greatest impact on *D. sericeum*, which declined from 25% at low grazing pressure to11% at high grazing pressure, while *T. loliiformis* increased from 13% to 28% under the same conditions.

Grazing pressure affects species frequency

The least desirable increaser perennial grasses at this site, *Aristida* spp., did not increase significantly at the high grazing pressure during the period of this study. In this region, the *Aristida* spp. have become dominant in significant areas under past management and seasonal conditions, especially along creek levees and minor valley floors. The high grazing pressure, 75% potential consumptive use of each autumn's standing forage, kept the plants grazed low, but did not kill large numbers of them, but seedlings were prevented from establishing in the open inter-tussock areas. The less palatable weed species, such as *Sclerolaena, Sida, Portulaca* and *Vittadinia* spp. increased marginally under high grazing pressure (Table 6.15). The mean frequency of taxa in the large, treeless COMM paddock reflected that of the Treeless treatments rather than the Treed ones (Table 6.14). The same grasses were commonest there, namely *C. divaricata*, *Enneapogon* spp., *D. sericeum* and *B. decipiens*.

Sorting the most frequent species at the 3 grazing pressures (Table 6.16) shows the decline of *D. sericeum* as grazing pressure increases, the dominance of *Enneapogon* spp. and *B. decipiens* in all treatments, and the increase in *T. loliiformis* and forbs, such as *Calotis* spp. and *Sclerolaena* spp., as the grazing pressure increased. *Bruniella australis* was the most widespread forb across the site in most years.

Table 6.16 Most frequent species at low, medium and high grazing pressure, averaged over the whole trial period (in descending order).

Sorted by: Low grazing pressure	Sorted by: Medium grazing pressure	Sorted by: High grazing pressure
Enneapogon spp.	*Enneapogon* spp.	*Enneapogon* spp.
Chloris divaricata	*Bothriochloa decipiens*	*Bothriochloa decipiens*
Dichanthium sericeum	*Chrysopogon fallax*	*Tripogon loliiformis*
Bothriochloa decipiens	*Brunoniella australis*	*Chloris divaricata*
Chrysopogon fallax	*Dichanthium sericeum*	Forbs - small
Brunoniella australis	Forbs - small	*Calotis* spp.
Aristida ramosa	*Chloris divaricata*	*Enteropogon ramosus*
Forbs - small	*Tripogon loliiformis*	*Chrysopogon fallax*
Aristida spp.	*Aristida ramosa*	*Brunoniella australis*
Enteropogon ramosus	Legume - palatable	*Aristida ramosa*
Tripogon loliiformis	*Aristida* spp.	*Sclerolaena birchii*
Legume - palatable	*Verbena tenuisecta*	*Tragus australianus*
Verbena tenuisecta	*Calotis* spp.	*Aristida* spp.

Increasing grazing pressure reduces 3P grass species frequency

6.2.1.4.8 Frequency of functional groups

The consistently increased frequency of the desirable 3P grasses (decreasers) after killing trees is shown in Figure 6.79. The effect of tree competition was not significant for the intermediate grasses, but the undesirable grasses (increasers), forbs and sedges were more frequent under the trees. Annual and short-lived grasses were most frequent in treeless paddocks.

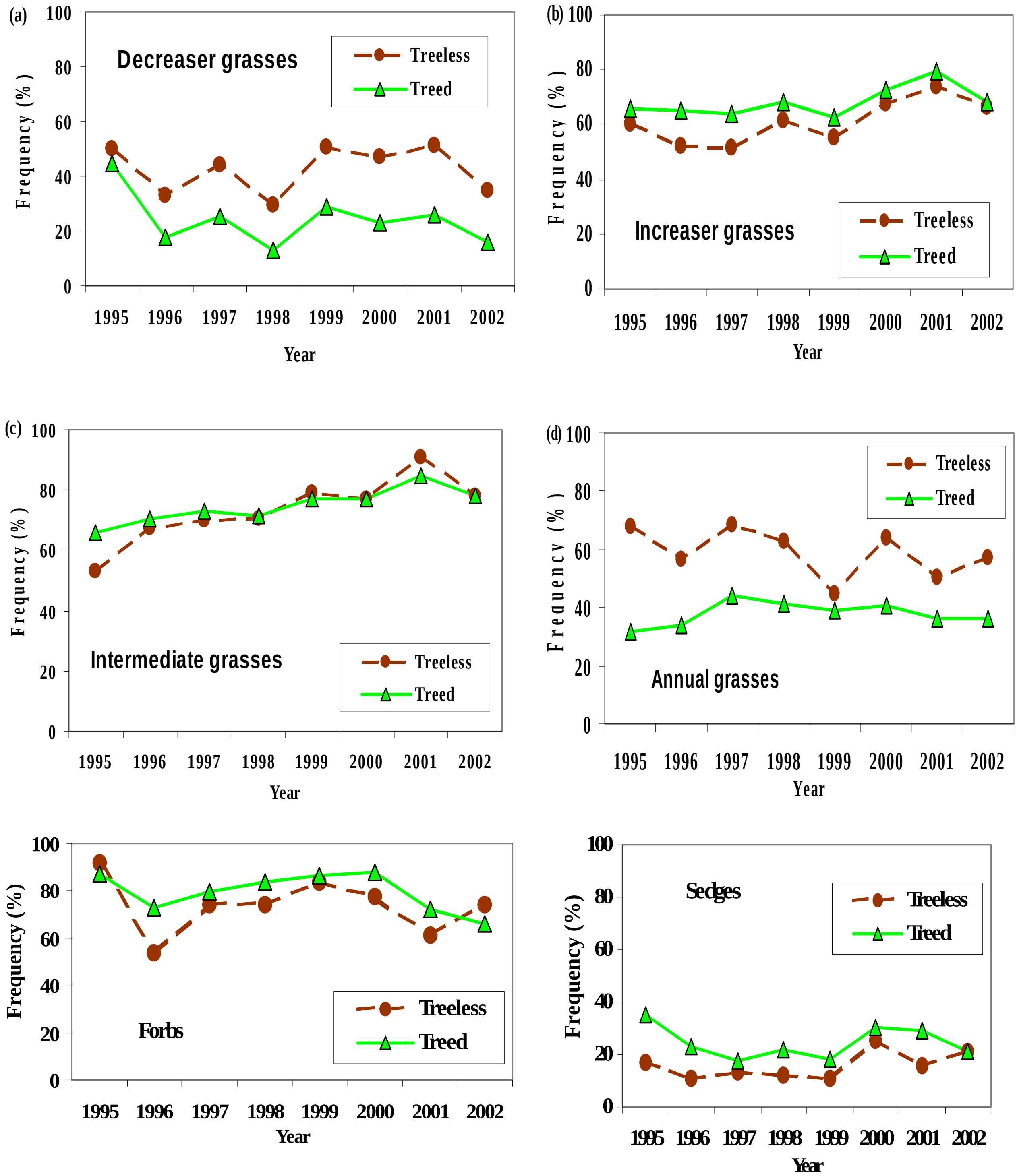


Figure 6.79 Effect of tree competition on changes in the frequency (%) of pasture functional groups over the years 1995 to 2002 under grazing.

Tree competition has greatest effect on decreaser grass species frequency

6.2.1.4.9 Pasture species diversity over time

There were more grass species recorded in the Botanal quadrats, usually in autumn, than there were forb species. The mean numbers in the grazed paddocks each year, show the most grasses were recorded in 2000, while the most forb species were recorded in 2001 (Figure 6.80). The most grass species recorded in a paddock was 32 in different paddocks on 2 occasions. The most forbs recorded in a paddock was 25 species. Of the 75 species or species groups for Botanal recording, 40 were grasses and 35 were forb groups.

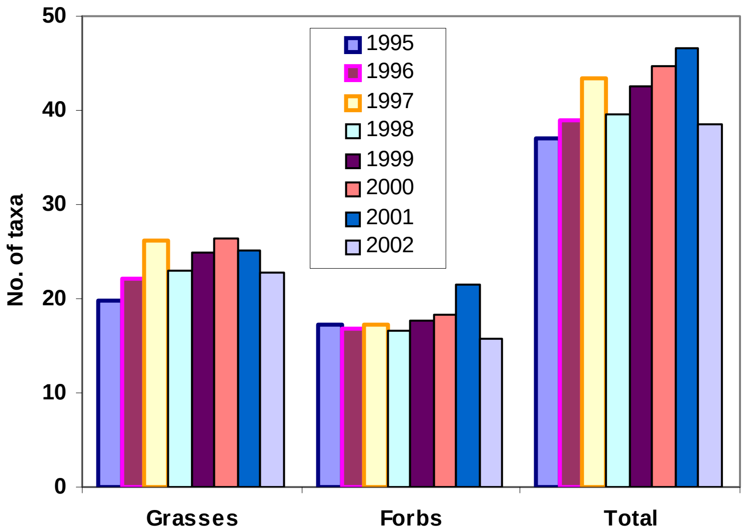


Figure 6.80 Pasture species diversity measured by number of grass and forb taxa present each year in the grazing trial in poplar box woodland in Botanal quadrats.

There were no significant difference in the mean numbers of grasses and forbs and total taxa recorded in Botanal quadrats over the years1995-2002, however, there were consistent trends in number of grasses and forb species present in response to grazing pressure. The low grazing pressure had the most grasses and forb taxa (27 and 19 respectively, averaged over all years) while the highest grazing pressure paddocks (21 and 18) and the ungrazed plots (20 and 12) had the lowest average numbers.

Pasture species diversity is increased at low grazing pressure

6.2.1.4.10 Perennial grass basal area

The mean site pasture basal area (%) at the poplar box grazing trial varied noticeably between years (Figure 6.81). The basal area increased following the drought of the early 1990s until the wet year of 1998. The decline in 1999 follows a wet winter and short summer season.

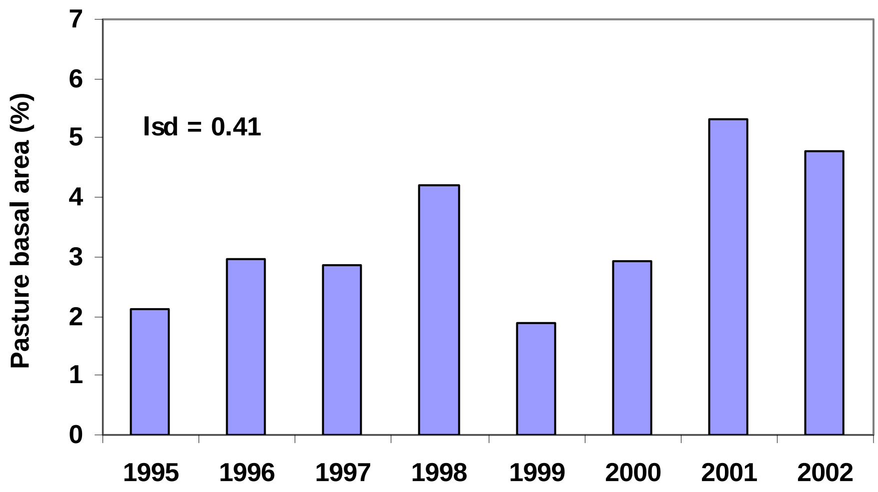


Figure 6.81 Mean winter pasture basal area (%) in the poplar box grazing trial.

The pasture basal area was consistently higher in the treeless paddocks than in the treed paddocks (Figure 6.82). The increased basal area was significant by the end of the second summer after clearing and remained around 1.5% higher than in the treed paddocks for the next 6 years. The annual fluctuations were similar in treeless and treed paddocks, and followed summer rainfall patterns. The decline in 2002 was the effect of the drought starting to reduce plant crown size.

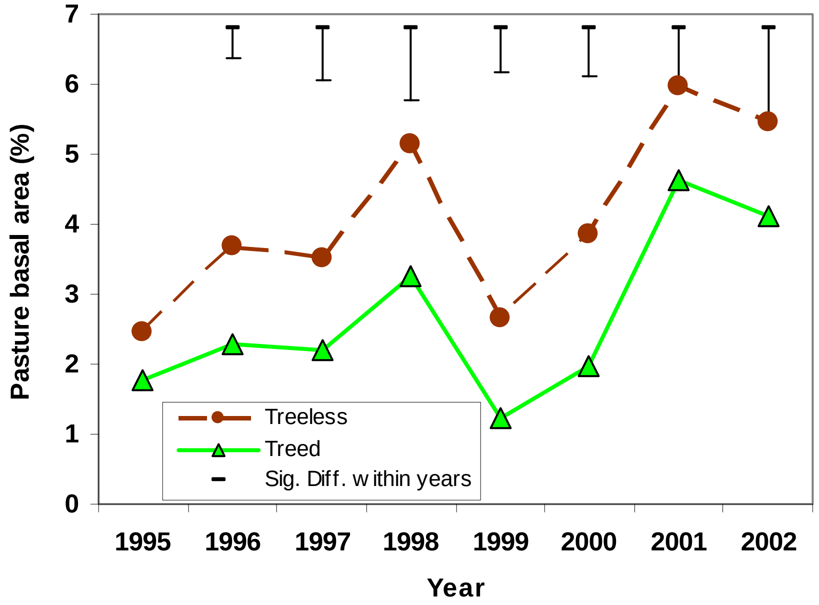


Figure 6.82 Mean pasture basal area (%) in treeless and treed paddocks in poplar box woodland. Bars show lsd (P<0.05).

Between the 6 treatments, there was a consistently higher pasture basal area in the treeless and low to medium grazing pressure treatments than in the treed paddocks. The high grazing pressure caused a reduced basal area after the first summer (Figure 6.83). This trend persisted throughout the trial, although the absolute values fluctuated with seasons.

Tree competition reduces pasture basal area

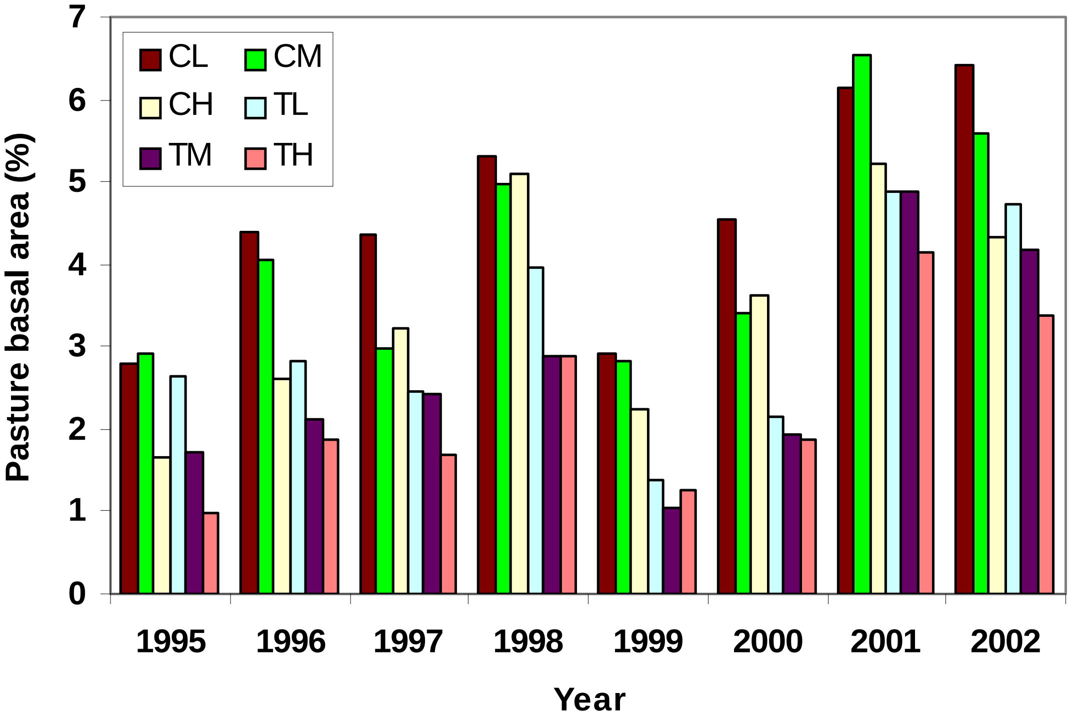


Figure 6.83 Pasture basal area (%) for 6 tree and grazing pressure treatments in poplar box woodland. (Treatment codes C = Chemically killed, T = Treed, L = Low grazing pressure, M = Moderate grazing pressure, H = High).

There was a consistent grazing pressure effect on pasture basal area throughout the trial with the low grazing pressure maintaining the highest basal area and the high pressure had the lowest basal area (Figure 6.84). As expected, the mean pasture basal area (1995-2002) decreased as grazing pressure increased, from 3.9% to 3.4% to 2.9%. In November 1997, the pasture basal area of the large COMM paddock was 3.2%, similar to that of the treeless moderate and high grazing pressure treatments (Figure 6.83).

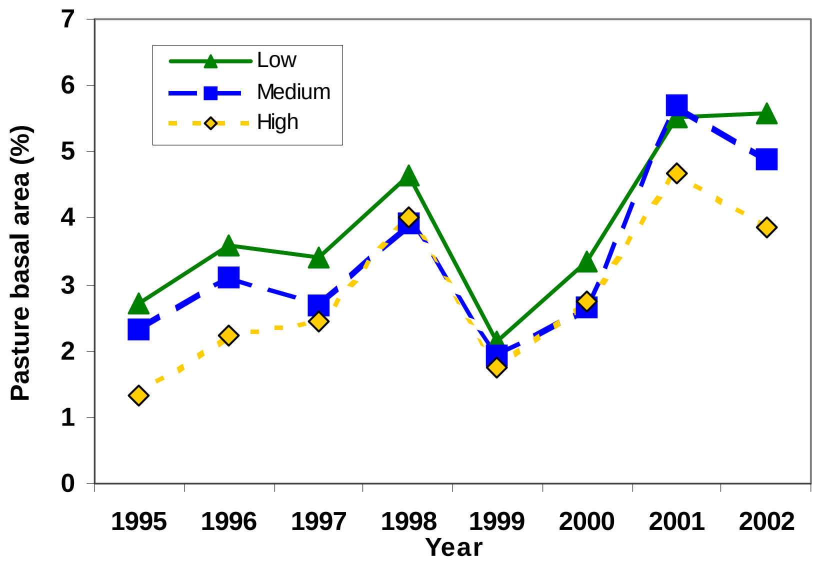


Figure 6.84 Annual pasture basal area (%) at 3 grazing pressures between 1995 and 2002 in poplar box woodland.

The mean of the 12 ungrazed plots of the burning trial had a marginally lower basal area (3.5%) than the low grazing pressure treatments, but it was higher than the medium and high grazing pressure treatments (Figure 6.85).

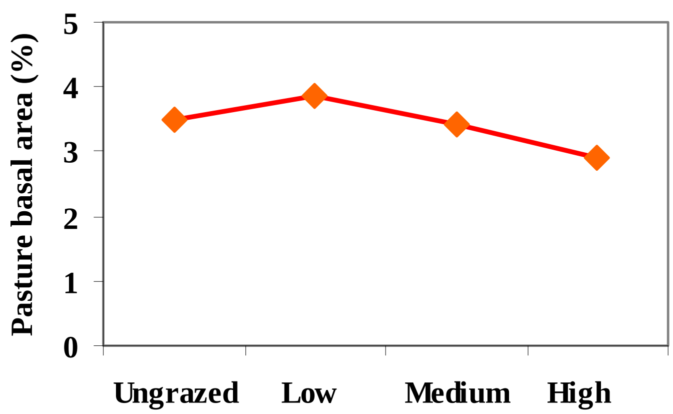


Figure 6.85 Mean pasture basal area (%) for the 12 ungrazed burning trial plots and the 3 grazing pressure treatments in the grazing trial in poplar box woodland from 1995–2002.

Increasing grazing pressure reduces pasture basal area

The point frame technique allows individual species strikes to be recorded to show which species contribute most to the data set. The sampling was done along exactly the same transects between fixed steel posts, so errors due to spatial variation across paddocks and plots were not involved.

6.2.1.4.11 Pasture greenness

The proportion of green material in the pasture was estimated in all Botanal sampling quadrats across each paddock. At sampling in January 1995 all the pasture was green (100 %), and in May 1996 an early finish to the growing season meant that there was little green material remaining in any treatment. In later years, sampling was earlier, near the end of the main growing season when green leaf and stem was still present (Figure 6.86). At these later times, there was often a marginally higher proportion of green pasture in the cleared paddocks than under the trees. April 2001 was unusual in having a lower proportion of green in the treeless paddocks.

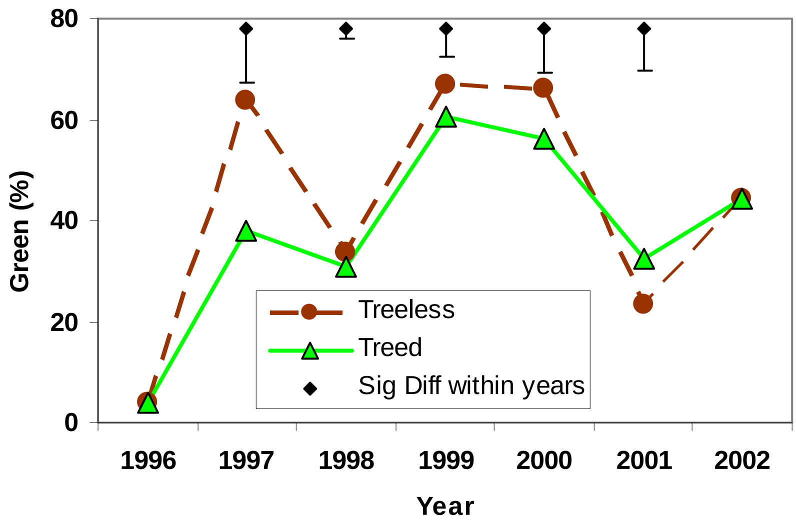


Figure 6.86 Tree competition effect on pasture greenness at Botanal sampling time at the end of the growing season in poplar box country. Bars indicate lsd (P<0.05).

Tree competition reduces pasture greenness in autumn

The autumn recordings have shown that tree killing often allows the pasture to remain green longer than if it was under trees. This was especially the case in 1997. There was a trend of reducing greenness with increasing utilisation rate in 1997, but the differences were negligible in the wet 1998 autumn (Figure 6.87). This is because dead leaf and litter accumulates at the low utilisation rate, while at the high utilisation rate, there is a high proportion of green grass stems and green forbs remaining in the more limited pasture then present at the end of summer. Greenness recording was in early summer in 1995 and all pastures were near 100% green from new growth following the early 1990's drought, and in 1996 recording was in autumn when most pasture was mature and dry.

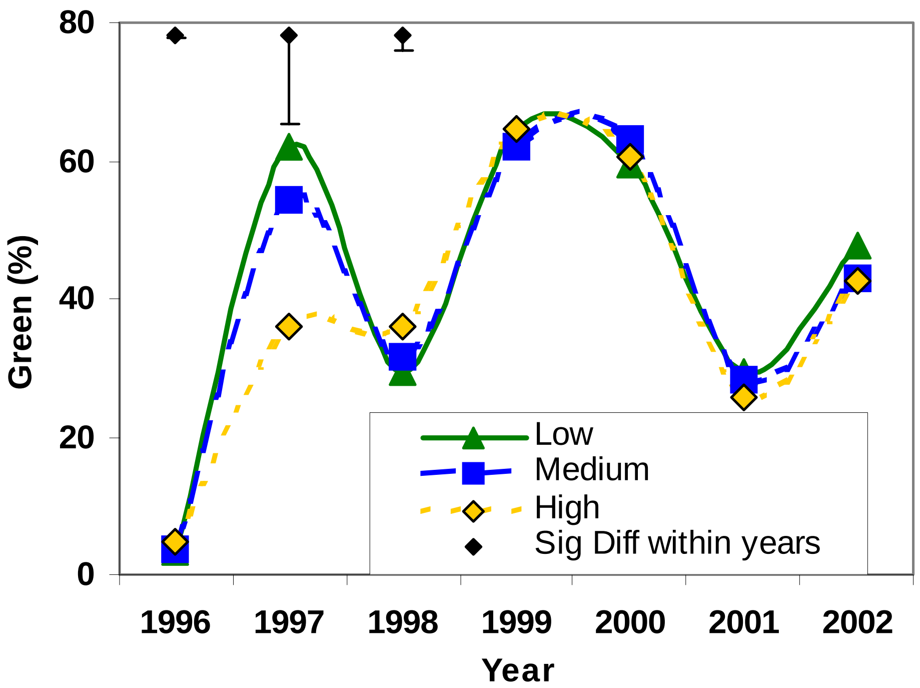


Figure 6.87 Grazing pressure effect on pasture greenness during Botanal sampling at the end of the growing season in poplar box country.

Seasonal conditions have a greater effect on pasture greenness than grazing pressure in autumn

The data for mean site pasture greenness at the end of the growing season shows there is can be 60% green in the grass, maintaining quality for animals much further into winter in some years (Figure 6.88). This is before frosts occur when all green disappears quickly.

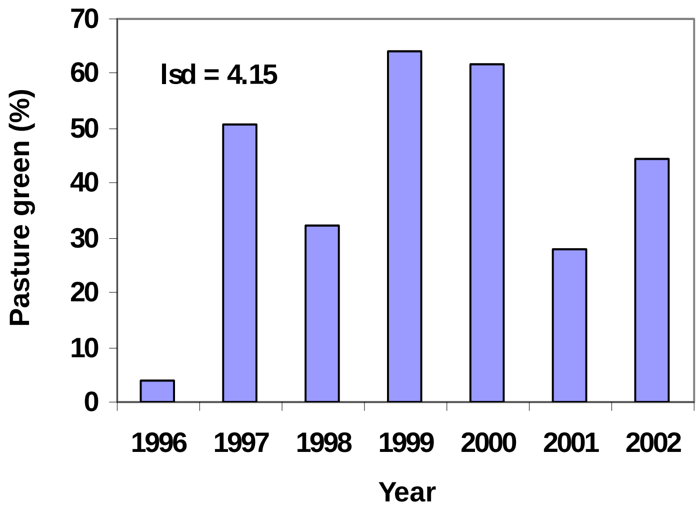


Figure 6.88 Mean pasture greenness (%) across the all treatments of the poplar box grazing trial at Botanal sampling time.

6.2.1.4.12 Grass species relative root dry matter yield

Pasture root mass was only measured towards the end of the trial, but gives an idea of what differences the treatments had induced after 6 years. Amongst the main grasses, *D. sericeum* and *E. ramosus,* which tend to grow on the deeper and heavier soil types, had the highest relative root yield, while *B. decipiens* had the lowest (Figure 6.89). This is an unexpected result because *B. decipiens* remains a dominant species and remains competitive in the face of tree competition. The higher yield of roots from *D. sericeum* could help explain its persistence in the cleared paddocks throughout the trial.

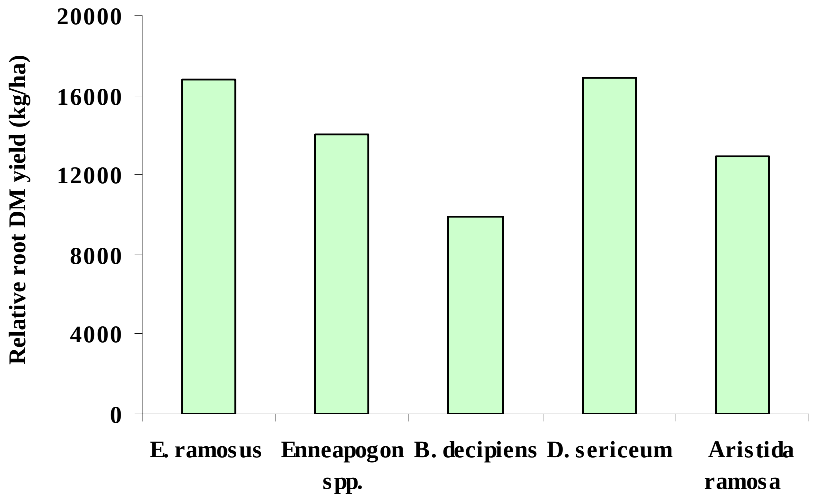


Figure 6.89 Relative grass root dry matter yield for main grass species in poplar box woodland.

About 69%, 9.5% and 7% of the total root yield of the top 60cm of soil was found in the depth intervals of 0-10cm, 10-20cm and 20-30cm respectively (Figure 6.90). The *Enneapogon* species had the least roots in the surface 10 cm and the highest yield below 30 cm (data not shown). *B. decipiens* had the lowest root yield of the species selected, with 85 % of its total roots found in the surface 10 cm.

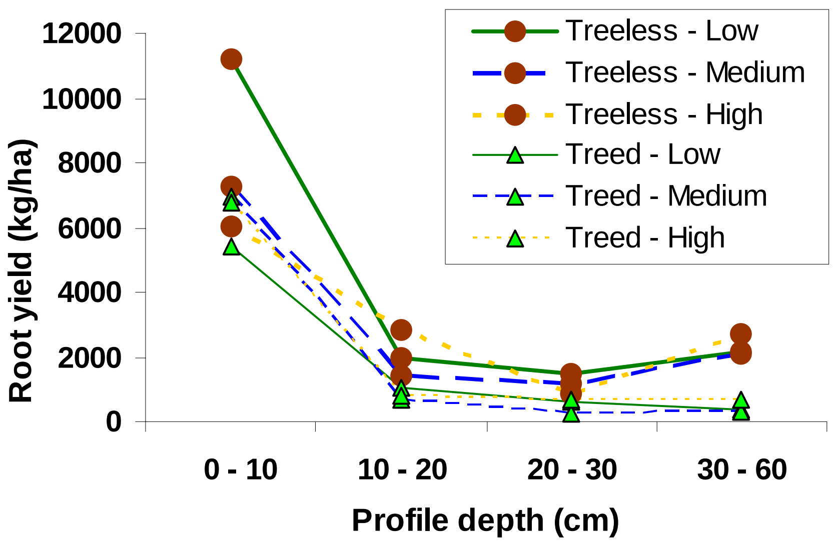


Figure 6.90 Relative grass root dry matter yield in Dec. 2000 at four profile depths for the main grasses in poplar box woodland.

There was a consistent trend in declining root yield with increasing grazing pressure and with tree competition across all treatments (Figures 6.90 & 6.91). The treeless, low utilisation treatment had the highest plant top (2440 kg/ha) and relative root (14,800 kg/ha) yields while the treed and high utilisation treatment had the lowest top (800 kg/ha) and relative root (6350 kg/ha) yields. The mean plant top yield in the treed treatments was 52% of the yield of the treeless treatments, while the relative root yield in the treed treatments was 68% of the root yield of the treeless paddocks (Figure 6.91). Treeless pastures showed greater pasture root biomass below 30cm than in treed areas (Figure 6.90).

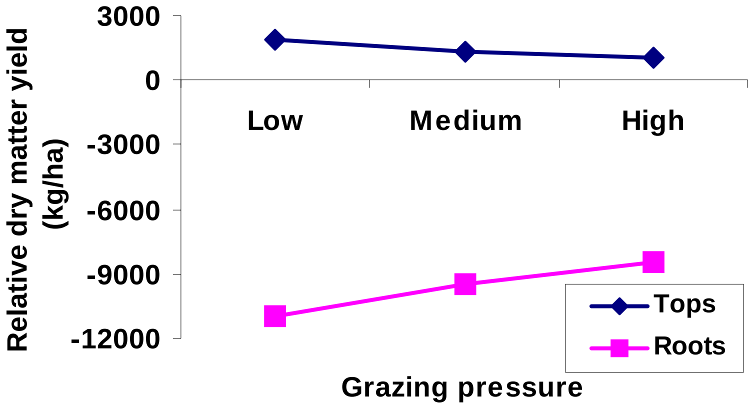


Figure 6.91 Relative grass top (above ground) and root (below ground) dry matter yield at different grazing pressure in Dec. 2000 in poplar box pastures.

6.2.1.4.13 Population dynamics of focus perennial grasses

6.2.1.4.13.1 Abstract

Beneath the gross, visual changes produced in native pastures by different grazing pressures, there are complex shifts in the number and size of the plants of the component species. This applies even to the perennial grasses that are far more resilient to grazing than annuals and also seemingly less affected by seasonal conditions than non-grass herbs. Our detailed charting of individual plants shows that Qld bluegrass loses the equivalent of half its population about every 2 years but that this is compensated for by new recruits. The mean expected lifespan of its established plants is 7 years but this is reduced by heavy grazing. On average heavy grazing pressure reduced expected lifespan by 2 years while light grazing pressure only increased such expectations by an average of 6 months.

Pastures growing under a moderate tree cover tended to have smaller individual plants but this reduction was greater for Qld bluegrass and pitted bluegrass than for the other four grasses monitored. Individual cohorts of new plants tended to follow a similar pattern of losses and crown size increase but good seasons could produce a marked increase in the rate of crown area growth in that year. Pasture composition in terms of both proportions of plant numbers and of biomass of the components was far more dynamic than overall pasture biomass change would suggest. Those composition changes at an individual grass species level were influenced by the age structure of the population, the quality of the seasonal rainfall and the grazing and burning management imposed on the pasture. Seasonal conditions often outweighed grazing management as the dominant driver of pasture composition change of the perennial grasses.

Where heavy grazing pressure increased the death rate of existing perennial grasses, this was partly compensated for by an increase in the rate of recruitment from seed of new plants of most species. Whether this enhanced recruitment is sustainable in the long term was not ascertained but we would expect that heavy grazing would reduce the amount of seed set and thus eventually constrain the ability of these grasses to recruit replacement plants into the open pasture.

6.2.1.4.13.2 Background

The gross botanical composition of each paddock was tracked using the BOTANAL technique but that data gives only limited insight into the dynamics of the populations of the perennial grasses. Some may be dying and re-establishing from seedlings very regularly while others may have very stable plant populations. Likewise, some species may fluctuate markedly in individual plant size while others may not. A better understanding of what is happening at an individual plant level would enable more responsive grazing management intervention to be used, where necessary, to maintain a desirable pasture composition.

This type of study is not often done in grazed pastures, especially over a prolonged period of time. Williams (1970) did it for two native grasses in southern NSW, Harper (1979) has done it in temperate pastures and Orr *et al.* (1997) and *Orr et al*. (2004) have used a charting technique for tropical bunch grasses. Most other studies of pasture dynamics use plant frequency or biomass changes to describe population dynamics. Such studies do not assess possible differential impacts of management or climatic events on perennial plants of widely differing ages. We believe this is important if we are to explain many of the complex or unexpected responses that are found in grazed woodland ecosystems.

6.2.1.4.13.3 Charting technique used to monitor plant dynamics

We used a mapping technique to monitor plant populations. Every plant of the 6 key or focus species within a small, fixed area was drawn to scale on a grided sheet of paper in the field. Three sets of three 0.5 sq m quadrats were located near the steel peg at one end of each of the 3 permanent transects in each paddock. Each set of three 50cm x 150cm quadrats was arranged as shown below. Three wooden pegs were driven into the ground at the locations shown in the diagram (Figure 6.92). The peg arrangement provided a unique orientation that allowed exact relocation for the quadrats on future visits. The reference peg was either post 1 in paddocks south of the powerline or post 4 in paddocks north of the powerline. A description of where each set of quadrats was located in relation to the post was written in a separate file and the orientation of the long axis noted to aid in repositioning the quadrats for subsequent re-charting of plants.

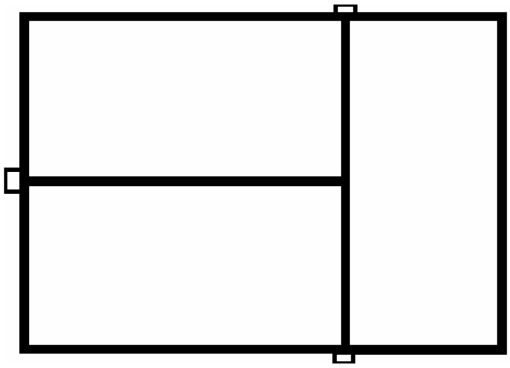


Figure 6.92 Layout of a set of three 0.5 m^2 quadrats plus permanent marker pegs.

This gave a total sample area in each paddock of 13.5 sq metres in which to locate the desired number of key plants. To achieve our target of about 50 plants of each key species per grazed paddock required an average occurrence of 5-6 plants per set of 3 quadrats. Key plant species charted at Glentulloch were

Aristida calycina
Aristida ramosa
Bothriochloa decipiens
Chrysopogon fallax
Dichanthium sericeum
and *Enteropogon ramosus*

Key species were chosen on the basis of the BOTANAL frequency & DM yield data as well as perenniality. Thus *Enneapogon gracilis* was excluded because it is too ephemeral and tends to be concentrated where there are few perennial plants. It was uncommon to encompass all key species in a set of three 0.5m^2 quadrats, so each set tended to be dominated by 2-3 of the key species. To compensate, other quadrat groups were dominated by the other species.

A full description of the method and the position of all the fixed quadrats within each treatment is given in Appendix Q.

Charting was carried out in autumn each year from 1995 to 2000. Very small seedlings were not recorded, so the data represents the dynamics of established plants and ignores the early seedling establishment phase of classical population dynamics. The exclusion of young seedlings was necessary because of resource constraints but we felt that, as very little was known in the mid-1990s about the population dynamics of these focus plants in the Maranoa, an invaluable start could be made towards our ultimate knowledge goal by doing this work.

Focus plants were charted freehand in pencil at 1:10 scale, sometimes with the backup of last years' charts to confirm plant losses. For large *C. fallax* areas, the charted area was annotated with the proportion of the total area that was covered by crown material. After the charts were all drawn, the size and location of each plant was transferred manually to a computer database, which is described in more detail in Appendix Q. That database recorded each plant uniquely, - its location, species and crown size (via two diameters at 90^o). From the two diameters, plant crown area was calculated using the formula for an ellipse ($A = \pi ab/4$). Later a tagging number was assigned manually to each database plant to compensate for the movement or splitting up of plant crowns. Data was then collated to provide information about -

- Plant numbers for each key species
- Recruitment and loss of plants over time
- Mean and Total plant crown area for each species
- Changes in crown area of each species over time

What constitutes a 'plant'?

For discussion and data presentation, each set of new plants is called an 'establishment cohort' which has a slightly different meaning from the cohort normally defined by plant demographers, eg. Orr 1998 and Harper 1977. The latter people closely monitor all newly emerged seedlings which thereafter normally have a rapid early death rate and a survivorship curve against time that is strongly exponential mathematically. Our recording technique did not attempt to pick up most seedlings, only those new plants which were well enough established to be identifiable by a seedhead. They may have only had a few tillers but they would have been at least a few months old by early winter when we charted them. Some may even have been nearly two years old before being charted for the first time. However they were still young compared to some in the initially recorded set that may have been 10 to 15 years old or more.

We did allow small plants to be classified as seedlings rather than 'new' plants where we were confident of that classification, often for non-flowering plants. In 1995 the original plants enumerated in Table 6.17 included 28 seedlings in the grazing trial but did not include any seedlings at the burn site (Table 6.46)

A debatable point is how to categorise fragments from existing plants when dealing with recruitment and population dynamics. Such crowns/plants are virtually independent plants but they are not new recruits in the sense of a new seedling. Likewise some adjacent grass plants of the same species sometimes merge into a unified crown that is impossible to compartmentalise. Here the formerly discreet plants are now combined/merged and their genetic line is visually indistinguishable. In our studies, fragmented crowns made up 1.6% of all records but with an increasing trend - 3.1% of the autumn 2000 records classified as fragments from an original plant. Only 0.75% of records were classed as merged entities but in 1996 they were over 2% of the records for that year when our technique was found wanting in ways described later.

A Note on the statistical analysis:

The ungrazed burning trial was physically isolated from the grazing trial at the poplar box site. Hence the results of each site were analysed separately. However, for the discussion of the management importance of the various results, the data is often presented together. In some cases, the fewer quadrats used in sampling the ungrazed burning trial plots (27 versus 54 per treatment) leads to the cumulative totals appearing nicely separated spatially from the totals of the grazing trial in the graphs, eg. Figure 6.110.

Due to the design of the trial and the non-random nature of the quadrat positioning, valid statistical comparisons amongst species across years are difficult to make. Comparison between the ungrazed and grazed plots is also problematic statistically but the trends are well worth noting. Hence, though discussion will concentrate on changes within a species under the four main grazing management options (high, medium and low grazing pressure, and ungrazed), assignment of statistical confidence to the differences is constrained to within-site ones, ie. amongst the grazed paddocks and amongst the ungrazed plots of the burn site.

Coefficients of Variation of over 100% were common under grazing for all species means, e.g. in 1995 353% for individual *C. fallax* crowns and a low of 108% for *D. sericeum*. Variability over all species in autumn 1995 was similar for all grazing pressures (CV about 200%) and at most other sampling times. Variability in plant size was initially greater amongst grass populations under trees - CV 250% compared to 170% in treeless areas; but this difference declined after 1996 and was reversed by 2000 (140% versus 180% respectively) due to a marked fall in the inter-plant variation in crown size in treed plots under grazing.

A Note on the Golden-beard grass (*C. fallax*) data

Some care needs to be taken when interpreting the golden-beard grass results as its crown structure was not well suited to our charting technique. This is partly because its crown is composed of deep underground rhizomes (Silcock 1999) that do not always send up tillers along their entire length each year. Hence the crown is often alive over a much larger area than shows via its foliage above ground and its rhizomes seem to mingle quite well with the crowns of other competing grasses, making the associated leaves hard to see. Also, the foliage is mostly long, thin leaves which wither in dry times and are selectively grazed when green. So the plant's presence is not always obvious to the person doing the charting, particularly when mingled with other more prominent, stalky plants. Its sparsely occurring flowering culms snap off very easily when dry or if pushed over by grazing stock while green and this further reduces the plant's visibility in a dense sward such as we often had.

A further point to note is that, where golden-beard grass occurred over a large area as sparse tillers or multiple small tufts, operators attempted to judge the proportion of the mapped area that the crowns probably occupied within that mapped area. This is a large potential source of error when comparing the calculated basal area of this species with that of a strongly tussocked species where the charted area faithfully represents the area of the crown. This shows in the data presented on the variability behind the means quoted (Table 6.19).

A Note on the *Aristida* (wiregrass) species data

There are two very similar varieties of *A. calycina* with racemose seedhead arms at the site, var. *calycina* and var. *praealta* (distinguished only by the presence of microscopic tubercules on the seeds) and there is a third form of the species that has a much-branched, panicle-like seedhead. The latter variety is quite rare but differentiation between any of them when collecting data was not done during our research. Also, there are two apparent forms of *A. ramosa* that occur in separate ecotones, one with a deep crown which grows on the heavy alluvial flats while the other, with a shallow crown, is found mainly on skeletal, sandy soils higher in the landscape.

Again, we did not distinguish between them in our data collection because we were not confident of identifying them consistently.

6.2.1.4.13.4 Results

The charting data can be presented in four different ways –

1. Total crown area
2. Mean crown area per plant
3. Plant numbers
4. Crown base area as a percentage of total ground area

Total crown area is merely the product of items 2 and 3. Basal area percent, in the normal pasture sense, is not very accurately calculated from our charts because some plants spread beyond the quadrat boundaries but were still measured. Another cause of the higher crown area % in this section compared to Section 6.2.1.4.10, is that the crowns here will occupy a slightly greater area than the point frame would record from actual vertical hits with its pins. The effect of this is to artificially increase the % crown area figures above true basal area percent.

The first set of charted data was collected six months after the treatments were imposed, so the effects of differing management will already have begun to show, especially with respect to plant crown area. However the population changes should have been minimal.

Total sample size

Table 6.17 shows the number of plants of each of the focus species that were originally charted in each grazing treatment at the end of the 1995 summer. Over the ensuing years, the number charted varied with the seasons and management, but there were always large numbers of plants to be charted each year within those fixed quadrats. The lowest total number was 2844 in 1999 and the maximum was 3570 in 1995. For an individual treatment, the minimum number of focal species plants charted in any year was 137 in Treeless-High Grazing Pressure in 1999 while the maximum was 787 in Treed-High Grazing Pressure in 1995.

The number of focus plants present initially in individual 1.5m^2 plots and paddocks varied greatly, as normally occurs in natural pastures at a small scale. At the grazed site, total numbers were almost 5 times greater than at the burning trial, which reflects the fact that 3 times as many quadrats were charted in the larger grazed paddocks compared to the 1 hectare plots at the ungrazed burn site. There was no significant difference in the initial number of plants measured in treed and treeless (chemically cleared) plots although there were 10% more in total in the treed grazed quadrats. Hence any potential bias in numbers associated with the killing of trees was not major.

Table 6.17 Numbers of charted plants of each focal species in each main treatment in June 1995

Treatment	Grazing		Species Arical#	Ariram	Botdec	Chrfal	Dicser	Entram	Treatment Total
Treeless	Low	LG	19	106	49	79	83	95	431
	Medium	MG	60	90	144	80	84	57	515
	High	HG	3	142	210	114	120	156	745
Treeless total	C		82	338	403	273	287	308	1691
Treed	Low		41	181	120	110	40	71	563
	Medium		27	141	123	124	32	82	529
	High		89	115	288	155	63	77	787
Treed total	T		157	437	531	389	135	230	1879
Species total			239	775	934	662	422	538	3570

In many tables, the following abbreviations will be used for the grasses –Arical: *A. calycina;* Ariram: *A. ramose*; Botdec: *B. decipiens;* Chrfal: *C. fallax;* Dicser: *D. sericeum;* Entram: *E. ramosus*

Pitted bluegrass (*B. decipiens*) plants were the most numerous and dark wiregrass (*A. calycina*) the least common (Table 6.17). This corresponds with their commonness in the local pasture and was closely aligned with the total crown area charted (Table 6.18). Total numbers of charted focal grasses remained relatively stable over time under a given management regime. Heavier defoliation was usually associated with greater numbers of these perennial grasses (Table 6.17), possibly because of greater crown disintegration or more frequent recruitment success in the more open sward produced by such management extremes. Greatest degree of change in numbers was in the high grazing pressure treatments and least in the ungrazed plots.

Charted crown area

At the first recording date, total cover charted and percent cover in the grazing trial was not significantly different in the various management regimes (Figure 6.94). However there was a smaller area of *A. calycina* and Qld Bluegrass charted than for the other 4 grasses (Table 6.18) because they are smaller-tufted plants naturally. Growing season rainfall appears to drive the growth of grasses in a predictable way, as did grazing pressure and tree management (Figures 6.93 & 6.94). As summer rainfall totals (October to March) increased after the drought, mean crown area also increased significantly (P<0.001) from about 5.5% to 9% but then a very dry, decile3 year in 2000 saw crown area of some grasses drop dramatically and overall crown cover fall significantly back to 8% in one year.

Table 6.18 Total crown area (cm^2) of charted plants of each focal species in each grazed treatment in June 1995.

Treatment	Grazing	Species *Arical*	*Ariram*	*Botdec*	*Chrfal*	*Dicser*	*Entram*	Treatment Total
Treeless	Low	487	3578	1661	2982	2193	5215	16116
	Moderate	864	4125	4415	2550	1711	3004	16669
	High	150	4208	3387	1624	1555	4127	15051
Treeless Totals		1501	11911	9463	7156	5459	12346	47836
Treed	Low	767	4719	2712	4690	482	2899	16270
	Moderate	691	3962	2579	2337	615	2634	12818
	High	546	2554	4587	3329	659	1858	13533
Treed Totals		2004	11235	9878	10356	1756	7391	42621
Species Total		3505	23146	19341	17512	7215	19737	90457

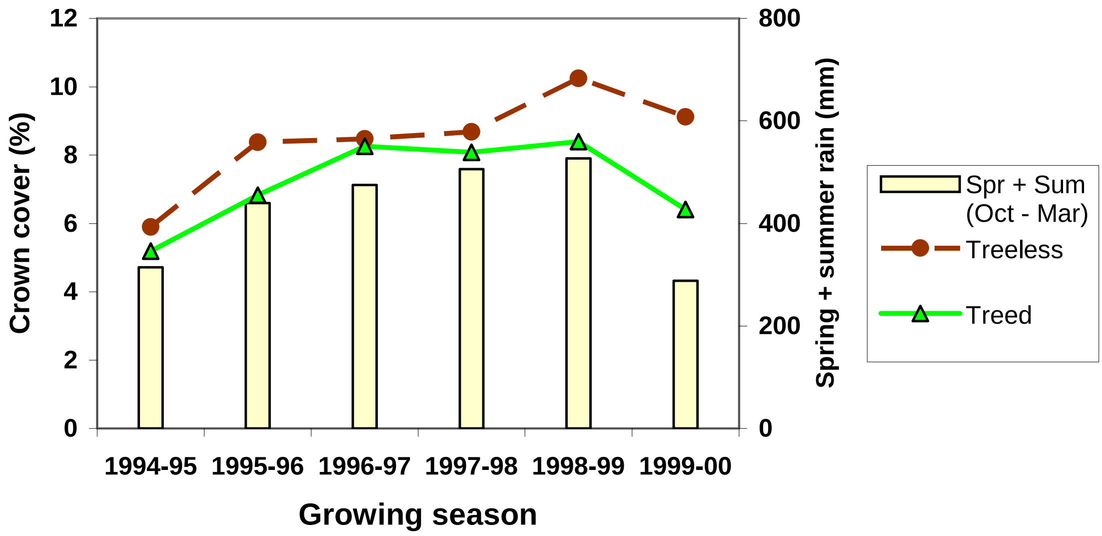


Figure 6.93 Grass crown area variations over time, related to tree killing and prior 'spring + summer' rainfall at the grazing trial.

Crown cover of perennial grasses is less when they grow beneath a significant tree canopy

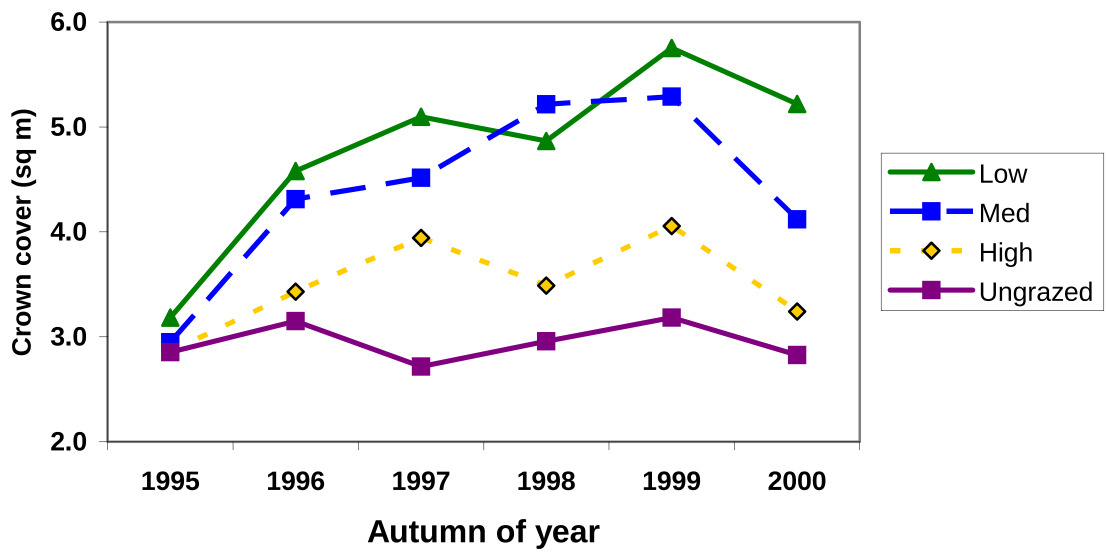


Figure 6.94 General change in crown cover of charted plants over time in the main grazing treatments.

However, for individual treatment combinations, this pattern was not consistent, eg. crown cover in Treeless-LG increased greatly from 1998 to 1999 while the Treed-LG treatment declined slightly. During other intervals, e.g. 1997-98, MG had an increase in crown area while the extremes either side, LG and HG, declined (Figure 6.94). Compared with the basal area data in the pasture composition chapter (Section 6.2.2.3), these values are relatively high because of the differing recording techniques, as explained in Section 6.2.1.4.13.2. Data from the nearby ungrazed, unburnt burning trial plots are included for comparison in some cases.

Crown cover percentage

Total crown cover of a grass species is the product of individual plant size and the number of plants. Both of these can vary over time in response to seasonal conditions and grazing management. Overall, total crown cover of the focus species under grazing increased as the annual (July–June) rainfall increased until 1999 and then the dry 1999-2000 year produced a significant decline (Figure 6.95). The correlation was even better if only spring (Oct-Dec) plus summer (Jan-Mar) rainfall was used (Figure 6.93). However, the overall pattern masks notable exceptions for individual species, and interactions between management and species, which will be discussed later. A full set of remaining graphs is presented in Appendix G.

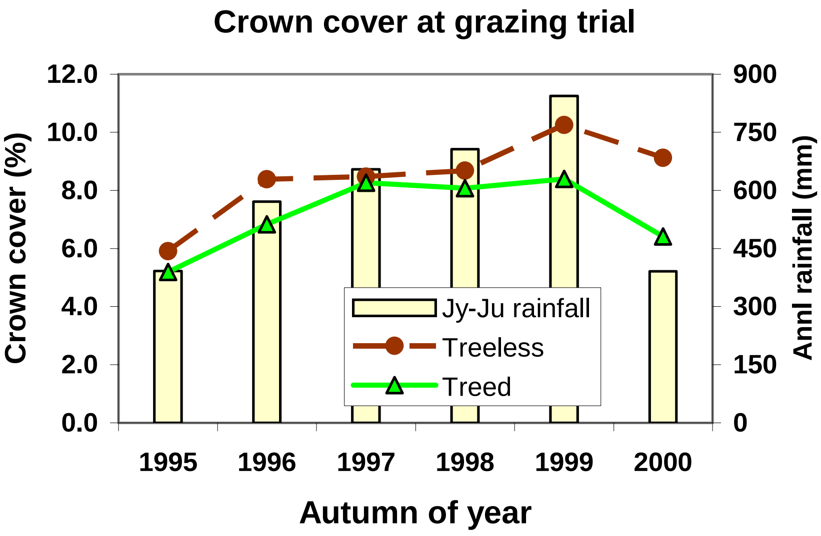


Figure 6.95 Annual Rainfall (July-June) effect on % crown cover by the 6 focal grasses under grazing

(compare with Figure 6.93, spring+ summer rain).

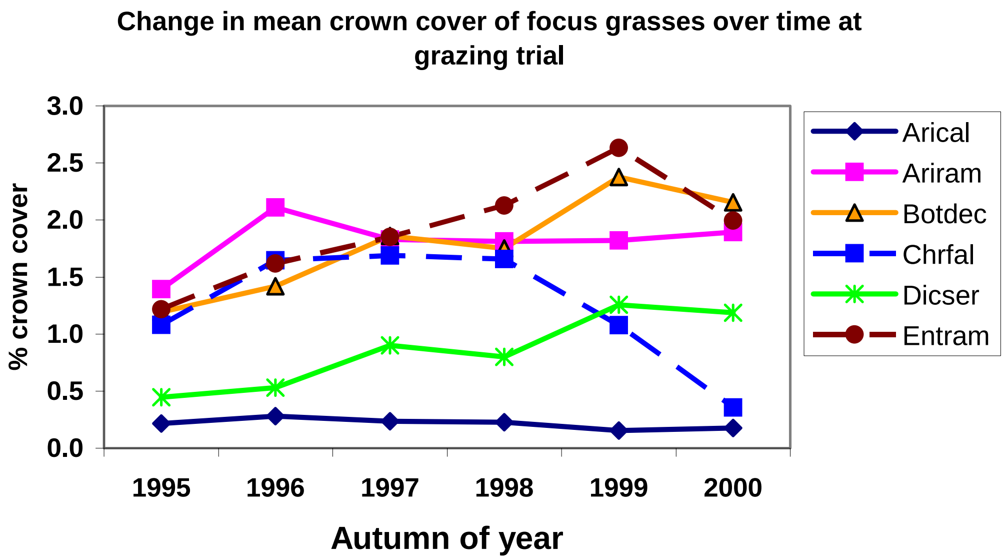


Figure 6.96 Mean crown cover (%) of each focal species in each year in the grazing trial.

The two wiregrasses reached a peak crown area in 1996 and then stabilised or fell away slightly (Figure 6.96) while the two bluegrasses continued to increase their area until the very dry 1999-2000 year. Twirly windmill likewise expanded steadily after the 1993 drought until the season of 1999-2000 caused a large drop in its crown area. Goldenbeard grass initially increased its crown size but that then fell away very rapidly after the 1998 autumn. This large overall fall was due to changes in the LOW and MED grazing pressure paddocks and could be caused by grass competition. The changes by goldenbeard grass under high grazing pressure were negligible or an increase over those last two years (Figure J in Appendix G) *albeit* from relatively low levels.

Tree effects

The immediate effect of killing the tree overstorey was not measured in this trial, - just the ongoing effect 9 to 12 months later and beyond. Overall the differences that existed after one year due to trees did not alter noticeably over time (Figure 6.95). This is in keeping with the total dry matter yield differences due to a poplar box woodland that occurred in all years at the site. Interactions of possible importance were for pitted bluegrass at high grazing pressure where it increased markedly beneath trees but did not change where the trees were not killed

Grazing pressure effects

The summed values for crown cover of the dominant perennial grasses range from 7 to 9%, which is a high cover compared to the paddock means for basal area, calculated from a point frame (Section 6.3). That is because the quadrats were deliberately chosen so as to contain plenty of healthy plants in as small an area as possible and because the point frame only scores living segments of a crown. However, relatively, they are in the same order as the more random paddock data, ie. lower under trees (Figure 6.95) and under high grazing pressure (Figure 6.97). When totalled to allow comparison of the main treatments, note how quickly the high grazing pressure mean splits away from the low and moderate grazing pressure crown area percentages after the first year (Figure 6.97).

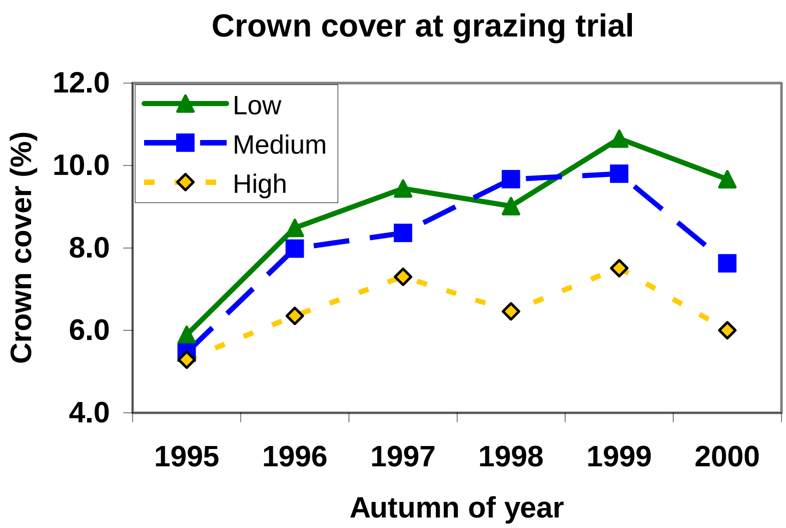


Figure 6.97 Changes in the crown area of focus grass species under differing grazing pressure.

Species differences in crown size

The average size of the crown of individual species differed. Table 6.19 shows the mean and median crown area of each species in the main grazed plots in the autumn of 1995 – 7.1 to 19.6cm^2 for the medians. Note the large mean but much lower median values for golden-beard grass and twirly windmill grass, and the associated large standard deviation. These two species had some very large plants, often over 100cm^2 crown area, especially in the LG treatment, compared to the rest. However, their mean crown area under grazing was much less – 26.5cm^2 for golden-beard and 36.7cm^2 for twirly windmill grass compared to 152 and 70cm^2 where ungrazed (Table 6.48).

Table 6.19 Mean crown area (cm^2) of the six focal species in the grazed treatments in June 1995.

	Arical	Ariram	Botdec	Chrfal	Dicser	Entram
Mean	**14.7**	**29.1**	**20.7**	**26.5**	**17.1**	**36.7**
Median	7.1	15.9	12.6	8.7	12.6	19.6
Std deviation	18.37	39.0	26.53	93.48	18.41	63.02
Mean LG	20.9	27.0	25.9	40.6	21.8	48.9
Mean MG	17.9	35.0	26.2	24.0	20.1	40.6
Mean HG	7.6	26.3	16.0	18.4	12.1	25.7

Grazing pressure had apparently produced noticeable differences in mean crown size of some perennial grasses within the first year, most notably in *A. calycina*, *C. fallax* and *E. ramosus* (Table 6.19). [There is the possibility that our sample selection unwittingly chose plants whose data gave the appearance of a grazing pressure effect on the meaned results.]

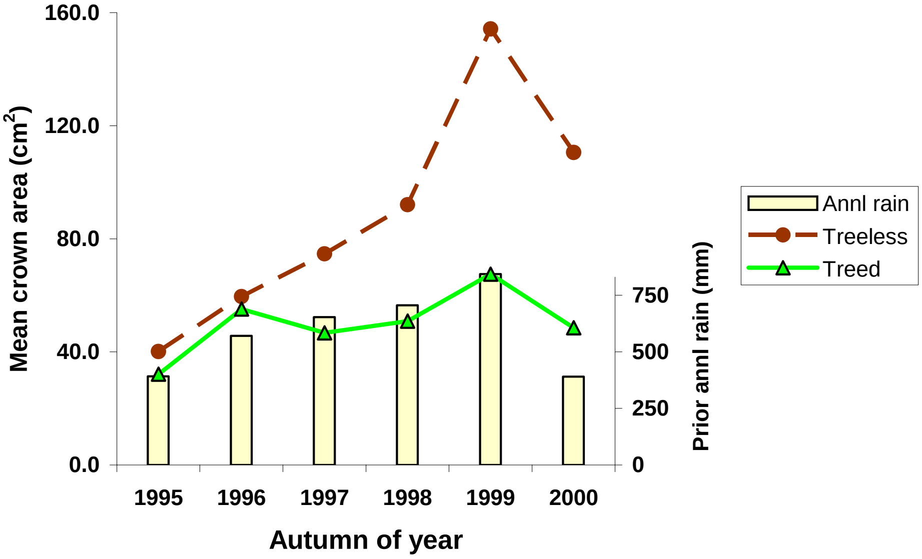


Figure 6.98 Effect of tree competition and annual rainfall on *E. ramosus* mean plant area under grazing conditions.

Over the ensuing years, the area of individual species fluctuated in response to seasonal rainfall in much the same way as the total crown area did. An example for *E. ramosus* is given in Figure 6.98 in the presence and absence of a tree overstorey. Killing trees in 1994 may have contributed to the steady increase in crown area after 1995, on top of the improved rainfall regime. The response of individual species will be dealt with under the major tree and grazing management sections ahead.

In summary, dark wiregrass (*A. calycina*) decreased in importance during the research period, purple wiregrass was little changed, pitted bluegrass and twirly windmill grass (*E. ramosus*) increased while golden beard grass and Qld bluegrass fluctuated markedly in response to seasonal conditions. A detailed summary of the likely statistical significance of most data analyses is given in Appendix N2.

Rainfall is a major pasture dynamics driver but individual species responses sometimes differ markedly in a particular year

Effect of tree cover

Removal of tree competition (5-7 m^2/ha) was associated with a significant ($P<0.001$) increase in grass crown area under grazing. Thereafter, response patterns changed in different ways for each main species. (Figures 6.98, 6.99, 6.100, 6.101 plus Appendix H).

Total crown area

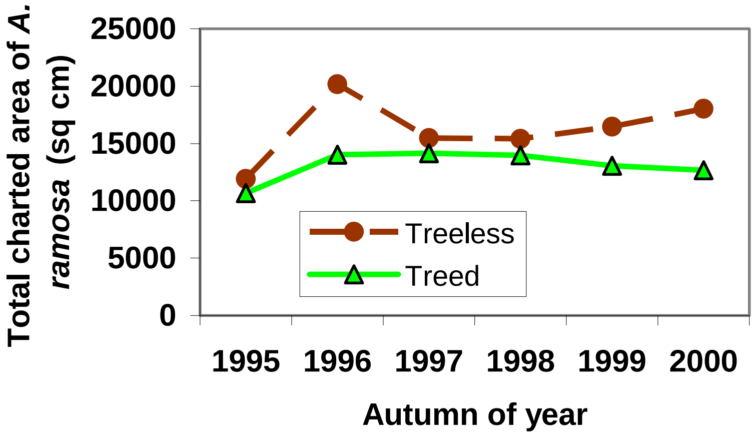


Figure 6.99 Effect over time of killing trees on the total charted crown area of *A. ramosa* plants in grazed paddocks.

Over the ensuing 5 years, the total area of *E. ramosus, A. ramosa,* and *D. sericeum* (Figures 6.98, 6.99 and 6.101) increased relatively more in the absence of trees than did similar plants under trees. The same did not occur for *A. calycina, B. decipiens* (Figure 6.100) and *C. fallax*. Hence, removal of tree cover, in itself, led to a change in pasture composition within a few years under grazed conditions (see also Section 6.2.1.4.2).

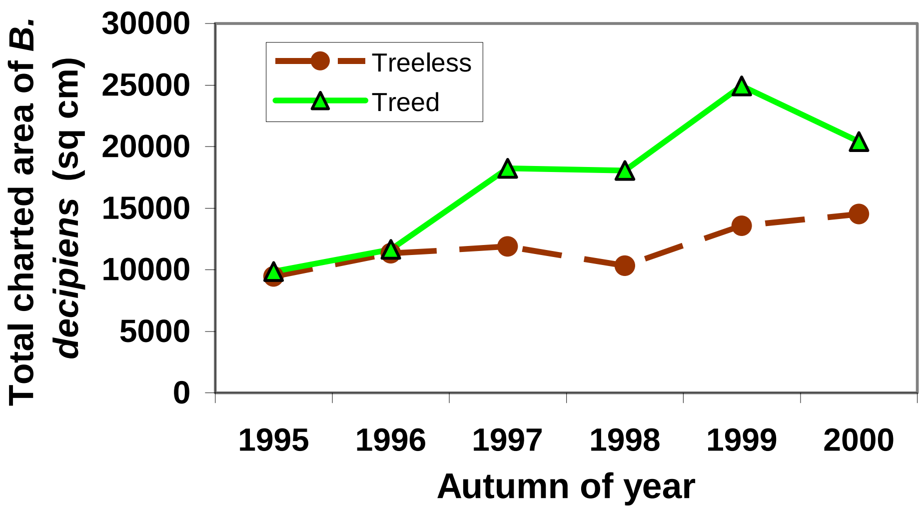


Figure 6.100 Tree effect on total charted crown area of *B. decipiens* in the grazing trial.

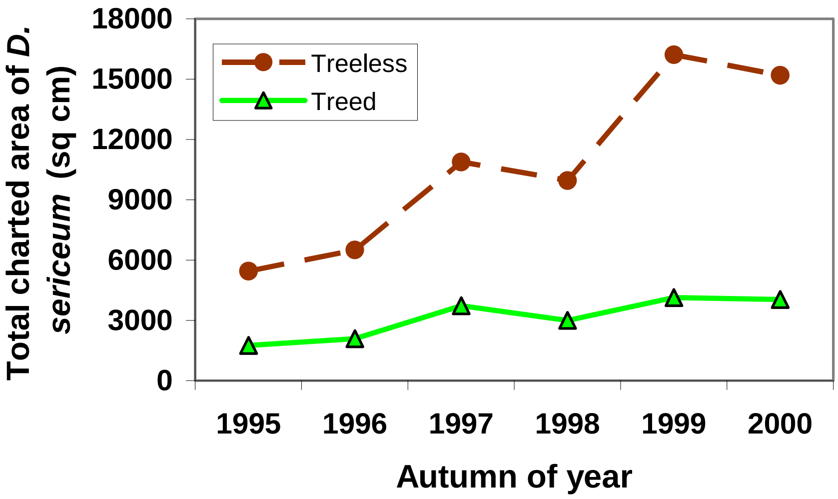


Figure 6.101 Effect over 5 years of sustained tree cover removal on total charted crown area of *D. sericeum* under grazing.

Mean crown area

Mean crown area of the focal species followed various patterns over time and in response to tree competition and management. Golden-beard grass (*C. fallax*) and twirly windmill grass tended to follow the rainfall, unaffected by tree competition, while such competition caused marked divergences in mean crown size at different times of Qld bluegrass (*D. sericeum*), pitted bluegrass (*B. decipiens*) and dark wiregrass. However, most of these converged again towards a similar crown size, irrespective of trees, by 2000 (Figure 6.103). Purple wiregrass (*A. ramosa*) differed in that it grew much larger in the absence of trees in the first few years and retained that difference to the end (Figure 6.102).

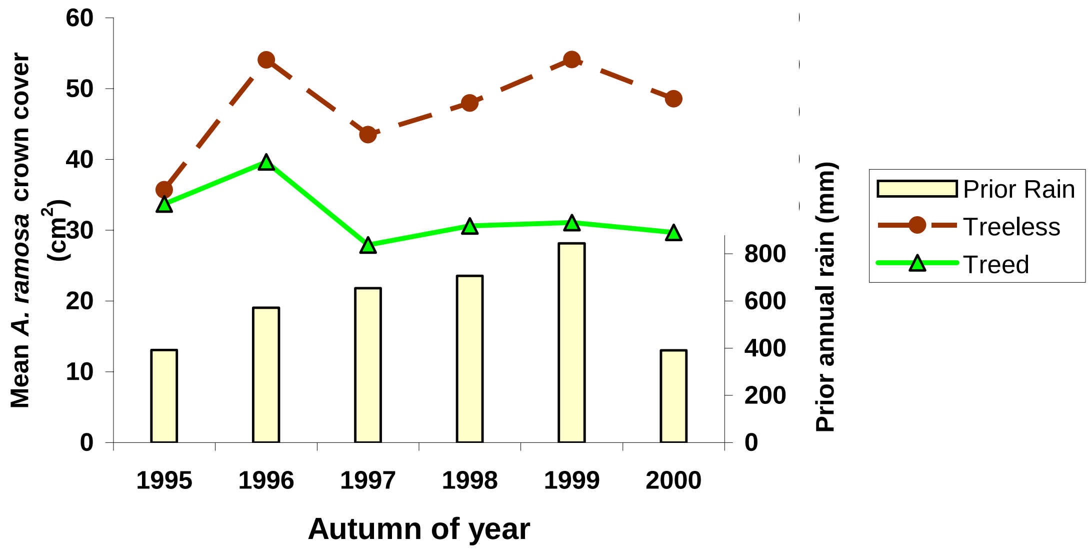


Figure 6.102 Mean crown area over time of *A. ramosa* under the influence of tree cover under grazing conditions.

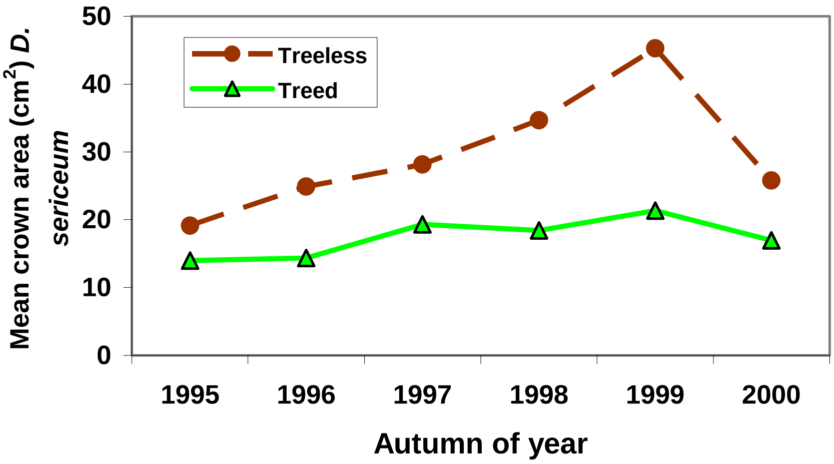


Figure 6.103 Mean crown area over time of *D. sericeum* under the influence of tree cover under grazing conditions.

Plant numbers

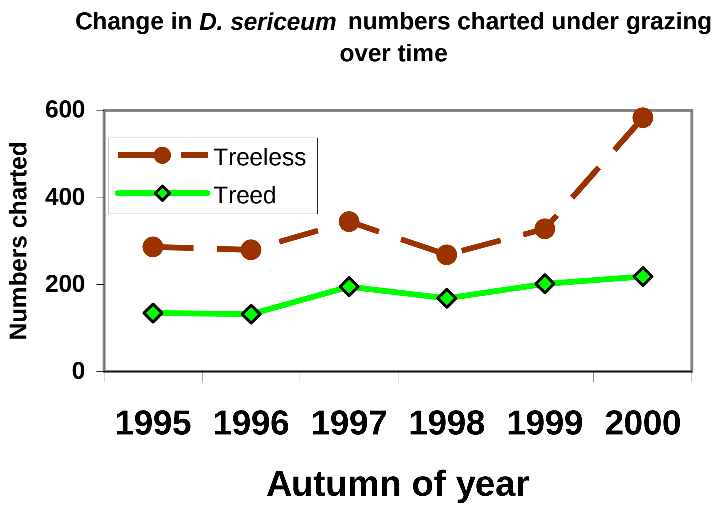


Figure 6.104 Changes over time in the number of Qld bluegrass (*D. sericeum*) plants in the grazed charted plots, as influenced by overstorey trees.

Total plant numbers in the charted areas tended to fall in the treeless plots over time but then in the 1999/2000 year they recovered to their original density. In the absence of trees, total numbers were relatively stable over the 6 years but always greater than in the areas charted under trees. In places where trees had been recently killed, there were initially many more plants of Qld bluegrass and twirly windmill grass than in similar plots under trees, but the opposite applied for the other 4 grasses. Relative plant numbers were generally not affected over time by tree cover but there was a steady decrease by purple wiregrass (Figure 6.105), twirly windmill and golden-beard grass and an increase under the trees by pitted bluegrass. Qld bluegrass displayed a large increase in numbers of its plants in treeless treatments in the 1999/2000 year (Figure 6.104) and this occurred when total pasture yield changed little (Section 6.2.1.4.2).

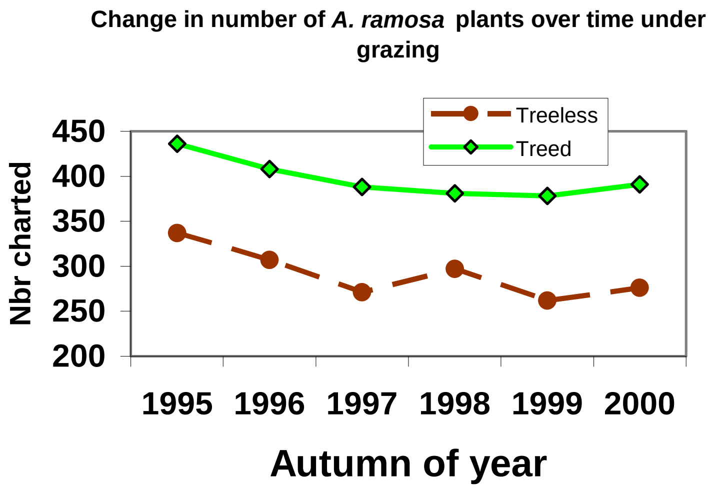


Figure 6.105 Influence of trees on the change in number of *A. ramosa* plants charted over time under grazing, in the fixed quadrat area.

Effect of grazing pressure

Total crown area

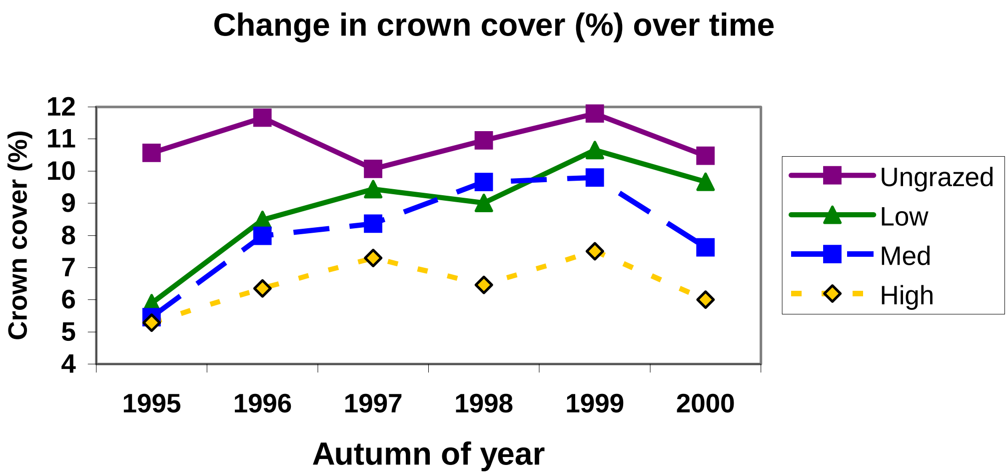


Figure 6.106 Effect of grazing pressure on changes in crown cover over time.

Under grazing, charted crown area increased from 5.5% to 10% of the ground available between autumn 1995 and 1999 at low and moderate grazing pressure (Figure 6.106) while reaching only 7.5% in the HG treatment from a similar starting cover. Crown cover dropped in all treatments between autumn 1999 and 2000 in that dry season, especially in the MG plots. The fall was much more than in the ungrazed plots. The data would suggest that a rapid change had occurred in crown cover during the first year of the experiment (1994/95), after the drought broke, where grazing was prevented (10% versus 5.5%). Thereafter, changes were slower under grazing but did occur in a manner that would be anticipated, ie. cover improved greatly in reasonable seasons under responsible grazing pressure but not under sustained heavy grazing. The drop in 2000 would indicate that the crown size attained by 1999 was not sustainable in lean seasons and the decline was proportional to the grazing pressure at the time.

Mean crown area

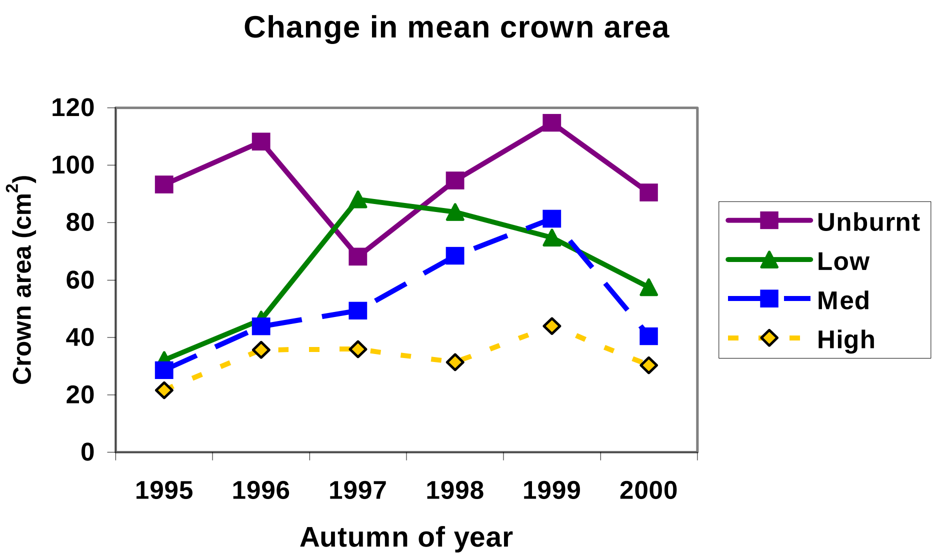


Figure 6.107 Changes over time in mean focal grass crown area under different grazing pressure.

Mean crown area for focus grasses in the main treatments was greater in 2000 from that of 1995, especially for the low grazing pressure plants (57cm^2 compared to 32 initially). During the intervening years, there were large changes between consecutive years in most treatments except the high grazing pressure one. Here the plants were never able to grow away from the intense grazing pressure, even in good seasons. When the dry 2000 season hit, the low grazing pressure paddock plants coped better than those under moderate grazing pressure in terms of crown size (Figure 6.107).

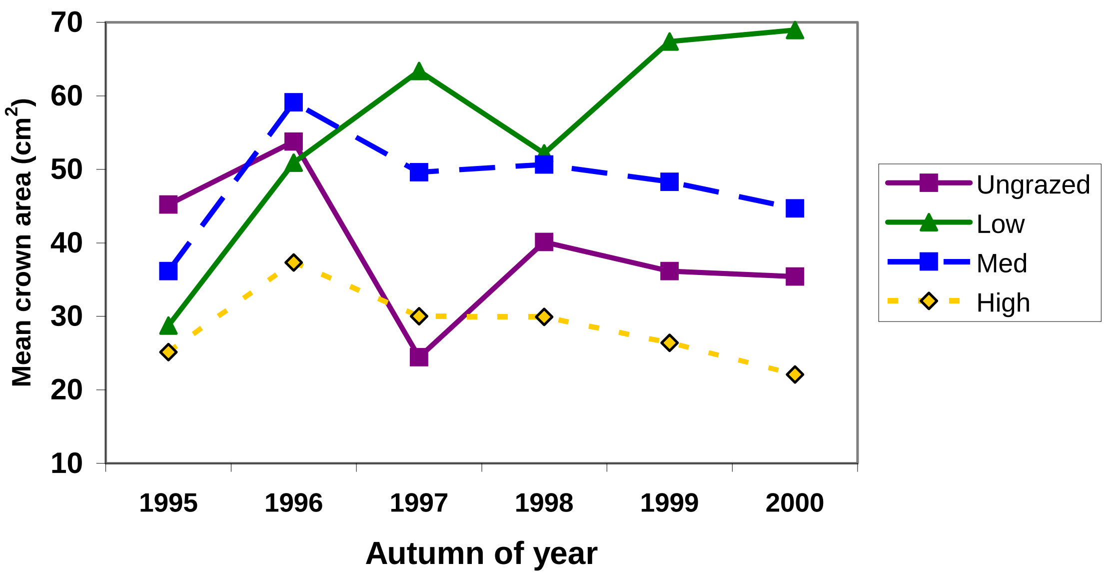


Figure 6.108 Changes over time in mean crown area of *A. ramosa* plants under different grazing pressure.

Grazing had least impact initially on the crown area of purple wiregrass (*A. ramosa*) (Table 6.19), probably because it is the least palatable and plants surviving the 1992-93 drought were already quite large. The mean crown size of its plants increased markedly in 1996 even where it was very heavily grazed (Figure 6.108). This is probably partly a result of the large areas of this species growing on the alluvial valley floor where conditions were right for healthy growth and where the cattle became very selective about where they grazed. Moderate grazing pressure did not control it, as Orr *et al.* (2004a) found.

Grazing pressure had no significant effect on *B. decipiens* plant size but it seems that, absence of grazing in the 1994-95 summer, allowed it to quickly develop larger crowns than were generally found in the grazing trial by the time the charting began in autumn 1995. Generally, the greater the grazing pressure, the smaller the crowns of this plant (Figure 6.109). Data from the ungrazed, unburnt burning trial plots are included for comparison against grazing by cattle.

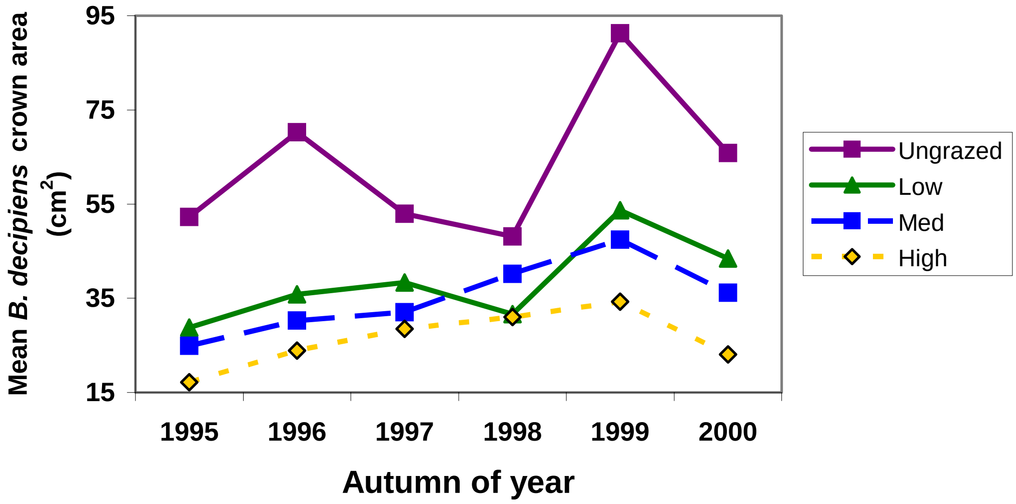


Figure 6.109 Effect over time of differing grazing pressure on mean crown size of *B. decipiens*.

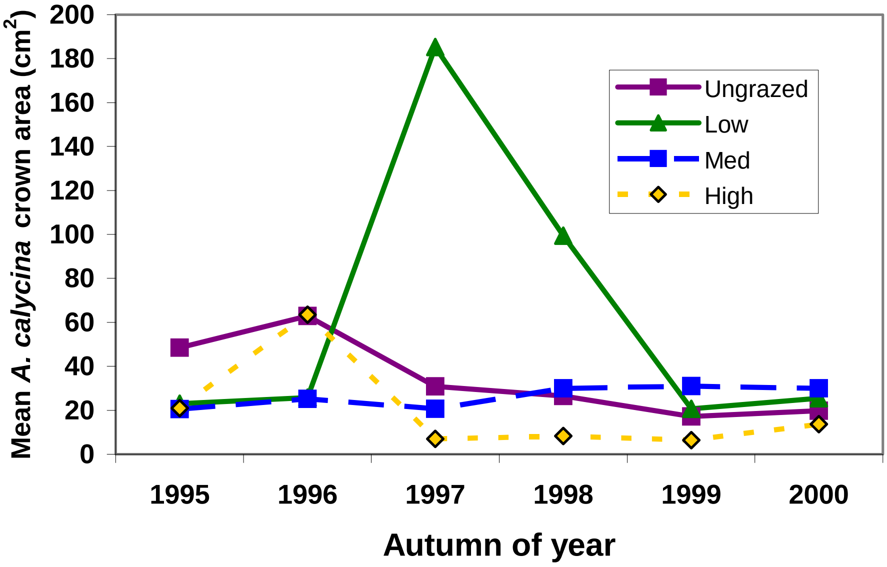


Figure 6.110 Mean crown area per plant for *A. calycina* over the years under differing grazing pressure.

Increased grazing pressure reduces the area of individual grass crowns

Consistent high grazing pressure also kept the crowns of *A. calycina* smaller than all other treatments. However, the means presented were greatly affected by the small number of these plants in some paddocks. As a result, the mean of the treeless, HG values was very high in 1997 and 1998 because there were no plants in rep 1 and the treeless, LG means were biased by 3 large plants and few if any others in one replicate (Figure 6.110).

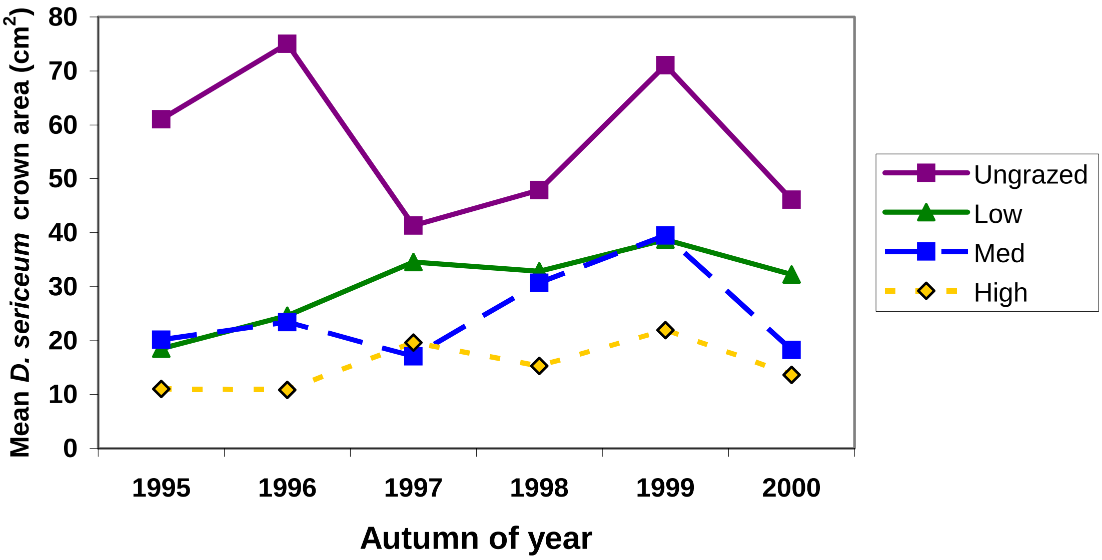


Figure 6.111 Changes in mean crown area of *D. sericeum* plants over time under differing grazing pressures.

Perennial grass species can differ in their response to management each year depending on population age structure and their natural recruitment patterns

Different grazing management had set up different mean plant sizes in *D. sericeum* by the end of the first summer of the trial and this difference remained virtually unchanged thereafter, except for short term changes induced by seasonal extremes at MG. Moderate and zero grazing pressure produced the greatest fluctuations in average crown size of Qld bluegrass. Absence of grazing meant crowns were much larger, 50-60cm^2 compared to 20-30cm^2 under grazing (Figure 6.111). Also plants under HG remained small at all times (generally below 20cm^2) and in good seasons (1996, 1998, 1999) their size was generally half that of those in the LG paddocks.

E. ramosus was sometimes difficult to record using the charting method we adopted. Very large plants may die out in the centre without clearly showing it under LG. Nonetheless they are easy to record under HG and after burning because the crown is clearly defined. Because it is not a very palatable species in summer, it grows quite rank and then is only grazed in winter in places where the stock already graze regularly and have kept smaller plants of it in a fairly leafy state. Figure 6.112 shows the pattern of change induced in this grass by differing grazing pressure. High grazing pressure restrained its crown development but in no way offered hope as a probable control measure in itself.

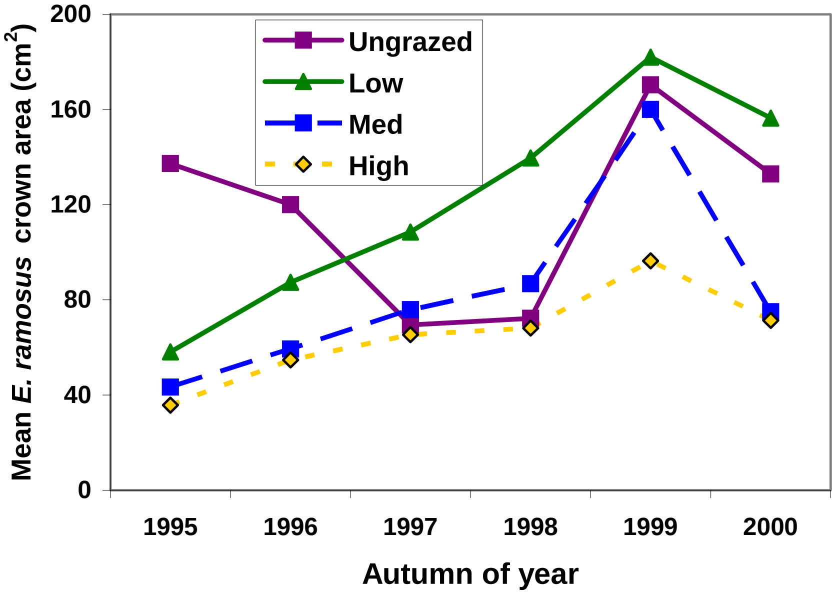


Figure 6.112 Effect of differing grazing pressure on the mean crown area of *E. ramosus* plants over time.

It was very tedious and difficult to differentiate the discreet crown segments of the strongly rhizomatous golden-beard grass. Hence its general crown position was often circumscribed and a basal area proportion assigned visually by the charter. This proportion can easily be overestimated and that is thought to have happened sometimes. From a practical management perspective, the ground beneath such a sward of grass is very stable and very few other perennial species penetrate into such well-colonised soil (Wandera 1993). Hence mean plant areas of 200 to 300cm^2 are feasible, but so are ones in the 20-30cm^2 range where grazing pressure is intense. It was common to have no aboveground sign of defoliated plants for much of the year, particularly in a dry autumn such as in 2000.

Plant numbers

Plant numbers did not change radically in response to grazing management but virtually all treatments had an increase in numbers over the 1999/2000 growing season (Figure 6.113). Numbers tended to drop in the early years in many treatments but that trend disguised great variation amongst individual species, especially in 1997. The drop was reinforced by a shift in charting technique for *C. fallax* after the first 2 years, as discussed before.

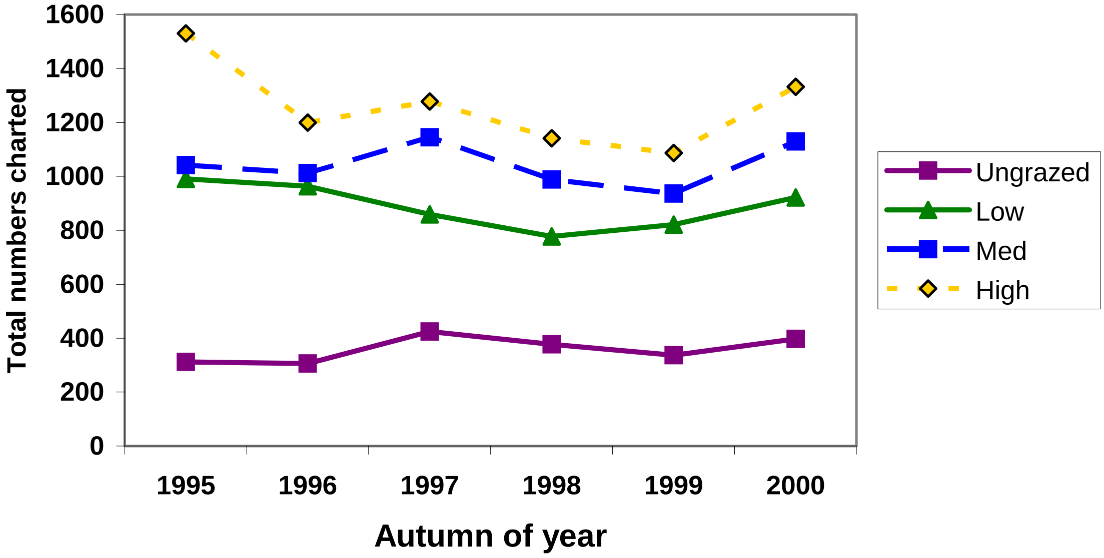


Figure 6.113 Grazing pressure effects on total perennial focal grass plant numbers over time at the poplar box site.

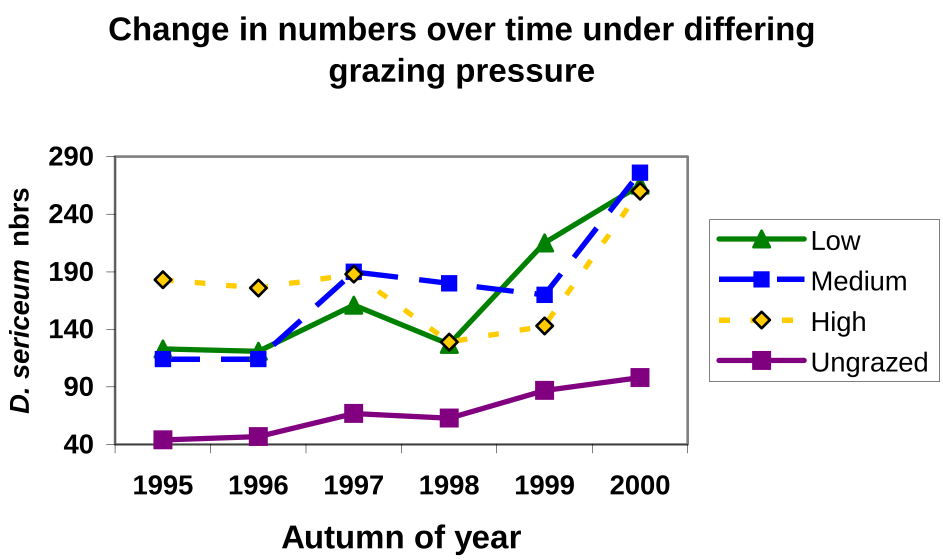


Figure 6.114 Change in numbers of *D. sericeum* plants in the charted area over time under differing grazing pressure.

The increase in plant numbers was particularly marked in Qld bluegrass (Figure 6.114) and occurred in 1999 as well as 2000 in lightly grazed pastures.

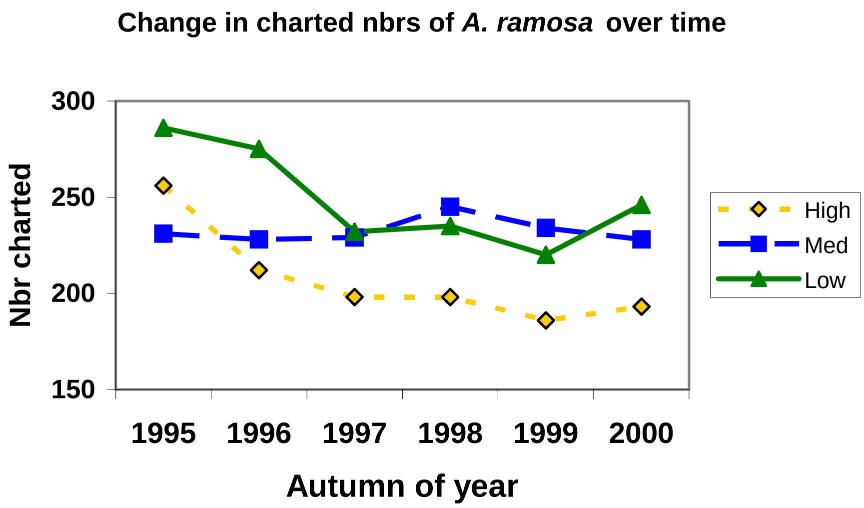


Figure 6.115 Change over time in numbers of *A. ramosa* plants existing in the charted quadrats under different grazing pressures.

A. calycina numbers were not stable and, apart from high grazing pressure under trees, often declined markedly after 1997. In contrast the *B.decipiens* numbers were stable with a tendency to increase over time. Numbers of *A. ramosa* (Figure 6.115) and *E. ramosus* were fairly stable while those of *D. sericeum* fluctuated in response to the interacting effects of seasons and grazing management (Figure 6.114). There was a major recruitment over the 1999/2000 summer in the grazed paddocks, irrespective of grazing pressure.

Over 5 years, seasonal conditions had a bigger influence on population sizes of the major perennial grasses than did grazing management as diverse as no grazing and heavy grazing.

Seasonal rainfall produces more rapid shifts in perennial grass populations than grazing pressure extremes

Effect of exclosure from grazing

Total crown area

Total crown area per square metre of the focal species was consistently lower in the grazed plots over the 5 years, with an average of 83% of that for ungrazed plots. The average charted crown area was 7.8% of the ground over all the grazed pastures compared to 9.4% for the ungrazed ones. The maximum discrepancy was recorded in the first year at 63% of the ungrazed while the minimum was at 99% of the ungrazed pastures in 1997. Because the charted areas were selected for having a good coverage of focus grasses, their overall basal cover was automatically greater than a mean calculated from point frame sampling along fixed transects that cross bare areas.

Mean crown area

In general, the size of individual grass crowns under grazing was smaller (35-50cm^2) than those in the ungrazed trial area (average about 80cm^2), even when spring burning was included in the calculations (Figure 6.116). The big drop in 1997 in the ungrazed mean was largely due to a fall in the size of the ungrazed *A. ramosa*. Standard deviation of each mean was high with the Coefficient of Variation ranging between 161 and 392% for ungrazed plants and between 177 and 252% for grazed plants in any year.

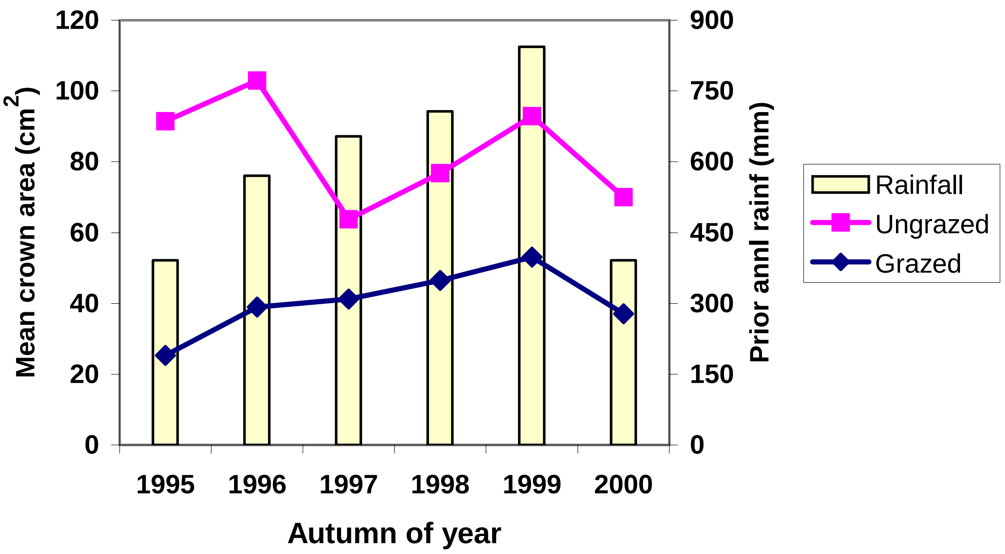


Figure 6.116 Difference between grazed and ungrazed grasses in mean crown area over time.

Plant numbers

On average, the grazed plots had a greater number of plants per square metre than those in the ungrazed plots, 24.2 compared to 14.4 averaged over the 6 recording dates (Table 6.20). The difference was initially 98% but fell to as low as 41% in 1998, for an average advantage of 69%. This probably reflects the way grazing breaks up crowns more than would occur through burning or natural attrition, as well as enabling extra recruits to establish in a more open pasture canopy in some cases.

Table 6.20 Mean number of plants / sq metre of the focal species each year in grazed versus ungrazed conditions.

	Year						
	1995	**1996**	**1997**	**1998**	**1999**	**2000**	**Mean**
Grazed	29.0	24.0	24.9	22.0	21.5	25.6	24.2
Ungrazed	13.6	13.1	15.8	15.6	12.7	15.4	14.4

Grazing reduces mean crown size of grasses but there are more plants per square metre unless grazing pressure is extreme

Interaction of grazing and tree cover

Under grazing, individual crowns were mostly much smaller, especially of the more palatable species like *D. sericeum* and *C. fallax* (Table 6.21). Tree competition tended to result in grass tussocks that were slightly smaller under grazing but the size of such differences was dependent on the grass species. This difference due to trees was more consistent under grazing (Table 6.21) but was contradicted by *C. fallax*. In the absence of grazing, only *E. ramosus* had larger crowns after the trees were killed but this was based on a total of 5-8 plants in treed plots. A few large plants skewed these results in the case of *C. fallax* and small numbers exaggerated the difference for the mean of the ungrazed *E. ramosus* plants.

Table 6.21 Average plant crown area (cm^2) at the end of each summer's grazing compared to ungrazed plots (mean of burnt and unburnt) and the effect of killing trees before the trials.

Treatment		Species						Treatment Mean
		Aristida calycina	*Aristida ramosa*	*Bothriochloa decipiens*	*Chrysopogon fallax*	*Dichanthium sericeum*	*Enteropogon ramosus*	
Ungrazed								
	Treeless	29.8	37.8	64.5	210.7	58.7	56.2	79.2
	Treed	26.2	31.8	46.8	149.5	42.1	182.6	53.8
Grazed								
	Treeless	28.0	56.4	33.1	66.7	31.1	88.6	48.8y
	Treed	12.7	33.5	28.1	71.0	17.5	50.3	33.7x
Species	**mean**	23.1	30.7	25.2	48.4	22.3	38.4	

Treatment means for tree cover were significantly different (P<0.001) in grazed paddocks. Interestingly, the mean plant size of ungrazed *A. ramosa* was much less than for grazed plants in the absence of tree competition. The size difference (and the *E. ramosus* aberration) was quite consistent between years despite the ongoing recruitment of new plants and death of older ones.

Population fluxes

Numbers of plants

As Table 6.17 showed, charted plant numbers in the fixed quadrats initially varied quite a lot for each species and treatment and they continued to vary as time progressed. The data is available on the project CD for each species in the various treatments. There was always a sizeable number of most species at all times with the average density of focal plants ranging between 3.0 and 10.8 per square metre for pitted bluegrass (depending on treatment) down to 0.4 to 4.0 m^{-2} for twirly windmill grass.

Each year a number of newly established plants was recorded and, because they are known to be young, they may respond to management somewhat differently to the initial 1995 population which included plants of varying age at the time.

Table 6.22 Number of recruits under differing grazing pressure each year in the grazing trial.

	Year						Total
Management	**1995***	**1996**	**1997**	**1998**	**1999**	**2000**	recruits
Low	994	n.d.	344	108	220	159	842
Moderate	1044	n.d.	521	150	152	263	1092
High	1532	n.d.	458	261	223	358	1307
No trees	1691	n.d.	615	274	307	512	1721
Treed	1879	n.d.	708	245	288	268	1520
Year totals	3570	n.d.	1323	519	595	780	3241

* = original plants of variable age; n.a. = no data

Very few new plants were charted in 1996 in the grazing trial, 24 in total, due to a different and ultimately unsatisfactory way of re-recording each quadrat that was used by the project team that year. Most new ones since autumn 1995 were picked up in the 1997 charting which thus includes the remainder of the 1996 cohort plus the 1997 one. Hence the total number of new plants in 1997 is about double that of each of the subsequent three years. Table 6.22 shows the count of newly recorded plants for each main management type in each year from 1996 to 2000, as well as the original numbers. Hereafter, each is said to be a member of a cohort, ie. Cohort95, Cohort97 etc.

By the end of 5 years, there had been many more recruits in total in the more heavily grazed pastures (except for *E. ramosus*) and tree cover had a minor, but inconsistent effect on grass recruitment. For individual species (Table 6.23) the cumulative rate of recruitment was greatest at 237% of the initial population for Qld bluegrass and least for golden-beard grass, at 28%. That equates to an average of almost 50% renewal per year for the bluegrass and only 6% per annum for golden-beard grass. At 8% for twirly windmill grass, it also had a low inherent recruitment rate. Such renewal rates fit nicely our perceived longevity of these plants. Grazing pressure only had an effect on the recruitment of dark wiregrass and pitted bluegrass– 3.5 versus 9.1 seedlings/sq metre over 5 years for pitted bluegrass (Table 6.24).

Table 6.23 Numbers of recruits recorded of each focus species each year in the grazing trial.

	Year						Total	% of orig.
Species	**1995***	**1996**	**1997**	**1998**	**1999**	**2000**	**recruits**	**population**
A. calycina	239	n.d.	138	44	44	50	276	115%
A. ramosa	775	n.d.	173	116	111	102	507	65%
Aristida sp.	54	n.d.	17	29	10	9	65	n.a.
B. decipiens	934	n.d.	467	146	200	242	1064	114%
C. fallax	662	n.d.	108	36	17	20	186	28%
D. sericeum	422	n.d.	334	123	203	337	1000	237%
E. ramosus	538	n.d.	103	54	20	29	208	39%
Focal species Total		n.d.	1323	519	595	780	3241	

Note: Unidentifiable *Aristida* species are included. * = original plants in plots

D. sericeum has a relatively high seedling recruitment rate while _E. ramosus_ has a low rate under grazing

Table 6.24 Mean density/sq m of successful seedling recruits under grazing over 5 years for the 6 focus grasses.

	A. calycina	***A. ramosa***	***B. decipiens***	***C. fallax***	***D. sericeum***	***E. ramosus***
Grazing pressure						
Low	0.9	2.9	3.5	1.2	6.0	1.1
Medium	1.1	3.3	7.1	1.3	5.9	1.4
High	3.1	3.1	9.1	0.9	6.6	1.4
Tree cover						
Treeless	0.8	3.0	6.1	1.0	8.9	1.5
Treed	2.6	3.3	6.6	1.3	3.4	1.1
Mean	**1.7**	**3.1**	**6.6**	**1.1**	**6.2**	**1.3**

Individual cohort recruits

Cohort95

Table 6.25 shows that *B. decipiens* and *A. ramosa* were the most numerous species of this cohort in the charted quadrats and *A. calycina* the least. Those numbers reflect their relative frequency in the original pastures in most treatments (Table 6.15) despite the quadrats being positioned so as to specifically sample the six focus species. Number of *C. fallax* plants was proportionately lower than its initial frequency (27%) while that of *A. ramosa* was higher than the mean of all paddocks (10%).

Table 6.25 Percentage of each cohort contributed by each focal grass species under grazed conditions.

Species	Originals 1995*	Recruit Cohort 1997	1998	1999	2000
A. calycina	6.7	10.4	8.5	7.4	6.4
A. ramosa	21.7	13.1	22.4	18.7	13.1
B. decipiens	26.2	35.3	28.1	33.6	31.0
C. fallax	18.5	8.2	6.9	2.9	2.6
D. sericeum	11.8	25.2	23.7	34.1	43.2
E. ramosus	15.1	7.8	10.4	3.4	3.7

* This is the original charted population, so is not an aged-based cohort like the others

Cohort97

As in most years, there were many new recruits in the 1996/97 year, with greatest numbers coming from pitted bluegrass and least from twirly windmill grass (Figure 6.117). Tree cover usually slightly reduced recruitment each cohort (Table 6.26), but not in this cohort (which was a combination of two growing seasons). However, the variability amongst reps and quadrat sets was too great to achieve statistical significance (P<0.05) for differences between the means in any cohort.

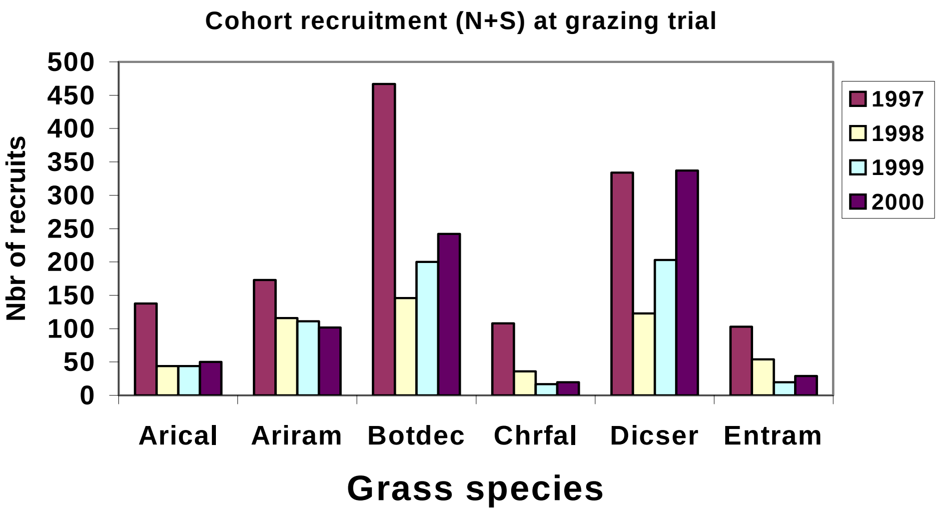


Figure 6.117 Recruits recorded in each cohort in the grazing trial, by species.

Low grazing pressure resulted in slightly less recruitment than under higher pressure. Maximal annual recruitment was at HG with 6.6 new plants recorded per square metre in autumn 2000 (Table 6.26) and the trend applied to all species except *A. calycina.*

Table 6.26 Density of recruits in each cohort in the main grazing treatments, compared to the original density per square metre in 1995.

Management	Cohort 1995*	1997	1998	1999	2000	Mean
Low grazing pressure	18.4	6.4	2.0	4.1	2.9	3.1
Med grazing pressure	19.3	9.6	2.8	2.8	4.9	4.0
High grazing pressure	28.4	8.5	4.8	4.1	6.6	4.8
Treeless	20.7	7.6	3.4	3.8	6.3	4.3
Treed	23.0	8.7	3.0	3.6	3.3	3.8

* Original population

Cohort98

Between autumn 1997 and 1998, there were slightly fewer recruits under trees. Recruitment under LG was generally less than in MG and much less than in HG paddocks (Table 6.26). Twice as many new recruits were found under HG compared to the two lower rates and the trend was consistent across all six species (data not shown). However, only for pitted bluegrass was the effect statistically significant (P<0.05). On average, there were fewer recruits under grazing than in its absence (Section 6.2.2.4.12.4).

The main recruiting grasses were the dominant ones in the pasture, pitted bluegrass, purple wiregrass and Qld bluegrass.

**Recruitment rates increased under heavy grazing pressure.
This assists to overcome the associated decline
in individual crown area**

Cohort99

After the wet 1998 winter and the relatively wet 1999 summer, recruitment was not exceptionally high, averaging just under 4 new perennial grasses per square metre. Tree cover had a negligible effect overall, and MG paddocks had considerably fewer recruits in total (Table 6.26). However, there were noticeable differences due to trees and grazing for individual species. Under trees, *A. calycina* had 36 new recruits vs. 8 in the treeless areas while the opposite applied for *D. sericeum* (140 where cleared vs. 63 where trees remained). *B. decipiens* established significantly more plants under HG (113 vs. 31 under low, P<0.05) while the reverse applied for *D. sericeum* (113 vs. 46) but this was not a statistically significant difference.

Cohort00

Tree cover reduced the numbers of new grasses establishing, but grazing pressure had the significant effect of reducing competition, thus allowing increased numbers of recruits as grazing pressure increased (Table 6.26). The grazing pressure effect was general across all 6 species, in particular for *A. calycina* and pitted bluegrass (116 plants at high vs. 29 at low pressure P<0.05).

The relative proportion of each species in the total cohort did not differ much from similar data for earlier years except for *C. fallax,* which had declined steadily, and *D. sericeum* which increased steadily in most years (Table 6.25).

Plant density

Recruitment numbers can be also expressed as density per square metre to allow comparison with other pasture communities. The original density is probably higher than the paddock average because each location was selected so that it had plenty of plants of the focus grasses in them. Bare areas were excluded whereas they do contribute to a paddock mean. However the recruitment density may be more representative because this would be lowered by competition from the good cover of existing perennial grasses at the quadrat sites. In general these pastures were recruiting, each year, between 2 and 10 established perennial grasses per square metre (Tables 6.26). It is not appropriate to read anything into the initial relative densities of the grasses because they were not a random or representative sample of the whole paddock or treatment. Only subsequent data is truly comparable for the treatment effects.

Average plant size under differing management

It would be expected that the crowns of recent grass cohorts would, on average, be smaller than that of older, well grown cohorts prior to their inevitable decline in old age (Orr et al. 2004b).

That decline stage would be species-dependent and in some cases occurs as a fragmentation of a large crown rather than near-simultaneous death of all tillers of the plant.

Crown area of pitted bluegrass averaged 40cm^2 at its peak in 1999. However, the mean crown area of Cohort97, Cohort98 and Cohort99 was smaller than this (Table 6.27) and much smaller than that of Cohort95 in the same year. If only those plants which persisted for the whole recording period are considered, their mean crown area in 1999 was bigger still at 66cm^2 and there were still a large number of them alive (345, Table 6.28).

Table 6.27 Annual variation in mean plant crown area of survivors from successive grass cohorts in the grazing trial.

		Autumn of year				
Species	**Cohort**	**1995**	**1997**	**1998**	**1999**	**2000**
A. ramosa	*1995**	*29.1* (1040)	*61.5* (648)	*59.1* (608)	*58.7* (512)	*57.8* (496)
	1997		17.4 (174)	26.7 (107)	32.0 (85)	52.8 (76)
	1998			14.6 (116)	19.8 (55)	36.0 (49)
	1999				18.6 (111)	29.1 (58)
	2000					13.7 (102)
B. decipiens	*1995**	*20.7* (1218)	*41.3* (794)	*43.1* (666)	*56.5* (577)	*40.5* (594)
	1997		16.4 (473)	22.6 (246)	31.7 (235)	29.5 (212)
	1998			15.3 (147)	27.0 (80)	25.6 (70)
	1999				17.1 (201)	19.4 (133)
	2000					16.4 (242)
D. sericeum	*1995**	*17.1* (553)	*42.9* (263)	*41.5* (207)	*45.6* (167)	*36.6* (158)
	1997		17.4 (341)	28.2 (171)	52.5 (150)	38.5 (137)
	1998			18.3 (125)	44.2 (60)	25.4 (65)
	1999				24.1 (204)	27.1 (138)
	2000					12.4 (337)

Numbers in parenthesis are the number of crowns from which each mean area was calculated.
[* = original multi-aged population]

The importance of plant age and source cohort varies with time and species but, generally, for some years after recruitment crown size of cohort members increased before declining.

Table 6.28 Mean crown area (cm^2) each year of recruits from sequential cohorts of key perennial grasses that survived until June 2000 under grazing.

			Autumn of year				
Species	**Cohort**	**Nbr†**	**1995**	**1997**	**1998**	**1999**	**2000**
A. ramosa	*1995**	*335*	*45.2*	*76.9*	*73.2*	*64.3*	*62.2*
	1997	54		21.5	31.1	37.4	53.8
	1998	39			15.1	21.3	39.1
	1999	58				17.8	25.3
	2000	102					14.3
B. decipiens	*1995**	*345*	*32.7*	*53.3*	*50.0*	*66.3*	*46.6*
	1997	133		19.4	25.7	35.0	35.1
	1998	58			24.4	53.3	41.5
	1999	131				21.8	23.1
	2000	242					16.0
D. sericeum	*1995**	*68*	*27.7*	*42.3*	*43.9*	*60.8*	*39.8*
	1997	78		24.7	38.5	63.3	42.5
	1998	42			18.9	57.5	39.9
	1999	138				39.4	29.3
	2000	337					12.3

[† = number of plants contributing to the means]

Mean crown size at first charting was about 20cm^2 and the area of the perenniating plants increased in the first few years normally. However, seasonal conditions could override this natural tendency and that was very evident between the 1999 and 2000 recordings. Many cohorts lost crown area that year and, in general, the unpalatable *A. ramosa* did not, the palatable Qld bluegrass did (Table 6.28), while the seasonally unpalatable pitted bluegrass remained stable in plant size. The wiregrass was initially slower to increase the size of its crown while those of Qld bluegrass grew fastest, especially in the wet 1998-99 year (Table 6.28). Recruiting plant numbers of *C. fallax*, *E. ramosus* and *A. calycina* were insufficient to allow similar meaningful comparisons.

Table 6.29 Effect of grazing regime on mean grass crown area (cm^2) at first recording.

Species	Cohort	Grazing pressure Low	Medium	High
A. ramosa	1998	21.9	13.8	10.5
	1999	34.7	8.0	10.2
	2000	52.6	31.3	13.4
B. decipiens	1998	25.4	18.3	11.3
	1999	29.9	17.3	13.5
	2000	54.6	38.4	19.5
D. sericeum	1998	14.3	26.7	13.4
	1999	29.4	17.3	17.6
	2000	31.1	22.3	21.9
Mean	**3 years**	**32.7**	**21.5**	**14.6**

Cohort differences

When new plants were recorded at the end of a summer, their initial size was proportional to the grazing regime that they had grown under. An example set is shown for three autumn cohorts in Table 6.29. Qld bluegrass in the 1997/98 year was an exception that may be due to the time of recruitment (late) compared to most other years and species.

Losses each year

Tree effects

The presence of trees made no appreciable difference to the number of plants that were lost each year but there were significant differences in total loss rates amongst years (Table 6.30). Relatively few plants were lost during 1995/96 and 1999/2000. The relatively dry 1999/2000 year did not seem to increase the rate of death of species above what seems to be the normal exponential loss rate over time (Figure 6.118).

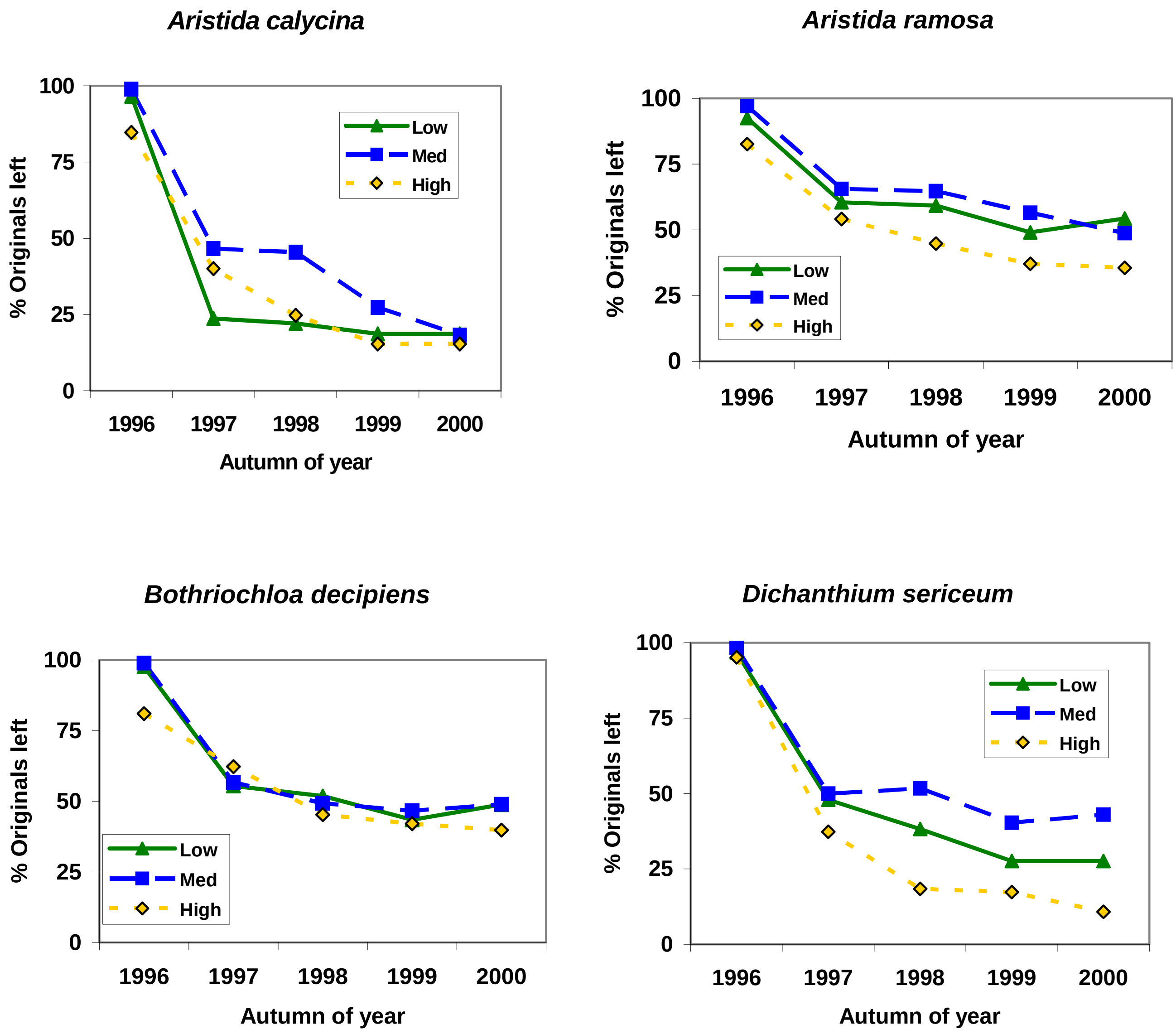


Figure 6.118 Decline in the population of the original plants under the effect of differing grazing regimes.

Grazing pressure effects

Loss rates recorded amongst grasses were higher in the ungrazed plots (1.55 times 1995 numbers) than grazed plots (mean 1.27 times). This seems unusual but is possibly explained if grazing removes more susceptible plants early, before our recording system included them as established plants. Average loss rates were also not significantly different amongst the 3 grazing pressures, which would suggest that the effect of grazing pressure was established very quickly in the 1994/95 summer before the first charting was done. However, losses were numerically quite consistently higher under HG (Table 6.31), especially for Qld bluegrass (Figure 6.118).

For individual species, the relative loss rates were as expected, except for *C. fallax* which was higher than expected because we tended to aggregate adjacent tufts in later years once we knew they most likely came from the same set of rhizomes. Loss rates over 5 years were highest for Qld Bluegrass (1.9 times the original numbers) and lowest for twirly windmill grass (0.87) (Table 6.30) with *A. calycina* also having a relatively high loss rate overall.

Table 6.30 Numbers of charted plants of each focal grass species that were lost each year from the grazing trial.

Species	Year						Grand Total	Losses / Orig nbr
	1995*	**1996**	**1997**	**1998**	**1999**	**2000**		
Arical	*239*	15	123	87	110	41	376	1.57
Ariram	*775*	69	265	152	200	142	828	1.07
Botdec	*934*	106	287	380	240	192	1205	1.29
Chrfal	*662*	146	347	156	132	74	855	1.29
Dicser	*422*	15	215	247	176	148	801	1.90
Entram	*538*	82	108	86	131	61	468	0.87
Grand Total	*3570*	433	1345	1108	989	658	4533	

[* original numbers charted]

Table 6.31 Numbers of plants lost each year under different grazing regimes

Management	1995 originals	Year						Losses / Orig nbr
		1996	**1997**	**1998**	**1999**	**2000**	**Total lost**	
Low	*994*	44	477	256	279	173	1229	1.24
Moderate	*1044*	39	424	354	302	196	1315	1.26
High	*1532*	350	444	498	408	289	1989	1.30
Year totals	*3570*	433	1345	1108	989	658	4533	

Loss rates were relatively high in the 1997/98 and 1998/99 years (Table 6.31). Over the 5 years, losses exceeded gains from new recruits in the grazing trial for these 6 grasses (Table 6.22). For the individual species, the bigger loss for *C. fallax* has been explained before and Qld bluegrass had a good recruitment period in the wet middle years, especially with the wet 1998 winter. The two wiregrasses lost more plants than they recruited while pitted bluegrass populations held steady overall, with counter-balancing annual fluctuations (Table 6.23 compared to Table 6.30). The overall fluidity of the perennial grass populations is clearly shown by this data. This means that grazing management and seasonal extremes are potentially able to shift pasture composition at any time.

Table 6.32 Gain (%) by survivors over prior area, crown area of new recruits and area lost due to deaths under grazing.

	Species						
	A. calycina	***A. ramosa***	***B. decipiens***	***C. fallax***	***D. sericeum***	***E. ramosus***	**Mean**
Cohort98 area	11	6	7	5	16	3	8
Survivor change	-12	-7	2	-7	-6	<u>33</u>	0
Lost since '97	24	11	25	32	34	7	22
Nett change '97	-25	-12	-16	-34	-24	+29	-14
Cohort99 area	12	7	12	2	<u>38</u>	1	12
Survivor change	<u>-25</u>	-5	42	0	46	41	16
Lost since '98	37	16	18	46	33	13	27
Nett change '98	-50	-14	+36	-44	+51	+29	+1
Cohort00 area	13	5	10	1	20	1	8
Survivor change	<u>17</u>	-3	-22	-61	-33	-31	-22
Lost since '99	29	12	11	32	17	7	18
Nett change '99	+1	-10	-23	-92	-30	-37	-32
3yr cohort mean	12	6	10	3	25	2	9
3yr avge change	-7	-5	7	-23	2	14	-2
3yr mean loss	30	13	18	37	28	9	22
3yr nett change	-25	-12	-1	-57	-1	+7	-15

Each year's calculations are based on the previous year's population of each focus species and expressed as a percentage of that species area the previous autumn. Outlier values are underlined.

If the results were calculated on crown areas (Table 6.32) a similar story emerges. Change in crown area over a year is the nett effect of new recruits minus losses plus nett change of crown area of the surviving plants. Using this method to calculate change, Qld bluegrass more than replaced crown area losses in most years for a nett steady crown area overall between 1997 and 2000, while the opposite applied for *C. fallax* and *A. calycina* over the same 3 years. Note particularly how *A. calycina* was expanding in the 1999-00 year when all the others were contracting and how individual species behaved differently in different years. Pitted bluegrass was less dynamic than all the others in its changes of crown area.

Individual species and their component cohorts often react differently to the same seasonal or grazing management factors in a given year

Individual cohort losses

Table 6.33 shows the general exponential pattern of plant cohort decline over time that all species exhibit. However the other data (Tables 6.29 and 6.30, Figure 6.118) show clearly that the mean rate of decline is very species dependent. The loss of only 36% of the 1999 cohort by the end of the dryish 2000 summer was unexpected given the 45 to 55% first year losses by earlier cohorts (Table 6.33).

1995 original plants

The death rate of plants that were present in autumn 1995 followed an exponential decline with time for all species (Figure 6.118). Exactly 40% of the 1995 cohort were still alive in June 2000 but for individual species that proportion ranged from 17% for dark wiregrass to 55% for twirly windmill grass. Pasture management had a minor impact with lowest overall survival at HG (Figure 6.119).

Table 6.33 Percentage of initial cohort members lost annually under grazing in subsequent years by four different cohorts.

	Percent loss in year interval			
Cohort	**1995-97**	**1997-98**	**1998-99**	**1999-2000**
1995	*44.5*	12.4	15.4	1.3
1997	**-**	46.9	18.5	7.1
1998	**-**	-	52.5	9.6
1999	**-**	-	-	36.2

However, at an individual species level, there were differences due to pasture management. A lack of sufficient plant numbers generally precluded the differences being statistically significant ($P<0.05$). MG was as favourable or more favourable a regime for plant survival as any. LG was no more conducive to the survival of *D. sericeum* than MG. This is probably a reflection of the high palatability of this grass along with the associated patch or selective grazing that occurred at very low grazing pressure.

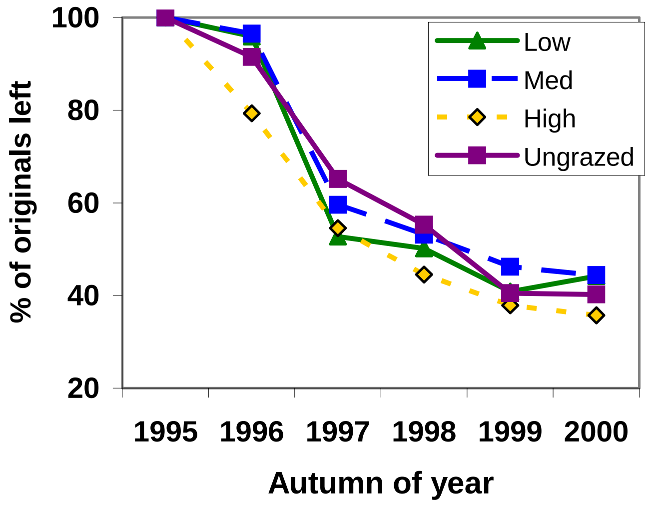


Figure 6.119 Effect of grazing management on survival of original 1995 perennial grass plants over time.

1997 cohort loss patterns

There was a variable management effect on mean losses for each species over time (data not shown). HG had a much greater impact on Qld bluegrass than any other treatment. This was counteracted by a high recruitment rate (Table 6.23) so that overall numbers of this species did not fall sharply over time and, in the last 2 years, they actually increased temporarily (Figure 6.114).

1998 cohort loss patterns

The individual species response to conditions after 1998 were again variable and not necessarily the same as for previous cohorts in the short term, except for the general rate of loss that is biologically predetermined for each one. So the differences for several of the grasses must centre on the other microclimatic conditions that existed in the pasture swards, eg. biomass, ground cover, competition, insect attack or fungal disease etc. We cannot explain this any better with the coarse level of monitoring detail that we were using. However, we note that a white scale insect existed in large numbers on *A. ramosa* in some seasons, like April 2000.

The graphs in Figures 6.118 and 6.119 show an apparent increase/resurrection of plant numbers for some species in 2000. There are several reasons possible for this but the main one was missed recordings of plants in 1999 – 5.5% of surviving pitted bluegrass and 4% of purple wiregrass.

Plant flux calculations

Plant flux calculations for the focus perennial grasses were done on the data, following the system of Sarukhan and Harper (1973), and as was done on the data from the ironbark site. The results are summarised in Table 6.34 for the grazing trial. The calculations are based on the original 1995 plants plus all the recruits and deaths/losses that occurred between then and autumn 2000 when the last charting data was collected. The following data was used –

(a) original numbers | (b) final numbers

(e) total plants recruited | (f) total plants lost

(g) original plants still present at the final recording | (j) j = a + e

Attempts to ascribe consistent outcomes to all species from the various management scenarios generally met with little success. Some species benefited from a treatment while others were relatively disadvantaged by that same treatment. For example, the rate of increase (item d in the Tables) was enhanced by low grazing pressure for most species but not for *A. calycina* (Table 6.34). Likewise, retention of tree cover produced inconsistent benefits for the same calculation for different species. The tendency for species to turn over populations was, however, fairly consistent with high rates for *D. sericeum* and low rates for *E. ramosus*. This result matches those reported earlier but based on other methods of assessment.

The *C. fallax* results should be ignored because plants that were originally drawn separately on the charts were later often amalgamated and thus 'lost' (item h) from the point of view of the Sarakhan and Harper calculation method for survival.

Higher grazing pressure reduced expected lifespans and there was approximately a 50 to 70% turnover of plants of all species each year.

The lifespan values seem a little low for *E. ramosus* at 7.8 years and a bit high for *D. sericeum* at 7.4 years, based on our memories and experience. We had no strong, preconceived ideas for the other plants, apart from *C. fallax* which we have already discarded because of the techniques used. A 7.4 year lifespan average for Qld bluegrass seems too high but we did not have a severe dry summer during the course of these recordings. A significant death rate occurred later in the 2002-2003 drought.

Table 6.34 Poplar box charted population dynamics – grazing trial.

					Species			
Data	**Factor**	**Arical**	**Ariram**	**Botdec**	**Chrfal**	**Dicser**	**Entram**	**Mean**
	n =	535	1353	2113	929	1472	808	
Average of Rate of increase [b/a] (d)								
	Species mean	1.3	0.9	1.4	0.3	2.4	0.9	1.2
	Treeless	1.4	0.9	1.2	0.2	2.9	0.8	1.2
	Treed	1.2	1.0	1.5	0.3	1.9	0.9	1.1
	High GP	2.6	0.8	1.2	0.3	1.2	0.7	1.1
	Med GP	0.8	0.9	1.2	0.3	3.2	0.8	1.2
	Low GP	0.5	1.0	1.7	0.3	2.7	1.1	1.2
*Average of Percent survival of original plants [(g/a)*100] (h)*								
	Species mean	19.7	47.3	45.3	16.8	27.7	55.6	35.6
	Treeless	7.8	47.6	34.1	15.0	29.0	52.6	31.7
	Treed	29.7	47.0	56.5	18.6	26.4	58.6	39.5
	High GP	12.6	35.3	37.1	16.3	5.5	46.5	26.1
	Med GP	15.1	56.7	48.3	17.2	33.4	57.0	37.9
	Low GP	29.7	49.9	50.6	16.8	44.2	63.4	42.4
*Average of Plant flux - % annual mortality of all individuals [(f/j)*100] (k)*								
	Species mean	72.2	60.7	56.7	92.6	56.8	53.5	65.4
	Treeless	82.7	63.8	58.0	94.0	54.8	56.1	68.2
	Treed	61.7	57.6	55.3	91.1	58.9	50.8	62.6
	High GP	68.5	65.4	57.1	91.6	62.6	63.8	68.2
	Med GP	74.0	62.7	60.3	97.7	56.1	53.7	67.4
	Low GP	74.1	53.9	52.6	88.4	51.8	42.9	60.6
*Average of Expected time for original plants to die (years) [no. yrs5 /(100-h)*100] (i)*								
	Species mean	7.0	10.9	9.9	6.0	7.4	11.9	8.9
	Treeless	5.5	12.2	7.8	5.9	7.7	11.4	8.5
	Treed	8.3	9.6	12.0	6.2	7.1	12.3	9.2
	High GP	5.8	7.9	8.4	6.0	5.3	9.7	7.3
	Med GP	6.1	14.5	10.2	6.0	7.9	11.9	9.4
	Low GP	8.9	10.2	11.0	6.0	9.1	14.0	9.9

6.2.1.4.13.5 Discussion

Data from six years of targeted research on the population dynamics of perennial grasses has shown how differently some species can behave under the same conditions. Not all species respond dramatically to the removal of tree competition. Qld bluegrass did (Figure 6.101) but pitted bluegrass did not (Figure 6.100). Good rainfall enhanced the growth of all grasses but did not automatically result in significantly greater seedling recruitment of perennial grass species. This is presumably associated with the huge increase in ephemeral plant establishment and growth but may also be due to high levels of disease attack, as seemed to occur in ungrazed pastures.

Heavy grazing pressure consistently reduced the size and average lifespan of perennial grasses. However, it increased the rate of seedling recruitment of Qld bluegrass to partly compensate. This effect is consistent with the ability of this grass to rapidly colonise abandoned cultivation or to respond to good seasonal rains. Conversely, golden-beard grass had a low level of apparent seedling recruitment but did produce appreciable numbers of new plant crowns in close proximity to existing plants, 28% of existing plant numbers (Table 6.23). The moderate grazing pressure treatment tended to behave more like the low grazing pressure one but was often between the two extremes for several measures.

Grazing pressure had a noticeable impact on recruitment of dark wiregrass but not of purple wiregrass. These species fall into different Sections within the genus *Aristida* (McIntyre and Filet 1996) but their response to grazing near Mundubbera was similar in terms of frequency of plants. In this study we measured actual density while the pasture frequency results via Botanal showed an effect of high grazing pressure on purple wiregrass but an inconsistent effect on dark wiregrass. Both tended to be more prominent under trees than where trees were killed, both in the Botanal results and the charted quadrats.

These charting studies have been time consuming both in the field and to analyse and interpret in the office afterwards. Some of the key species used for detailed study were not well suited to the technique, namely *C. fallax* and *E. ramosus*. Others, the *Aristidas,* posed problems because of the taxonomic complexity of the genus and this is potentially replicated in other genera such as *Iseilema* (Orr pers. comm.). The same does not apply to *H. contortus* or *T. triandra* in Queensland savannas but could in more mesic regions where *Themeda* has a number of ploidy levels possible. However, they provide guidance about what is feasible in future population dynamics research and an alternative process by which pastures can be studied where great detail is desired. We used a database to process the data while Orr *et al.* use spreadsheets to do that aspect of the work.

6.2.1.4.14 Soil seed loads under grazing

6.2.1.4.14.1 Abstract

Soil seed banks of the important pasture, tree and shrub species in grazed woodlands were not large and were very transient in most cases. Very few germinable tree seeds were detected by sampling in spring every year for seven years. Numbers for the perennial grasses were often relatively low, irrespective of whether they were desirable (Qld bluegrass) or undesirable (wiregrasses). Queensland bluegrass seeds were far more common in treeless pastures and where grazing pressure was low.

Total numbers of germinable seeds of 3P grasses in spring were of the order of 130 to 780 per square metre out of a total of 800 to 2100 germinable seeds. Sedges, rat’s-tail grasses, lovegrasses, daisies and bluebells had large germinable seed banks in comparison to their pasture biomass.

6.2.1.4.14.2 Background

The number of viable seeds in the soil and in surface litter is very important for maintaining a viable population of every pasture species. Some need more seeds than others because that species is only short-lived or because it is not strongly competitive in normal pastures. Others have special recruitment strategies that are dependent on strong germination control mechanisms, e.g. seed dormancy or specialised light or temperature regimes.

Studies of seed loads in tropical pastures have been done by McIvor (1987 & 2001), McIvor & Gardener (1994), McIvor *et al.* (2004), Orr (1991) and Orr *et al.* (2000), all in the speargrass areas of sub-coastal Queensland and by Graham *et al.* (2004) in the Pilbara District of Western Australia. Orr concentrated on black speargrass and its response to grazing pressure and spring burning while McIvor sampled for all species in pastures that differed greatly in their assessed condition or pasture type. All used a similar sampling and seed germination technique which effectively only finds germinable seeds rather than a complete count of all seeds in the soil and litter.

Other pertinent studies include those by Hodgkinson *et al.* (1980) in NSW poplar box woodlands, Westoby *et al.* (1988) in burnt spinifex pastures of Central Australia, O'Connor and Pickett (1992) in South Africa and Odgers (1994) in open eucalypt forest near Brisbane. Mostly they show relatively low numbers of seeds of the dominant grasses and much greater numbers for minor, small-seeded plants such as sedges, lovegrasses and *Sporobolus* spp. Tree and shrub species were poorly represented in their seedbanks and spatial variability within sites was large. Where a number of nearby sites were sampled, it was common to have many species found at only one site (Van Rooyen & Grobbelaar 1982, McIvor & Gardener 1994) and for taxa present in the vegetation not to be detected in the germinable seedbank (Hodgkinson *et al.* 1980, Odgers 1994 and McIvor & Gardener 1994). So the size of the important seedbanks at our trial sites under different treatments was not very predictable.

In Queensland, winters are normally fairly dry and our native vegetation is adapted primarily to summer growth and late summer seeding. Hence germination in late spring or summer is the commonest strategy for many native plants, particularly perennial grasses. However there are some species, particularly annual herbs, that only germinate in cooler weather (Silcock and Hall 1996). We were interested to document the diversity and abundance of seeds of pasture species that we were studying in relation to their response to grazing management and seasonal variability. As this study was primarily interested in perennial grass pastures, we timed our sampling to catch the peak of potentially germinable grass seeds each year.

6.2.1.4.14.3 Methods

Samples were collected in late August to early October so that last summer's seed would have matured well and lost most of any transient dormancy features but before significant germination could occur when warmer temperatures and storms came in spring or early summer.

Collection Method

Soils were sampled in the grazing and burn trials at the end of each winter. In the grazing trial, a set of four cores was taken at posts 2, 3 and 4 on each of the three permanent transect, ie. 9 sites per paddock. Cores were 5cm diameter and to 4cm depth. They were taken during dry weather at least 2 metres away from the post, between plants and so as not to be right on the basal area transects between posts.

The 4 cores at a post were bulked in the field into a paper bag. Roots and litter were separated out later, prior to spreading the soil into pots for testing. The bulked samples were allowed to dry out completely in a sunny area before being broken up through a 5mm sieve which assisted in the removal of large stones and woody material.

Germination technique

Germinable seeds were detected by wetting up the sieved soil which was spread in a thin layer (1-2cm deep) over the surface of a sand-filled pot 15cm in diameter. The pots were about 20cm deep and the sand was irrigated with liquid fertiliser beforehand so that seedlings could grow healthily until identified. Tests were begun in a Toowoomba glasshouse in early November each year (1994–2000) and ran for several months each time. In April 1995 and April 1996 the tests were re-run on the same soil samples after they had dried out and been broken up again.

The pots were gently watered from above several times a day initially and thereafter daily so that the surface soil remained moist for at least a month each time. Watering was then reduced to minimise the build-up of moss, algae and liverworts on the pot surface and to guard against excessive damping off of seedlings. Watering generally continued for at least a month or until there were no new seedlings emerging in a pot. Watering was by hand so that pots received individual amounts according to their needs. In this way waterlogging of slow-draining soils was minimised and under-watering of very sandy samples was eliminated. Seedlings were identified as early as was possible and then carefully removed so as not to disturb the soil surface. Age at removal tended to decrease each year as skill in identifying seedlings improved. Pots were frequently shifted around on the benches to cater for sampling and watering needs and to prevent excessive shading or sun exposure by individual pots.

In some cases seedlings had to be grown on for many months before they flowered or became identifiable and these ones sometimes needed additional supplies of fertiliser for growth in such small pots. Such fertiliser was absorbed in solution through the pot base, as was any extra water needed by large plants. In this way we further restricted the growth of mosses and starved them of nutrients as well. In some cases where there were numerous specimens of the same species, one or two were carefully dug out as very young plants (3-4 leaves) and transplanted into a new pot where they were grown out under ideal conditions until positively identified. By doing this we overcame the need to keep numerous examples of the same plant growing in many pots which had otherwise exhausted their supply of germinable seeds.

Seedlings were identified to a species level wherever possible but, in the case of some small, ephemeral genera, this was impractical and they were restricted to a genus. This occurred with the cudweed group (*Gnaphalium* sensu laxa), the bluebells (*Wahlenbergia* spp.), the stonecrops (*Crassula* spp.) and a few other minor annual herbs that were difficult to differentiate as seedlings and which are ecologically of minor and transient importance at the site. Such plants often emerged in large numbers after prolonged wetting under cool conditions or beneath the canopy of other seedlings.

These plants were often the ones which maintained a persistent seedbank in the soil and would emerged in a second wave if the soil was retained from the initial early summer test and retested in the next autumn. This sort of retesting was done deliberately for the poplar box site soils from the spring 1994 and 1995 samples to confirm our understanding of this phenomenon and those results are presented. Some seedlings were damped-off by fungi before being able to be positively identified, so they were identified to the most accurate level possible at that time, which in some cases was only as a monocotyledon or dicotyledon. Plants which we could not identify personally were preserved after they flowered and sent to the Brisbane herbarium for positive identification.

Other notes

We were beaten in our sampling intentions by mid-August rain in 1996 and, as a consequence, overall counts in the glasshouse were low that spring. There are also instances where extraneous seeds from either the underlying washed sand or blown in from nearby vegetation germinated and were initially included in the counts. However, we usually worked out later that they were interlopers, and excluded them from the results presented. Nonetheless, we cannot be absolutely certain that isolated specimens are not extraneous to the site samples.

Differentiating *Chloris divaricata* and *C. truncata* as young plants was impossible and so they were sometimes lumped as *Chloris* spp. In south Qld, they fulfil a very similar role ecologically but this makes the interpretation of the trends for them over time problematic at a species level. The same applies to *Enneapogon* species of which there were 4 species identified at the poplar box site. Note, there are some taxa that were readily identified to species level as seedlings while others were difficult beyond a genus prior to flowering, eg. some *Eragrostis* spp. and there are cases of changes in scientific names (eg. the *Gnaphalium* group) and potential misidentifications.

6.2.1.4.14.4 Results

Presence / Absence

Results were collected for seven consecutive years in November, 1994 to 2000. Of the 173 herbaceous and 61 woody species listed for our poplar box site in Appendix E, only 134 were recorded as having germinable seed at any time in the next 7 years. A further 48 species, mostly winter annuals, germinated from our soil samples but were not recorded in the initial census. This leaves about 110 species from the census for which no germinable seed was discovered from samples taken in 7 consecutive springs. This equates to 94% of all the woody plants, 45% of the non-grassy herbs but only 24% of all grasses, sedges and rushes failing to put any significant number of germinable seeds into the soil seedbank over seven consecutive years (Table 6.35).

Over the seven years, 97 of the taxa were found only at the grazing trial site. This reflects the greater soil and topographic variability and much larger area at the grazing site, including waterways and ridge crests. Four taxa (cudweeds, *Erodium crinitum*, a fern and a daisy) only emerged in the two April germination runs and, apart from the cudweeds and fern, were again very minor species in the germination tests and in the paddocks.

Presence in the seedbank was thus not a reliable indicator of presence in the field although almost all emergees were independently observed as adults from the site. *Laxmannia gracilis* and *Typha* sp. (cumbungi) were exceptions to this. The converse was very common, i.e. no records from the seedbank of species that are at the site and in some cases very common, eg. no *E. melanophloia* (silver leaved ironbark) nor *A. luehmannii* (bulloak) from the grazing site (see Table 6.35). It was commonly the woody species which were not seen from the seedbank and even common trees such as poplar box (*E. populnea*) were scarce (8 seedling over 7 years and all from treed paddocks). This readily fits with why so few poplar box recruits were recorded during the trial.

This apparent absence could be due to a lack of dormancy in seeds of some woody species such as the eucalypts and limebush, so that seed dropped in mid-summer rarely survives til the next spring when the soil was sampled. Many other woody species have a strong seed or fruit dormancy and have the potential to survive many years in or on the soil, provided they are not eaten by insects, eg. *Hovea* spp., *Grewia latifolia*, myall (*A. pendula*) and the wattles generally.

Some species tended to emerge in clusters, indicating either a predilection to blow or wash into pockets, or to be gathered by harvester ants, or a lack of movement from under a parent plant. Examples of the former two were *C. divaricata*, *E. ramosus* and *Enneapogon* spp. while the latter seemed true of *Sporobolus* and *Eragrostis* species (see Appendix I for details).

Sampling was consistently adjacent to the same marker posts each year, so seeds from the same perennial parent plants were potentially collected each year. Likewise the soil surface and type was fairly consistent at each site for each year. Notes made about the soil samples showed that some sites were noticeably different from the silty grey loam found over most of the site (See Appendix I).

Table 6.35 Species recorded from the combined sites for which no seeds ever germinated

Trees and shrubs	**(49 out of 52)**	
Acacia decora	*Acacia excelsa*	*Acacia farnesiana*
Acacia harpophylla	*Acacia leiocalyx*	*Acacia pendula*
Alectron diversifolius	*Alectron oleifolius*	*Allocasuarina luehmannii*
Alstonia constricta	*Apophyllum anonalum*	*Atalaya hemiglauca*
Brachychiton populneus	*Brachychiton rupestre*	*Callitris glaucophylla*
Canthium oleifolium	*Capparis lasiantha*	*Capparis loranthifolia*
Capparis mitchellii	*Carrisa ovata*	*Cassine australis*
Cassinia laevis	*Casuarina cristata*	*Corymbia tessellaris*
Dodonaea viscosa	*Ehretia membranifolia*	*Eremocitrus glauca*
Eremophila mitchellii	*Eucalyptus melanophloia*	*Eucalyptus orgadophila*
Geijera parviflora	*Grevillea striata*	*Grewia latifolia*
Hakea fraseri	*Hovea longipes*	*Jasminum linare*
Jasminum simplicifolium	*Maireana decalvans*	*Maytenus cunninghamii*
Melhamia oblongifolia	*Myoporum acuminatum*	*Myoporum deserti*
Opuntia stricta	*Owenia acidula*	*Pandorea jasminoides*
Parsonsia eucalyptophylla	*Petalostigma pubescens*	*Pittosporum phylliraeoides*
Santalum lanceolatum		
Herbs	**(45 out of 100)**	
Asperula conferta	*Atriplex semibaccata*	*Bidens pilosa*
Brachycombe trachycarpa	*Camptacra barbarta*	*Cheilanthes lasiophylla*
Chenopodium desertorum	*Crotalaria dissitiflora*	*Datura leichhardtii*
Desmodium brachypodum	*Desmodium varians*	*Dianellia spp.*
Eustrephus latifolius	*Glycine latifolia*	*Glycine tomentella*
Goodenia fascicularis	*Goodenia glabra*	*Hibiscus brachysiphonius*
Hibiscus sturtii	*Hibiscus trionum*	*Marsilea drummondii*
Mentha satureioides	*Minuria integerrima*	*Myoporum debile*
Nyssanthes diffusa	*Polymeria pusilla*	*Poranthera microphylla*
Pseuderathemum variable	*Ptilotus exaltatus*	*Ptilotus macrocephalus*
Pycnosorus chrysanthus	*Rapistrum rugosum*	*Rostellularia adscendens*
Salvia reflexa	*Sclerolaena calcarata*	*Sida trichopoda*
Solanum esuriale	*Spermacoce multicaulis*	*Thysanotus sp.*
Tricoryne elatior	*Vernonia cinerea*	*Wedelia spilanthoides*
Xanthium pungens	*Xanthium spinosum*	*Zinnia peruviana*
Grasses, sedges & rushes	**(17 out of 71)**	
Aristida lazarides	*Brachyachne convergens*	*Cyperus leiocaulon*
Cyperus rigidellus	*Dactyloctenium radulans*	*Dichanthium tenue*
Eulalia aurea	*Leptochloa digitata*	*Lomandra leucocephala*
Lomandra longifolia	*Melinis repens*	*Panicum simile*
Paspalum dilatatum	*Schoenus sp.*	*Scleria mackaviensis*
Stipa scabra	*Themeda avenaceus*	

Hence inter-year variation may be a better reflection of any trend controlled by grazing management or climate than absolute values for particular paddocks. Some locations had consistently low numbers of seeds emerging, eg. Pdk 12 T3 P4 (Post 4 of TRAPS transect 3 in paddock 12) averaged less than 1 emerging seedling/sq metre each year. Others with consistently low soil seed loads of about 4 germinable seeds/sq m were Pdk5 T3 P4, Pdk6 T3 P2 and Pdk8 T3 P3, none being a low grazing pressure paddock. Conversely there were some sites that produced consistently high counts of germinable seeds each year, eg. Pdk9 T3 P2 averaged over 30 seeds/sq m.

Table 6.36 Frequency information about the spatial and temporal variability of emergence by species and genera that emerged every year from at least one of the 120 soil samples taken each year from the grazing and burning sites combined.

Code	Taxon	Total Nbrs	% of total emergees MAX	% of total emergees MIN	% of total emergees MEAN	Germinable seeds /sq metre MAX	Germinable seeds /sq metre MIN	Germinable seeds /sq metre MEAN	Pots producing each taxon (max. 120) MAX	Pots producing each taxon (max. 120) MIN	Pots producing each taxon (max. 120) MEAN	Paddocks producing a taxon (max. 24) MAX	Paddocks producing a taxon (max. 24) MIN	Paddocks producing a taxon (max. 24) MEAN
			in any 1 year			in any 1 year			in any 1 year			in any 1 year		
Bode	*B. decipiens*	964	17.5	1.0	6.6	435	10	178	62	8	32.1	16	7	11.4
Cala	*C. lappulacea*	50	1.8	0.2	0.6	18	2	9	9	2	5.4	7	2	4.3
Cesp	*C. spicatum*	1001	14.2	0.2	8.1	567	4	185	73	3	34.4	16	3	11.4
Chdi	*C. divaricata*	1103	19.2	4.1	9.8	414	42	201	78	22	47.0	16	10	12.9
Chve	*C. ventricosa*	72	1.8	0.1	0.6	34	1	13	15	1	6.7	10	1	5.0
Cygr	*C. gracilis*	437	10.8	0.4	4.8	135	8	77	38	5	24.3	15	3	11.7
Dise	*D. sericeum*	232	3.1	0.5	1.6	134	7	43	29	5	13.1	12	4	7.1
Enne	*Enneapogon spp.*	329	5.5	0.3	2.9	217	6	61	52	4	20.4	13	3	8.4
Enra	*E. ramosus*	640	11.2	2.6	6.1	238	25	114	35	9	20.9	11	5	8.6
Erla	*E. lacunaria*	206	3.9	0.7	2.0	73	13	37	20	1	12.6	11	1	7.6
Ermo	*E. molybdea*	383	12.3	1.4	3.7	232	13	67	40	9	24.0	14	5	10.9
Erpa	*E. parviflora*	16	0.4	0.1	0.2	8	1	3	4	1	1.9	4	1	1.9
Erps	*E. pseudoacrotricha*	77	1.9	0.3	0.9	21	6	14	13	3	7.9	8	2	5.3
Fidi	*F. dichotoma*	283	18.0	0.3	3.9	198	3	53	48	2	18.1	16	2	9.6
Gnap	*Gnaphalium spp.*	124	4.7	0.1	1.4	51	2	23	28	2	11.0	11	2	6.0
Paco	*P. constrictum*	16	0.7	0.0	0.2	7	1	3	4	1	2.0	3	1	1.9
Poau	*P. australis*	106	3.6	0.2	1.2	68	4	18	10	2	5.3	7	2	4.4
Pool	*P. oleracea*	185	8.2	0.3	2.4	80	5	33	20	3	11.7	10	3	6.7
Spca	*S. carolii*	120	3.6	0.7	1.4	36	12	21	19	5	10.9	10	3	6.6
Spcr	*S. creber*	640	11.1	1.7	6.6	300	32	116	42	12	26.6	15	8	11.6
Trau	*T. australianus*	211	3.1	0.3	2.0	113	3	38	37	1	16.7	11	1	7.6
Trlo	*T. loliiformis*	168	3.4	0.4	1.8	63	7	31	35	5	17.1	14	4	8.9
Veof	*V. officinalis*	164	4.9	0.2	2.1	47	5	30	24	2	15.7	10	2	7.9
Vete	*V. tenuisecta*	36	1.0	0.2	0.4	10	2	7	6	2	4.1	5	2	3.6
Vitt	*Vittadinia spp.*	37	0.9	0.1	0.3	14	1	7	9	1	4.7	6	1	3.6
Wahl	*Wahlenbergia spp.*	272	4.6	0.3	2.5	190	6	50	60	5	20.1	15	2	8.3

Others locations to produce consistently good numbers of seedlings (between 25 and 28/sq m) were Pdk3 T1 P2, Pdk4 T1 P4, Pdk6 T2 P4, Pdk9 T2 P3 and Pdk10 T1 P2. These are from a mix of grazing pressure paddocks which seems to indicate that intra-paddock spatial variation is high in most paddocks, irrespective of grazing management. Sites showing great inter-year variation did not closely reflect annual or seasonal rainfall.

Annual & spatial variability (Spring tests)

An example of the extent of year to year and spatial variability of gemination by major species and genera across both trial sites is shown in Table 6.36. Some species occurred as isolated emergences but were there almost every year, eg. 22 plants of *P. virgatus* emerged in the 7 years and each was an isolated individual in a pot. Others to behave similarly but which were not present every year were *A. calycina, C. cristatum, C. fulvus, C. refractus, D. coenicola, E. populnea, E. alsinoides, P. buncei, P. constrictum* and *S. belloides*.

Greatest seed numbers were recorded for *C. divaricata*, *Centauria* spp., *E. ramosus, B. decipiens* and *S. creber* (Table 6.36). Seeds of *B. decipiens*, *C. divaricata* and *E. ramosus* are quite large but those of the others named above are tiny and are set in huge numbers by the parent plants.

Golden-beard grass seed was very rare (Tables 6.38 & 6.39, Appendix I), 3 in total from the grazing trial, despite its commonness in the pastures (average frequency 29% and often 2% of basal area). In a similar situation were *B. australis* (1 seed and 17% frequency in pasture), *C. scabiosifolia* (1 site only in 2 years) and *G. tabacina* (4 seeds in 3 separate years).

On the other hand, the method used produced far more cudweeds (1.4% of all seeds germinating) than are normally recorded in the paddock. The same applied to bluebells (*Wahlenbergia* spp.) which accounted for 2.5% of the total germinable seeds. Such comparisons are not able to be made for some other species because field botanical sampling did not differentiate between species in minor plant guilds/groups, eg. *Crassula* spp, and *Centauria* spp. were only included in a small forbs category. Likewise many of the small chenopods and daisies were grouped in the botanical sampling in the field because our focus was on perennials, and grasses in particular.

Autumn retesting

For two years (1994 and 1995) a repeat test was done the next April on the dried-out November soil to see what viable seeds remained to emerge after the first 6 week run. In these reruns, some species were then very common while others were non-existent (Table 6.37). The former usually emerged because cooler temperatures were needed for their germination, eg. *Centauria* spp., *Crassula* spp., *Plantago* spp and *Wahlenbergia* spp., or a longer dormancy breakdown time was required by fresh seed, eg. *Calotis lappulacea*. The latter missing group were mainly large-seeded grasses, eg. *B. decipiens*, *H. contortus* and *B. bladhii*, that appeared to have no long term seed dormancy mechanism operating. The most notable contrasts are shown in Table 6.37. Note there were no *Aristida* seedlings in the second runs. Plants with plenty of dormant seeds in the soil (maybe of several ages) were *Chloris* spp., *Cyperus* spp., *Eragrostis* spp., *Portulaca* spp. and *Sporobolus* spp.

Some species showed a strong preference for summer conditions but also had significant medium term seedbank persistence, eg. *D. sericeum*, *Portulaca* spp. and *Tragus*.

Table 6.37 Spring versus subsequent autumn seed germination of the main taxa from the same soil samples at the grazing trial.

Taxon	Nov '94 + Nov '95	Apr '95 + Apr '96	Ratio
Aristida spp.	49	0	∞
Bothriochloa decipiens	116	7	16.6
Calotis lappulacea	9	87	0.1
Centauria spp.	13	834	0.02
Chloris truncata & C. divaricata	221	132	1.7
Crassula spp.	101	607	0.2
Cyperus spp.	56	147	0.4
Dichanthium sericeum	32	6	5.3
Enteropogon ramosus	248	18	13.8
Epaltes australis	34	22	1.6
Eragrostis spp.	293	154	1.9
Fimbristylis spp.	34	115	0.3
Plantago spp.	5	18	0.3
Portulaca spp.	172	50	3.4
Sporobolus caroli	23	30	0.8
Sporobolus spp. (rat's-tail type)	80	57	1.4
Tragus spp.	66	32	2.1
Verbena spp.	31	142	0.2
Wahlenbergia spp.	28	516	0.05

Numbers

Variation in total numbers emerging each sample date was appreciable, ranging between 731 and 3008 from the grazing site (Table 6.38) with a mean of 1647 germinable seeds/m^2 in spring. Each year's results for the major grasses and plant groups are summarised in Table 6.38. Numbers for most other species and taxa were too small and variable for meaningful trends and treatment effects to be determined. The results are also summarised in terms of the percentage of the total numbers emerging at that sampling so as to show the relative importance of the seedbank of each taxon (Table 6.39). Rarely did one species have over 10% or the germinable seedbank in any spring

Table 6.38 Total numbers of seedlings of key taxa emerging in successive years from spring soil samples at the poplar box grazing trial.

Species/group	1994	1995	1996	1997	1998	1999	2000
Qld bluegrass (Dicser)	12	20	7	101	4	29	32
Pitted bluegrass (Botdec)	107	9	20	272	7	212	117
Twirly windmill (Entram)	179	69	37	181	19	33	101
Golden beardgrass (Chrfal)	0	0	0	0	0	0	1
Dark wiregrass (Arical)	3	5	0	9	1	8	5
Purple wiregrass (Ariram)	1*	3	0	118	2	28	81
g = grasses (all species)	1120	416	404	1892	248	521	745
a = Asteraceae (daisies)	42	30	47	110	59	54	52
m = Malvaceae (flannelweeds)	5	6	0	5	4	6	10
l = legume	3	6	11	6	3	3	1
c = chenopods (saltweeds)	39	45	4	46	2	7	14
s = sedges & lilies	38	71	227	85	219	67	85
w = woody tree/shrub	0	2	2	2	3	2	2
TOTAL nbr	1603	740	874	3008	731	1276	1547
TOTAL (seeds/sq m)	1889	872	1030	3546	862	1504	1824

* means species not well identified in this first year. Many (35) just called *Aristida* sp.

Table 6.39 Seedlings of key taxa emerging each year from spring soil samples at the poplar box grazing trial, expressed as a % of the total numbers that year.

Species/group	1994	1995	1996	1997	1998	1999	2000	Mean
Qld bluegrass (Dicser)	0.7	2.7	0.8	3.4	0.5	2.3	2.1	1.8
Pitted bluegrass (Botdec)	6.7	1.2	2.3	9.0	1.0	16.6	7.6	6.3
Twirly windmill (Entram)	11.2	9.3	4.2	6.0	2.6	2.6	6.5	6.1
Golden beardgrass (Chrfal)	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
Dark wiregrass (Arical)	0.2	0.7	0.0	0.3	0.1	0.6	0.3	0.3
Purple wiregrass (Ariram)	0.1	0.4	0.0	3.9	0.3	2.2	5.2	1.7
g = grasses (all species)	69.9	56.2	46.2	62.9	33.9	40.8	48.2	51.2
a = Asteraceae (daisies)	2.6	4.1	5.4	3.7	8.1	4.2	3.4	4.5
m = Malvaceae (flannelweeds)	0.3	0.8	0.0	0.2	0.5	0.5	0.6	0.4
l = legume	0.2	0.8	1.3	0.2	0.4	0.2	0.1	0.5
c = chenopods (saltweeds)	2.4	6.1	0.5	1.5	0.3	0.5	0.9	1.7
s = sedges & lilies	2.4	9.6	26.0	2.8	30.0	5.3	5.5	11.7
w = woody tree/shrub	0.0	0.3	0.2	0.1	0.4	0.2	0.1	0.2

Grasses make a significant contribution but not from the key perennial ones. When averaged, Qld bluegrass seeds were only 2.6% of the total germinable seedbank (Table 6.39) but pitted bluegrass reached a sizeable 6.3%. The wiregrasses had only a low 2.0% total proportion of all germinable seeds. Of the minor species, in biomass terms, the sedges have a large seedbank (11.7%) and that of the daisies is also sizeable (4.5%). Woody plants had negligible germinable seeds at any time.

Year by year the relative contributions of different species varied considerably (Figure 6.120), probably as a reflection of the prior seasonal conditions and its interaction with grazing pressure. Details are in Appendix I but a breakdown by major treatments by year for total species numbers is given in many following tables. There were few consistent differences in the relative presence of main species or species groups.

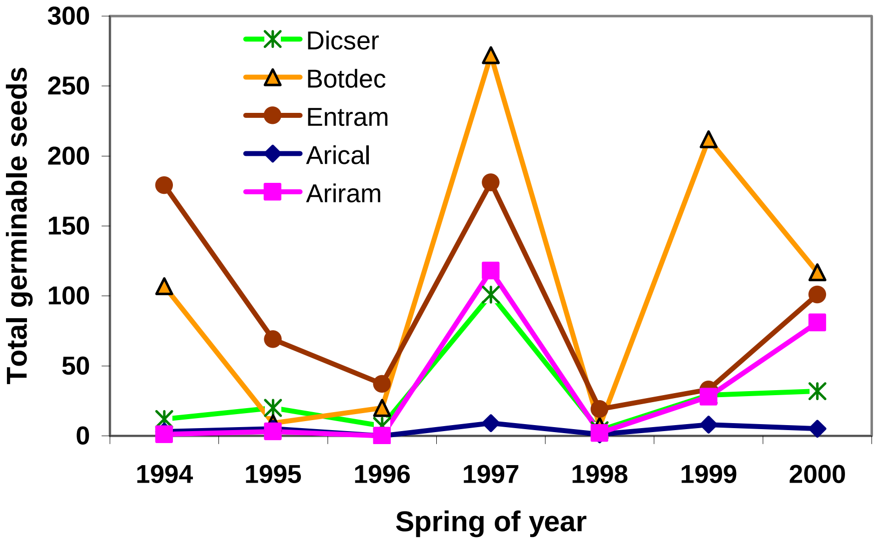


Figure 6.120 Annual fluctuation of germinable spring seed banks of 5 main perennial grasses at the grazing trial site.

Tree effects

Tree killing did influence soil seed loads in the seven years since half the paddocks were poisoned (Tables 6.40 & 6.41) but only in a minor way (Figure 6.121) and one that varied with the species. In the last two years (by which time major treatment effects should have been well established in the preceding 4 years), the average density of emerging seedlings was noticeably lower where the trees remained. The mean tree effect was consistent, though often tiny, for all years (Table 6.40).

Table 6.40 Variation between years in emerging seedling numbers per square metre of ground surface from grazing trial soil samples, for the main treatments.

Treatments	Spring	Treeless	Treed	High	Medium	Low	Mean
	Posts sampled	54	54	36	36	36	108
	1994	1914	1865	1895	1708	2065	1889
All species	1995	969	776	866	615	1135	872
(per sq metre)	1996	1037	1023	873	909	1308	1030
	1997	3741	3350	3794	3151	3692	3545
	1998	882	842	888	629	1068	862
	1999	1662	1346	1280	1803	1429	1504
	2000	2482	1165	2178	1634	1658	1823
	Mean	1812	1481	1682	1493	1765	1646

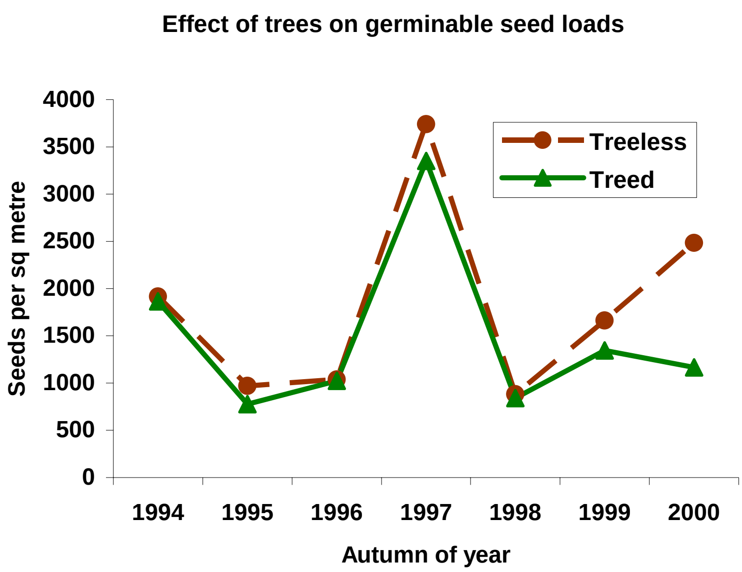


Figure 6.121 Effect of killing trees on total, germinable, springtime soil seed loads at the grazing trial.

Qld bluegrass and twirly windmill grass had more germinable seeds where trees were removed while the reverse applied to pitted bluegrass and the sedges (Table 6.41). Spring seed loads were not correlated with rainfall for the previous year (Figure 6.121 versus Figure 4.8) or summer.

Table 6.41 Effect of the main treatments on emergence of 6 key pasture taxa from soil samples from the grazed poplar box site. Total of years 1995-2000.

Species	Treeless	Treed	High	Medium	Low	Total
	All years summed					
Qld bluegrass (Dicser)	142	51	20	70	103	193
Pitted bluegrass (Botdec)	252	385	206	298	133	637
Twirly windmill (Entram)	331	109	182	20	238	440
g = grasses (all species)	2462	1764	1401	1230	1595	4226
c = chenopods (saltweeds)	70	48	69	15	34	118
s = sedges & lilies	338	416	253	215	286	754
Total	3595	2773	2131	1848	2389	
	per sq m					**Mean**
Qld bluegrass (Dicser)	335	120	71	247	364	227
Pitted bluegrass (Botdec)	594	908	728	1054	470	751
Twirly windmill (Entram)	780	257	644	71	842	519
g = grasses (all species)	5804	4158	4954	4349	5640	4981
c = chenopods (saltweeds)	165	113	244	53	120	139
s = sedges & lilies	797	981	895	760	1011	889

Significant individual species effects of tree killing on soil seed numbers were found for the following taxa-

Positive effect from tree retention

Eragrostis lacunaria, Fimbristylis dichotoma, Sporobolus creber, Wahlenbergia spp.

Negative effect from tree retention

Chloris divaricata, Dichanthium sericeum, Enneapogon spp., Plantago spp., Portulaca oleracea, Sporobolus caroli, Tragus australianus, Verbena officinalis

Grazing pressure effects

Increasing grazing pressure altered the seed stocks of the following taxa in the way shown but, overall, had no significant effect on total soil seed reserves (Tables 6.40 & 6.41).

Increased under heavier grazing

Calotis lappulacea, Enneapogon spp., Eragrostis spp., Gnaphalium spp., Sclerolaena birchii, Tripogon loliiformis, Wahlenbergia spp.

Decreased under heavier grazing

Aristida ramosa, Centauria spp., Cyperus gracilis, Dichanthium sericeum, Eriochloa pseudoacrotricha, Sporobolus caroli, Verbena tenuisecta

While these results seem encouraging in some cases, e.g. *A. ramosa* and *S. creber*, there was no rapid translation of this deficit into plant numbers in the paddock because each established tussock of these two species is strongly perennial, resistant to grazing pressure (Appendix I) and to burning (Table 6.44). The low grazing pressure treatments never had the least emerging seeds *in toto* but that did happen for some individual species, e.g. pitted bluegrass (Table 6.41). At this grazing pressure, this moderately low-statured species would be overtopped by taller, perennial tussock grasses. So this result seems logical. Conversely, the palatable Qld bluegrass had least seedlings emerging at high grazing pressure in the 6 years of this trial (Table 6.41) despite its maintenance of a sizeable population in the pasture (Table 6.17), *albeit* well eaten down (Figure 6.111).

6.2.1.4.14.5 Discussion

Seed banks of the main perennial grasses were tiny and not very persistent under grazing. This is a good thing with respect to the wiregrasses but not for the bluegrasses. The persistent seed banks of small-statured grasses like lovegrasses and rat's-tail grasses partly explains why such plants are often found where more desirable ones have been lost for some reason. This is a concern with respect to the rat's-tail grasses because they are not very palatable but have shown prolonged lifespans for individual plants charted at this site.

The vulnerability of black speargrass, forest, desert and Qld bluegrass to serious decline in A/B pastures at Injune is emphasised by the transient nature of their seedbanks and the relatively small number of seeds injected each year. O'Connor & Pickett (1992) and Orr (1999) also found that many important perennial savanna grasses have poorly persistent seedbanks. However, as our results hinted, *Eragrostis sororia* lasted for 3 years and *Epaltes* for 4 years when the same soil was repeatedly retested. Golden-beard grass has an even worse seed regeneration potential but its deep rhizomatous crown protects it well, even from digging animals like pigs and rat kangaroos. Hence its apparent increase in heavily grazed pastures in SE Qld (Wandera 1993).

The small numbers of germinable seeds of woody species has mixed virtues. Well-regarded ones like kurrajong, beefwood and boonaree have little chance of regenerating if parent trees are eliminated. Conversely, opportunities for mass regeneration of weedy types like poplar box, false sandalwood and bulloak are restricted and thus may be contained by targeted control measures on seedlings when they periodically establish.

The overall tendency for fewer seeds at low grazing pressure can be tentatively explained as being due to a reduction in the vigour of minor species such as sedges, annual grasses, forbs and saltweeds in those grassy pastures. The dominant grasses do not have large seed banks, as we have shown, even if they set a great deal of seed. In good years they do set a lot of seed but ants, in particular, harvest a large proportion of the seed and it is not available for germination. Ants often store such seed and, while it may often remain viable until consumed, it is in underground galleries where it stays dry and in darkness. This prevents germination, but even were it to sprout, the seed would be too deep to emerge and grow or the mound capping too dense to allow the seedling shoot to penetrate to reach light.

6.2.1.5 *Discussion – Grazed pasture dynamics*

Seasonal conditions strongly drove the results for parameters that can alter rapidly, such as pasture greenness, seedling recruitment (Figure 6.120) and dry matter yield. Meanwhile pasture parameters such as crown area and numbers of plants of perennial grasses were much slower to change but far from immune to change (Figures 6.96 and 6.113). The visual impact of grazing pressure was predictable at a paddock scale – heavy grazing reduced biomass and decreased ground cover. It then became harder to reliably interpret on a year-to-year basis when dealing with nominal groups such as increaser grasses. Some species such as *C. fallax* seem to increase on commercial properties under moderate to heavy grazing pressure while showing few of the traits normally ascribed to those plants. Predictions then seemed to become more reliable when dealing with an individual species where data existed for a number of years. Qld bluegrass recruits well from seed, is palatable and prefers treeless conditions and our data about specific aspects of its biology support this ecological behaviour.

The persistence of *Chloris divaricata* as a significant component of the pastures long after the good season of 1998, when it recruited well, was surprising. It is quite palatable and an important component of heavily utilised pastures in terms of keeping ground cover. It sets large amounts of seed that allow for regular recruitment but we had not identified it as a grass to study in detail when the trial commenced. Hence detailed crown dynamics were not recorded for it. Conversely, species like *Aristida ramosa* and *C. fallax* that had been chosen as key perennial grass species for detailed study from the outset, presented difficulties in their identification/taxonomy (*A. ramosa*) or in the use of our charting technique to follow individual plants (*C. fallax*). Hence the crown dynamics information for *C. fallax* is sketchy while the way we present ideas about *A. ramosa* is confounded by whether we are dealing with the ecotype that grows on the alluvial valleys or the type that grows on the ridges. Orr *et al.* (2004b) have also had difficulties in interpreting generic *Aristida* data from other trials because of the difficulty of definitively identifying individual species in the field.

Despite these constraints, this study has greatly enhanced our knowledge of key plants in the *Aristida/Bothriochloa* pasture type and further insights will be revealed as others conduct related studies or our data is reassessed in light of other research.

6.2.2 **Burning trial**

6.2.2.1 ***Abstract***

Regular spring burns in the absence of grazing did not shift poplar box pasture composition markedly after 8 years. Soil seed loads were significantly reduced by these burns but not sufficiently to threaten the persistence of any pasture species in the medium term. Positive responses to regular spring fires by desirable perennial grasses were slow and generally constrained to the periphery of existing plants. Conversely, the use of regular spring fires to suppress wiregrass was not shown to hold much hope in the absence of tactical grazing post-burn. Barbwire grass and dark wiregrass did show some susceptibility to burning. Minor non-grass species were sensitive to burning but in the short term, their possession of a persistent seedbank and a great potential to respond to unusually favourable seasons means their persistence in the pastures is not threatened by fires.

6.2.2.2 ***Background***

Regular burning of poplar box woodlands is practised in Queensland to contain the rate of regrowth of seedling trees, which helps keep the woodlands open for better pasture production and livestock management. Burning is also used to improve the palatability of some coarse grasses such as the wiregrass (*Aristida* spp.) group. Burning aims at burning different patches of country in most years so that the same area is re-burnt every 3-7 years, depending on the amount of rainfall received in the previous summers. Fires will be lit in spring after rain and before there is new pasture growth. This experiment in poplar box woodland aimed at having regular burns, every spring after rain for 8 years (October 1994 to October 2001) to show more rapidly any likely changes in pastures and tree composition and growth due to burning.

6.2.2.3 ***Methods***

The poplar box burning trial was the second main experiment at the Glentulloch core site. The main treatments were regular spring burning after 25 mm rain or no burning, both with treeless and treed treatments, making 4 combinations of treatments with 3 replications. The 12 plots, each 1 hectare, were marked out in one area, each with a cleared border and there was a double width cleared firebreak around the 6 adjacent burning treatment plots. This trial was separated from the grazing trial paddocks and was in a uniform, open poplar box woodland. The 12 ha site described in Section 5 (Figure 5.7) was fenced in June 1994 to exclude cattle and marsupials and the treeless plots were created using Tordon stem injection to kill all mature and seedlings trees in July 1994. The first fire across the 6 burning treatment plots was in October 1994.

Details of the burning regime, fire types and environmental conditions were given in Table 5.29. There was no grazing of this trial to avoid confounding the pasture responses with the usual selective grazing of fresh regrowth after a fire. Unfavourable spring burning conditions meant that no fire was achieved in the spring of 1995 and 1998.

Differences and similarities amongst the responses of pasture components to burning and tree competition provide a measure of the sensitivity of the various ecological processes that are critical in this woodland. Monitoring, based on a systems framework, measured the following key ground layer processes:

- pasture yield, cover and greenness in autumn
- pasture population dynamics, by species frequency, yield composition and basal area
- soil surface condition indicating erosion, hydrology and nutrient cycling

More details of the methods are shown in various Appendices.

6.2.2.4 ***Results***

6.2.2.4.1 Pasture species groups

The same species groups were recorded at both the grazing and burning trials in the poplar box woodland. There were 75 species and taxonomic groups, eg. forbs-small and *Portulaca* spp., recorded and analysed for each Botanal sampling. The species were also grouped into the same 7 functional groups for analysis at times so that they could be compared to data collected from QGraze and GRASSCheck sampling done under other monitoring activities. (see species groups and functional groups Appendices E5, E6 and F1).

6.2.2.4.2 Pasture dynamics

The effects of killing trees and tree competition on the 75 species groups and 7 functional groups was analysed separately at the burning trial. *B. decipiens* had the greatest change in composition from tree competition in the absence of grazing. It decreased 23% in the treeless treatments and increased 8% in treed treatments. Of the more desirable grasses, *D. sericeum, T. triandra* and *H. contortus* all increased to a greater extent without tree competition (Table 6.42).

Table 6.42 Botanical composition (% of total dry matter) of the important components in the burn site pastures at trial start and end, including the influence of tree competition after 7 years.

Taxon	1995		2002		Mean 1995-2002		Change 1995-2002	
	Treeless	Treed	Treeless	Treed	Treeless	Treed	Treeless	Treed
A. calycina	8.5	9.9	7.2	4	5.2	5	-1.3	-5.9
A. latifolia	2.3	0.8	1.1	0.6	1.5	0.8	-1.2	-0.2
A. leptopoda	0.5	0.8	0.1	0.1	0.4	0.7	-0.4	-0.7
A. ramosa	8.6	11.8	12.1	10.5	4.8	6.5	3.5	-1.3
Aristida spp.	0	0	0.5	0.6	2.9	3.2	0.5	0.6
B. bladhii	1.7	1.4	6.8	0.9	4	2.4	5.1	-0.5
B. decipiens	32.6	28.1	9.5	36.3	22	33.5	-23.1	8.2
B. australis	0.3	0.6	0.2	0	0.2	0.3	-0.1	-0.6
Calotis spp.	0.2	0.7	0.3	0.1	5.6	0.4	0.1	-0.6
C. ciliaris	0	0.2	2.9	5	2.9	2.1	2.9	4.8
C. divaricata	0.9	0.6	2.2	0.4	1.4	0.7	1.3	-0.2
C. fallax	11.6	13.9	8.3	9	10.3	11.1	-3.3	-4.9
Cymbopogon spp.	2	1.3	6.7	2.9	2.7	1.8	4.7	1.6
Cyperus spp.	0.2	0.6	0.3	1.2	0.2	0.7	0.1	0.6
D. sericeum	2.9	1.8	7.2	5.1	7.9	5.2	4.3	3.3
Enneapogon spp.	6.3	6.1	3.1	5.3	3.2	5.4	-3.2	-0.8
E. ramosus	1.7	1	5.4	2.4	2.1	1.6	3.7	1.4
Eragrostis spp.	0.6	0.5	2.1	0.6	1.9	1.2	1.5	0.1
E. molybdea	1.5	1.5	1	0.7	0.7	0.6	-0.5	-0.8
F. dichotoma	0.3	0	0.2	0	0.5	0.2	-0.1	0
Forb - small	0.6	1.4	0.3	0.3	0.7	0.8	-0.3	-1.1
H. contortus	0.1	0	6.1	4.7	2.2	1.7	6	4.7
Legume - palatable	0.4	0.6	0.3	0.3	0.4	0.6	-0.1	-0.3
M. americanum	0.2	0	0.2	0.2	0.1	0.1	0	0.2
P. effusum	2.2	0.6	1.8	0.2	0.7	0.5	-0.4	-0.4
Portulaca spp.	0	0	0	0	0	0	0	0
S. birchii	0.5	1.4	0	0	0.1	0.4	-0.5	-1.4
Sida spp.	0	0.3	0.1	0.2	0.3	0.4	0.1	-0.1
S. subspicatum	3	2.5	0.5	1.2	1	1.9	-2.5	-1.3
Solanum spp.	0.3	0.5	0.3	0.1	0.3	0.3	0	-0.4
Sporobolus (rats tail)	0.2	0	1.9	0.2	1.3	0.5	1.7	0.2
Sporobolus (small)	0.5	1.1	0	0	0.2	0.7	-0.5	-1.1
T. triandra	0.4	0	5	1.2	2.9	0.6	4.6	1.2
T. australianus	0.6	0.9	0	0.1	0.1	0.2	-0.6	-0.8
T. loliiformis	0.5	2.3	0.3	0	0.3	0.7	-0.2	-2.3
V. tenuisecta	0	0	0.4	0.2	1.4	1.7	0.4	0.2
Vittadinia spp.	0.2	0.5	0	0	0.1	0.1	-0.2	-0.5

The most desirable forage grasses, 3P species, increased in the absence of tree competition

Changes at the poplar box site in percentage composition after 7 years without grazing were generally not large (Table 6.42). Only pitted bluegrass at –23% in the treeless plots changed by more than 10%. It was interesting that under trees it had built up slightly (+8%) relative to its initial proportion of the pasture. This change was independent of the burning regime (Table 6.44). Overall, relative yields of *Enneapogon* spp., *Sida* spp., *T. loliiformis, C. fallax* and *A. calycina* tended to decrease during the 7 years while the 'decreaser' grasses *H. contortus, D. sericeum* and *T. triandra* tended to increase in the absence of grazing. Also, without grazing, buffel grass, barbwire grass and twirly windmill grass increased in terms of biomass and that was enhanced with regular spring burns in the case of black speargrass and Qld bluegrass. However, for barbwire grass and twirly windmill, the increase was enhanced by not burning (Figure 6.128f).

Killing the trees disadvantaged *Bothriochloa decipiens* the most amongst all the herbaceous species

6.2.2.4.3 Ground cover

Both regular burning and tree competition reduces pasture cover in poplar box. There was the greatest cover reduction from the combination of regular burning and tree competition in this woodland when ungrazed (Figure 6.122).

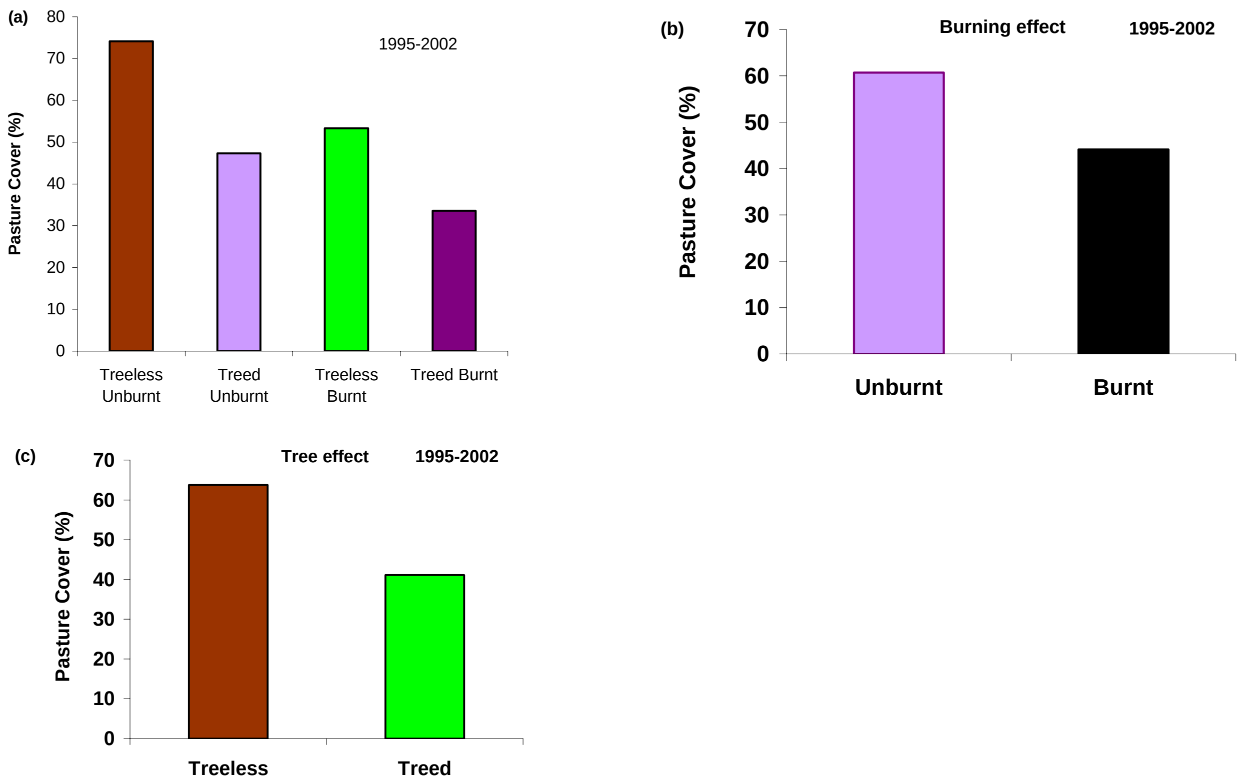


Figure 6.122 Mean (1995-2002) autumn pasture cover (%) in (a) burning*tree competition, (b) burning and (c) tree competition treatments of ungrazed pasture in poplar box woodland.

There was an initial rapid increase on pasture cover in the treeless plots of the burning trial, following the 1992-93 drought prior to initiating the burning treatments in October 1994. By 1996 cover was 20% higher then in the treed and burnt plots. The wet period of 1998-99 led to an increase in cover in all treatments which was most pronounced in the treeless and unburnt treatment (Figure 6.123).

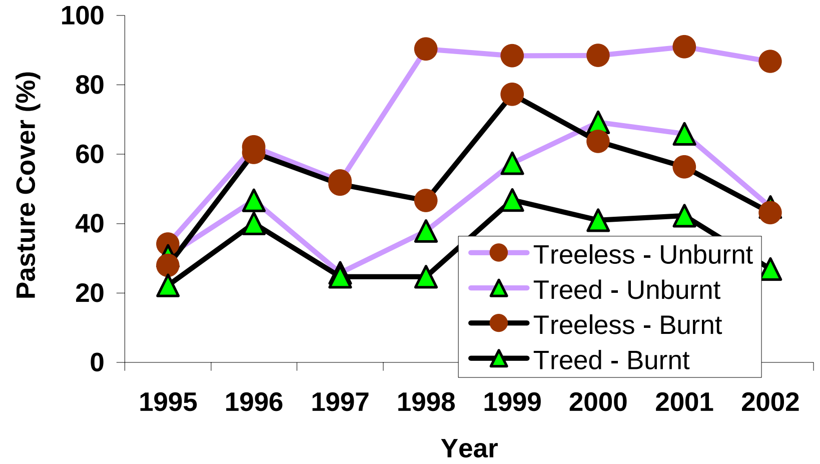


Figure 6.123 Autumn pasture cover (%) in burning * tree competition treatments of ungrazed pasture in poplar box woodland between 1995 and 2002.

Pasture cover is reduced by both regular burning and tree competition

6.2.2.4.4 Total pasture yield

There was a rapid 3-4 fold increase in pasture dry matter yield over the first 4 years after the initial killing of poplar box trees (Figure 6.124) in ungrazed plots. The initial yield increase occurred irrespective of the burning regime, but was not sustained in the treed plots after 6-7 years from the original clearing. The treed and burnt plots always had the lowest pasture production. The composition of the pastures changed most in the treeless and unburnt plots when rainfall was above average and there was good winter rain in 1998.

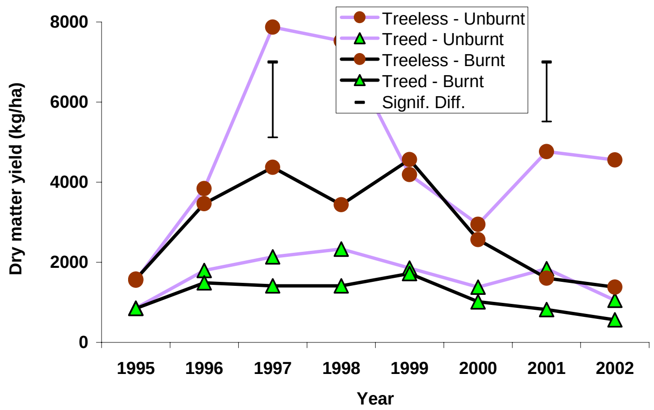


Figure 6.124 Standing autumn pasture dry matter yield (kg/ha) in burning * tree competition treatments in ungrazed pasture in poplar box woodland between 1995 and 2002.

Tree competition reduced pasture yield to a greater extent than regular burning

The unburnt plots had the highest pasture yield most years and had almost double the yield of the burnt plots (5000 kg/ha compared with 3000 kg/ha) after 3 years (Figure 6.125). The yield of the regularly burnt plots was declining significantly after the fifth year and showed no signs of recovering as the rainfall declined in 2002.

Regular burning reduces pasture yield with or without tree competition

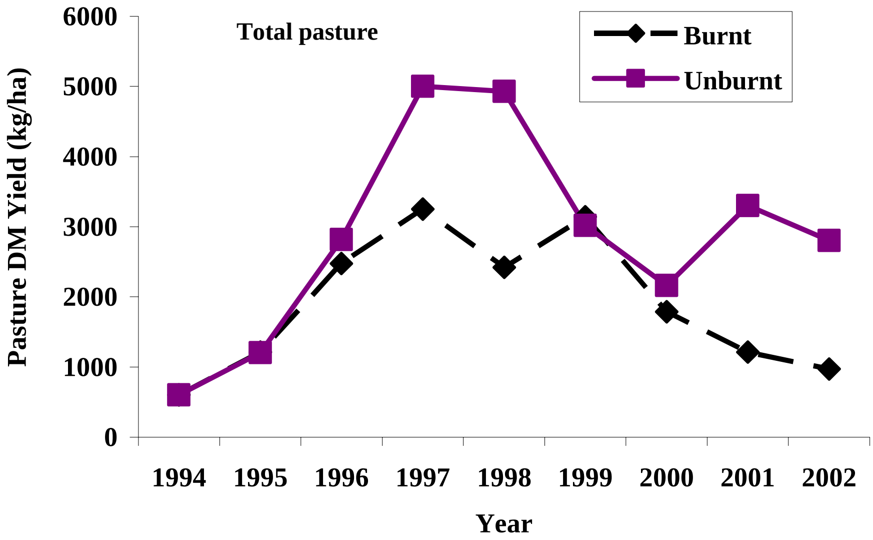


Figure 6.125 Standing autumn pasture dry matter yield (kg/ha) in burnt and unburnt treatments in ungrazed poplar box woodland.

No fire was possible prior to samples in autumn 1996 and 1999.

There was a pasture yield depression every year in the treed plots compared with the treeless plots (Figure 6.126). With tree competition, the yield peak was 2000 kg/ha even without grazing. The tree basal area at this site was between 8-10 m^2/ha. The peak yield was reached after 3 years in both treed and treeless plots, and there was a steady decline at different rates into the dry 2002 year. There was an accumulation of dead grass litter that prevented new pasture growth around the 4th and 5th years of exclosure from grazing.

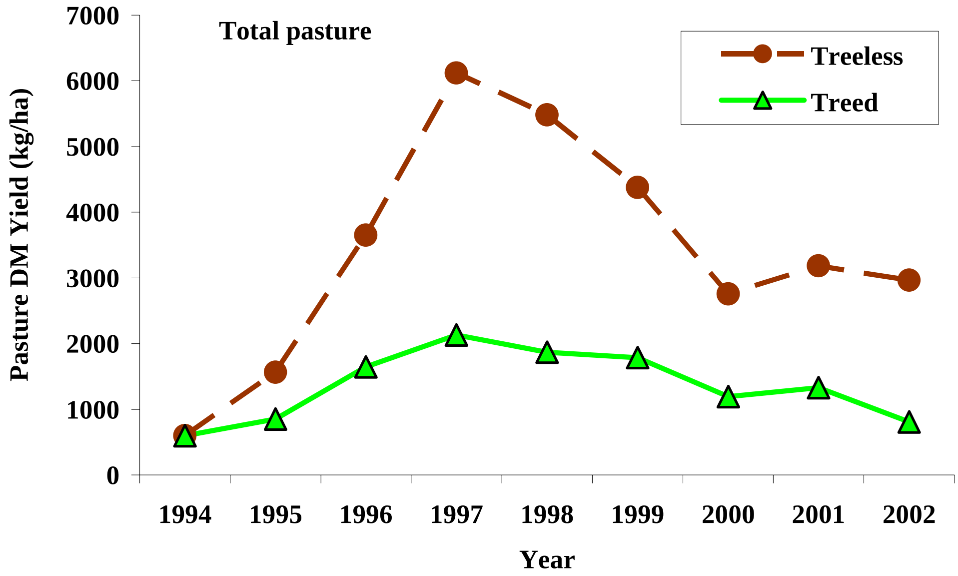
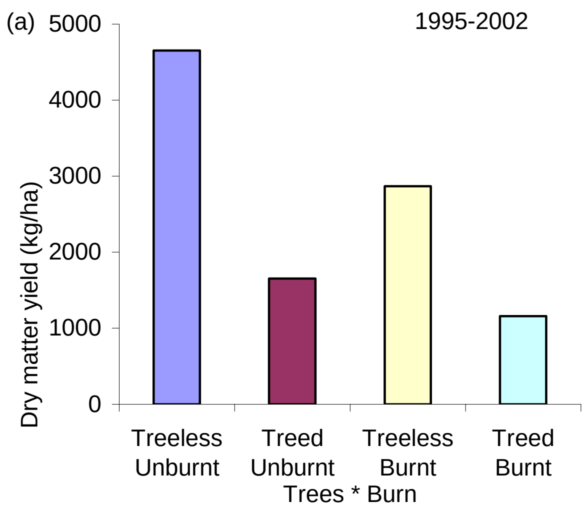


Figure 6.126 Tree competition effect on annual pasture dry matter yield (kg/ha) in the burning trial in ungrazed poplar box woodland.

Pasture yield nearly tripled with no tree competition, and there was a yield response for 8 years

The annual mean treatment dry matter yields of pasture (a) between 1995 and 2002, shows the strong yield response to the treeless and no burn treatment, as well as the higher yields from no burning (b) and reduced tree competition in the treeless treatments (c) (Figure 6.127).



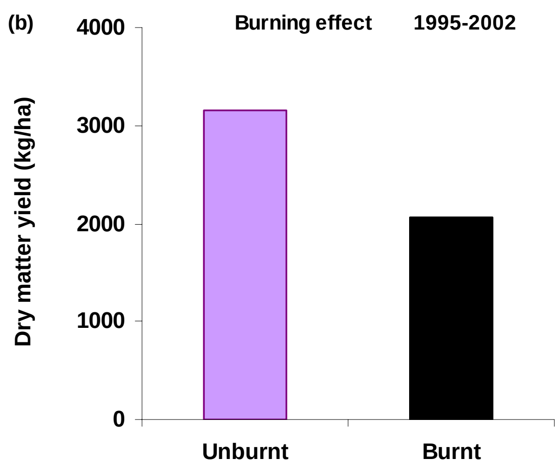
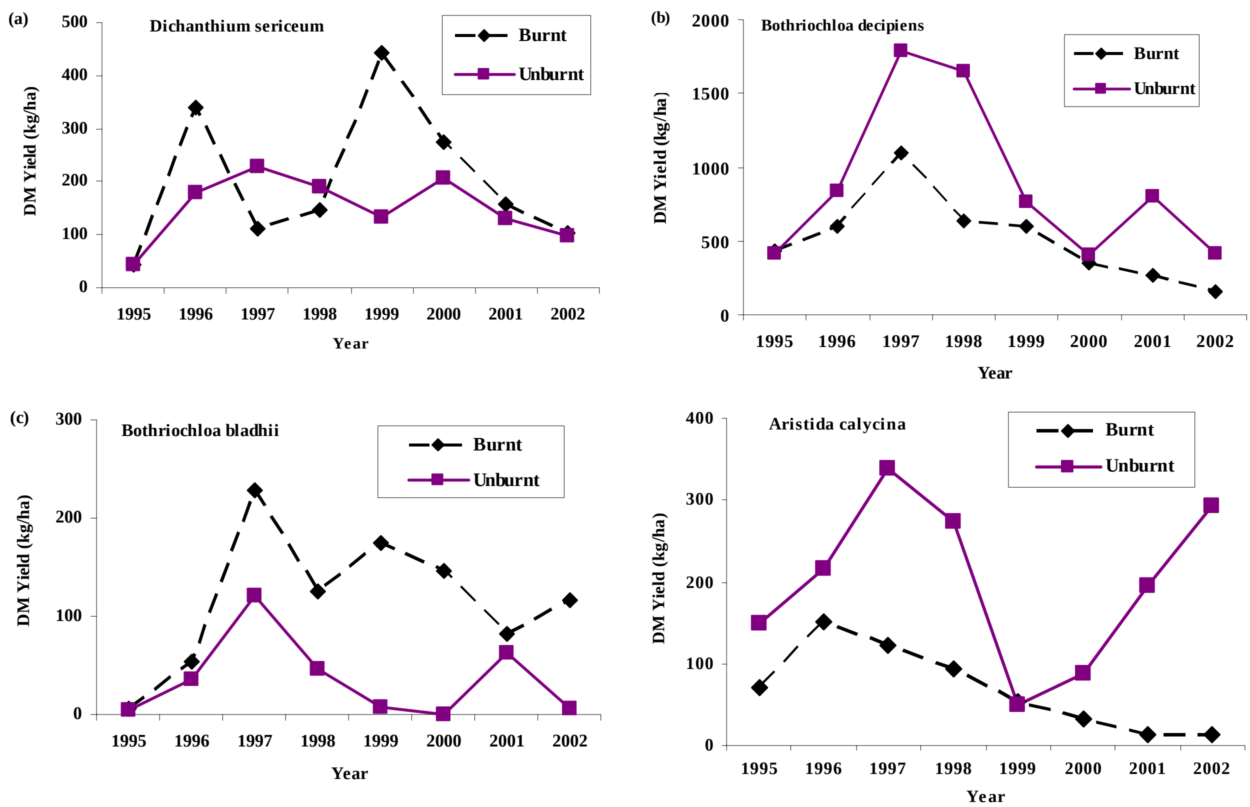


Figure 6.127 Mean (1995-2002) pasture dry matter yields (kg/ha) in (a) burning * tree competition, (b) burning and (c) tree competition treatments, in the burning trial in ungrazed poplar box woodland.

6.2.2.4.4.1 Individual species yield

The effects of burning on individual species varied over the trial, with an interaction with rainfall as well. There was an initial increase in yield of most species after killing trees and removing grazing. The highest yields also corresponded with the wetter years around 1997-98, which had a wet winter. The desirable 3P grasses, *D. sericeum* and *B. bladhii* both increased under regular burning, while the less desirable *B. decipiens* had higher yields when unburnt (Figure 6.128). There was a significant response by *Calotis lappulacea* for up to 4 years around the wet 1998-99 period in the absence of burning compared with regular burning.



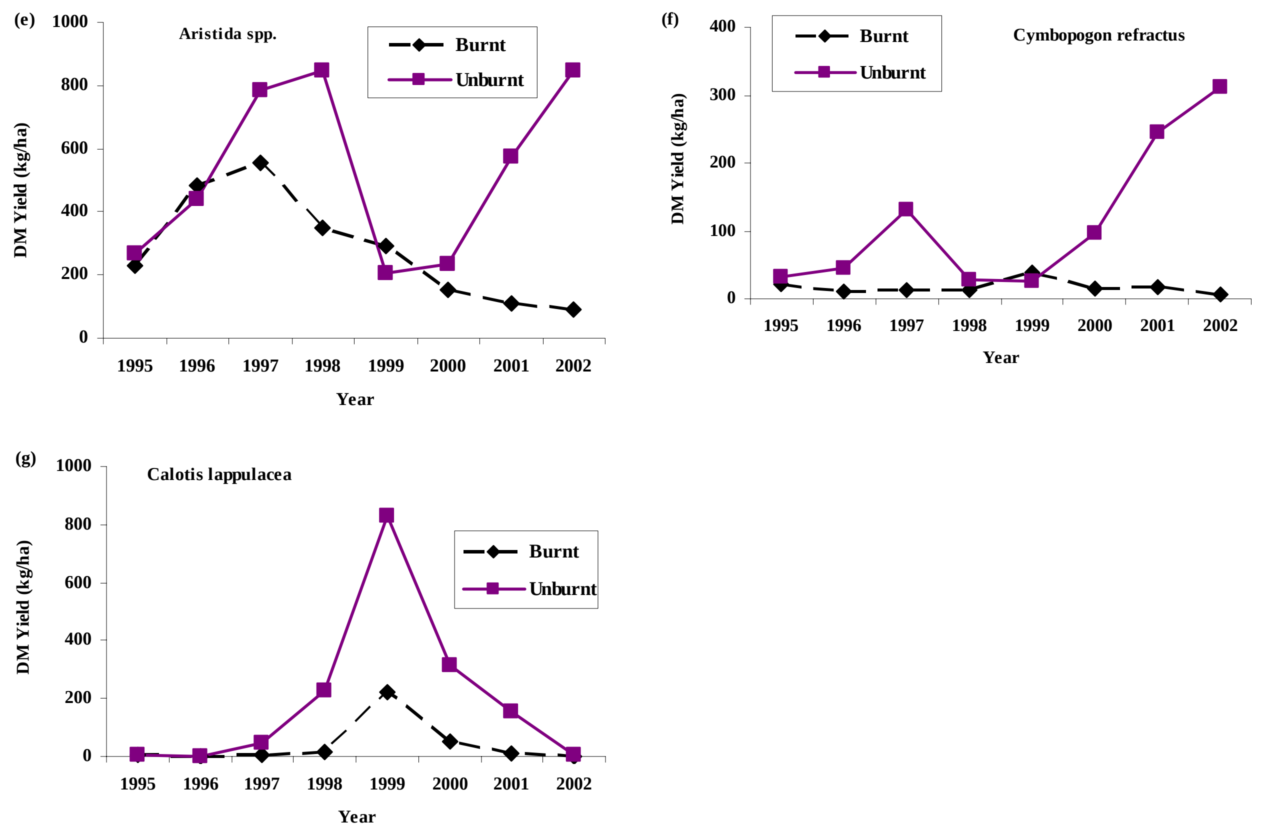


Figure 6.128 a,b,c,d,e,f,g. Standing autumn dry matter yield (kg/ha) of major pasture species in ungrazed pasture in response to regular spring burning of poplar box woodland.

The dry matter yields of *Cymbopogon refractus*, *Calotis lappulacea* and *Aristida calycina* (Figure 6.128 d,f,g) all responded to a lack of burning. There was a significant interaction with winter rainfall in 1998 in yield response by the Calotis, which then persisted for several years, before declining again in the drier winters of 2001 and 2002.

The species yield change in burnt and unburnt treatments between 1995 and 2002 (Table 6.43) shows *B. bladhii* and *C. divaricata* had the largest yield increases when burnt, while *A. ramosa, Cymbopogon* spp., *B. decipiens* and *A. calycina* had the largest yield increases when unburnt.

Regular burning increased the yield of desirable bluegrasses and reduced the yield of most other major pasture species

Table 6.43 Burning effect on change in species dry matter yield (kg/ha) between 1995 and 2002 in poplar box woodland

	Change between 1995 & 2002		
Species	**Burnt 2002-1995**	**Unburnt 2002-1995**	**Comparative Difference**
Bothriochloa bladhii	111.0	0.8	110.2
Chloris divaricata	33.5	9.2	24.3
Eragrostis spp.	19.5	9.6	9.9
Enneapogon spp.	35.4	25.6	9.8
Dichanthium sericeum	96.5	88.5	8.0
Enteropogon acicularis	-2.9	6.4	-9.3
Bothriochloa ewartiana	0.0	10.3	-10.3
Cyperus spp.	4.1	15.4	-11.3
Eulalia aurea	15.1	31.3	-16.2
Verbena tenuisecta	0.2	17.4	-17.2
Heteropogon contortus	70.0	90.7	-20.7
Aristida spp.	1.4	22.8	-21.4
Chloris spp.	1.9	29.2	-27.3
Sporobolus (ratstail)	10.9	47.9	-37.0
Panicum effusum	3.0	66.8	-63.8
Cenchrus ciliaris	21.9	109.9	-88.0
Themeda triandra	17.8	182.8	-165.0
Enteropogon ramosus	17.9	198.6	-180.7
Aristida calycina	-9.2	251.6	-260.8
Bothriochloa decipiens	42.6	307.2	-264.6
Cymbopogon spp.	3.0	303.4	-300.4
Aristida ramosa	20.9	477.9	-457.0

6.2.2.4.5 Species proportions

Regular burning increased the yield of the desirable 3P grasses, Queensland and forest bluegrasses, while reducing the yield of most other pasture species (Figure 6.128) along with the total pasture yield. The highest yielding forb, *Calotis lappulacea*, increased under all treatments in the wet winter of 1998, but the increase in cleared plots was greatest.

The change in main pasture species composition, as measured by the % contribution to total pasture dry matter yield, during the trial between 1995 and 2002 is shown in Figure 6.129 for the regular burning effects and in Figure 6.130 for the tree competition effects when ungrazed. *H. contortus, D. sericeum, B. bladhii* and *Cymbopogon* spp. had the greatest increase in composition in response to burning, while *B. decipiens, A. calycina* and *A. ramosa* had the largest declines in composition.

B. decipiens had the greatest increase on any species in treed plots and also had the greatest decrease in composition after clearing, in the treeless plots (Figure 6.130).

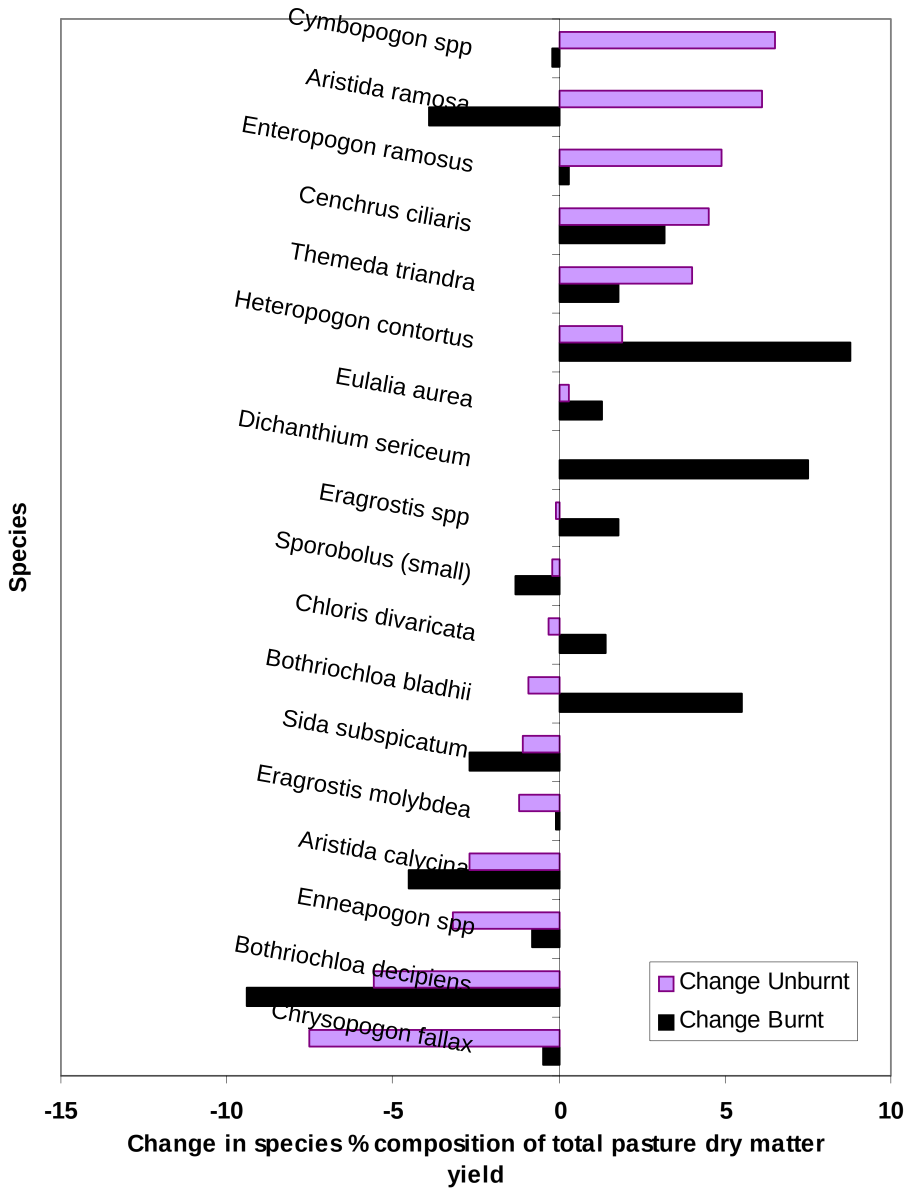


Figure 6.129 Regular spring burning effects on change in species composition % (proportion of total pasture dry matter yield) between 1995 and 2002 (mean of 12 treatment plots).

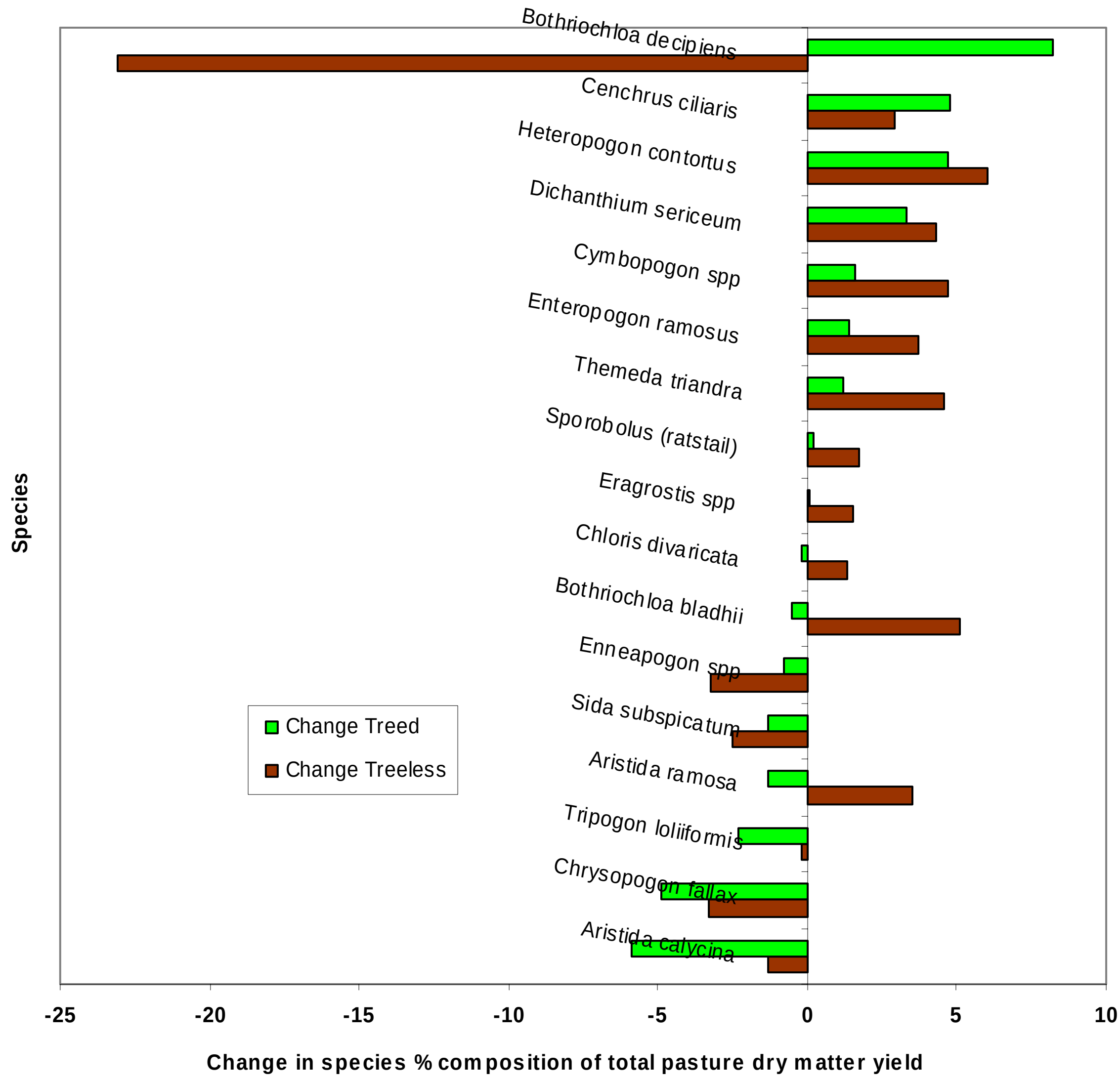
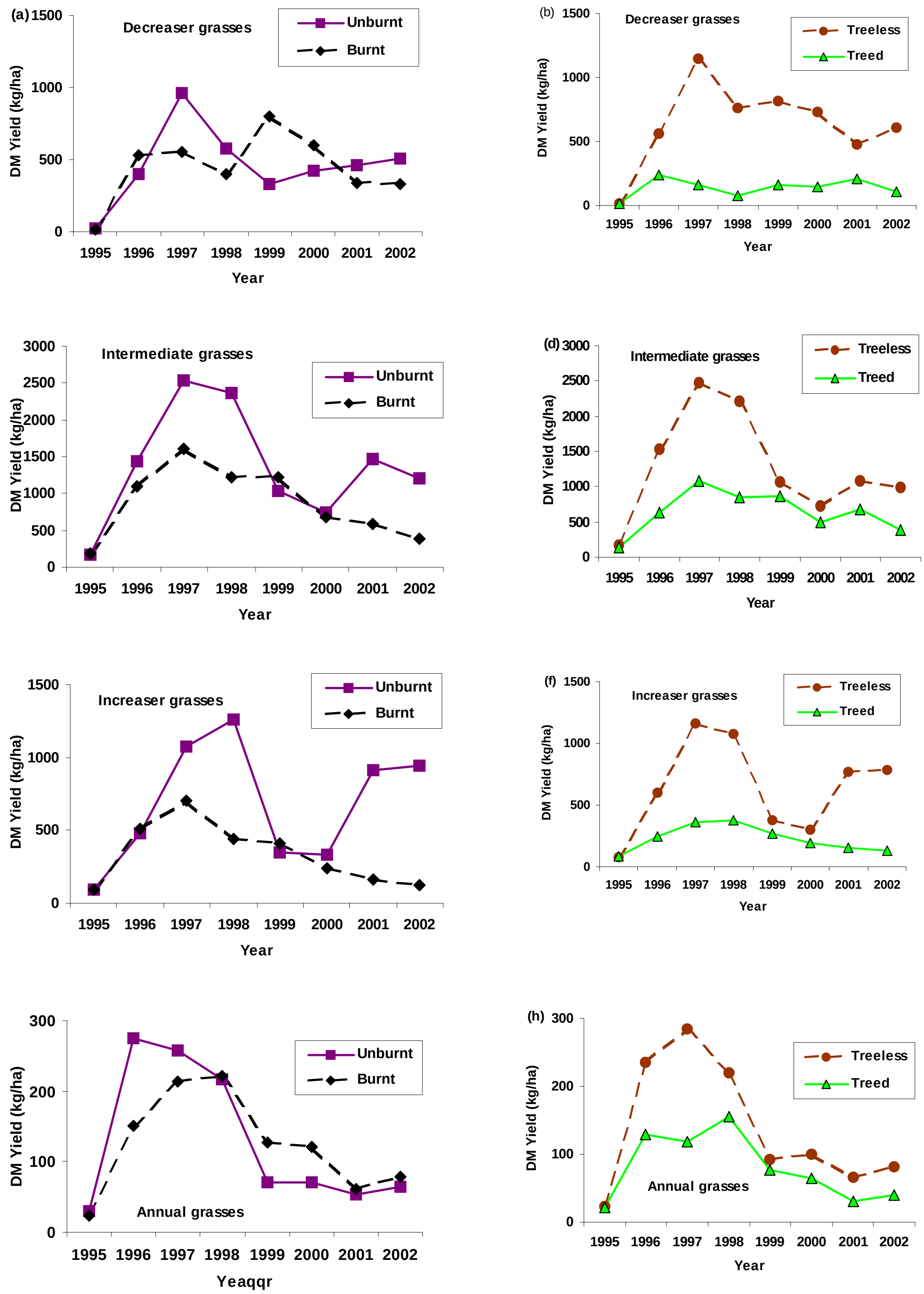


Figure 6.130 Effect of tree competition on change in species composition % (proportion of total pasture dry matter yield) between 1995 and 2002 (mean of 12 treatment plots).

6.2.2.4.6 Dry matter yield of functional groups

The removal of tree competition in the ungrazed burning trial paddocks immediately had a beneficial effect on the 3P decreaser grasses. This benefit was most pronounced after 2-4 years (Figure 6.131), but persisted throughout the trial. There were not the same consistent benefits to decreaser grasses from the burning treatment. In the burnt paddocks, the decreaser grasses, especially *T. triandra* and *H. contortus*, tended to grow in expanding patches, which were not necessarily recorded by our 2-line fixed transect sampling method. The *H. contortus* patches often started at the base of killed poplar box trees. The yield of forbs increased most without burning, with the most significant contribution from yellow daisyburr, which grew profusely in winter of 1998 and there was a yield carryover from this species into the next few years.

The yield of all functional groups was highest without tree competition (Figure 6.131) and showed a steady increase in the first few years after killing the poplar box trees. The yield differences were less after 6-8 years which was also a period of lower rainfall.


(a)
Decreaser grasses
Unburnt
Burnt
DM Yield (kg/ha)
Year
(b)
Decreaser grasses
Treeless
Treed
DM Yield (kg/ha)
Year
Intermediate grasses
Unburnt
Burnt
DM Yield (kg/ha)
Year
(d)
Intermediate grasses
Treeless
Treed
DM Yield (kg/ha)
Year
Increaser grasses
Unburnt
Burnt
DM Yield (kg/ha)
Year
(f)
Increaser grasses
Treeless
Treed
DM Yield (kg/ha)
Year
Annual grasses
Unburnt
Burnt
DM Yield (kg/ha)
Yeaqqr
(h)
Annual grasses
Treeless
Treed
DM Yield (kg/ha)
Year
1995 1996 1997 1998 1999 2000 2001 2002

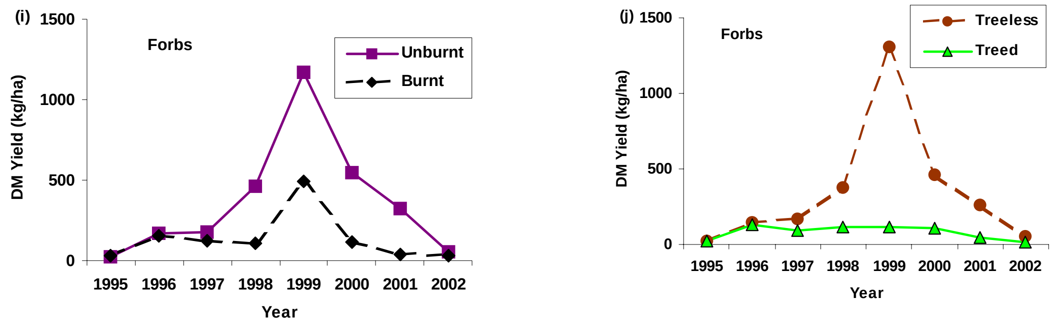


Figure 6.131 Effects of regular burning and killing trees on dry matter yield of the grass and forb species (excluding palatable legumes and sedges) component of pastures in ungrazed poplar box woodland.

6.2.2.4.7 Pasture component frequencies (%)

The major wiregrasses were suppressed by burning as was pitted bluegrass but golden-beard grass was suppressed more in the absence of fire, which fits in with its low-stature, increaser status.

When the data is examined on the basis of plant frequency, bigger shifts were recorded after 7 years (Figure 6.132), with 8 species showing over a 10% change in that time. The *Eragrostis* spp. appear to be favoured by spring burns, but year-to-year data was quite variable in between. Again pitted bluegrass showed a big loss where trees had been killed (-23%), but an increase (+14%) where trees had been retained (and presumably grew slightly bigger in that time). Blue trumpet declined markedly in all plots (15-26%), while consistent but smaller declines were also recorded for palatable legumes, *T. loliiformis, C. fallax, S. subspicata, T. australianus* and *E. lacunaria*. Consistent increases in frequency in the absence of grazing were recorded for *A. ramosa, C. divaricata* and the rats-tail *Sporobolus* species, mainly *S. elongata* or *S. creber*. Meanwhile variable responses based on tree cover were recorded for sedges, daisyburrs, bottlewasher grasses and *A. calycina* (Figure 6.133).

Table 6.44 Effect of regular spring fires on species composition (% dry matter yield) in ungrazed poplar box pastures after 7 years.

Taxon / species	1995		2002		Mean 1995-2002		Change 1995-2002		Max. 1995-2002		Min. 1995-2002	
	Burn	No burn	Burn	No burn	Burn	No burn	Burn	No burn	Burn	No burn	Burn	No burn
A. calycina	21.3	28.7	10.6	30.8	14.8	21.5	-10.7	2.1	21.3	30.8	10.6	11
A. latifolia	5.8	1.3	2.3	1	2.8	1.6	-3.5	-0.3	5.8	3.6	0	0
A. leptopoda	3.7	0.8	1.6	0.3	2.3	0.9	-2.1	-0.5	8	4	0.3	0
A. ramosa	25	30.4	25.2	43.1	15.9	18.7	0.2	12.7	25.2	43.1	0.3	0
Aristida spp.	0	0	0.9	2.2	9.8	9.5	0.9	2.2	22.2	23.3	0	0
B. bladhii	4.2	2.1	7.1	1.9	6.9	2.5	2.9	-0.2	10.6	5.8	2.6	0.3
B. decipiens	55	49	47.6	47.2	50.2	52.7	-7.4	-1.8	58.6	61.8	32.8	42.9
B. australis	32.9	18.2	6.1	3.9	10.1	6.4	-26.8	-14.3	32.9	18.2	4.3	2.9
Calotis spp.	9.2	7	3.2	5.8	10.4	18.1	-6	-1.2	23.9	34	0.3	0.4
C. ciliaris	0	0.4	2.2	6.1	1.4	4	2.2	5.7	2.6	6.1	0	0.4
C. divaricata	3.7	4.1	11.9	7.3	7.3	3.1	8.2	3.2	11.9	7.3	3.7	1
C. fallax	51.7	52.7	53.5	30.7	50.7	39.7	1.8	-22	59.7	52.7	41.9	30.7
Cyperus spp.	7.5	10.8	6.6	13	6	7.4	-0.9	2.2	10.3	16.1	1.1	0.3
D. sericeum	7.5	8.3	20.7	10.9	21.1	11.6	13.2	2.6	34.4	18.1	6.6	4.9
Enneapogon spp.	21.3	22.4	26.2	22.9	22	19.9	4.9	0.5	26.3	22.9	16.5	14.2
E. ramosus	4.6	3.3	4.5	6.7	3.2	3.5	-0.1	3.4	4.6	6.7	1.3	1
Eragrostis spp.	6.7	15.3	10	4.5	10.7	9.2	3.3	-10.8	14	15.3	6.7	3.6
E. molybdea	9.2	12	5.7	4.8	3.4	4.5	-3.5	-7.2	9.2	12	0	0
F. dichotoma	3.3	5	4.2	2.6	8.2	4.7	0.9	-2.4	22.6	10.6	0	0
Forb - small	16.2	11.2	19.1	7.7	19.7	15.6	2.9	-3.5	33.8	27.6	12.1	6.5
H. contortus	0	0.8	7.5	2.5	3.2	1.8	7.5	1.7	7.5	4.1	0	0.3
Legume - palatable	25.8	19.6	15	14.2	17.6	14.9	-10.8	-5.4	25.8	23.7	9.5	8.9
M. americanum	0.4	2.9	2.8	3.2	1.2	1.4	2.4	0.3	2.9	3.2	0	0.3
Portulaca spp.	2.1	5.8	0	0	0.4	0.8	-2.1	-5.8	2.1	5.8	0	0
S. birchii	2.5	4.9	0	1.3	0.8	2.1	-2.5	-3.6	3	4.9	0	0
Sida spp.	4.6	10.7	4.2	4.1	4.1	5	-0.4	-6.6	6.3	10.7	2.3	1.9
S. subspicatum	12.1	6.2	5.6	2.2	7	3.5	-6.5	-4	12.1	6.2	4.7	0.3
Solanum spp.	5	5.4	3.8	2.3	4.3	3.4	-1.2	-3.1	7.1	5.7	0	0
Sporobolus (ratstail)	0	2.9	5.4	5.2	3.7	3.5	5.4	2.3	8.3	5.9	0	0.9
Sporobolus (small)	5.4	3.7	0.7	0	3.6	1.6	-4.7	-3.7	6.7	4.4	0.7	0
T. triandra	0.4	0	3.4	2.9	1.5	1.8	3	2.9	3.4	2.9	0.3	0
T. australianus	6.2	6.6	0.3	0.3	2.5	1.8	-5.9	-6.3	6.2	6.6	0	0
T. loliiformis	7.5	16.5	6.4	2.9	6.9	6.5	-1.1	-13.6	13.9	16.5	3.5	0.7
V. tenuisecta	0.4	0	1.9	11.8	3.9	19.6	1.5	11.8	14.1	41.7	0.4	0
Vittadinia spp.	7.9	1.7	0	0	2	1.3	-7.9	-1.7	7.9	5.8	0	0

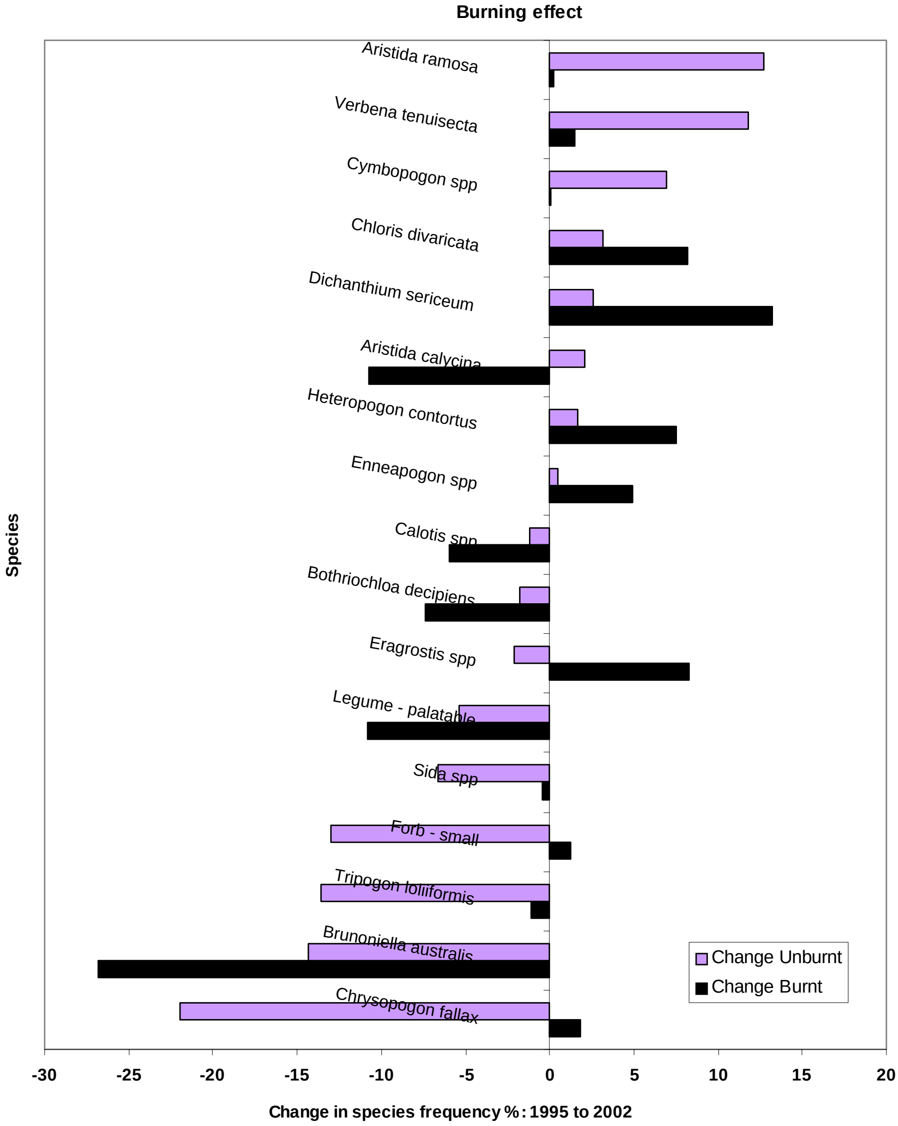


Figure 6.132 Change in species frequency over 7 years due to regular spring burns and no grazing.

The effect of burning on frequency was similarly large in many cases but sometimes contrasting. Lack of spring fires disadvantaged *C. fallax* greatly (-22%), small forbs (-13%) and *T. loliiformis* (-14%) while advantaging *A. ramosa* (+13%), Maynes pest and barbwire grass (Figure 6.132). Conversely burning in spring increased the presence of Qld bluegrass by 10%, *Eragrostis* spp. by 10% and black speargrass by 6% (7.5–1.7%) (Figure 6.132).

Most species showed marked inter-year variation in their presence but the differences were greatest for the less perennial species such as *V. tenuisecta* (0-42% where unburnt), daisyburrs (0-24% where burnt Figure 6.128), and blue trumpet (4-33% where burnt). The dominant perennial grasses could also fluctuate markedly but without losing their importance, e.g. *C. fallax* 31–53% where unburnt, pitted bluegrass 33–58% (burnt), *A. calycina* 11–31% (unburnt) and Qld bluegrass 7–34% (burnt). The most stable group for presence was the bottlewasher grasses (14-23%) but this data may hide a more dynamic picture for the 4-5 individual species that make up this group.

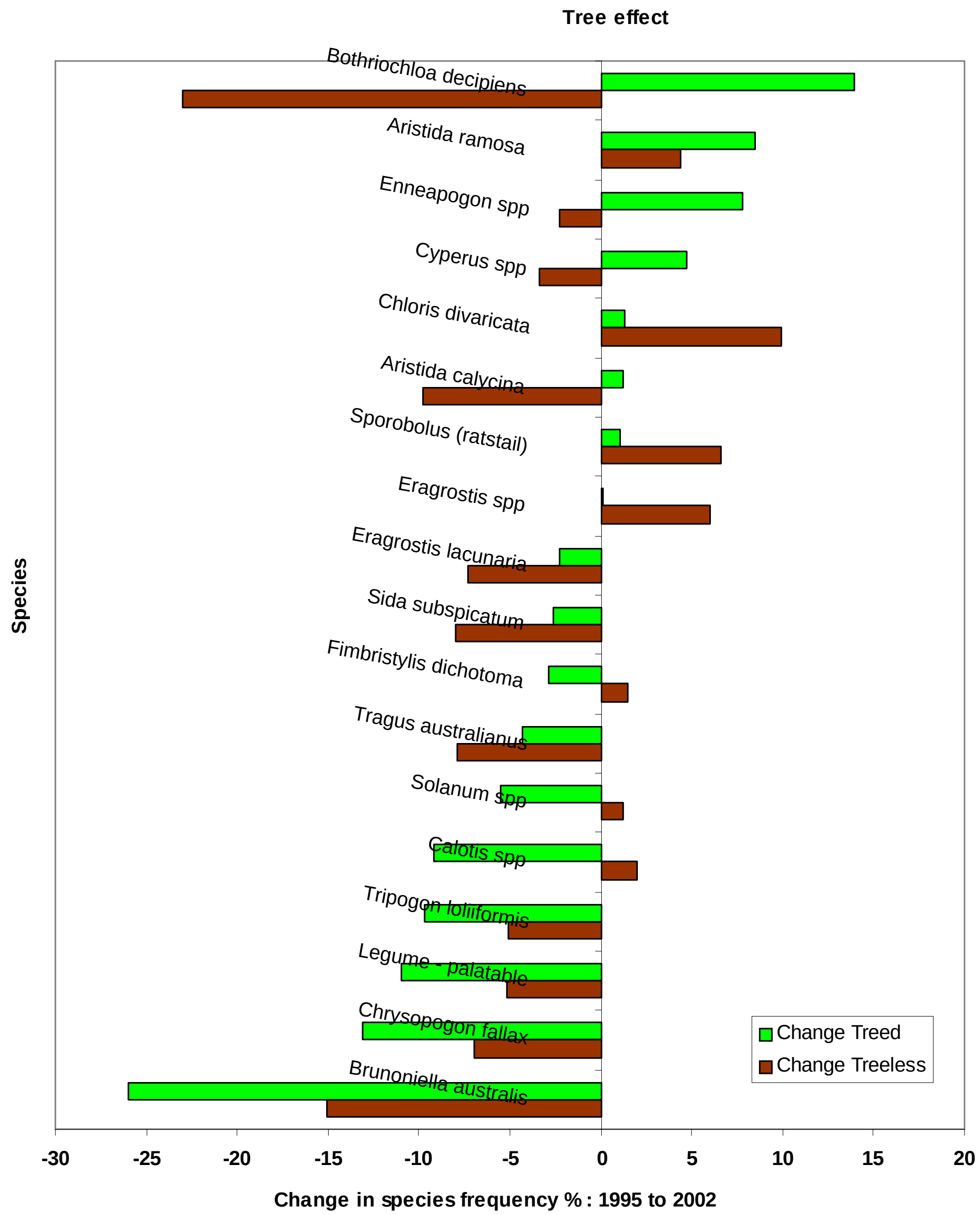


Figure 6.133 Change in species frequency in ungrazed pastures as affected by tree competition over 7 years.

Minor species were also fairly stable components in most years that rarely exceeded 10% frequency but were always recorded. The most stable examples of this group at this site were *E ramosus, B. bladhii, C. ciliaris, H. contortus,* rats-tail *Sporobolus* spp., small *Sporobolus* spp., *T. triandra, M. americanum* and *Sida* spp. Many of these are important perennial grasses in tropical savannas that happen to be in low abundance at this 12ha site. They were nonetheless consistently recorded by a random sampling system that had adequate numbers of sample points. The weed species, such as *Sida* spp., that are associated with overgrazing and landscape degradation were present but at low frequencies throughout the 8-year trial period.

The effect of the burning treatment on frequency of some main species between 1995 and 2002 shows *C. fallax, D. sericeum, B. bladhii* and *C. divaricata* frequency were positively influenced by regular spring burning (Figure 6.134), while *V. tenuisecta, Calotis spp., A. calycina* and *Cymbopogon* spp. frequency was negatively affected by the burning regime (Figure 6.135). The frequency of some common species, e.g. *B. decipiens* and *B. australis* was not affected by the burning treatment (Figure 6.136).

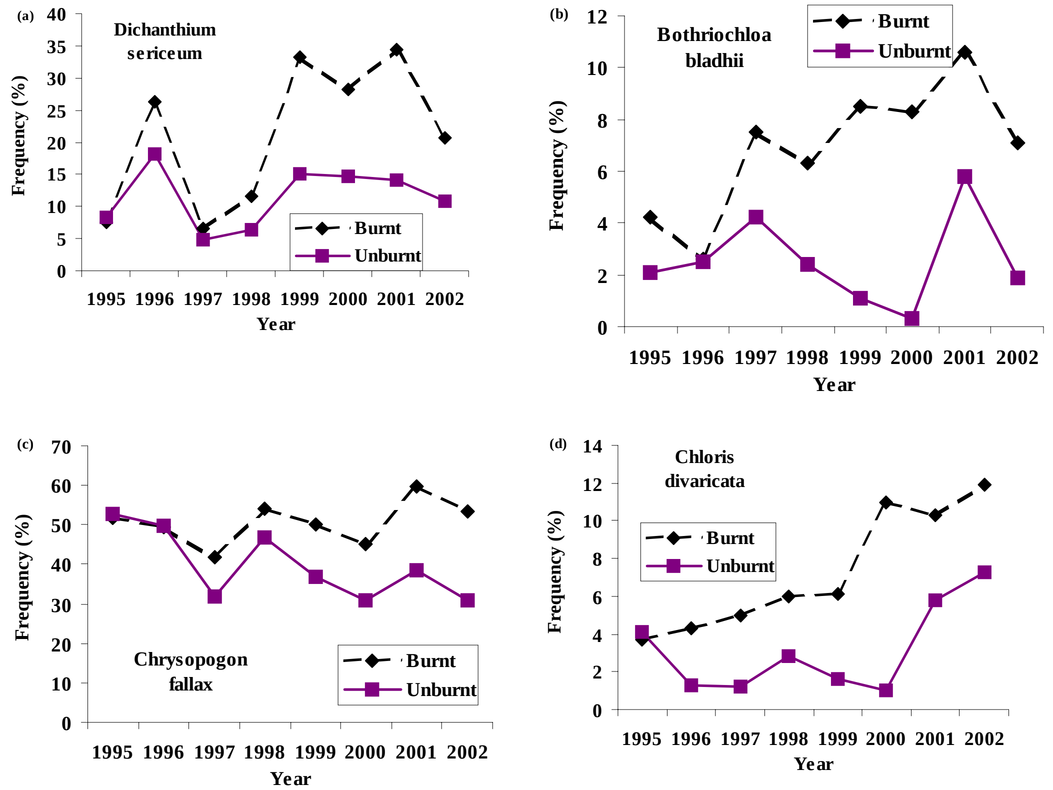


Figure 6.134 Positive frequency (%) response by *D. sericeum*, *B. bladhii* , *C. fallax* and *C. divaricata* to frequent spring burning of ungrazed pastures in poplar box woodland 1995-2002.

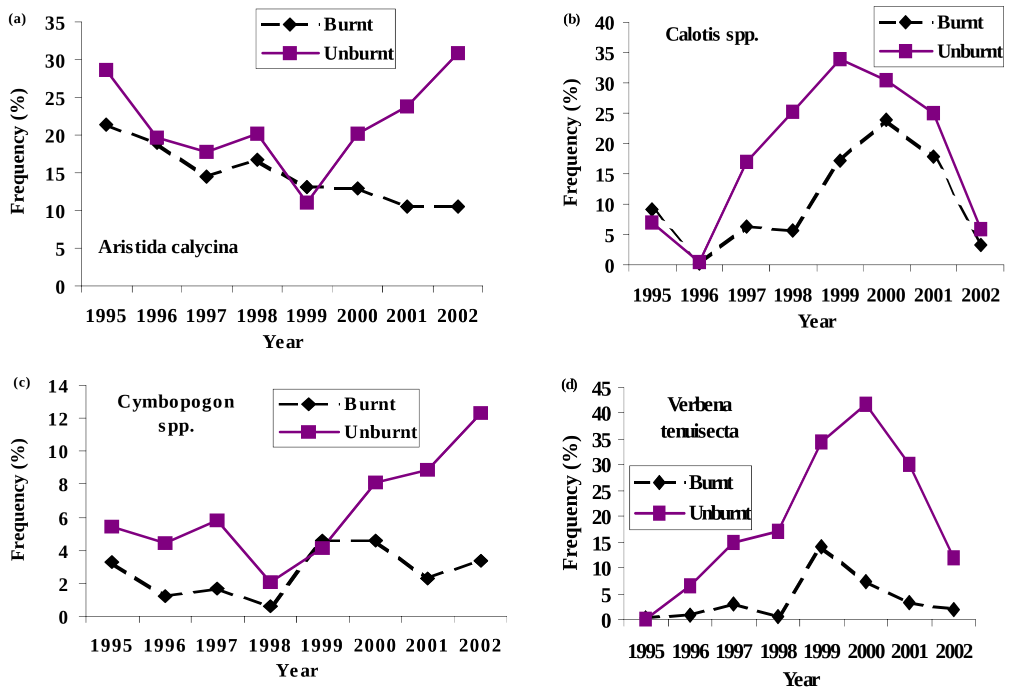


Figure 6.135 Negative frequency (%) response by *A. calycina*, *Calotis* spp., *Cymbopogon* spp. and *V. tenuisecta* to frequent spring burning of ungrazed pastures in poplar box woodland 1995-2002.

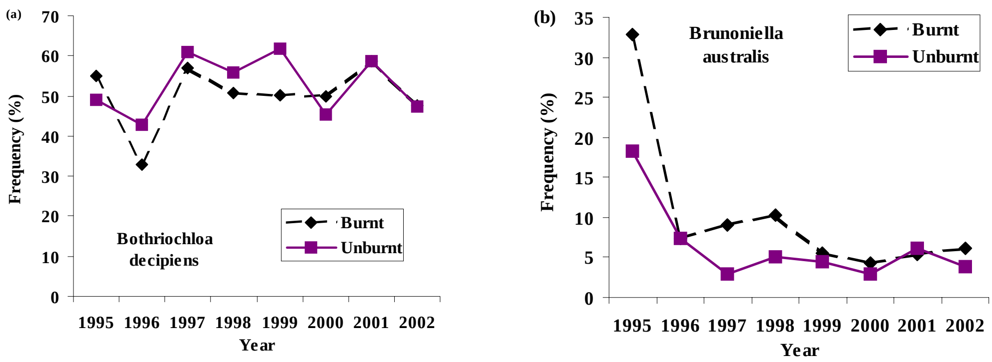
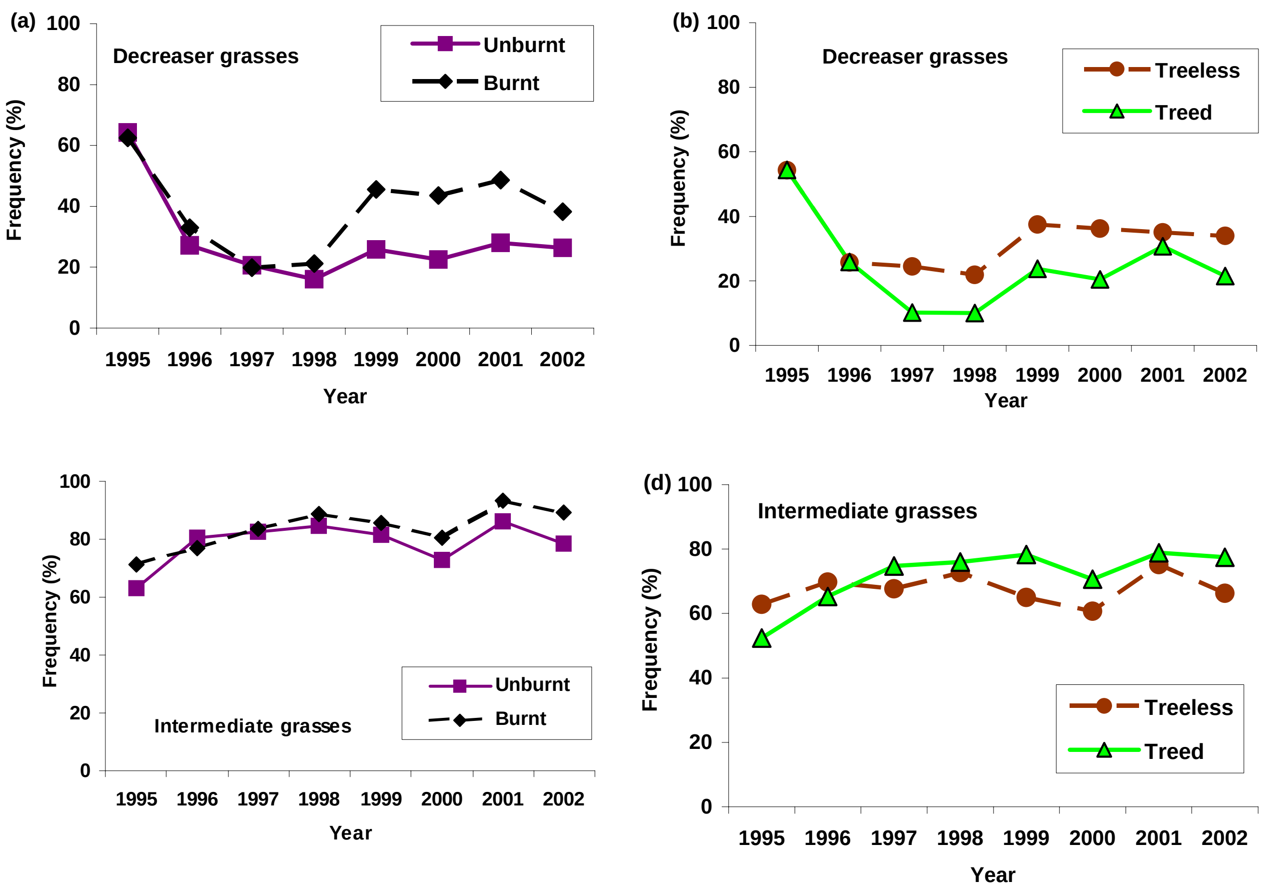
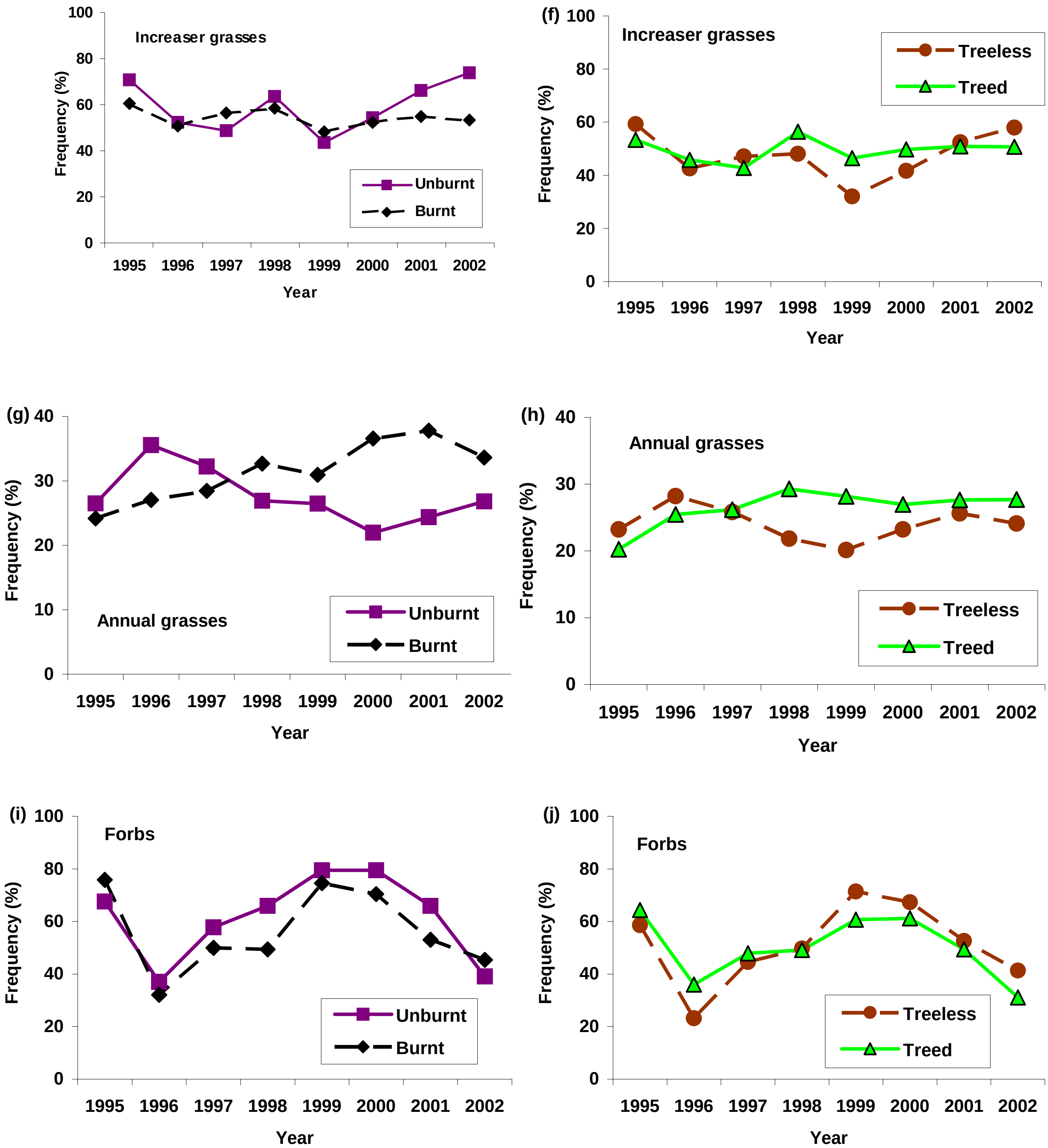


Figure 6.136 Effect of frequent spring burning on frequency of *Bothriochloa decipiens* and *Brunoniella australis* of ungrazed pastures in poplar box woodland between 1995 and 2002.

6.2.2.4.8 Frequency of functional groups




Increaser grasses
Frequency (%)
100
80
60
40
20
0
1995 1996 1997 1998 1999 2000 2001 2002
Year
Unburnt
Burnt
(f) 100
Increaser grasses
Treeless
Treed
Frequency (%)
80
60
40
20
0
1995 1996 1997 1998 1999 2000 2001 2002
Year
(g) 40
30
20
10
0
Frequency (%)
Annual grasses
Unburnt
Burnt
1995 1996 1997 1998 1999 2000 2001 2002
Year
(h) 40
Annual grasses
30
20
10
0
Frequency (%)
Treeless
Treed
1995 1996 1997 1998 1999 2000 2001 2002
Year
(i) 100
Forbs
80
60
40
20
0
Frequency (%)
Unburnt
Burnt
1995 1996 1997 1998 1999 2000 2001 2002
Year
(j) 100
Forbs
80
60
40
20
0
Frequency (%)
Treeless
Treed
1995 1996 1997 1998 1999 2000 2001 2002
Year

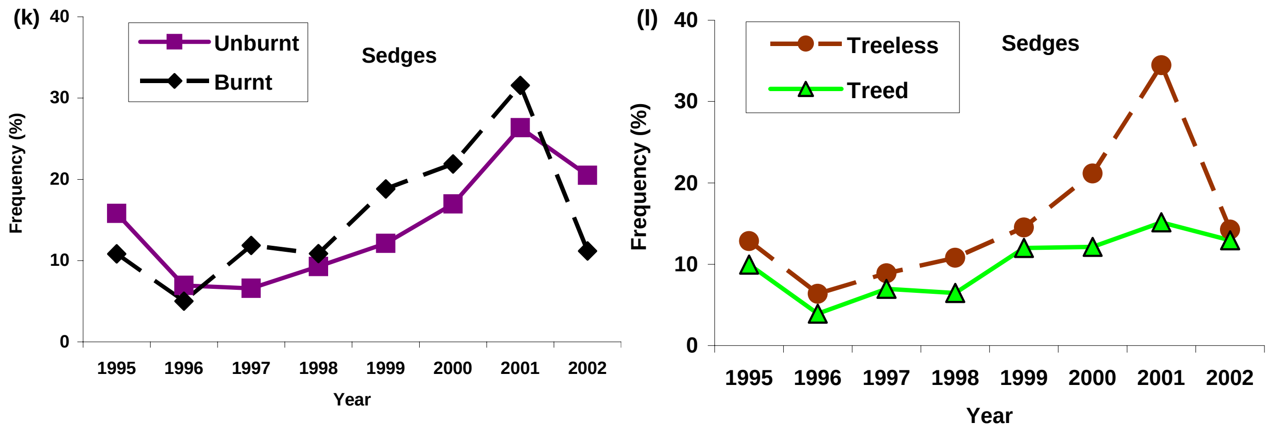


Figure 6.137 Species functional group frequency (%) in the poplar box burning trial – Burnt vs Unburnt and Treed vs Treeless.

Regular spring fires increased the frequency of the decreaser grass group (Figure 6.137 a) as did the lack of trees (Figure 6.137 b). Regular burning also increased the frequency of annual grasses noticeably over time but had no consistent effect on the forbs or the sedges as a group (Figure 6.137). The sedges increased markedly in 2000 and 2001 where the trees had been removed for 6 years prior but that effect was lost again in the dry summer of 2001/02. The grass/forb balance fluctuated over the years and, though it was significantly different in certain years, it did not change consistently where ungrazed for 8 years with regular burning of half the plots.

6.2.2.4.9 Pasture species diversity

The numbers of grasses and forbs recorded at in the poplar box burning trial remained relatively consistent across the 8 years, although there were significant differences between some years (Figure 6.138). There were about twice as many grass species as forbs recorded.

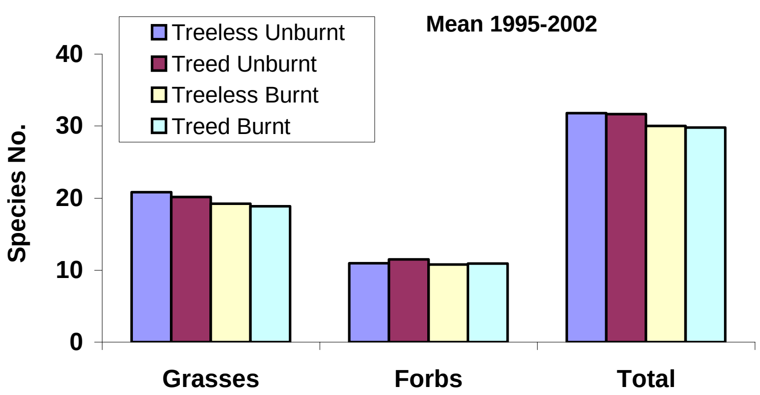


Figure 6.138 Mean numbers of grass, forb and total species recorded in botanal quadrats each year in the poplar box burning trial.

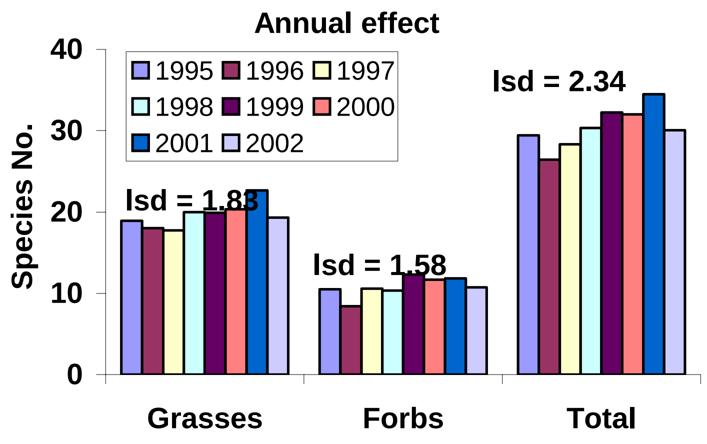


Figure 6.139 Annual numbers of grass, forb and total species recorded in botanal quadrats each year in the ungrazed poplar box burning trial.

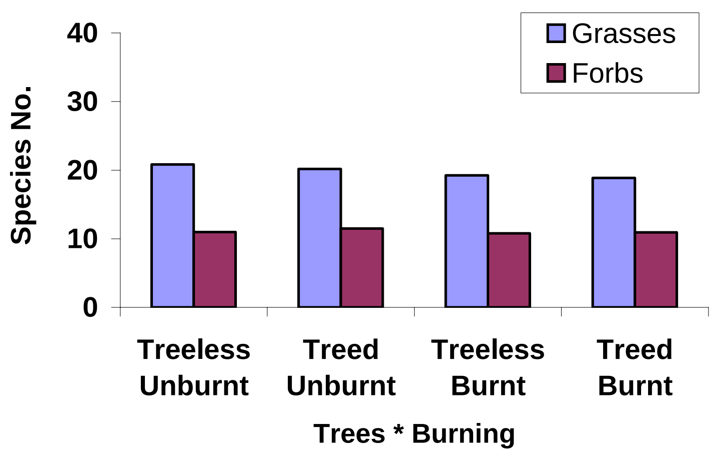


Figure 6.140 Mean effect (1995-2002) on grass and forb species numbers of the tree and spring burning interaction in the poplar box burning trial.

There were no significant effects on the numbers of species of grasses or forbs from burning (Figure 6.141) and tree competition (Figure 6.142) treatments in the burning trial in poplar box. There were different responses between individual species, but not in total number of species recorded each year. The average number of grasses was around 20 species and there were around 10 forbs, making a total of about 30 species recorded in the 50 quadrats (0.25 m^2) per 1 ha plot. There were more grasses than forb species each year.

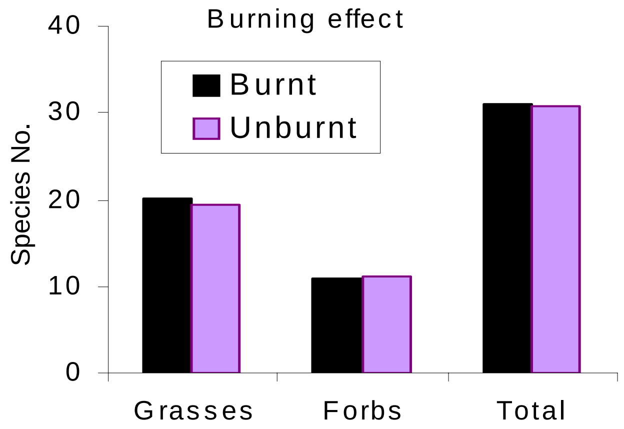


Figure 6.141 Mean (1995-2002) number of grass and forb species recorded in burnt and unburnt plots of the burning trial in poplar box woodland.

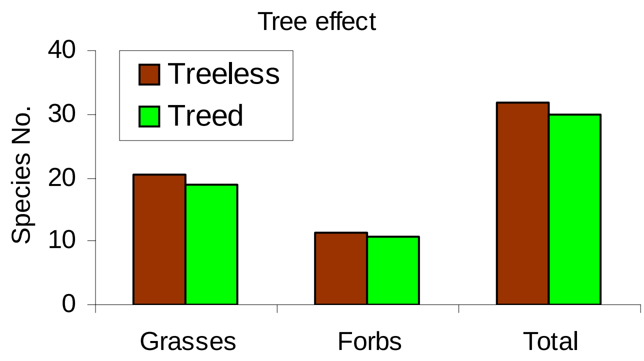


Figure 6.142 Mean (1995-2002) number of grass and forb species recorded in treed and treeless plots of the burning trial in poplar box woodland.

The burning trial was less diverse spatially than the nearby grazing trial as measured by the number of species, either grasses of forbs, present in the 0.25 m^2 Botanal quadrats (Figure 6.143). Some 30 % of quadrats in the grazed pasture had 6 species or more while less than 15% of quadrats in the burning trial had at least 6 species, most had 3 or 4 species. A maximum of 6 species only was recorded per quadrat.

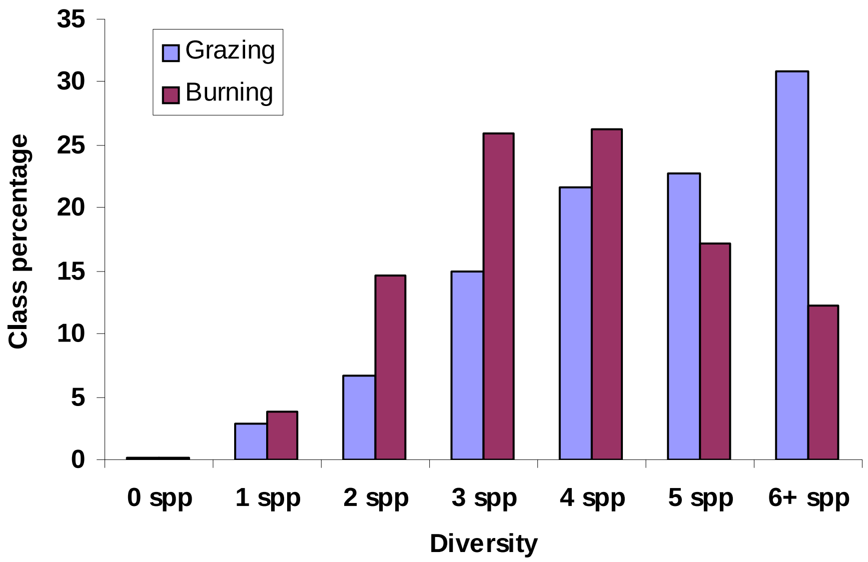


Figure 6.143 Percent of botanal quadrats with 0–6 grass or forb species present in the grazing and burning trials in poplar box woodland.

6.2.2.4.10 Perennial grass basal area

In the burning trial where grazing was excluded, there also was a significant increase in pasture basal area after clearing, which persisted throughout the trial (Figure 6.144).

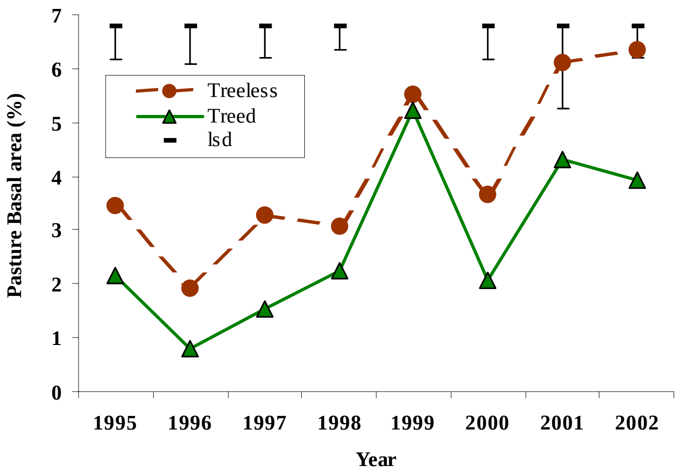


Figure 6.144 Pasture basal area in ungrazed cleared and treed plots of the burning trial in poplar box.

Pasture basal area in burnt and unburnt plots varied between years. The unburnt plots had a higher basal area in the early years and again in 2002, however in 2001, the burnt plots had the higher basal area (Figure 6.145). This was due to much higher basal area response in the treeless and burnt treatment over the previous summer. There was a trend in increasing basal area over years (Figure 6.146), especially in the unburnt plots.

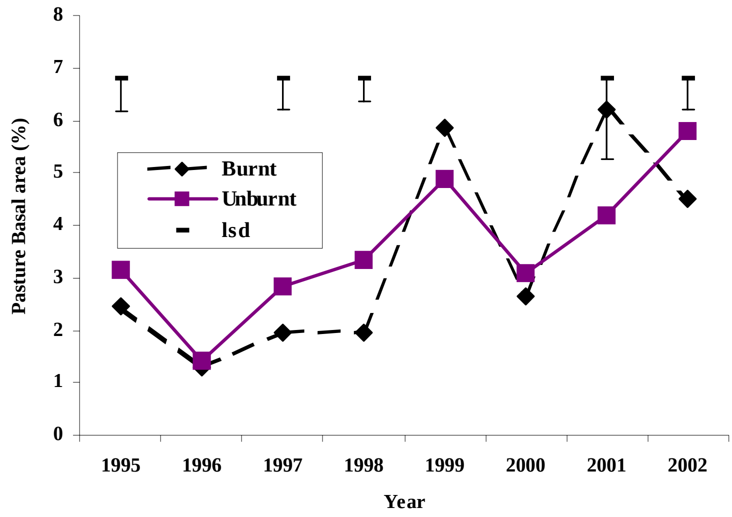


Figure 6.145 Pasture basal area shifts over time in the burnt and unburnt plots of the ungrazed burning trial in poplar box woodland. Bars show lsd (P<0.05).

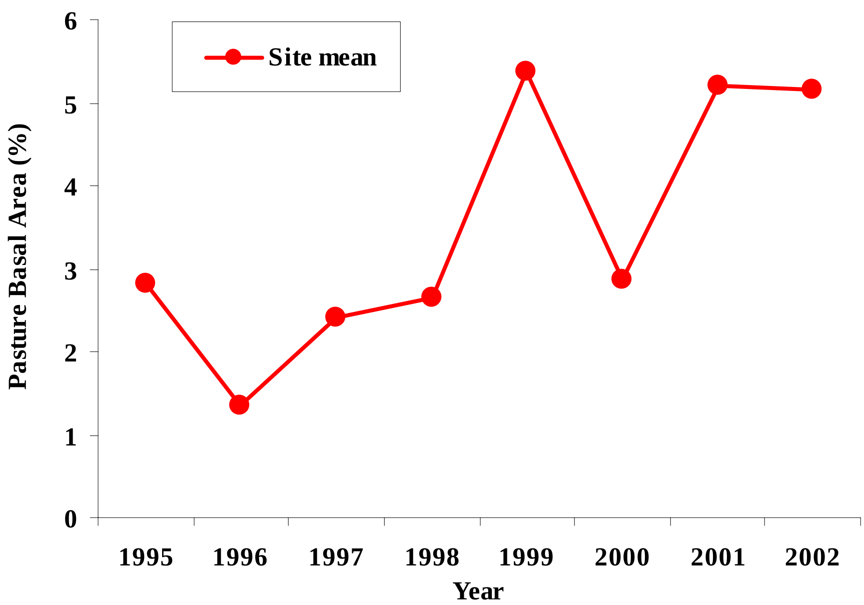


Figure 6.146 Mean autumn pasture basal area of the burning trial in a poplar box woodland.

Compared to the grazing trial, pasture basal area followed a similar pattern largely in response to rainfall. However there were a few notable exceptions. In 1996 the burning site was noticeably less but we do not have a sound biological explanation for this. The years 1998 and 1999 have a reverse pattern of change for which there is no easy biological explanation at the burn site. The sampling was done in October 1998 at both sites and then in June 1999 at the burn site and in October at the grazing trial site. In 1998 there could have been operator interpretation problems under the huge mass of prickly, winter herbage at the burn site. In 1999 the later recording at the grazing site could have allowed stock to consume more forage or for bottlewasher grasses to have died back badly prior to a new wave of seedlings establishing.

The point frame technique was not sufficiently intensive to produce reliable individual species strikes to measure treatment and annual species changes from this data set, although *B. decipiens, C. fallax* and *D. sericeum* consistently made high individual species contributions to pasture basal area in this trial. However, the sampling was done along exactly the same transects between fixed steel posts, so errors due to spatial variation across paddocks and plots were not involved. Both main treatment factors at the burn site responded in a similar manner in 1999, although the burnt paddocks were most responsive after burning which was prevented by wet conditions in the previous spring.

6.2.2.4.10.1 Species contribution to basal area

The mean site contribution to basal area by individual species at the burning trial in poplar box woodland was ranked for the 6 years 1995 to 2000, with the dominant species, *B. decipiens*, ranked at 100 (Table 6.45). Over the site, *C. fallax, Aristida spp., D. sericeum* and *Enneapogon* spp. were the main contributing species to basal area.

Table 6.45 Mean species contribution to pasture basal area relative to *B. decipiens*, in the poplar box burning trial site (1995-2000).

Species	Site mean
Bothriochloa decipiens	100.0
Aristida spp. (unidentified)	41.9
Aristida ramosus	36.6
Dichanthium sericeum	36.5
Enneapogon spp.	13.8
Bothriochloa bladhii	11.8
Aristida calycina	8.9
Calotis lappulacea	8.7
Chloris divaricata	8.1
Themeda triandra	7.8
Cenchrus ciliaris	7.4
Cymbopogon refractus	7.0
Enteropogon ramosus	7.0
Eragrostis spp.	6.4
Aristida latifolia	6.1
Tripogon loliiformis	6.0
Fimbristylis spp.	5.6
Chloris ventricosa	5.2
Panicum spp.	5.0
Heteropogon contortus	4.9
Sporobolus spp.	3.3
Cyperus spp.	3.1

6.2.2.4.11 Pasture greenness

The proportion of green material in the pasture was estimated in all Botanal sampling quadrats across each paddock. The time of sampling in 1995 was in January when all the pasture was almost 100% green in all treatments, and in 1996 sampling was in May after an early finish to the growing season, so there was around 20% green material remaining in all treatments. In later years, sampling was earlier, near the end of the main growing season when green leaf and stem was still present. In the burn treatments, there was only marginally higher green % in the burnt treatments compared with the unburnt plots (Figure 6.147). Also at this time, there was a marginally higher green proportion in the pasture in the treeless paddocks than under the trees from 1997 to 2000, then a lower proportion in 2001 while there was no difference in 2002 (Figure 6.148).

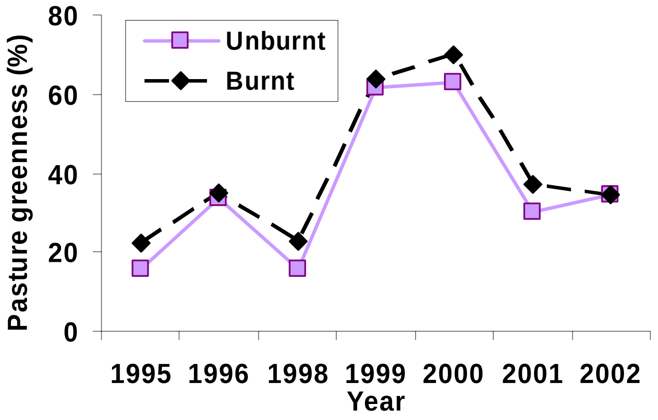


Figure 6.147 Pasture greenness in autumn in response to burning of poplar box woodland.

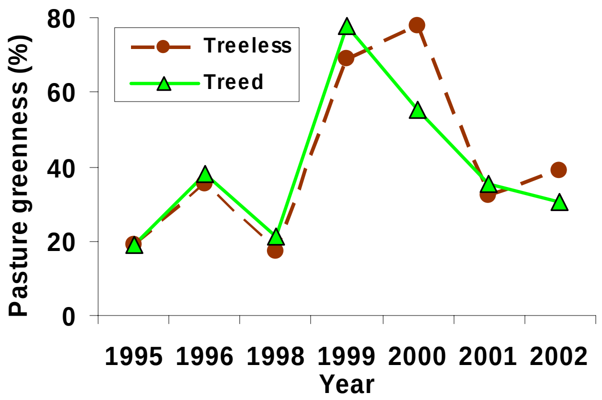


Figure 6.148 Pasture greenness in autumn of poplar box woodland in response to tree competition.

The mean site pasture greenness at the end of the growing season shows there is can be 60% green in the grass, maintaining quality (Figure 6.149). This is before frosts occur when all green disappears quickly.

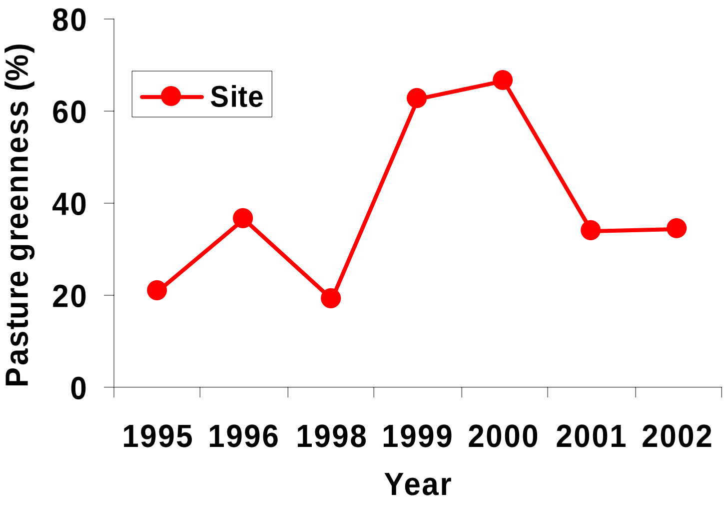


Figure 6.149 Mean pasture greenness (%) across the ungrazed poplar box site at autumn sampling time.

The mean pasture greenness (%) in autumn was marginally higher in the treeless plots and lowest in the treed and unburnt plot (Figure 6.150). This was from the carry-over of standing dead grass from previous years. There was a significantly ($P<0.01$) lower pasture greenness in the treed plots in 1998 and 2000 and a significantly ($P<0.05$) higher greenness in the burnt plots in 1996 and 1998.

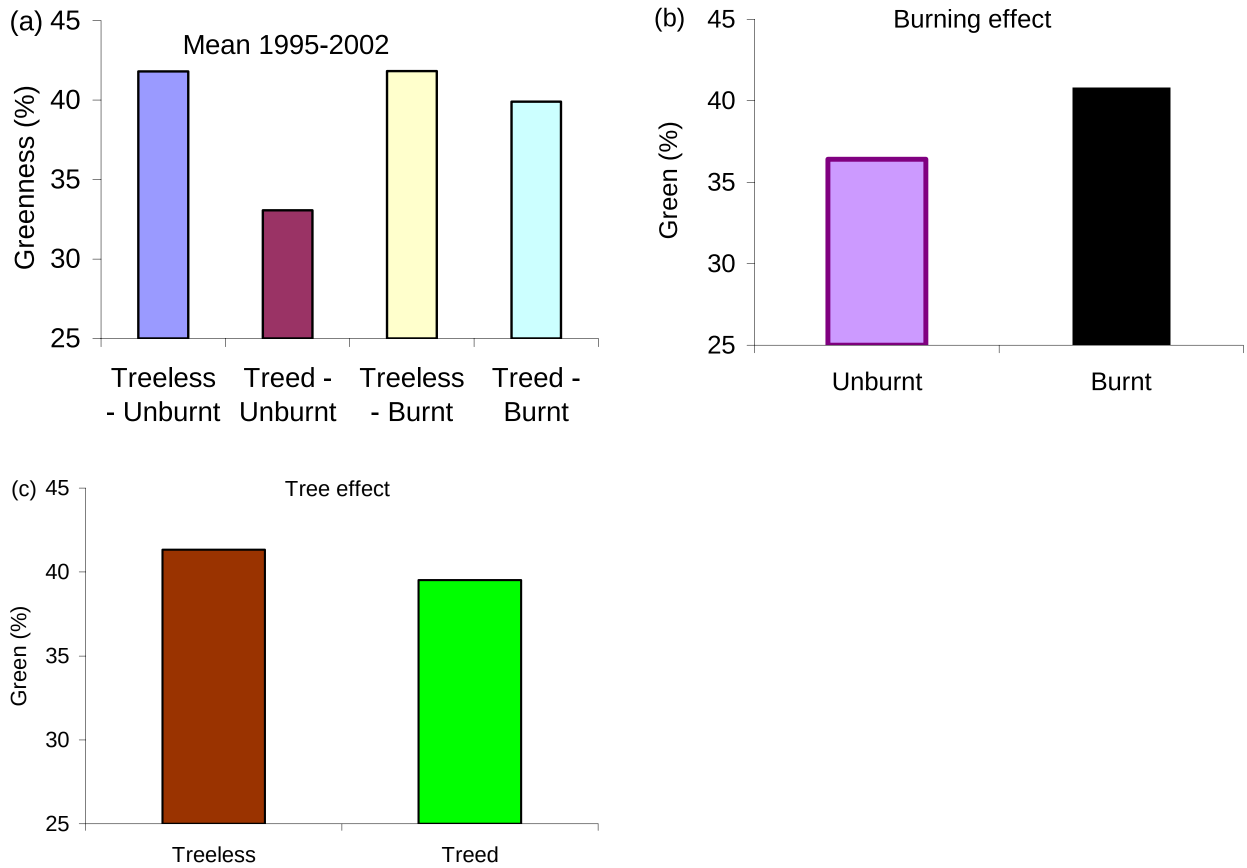


Figure 6.150 Mean tree cover and burning effects on pasture greenness (%) 1995-2002 at sampling time in autumn in ungrazed poplar box woodland.

6.2.2.4.12 Population dynamics of focus perennial grasses at burn site

6.2.2.4.12.1 Abstract

The retention or removal of woodland trees did not reliably influence the outcome of any spring burning strategy. Enhanced pasture biomass production resulting from tree removal did increase the fire intensity but not with any marked, consistent effect on the pasture.

The response to each spring fire by an individual grass species was not consistent and could differ depending on its preconditioning and the type of fire. By preconditioning we mean the recent seasonal conditions, the age structure of the current population, recent defoliation events and the pest and disease load carried by the plants at the time of the fire and immediately afterwards. Spring burning generally reduces the mean crown area of perennial grasses but long term exclosure from grazing more than compensates for this.

Regular spring burning in the absence of grazing reduced the population of dark wiregrass but not that of purple wiregrass in our trial. This difference was thought to be related to the more exposed crown and shorter inherent lifespan of dark wiregrass. Recruitment of Qld bluegrass was apparently discouraged by the removal of grazing animals.

An unusually high level of perennial grass plant loss occurred between autumn 1998 and autumn 1999, coincident with a very wet 1998 winter. The large bulk of standing pasture in late 1998 after 4 years without grazing may be implicated because losses were high in plant cohorts of all ages. A successful management fire in successive springs or in a particular spring time cannot be guaranteed because atmospheric plus pasture conditions sometimes will not allow it.

6.2.2.4.12.2 Background

This part of the project had identical aims and setup as the population dynamics study at the grazing trial. The difference was that only the effects of spring fires and tree killing on pasture and shrub dynamics were studied at this discreet site. However, the data does provide a contrast of pasture dynamics under grazed versus ungrazed conditions, depending on your view of the statistical legitimacy of comparing results from sites that were one kilometre apart in the landscape but on the same land type.

6.2.2.4.12.3 Methods

The dynamics of the pasture plants was studied using exactly the same charting methods that were described for the equivalent study at the grazing trial (see section 6.2.1.4.6.1). However, only 3 sets of quadrats were used per plot, giving a total charted area of 4.5m^2 per one hectare plot, but there was an extra replicate of each treatment. The quadrats were located in proximity to the central post of the diagonal transects used for monitoring treatments at this site. Thus the smaller number per plot compared to the grazing trial was partly compensated for by the extra replication of each treatment at the burn site. The same six key species were charted as at the grazing trial, namely *Aristida calycina*, *Aristida ramosa*, *Bothriochloa decipiens*, *Chrysopogon fallax*, *Dichanthium sericeum* and *Enteropogon ramosus.*

The comments made for the grazing trial about the statistical analysis and the idiosyncrasies of the method for some species apply to the burning trial too. The first set of charted data was likewise collected nine months after the treatments were imposed, so the effects of differing management will already have begun to show, especially with respect to plant crown area. However the changes should have been modest except for the plots that were burnt in early November 1994.

6.2.2.4.12.4 Results

Though it was intended to burn six/half of the plots each spring, green pastures and cool, light wind conditions prevented burns in 1995 and 1998. In the 1995 spring, 2 plots (CB1 and CB3) were burnt with great difficulty before the rest were abandoned. As a result, crown sizes recorded in autumn of 1996 and 1999 were larger in the 'burnt' treatments than should have been the case (see Figure 6.153). No data is available for these plots prior to the first spring burn in 1994 and prior to poisoning the box trees in the 1994 winter. Hence the much bigger crown area of the treeless unburnt plots in autumn 1995 may partly be due to the treatment and partly coincidence from the original positioning of the quadrats.

Only simple statistical measures such as standard deviations or coefficients of variation of means can be used to provide readers with an estimate of the reliability of the means quoted, because of the way the experiment was implemented. Coefficients of Variation of over 100% were common for some species means, e.g. 156% for *E. ramosus* crown area in 1995 but low for others such as *B. decipiens* (70%). Variability was higher for unburnt plants (CV=245% over all species) than for burnt ones (116%) in autumn 1995 but similar for plants charted in both treeless and treed areas. Year-to-year changes in the variability of individual plant size within the charted populations (ie. CV) varied with the species in an inconsistent way.

Plant numbers

Fewer (9) quadrats per treatment than the 18 at the grazing trial meant that fewer plants contributed to the burning site data. A scarcity of *E. ramosus* at the burn site meant that very few plants of this species were charted compared to the other key grasses, especially in the treed plots (Table 6.46). A greater area of golden-beard grass was initially charted at the unburnt plots, particularly where the trees were killed (Table 6.47).

Table 6.46 Numbers of charted plants of each focal species in each main treatment of the ungrazed burning trial in June 1995.

Treatment	Mgmnt		Species						Treatment Total
			Arical	*Ariram*	*Botdec*	*Chrfal*	*Dicser*	*Entram*	
Treeless	Burnt	B	28	50	56	34	44	11	223
	Unburnt	N	35	16	34	38	10	14	147
Treeless Totals		C	63	66	90	72	54	25	
Treed	Burnt		32	45	76	34	10	3	200
	Unburnt		44	39	13	34	34	2	166
Treed Totals		T	76	84	89	68	44	5	
Species Total			139	150	179	140	98	30	

Plant numbers of each main grass did vary over the years but no consistent pattern emerged as a result of regular spring burning except for dark wiregrass (Figure 6.151 compared to Figure 6.152). This may be because it has a high crown on or above the soil surface while purple wiregrass and pitted bluegrass have their crowns below ground level except on skeletal soils.

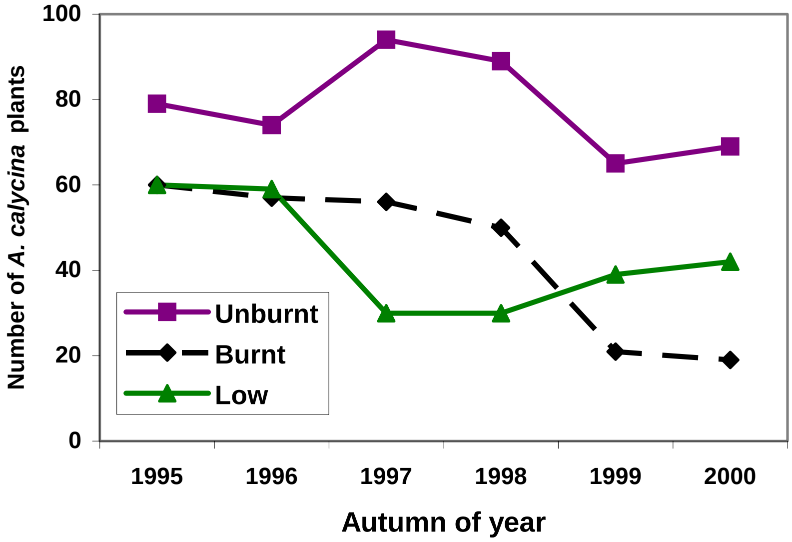


Figure 6.151 Effect of regular spring burns on dark wiregrass plant numbers.

Plant populations in the ungrazed exclosures fluctuated in a similar way to those under low grazing pressure. Data for pitted bluegrass is presented to illustrate this point (Figure 6.152). A general lack of twirly windmill grass (*E. ramosus*) at the ungrazed burn site meant that numbers were probably too low for treatment effects to be conclusively demonstrated for it, eg. a total of only 6 plants in 6 of the plots (from 18 quadrat sets), meaning 1plant / 4.5m^2 compared to an overall 13.7 focal plants/m^2 at the site.

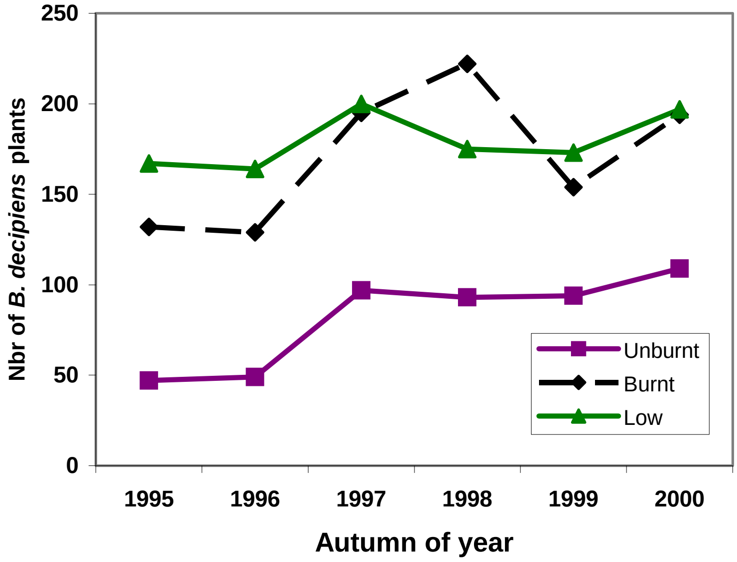


Figure 6.152 Changes in numbers of pitted bluegrass plants charted each year when ungrazed or grazed at low pressure.

Regular spring burning reduced the population of dark wiregrass but not that of purple wiregrass

Table 6.47 Total crown area (cm^2) of charted plants of each focal species in each treatment at the burn site in June 1995.

		Species						Treatment
Treatment	**Mgmnt**	***Arical***	***Ariram***	***Botdec***	***Chrfal***	***Dicser***	***Entram***	**Total**
Treeless	Burnt	657	1 437	3 010	3 617	1 749	432	10 902
	Unburnt	1 627	755	2 166	12 334	649	565	18 097
Treeless Totals		2 284	2 192	5 176	15 951	2 398	997	
Treed	Burnt	817	1 837	2 824	1 656	452	444	8 029
	Unburnt	2 144	1 808	683	3 709	1 516	660	10 519
Treed Totals		2 961	3 645	3 507	5 365	1 968	1 104	
Grand Total		5 245	5 837	8 683	21 316	4 366	2 101	

Total crown area

Total crown area of a grass species in a pasture is the product of individual plant size and the number of plants. Both these latter two vary over time in response to seasonal conditions, species biology and grazing management. Overall, total crown cover of the focus species was not closely aligned to annual (July–June) rainfall in an ungrazed situation (Figure 6.153). This differs from the grazed pastures discussed in 6.2.1.4.6.4. However, the overall pattern masks notable exceptions for individual species, and interactions between management and species, as discussed in the preceding sections. A full set of remaining graphs is presented in Appendix G.

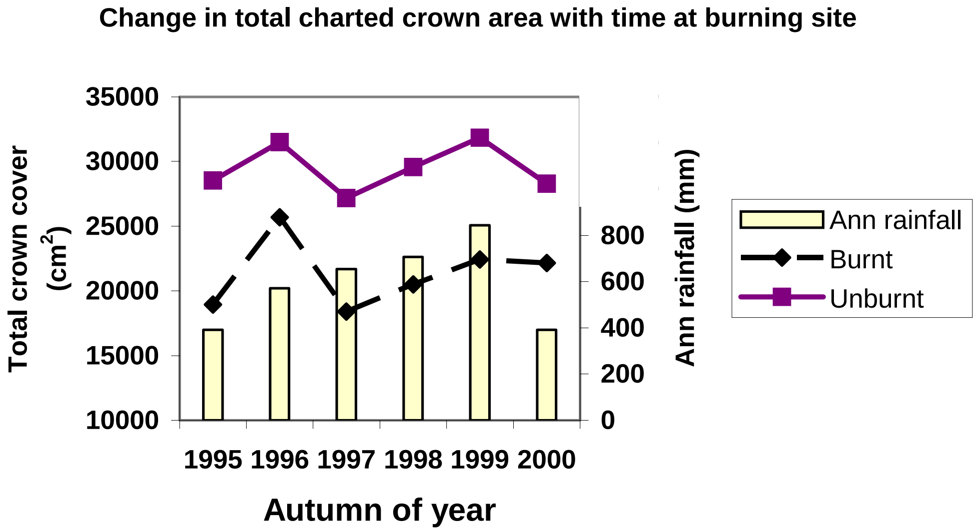


Figure 6.153 Annual Rainfall (July-June) effect on total crown area of the 6 focal plants over years at the burning site.

Tree effect

The immediate effect of killing the tree overstorey was not measured in this trial, - just the ongoing effect 10 months later and beyond. Overall the differences that existed after one year due to trees did not alter noticeably until 2000 (Figure 6.154). This grass crown area difference is in keeping with the total dry matter yield differences caused by trees in a poplar box woodland in all years at the site.

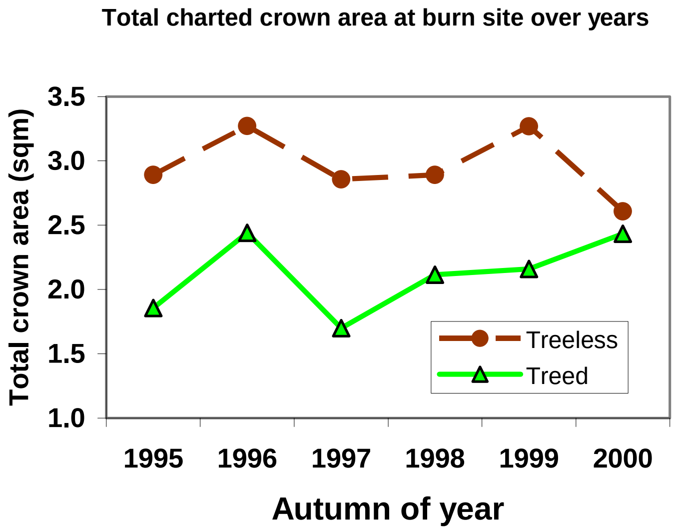


Figure 6.154 Total charted crown area over time for treed and treeless plots at the burn site.

Spring burning effects

Spring burning sometimes produced a temporary reduction in crown area throughout the next growing season, eg. in 1997, but this was not consistent over the years. In fact the curves over time of burnt versus unburnt plots were mostly parallel and reflected seasonal conditions as much as burning management except in 1999. Unsurprisingly, the ungrazed plants were generally bigger crowned than those under grazing if never burnt (Table 6.21 and Table 6.48 vs. 6.19). The lack of a spring burn in 1995 and 1998 is evident in the large crown sizes in the following autumns, particularly of 1996. Death of many grasses where unburnt after the wet 1998 winter led to a lower than expected crown area under trees and also in the treeless 'burnt' plots that could not be burnt in spring 1998.

Tree x Burning interaction

The opposing direction of change associated with tree cover in the unburnt plots between 1999 and 2000 is not easily explained. Perhaps the good 1998-99 year grew the big, undefoliated plants in treeless plots to an unsustainable size and widespread partial death occurred in the dry 1999-2000 year.

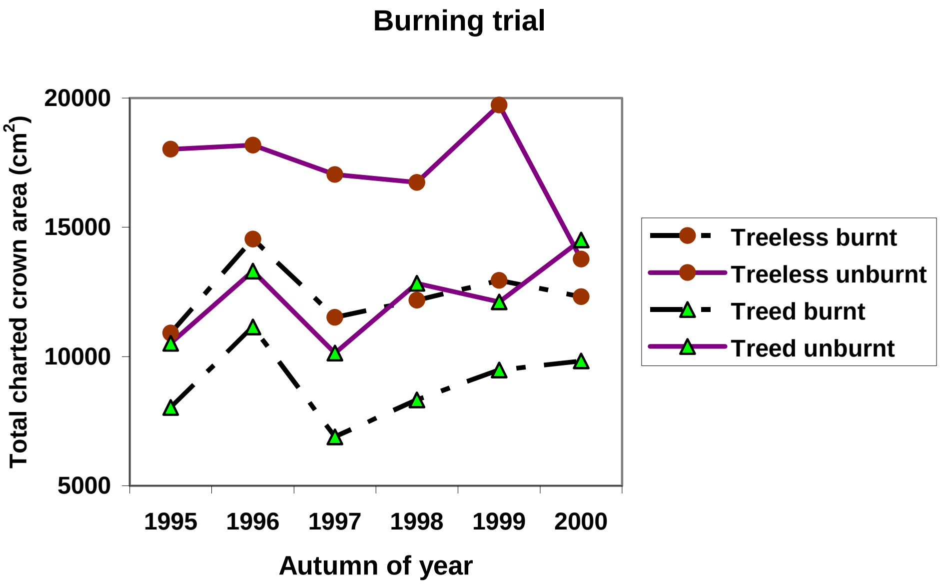


Figure 6.155 Pasture crown area response to regular spring fires in the absence of grazing and its interaction with tree competition on poplar box country.

Crown area percentage

The summed crown area values range from 8.5 to 11% of the total charted quadrat area, which is a high cover compared to the paddock means for basal plant area calculated from a point frame (2 to 6%, Section 6.2.1.4.3), as discussed before. However, relatively, they are in the same order as the more random paddock data, ie. lower under trees and under regular spring burning (Figure 6.155).

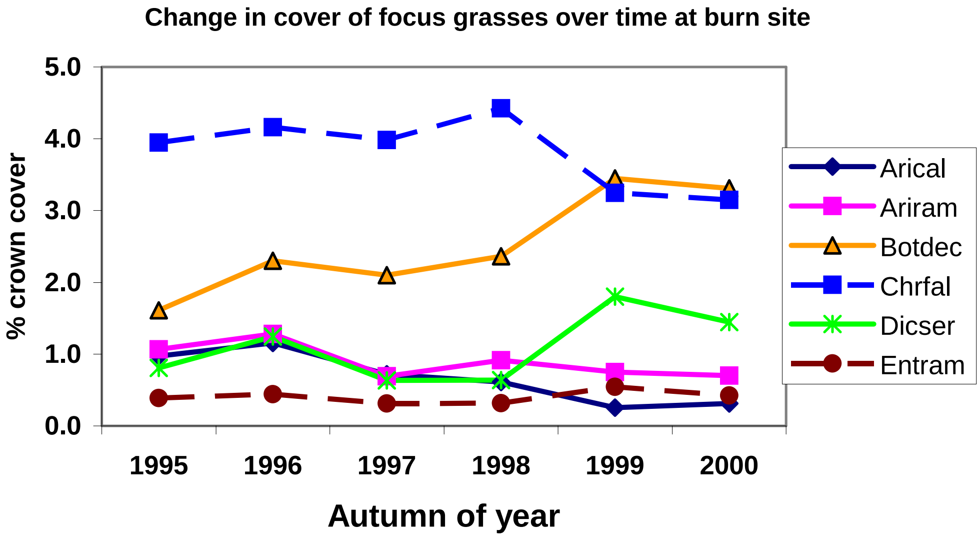


Figure 6.156 Mean crown cover (%) of each focal species in each year at the burning trial.

The crowns of focal grasses in unburnt plots averaged 11% coverage of the ground area while the burnt ones covered only 8% of the ground. This difference became established very quickly after the treatments were imposed some 10 months (1 growing season) before the 1995 recordings. This could be due to a big (un-documented) seedling recruitment after the initial 1994 burn that was not repeated to the same degree after subsequent burns or an inherent difference between the chosen areas.

The two wiregrasses reached a peak crown area in 1996 and then fell away slightly (Figure 6.156) while area of the two bluegrasses fluctuated in harmony over time. Pitted bluegrass showed a general and noticeable increase in crown cover during the experiment. Golden-beard grass held its crown size initially but that then fell away noticeably after the 1998 autumn. An Interaction of possible importance was that for dark wiregrass whose crown area declined under regular spring burning but did not change where the pasture was unburnt. This matches the change in numbers over time (Figure 6.151).

Mean crown area

The size of ungrazed grass crowns in the absence of burning was consistently greater than those from burnt plots (Figure 6.157, Table 6.48). Seven months after the initial burn in November 1994, crowns of *A. calycina* were half the size of those in unburnt plots while burning had only a small effect on Qld bluegrass crown size. The mean crown size of ungrazed plants was mostly much greater than plants in grazed paddocks (Table 6.19). Those of *A. calycina* averaged 37.7cm^2 compared to 14.7cm^2 where grazed but the Standard Deviation of the data was not proportionately greater. *A. ramosa* size differed least between grazed and ungrazed areas while plants of *C. fallax* were recorded as having the greatest size reduction due to grazing, to one fifth mean plant size. This huge effect probably includes a charting technique factor as discussed earlier.

The small increase in mean crown size between autumn 1998 and 1999 in the 'burnt' plots (Fig. 6.157) was less than might have been expected given the response in 1996 after a spring burn was unachievable in that year too. Burning kept crown area to about 65cm^2 (where it initially was) while in its absence and without grazing (except by visiting wallabies) the figure was usually about 50% more than that in most years.

Mean crown area for each species showed greater volatility over time than plant numbers (Figures 6.157, 6.159, 6.160). This could be an artefact of the recording technique given that different groups of recorders were sometimes used and they may have tended to over- or under-record the size of plants in general. Part of the cause was the inconsistent use of fire, especially in 1996 and 1999 when a spring burn was impossible the year before due to wet conditions. Nonetheless, the reason for any big changes in numbers or mean crown size may still mostly involve biological changes induced by pests or disease or from ageing of a particularly large cohort of plants that established before our trial began. Our intensity of sampling was insufficient to pick up such causes. Only the significant death of old grass after the wet 1998 winter was obvious to us visually in early 1999 (Figure 6.158).

Table 6.48 Mean crown area (cm^2) of the six focal species in the ungrazed treatments in June 1995.

		Arical	Ariram	Botdec	Chrfal	Dicser	Entram
Ungrazed							
	Mean	37.7	38.9	48.5	152.3	44.5	70.0
	Median	33.0	37.7	42.4	43.2	36.5	45.5
	Std deviation	28.1	24.3	34.1	327.9	37.5	108.9
	Mean Burnt	24.6	34.5	44.2	77.5	40.8	62.5
	Mean Unburnt	47.7	46.6	60.6	222.8	49.2	76.6

Spring burning reduces the mean crown area of perennial grasses

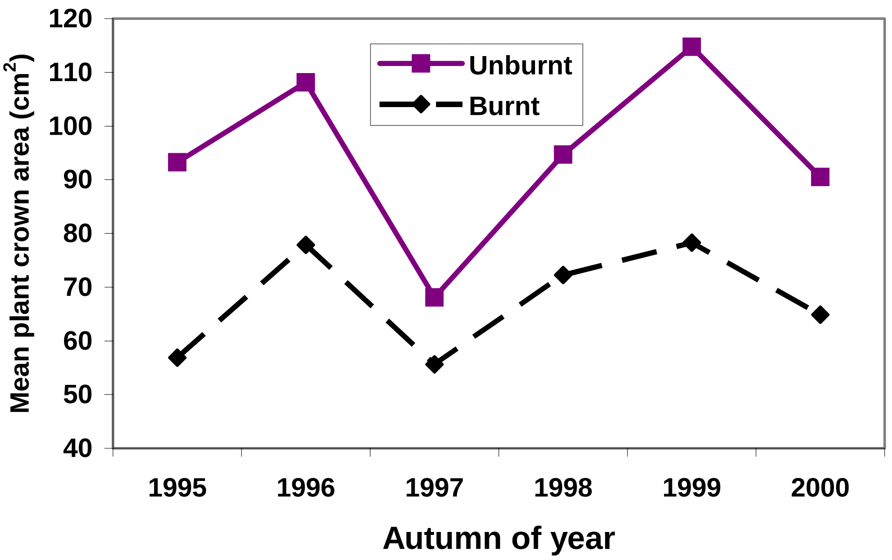


Figure 6.157 Effect of the main management treatments on mean focal grass crown area over time.

Figure 6.158 Widespread death of ungrazed perennial grasses after the very wet 1998 winter at the ungrazed poplar box site.

The response of individual grass species to regular spring burning was varied, as was their response compared to plants under low grazing pressure. Two examples are shown, Qld bluegrass (Figure 6.159) and purple wiregrass (Figure 6.160). Where excluded from grazing, Qld bluegrass plants quickly expanded their crown size to over 40cm^2 and it then fluctuated widely in response to seasonal conditions but not apparently in response to spring fires. In contrast, those in the low grazing pressure paddocks were kept smaller by selective grazing even as they were steadily expanding over the years (Figure 6.159).

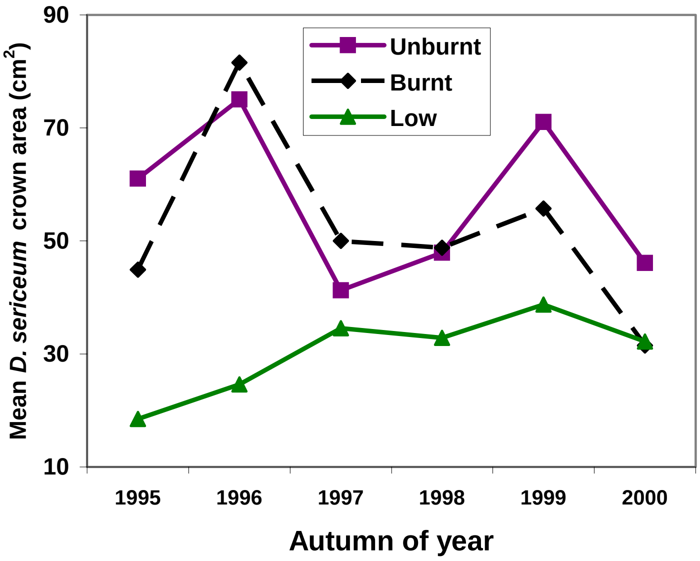


Figure 6.159 Effect of spring fires and light grazing on mean crown size over time of Qld bluegrass plants.

By comparison, ungrazed purple wiregrass plants were kept in check by regular spring fires while those under low grazing pressure expanded dramatically and fairly consistently in size over the years. Ungrazed and unburnt purple wiregrass plants decreased dramatically in mean size between 1996 and 1997 for some unexplained reason. Thereafter they were a similar size to those that were burnt each spring and much smaller than those under low grazing pressure at the grazing trial. This is probably partly because the grazing trial had large areas of the robust, creek-flat form of *A. ramosa* in the charted quadrats.

The size of *C. fallax* plants in the absence of grazing was consistently much larger than where the plants were burnt (over 200cm^2 compared to about 100cm^2). This could be an artefact of the recording system whereby adjacent plants were treated as one when they presented as a mass of ungrazed foliage when unburnt and ungrazed.

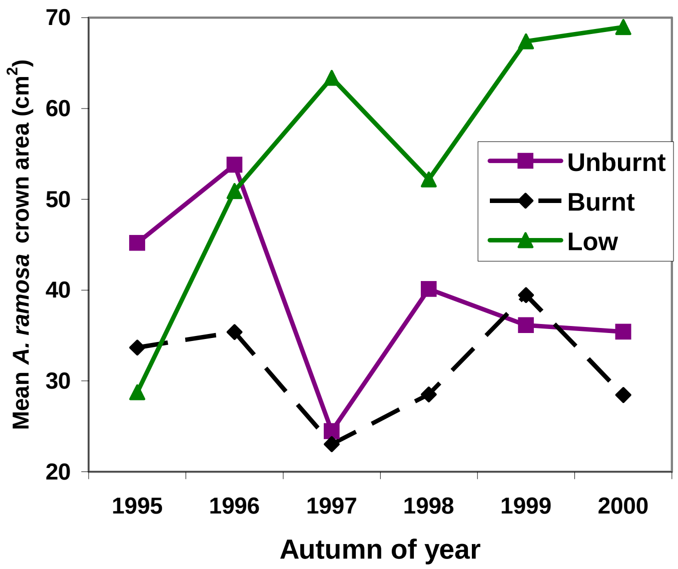


Figure 6.160 Effect of spring fires and light grazing on mean crown size over time of purple wiregrass plants.

The response to each spring fire by an individual grass species could differ depending on its preconditioning and the type of fire

There is an indication that established pastures on the box soil could only sustain increased mean crown size for 2 consecutive seasons, if ungrazed, before high death rates set in over the next year (Figure 6.157).

Interaction of tree cover and burning

The combined crown area of the six measured grasses in 1995 was almost significantly greater ($P<0.05$) in the burning trial where the trees had been killed (2.9 m^2 versus 1.8). Total cover then followed any major species variations during the intervening years and by 2000 this difference had diminished to 2.6 compared to 2.4 m^2.

Where grazing was excluded, moderate tree cover generally had an inconsequential effect on the outcome of regular spring burning on pasture dynamics as far as our data could show. Individual species had differing year-to-year responses and few settled patterns of change or difference persisted over 5 years.

Mean crown area

Figures 6.161 to 6.163 show changes in mean crown area over time for *B. decipiens, D. sericeum* and *A. ramosa* respectively. In 1997/98, crown size of *A. ramosa* increased markedly where unburnt in treeless areas while the other 2 grasses declined slightly in their mean crown size during the same time under those conditions.

Also of note is that crown size of *B. decipiens* increased markedly in 1999 after burning under tree cover while the other species did not alter their size during that time under the same conditions. Thus overall pasture crown dynamics is an amalgam of what the individual species are doing and very often that is counter-reactive to the same management. This results in a more consistent response to climate and management at a whole pasture level while masking quite major short term differences in individual species response to those factors. Such conflicting responses are probably strongly driven by plant demography and biology which can differ greatly amongst perennial grass species, eg. *C. fallax* versus *D. sericeum*.

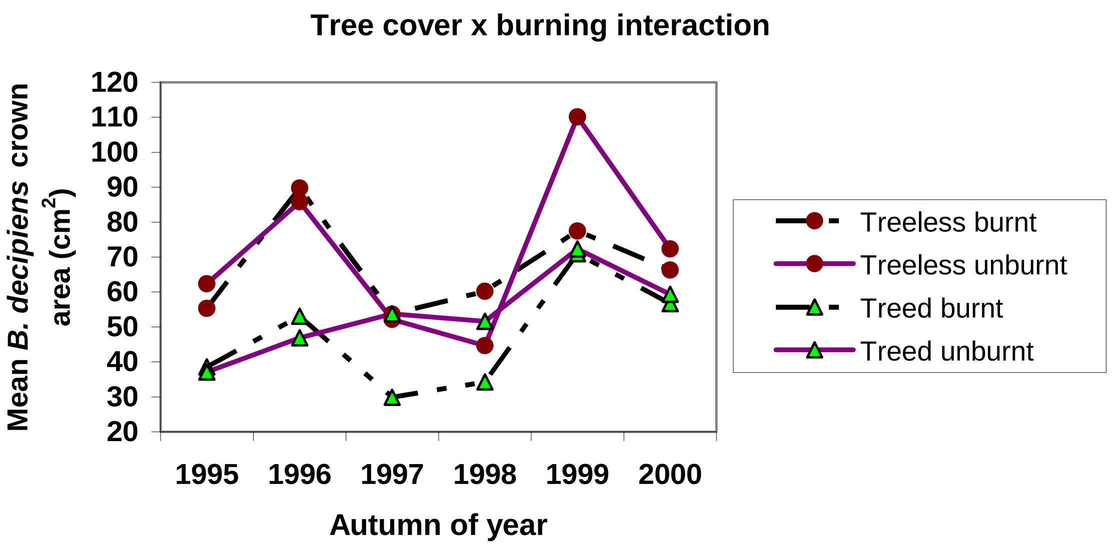


Figure 6.161 Fluctuation in mean crown area of *B. decipiens* under the interacting influences of tree cover and spring burning.

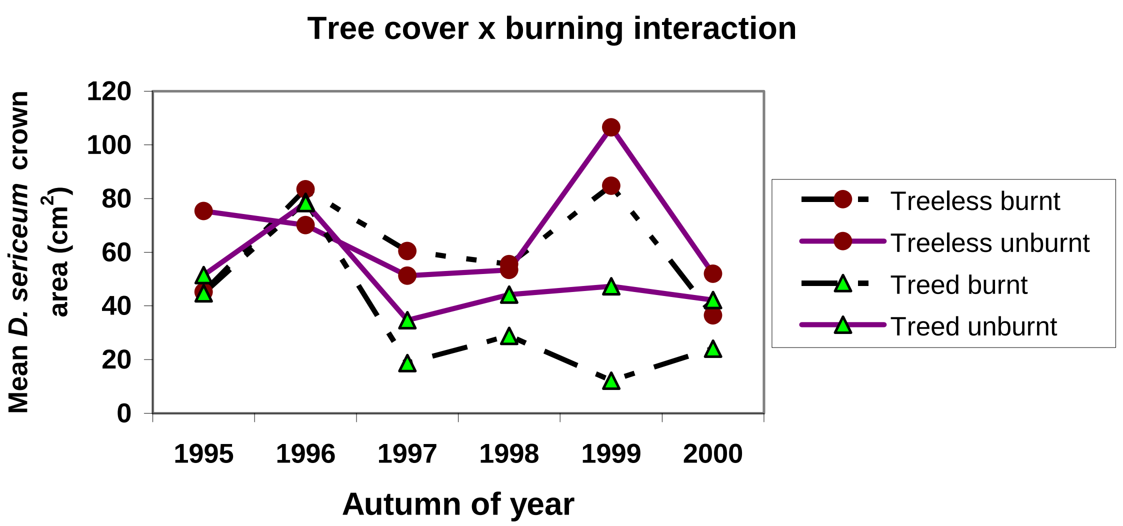


Figure 6.162 Fluctuation in mean crown area of *D. sericeum* under the interacting influences of tree cover and spring burning.

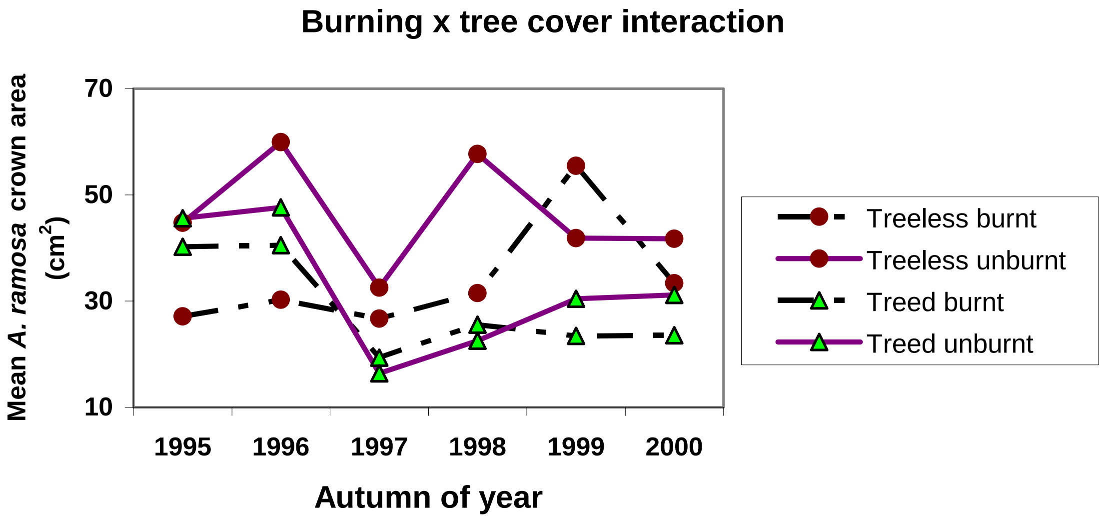


Figure 6.163 Fluctuation in mean crown area of *A. ramosa* under the interacting influences of tree cover and spring burning.

Plant numbers

When plant numbers are studied in the same way, the same mixed response by species to the same stimuli is found. Numbers of *A. ramosa* changed in different ways over time in the four treatments while those of *B. decipiens* generally increased from 1995 to 2000. For *A. ramosa,* burning treeless areas caused a steady decline in numbers while numbers generally increased in unburnt treeless areas (Figure 6.164). There was no such tree x burning interaction effect on *B. decipiens* numbers (Figure 6.165).

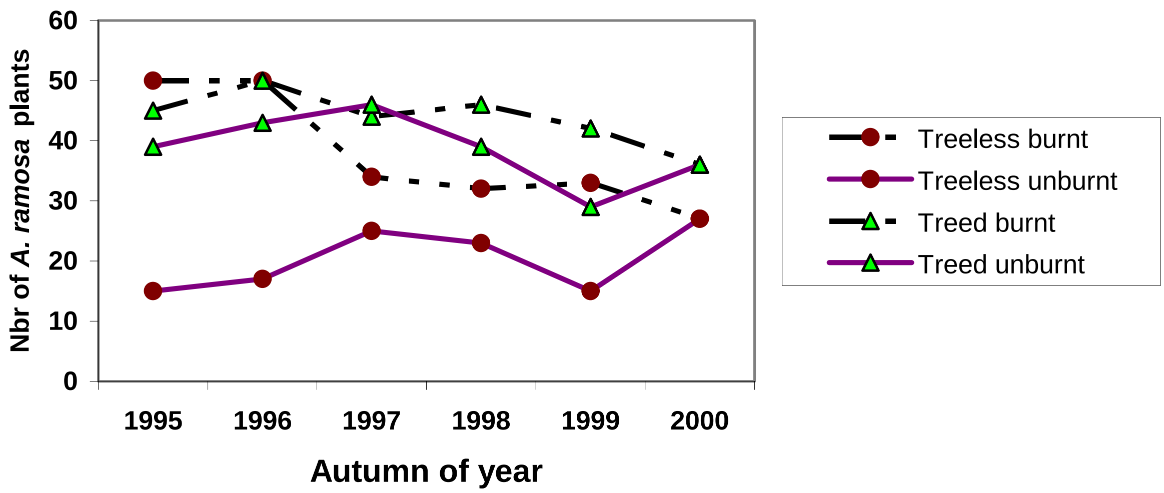


Figure 6.164 Tree x spring burning effect on charted, ungrazed *A. ramosa* numbers over time.

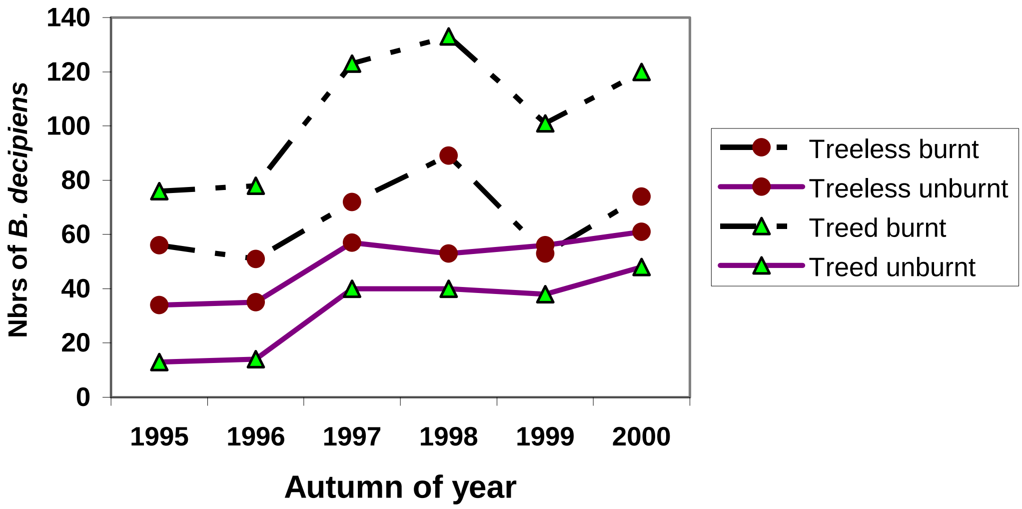


Figure 6.165 Tree x spring burning effect on charted, ungrazed *B. decipiens* numbers over time.

The effects of spring burning on pasture composition were not influenced in a predictable way by the presence of a significant tree overstorey

Population fluxes

Number of recruits

As Table 6.49 shows, initial charted plant numbers in the fixed quadrats varied quite a lot for each species and treatment and new recruit numbers continued to vary as time progressed. The data is available on the project CD for each species in the various treatments. The average density of all focal plants ranged between 3.0 and 10.8 per square metre for pitted bluegrass (depending on treatment) down to 0.4 to 4.0 m^{-2} for twirly windmill grass at this site.

Each year a number of newly established plants was recorded and, because they are known to be young, they may respond to management somewhat differently to the initial 1995 population which included plants of varying age at the time. Very few new plants were charted in 1996, 41 in total, due to the different and ultimately unsatisfactory way of re-recording each quadrat that was used by the project team that year. Most new ones since autumn 1995 were picked up in the 1997 charting which thus includes the remainder of the 1996 cohort plus the 1997 one. Hence the total number of new plants in 1997 is about double that of each of the subsequent three years. Table 6.49 shows the count of newly recorded plants for each main treatment in each year from 1996 to 2000, as well as the original numbers. Hereafter, each is said to be a member of a cohort, ie. Cohort95, Cohort97 etc.

Table 6.49 Number of recruits under differing management regimes each year at the burning trial.

	Year						Total
Management	1995*	1996	1997	1998	1999	2000	recruits
Burnt	*423*	27	183	114	97	67	488
Unburnt	*313*	14	195	69	115	70	463
Treeless	*369*	18	197	99	113	92	519
Treed	*366*	23	181	84	99	45	432
Year totals	*735*	41	378	183	212	137	951

* = original plants of variable age

By the end of 5 years, there was little difference in the total number of new recruits of the focal grasses due to burning treatment and only an insignificant difference due to competing tree cover. For individual species (Table 6.50) the general rate of recruitment was greatest at 214% of the initial population for Qld bluegrass and least for twirly windmill grass, at 40%. That equates to an average 43% renewal per year for the bluegrass and only 8% per annum for twirly windmill grass. Such renewal rates match nicely the perceived longevity of these plants, except for *C. fallax* (Table 6.50). In that case we believe that our charting technique is unsatisfactory for distinguishing between seedlings and new crowns derived by rhizomes from existing plants.

Individual recruit cohorts

Cohort95

Table 6.50 Numbers of recruits of each focus species each year at the burning site.

Species	*1995**	1996	1997	Year 1998	1999	2000	Total recruits	Recruits as % of orig. popn
A. calycina	*139*	3	69	35	34	20	161	116%
A. ramosa	*150*	8	60	29	33	20	150	100%
B. decipiens	*179*	11	144	68	56	43	322	180%
C. fallax	*140*	8	56	21	7	4	96	69%
D. sericeum	*98*	9	44	27	80	50	210	214%
E. ramosus	*30*	2	5	3	2	0	12	40%
Grand Total		41	378	183	212	137	951	

* = original plants in plots

Table 6.50 shows that *B. decipiens* was the most numerous species in the charted quadrats and *E. ramosus* the least. Those numbers reflect the biomass proportions in the pastures in most areas located away from valley floors (Section 6.2.1.4.2.3) despite the quadrats being positioned so as to sample the six focus species specifically.

Cohort97

As in most years, there were many new recruits over the previous year, with greatest numbers coming from pitted bluegrass and least from twirly windmill grass (Figure 6.166). Tree cover slightly reduced recruitment where ungrazed (Table 6.49) but the variability amongst reps and quadrat sets was too great to achieve statistical significance ($P<0.05$) for differences between the means. The relatively high numbers this year are probably the result of the inadequate re-recording system used in 1996, as discussed before, but the relativities amongst the 6 species is probably valid. The spring burn of 1995 was associated with a slightly reduced recruitment recording at the end of the 1996/97 summer, despite no burn in the 1996 spring (Table 6.49)

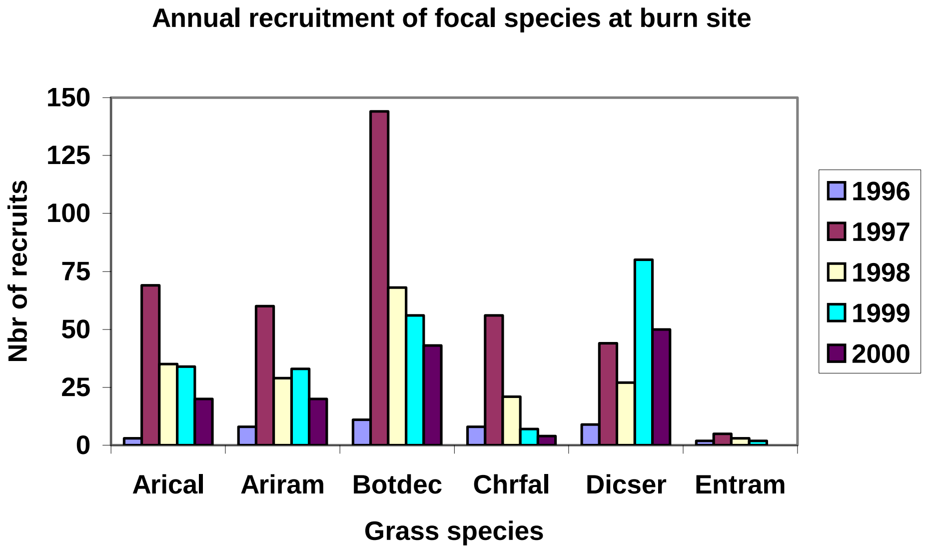


Figure 6.166 Recruits recorded each growing season at the burn site, by species.

Cohort98

During the 1997/98 summer, there were again more recruits where trees were absent. Recruitment under grazing was generally less than in its absence during this year (3.2 plants/sq m vs. 3.4 where ungrazed). Such a difference was not detected in all years and the reverse (4.8 vs. 2.5) occurred in 1999/2000.

Many more new grass plants established on the burnt plots after the spring 1997 fires than on the unburnt ones (Table 6.49). Again, *A. calycina* went against the trend of other species, 11 plants where burnt vs. 24 where unburnt.

Cohort99

After the wet 1998 winter and the relatively wet 1999 summer, recruitment was not exceptionally high, averaging just under 4 new perennial grasses per square metre. Tree cover again was associated with a small, insignificant reduction in recruit numbers (Table 6.49) and there was a similar small difference associated with the burning treatments. As a spring burn was impossible in 1998, any possible fire effect must have been the result of the spring 1997 fire. Previous fires seemed to suppress *A. calycina* (5 vs. 29 new plants) and promote *A. ramosa* (22 vs. 11 new plants) recruitment over the 1998/99 summer. The reasons for this contrast between wiregrasses can only be highly speculative, especially with such low total numbers.

Cohort00

Tree cover reduced the numbers of new grasses establishing (Table 6.49). Again, fire in the 1999 spring severely suppressed recruitment by *A. calycina* (0 vs. 20 new plants) while seeming to promote establishment of new plants of Qld bluegrass (34 vs. 16 new plants). Lack of grazing pressure again affected recruitment at this site versus the grazing trial but this year in the opposite direction to that of 1998, ie. fewer seedlings where ungrazed The discrepancy was greatest for Qld bluegrass where more than double the density of seedlings recruited under grazing.

The relative proportion of each species in the total cohort did not differ much from similar data for earlier years except that *D. sericeum* maintained the marked increase that it had achieved in the previous year (Table 6.51).

Recruitment of Queensland bluegrass was encouraged by regular grazing

Table 6.51 Percentage of each new cohort contributed by each focal grass species at the burn trial site.

Species	Original 1995*	Recruit Cohort 1997	1998	1999	2000
A. calycina	19	18	19	16	14
A. ramosa	20	16	16	16	15
B. decipiens	24	38	37	26	31
C. fallax	19	15	11	3	3
D. sericeum	13	12	15	38	37
E. ramosus	4	1	2	1	0

* This is the original charted population, so is not an aged-based cohort like the others

Plant density

To allow comparison with other pasture communities, recruitment numbers can be also expressed as density per square metre (Table 6.52). The original density is probably higher than the paddock average because each location was selected so that it had plenty of plants of the focus grasses in them. Bare areas were excluded whereas they do contribute to a paddock mean. However the recruitment density may be more representative because this would be lowered by competition from the good cover of existing perennial grasses at the sites.

Table 6.52 Mean density/sq m of successful seedling recruits in 5 years under differing management for the 6 focus grasses in the burning trial.

	A. calycina	*A. ramosa*	*B. decipiens*	*C. fallax*	*D. sericeum*	*E. ramosus*
Burnt	1.6	3.0	7.8	1.7	3.8	0.2
Unburnt	4.4	2.5	4.2	1.9	4.0	0.2
Treeless	3.3	2.7	5.8	2.3	4.7	0.4
Treed	2.6	2.9	6.2	1.2	3.0	0.1
Mean	**3.0**	**2.8**	**6.0**	**1.8**	**3.9**	**0.2**

In general, each year these pastures were recruiting between 2 and 7 established perennial grasses per square metre (Table 6.53). It is not appropriate to read anything into the initial relative densities of the grasses because they were not a random or representative sample of the whole paddock or treatment. Only subsequent data is truly comparable for the treatment effects.

Grazing trial vs Burning trial

Lack of grazing pressure had an effect on recruitment in some years but the trend was not consistent (Table 6.53 vs. Table 6.15). Mean annual grass seedling recruit density was 3.5 per square metre at the burn site over 5 years compared to an average of 4.0 in the grazing trial. Some years (1998) slightly favoured recruitment if pastures were ungrazed while the opposite applied in other years (2000). The discrepancy was sometimes by a factor of two or more, e.g. for Qld bluegrass and dark wiregrass, but the direction could be the opposite for different grasses. On average, grazed pastures recruited as many seedlings of pitted bluegrass and purple wiregrass as ungrazed. Over 5 years, dark wiregrass recruitment was strongly favoured by grazing rest (3.0 vs 1.7 plants/sq m) while that of Qld bluegrass was clearly favoured by grazing (6.1 vs 3.9).

Table 6.53 Density of recruits each growing season in the main treatments of the burning trial, compared to the original density per square metre of the focus grasses.

Management			Cohort			
Management	**1995***	**1997**	**1998**	**1999**	**2000**	**Mean**
Burnt	*15.7*	6.8	4.2	3.6	2.5	3.6
Unburnt	*11.6*	7.2	2.6	4.3	2.6	3.4
Treeless	*13.7*	7.3	3.7	4.2	3.4	3.8
Treed	*13.6*	6.7	3.1	3.7	1.7	3.2

* = Original population

Tree canopy cover did not consistently discouraged perennial grass seedling recruitment at a species level, but *in toto* that trend was consistent every year at the burning trial site (Table 6.53).

Average plant size under differing management

The range of mean crown area of two species over time was shown in Figures 6.159 and 6.160. For golden-beard grass and twirly windmill grass it fluctuated between about 50 and 250 cm^2. Crown area of pitted bluegrass averaged 83cm^2 at its peak in 1999. By comparison, the mean first year crown area of Cohort98, Cohort99 and Cohort00 was small (18 to 40 cm^2) compared to that of Cohort95 in the same year, as well as Cohort95 in 1995 (Table 6.54).

Table 6.54 Annual variation in mean plant crown area of survivors from successive grass cohorts in the ungrazed burning trial.

				Autumn of year		
Species	**Cohort**	**1995**	**1997**	**1998**	**1999**	**2000**
A. ramosa	1995*	*43.1*	*34.4*	*45.2*	*45.3*	*43.5*
	1997	-	15.5	26.3	26.2	28.7
	1998	-	-	11.4	23.8	20.1
	1999	-	-	-	13.4	13.5
	2000	-	-	-	-	10.9
B. decipiens	1995*	*49.2*	*51.0*	*48.1*	*94.1*	*75.0*
	1997	-	24.2	40.3	67.8	64.1
	1998	-	-	26.4	103.0	65.8
	1999	-	-	-	39.6	35.6
	2000	-	-	-	-	18.4
D. sericeum	1995*	*40.3*	*32.5*	*39.4*	*92.7*	*77.5*
	1997	-	29.0	37.9	69.7	60.1
	1998	-	-	15.9	79.9	71.8
	1999	-	-	-	57.8	34.1
	2000	-	-	-	-	13.7

[* = original multi-aged population]

Note that the mean crown size of plants that were destined to survive until at least the year 2000 was almost always greater than the mean of the total cohort of that species at that time (Table 6.55 vs Table 6.54).

Table 6.55 Mean crown area (cm^2) each year of recruits from sequential cohorts of key perennial grasses that survived until at least 2000.

			Autumn of year				
Species	**Cohort**	**Nbr**†	**1995**	**1997**	**1998**	**1999**	**2000**
A. ramosa	1995*	*31*	*55.6*	*35.6*	*62.6*	*69.5*	*46.3*
	1997	9		24.8	49.0	36.7	43.2
	1998	9			17.4	30.5	31.2
	1999	20				14.7	16.1
	2000	20					10.9
B. decipiens	1995*	*70*	*53.0*	*60.1*	*62.0*	*101.5*	*90.4*
	1997	57		31.3	44.6	74.2	74.1
	1998	19			42.1	122.6	80.2
	1999	37				31.2	35.6
	2000	43					18.4
D. sericeum	1995*	*20*	*45.3*	*44.1*	*64.9*	*132.1*	*115.6*
	1997	20		31.6	46.9	76.1	54.7
	1998	13			15.6	87.4	75.0
	1999	68				62.8	40.4
	2000	50					13.7

[† = number of plants contributing to the means; * = original plants]

Table 6.56 Effect of burn trial treatments on mean grass crown area (cm^2) at first recording of each new cohort.

		Management regime			
Species	**Cohort**	**Burnt**	**Unburnt**	**Treeless**	**Treed**
A. ramosa	1998	10.4	13.9	16.3	8.1
	1999	8.4	23.3	16.3	10.6
	2000	10.4	11.1	13.4	7.1
B. decipiens	1998	27.4	22.7	34.0	17.8
	1999	30.8	49.0	51.7	17.6
	2000	19.7	16.4	20.7	15.5
D. sericeum	1998	8.3	27.1	12.9	24.6
	1999	80.6	36.0	92.1	19.9
	2000	12.9	15.3	13.7	13.7

Mean crown size at first charting was about $20cm^2$ and the area of the perenniating plants usually increased in the first few years. However, seasonal conditions could override this natural tendency and that was very evident between the 1999 and 2000 recordings. Many cohorts lost crown area that year; in general, the unpalatable *A. ramosa* did not, the palatable Qld bluegrass did, while the seasonally unpalatable pitted bluegrass remained stable in plant size. Purple wiregrass was initially slower to increase the size of its crown while those of Qld bluegrass grew fastest, especially in the wet 1998-99 year (Table 6.55). Recruited plant numbers of *C. fallax*, *E. ramosus* and *A. calycina* were insufficient to allow similar meaningful comparisons.

Cohort differences

When new plants were recorded at the end of a summer, their initial size was proportional to the environment that they had grown under. An example set is shown in Table 6.56 for the three autumn cohorts where we are confident of plant age. The pattern is very consistent except for the *D. sericeum* plants in the burnt plots in 1999 and they are probably demonstrating the effect of a lack of a fire the previous spring when it was very wet. Tree competition mostly restricted the rate of early crown development as expected. The exception was again Qld bluegrass which is a very dynamic species in response to moisture and probably soil nitrogen too. Hence time since germination of a new cohort would have a greater influence on the charted crown size for it than for the slower-growing wiregrasses. There is no obvious explanation for the reversal of the tree effect on Qld bluegrass in 1998 but numbers of data values was low (7) for the treed mean, which lowers its reliability greatly.

Losses each year

Tree effects

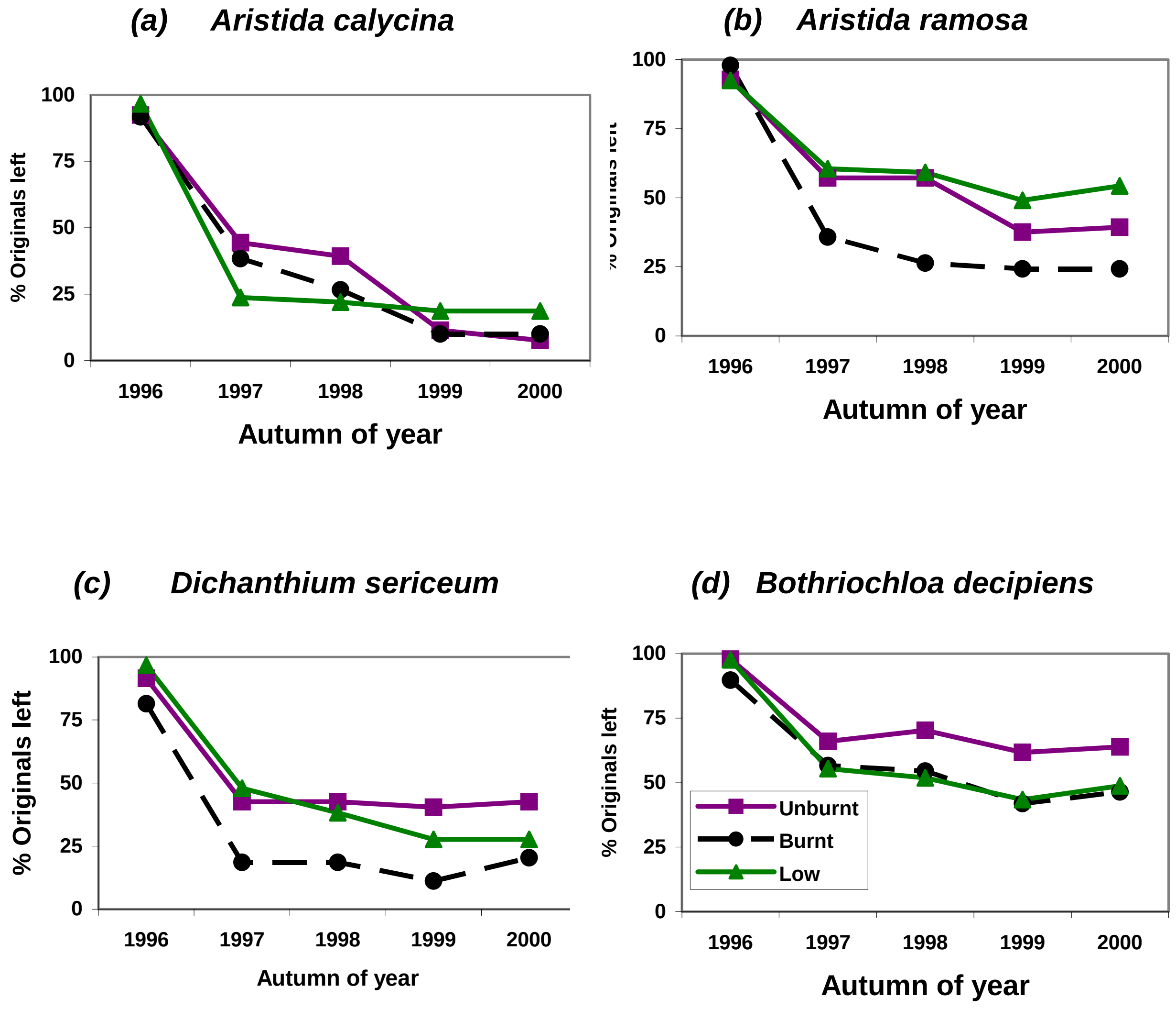


Figure 6.167 Decline in the population of original plants under the differing burning regimes.

The presence of trees made no appreciable difference to the number of plants that were lost each year but there were significant differences in total loss rates amongst years (Table 6.57). Relatively few plants were lost during 1995/96 and 1999/2000. The relatively dry 1999/2000 year did not seem to increase the rate of death of species above what seems to be the normal exponential loss rate over time (Figure 6.167). The dryness was expressed in the size of the plants.

Management effects

There was no difference in the overall level of plant losses due to burning (Table 6.57) if the total losses are calculated as a proportion of the original 1995 population (1.53 vs. 1.57 times). Loss rates recorded amongst grasses were higher in these ungrazed plots (1.55 times 1995 numbers) than from grazed plots (mean 1.27 times). This seems unusual but is possibly explained if grazing removes more susceptible plants early, before our annual autumn recording system included them as established plants.

For individual species, the relative loss rates were as expected, except for *C. fallax* which was higher than expected because we tended to aggregate adjacent tufts in later years once we knew they most likely came from the same set of rhizomes. Loss rates over 5 years were highest for dark wiregrass (1.73) and lowest for twirly windmill grass (0.80) (Table 6.58) with each species having higher than usual years for losses. The high losses in the 1998-99 year were obvious in the field (Figure 6.158).

Table 6.57 Numbers of focus plants lost each year under different growing regimes at the burn site.

Management	*Originals 1995**	1996	1997	Year 1998	1999	2000	Total lost	Losses / Orig nbr
Burnt	*423*	49	178	129	233	60	649	1.53
Unburnt	*313*	29	102	121	180	61	493	1.57
Treeless	*370*	32	165	137	232	63	629	1.70
Treed	*366*	46	115	113	181	58	513	1.40
Year totals	*736*	78	280	250	413	121	1142	

Table 6.58 Number of plants of each focal grass species lost each year at the burning site.

Species	1995*	1996	1997	Year 1998	1999	2000	Grand Total	Losses / Orig nbr
Arical	139	11	57	47	92	33	240	1.73
Ariram	150	3	75	45	64	27	214	1.43
Botdec	179	14	42	65	139	31	291	1.63
Chrfal	140	35	42	62	80	13	232	1.66
Dicser	98	14	51	24	35	17	141	1.44
Entram	30	1	13	7	3	0	24	0.80
Grand Total	736	78	280	250	413	212	1142	

Loss rates were relatively high in the 1997/98 and 1998/99 years (Table 6.58) and, over the 5 years, total losses exceeded gains from new recruits (Table 6.59) of these 6 grasses at this site. For individual species, this general story did not hold for pitted bluegrass and Qld bluegrass. The bigger-than-expected losses for *C. fallax* have been explained before. Qld bluegrass had a good recruitment period in the wet middle years, especially with the wet 1998 winter. The overall dynamics of the perennial grass populations is clearly shown by this data. This means that grazing management and seasonal extremes are potentially able to shift pasture composition at any time. If the plant flux results were calculated on crown areas (Table 6.59) a similar story emerges with Qld bluegrass more than replacing crown area losses each year for a nett gain overall while the opposite applied for *C. fallax* and *E. ramosus*. The biggest shift was in the crown area of existing plants that survived during a good growing season. They more than doubled crown area in one year (1998/99) while in a poor year (1999/00) crown area of surviving plants declined up to 26% only.

Table 6.59 Gain over prior area by survivors, crown area of new recruits, and area lost due to deaths each year from the previous year's population of each focus grass, as a percentage of that species area the previous autumn.

	Species						
	A. calycina	***A. ramosa***	***B. decipiens***	***C. fallax***	***D. sericeum***	***E. ramosus***	**Mean**
Cohort98 area	6	10	17	16	13	4	11
Survivor change	-24	25	-12	-21	30	14	2
Lost since '97	15	18	12	17	24	14	16
Cohort99 area	11	9	17	1	<u>141</u>	2	30
Survivor change	-23	-10	<u>74</u>	19	<u>110</u>	<u>101</u>	45
Lost since '98	<u>63</u>	27	30	31	27	10	31
Cohort00 area	<u>18</u>	5	4	1	7	0	6
Survivor change	<u>27</u>	-17	-13	-11	-23	-26	-11
Lost since '99	<u>32</u>	7	8	18	5	0	12
3yr cohort mean	12	8	13	6	54	2	16
3yr avge change	-7	-1	16	-4	39	30	12
3yr mean loss	37	17	17	22	19	8	20

Appreciably different values are underlined.

Individual cohort losses

Table 6.60 shows the general pattern of plant cohort decline over time that all species combined exhibited. However the other data (Tables 6.58 and 6.59, Figure 6.167) show clearly that the rate of decline is very species dependent. The loss of only 27% of the 1999 cohort by the end of the dryish 2000 summer was unexpected given the 36 to 62% first year losses by earlier cohorts (Table 6.60). In general the data in this table does not fit well with normal expectations, especially the large 'rediscovery' of missed plants after a bigger than expected fall in the 1998-99 year.

1995 original plants

The death rate of plants that were present in autumn 1995 followed an exponential decline with time for all treatments (Figure 6.168). About 36%% of the 1995 cohort were still alive in June 2000 but for individual species that proportion ranged from 9% for dark wiregrass to 55% for pitted bluegrass. Regular spring burning produced a modest but consistently greater rate of loss than fire suppression (Figure 6.168) but neither differed significantly from light grazing.

Table 6.60 Percentage of initial cohort members lost annually in subsequent years by four different cohorts at the burning trial site.

	Percent loss in year interval			
Cohort	**1995-97**	**1997-98**	**1998-99**	**1999-2000**
1995	*41.1*	13.0	30.5	-2.1
1997	**-**	36.1	46.2	-17.8
1998	**-**	-	61.8	-11.0
1999	**-**	-	-	27.3

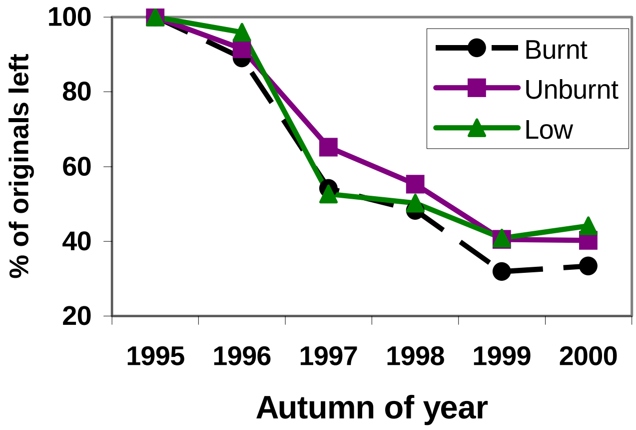


Figure 6.168 Effect of exclosure and spring burning on survival of the original 1995 perennial grass plants over time, compared to light grazing.

A high level of perennial grass plant death coincided with a very wet 1998 winter. The large bulk of standing pasture after 4 years without grazing may be implicated.

At an individual species level, there were noticeable differences associated with the different treatments. However, a lack of sufficient plant numbers for some species in particular treatments generally precluded the differences being statistically significant ($P<0.05$). The burn in spring 1996 had a dramatic effect on *A. ramosa* and *D. sericeum* but subsequent fires had little effect. Conversely, lack of burning and grazing seemed to favour *B. decipiens* more than any other management regime (Figure 6.167d). Qld bluegrass survived best where it was subjected to neither spring fires nor regular grazing, 55% compared to 15-43% in other treatments. This is probably a reflection of the high palatability of this grass along with the associated patch or selective grazing that occurred at very low grazing pressure.

The graphs in Figures 6.167 and 6.168 show an apparent increase/resurrection of plant numbers for some species in 2000. There are several reasons possible for this –

- Missed plants in 1999
- Fractured crowns being classed as separate identities in 2000 but from the same original plant
- Minor errors in the SQL query logic of the database holding the transcribed graphical data from the charts.

All three probably contributed and as no recording was done in 2001, we did not have the ability to see if it corrected later. Missed plants (7%) in 1999 was the main cause for the pitted bluegrass resurgence but the equivalent figure for the other species was only 2-3%. Part of the problem is the small number of surviving plants by 2000 which means an error in 1 or 2 cases can cause such an apparent resurrection, especially when data is expressed as a percentage.

1997 cohort loss patterns

There was a variable management effect on mean losses for each species over time (data not shown). Dark wiregrass was unaffected by burning while *B. decipiens*, *A. ramosa* and *D. sericeum* survived better where unburnt.

1998 cohort loss patterns

The individual species response to conditions after 1998 were again variable and not necessarily the same as for previous cohorts in the short term, except for the general rate of loss that is genetically predetermined for each one. There were large losses of dark wiregrass plants where ungrazed and unburnt which was reflected in the overall Botanal results after the very wet 1998 winter. A fungal-like disease seemed to kill many grass plants in the bulky unburnt, ungrazed plots in the 1998 winter and this data (Tables 6.58 and 6.60) shows that it applied to plants of all ages, even the younger new recruits that would normally not have reached senility.

The relatively wide discrepancy in losses of wiregrasses between 1998 and 1999 in the unburnt and burnt treatments cannot be due to burning because we could not effect a burn in the 1998 spring because it was too wet. So the differences for several of the grasses must centre on the other microclimatic conditions that existed in the pasture swards, eg. biomass, ground cover, competition etc. We cannot explain this any better with the coarse level of monitoring detail that we were using.

Plant flux calculations

Plant flux calculations for the focus perennial grasses were done, following the system of Sarukhan and Harper (1973). The results, summarised in Table 6.61, are based on the original 1995 plants plus all the recruits and deaths/losses that occurred between then and autumn 2000 when the last charting data was collected. The parameters are the same as those presented for the grazing trial in Table 6.34.

Attempts to ascribe consistent outcomes to all species from the various management scenarios generally met with little success. Some species benefited overall from spring burns or tree killing or wet years while others were relatively disadvantaged by the same thing. For example, the rate of increase in numbers (item d in Table 6.61) was enhanced by lack of fire for most species but not for *C. fallax* or *E. ramosus*. Likewise, retention of tree cover produced inconsistent benefits for the same calculation for different species, eg. Qld bluegrass versus pitted bluegrass.

The inherent rates at which species turn over populations were, however, fairly predictable with high death rates (item h) for *D. sericeum* and low rates for *E. ramosus*. There was between 45 and 75% turnover of plants of different species each year (item k), greatest for dark wiregrass and least for pitted bluegrass and twirly windmill grass. The figure of 45% flux for Qld bluegrass is unexpectedly low, given the high rate of increase and low percentage survival of the original plants. It does however fit with the calculated 7 year expected lifespan of plants (item i).

The *C. fallax* results should be ignored because plants that were originally drawn separately on the charts were later often amalgamated and thus ‘lost’ from the point of view of the Sarakhan and Harper calculation method for survival.

Spring burning resulted in variable changes to expected lifespans (item i) with increases for pitted bluegrass and twirly windmill grass and reductions for *A. ramosa* and Qld bluegrass. *A. calycina* had poor persistence under regular spring burns while pitted bluegrass was the most persistent of the 6 species under this regime.

The expected lifespan values seem a little low for *E. ramosus* at 7.8 years and a bit high for *D. sericeum* at 7.0 years, based on our memories and experience. We had no strong, preconceived ideas for the other plants, apart from *C. fallax* which we have already qualified because of the techniques used. A 7 year lifespan average for Qld bluegrass seems too high but we did not have a severe dry summer during the course of these recordings. A significant death rate occurred later in the 2002-2003 drought.

Table 6.61 Poplar box charting population dynamics – ungrazed burning trial.

		Species						
Data	Factor	**Arical**	**Ariram**	**Botdec**	**Chrfal**	**Dicser**	**Entram**	**Mean**
	n =	174	162	288	198	196	36	
Average of Rate of increase [b/a] (d)								
	Species mean	0.6	1.4	2.8	0.8	2.4	1.0	1.6
	Treeless	0.7	1.3	1.8	0.8	3.2	0.6	1.4
	Treed	0.6	1.5	3.9	0.8	1.8	1.3	1.7
	Burnt	0.3	0.6	1.6	0.8	1.4	1.0	0.9
	Unburnt	1.0	2.2	4.1	0.8	3.6	0.9	2.2
Average of Percent survival of orig plants [g/aX100] (h)								
	Species mean	8.8	26.9	52.7	36.6	17.4	64.6	31.9
	Treeless	9.2	29.2	49.6	33.2	9.8	29.3	27.0
	Treed	8.3	24.7	56.3	40.0	24.9	100.0	36.9
	Burnt	10.3	24.1	53.9	30.0	13.1	84.8	32.2
	Unburnt	7.2	29.8	51.2	43.2	21.6	44.4	31.6
Average of Plant flux - % annual mortality of all individuals [f/jX100] (k)								
	Species mean	76.7	59.6	44.1	67.2	45.2	43.9	57.4
	Treeless	76.6	64.0	49.1	68.3	52.1	71.1	63.2
	Treed	76.9	55.3	39.1	66.2	39.5	16.7	51.9
	Burnt	87.7	62.0	49.1	71.1	48.8	11.1	58.9
	Unburnt	65.8	57.3	39.2	63.3	40.9	76.7	55.9
Average of Expected time for original plants to die (years) [no. yrs5 /(100-h)X100] (i)								
	Species mean	5.5	7.6	11.5	9.4	7.0	7.8	8.1
	Treeless	5.6	8.3	11.2	7.8	5.7	7.8	7.8
	Treed	5.5	7.0	12.0	10.9	8.4	n.r.d.	8.5
	Burnt	5.6	6.8	13.0	8.5	5.9	11.0	8.1
	Unburnt	5.4	8.5	9.2	10.2	8.2	6.2	8.1

n.r.d. = no recorded data

6.2.2.4.12.5 Discussion

In this ungrazed trial, tree competition suppressed perennial grass growth and crown size just as it did in the grazing trial. The difference was that average plant diameter was greater in the absence of grazing and in the absence of burning. However, at the very end of the trial in 2000, that discrepancy due to the presence of trees disappeared because of a big fall in crown area of the two bluegrasses. The decline was not confined to a single cohort year (Table 6.54) and no obvious cause was noticed.

Regular spring burning maintained a smaller average crown size which is at variance with the findings of Orr *et al.* (2004c) but agrees with his earlier work at a different site (Orr *et al.* 1997). Orr *et al.* (2004c) acknowledged that different wiregrass species were possibly involved in the difference between his trials and named *A. ramosa* as a major species involved in the 1997 report. It is the major species in our study and so our results agree with respect to it. Our results also suggest that *A. calycina* recruits fewer seedlings where burnt and so support Orr *et al.* (2004c) when they suggest differential wiregrass species reactions to fire. Like us, Orr *et al.*

(2004c) were unable to burn every year in spring and thus the final results are influenced by the sequence of seasons that surrounded the burning events, as they affected seedset and seed germination (reported later). Big variations between reps and quadrats in the numbers of *A. calycina* plants, seedlings and recruits limits our confidence in the results for this species compared to some others.

For some reason, the mean size of the 1999 cohort of Qld bluegrass plants in burnt plots was much larger than for those recorded in unburnt plots, and counter to the trend of all other main species and cohort years (Table 6.56). A burn the previous spring was not possible, hence the cohort from the 'burnt' plots was unburnt since establishment like its 'unburnt' plot counterparts. Plants from that year cohort were unusually large compared to other cohort years (Tables 6.54 and 6.55) which is in keeping with the liking for good spring and autumn rains by this grass, as occurred that 1998-99 year. Whether there was also a greater pool of available nitrogen or other labile nutrients to enhance the effect from the 1997 spring burn is unknown but seems possible. Alternatively, lack of a burn in 1997 may have predisposed small Qld bluegrass plants in a dense sward to greater fungal attack during the wet 1998-99 summer.

Such speculation from annual field trial data sets highlights how complex the interactions can be within a pasture and how challenging it is to predict what the outcome of management decisions might be on individual species and more critically on individual cohorts of a perennial grass species.

Crown size of existing plants can double in good years for some species (Table 6.59) but in drier years declines were generally of the order of only 10 to 25%. Even in good years, a sizeable 10-63% (mean 31%) of existing grass plants were lost without any grazing occurring. Spring burning improved the mean lifespan of some grasses such as pitted bluegrass but not that of others such as purple wiregrass and Qld bluegrass.

6.2.2.4.13 Soil seed loads in response to spring fires

6.2.2.4.13.1 Abstract

Spring burning was associated with a reduced total number of germinable seeds at the end of the next winter, after the subsequent growing season. Over 6 years, the total number averaged about half that found in unburnt plots and that difference did not alter markedly amongst years. This effect was not obviously magnified by the lack of grazing at the burning trial site and applied across a wide range of plant types.

Sedges and daisies were the major groups that had noticeably fewer germinable seeds as a consequence of spring burning. No species had an enhanced density of germinable seeds in the regularly burnt plots.

6.2.2.4.13.2 Background

Sampling for soil seed loads was done at the burning trial site for the same reasons as at the grazing trial.

6.2.2.4.13.3 Methods

The methods used at the burn site were identical to those at the grazing trial, except that the number of samples taken was fewer. A single composite sample from four cores was collected around the central steel peg where the two diagonal sampling transects intersected (see Appendix A). Thus there were only 12 samples in each germination run at this site. Also, no samples were taken at the burn site in the spring of 1994 before the first fires were lit. So there is only one set of samples where remaining viable seeds were germinated in the following autumn, from spring 1995 samples.

6.2.2.4.13.4 Results

Numbers emerging

At an individual species level, year-to-year variation in numbers germinating was large (Table 6.62) but this was less obvious when species were amalgamated into genera or family groups. Grasses were always a major part of the total germinable seedbank in spring (Table 6.63) and sedges were also always significant, - mean of 18% of the germinating seeds. Only 3 golden beard grass seedlings emerged despite having free rein to set maximal seed numbers and having a large seed and a major presence in most plots. The major dicot group was the daisies with a mean 8% of the seedbank and a very consistent contribution every spring. By comparison, the chenopods were significant in only some years and virtually absent in others.

Wiregrasses made up only 2.3% of all emerging seeds over 6 years but in two springs our samples picked up no germinable seeds of them. Qld bluegrass averaged just 3.8% of the germinable seeds while pitted bluegrass was 13.5% on average (Table 6.63). Both were detected in all years and pitted bluegrass formed over 40% of the seedbank in spring 1999.

Seeds of woody species were almost non-existent at this site. Only 2 poplar box seedlings emerged in six spring samplings despite there being a large population of mature trees at the site in close proximity to all plots. Factors contributing to these low numbers are the same as were discussed for the grazing trial and lack of grazing livestock would not be expected to affect seed set by large woody species. Our test regime would most likely allow more seedlings to germinate and emerge than would occur in undisturbed areas where very obvious cryptogam crusts develop to impede seedling emergence.

Table 6.62 Numbers of seedlings of key taxa emerging in successive years from spring soil samples at the ungrazed poplar box burning trial.

Species/group	1995	1996	1997	1998	1999	2000
Qld bluegrass (Dicser)	1	6	9	1	24	4
Pitted bluegrass (Botdec)	7	2	13	1	109	31
Twirly windmill (Entram)	1	17	1	0	1	1
Golden beardgrass (Chrfal)	0	1	0	0	0	2
Dark wiregrass (Arical)	1	0	1	0	2	3
Purple wiregrass (Ariram)	0	0	3	0	11	6
g = grasses (all species)	31	81	83	29	27	94
a = Asteraceae (daisies)	5	12	12	10	19	15
m = Malvaceae (flannelweeds)	1	0	1	0	3	0
l = legume	0	1	0	1	0	0
c = chenopods (saltweeds)	3	0	1	0	0	0
s = sedges & lilies	6	51	9	49	23	14
w = woody tree/shrub	1	1	0	0	0	1
Total nbr (all species)	**51**	**165**	**172**	**104**	**261**	**200**
TOTAL (seeds/sq m)	**541**	**1751**	**1825**	**1103**	**2769**	**2122**

Table 6.63 Seedlings of key taxa emerging each year from soil samples at the poplar box burning trial, expressed as a percentage of the total numbers emerging that year.

Species/group	1995	1996	1997	1998	1999	2000	Mean
Qld bluegrass (Dicser)	2.0	3.6	5.2	1.0	9.2	2.0	3.8
Pitted bluegrass (Botdec)	13.7	1.2	7.6	1.0	41.8	15.5	13.5
Twirly windmill (Entram)	2.0	10.3	0.6	0.0	0.4	0.5	2.3
Golden beardgrass (Chrfal)	0.0	0.6	0.0	0.0	0.0	1.0	0.3
Dark wiregrass (Arical)	2.0	0.0	0.6	0.0	0.8	1.5	0.8
Purple wiregrass (Ariram)	0.0	0.0	1.7	0.0	4.2	3.0	1.5
g = grasses (all species)	60.8	49.1	48.3	27.9	10.3	47.0	40.6
a = Asteraceae (daisies)	9.8	7.3	7.0	9.6	7.3	7.5	8.1
m = Malvaceae (flannelweeds)	2.0	0.0	0.6	0.0	1.1	0.0	0.6
l = legume	0.0	0.6	0.0	1.0	0.0	0.0	0.3
c = chenopods (saltweeds)	5.9	0.0	0.6	0.0	0.0	0.0	1.1
s = sedges & lilies	11.8	30.9	5.2	47.1	8.8	7.0	18.5
w = woody tree/shrub	2.0	0.6	0.0	0.0	0.0	0.5	0.5

Spring vs autumn results

There were insufficient numbers to make many comparisons for individual species between testing dates at this site, but overall, the trends were the same as for the grazing trial. No wiregrass seedlings remained to emerge from the retest in autumn but small-seeded grasses and non-grasses were prominent in both runs. Six sedges and 9 *Eragrostis* species emerged in spring while 12 and 18 respectively emerged the next autumn. Amongst the dicotyledons, 1 bluebell and 4 daisies emerged in November 1995 and then a further 21 and 12 respectively emerged in April 1996.

Spring burning effects

Of those 75 taxa for which we recorded germinable seeds in spring, two (*Indigofera linnaei* and *Senecio lautus*) were recorded only at the burn site which is 1km away from the grazing site and, in each case, only 1 plant of the species was recorded (Appendix I). There were no *H. contortus* (black speargrass) emergees at the burn site despite obvious plants in parts of the area. As at the grazing trial, some sample locations produced consistently high counts of germinable seeds each year, eg. CN2 averaged over 30 seeds/sq m.

Regular spring burning did not increase soil seedloads of any plants but did reduce it for the following - *Calotis lappulacea, Centauria* spp*.* & *Wahlenbergia* spp. Seed loads of key grasses like Queensland and pitted bluegrass were unaffected (Table 6.64) but sedges seemed disadvantaged by spring burning.

Fire slightly reduced the overall seed density from 2865 to 2025 seeds/m^2 when averaged over the last two years of seed sampling (1999-2000) (Table 6.65). That effect was also there in earlier years of the burning trial (Table 6.64, Figure 6.169) but because a burn was not possible every spring, the conclusions need to be tempered. No burns were possible in spring of 1996 and 1999, so the data for 1997 and 2000 could lack an effect from the previous spring yet may show cumulative effects on very fire sensitive species such as barbwire grass (Figure 6.128f), *Calotis* (Figure 6.128g) and *Verbena* (Table 6.43).

Table 6.64 Numbers of seedlings emerging from burn site spring soils samples, summed for all years of the trial and aggregated for the main treatments.

Species		Treeless	Treed	Burned	Unburnt	Total
	All years summed					
Qld bluegrass (Dicser)		32	13	23	22	45
Pitted bluegrass (Botdec)		72	91	79	84	163
Twirly windmill (Entram)		6	15	3	18	21
g = grasses (all species)		200	145	154	191	345
c = chenopods (saltweeds)		0	4	0	4	4
s = sedges & lilies		115	37	35	117	152
Total		425	305	294	436	
	per sq metre					*Mean*
Qld bluegrass (Dicser)		679	276	488	467	477
Pitted bluegrass (Botdec)		1528	1931	1676	1782	1729
Twirly windmill (Entram)		127	318	64	382	223
g = grasses (all species)		4243	3076	3267	4052	3660
c = chenopods (saltweeds)		0	85	0	85	42
s = sedges & lilies		2440	785	743	2482	1612

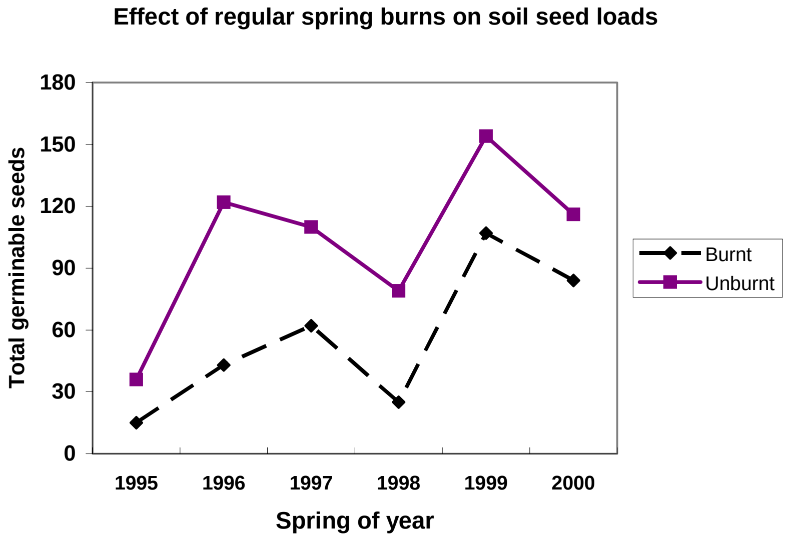


Figure 6.169 The impact of regular spring burns on total soil seed loads each spring in the absence of grazing at the poplar box site. No burns were possible in 1996 and 1999.

Unfortunately the amount of forest bluegrass at the site was initially low, so we have insufficient data from it but it is normally regarded as tolerant of burning but maybe not to very regular burning (Orr *et al.* 1999). In the absence of grazing, it seemed to increase its presence at our burn site with regular spring burns (Table 6.43), but again the data is inconclusive as to the cause. Emerging seed numbers from the wiregrasses were insufficient to allow any convincing conclusions to be reached about the impact of fire on their seed reserves.

Tree effects

In the last two years (when major treatment effects should have been well established), the average density of emerging seedlings at the ungrazed plots was 3140 seeds/m^2 where treeless, significantly more ($P<0.05$) than the 1750 seeds/m^2 where the trees remained. The mean tree effect was consistent, though often tiny, for all years except 1997 (Table 6.65).

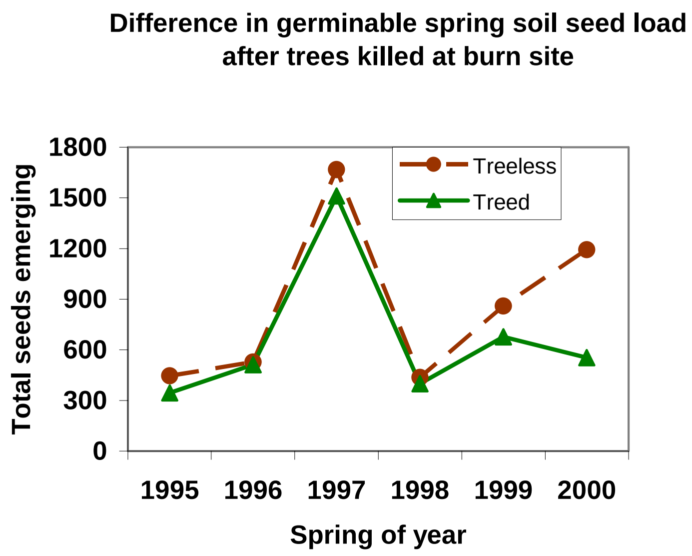


Figure 6.170 Effect of killing trees on total soil seed loads over time at the poplar box site where pastures were ungrazed.

Table 6.65 Seedling numbers emerging per square metre from the ungrazed poplar box burn site at each spring sampling, grouped into the main treatments.

Species	Spring	Treeless	Treed	Burned	Unburnt	Mean
	Posts sampled	6	6	6	6	12
All species	**1995**	743	339	318	764	541
(per sq metre)	**1996**	1846	1655	912	2588	1750
	1997	1719	1931	1315	2334	1825
	1998	1315	891	530	1676	1103
	1999	3289	2249	2270	3267	2769
	2000	2992	1252	1782	2461	2122
	Mean	1984	1386	1188	2182	1685

Spring burning reduced total germinable soil seedbanks at the start of the next spring

6.2.2.4.13.5 Discussion

By international standards, our seed banks were not large when compared to figures of 41,000 m^{-2} in South Africa (Van Rooyen & Grobbelaar 1982), 36,000 m^{-2} at Townsville (McIvor 1987) and 26,000 m^{-2} in NSW (Lodge 2001). Neither are they unusually low when compared to 6470 m^{-2} (Rabinowitz 1981) and 265 –5000 m^{-2} (Marlette & Anderson 1986) in USA prairies, and 2400-9800 m^{-2} in western NSW (Hodgkinson *et al.* 1980). For individual grass species, numbers like 100–1000 m^{-2} for Qld bluegrass and pitted bluegrass are normal for tropical perennial grasses (Westoby *et al.* 1988, Orr 1991, Odgers 1994). Very low seed numbers for *C. fallax* is exactly what McIvor & Gardener (1994) and McIvor et al. (2004) found and our low numbers for the wiregrasses matches what Orr *et al.* (2004c) found in more coastal pastures.

Thus increaser grasses like the wiregrasses do not behave that way because they have huge seedbanks, unlike *Bothriochloa pertusa* (McIvor & Gardener 1994), but because they are not eaten. Conversely, the increaser status of *C. fallax* is not because it is unpalatable, nor because it sets huge amounts of seed, but because it is long-lived and has a very deep crown that stock cannot reach. Each species has its own strengths and weaknesses that need to be borne in mind when devising land management strategies to deliver intended outcomes.

Killing trees did little to alter the numbers or proportions of germinable seeds available at the start of each growing season. In individual years, particular species were notably abundant or absent but the transient nature of the seedbank of the major tree and pasture species means that opportunities for land managers to exploit such extremes are very limited. They will have to work on existing plants to achieve desired outcomes.

No species showed a noticeable increase in germinable seed numbers in the burnt plots. However, because our sampling was done almost a year after each burn, there is still the possibility that seeds of some species were more germinable early in the summer immediately following, eg. hardseeded species such as the flannel weeds. Pasture composition changes did not point to this happening to any marked degree even though black speargrass, forest bluegrass and Qld bluegrass biomass and plant frequency increased under burning. Inadequate seed numbers do not allow any judgement to be made in this matter for the former two grasses. For Qld bluegrass we cannot conceive of fire enhancing germinability of its seeds (quite the opposite) but it may enhance its establishment and seed production. Perhaps *Eragrostis* species had their seed germinability enhanced by spring fires because their frequency in pastures increased noticeably where burnt (Figure 6.129). This trend is contrary to that found by Orr & Paton (1997) at Gayndah but climatic factors may be the major driver or change rather than spring burning.

Burning regularly in spring did reduce seedbanks noticeably but there was no evidence to suggest that individual species or guilds of related species were strongly advantaged or disadvantaged by spring fires. Fluffy seeded bottlewasher grasses and bluegrasses did not show marked shifts in their pre-burn numbers where fires were used. Overall pasture species seed densities increased at the ungrazed site but not by a huge amount, 20% over the last two years. Killing trees had a greater impact and seeds of 3P grasses (black speargrass, buffel grass, and the bluegrasses) were fewer where ungrazed over those 2 years (223 versus 425 germinable seeds/sq m).

6.2.2.5 *Overall Discussion*

After 8 years of pasture management to see how fire-responsive the poplar box pastures were, we must conclude that they are but only slowly when ungrazed between fires. Minor non-grass components such as daisyburrs and *Verbena* spp. did decrease when burnt regularly in spring but such change was transitory. Equally transitory but much more potent was their response to seasonal conditions which had a huge bearing on their seedling recruitment and vigour. These plants are short term perennials and their crowns are fire-resistant. Hence only fires that persistently prevent them from seeding will substantially alter their presence in these natural pastures. Both have relatively persistent seedbanks that can cope with occasional failures to receive new inputs and both flower over an extended period each year, if moisture is available.

The fires did reduce the level of ground cover but it was never to such an extent or for such a prolonged period that pasture health or land condition was threatened at our site. We never experienced a severe rainfall deficit in late spring and early summer, hence the dominant perennial plants regrew quite quickly to provide vital cover in the ungrazed pastures. Extra tree litter from scorched foliage was common after our mild fires in the treed plots. In the treeless plots, lack of competition for scarce soil moisture enabled the pastures to regrow adequate cover more rapidly than under the trees.

The perennial 3P grasses responded positively to spring fires and the proportion of *H. contortus*, *B. bladhii* and *D. sericeum* increased under that regime. Intermediate grasses such as *B. decipiens* and *E. ramosus* were not significantly affected by burning, which is not surprising for plants that have evolved in a fire-prone environment. Unfortunately, persistence and yield of the undesirable wiregrasses were not much affected by regular burning in the absence of heavy grazing straight afterwards (compare with Orr *et al.* 1997). *A. calycina* showed some signs of sensitivity to fire and that is not surprising in view of its high crown that would be well-heated by even a moderate fire. Scattered buffel grass plants were not discouraged by regular burning but we have insufficient data to measure if it benefited either.

A general lack of tree and shrub flowering and seed production during our trial time meant that regrowth suppression by fires was not necessary for continued pasture vigour. The interaction of spring fires and different spring/early summer seasonal conditions potentially may have big impacts when combined with tactical grazing but our trials are unable to confirm this. A role for autumn fires to burn heavy seedset by wiregrasses may be an option in some cases but, given the known detrimental effect on forage availability, we have nothing to suggest that the benefits from wiregrass seed destruction warrant such an approach. Such burns will also kill the new seeds of the valuable bluegrass species.

6.2.3 Comparison between grazed and ungrazed pastures

The slightly different location (700m apart) of the two Injune trial sites and differing levels of replication in each means that care has to be taken when comparing equivalent results between the sites, eg. tree clearing effects. The effect of tree clearing on botanical composition and pasture yield can be compared between the burning and the grazing trial but not with statistically defined precision. The results cannot be analysed easily as one statistical data set. However the effect was the same and was repeatable over consecutive years (Figures 6.71, 6.123 & 6.127).

Pre-existing tree cover, soil depth, land slope and pasture condition were all slightly different when we began the trials, both within and between trial paddocks. Paddock-scale sampling, such as the Botanal technique uses for pasture yield, produces an average result but says nothing about the spatial variability within that paddock. Nonetheless, there is merit in making observations about the impact of grazing as opposed to fire and no grazing where the results apply to the same species and to responses at an individual plant scale in a comparable environment.

6.2.3.1 *Site effects on pasture biomass and composition*

Table 6.66 summarises the differences in % frequency and changes since 1995 for 18 species or plant groups that were important pasture components. It shows that the initial site differences were large for *B. decipiens, C. fallax, E. ramosus, A. calycina* and *T. australianus*. By the trial's end, differences or changes due to grazing management could only be easily ascribed for *C. divaricata*, with a possibility in the case *T. loliiformis, T. australianus, F. dichotoma* and *Calotis* spp. Climatic effects seemed likely to explain the changes for *D. sericeum, T. australianus, V. tenuisecta* and *B. australis*.

Pasture biomass increased to greater amounts where grazing did not occur over a number of consecutive years at the burn trial. However it peaked at about 6000 kg/ha in 1997/98, after which available nutrients probably limited growth and accelerated decay rates set in during wet weather in the collapsed hamper of vegetation.

Twirly windmill grass was much less common at the burn site (mean about 2% plant frequency) so its mean proportion of total biomass was less than at the grazing trial. However, at an individual paddock scale, its presence at the grazing trial ranged from <1% frequency to over 40%. Hence data regarding its reaction to management is entirely dependent on how adequately the many quadrats thrown or charted captured changes that occurred in its vicinity within each paddock.

Mean purple wiregrass yields at the grazing trial were higher than at the burn site because of the presence of some alluvial flat in paddocks 2, 4 and 7 on which this species grows very well and thus inflated its proportion of the average paddock yield and frequency.

Table 6.66 Species frequency differences between the initial and final pasture composition at grazing and burn trial sites, averaged over all treatments.

Func. group	Species	Mean 1995-2002 Burn site	Mean 1995-2002 Graze site	1995 Burn site	1995 Graze site	Initial difference	Climate effect	Grazing effect
PG	Botdec	**51.4**	30.2	52.0	24.5	++	0	0
PG	Chrfal	**45.2**	23.3	52.2	26.3	++	0	0
PG	Ariram	17.3	20.6	27.7	30.7	0	0?	0
PG	Dicser	16.3	19.5	7.9	11.0	0	+	0
PG	Trilol	6.7	**22.6**	12.0	20.4	+	0	-?
PG	Entram	3.4	**14.3**	3.9	17.3	++	0	0
IG	Ennesp	20.9	**41.2**	21.8	38.5	+	0	0
IG	Chldiv	5.2	**25.5**	3.9	9.4	+	0	++
IG	Arical	**18.2**	6.5	25.0	6.0	++	0	0
AG	Traaus	2.1	**9.4**	6.4	23.5	++	+	+?
S	Cypspp	6.7	9.3	9.1	8.1	0	0	0
S	Fimdic	6.4	8.7	4.1	16.5	+	0	-?
L	Legume pal	16.2	12.5	22.7	11.6	+	0	0
F	forbs small	18.4	21.9	13.7	24.6	+	0	0?
F	Calotis	14.2	13.1	8.1	14.7	0?	0	-
F	Bruaus	8.2	**20.1**	25.5	33.0	0	-	0
F	Verten	11.7	10.2	0.2	2.1	0	+	0
F	Sidsub	5.3	3.1	9.1	2.1	0?	0	0?

Clear reasons for changes in that time are shown if possible. Consistent large differences are highlighted in bold.

Tree density and soil type were far more variable across the larger 120ha extent of the grazing trial. In places there were stoney knolls with dense stands of shrubs like hopbushes and yellow-berry bush that were virtually absent elsewhere. Some transects sampled these areas but that seemed to have no effect on the overall pasture yield or botanical composition data. Rather extra species were added to plant lists for the grazing trial that were not found at the burning trial. Rare species such as *Dichanthium setosum*, *Stipa scabra* and *Scleria mackaviensis* were found on these knolls but had no impact on overall botanical composition.

6.2.3.2 *Site effects on population dynamics*

Intrinsic trial site effects on population dynamics results should be minimal. A good case can be made for comparing crown turnover rates, sizes, plant recruitment and soil seed loads as five different management options (+/- tree cover), namely high, moderate and low grazing pressure, spring burning and exclosure. The small plots and localised regions or transects used to collect seed, chart plants, measure basal area and record tree and shrub population dynamics are merely a sample of the whole paddock on which a treatment was imposed. The area sampled was exactly or almost exactly the same each year, so the same locality and environment and plant population was sampled at all times.

Spatial variability around the two sites in terms of tree cover, shrub species, soil texture, depth and rockiness was as great within some paddock as between sampling locations at the different trial sites. Paddocks 1,2,4,7,10 and 11 were spatially variable in terms of soil depth, profile and rockiness while Paddocks 5,8 and 9 were quite internally homogeneous. Likewise at the burn site, plots 1 and 3 had a deal of cracking clay soil within them that grew *Aristida personata* which was seen nowhere else at either site. The remaining plots at the burn site were quite homogeneous internally and amongst themselves.

Hence the absolute values with respect to plant size, population fluxes and soil seed loads can be validly compared as the result of differing management just as much as other ecological studies make comparisons amongst large and spatially separated locations.

The fact that our samples were repeated over many consecutive years means that values which remained relatively consistent over years are meaningful. Also where sampling intensity was high enough and populations large enough, any changes are also meaningful in terms of the reaction to imposed treatments under the climatic conditions prevailing.

6.2.3.3 *Site effects on germinable seed loads*

Overall, more seedlings per square metre emerged at the burn trial site than in the grazing trial from the 6 samplings between spring 1995 and spring 2000 (1685 vs. 1606 per m^2 each spring). However, for individual species or groups, the comparison was often very different (Table 6.67). Twice as many Qld bluegrass, pitted bluegrass and sedge seedlings per square metre emerged from the burning trial compared to the grazing trial. Conversely, there were only 43% (twirly windmill grass) and 31% (chenopods) as many seeds of these two species from the burn site as from the grazing trial. The twirly windmill grass data complements the botanical composition data which showed a low level of this grass at the burn site (Table 6.66).

Table 6.67 Variability amongst species groups in their relative importance in the soil seed banks (Ungrazed/Grazed) at the 2 trial sites over the trial period

Key taxa	*per sq metre*	%
Qld bluegrass (Dicser)		210
Pitted bluegrass (Botdec)		230
Twirly windmill (Entram)		43
g = grass		73
c = chenopods (saltweeds)		30
s = sedges & lilies		181

An overall summary of the main management effects on seedloads during the final two years of sampling is given in Table 6.68. Only at the ungrazed site were any management effects statistically different (P<0.05) when meaned over those 2 years, that is starting 5 years after those treatments were first imposed. Daisies were more numerous at the burn site and chenopods much less common than at the grazing trial site. This is probably partly related to the proximity of the grazing trial to adjacent brigalow country with a much more saline surface soil.

Table 6.68 Gross effects of management on soil seed reserves in the last two years (1999-2000).

Treatment	Ungrazed site	Grazed site
Treed	1750 a	1255
Treeless	3140 c	2075
Burnt often	2025 a	
Unburnt	2865 b	
Low grazing pressure		1545
Moderate pressure		1720
High grazing pressure		1730

Data is expressed as emerging seedlings/m^2. Values within a column with differing letters after them are significantly different (P < 0.05).

A listing of all taxa recorded as germinating over the 7 sampling times, and showing which were the commonest and in how many years each was recorded, is given in Appendix I.

6.2.4 Primary productivity of the dominant grasses

6.2.4.1 *Abstract*

Forbs are a minor part of the total pasture yield of Injune poplar box pastures but minor grasses, *in toto*, make a large contribution. The dominant contributors to yield and cover are the perennial grasses but the quantum of their contribution is species specific. Pure *C. fallax* swards have a peak yield of less than 2000 kg/ha and, though greater, Qld bluegrass swards are lower yielding than pure stands of purple wiregrass and twirly windmill grass. Annual growth of over 4000 kg/ha is possible in good seasons, especially in run-on areas, with *Chloris divaricata* a common sub-dominant in wet seasons.

Moisture extraction by pastures is most significant in the 10-60cm depth interval on these solodic soils, i.e. the upper B horizon.

6.2.4.2 *Background*

Research trials in the field are always greatly affected by the prevailing seasonal conditions. Hence extrapolation to other sites and seasonal conditions must be done with a keen appreciation of the driving forces behind the measured plant growth and plant dynamics. Carefully collected data that captures all the environmental factors as well as the vegetation response at a site allows such extrapolation, via computer models or experienced biologists. We conducted a small amount of such comprehensive data collection early in the trial to enable more confident extrapolation of our results to other seasons and districts.

6.2.4.3 *Methods*

The Swiftsynd methodology used to calibrate the GRASP pasture growth model (Day and Philp 1997) was employed to measure the annual primary production from the main perennial grasses at the poplar box site. Each location was selected for a dominance of the desired grass species and sample sites were prepared and sampled after each growing season. Qld bluegrass (*D. sericeum*), golden-beard grass (*C. fallax*), twirly windmill grass (*E. ramous*) and purple wiregrass (*A. ramosa)* were sampled in treeless paddocks and pitted bluegrass (*B. decipiens*) was sampled in both treeless and treed locations. The sub-dominant and other grass species varied with location. Over the years, there were Swiftsynd sites in both the grazing and burning trials.

6.2.4.4 *Results*

6.2.4.4.1 Dichanthium sericeum [*Dicser*]

6.2.4.4.1.1 Seasonal growth pattern

The change in the seasonal growth pattern of *D. sericeum* (a main perennial grass in the poplar box woodland) following the 1992-94 drought (Figure 6.171), showed that there was a slow regrowth phase and that peak yield was in late summer. Once the dominant perennial grasses had re-established well, the forb population declined. The sub-dominant grass, *C. divaricata*, remained at a relatively constant yield over summer, but provided a higher proportion of the pasture yield from autumn to spring. This sub-dominant showed a rapid growth response to spring rain every year. Kangaroo grass (*Themeda triandra*), a 3P species in this community, became obvious in exclosures after several seasons of protection from grazing.

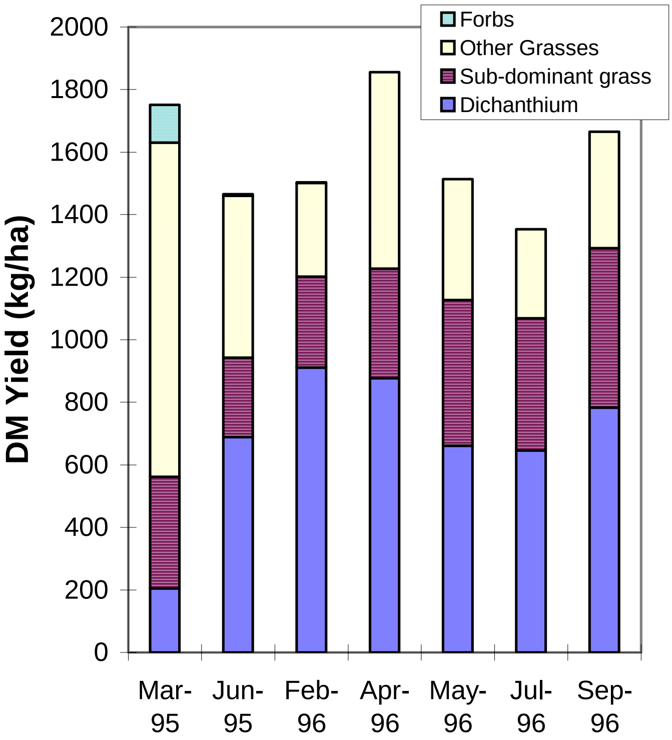


Figure 6.171 Dry matter yield of pasture components in a pasture dominated by *Dichanthium sericeum*.

6.2.4.4.1.2 Annual D. sericeum *production*

The annual production by *D. sericeum* (Figure 6.172) over consecutive years in pasture dominated by it, shows that the yield in any year can vary significantly, from around 500 kg/ha to nearly 3000 kg/ha, while the total pasture yield varied between 1000 to 4500 kg/ha. The additional yield was predominantly *Chloris* spp. There were few forbs present in these dense grassy areas. The dramatic yield increase in 1999 followed an unusually wet winter and then good summer rainfall. The change in the proportions of plant parts during a year is also shown (Figure 6.173) and follows a typical cycle for tropical grasses in southern Qld, with increasing stem as the summer advances.

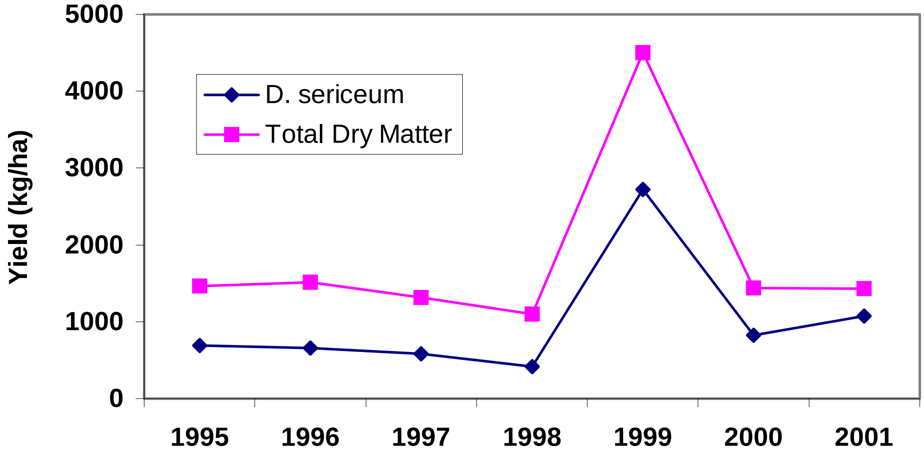


Figure 6.172 Dry matter yield (kg/ha) of *D. sericeum* and total pasture yield over time.

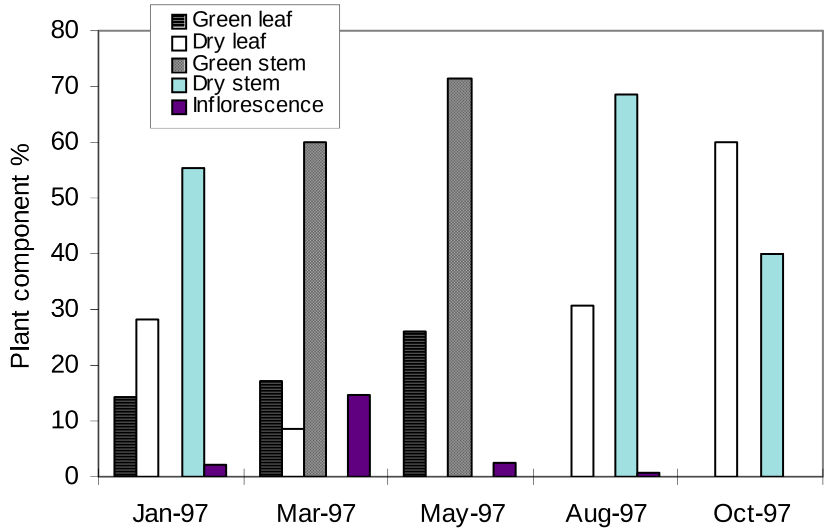


Figure 6.173 Changes in the proportion of the main grass parts by *D. sericeum* over a year.

6.2.4.4.1.3 Seasonal soil profile moisture

Examples of the changes occurring in soil profile moisture from late summer to spring (1996) are shown in Figure 6.174, and for and for a whole year (1996-1997) in Figure 6.175. There was most moisture at depth at the end of summer, while autumn rain (May) produced the most surface soil moisture. This was at a time when *D. sericeum* had seeded and was mature and thus not able to take full advantage of moisture in the main root zone. The dry soil profile in April would have limited grass growth late in the normal summer growing season in this year.

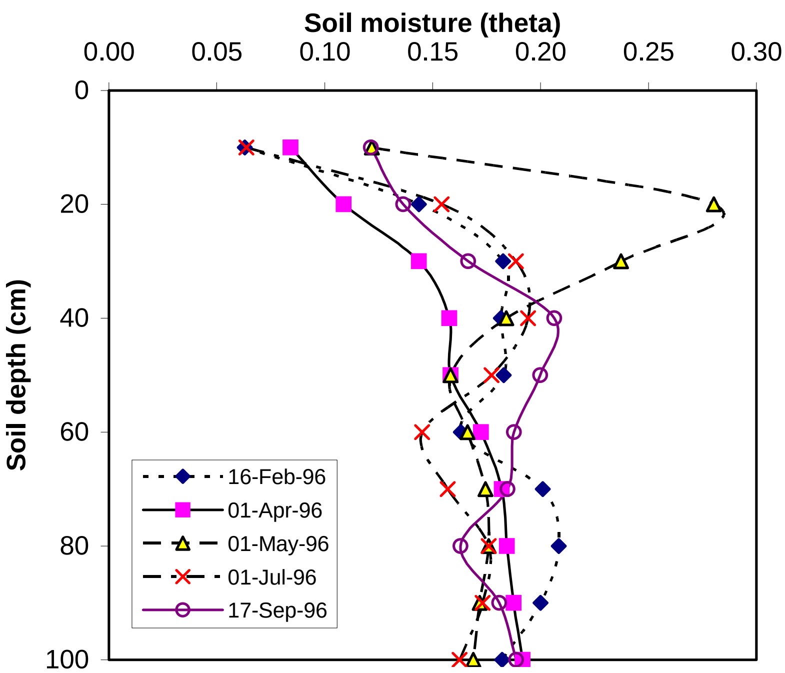


Figure 6.174 Soil moisture in the soil profile in a *Dichanthium sericeum* pasture in poplar box country between February and September 1996.

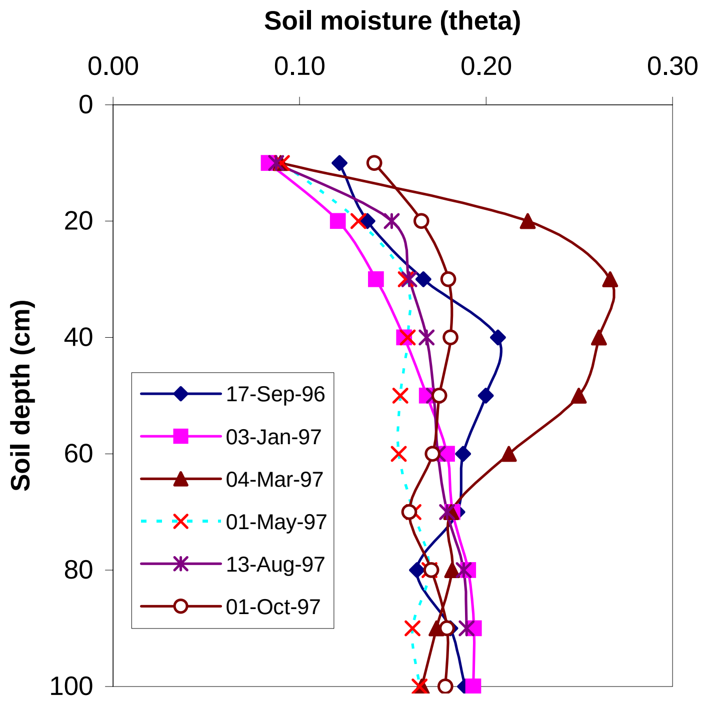


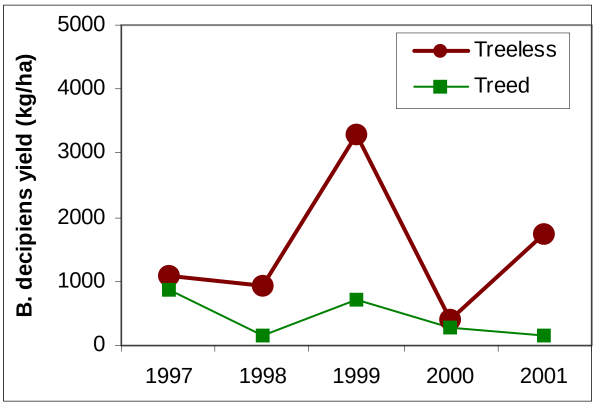
Figure 6.175 Annual change of moisture in the soil profile under a *Dichanthium sericeum* pasture in treeless poplar box country near Injune.

The pasture was efficient at extracting moisture in the 20–50 cm depth interval at the end of summer (March and April). In this community, pasture growth was most rapid in the latter half of summer, corresponding with this period of moisture extraction. At no time was there a significant change in moisture below 70 cm in the1996-1997 season. Other soil moisture data is archived on CD and available from Trevor Hall upon request.

6.2.4.4.2 Bothriochloa decipiens [*Botdec*]

The difference between treeless and treed sites in annual dry matter production in ungrazed areas dominated by *B. decipiens* was greater in high rainfall years, such as the 1998-1999 summer (Figure 6.176). Treeless sites always produced a higher total yield and mostly a higher *B. decipiens* yield each year. Grazed, mixed pastures in general showed a similar effect due to tree competition (Figure 6.71).

(a) *B. decipiens* only



(b) Total pasture

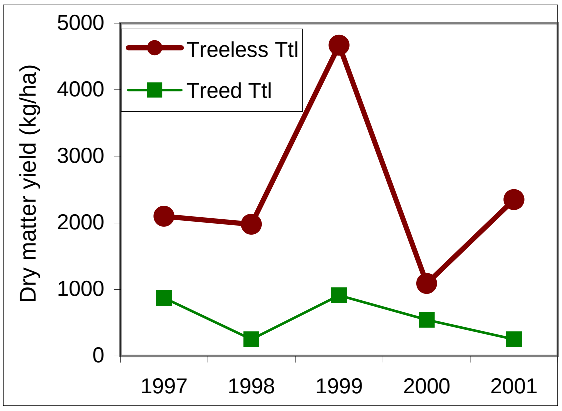


Figure 6.176 Tree competition effect on annual dry matter yield in successive years for (a) *B. decipiens* and (b) total autumn pasture.

6.2.4.4.3 Chrysopogon fallax [*Chrfal*]

For the golden-beard grass dominant site, its proportion of treeless pasture was very stable (Figure 6.177) over the years. It had an increasing trend in its annual yield from a very low base after the 1992-94 drought. This level of production comes from a solid, leafy sward with a very dense underground mat of rhizomes that is very resistant to cattle and sheep grazing. However, these crowns are much sought after as food and moisture by rat kangaroos in dry winters and springs and they dig them out with their front paws.

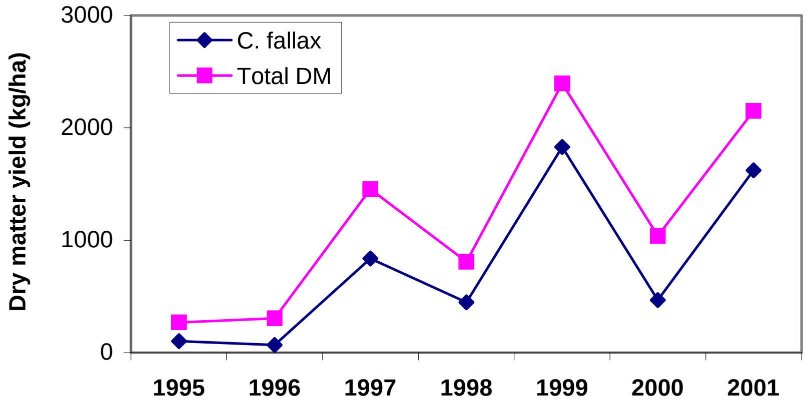


Figure 6.177 Inter-year variation in dry matter yield of *C. fallax* and of the total ungrazed pasture within which it grew as the dominant component at the poplar box trial.

6.2.4.4.4 Aristida ramosa [*Ariram*]

Purple wiregrass was a much more bulky grass than *C. fallax*, especially on alluvial floors where this Swiftsynd site was located. The large change in the proportion of the pasture contributed by wiregrass in 1998 and 1999 (Figure 6.56) was due to a big temporary increase in forest bluegrass.

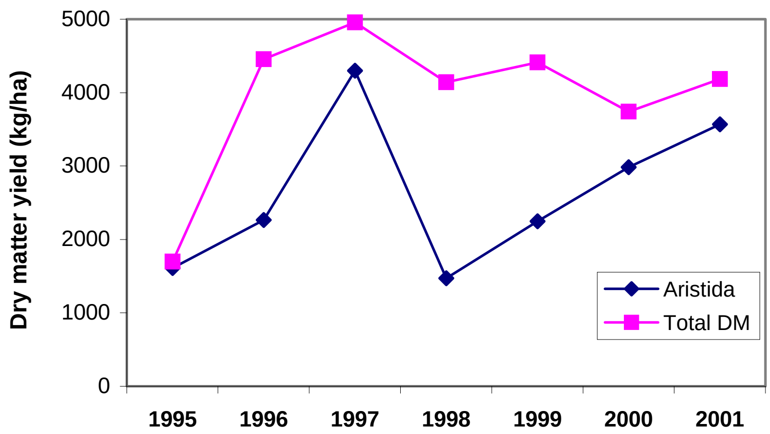


Figure 6.178 Yearly fluctuations in autumn pasture yield at the purple wiregrass Swiftsynd site at the poplar box trial.

6.2.4.4.5 Enteropogon ramosus [*Entram*]

In the absence of grazing, a pasture dominated by twirly windmill grass produced a high yield (>3000 kg/ha) but there was a significant contribution from other species, mostly grasses (Figure 6.179).

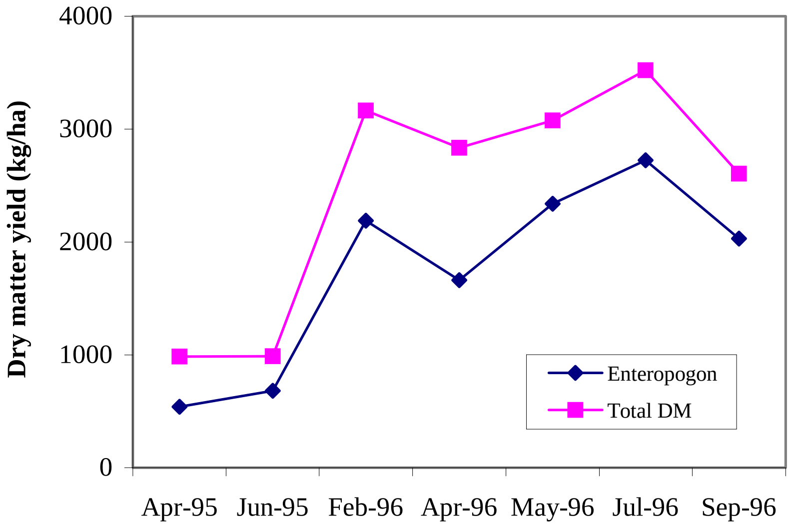


Figure 6.179 Change during 18 months in the yield of ungrazed *E. ramous* and its associated pasture species in an area where it was strongly dominant at the poplar box trial.

6.2.4.4.6 Average yields for all species

The mean yield (Figure 6.180) and mean ground cover % (Figure 6.181) for the years 1995-2000 for the dominant grasses show the dominance of wiregrass in potential yield and the significant effect the trees have on *B. decipiens* growth. These sites were all ungrazed and the material was all new growth each summer season. The *Aristida* for this data grew on the best soil at the poplar box trial, an alluvial, seasonally flooded fringe of a water course.

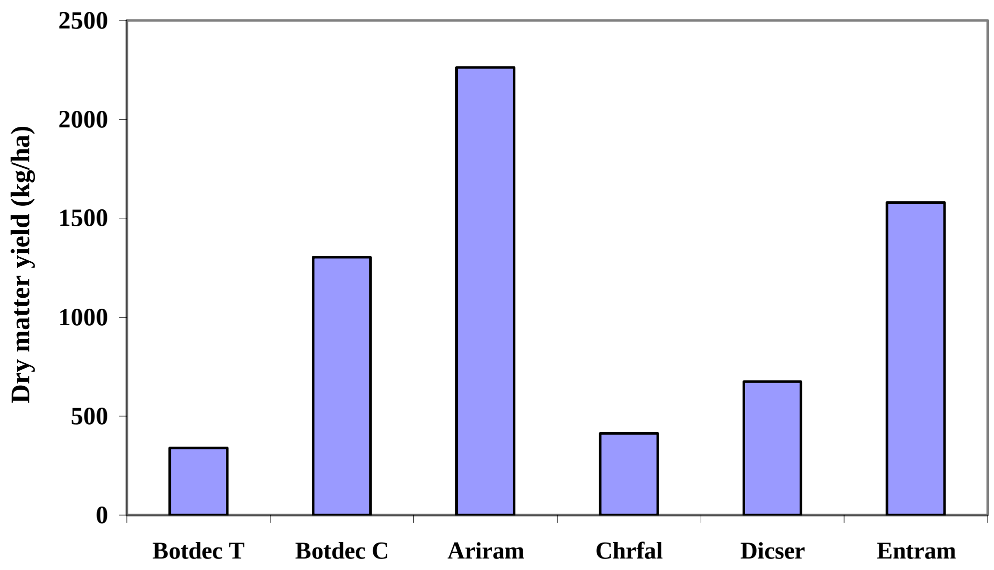


Figure 6.180 Mean dry matter yield of the main grasses in poplar box woodland (1995-2000).

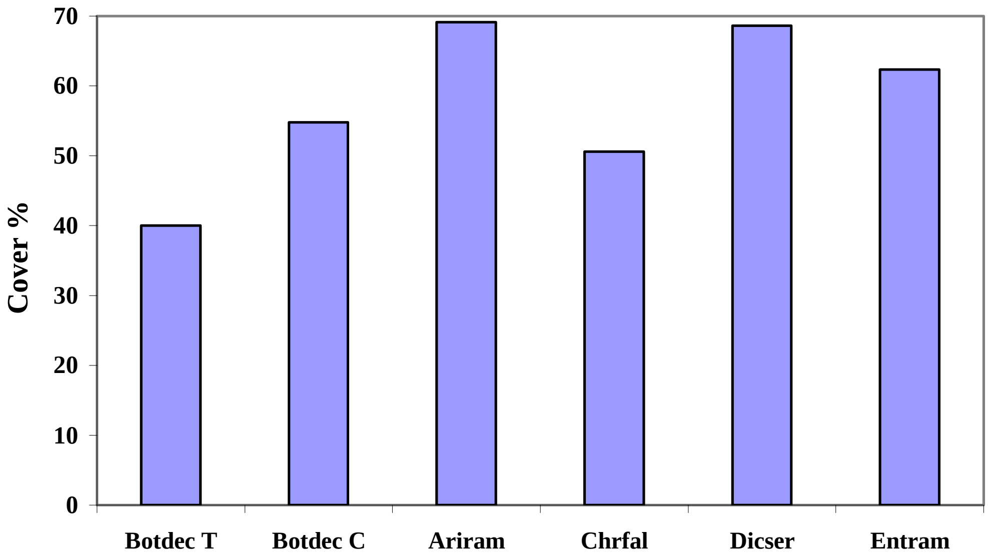


Figure 6.181 Mean autumn cover % of the main grasses in ungrazed poplar box pastures on grey solodics (1995-2000). Botdec T = *B. decipiens* under trees Botdec C = *B. decipiens* without tree competition

The autumn cover levels achieved are all above those needed to minimise runoff and soil erosion from heavy rain (Silburn *et al.* 1992) but the corresponding early summer cover levels are unknown. That is when potential soil loss is greatest when the pastures are at their most open each year, unless in severe drought.

More details of Swiftsynd data collected can be found in Appendix H or is available on a project CD upon request.

6.3 Comparing pasture composition across the two sites

Pastures at both sites were dominated in a biomass and abundance sense by a few grass species but the subdominant ones were probably as important for the productivity and biodiversity values of these pastures. The dominant grass species usually had a frequency greater than 20% at any time and their autumn dry matter yield, individually, was usually over 400kg/ha. Their maximum values for these parameters were often several times higher. The subdominant group is roughly defined as always having at least a 5% frequency but mostly less than 20%. Alternatively their standing forage yield was usually greater than 15-20kg/ha but less than 250kg/ha. A third and no less important group consists of reactive pasture species that can sometimes be virtually absent yet at other times contribute over 20% to plant frequency and at least 100kg/ha of dry matter. Annuals typically fit into this group but so too do some perennials that respond strongly to abnormally good or poor seasons, eg. early spring grass.

Typical dominants at the poplar box site were golden-beard grass and pitted bluegrass while at the ironbark site forest mitchell and black speargrass were examples. Subdominants were the bottlewasher grasses and five-minute grass in the box pastures and golden-beard grass at the ironbark site. Members of the reactive group include daisyburrs, small burrgrass and slender chloris at both sites and mayne's pest at the box site.

The appendices give lists of such species. From these, 35 major taxa were selected for special mention amongst the data presented for the poplar box site and 30 in the ironbark site data. Below are notes on some individual species that can help land managers to fashion their individual management strategies in light of our findings.

Black speargrass and desert bluegrass were major species at the ironbark site and only minor at the poplar box site (>30% frequency for the former site and <1% at the latter). Under light grazing and regular burning, there was a tendency for the black spear to increase at Injune.

Both sites had a significant amount of golden-beard grass and at both sites it was very stable and very few seedlings ever germinated.

Slender chloris increased at both sites after some good summers, especially the box country. It shows good early spring growth and is preferentially grazed at this time and was a very important part of the cattle's diet. However, plants do not survive droughts well.

Wiregrass was much more common in the poplar box pastures. The wiregrass species in the ironbark country were more akin to those found in speargrass pastures around the Burnett, such as at Mundubbera. Some were classified as 'fine' wiregrasses (to use Orr's terminology) and were not seen at Injune. Purple wiregrass forms dense swards on sandy, alluvial flats around Injune and needs to be constrained by management.

There was much more Qld bluegrass on the more clayey soils at Injune than at Rubyvale but other minor tropical bluegrasses such as *D. setosum* were often seen at Rubyvale that were extremely rare or absent at Injune. Tree killing led to a marked increase of this species at Injune.

There was almost no Red Natal grass at Injune and surprisingly little at the ironbark site, especially compared to the Mundubbera and Charters Towers pastures where it is very common.

Early spring grass was quite a common, useful grass at the poplar box site, but it never achieved a significant bulk in the pastures. Maybe its palatability and early summer growth phase leads to it being eaten down before our autumn pasture samplings.

There were very few annual grasses of note in either pasture, probably indicating that the pastures were in healthy condition from the start.

Pitted bluegrass is a dominant grass in the poplar box pastures but virtually unseen at the ironbark site. It is not regarded as a 3P grass because of its low palatability. It is common on both treeless and treed country.

Buffel grass was rare at Rubyvale but tended to increase along roadsides and fencelines where disturbance occurred at Injune. It did not seem to invade healthy native pastures unless they were very disturbed and the surface soil was ploughed up or graded. Then it tended to establish in the banks of loose soil at the edges of tracks.

Parthenium weed was in the vicinity of both trial sites but not recorded in our paddocks.

Silky browntop was present at both sites but never made a significant contribution to the diet or pasture. However, it seems to be a very grazing resistant plant of lowish palatability on these soils.

A range of saltweeds and saltbushes occur on the poplar box soils while such species are rare on the ironbark site. This is probably related to a combination of saline/sodic subsoils and greater winter rainfall at the more southern site.

Accompanying these saltweeds/bushes was a range of other chenopods from the copperburr /*Sclerolaena* group. The most obvious was galvanised burr which was initially common in a couple of paddocks after the early 1990s drought in the box country. Even under heavy grazing it did not increase any further during the better seasons but it could increase its presence greatly in a future drought if pastures were too sparse to compete effectively. Auld (1981) reports that it regenerates in waves but that open drought weakened pastures are at risk of its spread. There was certainly plenty of seed set at Injune.

Kangaroo grass came back quickly at both sites when grazing pressure was very light. Protection of young plants by bushes or difficult stock access allows seedlings to establish and to set seed. After 2-3 years some of that seed also germinates near the parent plant and a swarm of kangaroo grass plants can develop very well in restricted areas. If the pastures are burnt fairly frequently that favours this species even more as does a run of wet summers. Such wet summers allow the plants to grow better but also relaxes any local grazing pressure on them as stock move to more succulent pastures in the short term. It is not a very palatable plant when hayed-off in winter and can provide important shelter and breeding habitat to small marsupials and birds in these areas.

Both sites had a range of perennial *Panicum* and *Paspalidium* species but they rarely made even a modest contribution to pasture yields. They tend to colonise particular microsites and then persist there quite well. Hairy panic (*Panicum effusum*) can be locally common but it dies out in droughts and may cause photosensitization if it becomes a large proportion of the diet.

The commonest palatable legumes at both sites were rhynco pea (*Rhynchosia minima*) and glycine pea (*Glycine* aff. *tabacina*) while poisonous *Indigofera* species were also common at both sites. None are highly palatable but they may be contributing a little fixed nitrogen to the ecosystem. They never provided more than 5% of the pasture yields measured.

Sedges were quite common at both sites and they often retain soft, green leaf well into the winter, which stock can use to supplement the dry bulk of their diet at that time. The commonest species were slender sedge (*Cyperus gracilis*) and common fringerush (*Fimbristylis dichotoma*) but a range of species exist, occupying specialist niches (not necessarily wet places) and their digestibility can be good. They seem quite resistant to moderate grazing pressure.

A range of daisies exist in both pastures, the commonest being yellow billy-buttons (*Chrysocephalum apiculatum*) which was always present and is not grazed much. Hence it has the potential to build up in overgrazed pastures and especially on disturbed areas such as rabbit warrens, gravel dumps and pits, and along firebreaks. It will grow at any time of year so cannot be allowed to take hold at any time. It is very common on very sandy country such as cypress pine and on sandy alluvial lenses along larger creeks. Hence it has access to most parts of the landscape if conditions suit it.

Yellow daisyburr was very common and is grazed well in the early flowering stage before the burrs set. It is moderately perennial and encouraged by cool season rain. However, it stands summer heat quite well and is a source of protein in mature grassy winter pastures. Its burrs cause problems in wool and socks but not manes and tails because the ripe ‘burr’ disintegrates readily.

Other notes and photographs of common pasture plants in the region can be found in identification guides such as ‘Plants of southern inland Qld’ (Henry *et al.* 1995), ‘Plants of central Qld’ (Anderson 1993) and ‘Is your pasture past it?’ (Rolfe *et al.* 1997).

6.3.1 Silver-leaved ironbark site species

Wiregrasses seemed to build up in some high grazing pressure pastures and could be found in local paddocks as the dominant pasture plant. So they have the potential to replace more desirable grasses but we have no clear information from our research to explain exactly how the change might occur.

There was no clear sign that indian couchgrass was certain to invade the ironbark pastures if grazing pressure was maintained at a very high level. In 2001, there was a small patch of it in a treeless paddock grazed at moderate grazing pressure but it did not appear to have spread during our trial period.

Sedges appeared to decline over time, irrespective of grazing pressure. This may be symptomatic of a recovery from comparatively bare pastures after the early 1990s drought due to taller, robust grasses growth suppressing the smaller-statured perennial sedges.

Kangaroo grass built up markedly under light grazing pressure and recovered well in 1999 in the high grazing pressure treatments which were left lightly grazed for that good year to conform with our decision-making rules about annual stocking changes.

The annual grass summer grass (*Digitaria ciliaris*) seemed to increase with time at this site, especially in wetter summers

Slender bottlewasher grass (*Enneapogon gracilis*) did not maintain a large presence over time, unlike its behaviour at the poplar box site

Red Natal grass never exceeded 10% frequency in these pastures but was consistently recorded and often more prominent in the high grazing pressure treatments, especially where the trees had been killed. The bright pink fluffy seedhead of this grass can make it appear more common than it really is, compared to wiregrasses for instance.

Silky browntop declined steadily over time, independently of grazing pressure. It has sturdy rhizomes and so is regarded as grazing resistant but seedlings of it were not recorded from our soil samples, nor at the poplar box site.

Differing levels of skill in identifying individual species of *Panicum* and *Aristida* in the early years of the trial led to inconsistencies between years in tabulated data at a species level. However at a genus level of classification, the data was much more orderly. Plants identified as whitespear (*A. leptopoda*) in 1995-97 were probably always *A. lazarides* at this site.

When ungrazed, forest mitchell often failed to flower when pasture bulk became excessive. Nearby blackspear and kangaroo grass did flower, so we wonder if it lacked adequate nitrogen to flower properly at these times. Isolated buffel grass plants in similar circumstances also failed to flower. We have good evidence from other areas that forest bluegrass (*B. bladhii*) is a plant that flowers well under low available soil nitrogen as do the rat's-tail *Sporobolus* species such as *S. elongatus*.

6.3.2 Poplar box site species

Barbwire grass was fairly common at Injune but seemed to decline under persistent heavy grazing. Seedling colonisation around parent plants was often very dense and this plant would increase where domestic stock were excluded. It is not very palatable but is weakly rooted and so ripped out by hungry animals, especially in spring when it is leafy but dry.

Granite lovegrass (*Eragrostis molybdea*) is a plant that needs to be watched. It is strongly perennial, mostly stalk and seedhead and unpalatable. It made up 5-10% of the poplar box pasture frequency but only 1% of the biomass. It will grow well on scalded solodic soils and help retain surface soil and litter but has no forage value for animals.

Flannel weeds and *Sida* species always pose a threat of becoming weeds and spiked flannel weed (*S. subspicata*) did that in the box pastures but its vigour seemed as much linked to favourable seasonal conditions as heavy grazing pressure. Some sidas are not aggressive but can provide trailing cover over sparse pastures after a drought because they are perennial and not heavily grazed usually. They seem to be of low appeal to livestock but we do not know why. They have a good protein content, have no spines and are relatively leafy but may have an unpleasant taste.

Once the pastures recovered after the 1992-94 drought, small burrgrass declined steadily in its importance. However it will be there to recolonise bare areas if any exist after the next drought, especially is the drought breaks in warm weather.

We had expected the bottlewasher grasses to also decline after the drought receded, but that did not happen to nearly the same extent as for *Tragus.* They remained important components of the cattle's diet at both sites but especially at Injune. Here, under low overall grazing pressure, they became a preferred species in early summer and stock kept patches of them heavily grazed while ignoring bulkier, more strongly perennial species such as Qld bluegrass and forest bluegrass.

Observations suggest that forest bluegrass is a natural, bulky, desirable component of these poplar box pastures when they are in good condition, more so than black speargrass. Along with kangaroo grass, these 3 species have probably declined significantly since European settlement, especially during the eras when sheep were major grazers of these pastures.

Twirly windmill grass was locally dense but was not restricted to one microsite type. It seems shade tolerant and fire tolerant. Cattle graze it very well after it has been burnt and will suppress flowering by it while allowing flowers to develop on pitted bluegrass and wiregrasses. Dense stands of it provide little forage once the stemmy growth develops but that can be a useful shelter for small wildlife. Sporadic burning of large patches when it is dry may be a way to prevent it from becoming almost useless for cattle and sheep feed.

Mayne's pest is common on heavily grazed pastures and generally after good winter rains. It is only a mildly perennial plant but sets masses of seed that germinates readily. In frosty winters it will be selectively grazed by protein-starved stock, especially sheep.

7 Weaner Steer Growth

The project was primarily focussed on the dynamics of the pastures in response to management of trees, fire and grazing pressure. However, the cattle that were used as defoliation agents were in sufficient numbers that we could have some confidence in their mean liveweight performance, provided there were at least 3 animals in a paddock, that they were weighed regularly, and that they stayed in the same paddock for most of each year. These conditions were largely met at both sites in all paddocks except the high grazing pressure ones. As well, there was a single large paddock at each site which had at least 10 head and mostly 15 or more steers in it all the time. The pastures in that paddock were equivalent to those of the treeless medium grazing pressure paddocks at the poplar box site and were grazed according to local best practice for timbered woodlands at the ironbark site. The animal performance in the large paddock was used to check that the link to commercial operations and to modelled production scenarios from our small replicated paddocks was realistic.

The small number of healthy, young animals per paddock soon allowed us to collect consistent information about their rates of weight gain on our pastures. They acted as natural defoliating and trampling agents of the pastures. Our confidence in the data rose as the number of years of study increased and it gained credibility via repetition. We enhanced the value of the liveweight data after the first few years by assessing each animal as it was weighed for the common fat condition score used in the marketplace.

The performance of grazing animals integrates a wide range of other factors involved in a grazing enterprise. Year-round green pasture is the utopian goal but, in practice, 6-8 weeks of growing season each year is common. Extending such periods of growth as available green feed is the aim of managers, but, in most years, there is a period during winter when only dry, dead pasture is available. Over 6 years, the pattern of animal production was clearly defined and the relative difference between each of the treatments evident.

From the results we have calculated mean liveweight production and stocking rate figures for the whole trial period and they are used in many of the productivity calculations. Thus the wide range of seasonal conditions normal for this country and which our trials experienced, has been averaged in reaching many of our overall conclusions.

7.1 Cattle growth on Ironbark pastures

7.1.1 Abstract

While there was considerable data collected, some caution needs to be exercised when extrapolating the data to the broader scale, due to the small number of steers per paddock.

Annual growth rates varied considerably between years from a 242 kg/hd liveweight gain to a 23 kg/hd loss. Tree killing gave a significant improvement in liveweight gain per head in 1997/98. Generally, there was a consistent trend of decreasing liveweight gain per head with increasing grazing pressure, except for two years with above average rainfall. The Commercial (COMM) paddock liveweight gain per head was very similar to the low grazing pressure paddocks. Generally low grazing pressure gave the least liveweight gain per hectare and high grazing pressure was less productive than the medium grazing pressure. Tree killing gave an increase in liveweight gain per hectare in five out of seven years.

COMM paddock liveweight gain per hectare was not significantly different to low grazing pressure in any year of the trial. Winter weight loss for steers on treed pastures was not different from that of steers on treeless pastures. In some winters growth was excellent. In two years of the trial, winter weight loss increased with increasing grazing pressure. Maximum weight gains occurred in summer and were in the order of one kg/hd/day.

7.1.2 Background

Very little animal productivity information was available for the *A-B* region in central Qld, so the weights of the cattle in the grazing trial and the 'Commercial' paddock were recorded. The quantitative productivity data gave insights into the profitability associated with different measures of sustainability arising from the treatments. While there were only small numbers of steers (2-3) per paddock, trends over time can be interpreted, with caution, from the data for treatment responses.

7.1.3 Methods

Weaner brahman-cross steers aged 6 to 18 months were sought from the property owner in early winter each year for the trial. All animals were individually ear-tagged, drenched or vaccinated if deemed necessary by the beef cattle officer, and allotted in small groups to individual paddocks based on their weight. Animals were usually weighed unfasted from the paddock at 2-3 monthly intervals thereafter. Sometimes the animals were also individually scored for condition when weighed, using the commercial rating system of 1 (skin & bones) to 5 (fat).

If stock in a paddock lost too much weight over a short time, or the pasture became too heavily grazed in our opinion, some or all animals from that paddock were weighed and removed to better feed in laneways within the trial site. They were returned, after reweighing, to their home paddock once available feed had obviously improved. The exception to this was during the 1998-99 growing season where the two high grazing pressure, treeless paddocks had little pasture and were linked by a small laneway and left with only 2 animals on the aggregated paddocks (Figure 3.1). After being put on in winter, this arrangement remained unchanged for the whole year despite a big improvement in pasture bulk over the next summer.

The large 'Commercial' (COMM) paddock beside the main trial at the ironbark site was 54 hectares in area. Weaner numbers in it were kept at 15 each year but patches of rank dry pasture were burnt in 1998. These animals, plus the others, were weighed every 2 -3 months to link reliable animal performance data to pasture data at the same site. This COMM paddock was moderately timbered, 5 m^2 tree basal area/hectare.

The first mob of weaners went into the paddocks on 4 November 1994. For operational reasons, the 1999 mob of steers was retained for a second season in 2000. Hence their performance is not strictly comparable with that of the weaners every other year because they were initially heavier and a year older. However, most were still not fully grown.

7.1.4 Results

7.1.4.1 *Representativeness of the cattle production data*

While there were sufficient steers in the trial to statistically analyse the data, caution needs to be exercised when extrapolating the data to the broader scale. Several issues may detract from the defendability of the data in relation to the growth recorded and the stocking rates calculated. Mostly there was only 2 to 3 steers per replicate, and larger numbers may be needed to be more representative. The numbers sometimes changed during their 12 month stay in the trial due to animal welfare concerns, or problems with steers getting into adjoining trial plots. The 1999-2000 batch of steers had higher starting weights which may have detracted from their individual growth rates as well as the growth per hectare.

Cattle production in the paddocks with trees killed may not be representative of most local commercial tree clearing results. The trees were killed by stem injecting with Hexazinone while clumps of shrubs and saplings were killed by squirts of chemical to the soil surface. High mortalities of most height classes were achieved. Thus there was negligible regrowth throughout the trial because of the high initial mortality and the residual nature of the herbicide. This method of clearing (and regrowth suppression) is not common in the Central Highlands. Generally tree clearing of eucalypt woodland is done by chaining or stem injection alone. Chaining generally damages only the trees above 2 metres tall, leaving the majority of the undergrowth to regrow. Damaged trees with some intact roots also resprout and grow back. Stem injection is usually done with non-residual chemicals on trees above 2 metres tall and, again, the undergrowth can rapidly regrow. Hence our regrowth rates were much less than normal and so our animal production could be greater than that achieved commercially from this land type.

The time periods, start and finish dates, and stocking rates for each mob are shown in Table 7.1. While every effort was made to be consistent, this was not always possible. Production figures for each year were calculated on a "mobtime" basis. Mobtime was defined as the number of days from when a mob entered the paddock until the next mob of steers entered a paddock. This was always greater than, or equal to, the actual period of time that the steers were in the paddock. Stocking rates were calculated by dividing the paddock area by the number of beast days for the mobtime involved (See Appendix T3 for the calculation method). This was also done with A.E. days where stocking rates and grazing pressure were expressed in relation to AEs (Adult Equivalent weight, 450kg) rather than beasts or head which can have varying weights. We considered this the best way to describe the stocking rates imposed, to account for periods when there were no steers in the paddock. Periods with no cattle were in the autumn or winter and had minimal impact on pasture dynamics.

7.1.4.2 *Liveweight*

Starting liveweights of each new mob of steers are presented in Table 7.2. Steers were in the age bracket 6 to 18 months except those in the 1999/00 period. The steers in the grazing trial were much heavier in 1999/00 as the majority of them were carried over from the previous twelve month period. This was brought about by operational requirements involved with the transfer of ownership of the property. Steers in the COMM paddock in 1999/00 were a new batch of weaner steers and thus younger than the rest that year. Steers in the 2000/01 period were not homebred and, while not mature, were of unknown age.

Table 7.1 Stocking rates (ha/AE) and grazing periods at the ironbark site.

	Year							
Management	**1994/95**	**1995/96**	**1996/97**	**1997/98**	**1998/99**	**1999/00**	**2000/01**	**Av.**
Grazing periods	04/11/94-14/08/95	05/09/95-05/08/96	29/08/96-07/05/97	08/05/97-01/05/98	01/05/98-21/05/99	21/05/99-27/03/00	16/05/00-23/04/01	
Grazing days	283	314	251	360	386	300	342	
Mobtime- days	305	359	252	358	385	361	342	
Treeless								
Low	4.8	5.1	4.8	2.6	3.7	2.8	2.9	3.8
Medium	2.8	3.0	3.9	1.9	3.2	2.0	1.6	2.6
High	2.2	2.4	2.6	1.6	4.2	1.0	2.5	2.3
Treed								
Low	10.3	9.5	9.2	3.0	3.5	3.9	4.1	6.2
Medium	5.4	5.0	4.7	2.0	4.0	2.2	2.5	3.7
High	3.9	4.5	4.8	2.2	8.2	1.5	2.8	4.0
Av.								
Low	7.5	7.3	7.0	2.8	3.6	3.3	3.5	5.0
Medium	4.1	4.0	4.3	1.9	3.6	2.1	2.0	3.2
High	3.0	3.4	3.7	1.9	6.2	1.3	2.7	3.2
Av.								
Treeless	3.3	3.5	3.8	2.0	3.7	1.9	2.3	2.9
Treed	6.5	6.3	6.2	2.4	5.2	2.6	3.1	4.6
COMM.	5.7	5.5	4.8	5.1	4.3	5.3	3.7	4.9

Table 7.2 Average cattle starting liveweight (kgs) for each mob at the ironbark site.

	Year						
Management	**1994/95**	**1995/96**	**1996/97**	**1997/98**	**1998/99**	**1999/00**	**2000/01**
Treeless							
Low	270	247	242	307	261	486	319
Medium	237	254	241	270	209	494	323
High	218	256	241	243	273	470	237
Treed							
Low	233	242	244	292	252	460	303
Medium	215	244	244	305	266	480	329
High	226	243	245	282	272	444	295
COMM.	241	239	251	269	266	325	361

7.1.4.3 ***Liveweight gain per head and per hectare***

The trial gave some good insights into the variability of growth rates under different seasonal conditions. In the winter of 1996, all steers were removed from the high grazing pressure paddocks due to a lack of pasture and potential animal welfare concerns. In the 1998/99 period (good seasons) one mob of steers gained 242 kg/hd. In the following year, similar steers, but one year older, in the same paddock lost 23 kg/hd on average. The average annual growth rate under low grazing pressure was 150 kg/hd.

Annual growth rates vary from very good to very bad, with an average of 150 kg/head under low grazing pressure

Tree killing gave a significant improvement in liveweight gain per head and per hectare in 1997/98 (P<0.01). There was a consistent trend of decreasing liveweight gain per head with increasing grazing pressure in most years (Table 7.3). The years which did not follow this trend (1998/99 and 2000/01) had above average rainfall for both the summer period and for the twelve month period from July to June.

Generally liveweight gain per head decreased with increasing grazing pressure

Table 7.3 Liveweight gain (kg) per head by steers on silverleaf ironbark pastures

	Year							
Management	**1994/95**	**1995/96**	**1996/97**	**1997/98**	**1998/99**	**1999/00**	**2000/01**	**Avg / year**
Treeless	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	
Low	174	175	184	129	219	16	177	153
Medium	162	109	165	116	240	6	151	136
High	109	39	161	115	242	-16	192	120
Treed	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	
Low	180	209	184	93	209	4	147	147
Medium	174	156	163	76	227	-9	172	137
High	128	72	166	72	223	-27	150	112
Grazing press.	**	*	*	n.s.	n.s.	*	n.s.	
Low	177a	192a	184	111	214	10a	162	150
Medium	168a	133a	164	96	234	-1a	162	136
High	119	55	163	93	233	-21	171	116
Tree effect	n.s.	n.s.	n.s.	**	n.s.	n.s.	n.s.	
Treeless	148	108	170	120	234	2	173	136
Treed	161	146	171	80	220	-11	156	132
COMM.	141	157	181	99	221	59	159	145

n.s. - not significant (P>0.05); * - P <0.05; ** P< 0.01; Means followed by the same letter are not significantly different. Detailed example data is presented in Appendix M.

The large COMM paddock was also analysed in comparison to the replicated grazing trial. Liveweight gain per head of its steers was not significantly different to the low grazing pressure treatment in 6 of the 7 years of the trial. The average stocking rate for the treed COMM paddock (4.9 ha/AE) was also very close to the average for the low grazing pressure (5.0 ha/AE) meaned across 4 treed and treeless paddocks. In 1999/00, the COMM paddock had significantly more liveweight gain per head (59kg) than any of the grazing pressure treatments. However, its steers that year were a year younger than those in the rest of the grazing trial. The younger age of the steers may have helped them gain weight (from 325kg initially) while the others averaged over 470kg initially.

COMM paddock liveweight gain per head and per hectare was similar to the low grazing pressure treatment

Generally low grazing pressure resulted in the least liveweight gain per hectare (Table 7.4). High grazing pressure was generally less productive than the medium grazing pressure. Increasing grazing pressure gave a significant improvement in liveweight gain per hectare in the years 1994/95 (P<0.01), 1996/97 (P<0.01) and 1997/98 (P<0.05). In 1999/00, increasing grazing pressure significantly decreased liveweight gain per hectare (P<0.05). Tree killing resulted in a significant improvement in liveweight gain per hectare in the years 1994/95 (P<0.01), 1996/97 (P<0.001), 1997/98 (P<0.01), 1998/99 (P<0.01) and 2000/01 (P<0.01).

Low grazing pressure generally gave the least liveweight gain per hectare

High grazing pressure gave less liveweight gain per hectare than medium grazing pressure

The effect that tree clearing had on increasing liveweight gain per hectare is supported by the higher average stocking rate for the period of the trial. During the first three years of the trial stocking rates were set higher in the paddocks with trees killed, as higher pasture yields were expected (See Table 2.1 in Methods section). For the last three years of the grazing trial, tree killing did increase pasture yields and stocking rates were set at a higher level than the treed paddocks to achieve equivalent levels of grazing pressure.

The liveweight gain per hectare of the COMM paddock steers was not significantly different to the low grazing pressure treatment in any year of the trial (Table 7.4).

Tree killing generally increased liveweight gain per hectare

Table 7.4 Liveweight gain (kg) per hectare in all treatments at the ironbark site

	Year							
Management	**1994/95**	**1995/96**	**1996/97**	**1997/98**	**1998/99**	**1999/00**	**2000/01**	**Avg / year**
Treeless	n.s.	n.s.	*	n.s.	**	n.s.	n.s.	
Low	50	50	53a	62	73a	6	68	52
Medium	88	64	59a	84	105	3	109	73
High	90	31	89	111	67a	-17	107	68
Treed	n.s.	n.s.	*	n.s.	**	n.s.	n.s.	
Low	27	31	27	41	77a	1	43	35
Medium	53	47	49a	55	68a	-4	79	50
High	56	31	48a	46	32	-22	66	37
Graz press.	**	n.s.	**	*	***	*	*	
Low	38	41	40	51a	75	4a	55	43
Medium	70a	56	54	70a,b	86	-1a	94a	61
High	73a	31	69	79b	50	-19	86a	53
Tree effect	**	n.s.	***	**	**	n.s.	**	
Treeless	76	49	67	85	82	-3	95	64
Treed	45	36	41	48	59	-8	62	41
COMM.	39	44	51	27	61	16	44	40

n.s. - not significant (P>0.05); * - P <0.05; ** P< 0.01; *** - P <0.001.
Means followed by the same letter are not significantly different.

7.1.4.4 *Seasonal growth patterns*

From November 1994 to March 2000 the steers were weighed 4 to 5 times per year and that gave some insights into seasonal growth patterns. The extent of winter weight loss on treed pastures was no different from that of steers in treeless paddocks (Figure 7.2). This is different from the results from poplar box pastures (Figure 7.10). However, slow winter growth and even weight loss was not uncommon (Figure 7.3) but in some winters growth was excellent (Figure 7.1(e)). Three batches of steers lost weight during the winter period and the greatest weight loss occurred in mid-winter (July to September). For the 1995/96 batch of steers, weight loss did not occur under low grazing pressure. However, steers under high grazing pressure had to be removed from the trial (Figure 7.1 (b)). These steers lost weight from April through to August.

Winter weight loss was the same on treed and treeless pastures

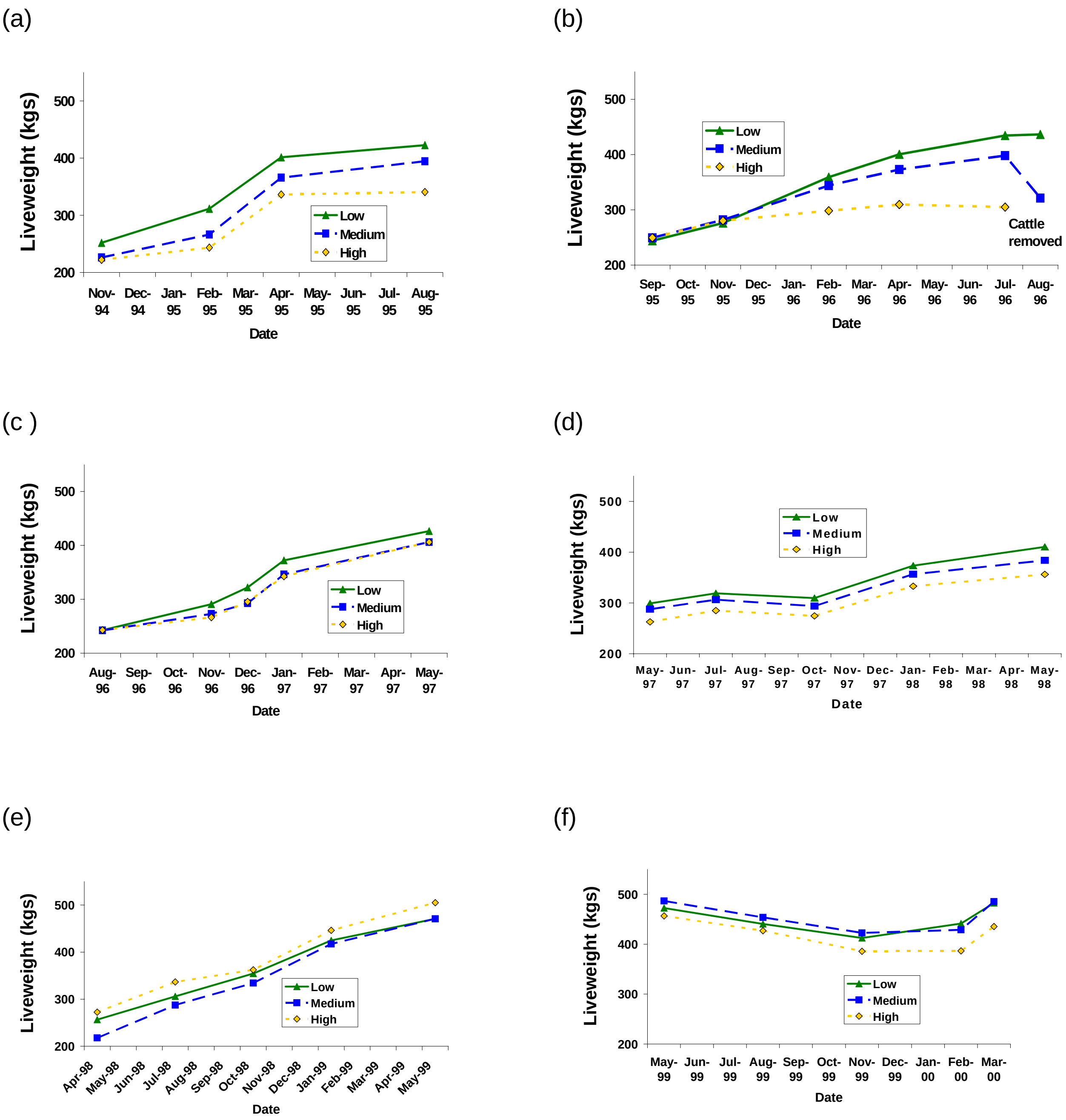


Figure 7.1 Grazing pressure effect on seasonal growth of cattle in (a) 1994/95, (b) 1995/96, (c) 1996/97, (d) 1997/98, (e) 1998/99 and (f) 1999/2000.

With the extended dry conditions prior to the 1996/97 summer, increasing grazing pressure considerably increased winter weight loss in the 1995/96 batch of steers. Under improving seasonal conditions, winter weight loss was not affected by grazing pressure (Figure 7.1(c) to 7.1(e)). The full extent of winter weight performance is a little constrained because many mobs were changed over in mid-winter to fit in with the availability of replacement weaners each year.

The 1997/98 batch of steers lost weight from July to October, however grazing pressure did not affect weight loss. The 1999/2000 steers lost weight from May to November and the weight loss was slightly increased with increasing grazing pressure. Periods of weight loss in the COMM paddock followed a similar pattern to steers in the grazing trial without consistently being similar to specific treatments. Tree killing did not have a consistent effect on winter weight loss.

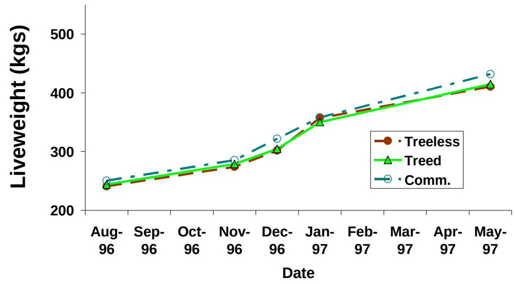


Figure 7.2 Tree effect on cattle liveweight at the ironbark site in 1996/97

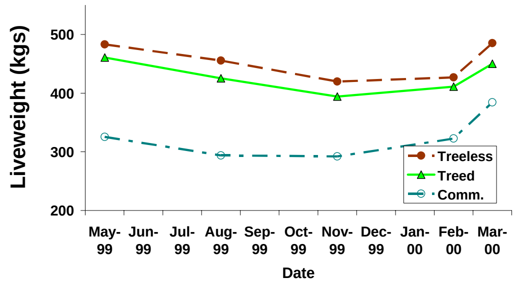


Figure 7.3 Tree effect on cattle grown at the ironbark site in 1999/2000

Generally, maximum weight gains occurred in summer (January to March) and were often in the order of 1 kg/head/day (Table 7.5). In 1996, a major rainfall event in late April gave rise to the good autumn growth rates and decreasing grazing pressure improved that steer growth even more. Increasing grazing pressure had a small effect by reducing liveweight gain/head/day during the dry summers in 1995/96 and 1997/98. Tree killing did not have a consistent effect on summer weight gain.

Maximum weight gains occurred in summer and were usually one kg/hd/day

7.1.4.5 *Tree clearing effect over time*

There was speculation after the first few years of results whether the lack of any significant effect of tree killing on pasture yield would persist until the end of the trial. Results from individual years are very variable (Table 7.3), driven by seasonal rainfall, but using the updated/running mean of previous data provides clearer trends. The running means of the tree killing effect and the grazing pressure effect on liveweight gain/ha (Figures 7.4 and 7.5) were calculated for each year by using the average of the value from that year plus all preceding years.

The animal liveweight benefit from killing the ironbark trees persisted at a consistent level throughout the trial (Figure 7.4). The initial advantage of high grazing pressure, in contrast, did not persist with time and fell below that of moderate grazing pressure after 5 years (Figure 7.5). The low grazing pressure treatment never looked like outperforming the moderate grazing pressure, but, as the economics section (Section 10.5) will discuss, raw beef production is not the only factor to consider when assessing the long term financial and environmental outcomes from grazing management strategies. An improving long term trend in the low grazing pressure results hinted of a cumulative benefit from such conservative management. More discussion of these outcomes occurs after the poplar box cattle results have been presented (Section 7.2).

Table 7.5 Liveweight gain/loss (kg) per head per day between weighings at the ironbark site

Date	Low	Medium	High	Treeless	Treed	COMM.
1994/95 steers						
4-Nov-94						
3-Feb-95	0.65	0.44	0.23	0.37	0.51	0.47
25-Apr-95	1.11	1.23	1.15	1.28	1.04	0.92
14-Aug-95	0.19	0.26	0.04	0.06	0.26	0.22
1995/96 steers						
5-Sep-95						
7-Nov-95	0.51	0.52	0.49	0.42	0.59	0.51
1-Feb-96	0.96	0.72	0.21	0.47	0.79	0.87
4-Apr-96	0.66	0.46	0.18	0.50	0.37	-0.02
4-Jul-96	0.37	0.28	-0.05	0.22	0.18	0.64
5-Aug-96	0.06	-0.36†	D*	-0.33†	0.00	-0.25
1996/97 steers						
29-Aug-96						
8-Nov-96	0.68	0.43	0.33	0.47	0.49	0.49
13-Dec-96	0.89	0.56	0.83	0.79	0.73	1.04
21-Jan-97	1.29	1.38	1.21	1.42	1.17	0.93
7-May-97	0.51	0.56	0.60	0.51	0.61	0.70
1997/98 steers						
6-May-97						
11-Jul-97	0.30	0.29	0.34	0.31	0.31	0.32
20-Oct-97	-0.09	-0.13	-0.10	-0.02	-0.19	-0.03
9-Jan-98	0.79	0.77	0.72	0.78	0.74	0.58
1-May-98	0.33	0.24	0.21	0.34	0.18	0.30
1998/99 steers						
28-Apr-98						
27-Jul-98	0.55	0.78	0.71	0.78	0.58	0.55
21-Oct-98	0.56	0.54	0.30	0.54	0.39	0.48
2-Jan-99	0.96	1.14	1.15	1.03	1.14	1.10
21-May-99	0.33	0.39	0.42	0.39	0.37	0.36
1999/2000 steers						
21-May-99						
16-Aug-99	-0.37	-0.38	-0.34	-0.32	-0.41	-0.36
15-Nov-99	-0.31	-0.34	-0.45	-0.39	-0.34	-0.02
11-Feb-00	0.33	0.07	0.01	0.08	0.19	0.34
27-Mar-00	0.91	1.26	1.08	1.30	0.87	1.37

* D = totally destocked for this period † means partially destocked over this period

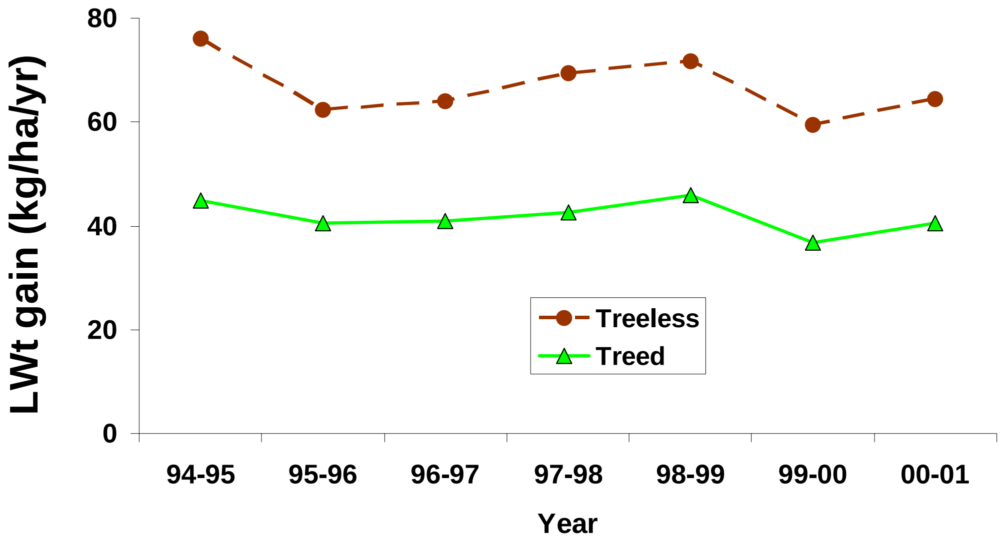


Figure 7.4 Running mean of liveweight gain per hectare on treed and treeless areas at the ironbark site.

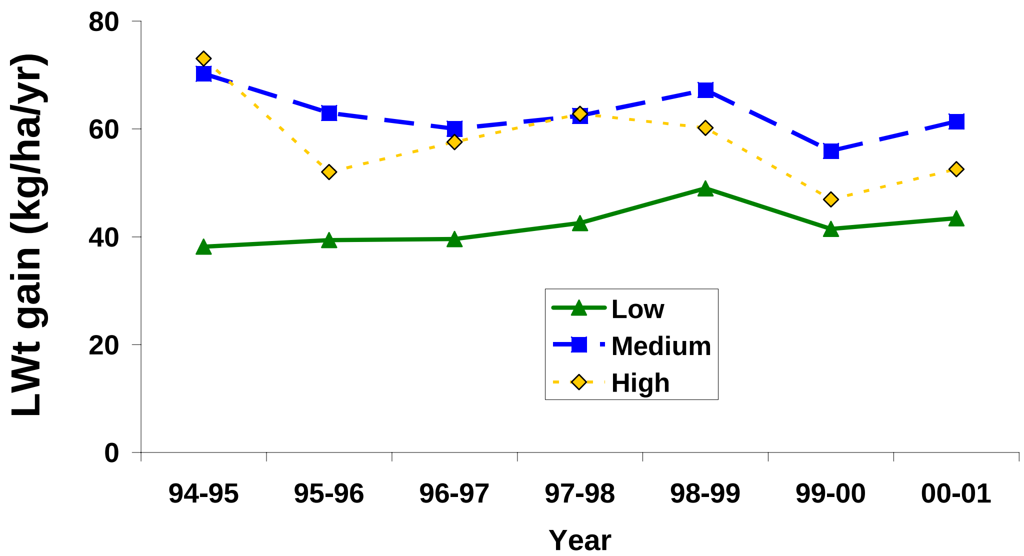


Figure 7.5 Running mean of liveweight gain per hectare under different grazing pressures at the ironbark site from 1994/95 to 2000/01.

7.1.4.6 *Patch burning in the COMM paddock in spring 1998*

In the spring of 1998, seasonal conditions lead to widespread burning in the district to provide green pick to enhance animal production. While there was a good body of feed, there was good soil moisture to encourage growth after the burn. The pasture was adequately cured to allow very slow, cool burns which were very safe and easy to manage. So the ironbark grazing trial

COMM paddock also was managed in a similar way. Twelve hectares in the 54 hectare paddock were burnt on the 21 October 1998 and the steers were left in the paddock. The burning treatment gave no subsequent benefit to animal production when compared to the main grazing trial growth rates (Figure 7.6). Woody weed growth, particularly of currant bush, was suppressed by the burns. However observations on adjoining property suggested that subsequent dry conditions can lead to reduced pasture yield and ground cover from preferential grazing of the burnt areas. Other desired benefits from burning were to remove unpalatable growth and to provide firebreaks. Generally about one third of the paddock area is burnt so that herds do not have to be moved.

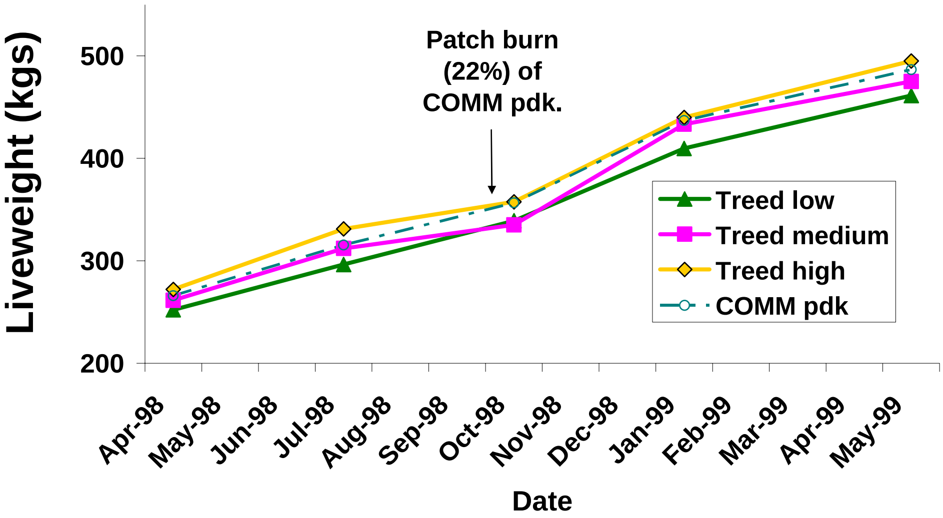


Figure 7.6 Liveweight change by steers in the grazing trial (unburnt) and the COMM paddock (burnt spring 1998) before and after the spring burn.

Patch burning followed by good growing conditions did not benefit COMM paddock liveweight gain

7.1.4.7 *COMM paddock compared to similar small paddocks*

The similarity in cattle performance between the semi-commercial COMM paddock and those of comparably managed moderate grazing pressure with similar tree cover is very close in many years (Figure 7.7) but not consistently so. Note that the animals used in the COMM paddock averaged only 325kg when the 1999-2000 year started, much less than the 480 kg average liveweight of the cattle in the comparable treed/moderate grazing pressure paddocks with which the comparison is being made (Figure 7.3). Hence they did not lose much weight whereas the heavier ones in the small paddocks did.

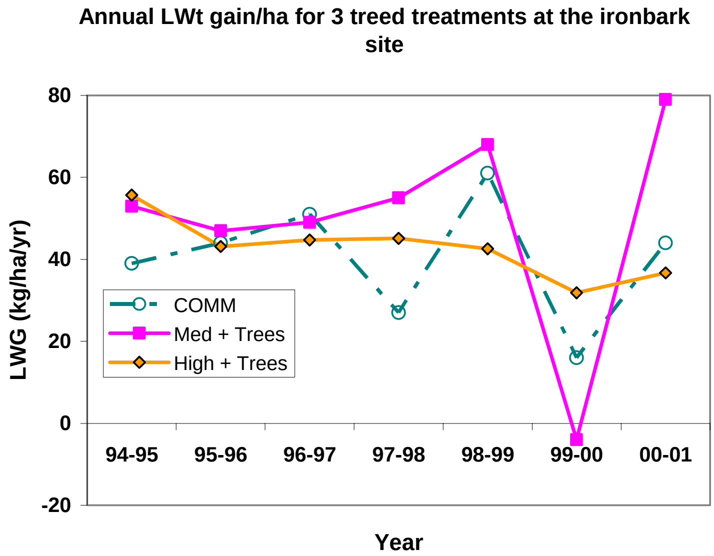


Figure 7.7 Annual liveweight gain for treatments most closely allied to the large paddock (COMM) at the silver-leaved ironbark site.

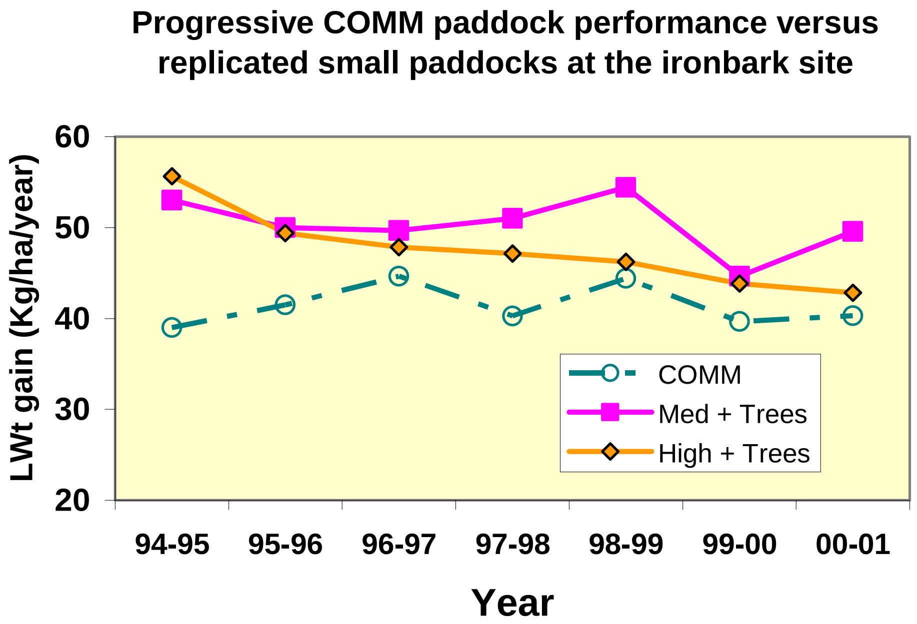


Figure 7.8 Closeness of fit of the large COMM paddock **progressive mean** production over time with that of its nearest equivalent replicated treatments at the ironbark site.

When the cumulative mean animal production from similar treed treatments are plotted over time, the COMM paddock did not achieve the same level of production per hectare (Figure 7.8). However, in good seasons it did not have animal numbers increased commensurate with available pastures like the replicated paddocks did. Thus in 1998 and 1999, its production was lower than was achievable and no immediate benefit was gained from burning part of the pastures (Figure 7.6) either.

7.1.5 Discussion

We were quite surprised at the high level of cattle production because previous studies with British breeds had suggested considerably lower levels would occur. The low grazing pressure treatment averaged 150 kg gain/hd per mob over 7 years. The variability in cattle production was also high with cattle having to be removed from the high grazing pressure treatments in 1995/96 due to serious weight loss, compared with a 242 kg/hd growth rate under low grazing pressure in 1998/99.

Burning 12 hectares of the 54 hectare COMM paddock during the 1998/99 spring did not give any animal production benefit when compared to the grazing trial growth rates. This raises questions around the overall benefit of burning for 'green pick.' The minimal animal production benefits may not compensate for the lack of ground cover and resultant area of preferential heavy grazing that often occurs with this management approach.

Tyler *et al*. (2004) recommends that to operate a beef business sustainably, demonstrating ecological sustainability is a vital component. Additionally the consumer awareness of environmental issues is reflected in the increasing demand for land to be managed to produce food sustainably. On this basis, long term carrying capacities based on 25% utilisation of standing autumn pasture (low grazing pressure) would have to be recommended. However, the variability around this average figure shows the flexibility in management that is required during extended dry or wet conditions.

7.2 Cattle growth on Poplar Box pastures

7.2.1 Abstract

Moderately heavily grazed pastures can produce annual growth per head of 135 kg from weaner steers. If the natural tree cover is removed, liveweight gains per hectare from native pastures are more than doubled over a span of years. Average steer production levels of 50 kg/ha/yr were achieved and over 40 kg/ha/yr was consistently recorded over 8 years under a moderate grazing pressure that always left a reasonable fodder reserve for emergencies. Loss of weight during winter was the chief factor that altered annual production figures.

7.2.2 Methods

Stocking policy and animal handling systems were essentially the same as those used at the ironbark site. Animals were assigned to each paddock based on their weight, the amount of pasture available and the level of consumption required to maintain a comparatively high, moderate or low grazing pressure (described in section 2.2.2.1). The treeless COMM paddock was stocked to meet a moderate level of grazing pressure each year and was not subjected to 'local best practice' like the ironbark site. Hence excess feed and wiregrass on the flats was never burnt even though spring burning of rank wiregrass is a common local practice.

In the paddocks where the trees were killed by Tordon, there was negligible regrowth by existing trees of all sizes and little seedling recruitment throughout the trial. However, some initially untreated young regrowth had to be poisoned with Tordon in the large COMM paddock in 1998.

The animals were first introduced on 30 November 1994. For operational reasons, the 1997/98 mob were retained for the 1998/99 year but the animals were re-randomised and reassigned to various paddocks to meet the grazing pressures needed that year. The same thing was done with the 1999/2000 mob for the 2000/01 year after dry conditions in the 2000/01 summer required a reduction of numbers in many paddocks.

7.2.3 Results

Cattle production in the paddocks with the trees killed is representative of some commercial tree clearing systems in the poplar box woodlands. However, tree clearing is also commonly done by chaining. Chaining generally damages only trees above 2 metres tall, leaving the majority of the undergrowth and seedling trees to regrow. Damaged trees with some intact roots also resprout and grow back. However, because we had negligible seedling recruitment during the trial period, which is unusual, our regrowth rates were much less than normal and so our animal production could be greater than that achieved commercially from clearing this land type.

The time periods, start and finish dates, and production levels for each mob are shown in Table 7.6. While every effort was made to be consistent, this was not always possible. We were also persuaded to change our mob replacement time from autumn to spring to better integrate with modelled data by avoiding possible compensatory growth effects by young animals that were stressed during their first winter. Production figures for each year were calculated on a "mobtime" basis as described for the ironbark site.

Table 7.6 Liveweight gain (kg) by 8 mobs of weaner steers on poplar box pastures.

	Year									**Mean**
Herd	H1	H2	H3	H4	H4.2	H5	H6	H7	Mean	**Stk rate**
Year	**94-95**	**95-96**	**96-97**	**97-98**	**98-99**	**99-00**	**00-01**	**01-02**	gain	ha/head
Mob dates	30/11/94- 21/8/95	25/10/95- 25/10/96	28/11/96- 5/11/97	10/11/97- 17/8/98	17/8/98- 28/6/99	2/7/99- 15/6/00	15/6/00- 27/4/01	6/11/01- 12/6/02		
Grazing days	264	366	342	280	315	349	316	218	306	
Mobtime	329	400	347	280	319	349	316	218	320	
Liveweight gain / hectare										
Low	37.1	38.9	25.4	27.2	40.3	48.9	38.8	38.1	36.8	4.6
Med	58.0	66.1	44.0	52.1	52.8	55.9	43.6	43.0	51.9	2.7
High	59.8	67.2	39.5	50.9	93.1	58.0	59.1	43.6	58.9	1.9
Treed	36.2	35.3	22.5	31.8	36.7	30.2	30.4	20.8	30.5	3.9
Treeless	67.1	79.5	50.0	55.0	87.4	78.4	64.0	69.8	68.9	2.3
COMM	53.7	69.2	43.6	63.3	79.8	73.6	57.2	-	(62.9)*	2.1
Liveweight gain / head										
Low	172.8	181.7	119.5	144.6	162.3	152.3	139.2	143.3	153.2	
Med	137.3	153.3	100.8	121.8	151.0	137.3	144.1	120.6	135.1	
High	97.3	99.7	59.2	83.3	183.4	130.0	134.4	105.0	112.5	
Treed	120.6	118.7	77.2	103.4	168.5	122.4	126.0	104.6	119.5	
Treeless	151.0	171.0	109.1	129.7	162.7	157.4	152.4	141.4	147.6	

* Mean of 7 years. The equivalent mean for treeless moderate grazing pressure was 53.2kg/ha
Note: The average starting weight for weaners was 165kg

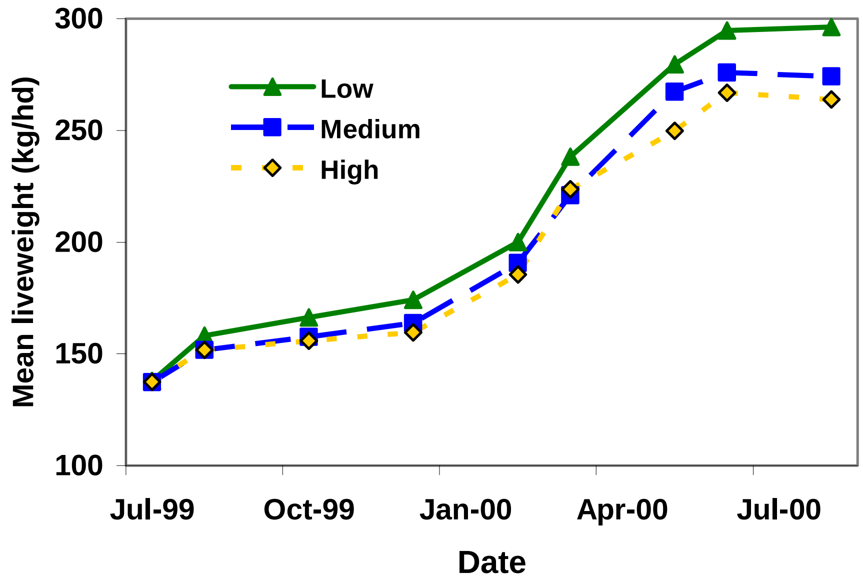


Figure 7.9 Pattern of weight gain and loss over a year by one mob of weaners at the poplar box site under different grazing pressures.

7.2.3.1 *Liveweight gain per head*

The average weight gain per head by each consecutive mob of steers during their time on the poplar box trial site is shown in Table 7.6. They were generally better than what was predicted prior to the trial on the basis of experience in the South Burnett (see Methods section 2.2.2.1). During the summer, all animals gained weight at a respectable rate, especially while the pastures were fresh and green. Rates in excess of 1kg/head per day at peak growth periods were recorded and so 150 kg/hd/summer was often achieved by weaners on healthy, green pastures. During winter, weight loss was common and was related to grazing pressure, tree cover and rainfall. The higher the grazing pressure the poorer the cattle growth (or loss) during non-summer months (Figure 7.9), while more trees meant poorer growth except in mid-summer (Figure 7.10).

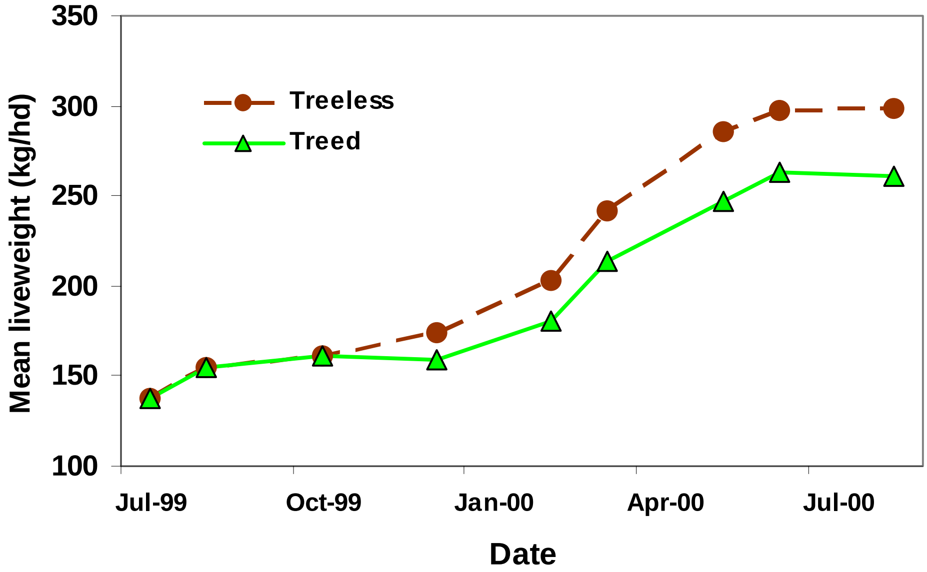


Figure 7.10 Weight change patterns of cattle grazing in treed paddocks compared to treeless ones at the poplar box site.

Retention of poplar box trees restricted potential liveweight gain significantly

Despite setting animal numbers to match available autumn feed, cattle under trees did not grow as well as those on treeless pastures (See Figure 7.10). Maybe this was due to a faster loss of greenness caused by the trees taking soil water more rapidly. The effect of small mobs of animals per paddock was not so great as to make the results unhelpful when extrapolating to commercial herds. The 15-odd head run in the large paddock (COMM treatment) at a medium grazing pressure generally performed like those in small paddocks with the equivalent management regime. On box country the bigger mob performed more like the high grazing pressure treatments (Table 7.6) while at the ironbark site they were nearer to the low treatments (Table 7.4). This is partly because we seemed to underestimate the carrying capacity of this poplar box land type and vice versa for the ironbark country, especially for older animals.

Generally animals grazing poplar box pastures at our low grazing pressure did not lose weight during winter even if little winter rain fell. A greater discussion about the fluctuations in diet quality during the year and between treatments is given in the NIRS section later (Section 7.2.3.5).

Heavy grazing consistently limits animal growth on native pastures in winter

7.2.3.2 *Liveweight gain per hectare*

When the liveweight gains are expressed on a per hectare basis, the relativities of the treatments clearly emerge. The actual mean stocking rate per hectare, allowing for short gaps between herds and for reduced stocking pressure during dry periods on some paddocks, is shown in

Table 7.7, along with the relative range of rates used. Averaging the range over both tree treatments produces meaningless results, so they are expressed as the quotient of the highest and lowest stocking rates, eg. a range of 9.5 to 4.75 ha/AE for treed/medium over 8 years gives 2.0 in Table 7.7.

Table 7.7 Mean stocking rate (ha/AE) for the three grazing pressures over the whole trial period at the poplar box site, plus degree of variation between years within grazing pressures.

	Grazing pressure		
	Low	**Medium**	**High**
Mean Stocking rate (ha/AE)	8.7	5.3	4.1
Stocking rate range (times lowest)	2.3	2.0	2.0

More details of animal movements and weights at each change are given in Appendix M. Over the trial period, the high grazing pressure at the poplar box site averaged out at 4.1 ha/AE which is a bit more than double that of the low treatment rather than three times as it would have been if the pastures could have been stocked all the time at the high rate.

Grazing pressure has its biggest effect on animal production in autumn and winter. At higher rates, animals fail to keep growing well in autumn and begin to lose weight faster and earlier in winter (Figure 7.9). The advantage from poisoning the trees was large (a 75% improvement) and was maintained throughout the trials in the absence of any significant regrowth. When LWG/ha was plotted as a running or progressive mean (Figure 7.11), the final relativity between the treeless and treed treatments was large and little changed over time, - 65 kg/ha versus 37 kg/ha. This occurred despite the fact that stocking rates for individual paddocks were reset annually after 1996 on the basis of available autumn feed.

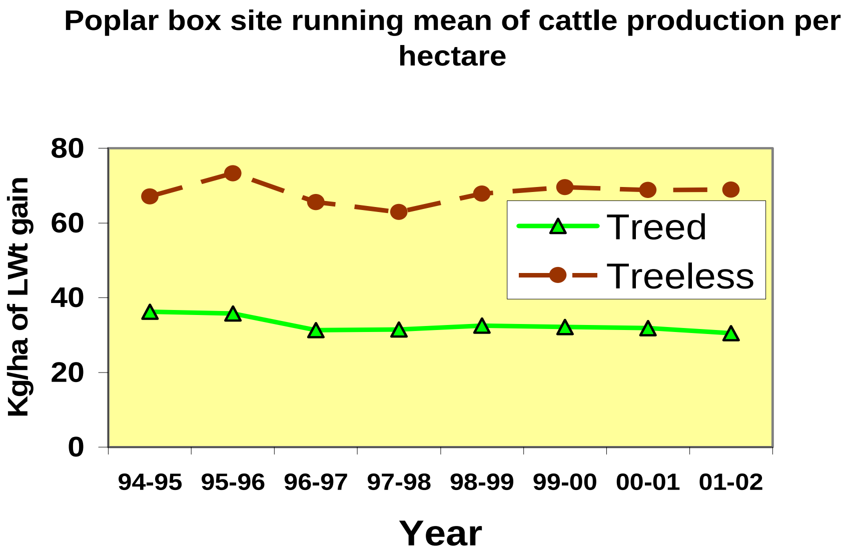


Figure 7.11 Progressive mean of cattle liveweight gain per hectare on poplar box pastures with or without tree competition.

The effect of grazing pressure on production per hectare was more consistent on these box pastures. There was a huge, predictable difference resulting from very conservative grazing but a much less predictable difference between high and moderate grazing pressure. High grazing pressure sometimes only just produced as much beef per hectare as that from moderate pressure (Figure 7.12). Inter-annual variation within a grazing pressure treatment was much less on poplar box pastures than on the ironbark site pastures.

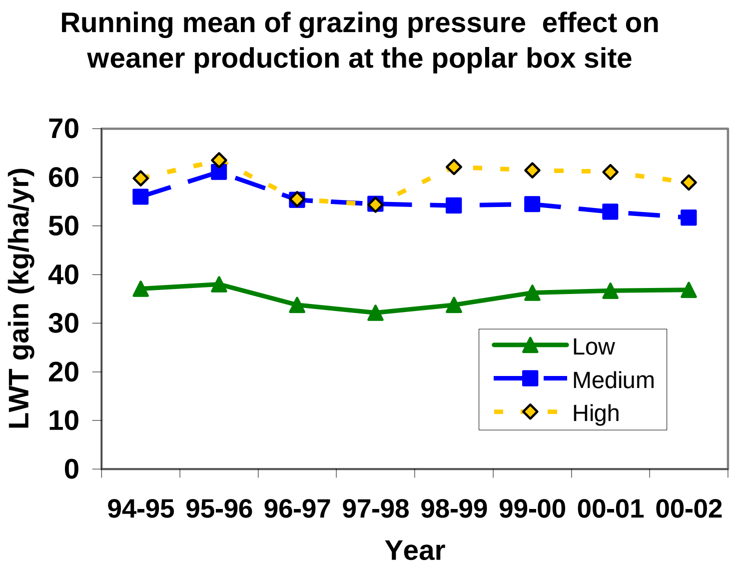


Figure 7.12 Effect of grazing pressure on the progressive average beef production per hectare from poplar box pastures, meaned for tree cover.

Heavy grazing pressure was not consistently or markedly beneficial to animal growth / hectare

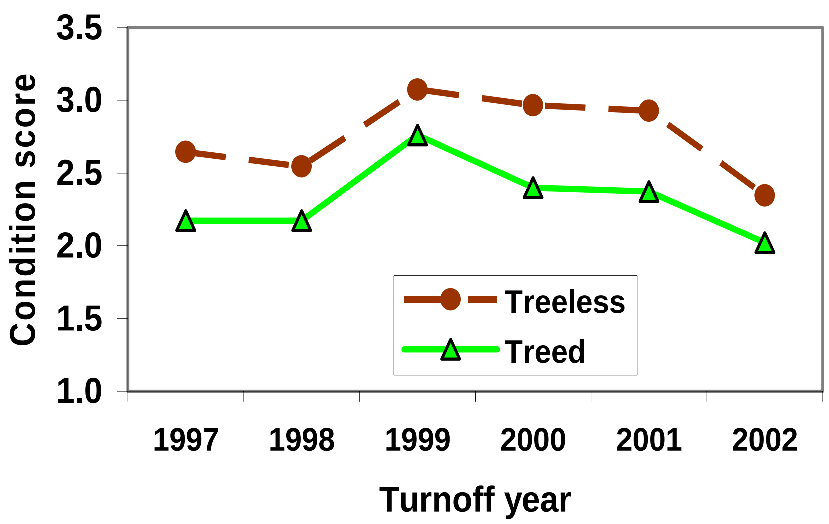


Figure 7.13 Effect of tree competition on cattle fat scores as animals turned off each year from poplar box pastures.

7.2.3.3 ***Effects on animal fat score***

The grazing pressure contrasts are also obvious in the fat score ratings assigned to mobs as each year's mob was taken out of the poplar box trial. These fat scores become very important when animals are presented for sale, especially as a forced sale. Figure 7.13 (at turnoff each year) and Figure 7.15 (within 1 year) show that animals in the treeless poplar box pastures maintained an average fat score advantage of about half a unit at all times from animals that entered the trial in similar condition in all paddocks. Such condition differences were less consistent over time when the tree factor was meaned over the 3 grazing pressures at turnoff (Figure 7.14). However, those at low grazing pressure were always better than those from the other higher grazing pressures (Figure 7.14 and 7.16).

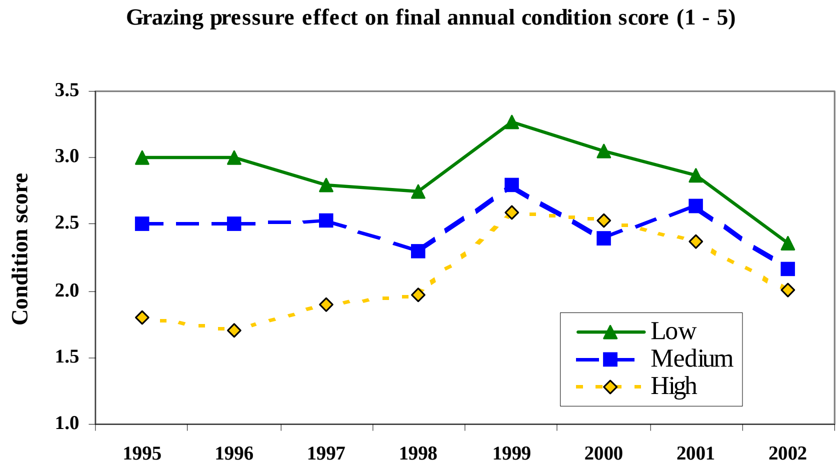


Figure 7.14 Effect of experimental grazing pressure on steer fat scores as animals were turned off each year from poplar box pastures.

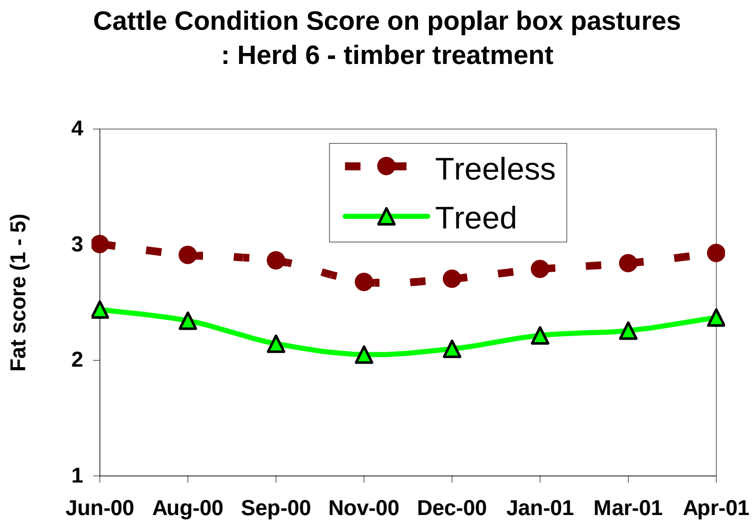


Figure 7.15 Effect of tree retention on cattle fat scores over one year at the poplar box site.

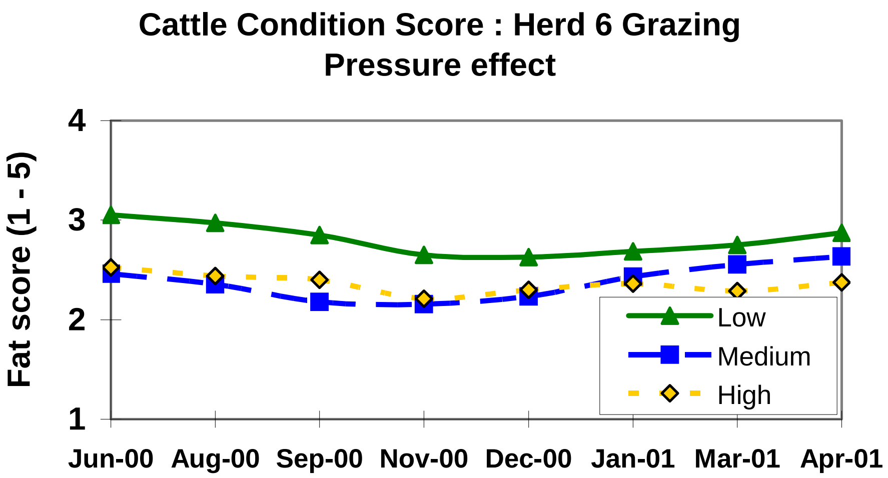


Figure 7.16 Effect of grazing pressure on steer fat scores during the year on poplar box pastures.

7.2.3.4 *Large versus small paddocks*

The overall results from the large COMM paddocks do not fit any better with the high or low grazing pressure results under the same tree cover. When expressed as a running mean, there seems to be a fairly consistent pattern of difference between the big paddock results and those from the replicated small paddocks (Figures 7.17 & 7.18) with similar tree cover.

So our confidence that our results from 3 animals/paddock can be closely extrapolated to bigger, even-land type paddocks is not very high, but the relative performance between grazing pressures was fairly consistent. The commercial implications of this are dealt with in the section on economics (Section 10.5).

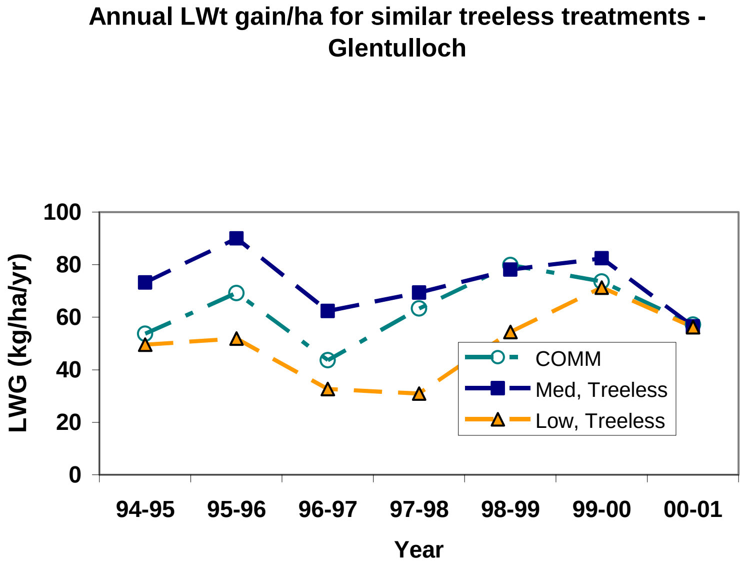


Figure 7.17 Annual liveweight gain for treatments most closely allied to the large paddock (COMM) at the poplar box site.

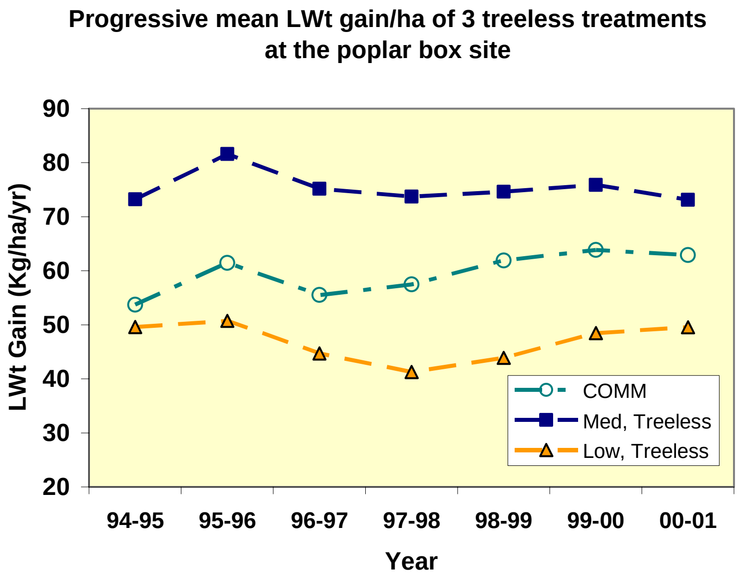


Figure 7.18 Closeness of fit of the COMM paddock **progressive mean** production over time and that of its nearest equivalent replicated treatments at the poplar box site.

7.2.3.5 *Cattle diet on poplar box pastures*

7.2.3.5.1 Near-infrared reflectance spectroscopy on faecal samples

Near Infrared Reflectance Spectroscopy (NIRS) is an analytical technique measuring the reflectance of near infrared radiation from a dried and ground cattle faecal sample to identify diet quality attributes and proportions of broadleaf (non-grass) species and grass in the diet. Quantitative estimates or predictions of different properties or attributes of the diet (e.g. protein, digestibility) can be derived from NIR spectra using previously derived calibration equations and mathematically derived relationships, for each attribute, based on similar pastures. Though faecal samples were regularly collected and analysed by NIRS from late 1997 to April 2001, only data from 1997 and 1998 are presented here. This was not an official requirement of the project but done to complement other MLA-supported research.

7.2.3.5.2 Predicted dietary nitrogen

Estimations of the diet quality selected from each paddock over seasons shows the response to rainfall in nitrogen available at low grazing pressure in treeless (7CL) and treed (10TL) paddocks (Figure 7.19). This represents the quality of the diet and has no relationship to the quantity available. The predictions are based on equations derived from mainly tropical pastures of known quality from north Queensland, fed to cattle in pens. The equations were not derived from these specific poplar box pastures, however the predictions appear to fit the observed and measured differences in pasture quality and cattle weight gain at this site. The winter of 1998 was the wettest during the trial and produced some winter forbs and would have caused a more rapid decline in grass pasture quality. The decline in predicted nitrogen in the diet in winter, May to July, can be seen in both paddocks and the strong response to rainfall in spring, September, is evident (Figure 7.19).

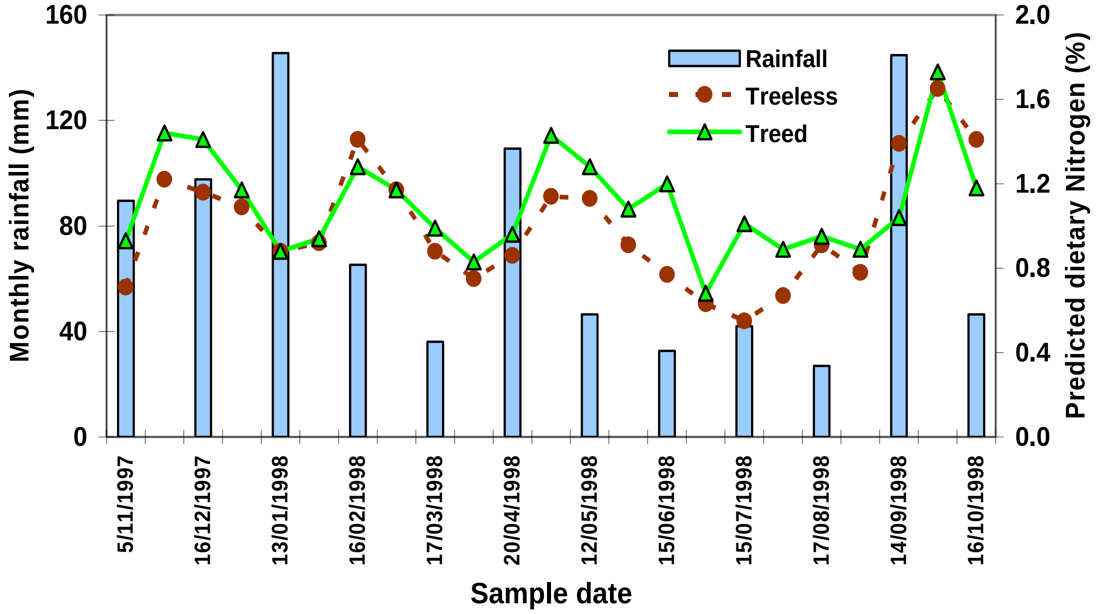


Figure 7.19 The effect of tree retention on predicted nitrogen levels in the steer's diet at low grazing pressure over a year.

7.2.3.5.3 Grass to non-grass ratio in steer diets

The proportion of broadleaf plants, both forbs and trees or shrubs (C_3), to C_4 grass species can be measured using NIRS and this shows the consistently higher proportion of broadleaves in the diet in treed paddocks than in treeless paddocks. The differences were greatest in the late autumn through winter period (Figure 7.20).

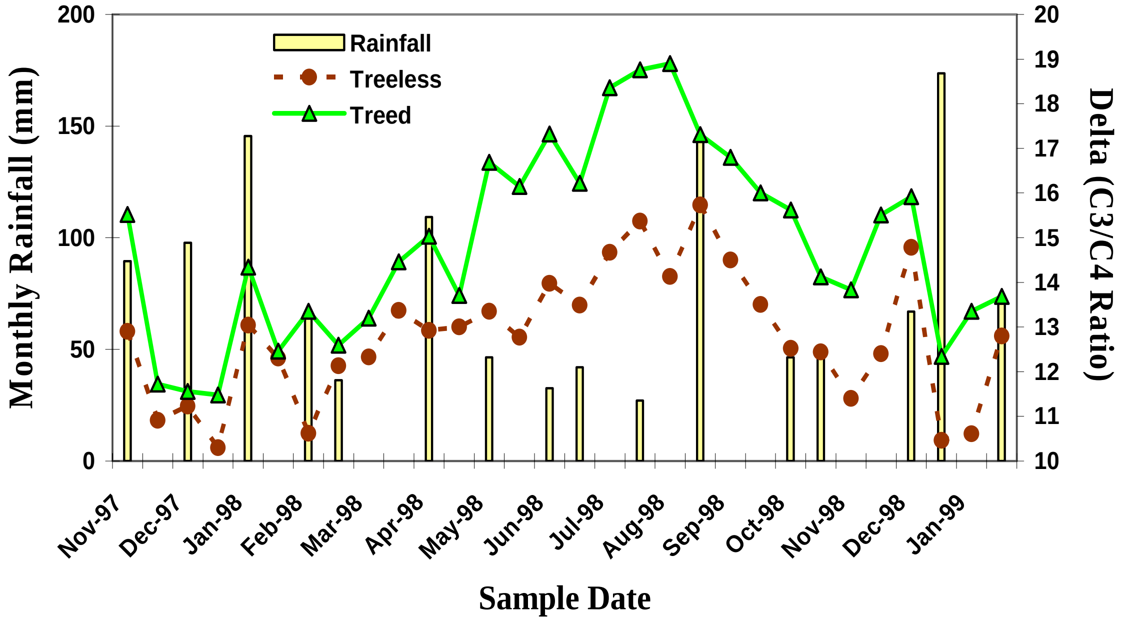


Figure 7.20 Proportion of broadleaf to grass plants in the steers' diet at low grazing pressure in a Treeless (7CL) and a Treed (10TL) paddock over 15 months.

Contribution of non-grasses to steer diets reaches a maximum in mid-winter

There was significant difference in non-grass to grass selected even at low grazing pressure. Comparing paddock 10TL (trees and low grazing pressure) with paddock 7CL (treeless and low grazing pressure) showed the same trend of consistently higher non-grass throughout the year with greatest differences in winter (Figure 7.20). This difference was least and negligible after good rains in mid-summer. In this figure, the higher the average delta carbon figure, the less the proportion of C_4 organic matter in the diet (Jones 1981). A value of about 11 indicates almost pure C_4 plant material in the diet while 15 indicates about 10% C_3 plant material and 19 represents about 40% C_3 forage material. In grasslands, large C_4 plants are almost exclusively tropical grasses while all legumes, trees and shrubs are C_3 plants (Tieszen *et al.* 1979).

Among the herbaceous C_4 non-grass species in central Qld are caltrop (*Tribulus terrestris*), some sedges, a few saltweeds and perhaps some succulents and cacti. Cacti and succulents photosynthesize primarily via crassulacean acid metabolism (CAM) which gives a delta carbon value between -13 and -34 depending on the time of day they were eaten. The only known C_3 grasses at the site were rough corkscrew grass (*Stipa scabra*) and slender bamboo grass (*S. verticillata*) and they were rare.

Conversely, from our site plant lists, the likely and known C_4 plants that are not grasses are

Sedges -	*Eleocharis* spp. (spikerushes), *Fimbristylis* spp., *Cyperus* spp.
Halophytes/saltweeds -	*Salsola kali* (soft rolypoly), *Atriplex* spp., *Einadia* spp.?
Caustic plants –	*Euphorbia* spp., *Phyllanthus* spp.
Amaranths –	*Amaranthus* spp., *Alternanthera* spp. (joyweeds)?
Succulents – C4	*Portulaca oleracea* (pigweed), *P. filiformis, P. australis*,
or CAM	*Trianthema portulocastrum* (black pigweed), *T. triquetra*?, *Tetragonia tetragonioides* (NZ spinach), *Crassula* spp. (stonecrops)
Others -	*T. terrestris*, *Gomphrena celosioides* (gomphrena weed), *Boerhaavia dominii* (tarvine), *Mollugo* spp., *Flaveria australasica* (speedyweed), *Evolvulus alsinoides* (tropical speedwell)?.

This is a surprisingly long list so it reinforces the idea that a high proportion of C_3 plants in the animal's diet means a lot of browse and/or non-succulent, non-halophyte plants are being selectively consumed at that time from a very grassy pasture.

Thus if animals were not actively selecting against our common tropical grasses, their faecal samples should have a delta carbon value of less than 15 because C_3 plants made up less than 10% of the treed and 4% of the treeless autumn pasture. In the treed paddocks, the cattle also had the opportunity to actively browse shrubs and low branches of a wide variety of trees to boost the poor protein content of their winter diet. Note that such protein may not be readily digestible because of high tannin levels in the leaves of many trees (Leng 1997). Figure 7.19 shows that the protein content of the diet of cattle in the treed paddocks generally did not fall nearly as far as that of animals in the treeless paddocks between April and August of 1998. That was a wet winter, so the general level of protein in the diet should have been higher than normal due to the forb growth and greater retention of green leaf by the grasses.

A crude protein content of about 7% in the diet is generally considered adequate for animals to maintain weight on tropical pastures (McLennan *et al.* 1988) and that equates to 1.1% nitrogen. However, the digestibility of that nitrogen source may alter this rule-of-thumb value by up to 0.3% N in either direction.

The main broadleaved herbs grazed in these poplar box pastures were forbs, such as *V. tenuisecta* and *Brunoniella australis* which were always present, *Calotis lappulacea* which was common after the wet winter of 1998, palatable legumes such as *Glycine* spp., and in paddock 10, tree and shrub leaves in the winter period when grasses were mature (Figure 7.20).

There were some small myall (*A. pendula*) trees in paddock 10 that were obviously browsed in winter, even though there was always adequate dry grass available to the cattle. Mature and frosted grass was not readily accepted by the cattle in any paddock. They preferred to repeatedly graze patches on the flats and lower slopes that were covered with short *Chloris divaricata* and *Dichanthium sericeum*, rather than grazing the mature *Bothriochloa decipiens* and *Aristida* species that dominated the paddock. Selecting the C_3 species, forbs, trees and shrubs provided additional quality to their diet. Intake was more restricted in treed, high grazing pressure paddocks than in the treeless and low grazing pressure paddocks that were dominated by grass and also had a higher proportion of decreaser 3P grasses.

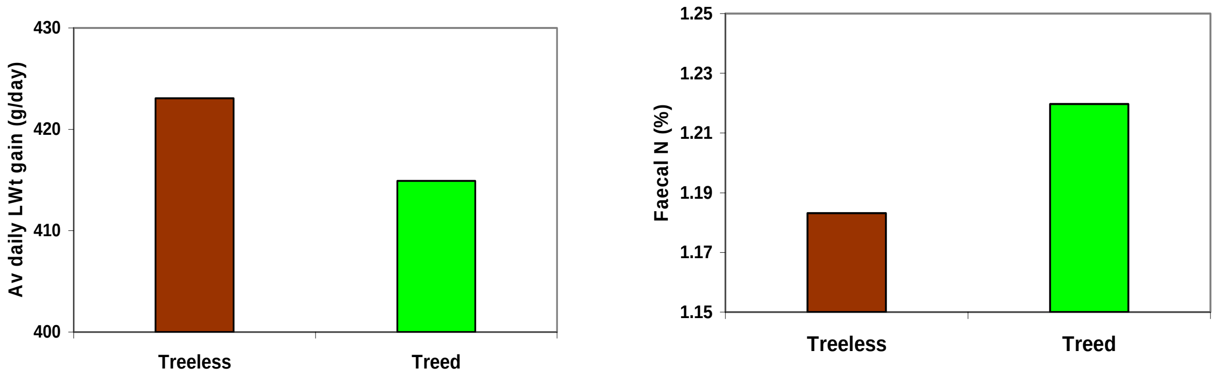
7.2.3.5.4 Poplar box tree effect on NIRS predictions

The mean effect of tree retention on NIRS predictions from 3 herds between 1997 and 2001, based on 1185 samples and January 2003 calibrations, was a larger predicted liveweight gain from treeless treatments than from treed treatments. However there is a higher proportion of non-grass species in the diet selected from treed paddocks, with a corresponding higher nitrogen content (Figure 7.21). Average faecal nitrogen was 1.22% from treed paddocks compared to 1.18 without trees (Figure 7.19) but daily liveweight gain should have been slightly less under trees (415 g/day compared to 423 g/day on treeless pastures). Such a difference in the predicted weight gain rate is probably not sufficient to account for the measured differences between the animals (120 kg/hd/yr versus 148 kg/hd/yr, Table 7.6).

The meaned data for the three different grazing pressures show a similar conundrum, higher faecal N% with higher grazing pressure. This can be explained in terms of short, leafier pastures under heavy grazing. However the liveweight gain rate, as currently calculated, takes no account of the quantity of feed available. Thus the NIRS technique is probably picking up the extra tree leaf consumed in the treed paddocks but does not appear to account adequately for forage digestibility or intake levels. The analyses report 77% of the diet to be tropical grasses in treed paddocks compared to 85% in the treeless ones.

The three grazing pressures resulted in an average consumption of 22, 19 and 17% of non-tropical grass at high to low grazing pressure respectively. This compares with measured autumn pasture proportions over the same period of 15, 7 and 6% non-grass. This indicates a strong selection for non-grasses in the grassy pastures under low grazing pressure and more tree leaf being eaten at high grazing pressure. It also suggests that more non-grass may be available at other times of year when we did not sample pasture, e.g. mid-summer.

(a) (b)



(c)

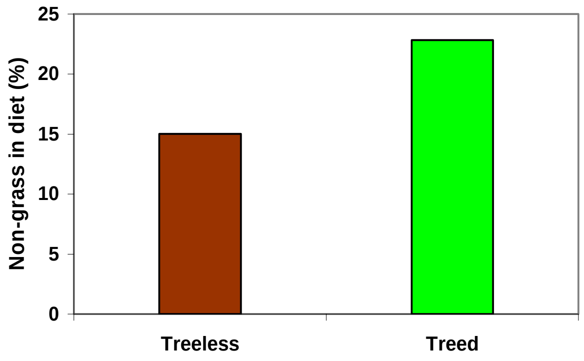


Figure 7.21 NIRS predicted (a) daily weight gain, (b) dietary nitrogen % and (c) non-grass to grass proportions in cattle diets from treeless and treed paddocks.

7.2.4 Discussion

Animal liveweight gain from poplar box pastures was surprisingly good and probably reflects the underlying geology of our site which was closely allied to that of nearby brigalow sandstones. In this subtropical environment, winter non-grass forbs can form a significant part of an animal's diet and thereby eliminate the loss of weight over winter that would normally occur on very grassy pastures in that region. The presence of a moderate density of trees seemed to also increase the proportion of non-grass in animal diets in winter, but whether that was from browse or herbaceous pasture plants was not clear. Our instinct was to attribute it to browse because the removal of trees did not markedly suppress the non-grasses in the pasture (Appendix H) and in some cases increased the total growth of such plants.

High grazing pressure could deliver greater total liveweight gain per hectare in many years but it never resulted in better individual animal condition. Hence the value/quality of production from heavily grazed pastures was not consistently better than that from moderately grazed ones, irrespective of any pasture condition considerations or level of risk taken in an unpredictable rainfall environment. What was consistent was the low level of animal production per hectare from very low grazing pressure (Figure 7.12). Also clearly evident was the large year-to-year fluctuations that can occur in animal production in response to seasonal conditions. The presence of green feed in winter was the chief factor controlling overall annual production.

Removal of the dominant eucalypt overstorey was shown to have a major impact on animal production in the absence of measurable tree regrowth. Pasture yield was the main response and the driver of the improved animal production. This was different to the response from the ironbark woodland site but local property management strongly reflects this biological data – people much more readily go to the expense of removing trees around Injune than they do around Rubyvale.

The ability to grow 150kg of beef per hectare in most summers provides the platform from which a sustainable, economic grazing industry can be built. The challenge is to retain those gains during each winter so that a marketable animal is produced in a consistently short timeframe.

7.3 Comparing sites

On initial inspection, the animal performance at the Injune poplar box site (Table 7.8) seemed better at heavy grazing pressure with the land able to keep increasing total liveweight gains/ha as grazing pressure increased from moderate to high grazing, despite serious individual animal performance drops (Table 7.8). However, when the stocking rate is converted to standard AEs (Adult Equivalents), it becomes clear that the grazing pressure on the ironbark country was higher overall than that at the poplar box site (Table 7.7). Hence the moderate grazing pressure at the ironbark site was higher than the high grazing pressure at the poplar box site and the high grazing pressure at the ironbark site was much higher than the highest levels used at the poplar box site. This resulted in a decline in production per hectare at the highest grazing pressure at the former but not at the latter. Weight gain per hectare was similar at both sites for low and moderate rates of grazing pressure despite the anticipated differences, as signalled by the paddock sizes first developed for 3 weaners.

Table 7.8 Average liveweight gain per head and per hectare over 7 years under 3 different grazing pressures rates at 2 sites, plus mean grazing rates during grazing.

	Average growth/year					
	Ironbark			**Poplar box**		
Grazing pressure	Grazing rate (ha/AE)	Kg/hd	Kg/ha	Grazing rate (ha/AE)	Kg/hd	Kg/ha
LOW	5.0	150	43	8.7	155	37
MED	3.2	136	61	5.3	136	52
HIGH	3.2	116	52	4.1	112	59
COMM	4.9	145	40	3.9	133	63*
Treed	4.6	132	40	7.8	121	37
Treeless	2.9	136	64	4.3	148	65

Note: 1 Adult Equivalent (AE) = 450kg liveweight (averaged for each mob)
COMM is the large mob data. * = no cattle in 2001-02

The actual mean stocking rate per hectare, allowing for short gaps between herds and for reduced stocking pressure during dry periods on some paddocks, is shown in Table 7.9, along with the relative range of rates used within a grazing pressure. Averaging the range over both tree treatments produces meaningless results, so they are expressed as the quotient of the highest and lowest stocking rates, eg. a range of 9.5 to 4.75 ha/AE for treed/medium over 8 years gives 2.0 in Table 7.9. Over the trial period, the high grazing pressure at the poplar box site averaged out at 4.1 ha/AE during the grazed period and at 3.2 ha/AE at the ironbark site, due largely to the greater age and size of the weaner animals used there. The ironbark site shows less inter-year variation than the poplar box site.

Table 7.9 Mean stocking rate (ha/AE) for the three grazing pressures over the whole trial period at both sites, plus degree of variation between years.

	Ironbark site			**Poplar box site**		
	LOW	MED	HIGH	LOW	MED	HIGH
Mean Stocking rate (ha/AE)	5.0	3.2	3.2	8.7	5.3	4.1
Av. Stocking rate range (times lowest)	3.9	3.3	4.3	2.3	2.0	2.0

At both the sites, the advantage from poisoning the trees was large (60–75%) and was maintained throughout the trials in the absence of any significant regrowth. When LWG/ha was plotted as a running or progressive mean (Figures 7.4 & 7.11), the final relativities between the treeless and treed treatments were large and little changed over time, - 65 kg/ha versus 37 kg/ha at the poplar box site and 64 versus 40 at the ironbark site. This occurred despite the fact that stocking rates for individual paddocks were reset annually after 1996 on the basis of available autumn feed.

The effect of grazing pressure was more complex. High grazing pressure was more detrimental to total beef production compared to moderate at the ironbark site (Figure 7.8 versus 7.12). Both figures show the huge, predictable difference resulting from a very conservative grazing pressure and the much less predictable difference between high and moderate grazing pressure. There was a tendency for the low grazing pressure treatments to improve their overall performance with time at both sites (Figures 7.5 & 7.12) while the higher grazing pressure treatments, at the ironbark site at least, gradually fell away. The drier final two years at the poplar box site would enhance that trend at that site. However, at the ironbark site the trend was probably a real one and may suggest that even the moderate grazing pressure used there was a bit too high for long term sustainable grazing. The Peakvale land system has been rated as carrying 1 AE / 6ha sustainably (MRC 1992) and our mean stocking rate, including treeless paddocks, during the trial was higher than that at 3.8 ha/AE. The published rating would have been for country with the normal and significant tree density found on this land system.

7.3.1 Discussion

Killing the trees resulted in greater animal growth per hectare at both sites, despite the lack of a significant initial pasture response on the ironbark country. If the low and moderate grazing pressure treatments are averaged, a two-thirds improvement in cattle growth per hectare was achieved on the ironbark country compared to a doubling in box country from killing the trees, in the absence of tree regrowth. Over all grazing pressures, the difference was 60% on ironbark land and 125% on poplar box, the latter matching a pasture yield response to tree removal of over 100%. Perhaps this benefit was assisted by the mineralisation of nitrogen from dead tree roots and twigs but we have no direct evidence to support this supposition. The effect was just as strong in the last four years of the trial as it was in the first three of 7 years (Figures 7.4 & 7.11).

In the low grazing pressure paddocks, forage availability would never have been a constraint to animal intake but protein content and digestibility could have been. Thus a general weight loss during some winters in the LOW paddocks indicates an inability to find a diet with adequate digestible protein in the paddock. Some stalky grasses such as wiregrasses and twirly windmill grass do retain green stalk in winter and cattle actively graze this, as evidenced by hedge-grazed tussocks in spring but not autumn. Such green stalk will, however, be relatively low in protein and inherent digestibility compared to leaf, and hence would barely reach maintenance quality for growing steers.

At the ironbark site, the dominant black speargrass and forest mitchell grasses do not retain greenness in their mature, winter stems even if they are alive and moisture-rich. So in winter, stock there depended on green leaf for digestible protein and fibre if they were to at least maintain their weight until summer. This they did not generally do nearly as well as the animals at the poplar box site where wiregrasses and windmill grasses are common. However, in a wet winter (1998), they gained plenty of weight when green herbage was available in the ironbark pastures (Table 7.5). The impact of low availability of green forage at any time was starkly evident at the ironbark site during the 1999-2000 summer. Only animals depastured at the lowest grazing pressure were able to retain their weight due to a combination of a dry summer and a large existing bulk of mature pasture from the previous wet summer. The situation was probably exacerbated compared to other years through the retention of well-grown (470 kg) animals from the previous year rather than replacing them with weaner steers as was done in all other years. Retention of animals for a second year was also done at the poplar box site for the 1998/99 year but without the same weight loss problems because the summer was wetter and the pastures not as mature beforehand.

8 Pasture Condition

8.1 Abstract

Our assessments of landscape condition or functionality seem logical when viewed in terms of the management treatments and are internally consistent in most cases. Higher grazing pressure gave reduced indices and unburnt, ungrazed plots had higher indices than those that had been repeatedly burnt. However, the discrimination amongst the grazing treatments is not large, e.g. 55.2 to 66.1 for the stability index and 22.2 to 28.9 for the nutrient cycling index at the ironbark site. Indices were consistently slightly higher for the treeless paddocks. We have no other published work against which to compare our results at present.

8.2 Background

With an increasing tendency for all land uses to be categorised and assessed for a range of environmental values, pasture condition is included on broad national assessments of rangelands (Audit 2001). In Qld we have attempted to contribute to such national goals by using our currently limited QGraze network of sites. More recently National Action Plans against salinity have conditions included whereby Regional NRM bodies are required to evaluate their investment outcomes against agreed standards and they are asking for methodologies that will allow them to comply. Queensland has recently begun assessing pasture condition with a proposed A,B,C,D framework (Stocktake) into which such assessments might be fitted (Aisthorpe *et al.* 2004). There are broad descriptions about what constitutes such condition classes for native pastures but no agreed methodology for capturing that information. A desktop/informed expert system by Tothill and Gilles (1992) assigned condition ratings to all northern Australian pasture types in a 3 category scale that has been moderately acceptable to scientists (Table 1.1). However, it was felt that a bit more discrimination was needed and hence the 4-part system currently proposed in stocktake.

In the meantime, Tongway has independently developed a system for assessing land condition which has been called Landscape Functional Analysis (LFA). It has been widely workshopped and used in a variety of rangeland types as well as on mine rehabilitation areas (Tongway and Hindley 1995). It was first developed in mulga country, then reworked for saltbush country in Western Australia and then for tropical savannas in northern Australia. The system comes with a detailed manual and sampling methods and with a data processing spreadsheet. Hence it can be used fairly readily by land managers with only a small amount of training. Validation of the landscape indices produced has not been widely done although a recent report on the condition of a wide range of rehabilitated minesites has addressed aspects of this deficiency (Tongway 2003). In Tongway's report, the indices were compared with independent assays of soils and vegetation health – with congruence ranging from very good to fair to absent for particular pairs of data.

We decided to use the LFA technique to see how well its assessments matched with the many other pasture criteria that we had measured over the previous 7 years of our trials.

8.3 Methods

8.3.1 Landscape function analysis (LFA)

LFA involves assessing the land surface for features that relate to the capture, retention and incorporation of biophysical resources within a stable, ecologically healthy landscape. Usually

4-5 categories are nominated by the assessor that pertain to soil, nutrients, water and litter processes. Then a survey tape is run out downslope for 50 or 100 metres from the starting point and the distance along it at which the surface changes markedly from one category to another is recorded, e.g. from bare soil to a grass tussock.

With all the distance data recorded and the intervening length assigned to a category, the operators then rates 5 examples of each chosen surface type for a wide range of features that are listed in the methodology manual (Tongway and Hindley 1995). Then calculations are done using a standard LFA spreadsheet to work out four indices that relate to the ability of that land to capture and retain important resources. The main ones that we used were -

1. Stability index, for the surface soil against erosion
2. Infiltration index, for potential rainfall infiltration rate
3. Nutrient cycling index, to show how tightly available nutrients are being retained
4. Landscape organisation index (L.O.I.) which shows what proportion of the land is acting as a capture or retention zone for soil, water and nutrients. This LOI is also sometimes described in terms of patch length within the total downslope length.

The indices are all on a 0 to 100 scale with bigger numbers indicating better condition. The L.O.I. is currently on a 0.00 to 1.00 scale but the concept is the same.

8.3.2 Assessment times

Assessments were made towards the end of each grazing trial in every paddock and burning trial plot to quantify what effect our various management systems had had on landscape condition, as assessed by LFA. The authors of the system provided data processing software and some comment on our data interpretation. At the ironbark site, recordings were done in January 2001 while at the poplar box site they were done in late 2000 in the grazing trial and again in all paddocks, plots and exclosures during Feb-Apr 2002. At the ironbark site sampling was done at three mid-slope locations per paddock while at the poplar box site it was done at three points down the hillside catena in each paddock.

8.4 Results

The results for the ironbark site are summarised in Table 8.1 and in Table 8.3 for early 2002 at the poplar box site.

All landscape health indices declined as grazing pressure increased

8.4.1 Silverleaf ironbark site

A summary of the results from the Ironbark site is given in Table 8.1. The same results, expressed in percentage terms relative to the baseline treatments, are given in Appendix J.

Table 8.1 Effect of differing grazing management over 7 years on land condition as assessed by the LFA technique at the ironbark site.

	Grazing pressure effect						
	Soil Surface Attribute	**High**	**Medium**	**Low**	**Mean**		
Treeless	Stability Index	60.3	62.3	66.1	62.9		
	Infiltration Index	47.0	50.0	54.0	50.3		
	Nutrient Cycling Index	23.6	25.0	28.9	25.8		
	Average Run-on (%)	42.1	57.5	71.7	57.1		
	Average Run-off (%)	57.9	42.5	28.3	42.9		
	Landscape organization Index	0.421	0.575	0.717	0.571		
Treed	Stability Index	55.2	60.5	63.5	59.7		
	Infiltration Index	44.3	49.9	51.3	48.5		
	Nutrient Cycling Index	22.2	27.1	26.8	25.4		
	Average Run-on (%)	39.3	45.3	69.0	51.2		
	Average Run-off (%)	60.7	54.7	31.0	48.8		
	L.O.I.	0.393	0.453	0.690	0.512		
						Treeless	**Treed**
Mean Stability Index		57.8	61.4	64.8	61.3	62.9	59.7
Mean Infiltration Index		45.7	50.0	52.7	49.4	50.3	48.5
Mean Nutrient Cycling Index		22.9	26.1	27.9	25.6	25.8	25.4
	Average Run-on (%)	40.7	51.4	70.4	54.2	57.1	51.2
	Average Run-off (%)	59.3	48.6	29.7	45.9	42.9	48.8
Avge	**L.O.I.**	0.407	0.514	0.704	0.542	0.571	0.512
	Burning effect						
	Soil Surface Attribute	**Burnt**	**Unburnt**	**Tree less**	**Treed**	**Mean**	**% of Graze**
	Stability Index	71.2	72.1	72.0	71.2	71.6	117
	Infiltration Index	53.5	59.4	58.6	54.3	56.5	114
	Nutrient cycling index	24.4	28.7	25.8	27.2	26.5	104
	Average of Run-on (%)	44.8	88.6	70.9	62.5	66.7	123
	Average of Run-off (%)	55.2	11.4	29.1	37.5	33.3	73
	L.O.I.	0.448	0.886	0.709	0.625	0.667	123

Vast differences were recorded in the down hill length of fertile patches and inter-patch zones. The fertile patches were characterised by swards of perennial grasses “top-dressed” with litter, topsoil and water from the bare areas between. The bare areas had no perennial grasses; were often sheet eroded; had a moderately hard surface nature and very low cover. Figure 8.1 shows the dramatic effect of increasing grazing pressure on the downhill length of grassy swards and bare areas, which characterise the landscape.

Despite the high rates of erosion described later in Section 9, there were no visible signs of rilling or gullying. The LFA recordings have confirmed that the soil loss was probably from the bare areas between grassy swards. It could be inferred that these changes to the structure of the pasture occurred in the second or third year of the trial and this is supported by the decreases in pasture yield and basal area, coupled with excessive runoff and erosion.

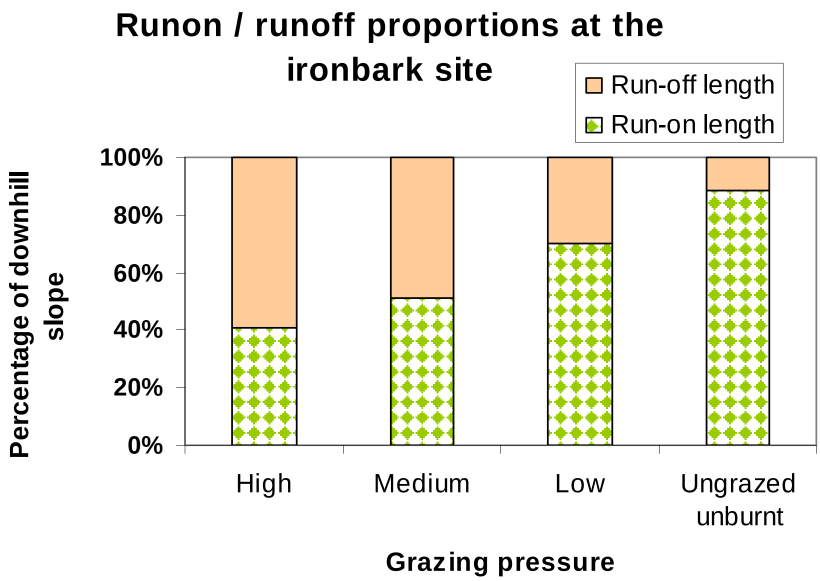


Figure 8.1 The effect of grazing pressure on the proportion of downhill slope covered by grassy swards (nutrient capture zones) and bare areas (run-off sites) at the ironbark site.

8.4.2 **Poplar box site**

8.4.2.1 ***Tree competition effects***

Eight years after killing the trees in half the paddocks, there was significantly better soil surface condition in the treeless paddocks with higher ($P<0.05$) indices of run-on patch area, stability, infiltration and nutrient cycling than in the treed paddocks. This improvement can be attributed to the consistently higher production of pasture and subsequently a greater amount of grass litter in the cleared treatments. Although there were areas of tree leaf litter of 600–1000 kg/ha (unpublished data) in late winter and spring in the treed paddocks on one occasion, this did not compare with the regular grass litter accumulation in improving soil surface condition. An overall assessment for both burn and grazing trial sites is given in Table 8.3.

8.4.2.2 ***Tree competition effects without grazing***

In the spring burning trial, which was ungrazed, tree clearing caused a significant ($P<0.05$) increase in total patch length (43.2 m), reduced run-off length (6.8 m), increased patch area (375 m^2), and higher indices of patch area (0.75), stability (66.6), infiltration (35.1) and nutrient cycling (log_e 3.29) compared with the treed plots (Table 8.2).

Table 8.2 Clearing effect on runoff zones and soil surface conditions (means across burning treatments) as assessed by the LFA technique at the poplar box burning trial site.

Soil Surface Attribute	Treeless	Treed	LSD (P=0.05)
Total Patch length (m/50m)	43.17	34.90	4.47
Total Runoff length (m)	6.83	15.1	4.47
No. of Patches /10m	2.64	3.91	ns
Total Patch Area (m^2)	375	198	58.4
Patch Area Index	0.752	0.397	0.116
Stability Index	66.62	62.76	3.28
Infiltration Index	35.05	32.39	2.66
Log_e (Nutrient Cycling Index)	3.293	3.193	0.053

Table 8.3 Effect of differing grazing management over 7 years on land condition as assessed by the LFA technique for both experiments at the poplar box site.

		Grazing pressure effect					
	Soil Surface Attribute	**High**	**Medium**	**Low**	**Mean**		
Treeless	Stability Index	53.8	60.6	63.2	59.2		
	Infiltration Index	30.2	31.8	36.0	32.7		
	Nutrient Cycling Index	19.6	23.2	27.7	23.5		
	Average Run-on (%)	14.0	16.3	57.6	29.3		
	Average Run-off (%)	86.0	83.7	42.4	70.7		
	L.O.I.	0.140	0.163	0.576	0.293		
Treed	Stability Index	57.2	57.9	58.6	57.9		
	Infiltration Index	31.1	32.0	33.5	32.2		
	Nutrient Cycling Index	20.1	21.9	22.6	21.5		
	Average Run-on (%)	27.3	36.6	49.1	37.6		
	Average Run-off (%)	72.7	63.4	50.9	62.4		
	L.O.I.	0.273	0.366	0.491	0.376		
						Treeless	**Treed**
Mean Stability Index		55.5	59.3	60.9	58.6	59.2	57.9
Mean Infiltration Index		30.7	31.9	34.7	32.4	32.7	32.2
Mean Nutrient Cycling Index		19.9	22.5	25.2	22.5	23.5	21.5
	Average Run-on (%)	20.6	26.4	53.4	33.5	29.3	37.6
	Average Run-off (%)	79.4	73.6	46.6	66.5	70.7	62.4
	Avge L.O.I.	0.206	0.264	0.534	0.335	0.293	0.376
		Burning effect					
	Soil Surface Attribute	**Burnt**	**Unburnt**	**Treeless**	**Treed**	**Mean**	**% of Graze**
	Stability Index	60.1	69.3	66.62	62.76	64.7	110
	Infiltration Index	28.2	39.2	35.05	32.39	33.7	104
	Nutrient Cycling Index	20.6	31.9	26.9	24.4	25.6	114
	Average Run-on (%)	70.6	85.6	86.4	69.8	78.1	233
	Average Run-off (%)	29.4	14.4	13.6	30.2	21.9	33
	Landscape organization Index	0.707	0.855	0.863	0.698	0.781	233

8.4.2.3 *Burning * Tree competition effects*

Regular spring burning under trees resulted in the greatest run-off length (20 m/50 m transect), while tree killing without burning had the highest patch length (45.7 m). Burning with trees had the most patches (5.8 patches /10 m), but the lowest ($P<0.05$) total patch area (115 m^2), ie. lots of small patches. Tree competition reduced the mean patch area compared to having no live trees, and patch area was lowest where regular burning occurred ($P<0.05$). The stability index was highest with no burning, irrespective of tree competition (Table 8.4).

Table 8.4 Interactions between burning and clearing on runoff control and soil surface conditions at the poplar box burning trial site.

Soil Surface Attribute	**Burnt/ Treed**	**Unburnt/ Treed**	**Burnt/ Treeless**	**Unburnt/ Treeless**	LSD P=0.05 **Burning * Tree cover**	**Mean**
Total Patch length (m)	29.98	39.82	40.65	45.70	ns	39.04
Total Runoff length (m)	20.02	10.18	9.35	4.30	ns	10.96
No. Patches/10m	5.83	2.00	2.61	2.67	2.27	3.28
Total Patch Area (m^2)	115.0	281.4	398.6	352.0	82.6	287.0
Patch Area Index	0.231	0.563	0.799	0.704	0.165	0.574
Stability Index	58.1	67.4	62.1	71.1	ns	64.7
Infiltration Index	28.6	36.2	27.8	42.3	3.76	33.4
Log_e (Nutrient Cycling Index)	3.034	3.353	3.015	3.572	0.172	3.243

Absence of spring fires after killing the trees produced the highest indices of stability (71.1), infiltration (42.3) ($P<0.05$) and nutrient cycling ($e^{3.572}$) ($P<0.05$) (Figure 8.2).

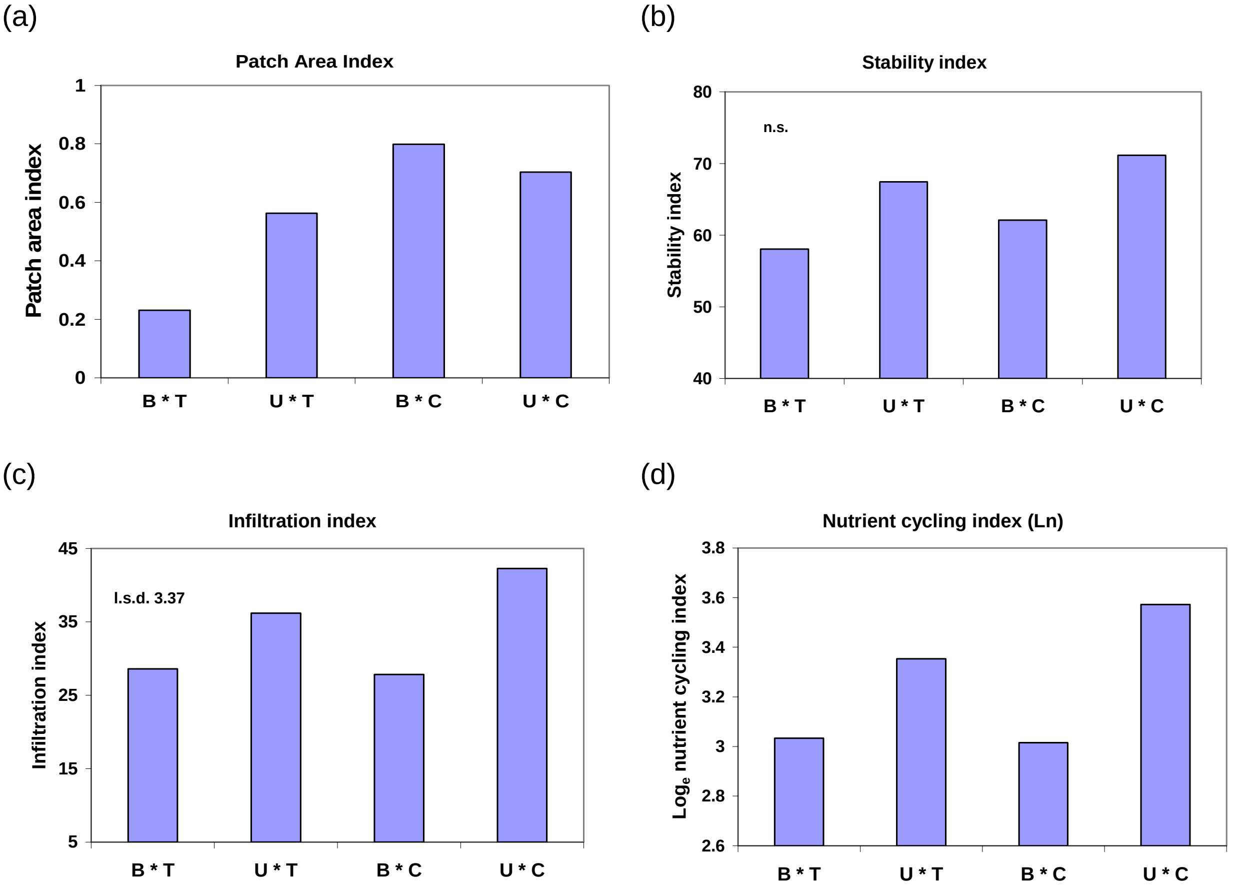


Figure 8.2 Indices of (a) patch areas, (b) stability, (c) infiltration and (d) nutrient cycling, meaned for each burning * tree killing treatment at the poplar box site. B = Burnt, U = Unburnt, T = Treed, C = Treeless.

At low and moderate grazing pressures, the land surface after tree killing was assessed by the LFA criteria as being in better condition with higher indices of stability, infiltration and nutrient cycling, than that under high grazing pressure, where the trees have a slight moderating effect (Figure 8.3). The proportion of the land (along a downslope transect) that was assessed as runoff surface, increased as grazing pressure rose and particularly where trees had been killed (Figures 8.4 and 8.5). This is a contrast to the overall soil cover figures recorded in the pasture dynamics section where tree killing increased overall assessments of ground cover (Section 6.2.1.4.3). The runon/runoff contrast was greater on the upper parts of the landscape and this is summarised in the stability index (Figure 8.6).

Regular spring burning without grazing produced poorer landscape health indices than continuous light grazing

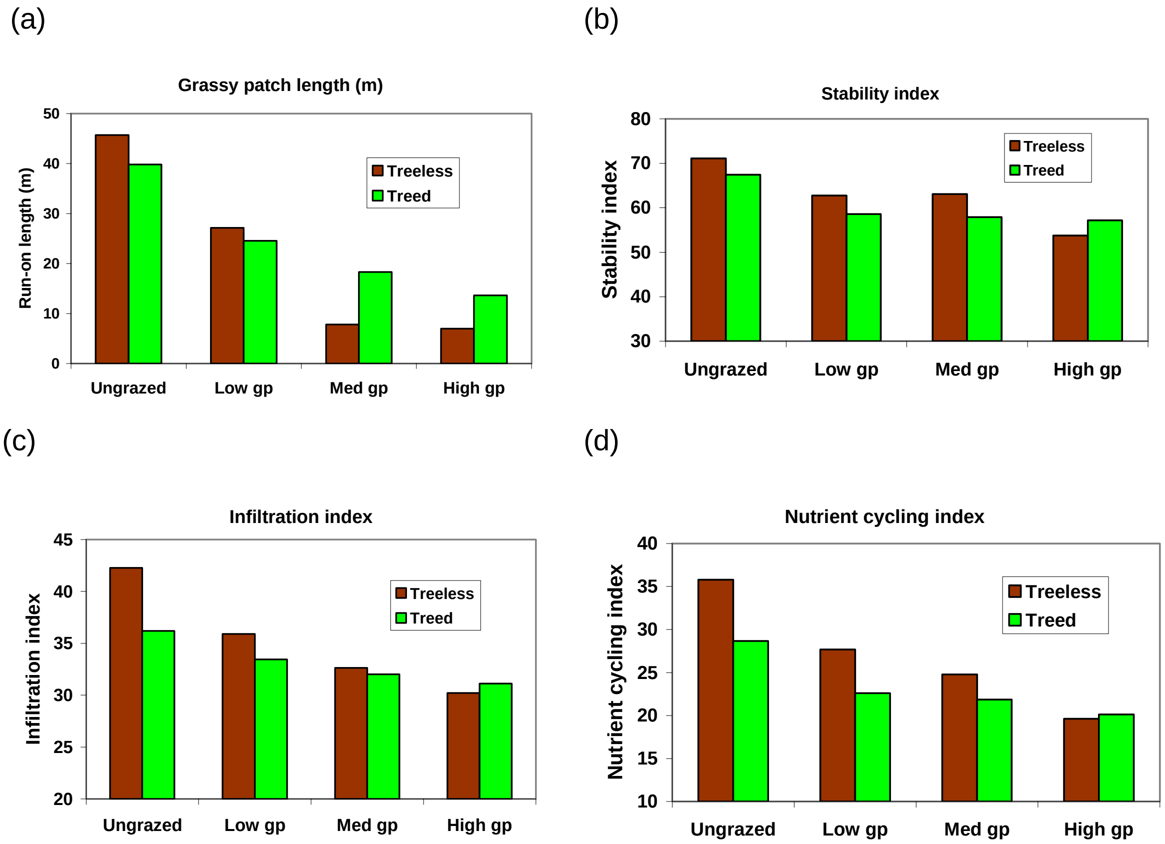


Figure 8.3 Tree retention effects on (a) run-on patch length and LFA indices of (b) stability, (c) infiltration and (d) nutrient cycling at 4 grazing pressures at the poplar box site.

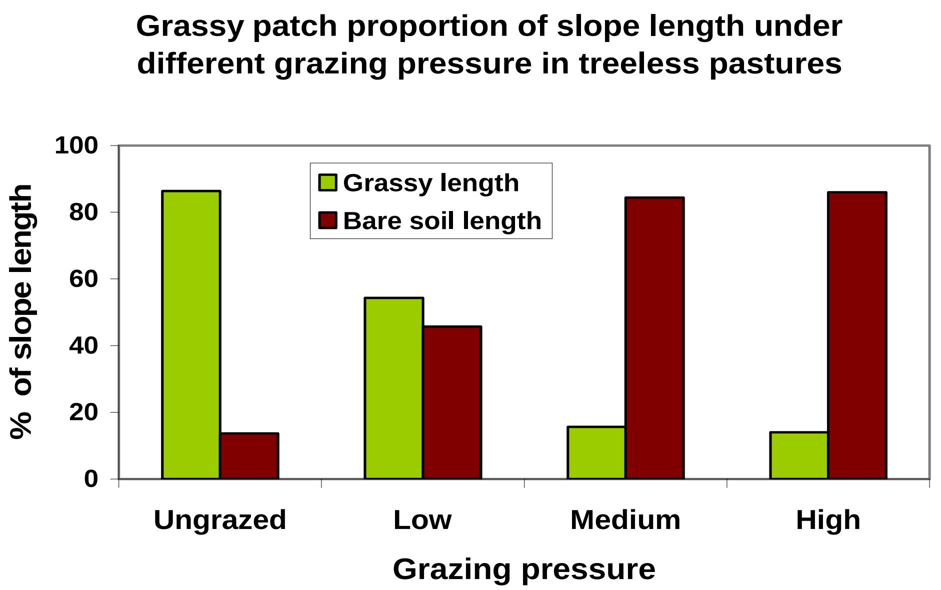


Figure 8.4 Relative proportion of runon and runoff land surface on treeless pastures after 7 years of different grazing management at the poplar box site.

Tree poisoning did not result in deteriorated landscape health indices

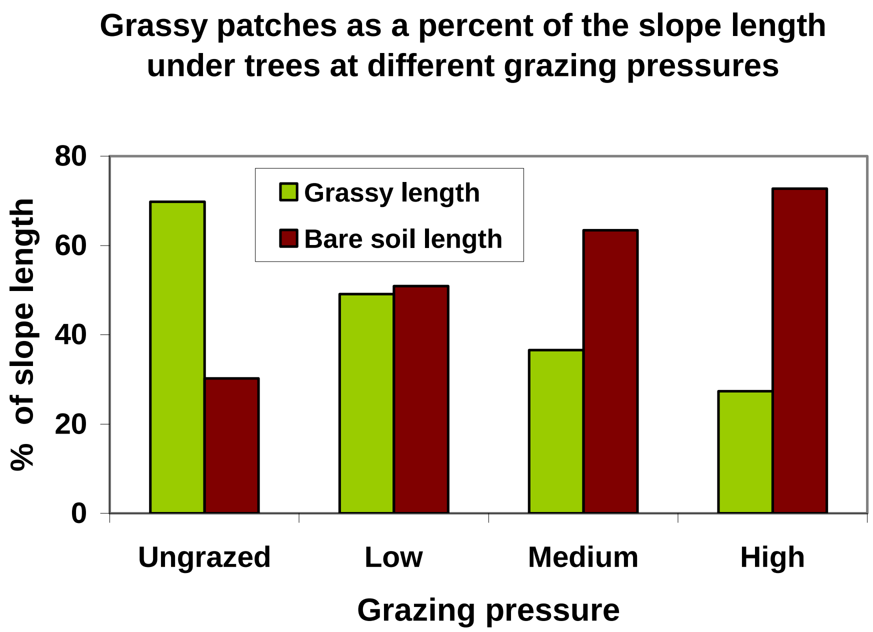


Figure 8.5 Relative proportion of runon and runoff land surface on treed pastures after 7 years of different grazing management at the poplar box site.

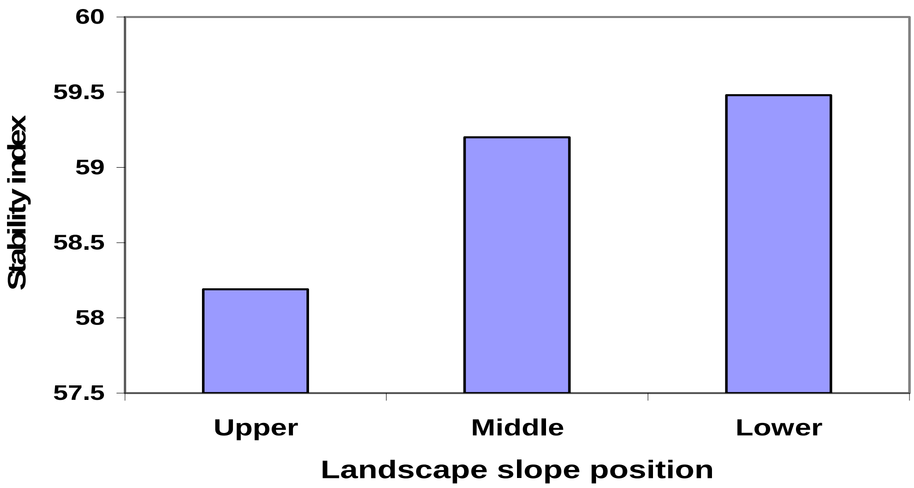


Figure 8.6 Influence of place in the landscape catena on the mean LFA Stability Index for native pastures at the poplar box site after 7 years of differing management.

8.5 Comparing the two sites based on LFA results

The same technique was used at both sites but different operators may have differing definitions of what is a run-on and a runoff patch. They also assigned their individual ratings to the standard scoring criteria for surface features used to develop the main indices. Hence it was useful to compare the results of a similar range of grazing management treatments from the 2 different sites.

The greatest difference was amongst the landscape organisation index where it ranged from 0.41 to 0.51 to 0.70 at the ironbark site for the mean of high, moderate and low grazing pressure respectively (Table 8.1). That compares with 58, 61 and 65 for the mean surface stability index at the same site. Meanwhile at poplar box site, the LOI was lower at 0.21, 0.26 and 0.53 for the equivalent treatments (Table 8.3) while the surface stability indices were much closer at 56, 59 and 61 respectively. This difference in LOI but not stability index indicates that the quality of the runoff areas/zones was assessed much more favourably at the poplar box site than at the ironbark site.

The nutrient cycling index is low for both sites (out of 100) because the method gives a high rating to self-mulching soils and both our sites had hard-setting, non-cracking surfaces. However, the calculated indices are internally logical and consistent in that they are highest at the low grazing pressure. The results have also been summarised in Appendix J as a percentage of the 'best' result for each main treatment, such as grazing pressure, tree retention and use of spring fires.

Nutrient cycling capacity of both sites was lowly rated

The trend in the results was very similar and reflects other perceptions of pasture condition (Figure 8.7). However, the amount of bare soil/runoff surface seemed higher visually at the ironbark site but the data did not reflect that. The relative difference between grazing pressures was similar for the 2 sites which are regarded as having a similar pasture type from a national perspective (Tothill and Gilles 1992). Both are perennial grass-dominant pastures and hence runoff and erosion rates are determined largely by the soil type and the intensity of rainfall events, for any given cover level.

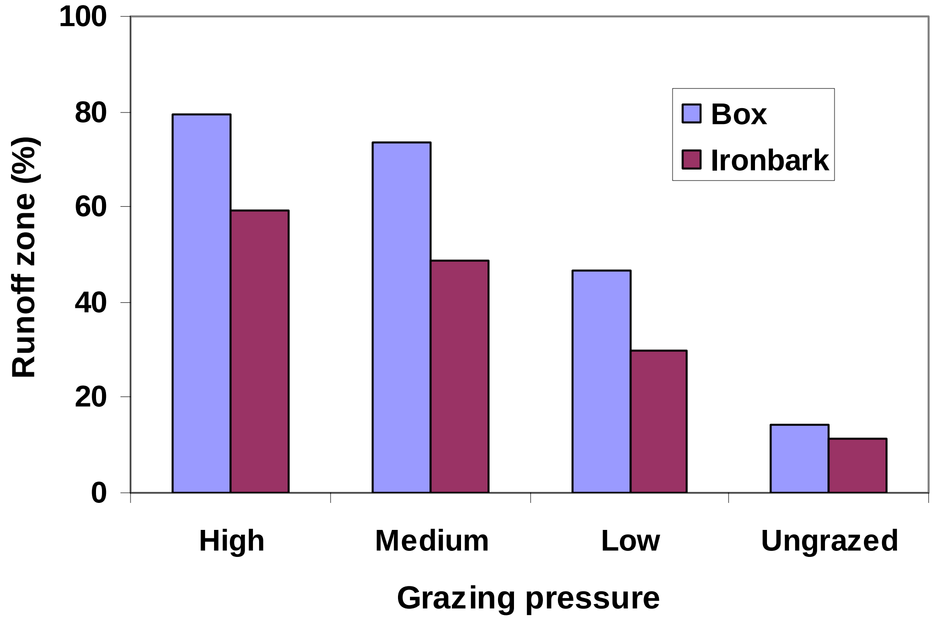


Figure 8.7 Percentage of the land surface acting as runoff areas by the end of the trial at both sites under differing grazing pressures.

8.6 Summary

The main points from the LFA data were –

- Both sites have much greater indices for surface soil STABILITY than for rainfall INFILTRATION and NUTRIENT cycling. **Main exceptions** are associated with **high runoff/runon ratios**
- Percentage of runoff surface was higher on grazed box country than Ironbark, especially under light grazing. This may be due to a 'definition' difference between operators for "standard soil surface". Also the presence of small grass plants between main tussocks at the poplar box site may contribute to a better quality litter cover or better 'standard soil surface'.
- The low INFILTRATION indices at the poplar box site are hard to explain, especially being about half those of the ironbark site which is rated poorly in Section 9 using other assessment methods.
- The only discordant piece of data is the Nutrient index at the ironbark site under trees at low grazing pressure
- NUTRIENT cycling index under MODERATE grazing at the ironbark site was abnormally high
- Generally the indices are greater where there were NO TREES - exception was run-on % at the poplar box grazed site
- Run-on % under trees at the poplar box site was only 78% of that for treeless pastures. Much of this due to very low cover at high grazing pressure
- Generally the Landscape indices are greatest under LOW and least/worst under HIGH grazing pressure at both sites. The only exception was the Nutrient cycling index in Treed MODERATE grazing pressure at the ironbark site
- Most differences between grazing management treatments are gradual but the poplar box site run-on zone % at MODERATE grazing pressure was unusually small
- The indices are greater/better where ungrazed & UNBURNT; however LOW grazing pressure plots generally had better indices than ungrazed plots that were regularly BURNT
- Spring burns greatly increased the runoff zone %age in the landscape at both sites, especially at the ironbark site
- Burning reduced the LOI at the ironbark site much more than at the poplar box site
- Spring burns had a much bigger impact on nutrient cycling indices at the poplar box site than at the ironbark site

8.7 Visual assessment of pasture condition

Most landholders assess their land's condition via a visual appraisal based on their experience and their vision for what is ideal for their operations. A basic recommendation of all formal pasture assessment systems is to take regular photographs of each main paddock (generally every 1-2 years) from the same position so as to incorporate the same view (Forge & Pegler 1997). We support that concept and used it to supplement our quantitative data for such things as tree killing and ground cover. It works particularly well for showing woody weed regrowth, bushfire effects and exceptional seasons.

A large album of photos now exists for both trial sites. Key sets have been collated into single page exposees to illustrate treatment effects that were very clearly captured by this method. A number of these from both sites are presented in Appendix L and an example is shown here of woody plant development over 7 years (Figure 8.8).

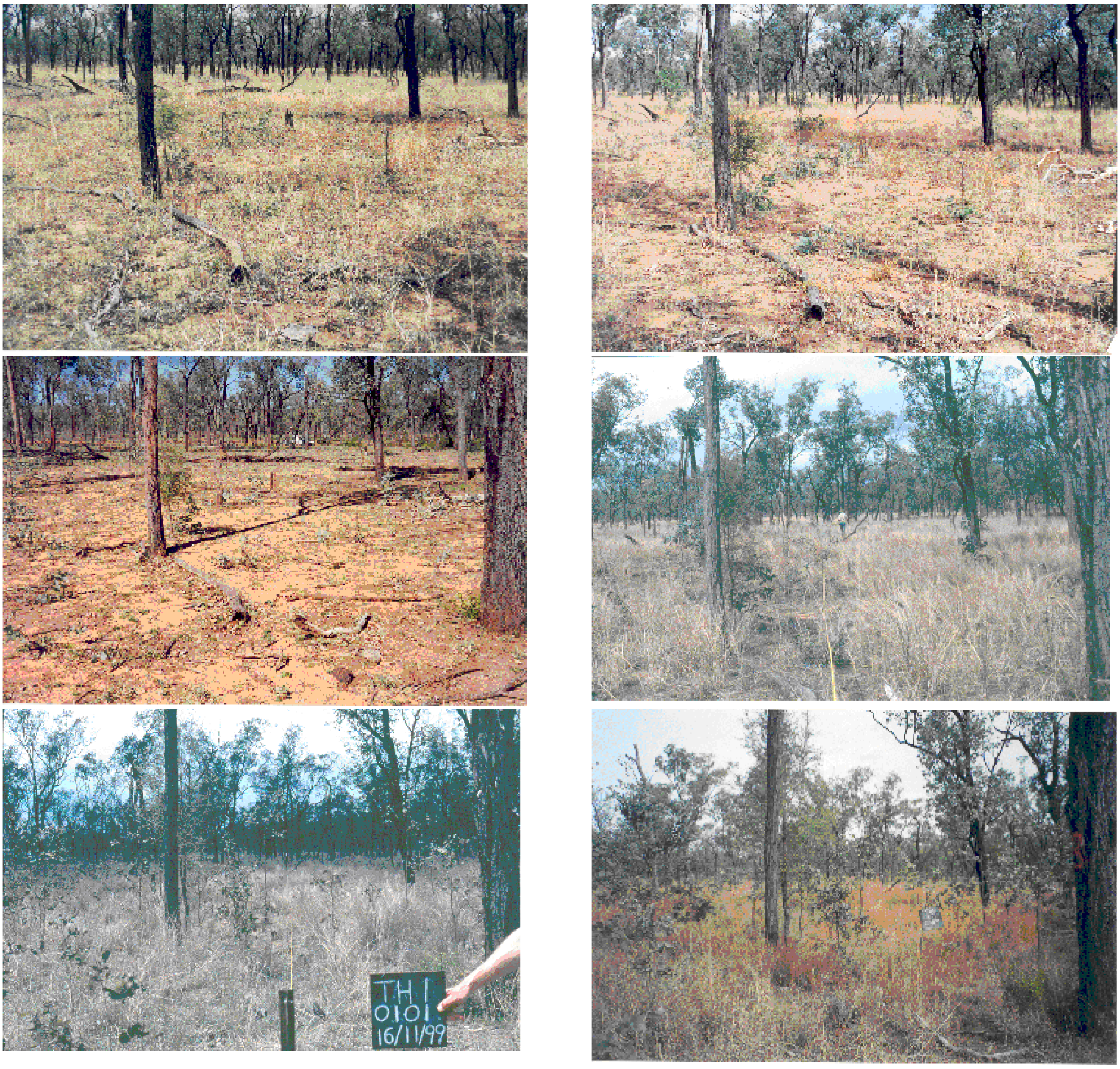


Figure 8.8 Photo sequence for Treed + High grazing pressure paddock, Rep1, transect line 1, post 1 at the ironbark site from 1994 to 2001. (top row: 1994, 1995, middle row: 1996, 1997, bottom row: 1999, 2001)

9 Runoff and Soil loss

9.1 Abstract

Runoff was 12% and 6% of annual rainfall for the ironbark and the poplar box site respectively. Runoff was highly variable depending on the season. Runoff increased linearly with rainfall amount and intensity, and decreased with increasing cover. Total soil loss ranged from 150kg/ha/yr to 11,000 kg/ha/yr depending on cover level. Suspended sediment made up 50% of total soil loss. Rainfall intensity, amount and ground cover were the three dominant parameters affecting event runoff. These accounted for 50-60% of the variability in runoff at both sites.

Where cattle were excluded from plots, within two years runoff and erosion were reduced to negligible levels. Loss of ground cover through increasing grazing pressure resulted in increased runoff and soil loss particularly when cover levels fell below 40%. Due to the highly variable rainfall, cover can vary considerably over time. Thus even the highest utilisation rate can maintain acceptable cover in good seasons, but periodically drops to low levels. This work suggests that by managing grazing pressure and hence ground cover levels, graziers can have a dramatic impact on erosion and runoff and therefore downstream water quality.

9.2 Background

The Northern Australian grazing industry relies heavily on native pastures for beef production. There is cause for concern over the deterioration of the pasture resource in much of Northern Australia, particularly Queensland (Tothill and Gillies 1992). Grazing management influences runoff and erosion processes and therefore the sustainability of rangeland ecosystems and regional water quality. Deterioration of the pasture resource can also be reflected in changes to hydrology and soil hydraulic properties (Sallaway & Waters 1994). Therefore, to gain a sound understanding of the impacts of grazing management on pastures, we must look at the changes to the soils and hydrology also. Also, management changes occurring at the paddock scale can have an impact on down stream water quality. To explain changes occurring downstream, it is vital to understand the soil hydrologic changes occurring at the local scale.

Previous soils and hydrology studies in North Queensland have been conducted on *Heteropogon contortus* and *Bothriochloa pertusa* dominant pasture (Ciesiolka 1987, Sallaway *et al*. 1994, Scanlan *et al*. 1996). Limited soil and hydrology data is available for the *Aristida /Bothriochloa* pastures in the eucalypt woodland communities which make up approximately 30% of Queensland's cattle grazing area.

As part of the larger study, the hydrology and soil loss processes were examined under various pasture utilisation rates or grazing pressures on treeless plots and in small catchments under trees. This report presents the soil/hydrology findings from the two research sites for six years from 1994–2000.

9.3 Objectives

The objectives of the runoff project as outlined in the initial proposal were:

- To determine rainfall, runoff, and infiltration relationships for three pasture conditions (high, moderate and nil grazing pressure) on those two soil types
- To quantify the soil hydraulic properties of representative *Aristida/Bothriochloa* pastures in central Queensland.
- To validate GRASP using quantified inputs of climate, soil properties, and management against field observations at the grazing trial site.

- To use validated models to compare the long term risks to profitability and sustainability associated with each pasture condition.

[This chapter does not address the latter two objectives in any detail but provides some of the data that is needed to achieve those aims]

9.4 Methods

9.4.1 Study Sites

Studies were conducted at two sites to measure the effects of grazing management on runoff and erosion processes over six years, commencing in 1994. Runoff and soil movement were recorded at plot scale (120 m^2) and small catchment scale (5,000 m^2) for three grazing pressures, high, moderate and nil.

The ironbark site is predominantly gently undulating with a silver-leaved ironbark *(Eucalyptus melanophloia)* overstorey and gritty, texture contrast red duplex soil. This soil has a shallow A horizon (5cm) and a 50cm deep B horizon overlying weathering granite parent material. Slopes range from 3-5%. Dominant pasture species are *Bothriochloa ewartiana* and *Heteropogon contortus.*

The poplar box site grazing site is predominantly undulating with a poplar box (*Eucalyptus populnea*) overstorey on shallow, silty duplex soils with semi-permeable medium to heavy clay subsoil. Pastures here are mainly *Bothriochloa decipiens* and *Aristida spp*. on 3-5% slopes.

Both sites receive predominantly summer rainfall with approximately 70% of annual rainfall occurring between October and March. Average annual rainfall is 653 and 627 mm for the ironbark site and the poplar box site respectively. The study areas were excised from large commercial cattle grazing properties and have been regularly grazed for more than 60 years.

Runoff and soil loss were measured at both the ironbark site and the poplar box site for three pasture grazing pressures (high, medium and ungrazed/exclosed) at the 'plot scale' (100-150 m^2) and a high and medium grazing pressure for two timbered 'mini-catchments' (0.25-0.5 ha). Each small plot was replicated in another paddock of the study site. Treatments were imposed in spring 1994 and the runoff sites were installed soon after.

9.4.2 Rainfall measurement

Rainfall intensity and depth data were recorded using pluviometer tipping buckets (minute interval) connected to data loggers. Pluviometers and manual rain gauges were located adjacent to each plot to account for the spatial variability across the 100 ha research sites.

9.4.3 Runoff measurement

Six runoff plots were installed at each site, 2 for each of three differing treatments. Plots (20 m long x 7 m wide) (Figure 9.2) were aligned perpendicular to the slope, with a Gerlach trough installed at the bottom end of the slope to collect bed load soil (Figure 9.1) and to channel runoff into the measuring equipment. Runoff rate and volume were measured via tipping buckets installed at the end of each Gerlach trough. Average plot slope was 3-5% and each plot was bounded on all sides by rubber belts to prevent surface runoff entering the plot area. For the mini-catchments (0.25-0.5 ha), surface runoff was measured through a Parshall Flume fitted with a capacitance water height measuring device and a chart recorder for backup. Artificial boundaries of earth were constructed around each mini-catchment. Average catchment slopes ranged from 4.5-7.5%.

9.4.4 Soil Loss

Bed load soil depositing in the Gerlach trough (Figure 9.3a) was removed and weighed after significant rainfall events. For the mini-catchments, bed load sampling traps were inserted upslope of the flume and similarly sampled (Figure 9.3b). A sub-sample of all runoff water was also collected using splitters placed beneath the tipping buckets. It was oven dried soon after collection and weighed to determine suspended sediment concentrations.

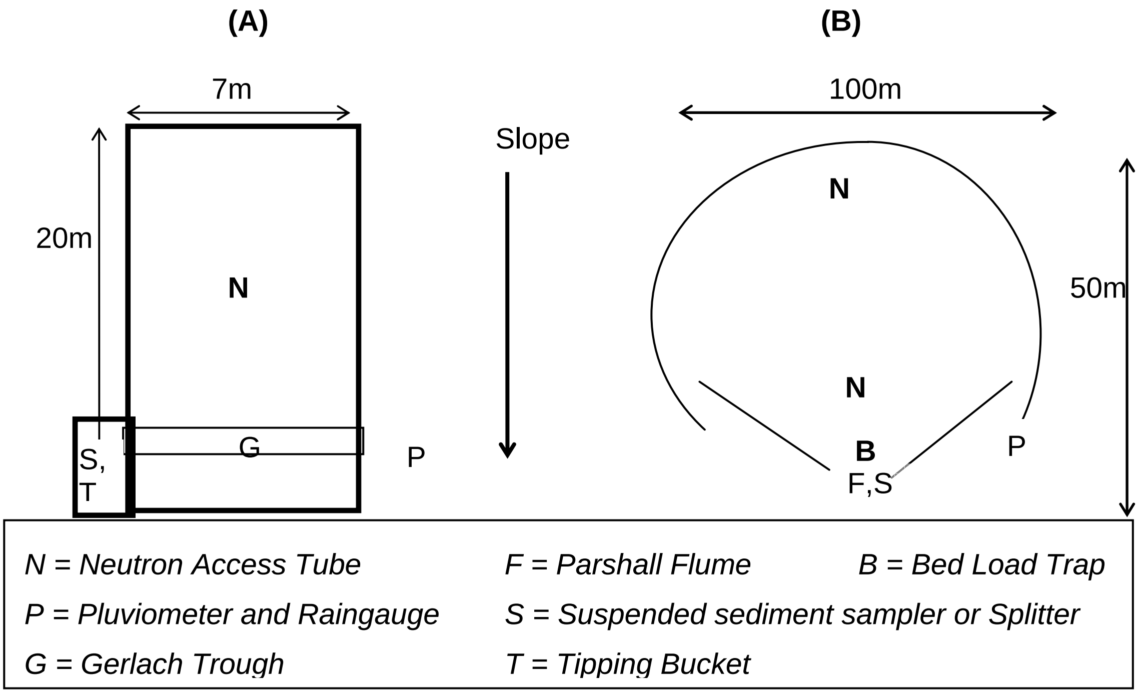


Figure 9.1 Plot (A) and Timbered mini-catchment (B) layouts showing where the rainfall, runoff, soil loss and soil moisture sampling equipment were located.

Figure 9.2 Picture of a bounded 7 x 20 m plot with Gerlach trough and runoff equipment in the foreground, from a high grazing pressure treatment paddock at the ironbark site.

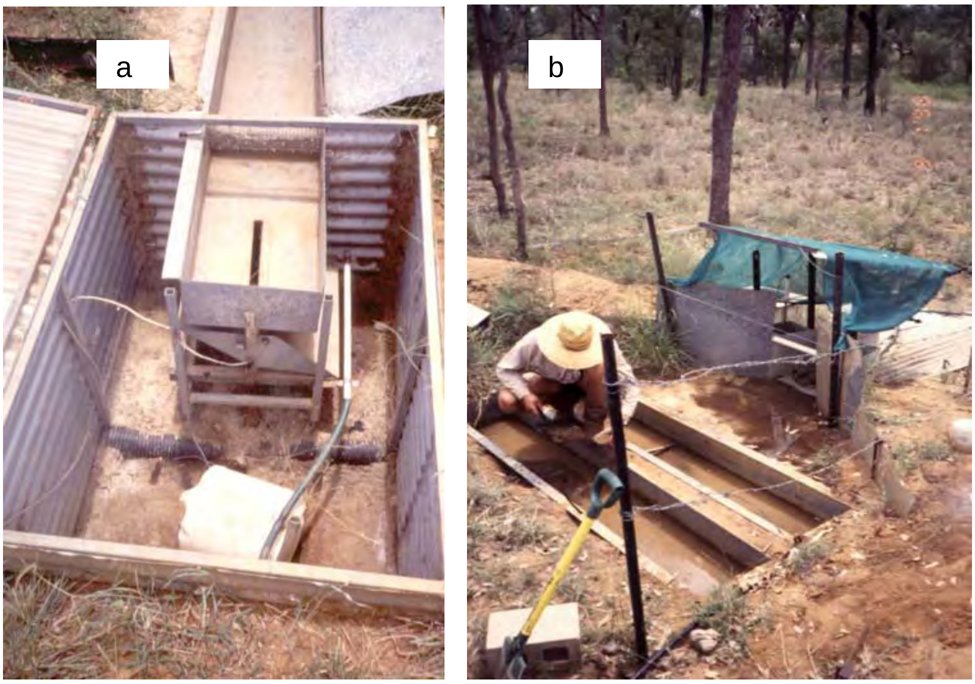


Figure 9.3 (a) Gerlach trough, tipping bucket and suspended sediment sampling equipment for plots, and (b) bed load sediment sampling trough upslope of a flume for a mini-catchment.

(a) (b)

Figure 9.4 Mini-catchment flume, bed load and suspended sediment sampling equipment at the poplar box site (a) from upslope and (b) from downslope of the flume.

9.4.5 Soil Moisture

A single Neutron probe access tube was installed at the centre of each small plot and two were installed in the upper and lower area of the small catchments. Neutron moisture meter (NMM) readings were collected after every runoff event. Additional Neutron metre access tubes were installed in the vicinity of the plots and the soil was wet artificially using ponded rings to derive a calibration curve for the NMM readings.

Based on the calibration data and the wetting and drying cycles occurring through time, an upper and lower moisture limit was derived for each plot and hence, the plant available water capacity (PAWC). The average PAWC across the 6 plots and 2 mini catchments was 69 mm for both sites. Individual site PAWC ranged from 36-124 mm at the poplar box site due to variable soil depth but had much less variability across the plots at Keilambete, ranging from 60-83 mm.

9.4.6 Ground Cover

Projected ground cover (%) was recorded after every runoff event. Ten replicates were recorded for each plot and averaged to give the percentage ground cover. Detailed species composition and biomass data was also collected annually for each plot using the Botanal method.

9.4.7 Nutrient analysis

Whilst nutrient analysis was not a major focus of the study, three different types of nutrient samples were collected

- surface soil collected from within each plot to a depth of 20 mm and bulked from 4 replicates.
- a sub-sample of the deposited bed load material in Gerlach troughs.
- a sub-sample of the runoff water.

The samples were collected to gain a better understanding of the nutrient concentration in soil and water for the *Aristida /Bothriochloa* rangelands. Nutrient samples were collected following an isolated runoff event after 125 mm of rain at the ironbark site in October 2000. A further two samplings were taken at the poplar box site in November 2000 and January 2001.

Samples were refrigerated immediately after collection and analysed at the Qld Health Laboratory in Brisbane for nitrogen and phosphorus.

9.4.8 Data analysis

Annual rainfall, runoff and soil loss was calculated from July to June each year to enable comparison of annual totals over the entire wet season. For the ironbark site, all year one data and for the poplar box site years one and two data, were omitted from individual event analysis as treatment effects were not established and soil surface disturbance lingered after trough installation or reseating (at the poplar box site).

All plot slopes ranged from 3-5% and thus it had no significant differential effect on run-off and soil loss and was therefore not considered in our analyses. Data was summarised by grazing pressure, ground cover class, maximum rainfall intensity class over any 15 minute period of an event (I_{15}), rainfall total class and soil moisture deficit.

When analysing grazing pressure effects, paired plots located in two different paddocks with the same grazing pressure imposed were treated as replicates. Where grazing pressure was not being considered, all plot data was pooled. Data are presented as means (± 95% confidence limit of the mean) of the interval classes rather than individual points. Where multiple lines were plotted, confidence limits were not included.

Rainfall events less then 10 mm made up 91% and 90% of the total number of events. However these rainfall events only contributed 3% and 7% of the runoff for the ironbark site and the poplar box site respectively. Therefore all rainfall events of less than 10mm were excluded from the analysis of individual events.

Average ground cover on the heaviest grazing pressure plots was 50-60% for both sites. Less then 5% of the total cover readings taken over the trial period were below 20% ground cover. Therefore this data was omitted from the analysis. Where logged data was not available for calculating annual runoff, the mechanical counters were used to estimate run-off. Derived estimates were not used in analysis apart from calculating yearly totals. Runoff data was analysed on an event basis from data loggers logging at 1 minute intervals.

Where suspended sediment concentration data were not available, the model of *Hairsine et al*. (1997) was used to calculate sediment concentration as a function of cover. Derived estimates were not used in single event analysis apart from calculating yearly totals. The Hairsine equation was of the form –

$$\text{Sediment concentration (g/l)} = 2700 * S * \lambda_{bare} * (1-C)^{y}$$

Where

S = plot gradient (m/m) - [all plot slopes were averaged]
λ_{bare} = efficiency of entrainment of bare soil
C = cover% /100
Y = exponent of cover

To obtain λ_{bare} and y, both terms were optimised to achieve the minimum SSE (Sums of Squares for Error) between predicted and observed event soil loss.

$$\text{Total sediment load} = \frac{\text{Runoff * sediment concentration}}{1000}$$

with sediment load measured in kg
runoff in litres, and
sediment concentration in g/l

Soil loss data was collected on a service interval basis not an event basis. A service interval is the time between successive site visits at which troughs were cleared and weighed, runoff samples bottled and data loggers downloaded. Therefore analysis of soil loss data contained multiple rainfall events in many cases.

9.5 Results

9.5.1 Ironbark Site Results

9.5.1.1 *Rainfall and Runoff*

Annual rainfall was below median rainfall (decile 5) for the first, second and fourth years. Consequently the ironbark site was in drought for much of year 2 of the trial (Table 9.1). The 1996/97 and 98/99 seasons yielded good falls with above average rainfall. The low annual rainfall totals were also reflected in lower annual runoff and soil loss figures in those years.

Table 9.1 Annual rainfall totals (mm) for the ironbark site during the record period.

Year (Jul–Jun)	Annual Rainfall (mm)
1994/1995	473
1995/1996	451
1996/1997	850
1997/1998	470
1998/1999	858
1999/2000	641

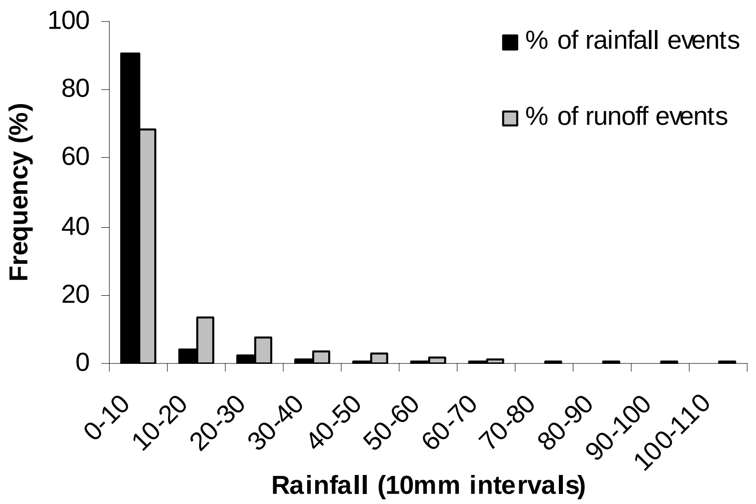
Note: Long term median rainfall is 549 mm

A number of observations about the rainfall and runoff data are:

- Over the six-year period, there were 939 rainfall events, with 91% < 10mm (figure 9.5a)

- Of the 9 % of rainfall events greater than 10mm, 92% produced runoff
- Rainfall events of less than 10mm contributed 3% of total runoff (figure 9.5b)
- Approximately three quarters (69%) of the runoff events were less than 2.5 mm and 85% were less than 10mm

Most rainfall events generate negligible runoff



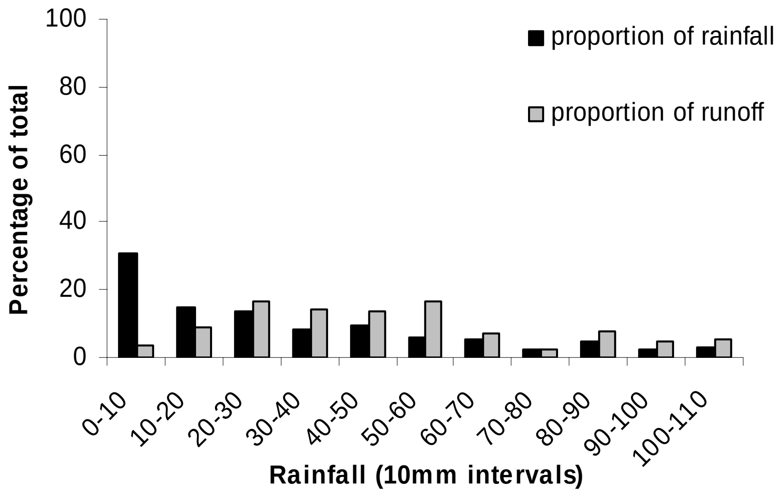


Figure 9.5 (a) Percentage of rainfall and runoff events contributed by each 10mm rainfall event class at the ironbark site (1994–2000). (b). Percentage of the total rainfall received over 6 years and the runoff generated, grouped by 10mm rainfall event class intervals at the ironbark site (1994–2000).

9.5.1.2 ***Runoff***

9.5.1.2.1 Annual Variation

Annual runoff totals were highly variable between years and treatments. They ranged from 1-72mm in the exclosed treatment and 38-261mm for the medium and high grazing pressure treatments (excluding year one settling in period) (Figure 9.6). Annual runoff was highly dependent on annual rainfall amounts. In 1996/97, runoff from the high treatment was 261mm from annual rainfall of 850mm and in 97/98, runoff was 77mm from annual rainfall of 470mm.

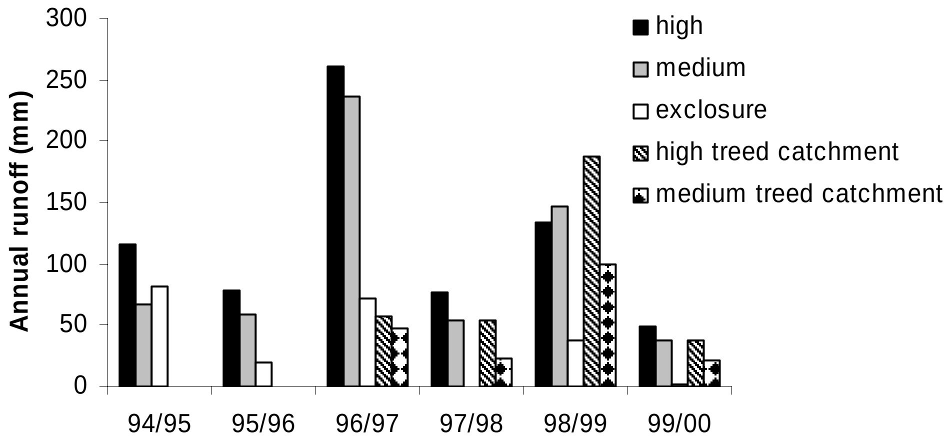


Figure 9.6 Annual runoff (mm) for grazed plots, exclosed plots and small, timbered catchments at the ironbark site from 1994–2000.

9.5.1.2.2 Within year variation

The majority of rainfall (58%) and runoff (68%) occurred in the summer period, November to February (Figure 9.7 a & d). Maximum rainfall intensities (I_{15}) were highest in this period also (30-70 mm/h) (Figure 9.7b). For the remainder of the year I_{15} was 0-30 mm/h.

Cover remained relatively constant at 60% throughout the year when cover was averaged across all plots (Figure 9.7e). Soil moisture deficits were lowest in the summer months when rainfall totals were highest (Figure 9.7f).

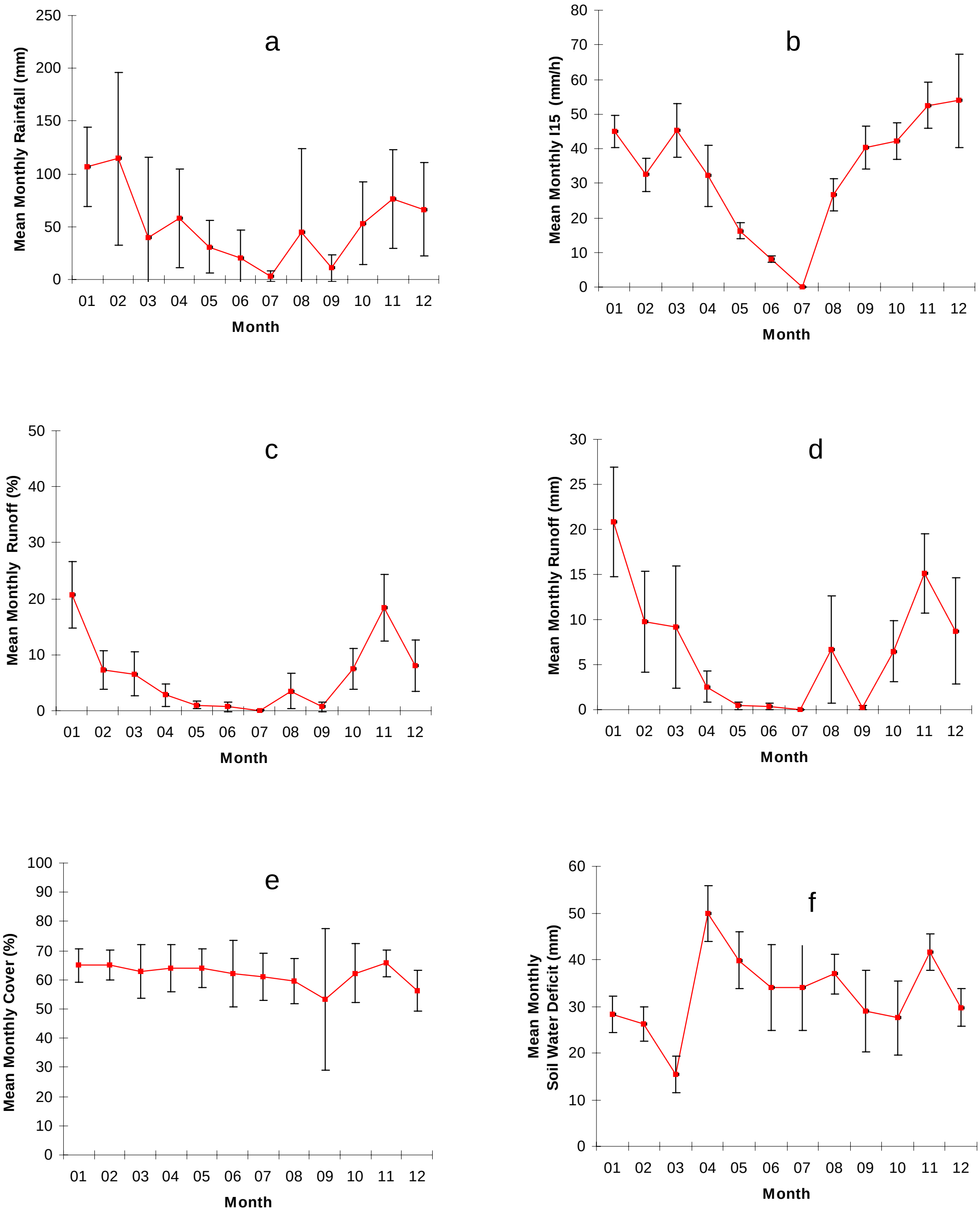


Figure 9.7 Mean Monthly (a) rainfall (mm), (b) I_{15} intensity (mm/h), (c) runoff (% of rainfall) (d) runoff (mm), (e) ground cover (%) and (f) soil water deficit (mm), averaged over all plots and five years at the ironbark site. [Bars on data points show the Standard Deviation of the value plotted.]

9.5.1.2.3 Influence of rainfall on runoff

Runoff was well correlated with rainfall total and intensity. Runoff total (mm) increased linearly with intensity (Figure 9.8a). Runoff increased linearly with rainfall amount for all rainfall events (Figure 9.8b). Confidence limits were much wider apart as intensities and rainfall totals increased due to the reduced number of data points at these ranges. The runoff data corresponding to the I_{15} class of 200-240mm/h was based on one runoff event where the maximum I_{15} intensity was in excess of a 1 in 100 year event (Appendix K5).

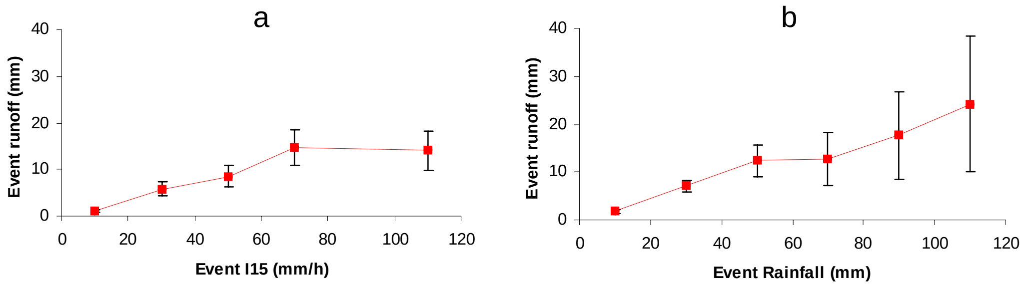


Figure 9.8 Event runoff for a range of (a) maximum I_{15} and (b) rainfall classes at the ironbark site.

9.5.1.2.4 Influence of cover on runoff

Cover had a significant effect on runoff. Runoff declined exponentially with increasing cover (Figure 9.9). Cover levels remained above 30% under all treatments for the majority of trial period, limiting availability of data at low cover levels <30%.

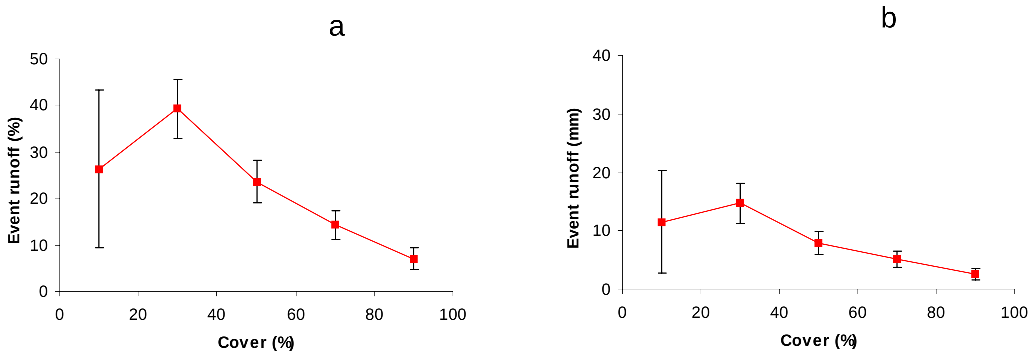


Figure 9.9 Event runoff amount (b) and percentage (a) for a range of cover classes (20 unit intervals) at the ironbark site.

9.5.1.2.5 Influence of soil water deficit on runoff

The wetter the soil before rain began, the more the runoff, particularly when soil water deficit was below 30mm. For soil water deficits in the 0-30mm range, runoff was approximately 7-10mm. Above 30mm deficit, average runoff halved (5mm) and remained relatively constant with increasing deficit (Figure 9.10). The maximum potential profile deficit was about 70mm at this site.

Soil profile dryness had a minor influence on runoff

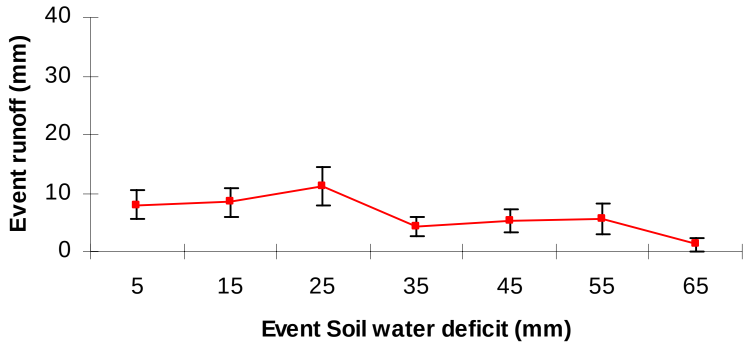


Figure 9.10 The effect of antecedent soil water deficit on runoff at the ironbark site.

9.5.1.2.6 Interactions between cover and other parameters influencing runoff

At low rainfall intensities, 0-20 mm/h, cover had little influence on runoff (as expected), particularly above 50% cover. For all rainfall intensities above 20 mm/h, runoff decreased linearly with increasing cover above 30% (Figure 9.11a). For low rainfall totals (<20 mm), cover again had little influence on runoff. When rainfall event totals exceeded 20 mm, runoff generally decreased linearly with increasing cover and was particularly evident when cover levels were low (<50%) (Figure 9.11b).

For all soil water deficit classes, increasing cover produced a decrease in runoff. At cover levels <40%, antecedent soil moisture deficit had little influence on runoff. For a given cover, runoff decreased with increasing deficit (Figure 9.11c).

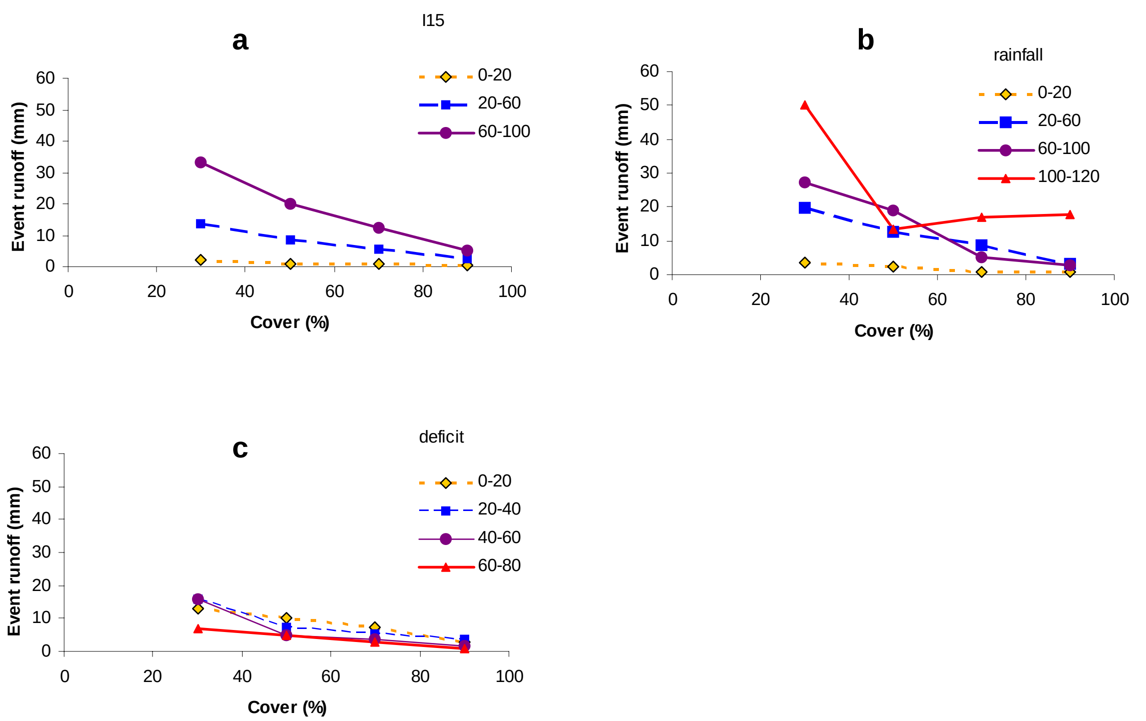


Figure 9.11 The effect of cover and a) maximum I_{15} (mm/h), b) rainfall event total (mm), and c) prior soil water deficit (mm) on runoff at the ironbark site.

9.5.1.2.7 Rainfall event total, intensity, soil water deficit and grazing pressure influences on runoff

For rainfall intensities above 40mm/h, increasing deficit produced a linear decrease in runoff. When deficit exceeded 30mm, intensity had no effect on runoff (Figure 9.12a). For all three pasture grazing pressures, runoff decreased with increasing deficit. When antecedent soil water deficit was in the range 30-60%, runoff increased with grazing pressure for any given deficit (Figure 9.12b).

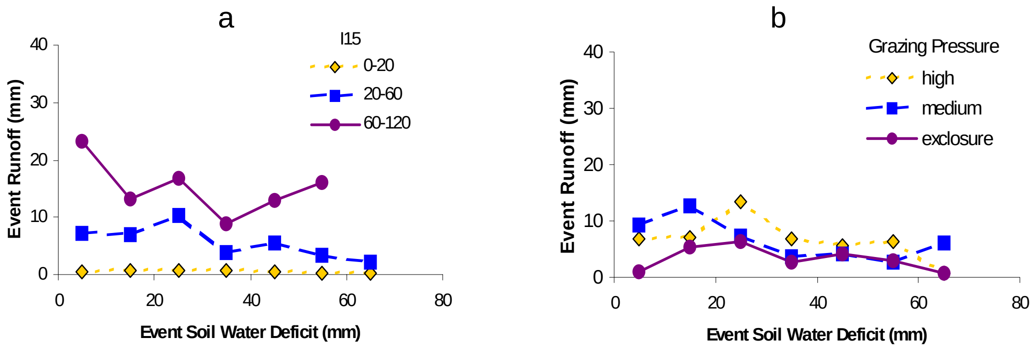


Figure 9.12 The effect of prior soil water deficit and a) maximum I_{15} intensity (mm/h), or b) grazing pressure on runoff at the ironbark site.

For all three grazing pressures, runoff increased with event intensity. At any given intensity, runoff increased with grazing pressure and was 2-3 times higher for the medium and high grazing pressure plots compared to the exclosure (Figure 9.13a).

For the exclosed treatment, rainfall event totals below 100mm had little effect on runoff (Figure 9.13b). When rainfall total exceeded 100mm there was a marked increase in their runoff. This would suggest that the soil profile for the exclosed treatment had exceeded its water storage capacity and that saturated overland flow may have been initiated. In contrast, runoff amount increased with rainfall total for both the high and medium grazing pressure treatments. There was no difference in runoff between the high and medium treatments for a given rainfall total (Figure 9.13b).

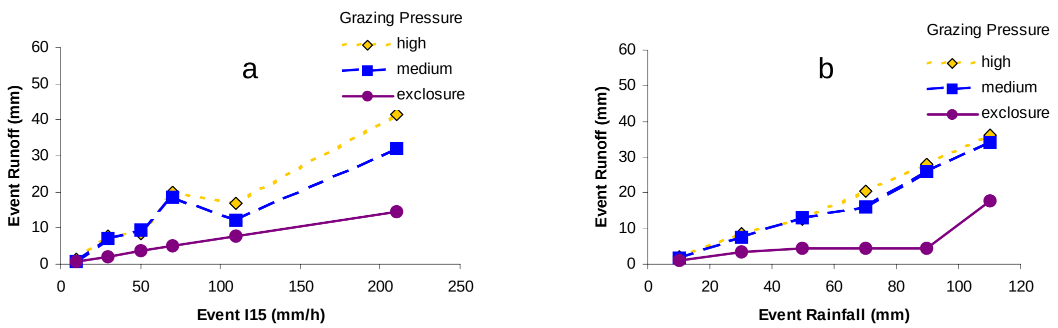


Figure 9.13 The effect of grazing pressure and a) maximum I_{15} intensity (mm/h), or b) rainfall event total (mm) on runoff at the ironbark site.

9.5.1.2.8 Treed mini-catchment relationships

Figure 9.1.6 shows the annual runoff totals for the treed medium and high grazing pressure mini-catchments. Runoff depths for the catchments were similar to those of the small plots at the respective grazing pressures for the final 3 years. Annual runoff ranged from 21-189 mm for medium and high treatments over the four years that catchment data was collected.

Similarly to the small treeless plots, runoff increased linearly with intensity. Runoff totals were similar to the small plots at a given intensity. Runoff increased linearly with rainfall up to 50 mm. Beyond 60 mm in an event, runoff totals decreased (see Figure 9.5b and Appendices K1 & K2).

9.5.1.2.9 The effect of pasture burning on runoff

Both of the exclosed/ungrazed runoff plots were burnt in August 1998 to remove some of the excess pasture biomass and to look at the effect of fire on the pasture, runoff and soil loss. Table 9.2 shows the pasture yield, cover and runoff prior to and after the burn. For two similar storms, there was little difference in runoff despite the fact that the amount of pasture cover had been reduced to less than half in the exclosures. Soil loss from the exclosures was negligible on both occasions as well.

Table 9.2 Pasture cover, yield, rainfall and runoff for high and medium grazing pressure plots and the ungrazed exclosures, before and after burning at the ironbark site.

	(28/08/98) 1 month prior to burn			(25/10/98) 1 month after burn		
	High	**Medium**	**Ungrazed**	**High**	**Medium**	**Ungrazed**
Pasture cover (%)	45	53	97	52	72	41
Pasture yield (kg/ha)	625	800	7500	625	800	500
Rainfall(mm)	74	74	74	72	72	72
Runoff (mm)	19	16	1	18	20	3

9.5.1.2.10 Multiple Regression analysis

A multiple regression analysis was carried out to predict event runoff using the key parameters rainfall event size, rainfall intensity, ground cover and soil water deficit (Eqn 1). The derived regression was able to explain 67% of the runoff variability, with rainfall event total accounting for 41% of it alone. The cover term was based on the equation of Hairsine *et al.* 1997. Runoff, rainfall event total and intensity were $\log_e$ transformed to account for the skewed distribution of the data towards the smaller events.

$$\mathrm{Ln(Runoff)} = -7.003 + 3.099*(1-\mathrm{cover})^{0.543} + 1.1242*\mathrm{Ln(rain)} + 0.7445*\mathrm{Ln}(I_{15}) - 0.000871*\mathrm{SWD} \quad (1)$$

where

Runoff is depth in mm
Cover is proportion of ground cover (ranging from 0-1)
Rain is total mm per event
I_{15} is the maximum intensity for any 15 minute period of an event in mm/h
Soil water deficit (SWD) is the difference between the actual soil water content of the top 60cm and the field capacity of the plot

There was reasonable correlation between predicted (from Eqn 1) and observed runoff across the full range of runoff depths (Figure 9.14). Predicted runoff was slightly lower than observed runoff, particularly when runoff totals were below 20 mm.

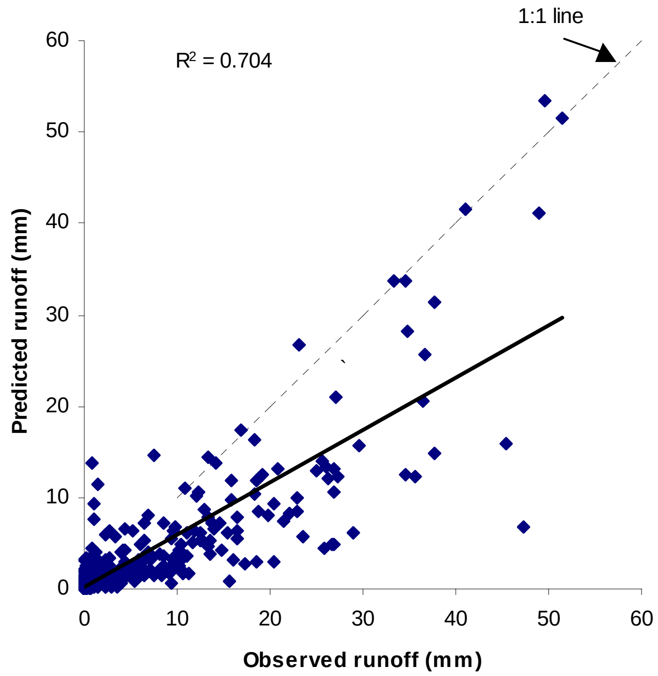


Figure 9.14 Predicted and observed runoff scatter for the ironbark site, based on the multiple regression formula in equation 1.

9.5.1.3 *Nutrients in sediment and runoff water*

The nutrient concentrations found on the soil surface and on bed load increased as grazing pressure decreased with the highest concentrations of nitrogen and phosphorus found in the exclosures (Table 9.3). The small catchments exhibited similar concentrations to the plots, with nutrient concentration in the soil surface higher for the lower grazing pressure. However this did not follow for the bed load. Concentrations in runoff were more variable and did not increase with lower grazing pressures. The variation in concentrations across grazing pressures may be due to the lag time between runoff occurring and sample collection, allowing for some volatilisation of nutrients from the sample. It may also be due to human error during collection of a sub-sample of the runoff.

High cover and litter levels translate into higher nutrient concentrations in any runoff

Table 9.3 Total phosphorus and nitrogen concentration of plot soil, bed load and runoff water for one runoff event at the ironbark site.

	Plot surface soil (0-20mm)		Trough bed load		Runoff sample		
Grazing pressure	**Total P (g/g)**	**Total N (g/g)**	**Total P (g/g)**	**Total N (g/g)**	**Total P (g/l)**	**Total N (g/l)**	**Runoff (litres)**
High	0.013	0.100	0.037	0.375	0.235	1.441	20,579
Medium	0.016	0.160	0.047	0.455	0.310	1.749	20,354
Exclosure	0.018	0.190	0.076	0.575	0.275	1.357	8,130
High catchment	0.011	0.100	0.011	0.050	0.250	1.770	905,184
Medium catchment	0.014	0.125	0.008	0.040	0.160	2.181	82,367

Rainfall for the service period (01/11/2000–21/11/2000) was 261mm with 80% of the runoff occurring in a 150mm rainfall event on 17/11/2000.

9.5.1.4 ***Soil loss***

9.5.1.4.1 Annual Variation

Annual soil loss totals were highly variable between years and treatments. They ranged from 28-193 kg/ha in the exclosed treatment to 1,446-10,300 kg/ha for the high grazing pressure (excluding year 1 settling in period) (Figure 9.15). Soil loss was not as well correlated to annual rainfall totals as runoff. Where a high rainfall year in 1996/97 followed a number of low rainfall years, soil loss was high.

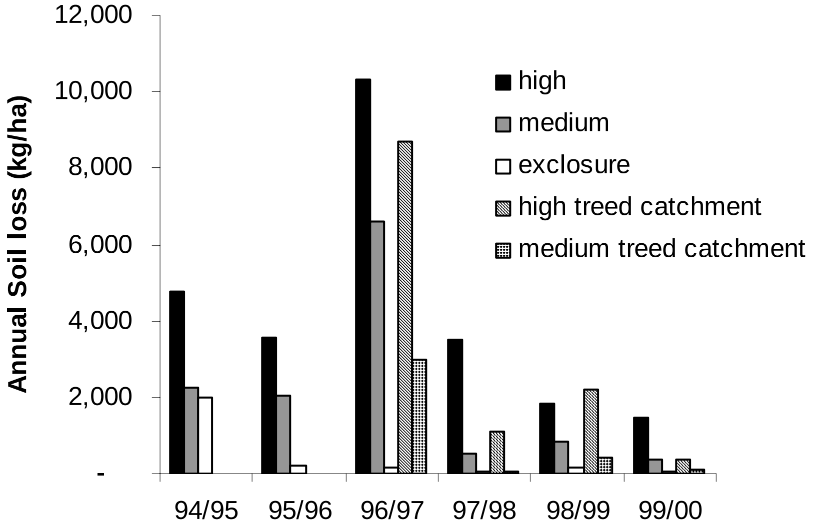


Figure 9.15 Annual soil loss (kg/ha) from grazed plots, exclosed plots and small timbered catchments at the ironbark site from 1994–2000.

9.5.1.4.2 Within year variation

The majority of soil loss (81%) occurred in the summer period, November to February (Figure 9.16) when rainfall and runoff were at their highest. Average monthly soil loss ranged from 200-600 kg/ha in these four months and was below 100 kg/ha for the remaining eight months of the year.

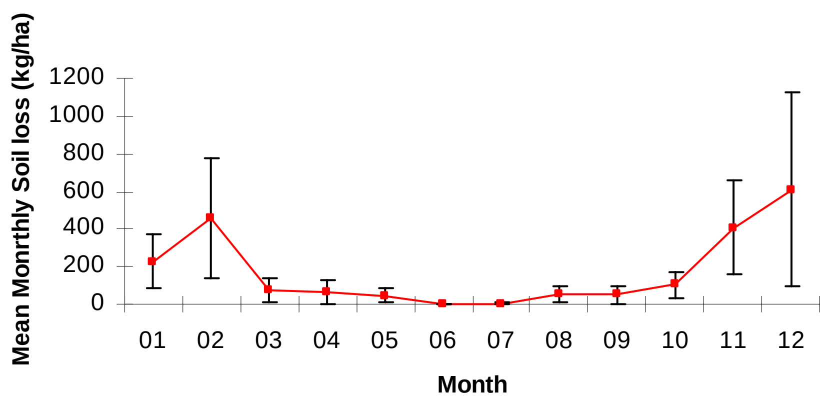


Figure 9.16 Monthly mean soil loss (kg/ha), averaged over all plots and five years at the ironbark site.

9.5.1.4.3 Interactions between parameters influencing soil loss

There was a good correlation between grazing pressure, soil loss and rainfall intensity (I_{15}). For high and medium grazing pressures, soil loss remained relatively constant for intensities up to 100mm/h. For the one major event when intensity exceeded this, there was a marked increase in soil loss from 1000 kg/ha to 7,000 kg/ha for the high pasture grazing pressure. For a given intensity, soil loss increased with grazing pressure (Figure 9.17).

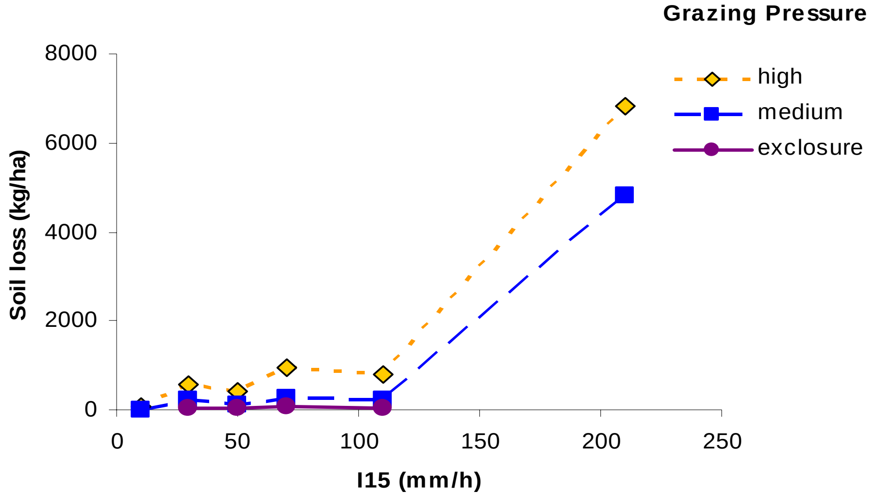


Figure 9.17 The effect of maximum (I_{15}) rainfall intensity (mm/h) and grazing pressure on soil loss*, averaged over all plots and five years at the ironbark site.
***Note, total load is the total soil loss occurring between site visits, so may include several runoff events**

Only 7 % of total soil loss occurred when low rainfall totals (0-40mm) were measured over a service period. The greatest proportion of total soil loss occurred when rainfall events were in the 120-160mm range (35% of total loss). A high proportion of soil loss (63%) occurred when runoff was < 40mm over a service period.

One exceptional runoff event produced 20% of the total soil loss for all the years combined. This event exceeded the 1 in 100 year recurrence interval for such rainfall and had a maximum 15-minute intensity in excess of 200 mm/h.

There were a total of 200 soil loss samples collected over the trial period with a number of runoff events generally occurring between site visits. Therefore soil loss figures on a given day may be due to a number of runoff events, depending on when the last site visit occurred. A total of 11% of soil loss samples generated half of the total soil loss.

Both bed load and suspended load decreased linearly with increasing cover. Total soil loss (kg/ha) decreased with increasing cover above 30%. Total sediment concentration ranged from a mean of 4g/l at 20-40% cover to 2 g/l at 80-100% cover (Figure 9.18b).

Suspended sediment concentration made up approximately half of the total concentration regardless of cover. Suspended sediment was 47% of total soil loss at 20-40% ground cover and 66% of total soil loss in the 80-100% cover range (data not shown).

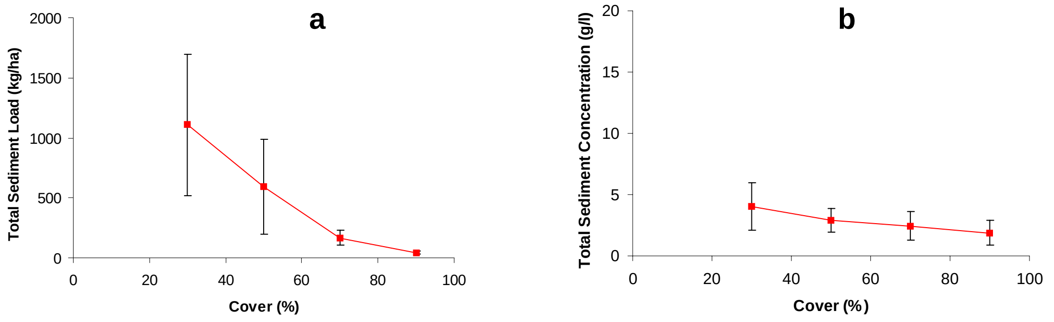


Figure 9.18 The effect of ground cover on a) total soil loss* (kg/ha) and b) total sediment concentration (g/l), averaged over all plots and five years at the ironbark site.

Both cover (Figure 9.19) and runoff (not shown here, see Appendices) influenced soil loss. Soil loss per mm of runoff decreased linearly with increasing cover above 30%. There was a high degree of variability in soil loss per mm of runoff, particularly at low cover levels. No data is shown for ground cover classes below 30% because this condition was rare and soil loss under those conditions was from an unrepresentative set of events.

Half of any soil loss occurs as fine suspended material that can be carried long distances

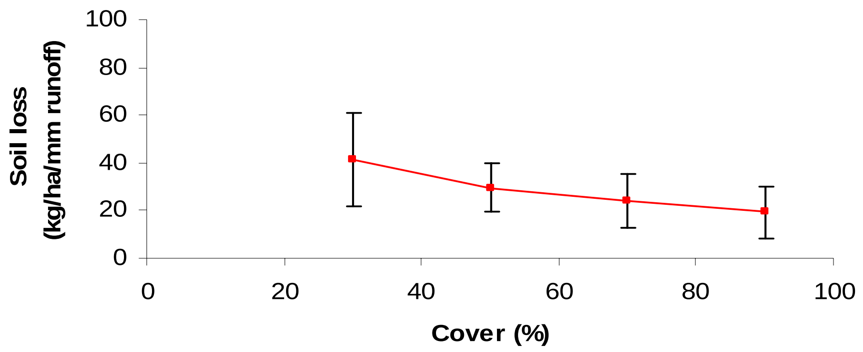


Figure 9.19 The effect of cover on total soil loss* (kg/ha/mm runoff), averaged over all plots and five years at the ironbark site.

9.5.2 **Poplar Box Site Results**

9.5.2.1 ***Rainfall and Runoff***

Annual rainfall totals were below median rainfall (decile 5) for the first and last years of the trial (Table 9.4). The 1998/99 season was well above the median rainfall with the remainder being in the decile 5 range. The low annual rainfall totals were also reflected in low annual runoff and soil loss figures in those years.

Table 9.4 Annual rainfall totals (mm) for the poplar box site

Year (Jul–Jun)	Annual Rainfall (mm)
1994/1995	384
1995/1996	569
1996/1997	692
1997/1998	682
1998/1999	932
1999/2000	528

Note: Long term median rainfall is 568 mm

Most rainfall events supply very little rain

A number of observations about the rainfall and runoff data (Figure 9.20) were:–

- Over the six-year period, there were 1091 rainfall events with 90% < 10mm
- Of the 10 % of rainfall events greater than 10mm, 97% produced runoff
- Rainfall events less than 10mm contributed less than 7% of the total runoff
- Approximately 75% of the runoff events were <2.5 mm and 92% were <10mm

Events of over 10mm of rain generally produce runoff

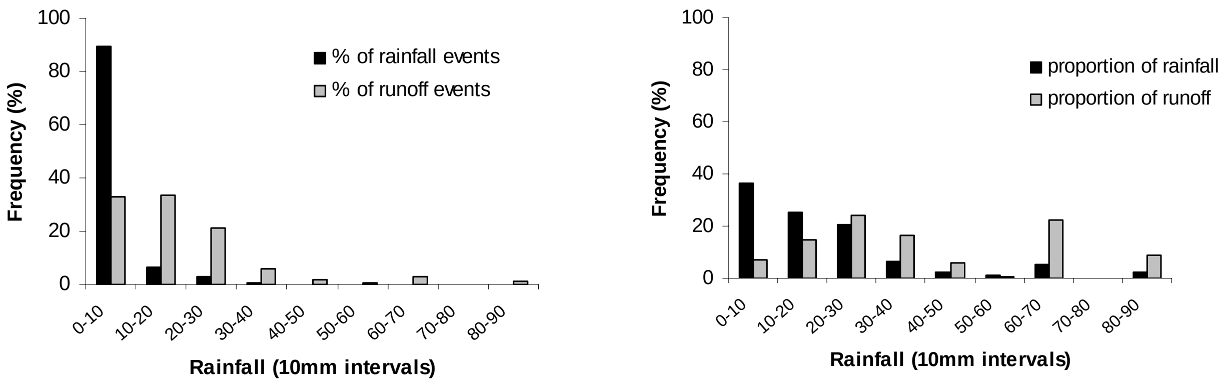


Figure 9.20 (a). Percentage of rainfall and runoff events contributed in each 10mm rainfall event class at the poplar site (1994–2000). (b). Percentage of the total 1994-2000 rainfall and runoff contributed by each 10mm rainfall event class at the poplar box site.

9.5.2.2 *Runoff*

9.5.2.2.1 Annual Variation

Annual runoff totals were highly variable between years and treatments. They ranged from 9-57 mm in the exclosed treatment and from 33-79mm for the medium and high treatments (excluding year one and two data to allow treatment effects to occur free of setup activity effects) (Figure 9.21). Annual runoff was not particularly well correlated to annual rainfall amounts and there appears to be some carry-over effect from the preceding season. For example, following the wet year in 98/99, runoff was quite low in comparison to three other years where similar rainfall occurred. The reduced runoff may be attributed to the increased pasture production in the previous high rainfall year allowing cover levels to remain high coming out of winter and resulting in a reduction in runoff.

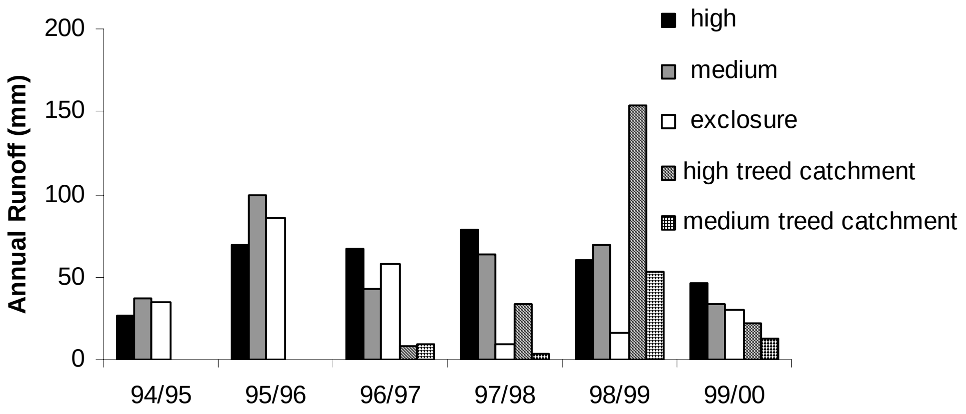


Figure 9.21 Annual runoff (mm) for grazed plots, exclosed plots and small, timbered catchments at the poplar box site from 1994–2000.

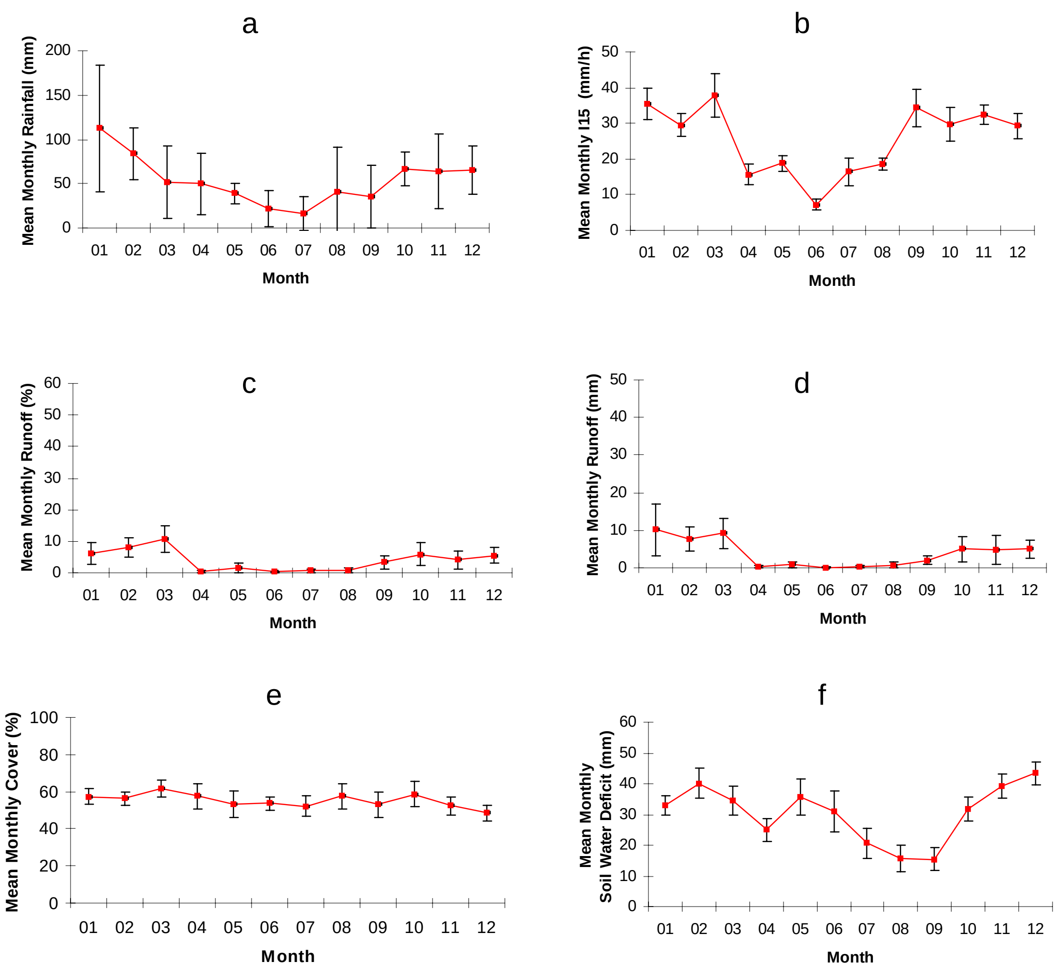


Figure 9.22 Mean Monthly (a) rainfall (mm), (b) I_{15} 15 min intensity (mm/h), (c) runoff (% of rainfall), (d) runoff (mm), (e) cover (%) and (f) soil water deficit (mm), averaged over all plots and five years at the poplar box site. [Bars on data points show the Standard Deviation of the value plotted]

9.5.2.2.2 Within year variation

Similar to the ironbark site, the majority of rainfall (51%) and runoff (60%) occurred in the summer period, November to February (Figure 9.22 a,c,d). Maximum 15 minute rainfall intensities (I_{15}) were highest in this period also (30-40 mm/h).

Average monthly ground cover ranged from 48–61% across all sites and remained relatively constant at around 50% throughout the year (Figure 9.22e). Soil moisture deficits did not follow this pattern and were actually lowest at the start of summer - not necessarily when rainfall totals were highest (Figure 9.22f).

9.5.2.2.3 Influence of rainfall on runoff

Runoff was well correlated against rainfall total and intensity (Figure 9.23a). Runoff total (mm) increased linearly with intensity. Runoff increased linearly with rainfall amount for all rainfall events (Figure 9.23b). Confidence limits were much wider as intensities and rainfall totals increased due to the reduced number of data points at higher rainfall totals.

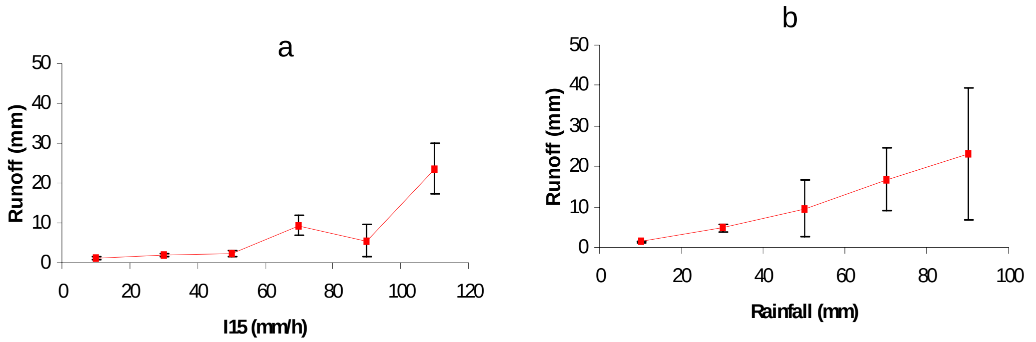


Figure 9.23 Event runoff (mm) at the poplar box site for a range of (a) maximum rainfall intensity I_{15} and (b) rainfall event size classes.

9.5.2.2.4 Influence of cover on runoff

Cover only had a moderate effect on runoff due to the limited cover range. Runoff decreased with increasing cover (Figure 9.24 a & b). For cover levels above 80%, runoff slightly increased although confidence limits were much wider for this cover class.

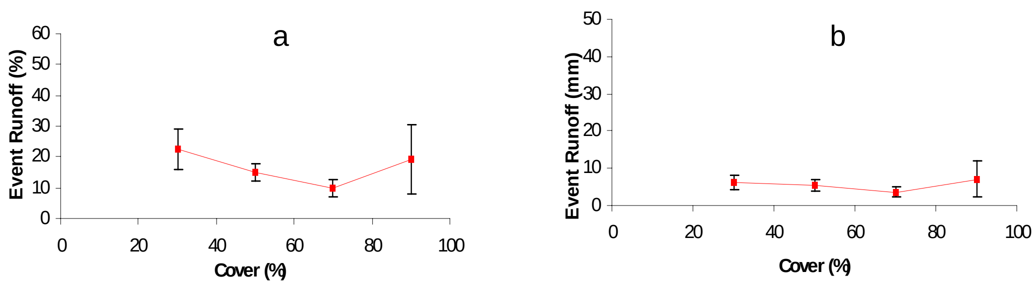


Figure 9.24 Event runoff amount and percentage for a range of cover classes (20 unit intervals) at the ironbark site.

9.5.2.2.5 Interactions between cover and other parameters influencing runoff

At low rainfall intensities (0-20 mm/h), cover had little influence on runoff. For all rainfall intensities above 20mm/h, runoff decreased with increasing cover above 30% (Figure 9.25a). For low rainfall event totals (<20mm), cover had little influence on runoff. When rainfall event totals exceeded 20mm, runoff generally decreased with increasing cover (Figure 9.25b).

There were no clear interactions between prior profile soil water deficit, cover and runoff (Figure 9.25c).

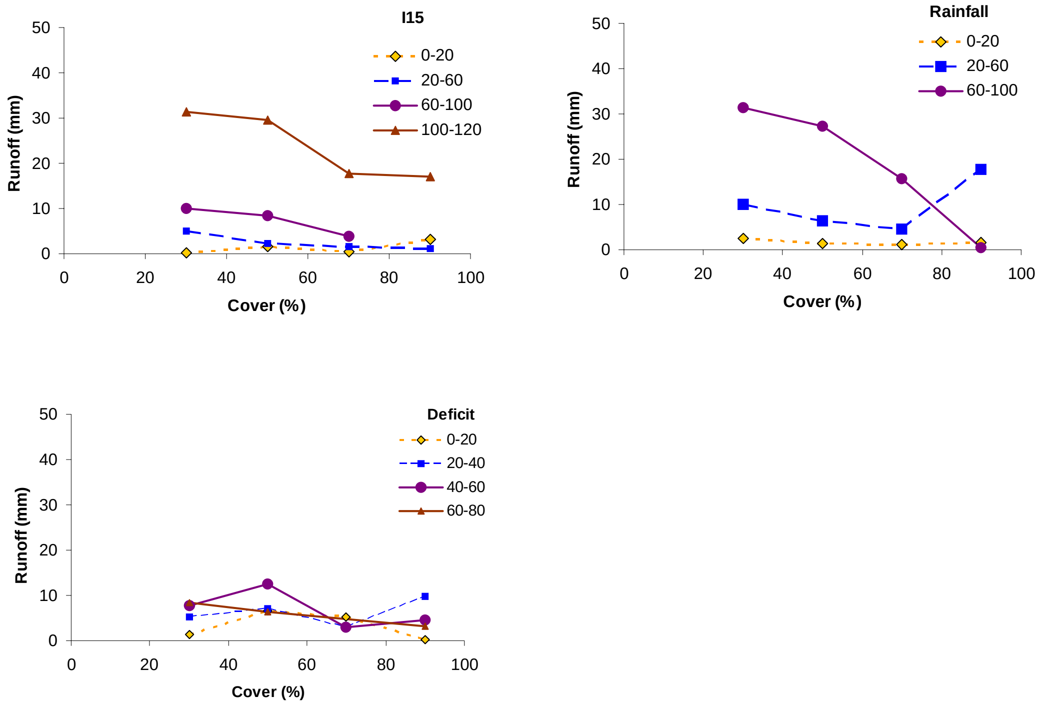


Figure 9.25 The effect on runoff at the poplar box site of ground cover and a) maximum I_{15} (mm/h), b) rainfall event total (mm) and c) prior profile soil water deficit (mm).

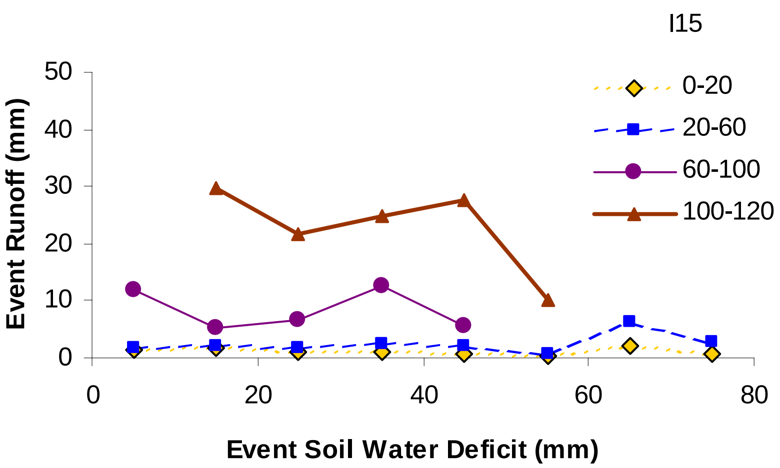


Figure 9.26 The effect on runoff of prior soil water deficit and maximum I_{15} (mm/h) at the poplar box site.

9.5.2.2.6 Influence of soil water deficit, rainfall intensity, event total and grazing pressure on runoff

At low and moderate rainfall intensities (<60 mm/h) soil water deficit had a small impact on runoff. For rainfall intensities above 60mm/h, the drier the soil, the lower the runoff (Figure 9.26).

For all three grazing pressures, runoff increased with rainfall intensity. When rainfall intensities were below 50 mm/h, runoff was influenced by grazing pressure with a higher grazing pressure resulting in more runoff, *albiet* still quite low. Above 50 mm/h peak intensity, grazing pressure had no clear effect on runoff (Figure 9.27a). Similarly for rainfall event total, runoff increased with rainfall amount for all grazing pressures. Grazing pressure had no clear effect on runoff when rainfall event totals exceeded 30mm (Figure 9.27b).

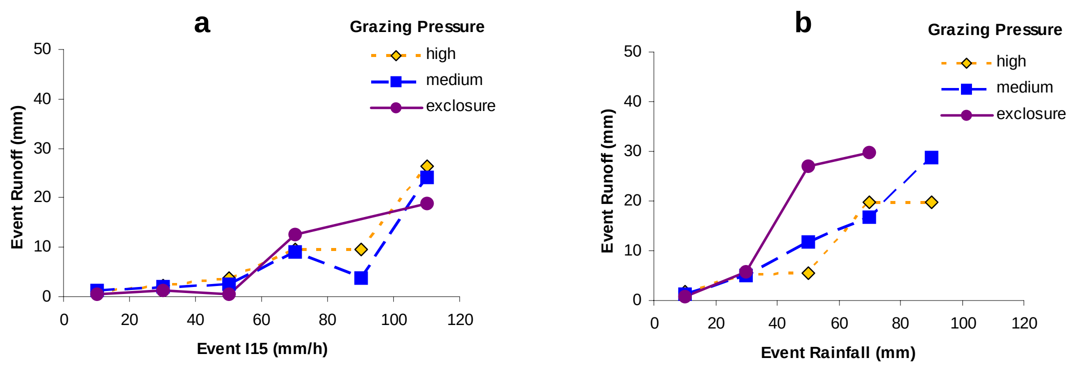


Figure 9.27 The effect on runoff of grazing pressure and a) maximum I_{15} (mm/h), or b) rainfall event total (mm) at the poplar box site.

9.5.2.2.7 Treed mini-catchment relationships

Figure 9.28 shows the annual runoff totals for the treed medium and high grazing pressure catchments. Runoff totals for the catchment were slightly lower than for the equivalent small plot runoff. Annual runoff ranged from 3-155mm for medium and high grazing pressure mini-catchments over the four years that catchment data was collected.

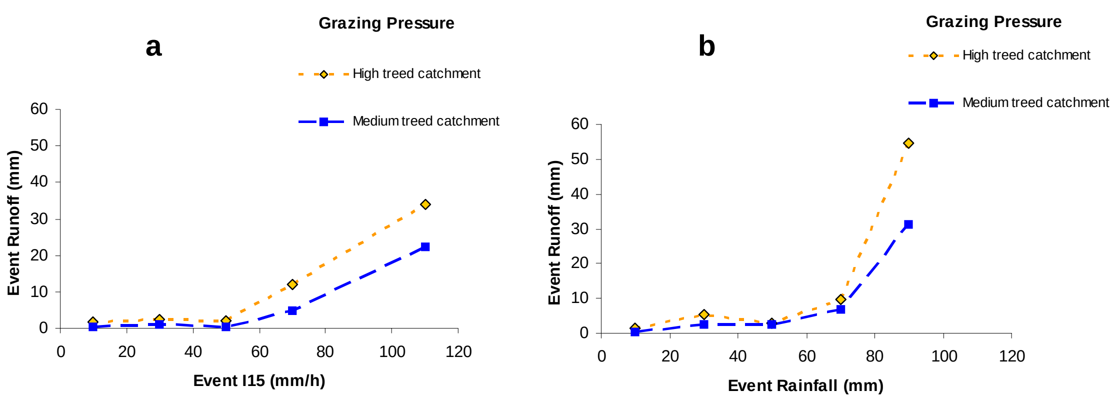


Figure 9.28 The effect on runoff of grazing pressure and a) maximum I_{15} (mm/h), b) rainfall event total (mm) for grazed, treed mini-catchments at the poplar box site.

The runoff response to rainfall total and intensity was quite different for the mini-catchments in comparison to the small plots. Significant runoff was not initiated on the catchments until rainfall intensity exceeded 50 mm/h and rainfall event totals were > 50mm (Figure 9.28 a&b). [All runoff and soil loss graphs or mini-catchment results are contained in Appendices K3 & K4]. The need for higher rainfall intensity and amount could be attributed to the longer travel time for runoff in the larger mini-catchments and the increased rainfall required over the larger area to initiate overland flow from the soil surface.

9.5.2.2.8 Multiple Regression analysis for runoff

A multiple regression analysis was carried out to predict event runoff at the poplar box site using the four key parameters, rainfall event size, rainfall intensity, ground cover and soil water deficit. An equation of the form used for the ironbark site was only able to account for 41% of the variability. Rainfall amount and intensity were the two variables that could account for the majority of the variability. The effect of cover was minor due to the limited range of cover measurements recorded, particular below 30%.

The relationship between runoff and rainfall event size, rainfall intensity and soil water deficit were all linear equations and the cover term was based on the equation of Hairsine *et al.* 1997. Keeping the equation of the same format as the ironbark site,

$$Ln(Runoff) = -1.775 + 2.078*(1- cover)^{1.5} + 0.01963*rain + 0.0281*I_{15} - 0.00054*SWD \quad (2)$$

where

Runoff is in mm
Cover is proportion of ground cover (ranging from 0-1)
Rain is total mm per event
I_{15} is the maximum intensity for any 15 minute period of an event in mm/h
Soil water deficit (SWD) is the difference between the actual soil water content of the top 60 cm and the field capacity of the plot immediately prior to the event.

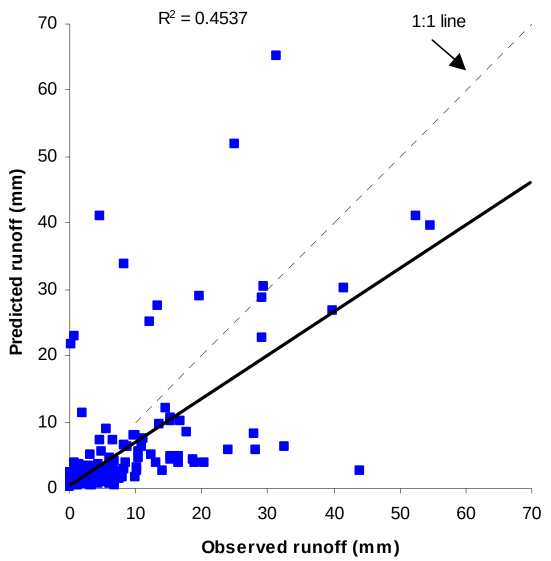


Figure 9.29 Predicted and observed runoff scatter for the poplar box site, derived from a multiple regression analysis.

If the natural log was not applied to runoff and a new relationship for runoff was predicted, then predictions can be improved and 52% of the variability can be accounted for compared to 41% for equation (2). The r^2 for predicted and observed runoff slightly improves also, from 0.45 to 0.50. The predicted and observed runoff gave a poor fit to the one-to-one line (Figure 9.29). The model estimates were highly variable when observed runoff was above 20 mm.

9.5.2.3 *Nutrients in sediment and runoff*

The nutrient concentrations found in runoff water increased as grazing pressure decreased, with the highest concentrations of nitrogen and phosphorus found in water from the treeless exclosures (Table 9.5). The treed mini-catchments exhibited slightly higher concentrations than the treeless plots. Nutrient concentrations at the poplar box site were generally double that of the ironbark site and this could be attributed to the more fertile clay soils at the poplar box site.

Table 9.5 Total Phosphorus and Nitrogen concentration of runoff water from various treatments for 2 runoff events at the poplar box site.

	Runoff sample			
	24/11/2000		30/01/2001	
Treatment	Total P (g/l)	Total N (g/l)	Total P (g/l)	Total N (g/l)
High Treeless	0.37	1.79	0.42	2.26
Medium Treeless	0.37	2.59	0.42	2.84
Exclosure Treeless	1.13	9.76	0.43	3.98
High Treed	no sample	no sample	1.08	5.77
Medium Treed	no sample	no sample	0.99	5.64

The total nitrogen content per litre of runoff water from individual plots ranged from 0.92 to 13.26 mg N/L, a 14-fold range but the replicates from the same plot were not wildly different (See Appendix K6). Total phosphorus concentrations were about one-fifth that of nitrogen with the N:P ratio ranging from 3.1:1 up to 8.2:1. The data indicate that nitrogen is the more mobile/variable of the two elements in runoff. Total P had only an 8-fold range although the highest P levels were from the same sample as the highest nitrogen concentration. More details are given in Appendix K6 (Table K6.1).

9.5.2.4 *Soil loss*

9.5.2.4.1 Annual Variation

Annual soil loss totals were highly variable between years and treatments. Soil loss ranged from 150-650 kg/ha in the exclosed treatment and 500-2,250 kg/ha for the high grazing pressure treatment (excluding year 1 & 2 settling-in period) (Figure 9.30). Soil loss was not as well correlated to annual rainfall totals as runoff was.

9.5.2.4.2 Within year variation

The majority of soil loss (67%) occurred in the summer period, November to February (Figure 9.31) when rainfall event size and runoff were at their peak. Average monthly soil loss ranged from 28-200 kg/ha in these four months and was generally below 60 kg/ha for the remaining eight months of the year.

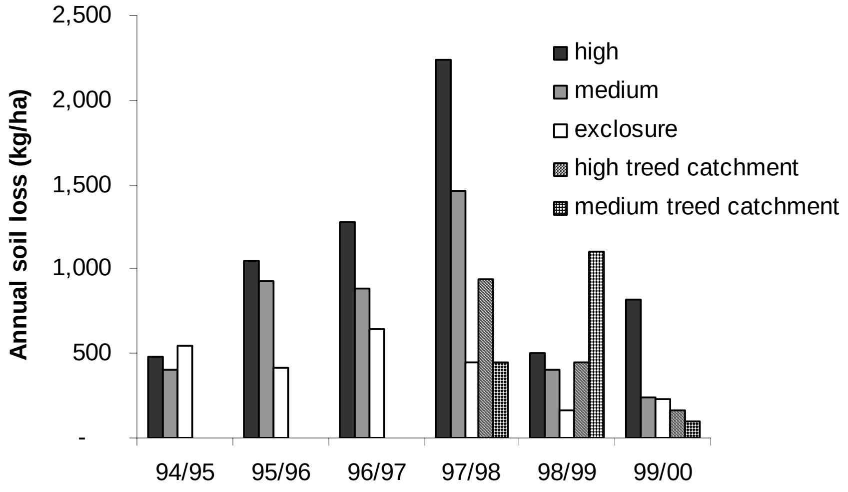


Figure 9.30 Annual soil loss (kg/ha) for grazed plots, exclosed plots and small timbered catchments at the poplar box site from 1994–2000.

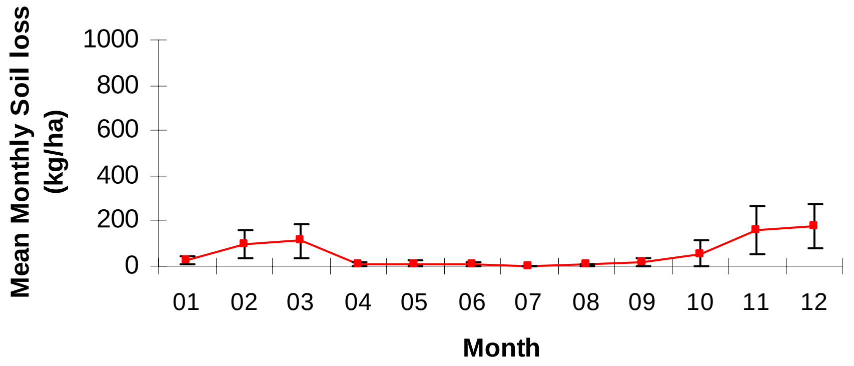


Figure 9.31 Mean monthly soil loss (kg/ha) averaged over all plots and four years at the poplar box site.

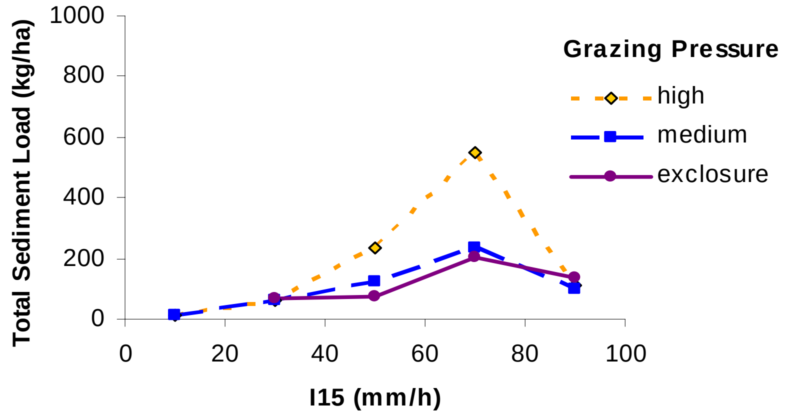


Figure 9.32 The effect of maximum (I_{15}) rainfall intensity (mm/h) and grazing pressure on soil loss*, averaged over all plots and four years at the poplar box site.
***Note total load is the total soil loss occurring between site visits so may include several runoff events**

Greatest soil loss was at high grazing pressure

9.5.2.4.3 Interactions between parameters influencing soil loss

There was a good correlation between grazing pressure, soil loss and rainfall intensity. For the high grazing pressures, soil loss increased when rainfall intensity (I_{15}) was greater then 20 mm/h (Figure 9.32). Soil loss from the medium grazing pressure and exclosures was similar for all rainfall intensities suggesting that cover levels maintained in the medium grazing pressure paddocks was sufficient to keep soil loss to a minimum under high intensity storms.

Total soil loss (kg/ha) slightly decreased with increasing cover above 30% (Figure 9.33a). Total mean sediment concentration ranged from 3g/l at 20-40% cover to 9 g/l at 80-100% cover (Figure 9.33b). Above 80% ground cover, there was large, unexplained variability in the recorded sediment concentration results.

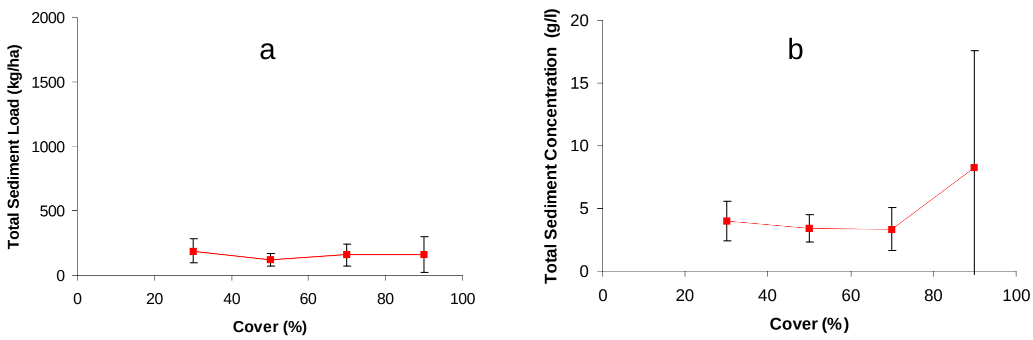


Figure 9.33 The effect of cover on total soil loss* (kg/ha) and total sediment concentration (g/l) averaged over all plots and four years at the poplar box site.

Suspended sediment concentration made up approximately half of the total soil moved, regardless of cover. Average suspended sediment concentration was 56% of total soil loss and was not significantly affected by ground cover (Appendix K4).

Both cover (Figure 9.34) and runoff influenced soil loss. Soil loss per mm of runoff increased as cover increased above 40%. There was a high degree of variability in soil loss per mm of runoff, particularly at high cover levels and that may account for the high mean value above 80% cover. The data presented for the ironbark site (Figure 9.19) and results of Scanlan *et al*. (1996) found that soil loss per mm of runoff generally increases with a reduction in ground cover.

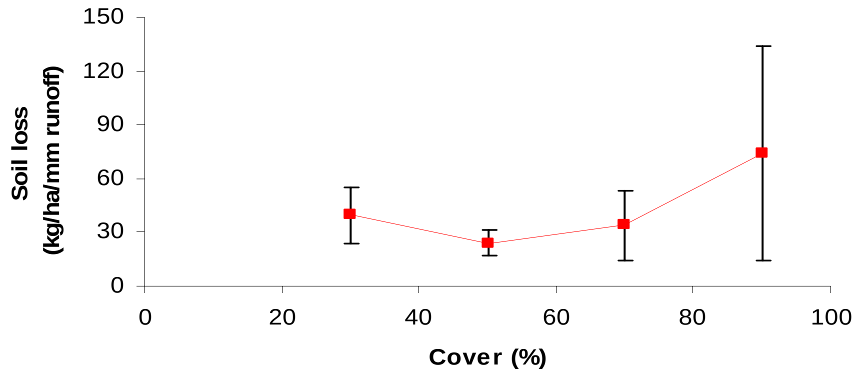


Figure 9.34 The effect of cover on total soil loss (kg/ha/mm runoff) averaged over all plots and four years at the poplar box site.

9.6 Discussion

9.6.1 Runoff

Runoff in the *Aristida/Bothriochloa* eucalypt woodlands of Queensland can be highly variable from year to year and is highly dependant on seasonal rainfall. The summer period particularly from November to February is the period when approximately three quarters of rainfall, runoff and soil loss occurs. This is also the period when rainfall intensity is highest. Whilst storms may be frequent in the summer months, the majority of storm events are small (<10mm) and produce negligible runoff. Less then 10% of rainfall events were greater then 10mm and over 90% of these events produced runoff. This pattern occurred for both sites and was similar to observations made by Scanlan *et al*. (1996) around Charters Towers. Approximately 70% of the total runoff occurred when rainfall events were between 20-60mm. Runoff was not dominated by one or two major rainfall events.

Cover had a moderate effect on runoff. Scanlan *et al.* (1996), McIvor *et al.* (1995) and Lang (1979) all concluded that cover was a major factor driving the runoff process. Due to the limited amount of low cover data for this trial, cover was not the dominant factor discriminating between runoff events. However small changes in cover produced significant changes in runoff, for example if ground cover increased from 30 to 60%, runoff sometimes halved from 40 to 20% (Figure 9.9). Where cattle were removed completely from grazing areas, cover increased to >90% within two years of exclusion and runoff was reduced to a negligible amount. This was particularly evident at the ironbark site. At the poplar box site the exclusion of stock from runoff plots took up to three years to cause a major reduction in runoff. This result suggests that under the current grazing management system for the sites, one short term locking up of a paddock (3-6 months) is unlikely to produce a measurable improvement in infiltration and soil loss rates.

There was little relationship between cover and runoff when rainfall totals were small (<20 mm) or above 100 mm. Similarly McIvor *et al.* (1995) and Scanlan *et al.* (1996) found little relationship between runoff and cover when rainfall totals were small (<20 mm). McIvor *et al.* (1995) also found little relationship between runoff and cover when a rainfall event was greater then 100 mm. For low rainfall events, the surface roughness due to plants and litter acting as a barrier, allowed for surface water detention and infiltration of rainfall. As ground cover reduces there is less protection of the soil surface against raindrop impact and increased bare areas generating runoff. Runoff generated from these bare areas is impeded and absorbed by vegetation and, as cover reduces, an unimpeded flow path is eventually formed resulting in less infiltration and increasing runoff. This process was particularly evident at the ironbark site with bare areas sometimes present, particularly under medium and high grazing pressure. Figure 9.2 highlights the patchy nature of the pasture in extremely dry conditions.

Similar to rainfall total, there was little relationship between cover and runoff when rainfall intensity was small (<20 mm/h). As rainfall intensity increased, runoff continued to increase for all intensities (Figure 9.11a). Once rainfall intensity exceeds the infiltration capacity of the soil then the remainder runs off.

The ironbark site exhibited quite high runoff, as a proportion of rainfall, for a given cover level. For example at 40% cover, average runoff % for the ironbark site was 32% but at the poplar box site it was only 20%. Scanlan *et al.* reported runoff of the order of only 12% of annual rainfall at 40% cover on their soil types. The higher average runoff % for the ironbark site could be attributed to the higher maximum rainfall intensity for the site in comparison to the other studies. Maximum I_{15} in the summer months for the ironbark site was 40-60mm/h compared to 25-40 mm/h at the poplar box site.

The unscheduled burning of some plots at the ironbark site demonstrated that, where stock are excluded in the short term after a burn, there was no significant effect on runoff despite cover levels being low, 41% (Table 9.2). This could be attributed to the improved soil physical properties built up from the exclusion of stock for three years prior. Studies by Sallaway & Waters (1994) and Orr (1975) found improvement in some soil physical properties, including macro-pore density, within two years after exclusion of stock. However, rainfall simulator studies by Emmerich & Heitschmidt (1999) have found that runoff can increase after burning where plots were grazed and burnt repeatedly over a number of seasons, compared to unburnt grazed plots.

The multiple regression analysis was able to explain a fair proportion of the variability in the runoff data. Combining rainfall event total, intensity, cover and soil water deficit explained 63% of the runoff variability for the ironbark site and 41% for the poplar box site. The observed and predicted runoff showed good correlation, particularly for the ironbark site, with an R^2 of 0.70.

Rainfall amount and intensity were the two dominant factors affecting runoff in this case. Prior soil water deficit had minimal effect on runoff at both sites. There was a suggestion that when soil water deficits were small (<30mm) runoff was increased from similar sized rainfall events. Grazing pressure was not significantly linked to runoff with ground cover being a more useful descriptor.

Previous studies have identified the importance of cover on runoff processes. Few recordings of cover levels below 30% occurred in this experiment. Ground cover in the high grazing pressure plots was usually 50-60% with fewer than 10% of all cover records being below 20%. Future grazing trials should ensure that runoff data is captured for the full range of surface conditions to quantify runoff and erosion responses at the extremities, ie. there should be extra very bare plots created artificially.

Runoff totals from the treed mini-catchments were similar to those of the treeless small plots. Typically runoff volume and rate are dampened with increasing catchment area for larger catchments (>20ha). However our treed mini-catchments were an order of magnitude smaller than this and had a low tree density (<5 m^2/ha) and small flow lengths to the catchment outlet. Hence it seems logical that their runoff response was similar to that of the small plots.

Whilst attempting to draw comparisons between cleared small plots and timbered mini-catchments is dangerous, the data suggests that at the grazing trial site, there was little difference in runoff response to cover and rainfall between the cleared plots and timbered mini catchments. Also the presence of trees at this density did not have a significant impact on runoff.

It is apparent from the chemical analyses that the concentration of nitrogen and phosphorus in runoff is affected by grazing pressure. For the ironbark site, total phosphorus and nitrogen concentration in the soil surface and the bed load sediment in the high grazing pressure treatments was half that found in samples collected from the ungrazed plots. For the poplar box site, the effects were even greater with the nutrient content of runoff samples for the high grazing pressure treatment being 2-3 times lower than in samples taken from the exclosures. Both the ironbark site and the poplar box site had high total nitrogen concentrations in runoff from the treed mini-catchments. In all cases, these elevated nutrient levels may be attributed to the additional organic matter build up from either tree litter or detached pasture litter.

9.6.2 Soil Loss

The period of maximum soil loss (November–February, Figure 9.16) is much more pronounced than that for runoff. Given that 80% of annual soil loss occurs from November to February, it is critical that good cover levels are maintained coming out of spring.

The ironbark site average total soil loss at a given cover level is similar to that found by Silburn *et al.* (1992) in central Queensland and an order of magnitude higher then those found by Scanlan *et al.* (1996). Average annual soil loss for the ironbark site was 4 t/ha under the high grazing pressure treatment, with an average ground cover of 54%, and 2t/ha for medium grazing pressure which had an average cover of 60%. The poplar box site average annual soil loss was 1.2 t/ha for the high grazing pressure treatment at 53% average cover and 0.75 t/ha at an average 47% cover for the medium grazing pressure treatment.

Rollins (1981) proposed that an acceptable soil loss for USA rangelands is 1 t/ha. Based on this figure and from field observations, the erosion rates under high grazing pressure at the ironbark site are not sustainable long term and, even under medium grazing pressure treatment, are just acceptable. The erosion rates recorded at the poplar box site under a medium pasture grazing pressure appear to be acceptable.

Critical cover levels have been discussed by a number of authors. In northern Queensland rangelands, a number of authors (McIvor *et al*. 1995, Silburn *et al*. 1992 and Ciesiolka 1987) have suggested critical cover levels of 40%. This study suggests that, for the ironbark site, cover levels of the order of almost 60% may be required to achieve sustainable erosion rates. Meanwhile at the poplar box site, cover in the range of 40-50% under moderate grazing maintains average soil loss at below 1t/ha/annum.

There was no distinct parameter which dominated the soil loss process. Soil water deficit had a small effect on soil loss when the soil water deficit was greater than 50mm. When the soil water deficit was below this, it had no effect on soil loss (See Appendices K2 & K4).

Rainfall total or maximum rainfall intensity between field visits did not have a major effect on soil loss. This result is not unexpected given that soil loss totals for a given storm are often grouped in our data with several events across the service period.

Suspended sediment generally remained at about 50% of total soil loss. Hence a high proportion of soil lost from the soil surface is carried completely away in channel runoff. This finding is supported by the findings of Silburn *et al.* (1992) and Miles and Johnston (1990) from central and western Queensland grazing trials. It highlights the importance of measuring both the suspended and bed load material. Secondly, suspended sediment material can remain in suspension for long periods and travel long distances downstream in runoff.

9.6.3 Nutrient transport

The highest suspended N levels were all from the ungrazed exclosures. That poses questions about possible greater short term N loss rates from areas where high litter cover exists compared to well grazed areas where litter is less abundant. Total loss will be determined by both the concentration in the runoff and the amount of runoff and, as runoff is substantially reduced by good cover, the total nutrient losses from moderate-sized events may not differ much amongst differing grazing management regimes. There is also the issue of the more clayey soil at the rep2 exclosure at the poplar box site and its potential to deliver sediment that had a higher microbial biomass than soils from the majority of the site.

At this stage all we can do is provide these data to the public in the hope that it may enhance an expanding knowledge base in this area.

9.6.4 Data incorporation into erosion models

Our data was used to validate and upgrade the calibration of existing simulation models such as PERFECT (for erosion predictions) and GRASP (for pasture production and runoff predictions) to improve long-term risk predictions. The outcome of that validation process and the generation of long term predictions about sustainable levels of production are still coming. However, if the recent successful use of a "Curve Number parameter" for getting better runoff predictions from other pasture soils in Central Qld (Owens *et al*. 2003) can be extended to our 2 sites, that would deliver great planning benefits to the region.

Where some modelling has been attempted by now, those results are discussed in Section 11.

9.6.5 Conclusions

- The period from November to February is the critical period where 70% of the annual runoff occurs and 80% of soil loss occurs.
- For the cover ranges experienced in this trial, rainfall amount and intensity accounted for 30-51% of variability in runoff and cover an additional 10% maximum.
- Removing cattle from paddocks can result in a rapid and marked improvement (within 2 years of removal) in perennial grass cover, infiltration and a reduction in soil loss.
- Average annual soil loss for the ironbark site (4 t/ha) and the poplar box site (1.2 t/ha) under high grazing pressure are not a sustainable option in the long term.
- Cover may need to be maintained at 50-60% under moderate grazing pressure on the silver-leaved ironbark type of grazing lands for them to be grazed sustainably without periodic spelling.
- Burning pastures where stock have been excluded for three years has no short term effects on the infiltration characteristics of the soil.

Higher cover levels seem needed for sustainable grazing at the ironbark site than at the poplar box site

9.6.6 Recommendations

Future grazing trials should ensure that runoff data is captured for the full range of surface cover conditions so as to quantify runoff and erosion responses at the extremities, in particular at cover levels below 30%. This may need to be achieved by removal of cover through cutting and herbicides if grazing alone does not achieve this.

Future trials should look at paired catchments, comparing timbered and cleared areas, for a number of grazing pressures to better assess the effect of trees on runoff.

From the author's observations, it is apparent that the spatial location of runoff plots relative to watering points and position in the landscape is important. Future work should consider the location of plots relative to fences, water, shade and context within the landscape. More recordings of cover and soil moisture are needed during dry times prior to rainfall events

9.6.7 Acknowledgements

Special thanks is given to past staff members who assisted in the initial design and/or contributed to data collection in some way over the six years. They include Evan Thomas, Russell Drysdale, Joff Van der Muelen, Brett Kuskopf and Steve Riches.

The runoff and soil loss studies were conducted under agreements with officers now in the Qld Dept Natural Resources & Mines. They have provided this report but this study could still provide extra insights to catchment processes if more resources were available to analyse the data more fully. At this point in time, far more processing of data has been done for the ironbark site than for the poplar box site.

9.7 Salt levels in the soil profile at the poplar box site

Another topic that was investigated in the last year of the trial at the poplar box site was the current soil salinity profile in different paddocks and at differing positions in the landscape. The soils were known to have high salt contents in the subsoil (Section 3 site description). Hence we were interested to know if our 8 years of different grazing pressure or the killing of trees had caused that salt to be mobilised. Hence samples were taken to profile depth in May 2002 at upper and lower slope locations in the moderate grazing pressure paddocks 5 and 8. Paddock 5 was covered in trees while the trees in paddock 8 were killed 8 years before in July 1994.

Chloride, pH and electrical conductivity profiles are shown in Figures 9.35, 9.36 and 9.37. There was less salt in the upper soil profile at the upper slope positions and greatest concentrations at depth in the lower slope positions. There was no clear evidence of enhanced mobilisation of salts in the medium term due to the killing of trees.

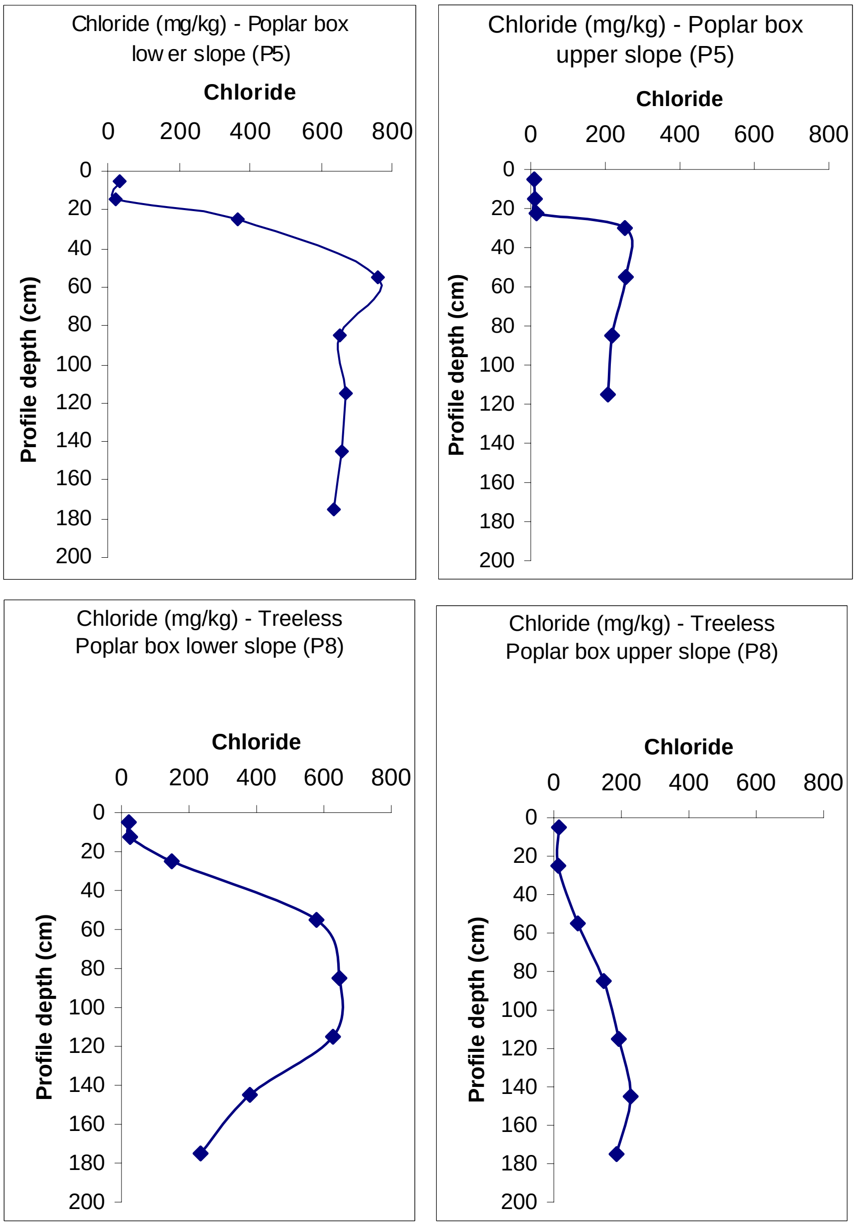


Figure 9.35 Soil profile chloride in treed (P5) and treeless (P8) poplar box native pastures at lower and upper slope positions in May 2002. Values are means of 2 or 3 reps.

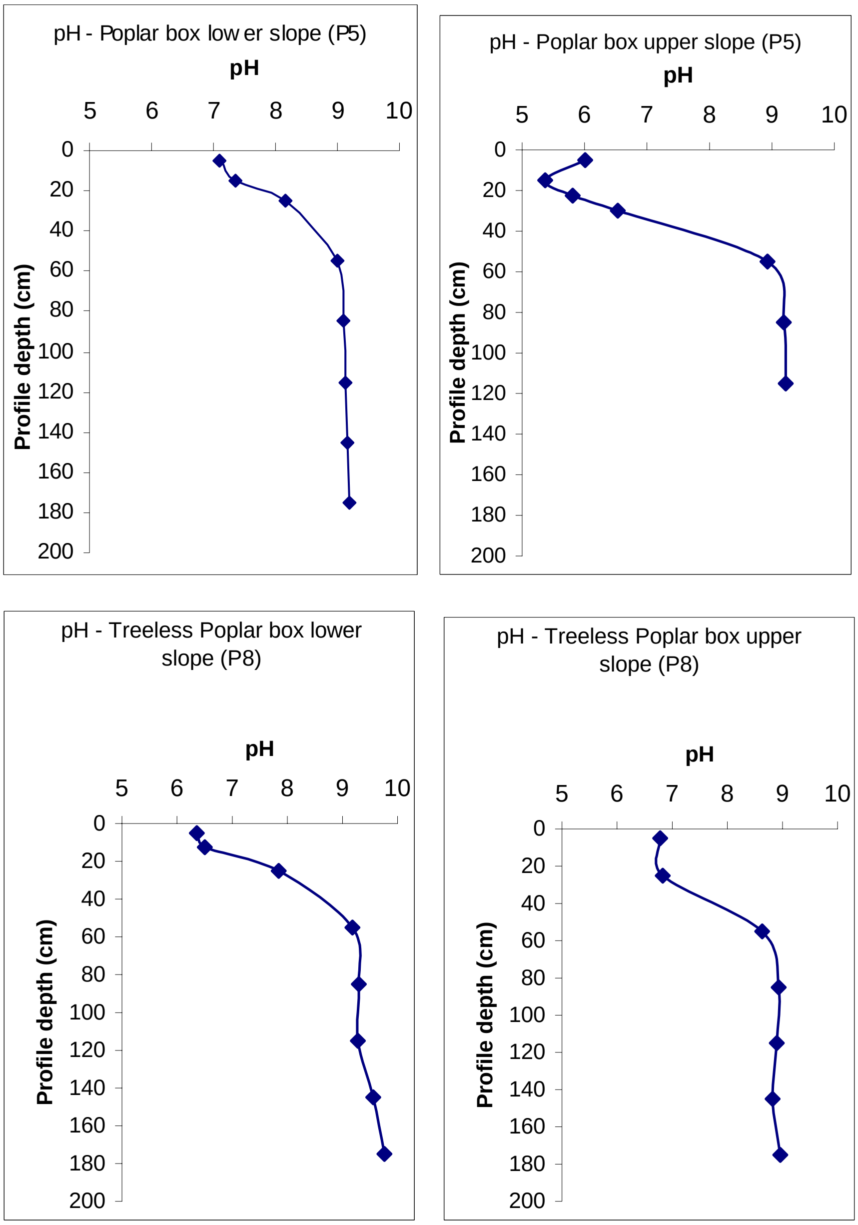


Figure 9.36 Soil profile pH in treed (P5) and treeless (P8) poplar box native pastures at lower and upper slope positions in May 2002.

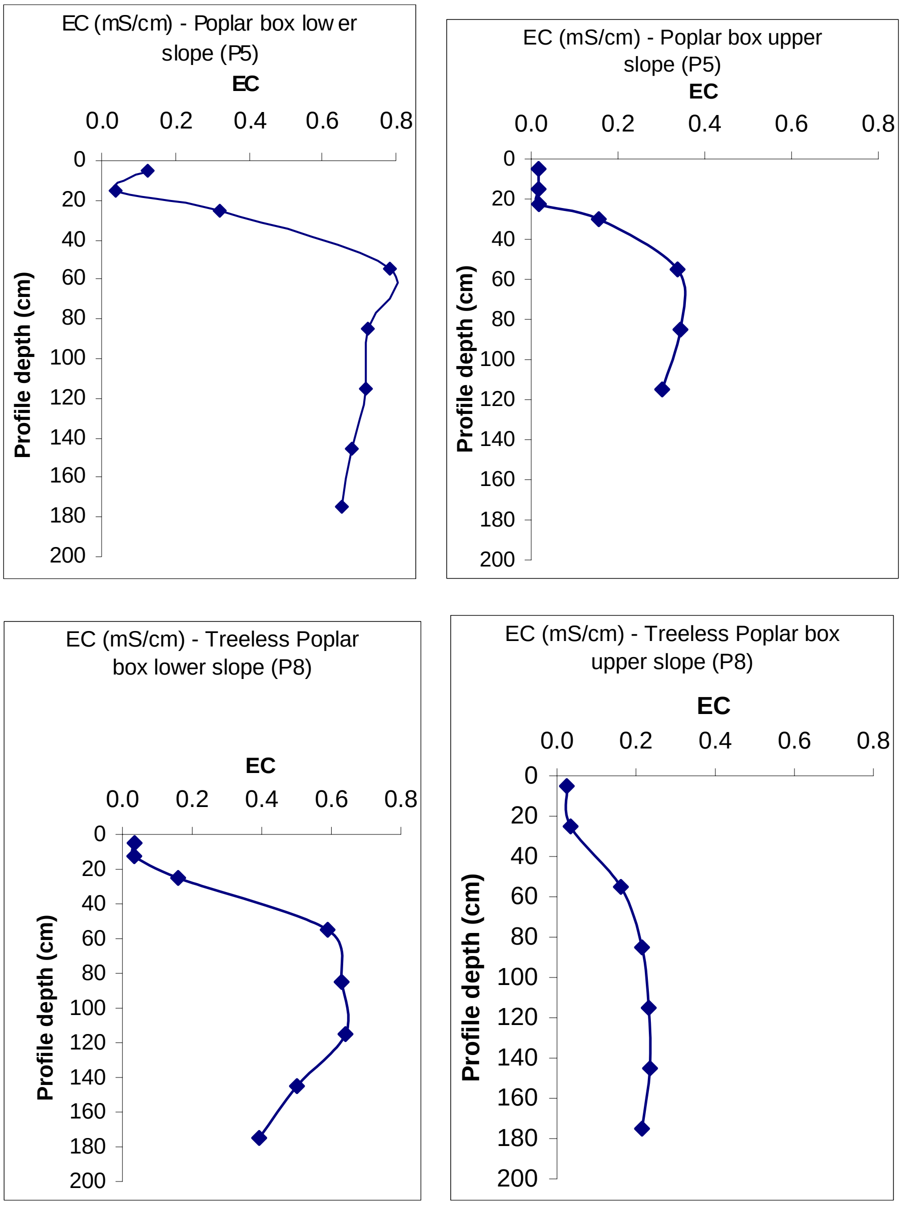


Figure 9.37 Soil profile electrical conductivity (EC) in treed (P5) and treeless (P8) poplar box native pastures at lower and upper slope positions in May 2002.

There are significant levels of salt at depth in the lower parts of the poplar box landscape, irrespective of tree cover

9.8 Soil surface carbon changes at the poplar box site

Excessive cropping, grazing and erosion of soils reduce the levels of soil organic matter, particularly in the surface layers. Such organic matter plays a major role in maintaining soil structure, porosity and fertility. If our differing grazing management treatments were detrimental or beneficial to the accretion of soil organic matter, then this should be measurable via standard laboratory methods (Dalal and Mayer 1986). However, the speed with which any change occurs is slow in grazed pastures and we have no prior data about the potential rate for our soil types. So we set out to derive some preliminary data on surface soil carbon changes that occurred as a result of the prolonged management differences imposed. Soil carbon is closely correlated with soil organic matter and both are related to total soil nitrogen levels.

9.8.1 Method

The soil surface of the 12 plots of the Burning trial and the 9 runoff plots of the Grazing trial was sampled over two depth intervals, 0- 2 cm and 0-10 cm, for various forms of carbon in November 2001, using a 50 mm corer. The centre post of each 1ha plot was used as the reference location for a sampling circle at the burning trial while an even grid was used to sample across the entire area of each runoff plot. A sample for analysis was bulked from 8–12 cores per location. The surface litter was brushed away to expose bare soil before sinking the corer. Litter was up to 10 cm thick after 7 years in the unburnt plots of the Burning trial. Only soil was sampled, with no loose litter included. All samples were analysed for carbon by 3 methods: organic carbon (%) (Walkley & Black), labile carbon (mg/kg) and LECO carbon (%), a recent high temperature furnace technique.

From the burning trial, each treatment mean reported is derived from 6 samples. For the runoff plots of the grazing trial, treeless means were from 6 samples (High, Medium and Exclosure with 2 reps of each), and treed means were from 3 samples (High, Medium and Exclosure). There were 3 ungrazed exclosures sampled.

9.8.2 Results

9.8.2.1 *Analysis method effect*

The LECO % carbon figures were consistently slightly higher than the W&B % organic carbon values for all treatments (Figure 9.38). Labile carbon was always much higher than the other two assays.

9.8.2.2 *Depth effect*

All 3 carbon forms were consistently higher for the 0-2 cm soil layer than from the 0-10 cm samples, across all treatments of both trial sites.

9.8.2.3 *Burning effect*

There were no differences in organic (W&B) and labile carbon between the ungrazed burnt and unburnt treatments for either the 0-2 cm or 0-10 cm cores (Figure 9.38). There was a marginally higher LECO carbon value in the burnt plots. The LECO carbon figures were higher than the organic carbon values and the labile carbon was greater again.

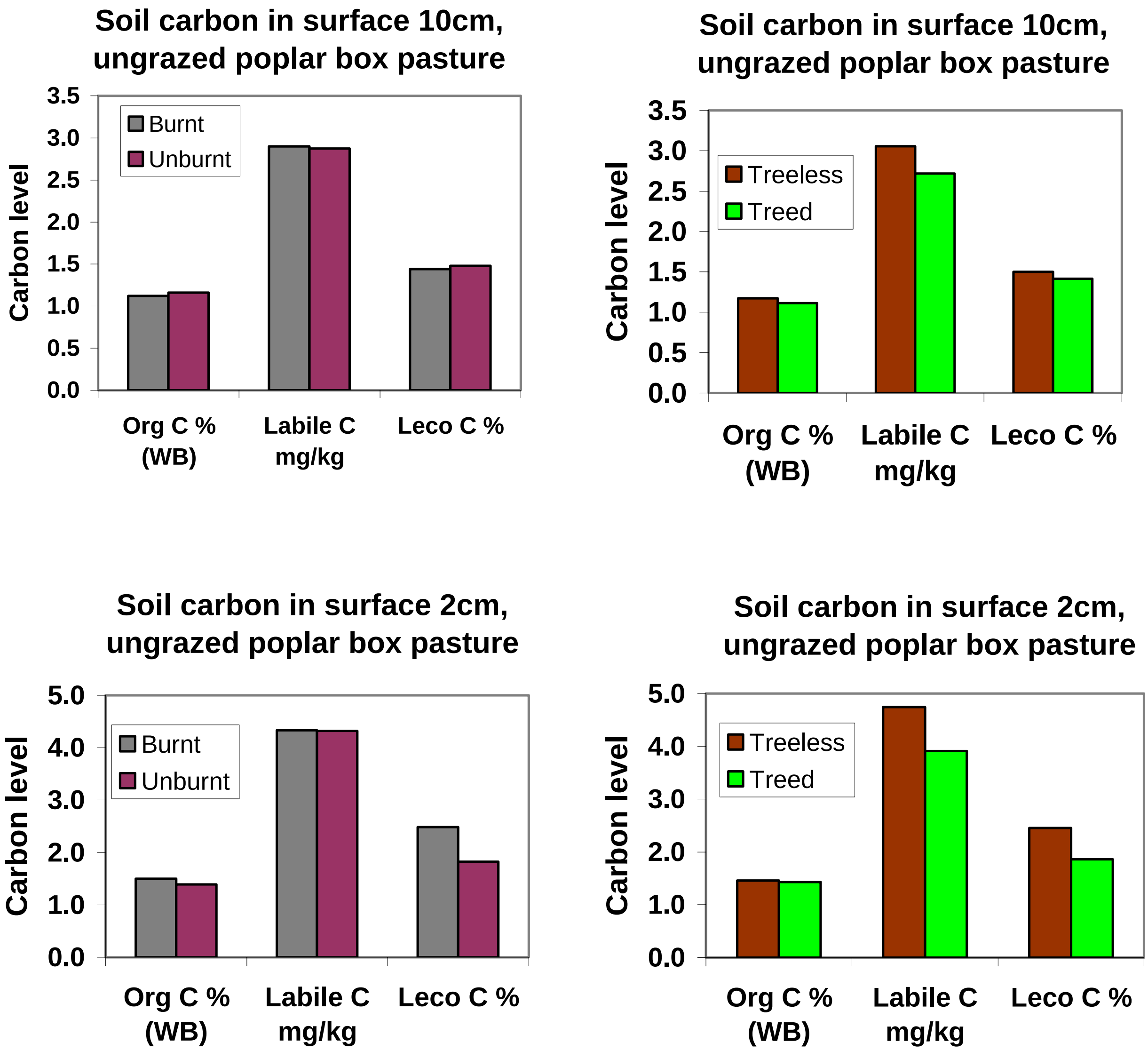


Figure 9.38 Carbon levels in the soil surface (0-2 cm or 0-10 cm) at the poplar box burning trial in 2001. Burning and tree killing effects were assayed by 3 different methods.

9.8.2.4 *Tree killing effect*

In the burning trial, there were similar values for organic carbon in both treeless and treed plots. However the labile and LECO carbon values were marginally higher in the treeless plots than in the treed plots (Figure 9.38). The opposite occurred in the runoff plots of the grazing trial. Consistently higher values, only marginally, were recorded for the 3 forms of carbon from treed paddocks than from the treeless paddocks for both depths (Figure 9.39).

9.8.2.5 *Grazing pressure effect*

The high grazing pressure treatments tended to have marginally higher soil carbon values than soil from the exclosures, for all 3 carbon forms at both depths, which in turn were marginally higher than the medium grazing pressure treatments (Figure 9.39). The mean carbon levels for both LECO and labile carbon analysis methods were marginally higher at the grazing trial than in the ungrazed burning trial.

Table 9.6 LECO and labile carbon (site means) at 0-10 cm depth, at the poplar box Burning and Grazing trial sites and on Mitchell grass downs at Roma

Carbon form	Burning trial	Grazing trial	Mitchell grass downs
Leco. C (%)	1.46	1.52	1.16
Labile C (mg/kg)	2.89	2.97	3.15

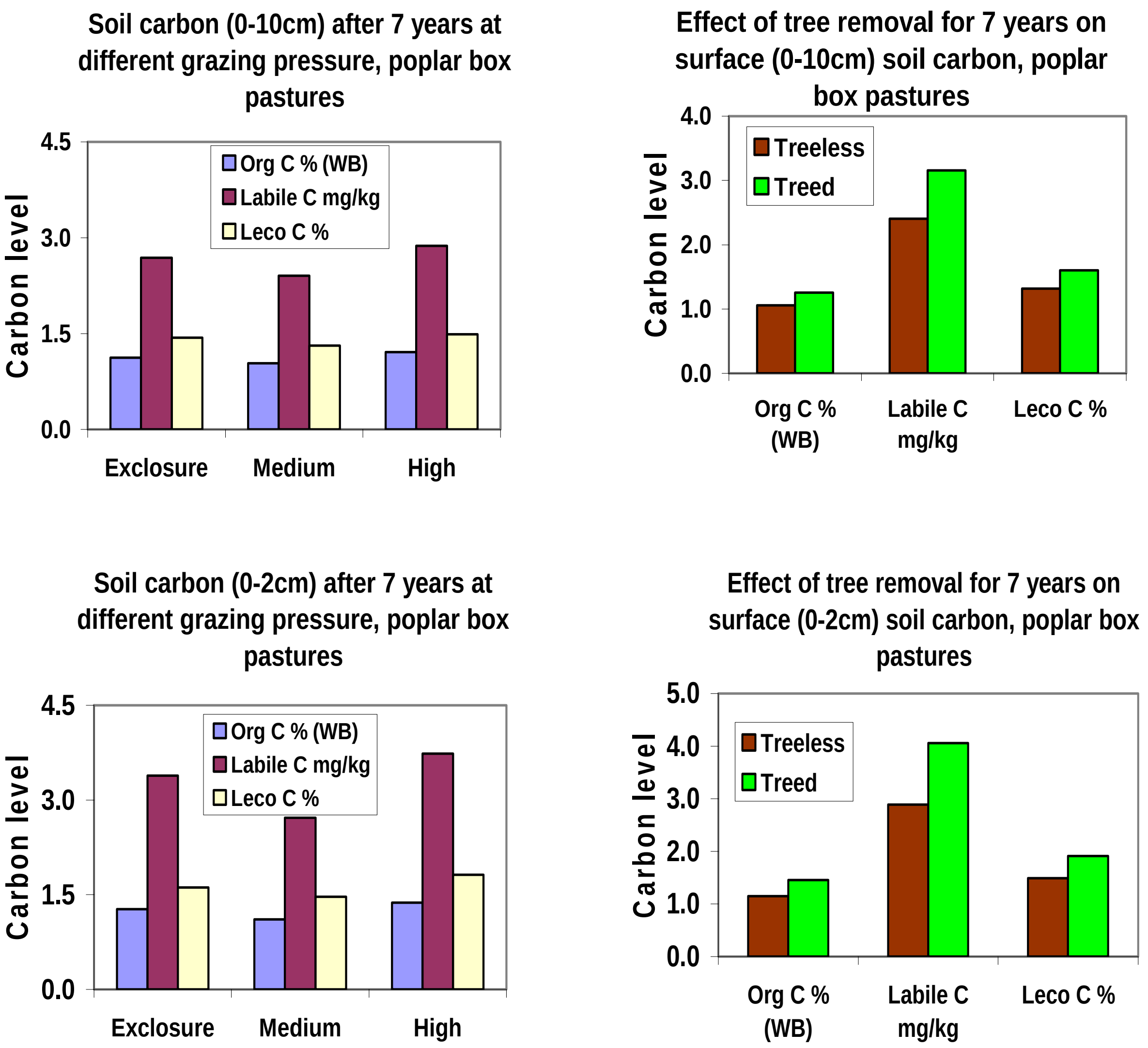


Figure 9.39 Carbon levels in the surface soil (0-2 cm and 0-10 cm) at the poplar box grazing trial in 2001. Grazing pressure and tree killing effects were assayed by 3 different methods.

9.8.3 Discussion

The sampling method removed all traces of organic matter from the surface soil, so only the bare soil was analysed. Removing the organic matter from sites with thick litter, to 10 cm deep, may also have removed several millimetres of humic soil, losing some carbon. In the burnt plots there was negligible litter at any site, so the very top of the surface soil was always included. At the Grazing trial, poplar box tree leaf litter would have contributed a significant amount of organic matter to the soil surface in the treed paddocks. Tree leaf litter of 1000 kg/ha was measured at one site in a treed paddock on one occasion (paddock 5, treed and medium grazing pressure). Despite pasture yields always being much higher in the treeless paddocks than in the treed paddocks, this didn't make a significant difference to the surface soil carbon after 7 years.

Any differences after 7 years in soil surface carbon due to pasture management were minimal. The 3 methods of analysing for soil carbon produced similar relative results for all treatments. However the results from LECO carbon were consistently higher than from the more commonly used W&B organic carbon method. The lack of significant treatment effects indicates that there was little additional organic matter incorporated into the surface soil during the 7-year trial period. In the Burning trial there were significant amounts of litter available (pasture yields to 7000 kg/ha), but there were no grazing animals to help break up this litter and to incorporate it into the soil. The marginally higher carbon in the high grazing pressure paddocks may have been from the heavier trampling pressure at these sites causing incorporation of some grass litter into the surface soil. The trend was consistent at both depths and for the 3 analysis methods. When the 6 ungrazed plots at the burn site are compared against the 3 ungrazed exclosures within the grazing trial paddocks, the burn site had a small but consistent advantage (Figures 9.38 & 9.39).

Both sites had higher LECO carbon levels than lightly grazed Mitchell grass downs at Roma, while the labile carbon levels at both sites were lower than on the cracking clay downs soil (Table 9.6). The contradictory results for the effect of tree killing at grazed and ungrazed sites pose interpretation difficulties. It also indicates that intensive sampling will be required to identify significant trends in surface soil carbon levels in grazing lands. Sampling to account for surface litter, which eventually becomes incorporated in the surface, needs to be considered.

10 Management Implications

A prior project (DAQ.090) had produced interim State and Transition management models (Westoby *et al.* 1989) for the two tree communities (Silcock *et al.* 1996) and a general *Aristida/Bothriochloa* community model based on visual evidence had been published (Hall *et al.* 1994). We will base our discussions around those models.

10.1 Silver-leaved ironbark country

10.1.1 State and Transition model

The published general A/B country model of Hall *et al.* was based on the existence of clearly delineated pasture 'States' but that was rejected in the DAQ.090 report as inappropriate for silverleaf ironbark vegetation of the Peakvale land system, based on further evidence that was available 3 years later (Silcock *et al.* 1996). The revised concept was for 3 pasture states, all with significant tree cover and a varying content of desirable and undesirable pasture species (Figure 10.1). A treeless state was considered unstable and always returning to woodland, at a rate influenced by fire frequency, seasonal extremes and grazing management. We would envisage that the undesirable State 3 pasture would often be like the town common of mining communities in the Central Highlands with obvious erosion, low cover and dominated by indian couch and five-minute grass. As such it would equate to Land Condition D of the Qld Grazing Land Management (GLM) package. Figure 10.2 shows examples of these 4 land conditions.

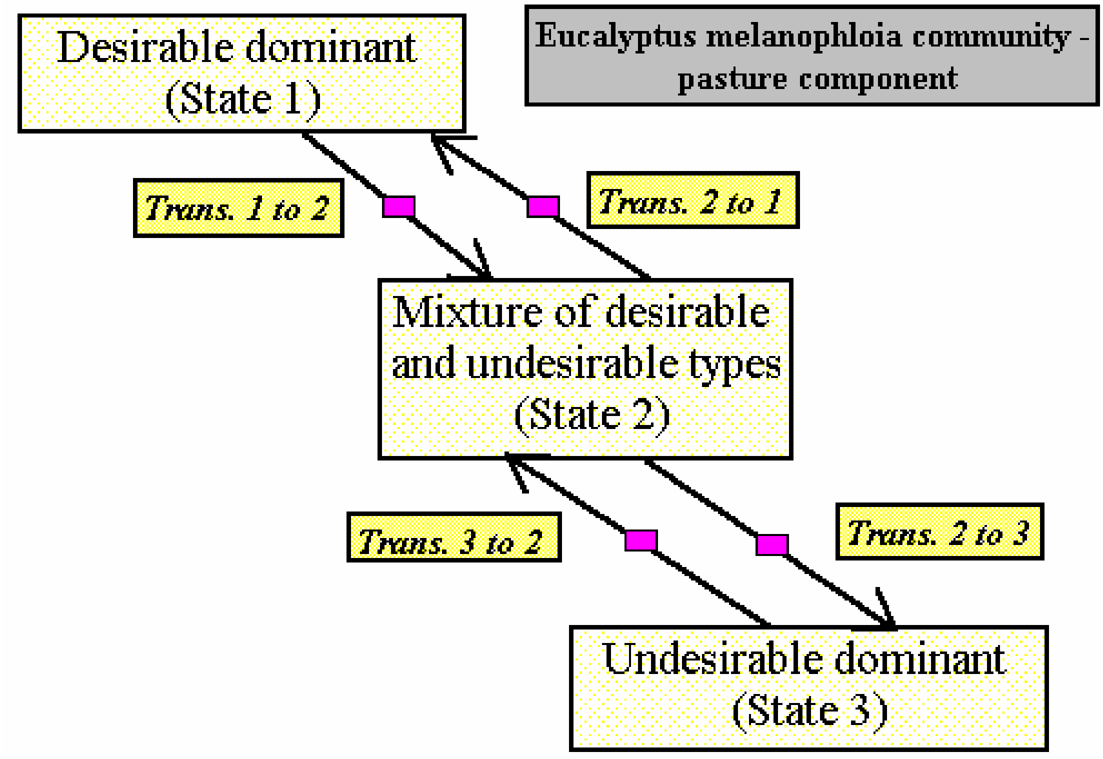


Figure 10.1 State and Transition model for Central Qld silverleaf ironbark country (from Silcock *et al.* 1996).

However, if recently cleared of mature trees and stick raked and burnt, the pasture could have much less of those two grasses and have some forest mitchell and black speargrass and be classed as C land condition. Wiregrasses are not common in State 3 but occur in State 2 pastures in moderate amounts (Figure 10.2(B)). Woody shrubs such a currant bush may be common in States 2 & 3 (Figure 10.2(C)). Thus there is no direct link between States in the State & Condition model concept and Land Condition as described in the GLM package. State 2 also has less gully erosion but would have some evidence of sheet erosion in the open spaces between grassy patches. It would equate to Land Condition B or C in the Qld GLM system (Chilcott *et al.* 2004).

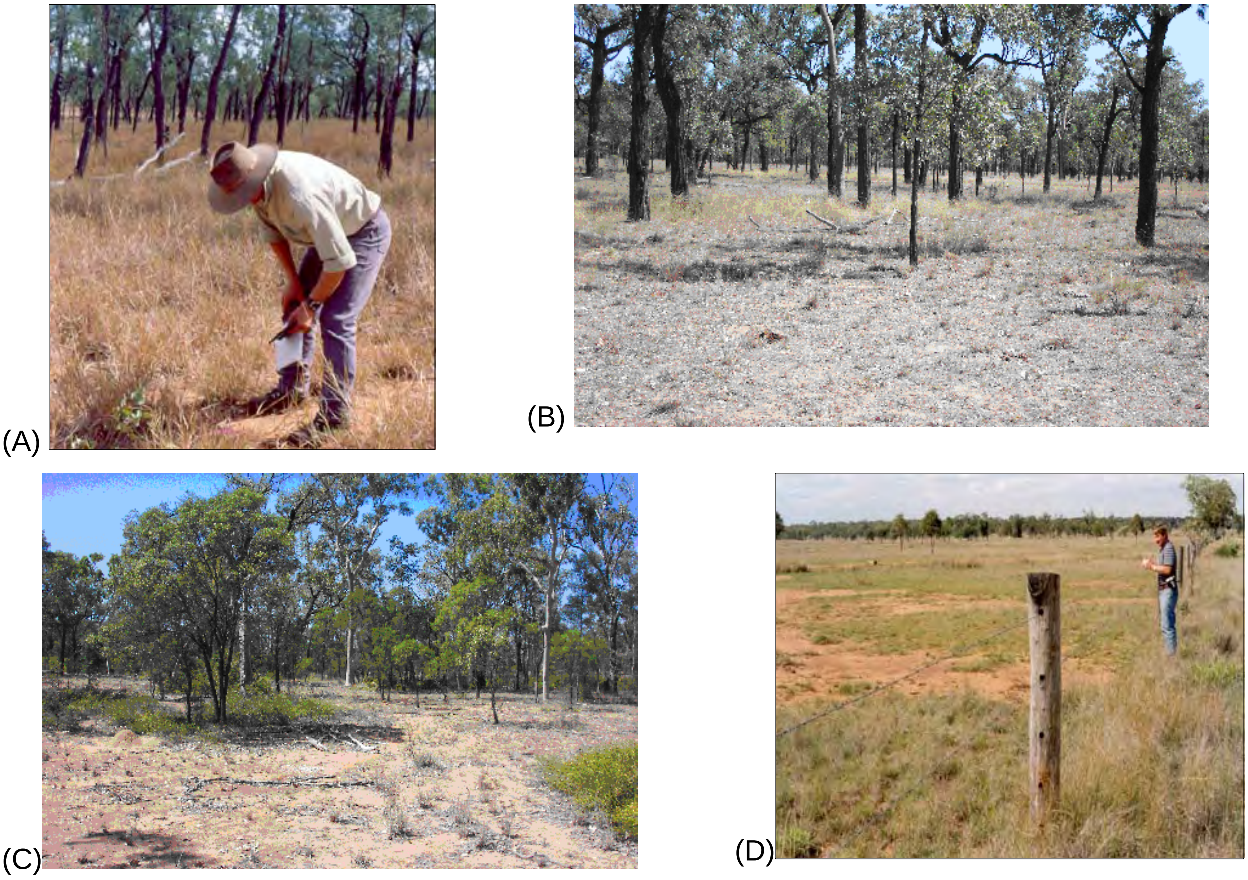


Figure 10.2 Examples of grazing land in condition states A, B, C and D.

State 1 would encompass land condition A and B in that pasture composition is quite good with varying degrees of woody weeds &/or some sheet erosion. If the proportion of wiregrasses was above 10% or the woody weeds were clearly visible, then it would be B condition. Our research would suggest that it is difficult to quickly alter the composition of the perennial grasses by grazing management alone but seasonal extremes may change the presence of black speargrass quite quickly. It dies out quite rapidly in a severe drought.

Another factor that seems to be triggered by severe drought is death or ill-thrift of silverleaf ironbark trees. At the ironbark site, protracted ironbark ill-thrift seemed to follow the 1992-94 drought, while around Charters Towers significant death of these trees occurred, yet bloodwoods (*Corymbia* spp.) survived (Fensham & Holman 1999). The cause of the tree ill-thrift is not known and may involve subsoil salt toxicity or root pathogens or canopy ill-health of some inconspicuous kind. Vigorous pasture growth and regular spring fires seemed to prolong this ill-thrift at our trial site more than normal grazing management (Figure 6.39 vs. Figure 6.3).

The lack of major pasture response to killing the trees with Velpar was a big surprise and we are at a loss to explain a 60% improvement in animal production due to tree killing (Figure 7.4), suggesting an improved quality in the animal's diet when there was negligible pasture yield improvement, and pasture sampling does not show any change in pasture species composition. We have no pasture chemical analyses from this site to aid our deliberations.

10.1.2 Putting pasture plants into management categories

On the basis of 7 years research, we would rate the recorded pasture plants on the Peakvale land system into the QGraze, GrassCheck and allied management categories in Table 10.1.

Table 10.1 Main ironbark site pasture species grouped by management category.

Category	Species or species group
Decreaser perennial grasses	*Bothriochloa bladhii, B. ewartiana, Dichanthium sericeum, D. setosum*, Heteropogon contortus, Themeda triandra*
Intermediate perennial grasses	*Capillipedium parviflorum, Cenchrus ciliaris, Cymbopogon bombycinus, Cymbopogon refractus, Dichanthium tenue, Digitaria ammophila, Digitaria brownii, Digitaria didactyla, Digitaria longiflora, Enneapogon clelandii, Enneapogon polyphyllus, Enneapogon truncatus, Enneapogon virens, Eremochloa bimaculata, Eriachne mucronata, Eriochloa procera, Eriochloa pseudoacrotricha, Eulalia aurea, Leptochloa decipiens, Panicum decompositum, Paspalidium caespitosum, Paspalidium constrictum, Paspalidium jubiflorum, Sehima nervosum, Sporobolus actinocladus, Sporobolus caroli, Sporobolus elongatus var. creber, Themeda avenacea, Triraphis mollis*
Increaser perennial grasses	*Aristida calycina var. calycina, Aristida calycina var. praealta, Aristida gracilipes, Aristida holathera var. holathera, Aristida ingrata, Aristida jerichoensis, Aristida latifolia, Aristida lazarides, Aristida leptopoda, A. perniciosa, Aristida schultzii, Bothriochloa pertusa, Chrysopogon fallax†, Eragrostis brownii, Eragrostis elongata, Eragrostis leptocarpa, Eragrostis molybdea, Eragrostis sororia, Eragrostis sterilis, Eragrostis tenuifolia, Panicum effusum†, Tripogon loliiformis*
Increaser annual & weakly perennial grasses	*Brachiaria whiteana, Chloris divaricata, C. inflata, C. pectinata, C. truncata, C. virgata, Dactyloctenium aegyptium, Dact. radulans, Digitaria ciliaris, D. parviflora, Echinochloa colona, Eleusine indica, Enneapogon gracilis, Eragrostis cilianensis, E. lacunaria, E. parviflora, Iseilema vaginiflorum, Melinis repens, Oxychloris scariosa, Perotis rara, Sporobolus australasicus, Tragus australianus*
Forbs	*Parthenium hysterophorus*#*, Abutilon oxycarpum, Achyranthes aspera, Aeschenomene brevifolia, Alternanthera denticulata, A. micrantha, A. nana, Alternanthera species, Amaranth species, Amaranthus viridis, Bidens bipinnata, Boerhavia paludosa, Boerhavia species, Brassica species, Brunoniella australis, Brunoniella species, Calotis lappulacea, Calotis squamigera, Camptacra barbata, Cassia concinna, Chamaecrista mimosoides, Cheilanthes distans, Cheilanthes sieberi, Cheilanthes species, Chenopodium carinatum, Chenopodium species, Chrysocephalum apiculatum, Conyza albida, Crotalaria medicaginea, C. montana, Crotalaria species, Desmodium brachypodum, Desmodium campylocaulon, D. varians, Dianella spp, Einadia polygonoides, Epaltes australis, Euphorbia prostrata, Euphorbia species, E. tannensis, E. wheeleri, Evolvulus alsinoides, Evolvulus species, Glycine clandestina, Glycine species, Glycine tabacina, Gnaphalium species, Gomphrena celosioides, Gomphrena species, Goodenia glabra, Goodenia species, Grewia retusifolia, Heliotropium strigosum, Hibiscus species, Hibiscus sturtii, Hybanthus enneaspermum, Hybanthus species, Hypoxis geometrica, Indigofera brevidens, I. colutea, I. hirsuta, I. linifolia, I. linneai, I. polygaloides, I. pratensis, Indigofera species, Malva species, Malvastrum americanum, M. coromandelianum, Melhania oblongifolia, Oxalis coniculata, Oxalis species, Phyllanthus maderaspatensis, Phyllanthus species, Physalis spp, Plantago species, Polycarpaea corymbosa, Polycarpaea species, Polygala linariifolia, Portulaca filifolia, Portulaca oleracea, Portulaca species, Psoralea australasica, Pterocaulon species, Rhynchosia minima, Rostellularia adscendens, Ruellia species, Salsola kali, Sclerolaena bicornis, S. birchii, S. muricata var. villosa, Sclerolaena species, Senecio species, Senna occidentalis, Sesbania species, Sida atherophora, S. fibulifera, S. pleiantha, Sida species, S. spinosa, S. subspicata, S. trichopoda, Solanum americanum, Solanum ellipticum, Solanum nigram, Solanum species, Sonchus species, Spermacoce species, Spermacoce spp, Tephrosia filipes, Tephrosia purpurea, Tephrosia species, Tribulus terrestris, Vernonia cineria, Vittadinia pustulata, Vittadinia species, Wahlenbergia granitica, Wahlenbergia species, Wedelia spilanthoides, Zornia muriculata var. angustata, Zornia species*
Sedges & others	*Cyperus bifax, C. concinnus, C. fulvus, C. iria, C. javanicus, C. polystachyos, Empodisma minus, Fimbristylis dichotoma, F. ovata, Scleria mackaviensis,* Cyperus spp., Lilies, Sedge

* indicates a rare species with conservation value [#] means a serious weed

† These species have a complex response to grazing. They increase in gaps in natural pastures under moderate to heavy grazing pressure because they have good recruitment capability. But then, because they are palatable, they decline at very heavy grazing pressure because their recruitment capability is exhausted.

10.1.3 Other notes on managing silverleaf ironbark country on gritty red solodics

- Broadscale clearing or killing of silver-leaved ironbark trees using commercial methods in the open woodlands of the Central Highlands is likely to result in a massive ironbark seedling regrowth explosion that will soon reduce pasture growth.
- Though the concept of 3P grasses is a valuable management guide, other shorter-lived perennial grasses can be extremely important for animal production and surface soil cover, e.g. slender chloris and golden-beard grass.
- The gritty, red duplex soils of the Peakvale Land System around Rubyvale are very prone to sheet erosion, so keep at least 40% ground cover on such land.
- Within 7 years, land condition can change from A (top) condition to B (slightly degraded) and return to A again, purely as the result of grazing pressure changes.

10.2 Poplar box country

10.2.1 State and Transition model

For poplar box country, our more recent/continued research has largely confirmed that the State & Transition model of Hall *et al.* (2004) is still appropriate (Figure 10.3). It is possible to have A condition land in both of States1(Woodland) and 3(Grassland +/- scattered trees or shrubs) as well as well as B, C and D condition land in both these 'states', depending on the extent of gully erosion and often the understorey woody shrub density. The cropping State falls outside the GLM pasture/land condition framework but is an important step in the establishment of sown pastures based on buffel grass and annual medics on more fertile soils.

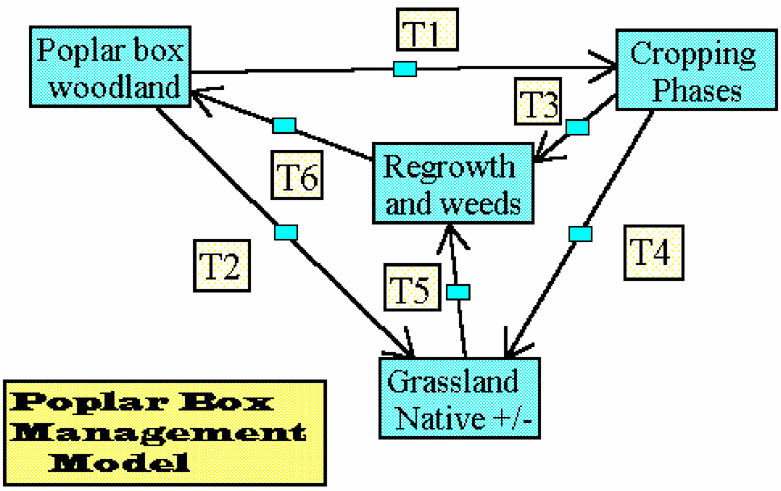


Figure 10.3 State and Transition model for central Qld poplar box country (Silcock *et al.* 1996).

The regrowth and weeds state (State 4) would never achieve A land condition because of the density of undesirable pasture plants. However, that state is rarely likely to reach D land condition because the soil fertility is high enough to allow intervention of cropping or stick-raking plus sown pasture, to retrieve a degrading pasture. Figure 10.2(D) shows example of D condition where cultivation has brought sodic subsoil to the surface of a very shallow duplex box soil.

Pasture condition is potentially very diverse on these soils but wiregrasses are a significant component that require management. The local solution to excessive wiregrass is to plough up the paddock and go through a crop phase or sow it after to buffel grass/barrel medic pasture. Spring burns are also used to gain some grazing from dense purple wiregrass (*A. ramosa*) on alluvial flats. As our research shows, this does not kill this wiregrass species but does open up the pasture to allow other more desirable species to flourish if grazing pressure is moderate. Under light grazing such species can include kangaroo grass and Qld bluegrass. On the very sandy extreme of this land type, cypress pine regrowth is a common problem that is easily overcome via a controlled hot fire in early summer.

Such burns will not kill established box suckers or saplings, so their management in the long term has either to be addressed very early (<30cm tall) or after decades via another tree clearing operation. If there are no parent box trees left and few suckers re-establish immediately after clearing, then it is unlikely that poplar box will regenerate other than at the edges of well-cleared land. This is because seeds of poplar box will not persist in the soil for more than a few months and it cannot blow in far on the wind (50 metres maybe). Seeds may be carried a short distance by ants and could possibly be washed downslope from timbered ridgelines by heavy rains. However, how far overland flow will carry tiny poplar box seeds is unknown. Because it does not set seed till at least 5-7 years old and does not flower every year, some effort to follow when or if seed is set could be rewarding. Seed often ripens in mid-summer and falls very quickly out of the open, ripe but still green capsules. Producers could then watch for seedlings in the next 6 months and if they find none, the potential crisis has been averted.

Poplar box seed, like that of silverleaf ironbark and many other inland eucalypts, will germinate at any time of year but seedlings are susceptible to fire, crash grazing and strong grass competition. So there are a number of ways to suppress them, if they emerge. They are easiest to see when amongst dry or frosted grass.

10.2.2 Categories for poplar box pasture species in the Injune area

On the basis of our research, we would place the main box pasture species from duplex clay loam soils into the following groups for QGraze, GrassCheck and other pasture classification studies (Table 10.2).

Table 10.2 Main Injune district poplar box pasture species grouped by management category.

Category	Species or species group
Decreaser perennial grasses	*Bothriochloa bladhii, B. ewartiana, Dichanthium sericeum, D. setosum *, Heteropogon contortus, Themeda triandra, Urochloa* spp.
Intermediate perennial grasses	*Bothriochloa decipiens, Cenchrus ciliaris, Chloris divaricata, Chloris* spp., *Cymbopogon refractus, Digitaria divaricatissima, Digitaria* spp., *Enneapogon* spp., *Enteropogon acicularis, E. ramosus, Eriochloa pseudoacrotricha, Eulalia aurea, Panicum* spp., *P. decompositum, Paspalidium* spp., *Sporobolus* spp. (small), *Stipa scabra*
Increaser perennial grasses	*Aristida calycina, A. lazarides, A. latifolia, A. leptopoda, A. ramosa, Aristida* spp., *Chrysopogon fallax†, Cynodon dactylon, Eragrostis* spp., *E. molybdea, E. sororia, Panicum effusum†, Tripogon loliiformis*
Increaser annual & weakly perennial grasses	Annual grasses, *Brachiaria* spp., *Digitaria ciliaris, Eragrostis lacunaria, Tragus australianus*
Forbs	Asteraceae (daisy), *Brunoniella australis, Calotis* spp., Chenopodaceae, *Euphorbia / Phyllanthus*, Ferns, *Hibiscus sturtii*, Legume – palatable, Legume – unpalatable, *Maireana* spp., *Malvastrum americanum, Parthenium hysterophorus*#, *Pimelea trichostachya*#, *Portulaca* spp., *Ptilotis* spp., *Rhynchosia minima, Rostellaria adscendens, Salsola kali, Sclerolaena birchii, Sclerolaena* spp. *Sclerolaena muricata, Sida* spp., *Sida subspicatum, Solanum* spp., Succulents, *Verbena tenuisecta, Vittadinia* spp., *Xanthium* spp.#
Sedges & others	*Cyperus* spp., *Fimbristylis dichotoma*, Lilies, *Lomandra* spp. (rushes), Sedges

* indicates a rare species with conservation value # means a serious weed

† These species have a complex response to grazing. They increase in gaps in natural pastures under moderate to heavy grazing pressure because they have good recruitment capability. But then, because they are palatable, they decline at very heavy grazing pressure because their recruitment capability is exhausted.

10.2.3 Other dot points about managing poplar box country in the Injune district

- Killing trees produced a major increase in pasture growth on the poplar box country but very little increase on the silver-leaved ironbark country.
- A dramatic change in stocking rate will not, in the short term, always cause rapid change in pasture composition despite a big change in available forage.
- Extreme seasonal rainfall can produce big changes in the species makeup of pastures, independent of recent grazing pressure.
- Spring burns do not appear to reduce wiregrass populations.

10.3 Animal turnoff options

Policy makers, banks, rural investors and industry lobby groups all want to know how productive, profitable and potentially degrading grazing enterprises are on different classes of country. Like all businesses, each property has something that differs from its neighbour and competitor, so no analysis is appropriate for all needs. However, a few examples do paint a picture that can be useful. By having 6 different treatments in our trial, we are able to offer direct comparisons between the main effects of tree control and grazing pressure, plus their interaction, on the rate of growth of weaner steers.

The values ascribed to the beef grown are for illustration purposes only, but are typical of recent years in the region. The market scenarios are likewise indicative only, as each processor has their own market niche and individual properties find it easier to sell to certain markets or processors. We do not attempt to make any comment about breeding enterprises because our data is from steers.

Generally we do not attempt to make judgements on whether it is better to sell or buy or hold existing stock in a particular market or seasonal situation. Rather we emphasise the marginal effect of undertaking our grazing management options when a producer is considering a range of marketing options. Likewise we do not attempt to model typical year-to-year seasonal variation because, in the short term (7 years), the final result will depend on whether there was an extreme year and whether the project 7 years will occur again in that sequence over any future 7 year period.

10.3.1 Our project findings on the marketing implications

There are several ways to assess the implications of our animal production studies in business terms. Many external factors such as wars, trade tariff changes, industrial disputes and health scares such as foot-and-mouth disease can dramatically alter the volume of beef sales in Australia. Seasonal meatworks closures also limit selling opportunities in December and January in northern Australia.

For the following set of scenarios, the following is assumed –

- animals weigh 180kg when weaned in April at 6 months of age, and
- over the winter and summer seasons these animals grow at the rates shown in Table 10.3 under the different management regimes (typical of our trials).
  [Note: The ironbark site animals that we used were usually about 240kg and weaned at 9 months in late July]

Table 10.3 Assumptions made for the discussions that follow. They apply after weaning to both locations, except for the poplar box tree cover scenarios.

Grazing regime	Gains over 6 winter mths (May–Oct) (kg)	Gain per mth over summer (Nov–Apr) (kg)	Months for steers to reach 300kg	Months for steers to reach 400kg
Grazing pressure				
Low	33	20	16	27
Medium	30	17.5	17	28
High	18	16	25	29
Box tree cover*				
Treed	21	16.5	18	29
Treeless	38	18.5	17	27

* Averaged over all grazing pressures .

Based on the assumptions in Table 10.3, Table 10.4 shows the likely age at which steers would reach certain liveweights, and thus particular market requirements, under a range of grazing management. The Korean P1 market (See Table 10.5) seems the most problematic to meet if seasonal conditions change unexpectedly. The domestic young animal market seems least sensitive to grazing management, provided the animals reach 300kg before mid-winter. Should they fail, then they are at risk of a hard, frosty winter which could cause them to loose weight rather than gain slowly. The Jap ox market for older animals shows clearly why Queensland producers use it as a fall-back market if they cannot achieve good growth with younger animals.

The 3 most common market scenarios are as follows -

1. The first is where the producer is growing animals to the requirements of different markets. This requires animals to be in a certain weight range at a certain age, judged by the number of adult teeth.

Grazing management differences did not impinge markedly on the ability to meet these targets except with very young animals aiming for 300kg liveweight. Running weaners at high grazing pressures on native pastures alone will preclude the achievement of 300 kg liveweight before the second winter sets in and those animals would have to be held over until the end of the next summer (Table 10.4).

2. The second scenario is that of a forced sale at, say, 2 years of age (end of October) after a fair summer but a very poor winter and with an El Nino (dry) summer forecast. Liveweight at sale would range from 315 kg for animals from high grazing pressure paddocks to 375 kg (Tables 10.5 and 10.6) for those from low grazing pressure paddocks. A moderate tree cover on poplar box country would see a differential of 45 kg in animal weights compared to treeless country, based on our data and using our method for setting stocking rates.

Table 10.4 Age at which steers from A/B country, run under differing management scenarios, would reach the minimal weight standards for various markets (months rounded up).

Grazing	Age (months) at which various target liveweights are reached			
Management	***300 kg***	***375 kg***	***400 kg***	***500 kg***
Low	16	26	27	37
Medium	18	27	28	39
High	25	28	30	42
Poplar box				
Treed	18	28	29	40
Treeless	17	26	27	37

3. A third scenario is that of selling animals of various "size-for-age classes" (Table 10.4) to feedlot back-grounders or restockers as either –

around 300kg at 16 to 18 months of age, or

around 400kg at 2 to 2.5 years of age.

In this case, the lighter the recent grazing pressure, the earlier the animals would have reached the target weight and the greater their probable fat score, and hence value per kg. There will always be a tail to any mob, so meaningful comparisons within this scenario are hard, but the proportion in the 'tail' is likely to be greater at the higher grazing pressure. Each step up in grazing pressure tended to delay by 1 to 2 months the date at which 300kg was reached, as did tree cover compared to treeless land. To reach 400kg, the interval tended to blow out to 2-3 months at high grazing pressure or where trees were competing with the pasture in poplar box country. In each case, the onset of winter did not markedly affect the outcome, but in certain circumstances, failure to achieve a market weight by May could delay sale by 7-8 months (Table 10.4) and possibly even deny access to that target market later, on the basis of age.

Some specific calculations are also done for each trial site based on the exact animals and growth rates that we recorded (Tables 10.5 and 10.6). In these two tables, there is also a wet years scenario which takes into account the much improved winter growth that will occur when green pasture is available for much of the winter. These conditions are likely to occur during and after La Nina (wet) summers and when good autumn or spring rains fall. Under those conditions, animals are able to continue to put on weight all winter and thus catch up by at least 6 months on planned marketing times. Other examples of potential weight/age relationships for animals under different starting or growing situations are given in Appendix M.

All our research and calculations have been based on weaner steers. Young heifers normally grow slightly slower than steers and weight gains for them would be less. We believe that they would be 30 kg lighter at weaning, have about 75% of the growth rate of steers in the first year thereafter and then 90% of steer growth rate in the second year after weaning.

A most important scenario from a sustainable grazing management perspective is to look at the marginal benefit gained from increasing the stocking rate from one management regime to another or from clearing trees. This will be done in the Economics section (Section 10.5) rather than here because other issues relating to sustainable land management as well as economics and attitude to risk are involved.

One point that should be stressed is our lack of robust data to show that fully grown animals gain and loose weight at similar rates to weaners on the same level of feed quality. There is a perception that young animals of around 250kg grow relatively better on scarce feed than nearly finished animals of 400kg because they have less tendency to lay down fat which is more energy rich per kilogram than muscle and connective tissue. If that is so, our predictions for winter weight gains or losses for 3-4 year old steers may be overly optimistic in Tables 10.5 and 10.6.

Table 10.5 Times for typical brahman-cross steers to reach various weights and market specifications, based on the ironbark site data.

Scenario	Start Wt 205kg	Start Date 1-Aug		Year 1				Year 2				Year 3				Year 4			
			1-Aug	1-Nov	1-Feb	1-May	1-Aug	1-Nov	1-Feb	1-May	1-Aug	1-Nov	1-Feb	1-May	1-Aug	1-Nov	1-Feb	1-May	1-Aug	1-Nov
		Age mths	9	12	15	18	21	24	27	30	33	36	39	42	45	48	51	54	57	60
	LWT gain/yr																		
Wet yr	221		205kg	227	294	375	426	448	515	596	647	669	736	$						
Low GP#	152		205kg	210	260	324	357	362	412	476	509	514	564	628	661	666	716	$		
Med GP	136		205kg	206	252	312	341	342	388	448	477	478	524	584	613	614	660	720	$	
High GP	113		205kg	200	241	295	318	313	354	408	431	426	467	521	544	539	580	634	657	652
	Time since wean		0	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48	51
	Adult teeth							2	2	4	4	6	6	6	8	8	8			
	Age (mths)		9	12		18		24		30		36		42		48		54		60

= Low grazing pressure (GP) in a year with average seasonal conditions

Base Data

Ironbark site		Liveweight gain (kg) **Scenarios**		
3mth period	Wet	Low	Med	High
1/8-31/10	22	5	1	-5
1/1-31/1	67	50	46	41
1/2-30/4	81	64	60	54
1/5-31/7	51	33	29	23
Total	221	152	136	113

Grassfed steers	**Age / teeth**	**LWt range (kg)**
Domestic	12-24	300-450
Korean P1	< 42	490-580
Jap grassfed	> 36	530-750
Feeders -Jap short feed	20-30 / 2	400-450
Feeders - Dom 70d feed	26-33	420-480
Feeders - Hotel 60-100d fed	-	240-310
Feeders	< 15	300-430

Note: Colours surrounding monthly liveweights in the upper half of the table match those highlighting the various target markets shown in the lower section.

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Table 10.6 Times for typical brahman cross steers to reach various weights and market specifications, based on poplar box site data.

Start Wt	Start Date																			
180kg	1-May		Year 1			Year 2				Year 3				Year 4				Year 5		
		1-May	1-Aug	1-Nov	1-Feb	1-May	1-Aug	1-Nov	1-Feb	1-May	1-Aug	1-Nov	1-Feb	1-May	1-Aug	1-Nov	1-Feb	1-May	1-Aug	1-Nov
	Age - mths	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48	51	54	57	60
Scenario	**LWT gain/yr**																			
Wet year	185	180kg	223	233	290	365	408	418	475	550	593	603	660	735 $						
Low GP#	153	180kg	215	219	268	333	368	372	421	486	521	525	574	639	674	678	727 $			
Med GP	135	180kg	210	210	255	315	345	345	390	450	480	480	525	585	615	615	660	720 $		
High GP	114	180kg	205	200	240	294	319	314	354	408	433	428	468	522	547	542	582	636	661	656
Treed	121	180kg	203	201	241	301	324	322	362	422	445	443	483	543	566	564	604	664	687	685
Treeless	148	180kg	213	218	263	328	361	366	411	476	509	514	559	624	657	662	707 $			
	Time since weaned	0	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48	51	54
	Adult teeth						2	2	4	4	6	6	6	8	8	8				
	Age (mths)	6	9	12		18		24		30		36		42		48		54		60

= Low grazing pressure (GP) in a year with normal seasonal conditions

Base

Data

Poplar box site	Liveweight gain (kg)					
			Scenarios			
3mth period	Wet	Low	Med	High	Treed	Treeless
1/5-31/7	43	35	30	25	23	33
1/8-31/10	10	4	0	-5	-2	5
1/11-31/1	57	49	45	40	40	45
1/2-30/4	75	65	60	54	60	65
Total	185	153	135	114	121	148

Grassfed steers	**Age / teeth**	**LWt range (kg)**
Domestic	12-24	300-450
Korean P1	< 42	490-580
Jap grassfed	> 36	530-750
Feeders - Jap short feed	20-30 / 2	400-450
Feeders - Dom 70d feed	26-33	420-480
Feeders–Hotel 60-100d fed	-	240-310
Feeders	< 15	300-430

10.3.2 Management actions involving cattle marketing strategies

Beef producers do have some predictive capacity about seasonal market prices but they are more relative than actual. Unfortunately they have no control over rapid overseas market changes induced by consumer anxiety or international and regional financial market collapses, e.g. Asia 1997-99. Hence our marketing extrapolations are constrained by those unpredictabilities.

Every property manager has to decide how the animals are managed and what marketing strategy is employed. Because disposing of stressed rangeland stock involves appreciable effort to muster and then transport them, it is often easier to put off that step if there seems to be any hope of getting good seasonal conditions in the next few months. Our climate, particularly in the Maranoa, offers rain at most times of year and the feed stands over in the paddock, even if of low quality. Hence many producers take an overly-optimistic view of pasture value and end up with the stress and cost of hand-feeding. Stories abound of the stresses of drought feeding but there are very few reports that link stress to early selling policies (Beeftalk 2003).

As biological scientists, we encourage producers to err on the side of early selling of steers in dry times to reduce the risk of environmental damage from over-stocking. At the same time, we seek documented examples of early sellers who got into financial difficulty by adopting that strategy. Our co-operator's data show that stressed animals never catch up to those that stayed on good feed, and larger animals always suffer more when feed quality is low (Figure 7.3). It seems better to concentrate management on breeders and their calves than half-grown steers or dry cows.

There is sometimes the possibility of using excess pasture by taking in animals on short term agistment. This provides an extra cash flow and may be a better option than borrowing money to finance the purchase of extra stock in certain cases. Agistment is seemingly fraught with extra risks these days due to more stringent health and marketing laws pertaining to livestock. Depending on a producer's attitude to risk, it may be easier to forego some agistment opportunities, both for others cattle on the home property and elsewhere for your own animals. Nowadays, there is a real risk that future market options may be severely restricted should any animal in a mob contract particular diseases or accidentally come into contact with banned pesticides.

10.4 Animal production vs Landscape stability

Amongst pioneer pastoral communities, there is a common belief that the more animals you own, the more affluent you are. By holding as many animals as possible, pastoralists tend to eat out most of the pasture in their vicinity partly because short resprouting pasture is more nutritious per kg than tall mature pasture. Under nomadic pastoralism, stock are moved on once the existing feed is eaten too short or dries off. In snowy climates, animals are moved into sheds or away to warmer areas once the snow builds up on the ground. In both cases, the pastures are generally destocked until the pasture has regrown.

In Australia's climate, there is no enforced destocking each year by climate or social custom when the pasture becomes dry or is heavily eaten down. Pastures never get a spell unless the producer deliberately destocks paddocks. Destocking paddocks was not a common practice in milder parts of Europe from whence our grazing heritage comes but there the pastures receive rainfall regularly so they are nearly always green and potentially growing to provide animal feed and ground cover. The European pastures also had a longer history of regular grazing under which the adapted pasture plants evolved. The 'tragedy of the commons' (Hardin 1968) was forgotten in the pioneering euphoria of developing a new dominion. The population was small so a slash and burn' grazing philosophy worked in the short term just like it did for farming.

Another view of pasture and farming systems is that they are prone to excessive soil erosion if inadequate living cover or stones remain on the surface. This is more so if the land is steep, winds strong or rain falls in high intensity storms. In Central Qld there is only a small amount of steep land, winds are light by world standards but high intensity storms are common. Previous studies by Silburn *et al.* (1992) and McIvor *et al.* (1995) have shown that around 30-40% of ground cover is critical to minimise runoff and especially soil movement. Cover estimates in autumn from our trials (Section 6) show that at that time of year our pastures are generally well above those minimal desired levels. Hence, do we have anything to concern us about potential soil loss? The soil movement data from the ironbark site (Section 9) would suggest that on some soils we can have a problem.

That problem is potentially greatest each year in spring when ground cover is at its least, the soil surface is very disturbed and dusty from animal traffic in the absence of rain to reform surface structure, and storm intensity is often high. Cover levels at some times were recorded below 30% at both the ironbark and the poplar box site (Section 10). The other obvious time when soil cover will be low is at the end of a prolonged drought or after a hot fire, even in the absence of grazing.

It needs to be said that localised soil loss from a plot at one point on the landscape may not translate into an equivalent loss into the local river. As the slope flattens, much sediment could drop out on the valley floor but conversely, much of the larger sediment entrained in a stream comes from bank erosion which is largely independent of the sheet erosion occurring on higher slopes. However, the runoff volume that carries sediment does contribute to the streamflow and it is its velocity and turbulence that has a big impact on bank erosion rates. Hence the local sediment entrainment levels will often relate to the amount measured in major streams further downstream.

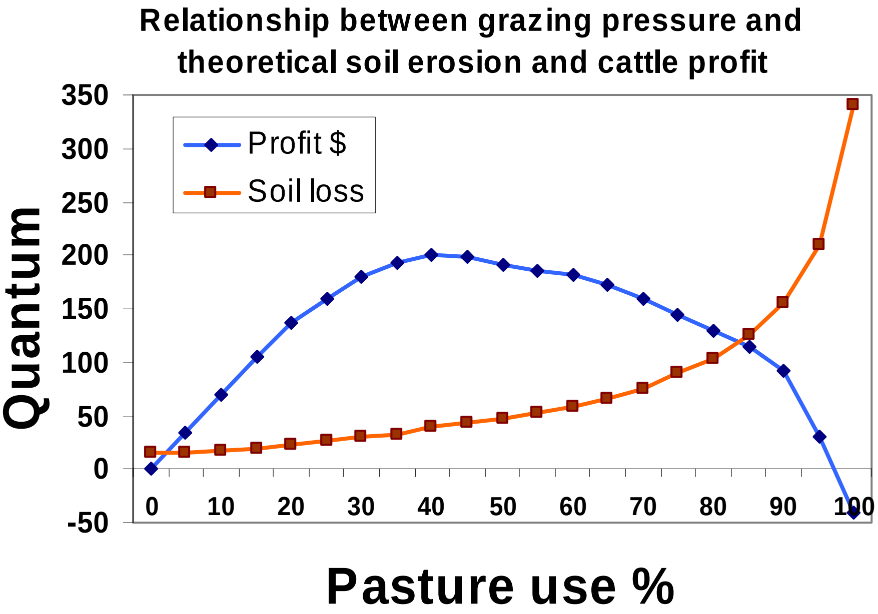
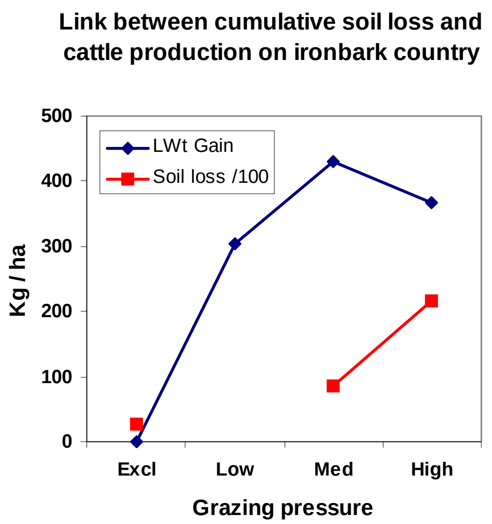


Figure 10.4 Theoretical relationships between grazing pressure and profit from cattle production and soil erosion losses.

We can assist the maintenance of cover by reducing grazing pressure but that potentially limits animal production and also income. However, the relationship between animal numbers and beef grown and between these two parameters and profit is not simple and certainly is not a straight line relationship. Nor is the relationship between runoff and erosion versus ground cover a straight line (Silburn *et al.* 1992). The curvature of the relationship between these two parameters and grazing pressure is in opposite directions (Figure 10.4). Thus there is theoretically a point or region where the rate of erosion increases disproportionately rapidly compared to the profit from running more animals. At the ironbark site this was evident after the first 4 years (April 1998) (Figure 10.8) but was that maintained over the full 7 years and it was a similar, though flatter, relationship on a different soil at the poplar box site (Figure 10.5b).

(a)



(b)

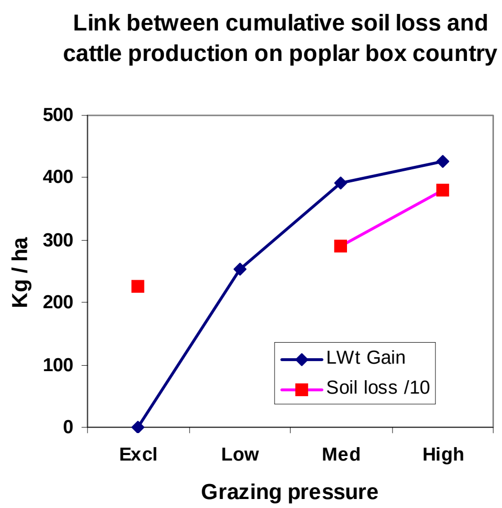


Figure 10.5 Cumulative surface soil movement and beef production over 7 years at (a) the ironbark site and (b) the poplar box site, as grazing pressure increased from zero to high.

Figures 10.5a and 10.5b summarise that cumulative amounts of beef grown and soil potentially lost over the life of our trials. The curves have only 3 or 4 data points each but they seem to conform to the theory shown in Figure 10.4. The cumulative animal production response over 6 years was of a similar form for treed and treeless pasture at the ironbark site. Only the amount of beef grown differed, being much less where trees remained. The soil loss also seemed less where the trees remained, about half that of the mean of the 2 treeless plots. Note how the animal performance at high grazing pressure (75% utilisation of autumn feed) declined compared to moderate pressure (50% of autumn feed) at the ironbark site whereas it did not at the poplar box site (Figure 10.5).

The soil loss graph at high grazing pressure at the poplar box site also did not flex upwards strongly like it did at the ironbark site. Also at the poplar box site the soil loss range was from 2 to 5.5 tonnes/ha compared to a range of 2.7 to 25 tonnes at the ironbark site over 6 years. Hence soil movement was comparable under treeless, ungrazed conditions at the 2 sites but 2-4 times greater at moderate to high grazing pressure at the ironbark site. Best beef growth rates per unit of soil moved were twice as good at the poplar box site at about 0.14 kg/kg soil loss (under moderate grazing pressure) compared to an estimated 0.07kg/kg soil moved at the ironbark site, under the low grazing pressure regime.

Also animal liveweight gain per hectare at the poplar box site did not decline overall although the increase was not large for such a big increase in risk. The value of the animals from high grazing pressure treatments often decreased compared to those from lower grazing pressures because their individual fat-scores decreased, especially in the treed paddocks (Figures 7.14 & 7.15). So the situation is not an economic disaster like in the ironbark country but the economic benefits are marginal at best for a big increase in risk to animals and land and the need for hand-feeding. If a gully does develop as a result of excessive erosion at one failure point where overland runoff is concentrated, that small gully can rapidly eat into the dispersive subsoil and migrate uphill

(Figure 10.7). The uphill migration of such gullies is very hard to stop on sloping country, quite apart from stabilising their side walls without major costs.

10.5 Economics

Assessing the implications of our animal production studies in monetary terms can be approached from several perspectives, - long term, short term, as well as in lifestyle or environmental terms. We will address most of these in some way. It must be stressed that external factors such as wars, trade tariff changes and health scares such as mad cow disease or foot-and-mouth disease can dramatically alter the prices received for beef in Australia. In the past 6 years, the EYCI (Eastern Young Cattle Index) has ranged between 149 and 385 with no clear trend (V. Edmondston, pers. comm. from National Livestock Reporting Service reports).

For the following set of scenarios, the following is assumed –

- animals weigh 180kg when weaned in late April at 6 months of age, or 205 kg if weaned at 9 months in late July
- over the winter and summer seasons these animals grow at the rates shown previously in Table 10.6 under the different management regimes (typical of our trials).
- Steer values, in $/kg LWt, from various grazing regimes are shown in Table 10.7 based on age and likely fat score.

When selling younger animals of various “size for age classes” to feedlot back-grounders or restockers, there can be significant penalties if animals are a little backward due to unfavourable recent pasture conditions. On the basis of our animal growth rates and Table 10.7 prices, steers from the main treatments would be likely to return the money shown in Table 10.8. The penalty for 400kg animals raised under high grazing pressures is quite substantial.

Where animals are sold to a predetermined market, the price is often set largely by the animal’s breed, age and weight. The younger and heavier the animal, the greater is its value and the more rapidly is the capital invested in its growth and management returned for further investment. For young Brahman-cross animals on tropical pastures, over-fatness (fat score >4) is never a problem but well-finished animals generally do not attract very high price premiums when markets are poor. They also tend to suffer heavier discounts if their fat score falls below 3 compared to European breeds.

Table 10.7 Price assumptions made for the economic analyses that follow.

Management regime	Value of a 400kg steer ($ / kg LWt)	Value of a 300kg steer ($ / kg LWt)
Grazing pressure		
LOW	1.85	1.60
MEDIUM	1.65	1.50
HIGH	1.30	1.25
Tree cover		
TREED	1.55	1.40
TREELESS	1.75	1.55

Another scenario (Table 10.9) is that of a forced sale at, say 2 years of age (end of October) after, say, a fair summer but a very poor winter and with a dry El Nino summer forecast. Values per kg are based on the assumptions from Table 10.7 but with a high likelihood of even lower values because of a low fat score in spring after a dry winter.

Table 10.8 Probable comparative value of steers sold at 2 different ages after being run at different grazing pressures on A/B country.

	300kg @16-18mths		400kg @ 24-30 mths	
Management regime since weaning	Age at sale (months)	Value at sale ($)	Age at sale (months)	Value at sale ($)
Grazing pressure				
LOW	16	480	25	740
MEDIUM	17	450	27	660
HIGH	18	375	30	520
Injune				
TREED	18	420	29	620
TREELESS	17	465	27	700

Note how decisively production from treeless pastures exceeded that from moderately timbered woodland. In some woodlands, tree clearing is likely to be severely restricted in future but in others it will be permitted under a permit system. So the economic benefit of potential tree clearing will be specific to individual properties and land types in the future.

Table 10.9 Economic scenario for the forced sale of 2 year-old unfinished steers in late October.

Grazing management since weaning	Liveweight at Sale (kg)	Value $/kg LWt	Value / head ($)
Grazing pressure			
LOW	375	1.75	656
MEDIUM	345	1.50	517
HIGH	315	1.25	394
Injune TREED	320	1.35	432
Injune TREELESS	365	1.70	620

10.5.1 The Triple Bottom Line Approach to Valuing Production

A fourth scenario, mentioned earlier, is to look at the marginal benefit gained from increasing the stocking rate from one management regime to another. We will base our calculations on a per 100 hectares basis. The calculation is done separately for both sites because the difference in production between them was very noticeable at the high grazing pressure although little different at the lower rates. Tree removal benefits were also very different between the sites.

The triple bottom line results of Table 10.10 can be expressed graphically as shown in Figure 10.6 for both sites. A high stocking rate does not produce well-finished animals, the quantum of beef grown is usually less than that achieved at a moderate stocking rate, the economics of the venture are demonstrably bad and the soil erosion rate from Section 9 is unsustainably high. On our poplar box site, the eventual severe detrimental effects were not expressed because the unstable subsoil was not yet exposed below the shallow surface layer after only 7 years. A photograph taken on identical country near our trial shows what will happen once the topsoil is eroded away at any point on the slope (Figure 10.7).

The results of Table 10.10 were expressed visually in 1998 for the ironbark site in the poster shown in Figure 10.8 where real data is extrapolated to the extremes of no grazing (equals no livestock income) and complete removal of all forage grown every year. The overall result has not changed from adding a further 3 years data to that of 1998 (See Section 10.6.11 on interactions).

The incentive to clear is obviously there if there are no big clearing or regrowth control costs. We had minimal regrowth problems but that is not the norm. Clearing eucalypt woodlands like that at our sites costs about $6200-$7400/100ha with herbicide and a similar amount with a chain between dozers (Paul Back, pers. comm.). This equates to between $186 and $222 per beast area at the moderate stocking policy of about 3 hectares per beast or 3.6ha/AE. This would have to be factored into a full economic analysis over a long timeframe. It would reduce the initial profit margin on box country from $237 per extra steer to $15-$51, which is much less appealing. On ironbark country, the cost of clearing eliminates the early profit benefit but may pay better in the long term if the regrowth rate is slow.

The cost of regrowth control is quite variable and there is a lot of luck involved. The time before re-clearing is required may be 20 years in a worst case scenario and probably 60 years in the best case. Hence the clearing cost, say $200 per beast area, may only cost $3.30/beast/yr but may be as high as $10/beast/year for a fast regrowth scenario. Burrows *et al.* (1999) have shown that a good fire 2 years after tree killing can do a very good, cheap job of poplar box regrowth control, with costs due entirely to light stocking for 1 season before the burn and half a growing season after, if rainfall is normal. If dry conditions descend shortly after clearing, the cost could be much higher because it would be difficult to achieve a hot burn for many years. By then the eucalypts would be too large and old to kill by fire.

Table 10.10 Marginal economics of running steers under increasing grazing pressure for a one year period.

	Stocking rate (ha/hd)	LWt gain/hd (kg)	Avge steers /100ha	LWt gain (kg)	Extra wgt (kg)	Extra steers (nbr)	Beef value ($/kg)	Extra $ / extra steer	Profit / extra steer ($)	Triple bottom line result#
Poplar Box										
Destocked	0	0	0	0	-	-	0	-	-	??
LOW	4.6	153	21.7	3326	3326	21.7	1.60	245	185	Excellent
MED	2.7	135	37.0	5000	1674	15.3	1.50	142	82	Good
HIGH	1.9	113	52.6	5947	947	15.6	1.25	-4	-64	Bad
TREED	3.9	120	25.6	3077	3077	25.6	1.40	168	108	V. good
TREELESS	2.3	148	43.5	6435	3358	17.8	1.50	300	240	Excellent
Ironbark										
Destocked	0	0	0	0	-	-	0	-	-	??
LOW	4.0	150	25.0	3750	3750	25.0	1.60	240	180	Excellent
							1.20a	180	120	V. good
MED	2.42	136	41.3	5620	1870	16.3	1.50	149	89	Good
							1.10a	103	43	Fair
HIGH	2.35	116	42.5	4936	-684	1.2*	1.25	-1836	-1896	Disaster
TREED	3.5	132	28.6	3771	3771	28.6†	1.40	185	125	V. good
TREELESS	2.3	136	43.5	5913	2142	14.9	1.50	241	181	Excellent

= Triple bottom line is the congruence of economic, environmental and social outcomes.
The beef values with ‘a’ after them represent a second, poor price range option.
† = compared to the destocked option
Operating costs per animal were set at $60 per year to cover everything, including interest on the capital tied up in the extra animals.
* Note that the high grazing pressure paddocks were often unable to sustain those numbers without destocking during dry periods. Therefore the long term average number of steers was not much greater than that of the medium grazing pressure (Table 7.1 in Section 7).
?? Means no value has been assigned to this destocked scenario although many nominal /speculative environmental values could be proposed.

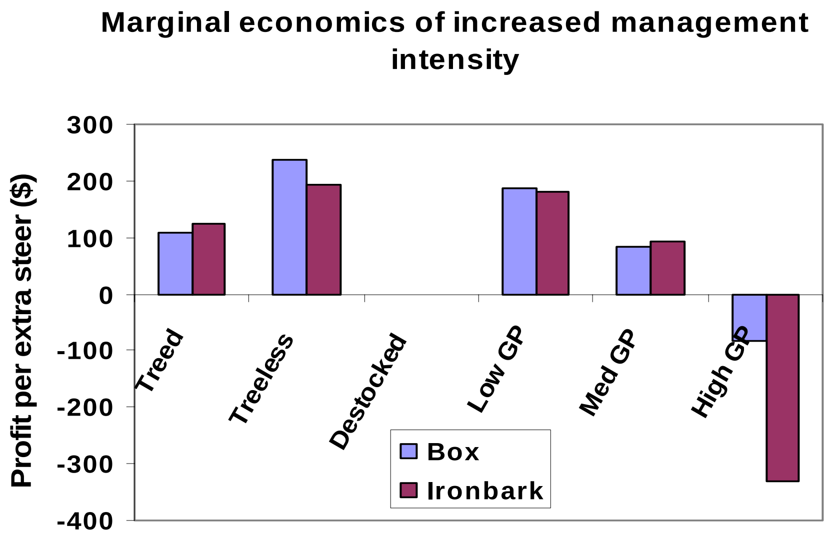


Figure 10.6 Graphical representation of the economic outcomes of the grazing management scenarios tested on *Aristida/Bothriochloa* pastures.

Some explanation of these economic results is needed, courtesy of Economist Bill Holmes.

When applying the marginal analysis approach, moving from a destocked to a lightly stocked (LOW grazing pressure) operation produces big financial gains because no income is generated while destocked, although no capital (say $60/hd) was invested in livestock. The same applies to the TREED option for each site, which uses meaned grazing pressure data in the calculations.

Figure 10.7 Gully erosion that will occur on our poplar box country if the surface A horizon is breached by erosion or deep surface disturbance, e.g. by roads.

Moving from low to medium grazing pressure requires an extra 15 head (37–21.7) on poplar box country to produce an extra 1674 kg (5000-3326) of liveweight (109 kg/yr per extra beast). On ironbark country the equivalent production gain was 115 kg/yr/extra beast from the Table 10.10 data.

Moving from medium to high grazing pressure requires an extra 16 head (53-37) to produce just 947 kg more liveweight (61 kg per year per extra beast) on poplar box country. Again, on ironbark country the equivalent 'benefit' was a huge loss of 570 kg/yr/extra beast.

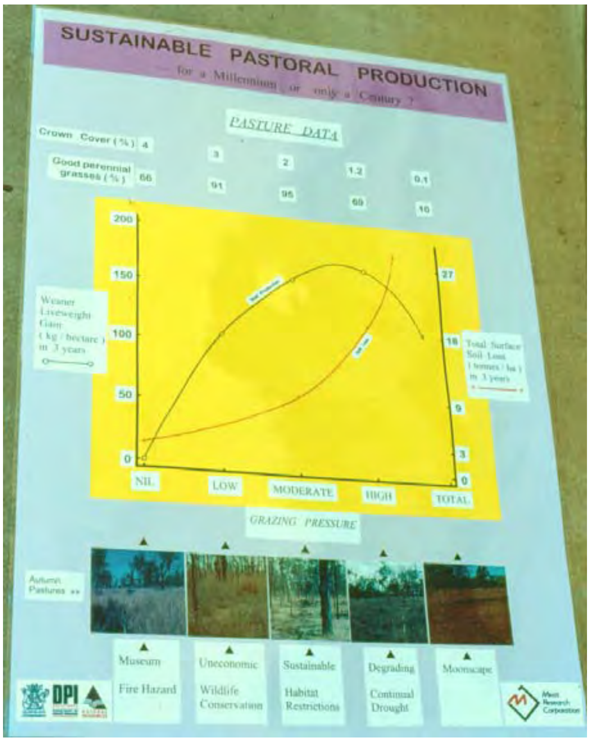


Figure 10.8 April 1998 poster displaying linked data relating to the triple bottom line concept.

Carrying a few extra cattle does not alter the fixed cost structure of the property, but it does incur extra variable costs (Definition: One more animal = one more unit of variable cost). The obvious ones are dips, drenches, vaccines, fodder and supplements (and maybe some labour for extra yard work). Less obvious but bigger is the capital (interest) cost of holding extra cattle. An extra beast worth perhaps $500 will cost whatever is the opportunity cost of capital (could be 10% if this is what would be saved by reducing the worst debt – usually the bank overdraft or stock firm debt). Now 10% of $500 is $50 per year just to carry that capital. Add another $10 ($5 absolute minimum) for other variables and we have $60/hd/yr tied up in animals as capital.

Producing 109 kg/yr of liveweight will cover $60/hd variable cost (subject to the following paragraphs), and 50kg/yr is about break even on box country, but negative liveweight gains per extra animal per year on ironbark country will certainly not. Therefore the heavy treatment can be dismissed on economic grounds even before it is condemned on soil loss or other risk factor grounds.

Cash costs of moving from moderate to high grazing pressure (if you use Table 10.10 values) are -$4 / head (5000 x 1.50 – 5947 x 1.25). This loss is before the extra $60/head mentioned before, ie. a total probable loss of $64 per extra beast at high stocking rates on box country. If the price differential was only 10 cents/kg ($1.40/kg for high grazing pressure animals), the loss is still about $7 per extra beast after livestock capital is included ($53-$60).

On silverleaf ironbark country, the profit margin in moving from LOW to MODERATE grazing pressure is good ($89 / extra steer) but the move from MOD to HIGH grazing pressure is even more disastrous than on box country – a loss of $1900 per extra steer run. On ironbark country, the financial benefit from killing the trees ($181 / extra steer) was not as good as on poplar box country ($240). Both land types have bad regrowth potential and the $59 lower profit margin/100ha may partly explain why less ironbark country has been cleared in the past.

The price sensitivity of these calculations was tested for ironbark country where we assumed the overall beef price dropped 40cents/kg to $1.20 and $1.10/kg. The resulting profit margin fell by 33% ($180-$120) in the LOW comparison for the 25% price drop ($1.60-$1.20) but from the moderate grazing pressure case the profit drop was 50% ($89-$43) from the 27% price drop ($1.50/kg-$1.10/kg).

Having done the sums, it is now important to say that cash isn't everything. Risk also matters. Adverse risk means less options in management and marketing. The high grazing pressure option seems to have no financial advantages but do the risks outweigh the benefits even at a moderate grazing pressure? With benefits of $2170 to $2430/100ha or $82 to $89/head in our case (Table 10.10), it does seem so for our run of seasons and recent prices. Ultimately much depends on how rapidly tree regrowth eliminates the initial clearing benefits or reduces the productivity of uncleared woodland.

10.5.2 Other Observations

1. Financial outcomes over the medium term (10 yrs) are frequently dominated by single events – a bonanza sale or a disastrous forced sale, or a good or bad drought decision. This is where risk is relevant. More adverse risk equals less options in dry times or times of depressed markets.

2. Stocking rates which maximise profits may turn out to be a wide range rather than a single point once capital costs (cattle value) are included, and especially when the cost of risk is factored in. An optimum stocking policy may encompass some wandering between "low" and "medium" according to seasons, breeding success, the need to burn for regrowth control and the need to withhold cattle from poor markets.

3. Data from grazing trials with sheep, based on a similar autumn pasture assessment stocking policy, such as "Burenda" Augathella (Beale *et al.* 1986), showed a coincidence of pasture stability (30% utilisation), most profitable stocking rate, and stable stocking (1 sheep : 3 acres). Unstable stocking risked trading losses if stock were sold off on depressed markets and bought back in on buoyant markets.

4. While low grazing pressure has a benefit on per head weight gain, there are some apparently worthwhile increases in total weight gain per hectare at medium grazing pressure. Weight gain at the low grazing pressure was 3325 kg/100 hectares off 22 weaner steers on box country. At the medium grazing pressure it was 5000 kg from 37 steers. Comparing these, we see that the extra 15 steers increased total weight gain by 1675 kg or about 110 kg per extra head, compared to 153kg/head total at LOW grazing pressure.

From this information we would have to say that the "medium" stocking rate appears more profitable than the "low" on Injune poplar box pastures. This ignores for the moment other considerations such as the impact of increasing stocking rates on risk, on loss of management options, and on land stability.

Some extra scenarios based on more extreme prices are provided in Appendix M.

10.6 Sustainable land management

The key objective of our research was to formulate improved and sustainable land management guidelines for *Aristida/Bothriochloa* pastures. So we now describe what we think needs to be borne in mind by land managers in central Qld in relation to natural resource management.

10.6.1 Management to control erosion

Maintain as much perennial grass crown cover as possible and try to keep over 40% total ground cover, always. This will be most difficult to achieve in spring, particularly after a dry summer. Assessing cover in mid-winter would be a good way to counteract this potential problem from early storms. If cover is too low then, you should quickly move animals to less sensitive or less denuded paddocks so that no further ground cover reduction occurs. Once growth resumes after spring rain the stock could be moved back, if necessary.

The gritty, red duplex soils of the Peakvale Land System around Rubyvale are very prone to sheet erosion, so keep at least 40% ground cover on such land. Use the method described in the GrassCheck monitoring Manual to estimate ground cover easily.

On the poplar box soils, efforts should concentrate on preventing active gullies because they can rapidly eat into hillsides and will undermine otherwise well-grassed or well timbered land.

10.6.2 Management for healthy grassy woodlands

We are unable to convincingly explain why killing the ironbark trees at Rubyvale did not result in a quick increase in pasture yield. We believe it could be because the tree roots remained in ill-health for many years after the severe 1992-94 drought. Their canopies were not as dense as those of this species in the South Burnett but this did seem to improve in the later years of the trial. Hence competition for soil moisture during the trial was probably more closely allied to canopy cover than to stem basal area, the measure by which such competition is normally calculated (Scanlan & Burrows 1990). Thus a significant effect of tree killing only became obvious in pasture yield data in the latter part of the trial and was still not visually obvious in the field (Figure 6.3).

Broadscale clearing or killing of silver-leaved ironbark trees in open woodlands around the Central Highlands (under commercial conditions) seems unlikely to result in much more pasture production in the medium term. It is most likely to result in massive regrowth of small ironbarks that the dozers or chemical contractors miss. This regrowth will reduce pasture growth and quickly counteract the improved cattle production that is initially achieved. We believe the lack of ironbark regrowth recorded in our trial is not typical because we squirted most small seedlings with herbicide, a practice which would not be economical commercially. That high level of regrowth control was retained for 7 years but will almost certainly be reversed in the next decade. Signs were obvious in some paddocks at the ironbark site in 2001 (Figure 5.2).

On poplar box country, clearing or poisoning the trees can produce enhanced pasture yield of 150–300% in individual years and that also translated into improved beef production in the short term (See Section 7). Part of this response would be due to the greater amount of Qld bluegrass and yellow daisyburr that grew after the trees were killed. This response was maintained for 7 years in this study, where tree regrowth was minimal, but regrowth is a very common problem in the district. Any tree clearing or thinning must receive a permit nowadays and be carefully planned because the soils have erodible subsoils and significant salt loads that may be mobilised if there is a high local groundwater table or increased rainfall infiltration. Areas where springs occur naturally should be addressed with particular caution if thinking about clearing trees rather than using cool fires to manage regrowth.

10.6.3 Management to control regrowth

Regrowth is best controlled by having a carefully planned timber pulling or poisoning program beforehand that only treats as much country at a time as can be well managed for regrowth control over the next few years. This is probably a maximum of 500 hectares at a time for most operators. All timber treatment must be approved by the relevant government agency and done in an environmentally friendly way. Thus leave large strips or clumps of untouched woodland, avoid all major watercourses and areas which may impact on groundwater or dryland salinity risk. Booklets with local tree clearing guidelines and regulations should soon be available for most regions of the State. Plan for a hot, controlled burn within the first 2 years after initial treatment to kill the first wave of new seedlings and soft root suckers (Burrows *et al.* 1999).

Grazing in the first year or two after tree clearing or thinning should be intermittent, timed to occur after seedlings of valuable grasses have multi-tillered crowns, and existing tufts are ripening their seed. Stocking rates while grazing recently cleared land may be quite high for short periods to minimise grazing selectivity and regrazing of the most palatable plants. However, the duration of each grazing must be short until the new pasture has stabilised.

10.6.4 Management for healthy pastures

Moderate grazing pressure is the best compromise for ensuring both good pasture quantity and quality and to allow greater management flexibility when seasonal conditions alter rapidly. Fortunately wiregrasses do not have large soil seedbanks, so controlling the existing plants is the main requirement in their overall management. This is in contrast to the huge soil seedbanks of grasses like giant rats-tail grass that make it difficult to eradicate them once they get established (GRT Project Team 1999).

Don't aspire to a significant proportion (>10%) of kangaroo grass in all your pastures if livestock are your only source of income. That would be an indication of low economic production from domestic livestock due to highly conservative grazing. Aim for a moderate grazing pressure but if circumstances force a heavy grazing pressure for a while, resting during the next wet summer will quickly restore perennial grass vigour. If grass crown area had slipped to very low levels, at least 2 consecutive growing seasons rest is required – the first to set seed and establish new seedlings, the second to grow those seedlings into robust crowns. Such paddocks should be grazed in the intervening winter to ensure seed is buried and minor inter-crown gaps are created.

A big change in stocking rate alone will not, in the short term (<9 months), cause a rapid change in the composition of perennial native pastures at a commercial paddock scale. Loss of pasture cover and soil surface instability are the things most at risk from greatly increased stocking rates. By comparison, extreme seasonal rainfall can produce big changes in the species makeup of pastures, independent of recent grazing pressure, eg. tree regeneration. Unfortunately it is not easy to reliably predict exactly which species will flourish in the short term because the germination of seeds is very sensitive to temperature and temperature fluctuations while they are moist. The pasture species that most commonly reappear or disappear in A/B pastures after extreme seasons are slender chloris, legumes, small burrgrass, annuals of all sorts, galvanised burr and sometimes black speargrass and Qld bluegrass.

Though the concept of 3P grasses is a valuable management guide, other shorter-lived perennial grasses can be extremely important for animal production and surface soil cover, eg. slender chloris and golden-beard grass. Seed reserves of 3P grasses are small and only weakly dormant, so they cannot easily return if established plants are killed or lost somehow or seedling flushes fail to survive.

10.6.5 Management for spring burning

Spring burns do not appear to reduce wiregrass populations on our two pasture types and, if done too frequently, may reduce surface soil cover and foster scalding of the soil surface. This seems contrary to the findings of Orr *et al.* (1997) and we have no simple explanation of why. Spring burning in both cases did favour black speargrass and disadvantage pitted bluegrass but in our trials the changes were small after 7 years. Nonetheless, burning did appear to reduce the soil seedload of wiregrasses and to keep them low in most years.

10.6.5.1 *Burning methods*

To prevent an increase or encroachment by woody vegetation, aim for a spring headfire, i.e. one that moves in the direction of the prevailing wind. A good flame height with a steady breeze has maximum affect on small trees and shrubs and keeps the heat of the fire away from the pasture crowns. A headfire will also ensure the heat of the fire passes over the pasture layer more quickly than a backfire. Burning with some moisture in the soil will give the pasture and old trees a good chance of a quick recovery.

Destocking or light stocking following a burn is essential to maintain or improve pasture vigour and the desirable grasses. Burning for out-of-season green pick or grazing immediately after burning leads to reduced vigour of many tufted perennial grasses. This can cause increased runoff and soil erosion or an influx of undesirable plants. However, it should be noted that burning of rank purple wiregrass (*A. armata*) on alluvial flats in the Injune district is a common practice which does not seem to reduce its density. The plant stalk is very unpalatable in spring and summer, even if green, but regrowth after a fire is more leafy and digestible and stock will preferentially graze it for a short while. The crowns of the established plants are 5-10cm below ground, so heavy grazing and fire never damages its basal growing points.

Hence if grazing management of the associated pastures is not sophisticated, the wiregrass can increase its hold on these fertile flats via its free-seeding, stalky autumn growth. This can be to the detriment of forest bluegrass, Qld bluegrass and kangaroo grass that would otherwise be more common.

10.6.6 Management to rehabilitate degraded pastures

The first step towards pasture rehabilitation is to reduce grazing pressure, especially after early summer rains when plants are rapidly growing.

The second objective is to increase the ground cover to something in excess of 40%, if it is not already above that. Sensible grazing pressure will achieve this without any other special steps being taken.

The third objective is to increase the proportion of useful perennial grasses in the pasture. This may involve tree and shrub management, burning, wet season spelling and weed control (if needed). This is the most difficult objective to achieve reliably because many of the driving forces are hard to control in advance, eg. rainfall, pests and diseases.

If a scalded surface soil is an issue, a light cultivation of strips of country on the contour may be warranted if reduced grazing pressure on its own does not enable seedling recruitment. However, deep ripping should only be considered after very careful consultation with a soils specialist. It may expose the erodible subsoil which, in places, is less than 15cm below the surface. When such subsoils erode, they develop deep gullies very rapidly with rapid upslope movement of the gully head and slumping of side walls (Figure 10.7).

Perennial grass pastures are best encouraged by summer wet season spelling. The period need only be 6-8 weeks and at any time between November and March, but must coincide with good rains. Be on the lookout in spring for predictions of a La Niña (above average rainfall) year from the climate experts so that important areas can be rested early with more confidence of receiving good summer rain.

If pastures have thinned out following a run of dry summers, it is important not to maintain more animals than an honest pasture assessment says you can run in the near future. Our results show clearly that high grazing pressure does not pay economically and the stress and risks involved interfere with all other aspects of property management. The financial answer to protracted dry years may lie in off-property employment and when seasons do improve there is scope for taking in agistment, hay-making and shifts in herd genetics to keep abreast of market shifts.

10.6.7 Managing to retain existing good pasture

Where a pasture is already in good (A) condition, it will still require ongoing steps to retain A condition.

- If unwanted trees begin to re-establish too thickly, try to have a fairly hot spring burn after the first rains to kill the young trees (<30cm tall).
- After a drought, destock the most stressed paddocks for the next growing season and then graze them conservatively prior to the next useful rains.
- Spot treatment of isolated weeds and resprouting tree suckers, such as limebush and current bush, using herbicide or a small root-plough is highly recommended.
- Seek advice from soil conservation specialists about the treatment of isolated active gully heads or old borrow pits.
- To encourage a specific plant species, remove stock as flower buds or seedheads start to appear and return them after the seed has ripened. Grasscheck is a good system to use to monitor the outcome from such strategies.

10.6.8 Management to achieve good cattle growth

Our economic and pasture analyses show that the "medium" stocking rate is more profitable than "low". If more importance is attached to the impact of increasing stocking rates on risk, on loss of management options, on wildlife conservation and on landscape stability, then a stocking rate below "moderate" is needed to achieve a more ecologically profitable outcome at the current value placed by some on those ecological services. Valuing such services is not well supported by objective data at present, so it is a very personal choice and value that each land holder makes for a strongly conservation biased land use.

Where feasible, run steers on native pastures during summer and then lock in those gains (of 150 kg/head) by

- selling immediately, or
- transferring them to higher quality improved pastures or forage crops for the whole winter or until ready for sale as 400kg plus steers.

Supplementing with urea during dry winters is another option but our trials cannot predict what impact that might have on spring ground cover, pasture composition or animal performance. Our expectation from the use of supplements would be for better animal performance, lower spring ground cover and no immediate change in pasture composition.

Green winter feed or winter diet supplements are the key to good long term animal production, especially further north where winter rain is less common. Look for ways to provide some extra green feed such as burning wiregrass patches or encouraging herbage growth in parts of the property by preventing summer grasses growing too rank. Native legumes fulfil this forage role and are normally encouraged by pasture burning. If using licks, supplements or water medication, take professional advice so that the supplement complements the forage quality on offer. What is needed will vary each year depending on the type of summer that has just concluded.

Rotating herds around to fresh paddocks is another way of spreading out available green feed in more southern areas where some winter rain is received. The speed with which this might be done and the mob sizes used are personal choices that need to suit individual operations and infrastructure. Rotational grazing theory assumes that the feed in the new paddock will be better than that remaining in the paddock where the animals currently are. If that is not so, then animal performance will suffer from the next move, even if the land or pasture benefits. The decision to cease a rotation or to reduce herd size in the face of poorer pasture has to be made on the basis of the needs of the property as a whole. Removing a significant proportion of a mob from a paddock usually gives the remaining animals a boost in available feed to choose form, so that several business outcomes are achieved at once – money from the animals sold and better health for those remaining.

10.6.9 Management of climate variability

There are records for over 100 years of the daily rainfall received at many locations in central Queensland. They confirm the folklore of droughts and flooding rains in newspaper archives along with the accounts of bushfires, locusts, disease, sickness, flies and other pestilence that afflict rural communities. So we are never guaranteed a crop or sleek animals and we know that poor seasons and even a run of poor years will occur again to reduce potential rural production.

Recently our skill in predicting future seasonal rainfall for broad regions has improved (Partridge 2000) and seasonal rainfall has been linked quite well to potential pasture growth and some crop yields (Carter *et al.* 2000; Hammer *et al.* 2000). However, there is little linkage between such climate predictions and individual or local storm events, bushfires or with the incidence of disease outbreaks -– apart from known seasonal predisposition, e.g. to buffalo flies or ephemeral fever in summer. There is some predictive value for seasonal market prices of some commodities, e.g. lucerne hay, but they are more relative than actual.

Beef producers have no control over rapid changes in overseas markets. Hence individual producers should plan on the basis of what they have and what is reasonably predictable in the medium term, eg winter frosts. That means placing management emphasis on

- how much edible feed they have at the end of summer,
- how much soil moisture still exists in autumn,
- how many stock they currently have, and
- the feed demand of those stock (based on size and lactation status).

Reliance on seasonal climate predictions should only involve discretionary management options such as sowing a new pasture, burning regrowth or desilting dams. The poorer the match between stock feed requirements for the next month (to achieve a future market goal) and current standing forage in the paddock, the more risky the business in terms of both financial and environmental goals.

10.6.10 Management for nature conservation

Human activities and natural phenomena (fires, vulcanism, cyclones etc.) have big impacts on natural ecosystems. Some ecosystems are removed completely and others modified in the short term. Most pastoral lands go through continual fluctuations in the dominance and balance of plants and animals. Intuitively, humans like to preserve an example of all natural things and that is one aim of biodiversity conservation. Our sustainable grazing management study covertly had the same aim but with a different emphasis.

Some species adapt well to changed circumstances, e.g. tree clearing or feral predators, while others have no defences and can be quickly exterminated, e.g. Tasmanian tiger, dodo, paradise parrot and specialised plants, eg. *Hemigenia clotteniana*. Animals seem more prone to extinction than plants but even some plants are critically endangered, especially by cultivation and the removal of protective vegetation, eg. the Australian thistle (*Stemmacantha australis*) and some native orchids (*Dipodium pictum*).

Extinction often occurs because of the overwhelming speed with which the change occurs. In northern Australian pastoral lands, changes due to human activity have been fairly gradual and this has presumably given most species an opportunity to adapt and to consolidate in favourable niches. For example, the northern hairy-nosed wombat seems to quite like eating buffel grass (Low 1997) and the spectacled hare-wallaby seems largely unaffected by pastoralism up to this time (Filet *et al.* 1997). Johnson (1997) reports that, even in brigalow lands where change has been comparatively rapid, no plant species appear endangered by clearing although many existing regional ecosystems (vegetation types) are endangered due to loss of integrity. The density of many species in a particular area have changed due to pastoral development on agricultural tenures (Hannah 2000) but quantification of the extent of changes is missing for most species.

So, can our research data point to ways to prevent endangerment of wildlife and plants? Many reports claim that conservative grazing land management and property development planned within a catchment framework, can deliver most of the realistic nature conservation goals (Curry & Hacker 1990, Cromwell 1999). Our grazed natural pastures can deliver “triple bottom line” outcomes and we provide data to support that position for the two communities studied. Our research showed that moderate grazing pressure preserved good habitat for the spectacled hare-wallaby in the Rubyvale district (Filet *et al.* 1997). Our trial sites showed no signs of accelerated ingress of exotic weeds and pasture species under moderate grazing after 7 years. Buffel grass did not build up and Indian couch grass did not invade under heavy grazing pressure. Parthenium weed did not invade either the grazing or the burning study sites, despite being common in both districts and along our access roads.

The greatest sources of potential degradation and unwanted biodiversity outcomes were vehicular access tracks, watering points and infrastructure such as powerlines, fences and pipeline trenches. These are not nature conservation issues but rather point source environmental problems for which there are published guidelines and codes of practice to minimise damage. At our sites, we discovered small numbers of several plant species during our detailed botanical monitoring whose existence was not known nor anticipated there, eg. *Dichanthium setosum and Aristida lazarides* at both sites, *Cymbopogon queenslandicum* at the ironbark site and a strain of *D. sericeum* at the poplar box site that has a non-shattering seedhead. This is a typical outcome of intensive sampling no matter what the organism discovered, unless the species has truly become extinct. As Filet *et al.* said, *inter alia*, nature conservation objectives will be achieved on grazing lands if the following are maintained –

- appropriate tree density
- adequate density of perennial grasses
- adequate ground cover and pasture biomass.

10.6.11 Interactions and trade-offs

The earlier sections have served to show how all these land management issues are inter-related. Every major grazing management decision impacts on soil, pasture, woodland and animal condition. An extreme emphasis on any one will result in detrimental impacts on something else (Figure 10.8). We think that taking a strong position on a single biological issue for a short time is not always detrimental in the long term, e.g. heavy grazing during a short drought or mob-stocking one paddock while others are rested for a season. However there is a risk that a chance combination of unfavourable factors could set in train serious long term damage if a high risk approach is taken too often, or for too long, or without subsequent rehabilitation measures.

We also recommend strategic spelling of pastures during the growing season on a regular, rotating basis. Many beneficial improvements will then flow through into soil and water health issues that may become assessable tenure conditions in the future. The benefits of summer spelling have been demonstrated by Ash *et al*. (2001) further north and of moderate grazing pressure by our marginal economic analysis. There are many paddocks that would respond well to a single wet season spell to allow 3P grasses to thicken up and to allow more litter to accumulate on the soil surface. That would result in better rainfall infiltration, thus more pasture growth, provided soil surface cover did not fall again below about 40%. The extra feed would also provide more options for controlled burning to reduce tree regrowth.

10.6.11.1 *Trees / pastures / soil / animals*

There are many complex interactions between these 4 major factors of a grazing system and perfect knowledge about the outcome is impossible (Danckwerts & Tainton 1993). The trees reduce the amount of moisture available to the pasture, so in a short summer wet season, it dries off more rapidly and hence animal performance starts to drop earlier in autumn. However, in spring and autumn, if any rain falls, the trees protect the new growth from frosts in the south of our region. Semi-deciduous trees don't compete as strongly for the limited winter soil moisture, so the pasture stays greener and the animals do better under them in the extreme north of the A/B region. Then there is the more complex interaction of these factors with the competing herbage species within the pastures plus their interaction with animal preference.

Hence, emphasise managing the quantity of the pasture and its greenness and only include other niceties when you are confident about your understanding and experience with the basics.

Potentially complex interactions extend into salinity risks and fire management. It will be advantageous to find out which country on your property is most at risk from potential dryland salinity and whether adjacent land that you control might be managed slightly differently to minimise future salinity risk, eg. by improving ground cover. When using fire for shrub and wiregrass control, the paddock will benefit from grazing the early regrowth of these target plants if there already is a good stand of other perennial 3P grasses. However, if the 3P grasses are fairly sparse, spelling after the spring burn will deliver a better outcome by encouraging re-establishment of 3P grass seedlings at the same time as the target undesirables are burnt.

On top of all this biological complexity comes the economic imperatives for which individual solutions are usually required, not industry-wide micro-economic adjustments or sweeping generalisations about market forces.

We can only deal here in broad recommendations. They suggest that keeping a moderate grazing pressure and not holding on to stock unnecessarily in the face of winter or dry seasons is probably the best long term strategy. Special or local challenges require a tailor-made assessment and plan, usually with input from technical specialists, to achieve the desired outcome.

11 Linking Project Data to Generalised Models

11.1 Pasture growth and consumption

Our data has been of significant interest to people who are trying to model landscape erosion processes and pasture growth. The primary production data from Swiftsynd sites and the linkage between animal data, pasture production, cover and runoff is all valuable to industry and the State in their attempts to achieve sustainable long term land management. The processing and integration of our data into broader landscape process models will continue for years but we present some early outputs that have already been synthesised. To date the emphasis has been on the ironbark site site.

One output has been an attempt to work out the actual pasture consumption level of various treatments by using the current animal intake and pasture growth algorithms from GRASP and to match that output with our assessment each autumn of the standing pasture biomass. The result is shown in Figure 11.1 as and it shows a reasonable correspondence between model and actual measurements. Of particular interest is the fact that the 6-year average level of consumption of the pasture grown was 72% for paddock CH1 (Treeless High grazing pressure Rep 1) and 45% for paddock CM1 at the ironbark site. This compares with our intention to consume 75 and 50% of the feed available each autumn over the forthcoming year. Note also how utilisation levels became relatively high in low rainfall years and low in high rainfall years.

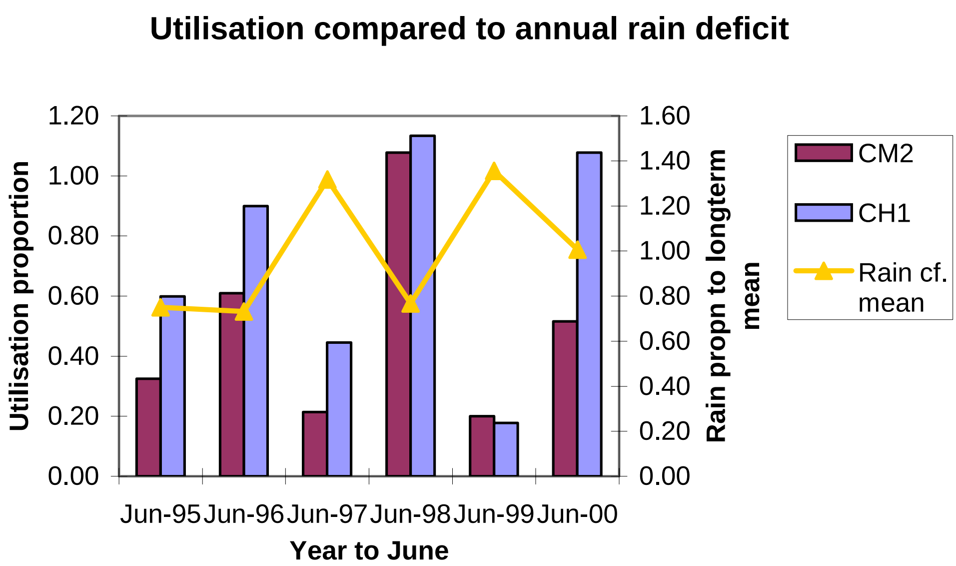


Figure 11.1 Estimated year-by-year consumption of annual pasture growth by our cattle in 2 paddocks at the ironbark site, based on GRASP parameters and algorithms. The annual rainfall as a proportion of the long term mean is also shown.

Another synthesis of the data was done in 2001 by a student (Iain Hume) working with Mr Ken Day of DNR&M, which looked at how well the modelled production of each paddock matched what grew in the various treatments. Nothing of this has yet been formally published but we provide examples of how our site data and the Swiftsynd studies are being used to improve the GRASP pasture growth model. These are accompanied by a critique of the results by Ken Day. Importantly, such studies point to where major discrepancies exist between the observed production and the calculated production as well as testing theoretical assumptions made when going from pasture growth to animal growth and soil erosion from a basis of incident rainfall. For example, to get the observed and calculated data to correspond adequately, the GRASP model's tree/grass relationship algorithms had to be set to 10% of the real site tree stem area.

11.2 Working notes on simulation of Ironbark site grazing trial (K. Day 30 Aug. 2001).

11.2.1 Methods

Notes on model parameters.

Parameter changes between treatments are as follows:

1) Soil water index at which growth stops, Soil water index at which cover is restricted

ungrazed	0.1;	light utilisation	0.2;
moderate utilisation	0.3;	heavy utilisation	0.4

2) Transpiration Use Efficiency

ungrazed	21;	light utilisation	18;
moderate utilisation	15;	heavy utilisation	12

Other notes

• Assume 100kg dry matter after burning (likely too low)

•Tree competition is minimal. Effective tree basal area (TBA) is estimated as 10% of default settings in GRASP. Rather than adjust GRASP parameters, TBA input is reduced to 10% of measured (Bitterlich Stick survey). For unsurveyed paddocks, TBA is assumed to be average of measured treed treatments.

•TBA of cleared paddocks assumed to be nil.

•Regrowth rate was adjusted by measured grass basal cover- basal area adjustments are made on date of measurement.

11.2.2 Results

11.2.2.1 *Time-series of observed (Botanal) and calculated (GRASP) biomass for all treatments.*

Daily growth, observed and calculated biomass and some statistics are provided in the file Kbete_Version_Hume.XLS.

Major findings are outlined below.

11.2.2.1.1 Calculated growth

Calculated growth by year (averaged across treatments, Table 11.1) and treatments (averaged across years, Table 11.2) are presented below. Growth declines with increased grazing pressure and slightly with trees (at 10% of actual size) as follows (Table 11.2):

Table 11.1 Calculated annual pasture growth (averaged across all treatments except COMM paddock).

Year	Annual growth (Jul-Jun)
1994/95	2349
1995/96	3136
1996/97	4479
1997/98	3129
1998/99	5275
1999/2000	4411

Table 11.2 Calculated pasture growth (averaged across 6 years 94/95–99/00).

TREATMENT	REP1	REP2	REP3	AVERAGE	% of CN
Burn trial					
CN	4466	4379	4566	4470	100
TN	4272	4498	4490	4420	98.9
CB	4333	4287	4427	4349	97.3
TB	4255	4253	4354	4287	95.9
Grazing trial					
CL	3949	3941		3945	88.3
TL	3850	3861		3855	86.2
CM	3316	3207		3261	73.0
TM	3030	3079		3054	68.3
CH	2950	2629		2789	62.4
TH	2311	2433		2372	53.1

11.2.2.2 *Observed vs calculated biomass*

Comparison of calculated and observed biomass provides some indication of the accuracy of the above growth calculations although it should be noted that as well as growth, standing biomass is a function of detachment, intake (grazing) and residual biomass after burning. Effects of growth and detachment are difficult to separate in calibrating the model (given only one biomass measurement per year) although detachment in burnt treatments generally minimal before April. Grazing by macropods is not accounted for in the model and residual biomass after burning was not measured. Detachment rates are held constant across treatments and for all plant material. Detachment rate due to cattle (trampling) is a function of stocking rate in GRASP.

Time-series of observed and calculated biomass indicate few major discrepancies. The major discrepancy is that biomass in the unburnt, ungrazed treatment (CN & TN) is underestimated in two years (97/98, 99/00). It is likely that this problem is due to less detachment than normal of tough, old grass that has not been knocked over by livestock rather than with the growth rates. The current simulation assumes all biomass has the same detachment rate. No attempt was made to split biomass into slow and fast detaching material although it is possible in the GRASP model. Biomass tends to be more widely underestimated across most treatments in 1997/98 (e.g. CB1, TB1, TB2, TL2, TM1, TM2, CM2) and this is considered in more detail below.

11.2.2.3 *Fit with grazing effect*

Comparison of observed and calculated biomass suggests that the model's grazing impacts are probably conservative. Biomass in heavy grazing treatments is, on average, slightly higher than observed. In more lightly grazed or ungrazed treatments, calculated biomass is slightly lower than observed. There would appear to be a consistent trend with grazing pressure (Table 11.3).

Table 11.3 Calculated versus observed grazing impact on biomass meaned over all reps and years (excluding the ungrazed and unburnt treatment).

TREATMENT	OBSERVED	CALCULATED	OBS /CALC
BURNT (ungrazed)	3453	2958	1.17
LOW G/Pressure	3036	2714	1.12
MODERATE	2103	1970	1.07
HIGH G/Pressure	1290	1413	0.91

11.2.2.4 *Fit with tree effect*

Tree impacts are, on average, well simulated (Table 11.4). There is some evidence that tree impact was less in burnt treatments than simulated for 97/98, 98/99.

Table 11.4 Calculated versus observed tree impact on biomass, averaged over all sites (excluding the ungrazed and unburnt treatment).

TREATMENT	OBSERVED	CALCULATED	OBS / CALC
TREELESS	2466	2252	1.10
TREED[#]	2334	2159	1.08

[#] Based on only 10% of the measured tree basal area.

11.2.2.5 *Fit for individual years*

For all sites (excluding the ungrazed and unburnt treatment) calculated biomass is slightly lower than observed biomass. Errors are greatest in 97/98 -on average calculations are lower than observed yields (Table 11.5). Excluding this year, calculated biomass is, on average, 2408 kg/ha compared to observed of 2500 kg/ha.

Table 11.5 Seasonal impact on the correlation between calculated and observed biomass for all treatments (excluding the ungrazed and unburnt treatment).

YEAR	OBSERVED	CALCULATED	OBS / CALC
All years	2400	2207	1.09
1994/95	1414	1353	1.05
1995/96	1299	1054	1.23
1996/97	3023	3408	0.89
1997/98	1900	1197	1.59
1998/99	3586	3233	1.11
1999/2000	3176	2988	1.06

11.2.2.6 *Regression analyses*

Regressions of observed vs calculated biomass have highest r-squared values in the burnt and in heavily grazed treatments (Table 11.6). The strength of the relationship between observed and simulated biomass is comparable to simulations for other grazing trials and pasture growth in general (see Day *et al.* 1997, Risks of Land and Pasture Degradation Report, RIRDC DAQ124A).

Table 11.6 Regressions for observed vs calculated standing pasture biomass at the ironbark site.

Burnt or Grazed	OBSSDM = 448 + 0.885*CALC	(RSQR=0.72, n=108)
Burn	OBSSDM = 182 + 1.05*CALC	(RSQR=0.75, n=36)
Burn Treeless	OBSSDM = -310 + 1.18*CALC	(RSQR=0.83, n=18)
Burn Trees	OBSSDM = 545 + 0.97*CALC	(RSQR=0.69, n=18)
Treeless	OBSSDM = 286 + 0.97*CALC	(RSQR=0.77, n=54)
Treed	OBSSDM = 605 + 0.80*CALC	(RSQR=0.66, n=54)
Grazed	OBSSDM = 567 + 0.76*CALC	(RSQR=0.66, n=72)
Grazed (low utiln)	OBSSDM = 930 + 0.75*CALC	(RSQR=0.58, n=24)
Grazed (mod utiln)	OBSSDM = 1056 + 0.51*CALC	(RSQR=0.53, n=24)
Grazed (high utiln)	OBSSDM = 132 + 0.82*CALC	(RSQR=0.80, n=24)

Note: OBSSDM = Observed Standing Dry Matter
CALC = Calculated Standing Dry Matter on 30 June.

11.2.2.7 *Recommendations for comparison with remote sensing data*

Care should be taken is using individual years, in particular 1997/98. Given that there no major biases are detected between observed and predicted, I would recommend that the daily growth data be used without correction (except 97/98 in which case it should be noted that the model underestimates biomass and most probably growth). I recommend avoiding using model calculation for the set stocked paddock (COMM) and the unburnt and ungrazed (CN, TN) treatments because:

- Botanal data on the COMM paddock was not obtained so there are no checks on calculations for this paddock.
- Biomass in the ungrazed and unburnt treatment is poorly modelled in two years (97/98, 99/00).

Care should be taken in interpreting calculated growth in 97/98 because it is likely to be higher than calculated. On average growth may be slightly underestimated by the model, particularly in more lightly grazed treatments. However it is difficult to suggest a correction factor for any given year or treatment. Where possible it would be most instructive to present results as averages across reps, years and treatments to avoid fine scale (paddock to paddock) variation and noise due to sampling error. We have not considered within year variation in growth as there was only one biomass measurement per year.

Hence assessment of remote sensing data vs monthly growth should be interpreted with caution, given the lack of validation data at this scale. Swiftsynd data does exist for 1994–1996 (soil water parameters were calibrated from this data as were some growth parameters) which addresses within season variation in growth, but only for small exclosures. In terms of evaluating the remote sensing model, it would be valuable to ascertain whether the model calculates differences in growth between treatments and years as presented in Tables 11.1 and 11.2.

Other graphs showing the goodness of fit between the 2001 GRASP model and the field data are shown in Figure 11.4.

11.3 Examples of the fit between modelled and observed yield from Iain Hume's study

Figure 11.2 shows that yields of ungrazed plots, with or without trees, were seriously underestimated by GRASP in 1997/98 and 1999/00 but showed good agreement in all other years. The fit was achieved by assuming that the tree competition effect was only 10% of what the normal level would be, based on Scanlan and Burrows's work. As the tree effect started to exert itself later in the trial a lack of consistency might have been expected in the treed plots in later years. There was inconsistency, but it occurred in both treed and treeless plots. At this time we have not had the resources or time to investigate this further but that will be done in new projects.

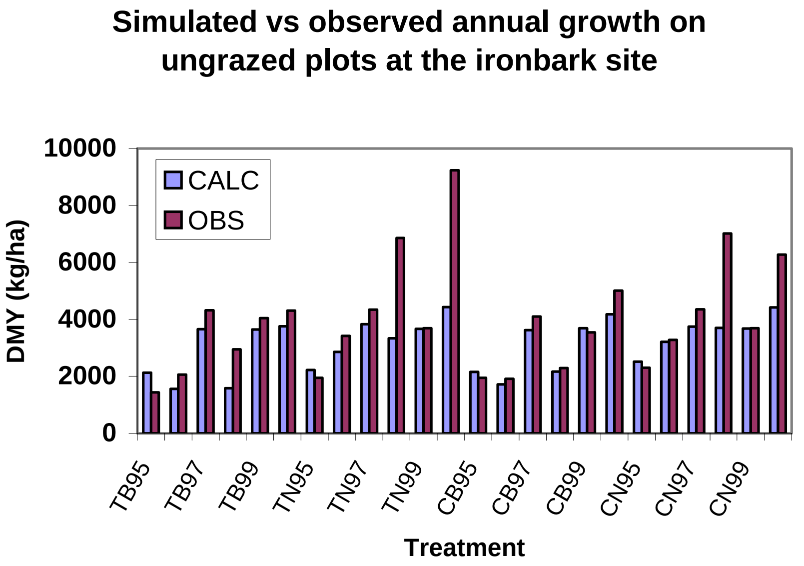


Figure 11.2 Comparison between observed pasture yield of ungrazed plots and those calculated using the GRASP model, for each year between 1994/95 and 1999/2000 at the ironbark site. T =Treed plot, C = Treeless, B = Burnt, N = Unburnt and the number is the year – thus TB95 is the mean of 3 reps from the Treed/Burnt plots for the 1994/95 year.

Figure 11.3 shows how well the model agreed with measured yields in 1995/96 but then had very poor fit for plots in 1996/97. The data is all from treeless plots and so includes 6 grazed paddocks and 6 ungrazed plots. None of the ungrazed plots were burnt in 1996/97 because the weather was too cool and moist in the spring burning period. However, the poor fit is not because the modellers failed to allow the growth to accumulate over a second year without grazing. A range of defoliation treatments were involved and some were over-estimated and some were under estimated.

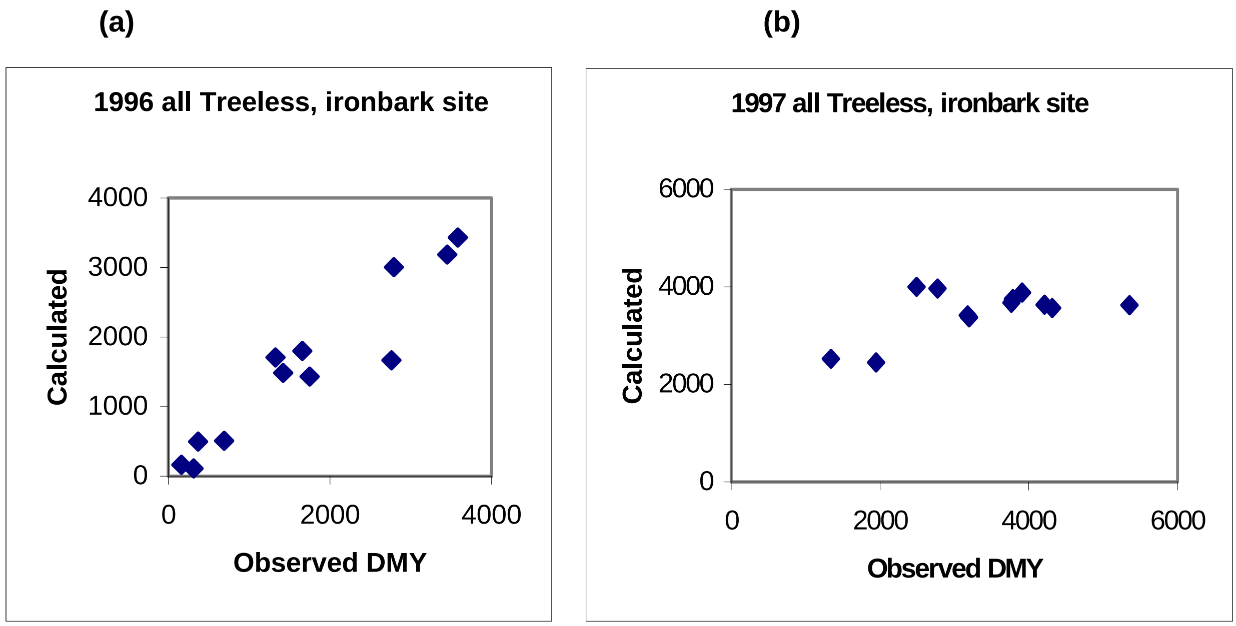


Figure 11.3 Mean observed versus calculated pasture yield at the ironbark site grazing trial for the same 12 treeless plots in consecutive years, (a) in 1995/96 and (b) in 1996/97. GRASP model run in mid 2001.

11.4 Linkage to predictive models

We have used the GRASP model to calculate at the ironbark site how much pasture growth probably occurred in the CM2 and CH1 treatments throughout the trial period and then to calculate the percentage utilised by our cattle each year. The nearness of fit with our annual assessments based on standing forage at the end of summer at the ironbark site is summarised in Table 11.7. The intended utilisation ratio for high : moderate was 3 : 2. The treed paddocks were not assessed because of the known lack of fit of our trial data with the GRASP model's theoretical relationship between trees and pasture growth.

Table 11.7 Mean percent utilisation over 6 years for two grazing treatments at the ironbark site, from simulations run in mid-2003.

	Treeless	
	Nominal	**GRASP**
Grazing pressure		
High	75	72
Moderate	50	49

With adequate confidence in the GRASP model outputs, there should be scope for extending that information to predictions of possible controlled fire frequencies for different runs of seasons and grazing management options. That would be a powerful predictive tool in woodland management where excessive regrowth can severely curtail production quite rapidly (in say 10 years) if fires are not used, compared to a 60 year expected period before re-treatment is needed if regrowth grows slowly.

Also we provide a summary of an analysis by Mr Grant Fraser of the runoff and erosion results from the ironbark site compared to those calculated by the model used by Scanlan *et al.* (1996) for pastures in the Charters Towers district. The work has been able to propose an improved model for predicting the runoff and soil movement at the ironbark site, based primarily on daily rainfall data. Antecedent soil moisture did not appear to be an important factor on this soil type where high intensity storms are common. Full details of this work are available from Grant at the Qld Dept Nat. Res & Mines. Further research is being proposed to use the results from ours and other grazing trials to improve our ability to model animal production, fire occurrence, rainfall, runoff and soil transportation by streams in rangelands.

11.5 Modelling soil-climate interactions at the ironbark site grazing trial to predict grazing management outcomes

G. Fraser (DNR&M, CINRS, Indooroopilly)

The computer simulation model GRASP (McKeon *et al.* 1990) provides a framework for analyses of land management effects on pasture growth, runoff and erosion. We used it to test the effectiveness of its existing runoff and erosion algorithms and for the development of new and improved algorithms based on the results of this trial.

The initial steps involved in the parameterisation of GRASP required setting the plant available water capacity and plant growth and detachment characteristics. The plant available water capacity estimate for all plots was approximately 70 mm for a profile depth of 60 cm, based on the neutron moisture meter readings. It can be seen that the model does predict total standing dry matter with a reasonable degree of accuracy (Figure 11.4). For more detailed model growth, cover and runoff simulations for each of the plots please refer to the more detailed report (Fraser 2004).

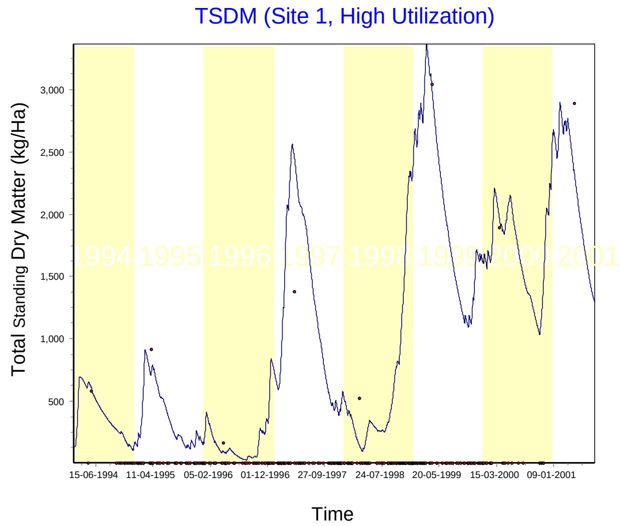


Figure 11.4 Goodness of fit of modelled results with measured autumn pasture yield (•) in the high utilisation rep1 paddock.

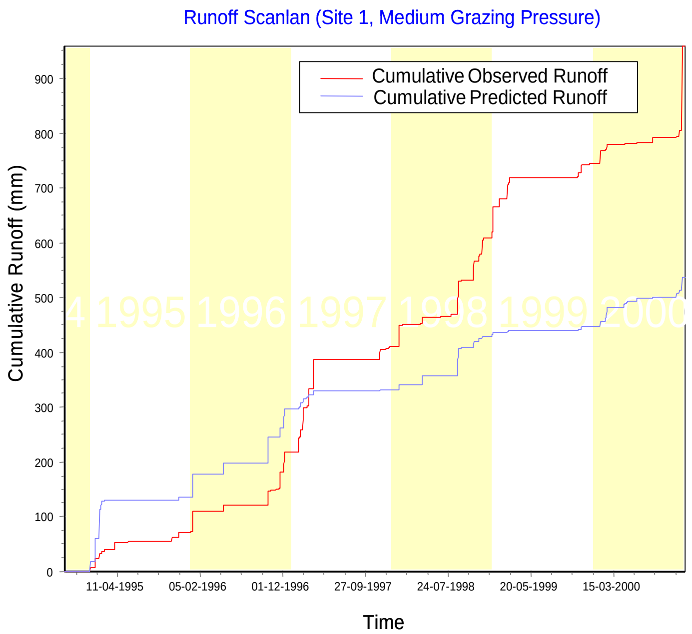


Figure 11.5 Poor fit between measured runoff and Scanlan model predictions at the ironbark site.

The existing runoff model options in the GRASP model include; a) the curve number runoff algorithm, b) the algorithm developed by Scanlan from a plot trial study in the Charters Towers region and c) the drainage restriction models developed by the USDA- GLEAMS and CREAMS. Each of these algorithms was used to assess their value in simulating the measured runoff data collected from this trial. The runoff results initially did not agree well using the Scanlan equation (Figure 11.5).

The curve number model provided the best fit for the data in comparison to the results obtained when using the Scanlan runoff equation. This result was expected as there is no capacity to calibrate the Scanlan runoff equation for site specific conditions, unlike the curve number method. Even though a reasonable calibration was achieved through fitting the curve number equation, I believe that this model poorly represented the rainfall- runoff processes occurring at this site. The curve number method uses the daily soil antecedent moisture as a primary influence on runoff processes. However a large number of runoff events occurred from storms falling on soil profiles which had low antecedent moisture status. The more important components found to be influencing runoff at this small plot scale were the surface cover and rainfall intensity (Figure 11.8). A runoff algorithm was developed based on these findings (Fraser & Waters 2004) where – Runoff (%) = (-0.0082 * I_{15} – 0.4108) * Cover (%) + (0.8074 *I_{15} + 41.68).

This model will be limited in its application to the soil type and scale of measurements undertaken in this trial. The model is however valuable in highlighting the importance that surface cover and rainfall intensity have on surface runoff in this environment. A potentially major difficulty with applying this model is to develop a method to estimate the 15 minute peak rainfall intensity. Development of a rainfall intensity model is required to further improve our capacity to model surface runoff.

Theoretically the infiltration capacity of soils is affected by their physical characteristics (e.g. structure and texture) and current soil moisture content. Soil moisture is dynamic but moisture levels just prior to rain falling appeared to be a fairly unimportant factor affecting runoff in our study. In these events, runoff often occurred due to the rainfall rate exceeding the infiltration capacity of a dry, unsaturated profile. There was little difference in the plant available water capacity estimate for all plots, which was generally 70mm for a profile depth of 60cm. Other results indicated that the lower part of the profile did wet up and dry out. Hence there is no major drainage restriction down to the depth of the weathered granite substrate.

We noted that the high grazing pressure treatments had a much coarser surface texture after 7 years compared to the exclosed treatments. This could be due to the lack of surface organic matter in the high grazing pressure treatment or due to erosion within this treatment preferentially removing the finer clay particles from the soil surface.

A complication was that the runoff for all treatments in Replicate 1 far exceeded that measured at the Replicate 2 sites (Figure 11.6) about 400metres away. This highlights the problem with small plots in that they sometimes do not effectively represent the whole landscape due to the spatial variability of soils. However investigation of runoff processes at these scales is still critical for quantifying the most important factors influencing runoff and erosion.

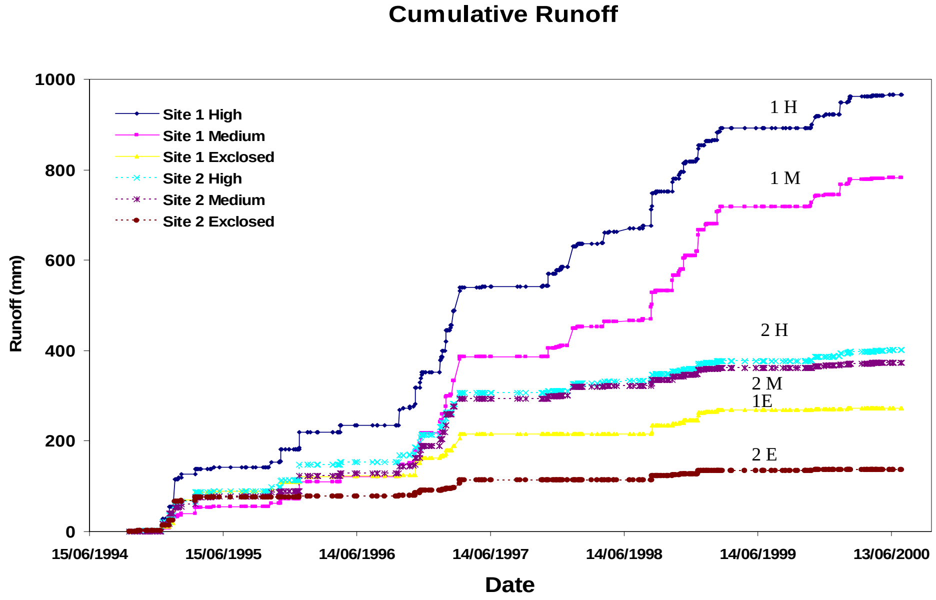


Figure 11.6 Measured cumulative runoff from each bounded plot at the ironbark site.

Runoff arising from storms accounted for the majority of runoff and erosion measured. Thus runoff events were coarsely divided into two rainfall categories before other tests of the model were run – 'storm' rainfall and 'depression' rainfall. This is a coarse method of subdividing rainfall events, but it emphasizes the need to be able model surface runoff with more than one equation.

During 'storm' rainfall events, the main factors affecting runoff were the interactions between rainfall intensity, surface cover and soil sodium concentration. To use an intensity-cover equation, storm intensity must be predicted within GRASP. A relationship between solar radiation and rainfall intensity was developed (Figure 11.7) but this equation is currently suitable for this site only.

The predicted runoff using the modelled cover estimates and intensity estimates can be seen in Figure 11.8. Our modelling also showed that total runoff is probably a poor indicator of a runoff event's erosivity. The clear trend in Figure 11.9 is that high measured runoff percentages are better correlated with the runoff rate/ transportation capacity of an event. This was due to the high percentage runoff events having the largest peak discharge rates and hence capacity/ energy to move surface sediment.

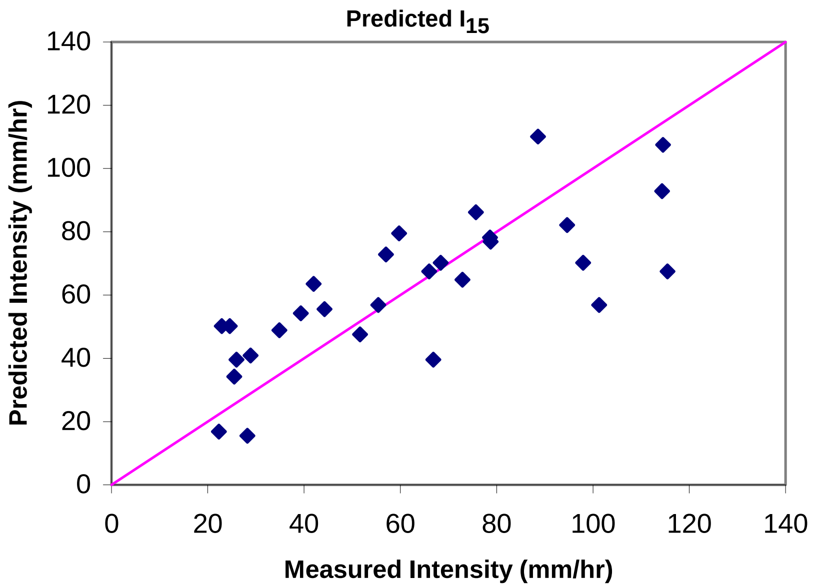


Figure 11.7 Correlation between measured I_{15} rainfall intensity and predicted intensity based on antecedent solar radiation.

Our modelling also showed that total runoff is probably a poor indicator of a runoff event's erosivity. The clear trend in Figure 11.10 is that high, measured runoff percentages are better correlated with the runoff rate/ transportation capacity of an event.

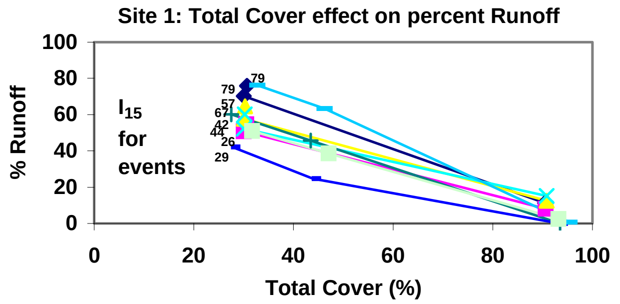


Figure 11.8 Relationship between total ground cover and runoff for selected events at the ironbark site.

Analysis of this trial has allowed testing of our existing capacity to model surface runoff and erosion. This highlighted the fact that there are significant areas where the models can be improved to represent runoff and erosion processes for these small plot scales. However improvements in our capacity to model surface runoff at a daily timestep will not be achieved without overcoming difficulties such as developing methods to model the 15 minute maximum rainfall intensity.

Including rainfall intensity into the model's predictive equations will also help define the high erosion risk periods within a yearly timeframe. During this trial the high-risk periods corresponded to the late spring-early summer period when intense rainfall was common and surface cover tended to be low after little growth during the winter period. The results from this study will improve our capacity to model and hence will improve our ability to provide information for sustainable grazing land management in Queensland.

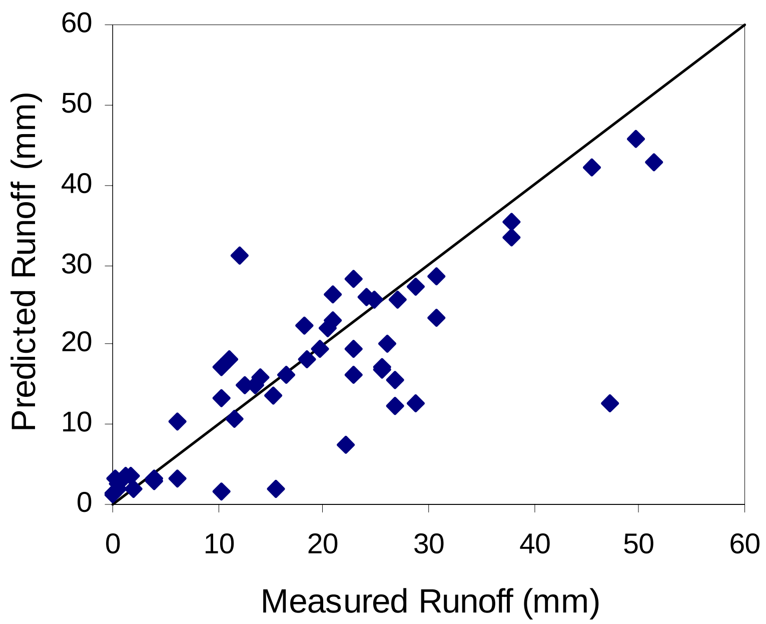


Figure 11.9 Relationship between measured runoff % and predicted runoff % based on ground cover and peak 15 minute rainfall intensity (I_{15}) during an event.

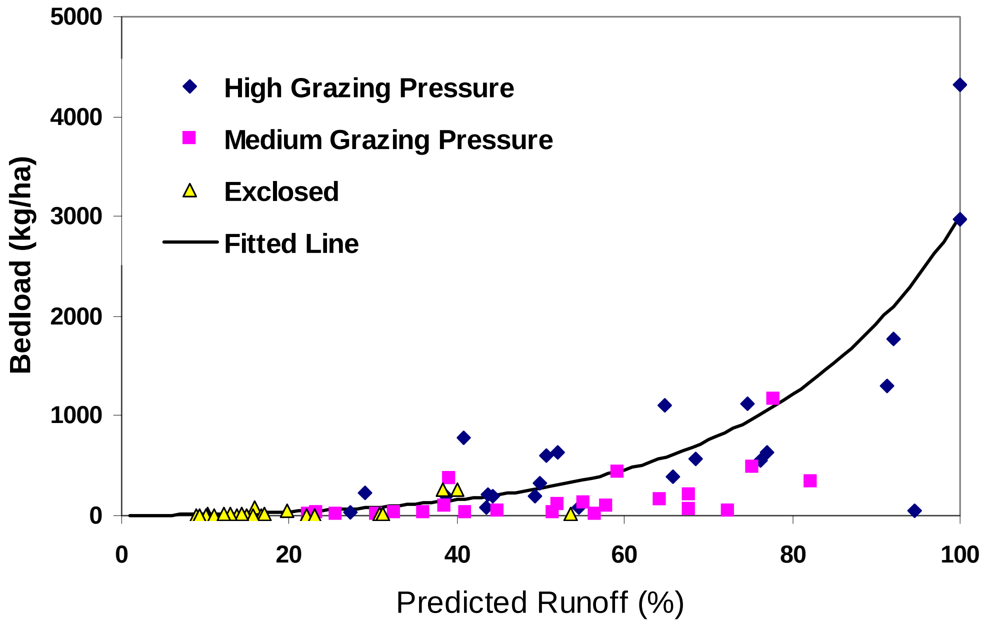


Figure 11.10 Relationship between the predicted % runoff using the storm runoff equation and measured coarse bedload sediment at the ironbark site.

12 Acknowledgements

The authors of this Final Report wish to sincerely acknowledge the input and assistance of a large number of people to this ten year project. Initial enthusiasm came from Dr Barry Walker who was then the meat industry's North Australia Program Technical Co-ordinator, Dr Piet Filet of Qld DPI at Emerald and the original project development team – Dr Gavin Graham, Mr Trevor Hall, Mr Evan Thomas, Ms Alison Kelly, Ms Carla Schefe and Mr Peter Knights.

Once the project concepts had been agreed between QDPI and MRC (Meat Research Corporation), progress from there was dependent completely on the co-operation and willing assistance of the owners of our two main trial sites. We are indebted to Charlie and Jacqui Hawkins of 'Keilambete', Rubyvale and John and Maree Chandler of 'Glentulloch', Injune for making land and water supplies available, for checking on stock when we could not, and for facilitating our holding of meetings and field days at our sites. We also thank the Hicks family who purchased 'Keilambete' towards the end of the study for helping the project to run its course there.

Further we sincerely thank the producer members of the consultative committees for each site. They assisted us to interpret our results and provided numerous ideas and suggestions to assist in running our trials. We hope our management suggestions and interpretation of the data reflect your wisdom and experience.

The collection of data and the day-to-day maintenance of the trials was greatly assisted by staff of QDPI and DNR&M from various centres plus the family members and staff of our host properties. They are listed under the participants at the start of this report and contributed in innumerable ways, not least by their enthusiasm and expertise. Special mention has to be made for sections written within this report by Dr Ken Day and Mr Grant Fraser of DNR&M, of the contributions of Mr Bill Holmes QDPI&F Townsville to the economics section and the help provided by Mr Cyril Ciesiolka, DNR&M to rehabilitate the Gerlach troughs at Glentulloch in 1997.

We thank the MLA, MRC and the NAP co-ordinators for their patient support of the project and subsequent protracted writing up and also Qld DPI&F senior management for their ongoing support under sometimes difficult circumstances.

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13.2 Glossary of terms used

3P grasses – grasses that are palatable, perennial and productive (high yielding); the most desirable grasses

Alluvial – soil that is derived from floodplain sediments

Bedload – the coarse, eroded soil from a catchment that quickly settles out once the water stops flowing.

Biomass – the total weight of a nominated type of living material, eg. pond life, pasture, trees

Biodiversity - the complex local mixture of all living organisms. It is an unquantified concept and includes microbes, fish and trees.

Bioregion – a mapped region that has a recognisable mix of climate, vegetation and landscapes.

Cainozoic – the most recent geological era, going back for 65 million years from the present

Cohort – a group of plants that all germinated on the one rainfall event or all in the one growing season

Curve Number – a value between 50 and 100 which is used in erosion models to calculate soil erosion from complex soil, slope and vegetation mixes

Decreaser plant – a plant that declines in its presence under prolonged heavy grazing; usually a most desirable grazing species

Digestible energy – useable energy that an animal can derive via its digestive processes from a given fodder

DM – Dry Matter, material left after drying in a hot oven, often 80 ^{o}C, without charring

Dormant seed – living seed that currently will not germinate if moistened

Duplex soil – a soil with a clearly delineated surface layer that is much sandier than the one below

Ecosystem – a recognisable mix of lifeforms in a consistent environment

EFA – Ecosystem Function Analysis; LFA with a measured biodiversity component added to it

Exclosure – a small area of land from which domestic stock are fenced out

Exotic plant – a plant species that is not native to the region

Forbs – non-woody, broad-leaved pasture plants that are not grasses or sedges

Frequency – the proportion of samples of a defined size that contain a nominated organism or item, eg. grass within a 1 sq metre quadrat

GRASP – a computer model than calculates pasture growth at a point from rainfall, soil, climate and defoliation data

Grazing pressure – is the frequency and intensity with which named pasture plants are grazed

Groundwater – water in the upper layers of the earth that has no sealing rock layer between it and the soil surface to prevent it moving upwards if added to

Igneous – rock, derived from the molten core of the earth, that intruded into or was forced out over the earth's crust

Increaser plant - a plant that increases in its presence under prolonged heavy grazing; usually a less desirable forage species

ISO 14001 – an international standard dealing with environmental values of production processes

Land condition – a rating of the health of a piece of country based on soil, vegetation and landscape criteria. There are 4 land conditions A,B,C and D normally recognised in Qld

Land zone - a landscape shape with a specific geology, soil or rock type, eg. sandplain. There are 12 land zones identified for Queensland

Legume – a type of plant that can metabolise free atmospheric nitrogen to enhance its growth

LFA – Landscape Functional Analysis: a method for categorising the health of land using soil and vegetation characteristics

LWt – Liveweight or living weight of an animal as it stands before us

Mesozoic – a geological era 225 to 65 million years ago, during the dinosaur age

Metadata – fairly basic numbers and data that can be used to produce more intuitively meaningful information, eg. raw data for maps or diagrams

Metamorphosed – a type of rock derived from sedimentary rock through the application of heat, force and/or liquid chemicals

Monitor – the repeated measurement of the same feature of an object or process so that predictions can be made of future behaviour or corrections made to the object

NIRS – Near Infrared Reflectance Spectroscopy. A tool for making decisions about the nutritional management of animals based on predicted dietary quality

Nutritive value – a general term used when referring to the overall feed value of a fodder source for a specified purpose. Protein, mineral and energy values are all included.

Pasture condition – the value of pasture for grazing animal production plus surface soil stability

Peakvale Land System – the silver-leaved ironbark country on gritty, granite-derived red loams in the Anakie-Sapphire region of the Central Highlands of Qld

PERFECT – a computer model that calculates soil erosion losses from a landscape under different climatic and soil cover conditions

Population dynamics – the fluxes in the numbers of a specified species in response to various factors

Precautionary principle – a recent concept which says that 'Where there are threats of serious or irreversible damage, lack of full scientific certainty should not be used as a reason for postponing cost-effective measures to prevent environmental degradation.'

Proterozoic – a geological age very early after the earth's creation before large lifeforms evolved or arrived here – 2,500 to 570 million years ago

Quadrat - a small defined area of ground, usually marked with a solid frame, from which samples are collected or data recorded, eg. plant or insect counts

Rangeland – non-cropping country that has livestock grazing as its chief rural industry

Recruitment – the birth, germination or creation of new members of a particular species

Regional ecosystem (RE) – readily recognised vegetation types that consistently occur on a common soil type and landscape and have particular plants as dominant or common components. About 1100 are identified for Qld.

Replication – repeated areas or examples of the same treatment within one experiment

Salinity – the existence of highly salty surface soil or subsoil in the landscape; salty

Scalding – the development of bare, smooth soil surfaces due to wind or water erosion

Sedge – a grass-like plant that is often found in damp or swampy areas. They are usually bright green, smooth or shiny leafed and the stems are mostly triangular

Seed reserves – the viable seeds of a species that exist in the soil, plus those trapped in litter, dead seedheads and pods

Sheet erosion – surface soil erosion that occurs without the creation of obvious gullies or channels

Skeletal soil – a very shallow soil, either on ridges or on newly deposited volcanic rocks

Soil hydrology – the infiltration, water transmission and absorption characteristics of a soil

Southern Oscillation Index – the difference in atmospheric pressure between Tahiti and Darwin that is associated at extreme values with abnormally wet or dry seasons in eastern Australia

State and Transition – an ecological theory that says vegetation communities tend to stay in one broad 'state' unless sizeable forces (like a severe fire, prolonged overgrazing, herbicide or machinery) shift the balance, via a 'transition', to another fairly consistent state

Stoloniferous – growth habit of plants where the stem lies on the soil surface and roots down regularly at its joints with associated leafy clumps

Sustainable management – human management of a natural resource so that there is no decline in its productive capacity while continuing to provide an economic return on its use

Top-feed – palatable browsed tree and shrub leaf from which stock can gain feed benefits

Tordoned – the killing of trees and woody plants by stem injection with the herbicide Tordon 50D®, a mixture of picloram and 2,4-D

Total grazing pressure – the impact of grazing from all larger animals such as wallabies, goats and domestic stock. Insects such as locusts and termites are not normally included

Triple bottom line – a business outcome summarised in economic, environmental and social outcomes or measures

Tussock grass – a grass that has a tufted growth habit with predominantly erect stems

Utilisation – is the proportion of available or measured pasture biomass than is consumed by livestock during a specified period

Water table – the existence of free water in the soil profile below a certain depth

Woodland – timbered country where the tallest trees are between 10 and 30 metres high

14 Communication Activities

The project put a large amount of its team's human resources into communicating our activities and our findings to a very wide audience. That audience included local producers from the neighbourhood surrounding each trial site, quite apart from the formal Consultative Group aligned with each site. Interaction with other agency staff at Roma and Emerald by the large number of project staff and the willing involvement of such non-project people in running field days ensured that our research results were widely known in Government.

Then there were all the industry focus days like Meat Profit Days and Beef2000 where we exhibited our findings to everyone in attendance who had an interest in grazing land management. For example, three 1-day workshops called "Grazing Lands Management - Building A Foundation" were conducted under a FarmBiz program at Chinchilla, Condamine and Wandoan in September 1999 and several project members spoke there. The list goes on – radio, newspapers, newsletters, conferences, workshops and MLA Peer Review meetings. These are now chronicled to show details of what was presented, where, when, by whom and to what audience.

14.1 AB Link (Project newsletter)

The project team produced a project newsletter called ABLink which was put out intermittently. It was circulated to a mailing list of about 70 people who had an interest in grazing land management. This included people in other MLA projects from the North Australia Program (NAP). In all 14 editions were published and an example is included here. They provide an insight into the progress of the work and the most pertinent findings along the way.

Publication times for AB Link were –

Issue 1	May 1993	Issue 8	February 1998
Issue 2	June 1993	Issue 9	July 1998
Issue 3	August 1993	Issue 10	January 1999
Issue 4	November 1993	Issue 11	July 1999
Issue 5	July 1994	Issue 12	February 2000
Issue 6	April 1995	Issue 13	July 2000
Issue 7	Sept 1997	Issue 14	January 2001

14.2 Glentulloch Consultative Group newsletter

Another project newsletter was put out specifically to members of the Glentulloch Consultative Group by Peter Knights and Trevor Hall. There were 10 editions of this publication and a few copies are included to show its style. Its content related largely to the animal production data for each mob of cattle run during the trial. Some of the producers ran *Bos indicus* crossbred animals but some ran herefords and there was always debate about the merits of each breed. Early on in the project, a debate was held about having half and half of each in our trial animals to allow such a comparison but our small numbers per paddock, often 3, meant that this was not a feasible option.

Publication dates of each issue were –

Nbr 1	April 1995	Nbr 6	November 1996
Nbr 2	November 1995	Nbr 7	April 1998
Nbr 3	April 1996	Nbr 8	December 1998
Nbr 4	May 1996	Nbr 9	July 2000
Nbr 5	September 1996	Nbr 10	November 2002

14.3 Statewide production and landscape process modelling teams

We provided early data to the GRASP modellers to allow them to update their preliminary models for pasture growth on A/B country. Newer data was supplied upon request. The outcome of this collaboration is rarely overt but the 'big picture' outputs are state maps showing potential pasture growth in future months based on current climate signals and past growth (Long paddock 2003).

The collated data from the runoff and soil erosion studies have been quite well tested for the Keilambete site (See Section 12) in erosion models developed initially by Scanlan *et al.* (1996). Further papers and interpretive work from this site are expected and some will appear in conferences in the near future. This research feeds directly into important decision-making forums such as regional groups set up under the National Action Plan for Salinity and Water Quality and the Grazing Management Education packages designed for individual producers.

There will be other flow-ons once the results have been more fully scrutinised – into water quality improvement initiatives such as the Great Barrier Reef Water Quality Protection Plan and the management of algal blooms in the Murray-Darling Basin.

14.4 Other unreported studies done at the trial sites

The big areas and significant infrastructure involved at each trial site, meant that we were able to allow other researchers to conduct certain types of experimentation or sampling without interfering with our studies. In most cases we held the hope that the extra studies may provide valuable associated data to complement our own. Such studies were encouraged by project staff in the hope of getting coastal Universities to undertake specialist studies in Qld rangelands. From that we hoped that the collaboration would foster enlightened debate about sustainable grazing land management and land use.

The studies were –

14.4.1 Poplar box site

- Ben Harms et al. (DNRM, Indooroopilly) "Know your soils project" funded by NHT
- Gregoire Dupont, MSc thesis, Univ of Qld "The Effects of Trees on Microclimate along a Rainfall Gradient in South-Queensland".
- Vanessa Alsemgeest (UQ Gatton) Masters project on Landscape Functional Analysis in rangelands

14.4.2 Ironbark site

- Wayne Houston (CQU) "Insect ecology and dynamics in different grazing regimes"
- Kamaljit, S. (CQU PhD) "Soil respiration"
- John Rolfe (CQU) "methane emissions of grazing industries"
- Iain Hume (ANU) PhD on modelling pasture production and remote sensing of the impact of trees on pasture production (with Ken Day, DNRM Indooroopilly)

It is also worth noting that parts of the Glentulloch site continue to be used for studies of –

- poplar box biomass, as part of a national greenhouse gas project (Hoffmann and Back, DPI Rockhampton) and
- pasture recovery after the 2001-2003 drought (Orr and Hall, DPI Rockhampton – an MLA project with Greg McKeon of DNRM, Indooroopilly).

14.5 Team publications about the project

14.5.1 Research papers:

Hall, T.J. and Alsemgeest, Vanessa M. (2002). Landscape Function Analysis as an indicator of grazing pressure. Proceedings of the 12th Biennial Conference, “Shifting Camp”, Australian Rangeland Society, Kalgoorlie, Western Australia. p. 287 - 288.

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14.6 Copies of project publications or front pages of large booklets

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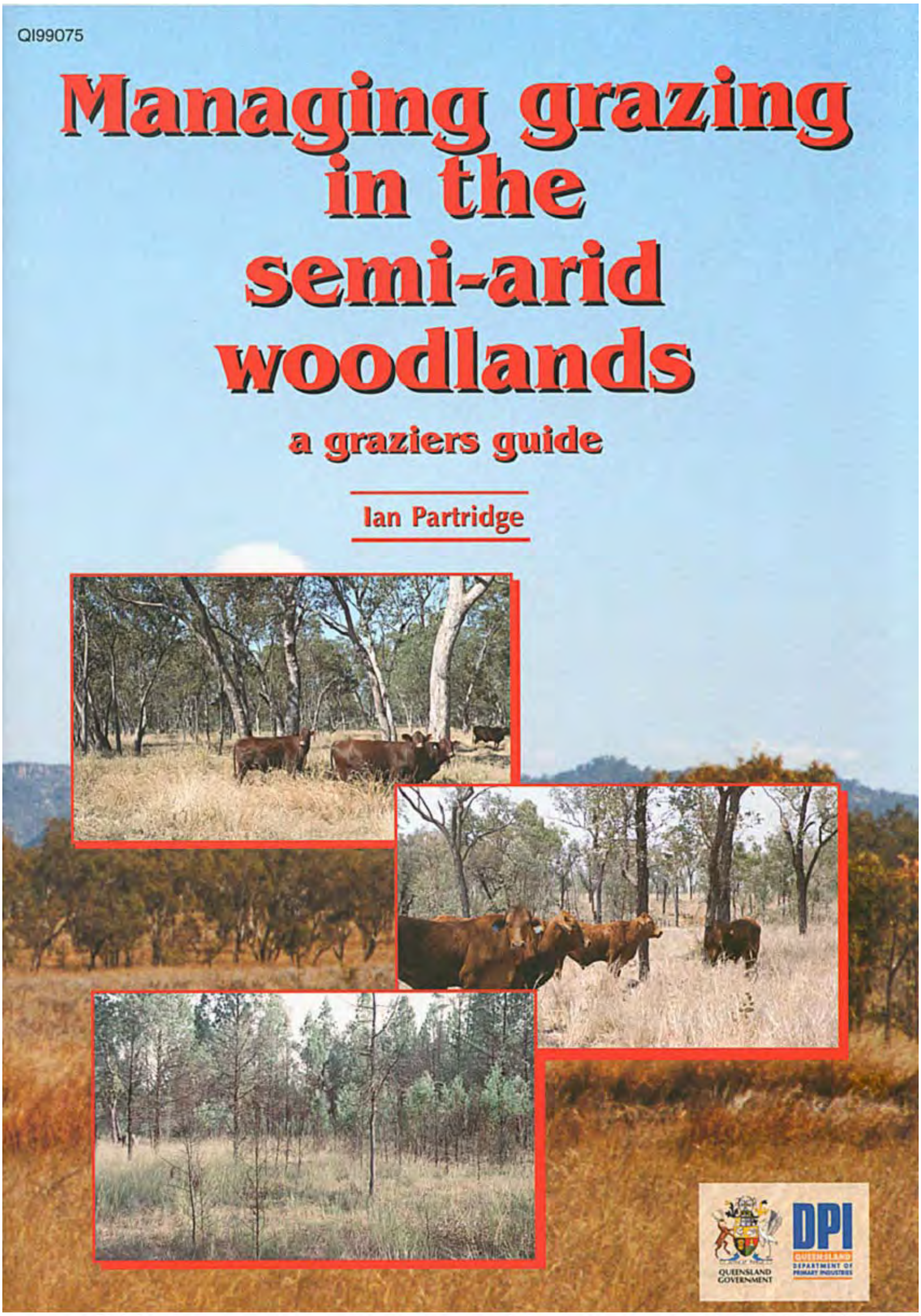
14.6.1 Dust Cover of Grazier Guide based on technical input from A/B project team (2000)



14.6.2 Conference papers and posters

1. [Poster paper at Aust. Rangelend Soc. Centennary Conf., Broken Hill, Sept. 2000]

CLEARING, GRAZING AND BURNING INTERACTIONS ON TREE DYNAMICS IN AN *ARISTIDA/BOTHRIOCHLOA* COMMUNITY

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ABSTRACT
Management options of clearing, altering grazing pressure and burning, were applied to trees and shrubs in poplar box (*Eucalyptus populnea*) woodlands of the *Aristida/Bothriochloa* community. Mature tree populations were stable over 5 years from 1994. Density of the shrubs, broad leaf hop bush (*Dodonaea viscosa*) and yellow-berry bush *(Maytenus cunninghamii),* and the small trees, false sandalwood (*Eremophila mitchellii*), myall (*Acacia pendula*) and whitewood (*Atalaya hemiglauca),* were most dynamic. Greatest population changes occurred in 1999, after a wet autumn and spring.

Keywords: tree, shrub, clearing, burning, grazing pressure, *Aristida, Bothriochloa*

INTRODUCTION
Stable and productive pastures with controlled woody vegetation competition can be developed from understanding tree dynamics under different management options. Commercial practice in the poplar box (*Eucalyptus populnea*) woodlands of the *Aristida/Bothriochloa* (A/B) native pasture community (Weston *et al.* 1981) is to clear mature trees to increase grass growth for cattle production. Subsequent woody regrowth control is by periodic burning. Understanding the interactions between management options of clearing, altering grazing pressure and burning, on populations and sizes of trees and shrubs can lead to the development of strategic management options to sustain productive pastures.

METHODS
There were 2 experiments in eucalypt woodland, in the A/B community near Injune (25^0 45'S, 148^0 25'E; mean annual rainfall 625 mm). Pastures were predominantly *Bothriochloa, Dichanthium, Aristida* and *Chloris* on yellow and brown duplex soils. Poplar box density was 210 trees/ha and basal area was 5 m^2/ha. Silver-leaved ironbark *(E. melanophloia*), bull oak *(Allocasuarina luehmannii)* and myall (*Acacia pendula*) trees were sub-dominants, but on different soils. Experiment 1 had three cattle grazing pressures (low, medium and high) under trees or clearing (by stem injection of Tordon^R) with 2 replications in 12 paddocks of 4-18 ha. The ungrazed experiment 2 had similar treed and cleared paddocks, burnt annually or unburnt, with 3 replications in 12 cells of 1 ha. Treatments were applied in mid-1994. Height, canopy cover, stem diameter at 30 cm and stem number of woody plants were recorded along permanent transects 4m wide by 450m (experiment 1) or 200m long (experiment 2) in the 24 treatments in 1995, 1996, 1997 and 1999 using the TRAPS methodology (Back *et al.* 1997). Annual rainfall (July-June) was 392, 571, 654, 707 and 844 mm for 1994-95 to 1998-99 respectively.

RESULTS
Of the 60 species recorded, poplar box was dominant (34.6%) in all treatments and its populations remained stable over 5 years. The shrubs, broad-leaf hop bush (*Dodonaea viscosa*) and yellow-berry bush *(Maytenus cunninghamii),* and the small trees, false sandalwood (*Eremophila mitchellii*), myall, bitter bark *(Alstonia constricta)* and whitewood (*Atalaya hemiglauca),* were most dynamic.

Clearing. Stem injection killed all mature eucalypt trees. There was no significant eucalypt, poplar box or ironbark, seedling recruitment in any treatment over the first 5 years. In the treed treatments, shrub populations increased by 43.4% over 5 years compared with a 5% increase after clearing. Limebush *(Eremocitrus glauca)* increased by 27% in one paddock under clearing and low grazing pressure on an area of clay soil.

Grazing pressure. Hop bushes, present under clearing and medium grazing pressure in 1995 and 1997, died in 1999. Under trees and high grazing pressure, hop bushes increased 340% and yellow-berry bush increased 170% between 1995 and 1999, while under trees and low grazing pressure, whitewood increased 215% and in one paddock bull oak increased 300%. Myall increased 12% under clearing and high grazing pressure, in one paddock over the 5 years. The high grazing pressure treatments caused total shrub population to increase 52%.

Burning. Populations of mature woody species were not affected by burning in experiment 2. There was an increase in small woody plants in the unburnt plots between 1997 and 1999 (Figure 1). A patch of 26 false sandalwood seedlings established in one cleared, unburnt replicate in 1999, following a wet autumn (192 mm), spring (241 mm) and summer (340 mm).

DISCUSSION

Eucalypt populations remained stable. In contrast, shrubs and small trees increased most under treed, high grazing pressure and no burning treatments. Burning was not an effective strategy to control mature trees, but it prevented establishment of most shrubs. Jones (pers. comm.) has also found that burning a mature silver-leaved ironbark woodland in central Queensland prevented seedling recruitment, while having no effect on the mature trees. Seedling recruitment of some woody species was promoted by the wet autumn to spring period in 1998. The need for parent plants nearby was evident for all significant recruitment and most new seedlings were in patches and not evenly spread.

The stable mature tree populations and sporadic recruitment of shrub species only in some paddocks during these experiments suggests that establishment events may only occur intermittently in this environment, and then under certain climatic and management conditions. Such ideal conditions may not have occurred during this 5-year period. A study of the main woody shrub species seeding, seed viability and recruitment over a wider range of seasonal conditions is needed to gain a better understanding of their establishment requirements. This will allow the development of strategic management options for maintaining pasture productivity and regrowth control after initial clearing.

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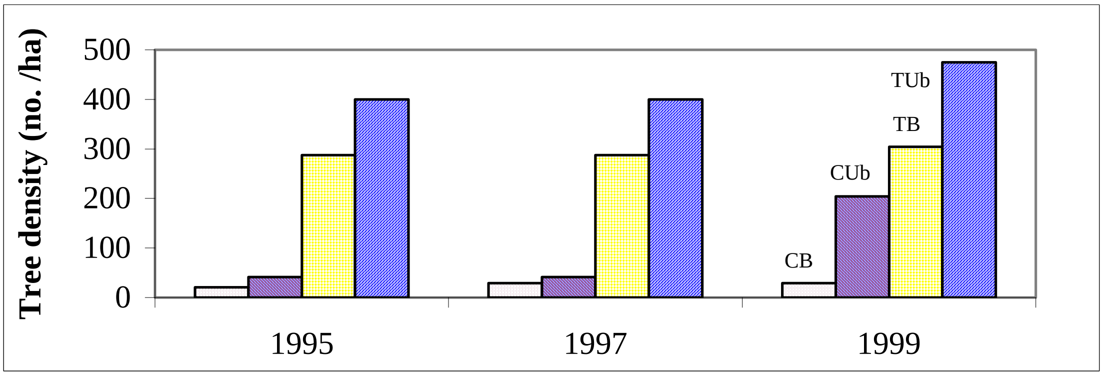

Figure 1. Tree density (no./ha) in cleared burnt (CB), cleared unburnt (CUb), treed burnt (TB), and treed unburnt (TUb) treatments in experiment 2 in 1995, 1997 and 1999.

2. [*Excerpt from Paper to 19th Intl Grassland Congress, Brazil Sept 2001*]

THEME: No 11. Biological constraints to animal production from grasslands

TREE COMPETITION REDUCES CATTLE GROWTH RATES IN EUCALYPT WOODLANDS OF QUEENSLAND

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Abstract
The wiregrass/bluegrass (*Aristida/Bothriochloa*) native pasture community in Eucalypt woodlands is a major cattle producing resource in Queensland. The effects of poplar box tree (*Eucalyptus populnea*) competition (at 5 m^2/ha tree basal area) and grazing pressure on pastures and growth of Brahman-cross steers were measured in a grazing experiment. Treatments were 2 tree competition levels (live trees or clearing) by 3 grazing pressures (low - 25%, medium - 50% and high - 75% utilisation of annual pasture growth).

Pasture yield and pasture foliage cover increased for 3 years from the reduction in tree competition by clearing and by low grazing pressure. Clearing increased pasture yield by 33% in the first summer growing season and by 94% in the third year. After 3 years, foliage cover at 51%, was 31% higher after clearing than in pastures with live trees. Pasture yield and cover were reduced by 34% and 33% respectively by high grazing pressure compared with the low rate.

Reducing tree competition by clearing produced a 39% increase in average daily steer weight gain (0.32 kg/day) over the third year, by eliminating weight loss in winter. Annual steer growth was highest at the low and medium grazing pressures. During summer when pastures were green and growing, steer growth was similar at the 3 grazing pressures. Highest liveweight in the third year occurred with clearing and low grazing pressure (gaining 131 kg/hd). There was greatest liveweight loss (14 kg/hd) during autumn and winter at high grazing pressure.

Keywords: cattle, tree competition, grazing pressure, Eucalypt woodland, *Dichanthium*, *Aristida*

Introduction

Native pastures of desirable bluegrasses (*Dichanthium* and *Bothriochloa* spp.) and undesirable wiregrasses (*Aristida* spp.) dominate the Eucalypt woodlands of the sub-tropics of southern inland Queensland. These summer growing, perennial grass pastures of the *Aristida/Bothriochloa* pasture community (Weston *et al.* 1981) support beef cattle. Over grazing will reduce the populations of the desirable perennial grass species and they can be replaced by unpalatable grasses and weeds. Tothill and Gillies (1992) suggest 50% of this pasture community could be improved by prudent grazing management. Cattle producers have the three main options of clearing trees, regulating cattle grazing pressure and burning, to manage this pasture community for long-term production and sustainability. The undulating poplar box (*Eucalyptus populnea*) woodland country has a range of soil types from clays to loams, including potentially highly erodible duplex soils, which need management of cattle grazing pressures to maintain adequate grass cover that will prevent damaging soil loss, gully erosion and pasture degradation.

A cattle grazing experiment was conducted to measure the effects of poplar box tree competition and varying grazing pressures on pasture production and on the growth rate of Brahman cross steers grazing native pastures in Eucalypt woodlands of Queensland.

Materials and Methods

A grazing experiment was established in 1994 at “Glentulloch”, Injune (25^0 45’ S, 148^0 25’ E, mean annual rainfall 625 mm) on duplex soils in poplar box woodland with a tree basal area of 5 m^2/ha in southern inland Queensland. The design was: 2 tree clearing treatments, kill trees (chemically with Tordon[R]) and leave live trees (at a basal area of 5 m^2/ha), by 3 grazing pressures; low (25% utilisation of the annual pasture growth), medium (50% utilisation) and high (75% utilisation). There were 2 replications and paddock size ranged from 4 – 18 ha. Brahman cross steers with a starting weight of 165-195 kg were grazed in the 12 treatment paddocks with numbers starting at 3 head per paddock. Numbers were adjusted annually, depending on end of summer pasture production, to graze the pasture at the required utilisation rate.

Pasture dry matter yield, foliage cover and composition were recorded annually using the BOTANAL program (Tothill and Gillies 1992) and steer liveweights were recorded every 2 months. The results of pasture production and foliage cover over the first 3 years, and of steer liveweight during the third year are reported.

Results

The experiment commenced after the 1993-94 drought which caused poor pasture growth of 600 kg/ha. Rainfall in the first 3 years (1994-95 to 1996-97) of grazing was 391, 571 and 654 mm respectively.

Pasture yield responses to tree competition and grazing pressures followed similar trends during the first 3 years (Table 1). Clearing produced higher yields than with tree competition in all years, for example, almost double at 3440 kg/ha in 1997. Yields increased in both the cleared and treed treatments to a peak of 4250 kg/ha in the cleared and low grazing pressure treatment in 1997. The treed and high grazing pressure treatment was lowest yielding consistently, although increasing to 1460 kg/ha over 3 years.

The low grazing pressure had the highest pasture yields, mean across all tree competition treatments of 3200 kg/ha at the end of the 1996-97 summer, compared with a peak yield at the high grazing pressure of 2120 kg/ha in the same season (Table 1). The medium grazing pressure treatment was between these yields at 2490 kg/ha.

Pasture foliage cover increased to 51% in the cleared treatments over 3 years (Table 1). Cover increased to 50% at the medium and low grazing pressures, while there was no change at high grazing pressure (33% in 1997).

Steer liveweight over the third year of grazing (1996-97) in the cleared treatments, meaned over grazing pressures, showed higher growth rates (mean 0.32 kg/day) than in the tree competition treatments (0.23 kg/day). The main difference was due to steers in the cleared treatments maintaining weight during winter and spring (average gain of 0.03 kg/day), while steers in the treed treatments lost weight (average –0.12 kg/day from May to November) (Figure 1).

3. [*Paper Abstract for Intl Soil Conservn Orgn Conference held in Brisbane, July 2004*]

Modelling sustainable grazing land management- what are the key attributes?

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As public awareness grows with respect to the ‘possible’ environmental impacts of our rural industries, such as salinity and surface water quality there is an increasing pressure to be able to simulate/model the impacts of land use. But, how reliable are the models? What are the important parameters and can these parameters be estimated spatially to the level of accuracy needed to effectively simulate/ model real world situations.

Field measured data sets provide an insight into model credibility. A grazing trial located 50 km northwest of Emerald in central Queensland investigated the impacts of stock management on grass productivity, animal productivity, runoff and erosion. The daily point scale pasture productivity and water balance model, GRASP, was used to simulate this trial. This model has a water balance component similar to most other point scale models currently being used for modeling agricultural systems in Queensland. Climatic conditions at the field site meant that for the majority of the time the soil profile had a high soil water deficit as annual pan evaporation was 2200mm and average annual rainfall was only 640mm. Runoff-generating rainfall often fell as high intensity storms. The model poorly predicted runoff events that occurred during low antecedent moisture and high rainfall intensity conditions. This was due to the model using antecedent moisture as a major component for runoff generation. A simple storm intensity-runoff model was developed.

As grazing intensities increased there was a marked increase in the runoff and erosion. The level of grazing pressure is thought to impact on the surface soil condition through a number of possible avenues including increased raindrop impact at lower soil surface cover and loss of surface soil aggregation due to trampling. A cover index was incorporated into the runoff model.

As the high intensity storms often fell on dry soil profiles, the soil’s unsaturated hydraulic conductivity is thought to be the major soil characteristic affecting runoff generation. In particular, soil sodicity had a significant influence on runoff generation and soil erosion. At this site, soil sodicity changed significantly over relatively short distances having a marked influence on the point scale water balance.

The results from this study do have implications for the application of GRASP and other similar point scale models. These models are currently being applied to larger catchment scale situations for water balance modeling (e.g. salinity risk modelling). This study shows that spatial variability in soil characteristics such as sodicity has a major influence on the point scale water balance. However detailed information on soil characteristics such as sodicity rarely exists at catchment scales and hence the water balance modelling at these scales is less realistic of field conditions. The outcomes from such modelling exercises often have solutions, which are not very specific in their application (e.g. for prevention of salinity- revegetate 80% of a catchment). This study indicates that soil characteristics such as sodicity are important for accurate water balance modelling and that to apply the model spatially there needs to be a sound understanding of how these characteristics vary in our landscape. This would improve model water balance estimates within catchments, and also allow for more targeted solutions to grazing land sustainability issues.

4. [*Paper to Workshop on Remnant Vegetation in the Brigalow Bioregion, Rockhampton, Feb 2002*]

The *A-B*, a fragile yet resilient native pasture community

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Abstract. The *Aristida – Bothriochloa* (*A-B*) native pasture community (Weston et al. 1981) of the Brigalow Bioregion is of significant importance ecologically and for cattle production. The pasture is quite resilient to disturbance, however nutrient loss can be readily accelerated to unsustainable levels under medium or high grazing pressure. Stressing the pasture through increasing grazing pressure caused decreases in yield, basal area, ground cover, and animal production; and caused increases in nutrient losses, mortality of decreaser species and a loss of landscape function. The density of the major grass species was not affected. Above average summer rainfall led to a pasture recovery in yield, crown cover, decreaser recruitment and animal production, however landscape function is still adversely affected.

Project background

The *A-B* native pasture community is a large productive area, however condition assessments have identified degradation problems and the potential for improvement (Weston et al. 1981 and Tothill and Gillies, 1992). The area was deficient in production and ecological knowledge, and technical studies are assisting to develop sustainable resource management practices. The project covers 10.7 M hectares in the Central Highlands (CH) and Maranoa and is a partnership between the Department of Primary Industries, Qld (DPI), Meat and Livestock Australia (MLA) and the Department of Natural Resources, Qld (DNR). Initially the project conducted an inventory of pasture resources from which State and Transition management models were developed. Detailed research has since been conducted from 1994 to 2000 at Injune and Rubyvale on the effect of different pasture management on the land resource and there is now a better understanding of the region's ecology. Producer consultative groups are active at each site. Field days, community consultations and show displays have been conducted and project staff also assisted with pasture monitoring workshops, fire workshops and the production of a pasture plant identification book. This paper concentrates on the Rubyvale site in the CH.

Climate

The CH area has a sub-tropical climate and the rainfall is variable. The main period of potential pasture growth is from October to March when temperatures are optimal and 75% of the rainfall occurs in this period. Most of the rain from September to December is from thunderstorms while January and February have the highest monthly rainfall and heaviest daily falls (Bourne and Tuck, 1993). Only 14% of daily totals are 25 mm or more (Spackman and Garside, 1995). Average storm intensity at Emerald is 35 mm/hr so only a minor proportion of annual rainfall events are likely to contribute to pasture growth (Willcocks, 1993).

Soils

Soils of the *A-B* community are mainly infertile earths, duplex soils or sandy soils. The CH grazing trial is on the Peak Vale Land System (Anon 1967). It is undulating country with silver-leaved ironbark (*Eucalyptus melanophloia*) and gritty red duplex soils.

Rainfall during the project

Rainfall during the project has been very variable. The interaction of rainfall variability and treatments applied has had a large affect on pasture yield, 3P (perennial, productive, palatable) grass dynamics, runoff, soil loss and animal production. Summer and yearly rainfall totals were very low during the two years prior to the trial resulting in large scale regional destocking and urea molasses feeding. Rainfall during the establishment year of the trial was also low, however good growth conditions prevailed. Figure 1 shows the summer rain (October – March) has either been well above or well below the median. The trial has run from 1994 to 2001 and did not experience the extended dry conditions that have occurred in 1992 to 1995.

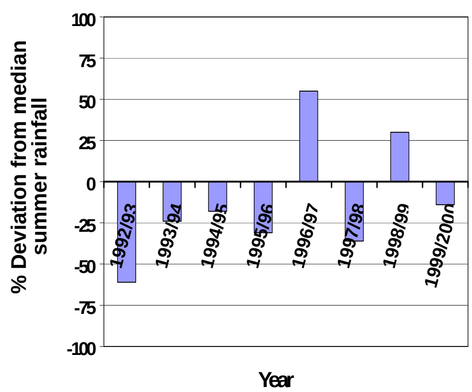

Fig. 1. Summer rainfall deviation from median at the CH grazing trial site.

5. [*Poster paper at Centenary Conf. Aust. Rangeland Society, Broken Hill, Aug. 2000*]

Native Rangeland Trees And Shrubs That Grow Readily From Seedlings

Richard Silcock
Department of Primary Industries

Seedling Recognition

Wilga

Corymbia spp.

Eucalyptus spp.

Vinetree

Wild Orange

Plumwood

Leopardwood

Kurrajong

Belah

Seed Germination

Test fresh seed as soon as possible and within a month of collection. Run the test on germination paper for 1 month. Clean seeds and replace paper if bad fungal attacks occur.
Room temperature is normally good enough.

If no germination, dry out seeds and try again after 9 to 12 months. If still no germination at moderate temperatures, scarify the seeds and repeat the germination test immediately.
Repeat annually after the first year.

Legume seeds should be scarified before any tests.

Seed Collection

Take care and be diligent with each species. Check in the field for seedfill well before planning to collect. Dry well the seed of non-fleshy fruits. Extract some 'seeds' of very fleshy fruits immediately and test germinability straight away. Control insect predation carefully as fruits dry out. Try to avoid using a chainsaw. Collection off the ground can be successful.

MEAT & LIVESTOCK

Queensland Government

6. *[Poster paper to the VIth int. Rangelands Congress]*

Chrysopogon fallax (Goldenbeard grass) regeneration – from seed and detached rhizomes

Richard Silcock

Qld Dept Primary Industries,
Toowoomba. Australia

QUEENSLAND GOVERNMENT
DPI QUEENSLAND DEPARTMENT OF PRIMARY INDUSTRIES
QUEENSLAND BEEF INDUSTRY INSTITUTE

Chrysopogon fallax is a grazing tolerant, increaser grass species in tropical Australian grasslands and woodlands. However it rarely has seed in the soil seedbank and recruitment from seed is not documented.

Plants persist for over 10 years and expand into dense, leafy swards several metres across (shown at right). The crown is a dense network of thick rhizomes, usually 5-15cm below the soil surface.

Studies were done to better understand its regeneration and spread methods.

Flowering and seed set

Flowering is restricted to a short period in mid-summer. Seed culms are fragile and sparse. Ripe seeds are large and fall with a long, hygroscopically active awn.

Germination

Less than 30% of fallen seeds contain a grain. Fresh seeds germinate quite well and hold viability in unsealed, lab storage for at least 18 months. Germination temperature is not critical.

Seedling emergence and growth

Sown 5mm 30mm

Seedlings do not emerge readily from seeds deeper than 10mm below the soil surface. A limited ability to elongate its sub-coleoptile internode seems to be the cause. Seedlings do not display tillers until 6-7 leaves have expanded. However, once 4 leaves are visible, a sturdy geotropic rhizome develops.

This rhizome enlarges fairly rapidly as shown in the photo alongside. The resulting crown differs markedly from most tropical grasses. The other grass shown to the right is *Cymbopogon refractus* of the same age.

Crown resistance to damage

If the crown of mature plants is uprooted by animals, or chopped up by ploughs, the rhizomes have a great ability to renew growth, survive significant dehydration and re-establish new crowns (photo). Heavy grazing pulls leaves from the ground but does not seriously damage the crown.

Conclusions

C. fallax has potential to regenerate from seed. Its increaser potential derives from its crown's resistance to damage.

Chrysopogon fallax (Goldenbeard grass) regeneration potential from seed and detached rhizomes

Richard G. Silcock
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Keywords: Germination, seedlings, persistence

Introduction

Chrysopogon fallax S.T. Blake (goldenbeard or ribbon grass) is a common perennial grass in Australian savannas. Its crown structure varies from strongly tussocked in far northern Australia to sward-forming in the subtropics of Queensland. It is regarded as a palatable, grazing tolerant, increaser species (Wandera 1993) but only a little research has been done on it. As there is conflicting evidence about how it spreads under grazing, further field and glasshouse investigations were made of this aspect of its ecology.

Tillering and flowering

Lazarides *et al.* (1965) studied its tillering and flowering phenology in the absence of grazing in the monsoonal tropics at Katherine (14.5^{o}S). They found it had a very short flowering period and that only a small proportion of tillers produced seedheads in the absence of burning. Even on burnt plants, only 10% of tillers turned reproductive. Most plants had fewer tillers than adjacent plants of *Heteropogon contortus* (black speargrass) and *Themeda triandra* (kangaroo grass). Seed fell very rapidly after anthesis compared to other grasses. Short stolons were noted on unburnt plants but most died, so the authors were uncertain whether it spread under grazing by vegetative means or by seed. The flowering period in the Roma area of south Queensland (26^{o}S) is also short, and the culms are easily snapped off if knocked by grazing cattle. Cross-pollination amongst genotypes seems essential for seed to be set by south Queensland ecotypes.

Wandera (1993) studied the dynamics of subtropical savanna pastures dominated by *C. fallax* near Mundubbera in south Queensland and found that *C. fallax* patches strongly excluded seedling recruitment of *H. contortus* and *Aristida ramosa* (purple wiregrass). There the species forms strong rhizomes and can spread slowly under heavy grazing, probably because the crown is 5-10cm below the soil surface. Crown spread always seems to be slow, measured in abandoned cultivation at Toowoomba in south Queensland as only one metre in 13 years and less than that in 10 years in grazed pastures near St George (28^{o}S)(Silcock *et al.* unpublished data). However, the existence and extent of rhizomes is not consistent in grazed swards and is very difficult to track by charting the presence of aboveground culms (Silcock *et al.* in the Roma district). Only digging marsupials, echidnas, rabbits and wild pigs damage the crown physically in grazed native pastures.

Seed germination

Mott (1978) conducted germination studies on seeds from the Katherine area and found fresh seed of goldenbeard grass to be mostly dormant and that this was steadily lost over the next 10 months. Three months after harvest, 16% of viable seeds were germinable and that increased to over 60% by 9 months. However, two thirds of naked caryopses extracted from seeds germinated at 3 months, especially if exposed to light. Hence, there was a seed coat restriction on the germination of fresh seed. Exposure to dry heat accelerated the loss of dormancy so that viable seed held in nylon bags on the soil surface in the field was 70% germinable by the following summer. By comparison, kangaroo grass seed was strongly dormant for 6 months in the field and for over 9 months in the laboratory. Optimal temperature for germination was in the range 30-35^{o}C.

Studies on seed collected from near St George also showed most caryopses are viable and that they hold their viability well in laboratory storage (Table 1), as did Mott's seeds. Germinability was similar in typical spring /autumn temperatures (15/27^{o}C) and mid-summer ones (20/35^{o}C) at all seed ages. The percentage of filled seeds was however only 7-18% in the sample (Silcock & Hall 1996). Though *C. fallax* caryopses were of good viability at Katherine, the percentage of seeds containing a caryopsis was not reported. No field emergence was reported but, though Mott had shown that recruitment was not primarily due to a lack of germinable seed being set, no measure of germinable seed in the surface soil was made. Surprisingly, studies of soil seed loads from other areas with significant amounts of *C. fallax* in the sward have never detected a germinable seed (McIvor & Gardener 1994; Orr *et al.* 1996; Silcock & Hall 1996). Seeds of other common grasses such as black speargrass and kangaroo grass are regularly detected in significant numbers from the same samples. Perhaps seeds are harvested by ants and birds?

Table 1. Germination at 20/35°C (+ light) of stored *C. fallax* seeds at different times after harvesting from near St George, Queensland.

Seed age	Percent germination
1 month	11.7
6 months	12.5
12 months	15.2
18 months	10.5

Table 2. Percentage of crown segments of grasses to regrow in 30 days after excavation and root removal, with or without significant exposure to dry air. Data is from 4 reps of 3 crown pieces.

Grass species	Kept moist	Air-dried 2 days
C. fallax	92	12
H. contortus	8	0
A. ramosa	8	0
B. ewartiana	58	8

Seedlings, rhizome development and resprouting

The caryopsis of *C. fallax* is quite large for a perennial grass at 2-3mg and pre-germinated seeds grown out in pots in a glasshouse produced robust seedlings in sand and clay soils. Emergence is rather atypical for a tropical grass. The seedling crown stays near seed depth and the coleoptile can elongate up to a maximum of 2cm towards the soil surface. However, this occurs very slowly and emergence would mostly only be successful from seed lying near or at the soil surface. Seedling leaves are 2-3mm wide, 5-10cm long and once 3 to 4 have expanded, a sturdy, geotropic rhizome forms and begins to push vertically downwards into the soil. The rhizome has a very blunt apex and eventually descends to 10cm or deeper while sending up new tillers from nodes close to or at the apex. Once well developed, the primary rhizome develops axillary ones of similar size and the basis of a dense sward is established. The rhizomes are tough, white, hairy surfaced, laterally compressed, 10-12mm thick and 6-8mm across, with nodes 5-10mm apart.

Similar rhizomes exist on mature plants in the field, and when crowns are excavated and broken up, the fragments resist pathogens well. In a trial, all such rhizome pieces retained good colour and firmness while buried afterwards in damp alluvial soil for 30 days and 92% resprouted. Of those that had been left drying on a glasshouse bench for 2 days in late summer before reburial, only 12% had resprouted.

14.6.3 Field Day and festival handouts

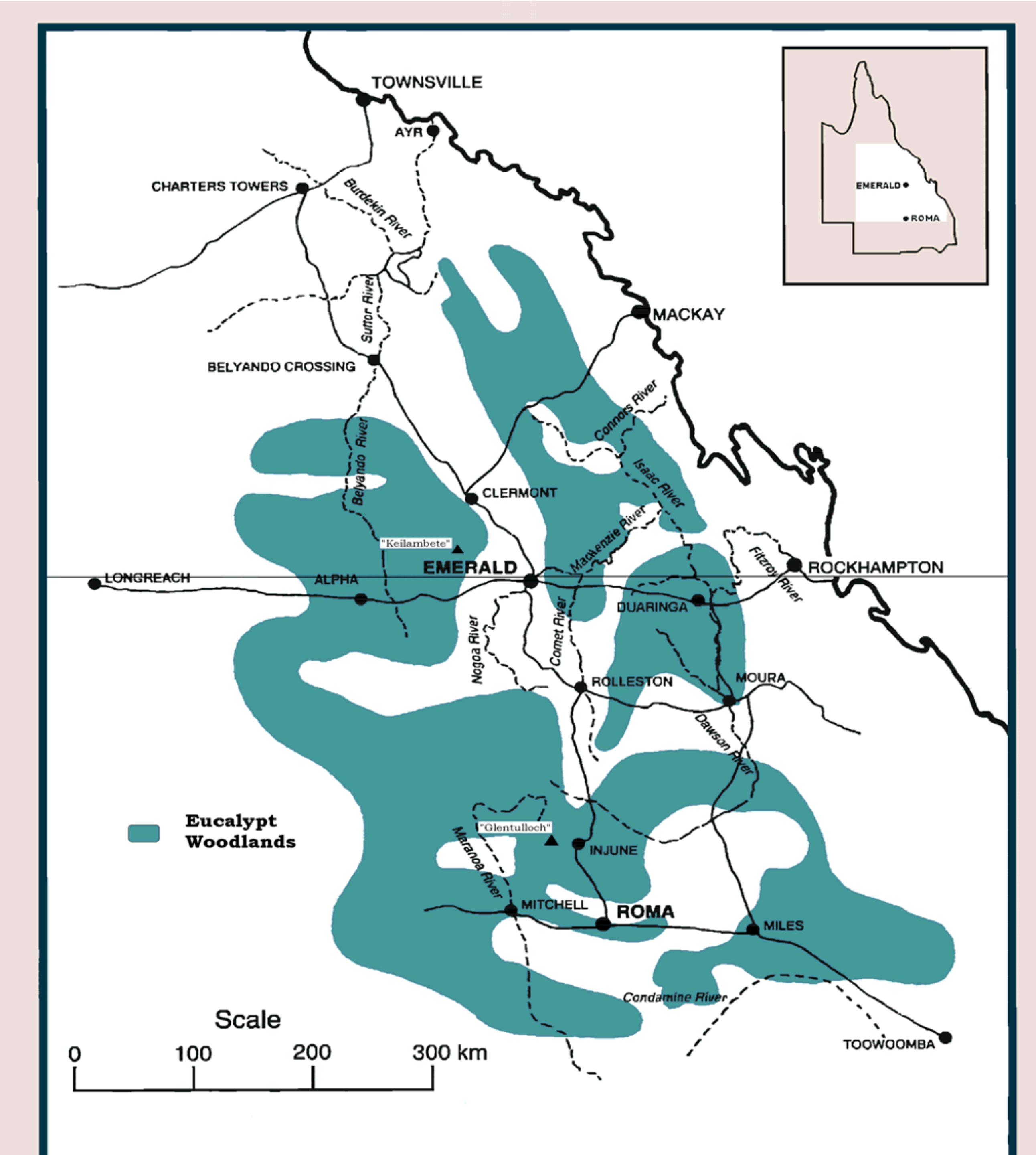
Jacket of Field Day Handouts

Sustainable Production from Eucalypt Woodlands

An activity of the North Australia Program (NAP 3)

Sponsored by

Meat Research Corporation



EUCALYPT WOODLANDS OF THE CENTRAL HIGHLANDS AND THE MARANOA

Main Research Sites

"Keilambete" Rubyvale (C.J. and J.J. Hawkins) "Glentulloch" Injune (J.C. and L.M. Chandler)

Native pastures are an important grazing resource

Native pastures of the eucalypt woodlands of the Central Highlands and Maranoa have supported the cattle industry for the last century. The area in the Central Highlands totals 6.1 million hectares and in the Maranoa is 4.6 million hectares.

Breeding and store cattle production is the main enterprise, and in some areas beasts fattened. It is estimated that 1.2 million cattle normally graze this area.

This community is a mixture of lands supporting poplar box, cypress pine, silver-leaved ironbark and narrow-leaved ironbark. Diversity of soil types and landforms is also a common feature. Together with adjacent areas of brigalow lands and downs country, grazing of native pastures will continue to be an important activity.

Sustainable use of native pastures in this mix of enterprises and resources is the project objective.

Issues

The productivity of the native pastures of these woodlands declines when surface soil is lost and where changes occur to less desirable vegetation. Recent reviews of native pastures in Northern Australia highlight the need for caution in property development and grazing management if viable cattle production is to be maintained.

Property sizes are large, markets fickle and management must deal with issues on an extensive scale. Consequently, options for maintaining or improving the pasture resource need to be reliable and long lasting.

The productivity and stability of the native pastures in these woodland communities are starting to be understood as a result of the earlier work done recently under NAP2. This knowledge is vital for formulating management options that will sustain continued profitable grazing.

Project Aims (1996-2001)

- Understand how pasture composition changes with different climatic conditions and management such as clearing, burning and grazing pressure

- Determine management practices that either maintain or improve pasture composition, or result in undesirable pasture composition

- Develop practical, sustainable management systems for maintaining or improving native pasture condition

- Communicate native pasture management knowledge to producers, resource managers and the general community

Activities Planned

- Refine current knowledge of the pastures' dynamics
  - detail the composition for good, moderate and poor states
  - identify the factors that change the pasture from one state to another

- Determine critical life cycle details for key native pasture species
  - how long do they usually live
  - what most threatens or enhances persistence
  - what impact does stocking pressure, fire or timber clearing have on key species
  - how can desirable species best be favoured and undesirable species discouraged

- Measure cattle growth rates from two pasture types, silver-leaved ironbark and poplar box

- Determine the amount of runoff and soil loss from these pastures under different management

- Hold field walks and workshops to help graziers and other land managers to recognise key pasture species and to manage them better

- Develop practical paddock management options for maintaining or improving pasture composition and adequate landscape biodiversity

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Field day snaps

2. [*Six page insert in Central Highlands Newsletter, Autumn 2001*]

Healthy Pastures Healthy Profits Healthy Environment

Background

The semi-arid eucalypt woodlands of the Central Highlands and Maranoa (Figure 1) is a large productive area, however condition assessments have identified degradation problems and the potential for improvement. Gaps were evident in production and ecological knowledge, and technical studies are assisting to develop sustainable resource management practices.

The project covers 10.7 M hectares in the Central Highlands (CH) and Maranoa and is a partnership between the Department of Primary Industries Qld, Meat and Livestock Australia (MLA) and the Department of Natural Resources and Mines.

Initially the project conducted an inventory of pasture resources from which State and Transition management models were developed. Detailed research has since been conducted from 1994 to 2000 at Rubyvale and Injune into the effect of different pasture management on the land resource. There is now a better understanding of the region's ecology.

Grazing trial

This study compares three grazing management options to measure the sensitivity of the various ecological processes that operate in a grazed woodland. Systematic monitoring measures the following key processes in response to grazing pressure and tree clearing.

- Pasture composition
- Animal production
- Pasture population dynamics
- Tree and shrub population dynamics
- Soil erosion and hydrology

A second investigation examined the effect of spring fires on vegetation in cleared and wooded pastures. The accompanying map (Figure 2) details the location of each treatment. The area labelled Stock paddock is a 53 ha wooded paddock grazed with 15 weaner steers at local Bestprac recommended long term stocking rate. The trial has run from 1994 to 2001 and did not experience the extended dry conditions that occurred between 1992 to 1995.

Queensland Government MEAT & LIVESTOCK AUSTRALIA

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14.6.4 AB Link project newsletter

In all 13 editions were published and they are included in the accompanying CD. One example (Nbr 8) is shown here for illustration. They provide an insight into the progress of the work and the most pertinent findings along the way.

Issue No. 8 **February 1998**

ABLink is a twice yearly newsletter of the project, "Enhancing Pasture Stability and Profitability for Producers in *Aristida/Bothriochloa* Woodlands" (NAP3.208). It is a Department of Primary Industries (DPI) project in partnership with the Meat Research Corporation (MRC) and the Department of Natural Resources (DNR) and aims to study and provide information on the sustainable management of woodlands in central Queensland.

Editor's Note

Welcome to 1998 and what a busy year it will be. I hope everyone had a very festive season and have recharged the batteries for what will be a full year ahead.

Since the last newsletter, five new people have joined the AB project team and bought with them many various skills and experiences. In this issue, we introduce them.

Also in this issue, we outline the milestones to be achieved in 1998 and provide an insight into the results and discussions of the last six months of the AB project. For new readers we summarise and explain what the AB project is.

As well as this, we feature an extract from Rod Fensham's (Senior Botanist, QLD Herbarium) paper on the Great Basalt Wall near Charters Towers.

Thanks to comments from our readers, ABLink will now have a more formalised layout. Regular contributions from all our readers is still encouraged. In future issues of ABLink we hope to bring to you special feature articles, interesting Internet sites, new books, journals and publications.

Happy reading
Melinda Cox - Editor

Inside

WHAT IS THE AB PROJECT? WHO SUPPORTS IT? WHEN DID IT START AND WHEN DOES IT END?

Melinda Cox

The AB project, as it is commonly called, refers to the project, "Enhancing Pasture Stability and Profitability for Producers in *Aristida/Bothriochloa* Woodlands". It is a DPI project in partnership with the MRC* and DNR to research and transfer information on the sustainable management of woodlands in central Queensland. The AB project is funded by the MRC's North Australia Program (NAP), which deals with on-farm issues in Queensland, Northern Territory, the Kimberley and Pilbara regions of Western Australia.

Under the NAP2 banner, the original AB project began in 1/10/92 and ran to 30/6/96. The AB project now continues under NAP3, which aims to see one quarter of all producers applying sustainable grazing principles by the program's completion in year 2001.

continued on page 2

continued from page 1
The AB project's aims for 1996-2001 are:

- to understand how pasture composition changes with different climatic conditions and management such as clearing, burning and grazing pressure;
- determine management practices that either maintain or improve pasture composition, or result in undesirable pasture composition;
- develop practical, sustainable management systems for maintaining or improving native pasture condition;
- communicate native pasture management knowledge to producers, resource managers and the general community.

*The MRC formed in 1985 and was established by the Commonwealth Government to improve the productivity and market performance of the Australian red meat industry.

A MESSAGE FROM RICHARD
Richard Silcock (Project Leader)

Project Staff Changes

It is with a great sense of relief that I report a near-full staff quota for the A/B project at the start of 1998. All we need now is a dedicated, part-time economist and I am hopeful that this will occur sometime this year.

Welcome to the new team members, roughly in order of enlistment:

Gavin Peck - Gavin is mostly involved with the Future Profit programme, but both our activities benefit from a close working association to deliver products and information to pastoralists. Gavin is based in Emerald and has already assisted via his involvement in a Consultative group meeting at Keilambete last December.

Russell Drysdale - Russell comes from Taroom. He is Dave Waters' technician on the runoff & erosion segment of the project, based in Emerald with DNR. Russell is an electronics whiz and, being a country lad, brings plenty of practical insights to the job.

Ross Warren - Ross is the recently appointed Beef Cattle Husbandry Officer at Emerald. Every grazing trial benefits from having a professional animal person involved and Keilambete is no exception. Ross, like Gavin and Peter Knights, bolsters the communications arm of the project as it heads towards writing reports and developing management systems for A/B communities in the Central Highlands.

Melinda Cox - Melinda joins us at Emerald from the wildlife research group of the Dept of Environment. She replaces Dave Osten and comes well skilled in bushcraft, native plant knowledge and some editorial skills. The latter are being put to good use in the production of the ABLink.

Jillian Aisthorpe - Jillian recently completed her degree in Ag Science at U of Q. Being a Roma girl, she is well placed to fill Bryan Robertson's position there. She also brings writing and communication skills to the project which will be invaluable as we develop management guidelines. Some of Jillian's time will also be taken up on Dave Lloyd's GRDC-funded ley legumes project.

Jodie Trace - Jodie is an unofficial member of the project, doing her 'industrial placement' semester for her Applied Science course in Rural Technology at UQ Gatton. Jodie will be based at the Roma Research Stn and will have a special role in transferring charted quadrat data into a database for analysis and manipulation. The project's obligation to Jodie is to give her an understanding of how agricultural research projects operate and to teach her skills in natural resource management.

Scott Brady - Scott is a temporary appointment to assist me after Cass Robertson (nee Finlay) followed her hubby Bryan to Adelaide. Scott has only a minor role in the project but he and Jodie provide a cheerful, youthful, co-operative atmosphere to the project. Scott will probably head for Roma to work on a Natural Heritage Project but his technical skills with computers will be very useful to everyone.

All up, this gets a viable group together at both Emerald and Roma which will allow sampling schedules to be met and leave time for data analysis and interpretation. I've just got to find enough computers for them all so they can do their work effectively. My old 386 *is persona non grata* on the DPI Network with Office97 about to be installed, yet it is such a serviceable machine for a baby-boomer like me.

Welcome to Byron, a second son for Paul and Dana Jones. Joff returned safely from his honeymoon in

New Zealand with wife Kylie and is now a fully fledged member of the Black Douglas clan.

Project Linkages

I'd like to say a little on where I see the A/B project fitting into other resource management activities going on around Queensland at the moment. We have, along with others, finally got a contract signed with the MRC so we know exactly what is expected and how much money they can contribute. Barry Walker has acted as a go-between and kept things rolling along despite the 18 months administrative impasse. There is still plenty of tight budgeting ahead but a few Samaritans have come our way.

The Natural Heritage Trust fund has agreed to fund 3 workshops on sustainable resource management this year. These will dovetail in with our project Communications Package and provide resources that the MRC could not. My problem is that the late release of NHT approvals, combined with the setting-up of the new DPI Institute structures, has slowed our getting staff appointed and resources provided. We have to keep the MRC core sampling work on track while organising, running and reporting on the 3 workshops by July.

Then we have to sit down and draft up chapters for the final booklet in the Grazing Management Series edited by Ian Partridge. This one is to cover the *Aristida/Bothriochloa* communities of CQ and is to be released by Christmas 1998. Ian has the format well in hand but we have to provide the nitty gritty on management options/systems. This will involve plenty of meetings and interaction, but with Jodie, Jillian, Melinda, Ross, Gavin and Knightsy to help, I think we can produce a great final edition.

Dave Waters and Russell have worked through all the runoff and soil movement data from both sites, so that we are now on top of that again. Their work is running smoothly and Dave has produced a short report summarising what we know so far. I'm still waiting to hear whether the DNR DEAP (Downstream Effects of Agricultural Production) project is to be revived to pull together landscape processes on a catchment scale for the Fitzroy Basin. I very much hope it will re-emerge and that our two grazing trial sites can be included. Most of the new work being done by Chris Chilcott and Mark Silburn looks like being in the Condamine River catchment but our sites may still be used in tracking nutrient fluxes.

Trevor and Paul are overseeing the summarisation of all the tree and regrowth data collected so far. Joff, Jillian and Melinda are helping to massage the data and we should have a short summary report together soon. That will leave us ready to get into the end of summer round of recordings of the pasture data - in between organising the workshops and doing the other things set out in the communications package.

I hope to have one workshop in the far north of our project region e.g. Moranbah, one at Emerald and one at Roma. Each centre has facilities that can hold 30 people in meeting and workshop formats for 2-3 days. Main topics to be worked over are:

1. Interaction between wildlife conservation and pastoral management,
2. Balancing landscape stability with moderate grazing pressure,
3. Can sustainable grazing management of native vegetation be profitable enough?

By shifting venues around, we can interact with a bigger cross-section of producers while still attracting outside specialists for the particular topics.

The project's interaction with the woodland management group continues strongly and we are a major source of outside testing for their TRAPS data collection and processing packages. Likewise Trevor is supplying fresh faecal samples to David Coates' NIRS (Near-Infrared Spectroscopy) trial to see how applicable this US technology is to Australian conditions

Bothriochloa ewartiana
Source: Roberts & Silcock 1982

1998 MILESTONES

Major AB milestones to be achieved in 1998 include:

- Attendance at field days and shows to report on focal site progress.
- Publish early ideas on practical systems of sustainable pasture management in AB region.
- Report on pasture dynamics to date.
- Workshop on sustainable grazing management.

AN INTRODUCTION TO 5 NEW AB STAFF

Melinda Cox

Hello, my name is Melinda Cox and I will be replacing Dave Osten as the experimentalist in the Emerald office.

My previous position was as a Resource Ranger with the Department of Environment (DoE). My move into the DPI office was not a traumatic one, as I have spent the last 17 months in the same building. One occupational hazard though was to walk to the right side of the building on my first day. Being so used to turning right to go to DoE, I nearly forgot to take a left to my new office room.

Much of my work with DoE was based on and around externally funded projects. My last project was to select and map areas that would be suitable for the translocation of one of Australia's most endangered mammals, the Northern-hairy Nosed Wombat. It was an exciting and very successful project that found nine potentially suitable areas in central and southern Queensland.

My main experience has been with resource assessment, describing landforms, soils, vegetation communities, compiling species lists and helping with plant identification. My main interest is botany and ecology and I am in my third external year of studying a Bachelor of Science. Another interest is GIS or Geographic Information Systems, which I had the pleasure of learning and practising with DoE.

This job as an experimentalist with the AB project will take me back to basic research, something that has been lacking in my previous position. I will also get to edit this newsletter!! I am very excited about my new job and look forward to collecting, analysing and reporting on the results of the AB project.

Jillian Aisthorpe

Greetings all! My name is Jillian Aisthorpe and I am the new Pasture Agronomist at Roma.

I was born, raised and schooled at Roma – don't laugh. I have just graduated from the University of Queensland in Brisbane with a Bachelor of Agricultural Science majoring in Animal Science. My family runs a beef/wool/grain enterprise south-west of Roma.

Over the past 4 years I have been involved with a wide variety of organisations including the Queensland Farmers' Federation, IAMA and Stanbroke Pastoral Company. I was a resident assistant at Union College, convened the inter-college touch football, women's rugby and athletics competitions for a couple of years and was Vice-President of the Queensland University Agricultural Student's Society last year. I enjoy playing sport and am always keen for a hit of tennis if you are in town.

Half of my time is devoted to the A/B project working with Trevor Hall and Richard Silcock and the other half is spent doing medic and general legume trial work with David Lloyd in the farming systems institute.

At present I am learning the ropes, filling out forms and furiously sampling sites with Joff and Jodie. (Lovely warm weather for it!) No doubt I shall meet you all in the near future, however, don't hesitate to give me a call if you need anything in the mean time. Cheers!

Jodie Trace

Hello everyone. My name is Jodie Trace and I am currently in the third year of my degree, (Rural Technology), at Gatton College.

As a part of the course requirements, I will be completing six months of industrial placement. I have decided to work under the supervision of Richard Silcock for the duration of this time.

Three weeks of my industrial placement has already been spent working with Richard in Toowoomba. However, for the remainder of my stay, I will be working at Roma. During this time, I will be working on a number of aspects of the AB project. This will include helping with the technical and field work as well as working on the database for charting basal areas.

I am from the Bunya Mountains area, (Maidenwell side), so I have yet to adjust to the rather large climate change.

Russell Drysdale

Hi, my name is Russell Drysdale and I am the new DNR experimentalist. I will be working with David Waters most of the time. More of an introduction to me can be found in David's Soils/Hydrology update section.

Scott Brady

I have predominantly been involved with the QPastures database since August 1997.The QPastures database is designed to be used by Pasture Scientists as a research tool. It serves as a source of information on pasture trials conducted in all regions throughout the state.

Before the age of computers, pasture trial data was recorded on cards. These cards were stored in an ordered manner, in a central location. In Queensland, these records were kept at the Indooroopilly Seed Store. These cards date back to the start of WWII.

As plant names are continuously changing, I am often required to investigate and confirm the origins of specific plant accessions. This is achieved by consulting the scientific literature.

I have also been involved in the Glentulloch Soil Seed Load Pot Trails. My interests include botany & computer technology.

SOILS/HYDROLOGY UPDATE
David Waters

1997/98 has seen reasonable rainfall for the season with 260mm at Glentulloch and 180mm at Keilambete to date. Several significant soil loss events have occurred at Glentulloch in particular. A big thanks must go out to Trevor and Joff for collecting soil between rainfall events. The collaboration makes my job a little easier, particularly at this time of year and also improves data integrity.

New staff
In October 1997, Russell Drysdale was appointed as my experimentalist for the next three years. The majority of his time will be taken up with cotton work, however Russell will assist with data collection and maintenance, instrumentation repairs and the annual botanal.

Russell has extensive experience in electronics and instrumentation and coming from a rural background will be a big asset to the project team

Communications
- A report on the runoff and soil loss data for the past three years was submitted to MRC in October as part of the milestone requirements.
- In early December, data was presented to the Keilambete Consultative Group. The information was well received as most of the group had not seen any of the soils/hydrology data.

Congratulations
To Paul and Dana Jones on the arrival of their second son, Byron Alexander Jones. Byron is a brother for young Connor. Everyone on the AB team would like to congratulate and pass on their best wishes to the Jones family.

INITIAL PASTURE RESPONSES TO GRAZING PRESSURE AND TREE CLEARING AT KEILAMBETE GRAZING TRIAL
Paul Jones

Tree and shrub monitoring
The majority of plants in the treed treatments are silver-leaved ironbark (*Eucalyptus melanophloia*) which are less than 0.5 m tall. However the majority of basal area is in those plants which are in the range 4.0 to 15 m tall. This is not new information and has regularly been reported by DPI officers in central Queensland.

However it has important management implications. The prolific regrowth which often occurs is well explained knowing that large numbers of suckers were present prior to clearing. Additionally, most clearing (stem injection, chaining) only effects the taller trees (>2.0 m).

The cleared treatments (Velpar stem injection) has reduced basal area to an insignificant level and has continued to reduce density up to 3 years after treatment. Contrasting results from the effect of silver-leaved ironbark on pasture production continues to puzzle us. Further monitoring will hopefully clarify the situation.

Pasture composition
After four years of low, medium and high grazing pressure treatments there are only changes in minor species occurring. Kangaroo grass (*Themeda triandra*) and slender chloris (*Chloris divaricata*) while contributing less than 5% of the pasture yield, are respectively showing decreaser and increaser response. Wiregrasses (*Aristida* spp.) have also recorded an increase due to low grazing pressure. Wiregrasses and chlorises (*Chloris* spp.) have also increased due to tree clearing, whereas kangaroo grass, Queensland bluegrass (*Dichanthium sericeum*) and panics (*Panicum* spp.) have decreased due to clearing.

Population dynamics
Black speargrass (*Heteropogon contortus*) has shown a decrease in density due to high grazing pressure while forest mitchell grass (*Bothriochloa ewartiana*) and golden beardgrass (*Chrysopogon fallax*) remain

fairly constant. The decrease in density of black speargrass is due to an increasing death rate with increasing grazing pressure. Forest mitchell grass had the same response, however maintained it's overall density by increasing establishment with increasing grazing pressure. Golden beardgrass is very stable.

Soil seed banks

Increasing grazing pressure appears to have decreased the germinable seed banks of black speargrass and forest mitchell grass with the resultant decreased establishment of black speargrass. Bottlewasher grasses (*Enneapogon* spp.) together with the previous two grasses had a high germinable seed bank. No woody plants have been recorded in the soil seed bank.

Perennial grass basal area

Increasing grazing pressure has decreased total basal area after two years of grazing. Black speargrass and forest mitchell grass followed this trend and are the main components of the pasture.

Conclusion

After four years of the trial only minor changes are occurring in pasture composition, dynamics and basal area. The dynamic nature of black speargrass is demonstrated as in other grazing trials while forest mitchell is less effected by treatments and goldenbeard grass is quite a stable component of the pasture. The responses to tree clearing have not been as expected and the reasons are still unclear.

Chrysopogon fallax
Source: Roberts & Silcock 1982

KEILAMBETE GRAZING TRIAL ADVISORY GROUP MEETING

Paul Jones

The Keilambete grazing trial advisory group met on site in December 1997. The aim of the day was for the group to hear a progress report on the project, to maintain their familiarity with the work and have the opportunity to advise the project team in the operation of the project.

Richard Silcock gave a project overview. Paul Jones presented some detailed results on the pasture and cattle production responses. David Waters presented runoff and soil movement information at one of the catchment plots. Ross Warren raised some interest on the Future Profit series and Gavin Peck gave a presentation on pasture monitoring.

The group was pleased with the progress of the project. Specific activities as a result of the meeting include information on the seed ecology of silver-leaved ironbark (*Eucalyptus melanophloia*); pasture information presented as comparisons with animal production, and with other land types; and regular updates on cattle production sent to advisory group members. The day concluded with an inspection of black speargrass (*Heteropogon contortus*) establishment in the burnt exclosures.

TROPICAL SAVANNA BEFORE CATTLE

Rod Fensham
Senior Botanist
Queensland Herbarium
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PH: 07 3896 9326

There are not many places in Queensland with a good cover of soil that have not been grazed by cattle or sheep.

Within the Great Basalt wall lava flow in north Queensland there are "pockets" of savanna woodland that are inaccessible to domestic stock, although the lava forms no barrier to the native herbivore, the common wallaroo.

The pockets were compared with areas that are grazed by stock in order to provide insights into the plant composition of ancestral woodlands prior to their use as pasture. There were no species in the pockets that are rare and endangered at the broadscale.

Thus species that appear to be sensitive to grazing at the Great Basalt Wall survive elsewhere on roadsides, rocky hills and other lightly grazed situations.

The most striking difference in the pockets was the abundance of scentgrass (*Capillipedium parviflorum*) compared to its absence in the grazed pasture. This soft grass may have been much more widespread prior to settlement.

There was no difference in the richness of exotic species between pocket and pasture, some species clearly being favoured and others disfavoured by stock. The African species red natal grass (*Melinis repens*) was clearly most abundant in the pockets. Its abundance in the ungrazed savanna is puzzling because it is not considered to be a useful pasture species, but presumably must be quite palatable if not nutritious.

The findings of the study from the Great Basalt Wall are described in more detail in a paper by Fensham and Skull in the journal *Biotropica*. The area may provide a useful study site providing insights into the nature of our grazed landscape prior to the introduction of hooved beasts.

Chloris divaricata
Source: Roberts & Silcock 1982

***ARTICLE REVIEW,** by Melinda Cox*

***Crosthwaite et al. 1996,* 'Native pasture and the farmer's choice - evaluation of management and sowing options', *New Zealand Journal of Agricultural Research,* vol. 39:pp.541-557.**

Although this article has been written from research conducted in New Zealand and the Basalt Plains in south-western Victoria, it highlights some important, *nation-wide* factors about native pasture and the value it can have for farmers.

Major points include:

- native pasture may have relatively little to offer farmers in areas that receive greater than 500 mm rainfall.
- disadvantages to native pasture include: lower stocking rates; poor tolerance of heavy grazing; stock damage caused by some native seeds; and the lack of knowledge of species composition and how species respond to different management techniques.
- native pasture has a clear role in non-arable country such as hilly or rocky areas and can provide a green pick in dry times
- financial benefits of retaining native pasture may not be immediately realised, but may only be recognised a long time into the future.
- native pasture can offer 'significant opportunities in the future and if not recognised now, may be irreversibly lost' (Crosthwaite et. al. 1996)
- financial returns from native pasture may vary greatly with management.
- one incentive to get farmers sowing native pasture would be to reduce native seed prices.

Crosthwaite *et. al.* (1996) also identify the need to research and monitor different stocking rates on pasture composition. Isn't it good to know that what we are doing, as AB project team members, will contribute to an increase in the knowledge of native pastures and their future sustainability!!!

Further information

For further information about any of the topics or articles, contact the author, whose details are provided at the beginning of the article or in the AB Project Team box below.

To be included on the ABLink mailing list, contact the Editor

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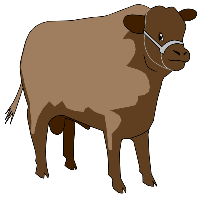
Grass illustrations from: Roberts, B.R. and Silcock, R.G. 1993, *Western Grasses, A Grazier's Guide to the Grasses of Southwest Queensland*, USQ Press, Toowoomba.

14.6.5 Glentulloch Consultative Group Newsletter

There were 10 editions of this publication and a few copies are included to show its style.
1. *[Newsletter from the middle of the trial period]*

GLENTULLOCH GRAZING TRIAL UPDATE
No 8 (QDPI - ROMA)



Dear Group Member

17th December 1998

Since the last newsletter in April, 450 mm of rain has been recorded at the site with a total of 880 mm over the last 12 months. There has been an unusually regular pattern of rain through spring, which produced green pick, although no body of feed. The old dry bluegrass deteriorated in winter.

Cattle: This is the fourth herd and again the high utilisation/grazing pressure paddocks have been more productive in terms of total **production per hectare** for the first half of the year than the low utilisation/ grazing pressure paddocks, but the cattle and pastures have suffered. One animal had to be removed from the two high utilisation plus trees treatments and the pasture condition has deteriorated with weeds becoming more frequent.

Over the 12 months, cattle performance in all paddocks averaged 0.4 kg/hd/day or 143 kg. The best paddock (Cleared/Low grazing pressure) did 0.6 kg/hd/day or 213 kg with the worst paddock (Trees/High grazing pressure) doing 0.2 kg/hd/day or 74 kg.

Cattle weights for the different utilisation rates were: 0.5 kg/hd/day or 193 kg for the Low, 0.4 or 127 kg for the Medium and 0.3 or 109 kg for the High utilisation. Average tree effect over all utilisation rates was 0.5 kg/hd/day or 164 kg for the tordoned paddocks (trees killed) and 0.3 kg/hd/day or 128 kg for the live tree paddocks.

There have been **consistent trends** in the effects of live trees verses tordoned (cleared) treatments and also between the three utilisation rates on cattle weights for the last three mobs. There is more grass and higher cattle weights from the killed tree treatments and highest individual animal weights from the low grazing pressure treatments. At the high utilisation rate the steers are in poor state (score 2 at best) and are not saleable, while at medium and low grazing pressure cattle remain in good condition and are gaining weight rapidly during this early summer period. This herd will be retained until about May, when new weaners will be introduced.

Botanical Composition: Over 173 grasses and forbs and 60 trees and shrubs have been recorded across the site. There have been fluctuations in species frequency, although no dramatic changes in desirable species to date. Some changes include: wiregrasses have increased marginally in the treed treatments; small burr grass has declined; and slender Chloris, twirly windmill and five-minute grass have increased across the site. Blue trumpet is the most significant forb and occurs over the site. Daisy burrs have increased in the cleared treatments. There were no significant changes in the desirable bluegrasses between the tree effects, but forest bluegrass and Queensland bluegrass have declined at the high utilisation rate. Some forbs, generally weeds, such as Malvastrum, pig weeds, galvanised burr and spiked Sida, have increased at the high utilisation rate.

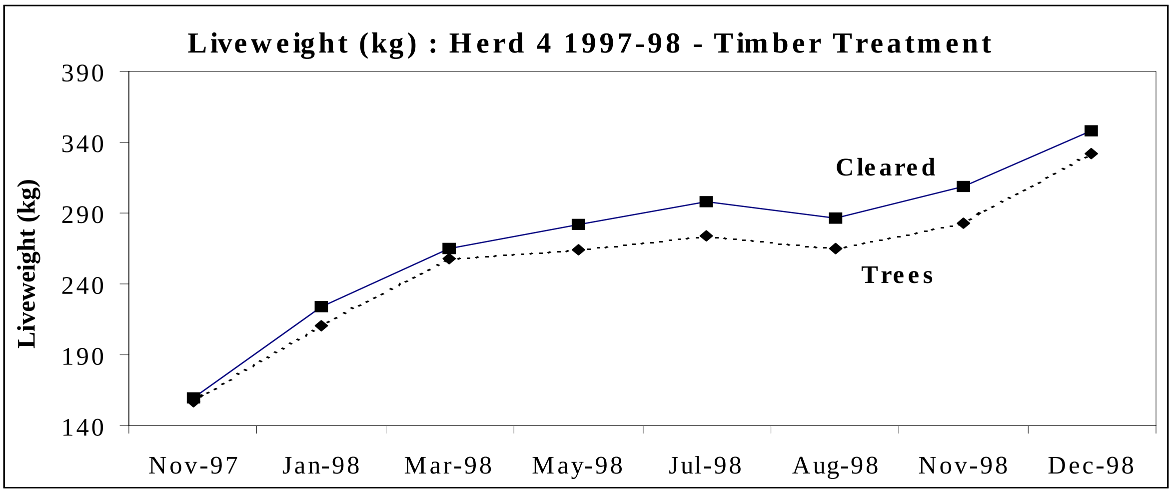
Yield: Site yield increased from 1994 to 1996 as the pastures recovered from drought and there was good rainfall during each summer even though the seasons finished early. There was little winter rain. There are consistent trends in treatment yields: clearing produces higher yields than the treed treatment; and there was a trend of highest yield from the low utilisation rate to medium rate to lowest yields at the high utilisation rate.

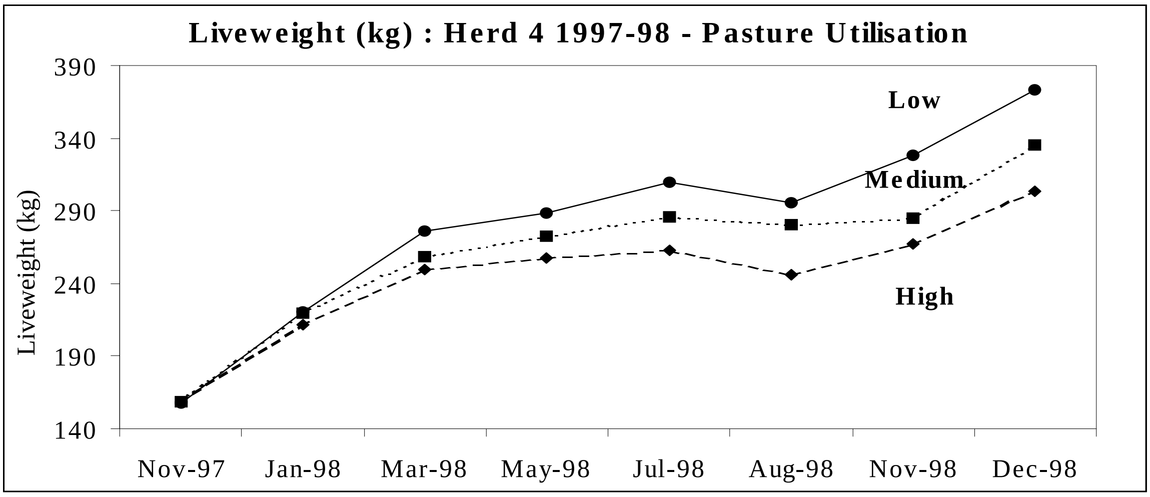
For the first three years, the grazing treatments were steadily changing the pasture yield between the utilisation rates. Cattle were forced to graze the less palatable species at the high utilisation rates. Any effects on composition from this continuous heavy grazing are expected to develop over the next few years. Three of the four summers have received around average annual rainfall, and there have been good pasture growth periods every year. These wet periods would have alleviated the effects of the trees and high grazing pressure on species survival.

Tree clearing has produced higher yields of bluegrasses and bottlewasher grasses. Yield of most grasses has been reduced by the high utilisation rate, with the exception of five-minute and twirly windmill grass, even though this normally unpalatable grass has been well grazed. The weedy forbs have the highest yields in the high utilisation paddocks.

Cover: Pasture cover shows similar trends to the yields. The clearing has had consistently higher cover than the treed treatments since 1996. There was reduced cover at the high utilisation rate every year since 1996 and a similar cover between the low and medium rates, except in 1998 when cover was less at the medium rate than at the low rate. Pasture cover protects your soil from erosion.

Greenness: Pasture greenness was 100% in the mid-growing season in January 1995 and low at 4% by May 1996 after an early finish to the growing season. Clearing maintains greenness (feed quality) in the pasture longer into autumn than occurs under the trees.





Peter Knights (Ph. 4622 9999) and Trevor Hall (Ph. 4622 3930) - (QDPI, Roma)

2. *[Final Consultative Group Newsletter, Nov. 2002]*

“GLENTULLOCH” GRAZING & PASTURE ECOLOGY TRIALS – COMPLETION
QDPI / MLA - ROMA

Dear Group Member 12th November 2002

The “Glentulloch” grazing and pasture ecology trials were established in poplar box woodlands to quantify the impacts of normal management practices, such as adjusting grazing pressures (stocking rates), controlling tree competition by clearing, and spring burning. These are every day management decisions for producing cattle from this country. The field trials are now completed.

The trials were established in 1994 to measure what happens to cattle, pastures, tree regeneration, soil and water runoff, and the landscape in general by adjusting the management practises. The main treatments were: 3 grazing pressures (grazing 25, 50 and 75% of end of summer pasture growth) and 2 tree competition rates (clearing with Tordon and trees at 5 m^2/ha basal area). A second trial had combinations of the same clearing, with annual spring burning and no burning. Cattle, pastures, trees, soils, water runoff, climate and soil surface conditions were monitored under the various treatments. A list of the main data sets is attached.

The information recorded is being assembled for recommendations on environmentally sustainable and economically viable grazing practises for this country and it is being compared with results from similar research in silver-leaved ironbark country near Rubyvale in central Queensland.

The following are a few notes from observations:

Rainfall: Summers were generally near average in total rainfall with short growing seasons and 1998 had the only wet winter. The last 2 years were drought conditions with periodic storms.

Pastures: The grass composition was more resilient than expected, except at high grazing pressure with tree competition. Preferred palatable, productive and perennial grasses (3P), such as bluegrasses, increased only after clearing. There was a consistent significant increase in pasture production with clearing allowing higher stocking rates and higher annual cattle growth rates. The low grazing pressure produced uneven utilisation with both over and under grazed patches.

The box communities have a diverse flora with 173 pasture species and 60 trees and shrubs recorded across the site.

Cattle: 7 herds of Brahman cross steers were grazed during the trial and liveweights and condition scores were consistently superior with clearing and conservative grazing pressures. There was often no difference in cattle performance between clearing and treed paddocks during the summer growing season, provided grazing pressures were not too high, but clearing produced highest growth rates, or the least weight loss, every winter. Grazing at high grazing pressures with tree competition was unsustainable within 3 years even with some supplementation.

Preliminary economic analysis suggests the most viable pasture utilisation rate, managed by adjusting grazing pressures, will be about 40% with clearing and about 25% in timbered country.

The research was supported with MLA and DPI funding and the cooperation of the Chandler family.

Trevor Hall (Ph. 4622 3930)
QDPI, Roma Research Station

`Glentulloch' Consultative Group Meeting

Jillian Aisthorpe

The 'Glentulloch consultative group meeting was held on the 31st of March 1999 at the trial site cattle yards. An excellent attendance of 18 graziers and 5 DPI and DNR staff made for interesting discussions throughout the day. Apart from the usual project reports and site inspections, the group also discussed recommendations for the soon-to-be-released `Managing Bluegrass/Wiregrass Pastures' grazier guide and finished by looking at options for the future of the project.

A few of the management issues that the group discussed for the grazier guide included: timing of management decisions about stock numbers, how often stock numbers are adjusted, SOI and what value it has to them, blade ploughing, spelling regimes, crocodile seeders and cell grazing. Another issue raised was what trees were the group confident that fire killed in the district. Responses from this discussion were: cypress pine, sandalwood, wilga, belah, softwood scrub dies better when dry, big old trees with a hollow in the middle (hot fire) and less response by pasture on self-mulching clay soils. Results from this discussion will be used to finalise recommendations in the grazier guide.

The day finished with discussion about the future of the trial categorised into threats and opportunities. Issues that group members perceived as threats to the future of the project were:

- Continued funding
- Parthenium invasion
- Wildfire
- Wallabies and other marsupials increasing grazing pressure
- Natural heritage
- Tree clearing guideline changes
- Secure land title
- Woody weeds
- Change of government

Opportunities that were highlighted for the project were:

- Carbon credits
- Long term continuation of the project
- Economics of seasonal land use
- Expand NIRS use in the region
- Soil organic matter as a carbon sink
- Diversification into other topics at the site
- Look at micro-organisms
- Trial different breeds of cattle
- Add urea lick/other supplement trials
- Introduction of legumes

Other interesting features of the morning were a display of native tree seedlings provided by Richard Silcock and a presentation by the Dawson Valley Catchment Coordinator, Michael Bent on the new Catchment Strategy.

14.6.6 Meat Profit Day articles and posters

1. *[Emerald Meat Profit Day Booklet item, April 1998]*

Enhancing the stability and composition of Bluegrass/Wiregrass pastures
Two large native pasture grazing trials began in 1994 at Rubyvale and Injune. They are jointly funded by the Qld DPI, the NAP3 program of the MRC and the Dept of Natural Resources (DNR).
The information being sought

- The **Rubyvale** site ("Keilambete") is silverleaf ironbark country on a gritty, granitic soil.
- The **Injune** ("Glentulloch") site is poplar box country on a silty, grey loam.
- Weaner steers are run at **3 grazing pressures** on **cleared or timbered pastures**. The animals are selected to remove in 12 months 25, 50 or 75% of the pasture standing over at the end of summer. This equates to LOW, MODERATE and HIGH grazing pressure on the land.
- There is another paddock with about 15 head in it that graze at the moderate grazing pressure. Animals are weighed 4-6 times a year and replaced annually.
- The **pastures are closely monitored** for forage yield, botanical composition, ground cover, soil seed reserves and timber regrowth.
- Some paddocks are also setup to **record runoff and surface soil movement**.

Results to-date

- After 3 sets of animals, in seasons ranging from fair to very good, animal liveweight gain per hectare differs little between the moderate and heavily grazed paddocks – at both grazing trial sites.
- The lightly grazed paddocks produce slightly fatter animals because they rarely lose weight in winter. However, this management is not an economic proposition at normal prices.
- Continual heavy grazing causes a major increase in soil movement above that occurring under moderate grazing pressure.
- At this stage of the research, no major changes in pasture composition have occurred. However, signs are emerging of a reduction in perennial, palatable grasses and increased weedy or ephemeral plants under heavy grazing.

What it all means

- **The current message** – long-term sustainable pastoral use will require producers not to exceed a **moderate level of grazing pressure**. The increase in soil loss and landscape instability at high grazing pressure is disproportionately large and there is no improvement in the value of animal product.
- Overutilised properties are characterised by being regularly 'droughted' compared to neighbours in fair to average seasons.
- These trials will continue until June 2000 and a full report with sustainable grazing management system recommendations will be prepared and presented to producers by June 2001.

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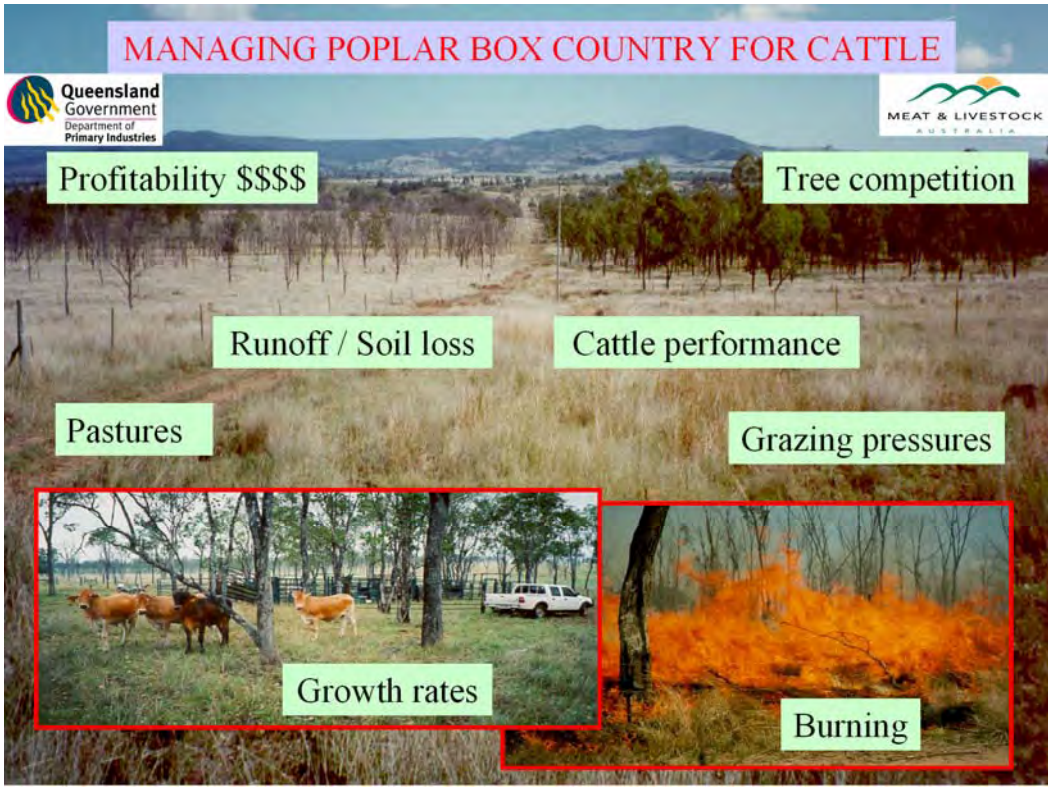
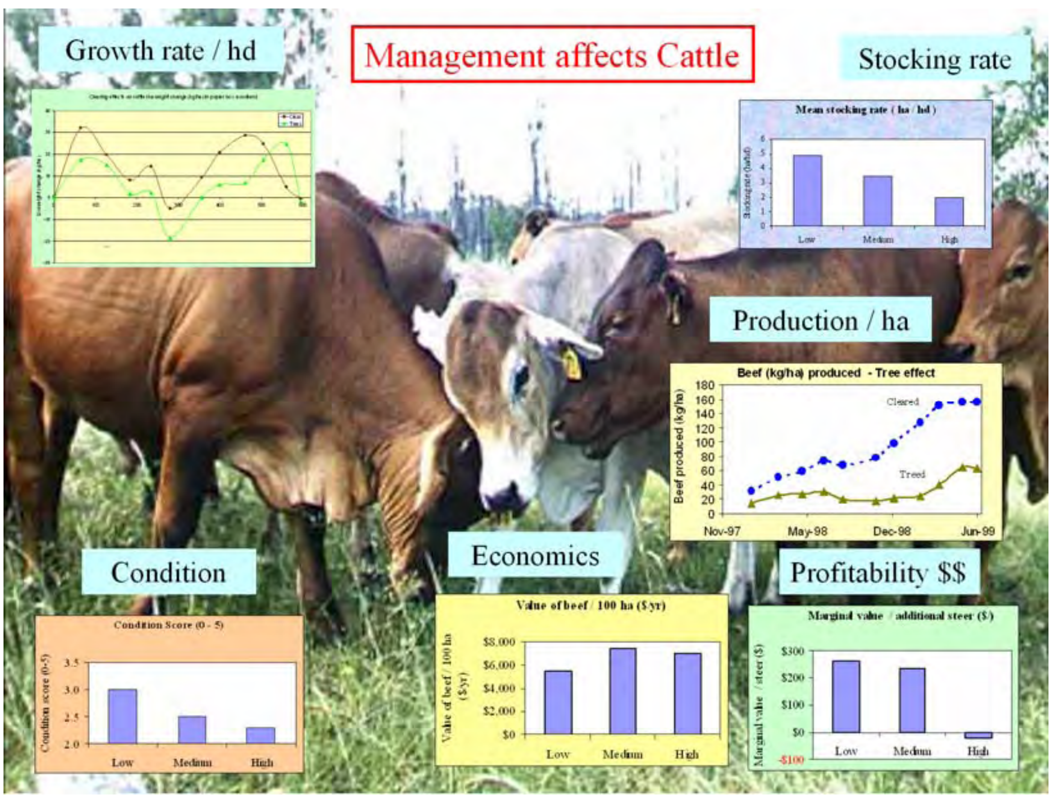
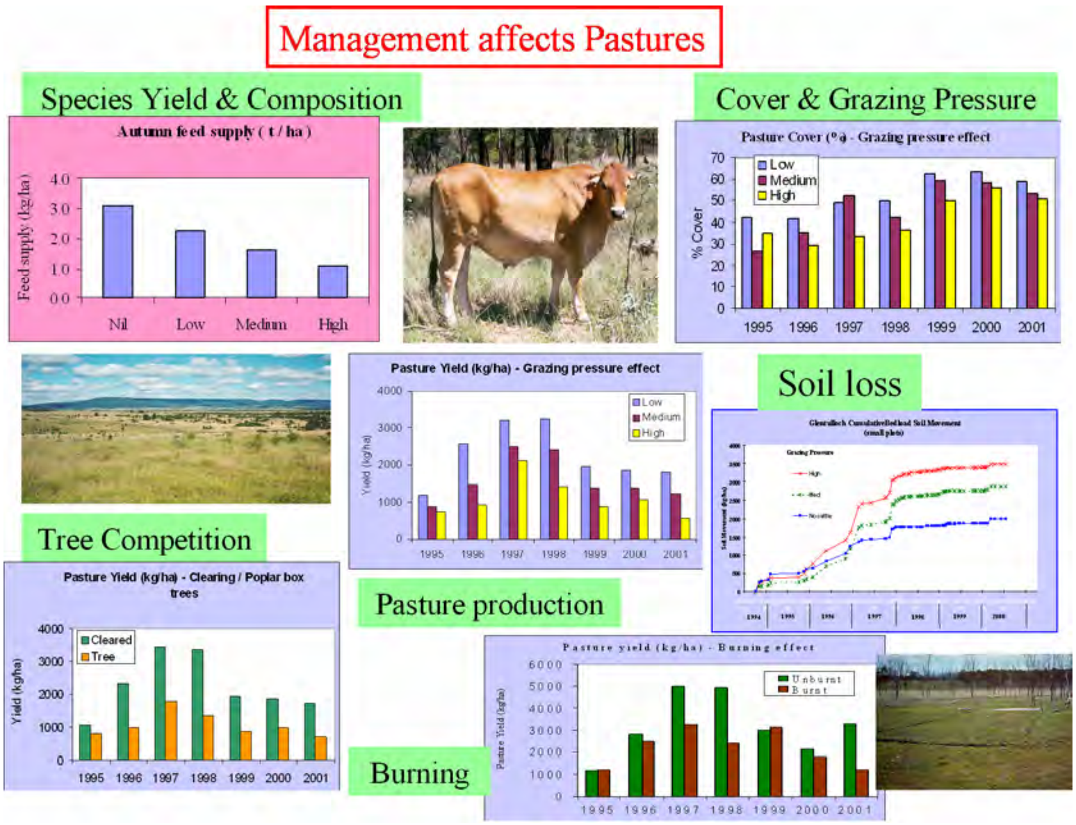
2. [Roma Meat Profit Day, July 2001]

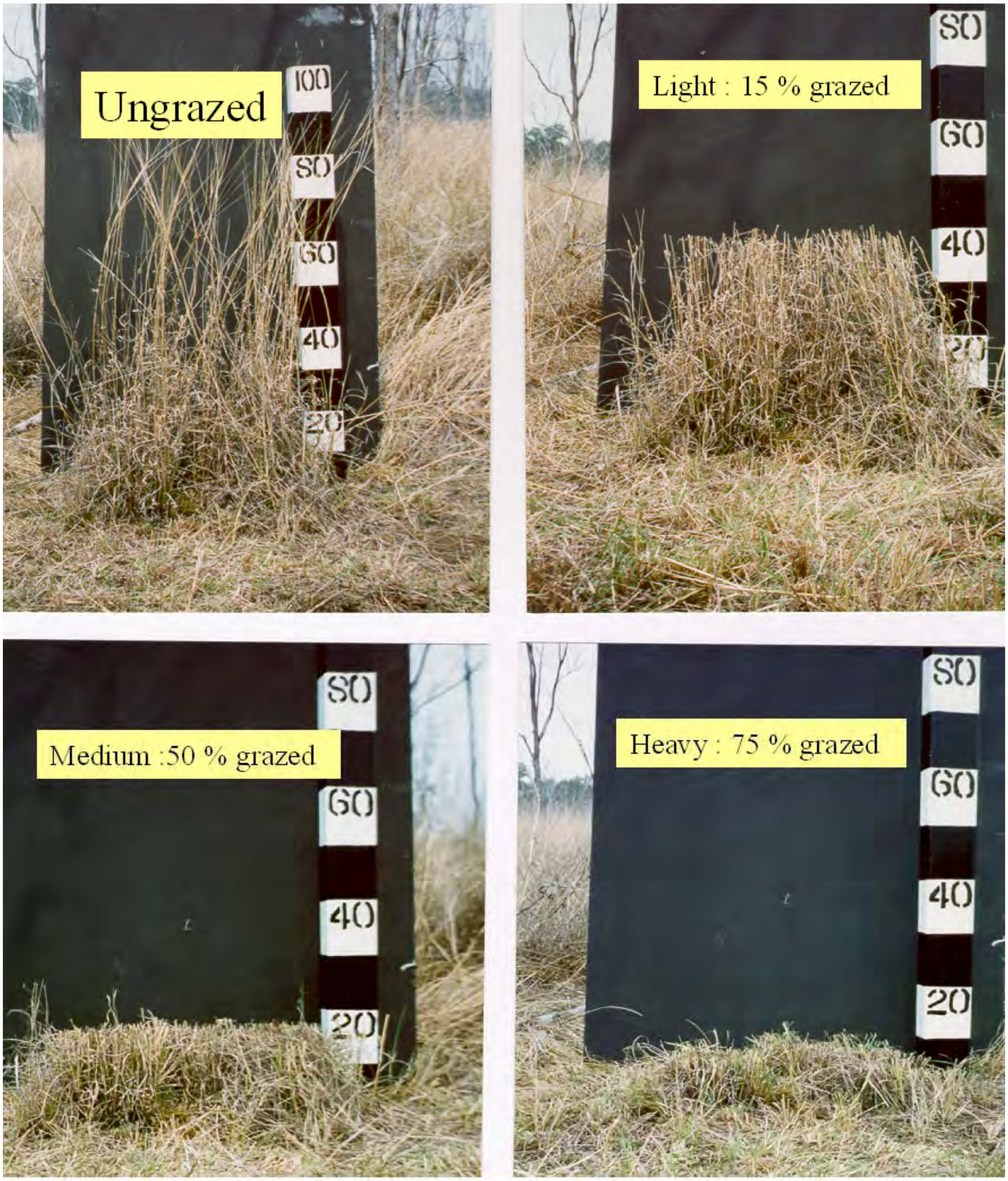
Posters from the Roma Meat Profit Day, July 2001 by Trevor Hall






Management affects Pastures
Species Yield & Composition
Autumn feed supply (t / ha)
Feed supply (kg/ha)
Nil
Low
Medium
High
Cover & Grazing Pressure
Pasture Cover (%) - Grazing pressure effect
% Cover
Low
Medium
High
1995
1996
1997
1998
1999
2000
2001
Pasture Yield (kg/ha) - Grazing pressure effect
Yield (kg/ha)
Soil loss
Tree Competition
Pasture Yield (kg/ha) - Clearing / Poplar box trees
Yield (kg/ha)
Cleared
Tree
Pasture production
Burning
Pasture yield (kg/ha) - Burning effect
Pasture Yield (kg/ha)
Unburnt
Burnt

Management of Grazing Pressure



Grazing Bluegrass - height by utilisation rate

[Booklet Summary from Roma MPD]

Grazing Management and Stocking Rates: more meat and 'cool' country

A grazing management trial near Injune has shown that moderate grazing pressure offers the best of just about everything to producers. Weaner steers running since mid-1994 on poplar box country have grown as much beef per hectare in most years as those at the very high stocking rate, while the pastures are better and much less topsoil has been washed downhill.

Good beef production Seven drafts of brahman cross steers averaged 53.2 kg of beef/hectare/year off native pastures under a continuous stocking policy compared to 61.1 kg at a 72% higher stocking rate (see Table). However, the poorer condition of the latter steers meant that their sale value would have been less. Prices used were $1.50, $1.40 and $1.15/kg.

Performance measures	Grazing Pressure			
	Nil	Low	Medium	High
Mean stocking rate (hectares / head)	0	4.85	3.45	2.00
Mean animal condition score (0-5 scale)	-	3.0	2.5	2.3
Average liveweight gain (kg / hectare / year)	0	36.6	53.2	61.1
Value of beef grown per 100 ha ($ / year)	0	$5490	$7448	$7027
Marginal value of each extra animal run ($)	-	$266	$234	-$20
Cumulative runoff (% of rainfall)	8.7	n.d.	11.4	14.2
Total soil loss from plots (tonnes / hectare)	2.26	n.d.	4.05	5.26
Mean autumn feed supply (tonnes / hectare)	3.08	2.24	1.59	1.09
Pasture crown cover in May 2001 (%)	4.2	5.5	5.7	4.7
Abundance of blackspear & kangaroo grass (%)	5.7	7.7	5.5	3.1

Tree clearing On this site, clearing trees has consistently allowed bulkier pastures to grow with more desirable grasses such as bluegrasses in them. This was reflected in cattle growth rates but the same improvement has not happened on a less fertile ironbark site at Rubyvale.

Good native pasture The moderately stocked pastures have also maintained a high proportion of desirable pasture species such as kangaroo and blackspear grass and excellent ground cover for that region. This is primarily because more rain is actually absorbed into the soil at the lighter stocking rates.

No burning effects Regular spring burns have not altered pasture composition as much as resting from grazing which has allowed blackspear and kangaroo grass to increase. Buffel grass has invaded only where the surface soil is very loose or disturbed by infrastructure.

Further work is proposed for a study of the long-term effects of the contrasting grazing pressures and tree clearing on soil surface condition and subsoil salinity.

Grazier Guides available Copies of regional Grazier Guide books about sustainable grazing management will be on display and available for purchase. The display stand will also deal with rundown of productivity in buffel pastures due to a lack of soil nitrogen.

This work and that at an equivalent site near Rubyvale has been conducted principally with the support of the Qld DPI and Meat & Livestock Australia.

Contacts:	Trevor Hall	Richard Silcock	Ian Partridge
	Qld DPI	Qld DPI	Qld DPI
	Roma	Toowoomba	Toowoomba
Ph.	(07) 4622 3930	(07) 4688 1263	(07) 4688 1375

3. *[Project Handout at Beef2000, Rockhampton]*

Grazing management in the semi-arid woodlands

Aristida / Bothriochloa project background

Management practices which maintain and enhance the long-term productivity of native pastures are critical for the grazing industry. Ecological studies and production measurements are the basis for the developing management strategies needed for economic viability and sustainable resource management.

The ***Aristida-Bothriochloa* native pasture community** (A-B) is a large cattle producing region. It extends from the Gulf of Carpentaria to the NSW border in a fragmented band between the coastal black speargrass to the east and the mitchell grass downs and mulga lands to the west. In the Central Highlands and Maranoa this community occupies 10.7 M ha. Until recently, the region lacked documented production and ecological knowledge, but our A/B Project studies are now assisting **to develop productive and sustainable resource management practices.**

Assessments suggest that about 1/3 of the A-B community is in good health, 1/3 fair and 1/3 in poor condition. Scope existed for **improving these pastures** without significant cost. Altered **management practices** can improve the condition of the country, but to implement the required changes, land managers need to be aware of the early warning signs indicating that undesirable changes are likely to occur.

Our **pasture ecology and grazing study** commenced in 1994 to provide a better understanding of the A-B community. Treatments include the normal property management decisions of adjusting grazing pressures, timber control and burning. We measure the pastures, trees, cattle production and soil/water runoff in poplar box country at Injune and in silver-leaved ironbark at Rubyvale. This objective data provides the basis for developing grazing management practices that can improve or maintain the condition and productivity of grazed A-B pastures and producer viability.

Key findings

Major threats to long-term production are **early summer soil erosion and excessive runoff**. Sustainable pastoral use requires producers not to exceed a moderate level of grazing pressure. The bottom quarter of **3P grass** (Palatable, Productive, Perennial) tussocks should always be saved to retain the good species and keep the pasture healthy and vigorous. 3P grasses include: desert bluegrass, golden-beard grass, black speargrass, Queensland bluegrass, forest bluegrass and kangaroo grass. Grazing mainly the leafy top part of the grasses ensures higher cattle weight gains. The 3P grasses provide most of the **forage** for grazing and the critical ground **cover** in spring and early summer. Their crowns help moisture **infiltration** and **soil retention** on slopes. 3P grasses also provide quality feed for longer than annuals and **fuel loads** for controlled burning to suppress woody regrowth.

MEAT & LIVESTOCK AUSTRALIA — QUEENSLAND GOVERNMENT — NATURAL RESOURCES Queensland — DPI QUEENSLAND DEPARTMENT OF PRIMARY INDUSTRIES — QUEENSLAND BEEF INDUSTRY INSTITUTE

[Beef2000 display being set up by Paul Jones and Anne Sullivan]


HEALTHY PASTURES = HEALTHY PROFITS
GRAZE THE TOP
SAVE THE BOTTOM
Low Grazing Pressure
High Grazing Pressure
Undesirable ('Increaser') Grass
Low Nutrient Loss
High Nutrient Loss

14.6.7 Miscellaneous

1. *[Display poster for Emerald Office and A/B Field Days by Melinda Cox]*

2. [General media release for May 1996]

"For DPI TODAY" and a general news release - 29 May 1996

PRODUCTION AND THE ENVIRONMENT ARE TRIAL ISSUES

The first practical information on how best to manage a large tract of environmentally sensitive land in the Maranoa and Central Highlands is emerging from a major trial.

The trial is focused on the eucalypt woodlands - a 15 million ha tract of land in the upper catchment for the important Fitzroy, Burdekin and Murray Darling basins.

The 10 year trial, now in year 4, is entering the information phase. Cattle liveweight gains are being measured from country grazed at three stocking rates, with the trees either killed by herbicide or left untouched.

Measurements being taken include the impact on the biodiversity and stability of the area, as well as water infiltration and runoff.

The eucalypt woodlands were selected for the trials because of a lack of detailed information from which land management recommendations can be developed, and the implications of unsustainable management systems for the Burdekin, Fitzroy and Murray Darling basins.

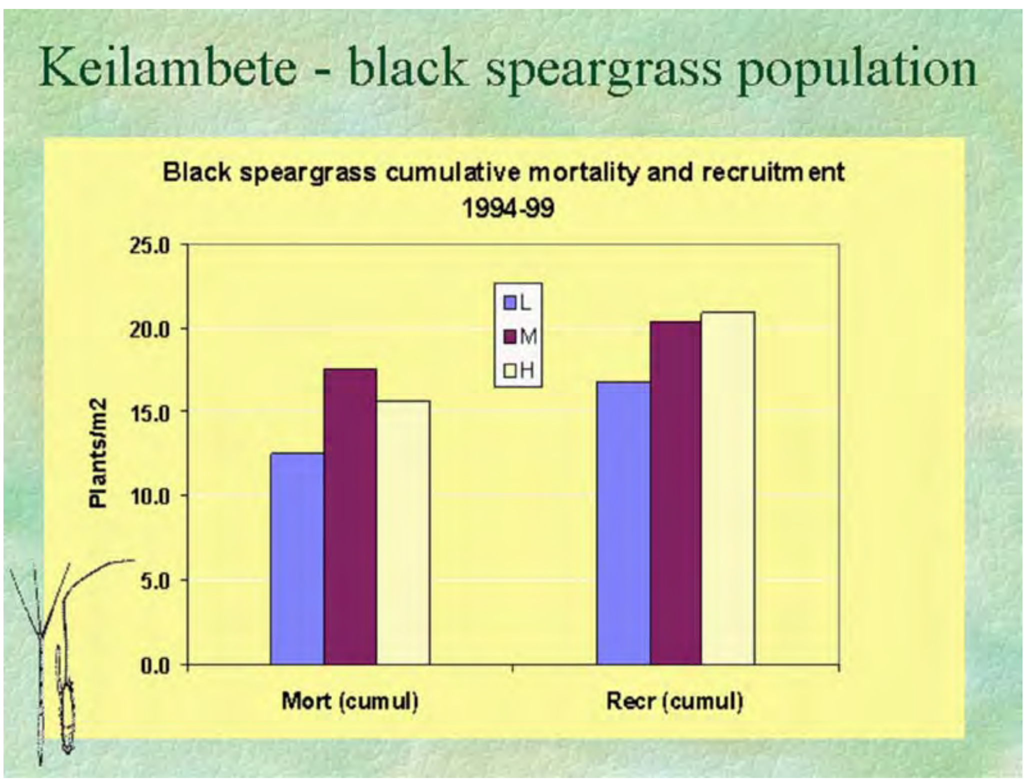
The two 140 ha trial sites are located west of Injune, in the Maranoa, and west of Rubyvale, in the Central Highlands.

The sites are being shared with other organisations interested in collecting a variety of information about the Central Queensland woodlands.

DPI contact: Richard Silcock

telephone (076) 314 263

3. *[Examples of Powerpoint presentations used in workshops and Peer Reviews]*



15 Summative Notes

15.1 Success in achieving objectives

The project was moderately successful in achieving its bold objectives. Staff changes occurred more regularly than desirable and that resulted in some measurements being delayed or reduced in their frequency. This also delayed the compilation of the final report.

We achieved very well the first objective of describing the dynamics of the resource in response to climate and grazing management.

We believe we have made practical, financially sound grazing management recommendations to fulfil the second objective. Only time will tell if they are adequate in the long term.

We have consistently and regularly communicated our findings to producers and land managers via contributions to field days, workshops, conferences, regional land management forums, booklets, newsletters, local newspapers and some scientific papers.

15.2 Impact on Meat and Livestock industry - now and in five years time

The data from this project and its progenitor come at a most opportune time as the industry launches a series of education packages for the northern Australian beef industry. The Northern Nutrition Workshops delivered via the Edge Network will benefit from the first-hand data linking animal performance to diet and pasture type. Of particular importance is the difference in winter performance between the two sites and the over-riding link to grazing pressure at different times of the year.

The other important beneficiaries will be the MLA Grazing Land Management and Stocktake packages. Both require local data and information to allow individual workshops to be tailored to local needs. Our 2 sites fill a critical gap between previous research in the speargrass country to the east and the mulga and mitchell grass lands to the west. We believe our insights from 7 years of integrated study go a long way towards making the right link between good theory and practical land management for progressive producers.

The Qld Leasehold Land Review which is currently underway and will be implemented within a year should also be well served by the information which our research can contribute towards setting the benchmarks needed for long term monitoring of rangeland and pasture health.

Finally, a synopsis of our results, along with suggestions for improving the management of the *Aristida/Bothriochloa* pasture type, will be delivered shortly to industry and government agencies in an easily readable booklet. The booklet will highlight the main points and alert readers to the potential for getting more specific or detailed data from our full report or the compact disc or website information sources quoted.

15.3 Conclusions and recommendations

(in particular for future work to commercially exploit the results)

The 1992 decision to fund research into grazing management and pasture ecology of *Aristida/Bothriochloa* pastures has been a sound decision. It allowed critical data to be collected on eight major aspects of land management and some ideas tested before many important land management changes were legislated. The results were not always unequivocal but they highlight where the greatest difficulties may lie and where compromises can be made. For example, 40% ground cover at the end of the growing season is readily achievable but 70% is not, compared to the recommendations coming from southern Australian research. The huge financial costs of very light grazing, as opposed to moderate rates, are also highlighted if wildlife or biodiversity goals are overemphasised without large monetary returns from that enhanced biodiversity.

The results of our research need to be closely studied and the implications discussed in suitable forums and compared with like data from other land types. A great deal of practical value can come from a critical but non-competitive forum before the information is incorporated into formal Grazing Land Management packages. Producers and the community would be well served by having land management experts tease out the strengths and weaknesses of results from numerous perspectives before being presented, virtually, '*fait accompli'* at workshops. This would help in understanding better why the variation that occurs from different regions and vegetation types has come about.

Future work in the realm of native pasture management should look at the interaction between management burns and grazing pressure immediately after the fires. We believe this can strongly affect the ensuing pasture composition and health as well as woody plant regrowth. A second area where work is needed is into tactical spelling of pastures and the impact that this has on animal performance.

The impact of different grazing pressure on breeder performance is a major deficiency currently as we try to extrapolate our results with young steers to whole property financial implications. This might be addressed by developing a theoretical model for predicting any differences and then testing critical components of that model in the field.

The effect of various levels of grazing pressure on some agreed biodiversity measures also needs to be addressed. Grazing lands can meet many important biodiversity goals very well but can never be wildlife conservation parks. Hence, the biodiversity goals being assessed need to be clearly stated and to meet current national targets for natural pastures.

Successful pastoral businesses will continue to be based on an optimal forage base, with both quantity and quality, which will then virtually guarantee that the broader soil erosion and land degradation challenges are addressed at the same time. Control of tree regrowth goes in parallel with optimal pasture production and the two are closely linked in these woodland communities. Always treat them as inter-related issues so that total management outlays will be optimised, perhaps at the cost of a little more planning effort on hot summer days and less stress during dry times.

final report

Project code: NAP3.208

Prepared by: R.G. Silcock, P. Jones, T.J. Hall, & D.K. Waters
Queensland Department of Primary Industries and Fisheries

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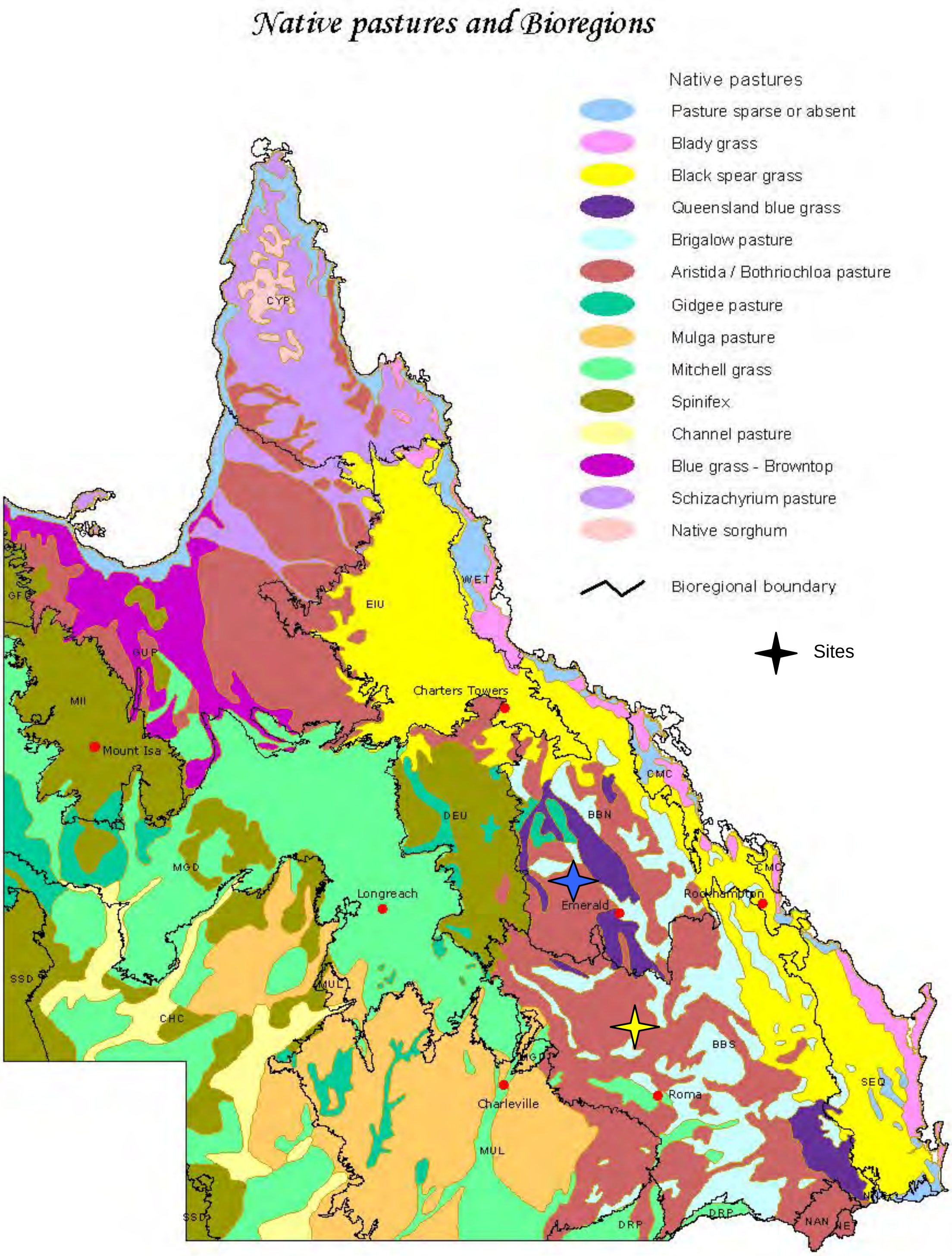
Appendices: Enhancing pasture stability and profitability for producers in Poplar Box and Silver-leaved Ironbark woodlands

Contents

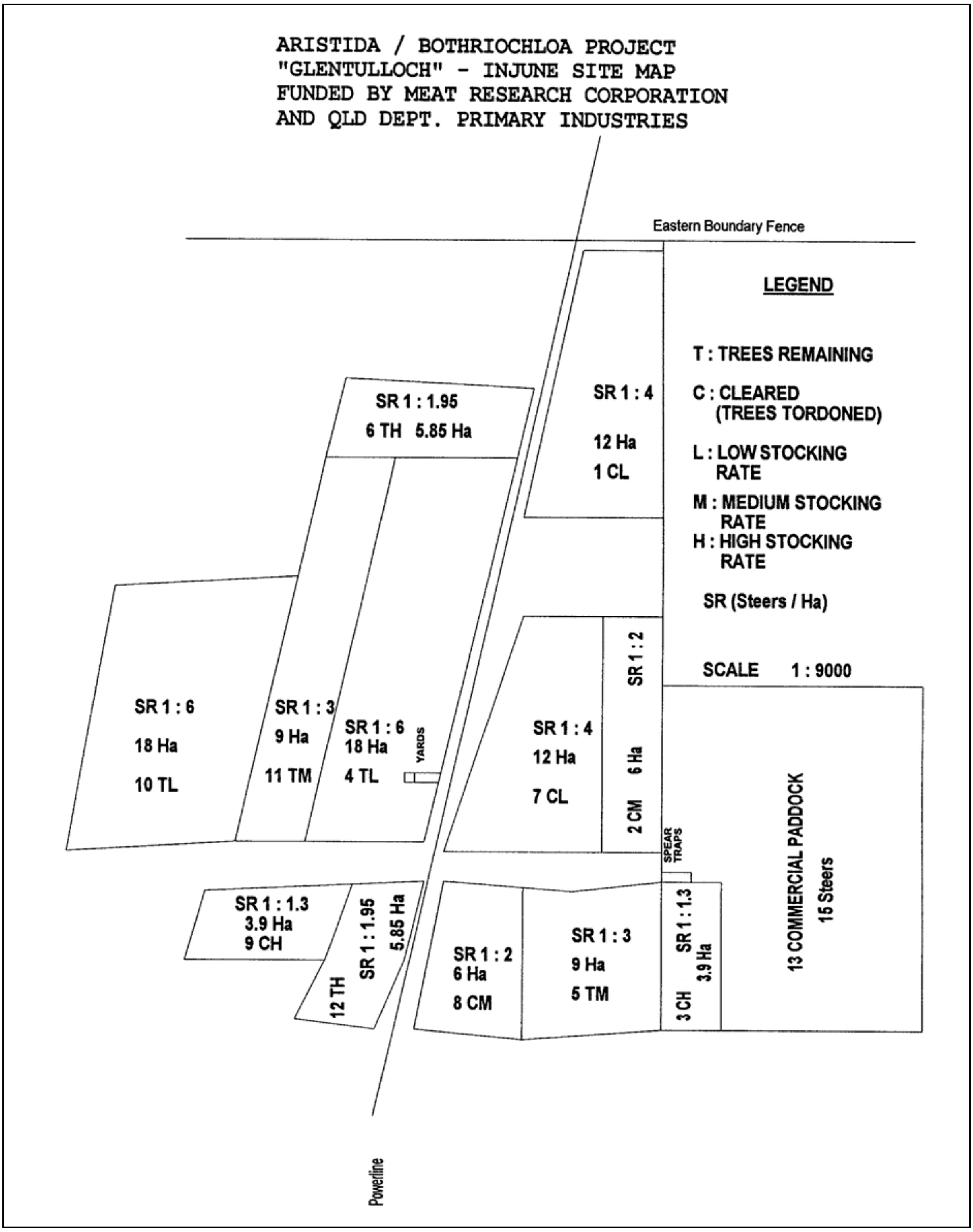
APPENDIX A. Maps and site layouts

Appendix A1

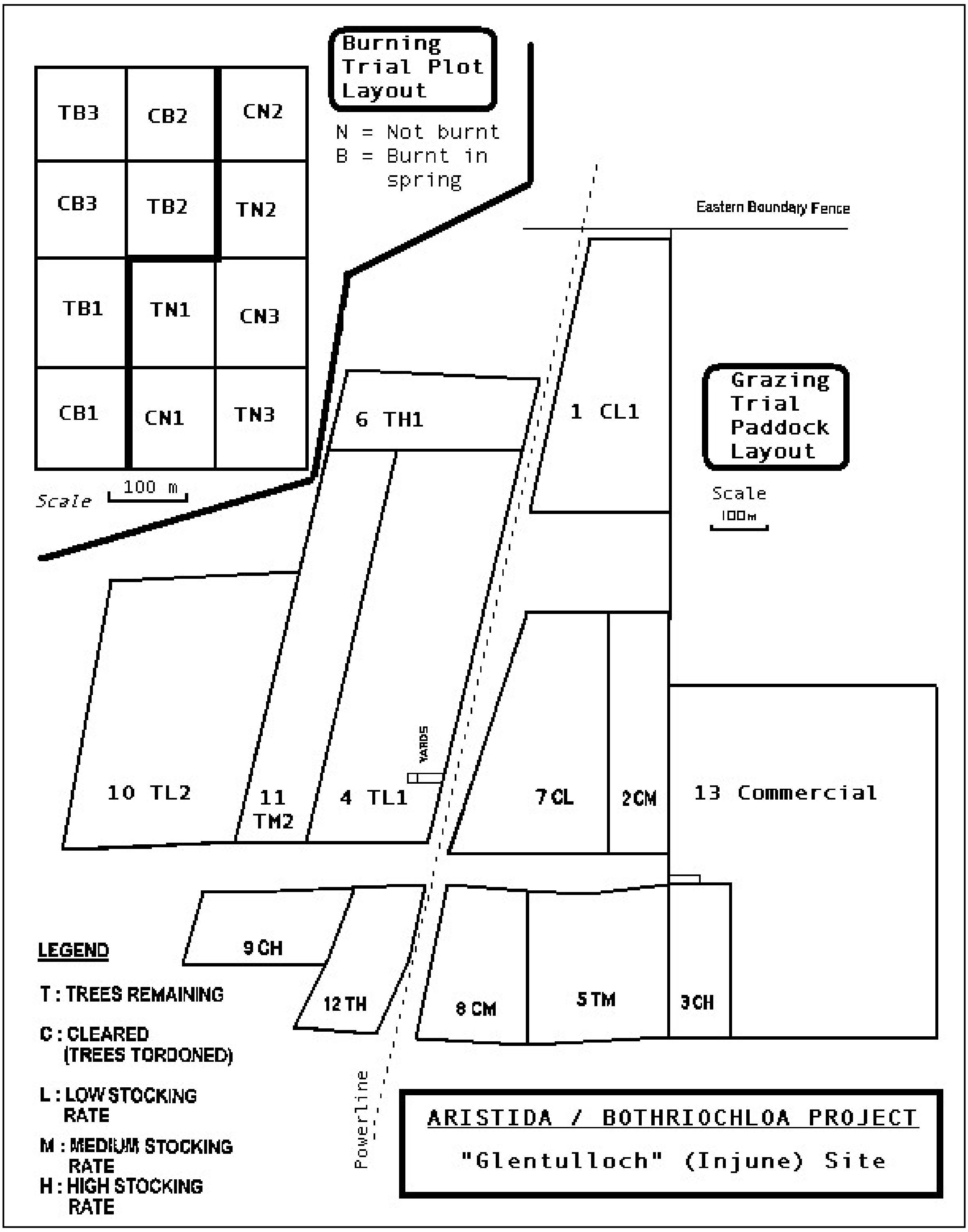


Trial sites shown as [blue star] for Keilambete and [yellow star] for Glentulloch in relation to towns and native pastures.

Appendix A2


ARISTIDA / BOTHRIOCHLOA PROJECT
"GLENTULLOCH" - INJUNE SITE MAP
FUNDED BY MEAT RESEARCH CORPORATION
AND QLD DEPT. PRIMARY INDUSTRIES
Eastern Boundary Fence
LEGEND
T : TREES REMAINING
C : CLEARED (TREES TORDONED)
L : LOW STOCKING RATE
M : MEDIUM STOCKING RATE
H : HIGH STOCKING RATE
SR (Steers / Ha)
SCALE 1 : 9000
SR 1 : 4 12 Ha 1 CL
SR 1 : 1.95 6 TH 5.85 Ha
SR 1 : 6 18 Ha 10 TL
SR 1 : 3 9 Ha 11 TM
SR 1 : 6 18 Ha 4 TL
YARDS
SR 1 : 4 12 Ha 7 CL
SR 1 : 2 6 Ha 2 CM
SPEAR TRAPS
13 COMMERCIAL PADDOCK 15 Steers
SR 1 : 1.3 3.9 Ha 9 CH
SR 1 : 1.95 5.85 Ha 12 TH
SR 1 : 2 6 Ha 8 CM
SR 1 : 3 9 Ha 5 TM
SR 1 : 1.3 3.9 Ha 3 CH
Powerline

Appendix A3

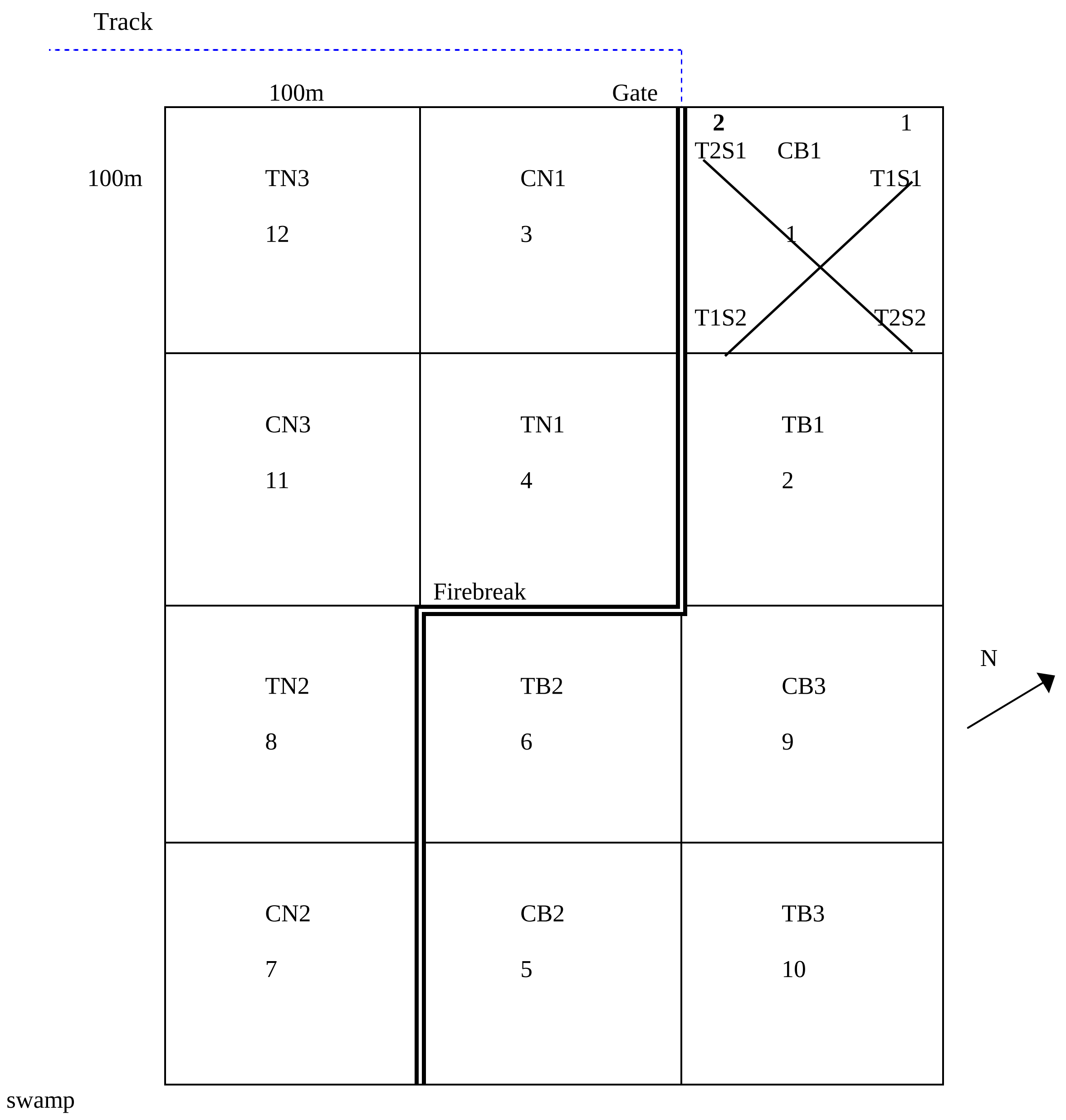

Burning Trial Plot Layout
N = Not burnt
B = Burnt in spring
TB3
CB2
CN2
CB3
TB2
TN2
TB1
TN1
CN3
CB1
CN1
TN3
Scale 100 m
Eastern Boundary Fence
Grazing Trial Paddock Layout
Scale 100m
6 TH1
1 CL1
10 TL2
11 TM2
4 TL1
YARDS
7 CL
2 CM
13 Commercial
9 CH
12 TH
8 CM
5 TM
3 CH
Powerline
LEGEND
T : TREES REMAINING
C : CLEARED (TREES TORDONED)
L : LOW STOCKING RATE
M : MEDIUM STOCKING RATE
H : HIGH STOCKING RATE
ARISTIDA / BOTHRIOCHLOA PROJECT
"Glentulloch" (Injune) Site

Appendix A4

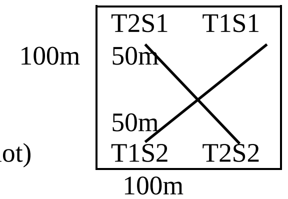
BURNING TRIAL OF A/B PROJECT, “GLENTULLOCH”, INJUNE

BURNING X TREE CONTROL PLOT LAYOUT
(12 x 1 ha blocks in Poplar box woodland)

(Established 14 June 1994; TJH)



TRAPS
2 Transects,
2 Segments
each 50 m
(Total 200 m/plot)



Treat.	Rep	Plot	Rep	Plot	Rep	Plot
1. CB	1	1	2	5	3	9
2. TB	1	2	2	6	3	10
3. CN	1	3	2	7	3	11
4. TN	1	4	2	8	3	12

Pasture Basal area: 50 x 1m long sets of 5 pins along transects (4 x 50 m – total 1000 pins)

APPENDIX B. Site soils details, Ironbark & Poplar box sites

Appendix B1

Soils at other places in the 'Glentulloch' grazing trial site

Taken from Anon (1998)

1. Poplar box. Drainage depressions (alluvial soils). Slope 1%. Light clay surface, strongly structured. [Sample Site 5 – bottom of paddock 7: cleared, low stocking rate]

pH	Org.C	Total N	Avail. P (bicarb)	Avail. K	SO4 - S	NO3-N	DTPA extractable trace elements (mg/kg)			
(lab.)	%	%	(mg/kg)	(meq %)	(mg/kg)	(mg/kg)	Fe	Mn	Cu	Zn
8.2 Moderately alkaline	2.1 medium	0.19 medium	47 high	1.6 Very high	3 Very low	5 low	8.9	7.2	0.51 Medium	1.8 medium

Note: Overall, this is a fertile soil (except for low sulfate sulphur). It contrasts with the other soils because it is derived from alluvial sources rather than the weathered rock as are the other sites.

2. Poplar box. Hillslope 5%. Texture contrast soil with bleached loamy surface (to15 cm) over greyish yellow clay. [Sample Site 16 – paddock 5: uncleared, medium stocking rate]

pH	Org. C	Total N	Avail. P (bicarb)	Avail. K	SO4 - S	NO3-N	DTPA extractable trace elements (mg/kg)			
(lab.)	%	%	(mg/kg)	(meq %)	(mg/kg)	(mg/kg)	Fe	Mn	Cu	Zn
7.2 neutral	1.4 low	0.1 low	13 marginal	0.59 high	5 low	2 very low	22.5	26	0.9 medium	0.63 low

Note: Phosphorus (P) adequate for native pasture, low for improved pasture.

3. Poplar box. Hillslope 4%. Gradational soil: clay loam surface grading into yellow brown medium clay subsoil. Linear Gilgai, shelf profile. [Sample Site 22 – paddock 3: cleared, high stocking rate]

pH	Org.C	Total N	Avail. P (bicarb)	Avail. K	SO4 - S	NO3-N	DTPA extractable trace elements (mg/kg)			
(lab.)	%	%	(mg/kg)	(meq %)	(mg/kg)	(mg/kg)	Fe	Mn	Cu	Zn
7.4 Mildly alkaline	1.5 moderate	0.11 low	17 low	0.85 high	3 very low	5 low	9.2	29	0.76 medium	3.9 medium

Note: Phosphorus (P) adequate for improved pasture. Sulfate-sulfur (SO_4-S) possibly a problem.

4. Poplar box bulloak. Hillslope 3%. Texture contrast soil with bleached loamy surface (to 25 cm) over brown clay subsoil. [Sample Site 34 – paddock 3: uncleared, low stocking rate]

pH	Org.C	Total N	Avail. P (bicarb)	Avail. K	SO4 - S	NO3-N	DTPA extractable trace elements (mg/kg)			
(lab.)	%	%	(mg/kg)	(meq %)	(mg/kg)	(mg/kg)	Fe	Mn	Cu	Zn
6.6 neutral	1.3 low	0.08 low	12 marginal	0.77 high	3 very low	3 very low	27.9	31	0.6 medium	0.7 medium

Note: Phosphorus (P) adequate for native pasture, low for improved pasture. Sulfate-sulfur (SO_4-S) possibly a problem.

5. Poplar box ironbark, bulloak. Hillcrest, slope 0.5%. Texture contrast soil with bleached loamy surface (to 13 cm) over very hard yellow brown clay subsoil. Rock outcrop and surface rock present. [Sample Site 35 – paddock 6: uncleared, high stocking rate]

pH	Org.C	Total N	Avail. P (bicarb)	Avail. K	SO4 - S	NO3-N	DTPA extractable trace elements (mg/kg)			
(lab.)	%	%	(mg/kg)	(meq %)	(mg/kg)	(mg/kg)	Fe	Mn	Cu	Zn
7.2 neutral	1.2 low	0.05 Very low	14 marginal	0.6 high	3 very low	2 very low	27.4	45	0.46 medium	0.96 medium

Note: Phosphorus (P) adequate for native pasture, low for improved pasture. Sulfate-sulfur (SO_4-S) possibly a problem.

Appendix B2
Detailed soil profile descriptions from the Glentulloch trial site

Project: GTL **Site:** 7 **Observation:** 1 **Soil Name:**

Date: 13/08/1996 **Described By:** Brian Slater

Location:	Paddock 7: Mid-paddock, mid-slope, north side of *Dichanthium sericeum* Swiftsynd fence (just above weather stn) Lat. 254526; Long. 1482505
Landform Element:	Hillslope (mid-slope)
Landform Pattern:	rises
Slope:	5 %
Great Soil Group:	Solodic
Principal Profile Form:	Db1.33
Australian Soil Classification:	BLACK SODOSOL
Vegetation:	Cleared poplar box woodland
Microrelief Component:	
Microrelief Description:	
Runoff:	moderately rapid
Permeability:	slowly permeable
Drainage:	Imperfectly drained
Substrate Lithology:	
Surface Coarse Fragments:	very few medium pebbles, subrounded Quartz
Surface Condition:	hard setting

Profile Morphology:

Horizon	Depth	Description
A1	0 to 0.05 m	brownish black (10YR3/2) moist; clay loam; fine sandy; weak 2-5mm angular blocky; clear to-
A2SB	0.05 to 0.08 m	dull yellowish orange (10YR7/2) dry; clay loam; fine sandy; abrupt to-
B21t	0.08 to 0.3 m	brownish black (10YR3/2) moist, greyish yellow-brown (10YR4/2) moist; medium heavy clay; moderate 10-20mm angular blocky, moderate 10-20mm prismatic; gradual to-
B22t	0.3 to 0.6 m	dark brown (10YR3/3) moist; medium clay; moderate 20-50mm prismatic, moderate 10-20mm angular blocky; very few fine calcareous nodules; gradual to-
B23t	0.6 to 0.9 m	brown (7.5YR4/4) moist; medium clay; moderate 10-20mm angular blocky; very few fine calcareous nodules; gradual to-
B24tk	0.9 to 1.25 m	orange (7.5YR6/6) moist, bright yellowish brown (10YR6/6) moist; fine sandy light medium clay; moderate 10-20mm angular blocky; few fine calcareous nodules, few medium calcareous nodules;
B25	1.25 to 1.6 m	dull yellowish orange (10YR6/4) moist, dull orange (7.5YR6/4) moist; fine sandy light clay; moderate 10-20mm angular blocky; few medium calcareous soft segregations, few fine calcareous nodules;

Field pH

Depth	pH
0.02	6.0
0.3	8.7
0.6	9.0
0.9	8.7
1.2	8.7
1.5	8.7

Project: GTL **Site:** 52 (2b) **Observation:** 1 **Soil Name:**
Date: 12/08/1996 **Described By:** Brian Slater

Location:	Just outside to north of Paddock 1 near *Enteropogon ramosus* Swiftsynd site, beside gilgai. Lat. 254000 Long. 1480000
Landform Element:	Hillslope; upper rise
Landform Pattern:	rises
Slope:	4 %
Great Soil Group:	No suitable group
Principal Profile Form:	Gn3.93
Australian Soil Classification:	BROWN DERMOSOL
Vegetation:	Mid-high isolated trees; *Brachychiton rupestris*
Microrelief Component:	mound
Microrelief Description:	melonhole gilgai;
Runoff:	slow
Permeability:	moderately permeable
Drainage:	moderately well drained
Substrate Lithology:	
Surface Coarse Fragments:	
Surface Condition:	Firm

Profile Morphology:

Horizon	Depth	Description
A11	0 to 0.08 m	brownish black (10YR2/2) moist; clay loam; fine sandy; moderate 2-5mm angular blocky;
A12	0.08 to 0.18 m	brownish black (10YR3/2) moist; light clay;
B21	0.18 to 0.32 m	dull yellowish brown (10YR5/3) moist; medium clay;
B22	0.32 to 0.44 m	dull yellowish orange (10YR6/3) moist; sandy light clay; few medium pebbles, angular shell;
C1	0.44 to 0.8 m	dull yellow (2.5Y6/3) moist;
C2	0.8 to 1.1 m	bright yellowish brown (2.5Y7/6) moist; few coarse calcareous soft segregations;
C3	1.1 to 1.4 m	dull yellow (2.5Y6/4) moist;

pH

Depth	pH
0 – 10	7.3
20 - 30	7.8
50 - 60	8.3
80 - 90	8.9
1.10 – 1.20	9.5

Project: GTL **Site:** 5 **Observation:** 1 **Soil Name:**
Date: 12/08/1996 **Described By:** Brian Slater

Location:	Paddock 7 near north western corner on flat outside *Aristida ramosa* Swiftsynd site - inverted soil over buried soil Lat. 254000 Long. 1480000
Landform Element:	embankment
Landform Pattern:	Alluvial plain; lower slope on flat
Slope:	1 %
Great Soil Group:	No suitable group
Principal Profile Form:	
Australian Soil Classification:	STRATIC RUDOSOL
Vegetation:	Tall open woodland; *Eucalyptus populnea*
Microrelief Component:	
Microrelief Description:	
Runoff:	slow
Permeability:	slowly permeable
Drainage:	imperfectly drained
Substrate Lithology:	
Surface Coarse Fragments:	
Surface Condition:	

Profile Morphology:

Horizon	Depth	Description
1A1	0 to 0.15 m	greyish yellow-brown (10YR4/2) moist; few coarse faint brown mottles; light clay; strong 2-5mm angular blocky; moderately moist moderately weak; clear to-
1A2	0.15 to 0.35 m	dull yellowish brown (10YR5/4) moist; fine sandy loam; weak 5-10mm angular blocky; moist very weak; gradual to-
2A3	0.35 to 0.48 m	greyish yellow-brown (10YR4/2) moist; common coarse distinct dark mottles; fine sandy light clay; weak 5-10mm angular blocky; moist moderately weak; gradual to-
2A1	0.48 to 0.55 m	brownish black (10YR3/2) moist; light clay; strong 2-5mm angular blocky; moist moderately weak; clear to-
2A2	0.55 to 0.57 m	dull yellowish orange (10YR7/2) dry; light clay; moderate 10-20mm prismatic; abrupt to-
2B21	0.57 to 0.92 m	greyish yellow-brown (10YR4/2) moist; medium clay; moderate 20-50mm prismatic, moderate 5-10mm lenticular; dry very firm; gradual to-
2B22	0.92 to 1.2 m	dull yellowish brown (10YR5/3) moist; moderate 20-50mm prismatic, moderate 5-10mm lenticular; very few fine calcareous nodules; dry moderately strong; gradual to-
2B23	1.2 to 1.5 m	dull yellowish brown (10YR5/4) moist; moderate 5-10mm lenticular; few fine calcareous nodules; dry moderately strong;

Field pH

Depth	pH
0.03	6.0
0.3	9.0
0.9	8.8
1.2	8.8

Project: GTL **Site:** 44 **Observation:** 1 **Soil Name:**
Date: 15/08/1996 **Described By:** Brian Slater

Location:	Burn site plot CN3 - near *Bothriochloa decipiens* Swiftsynd site Lat. 254424 Long. 1482541
Landform Element:	Hillslope, near top of ridge line
Landform Pattern:	undulating rises 9-30 m 3-10 %
Slope:	3 %
Great Soil Group:	Solodic
Principal Profile Form:	Db1.33
Australian Soil Classification:	Brown Sodosol
Vegetation:	*Eucalyptus populnea* (Poplar box) woodland
Microrelief Component:	
Microrelief Description:	
Runoff:	moderately rapid
Permeability:	slowly permeable
Drainage:	imperfectly drained
Substrate Lithology:	
Surface Coarse Fragments:	
Surface Condition:	hard setting

Profile Morphology:

Horizon	Depth	Description
A	0 to 0.1 m	greyish brown (7.5YR4/2) moist; sandy clay loam; weak 5-10mm angular blocky; moderately moist moderately weak; gradual to-
A	0.1 to 0.18 m	brown (7.5YR4/3) moist; sandy clay loam; moderately moist moderately weak; clear to-
A2sb	0.18 to 0.19 m	light brownish grey (7.5YR7/2) dry; abrupt to-
B21t	0.19 to 0.31 m	dull reddish brown (5YR4/4) moist; few medium faint grey mottles; medium heavy clay; moderate 10-20mm prismatic, moderate 5-10mm angular blocky; moist moderately weak; gradual to-
B22t	0.31 to 0.5 m	dull brown (7.5YR5/4) moist; medium clay; moderate 10-20mm prismatic, moderate 10-20mm angular blocky; dry very firm; gradual
B23t	0.5 to 0.78 m	dull brown (7.5YR5/4) moist; light medium clay; moderate 20-50mm prismatic, moderate 10-20mm angular blocky; very few medium calcareous nodules, very few fine calcareous nodules; dry moderately strong; gradual to-
B24t	0.78 to 1 m	very few medium calcareous nodules; gradual to-
B25t	1 to 1.2 m	bright yellowish brown (10YR6/6) moist; fine sandy light clay; dry moderately strong; gradual to-
B26t	1.2 to 1.35 m	dull yellowish orange (10YR7/4) moist; fine sandy light clay; moderate 10-20mm prismatic, moderate 10-20mm angular blocky; dry moderately strong;

Field pH

Depth	pH
0.01	6.0
0.3	6.2
0.6	8.0
0.9	8.0
1.2	7.5

Project: GTL **Site:** 35 **Observation:** 1 **Soil Name:**

Date: 15/08/1996 **Described By:** Brian Slater

Location:	Paddock 6, 50 m ESE water tank; 70 m W of eastern fence, towards S of centre paddock Lat. 254525 Long. 1482507
Landform Element:	Hillcrest, near top of rise
Landform Pattern:	rises
Slope:	0.5 %
Great Soil Group:	Solodized solonetz
Principal Profile Form:	Dy2.43
Australian Soil Classification:	GREY SODOSOL
Vegetation:	Silver leaved Ironbark, Poplar Box, Sandalwood
Microrelief Component:	
Microrelief Description:	
Runoff:	moderately rapid
Permeability:	slowly permeable
Drainage:	imperfectly drained
Substrate Lithology:	
Surface Coarse Fragments:	
Surface Condition:	hardsetting

Profile Morphology:

Horizon	Depth	Description
A1	0 to 0.11 m	dark brown (7.5YR3/3) moist; sandy clay loam; weak 5-10mm platy, weak 5-10mm angular blocky; dry moderately weak;
A2CB	0.11 to 0.13 m	light grey (10YR8/1) dry; sandy clay loam; dry moderately weak;
B21T	0.13 to 0.4 m	greyish yellow-brown (10YR6/2) moist, greyish yellow-brown (10YR5/2) moist; very few medium faint brown mottles; sandy medium heavy clay; moderate 10-20mm columnar; dry moderately
B22T	0.4 to 0.58 m	dull yellowish orange (10YR6/3) moist; sandy medium clay; moderate 20-50mm prismatic, moderate 20-50mm angular blocky; very few medium manganiferous veins; dry moderately strong;
B23T	0.58 to 0.92 m	dull yellowish orange (10YR6/3) moist; sandy light clay; moderate 10-20mm angular blocky; few medium calcareous nodules, very few medium calcareous soft segregations; dry moderately strong;
B24C	0.92 to 1.12 m	dull yellow (2.5Y6/4) moist; moderate 10-20mm angular blocky; very few medium calcareous nodules; dry moderately strong;

Field pH

Depth	pH
0.01	6.0
0.3	7.8
0.6	8.5
0.9	8.7
1.1	8.7

Project: GTL **Site:** 34 **Observation:** 1 **Soil Name:**

Date: 14/08/1996 **Described By:** Brian Slater

Location:	Paddock 4, near *Chrysopogon fallax* No. 1 Swiftsynd site, 50 m to N of southern fence along power Line, 100 m SE shed; Lat. 254522, Long. 1482507
Landform Element:	Hillslope; mid slope
Landform Pattern:	
Slope:	3%
Great Soil Group:	Solodic
Principal Profile Form:	Db1.43
Australian Soil Classification:	BROWN SODOSOL
Vegetation:	Open Woodland, *Eucalyptus populnea, Casuarina luehmannii*
Microrelief Component:	
Microrelief Description:	
Runoff:	moderately rapid
Permeability:	slowly permeable
Drainage:	Imperfectly drained
Substrate Lithology:	Mudstone and sandstone
Surface Coarse Fragments:	
Surface Condition:	hard setting

Profile Morphology:

Horizon	Depth	Description
A11	0 to 0.04 m	dark brown (7.5YR3/3) moist; sandy clay loam; moderate 2-5mm platy, moderate 2-5mm angular blocky; dry moderately weak;
A12	0.04 to 0.16 m	dark brown (7.5YR3/3) moist; sandy clay loam; dry moderately weak;
A21	0.16 to 0.22 m	brown (7.5YR4/3) moist;
A2cb	0.22 to 0.25 m	light grey (7.5YR8/1) moist; sandy clay loam; moderate 20-50mm columnar; dry moderately weak;
B21t	0.25 to 0.37 m	dark reddish brown (2.5YR3/3) moist, dull reddish brown (2.5YR4/4) moist; few medium faint grey mottles; fine sandy medium heavy clay; moderate 20-50mm prismatic, moderate 10-20mm angular blocky; moderately moist very firm;
B22	0.37 to 0.53 m	brown (7.5YR4/4) moist; medium heavy clay; moderate 20-50mm prismatic, moderate 5-10mm angular blocky; dry moderately strong;
B23	0.53 to 0.8 m	dull yellowish orange (10YR6/4) moist; medium heavy clay; moderate 20-50mm prismatic, moderate 10-20mm angular blocky; very few medium calcareous nodules; dry moderately strong;
BC1	0.8 to 1.05 m	dull yellowish orange (10YR6/4) moist; moderate 10-20mm angular blocky; dry moderately strong;
BCk	1.05 to 1.5 m	dull yellowish orange (10YR6/4) moist; medium clay; moderate 10-20mm angular blocky, moderate 5-10mm angular blocky; common coarse calcareous soft segregations, very few fine manganiferous veins; dry moderately strong;

Field pH

Depth	pH
0.01	6.0
0.3	7.2
0.6	8.3
0.9	8.5
1.2	7.8
1.5	7.8

Project: GTL **Site:** 22 **Observation:** 1 **Soil Name:**

Date: 14 Aug. 1996 **Described By:** Brian Slater

Location:	Paddock 3, N side and near Runoff trough bay (P3 High GP, Rep 1, grazed). Between linear gilgai. Lat. 254538, Long. 1482450
Landform Element:	Hillslope, upper slope
Landform Pattern:	
Slope:	4 %
Great Soil Group:	No suitable group
Principal Profile Form:	Gn3.93
Australian Soil Classification:	BROWN DERMOSOL
Vegetation:	
Microrelief Component:	shelf
Microrelief Description:	linear gilgai; 0.1m Vertical Interval; 5m Horizontal Interval
Runoff:	moderately rapid
Permeability:	slowly permeable
Drainage:	imperfectly drained
Substrate Lithology:	
Surface Coarse Fragments:	common medium pebbles, subangular tabular Quartz
Surface Condition:	periodic cracking, self-mulching

Profile Morphology:

Horizon	Depth	Description
A11	0 to 0.04 m	brownish black (10YR3/1) moist; clay loam; fine sandy; weak 2-5mm angular blocky, moderate <2mm granular; dry very weak; clear to-
A12	0.04 to 0.25 m	brownish black (10YR3/1) moist; light clay; moderate 5-10mm angular blocky; moderately moist moderately weak; gradual to-
B21	0.25 to 0.48 m	greyish yellow-brown (10YR4/2) moist, brownish grey (10YR4/1) moist; light medium clay; moderate 10-20mm angular blocky, moderate 5-10mm angular blocky; moderately moist moderately firm; gradual to-
B22	0.48 to 0.8 m	greyish yellow-brown (10YR4/2) moist; medium heavy clay; very few medium pebbles, angular Siltstone; moderate 10-20mm lenticular, moderate 5-10mm angular blocky; few medium calcareous nodules; dry moderately strong; gradual to-
B23	0.8 to 1 m	greyish yellow-brown (10YR4/2) moist; medium heavy clay; common medium calcareous nodules; dry moderately strong; gradual to-
BC	1 to 1.3 m	dull yellowish orange (10YR6/4) moist; medium heavy clay; moderate 20-50mm lenticular, moderate 10-20mm angular blocky; dry moderately strong; gradual to-
C	1.3 to 1.6 m	bright yellowish brown (10YR6/6) moist, light grey (10YR8/1); medium heavy clay; dry moderately strong;

Field pH

Depth	pH
0.02	8.0
0.3	8.5
0.6	8.5
0.9	8.5
1.2	7.0
1.5	6.0

Project: GTL **Site:** 16 **Observation:** 1 **Soil Name:**
Date: 13/08/1996 **Described By:** Brian Slater

Location:	Paddock 5, mid-slope, 30 m N fence (next to paddock 8) 150 m W of gate, Lat. 254525, Long. 1482448
Landform Element:	Hillslope, mid-slope
Landform Pattern:	rises
Slope:	5 %
Great Soil Group:	
Principal Profile Form:	Dy2.43
Australian Soil Classification:	GREY SODOSOL
Vegetation:	*Eucalyptus populnea* (poplar box) woodland
Microrelief Component:	
Microrelief Description:	
Runoff:	moderately rapid
Permeability:	slowly permeable
Drainage:	imperfectly drained
Substrate Lithology:	
Surface Coarse Fragments:	few medium pebbles, subrounded Quartz, few large pebbles, subrounded Quartz
Surface Condition:	hard setting, firm

Profile Morphology:

Horizon	Depth	Description
A1	0 to 0.11 m	brownish black (10YR3/2) moist; clay loam; fine sandy; weak 5-10mm angular blocky, weak 2-5mm angular blocky; dry moderately weak; clear to-
A2CB	0.11 to 0.14 m	greyish yellow-brown (10YR5/2) dry; clay loam; fine sandy; weak 5-10mm angular blocky; very few medium ferromanganiferous nodules; moderately moist moderately weak; abrupt to-
B21t	0.14 to 0.25 m	greyish yellow-brown (10YR4/2) moist; medium heavy clay; very few medium pebbles, subrounded Quartz; moderate 10-20mm columnar, moderate 5-10mm angular blocky; moist moderately weak; gradual to-
B22t	0.25 to 0.44 m	greyish yellow-brown (10YR4/2) moist; medium heavy clay; very few medium pebbles, angular tabular Quartz; moderate 10-20mm prismatic, moderate 5-10mm angular blocky; very few fine calcareous nodules; dry very firm; gradual to-
B23t	0.44 to 0.8 m	dull yellowish brown (10YR5/3) moist; medium clay; moderate 20-50mm prismatic; few medium calcareous soft segregations, very few medium calcareous nodules; dry moderately strong; gradual to-
B24t	0.8 to 1.1 m	dull yellowish orange (10YR6/4) moist; medium clay; moderate 10-20mm angular blocky; dry moderately strong; gradual to-
B25t	1.1 to 1.6 m	dull yellowish orange (10YR7/4) moist, light grey (2.5Y7/1) moist; fine sandy medium clay; dry very firm;

Field pH

Depth	pH
0.05	6.5
0.3	7.2
0.6	8.7
0.9	8.8
1.2	6.4
1.5	6.2

Appendix B3
profile details from the Keilambete site

SITE NO: 1 W edge of CL2 near lane
SOIL TYPE:
SUBSTRATE MATERIAL: granite
CONFIDENCE SUBSTRATE IS PARENT MATERIAL:
A.M.G. REFERENCE: 559 880 mE 7 414 850 mN ZONE 55
SLOPE: 1 %
GREAT SOIL GROUP: Non-calcic brown soil
LANDFORM ELEMENT TYPE: hillcrest
PRINCIPAL PROFILE FORM: Dr2.12
LANDFORM PATTERN TYPE: undulating rises 9-30m 3-10%
SOIL TAXONOMY UNIT:
FAO UNESCO UNIT:

AUSTRALIAN SOIL CLASSIFICATION: HAPLIC, EUTROPHIC, RED, CHROMOSOL; Thin, Non Gravelly, Sandy, Clayey, Shallow. (Confidence level 3).

STRUCTURAL FORM: Mid-high woodland
DOMINANT VEGETATION SPECIES*: Eucalyptus melanophloia, Eucalyptus erythrophloia,, Bursaria incana, Bothriochloa ewartiana, Heteropogon contortus, Enneapogon species, Chrysopogon fallax, Themeda triandra*

PROFILE MORPHOLOGY:
CONDITION OF SURFACE SOIL WHEN DRY: hard setting

HORIZON	DEPTH	DESCRIPTION
A1	0 to .05 m	Brownish black (7.5YR3/2) moist; loamy sand; massive. clear to-
B1	.05 to .10 m	Dark reddish brown (5YR3/2) moist; sandy light clay; massive. clear to-
B2	.10 to .40 m	Reddish brown (2.5YR4/6) moist; light medium clay; strong 20-50mm angular blocky. gradual to-
B3	.40 to .45 m	Reddish brown (2.5YR4/6) moist; medium clay; moderate 20-50mm angular blocky parting to moderate 10-20mm lenticular; common distinct slickenside. gradual to-
BC	.45 to .60 m	Weathering granite
C	.60 m	Hard granite

SITE NO: 2 150m E of site 1 on slope to creek and site 3
SOIL TYPE:
SUBSTRATE MATERIAL: granite
CONFIDENCE SUBSTRATE IS PARENT MATERIAL:
A.M.G. REFERENCE: 559 930 mE 7 414 900 mN ZONE 55
SLOPE: 4 %
GREAT SOIL GROUP: Non-calcic brown soil
LANDFORM ELEMENT TYPE: hillslope
PRINCIPAL PROFILE FORM: Dr2.12
LANDFORM PATTERN TYPE: undulating rises 9-30m 3-10%
SOIL TAXONOMY UNIT:
FAO UNESCO UNIT:
AUSTRALIAN SOIL CLASSIFICATION: HAPLIC, EUTROPHIC, RED, CHROMOSOL; Thin, Non

Gravelly, Sandy, Clayey, Shallow. (Confidence level 3).

STRUCTURAL FORM: Mid-high woodland
DOMINANT VEGETATION SPECIES: *Eucalyptus melanophloia, Eucalyptus erythrophloia, Bothriochloa ewartiana, Heteropogon contortus, Themeda triandra, Chrysopogon fallax, Panicum effusum, Enneapogon species*

PROFILE MORPHOLOGY:

CONDITION OF SURFACE SOIL WHEN DRY: hard setting

HORIZON	DEPTH	DESCRIPTION
-------	-----	-----------
A1	0 to .03 m	Brownish black (7.5YR3/2) moist; loamy sand; massive. clear to-
A3	.03 to .08 m	Dark reddish brown (5YR3/4) moist; sandy loam; massive. clear to-
B1	.08 to .12 m	Dark reddish brown (5YR3/2) moist; sandy light clay; massive. clear to-
B2	.12 to .35 m	Dark reddish brown (2.5YR3/4) moist; medium clay; strong 10-20mm angular blocky. gradual to-
B3	.35 to .50 m	Reddish brown (5YR4/6) moist; light medium clay; strong prismatic; few distinct slickenside. Gradual to-
BC	.50to .70 m	Weathering granite

SITE NO: 3 Just W of gully in CL2, 300m from shed

SOIL TYPE:
SUBSTRATE MATERIAL: granite
CONFIDENCE SUBSTRATE IS PARENT MATERIAL:
A.M.G. REFERENCE: 560 030 mE 7 414 950 mN ZONE 55
SLOPE: 4 %
GREAT SOIL GROUP: Non-calcic brown soil
LANDFORM ELEMENT TYPE: hillslope
PRINCIPAL PROFILE FORM: Dr2.12
LANDFORM PATTERN TYPE: undulating rises 9-30m 3-10%

SOIL TAXONOMY UNIT:

FAO UNESCO UNIT:
AUSTRALIAN SOIL CLASSIFICATION: HAPLIC, EUTROPHIC,
STRUCTURAL FORM: RED, CHROMOSOL; Thin, Non Gravelly, Loamy, Clayey, Moderately deep. (Confidence level 3).

DOMINANT VEGETATION SPECIES: *Eucalyptus melanophloia, Eucalyptus erythrophloia, Bothriochloa ewartiana, Heteropogon contortus, Themeda triandra, Chrysopogon fallax, Panicum effusum, Enneapogon species*

PROFILE MORPHOLOGY:
CONDITION OF SURFACE SOIL WHEN DRY: hard setting

HORIZON	DEPTH	DESCRIPTION
-------	-----	-----------
A11	0 to .05 m	Brownish black (10YR2/2) moist; sandy loam; massive. gradual to-
A12	.05 to .08 m	Brownish black (7.5YR3/2) moist; sandy clay loam; massive. clear to -
B1	.08 to .12 m	Dark reddish brown (5YR3/4) moist; sandy light clay; massive. clear to-
B2	.12 to .45 m	Reddish brown (5YR4/6) moist; medium clay; moderate 20-50mm angular blocky; few distinct slickenside. gradual to-
B3	45 to .60 m	Dark brown (7.5YR3/4) moist; light medium clay; moderate 10-20mm angular blocky; few distinct slickenside. gradual to-
BC	.60to .75 m	Weathering granite

SITE NO: 4 50m S of site 3 on W side of gully in CL2

SOIL TYPE:
SUBSTRATE MATERIAL: Altered substrate material
CONFIDENCE SUBSTRATE IS PARENT MATERIAL:
A.M.G. REFERENCE: 560 080 mE 7 414 900 mN ZONE 55
SLOPE: 0.8 %
GREAT SOIL GROUP: No suitable group

LANDFORM ELEMENT TYPE: valley-flat
PRINCIPAL PROFILE FORM: Um5.51
LANDFORM PATTERN TYPE: undulating rises 9-30m 3-10%
SOIL TAXONOMY UNIT:
FAO UNESCO UNIT:
AUSTRALIAN SOIL CLASSIFICATION: BASIC, STRATIC, RUDOSOL; Non Gravelly, Clay Loamy.

(Confidence level 3).

STRUCTURAL FORM: Tall isolated clump of trees
DOMINANT VEGETATION SPECIES: *Eucalyptus melanophloia, Eucalyptus papuana, Eucalyptus erythrophloia, Sida species, Archidendropsis basaltica, Enneapogon species, Chrysopogon fallax, Aristida species, Tripogon loliiformis*

PROFILE MORPHOLOGY:
CONDITION OF SURFACE SOIL WHEN DRY: hard setting

HORIZON	DEPTH	DESCRIPTION
-------	-----	-----------
A1	0 to .20 m	Brownish black (10YR2/2) moist; sandy clay loam; massive; dry; moderately firm. gradual to -
2D	.20 to .40 m	Dull yellowish brown (10YR4/3) moist, dull yellowish brown (10YR5/3) dry; loamy sand; massive; dry; moderately weak. clear to-
3D	.40 to .85 m	Brown (10YR4/4) moist; clayey sand; massive parting to single grain; dry; loose. diffuse to-
4D	.85 to 1.00 m	Brown (10YR4/4) moist; coarse sand; single grain; dry; loose. abrupt to-
5D1e	1.00 to 1.00 m	Dull yellowish orange (10YR7/2) dry.
5D2	.00 to 1.15 m	Brownish grey (10YR4/1) moist; sandy light clay; moderate subangular blocky; moist; very firm.

SITE NO: 5 In central lane on W end of CM1
SOIL TYPE:
SUBSTRATE MATERIAL: granite

CONFIDENCE SUBSTRATE IS PARENT MATERIAL:

A.M.G. REFERENCE: 559 890 mE 7 414 670 mN ZONE 55
SLOPE: 1 %
GREAT SOIL GROUP: Non-calcic brown soil
LANDFORM ELEMENT TYPE: hillcrest
PRINCIPAL PROFILE FORM: Dr2.12
LANDFORM PATTERN TYPE: undulating rises 9-30m 3-10%
SOIL TAXONOMY UNIT:
FAO UNESCO UNIT:
AUSTRALIAN SOIL CLASSIFICATION: HAPLIC, EUTROPHIC, RED, CHROMOSOL; Medium, Non Gravelly, Clay Loamy, Clayey, Shallow. (Confidence level 3).

STRUCTURAL FORM: Mid-high woodland
DOMINANT VEGETATION SPECIES: *Eucalyptus melanophloia, Eucalyptus erythrophloia, Bursaria incana, Heteropogon contortus, Bothriochloa ewartiana, Chrysopogon fallax, Enneapogon species*

PROFILE MORPHOLOGY:
CONDITION OF SURFACE SOIL WHEN DRY: hard setting

HORIZON	DEPTH	DESCRIPTION
-------	-----	-----------
A1	0 to .08 m	Brownish black (7.5YR3/2) moist; sandy clay loam; massive. gradual to-
A3	.08 to .12 m	Reddish brown (5YR4/6) moist; sandy clay loam; massive. clear to-

B2 .12 to .45 m Dark reddish brown (2.5YR3/6) moist; light medium clay; strong 10-20mm angular blocky.
BC .45 to .60 m Weathering granite
C .60 m Hard granite

SITE NO: 6 On perimeter track at corner of TL2 and TH2
SOIL TYPE:
SUBSTRATE MATERIAL: igneous rock (unidentified)
CONFIDENCE SUBSTRATE IS PARENT MATERIAL:
A.M.G. REFERENCE: 559 200 mE 7 414 580 mN ZONE 55
SLOPE: 1 %
GREAT SOIL GROUP: No suitable group
LANDFORM ELEMENT TYPE: hillcrest
PRINCIPAL PROFILE FORM: Dd1.12
LANDFORM PATTERN TYPE: undulating rises 9-30m 3-10%
SOIL TAXONOMY UNIT:

FAO UNESCO UNIT:

AUSTRALIAN SOIL CLASSIFICATION: VERTIC, EUTROPHIC, BLACK, CHROMOSOL; Medium, Non Gravelly, Clay Loamy, Clayey, Moderately deep. (Confidence level 3).

STRUCTURAL FORM: Mid-high woodland
DOMINANT VEGETATION SPECIES: *Eucalyptus melanophloia, Heteropogon contortus*
SURFACE COARSE FRAGMENTS: Common cobbles, angular igneous rock (unidentified)

PROFILE MORPHOLOGY:
CONDITION OF SURFACE SOIL WHEN DRY: hard setting

HORIZON	DEPTH	DESCRIPTION
-------	-----	-----------
A11	0 to .07 m	Black (10YR2/1); sandy clay loam; massive; moderately moist. gradual to-
A12	.07 to .15 m	Black (10YR2/1); clay loam, sandy; massive; moderately moist. clear to-
B21	.15 to .30 m	Brownish black (10YR3/2); few medium distinct dark mottles; sandy medium clay; strong subangular blocky; dry; very strong. gradual to-
B22	.30 to .50 m	Brownish black (10YR3/1); sandy medium heavy clay; strong lenticular; common prominent slickenside; dry; very strong.
BC	.50	Weathering rock

SITE NO: 7 SE corner of CH1 near Site 1 runoff plots
SOIL TYPE:
SUBSTRATE MATERIAL: granite
CONFIDENCE SUBSTRATE IS PARENT MATERIAL:
A.M.G. REFERENCE: 560 320 mE 7 414 680 mN ZONE 55
SLOPE: 4 %
GREAT SOIL GROUP: Non-calcic brown soil
LANDFORM ELEMENT TYPE: hillslope
PRINCIPAL PROFILE FORM: Dr2.12
LANDFORM PATTERN TYPE: undulating rises 9-30m 3-10%
SOIL TAXONOMY UNIT:
FAO UNESCO UNIT:

AUSTRALIAN SOIL CLASSIFICATION: HAPLIC, EUTROPHIC, RED, CHROMOSOL; Medium, Non Gravelly, Loamy, Clayey, Shallow. (Confidence level 3).

STRUCTURAL FORM: Mid-high woodland

DOMINANT VEGETATION SPECIES*: Eucalyptus melanophloia, Eucalyptus erythrophloia, Bothriochloa ewartiana, Heteropogon contortus, Themeda triandra, Chrysopogon fallax*

PROFILE MORPHOLOGY:
CONDITION OF SURFACE SOIL WHEN DRY: hard setting

HORIZON	DEPTH	DESCRIPTION
-------	-----	-----------
A1	0 to .07 m	Dark reddish brown (2.5YR3/2) moist; sandy loam; massive. clear to-
A3	.07 to .13 m	Dark reddish brown (5YR3/3) moist; coarse sandy clay loam; very few small pebbles, angular granite; massive. clear to-
B21	.13 to .35 m	Dark reddish brown (2.5YR3/6) moist; light medium clay; strong 10-20mm angular blocky. grading to-
B22	.35 to .45 m	Dark reddish brown (2.5YR3/4) moist; sandy light medium clay; strong 10-20mm lenticular; common distinct slickenside. gradual to-
BC	.45	Weathering granite

SITE NO: 8 NE corner of CM1 near Site 2 runoff plots
SOIL TYPE:
SUBSTRATE MATERIAL: granite

CONFIDENCE SUBSTRATE IS PARENT MATERIAL:

A.M.G. REFERENCE: 560 270 mE 7 414 870 mN ZONE 55
SLOPE: 5 %
GREAT SOIL GROUP: Non-calcic brown soil
LANDFORM ELEMENT TYPE: hillslope
PRINCIPAL PROFILE FORM: Dr2.12
LANDFORM PATTERN TYPE: undulating rises 9-30m 3-10%
SOIL TAXONOMY UNIT:
FAO UNESCO UNIT:
AUSTRALIAN SOIL CLASSIFICATION: HAPLIC, EUTROPHIC, RED, CHROMOSOL; Medium, Non

Gravelly, Loamy, Clayey, Shallow. (Confidence level 3).

STRUCTURAL FORM: Mid-high woodland
DOMINANT VEGETATION SPECIES: *Eucalyptus melanophloia, Eucalyptus erythrophloia, Bothriochloa ewartiana, Heteropogon contortus, Chrysopogon fallax, Themeda triandra*

PROFILE MORPHOLOGY:
CONDITION OF SURFACE SOIL WHEN DRY: hard setting

HORIZON	DEPTH	DESCRIPTION
-------	-----	-----------
A1	0 to .06 m	Brownish black (10YR2/2); sandy loam; massive. clear to-
A3	.06 to .12 m	Dark reddish brown (5YR3/3); sandy clay loam; massive. clear to-
B1	.12 to .18 m	Dark reddish brown (5YR3/4); sandy light clay; moderate subangular blocky. gradual to-
B21	.18 to .35 m	Reddish brown (2.5YR4/6); light medium clay; strong angular blocky. gradual to-
B22	.35 to .50 m	Dark reddish brown (2.5YR3/6); light clay; strong angular blocky; few faint slickenside. gradual to-
BC	.50 to .65 m	Weathering granite. gradual to-
C	.65	Hard granite

SITE NO: 9 NE corner of TB1 near perimeter road
SOIL TYPE:
SUBSTRATE MATERIAL: granite
CONFIDENCE SUBSTRATE IS PARENT MATERIAL:

A.M.G. REFERENCE: 560 270 mE 7 515 470 mN ZONE 55
SLOPE: 1 %
GREAT SOIL GROUP: Yellow podzolic soil
LANDFORM ELEMENT TYPE: hillcrest
PRINCIPAL PROFILE FORM: Dy2.22
LANDFORM PATTERN TYPE: undulating rises 9-30m 3-10%

SOIL TAXONOMY UNIT:

FAO UNESCO UNIT:
AUSTRALIAN SOIL CLASSIFICATION: HAPLIC, EUTROPHIC, BROWN, Clayey, Moderately deep. (Confidence level 3). CHROMOSOL; Medium, Non Gravelly, Sandy,

STRUCTURAL FORM: Mid-high woodland
DOMINANT VEGETATION SPECIES: *Eucalyptus melanophloia, Eucalyptus erythrophloia, Bursaria incana, Bothriochloa ewartiana, Heteropogon contortus, Enneapogon species, Themeda avenacea*

PROFILE MORPHOLOGY:
CONDITION OF SURFACE SOIL WHEN DRY: hard setting

HORIZON	DEPTH	DESCRIPTION
-------	-----	-----------
A1	0 to .05 m	Brownish black (10YR2/2) moist; loamy sand; massive. clear to-
A2	.05 to .15 m	Dark brown (10YR3/3) moist; coarse sandy loam; massive. clear to-
B21	.15 to .30 m	Yellowish brown (10YR5/6) moist; medium clay; weak subangular blocky parting to massive. gradual to-
B22	.30 to .50 m	Yellowish brown (10YR5/6) moist; few coarse distinct dark mottles; light medium clay; moderate 20-50mm subangular blocky; few distinct slickenside.
B23	.50 to .65 m	Yellowish brown (10YR5/6) moist; few coarse distinct dark mottles; medium clay; strong 10-20mm subangular blocky.
BC	.65 to .70 m	Weathering granite.

SITE NO: 10 NE edge of Stock paddock
SOIL TYPE:
SUBSTRATE MATERIAL: colluvium
CONFIDENCE SUBSTRATE IS PARENT MATERIAL:
A.M.G. REFERENCE: 560 360 mE 7 416 270 mN ZONE 55
SLOPE: 3 %
GREAT SOIL GROUP: Solodized solonetz
LANDFORM ELEMENT TYPE: hillslope
PRINCIPAL PROFILE FORM: Dy3.43
LANDFORM PATTERN TYPE: undulating rises 9-30m 3-10%
SOIL TAXONOMY UNIT:
FAO UNESCO UNIT:
AUSTRALIAN SOIL CLASSIFICATION: EUTROPHIC, MOTTLED-MESONATRIC, GREY, SODOSOL; Medium, Non-Gravelly, Sandy, Clayey, Deep. (Confidence level 3).

STRUCTURAL FORM: Mid-high woodland
DOMINANT VEGETATION SPECIES: *Eucalyptus melanophloia, Eucalyptus papuana, Archidendropsis basaltica, Carissa ovata, Bursaria incana, Bothriochloa ewartiana, Chrysopogon fallax, Aristida species*

PROFILE MORPHOLOGY:
CONDITION OF SURFACE SOIL WHEN DRY: hard setting

HORIZON	DEPTH	DESCRIPTION
-------	-----	-----------
A1	0 to .12 m	Brownish black (10YR3/2) moist; loamy sand; massive. gradual to-
A2e	.12 to .22 m	Dull yellowish brown (10YR4/3) moist, dull yellowish orange (10YR7/2) dry; clayey coarse sand; massive. abrupt to-

B21 .22 to .40 m Greyish yellow-brown (10YR4/2) moist; many medium prominent brown mottles; sandy medium clay; strong 50-100mm columnar. diffuse to-
B22 .40 to .70 m Dull yellowish brown (10YR5/4) moist; many medium prominent grey mottles; medium heavy clay; strong angular blocky parting to moderate lenticular; common coarse manganiferous soft segregations. gradual to-
B23 .70 to .90 m Yellowish brown (10YR5/6) moist; common fine faint dark mottles; light medium clay; moderate subangular blocky; few medium manganiferous soft segregations.

SITE NO: 11 Middle of TM2 between creek lines
SOIL TYPE:
SUBSTRATE MATERIAL: granite

CONFIDENCE SUBSTRATE IS PARENT MATERIAL:

A.M.G. REFERENCE: 559 600 mE 7 414 670 mN ZONE 55
SLOPE: 3 %
GREAT SOIL GROUP: Yellow podzolic soil
LANDFORM ELEMENT TYPE: hillslope
PRINCIPAL PROFILE FORM: Db2.23
LANDFORM PATTERN TYPE: undulating rises 9-30m 3-10%
SOIL TAXONOMY UNIT:
FAO UNESCO UNIT:
AUSTRALIAN SOIL CLASSIFICATION: VERTIC, EUTROPHIC, BROWN, CHROMOSOL; Medium,

Non Gravelly, Sandy, Clayey, Deep. (Confidence level 3).

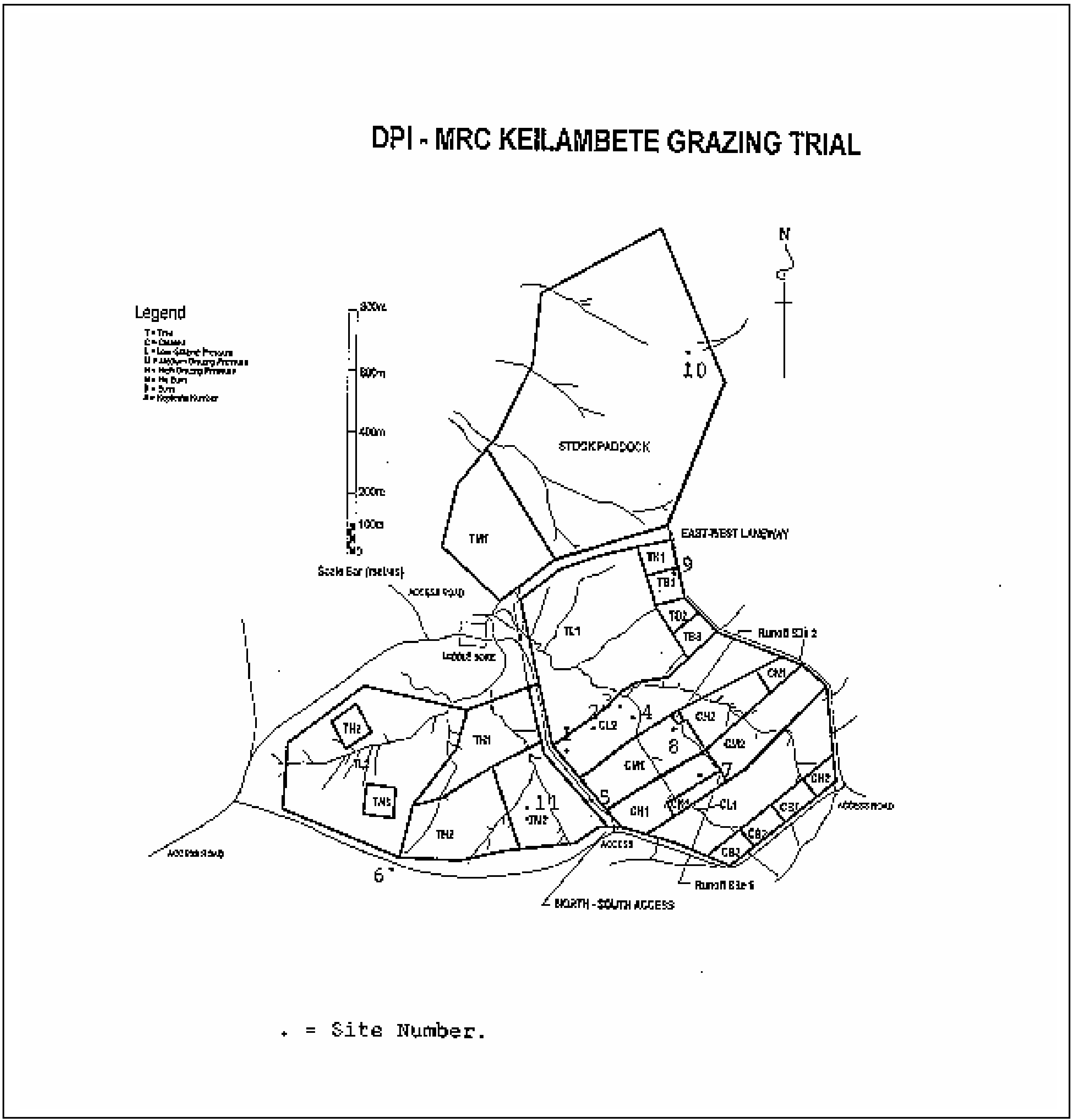
STRUCTURAL FORM: Mid-high woodland
DOMINANT VEGETATION SPECIES: *Eucalyptus melanophloia, Eucalyptus erythrophloia, Bursaria incana, Bothriochloa ewartiana, Heteropogon contortus, Chrysopogon fallax, Enneapogon species*

PROFILE MORPHOLOGY:
CONDITION OF SURFACE SOIL WHEN DRY: hard setting

HORIZON	DEPTH	DESCRIPTION
A1	0 to .07 m	Brownish black (10YR2/2) moist; loamy sand; massive. gradual to-
A2	.07 to .25 m	Dark brown (7.5YR3/4) moist; loamy sand; massive. gradual to-
A3	.25 to .35 m	Dull reddish brown (5YR4/3) moist; coarse sandy clay loam; massive. clear to-
B21	.35 to .50 m	Brown (7.5YR4/4) moist; common medium distinct red mottles, very few medium distinct dark mottles; sandy light clay; moderate 20-50mm subangular blocky parting to moderate 5-10mm lenticular; very few fine manganiferous soft segregations. gradual to-
B22	.50 to .75 m	Dull yellowish brown (10YR5/4) moist; light clay; strong 10-20mm angular blocky parting to moderate 5-10mm lenticular; few distinct slickenside; few medium manganiferous soft segregation gradual to-
B23	.75 to 1.05 m	Greyish yellow-brown (10YR4/2) moist; light clay; very few small pebbles, angular granite; strong 10-20mm lenticular; many prominent slickenside; few coarse manganiferous soft segregations.

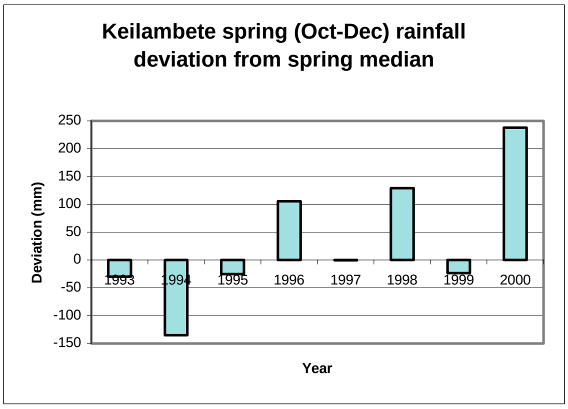
Appendix B4

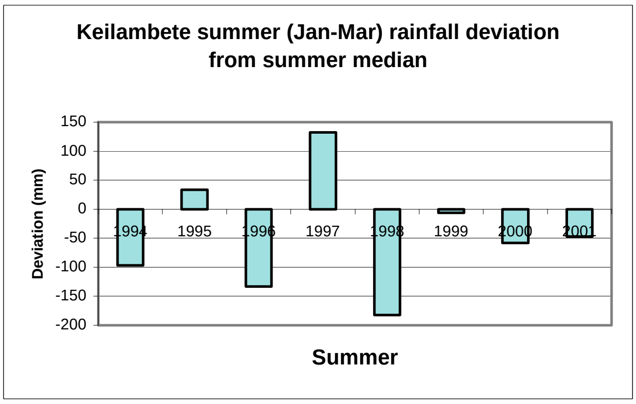
Map showing soil profile sampling sites 1 to 11 at Keilambete in 1995

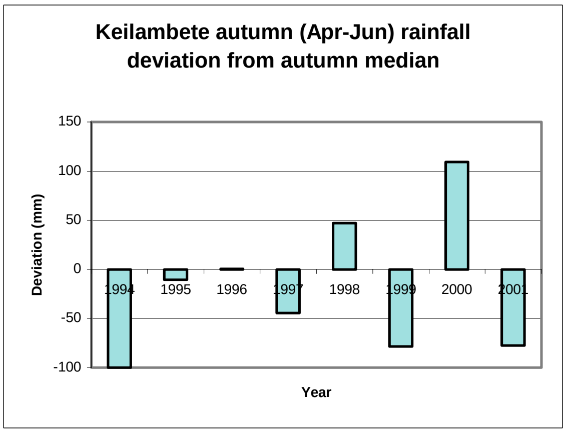


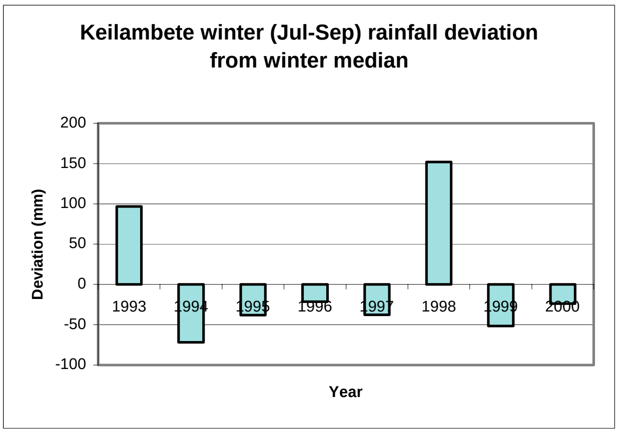
APPENDIX C. Site climate details

Appendix C1



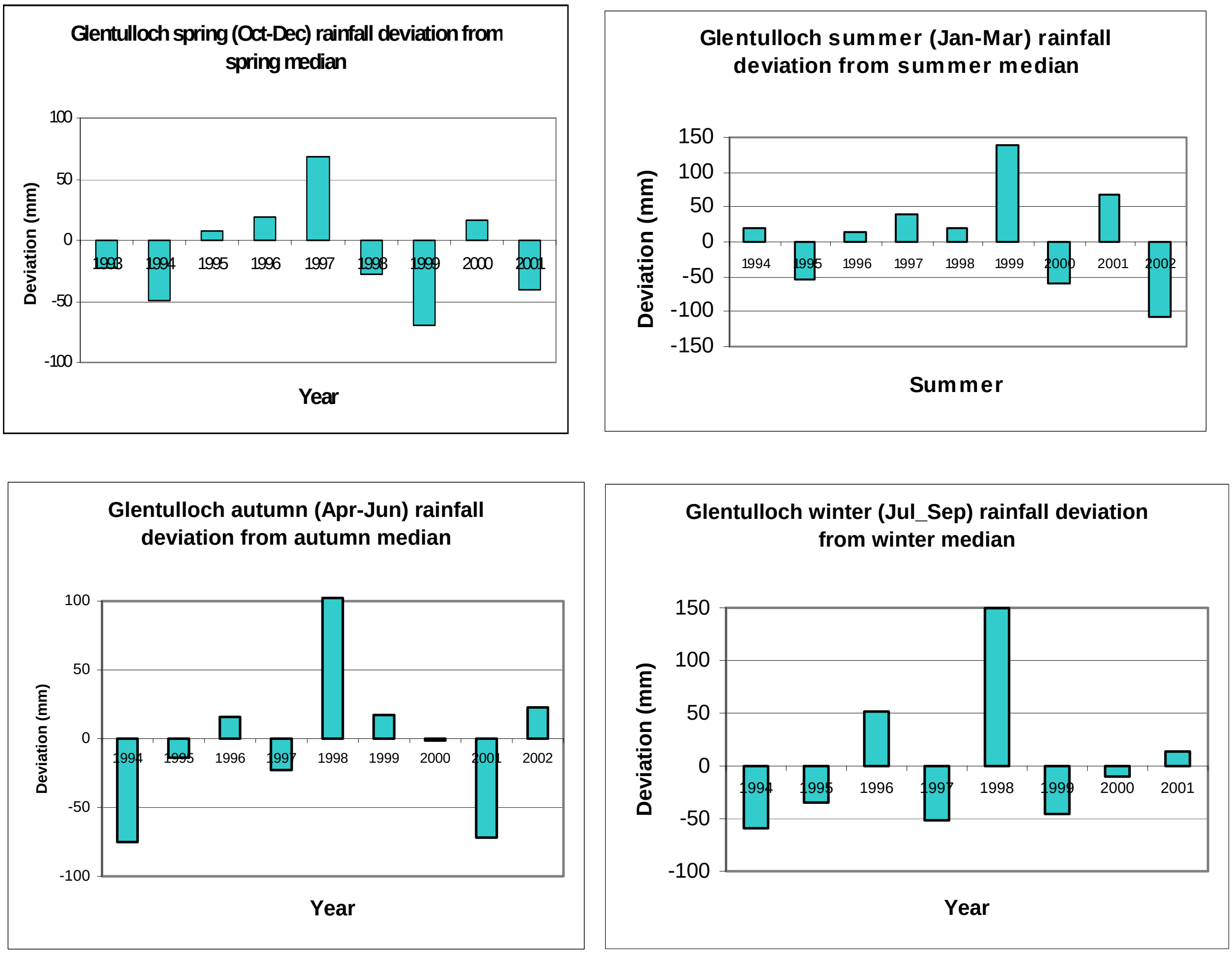






Figures C1 – C4. Summarised seasonal rainfall deviations from decile 5 long term values for Keilambete

Appendix C2



Figures C5 – C8. Summarised seasonal rainfall deviations from decile 5 long term values for Glentulloch

Appendix C3

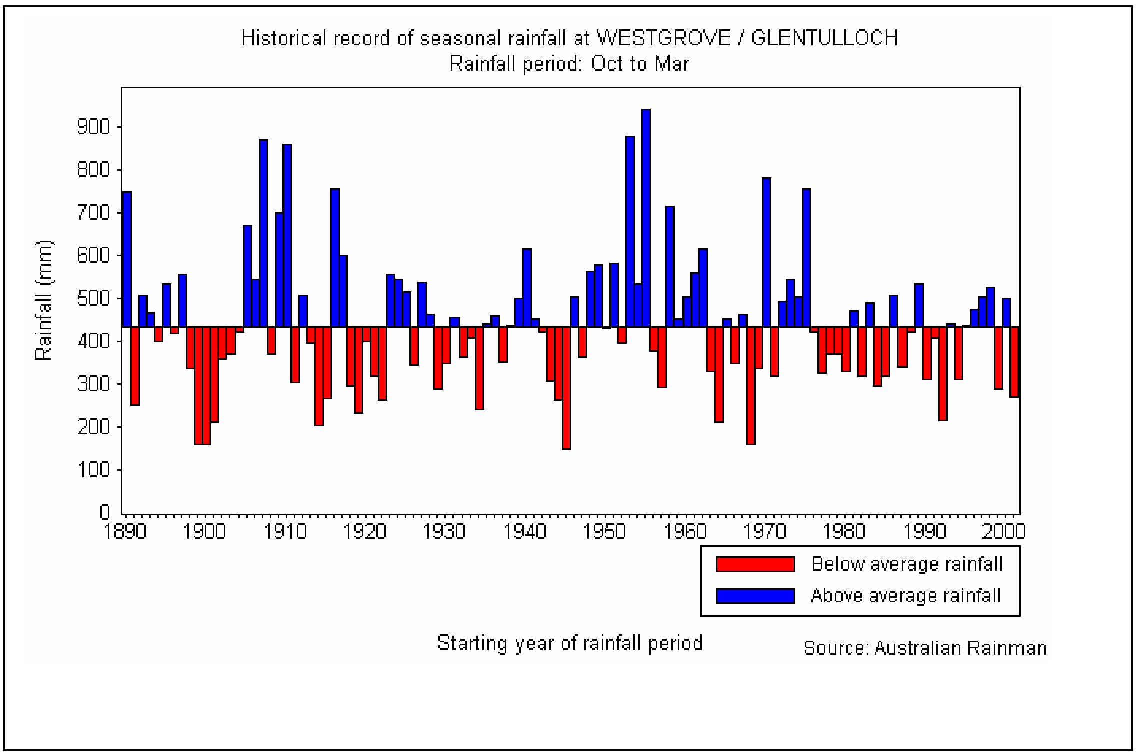


Figure C9. Historical summer rainfall deviation from the mean in the Glentulloch district

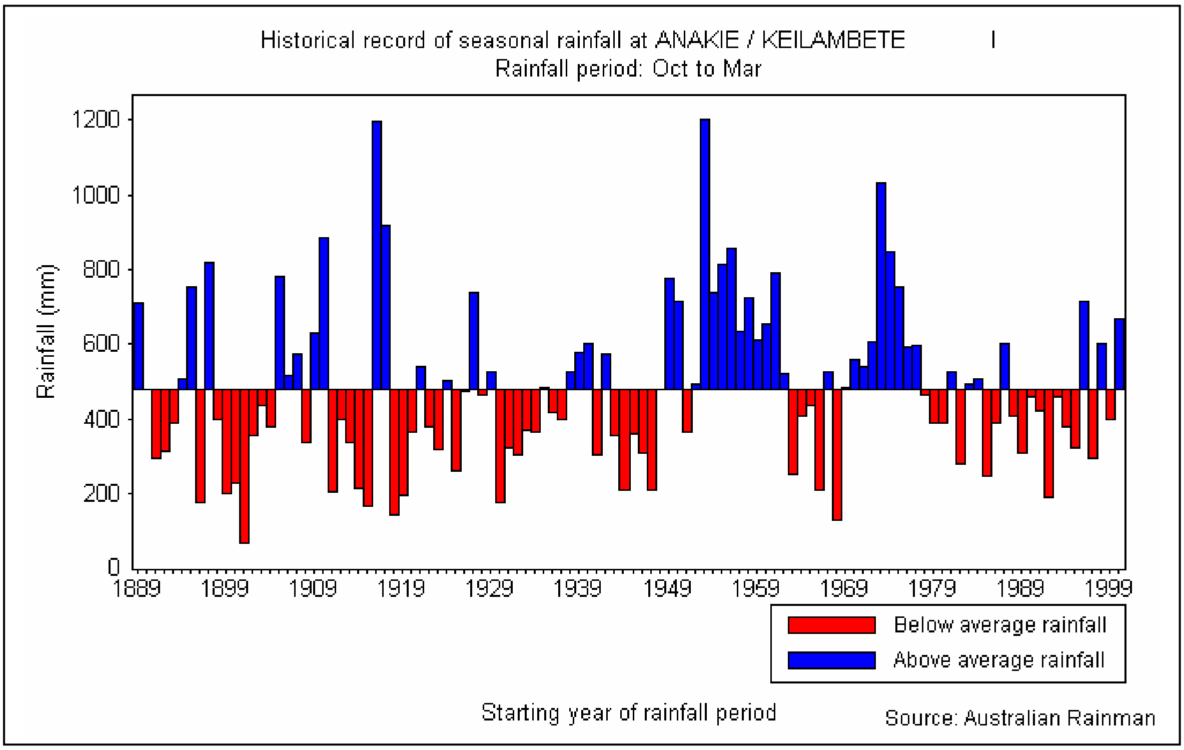


Figure C10. Historical summer rainfall deviation from the mean in the Keilambete district

APPENDIX D. TRAPS details, Ironbark and Poplar box sites

Appendix D1

Table D1(a),(b),(c) and (d). Density (plants/ha) and basal area (m^2/ha) of *E. melanophloia* in height classes for the treed treatments in 1995 and 1997

D1(a) **Density (plants/ha) in 1995**

Height class	Exclosure	Low	Med	High	Average
<0.5	777	1131	872	1047	897
0.5 - 1.5	469	306	244	172	355
1.5 - 4.0	200	175	167	139	180
4.0 - 7.0	107	81	64	56	87
7.0 - 10.0	23	70	50	36	38
10.0 - 15.0	11	25	53	42	25
>15.0	0	0	3	11	2
Total	1589	1786	1453	1502	1583

D1(b) **Density (plants/ha) in 1997**

Height class	Exclosure	Low	Med	High	Average
<0.5	440	861	781	886	641
0.5 - 1.5	561	398	337	264	447
1.5 - 4.0	244	161	128	137	193
4.0 - 7.0	84	75	56	50	72
7.0 - 10.0	27	42	31	14	28
10.0 - 15.0	6	20	42	34	19
>15.0	0	0	0	6	1
Total	1362	1556	1373	1390	1400

D1(c) **Basal area (m^2/ha) in 1995**

Height class	Exclosure	Low	Med	High	Average
<0.5	0.166	0.085	0.083	0.052	0.120
0.5 - 1.5	0.861	0.249	0.214	0.343	0.565
1.5 - 4.0	0.585	0.352	0.360	1.003	0.578
4.0 - 7.0	0.996	0.567	1.102	0.178	0.806
7.0 - 10.0	0.947	1.781	2.500	1.360	1.413
10.0 - 15.0	0.462	1.682	2.970	3.232	1.546
>15.0	0	0	0.459	1.036	0.249
Total	4.017	4.715	7.683	7.202	5.275

D1(d) **Basal area (m^2/ha) in 1997**

Height class	Exclosure	Low	Med	High	Average
<0.5	0.264	0.009	0.028	0.038	0.145
0.5 - 1.5	0.774	0.220	0.292	0.157	0.498
1.5 - 4.0	0.623	0.255	0.194	0.301	0.436
4.0 - 7.0	1.071	2.130	0.778	0.193	1.052
7.0 - 10.0	0.595	0.904	2.317	0.331	0.889
10.0 - 15.0	0.345	1.497	2.151	1.943	1.104
>15.0	0	0	0	0.591	0.099
Total	3.672	5.012	5.758	3.553	4.223

Appendix D2

Table D2(a),(b),(c) and (d). Density (plants/ha) and basal area (m^2/ha) of *B. incana* in height classes for the treed treatments in 1995 and 1997

D2(a) **Density (plants/ha) in 1995**

Height class	Exclosure	Low	Med	High	Average
<0.5	142	142	156	39	127
0.5 - 1.5	29	31	17	14	25
1.5 - 4.0	7	31	0	9	10
4.0 - 7.0	2	0	0	3	2
7.0 - 10.0	17	6	0	9	11
10.0 - 15.0	6	0	0	0	3
>15.0	0	0	0	0	0
Total	203	208	175	73	178

D2(b) **Density (plants/ha) in 1997**

Height class	Exclosure	Low	Med	High	Average
<0.5	115	128	125	28	104
0.5 - 1.5	52	25	47	3	39
1.5 - 4.0	13	33	9	23	17
4.0 - 7.0	9	0	0	3	5
7.0 - 10.0	6	3	0	3	4
10.0 - 15.0	4	3	0	3	3
>15.0	0	0	0	0	0
Total	199	192	181	63	172

D2(c) **Basal area (m^2/ha) in 1995**

Height class	Exclosure	Low	Med	High	Average
<0.5	0.005	0.005	0.003	0.001	0.004
0.5 - 1.5	0.004	0.052	0.002	0.041	0.018
1.5 - 4.0	0.013	0.0485	0	0.021	0.018
4.0 - 7.0	0.011	0	0	0.067	0.017
7.0 - 10.0	0.298	0.111	0	0.139	0.190
10.0 - 15.0	0.094	0	0	0	0.047
>15.0	0	0	0	0	0
Total	0.425	0.216	0.005	0.269	0.294

D2(d) **Basal area (m^2/ha) in 1997**

Height class	Exclosure	Low	Med	High	Average
<0.5	0.007	0.001	0.000	0.001	0.004
0.5 - 1.5	0.006	0.004	0.004	0.000	0.004
1.5 - 4.0	0.013	0.171	0.006	0.038	0.042
4.0 - 7.0	0.154	0.000	0.000	0.067	0.088
7.0 - 10.0	0.138	0.065	0.000	0.037	0.086
10.0 - 15.0	0.108	0.062	0.000	0.070	0.076
>15.0	0.000	0.000	0.000	0.000	0.000
Total	0.426	0.303	0.010	0.212	0.300

Appendix D3

Table D3(a),(b),(c) and (d). Density (plants/ha) and basal area (m^2/ha) of *C. erythrophloia* in height classes for the treed treatments in 1995 and 1997

D3(a) **Density (plants/ha) in 1995**

Height class	Exclosure	Low	Med	High	Average
<0.5	11	23	86	11	25
0.5 - 1.5	19	17	28	9	18
1.5 - 4.0	13	6	12	6	10
4.0 - 7.0	28	9	34	12	23
7.0 - 10.0	9	14	12	6	10
10.0 - 15.0	0	3	9	3	2
>15.0	0	0	0	3	1
Total	78	71	179	49	89

D3(b) **Density (plants/ha) in 1997**

Height class	Exclosure	Low	Med	High	Average
<0.5	4	14	70	11	18
0.5 - 1.5	15	9	25	9	14
1.5 - 4.0	15	3	12	9	11
4.0 - 7.0	27	14	31	9	23
7.0 - 10.0	9	14	12	14	11
10.0 - 15.0	2	3	9	0	3
>15.0	0	3	3	0	1
Total	72	60	160	51	81

D3(c) **Basal area (m^2/ha) in 1995**

Height class	Exclosure	Low	Med	High	Average
<0.5	0.008	0.263	0.001	0.000	0.048
0.5 - 1.5	0.004	0.004	0.002	0.001	0.003
1.5 - 4.0	0.016	0.030	0.021	0.017	0.019
4.0 - 7.0	0.183	0.039	0.276	0.156	0.170
7.0 - 10.0	0.227	0.303	0.176	0.295	0.243
10.0 - 15.0	0.000	0.253	0.536	0.077	0.144
>15.0	0.000	0.000	0.000	0.047	0.008
Total	0.438	0.892	1.010	0.592	0.635

D3(d) **Basal area (m^2/ha) in 1997**

Height class	Exclosure	Low	Med	High	Average
<0.5	0.000	0.000	0.000	0.001	0.000
0.5 - 1.5	0.002	0.002	0.007	0.001	0.002
1.5 - 4.0	0.025	0.005	0.358	0.014	0.075
4.0 - 7.0	0.182	0.150	0.178	0.100	0.162
7.0 - 10.0	0.121	0.354	0.181	0.537	0.239
10.0 - 15.0	0.126	0.313	0.402	0.000	0.182
>15.0	0.000	0.303	0.244	0.000	0.091
Total	0.455	1.125	1.368	0.651	0.751

Appendix D4

Table D4(a),(b),(c) and (d). Density (plants/ha) and basal area (m^2/ha) of all species in height classes for the treed treatments in 1995 and 1997

D4(a) Density (plants/ha) in 1995

Species	Height class							
	<0.5	0.5-1.5	1.5-4.0	4.0-7.0	7.0-10.0	10.0-15.0	>15.0	Total
ACLON	2.8	2.9	0.9	2.5	0.5	0.5	0.0	10.1
ARBAS	62.1	14.8	2.8	0.0	0.0	0.0	0.0	79.7
BUINC	127.4	24.8	9.8	1.6	10.8	3.2	0.0	177.5
CACAN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CAOVA	3.9	0.5	0.0	0.0	0.0	0.0	0.0	4.4
CASPP	1.4	0.0	0.0	0.0	0.0	0.0	0.0	1.4
EUERY	25.3	18.3	10.2	22.7	9.5	2.4	0.5	88.8
EUMEL	896.8	354.7	180.2	86.6	37.5	25.3	2.3	1583.4
EUPAP	5.1	0.5	0.0	0.0	0.0	0.9	0.0	6.5
JADID	3.7	2.5	0.0	0.0	0.0	0.0	0.0	6.2
JALIN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
JATRI	10.2	0.9	0.0	0.0	0.0	0.0	0.0	11.1
MACUN	4.7	0.5	0.0	0.5	0.0	0.0	0.0	5.7
OPSPP	1.6	0.0	0.0	0.0	0.0	0.0	0.0	1.6
PEPUB	3.3	0.9	1.1	0.5	0.0	0.0	0.0	5.8
ERLON	8.2	0.0	0.0	0.0	0.0	0.0	0.0	8.2
FLDIS	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.5
CAOLE	3.2	0.0	0.0	0.5	0.0	0.0	0.0	3.7
TOTAL	1159.9	421.3	204.9	114.8	58.3	32.3	2.8	1994.4

D4(b) Density (plants/ha) in 1997

Species	Height class							
	<0.5	0.5-1.5	1.5-4.0	4.0-7.0	7.0-10.0	10.0-15.0	>15.0	Total
ACLON	2.8	5.8	0.5	2.2	0.0	0.0	0.0	11.3
ARBAS	64.8	16.7	3.8	0.0	0.0	0.0	0.0	85.3
BUINC	104.2	38.7	17.0	4.8	4.2	3.1	0.0	171.8
CACAN	1.8	0.0	0.0	0.0	0.0	0.0	0.0	1.8
CAOVA	3.4	1.9	0.0	0.0	0.0	0.0	0.0	5.3
CASPP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
EUERY	17.9	14.4	11.2	22.5	10.8	3.0	1.0	80.8
EUMEL	641.3	446.8	192.9	71.9	27.9	18.9	0.9	1400.6
EUPAP	3.8	0.5	0.0	0.0	0.0	0.9	0.0	5.2
JADID	6.2	2.0	0.0	0.0	0.0	0.0	0.0	8.2
JALIN	24.2	0.0	0.0	0.0	0.0	0.0	0.0	24.2
JATRI	7.9	0.5	0.0	0.0	0.0	0.0	0.0	8.4
MACUN	6.5	0.0	0.0	0.0	0.0	0.0	0.0	6.5
OPSPP	1.6	0.0	0.0	0.0	0.0	0.0	0.0	1.6
PEPUB	8.4	1.9	1.1	0.5	0.0	0.0	0.0	11.9
ERLON	8.7	0.0	0.0	0.0	0.0	0.0	0.0	8.7
FLDIS	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.5
CAOLE	3.2	0.0	1.1	0.0	0.0	0.0	0.0	4.3
TOTAL	907.1	529.1	227.5	101.8	42.9	25.9	1.9	1836.3

D4(c) Basal area (m^2/ha) in 1995

Species	Height class <0.5	0.5-1.5	1.5-4.0	4.0-7.0	7.0-10.0	10.0-15.0	>15.0	Total
ACLON	0.000	0.000	0.001	0.024	0.005	0.000	0.000	0.030
ARBAS	0.003	0.004	0.003	0.000	0.000	0.000	0.000	0.010
BUINC	0.004	0.018	0.018	0.017	0.190	0.047	0.000	0.294
CACAN	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CAOVA	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CASPP	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
EUERY	0.048	0.003	0.019	0.170	0.243	0.144	0.008	0.635
EUMEL	0.120	0.565	0.578	0.806	1.413	1.545	0.249	5.275
EUPAP	0.000	0.000	0.000	0.000	0.000	0.039	0.000	0.039
JADID	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
JALIN	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
JATRI	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MACUN	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
OPSPP	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.001
PEPUB	0.000	0.000	0.002	0.005	0.000	0.000	0.000	0.008
ERLON	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
FLDIS	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CAOLE	0.000	0.000	0.000	0.002	0.000	0.000	0.000	0.002
TOTAL	0.177	0.591	0.621	1.023	1.851	1.774	0.257	6.294

D4(d) Basal area (m^2/ha) in 1997

Species	Height class <0.5	0.5-1.5	1.5-4.0	4.0-7.0	7.0-10.0	10.0-15.0	>15.0	Total
ACLON	0.000	0.001	0.000	0.021	0.000	0.000	0.000	0.022
ARBAS	0.000	0.004	0.010	0.000	0.000	0.000	0.000	0.014
BUINC	0.004	0.004	0.042	0.088	0.086	0.076	0.000	0.300
CACAN	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CAOVA	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.001
CASPP	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
EUERY	0.000	0.002	0.075	0.162	0.239	0.182	0.091	0.751
EUMEL	0.145	0.498	0.436	1.052	0.889	1.104	0.099	4.223
EUPAP	0.000	0.000	0.000	0.000	0.000	0.042	0.000	0.042
JADID	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
JALIN	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
JATRI	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MACUN	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
OPSPP	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.001
PEPUB	0.000	0.000	0.004	0.006	0.000	0.000	0.000	0.011
ERLON	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
FLDIS	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CAOLE	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
TOTAL	0.150	0.512	0.567	1.329	1.214	1.403	0.190	5.366

Appendix D5

Table D5(a),(b),(c) and (d). Density (plants/ha) and basal area (m^2/ha) of *E. melanophloia* in height classes for the cleared treatments in 1995 and 1997

D5(a) **Density (plants/ha) in 1995**

Height class	Exclosure	Low	Med	High	Average
<0.5	286	372	303	151	280
0.5 - 1.5	48	14	28	20	34
1.5 - 4.0	2	3	6	14	5
4.0 - 7.0	2	6	14	23	8
7.0 - 10.0	0	0	3	6	1
10.0 - 15.0	0	0	0	6	1
>15.0	0	0	3	0	1
Total	338	395	356	218	330

D5(b) **Density (plants/ha) in 1997**

Height class	Exclosure	Low	Med	High	Average
<0.5	142	145	164	56	132
0.5 - 1.5	80	9	14	9	45
1.5 - 4.0	2	0	3	11	3
4.0 - 7.0	2	3	3	9	4
7.0 - 10.0	0	6	6	11	4
10.0 - 15.0	0	0	0	9	1
>15.0	0	0	0	0	0
Total	226	162	190	103	189

D5(c) **Basal area (m^2/ha) in 1995**

Height class	Exclosure	Low	Med	High	Average
<0.5	0.025	0.007	0.009	0.013	0.017
0.5 - 1.5	0.007	0.004	0.015	0.007	0.008
1.5 - 4.0	0.000	0.002	0.017	0.263	0.050
4.0 - 7.0	0.017	0.036	0.347	0.507	0.157
7.0 - 10.0	0.000	0.000	0.067	0.333	0.067
10.0 - 15.0	0.000	0.000	0.000	0.329	0.055
>15.0	0.000	0.000	0.196	0.000	0.033
Total	0.050	0.048	0.650	1.451	0.383

D5(d) **Basal area (m^2/ha) in 1997**

Height class	Exclosure	Low	Med	High	Average
<0.5	0.010	0.000	0.008	0.004	0.007
0.5 - 1.5	0.018	0.001	0.000	0.002	0.009
1.5 - 4.0	0.001	0.000	0.002	0.264	0.045
4.0 - 7.0	0.018	0.001	0.239	0.060	0.059
7.0 - 10.0	0.000	0.060	0.109	0.295	0.077
10.0 - 15.0	0.000	0.000	0.000	1.303	0.217
>15.0	0.000	0.000	0.000	0.000	0.000
Total	0.046	0.062	0.357	1.926	0.414

Appendix D6

Table D6(a),(b),(c) and (d). Density (plants/ha) and basal area (m^2/ha) of *B. incana* in height classes for the cleared treatments in 1995 and 1997

D6(a) **Density (plants/ha) in 1995**

Height class	Exclosure	Low	Med	High	Average
<0.5	80	64	175	86	94
0.5 - 1.5	34	23	45	48	36
1.5 - 4.0	7	6	6	14	8
4.0 - 7.0	0	6	0	0	1
7.0 - 10.0	2	6	3	0	3
10.0 - 15.0	0	0	0	0	0
>15.0	0	0	0	0	0
Total	122	104	229	148	141

D6(b) **Density (plants/ha) in 1997**

Height class	Exclosure	Low	Med	High	Average
<0.5	40	20	37	34	35
0.5 - 1.5	44	9	53	45	40
1.5 - 4.0	11	12	11	36	15
4.0 - 7.0	0	9	0	0	1
7.0 - 10.0	4	0	0	0	2
10.0 - 15.0	0	0	0	0	0
>15.0	0	0	0	0	0
Total	99	48	101	114	93

D6(c) **Basal area (m^2/ha) in 1995**

Height class	Exclosure	Low	Med	High	Average
<0.5	0.003	0.002	0.006	0.009	0.004
0.5 - 1.5	0.020	0.003	0.018	0.039	0.020
1.5 - 4.0	0.014	0.008	0.009	0.020	0.013
4.0 - 7.0	0.000	0.227	0.000	0.000	0.038
7.0 - 10.0	0.067	0.135	0.053	0.000	0.064
10.0 - 15.0	0.000	0.000	0.000	0.000	0.000
>15.0	0.000	0.000	0.000	0.000	0.000
Total	0.103	0.374	0.086	0.068	0.140

D6(d) **Basal area (m^2/ha) in 1997**

Height class	Exclosure	Low	Med	High	Average
<0.5	0.010	0.000	0.062	0.000	0.015
0.5 - 1.5	0.045	0.001	0.013	0.016	0.027
1.5 - 4.0	0.043	0.023	0.022	0.058	0.039
4.0 - 7.0	0.000	0.000	0.000	0.000	0.038
7.0 - 10.0	0.103	0.000	0.000	0.000	0.052
10.0 - 15.0	0.000	0.000	0.000	0.000	0.000
>15.0	0.000	0.000	0.000	0.000	0.000
Total	0.200	0.254	0.096	0.074	0.171

Appendix D7

Table D7(a),(b),(c) and (d). Density (plants/ha) and basal area (m^2/ha) of *C. erythrophloia* in height classes for the cleared treatments in 1995 and 1997

D7(a) **Density (plants/ha) in 1995**

Height class	Exclosure	Low	Med	High	Average
<0.5	11	9	23	17	13
0.5 - 1.5	6	3	20	9	8
1.5 - 4.0	8	0	0	0	4
4.0 - 7.0	0	0	6	3	1
7.0 - 10.0	0	0	3	0	1
10.0 - 15.0	0	0	3	0	1
>15.0	0	0	0	0	0
Total	25	12	54	28	28

D7(b) **Density (plants/ha) in 1997**

Height class	Exclosure	Low	Med	High	Average
<0.5	11	6	0	0	6
0.5 - 1.5	2	0	0	0	1
1.5 - 4.0	0	0	0	0	0
4.0 - 7.0	0	0	9	3	2
7.0 - 10.0	0	0	6	0	1
10.0 - 15.0	0	0	3	0	1
>15.0	0	0	0	0	0
Total	13	6	17	3	11

D7(c) **Basal area (m^2/ha) in 1995**

Height class	Exclosure	Low	Med	High	Average
<0.5	0.000	0.000	0.000	0.003	0.001
0.5 - 1.5	0.001	0.001	0.002	0.019	0.004
1.5 - 4.0	0.261	0.000	0.000	0.000	0.130
4.0 - 7.0	0.000	0.000	0.066	0.083	0.025
7.0 - 10.0	0.000	0.000	0.075	0.000	0.012
10.0 - 15.0	0.000	0.000	0.391	0.000	0.065
>15.0	0.000	0.000	0.000	0.000	0.000
Total	0.261	0.001	0.533	0.104	0.237

D7(d) **Basal area (m^2/ha) in 1997**

Height class	Exclosure	Low	Med	High	Average
<0.5	0.001	0.000	0.000	0.000	0.000
0.5 - 1.5	0.000	0.000	0.000	0.000	0.000
1.5 - 4.0	0.000	0.000	0.000	0.000	0.000
4.0 - 7.0	0.000	0.000	0.158	0.105	0.044
7.0 - 10.0	0.000	0.000	0.125	0.000	0.021
10.0 - 15.0	0.000	0.000	0.397	0.000	0.066
>15.0	0.000	0.000	0.000	0.000	0.000
Total	0.001	0.000	0.680	0.105	0.131

Appendix D8

Table D8(a),(b),(c) and (d). Density (plants/ha) and basal area (m^2/ha) of all species in height classes for the cleared treatments in 1995 and 1997

D8(a) Density (plants/ha) in 1995

	Height class							
Species	<0.5	0.5-1.5	1.5-4.0	4.0-7.0	7.0-10.0	10.0-15.0	>15.0	Total
ACLON	3.1	0.5	0.0	0.5	0.0	0.0	0.0	4.1
ARBAS	11.8	0.0	0.0	0.0	0.0	0.0	0.0	11.8
BUINC	93.9	35.9	7.5	1.0	2.5	0.0	0.0	140.8
CACAN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CAOVA	3.3	6.5	0.0	0.0	0.0	0.0	0.0	9.8
CASPP	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.9
EUERY	13.2	8.3	4.2	1.4	0.5	0.5	0.0	28.1
EUMEL	280.4	34.3	4.8	8.1	1.4	0.9	0.5	330.4
EUPAP	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.5
JADID	37.8	4.2	0.0	0.0	0.0	0.0	0.0	41.9
JALIN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
JATRI	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MACUN	41.3	0.5	0.0	0.0	0.0	0.0	0.0	41.8
OPSPP	1.9	0.5	0.0	0.0	0.0	0.0	0.0	2.4
PEPUB	2.2	1.6	0.5	0.0	0.0	0.0	0.0	4.3
ERLON	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.5
FLDIS	2.7	0.0	0.0	0.0	0.0	0.0	0.0	2.7
CAOLE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL	492.8	92.3	17.0	11.0	4.9	1.4	0.5	619.9

D8(b) Density (plants/ha) in 1997

	Height class							
Species	<0.5	0.5-1.5	1.5-4.0	4.0-7.0	7.0-10.0	10.0-15.0	>15.0	Total
ACLON	1.8	1.0	3.2	0.5	0.0	0.0	0.0	6.5
ARBAS	1.1	0.5	0.0	0.0	0.0	0.0	0.0	1.6
BUINC	34.8	39.7	15.1	1.4	2.1	0.0	0.0	93.0
CACAN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CAOVA	1.5	4.7	0.0	0.0	0.0	0.0	0.0	6.2
CASPP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
EUERY	6.3	1.1	0.0	1.9	0.9	0.5	0.0	10.7
EUMEL	131.6	44.9	3.4	3.5	3.7	1.4	0.0	188.5
EUPAP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
JADID	12.0	7.8	0.0	0.0	0.0	0.0	0.0	19.8
JALIN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
JATRI	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MACUN	5.3	0.0	0.0	0.0	0.0	0.0	0.0	5.3
OPSPP	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.5
PEPUB	10.0	3.1	0.0	0.5	0.0	0.0	0.0	13.6
ERLON	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FLDIS	2.1	0.0	0.0	0.0	0.0	0.0	0.0	2.1
CAOLE	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.5
TOTAL	206.8	103.2	21.7	7.8	6.7	1.9	0.0	348.1

D8(c) Basal area (m^2/ha) in 1995

Species	<0.5	0.5-1.5	1.5-4.0	4.0-7.0	7.0-10.0	10.0-15.0	>15.0	Total
	Height class							
ACLON	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.001
ARBAS	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.001
BUINC	0.004	0.020	0.013	0.038	0.064	0.000	0.000	0.139
CACAN	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CAOVA	0.000	0.002	0.000	0.000	0.000	0.000	0.000	0.002
CASPP	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
EUERY	0.001	0.004	0.130	0.025	0.012	0.065	0.000	0.237
EUMEL	0.017	0.008	0.047	0.157	0.067	0.055	0.033	0.383
EUPAP	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
JADID	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001
JALIN	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
JATRI	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MACUN	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.001
OPSPP	0.001	0.002	0.000	0.000	0.000	0.000	0.000	0.003
PEPUB	0.000	0.000	0.004	0.000	0.000	0.000	0.000	0.004
ERLON	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
FLDIS	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CAOLE	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
TOTAL	0.025	0.036	0.194	0.221	0.144	0.120	0.033	0.772

D8(d) Basal area (m^2/ha) in 1997

Species	<0.5	0.5-1.5	1.5-4.0	4.0-7.0	7.0-10.0	10.0-15.0	>15.0	Total
	Height class							
ACLON	0.000	0.000	0.001	0.002	0.000	0.000	0.000	0.003
ARBAS	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
BUINC	0.015	0.027	0.039	0.038	0.052	0.000	0.000	0.171
CACAN	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CAOVA	0.000	0.002	0.000	0.000	0.000	0.000	0.000	0.002
CASPP	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
EUERY	0.000	0.000	0.000	0.044	0.021	0.066	0.000	0.131
EUMEL	0.007	0.009	0.045	0.059	0.077	0.217	0.000	0.414
EUPAP	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
JADID	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
JALIN	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
JATRI	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MACUN	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
OPSPP	0.000	0.002	0.000	0.000	0.000	0.000	0.000	0.002
PEPUB	0.000	0.000	0.000	0.008	0.000	0.000	0.000	0.008
ERLON	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
FLDIS	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CAOLE	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
TOTAL	0.022	0.040	0.084	0.151	0.150	0.283	0.000	0.731

Appendix D9

Table D9. TRAPS Glentulloch Grazing trial poplar box tree and prickly pear count change between 1995 and 2002.

		Taxa				Taxa								
		1995	**1995**	**1995**	**1995**	**2002**	**2002**	**2002**	**2002**		**Change '02 – '95**	**Change '02 – '95**	**Change '02 – '95**	**Change '02 – '95**
Pdk	Trtmnt	Pop Box	P'Box dead/gone	Pear total	Total woodies	Pop Box alive	P'Box dead/gone	Pear total	Total woodies	**Pdk**	Pop Box alive	P'Box dead/gone	Pear total	Total woodies
1	CL1	1	4	2	115	3	4	7	209	CL1	2	0	5	94
2	CM1	13	10	0	57	9	19	10	83	CM1	-4	9	10	26
3	CH1	1	3	0	17	0	2	4	26	CH1	-1	-1	4	9
4	TL1	30	2	0	84	31	3	3	135	TL1	1	1	3	51
5	TM1	74	9	1	88	87	9	11	112	TM1	13	0	10	24
6	TH1	20	4	0	154	20	6	18	240	TH1	0	2	18	86
7	CL2	4	21	3	29	2	25	12	40	CL2	-2	4	9	11
8	CM2	9	14	1	28	9	21	4	43	CM2	0	7	3	15
9	CH2	0	5	0	59	0	5	4	90	CH2	0	0	4	31
10	TL2	32	6	3	73	30	8	16	90	TL2	-2	2	13	17
11	TM2	26	7	1	51	28	7	13	76	TM2	2	0	12	25
12	TH2	43	6	1	60	49	10	12	87	TH2	6	4	11	27
Treat	CL	2.5	12.5	2.5	72.0	2.5	14.5	9.5	124.5	CL	0.0	2.0	7.0	52.5
	CM	11.0	12.0	0.5	42.5	9.0	20.0	7.0	63.0	CM	-2.0	8.0	6.5	20.5
	CH	0.5	4.0	0.0	38.0	0.0	3.5	4.0	58.0	CH	-0.5	-0.5	4.0	20.0
	TL	31.0	4.0	1.5	78.5	30.5	5.5	9.5	112.5	TL	-0.5	1.5	8.0	34.0
	TM	50.0	8.0	1.0	69.5	57.5	8.0	12.0	94.0	TM	7.5	0.0	11.0	24.5
	TH	31.5	5.0	0.5	107.0	34.5	8.0	15.0	163.5	TH	3.0	3.0	14.5	56.5
	Treeless	4.7	9.5	1.0	50.8	3.8	12.7	6.8	81.8	Treeless	-0.8	3.2	5.8	31.0
	Treed	37.5	5.7	1.0	85.0	40.8	7.2	12.2	123.3	Treed	3.3	1.5	11.2	38.3
	Low	16.8	8.3	2.0	75.3	16.5	10.0	9.5	118.5	Low	-0.3	1.8	7.5	43.3
	Medium	30.5	10.0	0.8	56.0	33.3	14.0	9.5	78.5	Medium	2.8	4.0	8.8	22.5
	High	16.0	4.5	0.3	72.5	17.3	5.8	9.5	110.8	High	1.3	1.3	9.3	38.3
	Site mean	21.1	7.6	1.0	67.9	22.3	9.9	9.5	102.6	Site mean	1.3	2.3	8.5	34.7
	Site total	253	91	12	815	268	119	114	1231	Site total	15	28	102	416

Appendix D10

Table D10. TRAPS Glentulloch Burning trial poplar box tree and prickly pear count change between 1995 and 2002.

	Taxa				Taxa					Change	Change	Change	Change
	1995	**1995**	**1995**	**1995**	**2002**	**2002**	**2002**	**2002**		**2002 - 1995**	**2002 - 1995**	**2002 - 1995**	**2002 - 1995**
Pdk	Pop Box alive	P'Box dead/gone	Pear total	Total woodies	Pop Box alive	P'Box dead/gone	Pear total	Total woodies	**Pdk**	Pop Box alive	P'Box dead/gone	Pear total	Total woodies
CB1	3	28	0	32	5	28	1	35	CB1	2	0	1	3
CB1	0	11	0	11	0	11	1	12	CB1	0	0	1	1
CB3	0	18	0	19	3	18	0	22	CB3	3	0	0	3
CN1	1	16	0	18	1	17	2	21	CN1	0	1	2	3
CN2	0	16	0	19	0	16	2	28	CN2	0	0	2	9
CN3	5	20	0	28	6	20	6	61	CN3	1	0	6	33
TB1	23	3	0	28	22	4	1	29	TB1	-1	1	1	1
TB2	15	2	0	17	15	3	0	22	TB2	0	1	0	5
TB3	27	0	0	29	27	0	2	33	TB3	0	0	2	4
TN1	35	4	0	47	33	6	6	57	TN1	-2	2	6	10
TN2	36	8	0	47	36	8	11	61	TN2	0	0	11	14
TN3	12	7	0	21	11	8	6	27	TN3	-1	1	6	6
CB	1.0	19.0	0.0	20.7	2.7	19.0	0.7	23.0	CB	1.7	0.0	0.7	2.3
CN	2.0	17.3	0.0	21.7	2.3	17.7	3.3	36.7	CN	0.3	0.3	3.3	15.0
TB	21.7	1.7	0.0	24.7	21.3	2.3	1.0	28.0	TB	-0.3	0.7	1.0	3.3
TN	27.7	6.3	0.0	38.3	26.7	7.3	7.7	48.3	TN	-1.0	1.0	7.7	10.0
Treeless	1.5	18.2	0.0	21.2	2.5	18.3	2.0	29.8	Treeless	1.0	0.2	2.0	8.7
Treed	24.7	4.0	0.0	31.5	24.0	4.8	4.3	38.2	Treed	-0.7	0.8	4.3	6.7
Burnt	11.3	10.3	0.0	22.7	12.0	10.7	0.8	25.5	Burnt	0.7	0.3	0.8	2.8
Unburnt	14.8	11.8	0.0	30.0	14.5	12.5	5.5	42.5	Unburnt	-0.3	0.7	5.5	12.5
SITE	13.1	11.1	0.0	26.3	13.3	11.6	3.2	34.0	SITE	0.2	0.5	3.2	7.7

Appendix D11

Table D11. Glentulloch TRAPS data – (Grazing trial) summarized for the 3 smallest classes for 2 paddocks (1995 - 1997)

	Mar–'95			Sep-'96			Sep–'97		
Hgt class	**0 - 0.5**	**0.5 – 1m**	**1 - 3**	**0 - 0.5**	**0.5 – 1m**	**1 - 3**	**0 - 0.5**	**0.5 – 1m**	**1 - 3**
					Pdk 3CH				
Species									
ACPEN	2	4		2	5		4	4	
ERMIT	5			6			5		
EUMEL	2			2	1		3		
EUPOP	2	1		2					
Total	11	5		12	6		12	4	
					Pdk 4TL				
Species									
ACFAR	1	4	3	1	6	1	1	3	4
ACPEN		1			1				1
ALCON	16	3	4	10	6	5	15	5	3
ALLUE	1			1			2		
ATHEM	13			14			26		
BRPOP		1			1			1	
ERMIT			1			1			1
EUPOP	7	4	4	5	9	3	8	4	4
EUSPP		1					1		
GRSTR	2			1	1		2	1	
Total	40	14	12	32	24	10	55	14	13

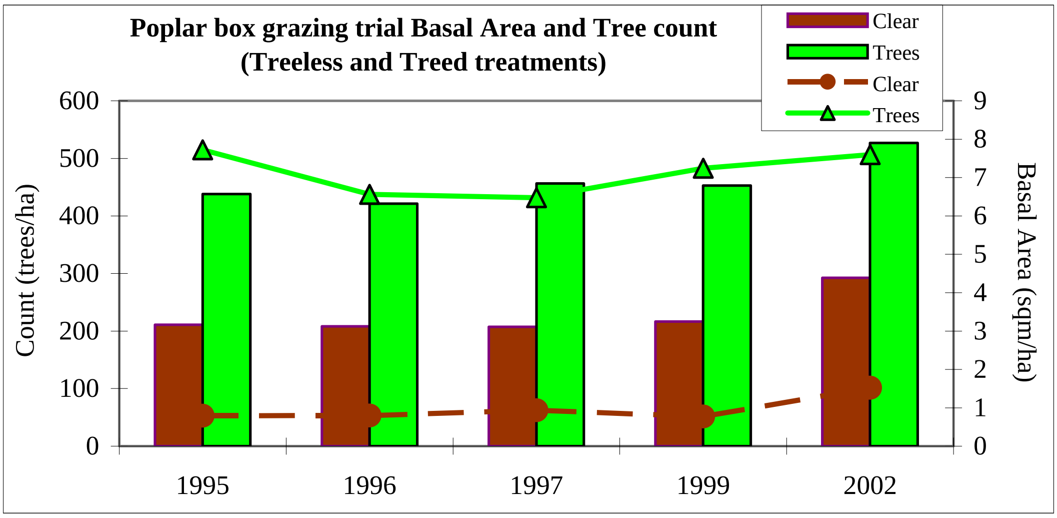
Table D12. Example of Glentulloch TRAPS meta data for Pdk 4 TL (1995-1997)

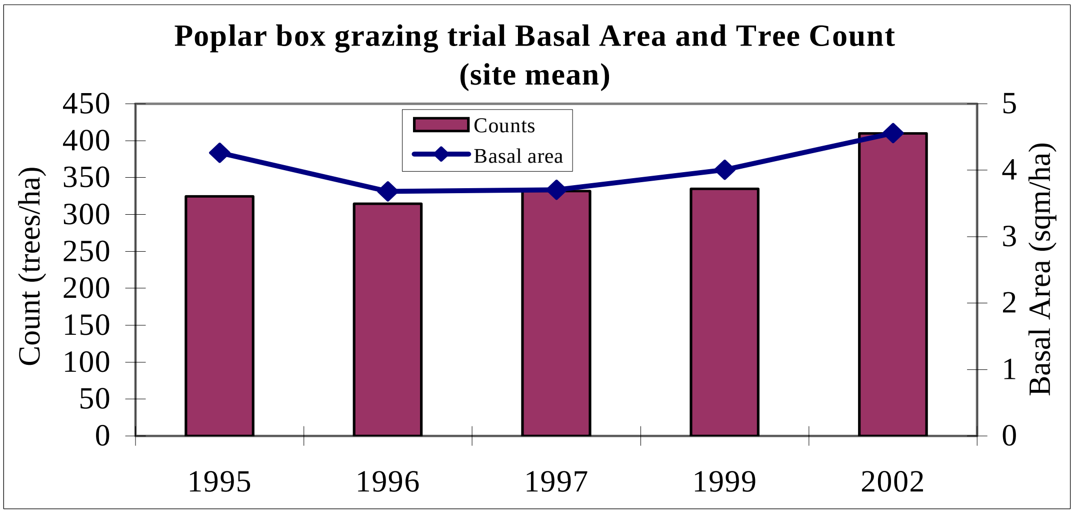
4TL1.TRD : COUNTS (no.) in 7 height classes

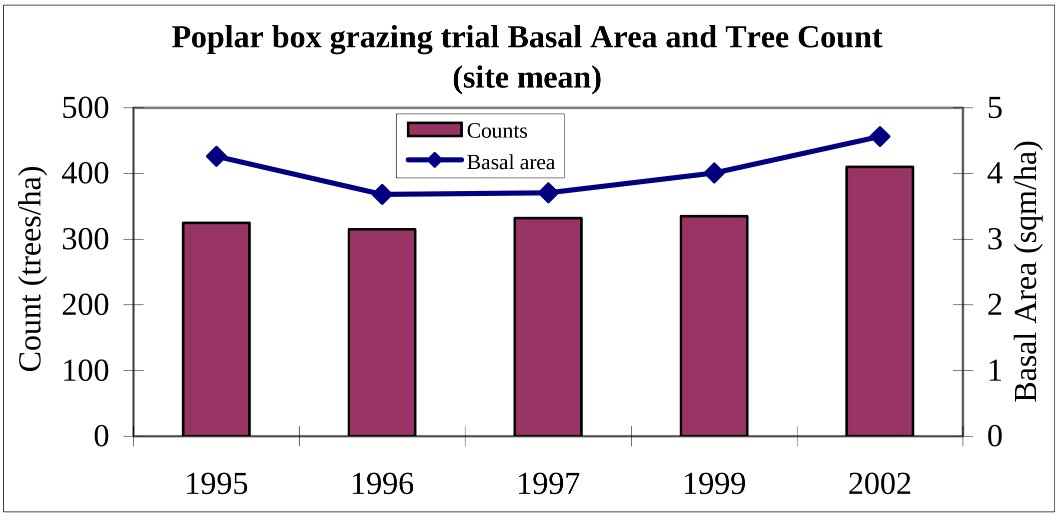
4/03/1995			**Height Class (m)**					
Species	**0 - 0.5**	**0.5 - 1**	**1 - 3**	**3 - 5**	**5 - 10**	**10 - 15**	**15 - 20**	**Total**
ACFAR	1	4	3					8
ACPEN		1						1
ALCON	16	3	4					23
ALLUE	1				1			2
ATHEM	13			1				14
BRPOP		1						1
ERMIT			1					1
EUPOP	7	4	4	1	10	3		29
EUSPP		1		1	1			3
GRSTR	2							2
Summary	40	14	12	3	12	3		84
4/09/1996								
Species	**0 - 0.5**	**0.5 - 1**	**1 - 3**	**3 - 5**	**5 - 10**	**10 - 15**	**15 - 20**	**Total**
ACFAR	1	6	1					8
ACPEN		1						1
ALCON	10	6	5					21
ALLUE	1				1			2
ATHEM	14			1				15
BRPOP		1						1
ERMIT			1					1
EUPOP	5	9	3	1	10	3		31
EUSPP				1	1			2
GRSTR	1	1						2
Summary	32	24	10	3	12	3		84
11/09/1997								
Species	**0 - 0.5**	**0.5 - 1**	**1 - 3**	**3 - 5**	**5 - 10**	**10 - 15**	**15 - 20**	**Total**
ACFAR	1	3	4					8
ACPEN			1					1
ALCON	15	5	3					23
ALLUE	2				1			3
ATHEM	26			1				27
BRPOP		1						1
ERMIT			1					1
EUPOP	8	4	4	2	10	3		31
EUSPP	1			1	1			3
GRSTR	2	1						3
Summary	55	14	13	4	12	3		101

Appendix D12

Figures D1 – D3. Poplar box grazing trial woody plant (TRAPS) data 1995 – 2002.

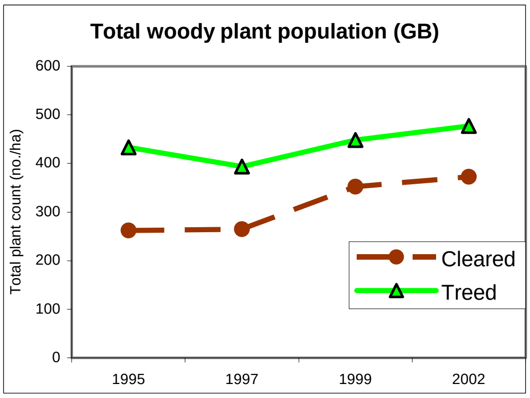


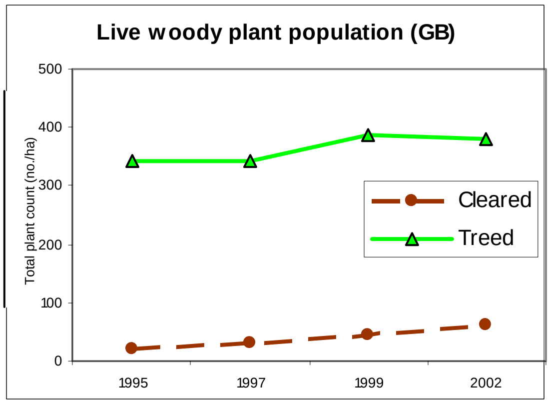


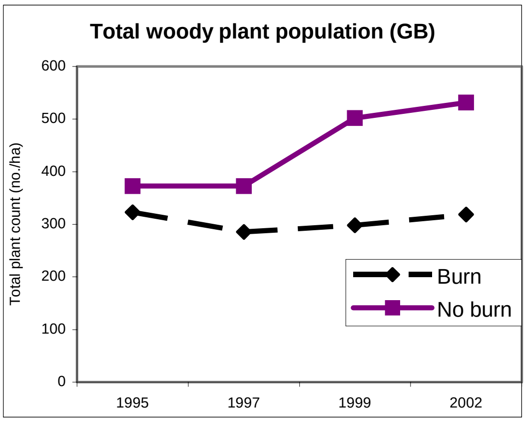


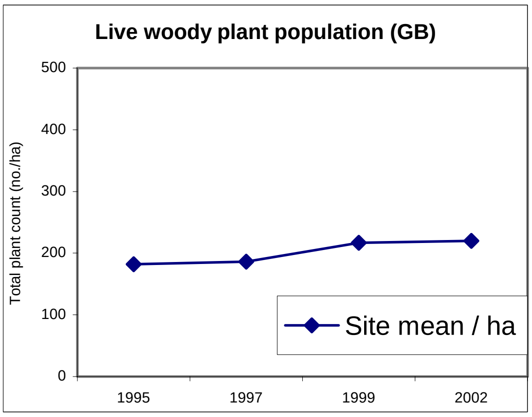
Appendix D13

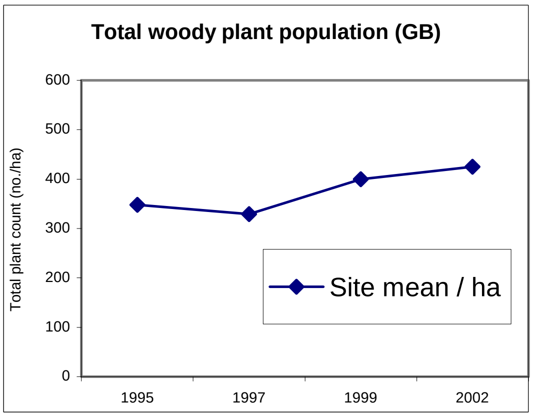
Figures D4 – D9. Poplar box burning trial woody plant count changes (TRAPS data) (1995 – 2002), with and without tree overstorey.

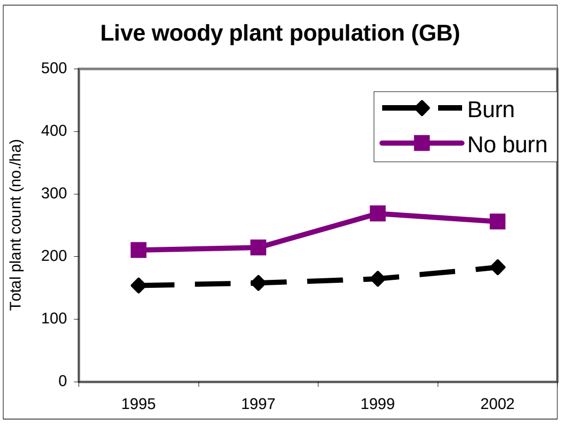




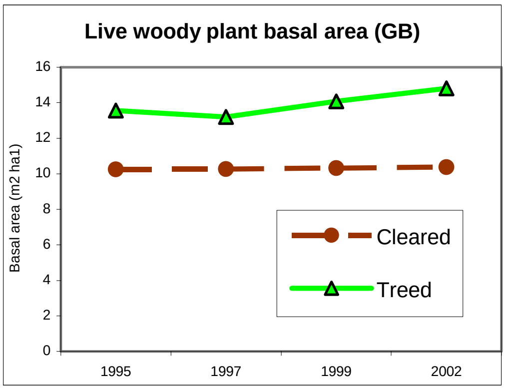


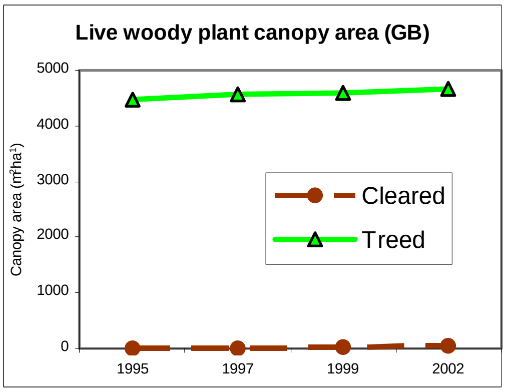


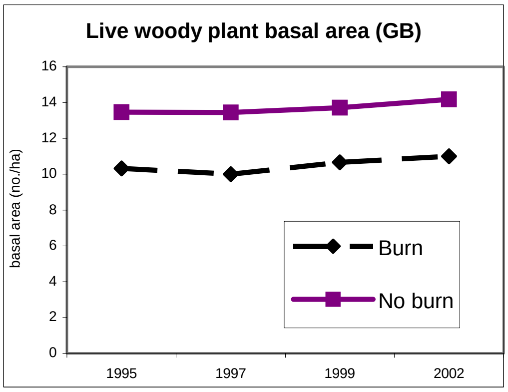


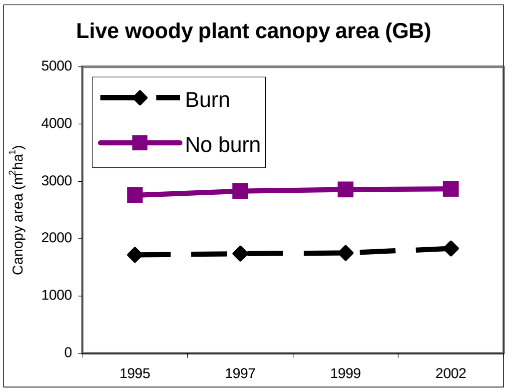


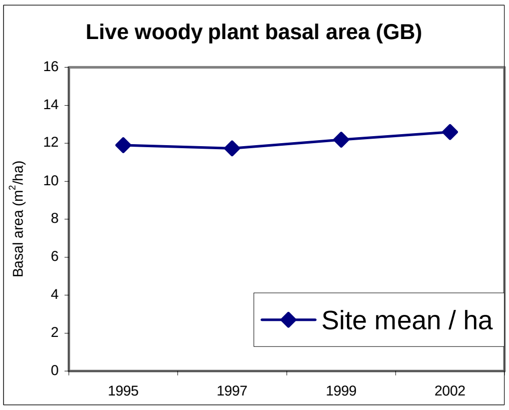
Figures D10 – D15. Tree basal area changes of ungrazed poplar box woodlands at Glentulloch between 1995 and 2002.

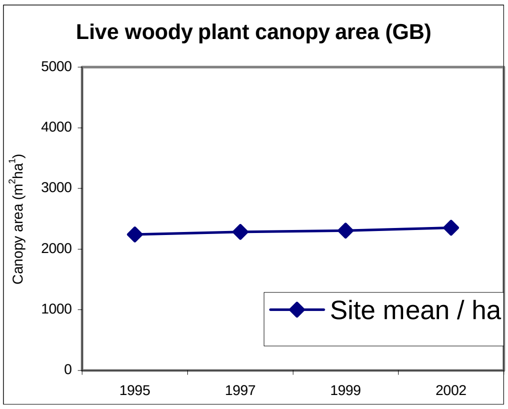












APPENDIX E. Species lists and functional groups, Ironbark and Poplar box sites

Appendix E1

Table E1. Pasture and woody species list, Keilambete

Scientific Name	Common name
GRASSES	
Aristida calycina var. praealta	branched wiregrass
Aristida calycina var. calycina	dark wiregrass
Aristida gracilipes	fine wiregrass
Aristida holathera var. holathera	erect kerosene grass
Aristida ingrata	
Aristida latifolia	feathertop wiregrass
Aristida lazarides	white speargrass
Aristida leptopoda	whitespear
Aristida schultzii	
Bothriochloa bladhii	forest bluegrass
Bothriochloa ewartiana	desert bluegrass
Bothriochloa pertusa	Indian bluegrass
Brachiaria whiteana	
Capillipedium parviflorum	scentedtop
Cenchrus ciliaris	Buffel grass
Chloris divaricata	slender chloris
Chloris inflata	purple-topped chloris
Chloris pectinata	comb windmill grass
Chloris truncata	windmill grass
Chloris virgata	feathertop rhodes grass
Chrysopogon fallax	golden beard grass
Cymbopogon bombycinus	silky oilheads
Cymbopogon refractus	barbwire grass
Dactyloctenium aegyptium	long arm button grass
Dactyloctenium radulans	button grass
Dichanthium sericeum	Qld bluegrass
Dichanthium tenue	small bluegrass
Digitaria ammophila	silky umbrella grass
Digitaria brownii	cotton panic grass
Digitaria ciliaris	summer grass
Digitaria didactyla	Qld blue couch
Digitaria longiflora	
Digitaria parviflora	small-flowered finger grass
Echinochloa colona	awnless barnyard grass
Eleusine indica	crowsfoot grass
Enneapogon clelandii	
Enneapogon gracilis	slender nineawn

Table E1. Pasture and woody species list, Keilambete (contd.)

GRASSES (contd.)	
Enneapogon polyphyllus	leafy nineawn
Enneapogon truncatus	nine awn bottlewasher
Enneapogon virens	
Eragrostis brownii	Brown's lovegrass
Eragrostis cilianensis	stinkgrass
Eragrostis elongata	clustered lovegrass
Eragrostis lacunaria	purple lovegrass
Eragrostis leptocarpa	
Eragrostis molybdea	granite lovegrass
Eragrostis parviflora	weeping lovegrass
Eragrostis sororia	woodland lovegrass
Eragrostis sterilis	
Eragrostis tenuifolia	elastic grass
Eremochloa bimaculata	poverty grass
Eriachne mucronata	wanderrie grass or rock grass
Eriochloa procera	spring grass
Eriochloa pseudoacrotricha	early spring grass
Eulalia aurea	silky browntop
Heteropogon contortus	black speargrass
Iseilema vaginiflorum	red Flinders grass
Leptochloa decipiens	slender canegrass
Melinis repens	red Natal grass
Oxychloris scariosa	winged chloris
Panicum decompositum	native millet
Panicum effusum	hairy panic
Paspalidium caespitosum	brigalow grass
Paspalidium constrictum	knottybutt grass
Paspalidium jubiflorum	Warrego grass
Perotis rara	comet grass
Sehima nervosum	rats tail grass
Sporobolus actinocladus	katoora or ray grass
Sporobolus australasicus	Australian dropseed
Sporobolus caroli	fairy grass
Sporobolus elongatus var. creber	slender rat's tail
Themeda avenacea	native oatgrass
Themeda triandra	kangaroo grass
Tragus australianus	small burr grass
Tripogon loliiformis	five minute grass
Triraphis mollis	purple plumegrass

Table E1. Pasture and woody species list, Keilambete (contd.)

FORBS	
Abutilon oxycarpum	flannel
Achyranthes aspera	chaff flower
Alternanthera denticulata	lesser joyweed
Alternanthera micrantha	
Alternanthera nana	hairy joyweed
Amaranthus viridis	green amaranthus
Bidens bipinnata	beggars-ticks
Boerhavia paludosa	tarvine
Brunoniella australis	blue trumpet
Calotis lappulacea	yellow daisy burr
Calotis squamigera	
Camptacra barbata	
Chamaecrista mimosoides	
Chenopodium carinatum	
Cheilanthes distans	fern
Cheilanthes sieberi	mulga fern
Chrysocephalum apiculatum	yellow buttons
Conyza albida	tall fleabane
Dianella spp	blue flax lily
Einadia polygonoides	knotted goosefoot
Epaltes australis	
Euphorbia prostrata	red creeping spurge
Euphorbia tannensis	desert spurge
Euphorbia wheeleri	
Evolvulus alsinoides	speedwell
Gomphrena celosioides	gomphrena weed
Goodenia glabra	fanflower
Grewia retusifolia	dognuts
Heliotropium strigosum	
Hibiscus sturtii	hill hibiscus
Hybanthus enneaspermum	spade flower
Hypoxis geometrica	nut lily
Malvastrum americanum	spiked malvastrum
Malvastrum coromandelianum	prickly malvastrum
Melhania oblongifolia	velvet hibiscus
Oxalis coniculata	creeping oxalis
Phyllanthus maderaspatensis	spurge
Polycarpaea corymbosa	hairy pretty poly
Polygala linariifolia	milkwort

Table E1. Pasture and woody species list, Keilambete (contd.)

FORBS (contd.)	
Portulaca filifolia	
Portulaca oleracea	pigweed
Psoralea australasica	tall verbine
Rostellularia adscendens	pink tongues
Salsola kali	soft roly poly
Sclerolaena bicornis	goat head burr
Sclerolaena birchii	galvanized burr
Sclerolaena muricata var. villosa	black roly poly
Senna occidentalis	coffee senna
Sida atherophora	
Sida fibulifera	pin sida
Sida pleiantha	
Sida spinosa	spiny sida
Sida subspicata	spiked sida
Sida trichopoda	high sida
Solanum americanum	glossy nightshade
Solanum ellipticum	potato weed
Solanum nigram	blackberry nightshade
Spermacoce spp	
Tribulus terrestris	caltrop
Vernonia cineria	vernonia
Vittadinia pustulata	fuzzweed
Wedelia spilanthoides	sunflower daisy
Wahlenbergia granitica	Australian bluebell

LEGUMES	
Aeschenomene brevifolia	joint vetch
Cassia concinna	dwarf cassia
Crotalaria medicaginea	trefoil rattlepod
Crotalaria montana	rattlepod
Desmodium brachypodum	large tick trefoil
Desmodium campylocaulon	creeping tick trefoil
Desmodium varians	slender tick trefoil
Glycine clandestina	twining glycine
Glycine tabacina	variable glycine
Indigofera brevidens	desert indigo
Indigofera colutea	sticky indigo
Indigofera hirsuta	hairy indigo
Indigofera linifolia	narrow-leaf indigo

Table E1. Pasture and woody species list, Keilambete (contd.)

LEGUMES (contd.)	
Indigofera linneai	Birdsville indigo
Indigofera polygaloides	
Indigofera pratensis	forest indigo
Rhynchosia minima	rhynchosia pea
Tephrosia filipes	
Tephrosia purpurea	
Zornia muriculata var. angustata	

SEDGES	
Cyperus bifax	downs nutgrass
Cyperus concinnus	
Cyperus fulvus	sticky sedge
Cyperus iria	rice flatsedge
Cyperus javanicus	
Cyperus polystachyos	
Empodisma minus	rope rush
Fimbristylis dichotoma	common fringerush
Fimbristylis ovata	
Scleria mackaviensis	

Species groups (used when identification to	**species not possible)**
FORBS	***FORBS (contd.)***
Alternanthera species	*Not Known Forb*
Amaranth species	*Oxalis species*
Boerhavia species	*Phyllanthus species*
Brassica species	*Physalis species*
Brunoniella species	*Plantago species*
Cheilanthes species	*Polycarpaea species*
Chenopodium species	*Portulaca species*
Crotalaria species	*Pterocaulon species*
Euphorbia species	*Ruellia species*
Evolvulus species	*Sclerolaena species*
Glycine species	
Gnaphalium species	***FORBS (contd.)***
Gomphrena species	*Senecio species*
Goodenia species	*Sesbania species*
Hibiscus species	*Sida species*
Hybanthus species	*Solanum species*
Indigofera species	*Sonchus species*
Malva species	*Spermacoce species*

Tephrosia species	*Panicum species*
Vittadinia species	
Wahlenbergia species	***SEDGES***
Zornia species	*Cyperus species*
	Fimbristylus species
GRASSES	*Sedge*
Aristida species	
Chloris species	***OTHER***
Digitaria species	*Acacia species*
Enneapogon species	*Lilium species*
Eragrostis species	

SHRUBS AND TREES		
Species	**Common name**	**TRAPS code**
Acacia harpophylla	brigalow	ACHAR
Acacia longispicata		ACLON
Allocasuarina luehmannii	bull oak	ALLUE
Alphitonia excelsa	red ash	ALEXC
Archidendropsis basaltica	dead finish	ARBAS
Breynia oblongifolia	coffee bush	BROBL
Bursaria incana	prickly pine	BUINC
Carissa ovata	currant bush	CAOVA
Corymbia erythrophloia	variable barked bloodwood	EUERY
Eremophila mitchellii	false sandalwood	ERMIT
Eucalyptus melanophloia	silver-leaved ironbark	EUMEL
Eucalyptus papuana	ghost gum	EUPAP
Flindersia dissosperma		FLDIS
Hakea cordophylla	bootlace tree	HACOR
Maytenus cunninghamii	yellow-berry bush	MACUN
Petalostigma pubescens	quinine berry	PEPUB
		CACAN
		CASPP
Jasmimum didymium		JADID
Jasmimum lineare		JALIN
		JATRI
Opuntia spp.		OPSPP
Eremophila longifolia		ERLON
Canthium oleiofolium	myrtle	CAOLE

Appendix E2

Table E2. Names and codes for species germinating from soil samples, Keilambete

Plant Name	ID Number	Plant type	Plant code
Acacia species	53	o	acacia
Alternanthera species	32	f	altsp
Amaranth	90	f	amasp
Aristida calycina var. calycina	83	g	arica
Aristida gracilipes	81	g	arigr
Aristida ingrata	50	g	ariing
Aristida latifolia	60	g	arilat
Aristida lazarides	101	g	arilaz
Aristida leptopoda	6	g	arilep
Aristida schultzii	42	g	arisch
Aristida species	37	g	arisp
Boerhavia species	55	f	boer
Bothriochloa ewartiana	7	g	botewa
Brachiaria spp	107	g	brasp
Brassica species	72	f	brasp
Brunoniella species	25	f	brun
Cenchrus ciliaris	56	g	cencil
Cheilanthes distans	92	f	chdis
Cheilanthes distans	93	f	chten
Cheilanthes species	80	p	chesp
Chenopodium carinatum	69	f	chcar
Chenopodium species	3	f	chensp
Chloris divaricata	31	g	chldiv
Chloris virgata	103	g	chlvir
Chrysocephalum apiculatum	82	h	chrap
Chrysopogon fallax	23	g	chrfal
Crotolaria species	61	l	crotsp
Cyperus fulvus	100	s	cypful
Cyperus species	8	s	cypsp
Dactyloctenium radulans	38	g	dacrad
Desmodium varians	15	l	desvar
Dicanthium serecium	21	g	dicser
Digitaria ammophila	52	g	digamm
Digitaria brownii	28	g	digbro
Digitaria ciliaris	34	g	digcil
Digitaria spp	102	g	digspp
Echinochloa colona	96	g	echcol
Enneapogon gracilis	76	g	engra
Enneapogon species	16	g	ennsp
Eragrostis brownii	30	g	erabro
Eragrostis elongata	88	g	eraelo
Eragrostis parviflora	97	G	erapar
Eragrostis species	19	g	erasp
Eriochloa procera	68	g	eripro
Eriochloa pseudoacrotricha	14	g	eripse
Eulalia aurea	51	g	eulaur
Euphorbia species	11	f	euphsp
Evolvulus species	48	f	evosp
Fimbristylis species	9	s	fimsp
Glycine species	26	l	glysp
Gnaphalium species	45	f	gnaph
Gomphrena species	67	f	gomph
Goodenia species	29	f	goodsp
Heteropogon contortus	5	g	hetcon
Hibiscus species	71	f	hibsp

Plant Name	ID Number	Plant type	Plant code
Hybanthus species	17	f	hybsp
Indigofera linifolia	77	l	inlini
Indigofera linneai	73	l	inlinn
Indigofera species	20	l	indigo
Leptopus decaisneii	63	f	lepdec
Lillium species	49	o	lilly
Malva speciea	78	f	malsp
Melinis repens	85	g	merep
Not Known Forb	1	f	forb
Not Known Grass	2	g	grass
Oxalis species	44	f	oxalis
Panicum decompositum	65	g	pandec
Panicum effusum	36	g	paneff
Paspalidium jubiflorum	35	g	pasjub
Paspelidium caespitosum	99	g	pascae
Phyllanthus species	22	f	phyll
Physalis spp	89	f	physal
Plantago species	64	f	plan
Polycarpaea	106	f	polysp
Polycarpaea corymbosa	59	f	polyca
Portulaca filifolia	75	f	pofil
Portulaca linifolia	87	l	porlin
Portulaca oleracea	70	f	poolea
Portulacca species	4	f	portsp
Pterocaulon species	33	f	ptero
Rhynchosia minima	12	l	rhymin
Ruellia species	24	f	ruell
Scleria mackaviensis	98	s	sclmac
Sclerolaena species	46	f	sclsp
Sedge	105	s	sedge
Sehima nervosa	104	g	sehner
Senecio species	41	f	senec
Sesbania species	39	l	sesban
Sida species	43	f	sidasp
Solanum americanum	95	f	solam
Solanum ellipticum	66	f	solell
Solanum nigram	74	f	sonig
Solanum species	79	f	solsp
Sonchus species	47	f	sonsp
Spermacoce species	10	f	sperm
Sporobolus actinocladus	91	g	spoact
Sporobolus australasicus	13	g	spoaus
Spp1	86	f	spp1
Tephrosia species	54	l	teph
Themeda triandra	58	g	thetri
Tragus australasicus	57	g	traaus
Tripogon lolliformis	40	g	trilol
Vernonia cinerea	84	f	verci
Vernonia cinerea	94	f	vercin
Vittadinia species	62	f	vitt
Wahlenbergia species	18	f	wahsp
Zornia species	27	l	zorsp

Appendix E3

Table E3. Species emerging from Keilambete soil during germination tests

Species	grp	Species	grp	Species	grp
Alternanthera species	f	Bothriochloa ewartiana	g	Fimbristylis species	s
Amaranth	f	Brachiaria spp	g	Scleria mackaviensis	s
Boerhavia species	f	Cenchrus ciliaris	g	Sedge	s
Brassica species	f	Chloris divaricata	g		
Brunoniella species	f	Chloris virgata	g		
Cheilanthes distans	f	Chrysopogon fallax	g		
Cheilanthes distans	f	Dactyloctenium radulans	g		
Chenopodium carinatum	f	Dicanthium serecium	g		
Chenopodium species	f	Digitaria ammophila	g		
Euphorbia species	f	Digitaria brownii	g		
Evolvulus species	f	Digitaria ciliaris	g		
Gnaphalium species	f	Digitaria spp	g		
Gomphrena species	f	Echinochloa colona	g		
Goodenia species	f	Enneapogon gracilis	g		
Hibiscus species	f	Enneapogon species	g		
Hybanthus species	f	Eragrostis brownii	g		
Leptopus decaisneii	f	Eragrostis elongata	g		
Malva speciea	f	Eragrostis parviflora	G		
Not Known Forb	f	Eragrostis species	g		
Oxalis species	f	Eriochloa procera	g		
Phyllanthus species	f	Eriochloa pseudoacrotricha	g		
Physalis spp	f	Eulalia aurea	g		
Plantago species	f	Heteropogon contortus	g		
Polycarpaea	f	Melinis repens	g		
Polycarpaea corymbosa	f	Not Known Grass	g		
Portulaca filifolia	f	Panicum decompositum	g		
Portulaca oleracea	f	Panicum effusum	g		
Portulacca species	f	Paspalidium jubiflorum	g		
Pterocaulon species	f	Paspelidium caespitosum	g		
Ruellia species	f	Sehima nervosa	g		
Sclerolaena species	f	Sporobolus actinocladus	g		
Senecio species	f	Sporobolus australasicus	g		
Sida species	f	Themeda triandra	g		
Solanum americanum	f	Tragus australasicus	g		
Solanum ellipticum	f	Tripogon lolliformis	g		
Solanum nigram	f	Chrysocephalum apiculatum	h		
Solanum species	f	Crotolaria species	l		
Sonchus species	f	Desmodium varians	l		
Spermacoce species	f	Glycine species	l		
Spp1	f	Indigofera linifolia	l		
Vernonia cinerea	f	Indigofera linneai	l		
Vernonia cinerea	f	Indigofera species	l		
Vittadinia species	f	Portulaca linifolia	l		
Wahlenbergia species	f	Rhynchosia minima	l		
Aristida calycina var. caly	g	Sesbania species	l		
Aristida gracilipes	g	Tephrosia species	l		
Aristida ingrata	g	Zornia species	l		
Aristida latifolia	g	Acacia species	o		
Aristida Lazarides	g	Lillium species	o		
Aristida leptopoda	g	Cheilanthes species	p		
Aristida schultzii	g	Cyperus fulvus	s		
Aristida species	g	Cyperus species	s		

Appendix E4

Table E4. List of Woody Species that were recorded at "Glentulloch".

Code nbr	Common name	Scientific name	* = common	Code
104	Gargaloo *	Parsonia	eucalyptophylla	PAEUC
200	Western golden wattle *	Acacia	decora	ACDEC
201	Ironwood	Acacia	excelsa	ACEXC
202	Mimosa	Acacia	farnesiana	ACFAR
203	Brigalow	Acacia	harpophylla	ACHAR
204	Black wattle	Acacia	leiocalyx	ACLEI
	Sydney golden wattle	Acacia	longifolia	ACLON
205	Myall *	Acacia	pendula	ACPEN
206	Shrub boonaree (holly)	Alectryon	diversifolius	ALDIV
207	Western Rosewood	Alectryon	oleifolius var. elongatus	ALOLE
208	Bull Oak *	Allocasuarina	luehmannii	ALLUE
209	Bitter bark	Alstonia	constricta	ALCON
210	Broom/Warrior bush	Apophyllum	anomalum	APANO
211	Whitewood *	Atalaya	hemiglauca	ATHEM
212	Kurrajong	Brachychiton	populneus	BRPOP
213	Bottle tree	Brachychiton	rupestre	BRRUP
214	Cypress pine	Callitris	glaucophylla	CAGLA
215	Myrtle	Canthium	oleifolium	CAOLE
216	Wait-a-while/Nipan *	Capparis	lasiantha	CALAS
217	Narrow-leaf bumble	Capparis	loranthifolia	CALOR
218	Native orange	Capparis	mitchellii	CAMIT
219	Currant bush *	Carissa	ovata	CAOVA
220	Native olive	Cassine	australis	CAAUS
221	Cough bush	Cassinia	laevis	CALAE
222	Carbeen	Corymbia	tessellaris	EUTES
223	Narrow-leaf hopbush *	Dodonaea	stenophylla (D. attenuata)	DOATT
224	Sticky hopbush	Dodonaea	viscosa	DOVIS
225	Peach bush	Ehretia	membranifolia	EHMEM
226	Lime bush *	Eremocitrus	glauca	ERGLA
227	False sandalwood *	Eremophila	mitchellii	ERMIT
228	Silver-leaved ironbark *	Eucalyptus	melanophloia	EUMEL
229	Mountain coolibah	Eucalyptus	orgadophila	EUORG
230	Poplar box *	Eucalyptus	populnea	EUPOP
231	Wombat berry	Eustrephus	latifolius	EULAT
232	Wilga	Geijera	parviflora	GEPAR
233	Beefwood *	Grevillea	striata	GRSTR
234	Grewia *	Grewia	latifolia	GRLAT
	Bootlace tree	Hakea	chordophylla	HACHO
235	Corkwood	Hakea	fraseri	HAFRA
236	Hovea	Hovea	longipes	HOLON
	Native jasmine	Jasminum	didymum	JADID
237	Native jasmine	Jasminum	simplicifolium	JASIM
238	Yellow-berry bush *	Maytenus	cunninghamii	MACUN
239	Boobialla	Myoporum	acuminatum	MYACU
240	Ellangowan poison bush	Myoporum	deserti	MYDES
242	Common prickly pear	Opuntia	stricta	OPSTR
243	Emu apple	Owenia	acidula	OWACI
244	Bower vine	Pandorea	jasminoides	PAJAS
246	Quinine	Petalostigma	pubescens	PEPUB
247	Cattle bush/Butterbush	Pittosporum	phylliraeoides	PIPHY
248	True sandalwood	Santalum	lanceolatum	SALAN
249	Desert cassia	Senna	desolata	CADES
250	Vine tree	Ventilago	viminalis	VEVIM
251	Belah	Casuarina	cristata	CACRI

Appendix E5

Table E5. Glentulloch **Herb** species list - OCT 2001 # = Rare

Code no.	Common name	Scientific name		Code
11	Small-leafed abutilon	Abutilon	malvifolium	abumal
15	Lantern bush #	Abutilon	oxycarpum	abuoxy
7	Lesser joyweed	Alternanthera	denticulata	altden
51	An amaranth	Amaranthus	macrocarpus	amamac
3	Dark wiregrass	Aristida	calycina	arical
71	Jericho wiregrass	Aristida	jerichoensis	arijer
86	Feathertop wiregrass	Aristida	latifolia	arilat
61	Whitespear	Aristida	leptopoda	arilep
91	Purple wiregrass	Aristida	ramosa	ariram
136	Lazarides wiregrass #	Aristida	sp. ridge	ariasr
92	A wiregrass	Aristida	unid	arispp
162	Common woodruff	Asperula	conferta	aspcon
107	Creeping saltbush	Atriplex	semibaccata	atrsem
171	Cobbler's pegs	Bidens	pilosa	bidpil
82	A tarvine	Boerhavia	sp.	boespp
16	Tarvine	Boerhavia	dominii	boedom
108	Forest bluegrass	Bothriochloa	bladhii	botbla
84	Pitted bluegrass	Bothriochloa	decipiens	botdec
79	Desert bluegrass #	Bothriochloa	ewartiana	botewa
95	Native couch	Brachyachne	convergens	bracon
132	Smooth daisy	Brachycome	trachycarpa	bratra
6	Blue trumpet	Brunoniella	australis	bruaus
13	Yellow daisyburr	Calotis	lappulacea	callap
57	Rough daisyburr	Calotis	scabiosifolia	calsca
78	Camptacra daisy	Camptacra	barbata	cambab
45	Buffel grass	Cenchrus	ciliaris Gayndah	cencil
143	Woolly cloak fern	Cheilanthes	lasiophylla	chelas
144	Mulga fern	Cheilanthes	sieberi	chesie
47	Green crumbweed	Chenopodium	cristatum	checri
167	Desert goosefoot #	Chenopodium	desertorum	chedes
46	Slender chloris	Chloris	divaricata	chldiv
18	Windmill grass	Chloris	truncata	chltru
26	Tall chloris	Chloris	ventricosa	chlven
76	Yellow buttons	Chrysocephalum	apiculatum	chrapi
63	Golden-beard grass	Chrysopogon	fallax	chrfal
88	Grey rattlepod #	Crotalaria	dissitiflora	crodis
137	Barbwire grass	Cymbopogon	refractus	cymref
	Green couch grass	Cynodon	dactylon	cyndac
122	Downs nutgrass	Cyperus	bifax	cypbif
142	Hard sedge	Cyperus	fulvus	cypful
98	Slender sedge	Cyperus	gracilis	cypgra
112	A sedge	Cyperus	leiocaulon	cyplei
118	Floodplain sedge	Cyperus	rigidellus	cyprig
124	Button grass	Dactyloctenium	radulans	dacrad
59	Native thornapple #	Datura	leichhardtii	datlei
53	Large tick trefoil #	Desmodium	brachypodum	desbra
81	Slender tick trefoil	Desmodium	varians	desvar

Code no.	Common name	Scientific name		Code
168	Flax-lily	Dianellia	lily	diaspp
44	Slender bluegrass	Dichanthium	sericeum var. affine	dicser
138	Small bluegrass #	Dichanthium	tenue	dicten
166	Cotton panic	Digitaria	brownii	digbro
37	Finger panic	Digitaria	coenicola	digcoe
30	Umbrella grass	Digitaria	divaricatissima	digdiv
58	Knotweed goosfoot	Einadia	polygonoides	einpol
83	Ruby saltbush	Enchylaena	tomentosa	enctom
2	Slender bottlewashers	Enneapogon	gracilis	enngra
24	Conetop bottlewashers	Enneapogon	pallidus	ennpal
135	Limestone bottlewashers	Enneapogon	polyphyllus	ennpol
141	Hairy nineawn	Enneapogon	pubescens	ennpub
68	Tall bottlewashers	Enneapogon	truncatus	enntru
96	Curly windmill grass	Enteropogon	acicularis	entaci
27	Twirly windmill grass	Enteropogon	ramosus	entram
40	Spreading nutheads	Epaltes	australis	epaaus
94	Stinkgrass	Eragrostis	cilianensis	eracil
139	Clustered lovegrass	Eragrostis	elongata	eraelo
5	Purple lovegrass	Eragrostis	lacunaria	eralac
170	Paddock lovegrass	Eragrostis	leptostachya	eralep
1	Granite lovegrass	Eragrostis	molybdea	eramol
97	Woodland lovegrass	Eragrostis	sororia	erasor
49	Early spring grass	Eriochloa	pseudoacrotricha	eripse
117	Silky browntop	Eulalia	aurea	eulaur
103	Caustic weed	Euphorbia	drummondii	eupdru
22	Tropical speedwell	Evolvulus	alsinoides	evoals
31	Common fringe-rush	Fimbristylis	dichotoma	fimdic
73	Cobbler's tack	Glossogyne	tenuifolia	gloten
145	Capella glycine #	Glycine	latifolia	glylat
20	Glycine pea	Glycine	tabacina	glytab
172	Woolly glycine	Glycine	tomentella	glytom
154	Gomphrena weed	Gomphrena	celosiodes	gomcel
54	Silky goodenia	Goodenia	fascicularis	velfas
14	Smooth goodenia	Goodenia	glabra	googla
8	Black speargrass	Heteropogon	contortus	hetcon
164	Low hibiscus	Hibiscus	brachysiphon	hibbra
4	Hill hibiscus	Hibiscus	sturtii	hibstu
126	Bladder ketmia	Hibiscus	trionum	hibtri
163	Native indigo	Indigofera	linifolia	indlif
157	Birdsville indigo	Indigofera	linnaei	indlin
106	Native jasmine	Jasmine	linare	jaslin
114	Umbrella canegrass	Leptochloa	digitata	lepdig
87	Woolly-headed matrush	Lomandra	leucocephala	lomleu
147	Long-leaved matrush	Lomandra	longifolia	lomlon
150	Black cottonbush	Maireana	decalvans	maidec
32	Wingless fissure-weed	Maireana	enchylaenoides	maienc
148	Small-leaved cottonbush	Maireana	microphylla	maimic
55	Spiked malvastrum	Malvastrum	americanum	malame
155	Common nardoo	Marsilea	drummondii	mardru
89	Velvet hibiscus #	Melhania	oblongifolia	melobl
101	Red Natal grass #	Melinis	repens	melrep

Code no.	Common name	Scientific name		Code
123	Native pennyroyal	Mentha	satureioides	mensat
140	Smooth minuria	Minuria	integerrima	minint
80	Amulla	Myoporum	debile	myodeb
65	Native sensitive plant	Neptunia	gracilis	nepgra
102	Barbwire weed	Nyssanthes	diffusa	nysdif
156	Prickly pear	Opuntia	stricta	opustr
12	Yellow wood sorrel	Oxalis	coniculatus	oxacon
90	Native panic	Panicum	buncei	panbun
153	Native millet	Panicum	decompositum	pandec
134	Hairy panic	Panicum	effusum	paneff
129	Yabila grass	Panicum	queenslandicum	panque
85	Pale green panic #	Panicum	simile	pansim
35	Knottybutt grass	Paspalidium	constrictum	pascon
127	Fine panic	Paspalidium	criniforme	pascri
130	Paspalum	Paspalum	dilatatum	pasdil
28	Little spurge	Phyllanthus	virgatus	phyvir
105	Sago weed	Plantago	cunninghamii	placun
151	Notched-leaf bindweed	Polymeria	pusilla	polpus
67	Small poranthera	Poranthera	microphylla	pormic
160	Thin-leaved pigweed	Portulaca	australis	poraus
19	Pigweed	Portulaca	oleracea	porole
41	Pastel flower	Pseuderathemum	variable	psevar
62	Lamb's tail	Ptilotus	exaltatus	ptiexa
173	Green pussytail #	Ptilotus	macrocephalus	ptimac
99	Golden billybuttons	Pycnosorus	chrysanthus	pycchr
152	Turnip weed	Rapistrum	rugosum	raprug
74	Rhyncho pea	Rhynchosia	minima	rhymin
72	Pink tongues	Rostellularia	adscendens	rosads
64	Soft rolypoly	Salsola	kali	salkal
50	Mintweed #	Salvia	reflexa	salref
56	Dwarf marigold	Schkuhria	pinnata var.abrotanoides	schpin
169	A bob-rush	Schoenus	sedge	schspp
146	Rough sedge #	Scleria	mackaviensis	sclmac
43	Yellow copperburr	Sclerolaena	anisacanthoides	sclcor
29	Galvanised burr	Sclerolaena	birchii	sclbir
52	Red copperburr	Sclerolaena	calcarata	sclcal
133	Black rolypoly	Sclerolaena	muricata	sclmur
125	A sedge	Sedge	sp. C	sedgec
60	Sand sida #	Sida	ammophila	sidamm
10	Corrugated sida	Sida	corrugata	sidcor
66	Hastate-leafed sida	Sida	hastate leaf	sidhas
159	Cluster sida	Sida	pleiantha	sidple
116	Shrub sida	Sida	rholenae	sidrho
149	Spiked sida	Sida	subspicata	sidsub
48	High sida	Sida	trichopoda	sidtri
9	Potato bush	Solanum	ellipticum	solell
69	Potato weed	Solanum	esuriale	solesu
165	Cluster weed	Spermacoce	multicaulis	spemul
158	Katoora	Sporobolus	actinocladus	spoact
36	Fairy grass	Sporobolus	carolii	spocar
131	Western rat's-tail grass	Sporobolus	creber	spocre

Code no.	Common name	Scientific name		Code
93	Slender rat's-tail grass	Sporobolus	elongatus	spoelo
75	Western stackhousia	Stackhousia	muricata	stamur
25	Stinking thread-petal	Stenopetalum	nutans	stenut
100	Rough speargrass	Stipa	scabra	stisca
115	Kangaroo oats #	Themeda	avenaceus	theave
113	Kangaroo grass	Themeda	triandra	thetri
161	Common fringe lily #	Thynosurus	tuberosus	thyspp
38	Small burr grass	Tragus	australianus	traaus
42	Red spinach	Trianthema	triquetra	tritri
39	Caltrop	Tribulus	terrestris	triter
33	Yellow rush-lily #	Tricoryne	elatior	triela
34	Five minute grass	Tripogon	loliiformis	trilol
119	Liverseed grass	Urochloa	panicoides	uropan
70	Common verbena	Verbena	officinalis	veroff
17	Mayne's pest	Verbena	tenuisecta	verten
23	Vernonia daisy	Vernonia	cinerea	vercin
111	Bristly fuzzweed	Vittadinia	hispidula	vithis
77	Small-leaved fuzzweed	Vittadinia	pustulata	vitpus
110	Wide-leafed fuzzweed	Vittadinia	sulcata	vitsul
109	Tufted bluebell	Wahlenbergia	communis	whacom
21	Rough sunflower daisy	Wedelia	spilanthoides	wedspi
121	Noogoora burr	Xanthium	pungens	xanpun
120	Bathurst burr #	Xanthium	spinosum	xanspi
128	Field zinnia	Zinnia	peruviana	xinper
326	Green couch	Cynodon	dactylon	cyndac
		172		

Appendix E6

Table E6. Botanal Functional groups for A/B species at "Glentulloch", Injune

Functional group	Grp nbr	Proj spp no.	Code	Species	Common name
Decr. grass	1	9	botbla	Bothriochloa bladhii	forest bluegrass
Decr. grass	1	11	botewa	Bothriochloa ewartiana	desert bluegrass
Decr. grass	1	15	cencil	Cenchrus ciliaris	buffel grass
Decr. grass	1	23	dicser	Dichanthium sericeum	Queensland bluegrass
Decr. grass	1	24	digdiv	Digitaria divaricatissima	blowaway grass
Decr. grass	1	32	eripse	Eriochloa pseudoacrotricha	early spring grass
Decr. grass	1	39	hetcon	Heteropogon contortus	black speargrass
Decr. grass	1	69	thetri	Themeda triandra	kangaroo grass
Decr. grass	1	72	urochs	Urochloa spp.	Sabi grass
Int. grass	2	10	botdec	Bothriochloa decipiens	pitted bluegrass
Int. grass	2	17	chldiv	Chloris divaricata	slender chloris
Int. grass	2	19	chrfal	Chrysopogon fallax	golden-beard grass
Int. grass	2	20	cymbos	Cymbopogon spp.	barbwire grass
Int. grass	2	21	cyndac	Cynodon dactylon	couch grasses
Int. grass	2	25	digits	Digitaria spp.	blowaway grasses
Int. grass	2	27	entaci	Enteropogon acicularis	curly windmill
Int. grass	2	28	entram	Enteropogon ramosus	twirly windmill grass
Int. grass	2	33	eulaur	Eulalia aurea	silky browntop
Int. grass	2	48	othgrl	Other grass (Perrennial)	other perennial grasses
Int. grass	2	49	paneff	Panicum effusum	hairy panic
Int. grass	2	50	panics	Panicum spp.	panics
Int. grass	2	51	paspas	Paspalidium spp.	shot grasses
Int. grass	2	66	sporsm	Sporobolus (small)	caroli / actinocladus sp.
Int. grass	2	67	stisca	Stipa scabra	rough stipa
Incr. grass	3	2	arical	Aristida calycina	branched wiregrass
Incr. grass	3	3	arilat	Aristida latifolia	feathertop
Incr. grass	3	4	arilep	Aristida leptopoda	white spear
Incr. grass	3	5	ariram	Aristida ramosa	purple wiregrass
Incr. grass	3	6	arists	Aristida spp.	wiregrass - unidentified
Incr. grass	3	18	chlors	Chloris spp	windmill /tall chloris
Incr. grass	3	30	eralac	Eragrostis lacunaria	purple lovegrass
Incr. grass	3	31	eramol	Eragrostis molybdea	granite lovegrass
Incr. grass	3	65	sporat	Sporobolus (tall)	rat's-tail grasses
Incr. grass	3	71	trilol	Tripogon loliiformis	five minute grass
Ann. grasses	4	1	anngra	Annual grasses	annual grasses
Ann. grasses	4	12	brachs	Brachiaria spp.	arm grasses
Ann. grasses	4	26	enneas	Enneapogon spp.	bottlewasher grasses
Ann. grasses	4	29	eragrs	Eragrostis spp.	lovegrasses
Ann. grasses	4	47	melrep	Melinis repens	red natal grass

Functional group	Grp nbr	Proj spp no.	Code	Species	Common name
Ann. grasses	4	70	traaus	Tragus australianus	small burr grass
Legumes	5	41	legpal	Legume - palatable	glycine, desmodium
Legumes	5	54	rhymin	Rhynchosia minima	rhynchosia pea
Forbs	6	7	asterd	Asteraceae (daisy)	true daisies
Forbs	6	8	asters	Asteraceae spp	billy-buttons
Forbs	6	13	bruaus	Brunoniella australis	blue trumpet
Forbs	6	14	calots	Calotis spp.	daisy-burrs
Forbs	6	16	chenos	Chenopodiaceae	saltweeds
Forbs	6	34	euphos	Euphorbia / Phyllanthus	caustic weeds
Forbs	6	37	forblg	Forb - large	other large forbs
Forbs	6	38	forbsm	Forb - small	other small forbs
Forbs	6	40	hibstu	Hibiscus sturtii	hill hibiscus
Forbs	6	42	legpoi	Legume - unpalatable	indigofera + rattlepods
Forbs	6	44	maircb	Maireana microphylla	eastern cottonbush
Forbs	6	45	maires	Maireana spp.	bluebushes
Forbs	6	46	malame	Malvastrum americanum	spiked malvastrum
Forbs	6	52	portus	Portulaca spp.	pigweeds
Forbs	6	53	ptilos	Ptilotis spp.	mulla mullas/ pussytails
Forbs	6	55	rosads	Rostellaria adscendens	pink tongues
Forbs	6	57	salkal	Salsola kali	soft roly-poly
Forbs	6	58	sclbir	Sclerolaena birchii	galvanised burr
Forbs	6	59	sclers	Sclerolaena spp.	copperburrs
Forbs	6	60	sclmur	Sclerolaena muricata	black roly-poly
Forbs	6	62	sidasp	Sida spp.	sidas generally
Forbs	6	63	sidsub	Sida subspicatum	spiked sida
Forbs	6	64	solans	Solanum spp.	potato weeds
Forbs	6	68	succul	Succulents (Chenopods)	succulents
Forbs	6	73	verten	Verbena tenuisecta	Mayne's pest
Forbs	6	74	vittad	Vittadinia spp.	fuzzweed
Forbs	6	75	xanths	Xanthium spp.	noogoora/bathurst burrs
Sedges etc.	7	22	cypers	Cyperus spp	nutgrasses
Sedges etc.	7	35	fern	Ferns	ferns
Sedges etc.	7	36	fimdic	Fimbristylis dichotoma	fringe rush
Sedges etc.	7	43	lilysp	Lilies	lilies
Sedges etc.	7	56	rush	Lomandra	rushes
Sedges etc.	7	61	sedge	Sedge	sedges

Decr. means Decreaser, Incr. means Increaser, Int. means Intermediate

Ann. grasses includes short-lived perennials

Sedges etc. includes rushes, lilies, mat rushes and ferns

APPENDIX F. Species frequency and dynamics details, Ironbark and Poplar box sites

Appendix F1

Table F1. "Glentulloch" grazing trial – Species frequency percent by TREES - meaned over Reps & Utilisation rate

75 Species set	code	1995		1996		1997		1998		1999		2000		2001		2002		Mean 1995-2002		Change 1995-2002	
		CLEAR	TREES	CLEAR	TREES	CLEAR	TREES	CLEAR	TREES	CLEAR	TREES	CLEAR	TREES	CLEAR	TREES	CLEAR	TREES	CLEAR	TREES	CLEAR	TREES
Annual grasses	anngra	0	0	0	0	0	0	0.1	0	0	0.3	0	0	0	0.3	0.3	0.1	0.05	0.1	0.3	0.1
A. calycina	arical	3	9.1	6.4	10.6	2.1	6.6	3.8	7.9	2.5	6.5	3	12.4	2.6	12.3	4.7	10.8	3.5	9.5	1.7	1.7
A. latifolia	arilat	4.6	1.2	3	0.4	3.1	1.4	4.3	0.5	3.7	1.3	2.4	1.4	3.9	2.3	3.4	0.6	3.5	1.1	-1.2	-0.6
A. leptopoda	arilep	6.1	0	2.3	0.3	5.5	1.9	3.4	0.1	3	0.4	4.6	1.5	5	0.1	6.6	0.5	4.6	0.6	0.5	0.5
A. ramosa	ariram	21.6	40.2	11.2	8.8	6.7	9.5	18.1	26.7	9.9	15.8	14.2	24.2	21	39.1	22.2	41	15.6	25.7	0.6	0.8
Aristida spp	arists	0.6	1.3	9.2	28.3	14.2	23.2	8.3	14	6.4	17.4	4.6	12.5	2.9	4.3	1.5	2.8	6.0	13.0	0.9	1.5
Asteraceae (daisy)	asterd	0	0	0	0.3	0.7	1	0.5	0.8	4.3	3.7	0.9	2.7	0.8	0.8	3.4	4.2	1.3	1.7	3.4	4.2
Asteraceae	asters	0	0	2.6	6.3	1.4	3.8	0.3	0.3	1.5	1.6	3.1	4.7	1.2	3.9	1.5	2.4	1.4	2.9	1.5	2.4
B. bladhii	botbla	6.2	3.3	9.3	8.9	6.2	6.6	5	3.1	7.1	7.7	4.8	3.5	4.3	2.7	3.2	2.2	5.8	4.7	-3.0	-1.1
B. decipiens	botdec	16.3	33	16	35.9	11.5	40.1	19.6	35	18.2	43.1	21.8	43.9	29.4	52.4	21.5	46.6	19.3	41.2	5.2	13.6
B. ewartiana	botewa	0.6	1	0.7	0	0.4	0.6	0.6	0	0.5	0.2	0.1	0	0.5	0.2	1	0	0.5	0.2	0.4	-1.0
Brachiaria spp	brachs	0	0	0.2	0.1	0	0	0.2	0	0	0	0	0	0.1	0.1	0.2	0	0.1	0.03	0.2	0.0
B. australis	bruaus	33.5	32.6	16.9	24.4	16.4	16.6	20.4	22.5	10.5	17	17.5	20.4	20.5	18.4	18.6	15.1	19.3	20.9	-14.9	-17.5
Calotis spp	calots	5.2	24.2	2.8	5.6	11.2	18.1	5.5	8	23.2	18.9	24.4	28.5	9	12.8	5.9	6.6	10.9	15.3	0.7	-17.6
C. ciliaris	cencil	1.6	0.6	1.3	0	2.8	0.2	5.1	1	3.3	1	3.1	0.9	1.2	0.8	4.2	1	2.8	0.7	2.6	0.4
Chenopodiaceae	chenos	1.3	1.3	0	0	0.6	0.4	6.8	5.5	1.7	0.9	2.6	1.8	2	1	4.5	2.6	2.4	1.7	3.2	1.3
C. divaricata	chldiv	11.8	7	17.4	9.6	38.9	14.3	33.2	10.8	47.8	14.7	40.5	12.3	62.8	25.7	41.6	20.3	36.7	14.3	29.8	13.3
Chloris spp	chlors	1.9	6.6	1.2	2.7	2	4.4	4.2	4.5	3.2	6.1	9.9	9.9	2.3	4.5	3.4	3.9	3.5	5.3	1.5	-2.7
C. fallax	chrfal	23.7	29.1	22	32	12.9	23.2	17.5	31.6	13.4	25.5	14.1	20.2	24.6	31.5	20.7	30.3	18.6	27.9	-3.0	1.2
Cymbopogon spp	cymbos	0.3	2.3	2	2.4	0.9	2.2	1.6	0.7	2.5	3	3.7	2.5	1.6	2.4	2.4	2	1.9	2.2	2.1	-0.3
C. dactylon	cyndac	0	0	0	0	0	0	0	0	0	0	0	0.1	0	0	0	0	0.0	0.01	0.0	0.0
Cyperus spp	cypers	4.2	12.8	2.1	3.8	3.5	4.5	9.4	14.9	4.1	9.8	10.2	20.1	7.5	16.9	9.7	15.4	6.3	12.3	5.5	2.6
D. sericeum	dicser	13.1	8.9	19.3	3.4	33	12.1	15.2	3.8	37.2	15.7	39.5	13.5	44.2	18	26.6	8.5	28.5	10.5	13.5	-0.4
D. divaricatissima	digdiv	3.2	0.7	1	0.6	0.9	0.6	0.1	0	0.1	0.3	0.6	0	0.3	0	0.5	0.1	0.8	0.3	-2.7	-0.6
Digitaria spp	digits	1.9	1.2	0.6	0.5	0.8	0.9	0	0	0.8	0.5	2.2	2.7	1	0.5	1.5	0.3	1.1	0.8	-0.4	-0.9
Enneapogon spp	enneas	54.8	23.4	44.6	27.2	62.5	33.3	57	32.4	40.1	31.2	58.1	33.5	46.1	29.7	54.4	32	52.2	30.3	-0.4	8.6
E. acicularis	entaci	1.9	0	0.3	0.1	1.7	2.1	0.7	0.1	0.1	0.5	0	0.2	0.3	0	0.2	0	0.6	0.4	-1.7	0.0
E. ramosus	entram	17.8	17	17.6	11.8	13.7	11	17.7	14.3	14.6	9.4	12.3	10.3	17.4	14.7	16.9	13.2	16.0	12.7	-0.9	-3.8
Eragrostis spp	eragrs	0	3.1	7.6	6.2	8	11.1	6.2	7.8	4	8	7.5	9.4	6	6.9	3.6	4	5.4	7.1	3.6	0.9

75 Species set	code	1995		1996		1997		1998		1999		2000		2001		2002		Mean 1995-2002		Change 1995-2002	
		CLEAR	TREES	CLEAR	TREES	CLEAR	TREES	CLEAR	TREES	CLEAR	TREES	CLEAR	TREES	CLEAR	TREES	CLEAR	TREES	CLEAR	TREES	CLEAR	TREES
E. lacunaria	eralac	1.6	3.3	0.2	2.4	0	2.6	0.7	2.3	0.8	2.2	2.5	6.1	0.9	5.3	2.1	3.9	1.1	3.5	0.5	0.6
E. molybdea	eramol	9.7	4.1	4.8	4.1	8	7.8	4.4	0.9	11.3	8.9	11.8	8.6	12.5	5.5	9.5	5.7	9.0	5.7	-0.2	1.6
E. pseudoacrotricha	eripse	4.5	3.6	1.9	0.6	5.9	1.2	2.8	0.6	9.1	3.6	1.8	1.2	3.8	1.5	1.6	0.5	3.9	1.6	-2.9	-3.1
E. aurea	eulaur	0.3	0.3	0	0	0.1	0	0.5	0	0.1	0	0	0.2	0	0.2	0.5	0.1	0.2	0.1	0.2	-0.2
Euphorbia / Phyllanthus	euphos	5.2	7	0.7	1.9	0.3	0.3	1.5	4.2	4.3	4	5.2	6.9	2.2	2.5	1.6	2.4	2.6	3.6	-3.6	-4.6
Ferns	fern	0.3	0.3	1.1	4.4	0.7	0.5	0.9	2	0.9	1.2	0.3	0.1	0.6	1.8	0.3	0.2	0.6	1.3	0.0	-0.1
F. dichotoma	fimdic	10	23.3	3.3	6.5	9.2	12.9	1.8	5.8	3.8	3.8	14.1	10.2	7.9	13	9	4.9	7.4	10.0	-1.0	-18.4
Forb - large	forblg	4.2	7	0	0.1	0.6	1	0.1	0.5	1.5	1.3	0.1	0.1	0.6	1	1	1.4	1.0	1.5	-3.2	-5.6
Forb - small	forbsm	53.4	36.9	9.8	27.6	31.5	30.2	29.3	43.1	27.8	30.9	23.7	28.4	10.3	19.2	18.8	22.5	25.6	29.8	-34.6	-14.4
H. contortus	hetcon	0.6	2.2	0.7	3.8	2.1	6.5	2.3	4.1	2.6	4.5	3.3	5.6	3.4	4.6	2.6	5.2	2.2	4.6	2.0	3.0
H. sturtii	hibstu	0	0	0.1	0.1	0.1	0.3	0.1	0	0	0.1	0	0	0	0	0	0	0.04	0.1	0.0	0.0
Legume - palatable	legpal	7.1	13.2	5.1	12.8	4.4	8.6	9.5	9.4	9.9	15.9	13	23	15.9	20.5	9.5	19	9.3	15.3	2.4	5.8
Legume – unpal.	legpoi	9.2	6.4	2	3.8	1.1	1.5	2.1	1	4.5	4.5	3.9	3.7	4.8	4.2	8.1	5.1	4.5	3.8	-1.1	-1.3
Lilies	lilysp	0	0.3	0.2	0.1	0	0	0	0	0.1	0	0	0	0	0.2	0.2	0.2	0.1	0.1	0.2	-0.1
M. microphylla	maircb	1.3	2	0.2	0.6	0	0.1	0.1	0.2	0	0	0	0.3	0.8	0.3	0	0.1	0.3	0.4	-1.3	-1.9
Maireana spp	maires	3.2	1.8	2.4	0.7	3.9	4.9	1.2	0.5	0.1	0	0.5	0.2	0.8	0.8	1.3	1.7	1.7	1.3	-1.9	-0.1
M. americanum	malame	11.3	1.9	2.5	1.4	7.4	4.9	8.6	8.7	6.1	3.5	3.2	4.4	2.9	3.9	10.3	4.4	6.5	4.1	-1.0	2.5
M. repens	melrep	0	0	0	0	0	0	0	0	0.1	0	0.1	0	0	0	0	0	0.03	0.0	0.0	0.0
Other per. grass	othgrl	0	0	0	0	0.5	0.8	0	0	0	0.4	0.1	0.4	0.4	0.1	1.1	2.4	0.3	0.5	1.1	2.4
P. effusum	paneff	2	1.2	0.2	0.1	0.6	0.3	1.1	0.4	1.6	3.3	0.5	0.6	1.3	1.1	0.8	0.6	1.0	0.9	-1.2	-0.6
Panicum spp	panics	2.2	0.3	3.5	1.6	2.3	2.8	4.2	3.2	3.7	4.8	5.6	5.5	1.4	2.1	2.1	0.6	3.1	2.6	-0.1	0.3
Paspalidium spp	paspas	1	5.2	1.1	2.6	0.3	0.7	0.2	0.1	2.9	1.2	1.4	1.8	0.7	2.2	1.1	0.8	1.1	1.8	0.1	-4.4
Portulaca spp	portus	0	0	6.8	2.1	1.1	1.2	6.8	1.3	0.1	0.2	1.5	1	1.3	0.1	1.9	0.8	2.4	0.8	1.9	0.8
Ptilotus spp	ptilos	0	0	0.1	0.1	0	0.3	0.2	0.2	0	0	0.6	0.4	0.5	0.4	1.1	0.7	0.3	0.3	1.1	0.7
R. minima	rhymin	1	0.9	1	0.7	1.6	1.3	3.1	0.2	5.7	1.3	5.1	1.6	4.1	0.4	5.2	4.9	3.3	1.4	4.2	4.0
R. adscendens	rosads	0.6	4.2	0.2	0	0	0.2	0	0	0	0	0.2	0.1	0.1	0.7	0.2	1	0.2	0.8	-0.4	-3.2
Lomandra (rush)	rush	0.3	0.3	0	0	0	0.2	0	0	0	0.1	0	0.2	0.2	0.4	0.2	0	0.1	0.1	-0.1	-0.3
S. kali	salkal	0.6	0.6	0	0.3	1.4	0.7	1.1	0.9	0.3	1.7	0.4	0.7	1.1	0.5	0.2	0.7	0.6	0.8	-0.4	0.1
S. birchii	sclbir	9.9	13	8.1	8.5	9.6	7.3	7.7	6.4	7.1	4.9	5	5.6	4.4	5.8	5.1	3.6	7.1	6.9	-4.8	-9.4
Sclerolaena spp	sclers	15.3	4.6	2.3	2.2	3.6	1.4	0.1	0.3	0.4	1	0.4	0.1	1.2	0.3	5.1	2.9	3.5	1.6	-10.2	-1.7
S. muricata	sclmur	0	0	0	0	0.1	0.1	0	0	0.1	0.1	0.5	0.1	0	0	0.2	0	0.1	0.04	0.2	0.0
Sedge	sedge	2.6	0.8	4.4	10.1	0	0.1	0	0	1.8	3.6	1.2	1	0.3	0.1	2.6	1.1	1.6	2.1	0.0	0.3
Sida spp	sidasp	14.4	8.6	6.8	7.4	5.7	3.1	6.1	8.4	5.4	9.9	7.3	14.1	8.4	12.1	10.9	7.6	8.1	8.9	-3.5	-1.0

75 Species set	code	1995		1996		1997		1998		1999		2000		2001		2002		Mean 1995-2002		Change 1995-2002	
		CLEAR	TREES	CLEAR	TREES	CLEAR	TREES	CLEAR	TREES	CLEAR	TREES	CLEAR	TREES	CLEAR	TREES	CLEAR	TREES	CLEAR	TREES	CLEAR	TREES
S. subspicatum	sidsub	2.3	2	2.1	7.9	1	5.6	0.5	4.9	2.2	6.7	0.4	1.1	1.9	3.6	1.4	6	1.5	4.7	-0.9	4.0
Solanum spp	solans	5.2	6	2	1.4	5.3	4.7	4.3	6.7	1.3	1.9	3.7	3	1.7	3.3	3.8	2.6	3.4	3.7	-1.4	-3.4
Sporobolus (r'tail)	sporat	3.9	3.3	1.9	2.1	4.1	2.6	1.6	2.1	6.8	5.7	11.3	8.5	13.9	8.1	8.9	2.3	6.5	4.3	5.0	-1.0
Sporobolus (small)	sporsm	12	5.3	10	4.3	6.4	5.7	5.6	2.7	5.7	3.3	8.7	6.2	14.3	5.4	8.6	2.2	8.9	4.4	-3.4	-3.1
S. scabra	stisca	0.3	0	0.2	0	0.2	0.2	0.1	0	0	0	0	0.1	0	0	0	0	0.1	0.04	-0.3	0.0
Succulents	succul	0	0	0.9	0.6	0	0.1	0.1	0.2	0.1	0	0.7	0.1	0.2	0.4	0.5	0.7	0.3	0.3	0.5	0.7
T. triandra	thetri	0.6	0.3	1.3	0.9	1.5	1	1.3	0.9	2	0.4	1.1	0.5	0.6	0.2	0.6	0.2	1.1	0.5	0.0	-0.1
T. australianus	traaus	33.3	13.8	25.2	7.4	17.2	8.1	10.7	6.4	2.6	4.1	9.1	3.8	2	2.8	2.2	1.8	12.8	6.0	-31.1	-12.0
T. loliiformis	trilol	23.7	17.1	22.8	20	15.1	24.2	28	26.5	19.5	19	24.3	17.1	32.7	28.7	26.6	17.2	24.1	21.2	2.9	0.1
Urochloa spp	urochs	1.9	0.9	2	0.2	0	0	0.4	0.2	0	0	0.2	0.1	0	0	0	0	0.6	0.2	-1.9	-0.9
V. tenuisecta	verten	1.3	3	2	4.1	7.3	9.8	9	9.8	26.5	26.4	18.6	22.9	4.2	8.6	5.2	4.9	9.3	11.2	3.9	1.9
Vittadinia spp	vittad	2.3	2.2	0.3	0	8.2	12.2	0.7	3.5	19.2	20.4	1.1	3.5	0.6	1	0.5	0.3	4.1	5.4	-1.8	-1.9
Xanthium spp	xanths	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0
Mean		6.58	6.23	4.77	5.14	5.73	5.70	5.65	5.53	6.16	6.20	6.64	6.56	6.45	6.34	6.09	5.46	6.01	5.90	-0.49	-0.77

Appendix F2

Table F2. Fluctuations in species frequency at Glentulloch Burn trial between 1995 and 2002, meaned for tree effects

		1995		1996		1997		1998		1999		2000		2001		2002		Mean 1995 - 2002		mean
	code	BURN	NO BURN	BURN	NO BURN	BURN	NO BURN	BURN	NO BURN	BURN	NO BURN	BURN	NO BURN	BURN	NO BURN	BURN	NO BURN	BURN	NO BURN	diffnce
Annual grasses	anng	0	0	0	0	0.4	0	0	0	0	0	0	0	0	0	0	0	0.05	0.00	0.05
A. calycina	aric	21.3	28.7	19	19.7	14.4	17.7	16.7	20.1	13.1	11	13	20.2	10.6	23.8	10.6	30.8	14.8	21.5	-6.7
A. latifolia	aril	5.8	1.3	0	0.3	3.3	2.1	1.6	2.1	4.8	0	1.3	3.6	3	2.4	2.3	1	2.8	1.6	1.2
A. leptopoda	aril	3.7	0.8	8	4	0.4	0.4	0.3	0	1.6	0.3	1.3	0.3	1.6	1	1.6	0.3	2.3	0.9	1.4
A. ramosa	arir	25	30.4	0.3	0	3.2	1.6	19.6	22.6	14.1	13.1	15	10.4	24.5	28.4	25.2	43.1	15.9	18.7	-2.8
Aristida spp	aris	0	0	21.7	23.3	22.2	18.2	10.2	9.4	5.8	8.9	12.7	10.8	5	3.4	0.9	2.2	9.8	9.5	0.3
Asteraceae (daisy)	aste	0	0	0	0	0	0	0	0	0	0.8	0.7	0.3	0.3	0	1	2	0.2	0.4	-0.1
Asteraceae	aste	0	0	2.3	0	1.6	0.8	0	0	1.3	1.3	7	1.3	1.3	1.7	1.3	0	1.8	0.6	1.2
B. bladhii	botb	4.2	2.1	2.6	2.5	7.5	4.2	6.3	2.4	8.5	1.1	8.3	0.3	10.6	5.8	7.1	1.9	6.9	2.5	4.3
B. decipiens	botd	55	49	32.8	42.9	57.1	60.8	50.8	55.7	50.1	61.8	49.9	45.3	58.6	58.6	47.6	47.2	50.2	52.7	-2.4
B. ewartiana	bote	0	0	0	0	0	0.4	0	0	0	0	0	0	0	0	0	0.3	0.0	0.1	-0.1
Brachiaria spp	brac	0	0	0	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.04	-0.03
B. australis	brua	32.9	18.2	7.3	7.3	9.1	2.9	10.3	5.1	5.5	4.5	4.3	2.9	5.3	6.1	6.1	3.9	10.1	6.4	3.7
Calotis spp	calo	9.2	7	0.3	0.4	6.2	16.9	5.6	25.3	17.1	34	23.9	30.4	17.9	24.9	3.2	5.8	10.4	18.1	-7.7
C. ciliaris	cenc	0	0.4	0.7	3.8	1.3	5.4	1.6	3.3	1.4	3.6	2.6	5.6	1	3.4	2.2	6.1	1.3	3.9	-2.6
Chenopodiaceae	chen	0	0	0.3	0.4	0.8	0	0.6	0.6	0.6	0	0	0	0	0	0.6	2.6	0.4	0.4	-0.1
C. divaricata	chld	3.7	4.1	4.3	1.3	5	1.2	6	2.8	6.1	1.6	11	1	10.3	5.8	11.9	7.3	7.3	3.1	4.1
Chloris spp	chlo	5	4.2	1.6	2.4	9.4	10.7	4.6	7.8	7.4	7	6	5.2	4.9	7.6	2.6	3.2	5.2	6.0	-0.8
C. fallax	chrf	51.7	52.7	49.4	49.6	41.9	31.9	54.2	46.7	50.2	36.8	45.1	30.7	59.7	38.5	53.5	30.7	50.7	39.7	11.0
Cymbopogon spp	cymb	3.3	5.4	1.2	4.4	1.7	5.8	0.6	2.1	4.6	4.1	4.6	8.1	2.3	8.9	3.4	12.3	2.7	6.4	-3.7
C. dactylon	cynd	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0
Cyperus spp	cype	7.5	10.8	1.1	0.3	4.4	1.2	4.9	4.2	6.6	5.9	6.3	7.5	10.3	16.1	6.6	13	6.0	7.4	-1.4
D. sericeum	dics	7.5	8.3	26.3	18.1	6.6	4.9	11.5	6.4	33.3	15.1	28.3	14.7	34.4	14.1	20.7	10.9	21.1	11.6	9.5
D. divaricatissima	digd	1.7	0.8	1.7	1.7	0	0	0.9	0	1.3	0.7	0	0.3	2	2.8	1.6	2.6	1.1	1.1	0.04
Digitaria spp	digi	1.3	1.7	0.4	0	0	0.8	0.6	0	1	0.6	4	4.2	0	0.4	1.3	1.3	1.1	1.1	-0.05
Enneapogon spp	enne	21.3	22.4	16.5	20.7	17.4	19.5	26	21.5	18.8	14.2	26.3	18.7	23.5	19	26.2	22.9	22.0	19.9	2.14
E. acicularis	enta	3.3	1.7	0	0.4	1.2	0.8	0.9	0.9	2.3	0.7	0	0	2	0.3	1.3	0.7	1.4	0.7	0.7

	code	1995 BURN	1995 NO BURN	1996 BURN	1996 NO BURN	1997 BURN	1997 NO BURN	1998 BURN	1998 NO BURN	1999 BURN	1999 NO BURN	2000 BURN	2000 NO BURN	2001 BURN	2001 NO BURN	2002 BURN	2002 NO BURN	Mean 1995 - 2002 BURN	Mean 1995 - 2002 NO BURN	mean diffnce
E. ramosus	entr	4.6	3.3	1.6	6	4.5	3.3	3.4	3	1.3	1	2	1.3	4	3.7	4.5	6.7	3.2	3.5	-0.3
Eragrostis spp	erag	1.7	6.6	11.5	14.8	11.6	14.5	7	6.7	11.4	8.8	13	3.6	14	5.4	10	4.5	10.0	8.1	1.9
E. lacunaria	erai	5	8.7	0	0	0.8	0.8	2.1	2.1	1.6	2.6	6.3	3.6	1.7	1.4	1.2	2.9	2.3	2.8	-0.4
E. molybdea	eram	9.2	12	0	0	1.6	2.5	2.2	0.9	2.8	2.8	2.3	6.2	3.3	6.8	5.7	4.8	3.4	4.5	-1.1
E.pseudoacrotricha	erip	0.8	2.5	0	0.3	1.6	1.2	0.6	0.3	3.8	1.3	1	0.7	3	2.1	0	0.7	1.3	1.1	0.2
E. aurea	eula	1.7	1.3	0	0	0	0	0	0.6	0.6	0.6	1	1.3	1.7	0.4	3.4	1.6	1.0	0.7	0.3
Euphorbiaceae	euph	0.8	3.3	0	0	0.4	0	0.3	0	2.2	1.6	1.7	0.7	0	0	0.3	0.3	0.7	0.7	-0.02
Ferns	fern	0.4	0.4	0.6	0.7	0.4	1.6	0.9	1.8	2.7	1.3	0	0	0.7	1.4	0.3	2.3	0.7	1.2	-0.4
F. dichotoma	fimd	3.3	5	0	0	7.5	3.7	5.9	3.6	6.1	2.3	15.6	9.8	22.6	10.6	4.2	2.6	8.1	4.7	3.4
Forb - large	forbl	9.6	5.8	0.7	0	0.4	0	0.3	0	12.7	12.4	0	0	2.6	4.4	0	0.3	3.3	2.9	0.4
Forb - small	forbs	17.9	20.7	12.1	11.2	13	16.1	23.6	27.6	33.8	20	25.5	24.6	14.6	6.5	19.1	7.7	19.9	16.8	3.1
H. contortus	hetc	0	0.8	1.9	1.3	2.5	4.1	1.8	1.5	3.3	2.4	4.3	0.3	4	1.4	7.5	2.5	3.2	1.8	1.4
H. sturtii	hibs	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0
Legume - palble	legpal	25.8	19.6	10.5	11.5	22.7	9.5	9.5	8.9	15.8	17.7	19.6	14	21.5	23.7	15	14.2	17.5	14.9	2.7
Legume – unpal.	legpoi	3.7	2.1	0	0	2.1	0.4	0.9	0.9	2.9	0.9	6.7	0	4	2.8	4.2	0	3.1	0.9	2.2
Lilies	lily	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0
M. microphylla	mair	0.4	0	0	0	0	0	0	0	0	0	0.3	0	0	0.3	0	0	0.1	0.04	0.05
Maireana spp	mair	2.9	1.7	0	0	0	0	0	0.3	0	0	0.3	0	1	0	1	0	0.6	0.2	0.4
M. americanum	mala	0.4	2.9	0	0.3	2.9	1.3	0	0.3	1.9	0.7	1.3	0.3	0.3	2.4	2.8	3.2	1.2	1.4	-0.2
M. repens	melr	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3	0.0	0.04	-0.04
Other per. grass	othgr	0	0	0.3	0	1.7	0.4	0	0	0.3	0	0	0	0	0	1.2	0.6	0.4	0.1	0.3
P. effusum	panef	5	6.2	0	0	0	0	0.3	0.9	2.2	4.8	0	0.3	5	8.5	2.9	5.2	1.9	3.2	-1.3
Panicum spp	panic	2.9	1.6	5.2	3.7	5.8	9	3.1	4	3.7	5	8.7	7.5	4.6	3.1	3.7	5.3	4.7	4.9	-0.2
Paspalidium spp	pasp	6.7	4.6	2	0.7	1.2	0.4	1.6	0.9	3.7	1.9	3	2.6	1	1	2.5	3.6	2.7	2.0	0.7
Portulaca spp	port	0	0	0.6	0.8	0.4	0	0.3	0	0	0	0	0	0	0	0	0	0.2	0.1	0.1
Ptilotus spp	ptil	0.4	0	0	0	0.4	0	0	0	0	0	2	0	0	0	0.3	2.4	0.4	0.3	0.1
R. minima	rhym	1.7	0.4	0	0	0.8	1.6	0.3	0.6	2.2	0.9	4	3.9	2.3	5.6	1.9	2.3	1.6	1.9	-0.3
R. adscendens	rosa	2.9	3.7	0	0	0	0.8	0	0	0	0	0	0	0	0.7	0.3	0.7	0.4	0.7	-0.3
Lomandra (rush)	rush	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3	0.0	0.04	-0.04
S. kali	salk	0.8	0.8	0.4	0.3	0.4	0.4	0	0	0	0	0	0.3	0	0	0.3	0	0.2	0.2	0.01
S. birchii	sclb	2.5	4.9	3	3.7	0	0.8	0	1.8	0.3	0	0.3	2.3	0	1.7	0	1.3	0.8	2.1	-1.3

	code	1995 BURN	1995 NO BURN	1996 BURN	1996 NO BURN	1997 BURN	1997 NO BURN	1998 BURN	1998 NO BURN	1999 BURN	1999 NO BURN	2000 BURN	2000 NO BURN	2001 BURN	2001 NO BURN	2002 BURN	2002 NO BURN	Mean 1995 - 2002 BURN	Mean 1995 - 2002 NO BURN	mean diffnce
Sclerolaena spp	scle	0.4	0.8	0.7	0	0	0	0	0	0.3	0	0	0	0	0	0	0	0.2	0.1	0.07
S. muricata	sclm	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0
Sedge	sedg	0	0	3.7	6	0	0	0	0	4.8	3	0.3	0	0	0	0	3.3	1.1	1.5	-0.4
Sida spp	sida	4.6	10.7	4	8.5	2.9	4.1	3.1	2.4	2.3	1.9	5.7	5.2	6.3	3	4.2	4.1	4.1	5.0	-0.8
S. subspicatum	sids	12.1	6.2	4.7	4.6	10.3	5.8	6.5	2.1	6.1	4.6	5.7	2	5.3	0.3	5.6	2.2	7.0	3.5	3.6
Solanum spp	sola	5	5.4	0	0	6.1	2.1	7.1	5.7	4.4	2.6	6	4.6	2.3	4.2	3.8	2.3	4.3	3.4	1.0
Sporobolus (r'tail)	spor	0	2.9	2	1.6	2.5	4.1	1.8	0.9	3.2	3.4	6.6	3.6	8.3	5.9	5.4	5.2	3.7	3.4	0.3
Sporobolus (small)	spor	5.4	3.7	6.7	4.4	6.2	2.5	3.7	0	3.2	1	1.7	0	1.3	1	0.7	0	3.6	1.6	2.0
S. scabra	stis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0
Succulents	succ	0	0	0	0	0	0	0.3	0	0	0.3	0	0	0	0	0	0	0.04	0.04	0
T. triandra	thet	0.4	0	1	1.6	2.5	2.5	0.3	2.4	0.8	2.3	1.7	2.3	1.7	0.7	3.4	2.9	1.5	1.8	-0.4
T. australianus	traa	6.2	6.6	3.9	4.1	2.3	1.2	3.4	0	1.6	1	0	0	2	1	0.3	0.3	2.5	1.8	0.7
T. loliiformis	tril	7.5	16.5	6.2	9.9	7.4	4.2	13.9	12.4	3.5	2.3	4	0.7	6	3.4	6.4	2.9	6.9	6.5	0.3
Urochloa spp	uroc	0	0.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.05	-0.05
V. tenuisecta	vert	0.4	0	0.7	6.4	2.9	14.9	0.6	17.2	14.1	34.5	7.3	41.7	3.3	30.1	1.9	11.8	3.9	19.6	-15.7
Vittadinia spp	vitt	7.9	1.7	0	0	2.9	5.8	0	1.8	3.4	0	1	0.7	0.7	0	0	0	2.0	1.2	0.7
Xanthium spp	xant	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0

Appendix F3

Table F3. "Glentulloch" Burning trial - Species % Frequency by Trees; meaned over Burning & Reps

	Code	2002		Mean 1995 - 2002		clear -trees Mean	CLEAR Change	TREES Change
		CLEAR	TREES	CLEAR	TREES	difference	1995 -2002	1995 -2002
Annual grasses	anng	0	0	0.05	0.00	0.1	0.0	0.0
A. calycina	aric	19.8	21.6	18.5	17.9	0.6	-9.8	1.2
A. latifolia	aril	2.3	1	3.15	1.19	2.0	-2.7	-1.1
A. leptopoda	aril	1	1	1.2	2.0	-0.8	-0.7	-1.9
A. ramosa	arir	31.1	37.2	14.6	20.0	-5.4	4.4	8.5
Aristida spp	aris	1.3	1.9	8.8	10.5	-1.6	1.3	1.9
Asteraceae daisy	dais	3	0	0.5	0.1	0.4	3.0	0.0
Asteraceae	aste	0.3	1	1.1	1.4	-0.3	0.3	1.0
B. bladhii	botb	6.4	2.5	5.8	3.6	2.2	2.7	0.0
B. decipiens	botd	29.9	65	45.4	57.4	-12.0	-23.0	13.9
B. ewartiana	bote	0	0.3	0.05	0.04	0.0	0.0	0.3
Brachiaria spp	brac	0	0	0.0	0.04	0.0	0.0	0.0
B. australis	brua	7.8	2.2	7.0	9.5	-2.5	-15.1	-26.0
Calotis spp	calo	7.8	1.2	22.9	5.6	17.3	2.0	-9.2
C. ciliaris	cenc	4.8	3.4	3.8	1.5	2.3	4.8	3.0
Chenopodiaceae	chen	3.2	0	0.5	0.3	0.2	3.2	0.0
C. divaricata	chld	14.5	4.6	7.0	3.4	3.5	9.9	1.3
Chloris spp	chlo	3.9	1.9	7.1	4.1	3.0	-2.3	-1.0
C. fallax	chrf	41.7	42.5	43.0	47.4	-4.4	-7.0	-13.1
Cymbopogon spp	cymb	8.8	6.9	5.3	3.8	1.4	3.0	4.0
C. dactylon	cynd	0	0	0.0	0.0	0.0	0.0	0.0
Cyperus spp	cype	6.2	13.4	5.2	8.1	-2.9	-3.4	4.7
D. sericeum	dics	19	12.6	19.3	13.4	5.9	9.0	6.8
D. divaricatissima	digd	2.6	1.6	1.5	0.8	0.7	0.9	0.8
Digitaria spp	digi	2.6	0	1.4	0.8	0.7	1.3	-1.7
Enneapogon spp	enne	20.2	28.9	17.5	24.3	-6.9	-2.3	7.8
E. acicularis	enta	1	0.9	1.1	0.9	0.2	-2.3	-0.8
E. ramosus	entr	6.5	4.7	4.0	2.8	1.2	1.9	1.4
Eragrostis spp	erag	9.7	4.7	10.6	7.5	3.2	6.0	0.1
E. lacunaria	eral	0.6	3.5	2.1	3.0	-0.9	-7.3	-2.3
E. molybdea	eram	6.7	3.8	4.4	3.5	1.0	-5.0	-5.7
E. pseudoacrotricha	erip	0.3	0.3	1.3	1.1	0.2	-1.8	-0.9
E. aurea	eula	1.6	3.4	0.9	0.8	0.1	-0.1	2.1
Euphorbiaceae	euph	0	0.7	0.3	1.1	-0.8	-2.1	-1.4
Ferns	fern	2.3	0.3	1.6	0.3	1.3	1.9	-0.1
F. dichotoma	fimd	6.9	0	10.1	2.8	7.3	1.5	-2.9
Forb - large	forb	0	0.3	4.2	1.9	2.3	-7.1	-8.0
Forb - small	forb	13.1	13.7	17.6	19.1	-1.5	-5.2	-6.6
H. contortus	hetc	6.4	3.7	2.7	2.2	0.5	5.6	3.7
H. sturtii	hibs	0	0	0.0	0.0	0.0	0.0	0.0
Legume - pal.	legp	15.2	14	13.5	18.9	-5.4	-5.2	-11.0
Legume - unpal.	legp	2.9	1.3	2.0	1.9	0.1	-0.4	-1.2

	Code	2002		Mean 1995 - 2002		clear -trees Mean difference	CLEAR Change 1995 -2002	TREES Change 1995 -2002
		CLEAR	TREES	CLEAR	TREES			
Lilies	lily	0	0	0.0	0.0	0.0	0.0	0.0
M. microphylla	mair	0	0	0.04	0.1	-0.1	0.0	-0.4
Maireana spp	mair	1	0	0.4	0.5	-0.1	-0.7	-2.9
M. americanum	mala	3.2	2.9	1.1	1.5	-0.4	1.5	1.3
M. repens	melr	0.3	0	0.04	0.0	0.0	0.3	0.0
Other per. grass	othg	0.3	1.5	0.2	0.3	-0.1	0.3	1.5
P. effusum	pane	6.5	1.5	2.8	2.4	0.4	-2.7	-0.6
Panicum spp	pani	4.7	4.3	5.0	4.6	0.4	1.8	2.7
Paspalidium spp	pasp	2.6	3.5	2.3	2.4	-0.1	-4.1	-1.1
Portulaca spp	port	0	0	0.2	0.04	0.2	0.0	0.0
Ptilotis spp	ptil	0	2.7	0.2	0.5	-0.4	0.0	2.3
R. minima	rhym	1.9	2.2	2.0	1.6	0.4	0.2	1.8
R. adscendens	rosa	0.7	0.3	0.2	0.9	-0.7	-0.6	-5.1
Lomandra (rush)	rush	0.3	0	0.04	0.0	0.0	0.3	0.0
S. kali	salk	0	0.3	0.2	0.3	-0.1	-1.3	-0.1
S. birchii	sclb	0.7	0.6	0.9	1.9	-1.0	-1.8	-4.3
Sclerolaena spp	scle	0	0	0.05	0.2	-0.2	-0.4	-0.8
S. muricata	sclm	0	0	0.0	0.0	0.0	0.0	0.0
Sedge	sedg	2	1.3	2.0	0.6	1.3	2.0	1.3
Sida spp	sida	3.9	4.4	3.3	5.8	-2.6	-1.9	-5.1
S. subspicatum	sids	2.8	4.9	4.5	6.0	-1.5	-8.0	-2.6
Solanum spp	sola	4.9	1.2	3.9	3.7	0.2	1.2	-5.5
Sporobolus (r'tail)	spor	8.7	1.9	5.0	2.1	2.9	6.6	1.1
Sporobolus (sml)	spor	0	0.7	1.4	3.8	-2.4	-3.7	-4.7
S. scabra	stis	0	0	0.0	0.0	0.0	0.0	0.0
Succulents	succ	0	0	0.0	0.1	-0.1	0.0	0.0
T. triandra	thet	4.8	1.6	2.7	0.6	2.1	4.4	1.6
T. australianus	traa	0	0.6	1.9	2.3	-0.3	-7.9	-4.3
T. loliiformis	tril	8.7	0.6	6.3	7.1	-0.8	-5.1	-9.7
Urochloa spp	uroc	0	0	0.0	0.05	-0.1	0.0	-0.4
V. tenuisecta	vert	8.1	5.6	10.0	13.5	-3.5	7.7	5.6
Vittadinia spp	vitt	0	0	1.4	1.8	-0.3	-3.3	-6.2
Xanthium spp	xant	0	0	0.0	0.0	0.0	0.0	0.0

Appendix F4

Table F4. Plant taxon frequency over the years of the main plants at the Keilambete grazing trial, grouped by grazing pressure

		YEAR								**Mean**	**Range**		All graz press.	
Graz	Taxon code	1994	1995	1996	1997	1998	1999	2000	2001	1994-2001	Max	Min	Max	Min
H	ari calc	1.2	1.7	1.4	2.8	4.3	4.6	5.7	4.4	3.2	5.7	1.2	7.2	1.2
H	ari laza									-	0.0	0.0	10.9	0.0
H	ari lept	8.1								8.1	8.1	8.1	14.2	0.6
H	ari schu									-	0.0	0.0	8.1	0.0
H	ari spp	16.8	0.0	0.4	0.0	5.7	0.8	0.9	7.7	4.0	16.8	0.0	21.5	0.0
H	bot ewar	31.7	38.1	38.3	40.1	57.3	59.4	50.3	56.9	46.5	59.4	31.7	64.8	31.7
H	chl diva	1.8	1.2	0.0	12.6	19.6	14.6	22.7	35.4	13.5	35.4	0.0	35.4	0.0
H	chr fall	38.9	35.6	36.4	36.0	15.0	34.2	34.1	37.9	33.5	38.9	15.0	45.4	14.6
H	dic seri	5.2	4.2	0.4	2.6	0.3	6.5	4.2	3.1	3.3	6.5	0.3	8.3	0.3
H	dig cili	0.6	1.6	0.0	2.7	2.9	6.4	12.9	2.9	3.7	12.9	0.0	12.9	0.0
H	enn grac	0.0	16.3	0.0	19.5	22.9	13.8	20.8	0.0	11.7	22.9	0.0	31.6	0.0
H	enne spp	19.9	0.0	23.5	0.0	2.0	0.1	0.2	12.1	7.2	23.5	0.0	23.9	0.0
H	era soro	7.2	3.1	0.0	3.5	3.3	8.0	0.2	4.8	3.8	8.0	0.0	10.4	0.0
H	eul aure	13.8	8.2	9.7	4.5	1.4	3.6	3.1	2.6	5.9	13.8	1.4	14.2	0.4
H	forbs	71.1	51.5	32.4	42.3	35.9	52.6	56.8	68.5	51.4	71.1	32.4	74.0	29.8
H	het cont	22.8	39.5	31.0	27.9	33.9	38.0	41.4	55.1	36.2	55.1	22.8	55.1	22.8
H	mel repe	1.0	0.6	0.3	4.6	0.0	8.9	4.3	6.0	3.2	8.9	0.0	8.9	0.0
H	nat legu	57.3	44.3	7.9	50.9	6.6	24.3	49.3	51.4	36.5	57.3	6.6	68.7	6.6
H	pan deco	6.9	4.8	1.4	5.3	2.1	3.5	5.5	0.5	3.7	6.9	0.5	6.9	0.5
H	pan effu	19.1	9.2	4.4	5.8	4.6	9.4	7.3	13.7	9.2	19.1	4.4	19.1	3.1
H	pani spp	26.0	0.0	0.0					0.7	6.7	26.0	0.0	26.0	0.0
H	sedges	19.4	28.7	22.7	25.4	9.9	11.3	17.5	11.0	18.2	28.7	9.9	31.3	7.1
H	the tria	17.2	12.8	5.7	5.2	2.3	11.2	5.0	9.5	8.6	17.2	2.3	26.9	2.3
H	tra aust	0.6	2.4	6.0	10.0	14.3	1.6	13.8	3.1	6.5	14.3	0.6	14.3	0.2
H	tri loli	12.1	12.8	15.4	12.6	30.7	11.9	19.8	29.1	18.0	30.7	11.9	30.7	6.1

		YEAR								Mean	Range		All graz press.	
Graz	Taxon code	1994	1995	1996	1997	1998	1999	2000	2001	1994-2001	Max	Min	Max	Min
L	ari calc	2.7	2.1	3.1	3.2	2.4	7.2	6.1	2.7	3.7	7.2	2.1		
L	ari laza		0.0	0.0	0.0	0.0	7.4	8.6	10.9	3.8	10.9	0.0		
L	ari lept	11.5	10.5	14.2	8.0	10.1	0.6	4.0	2.9	7.7	14.2	0.6		
L	ari schu		0.0	7.5	7.5	2.8	7.3	5.0	8.1	5.5	8.1	0.0		
L	ari spp	21.5	0.0	0.0	0.2	4.4	1.3	0.4	4.0	4.0	21.5	0.0		
L	bot ewar	32.1	34.5	41.1	42.5	56.7	59.6	54.6	59.6	47.6	59.6	32.1		
L	chl diva	2.3	1.3	0.2	5.4	10.2	9.2	10.0	13.6	6.5	13.6	0.2		
L	chr fall	41.1	45.4	39.5	29.7	14.6	22.5	31.3	35.8	32.5	45.4	14.6		
L	dic seri	4.1	3.3	1.8	3.5	1.7	8.3	7.0	5.2	4.3	8.3	1.7		
L	dig cili	0.2								0.2	0.2	0.2		
L	enn grac	0.7	10.1	0.0	24.8	31.0	29.8	26.2	0.0	15.3	31.0	0.0		
L	enne spp	14.8	0.0	22.1	0.1	1.2	0.4	0.0	16.7	6.9	22.1	0.0		
L	era soro	6.8	4.0	0.0	4.3	5.4	9.9	0.2	5.8	4.6	9.9	0.0		
L	eul aure	14.2	13.3	12.2	5.8	1.3	2.8	6.0	4.6	7.5	14.2	1.3		
L	forbs	74.0	58.5	37.5	34.8	29.8	52.6	62.8	51.8	50.2	74.0	29.8		
L	het cont	24.3	38.0	36.4	35.1	39.6	45.2	46.3	52.9	39.7	52.9	24.3		
L	mel repe	0.9	1.0	0.7	4.1	1.3	8.2	8.0	6.0	3.8	8.2	0.7		
L	nat legu	60.3	40.7	7.8	35.6	9.6	27.4	39.7	42.2	32.9	60.3	7.8		
L	pan deco	3.6	4.6	3.3	5.4	2.4	3.4	3.2	1.1	3.4	5.4	1.1		
L	pan effu	15.2	10.1	6.8	3.1	4.5	9.2	6.5	9.0	8.0	15.2	3.1		
L	pani spp	18.7	0.0	0.0					0.7	4.9	18.7	0.0		
L	sedges	30.9	31.3	27.4	15.6	10.5	8.0	14.0	8.1	18.2	31.3	8.0		
L	the tria	16.3	17.3	14.3	16.5	16.1	20.4	21.7	26.9	18.7	26.9	14.3		
L	tra aust	1.1								1.1	1.1	1.1		
L	tri loli	14.1	12.3	15.1	7.4	18.8	6.1	12.0	12.2	12.2	18.8	6.1		

		YEAR								Mean	Range		All graz press.	
Graz	Taxon code	1994	1995	1996	1997	1998	1999	2000	2001	1994-2001	Max	Min	Max	Min
M	ari calc	1.8	2.1	1.7	2.2	1.9	4.2	4.7	2.7	2.7	4.7	1.7		
M	ari laza		0.0	0.0	0.0	0.0	6.6	5.3	6.9	2.7	6.9	0.0		
M	ari lept	12.4	10.8	8.1	5.0	6.0	0.6	1.4	2.0	5.8	12.4	0.6		
M	ari schu									-	0.0	0.0		
M	ari spp	21.3	0.0	1.0	0.7	5.3	0.6	1.1	6.4	4.5	21.3	0.0		
M	bot ewar	36.1	41.2	50.3	44.9	61.8	59.3	55.8	64.8	51.8	64.8	36.1		
M	chl diva	3.5	2.1	0.0	8.0	15.0	17.7	19.8	29.0	11.9	29.0	0.0		
M	chr fall	43.4	42.1	40.2	35.1	14.8	29.0	35.3	38.0	34.7	43.4	14.8		
M	dic seri	6.4	4.9	1.4	4.6	0.6	7.1	8.3	7.6	5.1	8.3	0.6		
M	dig cili	0.5	0.9	0.4	1.6	1.3	8.4	5.4	1.1	2.4	8.4	0.4		
M	enn grac	1.4	14.2	0.0	27.3	29.8	26.4	31.6	0.0	16.3	31.6	0.0		
M	enne spp	16.9	0.0	23.9	0.2	1.7	0.3	0.2	22.7	8.2	23.9	0.0		
M	era soro	6.4	3.4	0.0	4.9	3.5	10.4	0.8	7.3	4.6	10.4	0.0		
M	eul aure	12.9	12.1	11.9	5.0	0.4	2.1	3.2	5.4	6.6	12.9	0.4		
M	forbs	73.3	64.5	41.0	49.7	36.2	57.7	66.1	65.7	56.8	73.3	36.2		
M	het cont	25.1	37.2	39.8	32.1	36.7	47.9	48.5	54.1	40.2	54.1	25.1		
M	mel repe	0.2								0.2	0.2	0.2		
M	nat legu	68.7	54.7	10.7	52.8	7.2	29.5	54.6	49.1	40.9	68.7	7.2		
M	pan deco	6.0	5.5	2.0	6.2	1.6	1.6	6.1	0.9	3.7	6.2	0.9		
M	pan effu	15.5	12.1	6.0	7.6	5.8	13.4	8.6	13.3	10.3	15.5	5.8		
M	pani spp	21.5	0.0	0.0					1.6	5.8	21.5	0.0		
M	sedges	24.5	14.9	14.5	13.6	7.1	8.9	9.7	8.8	12.7	24.5	7.1		
M	the tria	19.0	18.2	7.0	11.6	5.2	13.6	10.2	13.3	12.2	19.0	5.2		
M	tra aust	0.2	1.0	2.5	4.2	5.7	1.5	8.6	0.7	3.0	8.6	0.2		
M	tri loli	10.2	11.4	12.6	6.7	22.4	8.7	15.4	22.3	13.7	22.4	6.7		

Appendix F5

Table F5. Major pasture taxa frequency at Keilambete over the years, meaned for tree cover over all utilisation rates

Average frequency		YEAR								Mean	Range		All trees	
Trtmt	Plant taxon	1994	1995	1996	1997	1998	1999	2000	2001	1994-2001	Max	Min	Max	Min
C	ari calc	2.2	1.6	2.1	3.0	3.8	7.6	5.6	3.4	3.7	7.6	1.6	7.6	1.6
C	ari laza									-	0.0	0.0	0.0	0.0
C	ari lept	14.4	11.3	11.0	5.7	9.5	0.2	2.7	2.6	7.2	14.4	0.2	14.4	0.2
C	ari schu		0.0	4.8	6.2	1.7	6.4	2.9	5.5	3.9	6.4	0.0	6.4	0.0
C	ari spp	21.0	17.5	21.4	17.8	24.1	24.2	21.1	28.9	22.0	28.9	17.5	28.9	0.0
C	bot ewar	34.7	37.6	45.1	43.9	56.5	64.8	54.9	63.3	50.1	64.8	34.7	64.8	31.9
C	chl diva	1.9	1.5	0.0	12.3	20.8	16.8	21.3	28.1	12.8	28.1	0.0	28.1	0.0
C	chr fall	40.1	38.2	38.1	31.2	12.4	25.0	28.4	32.6	30.7	40.1	12.4	43.9	12.4
C	dic seri	4.2	4.6	0.7	3.7	0.9	5.3	5.8	4.1	3.7	5.8	0.7	9.3	0.7
C	dig cili	1.9	1.9	0.2	2.1	2.6	8.4	9.2	1.4	3.5	9.2	0.2	9.2	0.2
C	enn grac	1.4	13.1	0.0	25.7	30.3	18.2	24.4	0.0	14.1	30.3	0.0	30.3	0.0
C	enne spp	19.1	0.0	24.2	0.0	1.2	0.0	0.0	13.2	7.2	24.2	0.0	24.2	0.0
C	era soro	7.7	5.3	0.0	4.6	6.8	11.8	0.3	7.5	5.5	11.8	0.0	11.8	0.0
C	eul aure	14.3	11.2	11.7	5.2	0.6	1.6	3.8	3.5	6.5	14.3	0.6	14.3	0.6
C	forbs	74.9	59.5	37.5	46.4	38.1	50.0	63.4	60.7	53.8	74.9	37.5	74.9	29.9
C	het cont	24.5	40.7	38.8	33.5	38.0	44.9	47.0	57.5	40.6	57.5	24.5	57.5	23.7
C	mel repe	1.0	0.4	0.4	3.8	0.8	8.9	7.8	6.7	3.7	8.9	0.4	8.9	0.3
C	nat legu	62.3	51.8	12.4	53.4	9.4	27.3	53.3	51.8	40.2	62.3	9.4	62.3	5.3
C	pan deco	3.5	5.8	2.6	6.1	2.9	4.2	6.3	1.5	4.1	6.3	1.5	7.4	0.2
C	pan effu	19.2	13.7	7.0	7.5	6.1	9.9	8.1	12.6	10.5	19.2	6.1	19.2	3.5
C	pani spp	21.8	18.5	9.3	13.4	9.0	14.0	14.5	14.8	14.4	21.8	9.0	21.8	0.0
C	sedges	19.4	23.1	21.8	15.6	10.9	8.0	14.0	8.0	15.1	23.1	8.0	30.5	7.5
C	the tria	21.2	20.1	9.8	12.3	9.7	16.0	16.7	20.1	15.7	21.2	9.7	21.2	6.0
C	tra aust	0.5	1.0	3.3	5.1	6.4	0.4	8.8	1.4	3.4	8.8	0.4	8.8	0.4
C	tri loli	12.9	12.3	14.0	7.8	23.2	4.6	13.2	14.9	12.9	23.2	4.6	27.4	4.6

Average frequency						YEAR				Mean	Range Max	Min	All trees	
Trtmt	Plant taxon	1994	1995	1996	1997	1998	1999	2000	2001	1994-2001			Max	Min
T	ari calc	1.6	2.4	2.0	2.4	1.9	3.0	5.4	3.1	2.7	5.4	1.6		
T	ari laza									-	0.0	0.0		
T	ari lept	7.0	7.8	7.7	5.3	3.3	0.9	1.9	1.1	4.4	7.8	0.9		
T	ari schu		0.0	3.6	4.5	1.4	4.1	3.7	4.0	3.0	4.5	0.0		
T	ari spp	17.1	0.0	0.4	0.4	6.0	0.8	1.4	6.5	4.1	17.1	0.0		
T	bot ewar	31.9	38.3	41.4	41.1	60.7	54.0	52.2	57.6	47.1	60.7	31.9		
T	chl diva	3.2	1.6	0.1	5.1	9.1	10.9	13.6	23.9	8.4	23.9	0.1		
T	chr fall	42.2	43.9	39.3	36.0	17.2	32.2	38.7	41.8	36.4	43.9	17.2		
T	dic seri	6.2	3.6	1.7	3.4	0.8	9.3	7.2	6.6	4.9	9.3	0.8		
T	dif cili	3.6								3.6	3.6	3.6		
T	enn grac	0.0	13.9	0.0	22.0	25.5	28.4	28.1	0.0	14.7	28.4	0.0		
T	enne spp	15.3	0.0	22.2	0.2	2.0	0.5	0.2	21.0	7.7	22.2	0.0		
T	era soro	5.9	1.7	0.0	3.9	1.3	7.0	0.6	4.4	3.1	7.0	0.0		
T	eul aure	12.9	11.3	10.9	5.0	1.5	4.0	4.4	4.9	6.9	12.9	1.5		
T	forbs	70.7	56.9	36.5	38.1	29.9	58.6	60.3	63.3	51.8	70.7	29.9		
T	het cont	23.7	35.7	32.7	29.9	35.5	42.5	43.7	50.5	36.8	50.5	23.7		
T	mel repe	0.3								0.3	0.3	0.3		
T	nat legu	61.9	41.3	5.3	39.5	6.2	26.8	42.4	43.4	33.3	61.9	5.3		
T	pan deco	7.4	4.1	1.9	5.2	1.1	1.4	3.5	0.2	3.1	7.4	0.2		
T	pan effu	13.9	7.2	4.5	3.5	3.8	11.4	6.8	11.5	7.8	13.9	3.5		
T	pani spp	21.4	0.0	0.0					1.3	5.7	21.4	0.0		
T	sedges	30.5	26.8	21.3	20.8	7.5	10.8	13.5	10.6	17.7	30.5	7.5		
T	the tria	13.7	12.1	8.2	9.9	6.0	14.1	7.8	12.9	10.6	14.1	6.0		
T	tra aust	0.8	2.0	3.7	6.3	8.3	2.0	8.6	1.7	4.2	8.6	0.8		
T	tri loli	11.4	12.0	14.7	10.0	24.7	13.2	18.3	27.4	16.4	27.4	10.0		

APPENDIX G. Pasture basal area details – point frame method

Appendix G1

Table G1. Glentulloch - Pasture Basal Area (%) – Grazing Trial, by Transects and Paddock means
3000 + points Grazing trial; 1500 points Burning trial, 5-point frame

	Pdk 1 – CL1				Pdk 2 – CM1				Pdk 3 – CH1				Pdk 4 – TL1				Pdk 5 – TM1				Pdk 6 – TH1			
Year	**T 1**	**T 2**	**T 3**	**Pdk av**	**T 1**	**T 2**	**T 3**	**Pdk av**	**T 1**	**T 2**	**T 3**	**Pdk av**	**T 1**	**T 2**	**T 3**	**Pdk av**	**T 1**	**T 2**	**T 3**	**Pdk av**	**T 1**	**T 2**	**T 3**	**Pdk av**
1995	2.90	2.20	2.70	2.60	2.40	3.50	4.80	3.57	2.30	1.60	1.50	1.80	2.40	3.50	4.40	3.43	1.30	1.80	1.40	1.50	1.00	0.80	0.50	0.77
1996	4.40	5.20	3.20	4.27	3.20	3.47	5.70	4.12	4.53	3.20	3.07	3.60	2.93	3.60	2.93	3.15	1.73	2.13	1.73	1.86	2.00	1.47	1.87	1.78
1997	5.00	4.38	3.75	4.38	2.19	2.60	2.81	2.53	4.27	3.02	3.65	3.65	2.29	2.40	3.75	2.81	1.98	2.71	2.92	2.53	1.46	1.15	1.56	1.39
1998	6.60	5.40	4.40	5.47	4.50	5.90	4.40	4.93	5.00	6.30	4.60	5.30	3.70	4.00	7.00	4.90	1.40	2.70	3.60	2.57	3.00	0.90	3.40	2.43
1999	4.30	3.10	2.60	3.33	1.80	2.30	3.20	2.43	3.20	2.10	1.60	2.30	2.20	1.40	1.60	1.73	0.90	0.90	0.90	0.90	2.00	1.20	1.00	1.40
2000	5.78	4.50	3.73	4.67	2.83	3.51	3.63	3.32	2.34	3.24	4.20	3.26	2.16	2.55	3.22	2.64	1.47	2.06	1.66	1.73	2.05	1.27	1.37	1.56
2001	6.19	6.02	4.55	5.59	5.42	5.57	9.12	6.70	4.41	5.15	5.24	4.93	7.94	4.81	3.70	5.48	4.79	5.24	5.33	5.12	5.45	4.08	3.40	4.31
Mean	**5.03**	**4.40**	**3.56**	**4.33**	**3.19**	**3.84**	**4.81**	**3.95**	**3.72**	**3.52**	**3.41**	**3.55**	**3.37**	**3.18**	**3.80**	**3.45**	**1.94**	**2.51**	**2.50**	**2.32**	**2.42**	**1.55**	**1.87**	**1.95**

	Pdk 7 – CL2				Pdk 8 – CM2				Pdk 9 – CH2				Pdk 10 – TL2				Pdk 11 – TM2				Pdk 12 – TH2			
	T 1	**T 2**	**T 3**	**Pdk av**	**T 1**	**T 2**	**T 3**	**Pdk av**	**T 1**	**T 2**	**T 3**	**Pdk av**	**T 1**	**T 2**	**T 3**	**Pdk av**	**T 1**	**T 2**	**T 3**	**Pdk av**	**T 1**	**T 2**	**T 3**	**Pdk av**
1995	2.60	2.80	3.60	3.00	2.70	2.10	2.00	2.27	1.40	1.20	1.90	1.50	2.50	1.80	1.20	1.83	2.30	2.10	1.50	1.97	1.10	1.00	1.50	1.20
1996	5.47	3.73	4.27	4.49	3.47	4.13	4.67	4.09	2.00	2.40	3.07	2.49	2.67	2.53	2.27	2.49	2.13	2.67	2.40	2.40	1.87	2.13	1.87	1.96
1997	4.06	3.75	5.21	4.34	3.75	3.33	3.13	3.40	3.33	2.71	2.29	2.78	1.98	1.77	2.50	2.08	1.77	3.02	2.19	2.33	3.02	1.56	1.46	2.01
1998	5.80	5.20	4.50	5.17	5.50	4.40	5.20	5.03	6.30	3.20	5.20	4.90	3.00	2.90	3.20	3.03	3.40	3.90	2.30	3.20	3.60	3.60	2.90	3.37
1999	2.50	2.50	2.40	2.47	3.40	2.50	3.60	3.17	2.20	1.60	2.30	2.03	1.00	0.80	1.50	1.10	0.70	1.60	1.30	1.20	0.90	1.50	1.10	1.17
2000	4.17	4.00	5.00	4.39	4.02	3.04	3.33	3.46	4.83	3.68	3.47	3.99	1.67	1.17	2.15	1.66	1.27	3.33	1.85	2.15	1.96	3.33	1.20	2.16
2001	6.02	6.30	7.79	6.71	5.58	6.02	7.52	6.38	5.59	6.15	4.80	5.52	4.53	4.10	4.23	4.29	3.66	5.38	4.83	4.62	4.54	4.12	4.00	4.22
Mean	**4.38**	**4.04**	**4.68**	**4.37**	**4.06**	**3.65**	**4.21**	**3.97**	**3.66**	**2.99**	**3.29**	**3.32**	**2.48**	**2.15**	**2.44**	**2.36**	**2.18**	**3.14**	**2.34**	**2.55**	**2.43**	**2.46**	**2.00**	**2.30**

Table G2. Glentulloch - Pasture Basal Area (%) at Burning Trial site, by Transects and Plot means

	CB1	CB1		CB2	CB2		CB3	CB3		CN1	CN1		CN2	CN2		CN3	CN3	
Year	**T 1**	**T 2**	**Plot av**	**T 1**	**T 2**	**Plot av**	**T 1**	**T 2**	**Plot av**	**T 1**	**T 2**	**Plot av**	**T 1**	**T 2**	**Plot av**	**T 1**	**T 2**	**Plot av**
1995																		
1996	2.80	2.60	2.70	2.60	0.60	1.60	0.60	1.60	1.10	2.20	1.60	1.90	2.60	2.20	2.40	2.00	1.60	1.80
1997	2.80	3.00	2.90	3.00	2.60	2.80	1.60	3.20	2.40	4.20	3.20	3.70	4.00	2.40	3.20	4.40	5.00	4.70
1998																		
1999	7.00	4.80	5.90	7.40	5.80	6.60	7.20	7.40	7.30	4.20	2.40	3.30	6.20	6.00	6.10	4.80	3.00	3.90
2000	3.14	3.06	3.10	3.11	4.07	3.59	3.04	3.69	3.36	3.81	4.57	4.19	4.23	3.78	4.01	3.85	3.75	3.80
2001	11.11	8.40	9.75	6.26	5.48	5.87	8.38	7.59	7.98	5.19	5.20	5.20	4.88	4.16	4.52	2.93	3.67	3.30
Mean	**5.37**	**4.37**	**4.87**	**4.47**	**3.71**	**4.09**	**4.16**	**4.70**	**4.43**	**3.92**	**3.39**	**3.66**	**4.38**	**3.71**	**4.05**	**3.59**	**3.40**	**3.50**

	TB1	TB1		TB2	TB2		TB3	TB3		TN1	TN1		TN2	TN2		TN3	TN3	
	T 1	**T 2**	**Plot av**	**T 1**	**T 2**	**Plot av**	**T 1**	**T 2**	**Plot av**	**T 1**	**T 2**	**Plot av**	**T 1**	**T 2**	**Plot av**	**T 1**	**T 2**	**Plot av**
1995																		
1996	1.00	0.20	0.60	0.80	0.60	0.70	0.80	1.40	1.10	0.80	1.20	1.00	0.60	0.40	0.50	1.00	0.80	0.90
1997	0.80	1.20	1.00	1.00	1.20	1.10	1.80	1.40	1.60	2.00	1.60	1.80	1.20	2.00	1.60	2.00	2.20	2.10
1998																		
1999	2.60	4.00	3.30	6.60	5.20	5.90	6.40	6.00	6.20	4.00	3.60	3.80	5.80	6.00	5.90	5.40	7.00	6.20
2000	2.86	1.36	2.11	2.08	1.54	1.81	1.50	2.12	1.81	1.51	1.50	1.50	2.26	2.08	2.17	3.24	2.67	2.95
2001	5.69	4.55	5.12	6.06	4.29	5.17	2.69	4.10	3.40	3.65	4.53	4.09	4.72	3.46	4.09	3.20	4.69	3.94
Mean	**2.59**	**2.26**	**2.43**	**3.31**	**2.56**	**2.94**	**2.64**	**3.00**	**2.82**	**2.39**	**2.49**	**2.44**	**2.92**	**2.79**	**2.85**	**2.97**	**3.47**	**3.22**

Appendix G2

Table G3. Glentulloch Pasture Basal Area - Summary for species in the Grazing trial for 3 example paddocks 1995 - 2000
Numbers in body of table are strikes on crowns for that species in that paddock in that year

	1 CL						2 CM						3 CH					
Species	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
A. calycina						1					1	1						
A. ramosus						5					21	26						
Aristida spp.	18	16	12	8		2	45	38	25	35			14	6	1		3	1
B. bladhii		3	8	1				5	5	2		2			1			
B. decipiens		1	8	6	8	6	13	12	8	10	18	6	3	4	3	4		2
Brunoniella										1					2	2		
C. lappulacea										1								
C. ciliaris	5	6	9	5	2	3				2		1	1		2			
C. sieberi																		
C. divaricata		11	13	107	66	54	1	11	13	52	31	33	5	14	46	124	63	7
C. ventricosa						3												
C. fallax	9		2	3	3		9		2				2		2			
C. refractus											1							
Cyperus spp.			1					6		3				2		1		
D. sericeum		6	8	2	1	18	6		2	2		1	1	11	2	1		4
Digitaria spp																		
Enneapogon spp.	14	22	19			25	14	7	11	22		12	9	22	29	7		14
E. ramosus	24	24	38	29	17	18	3	1		4			5	8	1	9	3	2
Eragrostis spp.	2	1	1				1	1					1	1	3			
E. pseudoacrotrica		1	3															
E. alsinoides										1								
Fimbristylis spp.																		
G. tabacina										1								

	1 CL						2 CM						3 CH					
Species	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
H. contortus					1				1			5						
Ixiolaena spp.																		
Malvastrum																		
O. corniculata																		
Panicum spp.	1									1								
Paspalidium spp.																		
Pycnosorus spp.				1														
S. birchii																1		
Sida spp.																		
Sporobolus spp.	1	3				1		1					2	2			1	3
Stipa spp.																		
T. triandra						3				3					2			
T. australianus			2				2			2			3	5				
T. loliiformis	3	1		2		3	13	7	2	5	0	2	8	6		9	3	3
Urochloa spp.	1																	
Verbena			2		1				4	1					11	1		1
Basal Area (%)	2.60	4.22	4.38	5.47	3.30	4.67	3.57	3.96	2.53	4.93	2.40	3.32	1.80	2.70	3.65	5.30	2.43	3.26

Appendix G3

The next 6 figures show extra data from the charting of fixed quadrats at Glentulloch (Section 6.2)

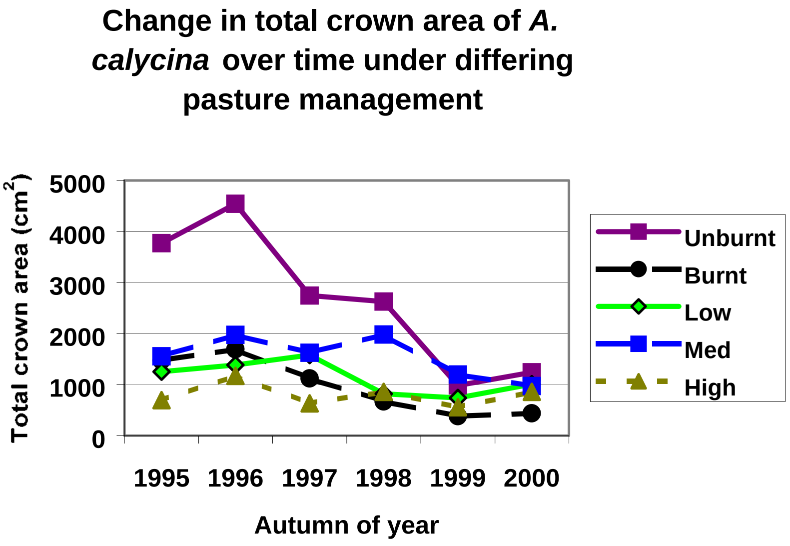


Figure E. *Aristida calycina* total crown area under different defoliation regimes

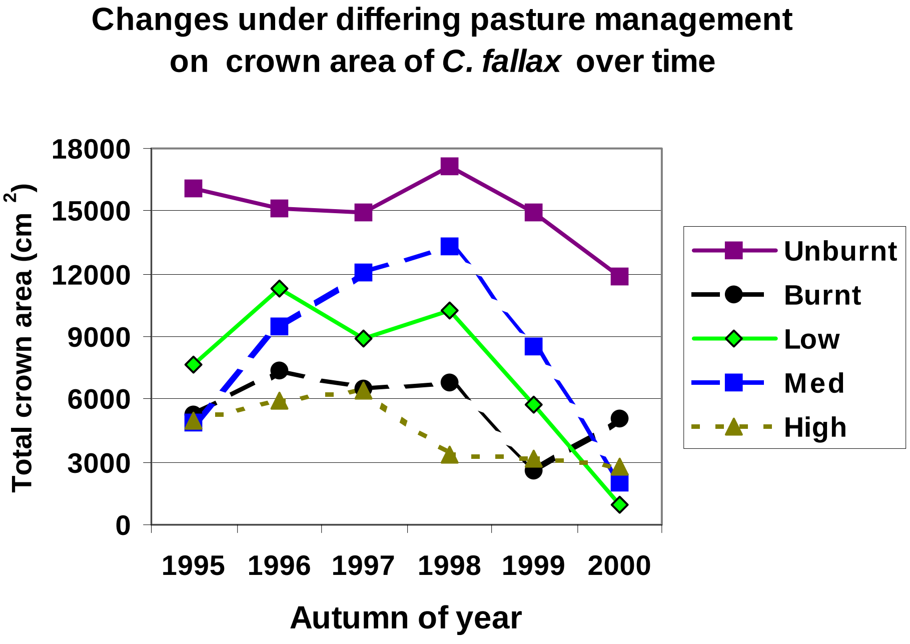


Figure J. Effect of defoliation management on total crown area of *Chrysopogon fallax*

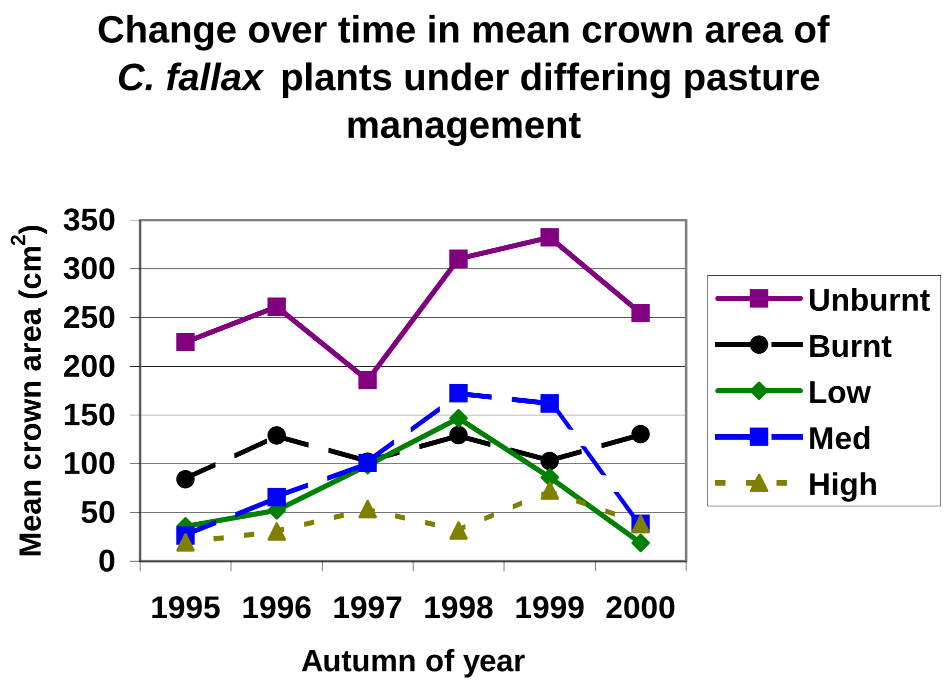


Figure P. Changes over time in the mean visible existence of *C. fallax* plants under differing defoliation regimes.

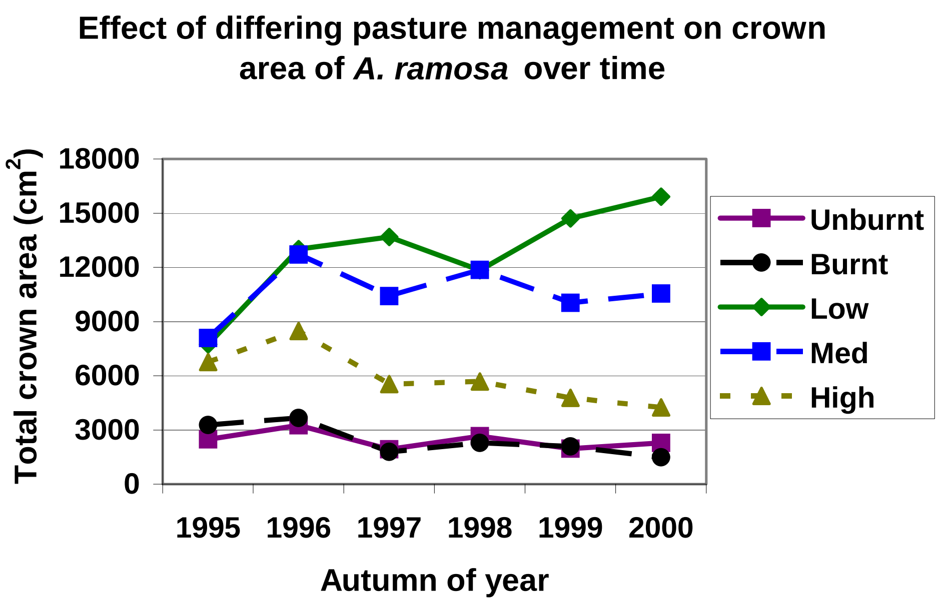


Figure U. Effect on *Aristids ramosa* crowns of differing defoliation regimes over time

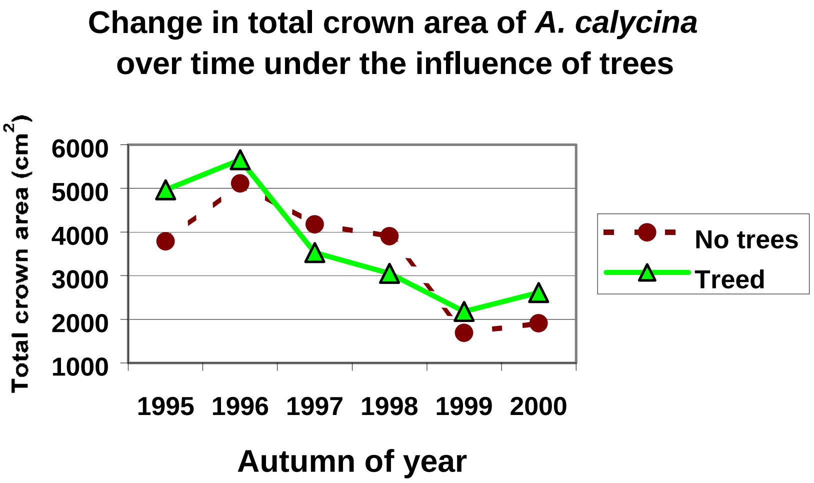


Figure W. Change in total crown area of *A. calycina* over time in the presence or absence of trees, summed over both trials.

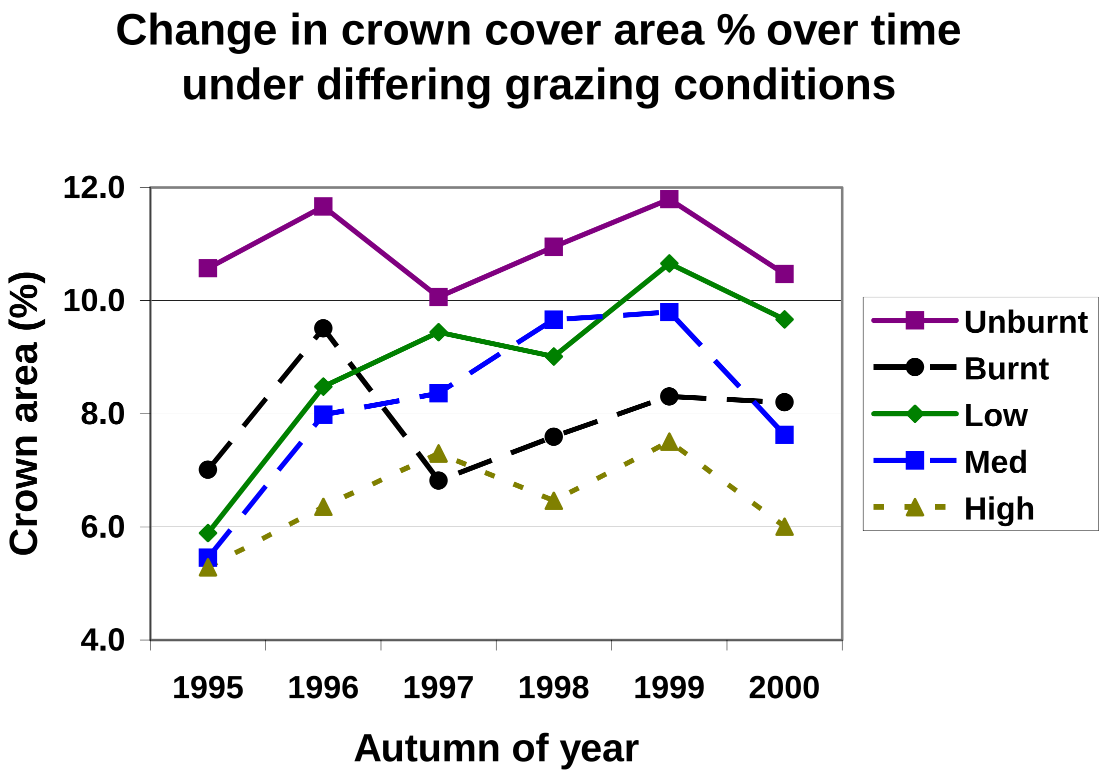


Figure Z1. Change in total crown area % over time of all 6 focus grasses under differing management

Appendix G4

Table G4. PASTURE BASAL AREA - FIXED TRANSECTS - SEPT/OCT 1997 KEILAMBETE (Example meta data from 2 paddocks)

	Cleared Low GP								*Cleared Medium GP*						
	Rep 1		Rep 2						Rep 1		Rep 2				
	Strikes	BA %	Strikes	BA %	Mean				Strikes	BA %	Strikes	BA %	Mean		
Bo ewa	24	0.80	30	1.00	0.90	R1	R2	Bo ewa	14	0.47	16	0.53	0.50	R1	R2
Ch fal	2	0.07	4	0.13	0.10	0.43	0.72	Ch fal	3	0.10	2	0.07	0.08	0.33	0.20
He con	23	0.77	51	1.70	1.23	Maj PG		He con	23	0.77	5	0.17	0.47	Maj PG	
Th tri	3	0.10	1	0.03	0.07	2.30		Th tri		0.00	1	0.03	0.02	1.07	
Dic ser		0.00		0.00	0.00			Dic ser		0.00		0.00	0.00		
Dig spp		0.00		0.00	0.00			Dig spp		0.00		0.00	0.00		
Eul aur		0.00		0.00	0.00	Min PG		Eul aur		0.00		0.00	0.00	Min PG	
Pan spp		0.00		0.00	0.00	0.00		Pan spp	1	0.03	1	0.03	0.03	0.03	
Ari spp	4	0.13		0.00	0.07	Und PG		Ari spp		0.00		0.00	0.00	Und PG	
Chl spp	1	0.03		0.00	0.02	0.07		Chl spp		0.00		0.00	0.00	0.00	
Enn spp	2	0.07	2	0.07	0.07			Enn spp		0.00	4	0.13	0.07		
Era spp	5	0.17		0.00	0.08			Era spp		0.00		0.00	0.00		
Eri spp		0.00		0.00	0.00			Eri spp		0.00		0.00	0.00		
Others		0.00		0.00	0.00			Others		0.00		0.00	0.00		
Pas spp		0.00		0.00	0.00	Mix G		Pas spp		0.00		0.00	0.00	Mix G	
Spo spp		0.00		0.00	0.00	0.17		Spo spp		0.00		0.00	0.00	0.07	
Dac rad		0.00		0.00	0.00			Dac rad		0.00		0.00	0.00		
Tra aus		0.00		0.00	0.00	Low G		Tra aus		0.00		0.00	0.00	Low G	
Tri lol	1	0.03		0.00	0.02	0.02		Tri lol		0.00		0.00	0.00	0.00	
	65	2.17	88	2.93					41	1.37	29	0.97			
						Min								Min	
						R1	R2							R1	R2
						0.03	0.00							0.00	0.01

APPENDIX H. Pasture composition details, Ironbark and Poplar box sites

Appendix H1

Table H1a. Dry matter yield (kg/ha) of major pasture species each year at Keilambete in the low grazing pressure paddocks

		DMY of main species									Range		All grz pres		
		Year								Mean	Max	Min			Type
Grazing pressure	Plant name	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	1994-2001			Max	Min	
L	ari calc	5.0	11.8	21.8	22.8	12.3	18.8	23.0	8.8	15.5	23.0	5.0	28.3	1.7	s
L	ari laza						27.0	44.5	106.5	59.3	106.5	27.0	106.5	4.8	r
L	ari lept	18.7	35.7	89.3	89.8	83.0	6.0	26.0	30.3	47.3	89.8	6.0	89.8	0.8	r
L	ari schu	8.2	0.0	14.9	64.8	10.5	45.0	19.0	37.3	25.0	64.8	0.0	64.8	0.0	r
L	ari spp	35.0	7.0	13.9	21.3	16.0	12.8	12.9	25.1	18.0	35.0	7.0	35.0	1.0	
L	bot ewar	194.7	438.5	964.3	1477.0	1400.0	1833.5	1360.0	1888.8	1194.6	1888.8	194.7	1888.8	88.2	d
L	chl diva	7.1	4.6	0.2	39.5	28.8	32.8	27.5	53.8	24.3	53.8	0.2	120.0	0.0	r
L	chr fall	103.7	195.5	51.6	226.3	34.5	112.8	110.0	206.0	130.0	226.3	34.5	226.3	11.0	d
L	dic seri	10.8	14.8	8.3	36.5	10.0	82.0	64.8	54.5	35.2	82.0	8.3	82.0	0.1	r
L	dig cili	0.3	2.4	0.0	8.5	0.3	13.3	6.0	1.5	4.0	13.3	0.0	22.5	0.0	
L	enn grac	0.5	21.3	0.0	168.8	74.5	80.3	56.3	0.0	50.2	168.8	0.0	168.8	0.0	r
L	enne spp	25.5	7.6	4.8	52.9	20.8	20.1	14.1	15.3	20.1	52.9	4.8	52.9	1.4	m
L	era soro	5.8	11.3	0.0	27.5	17.0	22.0	0.3	35.8	15.0	35.8	0.0	35.8	0.0	m
L	eul aure	55.7	83.2	47.9	105.8	9.3	42.8	56.0	62.8	57.9	105.8	9.3	105.8	0.5	s
L	forbs	33.2	29.4	11.5	35.5	14.0	30.0	46.8	15.3	26.9	46.8	11.5	66.3	5.6	s
L	het cont	145.0	445.8	421.2	1143.8	603.8	913.5	748.3	1684.3	763.2	1684.3	145.0	1684.3	39.6	d
L	mel repe	1.7	3.3	1.8	53.8	6.0	64.3	33.0	28.3	24.0	64.3	1.7	67.8	0.0	r
L	nat legu	16.7	11.3	2.2	37.0	6.0	21.5	31.8	16.5	17.9	37.0	2.2	80.0	0.4	r
L	pan deco	5.2	18.9	5.3	42.8	13.3	13.5	9.5	6.0	14.3	42.8	5.2	58.0	0.0	r
L	pan effu	25.4	26.6	8.8	17.8	21.5	38.0	19.0	43.5	25.1	43.5	8.8	48.5	2.0	m
L	pani spp	30.6	22.8	7.1	30.3	17.4	25.8	14.3	17.3	20.7	30.6	7.1	47.9	1.0	
L	sedges	17.9	27.0	4.8	20.3	6.5	3.8	2.3	6.8	11.1	27.0	2.3	27.0	0.8	m
L	the tria	26.9	92.4	42.3	310.8	294.3	487.5	485.0	993.0	341.5	993.0	26.9	993.0	1.8	d
L	tra aust	1.7	1.0	0.5	5.8	0.5	0.0	2.3	0.8	1.6	5.8	0.0	15.5	0.0	m
L	tri loli	2.7	3.6	4.0	5.5	13.8	4.5	3.0	6.5	5.4	13.8	2.7	15.5	1.6	m
	TOTAL	778.0	1515.6	1726.3	4044.1	2713.6	3951.2	3215.2	5344.3						

Table H1b. Dry matter yield (kg/ha) of major pasture species each year at Keilambete in the moderate grazing pressure paddocks

		DMY of main species Year									**Range**	
Grazing pressure	Plant name	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**Mean** 1994-2001	Max	Min
M	ari calc	2.4	5.2	4.4	9.8	3.0	10.3	13.3	3.8	6.5	13.3	2.4
M	ari laza						21.3	24.3	46.3	30.6	46.3	21.3
M	ari lept	20.8	28.6	18.1	22.5	23.5	1.0	9.3	6.0	16.2	28.6	1.0
M	ari schu	8.2	0.0	0.7	14.5	0.5	14.3	6.5	9.5	6.8	14.5	0.0
M	ari spp	34.3	4.6	2.8	7.9	4.4	5.8	8.1	11.8	9.9	34.3	2.8
M	bot ewar	257.7	417.3	562.4	1242.5	912.0	1454.5	1132.5	1878.0	982.1	1878.0	257.7
M	chl diva	10.2	4.8	0.0	39.8	27.5	60.8	60.0	85.5	36.1	85.5	0.0
M	chr fall	104.9	129.3	21.0	166.5	14.3	131.3	128.0	154.8	106.2	166.5	14.3
M	dic seri	12.2	19.0	4.2	52.3	0.3	42.3	47.5	43.3	27.6	52.3	0.3
M	dig cili	1.3	2.2	0.0	9.3	0.5	22.5	14.3	2.3	6.5	22.5	0.0
M	enn grac	0.4	31.0	0.0	99.5	38.5	49.3	64.0	0.0	35.3	99.5	0.0
M	enne spp	27.4	7.8	1.4	28.9	9.9	12.4	16.1	11.1	14.4	28.9	1.4
M	era soro	4.5	6.8	0.0	20.5	11.5	22.3	0.8	24.0	11.3	24.0	0.0
M	eul aure	47.8	62.6	20.6	53.5	0.5	13.3	25.5	38.3	32.7	62.6	0.5
M	forbs	23.2	26.7	10.9	66.3	11.5	18.8	37.3	15.5	26.2	66.3	10.9
M	het cont	128.3	389.5	163.3	738.8	202.0	824.5	669.5	1079.5	524.4	1079.5	128.3
M	mel repe	0.4	0.3	0.0	15.5	3.5	11.8	15.3	22.5	8.7	22.5	0.0
M	nat legu	15.8	22.3	0.5	76.0	3.5	12.3	32.5	9.5	21.6	76.0	0.5
M	pan deco	9.9	16.3	1.1	58.0	1.5	5.3	10.3	0.0	12.8	58.0	0.0
M	pan effu	20.8	27.9	2.3	37.8	16.0	48.5	19.0	26.0	24.8	48.5	2.3
M	pani spp	30.7	22.1	1.8	47.9	8.8	26.9	14.6	10.1	20.4	47.9	1.8
M	sedges	15.5	7.3	1.5	12.0	0.8	8.0	1.3	8.3	6.8	15.5	0.8
M	the tria	30.6	62.7	4.6	111.0	66.3	194.8	134.8	322.3	115.9	322.3	4.6
M	tra aust	0.4	0.2	0.3	2.5	2.5	1.0	9.3	1.8	2.2	9.3	0.2
M	tri loli	2.3	3.4	1.6	2.5	12.0	3.0	3.5	13.5	5.2	13.5	1.6
	TOTAL	809.9	1297.8	823.5	2935.4	1374.5	3015.5	2497.0	3823.2			

Table H1c. Dry matter yield (kg/ha) of major pasture species each year at Keilambete in the high grazing pressure paddocks

		DMY of main species									Range	
		Year								**Mean**	Max	Min
Grazing pressure	Plant name	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	1994-2001		
H	ari calc	1.7	4.0	2.0	16.5	22.3	28.3	11.0	11.8	12.2	28.3	1.7
H	ari laza						17.3	4.8	12.2	11.4	17.3	4.8
H	ari lept	9.8	14.3	2.6	21.5	12.5	0.8	3.8	1.5	8.3	21.5	0.8
H	ari schu	4.7	0.0	2.1	35.3	4.0	22.5	5.8	19.0	11.7	35.3	0.0
H	ari spp	20.7	3.2	1.0	9.0	5.2	10.1	3.0	8.3	7.6	20.7	1.0
H	bot ewar	210.3	284.9	88.2	617.0	219.3	1546.5	589.8	739.5	536.9	1546.5	88.2
H	chl diva	1.7	2.3	0.0	69.3	17.5	95.0	40.8	120.0	43.3	120.0	0.0
H	chr fall	96.6	80.0	21.9	194.8	11.0	223.8	93.3	97.3	102.3	223.8	11.0
H	dic seri	15.3	10.5	0.1	12.3	0.3	80.8	14.5	7.0	17.6	80.8	0.1
H	dig cili	2.2	3.4	0.0	7.5	2.8	21.5	21.8	1.5	7.6	21.8	0.0
H	enn grac	0.0	23.2	0.0	58.8	16.8	25.0	28.5	0.0	19.0	58.8	0.0
H	enne spp	33.1	5.9	1.5	15.5	4.6	6.3	7.1	3.3	9.6	33.1	1.5
H	era soro	3.7	2.0	0.0	6.5	7.3	22.0	0.0	8.3	6.2	22.0	0.0
H	eul aure	48.5	25.7	4.5	39.3	1.0	35.3	23.3	27.5	25.6	48.5	1.0
H	forbs	21.7	18.3	5.6	43.5	6.5	28.3	41.5	12.0	22.2	43.5	5.6
H	het cont	137.7	256.4	39.6	542.5	72.8	704.0	299.0	976.8	378.6	976.8	39.6
H	mel repe	2.7	0.9	0.0	40.3	0.0	67.8	7.5	14.3	16.7	67.8	0.0
H	nat legu	11.9	13.3	0.4	80.0	0.8	12.0	12.5	11.8	17.8	80.0	0.4
H	pan deco	15.6	7.3	0.2	21.8	1.5	29.8	5.5	0.0	10.2	29.8	0.0
H	pan effu	30.7	18.1	2.0	33.8	4.5	46.3	6.5	31.8	21.7	46.3	2.0
H	pani spp	46.3	12.7	1.0	27.8	3.0	38.0	6.0	11.2	18.2	46.3	1.0
H	sedges	9.1	20.0	4.1	22.5	3.8	6.8	2.5	3.8	9.1	22.5	2.5
H	the tria	42.4	37.3	1.8	61.5	3.8	190.8	38.8	104.8	60.1	190.8	1.8
H	tra aust	1.0	3.0	1.3	15.5	7.3	1.0	11.3	0.8	5.1	15.5	0.8
H	tri loli	2.6	4.9	2.9	6.3	15.5	7.3	5.0	13.0	7.2	15.5	2.6
	TOTAL	770	852	183	1998	443	3267	1283	2237			

Table H1d. Pasture composition data from the large COMM paddock at Keilambete during the later part of the trial period

Component yields (kg/ha)				Year		
Taxon unit	Spp. Number	1998	1999	2000	2001	Average 1998 - 01
Ari spp	11	157.1	67.7	82.8	69.0	94.2
Bot bla	24	12.3	0.0	2.5	88.0	34.3
Bot ewa	25	1286.1	899.0	1266.1	930.4	1095.4
Cen cil	7	0.0	0.3	2.7	0.0	1.5
Chloris spp	13	12.2	39.0	16.5	8.1	19.0
Chr fal	43	171.9	172.9	181.9	284.6	202.8
Dic ser	29	6.1	37.5	9.3	17.1	17.5
Dig spp	15	0.0	10.8	9.9	1.0	7.2
Enn spp	16	49.3	103.4	48.4	19.8	55.2
Erag spp	17	9.2	19.9	32.0	16.6	19.4
Eri spp	48	0.0	24.6	5.0	0.0	14.8
Eul aur	30	7.0	64.0	67.0	4.7	35.7
Fimb dich	453	0.6	0.0	0.0	0.0	0.6
Forbs	6	14.0	10.0	14.1	13.0	12.8
Het con	31	1058.0	868.1	1406.7	2002.5	1333.8
Mel rep	76	0.0	7.5	3.4	1.2	4.0
Native legume	4	12.0	11.7	17.7	16.8	14.6
Panicum spp	51	4.2	17.7	7.0	22.7	12.9
Pasp spp	52	0.0	2.1	0.0	0.0	2.1
Per rar	19	0.0	0.2	0.0	0.0	0.2
Sedges	3	2.1	5.1	2.9	0.1	2.6
Spor spp	21	0.0	0.1	0.0	0.0	0.1
The ave	317	4.4	3.0	24.7	0.0	10.7
The tri	36	76.4	241.8	347.7	504.8	292.7
Tra aus	22	0.0	0.1	1.8	0.0	1.0
Tri lol	63	12.2	1.5	10.4	3.7	7.0

Table H1e. Percent composition of the pasture by the main components in of the large COMM paddock at Keilambete

% Composition		Year				
Taxon unit	**Spp. Number**	**1998**	**1999**	**2000**	**2001**	**Average 1998 - 01**
Ari spp	11	5.4	2.6	2.3	1.7	3.0
Bot bla	24	0.4	0	0.1	2.2	0.9
Bot ewa	25	44.4	34.5	35.6	23.2	34.4
Cen cil	7	0	0	0.1	0	0.1
Chloris spp	13	0.4	1.5	0.5	0.2	0.7
Chr fal	43	5.9	6.6	5.1	7.1	6.2
Dic ser	29	0.2	1.4	0.3	0.4	0.6
Dig spp	15	0	0.4	0.3	0	0.2
Enn spp	16	1.7	4.0	1.4	0.5	1.9
Erag spp	17	0.3	0.8	0.9	0.4	0.6
Eri spp	48	0	0.9	0.1	0	0.5
Eul aur	30	0.2	2.5	1.9	0.1	1.2
Fimb dich	453	0	0	0	0	0.0
Forbs	6	0.5	0.4	0.4	0.3	0.4
Het con	31	36.5	33.3	39.5	50.0	39.8
Mel rep	76	0	0.3	0.1	0	0.1
Native legume	4	0.4	0.4	0.5	0.4	0.4
Panicum spp	51	0.1	0.7	0.2	0.6	0.4
Pasp spp	52	0	0.1	0	0	0.1
Per rar	19	0	0	0	0	0.0
Sedges	3	0.1	0.2	0.1	0	0.1
Spor spp	21	0	0	0	0	0.0
The ave	317	0.2	0.1	0.7	0	0.3
The tri	36	2.6	9.3	9.8	12.6	8.6
Tra aus	22	0	0	0.1	0	0.1
Tri lol	63	0.4	0.1	0.3	0.1	0.2

Table H1f. Frequency of occurrence of the main pasture taxa in the large COMM paddock at Keilambete, 1998 – 2001

Frequency %				Year		
Taxon unit	**Spp. Nbr**	**1998**	**1999**	**2000**	**2001**	**Average**
Aristida spp.	11	25.1	24.1	17.2	21.4	22.0
B. bladhii	24	0.4		0.4	3.6	1.5
B. ewartiana	25	66.3	54.9	58.8	58	59.5
C. ciliaris	7		0.7	0.4		0.6
Chloris spp.	13	3.7	8.1	5.6	8	6.4
C. fallax	43	40.4	41.4	36.4	52.7	42.7
D. radulans	14			0.4		0.4
D. sericeum	29	0.4	5.8	2	4.5	3.2
Digitaria spp.	15		3.4	2.4	0.9	2.2
Enneapogon spp.	16	26.2	26.4	18.4	17	22.0
Eragrostis spp.	17	4.1	10.8	9.2	6.2	7.6
Eriochloa spp.	48		3.1	2.4		2.8
E. aurea	30	0.4	6.1	4.8	0.9	3.1
F. dichotoma	453	2.2				2.2
Forbs	6	25.8	54.6	56	61.6	49.5
H. contortus	31	50.6	62	68	79.5	65.0
M. repens	76		1.4	1.6	1.8	1.6
Native legume	4	12.7	32.9	53.6	60.7	40.0
Other grasses	1			0.4		0.4
Other intro grasses	2			0.4		0.4
Panicum spp.	51	1.5	4.4	3.6	6.2	3.9
Paspalidium spp.	52		0.7	0.4		0.6
Paspalum spp.	54			0.4		0.4
P. rara	19		0.7			0.7
Sedges	3	6.4	5.4	7.2	5.4	6.1
Sporobolus spp.	21		0.7			0.7
T. avenacea	317	0.4	0.7	0.4		0.5
T. triandra	36	5.6	16.9	16.4	20.5	14.9
T. australianus	22		0.3	1.6		1.0
T. loliiformis	63	9	3.4	19.2	15.2	11.7

Appendix H2

Table H2. Typical Swiftsynd harvest data sheet from Keilambete

SITE KEILAMBETE - Clear | DATE 3.3.95 | Sp. 1 = BOTEWA | Species 3 = HETCON
HARVEST TWO | OPERATOR DO PF | Sp. 2 = CHRFAL

Q.	Pasture Height			Cover Estimate				Cover Point Photo				Yield estimate					Fresh weights (g/0.75m^2)				
no.	1	2	mean	green	dead	litter	bare	green	dead	litter	bare	1st	2nd	3rd	other	dicot	1st	2nd	3rd	other	dicot
1	5	7	6	98			2					1	95	0	1	5	17.5	0	372.4	12.8	185.1
2	6	11	8.5	90			10					50	30	1	1	20	64.7	2	43.5	12.9	370.8
3	3	15	9	55			45					0	60	30	1	10	0	32.3	170.9	2	99.1
4	11	15	13	65		5	30					5	80	0	5	10	22.5	10.8	148.1	28.9	140
5	9	14	11.5	90			10					20	60	5	1	15	7.3	18.8	116.4	22.3	288.9
6	10	4	7	25		5	70					85	0	0	10	5	52.6	0	0	32.2	37.3
7	10	3	6.5	35		5	60					80	0	0	15	5	114.6	0	0	11.7	31.7
8	7	7	7	35			65					45	0	0	45	10	47.8	0	0	90.2	31.2
9	5	7	6	25			75					40	30	0	20	10	30.1	0	28.9	26.5	18.9
10																					

Species		Fresh wts	Dry wts	% dry matter	
1	bag 1	80.1	28.1	0.35	
1	bag 2	66.4	25	0.38	
1	bag 3	86.8	34.2	0.39	0.3738
2	bag 1	17.7	7.5	0.42	
2	bag 2	16.1	8.3	0.52	
2	bag 3	0	0		0.4696
3	bag 1	154.2	42.6	0.28	
3	bag 2	201.7	70.9	0.35	
3	bag 3	156.3	52.4	0.34	0.3211
oth	bag 1	43.3	23	0.53	
oth	bag 2	49.5	21.7	0.44	
oth	bag 3	76.8	33.7	0.44	0.4695
dicot	bag 1	234.2	69.1	0.30	

Separations (grams)

Species	G. Leaf	%D.W.	D. Leaf	%D.W.	G. Stm	%D.W.	D. Stm	%D.W.	Inflor	%D.W.
1 WET	12.7	0.83	0.67	0.87	11.9	0.57		n.a.	2.3	0.39
DRY	10.5		0.58		6.8				0.9	
2 WET	20.3	0.49	2.09	0.86	5.5	0.42		n.a.	2.1	0.62
DRY	9.9		1.8		2.3				1.3	
3 WET	24.4	0.71	0.59	0.85	15.6	0.34		n.a.	1.3	0.31
DRY	17.3		0.5		5.3				0.4	

Appendix H3

Table H3. Typical Swiftsynd pasture & soil data from a treed plot at Keilambete

Date	6.09.95	16.11.95	1.02.96	9.04.96	13.06.96
Rain to:	start date	26.5	144.5	7	75
Soil Moisture - gravimetric(%)					
0-10 cm	5.75	5.90	6.65	4.65	7.19
10-30 cm	11.45	10.95	13.37	10.42	11.42
30-70 cm	10.99	8.68	9.52	9.80	9.59
Total Yield (kg DM/ha)		152	977	1181	1851
Bot ewa		7	84	500	433
Het con		58	374	440	799
Chr fal		24	136	146	205
Other grasses		45	346	81	346
Forbs		19	37	15	68
Plant Parts					
(%)	Bot ewa				
Green leaf		100	66	0	11
Dead leaf			15	46	10
Green stem			17	54	19
Dead stem			0	0	1
Seed head			2	0	2
	Het con				
Green leaf		100	85	0	25
Dead leaf			7	95	29
Green stem			9	0	13
Dead stem			0	5	0
Seed head			0	0	11
	Chr fal				
Green leaf		100	67	0	38
Dead leaf			19	95	20
Green stem			13	0	5
Dead stem			0	5	7
Seed head			1	0	3

Appendix H4

Table H4. "GLENTULLOCH" GRAZING TRIAL - SPECIES COMPOSITION BY WEIGHT by TREES - meaned over REPS & GRAZING PRESSURE

75 Species set	code	1995		1996		1997		1998		1999		2000		2001		2002		Mean 1995-2002	
		CLEAR	TREES	CLEAR	TREES	CLEAR	TREES	CLEAR	TREES	CLEAR	TREES	CLEAR	TREES	CLEAR	TREES	CLEAR	TREES	CLEAR	TREES
Species																			
Annual grasses	anngra	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0
Aristida calycina	arical	1.6	3.2	3	3.7	0.7	2	1.3	2.8	0.9	1.9	0.6	4.2	0.5	3.2	1.1	5	1.2	3.2
Aristida latifolia	arilat	1.6	0.2	1.4	0.4	1	0.9	1.2	0.3	0.9	0.4	0.9	0.8	0.9	0.7	0.9	0.6	1.1	0.5
Aristida leptopoda	arilep	0.9	0	0.8	0.1	2.7	0.5	1	0.1	0.9	0.1	1.6	0.4	1.3	0	2	0.1	1.4	0.2
Aristida ramosa	ariram	17.7	22.8	10.9	6.4	4.9	7.4	13.4	15.8	6.5	5.6	9.7	12.8	18.7	21.1	22.1	25.3	13.0	14.6
Aristida spp	arists	0.1	1.6	4.7	13.4	6.1	8.3	2.6	5.8	1.5	9	1.4	4	1.4	1.2	0.4	0.8	2.3	5.5
Asteraceae (daisy)	asterd	0	0	0	0.1	0	0	0	0.1	0.2	0.1	0	0.1	0	0.1	0.3	0.3	0.1	0.1
Asteraceae spp	asters	0	0	0.3	0.7	0	0.2	0	0	0.1	0.1	0.1	0.2	0	0.2	0	0.1	0.1	0.2
Bothriochloa bladhii	botbla	1.3	0.9	3	4.4	2.3	2.3	1.7	1.3	2.4	1.8	2	1.4	1.1	0.6	1.4	0.4	1.9	1.6
Bothriochloa decipiens	botdec	5.5	12.6	8.2	14.5	6.6	25.6	11.8	18.7	12.6	26.8	10.5	25.4	14.7	26.8	9.6	24.2	9.9	21.8
Bothriochloa ewartiana	botewa	0.1	0.1	0	0	0.1	0.1	0.2	0	0.1	0	0.1	0	0.1	0.1	0.3	0	0.1	0.04
Brachiaria spp	brachs	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0
Brunoniella australis	bruaus	0.5	0.8	0.8	2.1	0.7	0.7	0.7	0.9	0.2	0.5	0.4	0.6	0.3	0.4	0.6	0.5	0.5	0.8
Calotis spp	calots	0.1	1.1	0.2	0.3	1.2	1.6	0.4	1.3	3.1	1	2.4	2.1	0.2	0.6	0.1	0.4	1.0	1.0
Cenchrus ciliaris	cencil	0.8	0.3	0.4	0	0.5	0	0.7	0.2	0.3	0.2	0.5	0.2	0.2	0.2	0.5	0.3	0.5	0.2
Chenopodiaceae	chenos	0	0	0	0	0	0	0.3	0.3	0	0	0.1	0	0	0	0.2	0.4	0.1	0.1
Chloris divaricata	chldiv	2.1	1	3.6	2	7.5	3.1	7.6	2.3	11.7	5.3	8.4	3.7	7.6	4.2	5	3.4	6.7	3.1
Chloris spp	chlors	1.3	4	0.6	0.7	0.7	1.1	1.9	1.7	1.1	1.8	2.3	2.1	0.4	0.7	0.7	0.7	1.1	1.6
Chrysopogon fallax	chrfal	2	2.9	2.4	6.1	1.2	3.5	1.8	5.3	2.7	3.7	2.4	2.6	1.5	4.1	1.2	4.8	1.9	4.1
Cymbopogon spp	cymbos	0.2	0.7	1.1	1.4	0.3	0.8	1	0.5	1.2	1.5	2	1.1	1	0.5	2.4	0.6	1.1	0.9
Cynodon dactylon	cyndac	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0
Cyperus spp	cypers	0.3	0.8	0.2	0.2	0.2	0.5	0.5	1.3	0.3	1.2	0.5	1.6	0.4	0.9	0.4	1.4	0.3	1.0
Dichanthium sericeum	dicser	4.6	5.4	7.5	0.9	17	4.3	7.6	1.4	12.5	3.4	13.1	3.8	9.7	3	7.2	2.6	9.9	3.1
Digitaria divaricatissima	digdiv	0.3	0	0.2	0.1	0.1	0.3	0	0	0	0	0.1	0	0	0	0	0	0.1	0.05
Digitaria spp	digits	0.2	0.3	0.1	0.1	0.1	0.1	0	0	0.1	0	0.3	0.8	0.3	0.2	0.3	0	0.2	0.2
Enneapogon spp	enneas	10.3	4.8	9.6	6.3	13.1	6	11.9	7.8	5.6	5.4	11.8	4.9	5.5	4.2	7.5	5.7	9.4	5.6
Enteropogon acicularis	entaci	0.2	0	0.3	0	1.7	1.2	0.2	0.1	0	0.1	0	0	0	0	0	0	0.3	0.2
Enteropogon ramosus	entram	21.4	15.4	20.6	9.8	14.4	9.1	16.7	10.6	14.4	6.9	12.1	7.7	16.7	10.4	19.5	8.1	17.0	9.7
Eragrostis spp	eragrs	0	0.4	1.3	1	1.3	1.6	0.8	1.5	0.8	1.7	0.8	1.3	1	0.9	0.2	0.4	0.8	1.1
Eragrostis lacunaria	eralac	0.2	0.2	0	0.5	0	0.3	0.1	0.3	0.3	0.3	0.3	0.8	0.1	0.7	0.2	0.6	0.1	0.5
Eragrostis molybdea	eramol	1.5	1.6	0.8	0.5	1.5	1.3	0.8	0.2	1.5	1.8	2.3	1.6	1.9	0.9	1.1	1	1.4	1.1
Erio. pseudoacrotricha	eripse	0.3	0.6	0.8	0.1	1.1	0.2	0.4	0	1.1	0.4	0.2	0.1	0.8	0.4	0.1	0	0.6	0.2
Eulalia aurea	eulaur	0	0	0	0	0.1	0	0.2	0	0	0	0	0.1	0	0	0.2	0	0.1	0.01
Euphorbia / Phyllanthus	euphos	0	0.1	0	0	0	0	0	0.1	0	0.1	0.1	0.2	0	0.1	0.1	0.1	0.0	0.1

75 Species set	code	1995		1996		1997		1998		1999		2000		2001		2002		Mean 1995-2002	
		CLEAR	TREES	CLEAR	TREES	CLEAR	TREES	CLEAR	TREES	CLEAR	TREES	CLEAR	TREES	CLEAR	TREES	CLEAR	TREES	CLEAR	TREES
Species																			
Ferns	fern	0	0	0.1	0.9	0	0	0	0.1	0	0.1	0	0	0	0	0	0	0.0	0.1
Fimbristylis dichotoma	fimdic	0.4	1.1	0.1	0.6	0.4	1.2	0	2	0.2	0.3	0.5	0.4	0.1	0.7	0.5	0.3	0.3	0.8
Forb - large	forblg	0.2	0.1	0	0	0	0.2	0	0.2	0.3	0.2	0	0	0	0.1	0	0.2	0.1	0.1
Forb - small	forbsm	2.6	1.1	0.3	2.2	1.4	1.7	0.9	2.3	0.9	1	0.7	1	0.2	0.6	0.4	0.6	0.9	1.3
Heteropogon contortus	hetcon	0.1	0.4	0.4	0.9	1	2.2	0.9	1.5	1.2	1.5	0.8	1.6	0.5	0.9	1.5	1.1	0.8	1.3
Hibiscus sturtii	hibstu	0	0	0	0	0	0.1	0	0	0	0	0	0	0	0	0	0	0.0	0.01
Legume - palatable	legpal	0	0.2	0.3	0.8	0.1	0.3	0.4	0.3	0.5	0.6	0.3	0.7	0.3	0.5	0.2	0.8	0.3	0.5
Legume - unpalatable	legpoi	0.1	0.1	0.1	0.2	0	0.1	0	0	0.1	0.1	0	0.1	0	0.1	0.2	0.3	0.1	0.1
Lilies	lilysp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0
Maireana microphylla	maircb	0.5	0.5	0	0.1	0	0.2	0	0.2	0	0	0	0.3	0.1	0	0	0.1	0.1	0.2
Maireana spp	maires	0	0	0.3	0.1	0.2	0.2	0.1	0	0.2	0	0	0	0	0.1	0	0.1	0.1	0.06
Malvastrum americanum	malame	2.7	0.5	0.3	0.3	0.6	0.5	1	0.8	1.1	0.8	0.2	0.4	0.3	0.3	1.3	0.5	0.9	0.5
Melinis repens	melrep	0	0	0	0	0	0	0	0	0	0	0.1	0	0	0	0	0	0.01	0.0
Other grass (Perrennial)	othgrl	0	0	0	0	0	0.3	0	0	0	0.1	0	0	0.2	0	0.2	0.2	0.05	0.1
Panicum effusum	paneff	0.1	0.2	0	0	0.1	0	0.2	0.1	0.1	0.5	0	0.1	0.2	0.2	0.3	0.1	0.1	0.1
Panicum spp	panics	0.4	0.1	0.5	0.4	0.5	1.1	0.6	0.3	0.7	1	1	1.2	0.1	0.1	0.2	0	0.5	0.5
Paspalidium spp	paspas	0.1	0.7	0.3	0.4	0	0.4	0	0	0.3	0.1	0.2	0.4	0.2	0.2	0	0.1	0.1	0.3
Portulaca spp	portus	0	0	0.5	0.8	0	0.1	0.3	0.1	0	0	0.1	0.1	0	0	0.1	0.1	0.1	0.1
Ptilotus spp	ptilos	0	0	0	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.01
Rhynchosia minima	rhymin	0	0	0	0	0	0.1	0.1	0	0.2	0.1	0.2	0.2	0.1	0	0.1	0.1	0.1	0.06
Rostellaria adscendens	rosads	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0
Lomandra (rushes)	rush	0.1	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0	0.03	0.01
Salsola kali	salkal	0.2	0.1	0	0	0.1	0	0.1	0.1	0	0.2	0	0	0	0.1	0	0.1	0.05	0.1
Sclerolaena birchii	sclbir	7.3	6.4	3.1	3.7	1.7	1.6	1.5	0.7	1.5	1.4	0.5	1	0.7	1.5	1.4	1	2.2	2.2
Sclerolaena spp	sclers	0.7	0.4	0.4	0.3	0.3	0.1	0	0	0	0	0.1	0	0	0	0.4	0.3	0.2	0.1
Sclerolaena muricata	sclmur	0	0	0	0	0	0	0	0	0.1	0.1	0	0.1	0	0	0	0	0.01	0.03
Sedge	sedge	0.5	0.2	0.5	1.4	0	0	0	0	0.2	0.4	0.1	0.1	0	0	0.1	0.1	0.2	0.3
Sida spp	sidasp	0.7	0.5	0.7	0.7	0.2	0.1	0.4	0.8	0.5	0.7	0.4	0.8	0.1	0.4	0.5	0.7	0.4	0.6
Sida subspicatum	sidsub	0.1	0.1	0.4	2.9	0.3	1.2	0.1	1.5	0.7	2.2	0.1	0.4	0.7	1	0.5	1.8	0.4	1.4
Solanum spp	solans	0.1	0.3	0.3	0.2	0.2	0.4	0.1	0.7	0.1	0.2	0.4	0.4	0.1	0.1	0.3	0.5	0.2	0.3
Sporobolus (ratstail)	sporat	1.9	0.9	0.5	0.8	1.4	0.5	0.2	0.9	2.2	1.7	3.6	1.8	5.4	1.6	3	0.3	2.3	1.1
Sporobolus (small)	sporsm	1.2	0.7	1.7	1	0.7	0.5	0.5	0.3	0.4	0.2	0.8	0.8	1.1	0.6	0.8	0.4	0.9	0.6
Stipa scabra	stisca	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0
Succulents (Chenopods)	succul	0	0	0.1	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0.01
Themeda triandra	thetri	0.1	0.4	0.3	0.3	1.3	0.3	1.2	0.4	1.3	0.1	0.8	0.1	0.1	0.2	0.1	0	0.6	0.2
Tragus australianus	traaus	2	1	2.8	0.9	0.8	0.5	0.4	0.5	0	0.2	0.5	0.2	0	0.1	0.1	0.3	0.8	0.5
Tripogon loliiformis	trilol	1.9	1.9	2.2	3.3	0.6	1.5	3.2	4.6	1.4	1.6	0.9	1.2	2.6	3.3	1.6	1.4	1.8	2.3

75 Species set	**code**	**1995**		**1996**		**1997**		**1998**		**1999**		**2000**		**2001**		**2002**		**Mean 1995-2002**	
Species		**CLEAR**	**TREES**	**CLEAR**	**TREES**	**CLEAR**	**TREES**	**CLEAR**	**TREES**	**CLEAR**	**TREES**	**CLEAR**	**TREES**	**CLEAR**	**TREES**	**CLEAR**	**TREES**	**CLEAR**	**TREES**
Urochloa spp	urochs	0.6	0.1	0.6	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0.03
Verbena tenuisecta	verten	0.1	0.1	0.1	0.3	0.3	0.5	0.5	0.6	1.4	1.4	0.8	1.5	0.1	0.4	0.1	0.3	0.4	0.6
Vittadinia spp	vittad	0	0	0.1	0	0.6	0.8	0	0.2	1.3	1.8	0.1	0.2	0	0	0	0	0.3	0.4
Xanthium spp	xanths	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0

Appendix H5

Table H5. Effects of tree killing on pasture composition (%) at the ungrazed burning trial site at Glentulloch, meaned over reps and burning

Pasture Species % Composition by Tree Competition Effect						Species Composition % changes		
Sorted descending order Killed	Mean 1995 - 2002		*Sorted descending order Treed*	Mean 1995 - 2002			Killed Change	Treed Change
Species/ group	**KILLED**	**TREED**		**KILLED**	**TREED**		**1995-2002**	**1995-2002**
Bothriochloa decipiens	22.0	33.5	Bothriochloa decipiens	22.0	33.5	Annual grasses	0	0
Chrysopogon fallax	10.3	11.1	Chrysopogon fallax	10.3	11.1	Aristida calycina	-1.3	-5.9
Dichanthium sericeum	7.9	5.2	Aristida ramosa	4.7	6.5	Aristida latifolia	-1.2	-0.2
Calotis spp	5.6	0.4	Enneapogon spp	3.2	5.4	Aristida leptopoda	-0.4	-0.7
Aristida calycina	5.1	5.0	Dichanthium sericeum	7.9	5.2	Aristida ramosa	3.5	-1.3
Aristida ramosa	4.7	6.5	Aristida calycina	5.1	5.0	Aristida spp	0.5	0.6
Bothriochloa bladhii	4.0	2.4	Aristida spp	2.9	3.2	Asteraceae (daisy)	0.1	0
Enneapogon spp	3.2	5.4	Bothriochloa bladhii	4.0	2.4	Asteraceae spp	0	0.1
Themeda triandra	2.9	0.6	Cenchrus ciliaris	2.9	2.1	Bothriochloa bladhii	5.1	-0.5
Cenchrus ciliaris	2.9	2.1	Sida subspicatum	1.0	1.9	Bothriochloa decipiens	-23.1	8.2
Aristida spp	2.9	3.2	Cymbopogon spp	2.6	1.8	Bothriochloa ewartiana	0	0.7
Cymbopogon spp	2.6	1.8	Heteropogon contortus	2.2	1.7	Brachiaria spp	0	0
Chloris spp	2.5	1.2	Verbena tenuisecta	1.4	1.7	Brunoniella australis	-0.1	-0.6
Heteropogon contortus	2.2	1.7	Enteropogon ramosus	2.0	1.6	Calotis spp	0.1	-0.6
Enteropogon ramosus	2.0	1.6	Chloris spp	2.5	1.2	Cenchrus ciliaris	2.9	4.8
Eragrostis spp	1.8	1.2	Eragrostis spp	1.8	1.2	Chenopodaceae	0.1	0
Aristida latifolia	1.4	0.8	Panicum spp	1.1	1.2	Chloris divaricata	1.3	-0.2
Verbena tenuisecta	1.4	1.7	Forb - small	0.7	0.8	Chloris spp	-0.8	-0.3
Chloris divaricata	1.4	0.7	Aristida latifolia	1.4	0.8	Chrysopogon fallax	-3.3	-4.9
Sporobolus (ratstail)	1.3	0.5	Cyperus spp	0.2	0.7	Cymbopogon spp	4.7	1.6
Panicum spp	1.1	1.2	Tripogon loliiformis	0.3	0.7	Cynodon dactylon	0	0
Sida subspicatum	1.0	1.9	Chloris divaricata	1.4	0.7	Cyperus spp	0.1	0.6
Eulalia aurea	0.7	0.4	Aristida leptopoda	0.4	0.7	Dichanthium sericeum	4.3	3.3
Forb - small	0.7	0.8	Sporobolus (small)	0.2	0.7	Dig. divaricatissima	0	0.1
Panicum effusum	0.7	0.5	Legume - palatable	0.4	0.6	Digitaria spp	-0.1	-0.2
Eragrostis molybdea	0.6	0.6	Eragrostis molybdea	0.6	0.6	Enneapogon spp	-3.2	-0.8
Forb - large	0.6	0.2	Themeda triandra	2.9	0.6	Enteropogon acicularis	-0.6	-0.7
Fimbristylis dichotoma	0.5	0.2	Panicum effusum	0.7	0.5	Enteropogon ramosus	3.7	1.4
Legume - palatable	0.4	0.6	Sporobolus (ratstail)	1.3	0.5	Eragrostis spp	1.5	0.1

Pasture Species % Composition by Tree Competition Effect						Species Composition % changes		
Sorted descending order Killed	Mean 1995 - 2002		*Sorted descending order Treed*	Mean 1995 - 2002			Killed Change	Treed Change
Species/ group	KILLED	TREED		KILLED	TREED		1995-2002	1995-2002
Paspalidium spp	0.4	0.4	Eulalia aurea	0.7	0.4	Eragrostis lacunaria	-1.1	-0.6
Aristida leptopoda	0.4	0.7	Paspalidium spp	0.4	0.4	Eragrostis molybdea	-0.5	-0.8
Dig. divaricatissima	0.3	0.2	Calotis spp	5.6	0.4	Erio. pseudoacrotricha	-0.7	-0.4
Eragrostis lacunaria	0.3	0.4	Sclerolaena birchii	0.1	0.4	Eulalia aurea	0.9	0.9
Digitaria spp	0.3	0.1	Sida spp	0.2	0.4	Euphorbiaceae	0	-0.1
Enteropogon acicularis	0.3	0.3	Eragrostis lacunaria	0.3	0.4	Ferns	0	0
Solanum spp	0.3	0.3	Enteropogon acicularis	0.3	0.3	Fimbristylis dichotoma	-0.1	0
Erio. pseudoacrotricha	0.3	0.2	Solanum spp	0.3	0.3	Forb - large	0	-0.5
Tripogon loliiformis	0.3	0.7	Brunoniella australis	0.2	0.3	Forb - small	-0.3	-1.1
Sida spp	0.2	0.4	Erio. pseudoacrotricha	0.3	0.2	Heteropogon contortus	6	4.7
Cyperus spp	0.2	0.7	Tragus australianus	0.1	0.2	Hibiscus sturtii	0	0
Sedge	0.2	0.1	Digitaria divaricatissima	0.3	0.2	Legume - palatable	-0.1	-0.3
Brunoniella australis	0.2	0.3	Fimbristylis dichotoma	0.5	0.2	Legume - unpalatable	-0.1	-0.1
Sporobolus (small)	0.2	0.7	Forb - large	0.6	0.2	Lilies	0	0
Tragus australianus	0.1	0.2	Asteraceae spp	0.1	0.1	Maireana microphylla	0	0
Sclerolaena birchii	0.1	0.4	Digitaria spp	0.3	0.1	Maireana spp	0	-0.1
Vittadinia spp	0.1	0.1	Vittadinia spp	0.1	0.1	Malv. americanum	0	0.2
Ferns	0.1	0.0	Malvastrum americanum	0.1	0.1	Melinis repens	0.1	0
Salsola kali	0.1	0.04	Other grass (Perennial)	0.0	0.1	Other grass (Perennial)	0	0.4
Asteraceae spp	0.1	0.1	Bothriochloa ewartiana	0.03	0.1	Panicum effusum	-0.4	-0.4
Malv. americanum	0.1	0.1	Sedge	0.2	0.1	Panicum spp	0.6	0.3
Other grass (Perrennial)	0.04	0.1	Rhynchosia minima	0.04	0.1	Paspalidium spp	-0.1	-0.3
Rhynchosia minima	0.04	0.1	Sclerolaena spp	0.01	0.06	Portulaca spp	0	0
Bothriochloa ewartiana	0.03	0.1	Legume - unpalatable	0.03	0.04	Ptilotis spp	0	0.1
Legume - unpalatable	0.03	0.04	Ptilotis spp	0.0	0.04	Rhynchosia minima	0	0.1
Asteraceae (daisy)	.01	0.0	Salsola kali	0.1	0.04	Rostellaria adscendens	0	-0.2
Chenopodaceae	.01	0.01	Euphorbia / Phyllanthus	0.0	0.03	Lomandra (rushes)	0	0
Melinis repens	.01	0.0	Rostellaria adscendens	0.0	0.03	Salsola kali	-0.7	0.2
Portulaca spp	.01	0.0	Chenopodaceae	0.01	0.01	Sclerolaena birchii	-0.5	-1.4
Sclerolaena spp	.01	0.06	Maireana spp	0.0	0.01	Sclerolaena spp	-0.1	0
Annual grasses	0.0	0.0	Urochloa spp	0.0	0.01	Sclerolaena muricata	0	0
Brachiaria spp	0.0	0.0	Annual grasses	0.0	0.0	Sedge	0	0

Pasture Species % Composition by Tree Competition Effect						Species Composition % changes		
Sorted descending order Killed	Mean 1995 - 2002		*Sorted descending order Treed*	Mean 1995 - 2002			Killed Change 1995-2002	Treed Change 1995-2002
Species/ group	**KILLED**	**TREED**		**KILLED**	**TREED**			
Cynodon dactylon	0.0	0.0	Asteraceae (daisy)	0.01	0.0	Sida spp	0.1	-0.1
Euphorbia / Phyllanthus	0.0	0.03	Brachiaria spp	0.0	0.0	Sida subspicatum	-2.5	-1.3
Hibiscus sturtii	0.0	0.0	Cynodon dactylon	0.0	0.0	Solanum spp	0	-0.4
Lilies	0.0	0.0	Ferns	0.09	0.0	Sporobolus (ratstail)	1.7	0.2
Maireana microphylla	0.0	0.0	Hibiscus sturtii	0.0	0.0	Sporobolus (small)	-0.5	-1.1
Maireana spp	0.0	0.01	Lilies	0.0	0.0	Stipa scabra	0	0
Ptilotis spp	0.0	0.04	Maireana microphylla	0.0	0.0	Succulents	0	0
Rostellaria adscendens	0.0	0.03	Melinis repens	0.01	0.0	Themeda triandra	4.6	1.2
Lomandra (rushes)	0.0	0.0	Portulaca spp	0.01	0.0	Tragus australianus	-0.6	-0.8
Sclerolaena muricata	0.0	0.0	Lomandra (rushes)	0.0	0.0	Tripogon loliiformis	-0.2	-2.3
Stipa scabra	0.0	0.0	Sclerolaena muricata	0.0	0.0	Urochloa spp	0	-0.1
Succulents	0.0	0.0	Stipa scabra	0.0	0.0	Verbena tenuisecta	0.4	0.2
Urochloa spp	0.0	0.01	Succulents (Chenopods)	0.0	0.0	Vittadinia spp	-0.2	-0.5
Xanthium spp	0.0	0.0	Xanthium spp	0.0	0.0	Xanthium spp	0	0

Appendix H6

Table H6. "Glentulloch" Burning trial - Species % Composition by Burning treatment; meaned over Trees & Reps

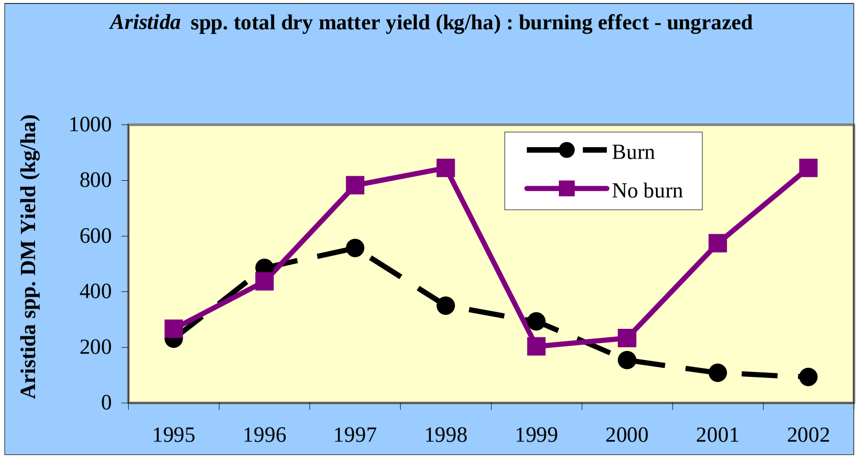
	1995		1996		1997		1998		1999		2000		2001		2002		BURN Change 1995-2002	NO BURN Change 1995-2002
	BURN	NO BURN	BURN	NO BURN	BURN	NO BURN	BURN	NO BURN	BURN	NO BURN	BURN	NO BURN	BURN	NO BURN	BURN	NO BURN		
Annual grasses	0	0	0	0	0	0	0	'	0	0	0	0	0	0	0	0	0.0	0.0
Aristida calycina	6.7	11.7	6.1	6.7	3.8	6.9	4.3	5.6	2.4	1.8	2.7	4.4	1.4	5.4	2.2	9	-4.5	-2.7
Aristida latifolia	2.4	0.7	0	0.6	2.4	2.3	1.1	1.6	2.5	0	0.5	1	0.8	0.7	1.4	0.3	-1.0	-0.4
Aristida leptopoda	1	0.3	3.1	0.8	0.1	0	0.5	0	0.5	0	0.9	0.1	0.5	0.4	0.2	0	-0.8	-0.3
Aristida ramosa	9.4	11	0.2	0	0.9	0.5	6	8.3	4.7	3.9	4.5	3.8	5.1	8.9	5.5	17.1	-3.9	6.1
Aristida spp.	0	0	10.2	6.5	7.9	6.7	3.3	3	1.3	2.1	2.9	2.3	0.8	0.5	0.2	0.9	0.2	0.9
Asteraceae (daisy)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0.0	0.1
Asteraceae spp	0	0	0.3	0	0.3	0.1	0	0	0.1	0.2	0.3	0.1	0	0.1	0.1	0	0.1	0.0
Bothriochloa bladhii	1.6	1.5	2.2	1.4	6.5	3.6	4.2	0.8	4.1	0.3	8.1	0	6.1	2.7	7.1	0.6	5.5	-0.9
Bothriochloa decipiens	31.4	29.4	23.7	29.3	37.4	35.2	27.2	32.5	22.7	30.5	21	23.5	25.5	29.3	22	23.8	-9.4	-5.6
Bothriochloa ewartiana	0	0	0	0	0	0.2	0	0	0	0	0	0	0	0	0	0.7	0.0	0.7
Brachiaria spp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0
Brunoniella australis	0.6	0.3	0.7	0.5	0.4	0.1	0.4	0.2	0.2	0.2	0.1	0	0.1	0.1	0.2	0	-0.4	-0.3
Calotis spp	0.6	0.3	0	0.1	0.1	0.7	0.5	3.5	4.9	19.9	2.1	11	0.7	3.6	0.2	0.2	-0.4	-0.1
Cenchrus ciliaris	0	0.2	0.8	2.2	1.2	3.3	1.6	1.8	1.5	3.6	2	4.4	1.8	7.3	3.2	4.7	3.2	4.5
Chenopodaceae	0	0	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0.0	0.1
Chloris divaricata	0.7	0.8	2	0.8	1.6	0.4	1.8	0.5	1.1	0.1	2	0.2	1.5	0.7	2.1	0.5	1.4	-0.3
Chloris spp	1.1	1.2	0.3	0.3	3.2	3.8	1.8	5.1	2.1	2.6	1.1	1.7	0.9	2.7	0.4	0.8	-0.7	-0.4
Chrysopogon fallax	13.5	11.9	12.3	12.4	9	7.8	17.5	9.9	14	7	9.2	5.9	15.3	7.4	13	4.4	-0.5	-7.5
Cymbopogon spp	1.2	2.1	0.5	1.4	0.6	2.6	0.4	0.7	1.6	1.2	0.9	4.3	2	6.7	1	8.6	-0.2	6.5
Cynodon dactylon	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0
Cyperus spp	0.2	0.6	0.1	0	0.3	0	0.4	0.6	0.6	0.9	0.4	0.6	0.6	1	0.5	1	0.3	0.4
Dichanthium sericeum	2.1	2.6	13.7	7.1	2.7	2.7	4.9	2.9	12.1	4	14.7	7.3	11.8	4.1	9.6	2.6	7.5	0.0
Digitaria divaricatissima	0.1	0.2	0.6	1.1	0	0	0.4	0	0.1	0.1	0	0	0.5	0.3	0.3	0.3	0.2	0.1
Digitaria spp	0.2	0.2	0	0	0	0.1	0.1	0	0.2	0.1	0.7	1.5	0	0.2	0.2	0.1	0.0	-0.1
Enneapogon spp	6.3	6.1	3.8	6.6	4	4.1	8.3	4.6	3.2	1.4	4.6	3.7	2.3	1.5	5.5	2.9	-0.8	-3.2
Enteropogon acicularis	1.5	0	0	0.1	0.4	0.1	0.4	0.9	0.7	0	0	0	0.6	0.1	0.2	0.1	-1.3	0.1
Enteropogon ramosus	1.2	1.5	0.8	3.8	1.5	2.5	1	3.9	0.3	0.4	1.5	0.5	2.4	0.6	1.5	6.4	0.3	4.9
Eragrostis spp	0.3	0.7	2.2	2.8	1.7	2.7	1.2	1.3	1.2	1.2	2.3	0.5	2.4	0.7	2.1	0.6	1.8	-0.1
Eragrostis lacunaria	0.7	1.3	0	0	0	0.1	0.3	0.4	0.2	0.3	1	0.5	0.1	0.1	0.2	0.1	-0.5	-1.2

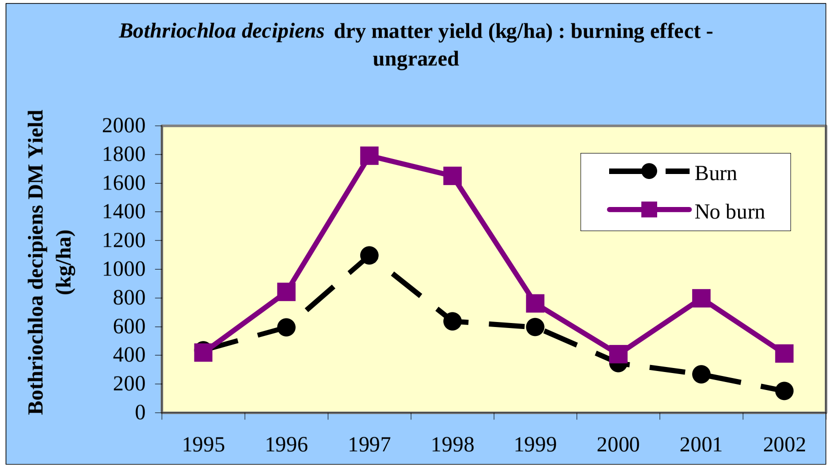
	1995		1996		1997		1998		1999		2000		2001		2002		BURN Change 1995-2002	NO BURN Change 1995-2002
	BURN	NO BURN	BURN	NO BURN	BURN	NO BURN	BURN	NO BURN	BURN	NO BURN	BURN	NO BURN	BURN	NO BURN	BURN	NO BURN		
Eragrostis molybdea	1.3	1.7	0	0	0.5	0.2	0.6	0.2	0.3	0.5	0.3	0.9	0.7	1.1	1.2	0.5	-0.1	-1.2
Erio. pseudoacrotricha	0.3	0.8	0	0.1	0.2	0	0.1	0	0.7	0.2	0.2	0.3	0.8	0.6	0	0	-0.3	-0.8
Eulalia aurea	0.9	0.6	0	0	0	0	0	0.3	0.2	0.5	0.8	1.1	1.4	0.3	2.2	0.9	1.3	0.3
Euphorbia / Phyllanthus	0	0.2	0	0	0	0	0	0	0	0	0.1	0	0	0	0	0	0.0	-0.2
Ferns	0	0	0	0.1	0	0	0.1	0.2	0.1	0.2	0	0	0	0	0	0	0.0	0.0
Fimbristylis dichotoma	0.1	0.2	0	0	0.2	0.4	0.6	0.2	0.4	0.2	0.7	0.6	1.2	0.7	0.2	0	0.1	-0.2
Forb - large	0.4	0.2	0.1	0	0	0	0	0	1.8	1.8	0	0	0.5	1.2	0	0	-0.4	-0.2
Forb - small	0.9	1.2	1.4	1.3	0.2	0.4	1	1.3	1.4	0.8	0.7	1.2	0.4	0.1	0.5	0.1	-0.4	-1.1
Heteropogon contortus	0	0.1	1.7	1.4	2.7	3	1.5	1	1.8	0.7	2.8	0.1	4.1	0.2	8.8	2	8.8	1.9
Hibiscus sturtii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0
Legume - palatable	0.7	0.3	1.1	0.9	0.9	0.3	0.3	0.3	0.6	0.6	0.6	0.4	0.5	0.5	0.3	0.3	-0.4	0.0
Legume - unpalatable	0.1	0.1	0	0	0	0	0	0	0.1	0.1	0.2	0	0.1	0	0.1	0	0.0	-0.1
Lilies	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0
Maireana microphylla	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0
Maireana spp	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-0.1	0.0
Malvastrum americanum	0.1	0	0	0	0.2	0.1	0	0	0.3	0.1	0.1	0	0	0.1	0.1	0.2	0.0	0.2
Melinis repens	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0.0	0.1
Other grass (Perennial)	0	0	0.1	0	0.3	0	0	0	0.3	0	0	0	0	0	0	0.4	0.0	0.4
Panicum effusum	1	1.8	0	0	0	0	0.4	0.3	0.3	0.7	0	0.2	0.8	2.3	0.5	1.6	-0.5	-0.2
Panicum spp	1.1	0.2	1.8	1.2	1.8	2.8	0.7	0.6	0.8	0.7	2	1.6	0.4	0.5	1.3	0.9	0.2	0.7
Paspalidium spp	0.7	0.5	1	0.2	0.2	0.2	0.2	0.2	1.3	0.2	0.5	0.3	0.1	0.1	0.4	0.3	-0.3	-0.2
Portulaca spp	0	0	0	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0
Ptilotis spp	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2	-0.1	0.2
Rhynchosia minima	0	0	0	0	0	0	0	0	0.1	0.1	0.1	0.4	0.1	0.1	0.1	0	0.1	0.0
Rostellaria adscendens	0	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	-0.1
Lomandra (rushes)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0
Salsola kali	0.4	0.3	0	0	0.1	0	0	0	0	0	0	0	0	0	0.2	0	-0.2	-0.3
Sclerolaena birchii	0.6	1.4	0.3	1.1	0	0.1	0	0.3	0.1	0	0	0.5	0	0	0	0.1	-0.6	-1.3
Sclerolaena spp	0	0.1	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	-0.1
Sclerolaena muricata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0
Sedge	0	0	0.4	1	0	0	0	0	0.8	0.3	0	0	0	0	0	0.1	0.0	0.1
Sida spp	0.1	0.3	1.2	1.3	0.1	0.1	0.1	0.1	0	0.1	0.2	0.6	0.4	0.1	0.2	0.2	0.1	-0.1
Sida subspicatum	4.1	1.4	2.5	1.4	2.7	1.1	2.3	0.3	2.4	0.8	1.1	0.4	1.3	0	1.4	0.3	-2.7	-1.1

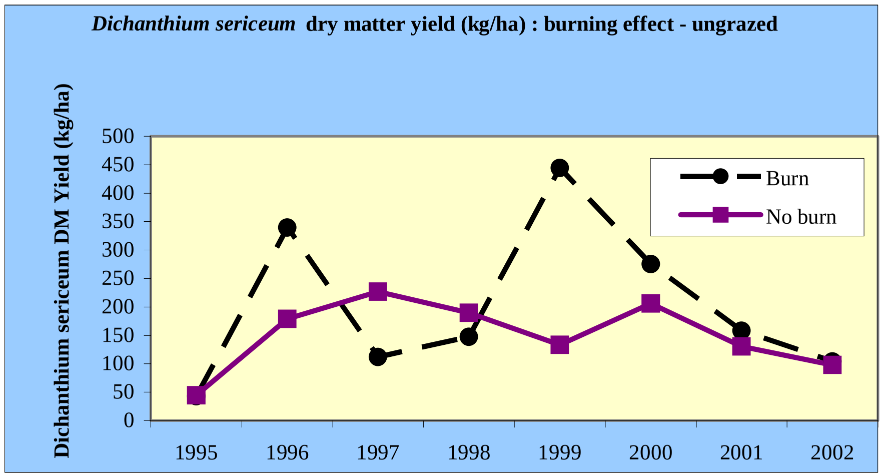
	1995		1996		1997		1998		1999		2000		2001		2002		BURN Change 1995-2002	NO BURN Change 1995-2002
	BURN	NO BURN	BURN	NO BURN	BURN	NO BURN	BURN	NO BURN	BURN	NO BURN	BURN	NO BURN	BURN	NO BURN	BURN	NO BURN		
Solanum spp	0.4	0.4	0	0	0.2	0	0.9	0.5	0.3	0.3	0.3	0.6	0.3	0.3	0.3	0.1	-0.1	-0.3
Sporobolus (rat's-tail)	0	0.2	0.4	0.2	0.2	1	0.5	0.4	0.6	0.8	1.4	1	1.7	3.3	0.9	1.1	0.9	0.9
Sporobolus (small)	1.3	0.2	1.3	1.5	0.4	0.4	0.7	0	0.5	0.1	0.3	0	0.1	0	0	0	-1.3	-0.2
Stipa scabra	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0
Succulents	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0
Themeda triandra	0.4	0	1.6	1.2	2.2	1.8	1.1	2.2	0.7	2.5	3.1	3.3	1.5	0.3	2.2	4	1.8	4.0
Tragus australianus	0.3	1.2	0.4	0.3	0	0	0.2	0	0.1	0	0	0	0.1	0	0	0	-0.3	-1.2
Tripogon loliiformis	1.1	1.8	0.7	0.9	0.2	0.3	1.1	0.9	0.2	0.2	0.1	0	0.2	0.1	0.2	0.1	-0.9	-1.7
Urochloa spp	0	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	-0.1
Verbena tenuisecta	0	0	0.1	1.4	0.2	0.7	0	2.3	1.3	6	0.6	8.7	0.2	2.7	0	0.5	0.0	0.5
Vittadinia spp	0.6	0	0	0	0.2	0.3	0	0.2	0.1	0	0	0.1	0	0	0	0	-0.6	0.0
Xanthium spp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0

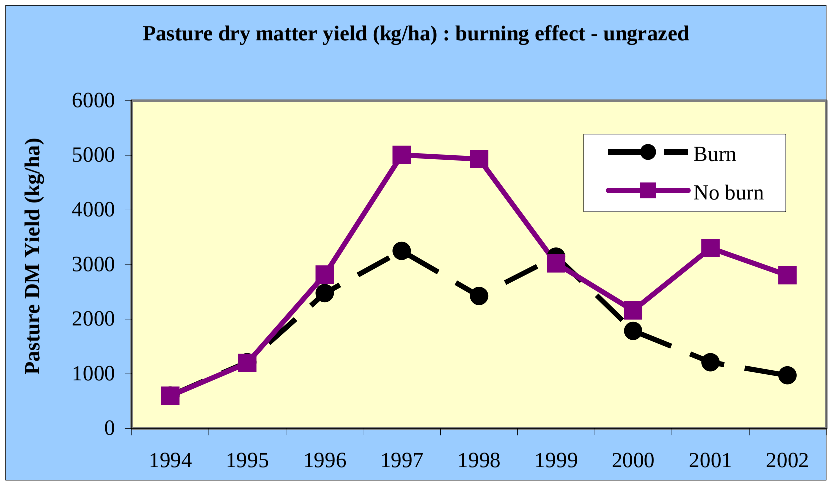
Appendix H7

Figures H1 to H4. Changes over time in autumn presentation yield of key species in ungrazed pastures (+/- spring fires) at Glentulloch.









Appendix H8

Table H8. GLENTULLOCH SWIFTSYND DATA SUMMARY 1995

PLOT date	Dominant SPECIES	DRY MATTER YIELD (kg/ha) SPP 1	SPP 2	O Grass	Forbs	Litter	Total	COVER (%) Height	Green	Dead	Litter	Bare	DOM. SPP. COMPONENTS (%) Gr leaf	Dry lf	Gr stem	Dry stm	Inflor
GA4																	
7/02/1995	Aristida	584	119	200	57	0	959						58	3	29	8	3
22/06/1995	Aristida	1610	25	38	25	57	1755	17	21	57		21	3	17	74	0	7
GD2																	
2/03/1995	Dichanthium	205	357	1069	121	0	1752	21	60	3		38	25	1	61	0	12
26/06/1995	Dichanthium	689	254	518	5	86	1551	11	17	53		30	9	27	28	36	0
GB5																	
2/03/1995	Bothriochloa	1213	168	592	94	0	2066	29	44	5		49	21	43	60	0	15
26/06/1995	Bothriochloa	1324	298	161	43	41	1867	15	6	44		50	3	29	0	64	4
GC3																	
2/03/1995	Chrysopogon	103	60	83	23	0	269	7	24	21		56	81	17	0	0	2
22/06/1995	Chrysopogon	41	55	59	11	0	166	6	2	25		73	36	64	0	0	0
GE1																	
27/04/1995	Enteropogon	542	286	107	48	12	996	12	19	23		58	19	9	57	8	7
22/06/1995	Enteropogon	681	214	58	34	185	1171	12	5	49		46	9	6	78	4	4

Appendix H9

Table H9. Detailed frequency data (%) for the 75 main taxa in the large COMM paddock at Glentulloch each autumn

				YEAR								
Taxon	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**mean**	**max**	**min**	**rank**	**trend**
Small annual grasses	1			'			0.5	0.8	1	0.5		
Aristida calycina	2	5	5	5.3	4	3	1.9	3.7	5.3	1.9		S
Aristida latifolia	3	3	1	5.8	5	1	6.5	3.6	6.5	1		
Aristida leptopoda	9	4	6	3.9	8	6	8.3	6.5	9	3.9		S
Aristida ramosa	25	14	4	16.9	17	28	26.4	18.8	28	4	3?	
Aristida spp	3	23	22	4.3	15	6	5.6	11.3	23	3		
Asteraceae	1	'	0	'	6	2	'	2.3	6	0		
Asteraceae spp	8	0	3	3.4	1	5	1.9	3.2	8	0		
Bothriochloa bladhii	4	4	6	8.2	8	1	3.7	5.0	8.2	1		
Bothriochloa decipiens	17	21	15	16.9	24	35	34.3	23.3	35	15	6	I
Bothriochloa ewartiana	'	'	'	'			'	'	0	0		
Brachiaria spp		'	'	'			'	'	0	0		
Brunoniella australis	28	28	24	27.5	18	27	18.5	24.4	28	18	5	S
Calotis lappulacea/scabiosifolia	14	5	6	5.3	9	28	13	11.5	28	5	12	
Cenchrus ciliaris	7	6	9	5.8	2	3	1.9	5.0	9	1.9		D?
Chenopodaceae	3		1	4.3	1	3	1.4	2.3	4.3	1		
Chloris divaricata	15	32	32	37.7	54	53	68.1	41.7	68.1	15	2	I
Chloris spp	1	3	3	1.4	6	4	1.4	2.8	6	1		
Chrysopogon fallax	13	22	14	31.4	13	18	25.5	19.6	31.4	13	7	S?
Cymbopogon spp	'	1	2	1	2	2	0.9	1.5	2	0.9		
Cynodon dactylon					0			0.0	0	0		
Cyperus spp	10	3	2	6.8	5	8	4.6	5.6	10	2		S
Dichanthium sericeum	9	18	24	15.9	42	35	39.8	26.2	42	9	4	I
Digitaria divaricatissima	9	'	0	1.4			0.5	2.7	9	0		
Digitaria spp	'	'	1	0.5	0	2	0.5	0.8	2	0		
Enneapogon spp	46	42	49	56	35	41	41.2	44.3	56	35	1	S
Enteropogon acicularis	2	'	0	'			'	1.0	2	0		
Enteropogon ramosus	6	8	7	7.7	6	6	6.9	6.8	8	6		S
Eragrostis spp	'	8	9	6.8	6	9	5.1	7.3	9	5.1		S
Eragrostis lacunaria	3	'	1	1.4	0	1	0.5	1.2	3	0		
Eragrostis molybdea	12	4	3	4.3	10	5	10.2	6.9	12	3		F

				YEAR								
Taxon	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**mean**	**max**	**min**	**rank**	**trend**
Eriochloa pseudoacrotricha	2	1	4	3.4	8	0	3.2	3.1	8	0		
Eulalia aurea	'		'	'			'	'	0	0		
Euphorbia / Phyllanthus	6	1	2	5.8	3	9	0.9	4.0	9	0.9		
Ferns	'	0	'	'		0	'	0.0	0	0		
Fimbristylis dichotoma	8	3	5	2.4	1	6	5.1	4.4	8	1		
Forb - large	6	0	0	1.9	2		1.4	1.9	6	0		
Forb - small	4	28	12	27.5	23	26	11.1	18.8	28	4	8	F
Heteropogon contortus	'	2	5	1.4		2	0.9	2.3	5	0.9		
Hibiscus sturtii		0	'	'				0.0	0	0		
Legume - palatable	13	13	8	8.2	11	19	16.2	12.6	19	8	11	S
Legume - unpalatable	9	'	2	0.5	4	3	4.2	3.8	9	0.5		
Lilies	'	'					'	'	0	0		
Maireana	4	0	1	'	1		1.4	1.5	4	0		
Maireana spp		'	1	1.4	0	0	0.5	0.6	1.4	0		
Malvastrum americanum	5	1	12	4.3	4	1	2.3	4.2	12	1		
Melinis repens					0	1		0.5	1	0		
Other grass			1				1.4	1.2	1.4	1		
Panicum effusum	'	'	'	'	2		0.9	1.5	2	0.9		
Panicum spp	7	1	1	4.8	4	2	0.9	3.0	7	0.9		
Paspalidium spp	1	'	0	'	2	1	0.9	1.0	2	0		
Portulaca	29	4	1	4.8		0	0.5	6.6	29	0		D?
Ptilotis spp	1	'	0	'		0	'	0.3	1	0		
Rhynchosia minima	2	3	2	1.9	5	7	1.4	3.2	7	1.4		F
Rostellaria adscendens	2	'	'				'	2.0	2	2		
Rushs	'		'				'	'	0	0		
Salsola kali	2	'	3	'	1		'	2.0	3	1		
Sclerolaena birchii	8	1	4	4.3	3	2	1.9	3.5	8	1		
Sclerolaena spp	10	4	0	'		0	'	3.5	10	0		
Sclerolaena muricata	'		'					'	0	0		
Sedge	'	1	'		0	3	0.5	1.1	3	0		
Sida spp	7	4	5	2.9	4	8	9.3	5.7	9.3	2.9		
Sida subspicatum	8	7	3	0.5	3	1	0.9	3.3	8	0.5		D
Solanum spp	4	2	5	4.3		5	0.5	3.5	5	0.5		
Sporobolus ratstail	3	1	2	6.3	7	12	13.9	6.5	13.9	1		I

Taxon	1995	1996	1997	YEAR 1998	1999	2000	2001	mean	max	min	rank	trend
Sporobolus caroli/actinocladus	6	5	6	5.8	6	8	16.7	7.6	16.7	5		S?
Stipa scabra	'	'	'	'				'	0	0		
Succulents	'	0	'	'			'	0.0	0	0		
Themeda triandra	2	3	1	1.4	0	2	0.9	1.5	3	0		
Tragus australianus	44	31	12	13	3	7	0.9	15.8	44	0.9	9	D
Tripogon loliiformis	11	20	8	12.6	8	8	24.1	13.1	24.1	8		F
Urochloa spp	2	2		'	0	1		1.3	2	0		
Verbena tenuisecta	10	6	9	14.5	30	28	6	14.8	30	6	10	F
Vittadinia spp	'	'	9	1	13	2	1.4	5.3	13	1		
Xanthium spp Burrs			1					1.0	1	1		

Table H10. Taxon % Composition by weight in the large COMM paddock at Poplar box site during the grazing trial

Taxon	1995	1996	1997	YEAR 1998	1999	2000	2001	mean	max	min	rank
Small annual grasses				'	'		0	0.0	0	0	
Aristida calycina	1.3	1.7	2.2	1.5	1.1	1	0.3	1.3	2.2	0.3	
Aristida latifolia	0.8	0.8	0.7	2.2	1.1	0.2	1	1.0	2.2	0.2	
Aristida leptopoda	2	1.5	3.3	1	1.6	1.1	3	1.9	3.3	1	
Aristida ramosa	17.1	16.1	2.7	14	20	21.1	31.6	17.5	31.6	2.7	1
Aristida spp	4.1	23.3	13.6	3.1	4.5	4.4	1	7.7	23.3	1	
Asteraceae (daisy)	'	'	0	'	0.2	0.1	'	0.1	0.2	0	
Asteraceae spp	0.1	0	1	0.1	0	0.1	0.1	0.2	1	0	
Bothriochloa bladhii	2.3	3.5	3	5.9	2.3	0.4	1.4	2.7	5.9	0.4	7
Bothriochloa decipiens	10.8	7.9	10.1	14.9	14.9	19.5	19	13.9	19.5	7.9	2
Bothriochloa ewartiana	1	'	'	'	'	'	'	1.0	1	1	
Brachiaria spp		'	'	'			'	'	0	0	
Brunoniella australis	0.4	1.2	1	0.7	0.2	0.4	0.2	0.6	1.2	0.2	
Calotis lappulacea/scabiosifolia	0.6	0.1	0.3	0.3	0.6	1.1	0.3	0.5	1.1	0.1	
Cenchrus ciliaris	4.7	2.8	3.5	2	0.4	0.4	0.7	2.1	4.7	0.4	9
Chenopodiaceae	0.1		0	0.2	0	0	0	0.1	0.2	0	
Chloris divaricata	5	5	7.7	10.2	11.9	11.4	8.2	8.5	11.9	5	4
Chloris spp	0.2	0.3	1.1	0.7	0.8	0.7	0.3	0.6	1.1	0.2	

Taxon	1995	1996	1997	YEAR 1998	1999	2000	2001	mean	max	min	rank
Chrysopogon fallax	0.8	2.7	2.2	4	1.7	2	2.2	2.2	4	0.8	8
Cymbopogon spp	'	0.3	0.9	0	1.4	1.1	0.2	0.7	1.4	0	
Cynodon dactylon					0.5	'		0.5	0.5	0.5	
Cyperus spp	0.5	0.1	0.1	1.2	0.4	0.3	0.9	0.5	1.2	0.1	
Dichanthium sericeum	2.9	4.4	12.5	5.8	15.2	11.6	7.3	8.5	15.2	2.9	3
Digitaria divaricatissima	1.8	'	0.1	0	'	'	0	0.5	1.8	0	
Digitaria spp	'	'	0.1	0	0	0.4	'	0.1	0.4	0	
Enneapogon spp	11.8	4.7	10.5	13	2.7	4.8	3.5	7.3	13	2.7	5
Enteropogon acicularis	0.5	'	0.1	'	'	'	'	0.3	0.5	0.1	
Enteropogon ramosus	6.2	4.6	8.3	3.9	6.9	4	8.4	6.0	8.4	3.9	6
Eragrostis spp	'	0.9	1.2	0.8	0.5	1.4	0.3	0.9	1.4	0.3	
Eragrostis lacunaria	0.6	'	0.1	0.2	'	0.1	0	0.2	0.6	0	
Eragrostis molybdea	4.7	0.8	0.7	0.7	0.8	0.5	0.6	1.3	4.7	0.5	
Eriochloa pseudoacrotricha	0.4	0.2	0.5	0.6	0.8	'	0.6	0.5	0.8	0.2	
Eulalia aurea	'		'	'	'	'	'	'	0	0	
Euphorbia / Phyllanthus	'	0	0	0.1	0	0.2	0	0.1	0.2	0	
Ferns		0.1	'	'	'	0	'	0.1	0.1	0	
Fimbristylis dichotoma	0.3	0.1	0.7	0.2	0	0.1	0.1	0.2	0.7	0	
Forb - large	0.3	0	0.1	0.2	0.4	'	0	0.2	0.4	0	
Forb - small	0.1	1.4	0.4	0.8	0.6	0.7	0.2	0.6	1.4	0.1	
Heteropogon contortus	'	0.5	1.5	0.2	'	0.3	0.1	0.5	1.5	0.1	
Hibiscus sturtii		'	'	'				'	0	0	
Legume - palatable	0.1	0.6	0.4	0.4	0.4	0.4	0.3	0.4	0.6	0.1	
Legume - unpalatable	'	'	0.1	0	0.1	0	0	0.0	0.1	0	
Lilies		'			'		'	'	0	0	
Maireana microphylla	0.9	0.1	0.4	'	0.3	'	0.1	0.4	0.9	0.1	
Maireana spp	'	'	0.1	0.1	0.1	0	0	0.1	0.1	0	
Malvastrum americanum	0.1	0.2	1.4	0.7	0.3	0.1	0.4	0.5	1.4	0.1	
Melinis repens					0.5	0.3		0.4	0.5	0.3	
Other grass			0.1		'	'	0.5	0.3	0.5	0.1	
Panicum effusum		'	'	'	0.1	'	0.2	0.2	0.2	0.1	
Panicum spp	1.5	0.1	0.2	0.6	0.2	0.7	0.3	0.5	1.5	0.1	
Paspalidium spp	0.1	'	0.2	'	0.1	0.2	0	0.1	0.2	0	
Portulaca	0.1	0.1	0	0.2	'	0	0	0.1	0.2	0	

				YEAR							
Taxon	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**mean**	**max**	**min**	**rank**
Ptilotis spp	0.2	'	0	'		0	'	0.1	0.2	0	
Rhynchosia minima		0	0.1	0	0.1	0.3	0	0.1	0.3	0	
Rostellaria adscendens	0.2	'	'			'	'	0.2	0.2	0.2	
Rushs	'		'	'	'	'	'	'	0	0	
Salsola kali	0.1	'	0.3		0	'	'	0.1	0.3	0	
Sclerolaena birchii	6	0.2	0.6	0.6	0.6	0.5	0.1	1.2	6	0.1	
Sclerolaena spp	0.5	0.9	0	'	'	0	'	0.4	0.9	0	
Sclerolaena muricata		0.2	'		'	'		0.2	0.2	0.2	
Sedges	'	0.2	'		0.1	0.2	'	0.2	0.2	0.1	
Sida spp	0.2	2.1	0.1	0.2	0.2	0.5	0.2	0.5	2.1	0.1	
Sida subspicatum	2.2		0.2	0	0.5	0.2	0	0.5	2.2	0	
Solanum spp	0.1	0	0.6	0.3	'	0.3	0.1	0.2	0.6	0	
Sporobolus (ratstail)	0.7	1	0.5	2.1	2.6	3	4.2	2.0	4.2	0.5	
Sporobolus caroli/actinocladus	0.4	0.9	0.7	0.4	0.4	0.5	0.6	0.6	0.9	0.4	
Stipa scabra	'	'	'	'		'		'	0	0	
Succulents	0.8	'	'	'	'	'	'	0.8	0.8	0.8	
Themeda triandra	0.5	3.3	0.5	2.7	0.1	1	0.4	1.2	3.3	0.1	
Tragus australianus	2.7	2.1	0.7	0.9	0.1	0.1	0	0.9	2.7	0	
Tripogon loliiformis	1	2	0.4	1.7	0.1	0.3	0.8	0.9	2	0.1	
Urochloa spp	0.4	0.1		'	0	0.4		0.2	0.4	0	
Verbena tenuisecta	0.5	0.8	0.5	0.8	1.2	1.2	0.2	0.7	1.2	0.2	
Vittadinia spp	'	'	0.3	0	0.3	0.1	0	0.1	0.3	0	
Xanthium spp			0.9					0.9	0.9	0.9	

Table H11. Variation in the frequency of the main pasture plant groups for the large COMM paddock each autumn during the project, poplar box site

Paddock		Glentulloch Grazing Trial - 7 Species Functional Groups - Botanal Species Frequency (%)						
		Decreaser grasses	Intermediate grasses	Increaser grasses	Annual grasses	Palatable legumes	Forbs	Sedges
13COMM	**1995**	42.9	48.6	59	68.6	12.4	85.7	17.1
	1996	34.4	67	63.4	57.1	15.2	68.3	7.6
	1997	39	61.9	47.4	58.7	9.4	67.1	6.8
	1998	31.4	72.9	55.6	61.4	9.7	77.3	8.7
	1999							
	2000	41.8	86.1	60.2	47	24.3	84.1	17.1
	2001	46.3	91.7	74.5	45.8	16.7	59.7	10.2
	2002	37.4	79.3	70	42.4	16.7	60.1	10.3
	Mean 95-02	39.0	72.5	61.4	54.4	14.9	71.8	11.1

APPENDIX I. Germinable seeds details, Ironbark and Poplar box sites

Appendix I1

Table I 1. Average number of emerging seedlings / sq metre of all species in all years from soil in both experiments, Keilambete

	Keilambete Grazing Trial Mean plants/sq m											Keilambete burn trial Mean seeds/sm								
Species group	**94-95**	**95-96**	**96-97**	**97-98**	**98-99**	**99-00**	**00-01**	Mean	%age	Yrs	**Species group**	**95-96**	**96-97**	**97-98**	**98-99**	**99-00**	**00-01**	Mean	%age	Yrs
Acacia spp		1.6				0.8		0.3	0.03	2										
Alternanthera sp	4.0			0.8	2.4	3.2		1.5	0.14	4	Alternanthera spp					3.2		0.5	0.04	1
Amaranth spp					1.6			0.2	0.02	1										
Aristida spp	8.7	7.9	2.4	29.3		22.2	4.0	10.6	1.02	6	Aristida spp	31.7	31.7	19.0		15.8	15.8	16.3	1.61	5
											Boerhamia spp	3.2						0.5	0.04	1
B. ewartiana	39.6	26.1	30.1	81.5	15.0	7.1	11.9	30.2	2.91	7	B. ewartiana	57.0	107.7	34.8	12.7	9.5	12.7	33.5	3.31	6
Brachiaria spp							8.7	1.2	0.12	1										
Brassica spp				0.8				0.1	0.01	1										
Brunoniella spp	18.2			2.4			0.8	3.1	0.29	3										
Cenchrus ciliaris		1.6	1.6					0.5	0.04	2	Cenchrus ciliaris		6.3					0.9	0.09	1
Cheilanthes distans						93.4		13.3	1.28	1										
Cheilanthes spp				1.6			133.8	19.3	1.86	2	Cheilanthes species						50.7	7.2	0.72	1
Chenopodium sp	2.4		0.8	10.3	16.6	18.2	15.0	9.0	0.87	6	Chenopodium spp				3.2	3.2		0.9	0.09	2
Chloris divaricata	10.3	7.1	11.1	254.9		45.9	84.7	59.1	5.70	6	Chloris spp	6.3	3.2	66.5		15.8	22.2	16.3	1.61	5
Chrys. apiculatum				0.8				0.1	0.01	1	Chrys. apiculatum			3.2				0.5	0.04	1
C. fallax	4.8	2.4		0.8				1.1	0.11	3	C. fallax	9.5						1.4	0.13	1
Crotolaria spp			1.6					0.2	0.02	1										
Cyperus spp	15.8	30.9	12.7	33.3	0.8	10.3		14.8	1.43	6	Cyperus spp	47.5	25.3	28.5				14.5	1.43	3
Dactylocteniun sp	0.8	3.2	4.0	12.7	4.8	4.8	0.8	4.4	0.42	7	D. radulans					3.2		0.5	0.04	1
D. varians	3.2				4.8	1.6		1.4	0.13	3	D. varians				3.2			0.5	0.04	1
D. serecium	7.9	2.4	0.8	12.7		7.1		4.4	0.42	5	D. serecium	9.5		6.3		3.2	6.3	3.6	0.36	4
Digitaria spp	17.4	3.2	2.4	30.1	2.4	59.4	40.4	22.2	2.13	7	Digitaria spp	19.0		9.5		9.5	12.7	7.2	0.72	4
E. colona						90.3	38.8	18.4	1.78	2										
Enneapogon spp	22.2	23.0	13.5	42.8		8.7	3.2	16.2	1.56	6	Enneapogon spp	31.7	79.2	34.8			3.2	21.3	2.10	4
Eragrostis spp	8.7	7.9	7.1	30.9	19.0	23.8	37.2	19.2	1.85	7	Eragrostis spp	6.3	3.2	3.2	6.3	3.2	12.7	5.0	0.49	6
Eriochloa spp	11.1	3.2		7.9	0.8	7.1	1.6	4.5	0.44	6										

Keilambete Grazing Trial										
	Mean plants/sq m									
Species group	**94-95**	**95-96**	**96-97**	**97-98**	**98-99**	**99-00**	**00-01**	Mean	%age	Yrs
Eulalia aurea		0.8						0.1	0.01	1
Euphorbia spp	17.4	38.8	18.2	4.0	18.2	8.7	14.3	17.1	1.64	7
Evolvolus spp		0.8	0.8				0.8	0.3	0.03	3
Fimbristylus spp	9.5	3.2		46.7	20.6	29.3	60.2	24.2	2.33	6
Glycine spp	7.1	2.4	0.8	7.1	1.6	7.1	4.8	4.4	0.42	7
Gnaphalium spp		9.5		1.6		24.5	7.9	6.2	0.60	4
Gomphrena spp			0.8				1.6	0.3	0.03	2
Goodenia spp	4.8	3.2			5.5	8.7	5.5	4.0	0.38	5
H. contortus	107.7	27.7	21.4	155.2	52.3	346.0	81.5	113.1	10.9	7
Hibiscus spp				1.6	2.4			0.6	0.05	2
Hybanthus spp	122.7	50.7	57.8	6.3	64.1	22.2	84.7	58.4	5.62	7
Indigofera spp	9.5	14.3	7.9	68.9	24.5	125.1	53.8	43.4	4.18	7
Leptopus decaisneii			1.6					0.2	0.02	1
Lillium spp		3.2		0.8				0.6	0.05	2
Melinis repens				1.6			1.6	0.5	0.04	2
Not Known Forb	42.8	87.9	39.6		0.8			24.4	2.35	4
Not Known Grass	11.9	7.9	8.7				4.8	4.8	0.46	4
Oxalis spp		1.6	3.2	3.2	0.8			1.2	0.12	4
Panicum spp	4.8	6.3	2.4	1.6	3.2	0.8	0.8	2.8	0.27	7
Pasp. caespitosum						3.2	0.8	0.6	0.05	2
P. jubiflorum	0.8		1.6	2.4	0.8			0.8	0.08	4
Phyllanthus spp	14.3	19.8	3.2	17.4	13.5	8.7	6.3	11.9	1.14	7
Physalis spp					4.0			0.6	0.05	1
Plantago spp			0.8					0.1	0.01	1
Polyc. corymbosa			5.5	4.8			4.0	2.0	0.20	3
Portulaca spp	2.4	12.7	18.2	30.9	5.5	27.7	4.8	14.6	1.40	7
Pterocaulon spp	9.5	9.5	6.3	11.1	12.7	30.1	49.1	18.3	1.76	7
R. minima	0.8		3.2					0.6	0.05	2
Ruellia spp		6.3	3.2			0.8		1.5	0.14	3

Keilambete burn trial									
	Mean seeds/sm								
Species group	**95-96**	**96-97**	**97-98**	**98-99**	**99-00**	**00-01**	Mean	%age	Yrs
Euphorbia spp	19.0	44.3	6.3	3.2			10.4	1.03	4
Evolvulus spp			6.3				0.9	0.09	1
Fimbristylus spp			41.2	53.8	50.7	139.3	40.7	4.03	4
Glycine spp	3.2	3.2	6.3		3.2	3.2	2.7	0.27	5
Gnaphalium spp			3.2		31.7	9.5	6.3	0.63	3
Goodenia spp				6.3		9.5	2.3	0.22	2
H. contortus	82.3	88.7	209.0	104.5	291.3	28.5	114.9	11.37	6
Hybanthus spp	25.3	41.2	9.5	53.8		47.5	25.3	2.51	5
Indigofera linifolia				3.2			0.5	0.04	1
Indigofera spp	3.2	22.2	9.5	3.2	12.7	9.5	8.6	0.85	6
Lillium spp	3.2						0.5	0.04	1
Malva spp			3.2				0.5	0.04	1
Not Known Forb	117.2	98.2					30.8	3.04	2
Not Known Grass	3.2	12.7				3.2	2.7	0.27	3
Oxalis spp			3.2	3.2			0.9	0.09	2
Panicum spp		19.0	3.2			3.2	3.6	0.36	3
Phyllanthus spp	6.3	6.3	12.7	6.3		15.8	6.8	0.67	5
Polyc. corymbosa		12.7	6.3			12.7	4.5	0.45	3
Portulaca spp	25.3	38.0	9.5	6.3	15.8		13.6	1.34	5
Pterocaulon spp	6.3		3.2	12.7	60.2	22.2	14.9	1.48	5
R. minima						3.2	0.5	0.04	1
Ruellia spp	12.7						1.8	0.18	1

Keilambete Grazing Trial

Mean plants/sq m

Species group	**94-95**	**95-96**	**96-97**	**97-98**	**98-99**	**99-00**	**00-01**	Mean	%age	Yrs
Scleria mackaviensis						0.8		0.1	0.01	1
Sclerolaena spp		0.8						0.1	0.01	1
Sedges							38.0	5.4	0.52	1
Sehima nervosa						1.6		0.2	0.02	1
Senecio spp	0.8							0.1	0.01	1
Sesbania spp	1.6							0.2	0.02	1
Sida spp		1.6		0.8	0.8	5.5	5.5	2.0	0.20	5
Solanum spp			1.6	2.4	1.6	2.4		1.1	0.11	4
Sonchus spp		2.4		26.9	132.2	77.6	21.4	37.2	3.58	5
Spermacoce spp	23.8	13.5	5.5	42.0	7.9	21.4	17.4	18.8	1.81	7
Sporobolus actinocladus					0.8		0.8	0.2	0.02	2
S. australasicus	8.7	7.9	18.2	2.4	31.7	1.6	0.8	10.2	0.98	7
Spp1					7.9			1.1	0.11	1
Tephrosia spp		0.8			0.8	1.6	5.5	1.2	0.12	4
T triandra		0.8					17.4	2.6	0.25	2
T australasicus		1.6	1.6	22.2	7.1	10.3	11.9	7.8	0.75	6
T loliiformis	8.7	15.0	5.5	68.9	2.4	59.4	42.8	29.0	2.79	7
Vernonia cinerea				1.6				0.2	0.02	1
Vittadinia spp			0.8					0.1	0.01	1
Wahlenbergia sp	11.1	130.6	177.3	337.3	387.9	542.3	467.9	293.5	28. 6	7
Zornia spp	3.2	3.2	0.8	25.3	1.6	45.9	19.0	14.1	1.36	7
TOTAL	598.5	604.8	504.3	1448.	881.1	1816.9	1416.	1038.		

Keilambete burn trial

Mean seeds/sm

Species group	**95-96**	**96-97**	**97-98**	**98-99**	**99-00**	**00-01**	Mean	%age	Yrs
Sida species						3.2	0.5	0.04	1
Sonchus spp	3.2			53.8	19.0	15.8	13.1	1.30	4
Spermacoce spp	12.7	19.0	22.2	9.5	12.7	9.5	12.2	1.21	6
S australasicus				9.5		3.2	1.8	0.18	2
Tephrosia species						9.5	1.4	0.13	1
Themeda triandra						6.3	0.9	0.09	1
T. australasicus		9.5					1.4	0.13	1
T. loliiformis	12.7	12.7	117.2		44.3	6.3	27.6	2.73	5
Wahlenbergia spp	199.5	98.2	538.3	886.7	1165.	760.0	521.1	51.57	6
Zornia spp	6.3	6.3	12.7		12.7	9.5	6.8	0.67	5
TOTAL	763.2	788.5	1228.	1241.	1786.	1266.7	1010.		

Appendix I2

Table I 2. Individual species emerges/ sq metre, grouped by grazing pressure and tree cover, Keilambete

Sum of Plants per m²		***Year***							
		All plants							
Graz press	Trees	94/95	95/96	96/97	97/98	98/99	99/00	2000/01	Total
H	C	2118.5	1187.5	1092.5	4930.5	2023.5	4284.5	4341.5	19978.5
	T	1320.5	912.0	779.0	1824.0	1520.0	3895.0	2394.0	12644.5
H Total		3439.0	2099.5	1871.5	6754.5	3543.5	8179.5	6735.5	32623.0
L	C	608.0	1539.0	570.0	3477.0	2109.0	3306.0	2954.5	14563.5
	T	1244.5	1482.0	1615.0	1824.0	1919.0	4237.0	2147.0	14468.5
L Total		1852.5	3021.0	2185.0	5301.0	4028.0	7543.0	5101.5	29032.0
M	C	655.5	1254.0	1026.0	3553.0	1814.5	3648.0	3287.0	15238.0
	T	1235.0	883.5	969.0	1767.0	1187.5	2432.0	1871.5	10345.5
M Total		1890.5	2137.5	1995.0	5320.0	3002.0	6080.0	5158.5	25583.5
Grand Total		7182	7258	6051.5	17375.5	10573.5	21802.5	16995.5	87238.5

Species grp ***Aristida*** spp.

Sum of Plants per m²					**Year**				
Graz	Trmt	94/95	95/96	96/97	97/98	98/99	99/00	2000/01	Total
H	C	19	9.5		57				85.5
	T	9.5			9.5		104.5	9.5	133
H Total		28.5	9.5		66.5		104.5	9.5	218.5
L	C	19	28.5	19	47.5		76		190
	T	9.5	38	9.5	114		47.5	19	237.5
L Total		28.5	66.5	28.5	161.5		123.5	19	427.5
M	C	38	19		114		28.5	9.5	209
	T	9.5			9.5		9.5	9.5	38
M Total		47.5	19		123.5		38	19	247
Grand Total		104.5	95	28.5	351.5		266	47.5	893

Appendix I3

Table I 3. Effect of grazing pressure on seedlings emerging (total/sq metre) from Keilambete spring soils each year

Trmt
Species grp ***Enneapogon*** spp

	Year							
Graz. Press.	94/95	95/96	96/97	97/98	98/99	99/00	2000/01	Total
H	47.5	66.5		123.5		38		275.5
L	114	123.5	85.5	266		38	38	665
M	104.5	85.5	76	123.5		28.5		418
Grand Total	266	275.5	161.5	513	0	104.5	38	1358.5

Trmt
Species grp ***Hybanthus*** spp

	Year							
Graz press.	9495	9596	9697	9798	9899	9900	200001	Total
H	921.5	180.5	275.5	28.5	228	66.5	294.5	1995
L	142.5	294.5	76	19	247	85.5	342	1206.5
M	408.5	133	342	28.5	294.5	114	380	1700.5
Grand Total	1472.5	608	693.5	76	769.5	266	1016.5	4902

Trmt
Species grp ***Sporobolus australasicus***

	Year							
Graz	9495	9596	9697	9798	9899	9900	200001	Total
H	66.5	28.5	47.5	9.5	304			456
L	9.5		9.5		38			57
M	28.5	66.5	161.5	19	38	19	9.5	342
Grand Total	104.5	95	218.5	28.5	380	19	9.5	855

Trmt
Species grp ***Tripogon loliiformis***

	Year							
Graz	9495	9596	9697	9798	9899	9900	200001	Total
H	57	85.5	38	256.5	9.5	199.5	180.5	826.5
L	47.5	47.5		342	19	304	152	912
M		47.5	28.5	228		209	180.5	693.5
Grand Total	104.5	180.5	66.5	826.5	28.5	712.5	513	2432

Trmt
Species grp ***Chloris divaricata***

				Year				
Graz	9495	9596	9697	9798	98/99	9900	200001	Total
H	76	66.5	57	2403.5		323	750.5	3676.5
L	38		57	190		85.5	133	503.5
M	9.5	19	19	465.5		142.5	133	788.5
Grand Total	123.5	85.5	133	3059	0	551	1016.5	4968.5

Appendix I4

Notes on the locations of extreme soil surface types sampled during seed load testing at Glentulloch. The surface soil was typically a grey loam.

Table I 4. Sample locations with markedly different surface soil features

Pdk nbr	Transect	Post	Soil characteristics
2	1	3	Clay
2	1	4	Red, sandy
2	3	4	Yellowish colour
3	1	2	Dark colour
3	3	2	Brown & gravelly
4	1	4	Sandy
4	3	3	Clay; cracks and crumbles
4	3	3	Crumbles
6	2	3	Red sand
6	3	4	Red, sandy
7	3	2	Clay
8	3	2	Clay
9	1	3	Fine silt
10	1	3	Yellowish
11	1	4	Sand
12	3	3	Black, clayey
TB2			Clay

Appendix I5

Table I 5. Frequency of occurrence of taxa over the 7 years plus the mean and maximum densities recorded in any one year (all samples together) if not present in all years

Nbrs	Code	Taxon	Year	Locale*	MEAN PERCENT of total emergees	Germinable seeds / sq m TOTAL over 7 years	MAX	MEAN
	1 Plant in 1 pot only [37]							
1	Abma	A. malvifolium	2000	P1 3/3	0.01	1.3	-	0.19
1	Acas	A. aspers	2000	P1 3/4	0.01	1.3	-	0.19
1	Amcr	A. cruentus	1995	P6 2/4	0.02	1.3	-	0.19
1	Amma	A. macrocarpa	1995	P2 3/4	0.02	1.3	-	0.19
1	Bodo	B. dominii	2000	TN2	0.00	1.3	-	0.19
1	Boew	B. ewartiana	1996	P10 2/2	0.02	1.1	-	0.15
1	Brau	B. australis	1995	P11 3/3	0.02	1.3	-	0.19
1	Brci	B. ciliaris	1996	P10 2/2	0.02	1.1	-	0.15
1	Cacr	C. cristata	1997	P1 1/3	0.00	1.3	-	0.19
1	Cahi	C. hispidula	1994	P8 3/2	0.01	1.2	-	0.17
1	Casq	C. squamigera	1994	P8 1/4	0.01	1.2	-	0.17
1	Civu	C. vulgare	1997	P6 1/4	0.00	1.3	-	0.19
1	Digi	Digitaria spp.	1994	P5 3/3	0.01	1.2	-	0.17
1	Dodo	Dodonaea spp.	1995	P2 1/4	0.02	1.3	-	0.19
1	Elin	E. indica	1994	P8 1/3	0.01	1.2	-	0.17
1	Ento	E. tomentosa	2000	P1 2/3	0.01	1.3	-	0.19
1	Eusp	E. sphaericus	1999	P3 1/2	0.01	1.3	-	0.19
1	Inli	I. linnaei	1996	TN3	0.00	1.1	-	0.15
1	Lagr	L. gracilis	1995	P6 2/3	0.02	1.3	-	0.19
1	Lebo	L. bonariense	1999	P9 3/2	0.01	1.3	-	0.19
1	lily	lily	1994	P9 3/3	0.01	1.2	-	0.17
1	Limi	L. microcephala	1996	P9 1/4	0.02	1.1	-	0.15
1	Maci	M. ciliata	1995	P9 3/3	0.02	1.3	-	0.19
1	Mair	Maireana spp.	1994	P3 1/4	0.01	1.2	-	0.17
1	Mein	M. indica	1997	P11 3/3	0.00	1.3	-	0.19
1	mono	monocot	1995	P9 1/3	0.02	1.3	-	0.19
1	Plcu	P. cunninghamii	1994	P10 1/4	0.01	1.2	-	0.17
1	Scle	Sclerolaena spp.	1994	P3 1/4	0.01	1.2	-	0.17
1	Sela	S. lautus	1999	CN3	0.00	1.3	-	0.19
1	Sequ	S. aff. quadridentatus	2000	P9 3/2	0.01	1.3	-	0.19
1	Sida	Sida spp.	1994	P8 3/2	0.01	1.2	-	0.17
1	Spac	S. actinocladus	2000	P9 2/2	0.01	1.3	-	0.19
1	Stac	Stackhousia spp.	1997	P12 1/4	0.00	1.3	-	0.19
1	Stnu	S. nutans	1994	P2 1/2	0.01	1.2	-	0.17
1	Trte	T. terrestris	1995	P12 2/2	0.02	1.3	-	0.19
1	Typh	Typha spp.	1998	P11 3/4	0.02	1.3	-	0.19
1	Visu	V. sulcata	1994	P2 2/2	0.01	1.2	-	0.17
Multiple plants - 1 pot, 1 time [6]								
2	Abox	A. oxycarpon	1994	P12 2/3	0.02	2.4	-	0.34
4	Eitr	E. trigonos	2000	P9 3/2	0.04	5.2	-	0.75
2	Enpo	E. polyphyllus	1994	P7 3/3	0.02	2.4	-	0.34
2	Mami	M. microphylla	2000	P9 3/3	0.02	2.6	-	0.37

Nbrs	Code	Taxon	Year	Locale*	MEAN PERCENT of total emergees	Germinable seeds / sq m TOTAL over 7 years	MAX	MEAN
3	Ptre	P. redolens	1996	P6 2/3	0.05	3.2	-	0.45
2	Sonc	Sonchus spp.	1996	P11 1/2	0.03	2.1	-	0.30
		Multiple plants - 1 year only, >1 pot [17]						
8	Alte	Alternanthera spp.	1994		0.07	9.4	-	1.3
21	Both	Bothriochloa spp.	1994		0.19	24.8	-	3.5
2	Calo	Calotis spp.	1996		0.03	2.1	-	0.3
5	Cycy	C. cyperoides	1998		0.08	6.5	-	0.9
28	Engr	E. gracilis	1994		0.25	33.0	-	4.7
8	Ente	Enteropogon spp.	1994		0.07	9.4	-	1.3
15	Erbr	E. brownii	1997		0.06	19.6	-	2.8
2	Euph	Euphorbia spp.	1994		0.02	2.4	-	0.3
3	Fibi	F. bisumbellata	2000		0.03	3.9	-	0.6
2	legu	legume	1994		0.02	2.4	-	0.3
2	Nime	N. megalosiphon	1996		0.02	2.1	-	0.3
2	Paqu	P. queenslandicum	1995		0.04	2.6	-	0.4
3	sedgT	sedgeT	1996		0.05	3.2	-	0.4
2	Sifi	S. fibulifera	1995		0.04	2.6	-	0.4
3	Thad	T. advena	1996		0.03	3.2	-	0.4
4	Vicu	V. cuneata	1994		0.04	4.7	-	0.7
2	Zorn	Zornia spp.	1995		0.04	2.6	-	0.4
		2 years, 1plant each time [8]						
2	Abut	Abutilon spp.	1994, '95		0.03	2.5	1.3	0.4
2	Brpi	B. piligera	1995, '97		0.02	2.6	1.3	0.4
2	Dici	D. ciliaris	1995, '96		0.04	2.4	1.3	0.3
2	Goce	G. celosioides	1999, '00		0.02	2.6	1.3	0.4
2	Lehy	L. hyssopifolium	1999, '00	$	0.02	2.6	1.3	0.4
2	Malv	Malvaceae	1994, '00		0.02	2.5	1.3	0.4
2	Rhmi	R. minima	1995, '97		0.02	2.6	1.3	0.4
2	Stmu	S. muelleri	1997, '98		0.02	2.6	1.3	0.4
		2 years, 1pot each time [4]						
4	Casc	C. scabiosifolia	1994, '97		0.02	5.1	3.9	0.7
4	Chei	Cheilanthes spp.	1995, '99		0.05	5.2	3.9	0.7
11	Lefa	L. fasciculatum	1997, '99		0.12	14.4	13.1	2.1
3	Verb	Verbena spp.	1994, '96		0.04	3.3	2.1	0.5
		2 years, many pots [16]						
27	Cent	Centauria spp.	1994, '96	$	0.37	29.0	25.5	4.1
3	Chap	C. apiculatum	1995, '97		0.03	3.9	2.6	0.6
4	Chfa	C. fallax	1996, '00		0.01	5.0	3.9	0.7
5	Crsp	Craspedia spp.	1996, '97		0.05	6.0	3.9	0.9
3	Cyda	C. dactylon	1995, '99		0.05	3.9	2.6	0.6
4	Cype	Cyperus spp.	1995, '96		0.07	5.0	3.9	0.7
18	Diaf	D. affine	1995, '97	$	0.23	23.6	13.1	3.4
9	Disa	D. sanguinalis	1994, '97		0.07	11.0	7.1	1.6

Nbrs	Code	Taxon	Year	Locale*	MEAN PERCENT of total emergees	Germinable seeds / sq m TOTAL over 7 years	MAX	MEAN
3	Enac	E. acicularis	1994, '00		0.03	3.7	2.4	0.5
130	Fimb	Fimbristylis spp.	1994, '96		1.96	138.3	134.7	19.8
7	Pami	P. mitchellii	1996, '98		0.08	8.9	7.9	1.3
17	Pasp	Paspalidium spp.	1994, '97		0.08	22.1	21.0	3.2
9	Scan	S. anisacanthoides	1995, '97	$	0.14	11.8	9.2	1.7
20	sedg	sedge	1994, '99		0.18	23.7	22.4	3.4
3	Soel	S. ellipticum	1996, '00		0.03	3.7	2.6	0.5
4	Soni	S. nigrum	1994, '96		0.04	4.6	3.5	0.7
	3 years, many pots [18]							
40	Aris	Aristida spp.			0.34	47.8	41.3	6.8
6	Arle	A. leptopoda			0.04	7.7	5.2	1.1
4	Bodi	B. diffusa			0.04	5.0	2.4	0.7
12	Ceci	C. ciliaris		#	0.10	14.3	6.5	2.0
9	Dagl	D. glochidiatus		$	0.14	11.4	6.5	1.6
3	Didi	D. divaricatissima			0.03	3.5	1.3	0.5
15	Erag	Eragrostis spp.			0.14	17.9	15.3	2.6
6	Eudr	E. drummondii			0.07	7.1	3.2	1.0
4	Glta	G. tabacina			0.03	5.1	2.6	0.7
5	Glte	G. tenuifolia			0.04	6.4	3.9	0.9
5	Heam	H. amplexicaule			0.07	6.0	2.6	0.9
11	Junc	Juncus spp.		$	0.08	14.4	7.9	2.7
5	Maen	M. enchylaenoides			0.06	6.3	2.6	0.9
8	Oxco	O. corniculata			0.09	10.5	6.5	1.5
13	Pacr	P. crinitum			0.18	17.0	7.9	2.4
4	Pani	Panicum spp.			0.04	5.0	2.4	0.7
11	Saka	S. kali		$	0.10	13.5	8.2	1.9
76	Trtr	T. triquetra			0.91	92.9	60.1	13.3
	4 years, many pots [13]							
18	Cemi	C. minima			0.16	23.6	11.8	3.4
41	Cile	C. leptophllum			0.46	53.7	17.0	7.7
27	Cony	Conyza spp.			0.15	35.4	21.0	5.0
14	Cyfu	C. fulvus		#	0.14	17.1	9.2	2.4
54	dic	dicot			0.51	64.2	58.9	9.2
22	Epal	Epaltes spp.			0.34	28.1	18.3	4.0
8	Heco	H. contortus			0.06	10.1	3.9	1.4
17	Paef	P. effusum			0.23	21.5	7.9	3.1
6	Plan	Plantago spp.			0.06	7.5	3.5	1.1
41	Scbi	S. birchii			0.50	51.9	18.3	7.4
10	Scpi	S. pinnata		$	0.05	12.6	7.9	1.8
12	Sisu	S. subspicatum		$	0.11	15.7	5.2	2.2
5	Vebo	V. bonariensis		$	0.04	6.0	2.1	0.9
	5 years, many pots [18]							
6	Alno	A. nodiflora			0.07	7.9	2.6	1.1
27	Bobl	B. bladhii		#	0.21	33.0	21.2	4.7

Nbrs	Code	Taxon	Year	Locale*	MEAN PERCENT of total emergees	Germinable seeds / sq m TOTAL over 7 years	MAX	MEAN
9	Chcr	C. cristatum		$	0.10	11.3	3.9	1.6
124	Chtr	C. truncata			1.17	162.4	62.9	23.2
415	Cras	Crassula spp.			2.58	530.5	382.5	75.8
16	Dibr	D. brownii		$	0.13	20.8	10.5	3.0
9	Dico	D. coenicola			0.08	11.5	3.9	1.6
74	Eipo	E. polygonoides			0.80	93.9	32.7	13.4
81	Erle	E. leptostachya			0.79	99.9	43.2	14.3
17	Eval	E. alsinoides			0.20	21.8	6.5	3.1
20	Maam	M. americanum			0.24	26.2	9.2	3.7
22	Negr	N. gracilis		#	0.32	26.1	11.7	3.7
21	Paca	P. caespitosum			0.24	25.8	13.0	3.7
23	Pter	Pterocaulon spp.			0.21	30.1	11.8	4.3
11	Sobe	S. belloides		$	0.09	14.2	3.9	2.0
185	Spel	S. elongatus			1.83	241.1	137.5	34.4
76	Thtr	T. triandra			0.11	22.0	6.5	3.1
16	Urpa	U. panicoides		#	0.15	21.0	7.9	3.0
	6 years, many pots [12]		**Year missed**					
35	Arca	A. calycina	1996		0.28	45.4	13.1	6.5
36	Arla	A. latifolia	1994		0.20	46.9	28.8	6.7
256	Arra	A. ramosa	1996		1.79	335.2	158.5	47.9
32	Cybi	C. bifax	2000		0.45	38.3	14.8	5.5
15	Cyre	C. refractus	1994	#	0.15	19.1	5.2	2.7
125	Epau	E. australis	1995		1.14	153.5	31.8	21.9
17	Erci	E. cilianensis	1999		0.23	21.4	6.5	3.0
58	Erso	E. sororia	1994		0.63	74.2	21.0	10.6
10	Eupo	E. populnea	1994	$	0.12	12.8	3.9	1.8
158	gras	grass	1996		1.35	188.8	163.9	27.0
19	Pabu	P. buncei	1996		0.17	24.2	6.5	3.5
22	Phvi	P. virgatus	1994	#	0.27	27.6	6.5	3.9

Note: $ means this taxon was recorded from the same locality twice during the trial.
means the same species occurred repeatedly at 2 different locations.
* Locale code logic – P6 = Paddock 6 etc;
2/4 = TRAPS Transect 2 / 4th post from N end of transect etc.

Appendix I6

Table I 6. Details of **Glentulloch g**erminable soil seed populations over 6 spring times

Plant type	Species code	Genus	species	Total germinants	Percentage of all germinating seeds	Germinable Seeds / sq metre	Times recorded from pots	transects	pdks
m	Abma	Abutilon	malvifolium	1	0.009	1.31	1	1	1
m	Abox	Abutilon	oxycarpon	2	0.019	2.36	1	1	1
m	Abut	Abutilon	spp	2	0.019	2.49	2	2	2
d	Acas	Achyranthes	aspers	1	0.009	1.31	1	1	1
d	Alno	Alternanthera	nodiflora	6	0.056	7.86	6	6	6
d	Alte	Alternanthera	spp	8	0.075	9.43	7	7	6
d	Amcr	Amaranthus	cruentus	1	0.009	1.31	1	1	1
d	Amma	Amaranthus	macrocarpa	1	0.009	1.31	1	1	1
g	Arca	Aristida	calycina	35	0.326	45.45	32	29	24
g	Aris	Aristida	spp	40	0.373	47.81	30	24	15
g	Arla	Aristida	latifolia	36	0.336	46.91	20	19	17
g	Arle	Aristida	leptopoda	6	0.056	7.73	6	6	5
g	Arra	Aristida	ramosa	256	**2.386**	335.21	87	63	43
g	Bobl	Bothriochloa	bladhii	27	0.252	33.01	12	10	9
g	Bode	Bothriochloa	decipiens	964	**8.986**	1243.27	225	141	80
d	Bodi	Boerhavia	diffusa	4	0.037	4.98	4	4	4
d	Bodo	Boerhavia	dominii	1	0.009	1.31	1	1	1
g	Boew	Bothriochloa	ewartiana	1	0.009	1.06	1	1	1
g	Both	Bothriochloa	spp	21	0.196	24.76	14	10	8
d	Brau	Brunoniella	australis	1	0.009	1.31	1	1	1
a	Brci	Brachycombe	ciliaris	1	0.009	1.06	1	1	1
g	Brpi	Brachiaria	piligera	2	0.019	2.62	2	2	2
w	Cacr	Casuarina	cristata	1	0.009	1.31	1	1	1
a	Cahi	Calotis	hispidula	1	0.009	1.18	1	1	1
a	Cala	Calotis	lappulacea	50	0.466	64.61	38	35	30
a	Casc	Calotis	scabiosifolia	4	0.037	5.11	2	2	2
a	Calo	Calotis	spp	2	0.019	2.12	2	2	2
a	Casq	Calotis	squamigera	1	0.009	1.18	1	1	1
g	Ceci	Cenchrus	ciliaris	12	0.112	14.33	8	8	8
a	Cemi	Centipeda	minima	18	0.168	23.58	6	5	5
d	Cent	Centauria	spp	27	0.252	29.00	10	8	8
d	Cesp	Centauria	spicatum	1001	**9.331**	1295.40	241	149	80
a	Chap	Chrysocephalum	apiculatum	3	0.028	3.93	3	3	3
c	Chcr	Chenopodium	cristatum	9	0.084	11.29	8	8	8
g	Chdi	Chloris	divaricata	1103	**10.282**	1408.91	329	182	90
f	Chei	Cheilanthes	spp	4	0.037	5.24	2	2	2
g	Chfa	Chrysopogon	fallax	4	0.037	4.99	4	4	4
g	Chtr	Chloris	truncata	124	**1.156**	162.43	65	56	33
g	Chve	Chloris	ventricosa	72	0.671	89.27	47	41	35
d	Cile	Ciclospermum	leptophllum	41	0.382	53.71	14	10	10
a	Civu	Cirsium	vulgare	1	0.009	1.31	1	1	1
a	Cony	Conyza	spp	27	0.252	35.37	18	17	16
d	Cras	Crassula	spp	415	**3.868**	530.52	120	73	35
a	Crsp	Craspedia	spp	5	0.047	6.05	3	3	3
s	Cybi	Cyperus	bifax	32	0.298	38.30	22	20	18
s	Cycy	Cyperus	cyperoides	5	0.047	6.55	5	5	5
g	Cyda	Cynodon	dactylon	3	0.028	3.93	3	2	2
s	Cyfu	Cyperus	fulvus	14	0.130	17.09	13	13	11
s	Cygr	Cyperus	gracilis	437	**4.073**	540.65	170	137	82
g	Cyre	Cymbopogon	refractus	15	0.140	19.15	14	13	12

Plant type	Species code	Genus	species	Total germinants	Percentage of all germinating seeds	Germinable Seeds / sq metre	Times recorded from pots	transects	pdks
s	Cype	Cyperus	spp	4	0.037	4.99	3	3	3
d	Dagl	Daucus	glochidiatus	9	0.084	11.40	9	9	8
g	Diaf	Dichanthium	affine	18	0.168	23.58	10	10	9
g	Dibr	Digitaria	brownii	16	0.149	20.83	12	12	11
d	dic	dicot	Unidentifiable	54	0.503	64.19	33	29	16
g	Dici	Digitaria	ciliaris	2	0.019	2.37	2	2	2
g	Dico	Digitaria	coenicola	9	0.084	11.53	9	9	9
g	Didi	Digitaria	divaricatissima	3	0.028	3.55	3	3	3
g	Digi	Digitaria	spp	1	0.009	1.18	1	1	1
g	Disa	Digitaria	sanguinalis	9	0.084	11.00	8	8	7
g	Dise	Dichanthium	sericeum	232	**2.163**	299.09	92	69	50
w	Dodo	Dodonaea	spp	1	0.009	1.31	1	1	1
c	Eipo	Einadia	polygonoides	74	0.690	93.93	37	32	20
c	Eitr	Einadia	trigonos	4	0.037	5.24	1	1	1
g	Elin	Eleusine	indica	1	0.009	1.18	1	1	1
g	Enac	Enteropogon	acicularis	3	0.028	3.67	3	3	3
g	Engr	Enneapogon	gracilis	28	0.261	33.01	15	11	7
g	Enne	Enneapogon	spp	329	**3.067**	424.33	143	101	59
g	Enpo	Enneapogon	polyphyllus	2	0.019	2.36	1	1	1
g	Enra	Enteropogon	ramosus	640	**5.966**	801.46	146	104	60
g	Ente	Enteropogon	spp	8	0.075	9.43	5	5	5
c	Ento	Enchylaena	tomentosa	1	0.009	1.31	1	1	1
a	Epal	Epaltes	spp	22	0.205	28.07	13	12	10
a	Epau	Epaltes	australis	125	**1.165**	153.52	32	27	23
g	Erag	Eragrostis	spp	15	0.140	17.95	11	10	8
g	Erbr	Eragrostis	brownii	15	0.140	19.65	9	7	4
g	Erci	Eragrostis	cilianensis	17	0.158	21.36	14	14	13
g	Erla	Eragrostis	lacunaria	206	**1.920**	258.20	88	69	53
g	Erle	Eragrostis	leptostachya	81	0.755	99.88	34	25	18
g	Ermo	Eragrostis	molybdea	383	**3.570**	469.17	168	124	76
g	Erpa	Eragrostis	parviflora	16	0.149	19.54	13	13	13
g	Erps	Eriochloa	pseudoacrotricha	77	0.718	98.47	55	48	37
g	Erso	Eragrostis	sororia	58	0.541	74.23	40	35	31
d	Eudr	Euphorbia	drummondi	6	0.056	7.11	4	4	4
d	Euph	Euphorbia	spp	2	0.019	2.36	2	2	2
w	Eupo	Eucalyptus	populnea	10	0.093	12.85	10	10	10
a	Eusp	Euchiton	sphaericus	1	0.009	1.31	1	1	1
d	Eval	Evolvulus	alsinoides	17	0.158	21.77	15	15	14
s	Fibi	Fimbristylis	bisumbellata	3	0.028	3.93	3	3	3
s	Fidi	Fimbristylis	dichotoma	283	**2.638**	368.91	127	99	67
s	Fimb	Fimbristylis	spp	130	**1.212**	138.29	51	33	16
l	Glta	Glycine	tabacina	4	0.037	5.11	4	4	4
a	Glte	Glossogyne	tenuifolia	5	0.047	6.42	4	4	4
a	Gnap	Gnaphalium	spp	124	**1.156**	159.68	77	62	42
d	Goce	Gomphrena	celosioides	2	0.019	2.62	2	2	2
g	gras	grass		158	**1.473**	188.76	67	45	26
d	Heam	Heliotropium	amplexicaule	5	0.047	6.05	5	5	5
g	Heco	Heteropogon	contortus	8	0.075	10.09	6	6	6
l	Inli	Indigofera	linnaei	1	0.009	1.06	1	1	1
s	Junc	Juncus	spp	11	0.103	14.41	11	11	9
o	Lagr	Laxmannia	gracilis	1	0.009	1.31	1	1	1
l	legu	legume		2	0.019	2.36	2	2	2
d	Lebo	Lepidium	bonariense	1	0.009	1.31	1	1	1
d	Lefa	Lepidium	fasciculatum	11	0.103	14.41	2	2	2
d	Lehy	Lepidium	hyssopifolium	2	0.019	2.62	2	2	2

Plant type	Species code	Genus	species	Total germinants	Percentage of all germinating seeds	Germinable Seeds / sq metre	Times recorded from pots	transects	pdks
o	lily	lily		1	0.009	1.18	1	1	1
s	Limi	Lipocarpha	microcephala	1	0.009	1.06	1	1	1
m	Maam	Malvastrum	americanum	20	0.186	26.20	13	11	11
c	Maci	Maireana	ciliata	1	0.009	1.31	1	1	1
c	Maen	Maireana	enchylaenoides	5	0.047	6.29	5	5	5
c	Mair	Maireana	spp	1	0.009	1.18	1	1	1
m	Malv	Malvaceae		2	0.019	2.49	2	2	2
c	Mami	Maireana	microphylla	2	0.019	2.62	1	1	1
l	Mein	Melilotus	indica	1	0.009	1.31	1	1	1
i	mono	monocotyledon		1	0.009	1.31	1	1	1
l	Negr	Neptunia	gracilis	22	0.205	26.08	14	14	14
d	Nime	Nicotiana	megalosiphon	2	0.019	2.12	2	2	2
d	Oxco	Oxalis	corniculata	8	0.075	10.48	7	7	7
g	Pabu	Panicum	buncei	19	0.177	24.23	16	16	15
g	Paca	Paspalidium	caespitosum	21	0.196	25.82	12	10	9
g	Paco	Paspalidium	constrictum	16	0.149	20.33	14	14	13
g	Pacr	Paspalidium	crinitum	13	0.121	17.03	5	4	4
g	Paef	Panicum	effusum	17	0.158	21.52	12	11	10
g	Pami	Panicum	mitchellii	7	0.065	8.92	5	5	5
g	Pani	Panicum	spp	4	0.037	4.98	4	4	4
g	Paqu	Panicum	queenslandicum	2	0.019	2.62	2	2	2
g	Pasp	Paspalidium	spp	17	0.158	22.14	5	4	3
d	Phvi	Phyllanthus	virgatus	22	0.205	27.57	21	21	21
d	Plan	Plantago	spp	6	0.056	7.47	6	6	6
d	Plcu	Plantago	cunninghamii	1	0.009	1.18	1	1	1
d	Poau	Portulaca	australis	106	0.988	126.77	37	34	31
d	Pool	Portulaca	oleracea	185	**1.724**	229.47	82	70	47
a	Pter	Pterocaulon	spp	23	0.214	30.13	17	16	16
a	Ptre	Pterocaulon	redolens	3	0.028	3.18	1	1	1
l	Rhmi	Rhynchosia	minima	2	0.019	2.62	2	2	2
c	Saka	Salsola	kali	11	0.103	13.49	9	9	8
c	Scan	Sclerolaena	anisacanthoides	9	0.084	11.79	6	6	6
c	Scbi	Sclerolaena	birchii	41	0.382	51.87	19	16	14
c	Scle	Sclerolaena	spp	1	0.009	1.18	1	1	1
a	Scpi	Schkuhria	pinnata	10	0.093	12.60	4	4	4
s	sedg	sedge		20	0.186	23.71	13	11	6
s	sedgT	Cyperaceae	unidentified	3	0.028	3.18	2	2	1
a	Sela	Senecio	lautus	1	0.009	1.31	1	1	1
a	Sequ	Senecio	quadridentatus	1	0.009	1.31	1	1	1
m	Sida	Sida	spp	1	0.009	1.18	1	1	1
m	Sifi	Sida	fibulifera	2	0.019	2.62	2	2	2
m	Sisu	Sida	subspicatum	12	0.112	15.72	8	7	7
a	Sobe	Solenogyne	belloides	11	0.103	14.16	9	9	9
d	Soel	Solanum	ellipticum	3	0.028	3.68	3	3	3
d	Soni	Solanum	nigrum	4	0.037	4.60	3	3	3
a	Sonc	Sonchus	spp	2	0.019	2.12	1	1	1
g	Spac	Sporobolus	actinocladus	1	0.009	1.31	1	1	1
g	Spca	Sporobolus	carolii	120	**1.119**	147.16	76	65	46
g	Spcr	Sporobolus	creber	640	**5.966**	808.93	186	135	81
g	Spel	Sporobolus	elongatus	185	**1.724**	241.09	70	50	37
d	Stac	Stackhousia	spp	1	0.009	1.31	1	1	1
a	Stmu	Stuartina	muelleri	2	0.019	2.62	2	2	2
d	Stnu	Stenopetalum	nutans	1	0.009	1.18	1	1	1
g	Thad	Thellungia	advena	3	0.028	3.18	3	3	3
g	Thtr	Themeda	triandra	17	0.158	22.02	11	11	11

Plant type	Species code	Genus	species	Total germinants	Percentage of all germinating seeds	Germinable Seeds / sq metre	Times recorded from pots	transects	pdks
g	Trau	Tragus	australianus	211	**1.967**	265.28	117	91	53
g	Trlo	Tripogon	loliiformis	168	**1.566**	216.04	120	100	62
d	Trte	Tribulus	terrestris	1	0.009	1.31	1	1	1
d	Trtr	Trianthema	triquetra	76	0.708	92.87	22	18	14
I	Typh	Typha	spp	1	0.009	1.31	1	1	1
g	Urpa	Urochloa	panicoides	16	0.149	20.96	11	11	11
d	Vebo	Verbena	bonariensis	5	0.047	6.05	5	4	4
d	Veof	Verbena	officinalis	164	**1.529**	206.59	110	86	55
d	Verb	Verbena	spp	3	0.028	3.30	2	2	2
d	Vete	Verbena	tenuisecta	36	0.336	46.00	29	28	25
a	Vicu	Vittadinia	cuneata	4	0.037	4.72	2	2	1
a	Visu	Vittadinia	sulcata	1	0.009	1.18	1	1	1
a	Vitt	Vittadinia	spp	37	0.345	47.30	33	32	25
d	Wahl	Wahlenbergia	spp	272	**2.535**	352.16	141	98	58
l	Zorn	Zornia	spp	2	0.019	2.62	2	2	2
Total	**taxa**	**176**	**Total seed germd**	**10728**		**Total items**	**804**	**324**	**156**

Plant type codes:

d = dicot
g = grass
a = asteraceae
m = malvaceae
l = legume
c = chenop
s = sedge & lilies
f = ferns
w = woody tree/shrub
o = odd bodds
i = monocot

25 taxa averaged over 1% of all germinable seeds
Those 25 contributed 82.5% of all germinations

26 species were recorded every spring

Appendix I7

Table I 7. Germinable spring soil seed loads, meaned for main treatments, at the Glentulloch grazing site

Species	Spring	Treeless	Treed	High	Medium	Low	TOTAL
Species	**1995**						
Qld bluegrass (Dicser)		12	8	8	6	6	20
Pitted bluegrass (Botdec)		7	2	0	5	4	9
Twirly windmill (Entram)		48	21	21	5	43	69
g = grass		249	167	123	87	206	416
c = chenopods		23	22	18	10	17	45
s = sedges & lilies		21	50	22	18	31	71
TOTAL		411	329	245	174	321	740
Species	**1996**						
Qld bluegrass (Dicser)		5	2	0	0	7	7
Pitted bluegrass (Botdec)		16	4	1	6	13	20
Twirly windmill (Entram)		27	10	2	2	33	37
g = grass		224	180	83	114	207	404
c = chenopods		1	3	2	0	2	4
s = sedges & lilies		98	129	85	73	69	227
TOTAL		440	434	247	257	370	874
Species	**1997**						
Qld bluegrass (Dicser)		71	30	10	28	63	101
Pitted bluegrass (Botdec)		76	196	115	113	44	272
Twirly windmill (Entram)		127	54	74	3	104	181
g = grass		1026	866	592	595	705	1892
c = chenopods		31	15	31	4	11	46
s = sedges & lilies		40	45	18	18	49	85
TOTAL		1587	1421	1073	891	1044	3008
Species	**1998**						
Qld bluegrass (Dicser)		3	1	0	1	3	4
Pitted bluegrass (Botdec)		4	3	3	3	1	7
Twirly windmill (Entram)		15	4	6	0	13	19
g = grass		135	113	64	61	123	248
c = chenopods		0	2	0	0	2	2
s = sedges & lilies		99	120	78	66	75	219
TOTAL		374	357	251	178	302	731
Species	**1999**						
Qld bluegrass (Dicser)		24	5	1	17	11	29
Pitted bluegrass (Botdec)		91	121	52	115	45	212
Twirly windmill (Entram)		27	6	2	5	26	33
g = grass		288	233	181	183	157	521
c = chenopods		2	5	6	1	0	7
s = sedges & lilies		40	27	15	16	36	67
TOTAL		705	571	362	510	404	1276
Species	**2000**						
Qld bluegrass (Dicser)		27	5	1	18	13	32
Pitted bluegrass (Botdec)		58	59	35	56	26	117
Twirly windmill (Entram)		87	14	77	5	19	101
g = grass		540	205	358	190	197	745
c = chenopods		13	1	12	0	2	14
s = sedges & lilies		40	45	35	24	26	85
TOTAL		1053	494	616	462	469	1547

Table I 8. Germinable spring soil seed loads, meaned for main treatments, at the Glentulloch burning trial

Species	Spring	Treeless	Treed	Burned	Unburnt	Total
Species	**1995**					
Qld bluegrass (Dicser)		0	1	1	0	1
Pitted bluegrass (Botdec)		7	0	7	0	7
Twirly windmill (Entram)		0	1	1	0	1
g = grass		22	9	13	18	31
c = chenopods		0	3	0	3	3
s = sedges & lilies		5	1	0	6	6
TOTAL		35	16	15	36	51
Species	**1996**					
Qld bluegrass (Dicser)		6	0	0	6	6
Pitted bluegrass (Botdec)		0	2	1	1	2
Twirly windmill (Entram)		5	12	2	15	17
g = grass		32	49	26	55	81
c = chenopods		0	0	0	0	0
s = sedges & lilies		40	11	4	47	51
TOTAL		87	78	43	122	165
Species	**1997**					
Qld bluegrass (Dicser)		8	1	1	8	9
Pitted bluegrass (Botdec)		1	12	13	0	13
Twirly windmill (Entram)		0	1	0	1	1
g = grass		42	41	39	44	83
c = chenopods		0	1	0	1	1
s = sedges & lilies		5	4	6	3	9
TOTAL		81	91	62	110	172
Species	**1998**					
Qld bluegrass (Dicser)		1	0	0	1	1
Pitted bluegrass (Botdec)		1	0	0	1	1
Twirly windmill (Entram)		0	0	0	0	0
g = grass		15	14	5	24	29
c = chenopods		0	0	0	0	0
s = sedges & lilies		34	15	17	32	49
TOTAL		62	42	25	79	104
Species	**1999**					
Qld bluegrass (Dicser)		15	9	19	5	24
Pitted bluegrass (Botdec)		45	64	47	62	109
Twirly windmill (Entram)		0	1	0	1	1
g = grass		17	10	14	13	27
c = chenopods		0	0	0	0	0
s = sedges & lilies		19	4	5	18	23
TOTAL		155	106	107	154	261
Species	**2000**					
Qld bluegrass (Dicser)		2	2	2	2	4
Pitted bluegrass (Botdec)		18	13	11	20	31
Twirly windmill (Entram)		1	0	0	1	1
g = grass		72	22	57	37	94
c = chenopods		0	0	0	0	0
s = sedges & lilies		12	2	3	11	14
TOTAL		141	59	84	116	200

APPENDIX J. Landscape Functional Analysis Extras, Ironbark and Poplar box sites

Appendix J1

Table J1. Indices of landscape functionality after 7 years under different treatments at Glentulloch, expressed as a percentage of the most conservative management result.

Trtmnt	Data	**High**	**Medium**	**Low**	Tree mean			
Treeless	Stability	85	96	100	94			
	Infiltration	84	88	100	91			
	Nutrients	71	84	100	85			
	Runon	24	28	100	51			
	Runoff	203	198	100	167			
	LOI	24	28	100	51			
Treed	Stability	98	99	100	99			
	Infiltration	93	96	100	96			
	Nutrients	89	97	100	95			
	Runon	56	75	100	77			
	Runoff	143	125	100	122			
	LOI	56	75	100	77			**cf. KB**
						Treeless	**Treed**	**Mean**
Mean	Stability	91	97	100	96	102	100	95
	Infiltration	88	92	100	93	101	100	66
	Nutrients	79	90	100	90	109	100	88
	Runon	39	50	100	63	78	100	
	Runoff	170	158	100	143	113	100	
	LOI	39	50	100	63	78	100	62

Burning effect

Attribute	**Burnt**	**Unburnt**	Treeless	Treed	**cf. Keilambete Mean**
Stability	87	100	106	100	90
Infiltration	72	100	108	100	60
Nutrients	64	100	111	100	97
Runon	82	100	124	100	
Runoff	204	100	45	100	
LOI	83	100	124	100	117

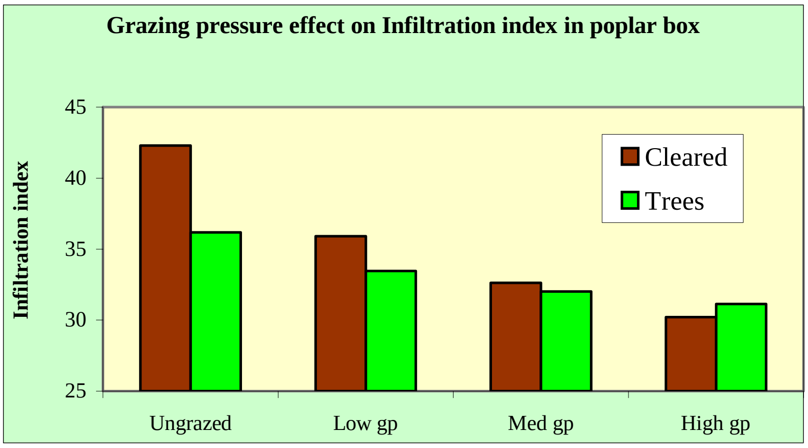
Table J2. Indices of landscape functionality due to different treatments after 7 years at Keilambete, expressed as a percentage of the most conservative management result.

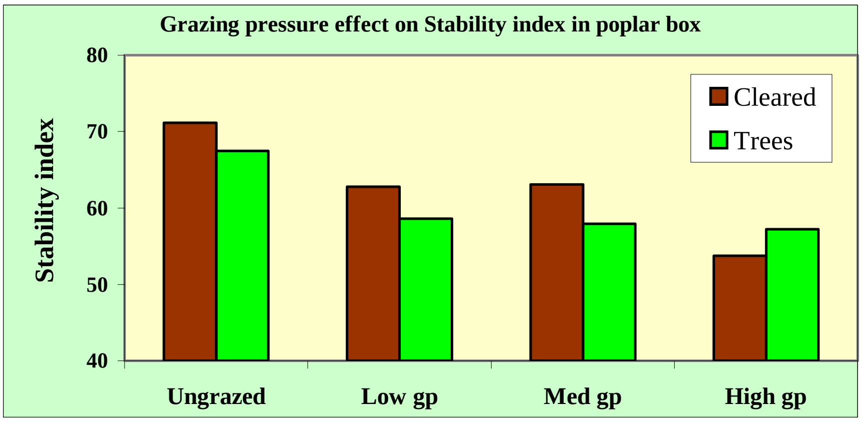
Trtmt	Data	**High**	**Medium**	**Low**	Tree mean	Treeless	Treed	**cf. Glth Mean**
Treeless	Stability	91	94	100	95			
	Infiltration	87	93	100	93			
	Nutrients	82	87	100	89			
	Runon	59	80	100	80			
	Runoff	205	150	100	152			
	LOI	59	80	100	80			
Treed	Stability	87	95	100	94			
	Infiltration	86	97	100	95			
	Nutrients	83	101	100	95			
	Runon	57	66	100	74			
	Runoff	196	176	100	157			
	LOI	57	66	100	74			
Mean	Stability	89	95	100	95	105	100	105
	Infiltration	87	95	100	94	104	100	152
	Nutrients	82	94	100	92	102	100	114
	Runon	58	73	100	77	112	100	
	Runoff	200	164	100	155	88	100	
	LOI	58	73	100	77	112	100	162

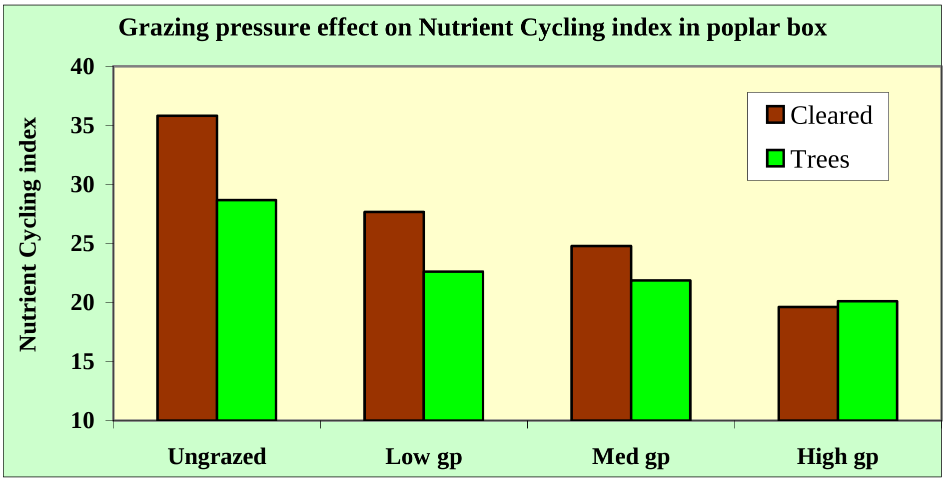
K'bete	**Burning effect Attribute**	**Burnt**	**Unburnt**	Treeless	Treed	**cf. Glentulloch Mean**
	Stability	99	100	101	100	111
	Infiltration	90	100	108	100	167
	Nutrients	85	100	95	100	103
	Runon	51	100	113	100	
	Runoff	484	100	78	100	
	LOI	51	100	113	100	85

Appendix J2

Figures J1 – J3. Histograms showing differences in landscape functional indices due to different grazing management at Glentulloch, with and without tree cover.

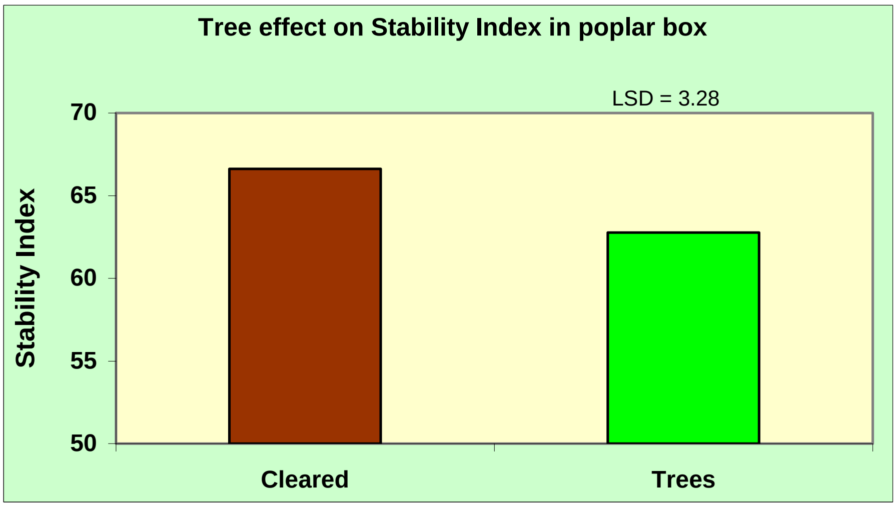


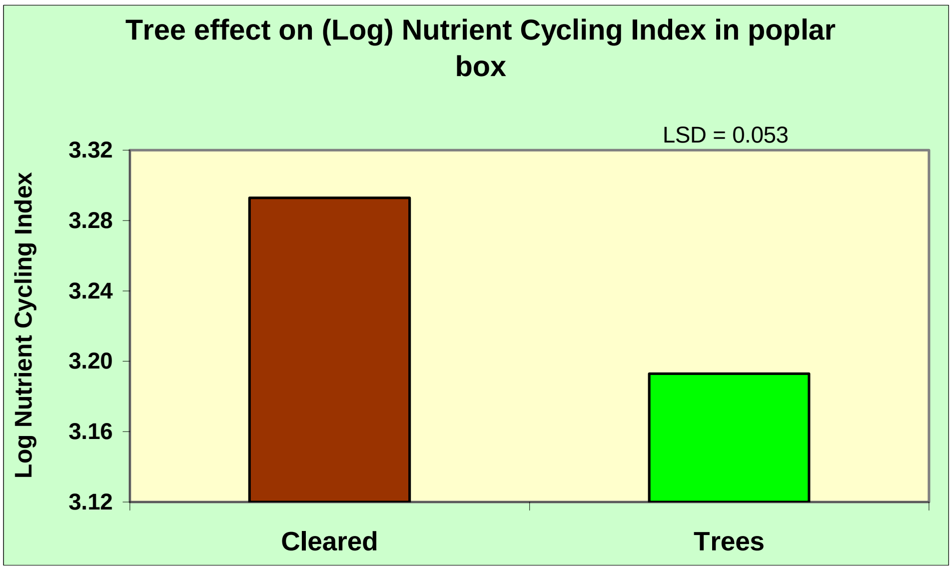


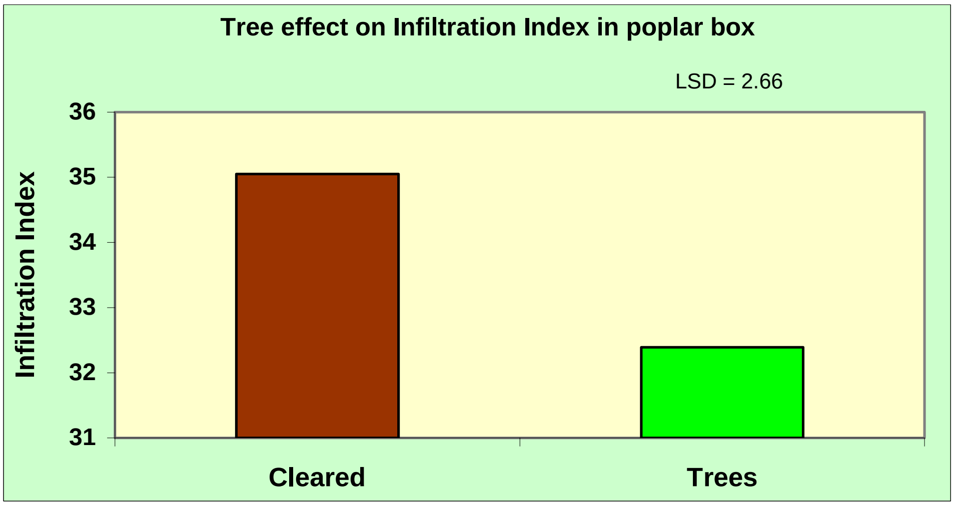


Appendix J3

Figures J4 – J6. Histograms showing the effect of trees on landscape functionality indices after 7 years at the ungrazed burning trial at Glentulloch

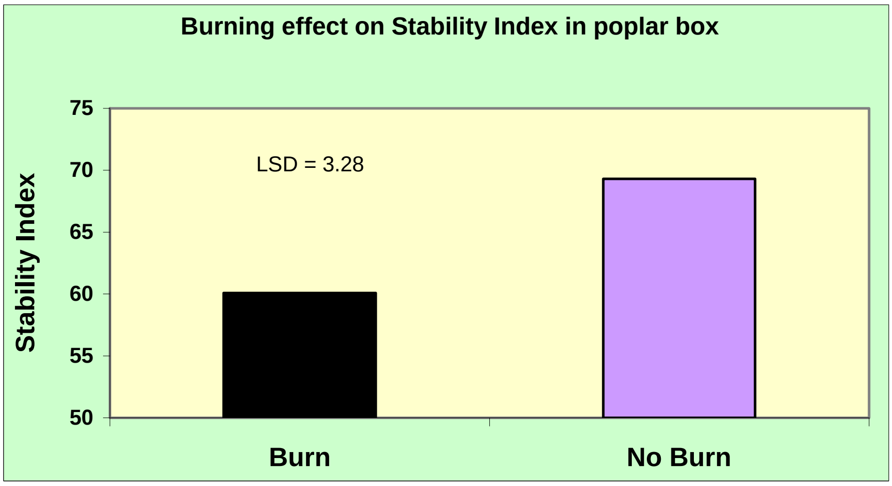


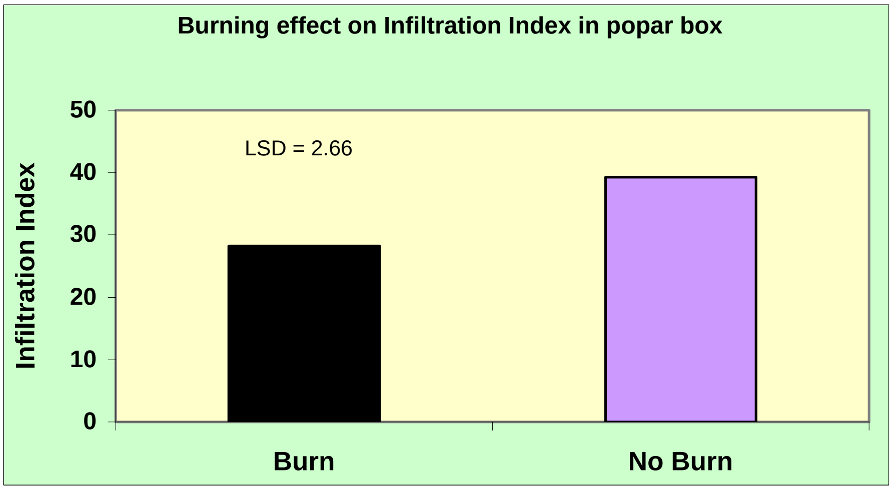


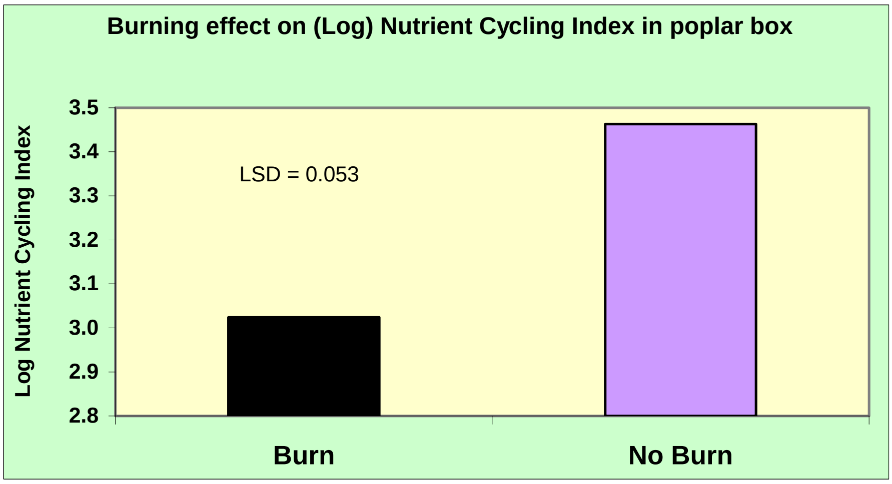


Appendix J4

Figures J7 – J9. Histograms showing the effect of regular spring burns on three landscape indices after 7 years without grazing at Glentulloch

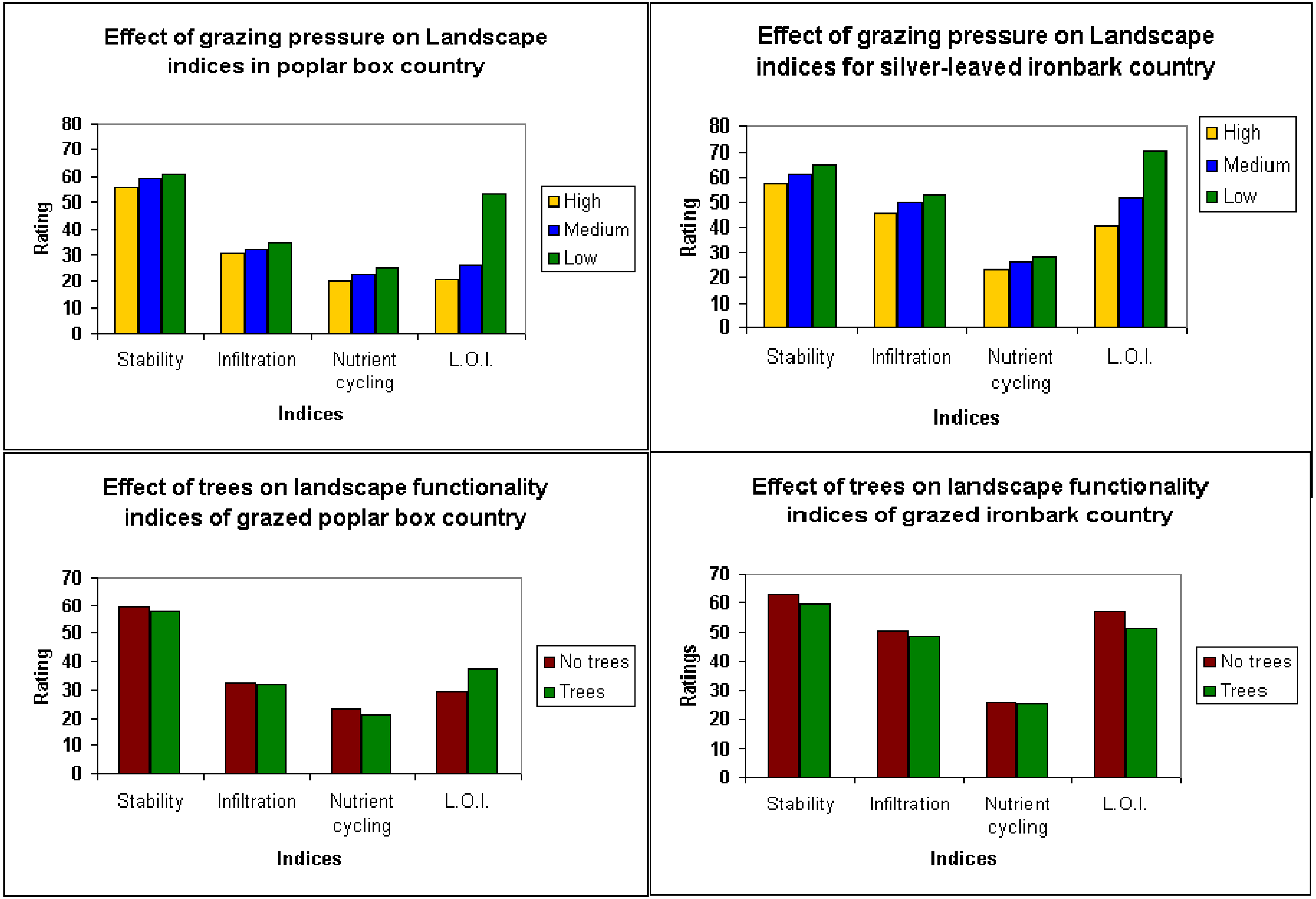






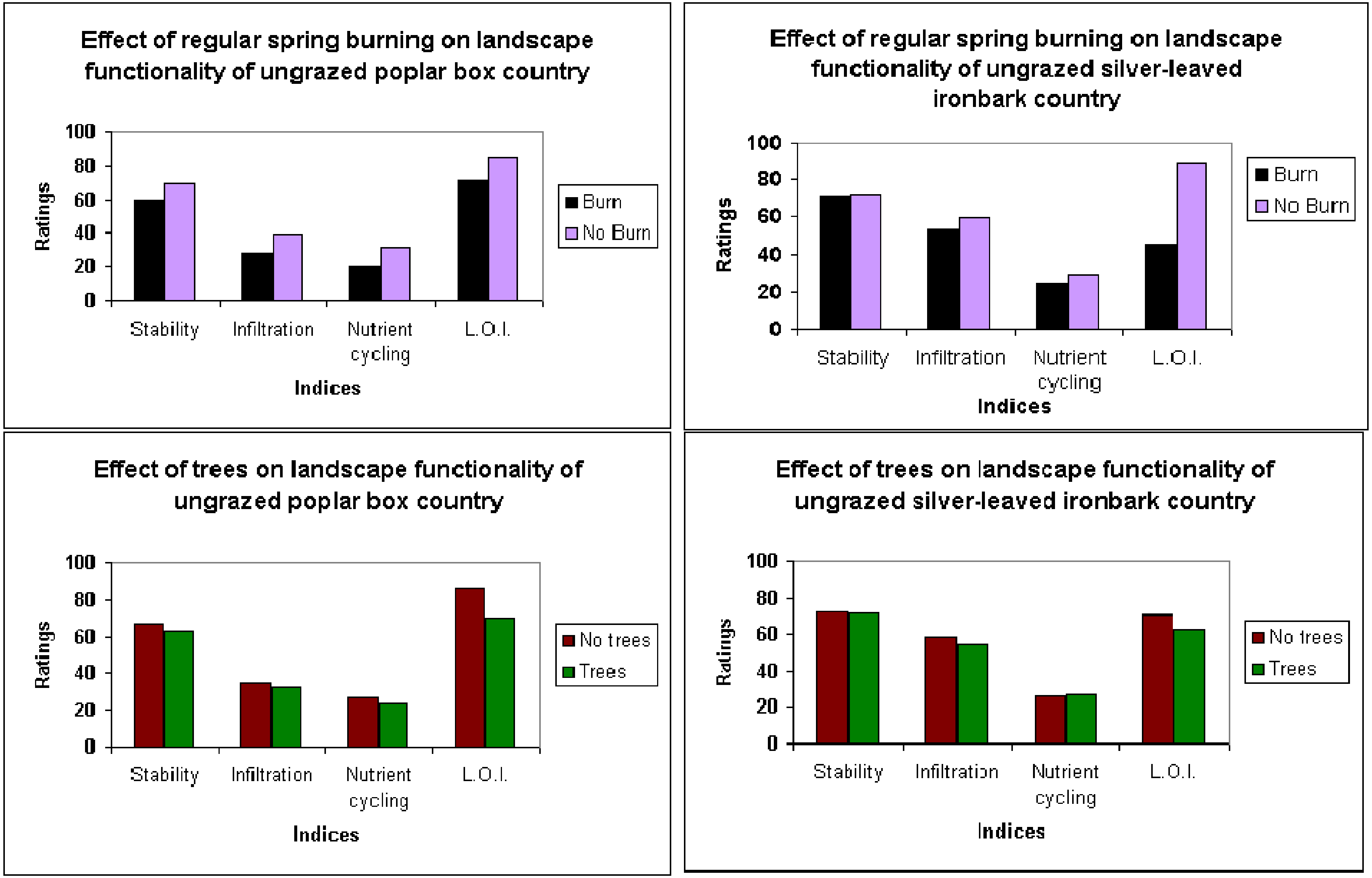
Appendix J5

Figure J10. Histograms showing LFA indices for Poplar box & Ironbark woodlands after 7 years of differing grazing and timber management



Appendix J6

Figure J11. Histograms showing LFA indices for Poplar box & Ironbark woodlands after 7 years of spring burns vs. exclosure from grazing



Appendix J7

Format of LFA data analysis sheets supplied by Tongway and Hindley, CSIRO (2003)

(A) Start sheet of Excel workbook

This spreadsheet (workbook) has been developed by CSIRO Division of Wildlife and Ecology to assist you in entering and interpreting data collect whilst accessing your Landscape using the LFA and SSCC method. The spreadsheet is divided up into 10 sheets.

A separate workbook is used for each transect. The sheets are used in the following way for entering data

Sheet 1	Start	In this sheet below the unique identifier for the transect. The identified strata The identified obstruction encountered
Sheet 2	Summary	This page is the collected data summarised.
Sheet 3	LFA	The log of the transect.
Sheet 4-10	SSCC	The assessed soil surface condition for each strata recorded (a separate sheet is used for each strata.)

Data is entered into bold outlined boxes

Site Name

Location

Transect Name

Transect Strata

Strata	Code

Transect obstructions

Obstruction	Code

(B) Summary sheet of workbook

Site Name
Location
Transect Name

Landscape

Strata	Mean Fetch Length (m)	%
Total		0.0

Obstructions

Obstruction	Code	Width (cm)	No	Mean
Total		0	0	

Number of Obstructions/10m 0.00
Total Obstruction Width (m/10m) 0 cm
Average Fetch Length (m) 0.00 m
Obstruction Index* 0.00 m

* total length of obstructions/transect length

Soil Surface Condition **Full Strata**

Strata	Stability	Std err	Infiltration	Std err	Nutrients	Std err

Soil Surface Condition **Landscape proportion of each strata**

Strata	Stability	Std err	Infiltration	Std err	Nutrients	Std err
Total	0.0		0.0		0.0	

(C) LFA raw data sheet headings. Number of rows is limited to 195 by default

Transect	

Distance (m)	obs/width (cm)	Strata/Obstruction
0		

(D) LFA_work sheet layout

Fetch

Fetch	Strata	code	Fetch	No	Mean	Proportion	%
	Total		0	0	0	0	0

Obstruction	Code	Width	No	Mean Width (cm)
Total		0	0	

Total Obstruction Length	0
Total Obstruction Width	0

(E) SSCC worksheet example from LFA workbook.
These sheets are used to assign quantified values/scores to each of the identified Strata along the transect. From these replicated (up to 6) ratings, the indices are calculated

Soil Surface Condition Assessment
Site
Stratification -

Features	Max score	Rep1	Rep 2	Rep 3	Rep 4	Rep 5	Rep 6
Soil Cover	5	0	0	0	0	0	0
Per. Basal Cover	4	0	0	0	0	0	0
Litter cover (simple)	10	0	0	0	0	0	0
Litter (Org & Incorp)	30	0	0	0	0	0	0
Crytogam cover	4	0	0	0	0	0	0
Crust broken-ness	4	0	0	0	0	0	0
Erosion features	4	0	0	0	0	0	0
Deposited materials	4	0	0	0	0	0	0
Microtopography	5	0	0	0	0	0	0
Surface nature	5	0	0	0	0	0	0
Slake test	4	0	0	0	0	0	0
Texture	4	0	0	0	0	0	0

Stability

Features	Max score	Rep1	Rep 2	Rep 3	Rep 4	Rep 5	Rep 6
Soil Cover	5	0	0	0	0	0	0
Litter cover (simple)	10	0	0	0	0	0	0
Crytogam cover	4	0	0	0	0	0	0
Crust broken-ness	4	0	0	0	0	0	0
Erosion features	4	0	0	0	0	0	0
Deposited materials	4	0	0	0	0	0	0
Surface nature	5	0	0	0	0	0	0
Slake test	4	0	0	0	0	0	0
Total		0	0	0	0	0	0
Divide by		0	0	0	0	0	0
%							

Proportion							

Grand Total	0	0
Number of Reps	0	0
Mean		
Std Dev	n/a	n/a
Std Err	n/a	n/a

Infiltration/runoff

Features	Max score	Rep1	Rep 2	Rep 3	Rep 4	Rep 5	Rep 6
Litter cover (simple)	10	0	0	0	0	0	0
Microtopography	5	0	0	0	0	0	0
Slake test	4	0	0	0	0	0	0
Texture	4	0	0	0	0	0	0
Total		0	0	0	0	0	0
Divide by		0	0	0	0	0	0
%							

Proportion							

Grand Total	0	0
Number of Reps	0	0
Mean		
Std Dev	n/a	n/a
Std Err	n/a	n/a

Nutrient cycling status

Features	Max score	Rep1	Rep 2	Rep 3	Rep 4	Rep 5	Rep 6
Per. Basal Cover	4	0	0	0	0	0	0
Litter (Org & Incorp)	30	0	0	0	0	0	0
Crytogam cover	4	0	0	0	0	0	0
Microtopography	5	0	0	0	0	0	0
Total		0	0	0	0	0	0
Divide by		0	0	0	0	0	0
%							

Proportion							

Grand Total	0	0
Number of Reps	0	0
Mean		
Std Dev	n/a	n/a
Std Err	n/a	n/a

APPENDIX K. ROSL data detail and examples, Ironbark and Poplar box sites

Appendix K1

Keilambete – additional Runoff data, 1994-2000

NOTE: Many graphs have high, medium, high catch, medium catch & exclosure in the 'Utilisation rate' legend. These mean the same as the grazing pressure terms used in the main section of the report with catch referring to the treed mini-catchments as opposed to the treeless microplots equipped with Gerlach troughs.

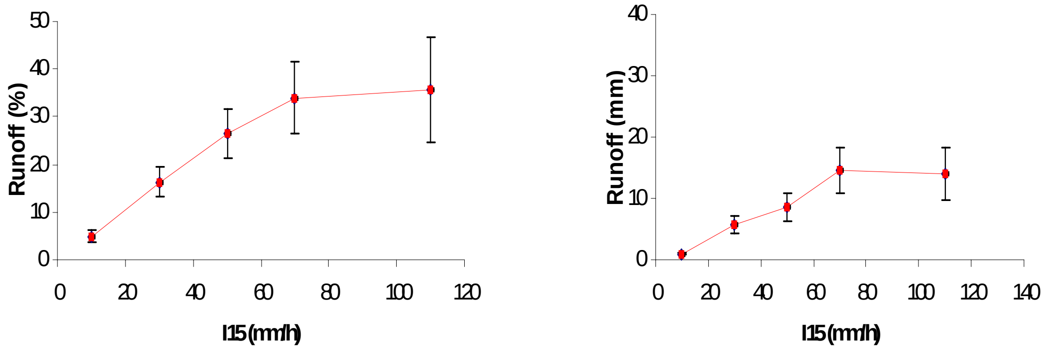


Figure K1.1. The effect of rainfall intensity (mm/h) on runoff, averaged over all plots and five years at Keilambete.

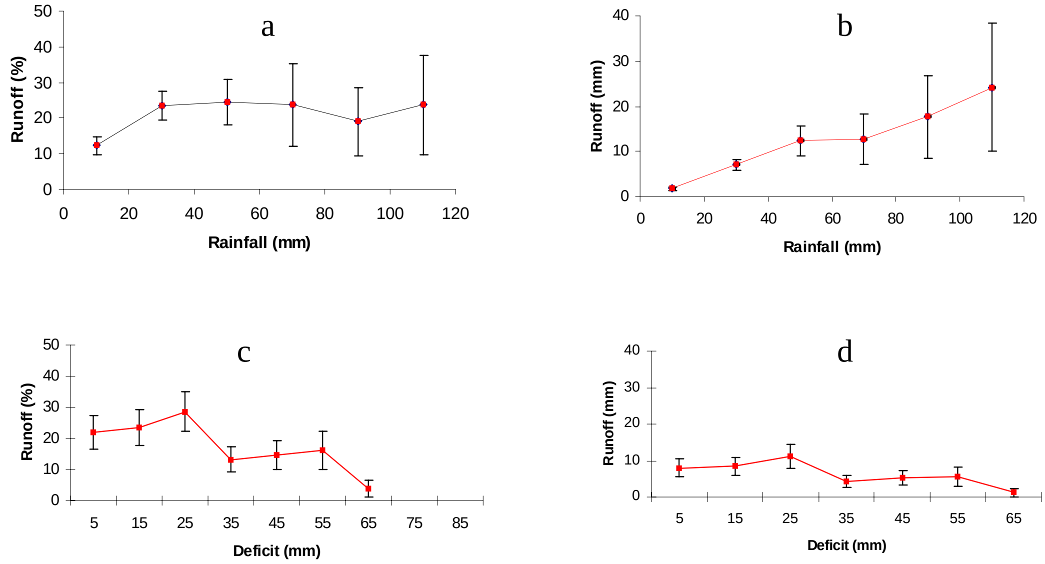


Figure K1.2. The effect of rainfall event size (mm) (**a**) & (**b**) and soil water deficit (mm) (**c**) & (**d**) on runoff, averaged over all plots and five years at Keilambete.

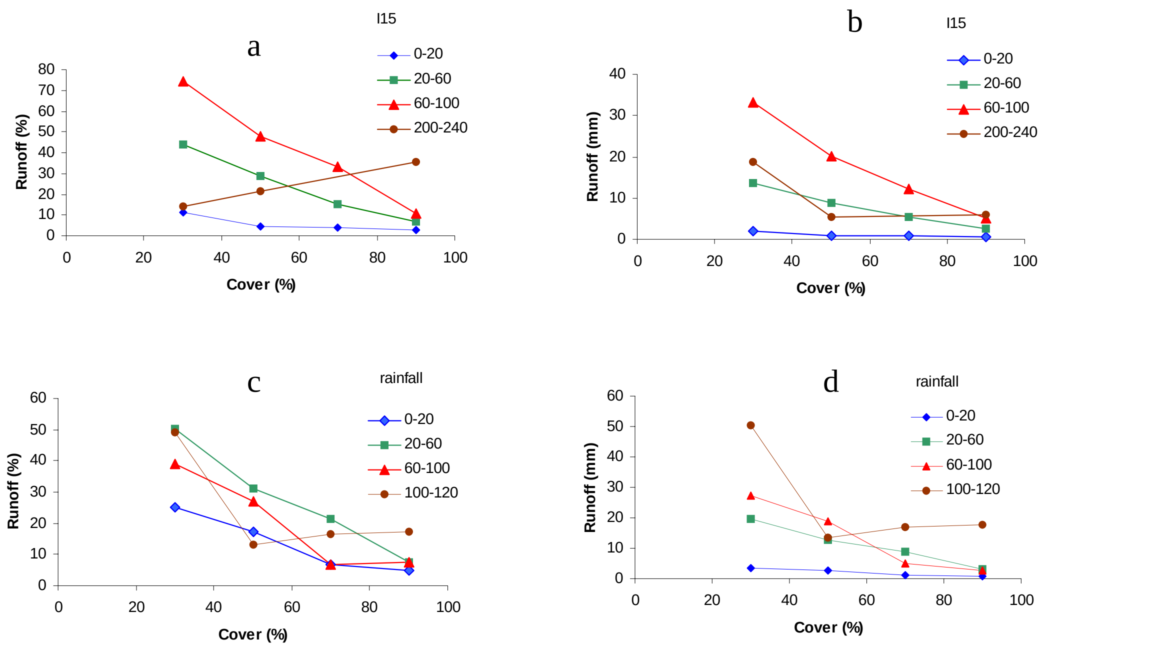


Figure K1.3. The effect of ground cover and rainfall intensity (mm/h) on (**a**) runoff % and (**b**) runoff amount (mm) and the effect of cover and rainfall intensity (I_{15}) on (**c**) runoff % and (**d**) runoff amount, averaged over all plots and five years at Keilambete.

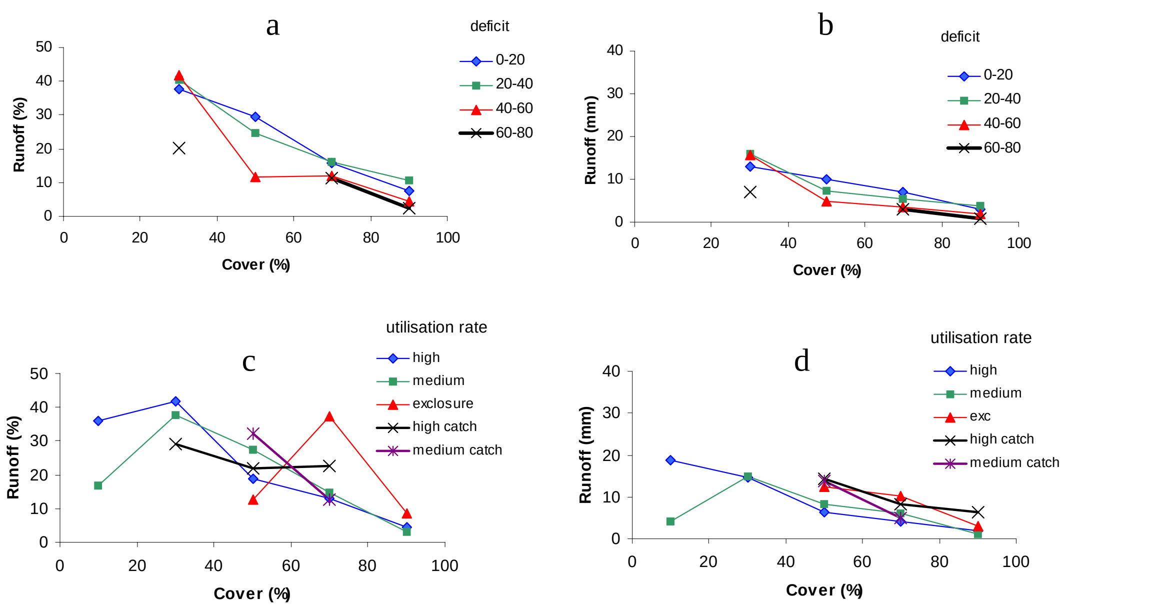


Figure K1.4. The effect of ground cover and (**a**) & (**b**) prior soil water deficit (mm) plus cover & utilisation rate (**c** & **d**) on runoff, averaged over all plots and five years at Keilambete.

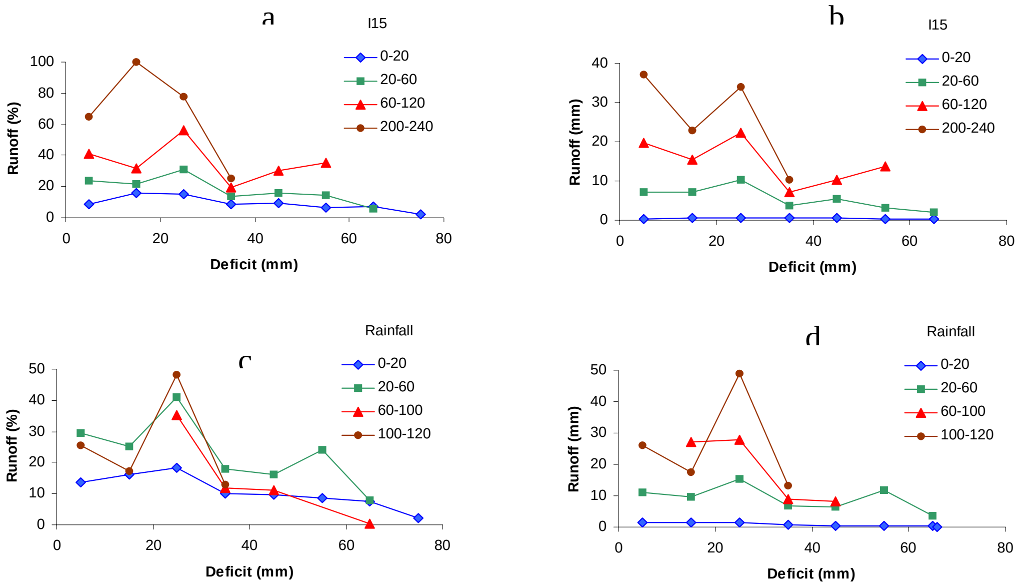


Figure K1.5. The effect of soil water deficit and (**a**) & (**b**) rainfall intensity (mm/h) and (**c**) & (**d**) Rainfall event size (mm) on runoff, averaged over all plots and five years at Keilambete.

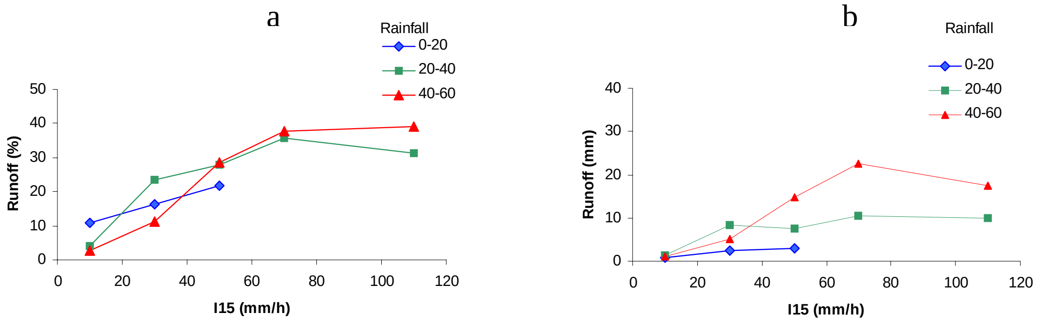


Figure K1.6. The effect of rainfall intensity (mm/h) and rainfall event size (mm) on runoff (**a**) % and (**b**) amount, averaged over all plots and five years at Keilambete.

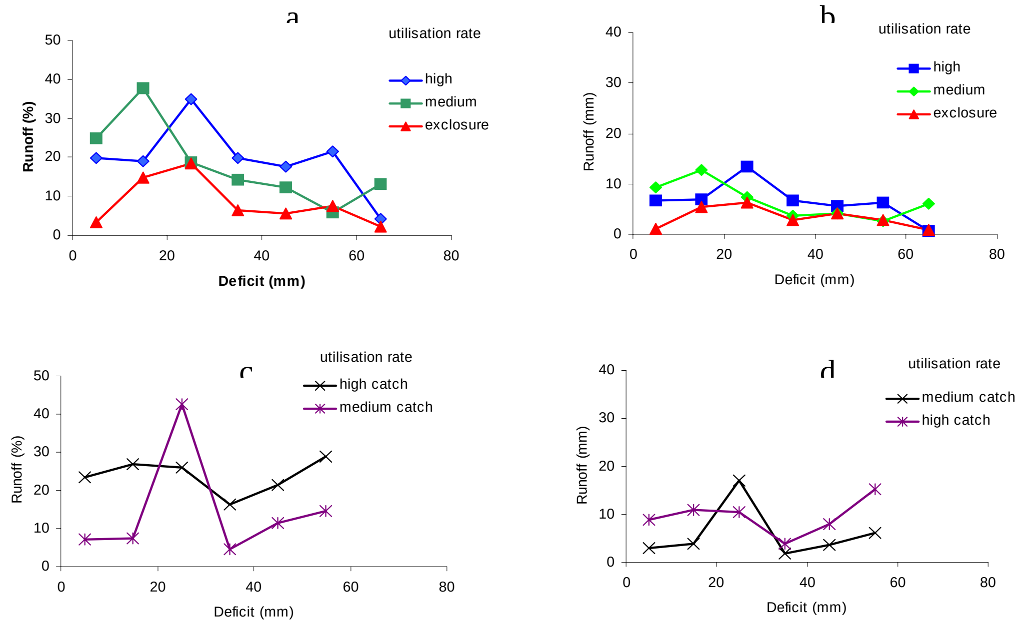


Figure K1.7. The effect of soil water deficit and pasture utilisation rate on runoff amount (**b** & **d**) and runoff % (**a** & **c**), averaged over five years at Keilambete.

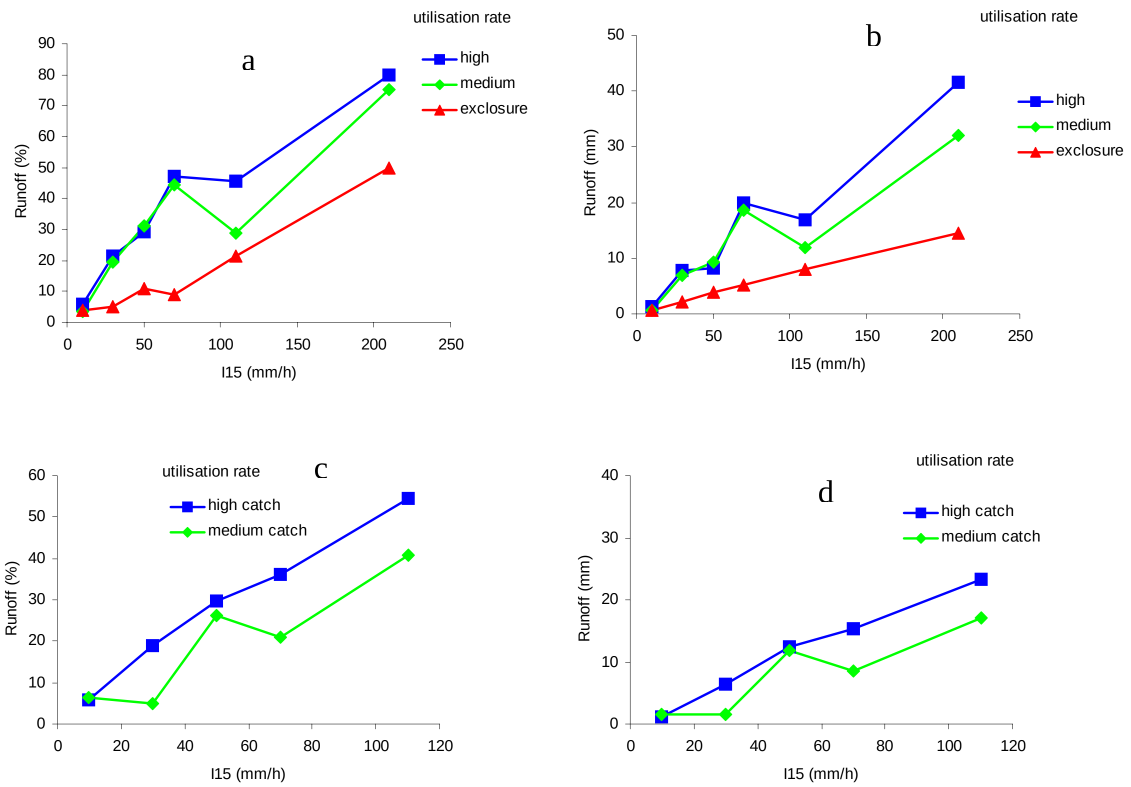


Figure K1.8. The effect of rainfall Intensity (mm/h) and pasture utilisation rate on runoff amount and % from treeless (**a** & **b**) and treed (**c** & **d**) land, averaged over five years at Keilambete.

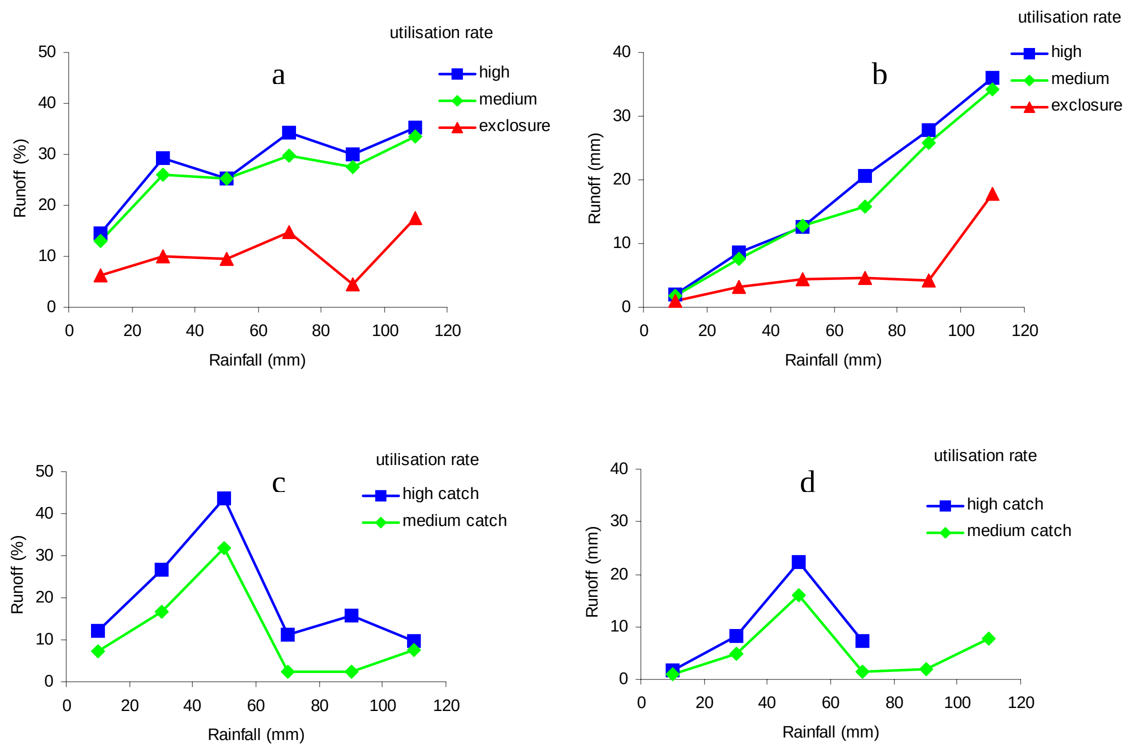


Figure K1.9. The effect rainfall event total (mm) and pasture utilisation rate on runoff % and amount for treeless (**a** & **b**) and treed (**c** & **d**) land, averaged over five years at Keilambete.

Appendix K2

Keilambete – additional Soil loss data, 1994-2000

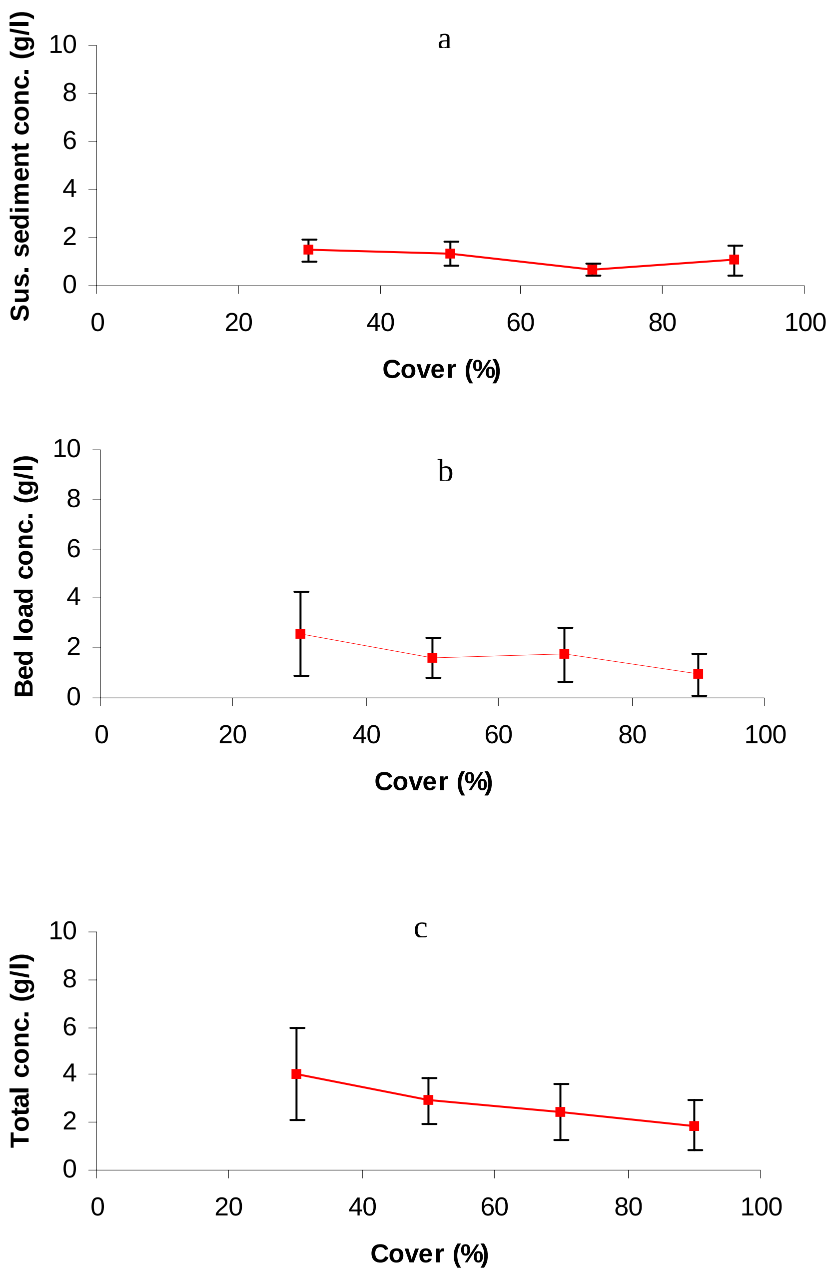


Figure K2.1. The effect of cover on (**a**) suspended sediment concentration (g/l) (**b**) bed load concentration (g/l) (**c**) total sediment concentration (g/l) for the Keilambete grazing trial from 1994 - 2000

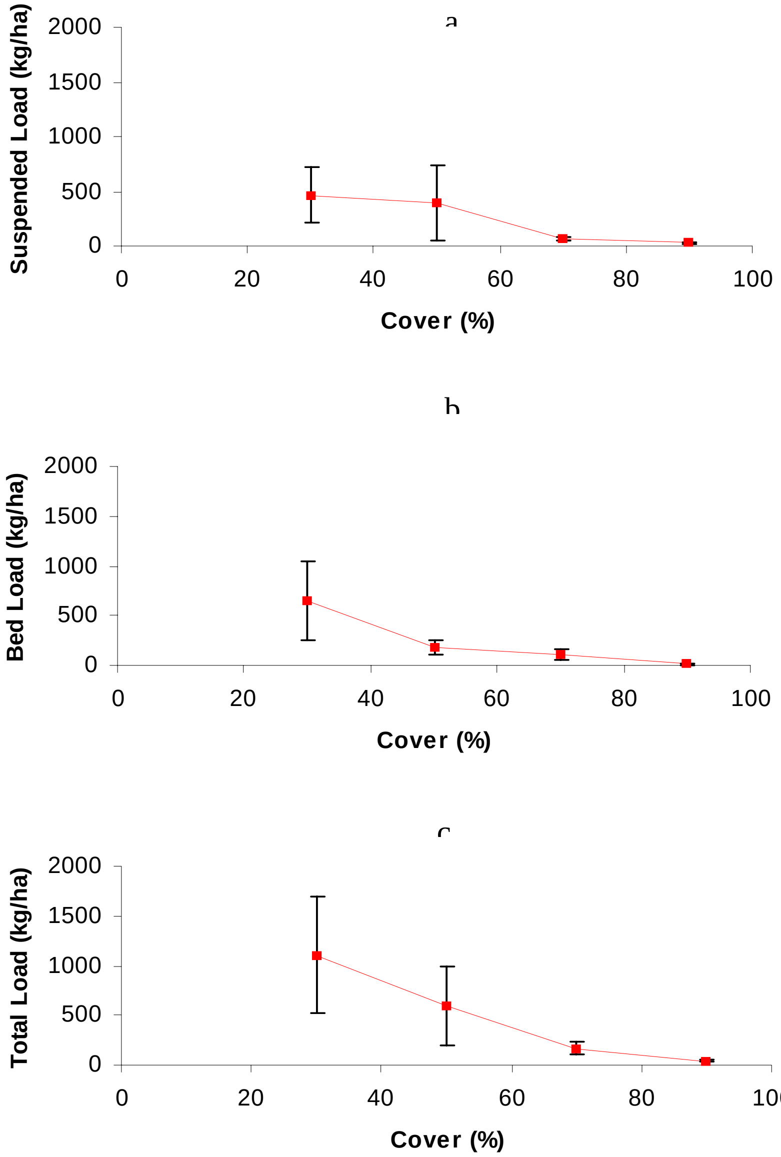


Figure K2.2. The effect of cover on (**a**) suspended sediment concentration (kg/ha), (**b**) bed load concentration (kg/ha) and (**c**) total sediment concentration (kg/ha) for the Keilambete grazing trial from 1994 – 2000.

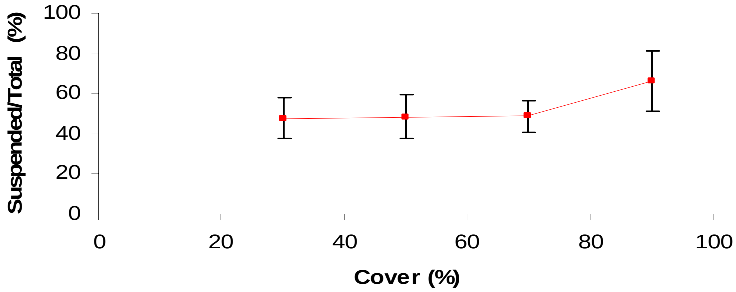


Figure K2.3. The effect of cover on the proportion of suspended sediment in total soil movement at Keilambete.

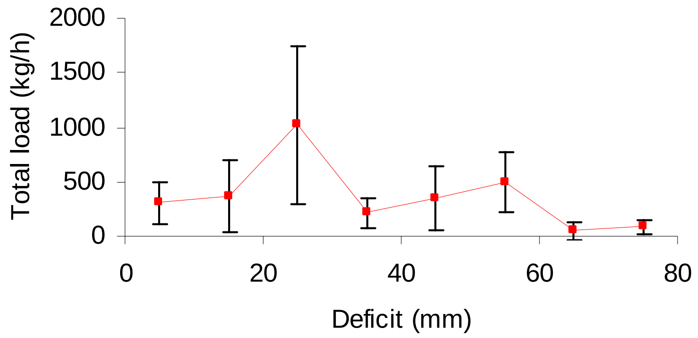


Figure K2.4. The effect of soil water deficit on soil movement for Keilambete, averaged over 5 years and all plots.

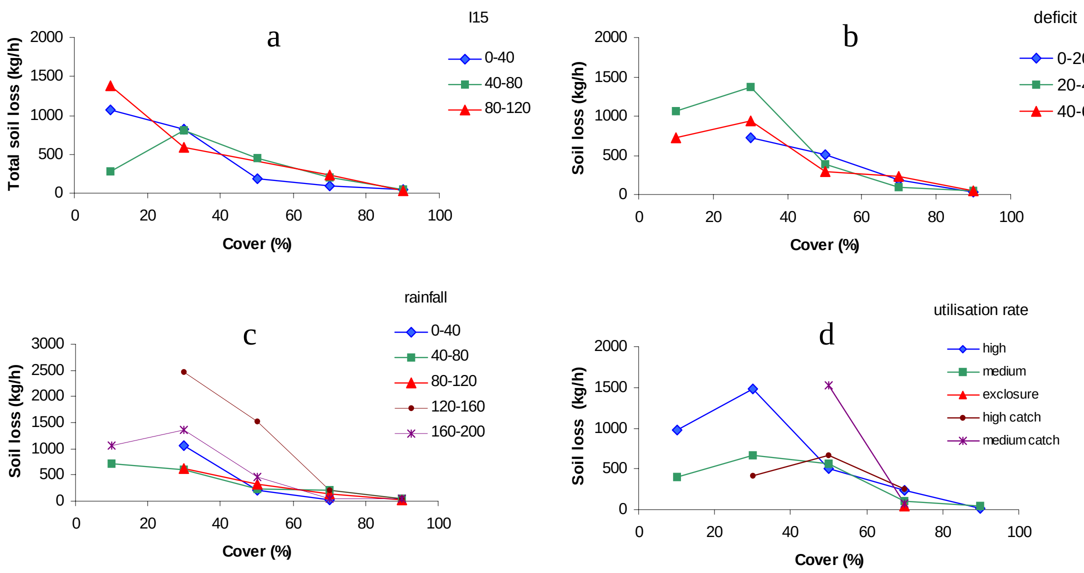


Figure K2.5. The effect of cover and (**a**) rainfall intensity (mm/h), (**b**) soil water deficit (mm), (**c**) rainfall total over service period (mm) and (**d**) utilisation rate on total soil movement for Keilambete, averaged over 5 years and all plots.

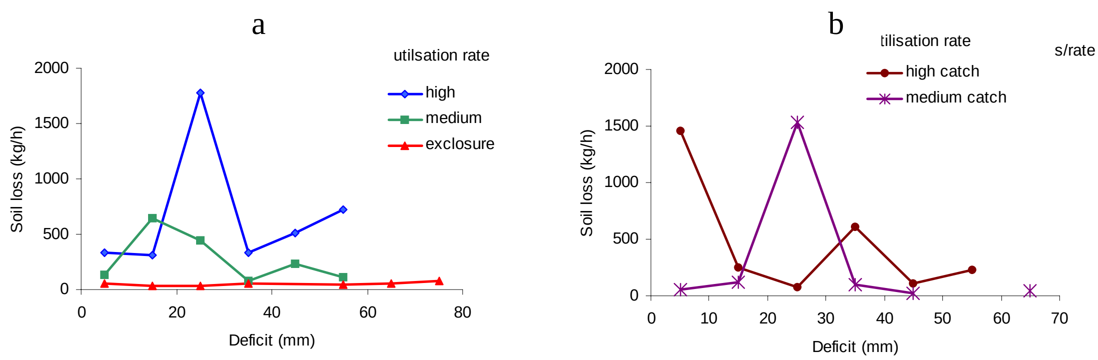


Figure K2.6. The effect of soil water deficit (mm) and pasture utilisation rate on total soil movement from (**a**) treeless and (**b**) treed land at Keilambete, averaged over 5 years.

(a) (b)

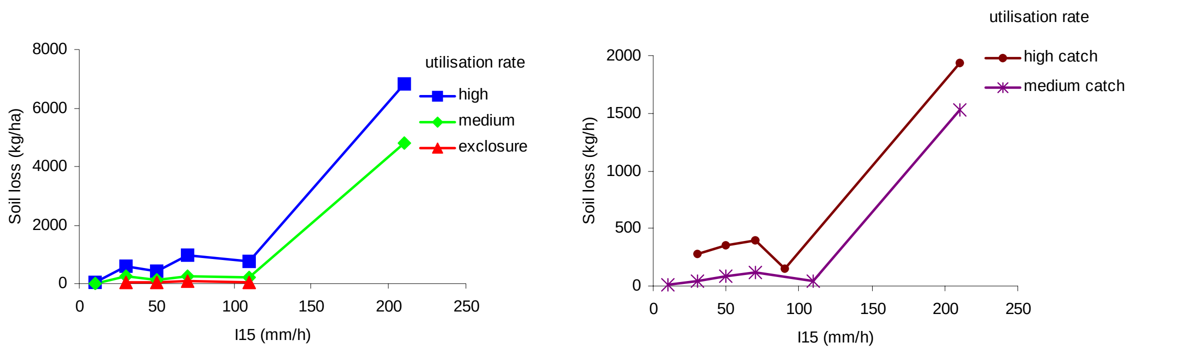


Figure K2.7. The effect of rainfall intensity (mm/h) and pasture utilisation rate on total soil movement from (**a**) treeless and (**b**) treed land at Keilambete averaged over 5 years.

(a) (b)

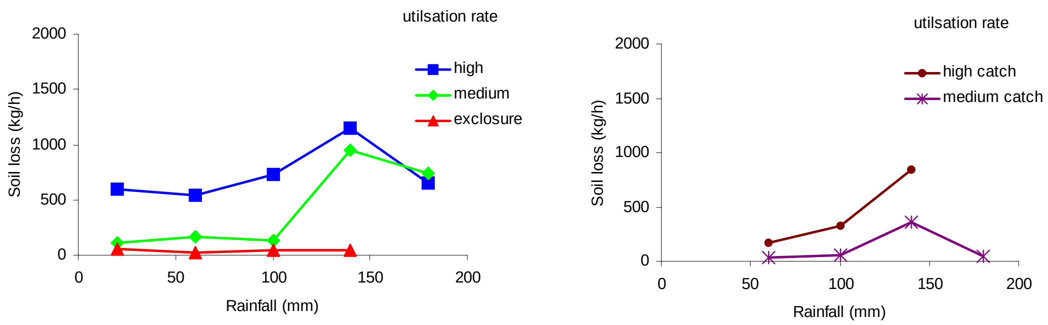


Figure K2.8. The effect of rainfall total for the service period (mm) and utilisation rate on total soil movement from (**a**) treeless and (**b**) treed land at Keilambete averaged over 5 years.

Appendix K3

Glentulloch – additional Runoff data, 1994-2000

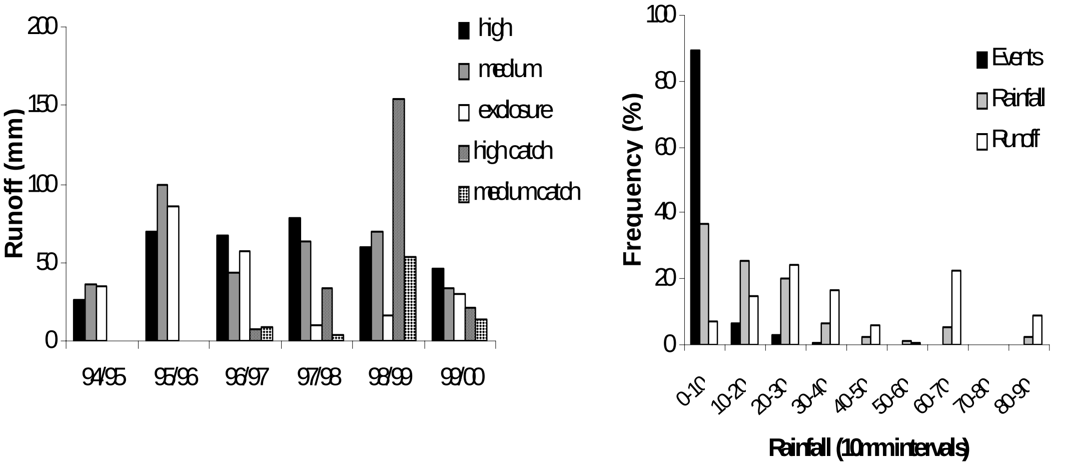


Figure K3.1. **a**) Annual runoff and **b**) proportion of total rainfall events, rainfall (mm) and runoff (mm) in 10mm event class intervals for the Glentulloch grazing trial from 1994 – 2000.

(a) (b)

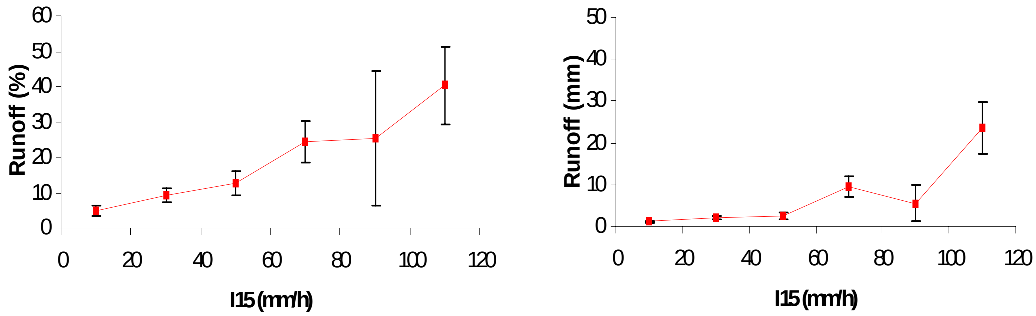


Figure K3.2. The effect of rainfall intensity (mm/h) on (**a**) runoff % and (**b**) runoff amount at Glentulloch, averaged over all plots and five years.

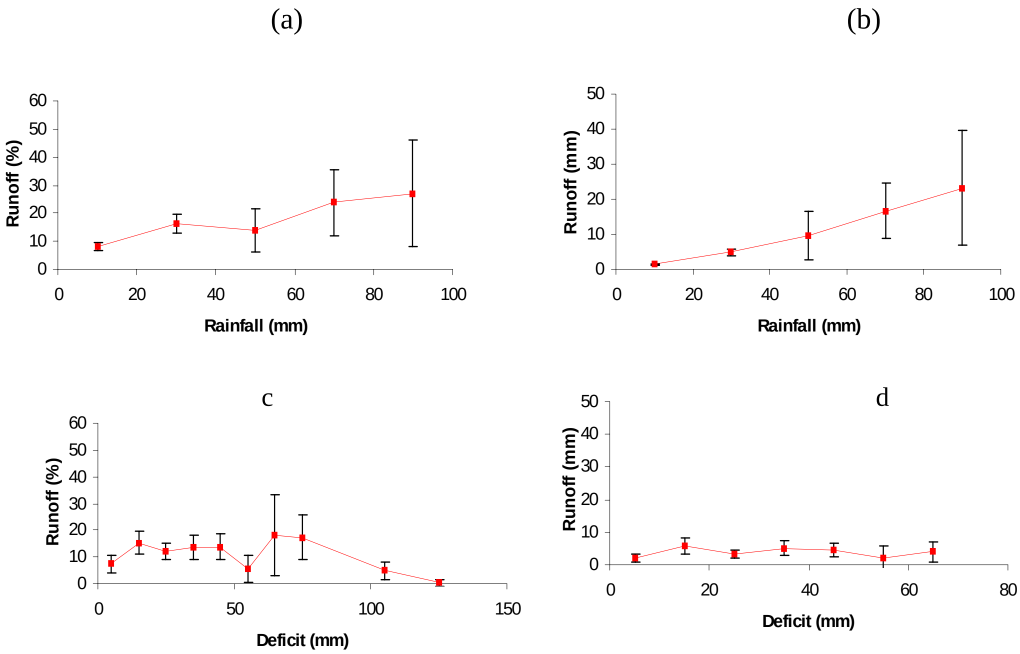


Figure K3.3. The effect of (**a**) & (**b**) rainfall event size (mm) (**c**) & (**d**) soil water deficit (mm) on runoff at Glentulloch, averaged over all plots and five years.

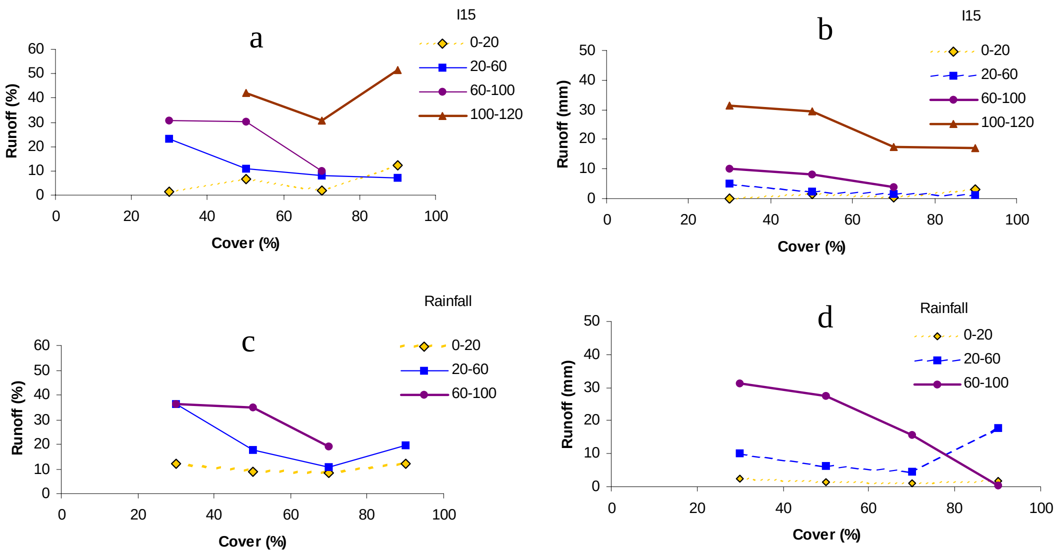


Figure K3.4. The effect of cover and (**a**) & (**b**) rainfall intensity (mm/h) or (**c**) & (**d**) rainfall event size (mm) on runoff at Glentulloch, averaged over all plots and five years.

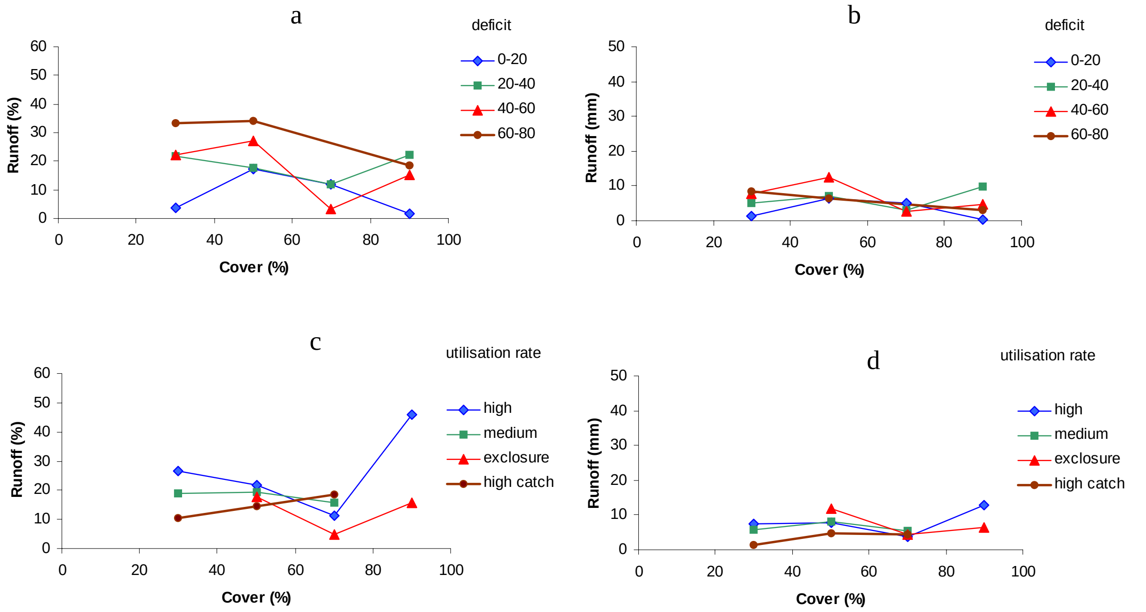


Figure K3.5. The effect of cover and (**a**) & (**b**) soil water deficit (mm) or (**c**) & (**d**) pasture utilisation rate on runoff at Glentulloch, averaged over all plots and five years.

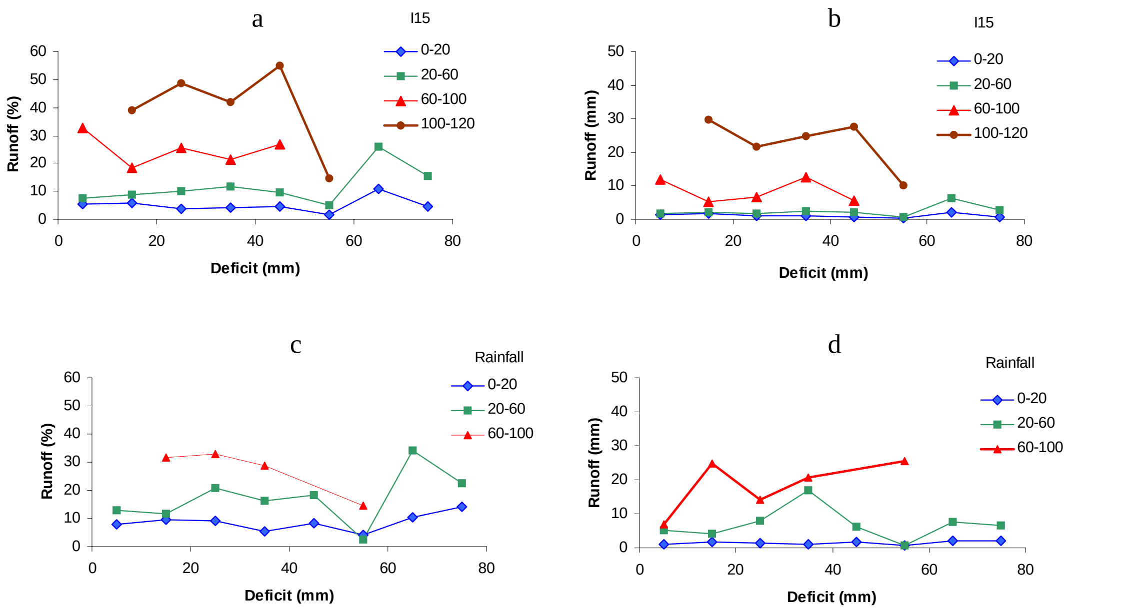


Figure K3.6. The effect of soil water deficit and (**a**) & (**b**) rainfall intensity (mm/h) or (**c**) & (**d**) rainfall event size (mm) on runoff at Glentulloch, averaged over all plots and five years.

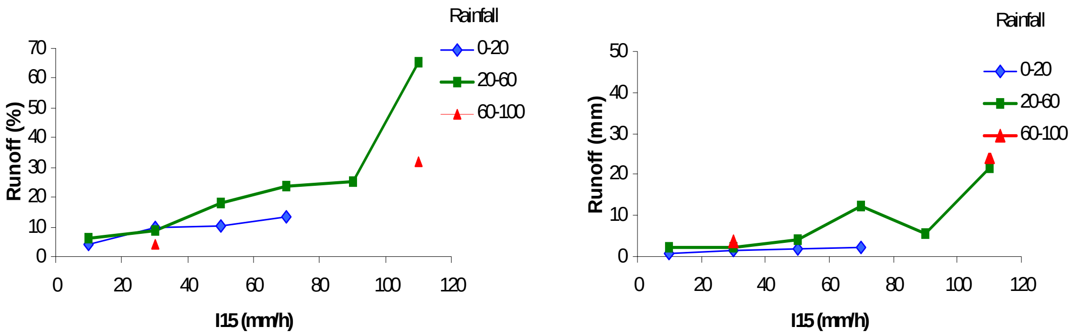


Figure K3.7. The effect of rainfall intensity (mm/h) and rainfall event size (mm) on (**a**) runoff % and (**b**) runoff (mm) at Glentulloch, averaged over all plots and five years.

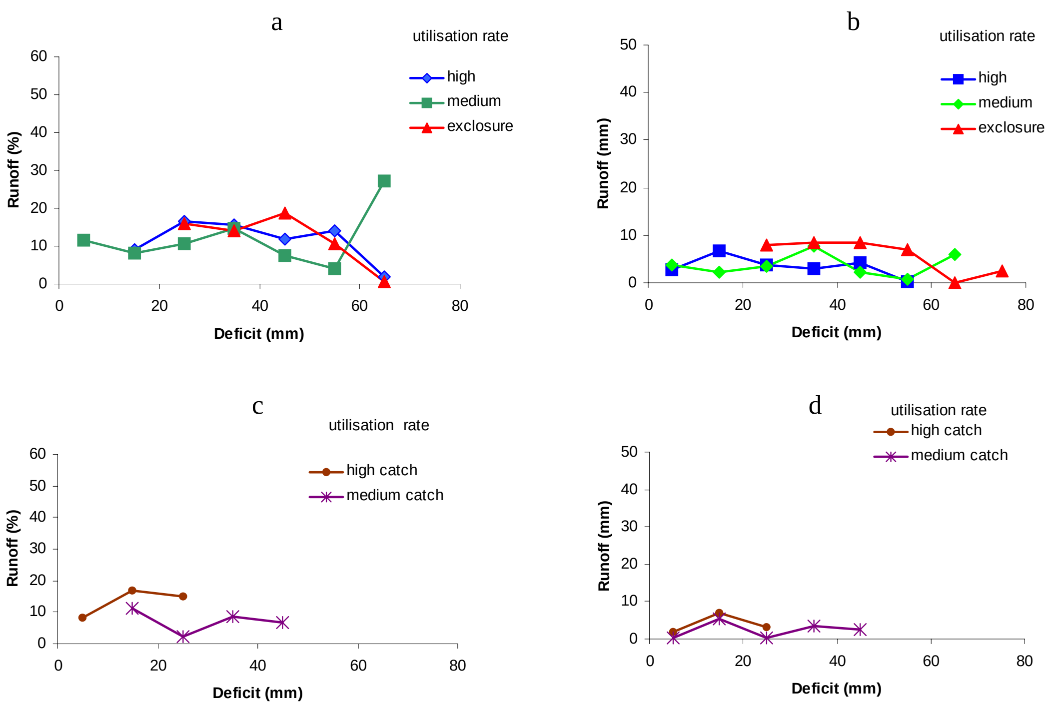


Figure K3.8. The effect of soil water deficit and pasture utilisation rate on runoff from (**a** & **b**) treeless or (**c** & **d**) treed land at Glentulloch, averaged over five years.

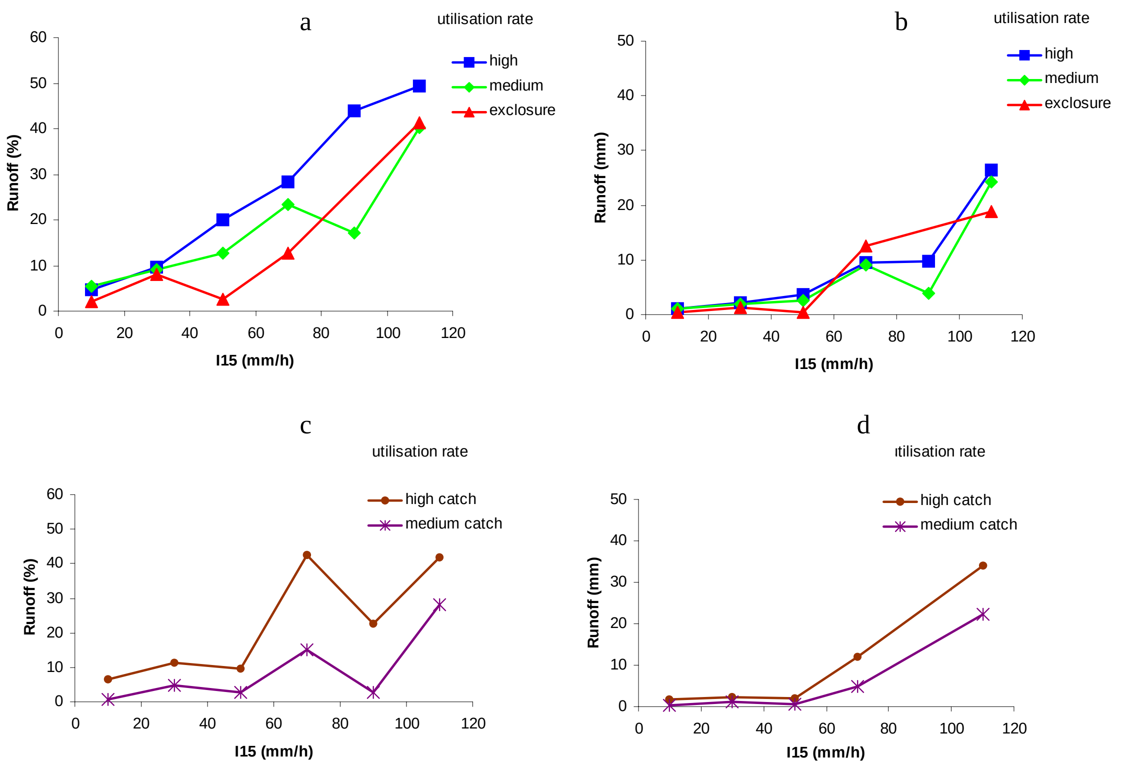


Figure K3.9. The effect of rainfall intensity (mm/h) and pasture utilisation rate on runoff from treeless (**a** & **b**) and treed (**c** & **d**) land at Glentulloch, averaged over five years.

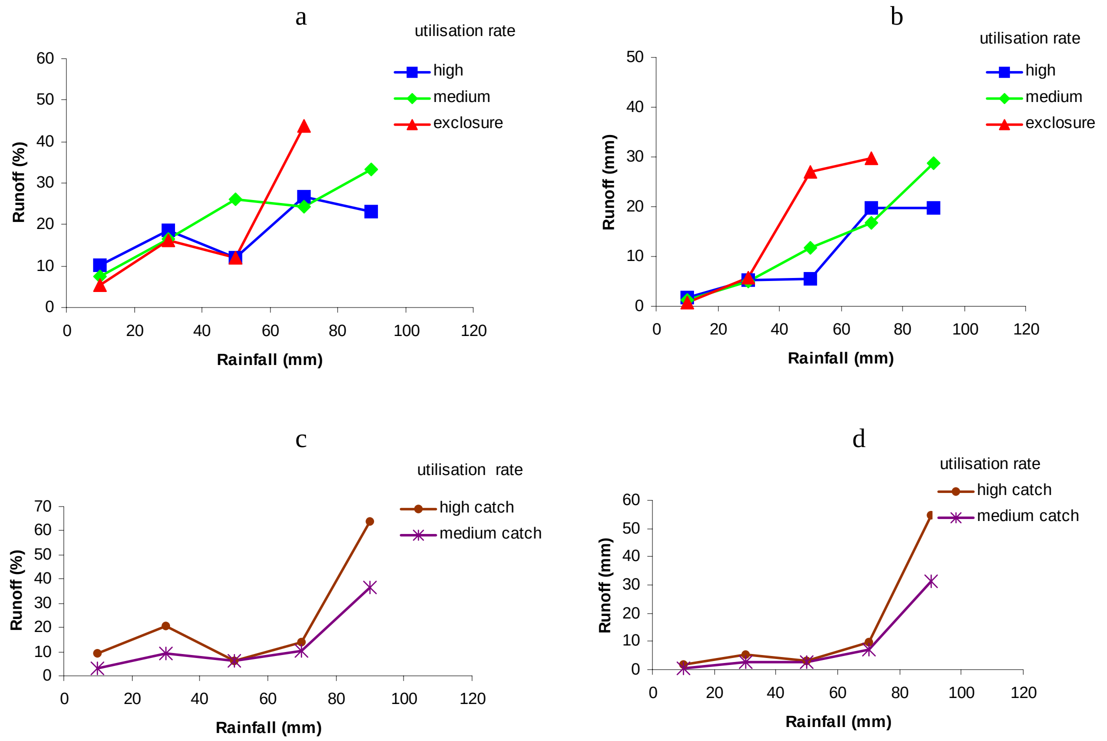


Figure K3.10. The effect rainfall event total (mm) and pasture utilisation rate on runoff from treeless (**a** & **b**) and treed (**c** & **d**) land at Glentulloch, averaged over five years.

Appendix K4

Glentulloch – additional Soil loss data, 1994-2000

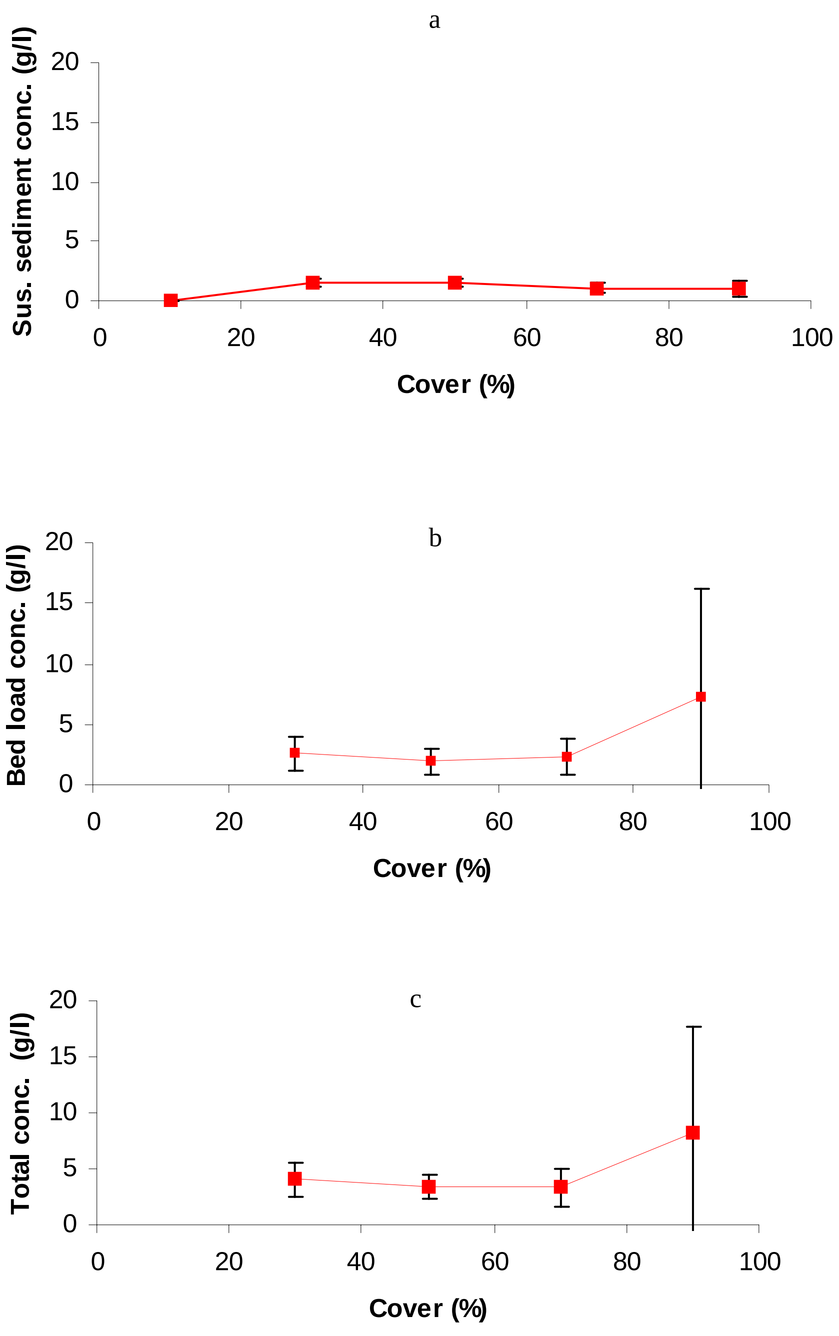


Figure K4.1. The effect of ground cover on (**a**) suspended sediment concentration (g/l), (**b**) bed load concentration (g/l) and (**c**) total sediment concentration (g/l) for the Glentulloch grazing trial from 1994 – 2000.

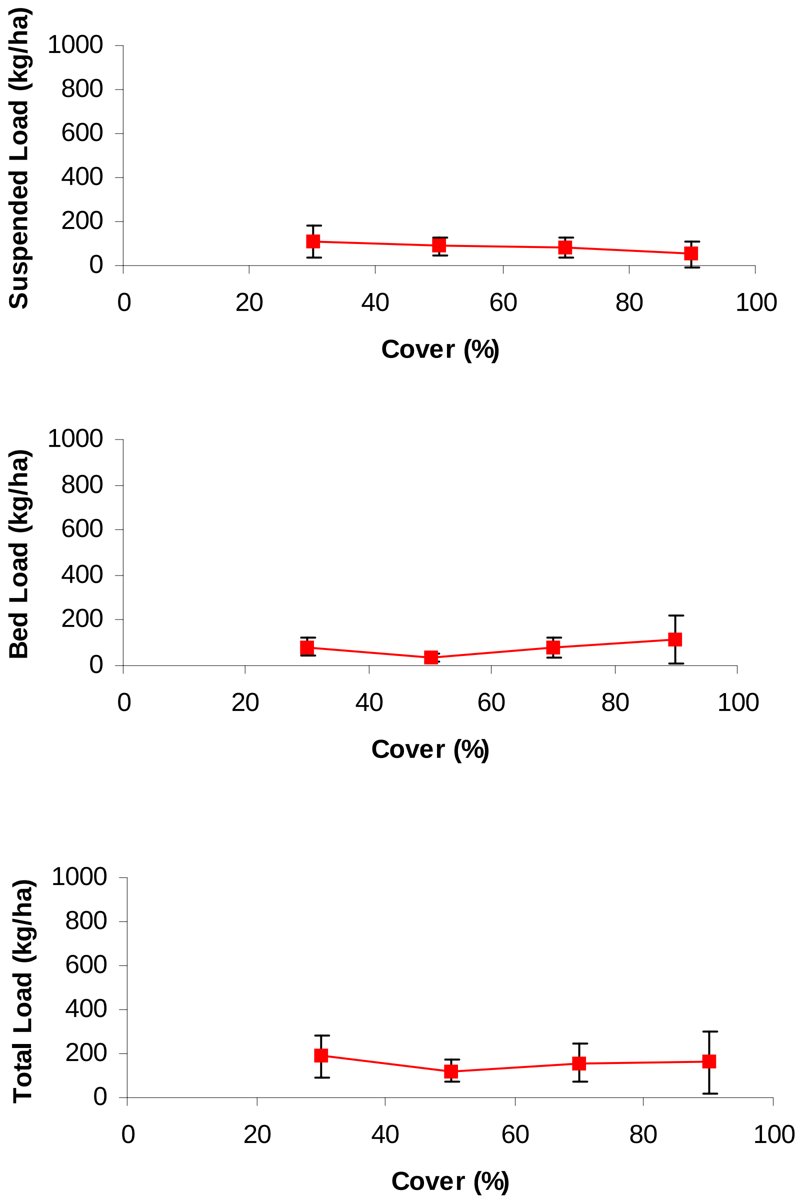


Figure K4.2. The effect of ground cover on (**a**) suspended sediment load (kg/ha), (**b**) bed load (kg/ha) (**c**) total sediment load (kg/ha) for the Glentulloch grazing trial from 1994 – 2000.

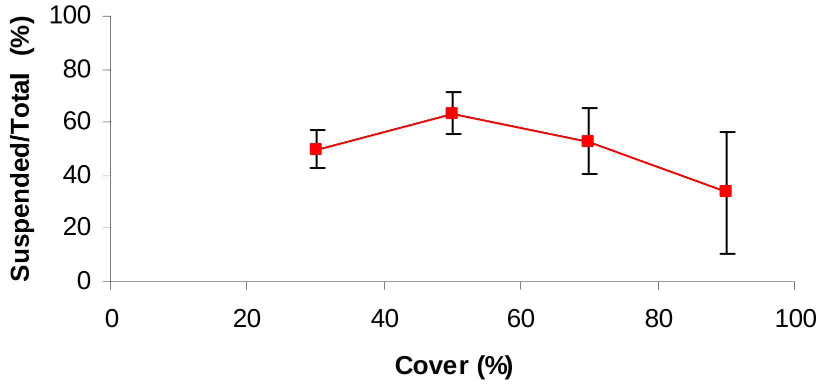


Figure K4.3. The effect of ground cover on the proportion of suspended sediment in the total soil movement calculated from samples collected at Glentulloch.

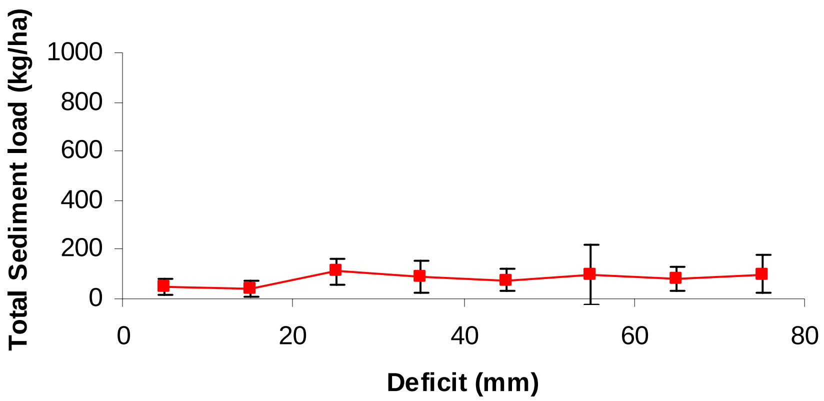


Figure K4.4. The effect of antecedent soil water deficit on soil movement at Glentulloch, averaged over 5 years and all plots.

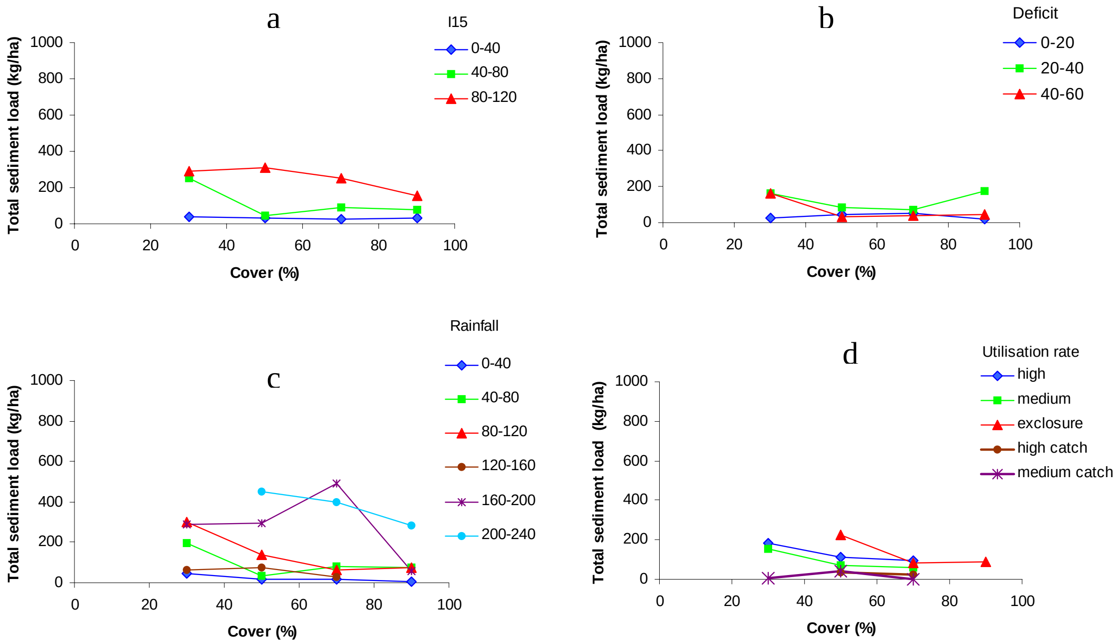


Figure K4.5. The effect of ground cover and (**a**) rainfall intensity (mm/h) (**b**) soil water deficit (mm) (**c**) rainfall total over service period (mm) and (**d**) pasture utilisation rate on total soil movement at Glentulloch, averaged over 5 years and all plots.

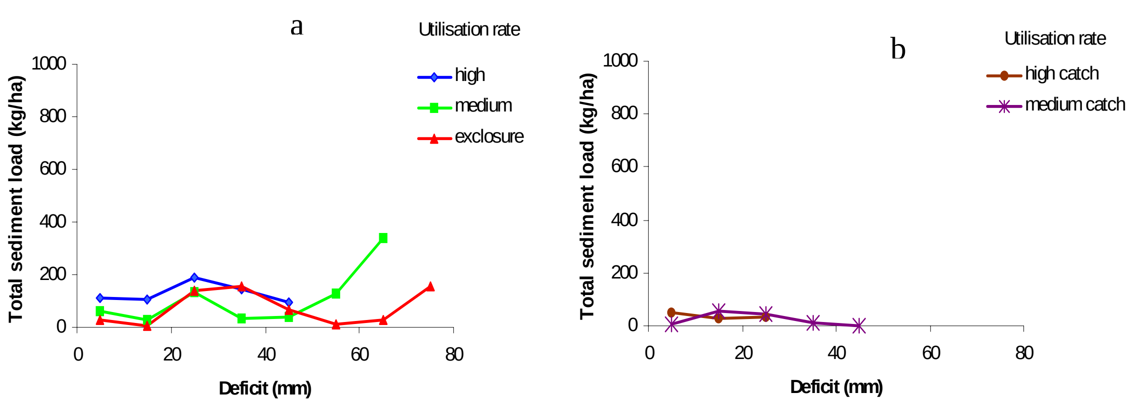


Figure K4.6. The effect of soil water deficit (mm) and pasture utilisation rate on total soil movement for (**a**) treeless and (**b**) treed land at Glentulloch, averaged over 5 years.

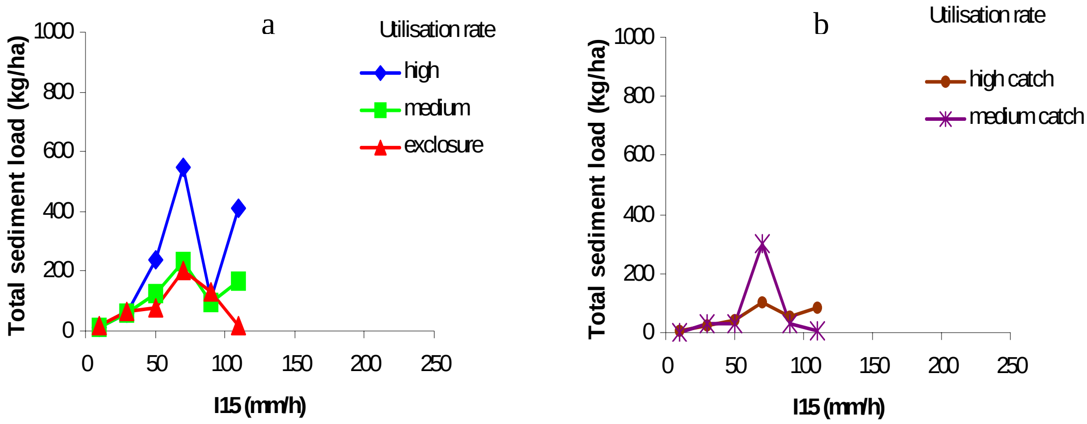


Figure K4.7. The effect of rainfall intensity (mm/h) and pasture utilisation rate on total soil movement for (**a**) treeless and (**b**) treed land at Glentulloch, averaged over 5 years.

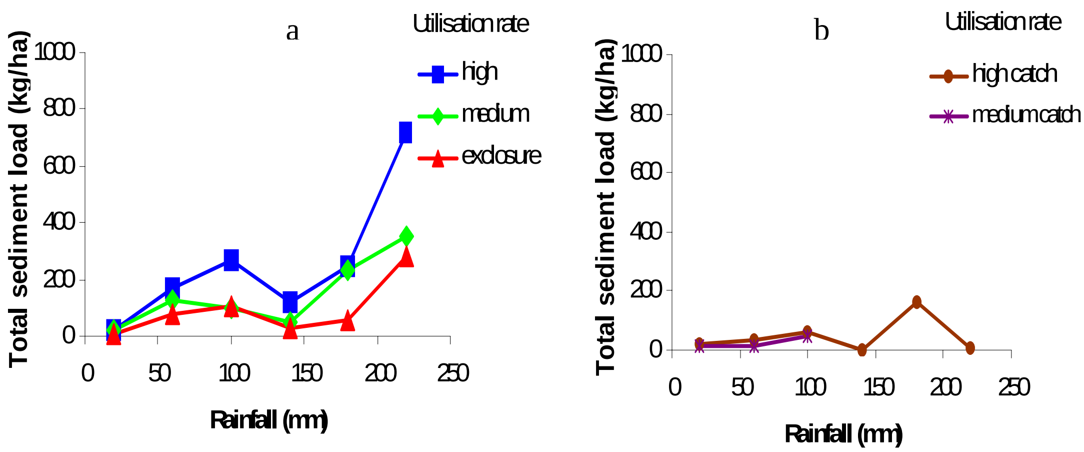


Figure K4.8. The effect of rainfall total for the service period (mm) and pasture utilisation rate on total soil movement for (**a**) treeless and (**b**) treed land at Glentulloch, averaged over 5 years.

Appendix K5

Rainfall Intensity - Frequency - Duration Curves

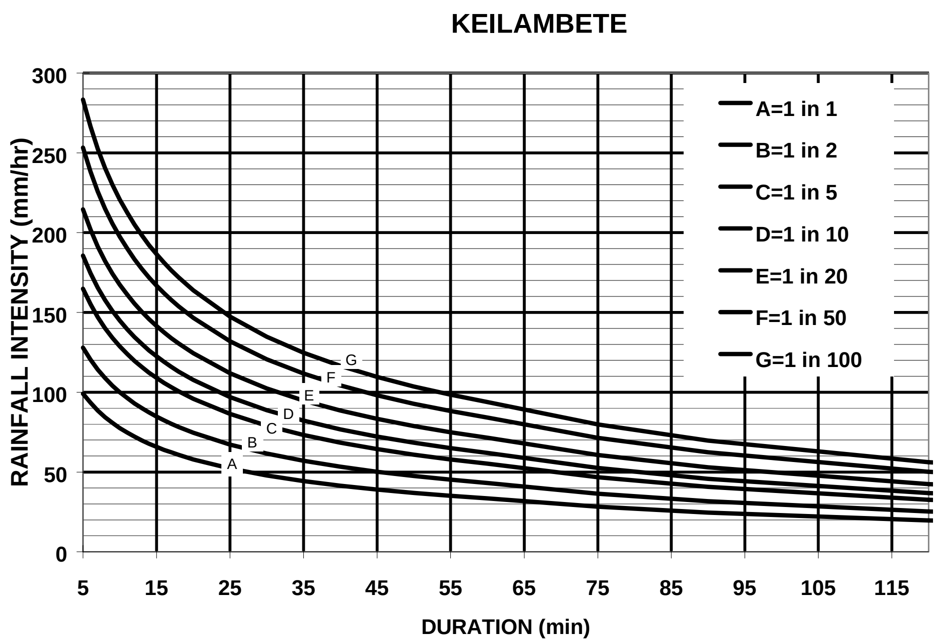


Figure K5.1. Rainfall Intensity - Frequency - Duration Curves for Keilambete.

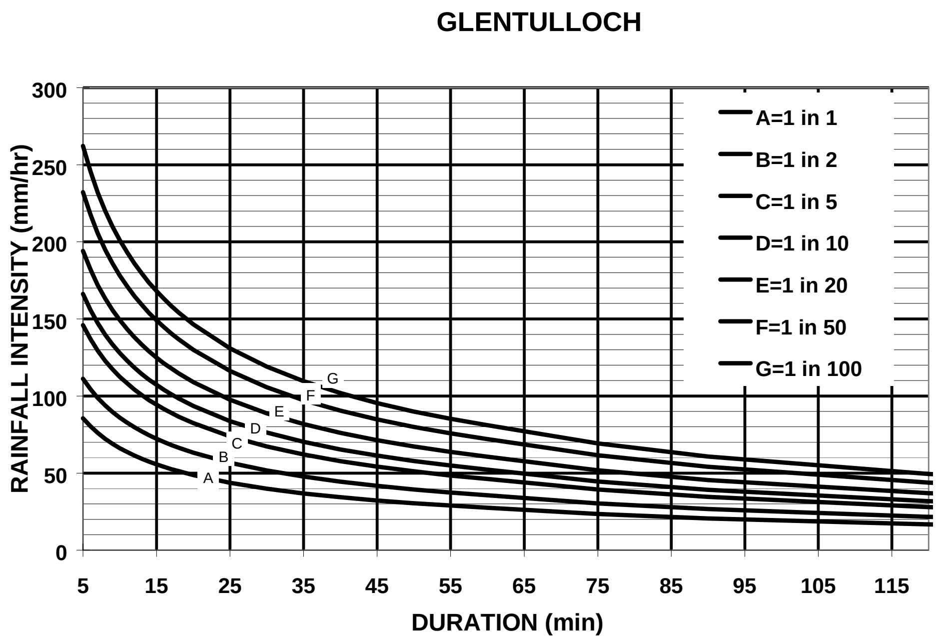


Figure A5.2. Rainfall Intensity - Frequency - Duration Curves for Glentulloch.

NOTE: *Intensity - Frequency - Duration curves were developed by Dave Waters from "Australian Rainfall and Runoff" (1991)*

Appendix K6

(A) Nutrients in runoff water

The results for suspended sediments and runoff water for one isolated event (63.4 mm ± SD 2.8) on 24/11/2000 are given in Table K6.1 for the 7 different bounded runoff plots at Glentulloch. Four are replicate samples from the same event.

Table K6.1. Suspended sediment water analysis for runoff from individual plots at the Glentulloch trial after a storm on 24/11/2000

Trough	*Paddock*	*Rep*	*Trtmt*	*Graze/ Excl.*	*NH_4^+ nitrogen* mg/L	*Oxidised -N* mg/L	*Ortho - phosphate-P* mg/L	*Total Kjeldahl N* mg/L	*Total Phosphorus* mg/L
1	3	1	CH	G	0.222	0.217	0.216	1.82	0.35
2	9	2	CH	G	0.1	0.325	0.104	0.92	0.3
2	9	2	CH	G	0.145	0.298	0.111	1.56	0.46
Mean CH Grazed			CH	G	0.156	0.280	0.144	1.433	0.370
3	2	1	CM	E	0.256	1.845	0.499	3.84	0.74
4	8	2	CM	E	3.15	2.86	0.999	8.75	1.43
4	8	2	CM	E	2.75	2.78	0.996	13.26	1.61
Mean CM Exclosed			CM	E	2.052	2.495	0.831	8.617	1.260
5	2	1	CM	G	0.066	1.459	0.272	1.92	0.53
5	2	1	CM	G	0.053	1.685	0.281	2.59	0.57
6	8	2	CM	G	0.07	0.095	0.063	1.26	0.19
6	8	2	CM	G	0.072	0.085	0.061	1.28	0.19
Mean CM Grazed			CM	G	0.065	0.831	0.169	1.763	0.370
7	4	1	TL	E	0.312	3.68	0.117	3.76	0.62

CH = treeless & high grazing pressure CM = treeless & moderate grazing pressure
TL = Treed & low grazing pressure

(B) Available water holding capacity of soils

The available water holding capacity (AWHC) of a soil profile is very important for determining the potential growth that can be achieved at that site in savanna environments. The figures for the two trial sites shown in Table K6.2 illustrate how much more variable the Glentulloch site could be spatially than the Keilambete site.

The very high figure for the exclosure in rep2 at Glentulloch was associated with significantly more clay in that 20 x 5metre area than in most other places in the trial. Likewise the mini-catchment equipped with a Parshall flume (flu hi) under trees at high grazing pressure had much more large sandstone rock in the area which would contribute to a lower AWHC at that site. Hence there was a greater runoff potential at this rocky site due to the combination of rocky cover, shallow depth and less soil matrix in the profile. Conversely, the more clayey exclosure had a relatively low soil movement rate which may be due to the greater growth potential of the pasture or for runoff to move into small cracks and thus slow the soil entrainment process.

Table K6.2. Calculated available soil water holding capacity (AWHC) of the soil profiles at each of the runoff sites at Keilambete and Glentulloch

Keilambete soil moisture - upper and lower limits(mm) to 60cm depth

	Utilisation	upper	lower	AWHC (mm)	Notes
Rep 1	hi	186	121	65	
	med	166	102	64	
	excl	191	108	83	
Rep 2	hi	178	107	71	
	med	173	113	60	
	excl	205	136	69	
	flu hi	166	97	69	
	flu med	175	106	69	

Glentulloch soil moisture - upper and lower limits(mm) to 60cm depth

	Utilisation	upper	lower	AWHC	Notes
Rep 1	hi	185	129	56	pebbly
	med	190	130	60	
	excl	196	137	59	
Rep 2	hi	195	143	52	
	med	246	140	106	some clay
	excl	255	131	124	clay A
	flu hi	167	131	36	rocky
	flu med	214	157	57	variable profiles

Appendix K7

(A) Statistics of runoff versus rainfall intensity and ground cover, Keilambete

Table K7.1. Ranked means of event runoff vs. ground cover % class at Keilambete

Cover class	reps	Mean Runoff %
40-60%	192	15.4 a
80-100%	106	15.8 a
60-80%	128	15.8 a
20-40%	70	24.7 b
0-20%	2	53.2 b

NB: Means with the same subscript are not significantly different at the 5% level

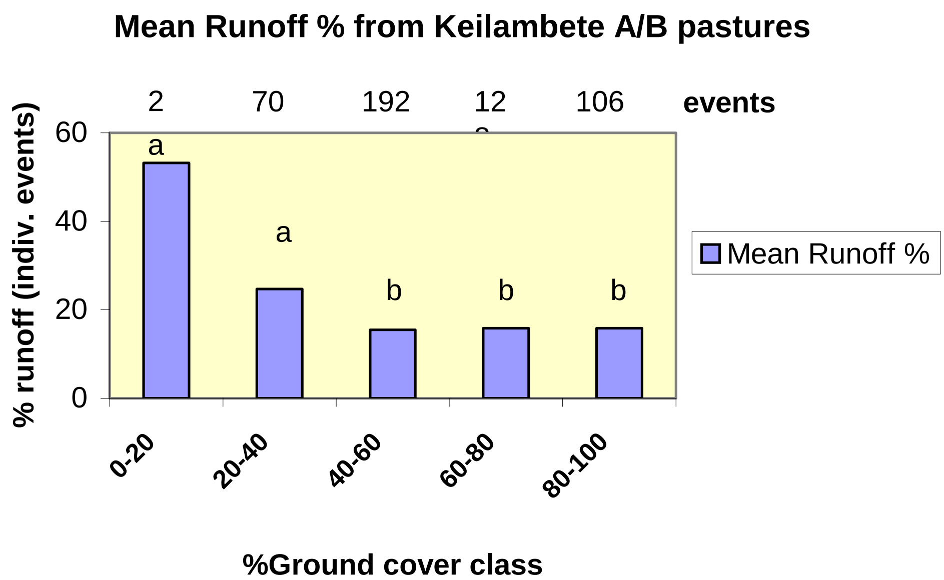


Figure K7.1. Relationship between mean event runoff % and ground cover class

Table K7.2. Runoff vs. Rainfall intensity class, statistical analysis summary, Keilambete

I_{15} (mm/h)	reps	Mean (log transf.)	Back-transformed means	Raw means
0-20	344	1.361 a	3.9	8.55 a
20-40	244	1.864 b	6.4	15.55 b
40-60	81	2.118 b	8.3	17.10 b
60-80	44	2.933 c	18.8	28.20 c
80-100	13	3.430 c	30.9	43.68 d

(B) Details of the main runoff events at Keilambete during the trial

Table K7.3. Summary of the features of the main runoff events at site 1 (CH1, CM2 & CN3) at Keilambete during the trial

		Rainfall (mm)	Intensity (mm/hr)	Antecedant Moisture	Runoff (mm)			Runoff (%)			Runoff Rate		
Event	Date				High	Medium	Exclosed	High	Medium	Exclosed	High	Medium	Exclosed
1	2/1/95	44.3	89	13.0	27.6	6.2	9.7	62	14	22	88	25	36
2	20/1/95	68.3	39	1.2	26.5	17.3	8.7	39	25	13	30	19	10
3	5/2/95	84.7	95	7.9	59.1	8.4	48.4	70	10	57	84	25	67
4	2/4/95	29.9	98	10.0	12.4	13.1	16.6	41	44	56	40	57	78
5	26/10/95	21.6	60	12.5	11.2	6.9	4.5	52	32	21	57	18	16
6	21/11/95	30.3	101	29.9	26.3	8.7	16.1	87	29	53	162	31	112
7	10/1/96	99.6	35	18.3	37.7	36.8	12.4	38	37	12	35	35	12
8	1/5/96	51.5	28	29.1	14.1	11.8	2.0	27	23	4	29	22	5
9	9/10/96	80.6	25	7.4	34.7	25.9	1.6	43	32	2	24	16	3
10	21/11/96	50.1	115	5.6	40.9	29.2	25.8	82	58	52	124	104	130
11	6/12/96	62.1	212	0.3	10.5	15.0	8.4	17	24	13	47	51	32
12	29/1/97	35.5	79	6.2	26.9	24.9	4.0	76	70	11	89	84	12
13	4/2/97	24.6	44	48.6	13.4	12.5	2.0	55	51	8	57	43	6
14	13/2/97	31.7	57	4.9	20.5	18.3	4.0	65	58	13	62	65	10
15	15/2/97	40.3	42	38.2	24.2	21.0	6.1	60	52	15	62	50	17
16	6/3/97	52.9	68	0.2	30.8	30.8	10.2	58	58	19	86	87	47
17	23/3/97	108.3	73	0.0	49.6	51.5	22.2	46	48	20	82	96	63
18	19/11/97	25.5	67	8.7	15.3	11.7	0.0	60	46	0	91	62	
19	20/11/97	24.6	29	33.7	10.4	6.1	0.0	42	25	0	31	14	
20	28/1/98	59.7	79	0.0	45.5	37.8	0.4	76	63	1	114	96	4
21	23/4/98	67.0	26	0.0	22.9	12.0	0.1	34	18	0	31	13	4
22	29/8/98	74.5	26	25.6	38.0	28.8	1.8	51	39	2	39	28	4
23	31/8/98	41.3	22	118.7	26.9	26.7	15.6	65	65	38	43	35	18
24	25/10/98	49.6	55	0.0	20.8	23.0	2.3	42	46	5	82	79	9
25	13/11/98	47.3	23	1.2	11.0	10.3	0.5	23	22	1	15	14	4
26	26/11/98	42.2	76	4.8	19.6	26.1	5.7	46	62	13	91	87	13
27	4/1/99	55.8	52	78.4	28.9	47.2	17.3	52	85	31	43	71	22
28	25/2/99	59.9	115	0.2	18.4	25.6	4.3	31	43	7	55	75	13
29	19/11/99	35.4	114	0.0	16.6	13.9	1.3	47	39	4	159	100	9
30	28/1/00	49.7	66	3.5	25.5	22.9	0.5	51	46	1	86	62	4
31	6/8/00	38.8		0.0	10.8	9.9	0.7	28	26	2	47	51	4
32	20/11/00	131.0		33.6	122.3	131.0	111.2	93	100	85	226	244	323
33	22/11/00	28.9		163.9	22.6	21.4	8.1	78	74	28	244	244	79
33 event Total					922.1	792.6	372.6						
Total Measured					1135.4	1004.5	393.1						
% of Total Measured					81	79	95						

Table K7.3 (contd)

Site 1

	Bedload (kg/ha)			Total Soil Loss (kg/ha)			Cover (%)			Days since Cover estimate
Event	**High**	**Medium**	**Exclosed**	**High**	**Medium**	**Exclosed**	**High**	**Medium**	**Exclosed**	
1							59	74	88	11
2	557	216	265	687	280	292	69	76	89	11
3	1769	480	261	2741	567	645	78	80	91	5
4	1108	376	86	1327	487	138	95	88	99	4
5	55	54	43	225	107	43	38	52	89	15
6	1122	432	0	2030	597	21	25	32	86	23
7	395	118	0	1593	1667	0	18	16	57	2
8	196	94	0	260	124	0	36	31	84	14
9	633	69	0	752	103	0	34	30	88	138
10	2964	336	18	4579	760	23	32	30	89	95
11	4323	1170	0	5086	2485	0	32	30	89	80
12							31	30	90	26
13							31	30	91	20
14							30	30	91	11
15							30	30	91	9
16	326	18	11	526.0	107	11	55	45	97	0
17	218	19	0	342	109	0	55	58	92	10
18							27	43	94	27
19							28	44	93	27
20	1300	92	11	1781	278	12	33	46	95	5
21	564	21	0	652	54	0	43	37	93	17
22	85	26	6	230	25	30	32	47	93	3
23	85	26	1	230	25	30	32	46	93	5
24	596	45	10	774	136	10	47	55	52	3
25	190	29	20	320	135	29	53	56	49	16
26	190	29	10	320	135	29	58	57	49	19
27	39	14	12	40	15	12	72	72	67	4
28	228	30	11	288	87	39	68	70	67	2
29	636	157	4	824	215	78	61	61	91	2
30	782	134	6	818	270	6	64	66	96	11
31										10
32										79
33										77
33 event Total										
Total Measured										
% of Total Measured										

Table K7.4. Summary of major runoff events at Site 2 (CH2, CM1 & X2) at Keilambete during the trial period

Site 2		Rainfall (mm)	Intensity (mm/hr)	Antecedant Moisture	Runoff (mm)			Runoff (%)			Cover (%)			Days since Cover Estimate
Event	Date				High	Medium	Exclosed	High	Medium	Exclosed	High	Medium	Exclosed	
1	2/1/95	44.3	89	13.0	20.4	15.7	11.8	46	36	27	74	64	93	11
2	20/1/95	68.3	39	1.2	14.5	23.3	10.5	21	34	15	77	60	93	11
3	5/2/95	84.7	95	7.9	23.1	12.6	42.1	27	15	50	77	64	94	5
4	2/4/95	29.9	98	10.0	22.2	15.1	6.5	74	51	22	86	77	86	4
5	21/11/95	30.3	101	29.9	13.5	0.9	0.0	45	3	0	25	24	96	23
6	10/1/96	99.6	35	18.3	34.6	34.8	2.7	35	35	3	11	10	100	2
7	9/10/96	80.6	25	7.4	13.8	13.4	0.5	17	17	1	73	59	98	138
8	21/11/96	50.1	115	5.6	15.9	18.3	7.3	32	37	14	66	56	99	95
9	6/12/96	62.1	212	0.3	10.2	6.4	3.2	16	10	5	63	55	99	80
10	7/12/96	15.7	40	62.4	10.5	9.3	1.0	67	60	6	63	55	99	79
11	29/1/97	35.5	79	6.2	16.6	12.9	0.5	47	36	1	54	52	100	26
12	15/2/97	40.3	42	38.2	13.0	24.0	1.8	32	60	5	51	51	100	9
13	6/3/97	52.9	68	0.2	18.9	16.8	2.6	36	32	5	47	49	100	0
14	23/3/97	108.3	73	0.0	23.2	17.0	13.4	21	16	12	68	66	97	10
15	28/1/98	59.7	79	0.0	15.9	19.2	0.1	27	32	0	68	54	97	5
16	31/8/98	41.3	22	118.7	10.1	8.5	9.4	24	21	23	64	56	99	5
17	4/1/99	55.8	52	78.4	10.9	9.8	9.2	20	18	16	43	90	65	4
Sub Total					287	258	123							
% of Total					71	69	90							

Table K7.5. Example of the data collected about rainfall and runoff events at Keilambete, Aug to Oct 1998

		Rainfall			rep1 hi	rep1 med	rep1 exc	rep2 hi	rep2 med	rep2 exc	flu hi	flu med
Event date and time From	To	rep1 Total rain (mm)	rep2 Total rain (mm)	combined rain (mm)	a Total runoff (mm)	b Total runoff (mm)	c Total runoff (mm)	d Total runoff (mm)	e Total runoff (mm)	f Total runoff (mm)	g Total runoff (mm)	h Total runoff (mm)
4/08/1998 20:17	5/08/1998 3:54	10.09	10.43	10.26		0.06		0.18	0.12			
5/08/1998 7:54	5/08/1998 9:58	12.64	11.99	12.32	5.93	4.34		0.82	0.49		0.79	0.00
5/08/1998 10:36	5/08/1998 10:36								0.06			
5/08/1998 11:43	5/08/1998 11:43				0.06							
6/08/1998 1:38	6/08/1998 2:24	3.38	3.76	3.57	0.67	0.11		0.12				
6/08/1998 3:18	6/08/1998 3:18								0.06			
6/08/1998 7:32	6/08/1998 7:32	0.17		0.17								
27/08/1998 5:41	27/08/1998 5:41		0.19	0.19								
27/08/1998 6:16	27/08/1998 6:34	1.76	1.49	1.62								
27/08/1998 7:09	27/08/1998 8:04	0.52	0.56	0.54								
27/08/1998 9:56	27/08/1998 11:54	4.63	4.32	4.47	0.18							
27/08/1998 12:53	27/08/1998 13:58	1.92	2.05	1.99					0.06			
28/08/1998 3:56	29/08/1998 0:46	83.81	81.06	82.44	35.52	27.19	1.77	3.29	4.27	0.26	0.20	
29/08/1998 1:20	29/08/1998 1:32	0.17	0.19	0.18								
29/08/1998 2:58	29/08/1998 2:58								0.06			
29/08/1998 6:29	29/08/1998 9:20	7.58	7.30	7.44	2.47	1.62		0.12	0.06		1.85	
29/08/1998 9:52	29/08/1998 17:00	17.42	16.94	17.18	5.46	3.96	2.37	0.29	0.25	0.71		
29/08/1998 17:37	29/08/1998 17:37					0.06						
29/08/1998 18:36	29/08/1998 18:36								0.06			
30/08/1998 2:38	30/08/1998 3:38	0.70	0.74	0.72								
30/08/1998 4:28	30/08/1998 4:28	0.17		0.17								
30/08/1998 10:51	30/08/1998 11:06	0.17	0.19	0.18					0.06			
30/08/1998 13:32	30/08/1998 14:09	0.52	0.56	0.54								
30/08/1998 14:49	30/08/1998 16:00	0.35	0.37	0.36								
30/08/1998 17:36	31/08/1998 3:52	39.76	39.27	39.52	26.90	26.68	15.60	10.08	8.46	9.37		
31/08/1998 4:38	31/08/1998 4:38		0.19	0.19								
31/08/1998 5:24	31/08/1998 5:24	0.17		0.17								
31/08/1998 5:58	31/08/1998 6:24	0.17	0.19	0.18							0.06	
31/08/1998 7:36	31/08/1998 7:58	0.17	0.19	0.18								
31/08/1998 10:51	31/08/1998 11:38	0.35	0.19	0.27								
31/08/1998 12:58	31/08/1998 13:05	0.35	0.19	0.27								
31/08/1998 13:37	31/08/1998 13:54	0.17	0.19	0.18								
31/08/1998 16:02	31/08/1998 16:02	0.17		0.17								

		Rainfall			rep1 hi	rep1 med	rep1 exc	rep2 hi	rep2 med	rep2 exc	flu hi	flu med
Event date and time From	To	rep1 Total rain (mm)	rep2 Total rain (mm)	combined rain (mm)	a Total runoff (mm)	b Total runoff (mm)	c Total runoff (mm)	d Total runoff (mm)	e Total runoff (mm)	f Total runoff (mm)	g Total runoff (mm)	h Total runoff (mm)
31/08/1998 17:17	31/08/1998 17:27		0.19	0.19	0.06							
31/08/1998 22:09	31/08/1998 22:09	0.17		0.17								
31/08/1998 23:08	31/08/1998 23:08		0.19	0.19								
1/09/1998 3:01	1/09/1998 3:01	0.17		0.17								
1/09/1998 4:00	1/09/1998 4:24	0.17	0.19	0.18								
1/09/1998 9:05	1/09/1998 9:05		0.19	0.19								
1/09/1998 14:06	1/09/1998 14:06	0.17		0.17								
9/09/1998 20:24	9/09/1998 20:43	0.35	0.37	0.36								
10/09/1998 1:04	10/09/1998 1:04		0.19	0.19								
10/09/1998 5:47	10/09/1998 8:20	3.13	2.98	3.06								
10/09/1998 10:22	10/09/1998 11:34	1.04	1.12	1.08								
10/09/1998 12:51	10/09/1998 14:50	11.31	10.73	11.02	3.73	2.81		0.23	0.25			
10/09/1998 18:03	10/09/1998 18:20	0.17		0.17					0.06			
10/09/1998 22:12	10/09/1998 23:03	0.52	0.56	0.54								
11/09/1998 0:32	11/09/1998 0:49	0.70	0.56	0.63								
11/09/1998 3:07	11/09/1998 3:10	0.17	0.19	0.18								
11/09/1998 4:01	11/09/1998 4:21	0.17	0.19	0.18								
11/09/1998 4:58	11/09/1998 8:42	0.17		0.17								
12/09/1998 2:08	12/09/1998 8:54										0.20	
12/09/1998 23:40	13/09/1998 10:50	1.77	1.68	1.72							0.00	
13/09/1998 18:50	14/09/1998 9:50	3.51	3.73	3.62	0.06				0.06		0.50	
14/09/1998 18:40	14/09/1998 18:40				0.06							
15/09/1998 2:30	15/09/1998 6:22	1.74	1.68	1.71								
19/09/1998 11:44	19/09/1998 11:44	0.17		0.17								
24/09/1998 20:26	24/09/1998 22:17	3.13	2.79	2.96								
25/09/1998 0:26	25/09/1998 0:41	0.70	0.93	0.81								
25/09/1998 3:37	25/09/1998 4:04	0.17	0.19	0.18					0.06			
25/09/1998 6:23	25/09/1998 6:23					0.06						
25/09/1998 10:13	25/09/1998 10:13	0.17		0.17								
1/10/1998 13:55	1/10/1998 13:55	0.17		0.17								
9/10/1998 18:25	9/10/1998 19:25	7.72	5.26	6.49	0.86	0.28		0.06				
9/10/1998 20:03	9/10/1998 20:03				0.06							
9/10/1998 21:04	9/10/1998 21:04								0.06			
9/10/1998 22:41	9/10/1998 22:41		0.19	0.19								

		Rainfall			rep1 hi	rep1 med	rep1 exc	rep2 hi	rep2 med	rep2 exc	flu hi	flu med
Event date and time From	To	rep1 Total rain (mm)	rep2 Total rain (mm)	combined rain (mm)	a Total runoff (mm)	b Total runoff (mm)	c Total runoff (mm)	d Total runoff (mm)	e Total runoff (mm)	f Total runoff (mm)	g Total runoff (mm)	h Total runoff (mm)
9/10/1998 23:44	9/10/1998 23:44	0.17		0.17								
10/10/1998 1:58	10/10/1998 2:57	0.52	0.74	0.63								
10/10/1998 3:33	10/10/1998 4:13	0.35	0.19	0.27								
12/10/1998 23:50	13/10/1998 0:53	1.74	1.68	1.71								
13/10/1998 1:50	13/10/1998 1:50		0.19	0.19								
13/10/1998 2:45	13/10/1998 2:45								0.06			
15/10/1998 11:27	15/10/1998 11:27	0.17		0.17								
24/10/1998 23:42	25/10/1998 8:41	49.73	50.77	50.25	20.78	22.98	2.30	6.45	5.25	0.44	14.47	5.07
25/10/1998 9:14	25/10/1998 9:14					0.06						
25/10/1998 11:35	25/10/1998 11:36		0.19	0.19			0.07					
25/10/1998 23:03	26/10/1998 2:04	17.64	17.84	17.74	8.07	10.67	1.18	0.35	0.99	0.79	4.92	0.75
26/10/1998 2:52	26/10/1998 3:18	0.17		0.17						0.09		
26/10/1998 5:25	26/10/1998 5:25		0.19	0.19								
26/10/1998 6:41	26/10/1998 8:02	3.48	3.35	3.42		0.06						
26/10/1998 8:36	26/10/1998 8:36		0.19	0.19								
26/10/1998 10:43	26/10/1998 13:57	4.87	4.84	4.86	0.12				0.12			
26/10/1998 14:43	26/10/1998 15:34	1.57	1.68	1.62								
26/10/1998 20:09	26/10/1998 20:17	0.17	0.19	0.18								
26/10/1998 22:16	26/10/1998 22:30	0.35	0.37	0.36								
26/10/1998 23:28	26/10/1998 23:28	0.17		0.17								
27/10/1998 0:28	27/10/1998 0:28		0.19	0.19								
27/10/1998 1:10	27/10/1998 1:15	0.17	0.19	0.18								
27/10/1998 4:21	27/10/1998 5:53	3.18	3.57	3.38	0.12				0.06			

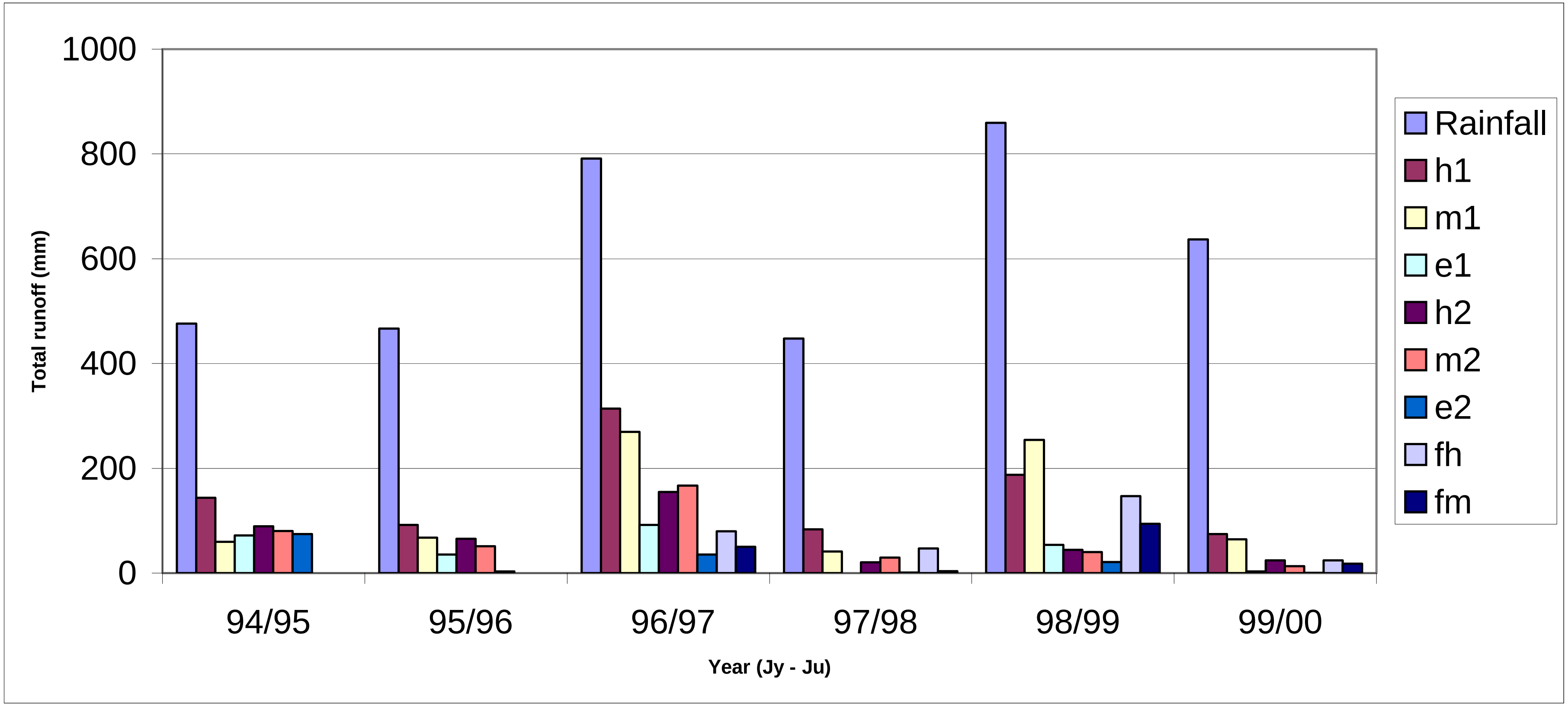


Figure K7.2. Summarised annual runoff from plots at Keilambete continually exposed to different grazing pressure. [h = high, m = moderate, e = exclosure in bounded plots; fh = high grazing pressure treed flume recorder, fm = moderate grazing pressure treed flume recorder]

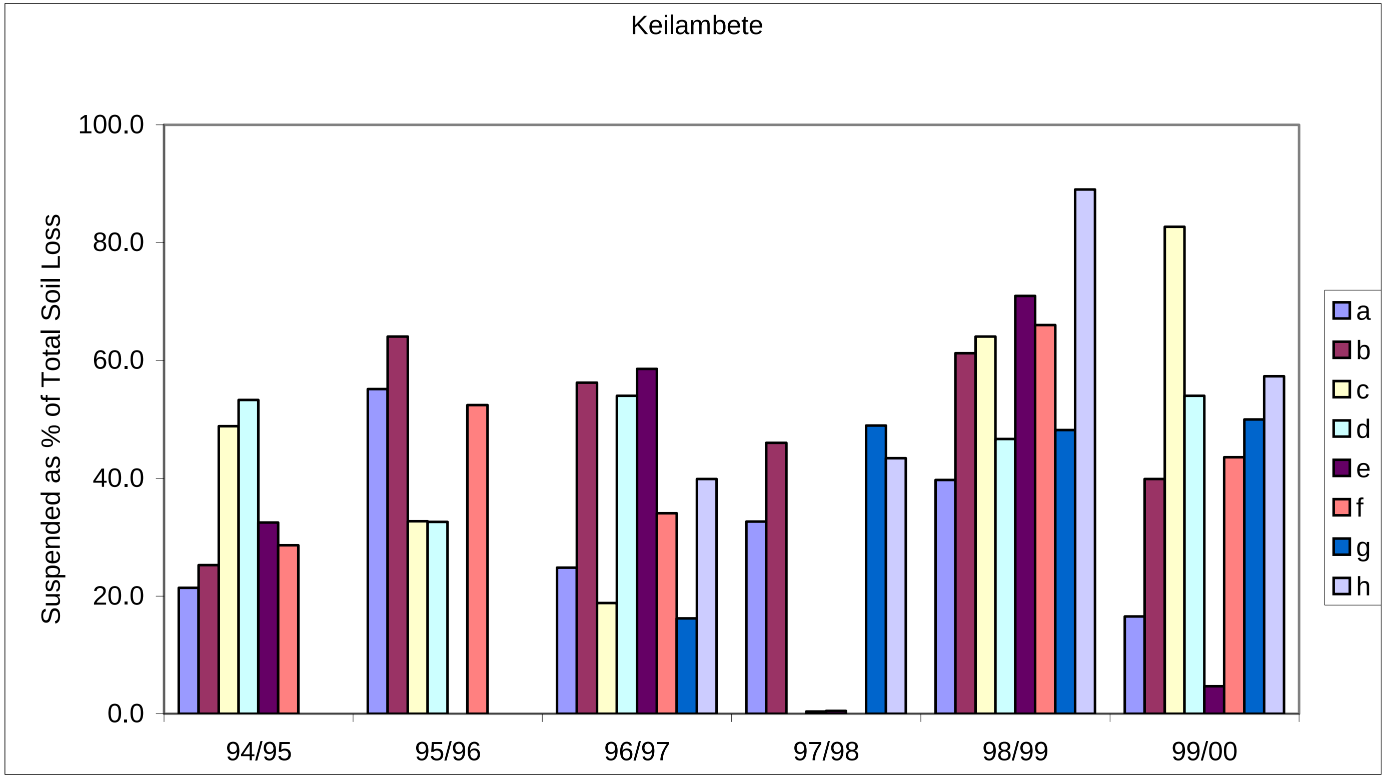


Figure K7.3. Proportion of the total annual soil movement that occurred as suspended sediment each year from each runoff plot (a – h)

a = high rep1	b = medium rep1	c = exclosure rep1
d = high rep2	e = medium rep2	f = exclosure rep2
g = treed flume high	h = treed flume medium	

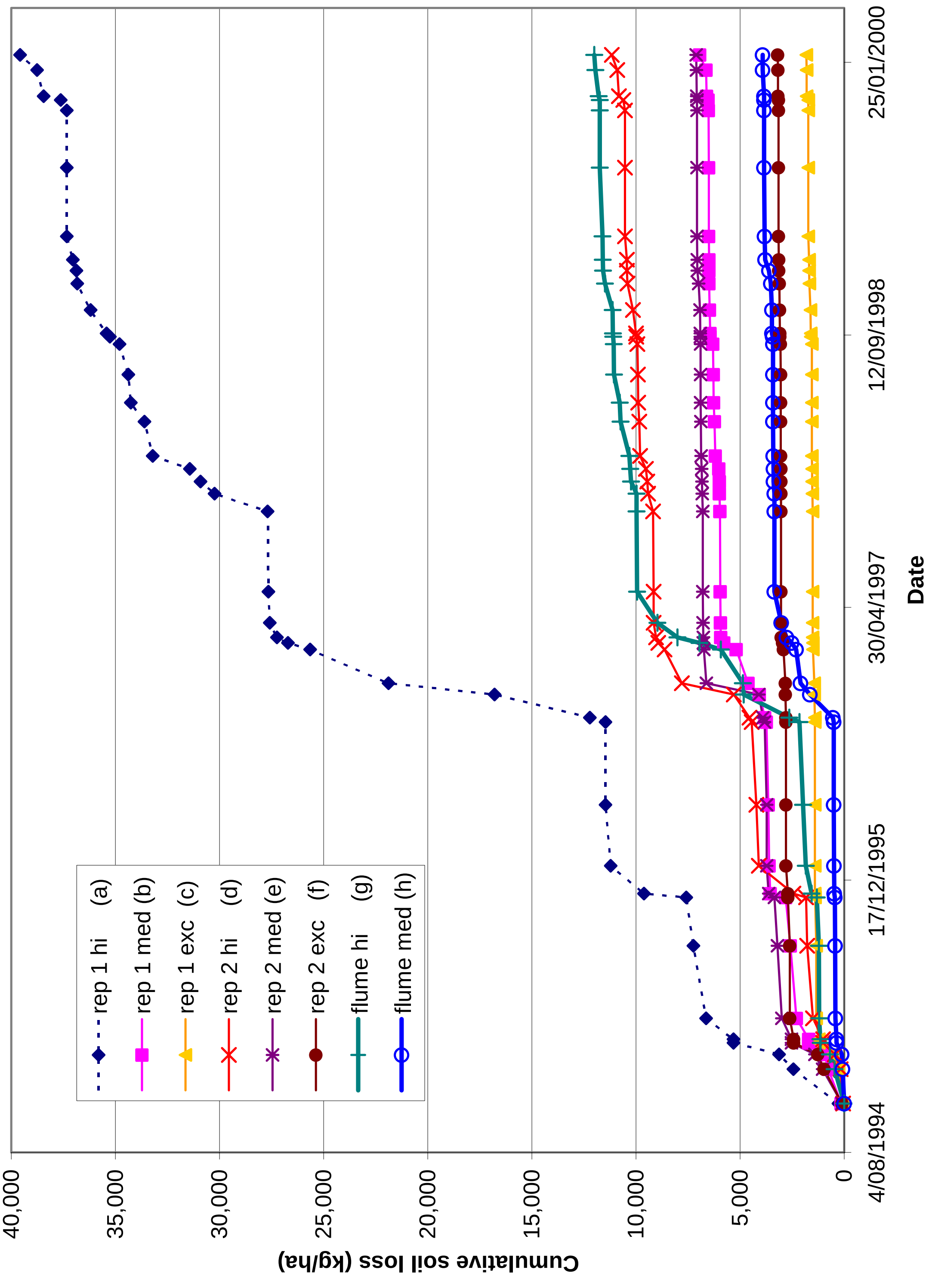


Figure K7.4. Cumulative soil loss (kg/ha) over time from each runoff plot at Keilambete

Table K7.6. Mean cover, runoff and soil movement for individual plots at Keilambete.

(a) Keilambete cover (%)

	rep1 hi a Total h1	rep1 med b Total m1	rep1 exc c Total e1	rep2 hi d Total h2	rep2 med e Total m2	rep2 exc f Total e2	flu hi g Total fh	flu med h Total fm
94/95	81	83	94	80	74	92	83	84
95/96	36	42	82	53	43	98	47	63
96/97	47	49	92	64	61	98	54	55
97/98	40	44	95	63	59	99	44	66
98/99	57	61	77	79	76	82	52	70
99/00	61	65	93	80	79	98	60	70

(b) Keilambete Soil loss (kg/ha)

	rep1 hi a Total h1	rep1 med b Total m1	rep1 exc c Total e1	rep2 hi d Total h2	rep2 med e Total m2	rep2 exc f Total e2	flu hi g Total fh	flu med h Total fm
94/95	7345	1704	1310	2313	3232	2559	1200	429
95/96	4908	2342	89	2071	1150	142	1110	379
96/97	17148	5148	157	3251	4857	487	9488	2675
97/98	4213	405	26	354	290	23	849	47
98/99	4520	1200	308	228	336	214	2122	522
99/00	2763	687	89	533	72	31	409	89

(c) Keilambete Runoff (mm)

	rep1 hi a Total h1	rep1 med b Total m1	rep1 exc c Total e1	rep2 hi d Total h2	rep2 med e Total m2	rep2 exc f Total e2	flu hi g Total fh	flu med h Total fm
94/95	144	60	72	89	81	74	0	0
95/96	92	68	36	65	51	3	0	0
96/97	314	269	92	155	167	35	80	50
97/98	84	41	0	21	29	1	47	4
98/99	188	254	54	44	40	21	147	94
99/00	75	65	3	24	13	1	24	18

Table K7.7. Annual Rainfall and Runoff Summary for Keilambete (meaned for 2 reps)

(a) Keilambete Rainfall & mean treatment Runoff

	Rainfall	Runoff				
		High	Medium	Exclosure	Flume High	Flume Medium
	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)
94/95	476	117	70	73	0	0
95/96	467	79	59	19	0	0
96/97	791	234	218	64	80	50
97/98	447	52	35	1	47	4
98/99	860	116	147	37	147	94
99/00	637	49	39	2	24	18

(b) Soil loss Summary, Keilambete

	Rainfall	Soil Loss (Bedload + Suspended sediment)				
		High	Medium	Exclosure	Flume High	Flume Medium
	(mm)	(kg/ha)	(kg/ha)	(kg/ha)	(kg/ha)	(kg/ha)
94/95	476	4829	2468	1934	1200	429
95/96	467	3490	1746	116	1110	379
96/97	791	10199	5002	322	9488	2660
97/98	447	2284	347	25	849	47
98/99	860	2374	768	261	2122	522
99/00	637	1648	380	60	409	89
		24823	10712	2718	15178	4125

(c) Cover Summary, Keilambete

	Rainfall	Ground Cover				
		High	Medium	Exclosure	Flume High	Flume Medium
	(mm)	(%)	(%)	(%)	(%)	(%)
94/95	476	80	78	93	83	84
95/96	467	44	42	90	47	63
96/97	791	55	55	95	54	55
97/98	447	52	52	97	44	66
98/99	860	68	68	80	52	70
99/00	637	70	72	96	60	70

Appendix K8

Table K8.1. Raw data from runoff events at the Glentulloch sites 1994 to 2000

GLTH SOIL MOVEMENT * nc= not collected nd=no data dd=disgard data Pits popped out of ground, so estimated = values estimated as no data available

Site	Date Collected	BED LOAD (kg/ha)									SUSPENDED SEDIMENT (g/l)								
		small plot rep 1			small plot rep 2			Flume		Treed	small plot rep 1			small plot rep 2			Flume		Treed
		high	medium	exclose	high	medium	exclose	High	Medium	exclose	high	medium	exclose	high	medium	exclose	High	Medium	exclose
Glth	1/10/1994	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00									
Glth	3/11/1994	63.35	182.97	297.62	378.15	86.22	199.36	nd	nd		0	0	0	0.31	1.98	0	nd	nd	
Glth	21/11/1994	11.72	14.07	36.31	47.27	8.01	38.38	nd	nd		0	0	0	0.31	1.98	0	nd	nd	
Glth	20/01/1995	31.68	21.11	35.71	140.06	30.79	49.84	194.75	4.56		0.67	0	0.4	1.03	0.6	0.68	0.26	0.2	
Glth	6/02/1995	31.68	105.56	238.10	35.01	30.79	49.84	0.00	0.00		0	0	0	0	0	0	0	0	
Glth	4/10/1995	0.00	0.00	0.00	35.01	30.79	49.84	0.94	5.70		0	0	0	0.86	0.4	0.83	nd	nd	
Glth	16/11/1995	95.03	35.19	59.52	105.04	30.79	49.84	2.81	9.12		0	0	0	0	0	0	0	0	
Glth	6/12/1995	31.68	70.37	59.52	210.08	30.79	49.84	10.08	68.42		0.16	0	0	0.74	0.19	0	nd	nd	
Glth	30/01/1996	31.68	35.19	59.52	280.11	61.58	0.00	10.08	70.18		0.16	0	0	0.74	0.19	0	0.02	0.69	
Glth	21/05/1996	272.41	499.65	238.10	434.17	117.01	139.55	0.00	38.77		0.16	0	0	0.74	0.19	0	nd	nd	
Glth	1/11/1996	288.00	137.00	255.00	297.00	271.00	171.00	8.05	41.74		0.7	3.17	0.82	2	0.9	0	2.5	1.1	
Glth	13/12/1996	120.37	211.12	202.38	301.12	320.24	219.30	nd	nd		1.77	1	2.4	1.77	1.17	0	nd	nd	
Glth	21/02/1997	140.39	76.34	130.55	1283.23	1115.00	110.11	nc	81.94		2.03	2.22	0.77	1.07	1.36	0.77	nd	nd	
Glth	17/03/1997	70.67	76.97	0.00	77.70	27.43	93.34	7.49	13.68		0.16	0.00	0.00	0.44	4.01	0.00	nd	nd	
Glth	5/06/1997	22.29	9.97	25.99	36.86	54.15	17.13	0.72	9.17		0.13	0	0	1.59	5.03	0	nd	nd	
Glth	3/10/1997	20.00	15.31	13.43	246.06	112.67	27.95	3.99	7.12	149.85	1.23	2.41	17.77	3.33	2.50	0.00	1.11	0.00	0
Glth	14/10/1997	6.75	5.60	0.00	34.02	40.06	0.00	1.40	8.02	36.15	0.77	3.21	0	1.64	1.47	0	3.25	0	1.99
Glth	10/11/1997	30.94	40.47	68.33	223.82	134.75	23.00	1.95	12.28	396.47	0.86	1.49	1.67	4.1	1.53	0	1.58	0	3.58
Glth	1/12/1997	188.93	144.35	136.35	461.40	590.67	312.89	5.46	12.11	1184.02	0.35	0.48	5.32	1.16	0.71	1.96	1.28	0	1.51
Glth	16/12/1997	2.38	5.4	16.52	11.49	21.00	18.18	1.55	2.04	56.95	0.39	3.72	13.18	0.93	1.28	14.77	nr	nr	1.67
Glth	30/12/1997	12.36	8.36	37.19	125.91	177.60	28.72	3.76	2.80	171.30	0.42	0.78	0.75	1.73	1.01	0	0	114.34	1.8
Glth	28/01/1998	3.94	0	0.00	40.58	54.54	0.00	1.03	4.49	146.52	0	0	0	1.46	1.87	0	3.94	11.29	1.65
Glth	16/02/1998	0.00	4.98	0.00	44.31	67.36	0.00	0.68	7.50	52.83	0	0	0	0.6	0.15	0	1.32	0	0.62
Glth	2/03/1998	1.63	1.74	0.00	55.49	36.97	0.00	0.53	6.11	147.88	1.65	0	0	1.37	0.75	0	2.23	7.42	1.66
Glth	12/03/1998	0.00	0	0.00	28.81	23.10	0.00	0.83	4.02	50.76	0	0	0	1.76	1.87	0	0	0	4.85
Glth	20/04/1998	3.32	3.47	0.00	11.64	10.57	0.00	0.25	1.48	38.04	0	0.43	0	0.69	3.8	10.67	1.61	0	0.86
Glth	27/04/1998	0.00	0	0.00	7.79	2.69	0.00	0.05	0.33	12.12	0	0	0	1.11	0	0	0	0	2.99
Glth	12/05/1998	0.00	0	0.00	87.27	35.12	0.00	1.03	3.73	90.21	0	0	0	1.01	0.84	0	0	0	2.24
Glth	30/06/1998	0.00	0	0.00	7.87	11.10	0.00	0.23	0.63	74.99	0	0	0	0.81	0.62	0	0.87	0	0

Glth	23/07/1998	0.00	0	0.00	5.80	4.99	0.00	0.25	1.40	24.04	0	0	0	1.27	0	0	0.17	0	0
Glth	31/07/1998	0.00	0	0.00	3.02	0.00	0.00	0.08	1.00	7.49	0	0	0	0	0	0	0	0	0
Glth	12/08/1998	2.83	2.1	4.17	7.82	10.48	0.00	0.47	1.25	29.25	0.73	0	0	0.26	0.02	0	3.54	0	1.22
Glth	18/09/1998	3.28	4.25	26.78	27.59	27.54	27.40	0.38	5.07	123.91	0.2	0	0.76	1.39	0.64	0	0	0	0.52
Glth	29/09/1998	0.00	0	0.00	3.68	3.49	0.00	0.50	2.12	22.99	0	0	0	0.46	1.14	0	0	0	5.86
Glth	29/10/1998	0.00	0.00	0.00	0.00	10.49	0.00	0.44	2.56	48.94	0	0	0	0	0	0	0	0	1.05
Glth	17/11/1998	0.00	0.00	0.00	10.29	0.00	0.00	0.00	0.49	7.30	0	0	0	0.09	0	0	0	0	0
Glth	30/11/1998	0.00	4.28	0.00	8.51	0.00	0.00	0.29	1.34	42.08	0	0	0	1.45	0	0	0	4.45	1.7
Glth	22/12/1998	3.64	3.53	0.00	25.67	20.06	0.00	1.07	11.68	207.80	0	0	0	1.18	0.34	0	0.42	0.58	1.65
Glth	6/01/1999	0.00	2.73	10.91	5.86	10.04	0.00	0.63	6.02	55.34	0	0	0	0.24	0.02	0	0.96	1.73	1.31
Glth	3/02/1999	4.14	4.06	9.87	75.86	146.18	5.99	2.02	32.25	350.19	1.16	0.53	0.52	0.41	0.37	0.43	0.35	0.54	0.95
Glth	15/02/1999	0.00	0.00	0.00	13.10	0.00	0.00	0.33	0.82	33.42	0.00	0.00	0.00	2.88	0.00	0.00	0.87	2.21	36.42
Glth	25/02/1999	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0	0	0	0	0.31	0	0
Glth	5/03/1999	0.75	1.48	4.68	18.10	19.66	76.59	0.20	6.33	33.58	0.40	1.59	0.37	0.14	0.28	0.27	0.02	0.00	0.49
Glth	23/03/1999	0.00	0.00	0.00	3.63	7.01	16.26	0.14	0.65	9.25	0	0	0	0.82	5.78	0	0	0	1.22
Glth	7/04/1999	0.00	0.00	0.00	2.81	2.84	0.00	0.10	0.12	6.76	0	0	0	1.88	4.55	0	0	0	1.82
Glth	13/05/1999	0.00	0.00	0.00	1.15	0.00	0.00	0.00	0.15	1.18	0	0	0	1.31	0	0	0	0	0
Glth	16/06/1999	0.00	0.00	1.85	1.43	0.00	0.00	0.00	0.06	1.89	0	0	2.04	0.97	0	0	0	0	1.75
Glth	30/06/1999	0.00	0.00	0.00	0.69	0.00	0.00	0.00	0.00	0.00	0	0	0	0.31	0	0	0	0	0
Glth	29/07/1999	0.00	0.00	0.00	1.04	0.00	0.00	0.00	0.00	4.01	0	0	0	1.65	0	0	0	0	9.75
Glth	13/10/1999	0.00	0.00	0.00	2.34	0.00	0.00	0.16	0.00	3.53	0	0	0	2.28	0	0	0	0	7.36
Glth	31/10/1999	1.81	0.00	0.00	3.30	0.00	0.00	0.18	0.57	1.69	0	0	0	3.72	0	0	0	0	0
Glth	11/11/1999	0.00	0.00	0.00	4.34	0.00	0.00	0.18	0.37	6.20	0	0	0	2.82	0	0	0	0	0
Glth	14/12/1999	0.00	0.00	0.00	3.84	0.00	0.00	0.14	0.34	3.78	0	0	0	4.34	0	0	0	0	0
Glth	6/01/2000	0.00	0.00	0.00	4.00	0.00	0.00	0.09	0.32	2.21	0	0	0	4.22	0	0	0	0	0
Glth	12/01/2000	0.00	0.00	0.00	2.21	1.44	0.00	0.11	0.07	1.36	0	0	0	0.58	0	0	0	0	0
Glth	20/01/2000	0.00	0.00	0.00	0.00	8.11	0.00	0.00	0.00	0.00	0	0	0	0	0	0	0	0	0
Glth	31/01/2000	0.00	30.15	0.00	12.03	12.11	0.00	0.83	0.86	12.55	0	0.7	0	2.55	0	0	0	0	0
Glth	18/02/2000	4.68	7.30	0.00	16.30	11.47	0.00	1.60	1.25	11.43	0.4	0	0	0.77	0.22	0	0	0	0
Glth	15/03/2000	2.90	52.99	89.05	129.83	111.34	158.17	1.85	10.15	90.13	0.36	0.48	0.16	2.69	0.24	0.73	1.14	0.38	0.1
Glth	20/04/2000	0.98	0.00	0.00	2.68	0.00	0.00	0.00	0.00	16.75	0	0	0	0	0	0	0	0	0
Glth	9/06/2000	0.00	0.00	0.00	1.49	0.00	0.00	0.00	0.00	4.94	0	0	0	0	0	0	0	0	0
Glth	20/07/2000	0.00	0.00	0.00	1.43	0.00	0.00	0.00	0.00	6.95	0	0	0	0	0	0	0	0	0

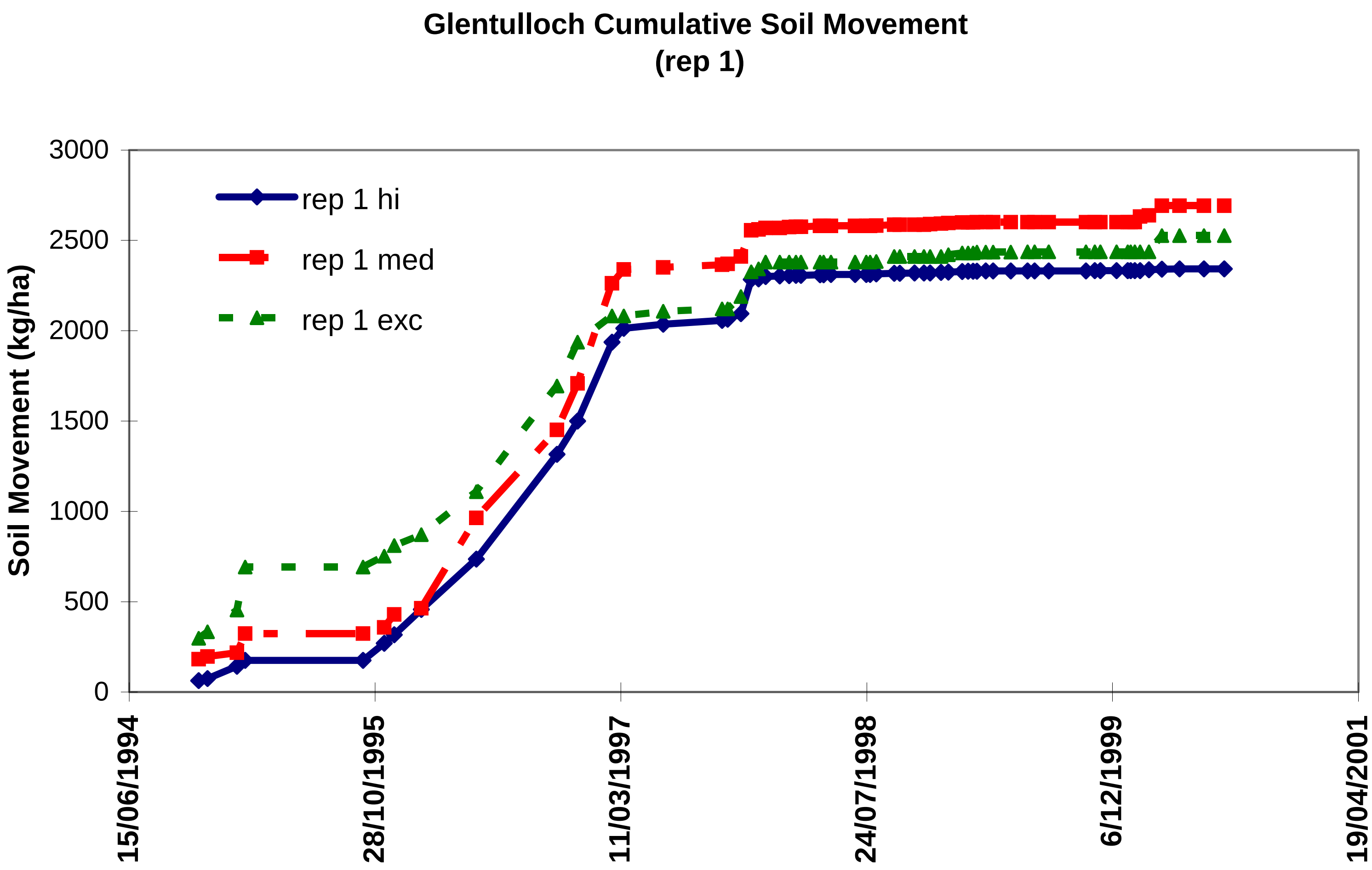


Figure K8.1. Cumulative soil loss (bedload + suspended sediments) for the 3 rep1 plots at Glentulloch from Oct 1994 to June 2000
Note the differences from the Rep 2 plots of the same treatments (Figure K8.2)

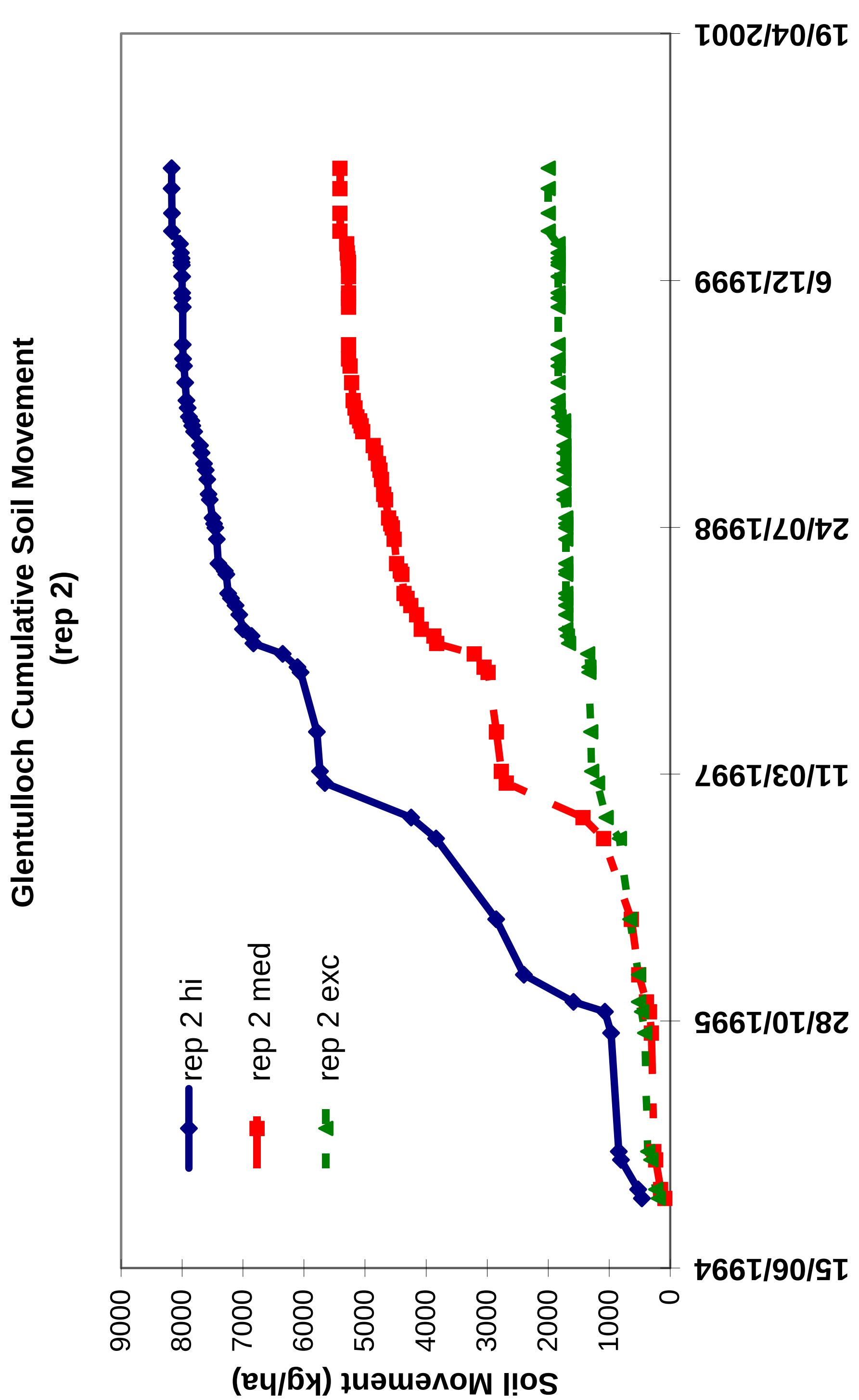


Figure K8.2. Cumulative soil loss (bedload + suspended sediments) for the 3 rep2 plots at Glentulloch from Oct 1994 to June 2000

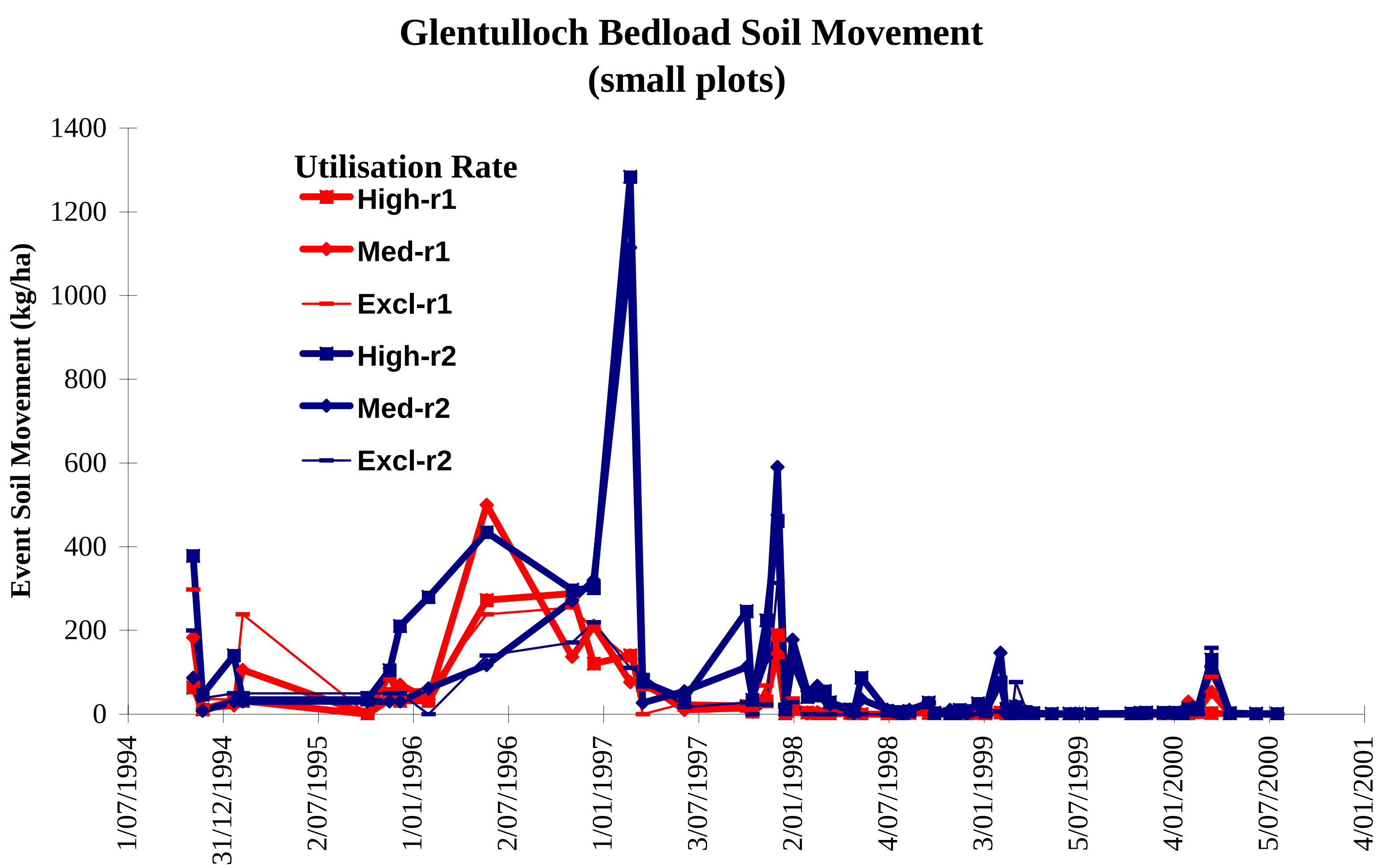


Figure K8.3. Bedload soil movement during individual service periods under various grazing management regimes at Glentulloch

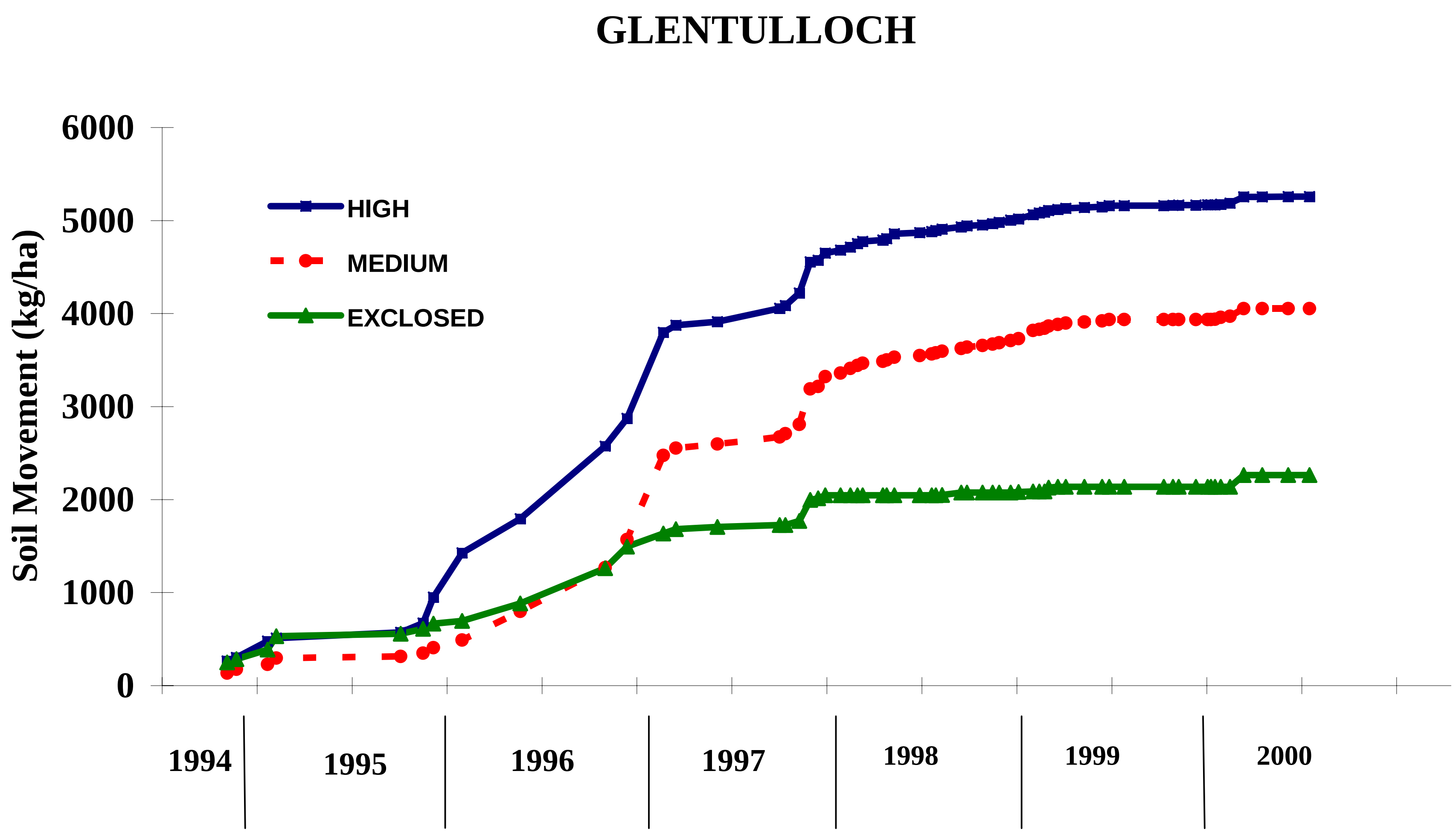


Figure K8.4. Meaned cumulative total soil movement under 3 grazing regimes on treeless poplar box country at Glentulloch

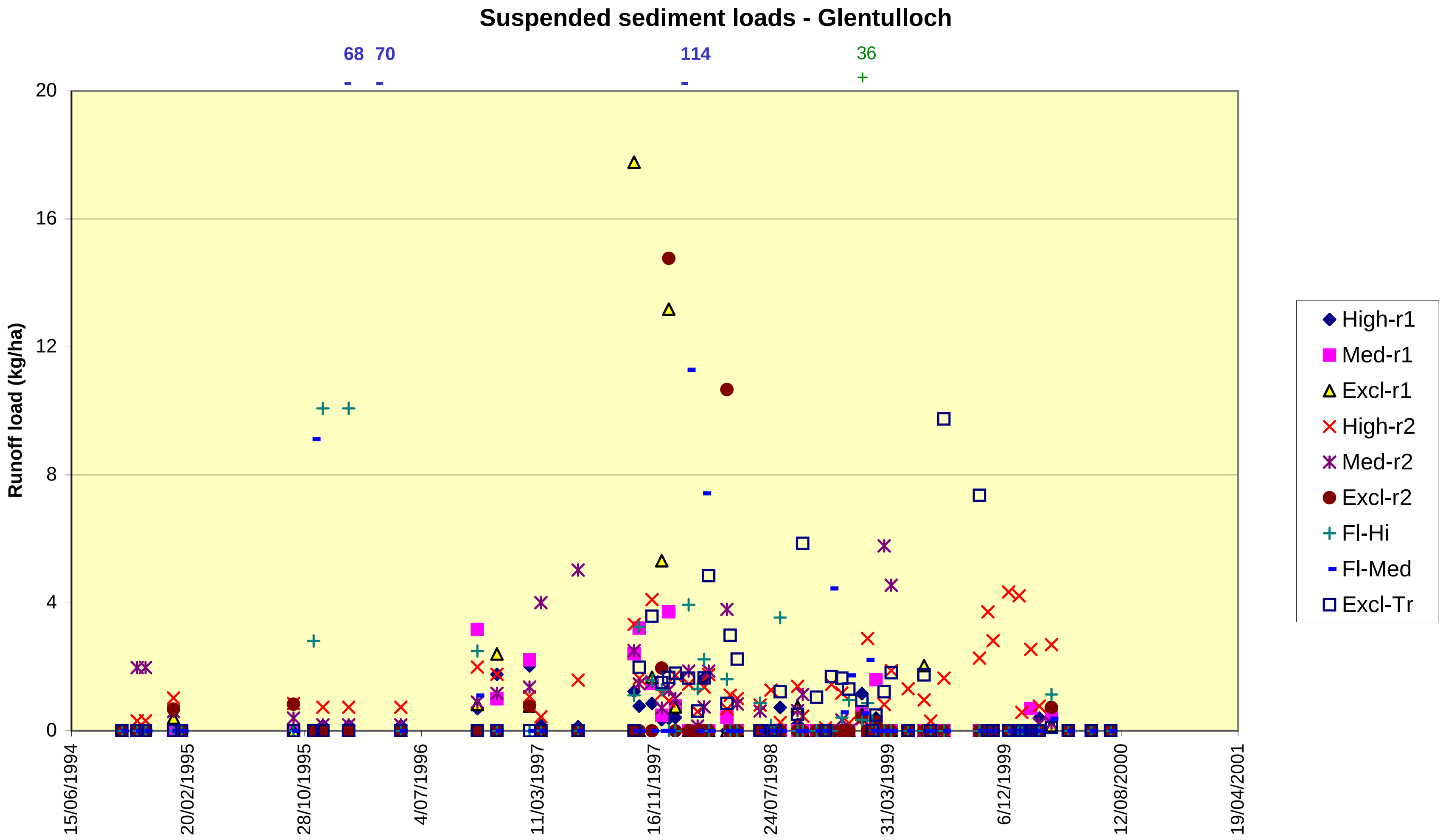


Figure K8.5. Suspended sediment loads in runoff water from individual events at Glentulloch of plots under differing grazing pressure and tree cover. Values above chart are for isolated, large sediment movement events (values show amount)

Table K8.2. Runoff plot areas for each mini-catchment and bounded plot at Glentulloch

		Plot nbr	Plot code	Pdk Nbr	Area (m^2)	Area (ha)
high	rep1	9	h1	3	157.85	0.015785
medium	rep1	10	m1	2	142.1	0.01421
exclosure	rep1	11	e1	2	84.0	0.0084
high	rep2	12	h2	9	142.8	0.01428
medium	rep2	13	m2	8	162.38	0.016238
exclosure	rep2	14	e2	8	100.32	0.010032
high	flume	15	hf	12	5340.3	0.53403
medium	flume	16	mf	5	4384.6	0.43846
exclosure	treed	17	et	4	96.8	0.00968

APPENDIX L. Fixed point photos, Ironbark and Poplar box sites

The following photographs are a selection from amongst a huge library of colour snaps taken at about annual intervals with a predetermined, fixed view. The view was generally along the permanent transects used for recording woody plant dynamics, pasture basal area and soil seed loads.

Plates 1 to 8 are from the poplar box site at Glentulloch.

Plates 9 to 17 are from the silverleaf ironbark site at Keilambete.

The locations shown have been chosen to depict areas where trees were killed in 1994, where they were left untreated and to show comparisons between the ungrazed burning trial plots and ones with similar tree cover in the grazing trial. Some also show the differences in pasture biomass amongst the three grazing pressures employed.

Plate L1. Glentulloch Grazing trial : Paddock 4 Transect 1 – Low Grazing Pressure plus Trees

1994 (top left), 1995 (top right), 1996, 1997, 1998, 1999, 2000, 2002 (bottom right)
Patch grazing of preferred grasses is very obvious even with a low grazing pressure. Purple wiregrass is the main rejected species.

Plate L2. Glentulloch Grazing trial : Paddock 7 Transect 2 – Low Grazing Pressure; Trees killed 1994 (top left), 1995 (top right), 1996, 1997, 1998, 1999, 2000, 2002 (bottom right)

Plate L3. Glentulloch Grazing trial : Paddock 8 Transect 2 – Medium Grazing Pressure; Trees killed

1994 (top left), 1995 (top right), 1996, 1997, 1998, 1999, 2000, 2002 (bottom right)
Note the increased pasture cover grown in 2 years after the trees were killed

Plate L4. Glentulloch Grazing trial : Paddock 12 Transect 2 – High Grazing Pressure plus Trees

1994 (top left), 1995 (top right), 1996, 1997, 1998, 1999, 2000, 2002 (bottom right)

Size increase by some of the young myall trees is very clear

Plate L5. Glentulloch Grazing trial : Paddock 9 Transect 1 – High Grazing Pressure, Trees killed
1994 (top left), 1995 (top right), 1996, 1997, 1998, 1999, 2000, 2002 (bottom right)
Lightly grazed, stalky tufts are purple wiregrass and twirly windmill grass. Pasture composition change at high grazing pressure was slow because most grasses are strongly perennial and take years to become so debilitated that they die.

2002 Hot fire (1997)

Plate L6. Glentulloch Burning trial : Plot 1, CB1 – Burnt plus Trees killed

1996 (top right), 1997, 1998, 1999, 2000, 2001, 2002, 1997 fire (bottom right)
Though completely covered by long grass in late summer, after a fire the significant amount of bare soil surface at crown level is obvious in the spring 2002 photo.

2002 Calotis lappulacea (2000)

Plate L7. Glentulloch Burning trial : Plot 3, CN1 – Not Burnt plus Trees killed

1996 (top right), 1997, 1998, 1999, 2000, 2001, 2002, Calotis 2000 (bottom right)

Note the complete lack of early woody regrowth during our trial period, despite the lack of fires.

Plate L8. Glentulloch burn site showing tree density, fire patterns, plus close-ups of typical litter cover after 6 years of spring burns or not

1

Plate L9. Keilambete Low Grazing pressure, Trees killed (CL1 Transect 2) 1994(top left), 1995, 1996, 1997, 1999, 2001(bottom right)
There was significant ironbark regrowth only after 1999

Plate L10. Keilambete Low Grazing pressure, Trees present (TL2 Transect 2), 1994(top left), 1995, 1996, 1997, 1999, 2001(bottom right)
The prickly pine (*B.incana*) in the middle ground on the left has grown a lot over 7 years.

Plate L11. Keilambete Moderate Grazing pressure, Trees killed (CM2 Transect 1) – 1994(top left), 1995, 1996, 1997, 1999, 2001(bottom right)

The smaller poisoned trees did not remain upright for very long once dead. Woody regrowth rate was slow from the existing small, unpoisoned ironbark plants

Plate L12. Keilambete Moderate grazing pressure, Treed (TM2 Transect 2) - 1994(top left), 1995, 1996, 1997, 1999 and 2001(bottom right)

Patch grazing was not very obvious at this site compared to the poplar box site.

Plate L13. Keilambete High grazing pressure, Trees killed (CH2 Transect 3) - 1994(top left), 1995, 1996, 1997, 1999, 2001(bottom right)

The consequences of setting stock numbers only once each year in late autumn shows in the 1999 photo after an excellent 1998-99 summer followed a poor 1997-98 summer. The paddock, which was still in fair condition, responded rapidly to a single summer of effective light grazing.

Plate L14. Keilambete high grazing pressure, Treed (TH1 Line 1) in 1994(top left), 1995, 1996, 1997, 1999, 2001(bottom right)

Rapid regrowth of small woody plants occurred in the wet 1998-99 period when cattle would not have browsed them as they had previously in drier winters.

Plate L15.

Keilambete

Ungrazed,
Unburnt,
Trees killed
(CN1)
1997 & 1999

Ungrazed,
Unburnt,
Trees left
(TN1)
1997 & 1999
left right

Plate L16. Keilambete Trees killed plus spring burns (CB3) – 1997(top), 1999, 2000(bottom)

Note the lack of woody plant regrowth under regular spring burning

Plate L17. Keilambete trees killed, spring burns (TB2) –
1997(top), 1999 and 2000(bottom)

Spring fires are keeping the small ironbarks in check. Old trees have only sparse foliage.

APPENDIX M. Cattle growth details, Ironbark and Poplar box sites

Appendix M1

Table M1. Typical cattle liveweight data from Glentulloch from Mob 3 (1996 – 1997)

Glentulloch	Draft 3 1996-97					28 Nov 96 to 5 Nov 97 (ex Rostock second mob)						
Pdk nbr				Weigh date								sold 11 Nov 97
.	**Tag**	28/11/96	6/02/97	13/05/97	1/07/97	17/07/97	17/07/97	26/08/97	17/09/97	17/09/97	5/11/97	5/11/97
TREAT	**No.**	1	2	3	4	5	Fat Score		**6**	Fat Score	**7**	Fat Score
		Days 0	70	96	49	65			62		49	
1 - C L 1	515	184	230	284		284	3		302	3	302	3
1 - C L 1	516	170	221	302		306	3		309	3	329	3
1 - C L 1	543	173	226	306		302	3		304	3	315	3
2 - C M 1	536	170	204	282		270	2		272	2	284	3
2 - C M 1	540	173	214	292		282	2		272	2	281	2+
2 - C M 1	551	184	232	304		296	3		296	2	315	3+
3 - C H 1	509	183	206	250		244	2		237	2	233	2
3 - C H 1	518	173	204	226		234	2		243	2	240	2
3 - C H 1	523	169	205	262		264	2		266	2	274	2
4 - T L 1	517	183	226	308		292	3	306	300	3	310	2+
4 - T L 1	527	169	212	292		274		est.	265	2	270	2+
4 - T L 1	548	174	214	303		274	2	282	274	2	283	2+
5 - T M 1	526	183	214	294		272	2		271	2	260	2
5 - T M 1	531	167	202	266		250	2		245	2	240	2
5 - T M 1	539	174	222	300		300	2		295	2	293	3
6 - T H 1	504	165	176	220	210	214	2		204	2	203	2 -
6 - T H 1	520	174	185	220	214	219	2		213	2	204	2 -
6 - T H 1	547	183	192	244	230	234	2		228	2	224	2 -
7 - C L 2	501	174	212	298		290	3		285	3	307	3
7 - C L 2	524	165	210	272	252	244	3		248	3	273	3
7 - C L 2	554	183	220	294	282	284	3		286	3	308	3
8 - C M 2	505	180	212	296		276	3		270	3	287	3

Glentulloch Draft 3 1996-97 — 28 Nov 96 to 5 Nov 97 (ex Rostock second mob)

Pdk nbr . TREAT	Tag No.	28/11/96 1	6/02/97 2	Weigh date 13/05/97 3	1/07/97 4	17/07/97 5	17/07/97 Fat Score	26/08/97	17/09/97 6	17/09/97 Fat Score	5/11/97 7	sold 11 Nov 97 5/11/97 Fat Score
8 - C M 2	529	165	200	288		294	3		297	3	315	3
8 - C M 2	553	175	214	306		294	3		294	3	313	3
9 - C H 2	519	180	210	263		250	2		240	2	255	2
9 - C H 2	545	175	201	266		270	2		260	2	260	2
9 - C H 2	549	164	174	226		224	2		205	2	213	2 -
10 - T L 2	503	162	198	268		255	3		245	2	245	2
10 - T L 2	532	180	226	303		290	3		281	3	287	3
10 - T L 2	535	175	226	308		285	3		280	3	297	3
11 - T M 2	533	175	208	262		246	2		248	2	253	2
11 - T M 2	542	180	211	279		254	2		250	2	240	2 -
11 - T M 2	546	161	186	239		222	2		222	2	215	2 -
12 - T H 2	507	160	182	252		232	2		218	2	215	2 -
12 - T H 2	514	175	192	252		235	2		229	2	225	2
12 - T H 2	522	179	210	282		255	3		241	2	244	2 -
COM	502	154	184	247		224	2		226	2	233	2 +
COM	506	157	184	266		250	2		260	2	268	2
COM	508	185	230	326		292	3		296	3	308	3
COM	511	160	202	268		254	3		241	3	247	3
COM	512	157	190	270		252	2		240	3	249	3
COM	513	187	226	324		306	3		296	3	303	3
COM	525	153	174	232		214	2		208	2	217	2
COM	528	185	208	306		274	3		270	2	275	2 +
COM	530	150	176	250		236	2		234	2	244	2 +
COM	537	189	212	298		270	3		271	3	258	2 +
COM	538	185	204	280		268	3		260	3	265	3
COM	541	190	210	290		258	2		251	2	270	2
COM	544	138	164	212		202	2		204	2	207	2
COM	550	187	202	284		256	2		259	3	260	2 +
COM	552	188	200	302		272	3		266	3	268	3

Appendix M2

Table M2. Example cattle liveweights for Keilambete in the 1997/98 year

		Weigh date			
Pdk	Tag nbr	6/05/1997	11/07/1997	20/10/1997	9/01/1998
CH1	14	238	266	254	295
CH1	414	242	266	251	318
CH1	417	232	241	259	316
CH1	422	224	259	259	320
CH2	2	250	270	272	332
CH2	421	252	274	272	340
CH2	721	256	266	279	338
CL1	250	296	326	310	392
CL1	405	280	308	314	396
CL1	752	308	328	332	388
CL1	768	312	346	344	414
CL1	913	312	332	326	406
CL2	335	316	346	332	394
CL2	551	318	334	322	378
CL2	623	312	328	324	378
CL2	723	320	332	332	388
CL2	867	292	316	318	370
CM1	885	266	286	273	326
CM1	886	268	289	295	348
CM1	894	266	272	267	324
CM1	945	268	280	276	338
CM2	20	274	298	302	376
CM2	423	270	285	278	352
CM2	576	272	291	289	354
CM2	881	276	293	285	374
TH1	80	256	283	264	330
TH1	242	264	290	268	324
TH1	412	264	287	259	310
TH1	580	258	280	273	332
TH2	18	316	328	302	350
TH2	404	318	354	324	378
TH2	523	278	300	272	336
TH2	555	292	302	283	342
TH2	698	318	354	332	390
TL1	12	282	304	302	354
TL1	413	282	287	267	334
TL1	584	286	302	302	366
TL1	587	284	295	294	346
TL1	635	282	296	282	330
TL1	753	282	306	302	352
TL1	841	296	308	284	348

		Weigh date			
Pdk	Tag nbr	6/05/1997	11/07/1997	20/10/1997	9/01/1998
TL1	869	284	298	297	366
TL1	904	294	304	304	382
TL2	98	300	326	286	356
TL2	465	296	332	306	366
TL2	478	300	310	295	356
TL2	550	294	306	285	342
TL2	557	296	302	300	366
TL2	581	302	314	300	366
TL2	866	304	316	297	370
TL2	903	298	330	287	352
TL2	917	296	314	304	366
TM1	230	300	320	286	342
TM1	238	290	312	288	332
TM1	365	306	334	304	384
TM1	494	306	342	302	382
TM1	546	308	330	298	372
TM1	652	300	310	267	314
TM1	656	294	312	288	364
TM1	687	294	306	268	330
TM1	887	292	312	285	350
TM1	919	306	328	291	356
TM2	232	312	338	320	382
TM2	610	310	334	314	374
TM2	659	310	326	320	352
TM2	689	310	330	316	382
TM2	940	314	334	336	386
COMM	112	229	244	216	235
COMM	113	254	270	277	332
COMM	124	262	278	285	352
COMM	125	238	254	265	332
COMM	134	242	258	258	312
COMM	135	242	258	254	304
COMM	150	266	282	291	332
COMM	189	270	286	283	338
COMM	210	228	244	263	296
COMM	224	260	276	283	332
COMM	642	308	338	326	384
COMM	901	308	344	326	352
COMM	909	308	334	318	370
COMM	911	318	364	344	382
COMM	926	302	318	314	352

Appendix M3

Table M3. Change in the individual paddock stocking rates (full year) over time at Glentulloch as mobs were replaced

		Herd 1	**Herd 2**	**Herd 3**	**Herd 4**	**Herd 5**	**Herd 6**	**Herd 7**	**Herd 8**	**Mean**	**Max**	**Min**
Paddock	**Treatment**	' 94 - ' 95	' 95 - ' 96	' 96 - '97	' 97 - ' 98	' 98 - ' 99	' 99 - ' 00	' 00 - ' 01	‘ 01 - 02			
1	CL1	5.53	3.99	4.27	4.94	3.48	2.51	3.34	4.02	4.01	5.53	2.51
2	CM1	2.77	1.99	2.13	2.61	2.32	1.70	2.02	2.51	2.22	2.77	1.70
3	CH1	1.80	1.30	1.39	1.69	1.51	2.04	2.25	3.26	1.71	2.25	1.30
4	TL1	8.30	5.98	6.40	7.82	6.71	4.71	5.20	10.05	6.45	8.30	4.71
5	TM1	4.15	2.99	3.20	3.91	4.43	4.71	5.20	7.53	4.08	5.20	2.99
6	TH1	3.11	1.94	2.08	2.69	3.39	3.06	3.38	4.90	2.81	3.39	1.94
7	CL2	5.53	3.99	4.27	5.75	3.48	3.14	3.34	4.02	4.21	5.75	3.14
8	CM2	2.77	1.99	2.13	2.61	2.32	2.09	3.23	5.02	2.45	3.23	1.99
9	CH2	2.08	1.30	1.39	1.69	1.51	2.04	2.25	3.26	1.75	2.25	1.30
10	TL2	8.30	5.98	6.40	7.82	6.95	6.28	9.68	15.07	7.34	9.68	5.98
11	TM2	4.15	2.99	3.20	3.91	4.43	4.71	5.20	7.53	4.08	5.20	2.99
12	TH2	3.11	1.94	2.08	2.69	3.86	3.06	3.38	4.90	2.88	3.86	1.94
13	COMM	2.85	1.99	2.13	2.61	2.32	2.09	2.78		2.40	2.85	1.99
	Mean	4.30	3.03	3.25	4.01	3.70	3.34	4.04	6.01			
Means	CL	5.53	3.99	4.27	5.35	3.48	2.82	3.34	4.02	4.11	5.53	2.82
	CM	2.77	1.99	2.13	2.61	2.32	1.89	2.62	3.77	2.33	2.77	1.89
	CH	1.94	1.30	1.39	1.69	1.51	2.04	2.25	3.26	1.73	2.25	1.30
	TL	8.30	5.98	6.40	7.82	6.83	5.49	7.44	12.56	6.89	8.30	5.49
	TM	4.15	2.99	3.20	3.91	4.43	4.71	5.20	7.53	4.08	5.20	2.99
	TH	3.11	1.94	2.08	2.69	3.63	3.06	3.38	4.90	2.84	3.63	1.94
	Treeless	3.41	2.43	2.60	3.22	2.43	2.25	2.74	3.68	**2.73**	3.41	2.25
	Treed	5.19	3.64	3.90	4.81	4.96	4.42	5.34	8.33	**4.61**	5.34	3.64
	Low	6.91	4.99	5.34	6.58	5.15	4.16	5.39	8.29	**5.50**	6.91	4.16
	Moderate	3.46	2.49	2.67	3.26	3.38	3.30	3.91	5.65	**3.21**	3.91	2.49
	High	2.52	1.62	1.73	2.19	2.57	2.55	2.82	4.08	**2.29**	2.82	1.62
	COMM	2.85	1.99	2.13	2.61	2.32	2.09	2.78		2.40	2.85	1.99

Appendix M4

Table M4. Hypothetical time for steers to achieve specified markets if they grow at the rates shown, indicative of our experimental results

		Start Wt	Start Date			Year 1				Year 2				Year 3				Year 4				Year 5		
		160kg	1-May	1-Aug	1-Nov	1-Feb	1-May	1-Aug	1-Nov	1-Feb	1-May	1-Aug	1-Nov	1-Feb	1-May	1-Aug	1-Nov	1-Feb	1-May	1-Aug	1-Nov	1-Feb	1-May
	Lwt gain/yr	Age (mths)	**6**	**9**	**12**	**15**	**18**	**21**	**24**	**27**	**30**	**33**	**36**	**39**	**42**	**45**	**48**	**51**	**54**	**57**	**60**	**63**	**66**
Wet	150		160	165	168	260	310	325	330	400	460	470											
Low	120		160	162	165	250	280	290	295	345	400	410	415	460	520	515	510	575	640	645	650	710	764
Med	105		160	160	160	245	265	265	260	315	370	370	360	415	475	470	460	520	580	575	565	620	680
High	80		160	155	150	225	240	235	225	275	320	315	305	350	400	390	375	425	480	470	455	505	560
Time since weaned			0	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48	51	54	57	60
Adult teeth								2	2	4	4	6	6	6	8	8	8						
								end dom				end feed			end P1								
										end EC				start Jap									

Messages;

1 In a very good year, with light stocking, could turn off domestic steers for slaughter @ 18 mths of age, 1 year after weaning

2 In normal seasons, with light stocking, could turn off EC/US steers @ 30 months of age, 2 yrs after weaning

3 In normal seasons with light stocking pressure, could turn off Korean steers @ 42mths of age, 33 mths after weaning

4 In normal years, with light stocking, could not turn off Jap ox until over 4yrs old, 45 mths after weaning

5 In a normal year, with light or moderate stocking, could turn off domestic feeder steers @ 15 mths of age, 9 mths after weaning

6 In normal years, with moderate stocking rates, could not turn off Jap ox until 54 mths of age

7 In normal years, with heavy stocking, could not turn off feeder steers until 30 mths of age, 2yrs after weaning

8 In normal seasons, under heavy grazing pressure, could not turn off Jap ox until they were 66 mths old

See Appendix M5 for weights x Age x Market categories

LWT gain assumptions (based on 20-30% discount from research data)

3mth Gains	Wet	Low	Med	High
1/5-31/7	5	2	0	-5
1/8-31/10	3	3	0	-5
1/11-31/1	92	85	85	75
1/2-30/4	50	30	20	15
Total	150	120	105	80

Table M5. Possible target weights of steers for specified markets based on an alternative experimental growth model listed below

	Start Wt(kg)	Start Date	Year 1				Year 2				Year 3				Year 4				Year 5			
UTILN	**180kg**	1-May	1-Aug	1-Nov	1-Feb	1-May	1-Aug	1-Nov	1-Feb	1-May	1-Aug	1-Nov	1-Feb	1-May	1-Aug	1-Nov	1-Feb	1-May	1-Aug	1-Nov	1-Feb	1-May	1-Aug
	age (mths)	**6**	**9**	**12**	**15**	**18**	**21**	**24**	**27**	**30**	**33**	**36**	**39**	**42**	**45**	**48**	**51**	**54**	**57**	**60**	**63**	**66**	**69**
	LWT gain/yr																						
Wet	175	180	197	207	289.5	352.5	369.5	379.5	462	525	542	552	634.5	697.5	714.5	724.5	807 $						
Low	153	180	187	190	272.5	332.5	339.5	342.5	425	485	492	495	577.5	637.5	644.5	647.5	730	790 $					
Med	135	180	180	172	254.5	314.5	314.5	306.5	389	449	449	441	523.5	583.5	583.5	575.5	658	718	718	710	792.5 $		
High	114	180	176	167	241.4	294	290	281	355.4	408	404	395	469.4	522	518	509	583.4	636	632	623	697.4	750	746
Time since weaned		0	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48	51	54	57	60	63

Data assumptions

	Summer (Nov-Mar)	May-Jul	Aug-Oct	Nov-Jan	Feb-Apr	Sumr chk	Winter Ap-Oc	April	May	Jun	July	Aug	Sep-Oct	Winter chk	YEAR	
Wet	27.5	17	10	82.5	63	137.5	35	8	7	6	4	0	10	35	172.5	
Low	27.5	7	3	82.5	60	137.5	15	5	4	3	0	-2	5	15	152.5	
Med	27.5	0	-8	82.5	60	137.5	-3	5	3	1	-4	-6	-2	-3	134.5	
High	24.8	-4	-9	74.4	52.6	124	-10	3	1	0	-5	-7	-2	-10	114.0	133.7

	Start Wt(kg)	Start Date	Year 1				Year 2				Year 3				Year 4				Year 5			
TREES	180	1-May	1-Aug	1-Nov	1-Feb	1-May	1-Aug	1-Nov	1-Feb	1-May	1-Aug	1-Nov	1-Feb	1-May	1-Aug	1-Nov	1-Feb	1-May	1-Aug	1-Nov	1-Feb	1-May	1-Aug
	age (mths)	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48	51	54	57	60	63	66	
	LWT gain/yr																						
Treed	120	180	176	169	244	300	296	289	364	420	416	409	484	540	536	529	604	660	656	649	724	780 $	
No trees	148	180	181	177	261.6	328	329	325	409.6	476	477	473	557.6	624	625	621	705.6	772 $					

Data assumptions

	Summer (Nov-Mar)	May-Jul	Aug-Oct	Nov-Jan	Feb-Apr	Sumr chk	Winter Ap-Oc	April	May	Jun	July	Aug	Sep-Oct	Winter chk	YEAR	
Treed	25	-4	-7	75	56	125	-5	6	2	-1	-5	-6	-1	-5	120	
No trees	28.2	1	-4	84.6	66.4	141	7	10	4	0	-3	-5	1	7	148	134

Table M6. Hypothetical time for larger weaner steers to achieve specified markets if they grow at the rates shown, indicative of Keilambete results

	Start Wt 205kg	Start 1-Aug			Year 1				Year 2			Year 3				Year 4				Year 5
			1-Aug	1-Nov	1-Feb	1-May	1-Aug	1-Nov	1-Feb	1-May	1-Aug	1-Nov	1-Feb	1-May	1-Aug	1-Nov	1-Feb	1-May	1-Aug	1-Nov	1-Feb
		Age - mths	**9**	**12**	**15**	**18**	**21**	**24**	**27**	**30**	**33**	**36**	**39**	**42**	**45**	**48**	**51**	**54**	**57**	**60**	**63**
	LWT gain/yr																				
Wet year	220	205		227	274	355	406	428	495	576	627	649	716 $								
Low GP[#]	153	205		210	260	324	357	362	412	476	509	514	564	628	661	666	716 $				
Med GP	135	205		206	252	312	341	342	388	448	477	478	524	584	613	614	660	720 $			
High GP	116	205		200	241	295	318	313	354	408	431	426	467	521	544	539	580	634	657	652	693
	Time since weaned		0	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48	51	54
	Adult teeth							2	2	4	4	6	6	6	8	8	8				
	AGE (mths)		9	12		18		24		30		36		42		48		54		60	

[#] = Low grazing pressure (GP) in a year with normal seasonal conditions

Keilambete	Liveweight gains (kg) Scenarios			
3mth period	Wet	Low	Med	High
1/8-31/10	22	5	1	-5
1/1-31/1	67	50	46	41
1/2-30/4	81	64	60	54
1/5-31/7	51	33	29	23
Total	221	152	136	113

Grassfed steers	***Age / teeth***	**LWt range (kg)**
Domestic	12 - 24	300 -450
Korean P1	< 42	490 - 580
Jap grassfed	> 36	530 - 750
Feeders Jap short feed	20-30 / 2	400 - 450
Feeders Dom 70d feed	26-33	420 - 480
Feeders HRI 60-100d	-	240 - 310
Feeders	< 15	300 - 430

Table M7. Times for typical brahman cross steers to reach various weights and market specifications, based on **Glentulloch** data

	Start Wt 180kg	Start Date 1-May	Year 1				Year 2				Year 3				Year 4				Year 5			
			1-May	1-Aug	1-Nov	1-Feb	1-May	1-Aug	1-Nov	1-Feb	1-May	1-Aug	1-Nov	1-Feb	1-May	1-Aug	1-Nov	1-Feb	1-May	1-Aug	1-Nov	1-Feb	1-May
		Age -mths	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48	51	54	57	60	63	66
Scenario	LWT gain/yr																						
Wet year	185		180kg	223	233	290	365	408	418	475	550	593	603	660	735 $								
Low GP#	153		180kg	215	219	268	333	368	372	421	486	521	525	574	639	674	678	727 $					
Med GP	135		180kg	210	210	255	315	345	345	390	450	480	480	525	585	615	615	660	720 $				
High GP	113		180kg	205	200	240	294	319	314	354	408	433	428	468	522	547	542	582	636	661	656	696	750
Treed	121		180kg	203	201	241	301	324	322	362	422	445	443	483	543	566	564	604	664	687	685	725 $	
No trees	148		180kg	213	218	263	328	361	366	411	476	509	514	559	624	657	662	707 $					
	Time since weaned		0	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48	51	54	57	60
	Adult teeth							2	2	4	4	6	6	6	8	8	8						

= Low grazing pressure (GP) in a year with normal seasonal conditions

Glentulloch 3mth period	Liveweight gains (kg) **Scenarios** Wet	Low	Med	High	Treed	No trees
1/5-31/7	43	35	30	25	23	33
1/8-31/10	10	4	0	-5	-2	5
1/11-31/1	57	49	45	40	40	45
1/2-30/4	75	65	60	54	60	65
Total	185	153	135	114	121	148

Grassfed steers	**Age / teeth**	**LWt range (kg)**
Domestic	12 - 24	300 -450
Korean P1	< 42	490 - 580
Jap grassfed	> 36	530 - 750
Feeders Jap short feed	20-30 / 2	400 - 450
Feeders Dom 70d feed	26-33	420 - 480
Feeders HRI 60-100d	-	240 - 310
Feeders	< 15	300 - 430

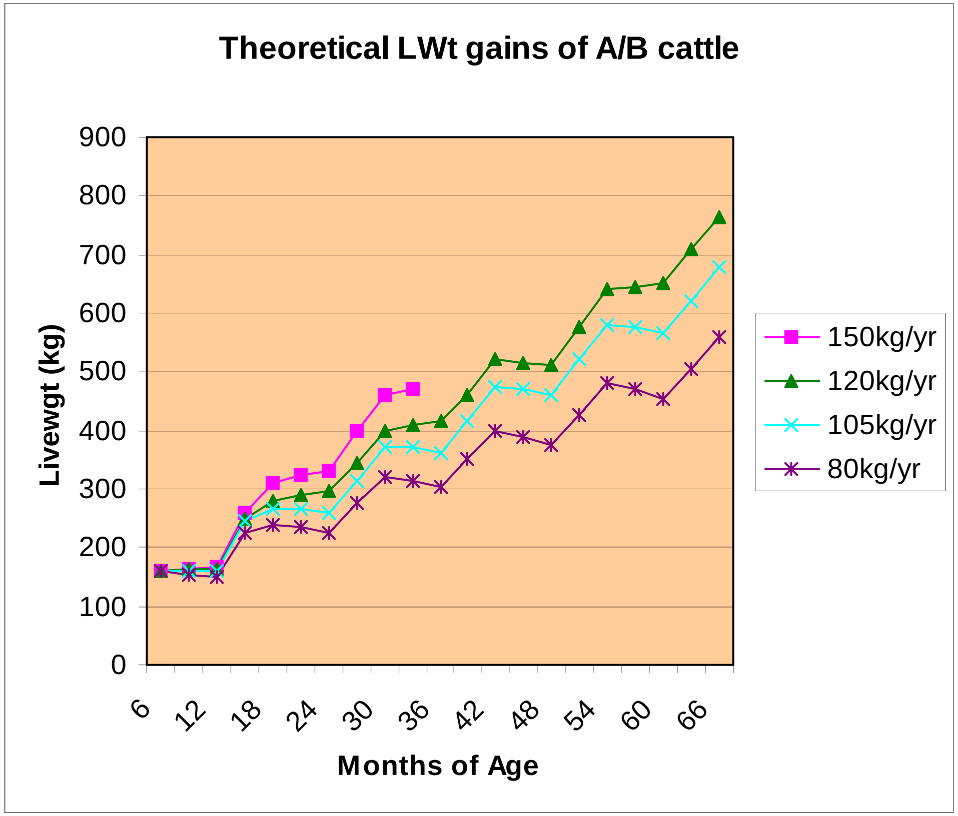
Appendix M5

Cattle market specifications and their likely influence on the saleability of steers from *Aristida/Bothriochloa* pastures

Table M8. Cattle weights for different markets

Lwt	Dressd wt	[54%]	Market				
			Dom	Korea	EC/US	Japan	Feeder
kg	kg		12-24	<42	<30	>36	<39*
		0.54			B.taur		<480
250	135						
275	149						
300	162						
325	176						
350	189						
375	203						
400	216						
425	230						
450	243						
475	257						
500	270						
525	284						
550	297						
575	311						
600	324						
625	338						
650	351						
675	365						
700	378						
725	392						
750	405						
775	419						

Figure M1.
Weight increase over time for differing annual total gains on A/B country



Further notes on the market specifications used for turnoff and economic analyses are given in Appendix V.

APPENDIX N1. Ironbark site statistical analyses summary

Appendix N1.1 Statistical models used to analyse the Keilambete research data

Below is Genstat output showing the models used

***** Analysis of variance *****

Variate: ForbsNo

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Plot stratum					
BurnTrt	1	1.042	1.042	0.24	0.635
TreeTrt	1	0.000	0.000	0.00	1.000
BurnTrt.TreeTrt	1	0.042	0.042	0.01	0.924
Residual	8	34.250	4.281	0.99	
Plot.*Units* stratum					
Year	7	158.667	22.667	5.24	<.001
Year.BurnTrt	7	14.125	2.018	0.47	0.855
Year.TreeTrt	7	19.167	2.738	0.63	0.727
Year.BurnTrt.TreeTrt	7	12.125	1.732	0.40	0.898
Residual	56	242.417	4.329		
Total	95	481.833			

*** Residual variance model ***

Term	Factor	Model(order)	Parameter	Estimate	S.e.
Plot.Year			Sigma2	11.85	2.30
Plot		Identity	-	-	-
Year		AR(1)	phi_1	0.3519	0.1143

*** Wald tests for fixed effects ***

Fixed term	Wald statistic	d.f.	Wald/d.f.	Chi-sq prob
* Sequentially adding terms to fixed model				
Year	38.14	7	5.45	<0.001
BurnTrt	0.07	1	0.07	0.796
TreeTrt	0.91	1	0.91	0.340
Year.BurnTrt	6.31	7	0.90	0.504
Year.TreeTrt	9.19	7	1.31	0.239
BurnTrt.TreeTrt	0.03	1	0.03	0.864
Year.BurnTrt.TreeTrt	3.24	7	0.46	0.862

Appendix N1.2. Tree killing and grazing pressure effects on autumn ground cover % at Keilambete (grazing study)

% Cover	1994	1995	1996	1997	1998	1999	2000	2001
Grazing pressure	n.s.	*	***	**	***	n.s.	**	***
Low	49.3	49.8	41.7	81.2	71.0	82.8	75.2	78.2
Medium	52.7	44.9	29.3	68.8	55.0	80.4	72.0	68.1
High	47.3	39.1	18.4	59.9	45.5	76.9	58.8	58.4
lsd	5.5	6.0	6.0	11.1	5.0	6.4	8.4	4.7
Treatment	***	*	n.s.	n.s.	*	*	n.s.	***
Treeless	55.7	47.4	27.9	71.7	59.6	83.7	71.2	73.0
Treed	43.8	41.8	31.7	68.2	54.6	76.3	66.2	63.5
lsd	4.5	4.9	4.9	9.1	4.1	5.3	6.8	3.8
Treatment.Graze	n.s.	n.s.	P=0.050	n.s.	n.s.	n.s.	n.s.	n.s.

Note: n.s. = not significant (P>0.10); * = P<0.05; ** = P<0.01; *** = P<0.001

Appendix N1.3. Tree killing and grazing pressure effects on total pasture yields at Keilambete (grazing study)

Yield	1994	1995	1996	1997	1998	1999	2000	2001
Grazing pressure	n.s.	***	**	***	***	**	**	***
Low	743	1588	1755	3374	2776	3990	3287	5509
Medium	765	1335	908	2409	1391	3141	2665	4054
High	750	900	203	1510	454	3320	1353	2323
lsd	200	190	630	588	541	384	735	892
Treatment	*	n.s.	n.s.	n.s.	n.s.	***	P=0.053	**
Treeless	645	1242	783	2488	1590	3963	2729	4840
Treed	860	1307	1127	2374	1490	3004	2140	3083
lsd	163	155	514	480	442	314	600	729
Treatment.Graze	n.s.	n.s.	n.s.	n.s.	n.s.	*	n.s.	n.s.

Note: n.s. = not significant (P>0.10); * = P<0.05; ** = P<0.01; *** = P<0.001

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Appendix N1.4a. Statistical significance of tree killing and burning on tree and shrub density plus stem basal area at Keilambete

	Density			Basal area		
	1995	**1997**	**1999**	**1995**	**1997**	**1999**
All species						
Treatment	***	***	**	**	**	**
Burnt	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Treatment.Burnt	P=0.066	n.s.	n.s.	n.s.	n.s.	n.s.
Buinc						
Treatment	n.s.	P=0.094	n.s.	n.s.	n.s.	n.s.
Burnt	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Treatment.Burnt	**	P=0.073	*	n.s.	n.s.	n.s.
Coery						
Treatment	n.s.	P=0.083	P=0.091	n.s.	*	P=0.059
Burnt	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Treatment.Burnt	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Eumel						
Treatment	***	***	***	**	**	*
Burnt	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Treatment.Burnt	P=0.070	n.s.	n.s.	n.s.	n.s.	n.s.
***Buinc* - height (m)**						
<0.5						
Treatment	n.s.	*	n.s.	n.s.	n.s.	
Burnt	n.s.	n.s.	n.s.	n.s.	n.s.	
Treatment.Burnt	*	P=0.085	P=0.078	n.s.	n.s.	
0.5-1.5						
Treatment	n.s.	n.s.	n.s.	n.s.	n.s.	
Burnt	n.s.	n.s.	n.s.	n.s.	n.s.	
Treatment.Burnt	**	P=0.094	P=0.052	P=0.074	n.s.	
1.5-4						
Treatment	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Burnt	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Treatment.Burnt	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
4-7						
Treatment	n.s.	P=0.078	n.s.	n.s.	P=0.069	n.s.
Burnt	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Treatment.Burnt	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
7-10						
Treatment	P=0.079	n.s.	n.s.	n.s.	n.s.	n.s.
Burnt	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Treatment.Burnt	n.s.	P=0.093	n.s.	n.s.	n.s.	n.s.

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Appendix N1.4a (contd). Statistical significance of tree killing and burning on tree and shrub density plus stem basal area at Keilambete

	Density			Basal area		
	1995	**1997**	**1999**	**1995**	**1997**	**1999**
Buinc (cont.)						
10-15						
Treatment	n.s.	n.s.	*	n.s.	n.s.	P=0.065
Burnt	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Treatment.Burnt	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
>15						
Treatment						
Burnt		insufficient	numbers			
Treatment.Burnt						
Coery **- height (m)**						
<0.5						
Treatment	n.s.	n.s.	n.s.	n.s.	**	
Burnt	n.s.	n.s.	*	n.s.	P=0.081	
Treatment.Burnt	n.s.	n.s.	n.s.	n.s.	P=0.081	
0.5-1.5						
Treatment	n.s.	n.s.	n.s.	n.s.	n.s.	
Burnt	n.s.	n.s.	n.s.	n.s.	n.s.	
Treatment.Burnt	n.s.	n.s.	n.s.	n.s.	n.s.	
1.5-4						
Treatment	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Burnt	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Treatment.Burnt	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
4-7						
Treatment	**	**	**	*	**	**
Burnt	n.s.	n.s.	n.s.	n.s.	n.s.	P=0.070
Treatment.Burnt	n.s.	n.s.	n.s.	n.s.	n.s.	P=0.070
7-10						
Treatment	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Burnt	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Treatment.Burnt	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
10-15						
Treatment		n.s.	n.s.		n.s.	n.s.
Burnt		n.s.	n.s.		n.s.	n.s.
Treatment.Burnt		n.s.	n.s.		n.s.	n.s.
>15						
Treatment						
Burnt			insufficient	numbers		
Treatment.Burnt						

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Appendix N1.4a (contd). Statistical significance of tree killing and burning on tree and shrub density plus stem basal area at Keilambete

	Density			Basal area		
	1995	**1997**	**1999**	**1995**	**1997**	**1999**
***Eumel* - height (m)**						
<0.5						
Treatment	**	***	*	P=0.052	n.s.	n.s.
Burnt	n.s.	**	n.s.	n.s.	n.s.	n.s.
Treatment.Burnt	*	P=0.068	n.s.	n.s.	n.s.	n.s.
0.5-1.5						
Treatment	***	***	**	**	**	**
Burnt	**	n.s.	n.s.	*	n.s.	*
Treatment.Burnt	**	*	P=0.077	*	n.s.	*
1.5-4						
Treatment	**	**	**	**	**	***
Burnt	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Treatment.Burnt	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
4-7						
Treatment	*	*	n.s.	*	n.s.	n.s.
Burnt	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Treatment.Burnt	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
7-10						
Treatment	***	*	*	P=0.091	P=0.098	n.s.
Burnt	**	P=0.094	n.s.	n.s.	n.s.	n.s.
Treatment.Burnt	**	P=0.094	n.s.	n.s.	n.s.	n.s.
10-15						
Treatment	*	n.s.	**	*	n.s.	*
Burnt	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Treatment.Burnt	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
>15						
Treatment			n.s.			n.s.
Burnt			n.s.			n.s.
Treatment.Burnt			n.s.			n.s.

Note: n.s. = not significant (P>0.10); * = P<0.05; ** = P<0.01; *** = P<0.001

Buinc = *Bursaria incana*

Eumel = *Eucalyptus melanophloia*

Coery = *Corymbia erythrophloia*

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Appendix N1.4b. Statistical significance of tree killing and grazing pressure on tree and shrub density plus stem basal area at Keilambete (grazing study)

	Density			Basal area		
	1995	**1997**	**1999**	**1995**	**1997**	**1999**
All species						
Trees	***	***	***	**	**	**
Grazing pressure	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Trees.Graze	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Buinc						
Trees	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Grazing pressure	n.s.	n.s.	n.s.	n.s.	*	P=0.080
Trees.Graze	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Coery						
Trees	**	***	**	P=0.063	P=0.093	n.s.
Grazing pressure	**	*	*	n.s.	n.s.	n.s.
Trees.Graze	P=0.069	*	P=0.095	n.s.	n.s.	n.s.
Eumel						
Trees	***	***	***	**	*	**
Grazing pressure	*	n.s.	*	n.s.	n.s.	n.s.
Trees.Graze	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
***Buinc* - height (m)**						
<0.5						
Trees	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Grazing pressure	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Trees.Graze	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
0.5-1.5						
Trees	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Grazing pressure	*	n.s.	n.s.	n.s.	n.s.	P=0.052
Trees.Graze	*	n.s.	n.s.	P=0.093	n.s.	*
1.5-4						
Trees		n.s.	n.s.		n.s.	n.s.
Grazing pressure		n.s.	n.s.		n.s.	n.s.
Trees.Graze		n.s.	n.s.		n.s.	n.s.
4-7						
Trees	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Grazing pressure	n.s.	P=0.092	n.s.	n.s.	n.s.	n.s.
Trees.Graze	*	*	n.s.	n.s.	P=0.091	P=0.098
7-10						
Trees	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Grazing pressure	n.s.	n.s.	*	n.s.	n.s.	n.s.
Trees.Graze	n.s.	n.s.	*	n.s.	n.s.	n.s.

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Appendix N1.4b (contd). Statistical significance of tree killing and grazing pressure on tree and shrub density plus stem basal area at Keilambete (grazing study)

	Density			Basal area		
	1995	**1997**	**1999**	**1995**	**1997**	**1999**
10-15						
Trees	n.s.	n.s.	n.s.	P=0.096	n.s.	
Grazing pressure	n.s.	n.s.	n.s.	n.s.	n.s.	
Trees.Graze	n.s.	n.s.	n.s.	*	n.s.	
>15						
Trees						
Grazing pressure		insufficient	numbers			
Trees.Graze						
***Coery* - height (m)**						
<0.5						
Trees	P=0.096	***	n.s.	n.s.	n.s.	
Grazing pressure	*	**	n.s.	n.s.	n.s.	
Trees.Graze	n.s.	**	n.s.	n.s.	n.s.	
0.5-1.5						
Trees	*	*	**	P=0.067	n.s.	n.s.
Grazing pressure	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Trees.Graze	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
1.5-4						
Trees	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Grazing pressure	n.s.	P=0.067	P=0.098	n.s.	n.s.	n.s.
Trees.Graze	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
4-7						
Trees	**	*	**	n.s.	n.s.	**
Grazing pressure	*	n.s.	P=0.059	n.s.	n.s.	**
Trees.Graze	P=0.094	n.s.	n.s.	n.s.	n.s.	*
7-10						
Trees	n.s.	*	n.s.	n.s.	n.s.	n.s.
Grazing pressure	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Trees.Graze	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
10-15						
Trees	*	**	***	n.s.	n.s.	n.s.
Grazing pressure	**	*	**	n.s.	n.s.	n.s.
Trees.Graze	*	**	***	n.s.	n.s.	n.s.
>15						
Trees	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Grazing pressure	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Trees.Graze	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.

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Appendix N1.4b (contd). Statistical significance of tree killing and grazing pressure on tree and shrub density plus stem basal area at Keilambete (grazing study)

	Density			Basal area		
	1995	**1997**	**1999**	**1995**	**1997**	**1999**
***Eumel* - height (m)**						
<0.5						
Trees	**	**	***	P=0.055	P=0.061	**
Grazing pressure	n.s.	n.s.	*	n.s.	n.s.	*
Trees.Graze	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
0.5-1.5						
Trees	**	**	*	n.s.	n.s.	*
Grazing pressure	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Trees.Graze	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
1.5-4						
Trees	P=0.055	*	*	*	P=0.064	P=0.090
Grazing pressure	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Trees.Graze	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
4-7						
Trees	**	***	***	*	n.s.	P=0.096
Grazing pressure	n.s.	n.s.	n.s.	*	n.s.	n.s.
Trees.Graze	n.s.	n.s.	*	*	n.s.	*
7-10						
Trees	***	*	*	***	P=0.064	**
Grazing pressure	n.s.	n.s.	n.s.	n.s.	n.s.	*
Trees.Graze	n.s.	n.s.	n.s.	n.s.	n.s.	P=0.085
10-15						
Trees	***	***	***	P=0.058	n.s.	
Grazing pressure	P=0.083	n.s.	n.s.	n.s.	n.s.	
Trees.Graze	n.s.	n.s.	n.s.	n.s.	n.s.	
>15						
Trees	*	n.s.	n.s.	n.s.	n.s.	n.s.
Grazing pressure	P=0.052	n.s.	n.s.	n.s.	n.s.	n.s.
Trees.Graze	*	n.s.	n.s.	n.s.	n.s.	n.s.

Note: n.s. = not significant (P>0.10); * = P<0.05; ** = P<0.01; *** = P<0.001

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Appendix N1.5a. Tree killing and grazing pressure effects on plant frequency (%) in autumn at Keilambete (grazing study)

Frequency	1994	1995	1996	1997	1998	1999	2000	2001
Aristida spp.								
Trees	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Grazing pressure	n.s.	n.s.	*	n.s.	n.s.	n.s.	n.s.	n.s.
Trees.Graze	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Bothriochloa ewartiana								
Trees	n.s.	n.s.	n.s.	n.s.	n.s.	*	n.s.	n.s.
Grazing pressure	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Trees.Graze	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Chloris spp.								
Trees	n.s.	n.s.	*	*	*	n.s.	n.s.	n.s.
Grazing pressure	n.s.	n.s.	n.s.	P=0.068	n.s.	n.s.	P=0.092	P=0.072
Trees.Graze	n.s.	n.s.	n.s.	P=0.079	n.s.	n.s.	n.s.	n.s.
Chrysopogon fallax								
Trees	n.s.	n.s.	n.s.	n.s.	*	P=0.056	P=0.080	*
Grazing pressure	n.s.	n.s.	n.s.	n.s.	n.s.	P=0.056	n.s.	n.s.
Trees.Graze	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Digitaria spp.								
Trees	*	n.s.	n.s.	n.s.	n.s.	**	**	n.s.
Grazing pressure	n.s.	n.s.	n.s.	n.s.	n.s.	*	**	n.s.
Trees.Graze	n.s.	n.s.	n.s.	n.s.	n.s.	*	n.s.	n.s.
Enneapogon spp.								
Trees	P=0.096	n.s.	n.s.	n.s.	n.s.	**	n.s.	n.s.
Grazing pressure	n.s.	n.s.	n.s.	n.s.	n.s.	**	*	P=0.052
Trees.Graze	n.s.	P=0.076	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Eragrostis spp.								
Trees	n.s.	n.s.	P=0.075	n.s.	n.s.	n.s.	n.s.	n.s.
Grazing pressure	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Trees.Graze	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Eulalia aurea								
Trees	n.s.	n.s.	n.s.	n.s.	n.s.	P=0.062	n.s.	n.s.
Grazing pressure	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Trees.Graze	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.

Note: n.s. = not significant (P>0.10); * = P<0.05; ** = P<0.01; *** = P<0.001

Appendix N1.5a (contd). Tree killing and grazing pressure effects on plant frequency (%) in autumn at Keilambete (grazing study)

Frequency	1994	1995	1996	1997	1998	1999	2000	2001
Forbs								
Trees	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Grazing pressure	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Trees.Graze	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Heteropogon contortus								
Trees	n.s.	n.s.	P=0.074	n.s.	n.s.	n.s.	n.s.	n.s.
Grazing pressure	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Trees.Graze	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Native legume								
Trees	n.s.	P=0.069	***	**	n.s.	n.s.	*	*
Grazing pressure	n.s.	n.s.	n.s.	**	n.s.	n.s.	*	P=0.070
Trees.Graze	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	P=0.052
Panicum spp.								
Trees	n.s.	*	n.s.	*	n.s.	n.s.	n.s.	n.s.
Grazing pressure	n.s.	n.s.	n.s.	P=0.078	n.s.	n.s.	n.s.	n.s.
Trees.Graze	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Sedges								
Trees	n.s.	n.s.	n.s.	n.s.	n.s.	P=0.062	n.s.	*
Grazing pressure	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	*
Trees.Graze	n.s.	n.s.	n.s.	n.s.	n.s.	*	n.s.	*
Themeda triandra								
Trees	*	**	n.s.	n.s.	n.s.	n.s.	*	P=0.095
Grazing pressure	n.s.	*	**	*	*	n.s.	**	*
Trees.Graze	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Tragus australianus								
Trees	n.s.	P=0.083	n.s.	n.s.	n.s.	**	n.s.	n.s.
Grazing pressure	n.s.	n.s.	*	**	***	*	*	P=0.075
Trees.Graze	n.s.	n.s.	n.s.	n.s.	n.s.	*	n.s.	n.s.
Tripogon loliiformis								
Trees	n.s.	n.s.	n.s.	n.s.	n.s.	**	n.s.	*
Grazing pressure	n.s.	n.s.	n.s.	n.s.	n.s.	P=0.078	n.s.	P=0.073
Trees.Graze	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.

Note: n.s. = not significant (P>0.10); * = P<0.05; ** = P<0.01; *** = P<0.001

Appendix N1.5b. Tree killing and grazing pressure effects on pasture biomass proportions (%) at Keilambete (grazing study)

Pasture biomass proportions (%)	1994	1995	1996	1997	1998	1999	2000	2001
Aristida spp.								
Trees	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Grazing pressure	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Trees.Graze	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Bothriochloa ewartiana								
Trees	n.s.	*	n.s.	n.s.	P=0.055	n.s.	n.s.	n.s.
Grazing pressure	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	P=0.085
Trees.Graze	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Chloris spp.								
Trees	n.s.	n.s.	n.s.	n.s.	*	n.s.	n.s.	n.s.
Grazing pressure	n.s.	n.s.	n.s.	n.s.	*	n.s.	n.s.	n.s.
Trees.Graze	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Chrysopogon fallax								
Trees	n.s.	n.s.	n.s.	n.s.	*	*	n.s.	P=0.061
Grazing pressure	n.s.	n.s.	**	n.s.	*	*	n.s.	n.s.
Trees.Graze	n.s.	n.s.	n.s.	n.s.	n.s.	P=0.084	n.s.	P=0.093
Digitaria spp.								
Trees	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Grazing pressure	n.s.	n.s.	n.s.	n.s.	*	n.s.	*	n.s.
Trees.Graze	n.s.	n.s.	n.s.	n.s.	n.s.	*	n.s.	n.s.
Enneapogon spp.								
Trees	n.s.	n.s.	n.s.	n.s.	n.s.	*	P=0.069	n.s.
Grazing pressure	n.s.	n.s.	**	n.s.	n.s.	P=0.051	n.s.	n.s.
Trees.Graze	n.s.	n.s.	P=0.066	n.s.	n.s.	n.s.	n.s.	n.s.
Eragrostis spp.								
Trees	n.s.	n.s.		n.s.	n.s.	n.s.	n.s.	n.s.
Grazing pressure	n.s.	n.s.		n.s.	n.s.	n.s.	n.s.	n.s.
Trees.Graze	n.s.	n.s.		n.s.	n.s.	n.s.	n.s.	n.s.
Eulalia aurea								
Trees	n.s.	n.s.	n.s.	n.s.	n.s.	P=0.074	n.s.	n.s.
Grazing pressure	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Trees.Graze	n.s.	n.s.	n.s.	n.s.	n.s.	*	n.s.	n.s.

Note: n.s. = not significant (P>0.10); * = P<0.05; ** = P<0.01; *** = P<0.001

Appendix N1.5b (contd). Tree killing and grazing pressure effects on pasture biomass proportions (%) at Keilambete (grazing study)

Pasture biomass proportions (%)	1994	1995	1996	1997	1998	1999	2000	2001
Forbs								
Trees	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Grazing pressure	*	n.s.	n.s.	*	**	n.s.	n.s.	n.s.
Trees.Graze	n.s.	n.s.	n.s.	n.s.	n.s.	P=0.082	n.s.	n.s.
Heteropogon contortus								
Trees	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Grazing pressure	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	P=0.064
Trees.Graze	n.s.	n.s.	P=0.074	n.s.	n.s.	n.s.	n.s.	P=0.058
Native legume								
Trees	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Grazing pressure	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Trees.Graze	P=0.052	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Panicum spp.								
Trees	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Grazing pressure	*	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Trees.Graze	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Sedges								
Trees	n.s.	n.s.	*	n.s.	n.s.	n.s.	P=0.079	n.s.
Grazing pressure	n.s.	n.s.	**	n.s.	P=0.092	n.s.	n.s.	n.s.
Trees.Graze	n.s.	n.s.	*	n.s.	n.s.	n.s.	P=0.065	n.s.
Themeda triandra								
Trees	n.s.	*	n.s.	***	n.s.	n.s.	*	*
Grazing pressure	n.s.	n.s.	**	***	*	n.s.	**	**
Trees.Graze	n.s.	n.s.	n.s.	**	n.s.	n.s.	n.s.	n.s.
Tragus australianus								
Trees	n.s.	n.s.	*	n.s.	n.s.	*	n.s.	n.s.
Grazing pressure	n.s.	n.s.	*	n.s.	***	n.s.	n.s.	n.s.
Trees.Graze	n.s.	n.s.	*	n.s.	n.s.	n.s.	n.s.	n.s.
Tripogon loliiformis								
Trees	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	P=0.074
Grazing pressure	n.s.	n.s.	*	n.s.	n.s.	n.s.	n.s.	n.s.
Trees.Graze	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.

Note: n.s. = not significant (P>0.10); * = P<0.05; ** = P<0.01; *** = P<0.001

Appendix N1.5c. Tree killing and grazing pressure effects on pasture component yields at Keilambete (grazing study)

Component yields	1994	1995	1996	1997	1998	1999	2000	2001
Aristida spp								
Trees	n.s.	n.s.	n.s.	n.s.	n.s.	P=0.087	n.s.	n.s.
Grazing pressure	n.s.	*	***	P=0.061	*	n.s.	*	P=0.083
Trees.Graze	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Bothriochloa ewartiana								
Trees	P=0.058	P=0.069	n.s.	n.s.	n.s.	*	n.s.	P=0.059
Grazing pressure	n.s.	*	**	P=0.060	**	n.s.	**	**
Trees.Graze	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Chloris spp								
Trees	n.s.	n.s.	n.s.	n.s.	*	n.s.	n.s.	n.s.
Grazing pressure	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Trees.Graze	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Chrysopogon fallax								
Trees	n.s.	n.s.	n.s.	n.s.	*	n.s.	n.s.	n.s.
Grazing pressure	n.s.	**	*	n.s.	**	P=0.050	n.s.	*
Trees.Graze	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Digitaria spp								
Trees	*	P=0.066	n.s.	n.s.	P=0.080	P=0.069	n.s.	n.s.
Grazing pressure	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Trees.Graze	n.s.	n.s.	n.s.	n.s.	n.s.	*	n.s.	n.s.
Enneapogon spp								
Trees	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Grazing pressure	n.s.	n.s.	**	**	*	*	***	**
Trees.Graze	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Eragrostis spp								
Trees	n.s.	n.s.		n.s.	P=0.058	n.s.	n.s.	*
Grazing pressure	n.s.	n.s.		n.s.	n.s.	n.s.	n.s.	P=0.089
Trees.Graze	n.s.	n.s.		n.s.	n.s.	n.s.	n.s.	P=0.098
Eulalia aurea								
Trees	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Grazing pressure	n.s.	*	**	n.s.	P=0.090	P=0.082	n.s.	n.s.
Trees.Graze	n.s.	n.s.	n.s.	n.s.	n.s.	*	n.s.	n.s.

Note: n.s. = not significant (P>0.10); * = P<0.05; ** = P<0.01; *** = P<0.001

Appendix N1.5c (contd). Tree killing and grazing pressure effects on component yields at Keilambete (grazing study)

Component yields	1994	1995	1996	1997	1998	1999	2000	2001
Forbs								
Trees	*	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	***
Grazing pressure	*	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Trees.Graze	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	P=0.099	n.s.
Heteropogon contortus								
Trees	n.s.	n.s.	n.s.	n.s.	P=0.066	*	n.s.	***
Grazing pressure	n.s.	P=0.050	***	**	***	n.s.	P=0.069	**
Trees.Graze	n.s.	n.s.	n.s.	n.s.	P=0.095	n.s.	n.s.	*
Native legume								
Trees	*	n.s.	n.s.	***	n.s.	*	n.s.	n.s.
Grazing pressure	P=0.069	n.s.	*	***	*	n.s.	P=0.061	n.s.
Trees.Graze	**	n.s.	n.s.	**	n.s.	n.s.	n.s.	n.s.
Panicum spp								
Trees	n.s.	P=0.057	n.s.	*	P=0.060	n.s.	*	n.s.
Grazing pressure	*	n.s.	**	n.s.	n.s.	n.s.	**	n.s.
Trees.Graze	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Sedges								
Trees	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	*	n.s.
Grazing pressure	n.s.	P=0.085	n.s.	n.s.	*	n.s.	n.s.	n.s.
Trees.Graze	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	P=0.091	n.s.
Themeda triandra								
Trees	n.s.	*	n.s.	n.s.	n.s.	P=0.091	***	**
Grazing pressure	n.s.	*	**	**	**	P=0.071	***	***
Trees.Graze	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	*	n.s.
Tragus australianus								
Trees	P=0.065	n.s.	*	n.s.	n.s.	n.s.	n.s.	n.s.
Grazing pressure	n.s.	n.s.	*	**	**	n.s.	n.s.	n.s.
Trees.Graze	n.s.	n.s.	**	n.s.	n.s.	n.s.	n.s.	n.s.
Tripogon loliiformis								
Trees	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Grazing pressure	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Trees.Graze	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.

Note: n.s. = not significant (P>0.10); * = P<0.05; ** = P<0.01; *** = P<0.001

Appendix N1.5d. Tree killing and grazing pressure effects on perennial grass basal area at Keilambete (grazing study)

Basal area %	1994	1995	1996	1997	1998	1999	2000
Grazing pressure	n.s.	P=0.071	***	*	**	n.s.	*
Low	1.9	2.3	2.7	2.2	2.2	3.6	3.6
Medium	1.8	2.2	1.9	1.2	1.9	2.6	2.1
High	2.0	1.8	1.5	1.0	1.3	3.1	1.5
lsd	0.38	0.38	0.29	0.69	0.49	1.18	1.16
Trees	P=0.081	P=0.067	P=0.065	n.s.	n.s.	**	n.s.
Treeless	2.0	2.2	2.1	1.7	1.9	4.0	2.4
Treed	1.8	2.0	1.9	1.3	1.7	2.3	2.3
lsd	0.31	0.31	0.24	0.56	0.40	0.96	0.95
Trees.Graze	n.s.	n.s.	*	n.s.	P=0.07	n.s.	n.s.

Note: n.s. = not significant (P>0.10); * = P<0.05; ** = P<0.01; *** = P<0.001

Appendix N1.5e. Tree killing and grazing pressure effects on the density (plants/15m^2) of *B. ewartiana*, *C. fallax* and *H. contortus* at Keilambete (charting study)

Density	1994-95	1995-96	1996-97	1997-98	1998-99	1999-2000
B. ewartiana						
Trees	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Treeless	87.5	74.2	93.5	78.8	88.3	90.3
Treed	82.0	77.7	104.2	81.5	95.3	108.8
LSD	12.7	16.7	23.9	27.1	34.8	39.3
Grazing Pressure	n.s.	n.s.	P=0.050	n.s.	n.s.	n.s.
Low	77.2	71.7	76.5	71.0	80.7	86.5
Medium	87.5	79.7	108.5	88.2	102.0	102.5
High	89.5	76.2	111.5	81.2	92.7	109.7
LSD	15.5	20.5	29.3	33.3	42.7	48.1
Trees.Graze	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Treeless						
Low	83.0	77.5	81.5	76.5	86.0	89.5
Medium	82.5	75.5	107.5	81.5	91.5	91.5
High	97.0	69.5	91.5	78.5	87.5	90.0
Treed						
Low	71.5	66.0	71.5	65.5	75.5	83.5
Medium	92.5	84.0	109.5	95.0	112.5	113.5
High	82.0	83.0	131.5	84.0	98.0	129.5
LSD	21.9	28.9	41.5	47.0	60.3	68.1
C. fallax						
Trees	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Treeless	89.5	89.0	83.3	82.5	84.3	91.5
Treed	81.7	75.3	73.7	70.0	71.5	82.2
LSD	15.0	20.6	20.5	22.4	25.6	25.7
Grazing Pressure	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Low	90.0	84.7	81.2	78.2	81.0	88.5
Medium	83.2	82.2	79.5	74.5	73.2	84.0
High	83.5	79.5	74.7	76.0	79.5	88.0
LSD	18.3	25.3	25.2	27.4	31.4	31.5
Trees.Graze	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Treeless						
Low	95.0	94.0	89.5	85.5	89.5	98.5
Medium	85.5	86.0	81.0	75.5	73.5	82.0
High	88.0	87.0	79.5	86.5	90.0	94.0
Treed						
Low	85.0	75.5	73.0	71.0	72.5	78.5
Medium	81.0	78.5	78.0	73.5	73.0	86.0
High	79.0	72.0	70.0	65.5	69.0	82.0
LSD	25.9	35.7	35.6	38.8	44.4	44.5

Note: n.s. = not significant (P>0.10); * = P<0.05; ** = P<0.01; *** = P<0.001

Appendix N1.5e (contd). Tree killing and grazing pressure effects on the density (plants/15m^2) of *B. ewartiana*, *C. fallax* and *H. contortus* at Keilambete

Density	1994-95	1995-96	1996-97	1997-98	1998-99	1999-2000
H. contortus						
Trees	n.s.	n.s.	n.s.	n.s.	n.s.	**
Treeless	272.0	136.0	102.0	108.3	142.0	218.7
Treed	232.0	103.0	85.0	90.3	116.3	156.3
LSD	179.1	79.8	53.8	24.3	36.9	39.1
Grazing Pressure	n.s.	n.s.	n.s.	n.s.	n.s.	*
Low	221.0	124.0	111.0	108.7	128.8	148.3
Medium	278.0	116.0	89.0	102.5	115.2	179.3
High	257.0	118.0	81.0	86.7	143.5	235.0
LSD	219.4	97.7	65.8	29.7	45.1	47.9
Trees.Graze	n.s.	n.s.	n.s.	P=0.073	n.s.	n.s.
Treeless						
Low	265.0	146.0	129.0	115.5	143.0	170.0
Medium	259.0	109.0	74.0	76.5	122.0	202.5
High	292.0	154.0	102.0	133.0	161.0	283.5
Treed						
Low	177.0	103.0	93.0	89.5	114.5	126.5
Medium	298.0	124.0	103.0	97.0	108.5	156.0
High	222.0	83.0	59.0	84.5	126.0	186.5
LSD	310.3	138.1	93.1	42.1	63.8	67.8

Note: n.s. = not significant (P>0.10); * = P<0.05; ** = P<0.01; *** = P<0.001

Appendix N1.5f. Tree killing and grazing pressure effects on the recruitment of *B. ewartiana*, *C. fallax* and *H. contortus* at Keilambete (charting study)

	1994-95	1995-96	1996-97	1997-98	1998-99	1999-2000
B. ewartiana						
Trees	*	n.s.	n.s.	n.s.	n.s.	n.s.
Treeless	32.8	3.8	31.3	12.2	13.5	9.5
Treed	17.2	6.7	35.3	6.3	16.3	26.3
LSD	10.9	8.0	20.0	12.8	18.2	22.9
Grazing Pressure	*	n.s.	*	n.s.	n.s.	n.s.
Low	14.0	3.0	12.0	5.5	13.0	12.3
Medium	25.5	3.5	35.7	8.0	17.5	13.5
High	35.5	9.3	52.2	14.3	14.3	28.0
LSD	13.3	9.7	24.5	15.6	22.3	28.0
Trees.Graze	P=0.069	n.s.	n.s.	n.s.	n.s.	n.s.
Treeless						
Low	21.5	5.5	13.0	8.0	14.0	8.0
Medium	25.5	3.0	40.0	8.5	14.5	8.5
High	51.5	3.0	41.0	20.0	12.0	12.0
Treed						
Low	6.5	0.5	11.0	3.0	12.0	16.5
Medium	25.5	4.0	31.5	7.5	20.5	18.5
High	19.5	15.5	63.5	8.5	16.5	44.0
LSD	18.8	13.8	34.6	22.1	31.5	39.6
C. fallax						
Trees	P=0.073	n.s.	n.s.	P=0.092	n.s.	n.s.
Treeless	19.8	5.0	3.7	7.8	5.2	11.3
Treed	13.0	1.7	1.2	3.8	5.5	14.0
LSD	7.8	6.2	4.4	5.0	5.5	5.0
Grazing Pressure	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Low	12.5	2.5	2.8	3.8	4.7	9.8
Medium	18.0	3.0	3.0	4.8	6.0	13.8
High	18.8	4.5	1.5	9.0	5.2	14.5
LSD	9.5	7.6	5.4	6.1	6.7	6.1
Trees.Graze	n.s.	n.s.	n.s.	P=0.050	n.s.	n.s.
Treeless						
Low	16.0	4.0	4.5	4.5	5.5	10.5
Medium	17.0	4.5	4.0	3.5	6.0	13.0
High	26.5	6.5	2.5	15.5	4.0	10.5
Treed						
Low	9.0	1.0	1.0	3.0	4.0	9.0
Medium	19.0	1.5	2.0	6.0	6.0	14.5
High	11.0	2.5	0.5	2.5	6.5	18.5
LSD	13.4	10.8	7.7	8.6	9.5	8.7

Note: n.s. = not significant (P>0.10); * = P<0.05; ** = P<0.01; *** = P<0.001

Appendix N1.5f (contd). Tree killing and grazing pressure effects on the recruitment of *B. ewartiana*, *C. fallax* and *H. contortus* at Keilambete (charting study)

	1994-95	1995-96	1996-97	1997-98	1998-99	1999-2000
H. contortus						
Trees	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Treeless	217.0	10.0	14.2	32.0	46.5	91.7
Treed	179.0	8.0	12.2	25.3	39.7	63.5
LSD	175.8	7.8	7.4	12.5	23.2	40.6
Grazing Pressure	n.s.	n.s.	n.s.	*	n.s.	*
Low	167.0	9.3	16.8	21.3	38.5	38.0
Medium	223.0	7.7	13.3	21.8	4.0	77.0
High	205.0	10.0	9.5	43.0	47.7	117.7
LSD	215.3	9.6	9.1	15.3	28.4	49.8
Trees.Graze	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Treeless						
Low	211.0	11.0	18.5	29.5	40.5	38.5
Medium	200.0	7.5	13.0	19.5	54.0	90.0
High	241.0	11.5	11.0	47.0	45.0	146.5
Treed						
Low	122.0	7.5	15.0	13.0	36.5	37.5
Medium	246.0	8.0	13.5	24.0	32.0	64.0
High	169.0	8.5	8.0	39.0	50.5	89.0
LSD	304.4	13.6	12.9	21.6	40.1	70.4

Note: n.s. = not significant ($P>0.10$); * = $P<0.05$; ** = $P<0.01$; *** = $P<0.001$

Appendix N1.5g. Tree killing and grazing pressure effects on the soil seed banks of *B. ewartiana*, *C. fallax* and *H. contortus* at Keilambete (grazing trial)

Soil seed bank	1994-1995	1995-1996	1996-1997	1997-1998	1998-1999	1999-2000	2000-2001	overall (wald)
Aristida spp								
Trees	n.s.	n.s.	n.s.	n.s.		n.s.	n.s.	n.s.
Grazing pressure	n.s.	n.s.	*	n.s.		n.s.	n.s.	n.s.
Trees.Graze	n.s.	n.s.	n.s.	n.s.		n.s.	n.s.	n.s.
Both. ewartiana								
Trees	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	*	n.s.
Grazing pressure	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	*
Trees.Graze	n.s.	P=0.096	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Chloris divaricata								
Trees	n.s.	n.s.	n.s.	n.s.		n.s.	n.s.	n.s.
Grazing pressure	n.s.	n.s.	n.s.	n.s.		n.s.	n.s.	n.s.
Trees.Graze	n.s.	n.s.	n.s.	n.s.		n.s.	n.s.	n.s.
Cyperus spp								
Trees	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.		n.s.
Grazing pressure	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.		*
Trees.Graze	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.		n.s.
Digitaria spp								
Trees	n.s.	n.s.	*	n.s.	n.s.	n.s.	n.s.	n.s.
Grazing pressure	n.s.	n.s.	n.s.	n.s.	n.s.	*	n.s.	***
Trees.Graze	n.s.	n.s.	n.s.	n.s.	n.s.	*	n.s.	P=0.078
Enneapogon spp								
Trees	n.s.	n.s.	*	n.s.		n.s.	n.s.	n.s.
Grazing pressure	n.s.	n.s.	*	n.s.		n.s.	n.s.	P=0.069
Trees.Graze	n.s.	n.s.	*	n.s.		n.s.	n.s.	P=0.093
Eragrostis spp								
Trees	n.s.	n.s.	n.s.	***	P=0.054	n.s.	P=0.078	**
Grazing pressure	n.s.	*	n.s.	***	P=0.053	n.s.	n.s.	***
Trees.Graze	*	n.s.	n.s.	***	*	n.s.	n.s.	**
Euphorbia spp								
Trees	n.s.	*	**	n.s.	n.s.	n.s.	n.s.	*
Grazing pressure	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Trees.Graze	n.s.	n.s.	*	n.s.	n.s.	n.s.	n.s.	n.s.
Fimbristylis spp								
Trees	n.s.	n.s.		*	P=0.075	n.s.	n.s.	**
Grazing pressure	n.s.	n.s.		*	n.s.	n.s.	n.s.	*
Trees.Graze	n.s.	n.s.		*	n.s.	n.s.	n.s.	n.s.

Note: n.s. = not significant (P>0.10); * = P<0.05; ** = P<0.01; *** = P<0.001

Appendix N1.5g (contd). Tree killing and grazing pressure effects on the soil seed banks of *B. ewartiana, C. fallax* and *H. contortus* at Keilambete (grazing trial)

Soil seed bank	1994-1995	1995-1996	1996-1997	1997-1998	1998-1999	1999-2000	2000-2001	overall (wald)
Het. contortus								
Trees	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Grazing pressure	n.s.	n.s.	*	n.s.	n.s.	n.s.	n.s.	n.s.
Trees.Graze	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Hybanthus spp								
Trees	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Grazing pressure	n.s.	n.s.	*	n.s.	n.s.	n.s.	n.s.	n.s.
Trees.Graze	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Indigofera spp								
Trees	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	P=0.065
Grazing pressure	n.s.	n.s.	n.s.	n.s.	n.s.	P=0.083	n.s.	***
Trees.Graze	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Portulaca spp								
Trees	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	*
Grazing pressure	n.s.	P=0.080	n.s.	n.s.	n.s.	P=0.092	n.s.	P=0.096
Trees.Graze	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Pterocaulon spp								
Trees	n.s.	P=0.099	n.s.	n.s.	n.s.	n.s.	*	P=0.053
Grazing pressure	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Trees.Graze	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	P=0.069	n.s.
Sonchus spp								
Trees		n.s.		n.s.	n.s.	n.s.	n.s.	n.s.
Grazing pressure		n.s.		n.s.	n.s.	n.s.	n.s.	n.s.
Trees.Graze		*		n.s.	n.s.	n.s.	n.s.	n.s.
Spermacoce spp								
Trees	n.s.	n.s.	n.s.	n.s.	n.s.	P=0.058	n.s.	n.s.
Grazing pressure	P=0.083	n.s.	n.s.	n.s.	n.s.	P=0.055	n.s.	n.s.
Trees.Graze	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Spor. australasicus								
Trees	n.s.	n.s.	n.s.	n.s.	P=0.050	n.s.	n.s.	n.s.
Grazing pressure	n.s.	n.s.	n.s.	n.s.	*	n.s.	n.s.	P=0.060
Trees.Graze	n.s.	n.s.	n.s.	n.s.	*	n.s.	n.s.	*
Tripogon loliiformis								
Trees	**	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Grazing pressure	**	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Trees.Graze	***	P=0.078	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Wahlenbergia spp								
Trees	n.s.	n.s.	n.s.	P=0.077	n.s.	n.s.	P=0.073	**
Grazing pressure	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	**
Trees.Graze	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	**

Note: n.s. - not significant (P>0.10); * = P<0.05; ** = P<0.01; *** = P<0.001

Appendix N1.5h. Statistical significance of tree killing and grazing pressure treatments on the survival of *B. ewartiana*, *C. fallax* and *H. contortus* at Keilambete (charting study)

	Cohort 1994	1995	1997
B. ewartiana			
Year	***	***	***
Trees	n.s.	n.s.	n.s.
Grazing Pressure	***	**	P=0.061
Trees.Graze	P=0.091	n.s.	n.s.
C. fallax			
Year	***	n.s.	***
Trees	n.s.	n.s.	***
Grazing Pressure	n.s.	n.s.	***
Trees.Graze	n.s.	n.s.	***
H. contortus			
Year	***	***	**
Trees	n.s.	n.s.	n.s.
Grazing Pressure	**	P=0.086	n.s.
Trees.Graze	n.s.	n.s.	n.s.

Note: n.s. = not significant (P>0.10); * = P<0.05; ** = P<0.01; *** = P<0.001

Appendix N1.5i. Survival hazard analysis* of *B. ewartiana*, *C. fallax* and *H. contortus* at Keilambete (charting study)

Cohort	**1994**			**1995**			**1997**		
	Estimate	Var	Hazard ratio	Estimate	Var	Hazard ratio	Estimate	Var	Hazard ratio
B. ewartiana									
Treatment (treed vs treeless)	-0.0447	0.0270	0.96	-0.1303	0.0200	0.88	-0.0870	0.0241	0.92
Grazing Pressure (High)									
Low	-0.8231	0.0435	0.44	-0.0226	0.0284	0.98	-0.6007	0.0714	0.55
Medium	-0.5200	0.0362	0.59	-0.5325	0.0236	0.59	-0.1576	0.0281	0.85
C. fallax									
Treatment (treed vs treeless)	-0.0110	0.0286	0.99	0.0458	0.0643	1.05			
Grazing Pressure (High)									
Low	0.0366	0.0473	1.04	-0.4764	0.1095	0.62			
Medium	0.3087	0.0448	1.36	-0.2253	0.0785	0.80			
H. contortus									
Treatment (treed vs treeless)	0.1558	0.0199	1.17	0.0721	0.0074	1.07	0.2653	0.0757	1.30
Grazing Pressure (High)									
Low	-0.6298	0.0330	0.53	-0.0147	0.0127	0.99	-0.1157	0.1247	0.89
Medium	-0.1389	0.0270	0.87	0.1942	0.0101	1.21	0.1700	0.1301	1.19

* Hazard analysis estimates a hazard ratio as the proportion of the change that occurred relative to the least hazardous treatment

Appendix N1.5j. Tree killing and grazing pressure effects on the charted basal area of *B. ewartiana*, *C. fallax* and *H. contortus* at Keilambete

	1994		1995		1996		1997		1998		1999		2000	
	Basal area (cm^2)	Basal area per plant (cm^2)	Basal area (cm^2)	Basal area per plant (cm^2)	Basal area (cm^2)	Basal area per plant (cm^2)	Basal area (cm^2)	Basal area per plant (cm^2)	Basal area (cm^2)	Basal area per plant (cm^2)	Basal area (cm^2)	Basal area per plant (cm^2)	Basal area (cm^2)	Basal area per plant (cm^2)
B. ewartiana														
Treatment	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Treeless	504.0	8.0	766.0	13.9	1012.0	18.8	1570.0	32.7	2616.0	59.7	2848.0	63.8	3002.0	69.6
Treed	561.0	7.6	921.0	14.0	1180.0	19.1	1578.0	27.5	2715.0	53.3	2890.0	56.9	2633.0	54.9
LSD	198.2	3.1	306.7	4.6	454.5	6.6	535.3	8.3	634.8	10.4	1127.1	19.8	1416.2	28.0
Grazing Pressure	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	P=0.076	n.s.	n.s.	n.s.
Low	509.0	7.5	870.0	13.7	1290.0	21.3	1741.0	30.7	2669.0	49.7	3460.0	66.1	3162.0	62.3
Medium	548.0	7.7	1008.0	16.1	1192.0	19.7	1769.0	30.9	2973.0	57.1	3196.0	62.7	3095.0	62.7
High	541.0	8.2	653.0	12.1	807.0	15.8	1213.0	28.6	2354.0	62.7	1951.0	52.2	2197.0	61.7
LSD	242.7	3.7	375.7	5.6	556.6	8.1	655.6	10.1	777.5	12.7	1380.4	24.2	1734.5	34.3
Trees.Graze	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Treeless														
Low	410.0	6.3	746.0	12.2	1369.0	22.9	1924.0	34.2	2964.0	55.3	3720.0	73.3	3726.0	73.9
Medium	538.0	8.5	963.0	16.8	1053.0	19.1	1732.0	32.7	2828.0	59.5	3342.0	70.0	3667.0	79.0
High	564.0	9.0	588.0	12.6	613.0	14.4	1054.0	31.1	2056.0	64.4	1482.0	48.1	1614.0	55.8
Treed														
Low	607.0	8.6	994.0	15.2	1212.0	19.8	1557.0	27.2	2374.0	44.1	3200.0	58.9	2597.0	50.6
Medium	558.0	6.8	1052.0	15.3	1330.0	20.3	1806.0	29.2	3118.0	54.8	3050.0	55.4	2523.0	46.5
High	517.0	7.4	718.0	11.5	1000.0	17.3	1372.0	26.1	2653.0	61.0	2420.0	56.3	2780.0	67.7
LSD	343.2	5.3	531.3	7.9	787.2	11.5	927.1	14.3	1099.6	18.0	1952.2	34.3	2453.0	48.5

Note: n.s. = not significant (P>0.10); * = P<0.05; ** = P<0.01; *** = P<0.001

Appendix N1.5j (contd). Tree killing and grazing pressure effects on the charted basal area of *B. ewartiana*, *C. fallax* and *H. contortus* at Keilambete

	1994		**1995**		**1996**		**1997**		**1998**		**1999**		**2000**	
	Basal area (cm^2)	Basal area per plant (cm^2)	Basal area (cm^2)	Basal area per plant (cm^2)	Basal area (cm^2)	Basal area per plant (cm^2)	Basal area (cm^2)	Basal area per plant (cm^2)	Basal area (cm^2)	Basal area per plant (cm^2)	Basal area (cm^2)	Basal area per plant (cm^2)	Basal area (cm^2)	Basal area per plant (cm^2)
C. fallax														
Treatment	P=0.096	**	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Treeless	174.9	2.2	383.0	5.5	329.0	4.8	628.0	10.3	835.0	14.9	647.0	11.8	595.0	11.0
Treed	210.8	2.7	319.0	4.6	366.0	5.7	548.0	8.8	762.0	13.4	689.0	12.5	521.0	9.9
LSD	45.0	0.3	151.0	1.9	159.8	1.9	203.1	1.9	292.9	2.7	334.4	4.3	202.5	3.3
Grazing Pressure	n.s.	**	n.s.	n.s.	P=0.070	P=0.079	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	P=0.070	n.s.
Low	176.7	2.0	397.0	5.1	483.0	6.8	686.0	10.4	913.0	14.8	845.0	14.0	730.0	12.3
Medium	196.6	2.5	339.0	5.2	275.0	4.5	539.0	9.0	719.0	13.6	577.0	11.7	463.0	9.6
High	205.3	2.8	315.0	4.9	285.0	4.5	539.0	9.3	762.0	14.1	581.0	10.8	482.0	9.5
LSD	55.1	0.3	185.0	2.3	195.7	2.3	248.7	2.3	358.7	3.3	409.5	5.2	248.0	4.0
Trees.Graze	n.s.	*	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	P=0.072	n.s.	n.s.	n.s.	P=0.093
Treeless														
Low	176.4	2.0	443.0	5.6	483.0	6.4	694.0	10.3	896.0	14.1	747.0	11.8	743.0	11.8
Medium	188.3	2.4	329.0	4.8	197.0	3.0	616.0	10.1	880.0	16.6	648.0	13.1	601.0	12.6
High	160.1	2.2	376.0	6.1	306.0	5.1	573.0	10.5	729.0	14.0	544.0	10.4	442.0	8.6
Treed														
Low	177.0	2.1	352.0	4.6	483.0	7.2	677.0	10.6	930.0	15.5	943.0	16.2	716.0	12.8
Medium	204.9	2.6	350.0	5.6	354.0	5.9	461.0	7.8	558.0	10.6	507.0	10.3	325.0	6.5
High	250.6	3.4	254.0	3.6	263.0	4.0	506.0	8.1	796.0	14.1	618.0	11.1	522.0	10.5
LSD	78.0	0.5	261.6	3.3	276.8	3.2	351.7	3.2	507.3	4.7	579.2	7.4	350.7	5.7

Note: n.s. = not significant ($P>0.10$); * = $P<0.05$; ** = $P<0.01$; *** = $P<0.001$

Appendix N1.5j (contd). Tree killing and grazing pressure effects on the charted basal area of *B. ewartiana*, *C. fallax* and *H. contortus* at Keilambete

	1994		1995		1996		1997		1998		1999		2000	
	Basal area (cm^2)	Basal area per plant (cm^2)	Basal area (cm^2)	Basal area per plant (cm^2)	Basal area (cm^2)	Basal area per plant (cm^2)	Basal area (cm^2)	Basal area per plant (cm^2)	Basal area (cm^2)	Basal area per plant (cm^2)	Basal area (cm^2)	Basal area per plant (cm^2)	Basal area (cm^2)	Basal area per plant (cm^2)
H. contortus														
Trees	*	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	*	n.s.	**	*	***
Treeless	153.3	2.3	508.0	9.3	555.0	14.0	907.0	28.4	1738.0	72.3	1843.0	76.9	1879.0	80.9
Treed	187.7	2.8	438.0	8.2	496.0	12.0	694.0	21.2	1119.0	46.2	1178.0	51.7	772.0	40.7
LSD	31.7	0.8	228.2	3.8	322.4	4.5	814.4	17.0	1050.0	25.1	1260.8	11.1	962.3	13.7
Grazing Pressure	*	P=0.072	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	*	n.s.	n.s.
Low	135.3	2.1	534.0	9.7	720.0	15.7	961.0	23.6	1672.0	51.2	1948.0	62.7	1809.0	62.7
Medium	173.2	2.4	503.0	9.2	505.0	12.3	966.0	31.4	1565.0	70.0	1575.0	74.3	1276.0	62.9
High	203.0	3.2	382.0	7.4	352.0	11.0	476.0	19.4	1049.0	56.6	1010.0	56.0	891.0	56.7
LSD	38.9	0.9	279.5	4.6	394.9	5.5	997.5	20.9	1286.0	30.8	1544.2	13.6	1178.6	16.8
Trees.Graze	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	P=0.097	n.s.	*
Treeless														
Low	132.6	2.1	601.0	11.2	742.0	17.5	1124.0	28.8	2077.0	68.5	2165.0	71.6	2465.0	86.2
Medium	150.5	2.0	478.0	8.2	475.0	11.3	1064.0	34.6	1869.0	85.4	2070.0	95.4	1967.0	93.6
High	176.8	2.8	445.0	8.6	447.0	13.3	535.0	21.8	1269.0	63.0	1295.0	63.8	1207.0	62.8
Treed														
Low	137.9	2.0	467.0	8.3	698.0	14.0	798.0	18.4	1267.0	33.9	1730.0	53.8	1153.0	39.3
Medium	195.9	2.9	527.0	10.2	534.0	13.4	686.0	28.2	1260.0	54.6	1079.0	53.2	586.0	32.1
High	229.1	3.5	319.0	6.3	257.0	8.7	418.0	17.0	829.0	50.2	725.0	48.2	576.0	50.7
LSD	55.0	1.3	395.3	6.6	558.5	7.8	1410.6	29.5	1818.6	43.5	2183.8	19.2	1666.8	23.7

Note: n.s. = not significant (P>0.10); * = P<0.05; ** = P<0.01; *** = P<0.001

Appendix N1.6a. Statistical significance of tree killing and burning on basal area of B. ewartiana, C. fallax and H. contortus at Keilambete

	1995		1996		1997		1998		1999		2000	
	Basal area (cm^2)	Basal area per plant (cm^2)	Basal area (cm^2)	Basal area per plant (cm^2)	Basal area (cm^2)	Basal area per plant (cm^2)	Basal area (cm^2)	Basal area per plant (cm^2)	Basal area (cm^2)	Basal area per plant (cm^2)	Basal area (cm^2)	Basal area per plant (cm^2)
B. ewartiana												
Trees	n.s.	*	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Trees killed	200.0	18.7	295.0	26.1	363.0	33.9	549.0	50.0	812.0	74.2	914.0	82.0
Treed	150.0	9.9	267.0	19.9	327.0	24.0	586.0	51.4	870.0	66.9	843.0	62.0
LSD	98.3	7.5	111.1	14.5	200.8	24.0	203.4	32.3	376.0	41.9	441.0	51.7
Burnt	n.s.	*	n.s.	*	n.s.	n.s.	P=0.067	n.s.	n.s.	n.s.	n.s.	n.s.
Burnt	141.0	9.2	245.0	15.3	330.0	22.0	661.0	52.7	916.0	68.3	932.0	67.0
Not burnt	209.0	19.4	317.0	30.7	359.0	35.9	475.0	48.6	766.0	72.8	825.0	77.0
LSD	98.3	7.5	111.1	14.5	200.8	24.0	203.4	32.3	376.0	41.9	441.0	51.7
	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	P=0.062	n.s.	*	n.s.	n.s.
Trees killed												
Burnt	173.0	11.3	300.0	16.2	348.0	19.1	613.0	37.0	831.0	48.6	959.0	57.0
Not burnt	228.0	26.1	290.0	36.0	378.0	48.7	484.0	63.0	794.0	99.8	868.0	107.0
Treed												
Burnt	108.0	7.2	190.0	14.5	313.0	24.9	708.0	68.5	1001.0	88.0	905.0	76.0
Not burnt	191.0	12.7	344.0	25.4	340.0	23.0	465.0	34.2	738.0	45.8	781.0	47.0
LSD	139.0	10.7	157.2	20.5	283.9	33.9	287.6	45.7	531.7	59.2	623.7	73.1
C. fallax												
Trees	n.s.	*	n.s.	P=0.094	n.s.	P=0.080	n.s.	*	n.s.	**	n.s.	n.s.
Trees killed	77.8	6.6	165.0	14.3	328.0	29.6	419.0	40.0	431.0	40.5	425.0	38.4
Treed	80.1	4.1	186.0	9.9	342.0	17.8	374.0	21.2	406.0	22.9	457.0	25.3
LSD	42.0	2.0	106.5	5.4	218.5	13.7	217.3	13.0	199.5	11.1	269.2	17.3
Burnt	n.s.	n.s.	n.s.	P=0.092	n.s.	n.s.	n.s.	*	n.s.	n.s.	n.s.	n.s.
Burnt	77.8	4.9	151.0	9.9	310.0	20.9	344.0	23.7	402.0	27.7	414.0	27.0
Not burnt	80.1	5.8	200.0	14.3	360.0	26.5	448.0	37.5	435.0	35.7	467.0	36.8
LSD	42.0	2.0	106.5	5.4	218.5	13.7	217.3	13.0	199.5	11.1	269.2	17.3

Appendix N1.6a (contd). Statistical significance of tree killing and burning on basal area of *B. ewartiana*, *C. fallax* and *H. contortus* at Keilambete

	1995		1996		1997		1998		1999		2000	
	Basal area (cm^2)	Basal area per plant (cm^2)	Basal area (cm^2)	Basal area per plant (cm^2)	Basal area (cm^2)	Basal area per plant (cm^2)	Basal area (cm^2)	Basal area per plant (cm^2)	Basal area (cm^2)	Basal area per plant (cm^2)	Basal area (cm^2)	Basal area per plant (cm^2)
C. fallax (cont.)												
	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	*	n.s.	*	n.s.	n.s.
Trees killed												
Burnt	75.0	5.9	148.0	11.7	301.0	24.3	321.0	25.9	354.0	28.6	351.0	27.2
Not burnt	80.6	7.2	182.0	16.9	356.0	34.9	516.0	54.1	508.0	52.4	499.0	49.6
Treed												
Burnt	80.5	3.9	154.0	8.1	319.0	17.5	368.0	21.5	450.0	26.8	477.0	26.7
Not burnt	79.7	4.4	218.0	11.8	365.0	18.1	380.0	20.9	362.0	19.0	436.0	24.0
LSD	59.4	2.8	150.6	7.6	309.0	19.4	307.3	18.4	282.2	15.8	380.7	24.5
H. contortus												
Trees	**	**	n.s.	P=0.085	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Trees killed	174.0	10.7	191.0	16.3	382.0	30.8	545.0	46.6	808.0	36.9	971.0	32.4
Treed	65.0	3.7	137.0	19.3	354.0	29.2	533.0	51.1	815.0	34.5	1066.0	18.6
LSD	60.6	4.2	113.9	8.3	156.3	25.7	288.9	26.4	490.3	35.1	654.5	23.1
Burnt	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	*	n.s.	n.s.
Burnt	142.0	7.1	174.0	12.5	312.0	25.3	515.0	49.5	748.0	57.7	847.0	28.0
Not burnt	97.0	7.2	154.0	13.1	425.0	34.7	562.0	48.2	875.0	13.8	1189.0	23.0
LSD	60.6	4.2	113.9	8.3	156.3	25.7	288.9	26.4	490.3	35.1	564.5	23.1
	n.s.	n.s.	n.s.	n.s.	P=0.060	n.s.	n.s.	n.s.	P=0.057	n.s.	P=0.057	n.s.
Trees killed												
Burnt	202.0	10.5	192.0	15.5	252.0	24.8	409.0	45.2	508.0	53.9	528.0	30.7
Not burnt	147.0	10.9	190.0	17.1	513.0	36.8	680.0	48.0	1107.0	20.0	1413.0	34.0
Treed												
Burnt	82.0	3.8	156.0	9.6	372.0	25.9	621.0	53.8	989.0	61.5	1167.0	25.3
Not burnt	47.0	3.6	118.0	9.1	337.0	32.6	445.0	48.4	642.0	7.6	966.0	12.0
LSD	85.7	6.0	161.1	11.7	221.0	36.4	408.6	37.3	693.3	49.7	798.4	32.7

Note: n.s. = not significant (P>0.10); * = P<0.05; ** = P<0.01; *** = P<0.001

Appendix N1.6b. Tree killing and burning effects on autumn ground cover % at Keilambete (fire study)

% Cover	1994	1995	1996	1997	1998	1999	2000	2001
Burning	n.s.	n.s.	**	n.s.	***	n.s.	***	***
Burn	50.4	48.2	42.5	85.7	60.7	87.8	58.9	75.9
No burn	57.0	53.6	60.4	86.2	87.6	86.2	86.5	92.6
lsd	11.0	8.7	11.9	6.8	4.0	5.6	7.6	7.0
Trees	**	n.s.	n.s.	n.s.	n.s.	P=0.084	n.s.	n.s.
Treeless	45.6	52.0	52.0	84.1	74.3	84.6	72.2	82.9
Treed	61.8	49.8	50.9	87.8	74.0	89.4	73.2	85.5
lsd	11.0	8.7	11.9	6.8	4.1	5.6	7.6	7.0
Trees.Burn	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	P=0.084	n.s.

Note: n.s. = not significant (P>0.10); * = P<0.05; ** = P<0.01; *** = P<0.001

Appendix N1.6c. Tree killing and burning effects on total pasture yield at Keilambete (fire study)

Yield	1994	1995	1996	1997	1998	1999	2000	2001
Burning	n.s.	*	**	n.s.	***	n.s.	***	
Burn	662	1695	1987	4208	2618	3792	4658	7164
No burn	772	2127	3346	434.2	6937	3692	7755	8945
lsd	115.2	425.8	856.1	723.6	1303.3	472.0	909.5	975
Trees	n.s.	*	n.s.	n.s.	n.s.	n.s.	*	n.s.
Treeless	715	2127	2595	4223	4650	3617	5642	7970
Treed	668	1695	2738	4328	4906	3867	6770	8138
lsd	115.2	425.8	856.1	723.6	1303.3	472.0	909.5	975
Trees.Burn	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	**	n.s.

Note: n.s. = not significant (P>0.10); * = P<0.05; ** = P<0.01; *** = P<0.001

Appendix N1.6d. Tree killing and burning effects on perennial grass basal area at Keilambete (fire study)

Basal area %	**1995**	**1997**	**1998**	**1999**	**2000**
Burning	n.s.	n.s.	n.s.	P=0.092	***
Burnt	2.18	2.46	2.43	3.14	4.95
Unburnt	1.84	2.16	2.14	2.49	2.15
lsd	0.90	0.70	0.58	0.79	0.60
Trees	n.s.	n.s.	n.s.	n.s.	n.s.
Treeless	2.00	1.66	1.89	3.96	3.50
Treed	2.02	1.27	1.68	2.25	3.60
lsd	0.90	0.56	0.40	0.96	0.60
Trees.Burn	n.s.	n.s.	n.s.	n.s.	n.s.

Note: n.s. = not significant (P>0.10); * = P<0.05; ** = P<0.01; *** = P<0.001

Appendix N1.6e. Tree killing and burning effects on plant frequency (%) at Keilambete (fire study)

Frequency	**1994**	**1995**	**1997**	**1998**	**1999**	**2000**	**2001**
Aristida spp.							
Trees	n.s.	*	n.s.	n.s.	*	n.s.	n.s.
Burn	n.s.	*	n.s.	n.s.	n.s.	n.s.	n.s.
Trees.Burn	P=0.072	**	n.s.	n.s.	n.s.	n.s.	n.s.
Bothriochloa ewartiana							
Trees	*	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Burn	n.s.	n.s.	n.s.	**	n.s.	*	n.s.
Trees.Burn	n.s.	*	n.s.	n.s.	P=0.098	n.s.	*
Chloris spp.							
Trees	n.s.	P=0.075	n.s.	*	n.s.	n.s.	n.s.
Burn	n.s.	**	n.s.	n.s.	n.s.	n.s.	n.s.
Trees.Burn	n.s.	P=0.075	n.s.	n.s.	n.s.	n.s.	n.s.
Chrysopogon fallax							
Trees	*	*	***	n.s.	***	n.s.	**
Burn	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	P=0.09
Trees.Burn	n.s.	n.s.	n.s.	n.s.	**	n.s.	P=0.07
Digitaria spp.							
Trees	P=0.057	n.s.	n.s.	P=0.071	n.s.	n.s.	
Burn	n.s.	n.s.	**	*	P=0.068	P=0.067	
Trees.Burn	n.s.	n.s.	n.s.	P=0.082	n.s.	n.s.	
Enneapogon spp.							
Trees	P=0.059	n.s.	*	n.s.	n.s.	*	P=0.07
Burn	n.s.	n.s.	*	*	**	**	**
Trees.Burn	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	P=0.08
Eragrostis spp.							
Trees	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Burn	n.s.	n.s.	n.s.	n.s.	n.s.	P=0.055	n.s.
Trees.Burn	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Eulalia aurea							
Trees	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Burn	n.s.	P=0.074	n.s.	*	**	n.s.	n.s.
Trees.Burn	n.s.	n.s.	n.s.	n.s.	n.s.	*	n.s.

Note: n.s. = not significant (P>0.10); * = P<0.05; ** = P<0.01; *** = P<0.001

Appendix N1.6e (contd). Tree killing and burning effects on plant frequency (%) in autumn at Keilambete (fire study)

Frequency	**1994**	**1995**	**1997**	**1998**	**1999**	**2000**	**2001**
Forbs							
Trees	n.s.	n.s.	n.s.	**	n.s.	n.s.	n.s.
Burn	n.s.	n.s.	n.s.	n.s.	***	n.s.	n.s.
Trees.Burn	n.s.	n.s.	n.s.	**	n.s.	n.s.	n.s.
Heteropogon contortus							
Trees	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Burn	n.s.	n.s.	n.s.	n.s.	**	n.s.	n.s.
Trees.Burn	n.s.	n.s.	n.s.	P=0.056	n.s.	n.s.	n.s.
Native legume							
Trees	n.s.	*	*	n.s.	n.s.	n.s.	n.s.
Burn	P=0.078	n.s.	n.s.	n.s.	**	**	*
Trees.Burn	n.s.	n.s.	n.s.	n.s.	n.s.	P=0.057	n.s.
Panicum spp.							
Trees	P=0.098	n.s.	n.s.	*	*	n.s.	n.s.
Burn	n.s.	n.s.	n.s.	**	n.s.	n.s.	n.s.
Trees.Burn	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Sedges							
Trees	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Burn	n.s.	n.s.	n.s.	*	n.s.	**	n.s.
Trees.Burn	n.s.	*	P=0.094	n.s.	n.s.	n.s.	n.s.
Themeda triandra							
Trees	P=0.081	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Burn	n.s.	n.s.	n.s.	n.s.	n.s.	P=0.064	n.s.
Trees.Burn	n.s.	**	*	n.s.	n.s.	**	P=0.06
Tragus australianus							
Trees	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	P=0.06
Burn	n.s.	n.s.	P=0.086	P=0.072	n.s.	n.s.	P=0.06
Trees.Burn	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Tripogon loliiformis							
Trees	n.s.	n.s.	P=0.065	P=0.081	n.s.	n.s.	
Burn	n.s.	n.s.	n.s.	n.s.	P=0.051	*	
Trees.Burn	*	n.s.	n.s.	n.s.	n.s.	n.s.	

Note: n.s. = not significant (P>0.10); * = P<0.05; ** = P<0.01; *** = P<0.001

Appendix N1.6f. Tree killing and burning effects on pasture component yields (kg/ha) in autumn at Keilambete (fire study)

Component yields	1994	1997	1998	1999	2000	2001
Aristida spp.						
Trees	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Burn	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Trees.Burn	**	n.s.	n.s.	n.s.	n.s.	n.s.
Bothriochloa ewartiana						
Trees	**	n.s.	n.s.	n.s.	P=0.065	n.s.
Burn	n.s.	**	**	n.s.	***	n.s.
Trees.Burn	n.s.	*	n.s.	n.s.	**	n.s.
Chrysopogon fallax						
Trees	P=0.094	P=0.079	n.s.	**	n.s.	*
Burn	n.s.	n.s.	n.s.	*	n.s.	n.s.
Trees.Burn	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Digitaria spp.						
Trees	P=0.085	P=0.086	n.s.	n.s.	n.s.	
Burn	n.s.	P=0.077	*	n.s.	n.s.	
Trees.Burn	n.s.	P=0.086	*	n.s.	n.s.	
Enneapogon spp.						
Trees	n.s.	n.s.	n.s.	*	n.s.	*
Burn	n.s.	n.s.	n.s.	**	*	***
Trees.Burn	n.s.	n.s.	n.s.	n.s.	n.s.	P=0.060
Eragrostis spp.						
Trees	n.s.	n.s.	n.s.	P=0.060	n.s.	n.s.
Burn	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Trees.Burn	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Eulalia aurea						
Trees	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Burn	n.s.	*	P=0.088	*	n.s.	n.s.
Trees.Burn	n.s.	*	P=0.085	n.s.	*	n.s.

Note: n.s. = not significant (P>0.10); * = P<0.05; ** = P<0.01; *** = P<0.001

Appendix N1.6f (contd). Tree killing and burning effects on component yields (kg/ha) in autumn at Keilambete (fire study)

Component yields	1994	1997	1998	1999	2000	2001
Forbs						
Trees	n.s.	n.s.	n.s.	**	*	n.s.
Burn	n.s.	*	n.s.	P=0.053	n.s.	n.s.
Trees.Burn	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Heteropogon contortus						
Trees	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Burn	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Trees.Burn	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Native legume						
Trees	n.s.	P=0.069	n.s.	n.s.	*	n.s.
Burn	n.s.	n.s.	n.s.	P=0.089	**	n.s.
Trees.Burn	n.s.	n.s.	n.s.	n.s.	*	n.s.
Panicum spp.						
Trees	P=0.087	P=0.051	n.s.	n.s.	n.s.	n.s.
Burn	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Trees.Burn	n.s.	*	n.s.	n.s.	n.s.	n.s.
Sedges						
Trees	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Burn	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Trees.Burn	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Themeda triandra						
Trees	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Burn	n.s.	n.s.	*	n.s.	*	n.s.
Trees.Burn	n.s.	P=0.069	P=0.064	*	n.s.	*
Tripogon loliiformis						
Trees	n.s.	n.s.	n.s.	n.s.	n.s.	*
Burn	n.s.	n.s.	n.s.	n.s.	n.s.	**
Trees.Burn	n.s.	n.s.	n.s.	n.s.	n.s.	*

Note: n.s. = not significant (P>0.10); * = P<0.05; ** = P<0.01; *** = P<0.001

Appendix N1.6g. Tree killing and burning effects on pasture biomass proportions (%) in autumn at Keilambete (fire study)

% Composition	1994	1997	1998	1999	2000	2001
Aristida spp.						
Trees	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Burn	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Trees.Burn	*	n.s.	n.s.	n.s.	n.s.	n.s.
Bothriochloa ewartiana						
Trees	**	n.s.	n.s.	n.s.	n.s.	n.s.
Burn	n.s.	*	*	n.s.	*	n.s.
Trees.Burn	n.s.	P=0.070	n.s.	n.s.	*	P=0.095
Chrysopogon fallax						
Trees	P=0.080	n.s.	n.s.	**	n.s.	*
Burn	n.s.	n.s.	n.s.	*	P=0.072	n.s.
Trees.Burn	n.s.	n.s.	n.s.	**	n.s.	n.s.
Digitaria spp.						
Trees	P=0.081	P=0.087	P=0.090	n.s.	n.s.	
Burn	n.s.	P=0.075	**	n.s.	n.s.	
Trees.Burn	n.s.	P=0.087	P=0.090	n.s.	n.s.	
Enneapogon spp.						
Trees	n.s.	n.s.	P=0.057	**	n.s.	**
Burn	n.s.	n.s.	*	***	**	***
Trees.Burn	n.s.	n.s.	n.s.	n.s.	n.s.	*
Eragrostis spp.						
Trees	n.s.	n.s.	n.s.	P=0.060	n.s.	n.s.
Burn	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Trees.Burn	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Eulalia aurea						
Trees	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Burn	n.s.	P=0.053	n.s.	*	n.s.	n.s.
Trees.Burn	n.s.	*	n.s.	n.s.	*	n.s.

Note: n.s. = not significant (P>0.10); * = P<0.05; ** = P<0.01; *** = P<0.001

Appendix N1.6g (contd). Tree killing and burning effects on pasture biomass proportions (%) in autumn at Keilambete (fire study)

% Composition	**1994**	**1997**	**1998**	**1999**	**2000**	**2001**
Forbs						
Trees	n.s.	n.s.	n.s.	*	*	n.s.
Burn	n.s.	P=0.082	n.s.	n.s.	n.s.	n.s.
Trees.Burn	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Heteropogon contortus						
Trees	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Burn	n.s.	n.s.	*	n.s.	n.s.	n.s.
Trees.Burn	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Native legume						
Trees	n.s.	P=0.057	n.s.	n.s.	**	n.s.
Burn	n.s.	n.s.	n.s.	*	**	n.s.
Trees.Burn	n.s.	n.s.	n.s.	n.s.	**	n.s.
Panicum spp.						
Trees	P=0.059	*	n.s.	n.s.	n.s.	n.s.
Burn	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Trees.Burn	n.s.	*	n.s.	n.s.	n.s.	n.s.
Sedges						
Trees	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Burn	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Trees.Burn	n.s.	n.s.	n.s.	P=0.095	n.s.	n.s.
Themeda triandra						
Trees	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Burn	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Trees.Burn	n.s.	*	*	*	**	*
Tragus australianus			not	enough	data	
Tripogon loliiformis						
Trees	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Burn	n.s.	n.s.	n.s.	P=0.095	n.s.	n.s.
Trees.Burn	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.

Note: n.s. = not significant (P>0.10); * = P<0.05; ** = P<0.01; *** = P<0.001

Appendix N1.6h. Statistical significance of tree killing and burning on the density of *B. ewartiana*, *C. fallax* and *H. contortus* at Keilambete (charting study)

	1995-96	1996-97	1997-98	1998-99	1999-2000
B. ewartiana					
Trees	n.s.	n.s.	n.s.	n.s.	n.s.
Trees killed	75.8	68.3	63.3	64.2	63.3
Treed	69.2	69.2	63.3	72.5	75.8
LSD	43.2	22.8	25.0	27.9	27.5
Burning	n.s.	n.s.	n.s.	n.s.	n.s.
Burnt	85.0	75.8	69.2	73.3	73.3
Not burnt	60.0	61.7	57.5	63.3	65.8
LSD	43.2	22.8	25.0	27.9	27.5
Trmt.Burnt	n.s.	*	*	*	*
Trees killed					
Burnt	105.0	88.3	83.3	85.0	81.7
Not burnt	46.7	48.3	43.3	43.3	45.0
Treed					
Burnt	65.0	63.3	55.0	61.7	65.0
Not burnt	73.3	75.0	71.7	83.3	86.7
LSD	61.2	32.2	35.4	39.5	38.8
C. fallax					
Trees	*	P=0.055	*	*	*
Trees killed	59.2	56.7	55.0	55.0	58.3
Treed	91.7	92.5	92.5	90.0	93.3
LSD	25.8	36.8	26.5	32.6	33.7
Burning	n.s.	n.s.	n.s.	n.s.	n.s.
Burnt	80.8	78.3	74.2	73.3	78.3
Not burnt	70.0	70.8	73.3	71.7	73.3
LSD	25.8	36.8	26.5	32.6	33.7
Trmt.Burnt	n.s.	n.s.	n.s.	n.s.	n.s.
Trees killed					
Burnt	65.0	63.3	61.7	61.7	65.0
Not burnt	53.3	50.0	48.3	48.3	51.7
Treed					
Burnt	96.7	93.3	86.7	85.0	91.7
Not burnt	86.7	91.7	98.3	95.0	95.0
LSD	36.4	52.0	37.4	46.1	47.7

Appendix N1.6h(contd). Statistical significance of tree killing and burning on the density of *B. ewartiana, C. fallax* and *H. contortus* at Keilambete (charting study)

	1995-96	**1996-97**	**1997-98**	**1998-99**	**1999-2000**
H. contortus					
Trees	n.s.	n.s.	n.s.	n.s.	n.s.
Trees killed	60.8	69.2	62.5	198.0	193.0
Treed	77.5	69.2	56.7	247.0	316.0
LSD	35.4	44.0	35.8	206.3	200.5
Burning	n.s.	n.s.	n.s.	*	P=0.072
Burnt	75.0	62.5	50.8	73.0	165.0
Not burnt	63.3	75.8	68.3	372.0	343.0
LSD	35.4	44.0	35.8	206.3	200.5
Trmt.Burnt	n.s.	n.s.	n.s.	n.s.	n.s.
Trees killed					
Burnt	65.0	51.7	43.3	52.0	97.0
Not burnt	56.7	86.7	81.7	343.0	288.0
Treed					
Burnt	85.0	73.3	58.3	93.0	233.0
Not burnt	70.0	65.0	55.0	400.0	398.0
LSD	50.0	62.2	50.6	291.7	283.6

Note: n.s. = not significant (P>0.10); * = P<0.05; ** = P<0.01; *** = P<0.001

Appendix N1.6i. Statistical significance of tree killing and burning on perennial grass basal area (%) at Keilambete (charting study)

Basal area %	**1995**	**1997**	**1998**	**1999**	**2000**
Burning	n.s.	n.s.	n.s.	P=0.092	***
Burnt	2.18	2.46	2.43	3.14	4.95
N (Unburnt)	1.84	2.16	2.14	2.49	2.15
lsd	0.90	0.70	0.58	0.79	0.60
Trees	n.s.	n.s.	n.s.	n.s.	n.s.
Trees killed	2.00	1.66	1.89	3.96	3.50
Treed	2.02	1.27	1.68	2.25	3.60
lsd	0.90	0.56	0.40	0.96	0.60
Burnt.Burnt	n.s.	n.s.	n.s.	n.s.	n.s.

Note: n.s. = not significant (P>0.10); * = P<0.05; ** = P<0.01; *** = P<0.001

Appendix N1.6j. Statistical significance of tree killing and burning on the recruitment of *B. ewartiana*, *C. fallax* and *H. contortus* at Keilambete (charting study)

	1995-96	1996-97	1997-98	1998-99	1999-2000
B. ewartiana					
Trees	n.s.	n.s.	n.s.	P=0.096	n.s.
Trees killed	15.0	7.5	8.3	3.3	1.7
Treed	4.2	3.3	2.5	11.7	5.0
LSD	35.7	7.0	17.2	10.3	7.2
Burning	n.s.	n.s.	n.s.	n.s.	n.s.
Burnt	16.7	5.8	5.8	6.7	3.3
Not burnt	2.5	5.0	5.0	8.3	3.3
LSD	35.7	7.0	17.2	10.3	7.2
Trees.Burnt	n.s.	*	n.s.	n.s.	n.s.
Trees killed					
Burnt	30.0	11.7	11.7	5.0	1.7
Not burnt	0.0	3.3	5.0	1.7	1.7
Treed					
Burnt	3.3	0.0	0.0	8.3	5.0
Not burnt	5.0	6.7	5.0	15.0	5.0
LSD	50.5	9.9	24.3	14.6	10.1
C. fallax					
Trees	n.s.	n.s.	n.s.	n.s.	n.s.
Trees killed	0.8	0.0	3.3	0.0	3.3
Treed	0.8	6.7	3.3	2.5	3.3
LSD	3.1	14.8	11.3	3.5	7.0
Burning	n.s.	n.s.	n.s.	n.s.	n.s.
Burnt	0.8	0.8	1.7	0.0	5.0
Not burnt	0.8	5.8	5.0	2.5	1.7
LSD	3.1	14.8	11.3	3.5	7.0
Trmt.Burnt	n.s.	n.s.	n.s.	n.s.	n.s.
Trees killed					
Burnt	1.7	0.0	3.3	0.0	3.3
Not burnt	0.0	0.0	3.3	0.0	3.3
Treed					
Burnt	0.0	1.7	0.0	0.0	6.7
Not burnt	1.7	11.7	6.7	5.0	0.0
LSD	4.4	20.9	16.0	5.0	9.9

Appendix N1.6j (contd). Statistical significance of tree killing and burning on the recruitment of *B. ewartiana, C. fallax* and *H. contortus* at Keilambete (charting study)

	1995-96	1996-97	1997-98	1998-99	1999-2000
H. contortus					
Trees	n.s.	n.s.	n.s.	n.s.	*
Trees killed	5.0	22.5	4.2	141.0	53.0
Treed	4.2	5.8	4.2	197.0	128.0
LSD	8.4	33.7	11.3	196.0	51.6
Burning	n.s.	n.s.	n.s.	*	n.s.
Burnt	2.5	8.3	2.5	27.0	102.0
Not burnt	6.7	20.0	5.8	311.0	79.0
LSD	8.4	33.7	11.3	196.0	51.6
Trees.Burnt	n.s.	n.s.	n.s.	n.s.	n.s.
Trees killed					
Burnt	5.0	8.3	3.3	13.0	57.0
Not burnt	5.0	36.7	5.0	268.0	50.0
Treed					
Burnt	0.0	8.3	1.7	40.0	147.0
Not burnt	8.3	3.3	6.7	353.0	108.0
LSD	11.9	47.7	16.0	277.1	72.9

Note: n.s. = not significant (P>0.10); * = P<0.05; ** = P<0.01; *** = P<0.001

Appendix N1.6k. Statistical significance of tree killing and burning on the soil seedbank of *Aristida* spp., *B. ewartiana*, *Chloris* spp. and *Cyperus* spp. at Keilambete (fire study)

Soil seed bank	1995-1996	1996-1997	1997-1998	1998-1999	1999-2000
Aristida spp					
Trees	n.s.	n.s.	n.s.		*
Trees killed	38.0	32.0	25.0		31.7
Treed	25.0	32.0	13.0		0.0
lsd	65.1	56.6	50.6		26.8
Burning	n.s.	n.s.	n.s.		n.s.
Burnt	32.0	32.0	6.0		19.0
Not burnt	32.0	32.0	32.0		12.7
lsd	65.1	56.6	50.6		26.8
Trees.Burnt	n.s.	n.s.	n.s.		n.s.
Bothriochloa ewartiana					
Trees	n.s.	n.s.	n.s.	n.s.	n.s.
Trees killed	44.0	146.0	32.0	6.3	12.7
Treed	70.0	70.0	38.0	19.0	6.3
lsd	89.9	130.0	76.4	40.0	36.9
Burning	n.s.	P=0.075	n.s.	n.s.	n.s.
Burnt	57.0	165.0	25.0	12.7	6.3
Not burnt	57.0	51.0	44.0	12.7	12.7
lsd	89.9	130.0	76.4	40.0	36.9
Trees.Burnt	n.s.	n.s.	n.s.	n.s.	n.s.
Chloris spp					
Trees	n.s.	n.s.	n.s.		n.s.
Trees killed	6.3	6.3	13.0		32.0
Treed	6.3	0.0	120.0		0.0
lsd	23.7	15.5	192.1		60.0
Burning	n.s.	n.s.	n.s.		n.s.
Burnt	6.3	0.0	57.0		19.0
Not burnt	6.3	6.3	76.0		13.0
lsd	23.7	15.5	192.1		60.0
Trees.Burnt	n.s.	n.s.	n.s.		n.s.
Cyperus spp					
Trees	n.s.	n.s.	n.s.		
Trees killed	51.0	25.0	44.0		
Treed	44.0	25.0	13.0		
lsd	86.3	52.9	55.9		
Burning	n.s.	n.s.	n.s.		
Burnt	44.0	19.0	13.0		
Not burnt	51.0	32.0	44.0		
lsd	86.3	52.9	55.9		
Trees.Burnt	n.s.	n.s.	n.s.		

Appendix N1.6k (contd). Statistical significance of tree killing and burning on the soil seedbank of *Digitaria spp.*, *Enneapogon spp.*, *Eragrostis spp.* and *Euphorbia spp.* at Keilambete (fire study)

Soil seed bank	**1995-1996**	**1996-1997**	**1997-1998**	**1998-1999**	**1999-2000**
Digitaria spp					
Trees	n.s.		n.s.		n.s.
Trees killed	19.0		6.3		12.7
Treed	19.0		12.7		6.3
lsd	46.5		36.9		25.3
Burning	P=0.092		n.s.		n.s.
Burnt	38.0		12.7		12.7
Not burnt	0.0		6.3		6.3
lsd	46.5		36.9		25.3
Trees.Burnt	n.s.		n.s.		n.s.
Enneapogon spp					
Trees	n.s.	n.s.	n.s.		
Trees killed	32.0	108.0	51.0		
Treed	32.0	51.0	19.0		
lsd	51.4	131.8	114.9		
Burning	n.s.	n.s.	n.s.		
Burnt	51.0	70.0	38.0		
Not burnt	13.0	89.0	32.0		
lsd	51.4	131.8	114.9		
Trees.Burnt	n.s.	n.s.	n.s.		
Eragrostis spp					
Trees	n.s.	n.s.	n.s.	P=0.092	n.s.
Trees killed	12.7	6.3	6.3	12.7	6.3
Treed	0.0	0.0	0.0	0.0	0.0
lsd	23.7	15.5	15.5	15.5	15.5
Burning	n.s.	n.s.	n.s.	P=0.092	n.s.
Burnt	6.3	6.3	0.0	0.0	0.0
Not burnt	6.3	0.0	6.3	12.7	6.3
lsd	23.7	15.5	15.5	15.5	15.5
Trees.Burnt	n.s.	n.s.	n.s.	P=0.092	n.s.
Euphorbia spp					
Trees	P=0.073	n.s.	n.s.	n.s.	
Trees killed	38.0	57.0	0.0	6.3	
Treed	0.0	31.7	12.7	0.0	
lsd	42.9	48.2	23.7	15.5	
Burning	n.s.	n.s.	n.s.	n.s.	
Burnt	12.7	44.3	6.3	0.0	
Not burnt	25.3	44.3	6.3	6.3	
lsd	42.9	48.2	23.7	15.5	
Trees.Burnt	n.s.	n.s.	n.s.	n.s.	

Appendix N1.6k (contd). Statistical significance of tree killing and burning on the soil seedbank of *Fimbristylis spp., H. contortus, Hybanthus spp.,* and *Indigofera spp.* at Keilambete (fire study)

Soil seed bank	**1995-1996**	**1996-1997**	**1997-1998**	**1998-1999**	**1999-2000**
Fimbristylis spp					
Trees			n.s.	n.s.	n.s.
Trees killed			57.0	70.0	51.0
Treed			25.0	38.0	51.0
lsd			99.2	104.0	63.9
Burning			n.s.	n.s.	n.s.
Burnt			6.0	13.0	32.0
Not burnt			76.0	95.0	70.0
lsd			99.2	104.0	63.9
Trees.Burnt			n.s.	n.s.	n.s.
Heteropogon contortus					
Trees	n.s.	n.s.	n.s.	n.s.	n.s.
Trees killed	133.0	70.0	209.0	114.0	329.0
Treed	32.0	108.0	209.0	95.0	253.0
lsd	247.8	154.7	190.9	177.8	178.3
Burning	n.s.	n.s.	n.s.	P=0.072	n.s.
Burnt	32.0	120.0	165.0	25.0	348.0
Not burnt	133.0	57.0	253.0	184.0	234.0
lsd	247.8	154.7	190.9	177.8	178.3
Trees.Burnt	n.s.	n.s.	n.s.	n.s.	n.s.
Hybanthus spp					
Trees	n.s.	n.s.	n.s.	n.s.	
Trees killed	38.0	51.0	6.3	89.0	
Treed	12.7	32.0	12.7	19.0	
lsd	35.8	52.9	26.8	100.0	
Burning	*	n.s.	n.s.	n.s.	
Burnt	44.3	25.0	12.7	63.0	
Not burnt	6.3	57.0	6.3	44.0	
lsd	35.8	52.9	26.8	100.0	
Trees.Burnt	*	n.s.	n.s.	n.s.	
Indigofera spp					
Trees	n.s.	n.s.	P=0.059	n.s.	n.s.
Trees killed	0.0	13.0	19.0	6.3	6.3
Treed	6.3	32.0	0.0	6.3	19.0
lsd	15.5	49.8	20.0	23.7	31.0
Burning	n.s.	P=0.072	n.s.	n.s.	P=0.092
Burnt	0.0	0.0	12.7	0.0	0.0
Not burnt	6.3	44.0	6.3	12.7	25.3
lsd	15.5	49.8	20.0	23.7	31.0
Trees.Burnt	n.s.	n.s.	n.s.	n.s.	n.s.

Appendix N1.6k (contd). Statistical significance of tree killing and burning on the soil seedbank of *Portulaca spp.*, *Pterocaulon spp.*, *Sonchus spp.* and *Spermacoce spp.* at Keilambete (fire study)

Soil seed bank	**1995-1996**	**1996-1997**	**1997-1998**	**1998-1999**	**1999-2000**
Portulaca spp					
Trees	n.s.	n.s.	n.s.	n.s.	n.s.
Trees killed	6.0	13.0	6.3	6.3	25.3
Treed	44.0	63.0	12.7	6.3	6.3
lsd	65.1	107.4	29.7	23.7	42.9
Burning	n.s.	n.s.	n.s.	n.s.	n.s.
Burnt	19.0	63.0	19.0	6.3	12.7
Not burnt	32.0	13.0	0.0	6.3	19.0
lsd	65.1	107.4	29.7	23.7	42.9
Trees.Burnt	n.s.	n.s.	n.s.	n.s.	n.s.
Pterocaulon spp					
Trees	n.s.		n.s.	n.s.	n.s.
Trees killed	0.0		0.0	12.7	44.0
Treed	12.7		6.3	12.7	76.0
lsd	17.9		15.5	34.7	154.7
Burning	n.s.		n.s.	n.s.	n.s.
Burnt	6.3		0.0	12.7	89.0
Not burnt	6.3		6.3	12.7	32.0
lsd	17.9		15.5	34.7	154.7
Trees.Burnt	n.s.		n.s.	n.s.	n.s.
Sonchus spp					
Trees	n.s.			n.s.	n.s.
Trees killed	0.0			70.0	6.0
Treed	6.3			38.0	32.0
lsd	15.5			59.3	53.7
Burning	n.s.			n.s.	n.s.
Burnt	0.0			44.0	25.0
Not burnt	6.3			63.0	13.0
lsd	15.5			59.3	53.7
Trees.Burnt	n.s.			n.s.	n.s.
Spermacoce spp					
Trees	n.s.	n.s.	n.s.	n.s.	n.s.
Trees killed	0.0	38.0	19.0	19.0	12.7
Treed	25.3	0.0	25.0	0.0	12.7
lsd	34.7	93.0	58.7	46.5	20.0
Burning	n.s.	n.s.	n.s.	n.s.	n.s.
Burnt	19.0	0.0	13.0	0.0	19.0
Not burnt	6.3	38.0	32.0	19.0	6.3
lsd	34.7	93.0	58.7	46.5	20.0
Trees.Burnt	n.s.	n.s.	n.s.	n.s.	n.s.

Appendix N1.6k (contd). Statistical significance of tree killing and burning effect on the soil seedbank of *T. loliiformis, Wahlenbergia spp.* and *Zornia spp.* at Keilambete (fire study)

Soil seed bank	1995-1996	1996-1997	1997-1998	1998-1999	1999-2000
Tripogon loliiformis					
Trees	n.s.	n.s.	n.s.		n.s.
Trees killed	12.7	19.0	146.0		57.0
Treed	12.7	6.3	89.0		32.0
lsd	20.0	36.9	204.6		53.7
Burning	n.s.	n.s.	n.s.		*
Burnt	19.0	6.3	89.0		76.0
Not burnt	6.3	19.0	146.0		13.0
lsd	20.0	36.9	204.6		53.7
Trees.Burnt	n.s.	n.s.	n.s.		n.s.
Wahlenbergia spp					
Trees	*	n.s.	n.s.	P=0.053	*
Trees killed	108.0	114.0	443.0	602.0	652.0
Treed	291.0	82.0	533.0	1172.0	1678.0
lsd	176.5	213.0	564.2	578.5	740.6
Burning	n.s.	n.s.	P=0.095	**	n.s.
Burnt	152.0	38.0	310.0	380.0	963.0
Not burnt	247.0	158.0	766.0	1393.0	1368.0
lsd	176.5	213.0	564.2	578.5	740.6
Trees.Burnt	n.s.	n.s.	n.s.	n.s.	n.s.
Zornia spp					
Trees	n.s.	P=0.092	n.s.		n.s.
Trees killed	0.0	0.0	12.7		12.7
Treed	12.7	12.7	12.7		12.7
lsd	31.0	15.5	34.7		17.9
Burning	n.s.	P=0.092	n.s.		*
Burnt	12.7	0.0	12.7		25.3
Not burnt	0.0	12.7	12.7		0.0
lsd	31.0	15.5	34.7		17.9
Trees.Burnt	n.s.	P=0.092	n.s.		n.s.

Note: n.s. = not significant (P>0.10); * = P<0.05; ** = P<0.01; *** = P<0.001

Appendix N1.6l. Statistical significance of tree killing and burning on the survival of *B. ewartiana*, *C. fallax* and *H. contortus* at Keilambete (charting study)

Survival	**1995-96**	**1996-97**	**1997-98**	**1998-99**	**1999-2000**
B. ewartiana					
Trees	n.s.	n.s.	n.s.	n.s.	n.s.
Trees killed	0.958	0.897	0.844	0.971	0.968
Treed	0.893	0.955	0.868	0.950	0.975
LSD	0.094	0.253	0.250	0.119	0.067
Burning	n.s.	n.s.	n.s.	n.s.	n.s.
Burnt	0.921	0.898	0.839	0.967	0.951
Not burnt	0.930	0.954	0.873	0.954	0.991
LSD	0.094	0.253	0.250	0.119	0.067
Trees.Burnt	n.s.	n.s.	n.s.	n.s.	n.s.
Trees killed					
Burnt	0.959	0.817	0.813	0.967	0.936
Not burnt	0.958	0.978	0.875	0.974	1.000
Treed					
Burnt	0.884	0.979	0.864	0.967	0.967
Not burnt	0.902	0.931	0.871	0.933	0.982
LSD	0.133	0.358	0.353	0.168	0.095
C. fallax					
Trees	n.s.	n.s.	n.s.	n.s.	
Trees killed	0.985	0.956	0.905	1.000	1.000
Treed	0.936	0.944	0.960	0.947	1.000
LSD	0.101	0.062	0.139	0.094	0.000
Burning	n.s.	n.s.	n.s.	n.s.	
Burnt	0.971	0.965	0.926	0.991	1.000
Not burnt	0.949	0.934	0.938	0.955	1.000
LSD	0.101	0.062	0.139	0.094	0.000
Trees.Burnt	n.s.	n.s.	n.s.	n.s.	
Trees killed					
Burnt	1.000	0.978	0.920	1.000	1.000
Not burnt	0.970	0.933	0.889	1.000	1.000
Treed					
Burnt	0.942	0.952	0.931	0.982	1.000
Not burnt	0.929	0.935	0.988	0.911	1.000
LSD	0.143	0.088	0.197	0.134	0.000

Appendix N1.6l (contd). Statistical significance of tree killing and burning on the survival of *B. ewartiana*, *C. fallax* and *H. contortus* at Keilambete (charting study)

	1995-96	**1996-97**	**1997-98**	**1998-99**	**1999-2000**
H. contortus					
Trees	n.s.	n.s.	n.s.	n.s.	n.s.
Trees killed	0.693	0.794	0.851	0.913	0.739
Treed	0.785	0.833	0.786	0.891	0.834
LSD	0.164	0.125	0.198	0.171	0.167
Burning	n.s.	*	n.s.	n.s.	*
Burnt	0.685	0.735	0.777	0.902	0.879
Not burnt	0.793	0.892	0.859	0.902	0.694
LSD	0.164	0.125	0.198	0.171	0.167
Trees.Burnt	n.s.	n.s.	n.s.	n.s.	n.s.
Trees killed					
Burnt	0.610	0.671	0.776	0.893	0.802
Not burnt	0.775	0.917	0.926	0.933	0.677
Treed					
Burnt	0.761	0.800	0.779	0.911	0.956
Not burnt	0.810	0.867	0.792	0.872	0.712
LSD	0.232	0.176	0.280	0.241	0.236

Note: n.s. = not significant (P>0.10); * = P<0.05; ** = P<0.01; *** = P<0.001

Appendix N1.6m. Statistical significance of tree killing and burning on the survival hazard analysis of *B. ewartiana*, *C. fallax* and *H. contortus* in the grazing and burning trial at Keilambete (charting study)

	1994	1995	1997
Grazing Trial			
B. ewartiana			
Year	***	***	***
Trees	n.s.	n.s.	n.s.
Grazing Pressure	***	**	P=0.061
Trees.Graze	P=0.091	n.s.	n.s.
C. fallax			
Year	***	n.s.	***
Trees	n.s.	n.s.	***
Grazing Pressure	n.s.	n.s.	***
Trees.Graze	n.s.	n.s.	***
H. contortus			
Year	***	***	**
Trees	n.s.	n.s.	n.s.
Grazing Pressure	**	P=0.086	n.s.
Trees.Graze	n.s.	n.s.	n.s.
Burning Trial			
B. ewartiana			
Year		*	
Trees		n.s.	
Burning		n.s.	
Trees.Burnt		n.s.	
C. fallax			
Year		**	
Trees		n.s.	
Burning		n.s.	
Trees.Burnt		n.s.	
H. contortus			
Year		***	
Trees		n.s.	
Burning		*	
Trees.Burnt		n.s.	

Note: n.s. = not significant (P>0.10); * = P<0.05; ** = P<0.01; *** = P<0.001

Appendix N1.7a. Statistical significance of tree killing and grazing pressure on the liveweight gain per head and per hectare of weaners at Keilambete

	1994-95		1995-96		1996-97		1997-98		1998-99		1999-2000		2000-2001	
	Kg/ha	Kg/hd	Kg/ha	Kg/hd	Kg/ha	Kg/hd	Kg/ha	Kg/hd	Kg/ha	Kg/hd	Kg/ha	Kg/hd	Kg/ha	Kg/hd
Trees	**	n.s.	n.s.	n.s.	***	n.s.	**	**	**	n.s.	n.s.	P=0.086	**	P=0.097
Trees killed	76	148	49	108	67	170	86	120	82	234	-3	2	95	173
Treed	45	161	36	146	41	171	48	80	59	220	-8	-11	63	156
lsd	14	21	34	58	7	26	16	19	9	41	10	15	19	22
Grazing Pressure	**	**	n.s.	*	**	n.s.	*	n.s.	***	n.s.	*	*	*	n.s.
Low	38	177	41	192	40	184	51	111	75	214	4	10	55	162
Medium	70	168	56	132	54	164	70	96	87	234	-1	-1	94	162
High	73	119	31	55	69	163	79	93	50	233	-19	-22	86	171
lsd	17	26	42	71	9	32	20	24	11	50	12	19	23	26
Trees. Graze	n.s.	n.s.	n.s.	n.s.	*	n.s.	P=0.071	n.s.	**	n.s.	n.s.	n.s.	n.s.	P=0.060
Trees killed														
Low	50	174	50	175	53	184	62	129	73	219	6	16	68	177
Medium	88	162	64	109	59	165	84	116	105	240	3	6	109	151
High	90	109	31	39	89	161	111	115	67	242	-17	-16	107	192
Treed														
Low	27	180	31	209	27	184	41	93	77	209	1	4	43	147
Medium	53	174	47	156	49	163	55	76	68	227	-4	-9	79	172
High	56	128	31	72	48	166	46	72	32	223	-22	-27	66	150
lsd	24	37	60	101	12	46	28	33	15	70	17	27	33	37

Note: n.s. = not significant (P>0.10); * = P<0.05; ** = P<0.01; *** = P<0.001 ; lsd = least significant difference (P < 0.05)

Appendix N1.7b. Statistical significance of tree killing and grazing pressure on the liveweight gain per head & per hectare of weaner steers in the grazing trial compared with the COMM paddock, Keilambete

	1994-95		1995-96		1996-97		1997-98		1998-99		1999-2000		2000-2001	
	kg/ha	kg/hd	kg/ha	kg/hd	kg/ha	kg/hd	kg/ha	kg/hd	kg/ha	kg/hd	kg/ha	kg/hd	kg/ha	kg/hd
	P=0.082	n.s.	n.s.	n.s.	n.s.	n.s.	*	n.s.	n.s.	n.s.	*	**	*	n.s.
Trial (other)	61	155	43	127	54	171	67	100	71	227	-5	-4	79	165
COMMk	38	141	41	152	50	179	23	97	60	214	15	55	42	153
LSD	26	40	64	109	13	49	30	36	16	76	19	29	35	40
	**	n.s.	n.s.	n.s.	***	n.s.	**	**	**	n.s.	n.s.	P=0.086	**	P=0.097
Trees killed	76	148 a	49 a	108 a	67	170 a	86	120 a	82	234 a	-3 a	3	95	174 a
Treed	45 a	161 a	37 a	146 a	42 a	171 a	48 a	81 a	59 a	220 a	-8 a	-10	63 a	157 a
COMM	38 a	141 a	41 a	152 a	50 a	179 a	23 a	97 a	60 a	214 a	15 a	55 a	42 a	153 a
LSD[1]	14	21	34	58	7	26	16	19	9	41	10	15	19	22
LSD[2]	27	41	67	112	14	51	31	37	17	78	19	30	37	42
Grazing	**	**	n.s.	*	**	n.s.	*	n.s.	***	n.s.	*	*	*	n.s.
Low	38 a	177 a	41 a	193 a	40 a	184 a	52 a	111 a	75 a	215 a	4 a	10	56 a	162 a
Medium	70	168 a	56 a	133 a	54 a	164 a	70	96 a	87	234 a	-1 a	-1	94	162 a
High	73	119 a	31 a	56 a	69	163 a	79	93 a	50 a	233 a	-19	-21	86	172 a
COMM	38 a	141 a	41 a	152 a	50 a	179 a	23 a	97 a	60 a	214 a	15 a	55 a	42 a	153 a
LSD[1]	17	26	42	71	9	32	20	24	11	50	12	19	23	26
LSD[2]	28	42	69	116	14	53	32	38	17	81	20	31	38	43
	n.s.	n.s.	n.s.	n.s.	*	n.s.	P=0.071	n.s.	**	n.s.	n.s.	n.s.	n.s.	P=0.060
Trees killed														
Low	50 a	174 a	51 a	176 a	53 a	184 a	62	129 a	73 a	220 a	6 a	16	68 a	177 a
Medium	88	162 a	65 a	109 a	59 a	165 a	84	116 a	105	241 a	3 a	7	110	152 a
High	91	109 a	32 a	39 a	90	161 a	111	115 a	67 a	243 a	-17	-15	107	193 a
Low	27 a	180 a	31 a	210 a	27	184 a	42 a	94 a	77 a	210 a	1 a	4	43 a	147 a
Medium	53 a	174 a	47 a	157 a	49 a	164 a	56 a	76 a	69 a	227 a	-4 a	-8	79 a	172 a
High	56 a	128 a	31 a	72 a	48 a	166 a	47 a	72 a	33	224 a	-22	-27	66 a	151 a
COMM	38 a	141 a	41 a	152 a	50 a	179 a	23 a	97 a	60 a	214 a	15 a	55 a	42 a	153 a
LSD[1]	24	37	60	101	12	46	28	33	15	70	17	27	33	37
LSD[2]	31	46	75	126	15	57	35	42	19	88	22	34*	41	47

Note: n.s. = not significant (P>0.10); * = P<0.05; ** = P<0.01; *** = P<0.001
LSD[1] – comparing means within trial (Trmt, Graz, Trmt.Graz); LSD[2] – comparing trial means with COMM mean. * younger animals in COMM pdk
Means followed by same letter are not significantly different (here only given for comparing means with COMM)

APPENDIX N2. Poplar box site statistical analyses summary (part)

Appendix N2.1. Statistical models used to analyse research data from Glentulloch

Glentulloch

Burn Trial model

Burn trial without comparison across years (ex KerryB)

Variate : Cover %

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
BurnTrt	1	161.333	161.333	16.28	0.004
TreeTrt	1	61.653	61.653	6.22	0.037
BurnTrt.TreeTrt	1	3.853	3.853	0.39	0.550
Residual	8	79.267	9.908		
Total	11	306.107			

Variate : Cover % over Years

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Plot stratum					
BurnTrt	1	4473.44	4473.44	60.06	<.001
TreeTrt	1	9919.09	9919.09	133.16	<.001
BurnTrt.TreeTrt	1	190.20	190.20	2.55	0.149
Residual	8	595.91	74.49	2.26	
Plot.*Units* stratum					
Year	6	14679.97	2446.66	74.38	<.001
BurnTrt.Year	6	3241.57	540.26	16.42	<.001
TreeTrt.Year	6	1910.57	318.43	9.68	<.001
BurnTrt.TreeTrt.Year	6	715.08	119.18	3.62	0.005
Residual	48	1579.00	32.90		
Total	83	37304.84			

Grazing Trial model

Year = 1995

Variate : Cover %

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
GrazPr	2	531.9	266.0	1.63	0.271
TreeTrt	1	38.9	38.9	0.24	0.642
GrazPr.TreeTrt	2	42.4	21.2	0.13	0.880
Residual	6	977.1	162.9		
Total	11	1590.3			

Grand mean 34.6

RESPONSE VARIATE : COVER BETWEEN YEARS 1995 - 2001

***** **Analysis of variance** *****

Variate : Cover %

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Plot stratum					
GrazPr	2	1763.94	881.97	4.36	0.068
TreeTrt	1	5118.36	5118.36	25.28	0.002
GrazPr.TreeTrt	2	328.27	164.14	0.81	0.488
Residual	6	1214.66	202.44	5.49	
Plot.*Units* stratum					
Year	6	7356.51	1226.08	33.25	<.001
GrazPr.Year	12	918.66	76.55	2.08	0.045
TreeTrt.Year	6	990.96	165.16	4.48	0.002
GrazPr.TreeTrt.Year	12	208.53	17.38	0.47	0.919
Residual	36	1327.67	36.88		
Total	83	19227.56			

Appendix N2.2. Statistical significance and differences for numerous parameters from the plant charting data.

Codes used for the various parameters are –
Site: GS = Grazing study BS = Burn study **Trtmnt :** T = Treed, C = Trees killed
Transf?: N = data not transformed, Y = transformed, **0.5 = Sqrt transf, Ln = Log_e transformation
Mangmnt: B = Burnt, N = Unburnt, H = High grazing pressure, M = Moderate grazing pressure, L = Low grazing pressure
trt X mgt : CH = Trees killed and High grazing pressure etc **Species :** Ac = *Aristida calycina*, Ds = *D. seriecum*, Cf = *C. fallax* etc.
Plots : Uses plot or paddock numbers from Appendix A
eg. 9=6=12|5=11=8 means plots 9,6&12 were n.s. but all 3 were signif. diff from plots 5,11&8 which were themselves internally n.s.

					FACTORS							
Output file name	**Site**	**Year**	**Parameter**	**Transf?**	**Mangmnt**	**Trtmnt**	**trt X mgt**	**Reps**	**Plots**	**Species**	**Year**	**Yr interactns**
1995 BS initial variaby anal .out	BS	1995	Area95	N	<0.001; B << N	0.014 ; T < C		n.s.	<0.001; 6=5=2=12| 1=4=10=9=3|8= 11=7	<0.001; Ac=Ar=Ds=Bd=Er,Cf? ?	-	
1995 GS initial variaby anal .out	GS	1995	Area95	N	<0.001 ; H<M=L	< 0.001 ; T < C		0.006 ; 2 < 1	<0.001 ; 9=6=12|5=11=8| 4=3=10 , 7=2=1	< 0.001 ; Ac=Bd < Cf=Ar < Er	-	
Arical Absent %age BS anal	BS	All	%loss	N	ns	ns				na	<0.001; 1998<1999 & 2000<1999	
Arical Absent %age GS anal	GS	All	%loss	N	ns	ns				na	<0.006; 98=00; 97>98&00	
Arical Absent nbrs BS anal x	BS											
Arical Absent nbrs GS anal	GS	All	Nbr_lost	N	ns	ns	0.01			na	<0.001: 00<97-8-9	
Arical BS Gones anal .out	BS	96 - 00	Gone1	**0.5	n.s.	n.s.		n.s.		-	<0.001; 96<00<97<98<99	
Arical GS Gones anal .out	GS	All	Gone	**0.5	ns	0.036; T>C	0.004; CH<CM&T H&TL;TH> TL&TM				<0.001; 00<97&99	

Output file name		Site	Year	Parameter	Transf?	FACTORS: Mangmnt	Trtmnt	trt X mgt	Reps	Plots	Species	Year	Yr interactns
Arical BS orig areas anal .out		BS	1995	Area95	Ln	<0.001; N>B	ns	ns			na	na	
Arical GS orig areas anal .out	x	GS											
Arical BS recruits anal .out		BS	All	Nbr_new	N	0.058; N>B	ns	ns				<0.001; 97>all: 00<98&99	yrXmgmt
Arical GS recruits anal .out	x	GS											
Arical BS rep areas anal .out		BS	All	Area ttl	**0.5	0.039; B<N	ns	ns				<0.001; 96>95>97>98>00>99	
Arical GS rep areas anal .out		GS	All	Area(pdk totls)	N	ns	ns	ns				ns	
Ariram Absent %age BS anal		BS	All	%loss	N	ns	ns	ns				0.001;00<98<99=97	
Ariram Absent %age GS anal		GS	All	%loss	N	0.009;M=L<H	0.016; T<C	0.026; CH>rest;TL>TM					
Ariram Absent nbrs BS anal.out	x	BS											
Ariram Absent nbrs GS anal.out	x	GS											
Ariram BS Gones anal .out		BS	All	Gone	**0.5	ns	ns	ns				<0.001; 97=99>98>00	
Ariram GS Gones anal .out		GS	All	Gone	**0.5	ns	ns	ns				<0.001; 97>99=98;99>00	
Ariram BS recruits anal .out		BS	All	Nbr_new	N	ns	ns	ns				<0.001; 97>99=98>00	
Ariram GS recruits anal .out	x	GS											
Ariram BS orig areas anal .out	x	BS											
Ariram GS orig areas anal .out	x	GS											
Ariram BS rep areas anal .out	x	BS											
Ariram GS rep areas anal .out		GS	All	Area	N	ns	ns	ns				<0.004; 95<rest;	yrXmgt
Botdec Absent %age BS anal		BS	All	%loss	N	ns	ns	ns				<0.001; 99>98=97=00;98>00	
Botdec Absent %age GS anal		GS	All	%loss	N	ns	0.007; C>T	ns				<0.001; 97=98>99>00	
Botdec Absent nbrs BS anal	x	BS											
Botdec Absent nbrs GS anal	x	GS											

Output file name	Site	Year	Parameter	Transf?	FACTORS Mangmnt	Trtmnt	trt X mgt	Reps	Plots	Species	Year	Yr interactns
Botdec BS Gones anal .out	BS	All	Gone	**0.5	ns	ns	ns				<0.001; 99>98>97=00	yrXmgmt
Botdec GS Gones anal .out	GS	All	Gone	**0.5	ns	ns	ns				<0.001; 98>97=99=00; 00<97	
Botdec BS orig areas anal x	BS											
Botdec GS orig areas anal x	GS											
Botdec BS recruits anal .out	BS	All	Nbr_new	N/Y	ns	ns	ns				<0.001; 97>98=99>00	
Botdec GS recruits anal .out x	GS											
Botdec BS rep areas anal .out	BS	All	Area	**0.5	ns	ns	ns				<0.001; 99=00>98=97=96 >95	yrXmgmt
Botdec GS rep areas anal .out	GS	All	Area	**0.5	ns	ns	ns				<0.001; 99=00>97=98>96 >95	yrXtrtmt
Chrfal Absent %age BS anal	BS	All	%loss	N	ns	ns	ns				0.001;99….	
Chrfal Absent %age GS anal	GS	All	%loss	N	ns	0.032; C>T	ns				<0.001; 97=99=98>00	
Chrfal BS recruits anal .out	BS	All	Nbr_new	N/Y	ns	ns	ns				<0.001; 97>98>00=99>96	
Chrfal GS recruits anal .out x	GS											
Chfal GS orig areas anal x	GS											
Chfal BS orig areas anal x	BS											
Chrfal Absent nbrs BS anal .out x	BS											
Chrfal Absent nbrs GS anal .out x	GS											
Chrfal BS Gones anal .out	BS	All	Gone	**0.5	ns	ns	ns				<0.001; 99=98>97>00	
Chrfal GS Gones anal .out	GS	All	Gone	**0.5	ns	ns	ns				<0.001; 97>98>99>00	yrXtrtmt;yrX mgmnt
Chrfal BS rep areas anal .out	BS	All	Area	**0.5	ns	ns	ns				ns	
Chrfal GS rep areas anal .out	GS	All	Area	**0.5	ns	ns	ns				<0.001; 97=98=96>95=99 >00	yrXmgmt
Cohort 1995 initial BS indiv area .out	BS	1995	Indiv plant area - origs Area95	Ln	<0.001 N > B	<0.001 C > T		<0.001 2=1 < 3	<0.001; 6=5|4=1=2|8=12| 9=10=3=11=7	0.029 Ac=Ar=Ds ; Ar<Bd ; Ds=Bd=Cf=Er		

Output file name	Site	Year	Parameter	Transf?	FACTORS: Mangmnt	Trtmnt	trt X mgt	Reps	Plots	Species	Year	Yr interactns
Cohort 1995 initial GS indiv area .out	GS	1995	Area95	Ln	<0.001; H<L=M	<0.001; C>T		0.002; 1>2	<0.001;9=12<4= 6<3<5=11=10=8 |2=7<1	<0.001; Cf=Ac|=Ds<Bd<Ar=Er		
Cohort 1997 initial BS indiv area .out	BS	1997	Area97	Ln	ns	ns		ns	0.049; 11=3=12=6|5=4 =8=2=10|7=1=9	0.006; Ac=Ar|Bd=Ds|Er=Cf		
Cohort 1997 initial GS indiv area .out	GS	1997	Area97	Ln	<0.001; H<M<L	<0.001; T<C		ns	<0.001; 6<12=9|11=5=4 =2=10=8=3|7=1	<0.001; Ac<Ar=Bd=Er|Ds=Cf		
Cohort 1998 initial BS indiv area .out	BS	1998	Area98	Ln	ns	ns		ns	ns	0.004; Ac=Er=Ar|Ds=Bd=Cf		
Cohort 1998 initial GS indiv area .out	GS	1998	Area98	Ln	0.003; H<L=M	0.028; T<C		0.033; 2<1	<0.001; 9=11=6|10=12=4 |3=5=7=1=8=2	0.044; Cf=Ac|Ar=Ds=Bd|Er		
Cohort 1999 initial BS indiv area .out	BS	1999	Area99	Ln	ns	<0.001; T<C		ns	<0.001; 2=11=8|1=6=10= 12|4=7=3|5=9	<0.001; Ac=Ar=Cf=Er|Bd=Ds		
Cohort 1999 initial GS indiv area .out	GS	1999	Area99	Ln	<0.001; H<M<L	<0.001; T<C		ns	<0.001; 11=9=12=3|6=5 =4=10|2=1=8<7	<0.001; Ac=Ar=Er|Bd=Cf<Ds		
Cohort 2000 initial BS indiv area .out	BS	2000	Area00	N	ns	ns			ns	ns		
Cohort 2000 initial GS indiv area .out	GS	2000	Area00	Ln	<0.001; H<M=L	<0.001; T<C		ns	<0.001; 6=12=9<3=11|8 =5=1=10=4|2=7	<0.001; Ac=Cf>Er=Ar=Ds<Bd		
Dicser Absent %age BS anal	BS	All	%loss	N	ns	0.018; T<C					<0.001; 97>99>98>00	yrXmgmt
Dicser Absent %age GS anal	GS	All	%loss	N	ns	ns	ns				<0.001; 97=98>99>00	
Dicser BS Gones anal .out	BS	All	Gone	N	ns	ns	ns				0.047; 97=99|98|00	
Dicser GS Gones anal .out	GS	All	Gone	**0.5	ns	ns	ns				<0.001; 98=97|99=00	
Dicser BS recruits anal .out	BS	All	Nbr_new	**0.5	ns	ns	0.041; TB= CN=TN|CB				<0.001; 99=97|00=98	
Dicser GS recruits anal .out x	GS											

						FACTORS							
Output file name		Site	Year	Parameter	Transf?	Mangmnt	Trtmnt	trt X mgt	Reps	Plots	Species	Year	Yr interactns
Dicser Absent nbrs BS anal .out	x	BS											
Dicser Absent nbrs GS anal .out	x	GS											
Dicser BS orig areas anal	x	BS											
Dicser GS orig areas anal	x	GS											
Dicser BS rep areas anal .out		BS	All	Area	**0.5	ns	ns	0.031; TB=CN=TN| CB?				0.001; 99=00=96>95>97 =98	
Dicser GS rep areas anal .out		GS	All	Area	**0.5	ns	ns	ns				<0.001; 99=00>97>98>96 >95	yrXmgmt
Entram BS orig areas anal	x	BS											
Entram GS orig areas anal	x	GS											
Entram BS recruits anal .out		BS	not enough data to analyse										
Entram GS recruits anal .out	x	GS											
Entram Absent nbrs BS anal.out	x	BS											
Entram Absent nbrs GS anal .out	x	GS											
Entram BS rep areas anal .out		BS	All	Area	Ln	ns	ns	ns	too many zeros for worthwhile analysis			ns	
Entram GS rep areas anal .out		GS	All	Area	**0.5	ns	ns	ns				<0.001; 99>98>00 =97>96>95	
Entram Absent %age BS anal		BS	All	%loss	N	ns	ns	ns				0.044;no REML done yet	
Entram Absent %age GS anal		GS	All	%loss	N	ns	ns	ns				0.006;no REML done yet	
Entram BS Gones anal .out	x	BS											
Entram GS Gones anal .out		GS	All	Gone	**0.5	ns	ns	ns				ns	
Orig plant size varn .out		BS	1995	Area95	N								

Appendix N2.3. Statistical summary of the Glentulloch Burning trial main results

	Autumn of year						
Variate	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**
Cover %							
Burning	***	0.083	n.s.	***	*	***	**
Trees	*	***	***	***	***	***	*
Burn * Trees	n.s.	n.s.	n.s.	***	n.s.	n.s.	n.s.
lsd B*T	5.93	6.81	12.7	5.32	13.13	7.38	21.58
% Green							
Burning	***	*	n.d.	*	n.s.	n.s.	n.s.
Trees	n.s.	n.s.	n.d.	n.s.	***	<0.001	n.s.
Burn * Trees	n.s.	n.s.	n.d.	n.s.	n.s.	n.s.	n.s.
lsd B*T	5.99	5.94		9.02	8.27	13.01	19.24
DMY (kg/ha)							
Burning	n.s.	n.s.	*	<0.001	n.s.	0.076	**
Trees	<0.001	<0.001	**	<0.001	<0.001	<0.001	**
Burn * Trees	n.s.	n.s.	*	<0.001	n.s.	n.s.	*
lsd B*T	369	693	1882	1022	765	597	1486

	All years
Cover % over years	
Burning	***
Trees	***
Burn * Trees	n.s.
Year	***
Burning * Year	***
Trees * Year	***
Burn * Trees * Year	**
% Green over years	
Burning	*
Trees	**
Burn * Trees	*
Year	<0.001
Burning * Year	*
Trees * Year	<0.001
Burn * Trees * Year	n.s.
DMY over years	
Burning	**
Trees	<0.001
Burn * Trees	n.s.
Year	<0.001
Burning * Year	<0.001
Trees * Year	n.s.
Burn * Trees * Year	n.s.

Appendix N2.4. Statistical summary of the main grazing trial data from Glentulloch

	Autumn of year						
Variate	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**
Cover %							
Graz pressure	n.s.	0.069	0.072	*	*	n.s.	0.069
Trees	n.s.	<0.001	0.094	<0.001	<0.001	*	***
Grz press * Trees	n.s.	n.s.	n.s.	n.s.	n.s	n.s.	0.076
lsd GP * T	31.23	15.26	24.3	13.49	10.1	19.13	9.42
% Green							
Graz pressure	n.d.	<0.001	**	<0.001	n.s.	n.s.	n.s.
Trees	n.d.	n.s.	***	**	*	*	*
Grz press * Trees	n.d.	n.s.	n.s.	*	n.s.	n.s.	n.s.
lsd GP * T		15.9	18.17	21.5	9.79	14.87	14.65
DMY (kg/ha)							
Graz pressure	n.s.	*	0.059	*	**	0.061	*
Trees	n.s.	**	***	***	<0.001	**	**
Grz press * Trees	n.s.	0.088	n.s.	n.s.	*	n.s.	n.s.
lsd GP * T	772	1350	1237	1538	548	901	561
		All years					
Cover % over years							
Graz pressure		0.068					
Trees		**					
Grz press * Trees		n.s.					
Year		<0.001					
Grz press * Year		*					
Trees * Year		**					
GP * Trees * Year	n.s.						
% Green over years							
Graz pressure		n.s.					
Trees		*					
Grz press * Trees		n.s.					
Year		<0.001					
Grz press * Year		<0.001					
Trees * Year		<0.001					
GP * Trees * Year	n.s.						
DMY over years							
Graz pressure		**					
Trees		<0.001					
Grz press * Trees		n.s.					
Year		<0.001					
Grz press * Year		n.s.					
Trees * Year		0.066					
GP * Trees * Year	0.078						

Appendix N2.5. Statistical summary for the Cattle performance at the Glentulloch grazing trial

Glentulloch : Cattle liveweight change (kg / ha and kg / hd) for Herds 1 to 7 (Nov. 1994 to Jun. 2002)

	1994-95		1995-96		1996-97		1997-99		1999-2000		2000-01		2001-2002		Mean 1994-2002	
	kg/ha	**kg/hd**	**kg/ha**	**kg/hd**	**kg/ha**	**kg/hd**	**kg/ha**	**kg/hd**	**kg/ha**	**kg/hd**	**kg/ha**	**kg/hd**	**kg/ha**	**kg/hd**	**kg/ha**	**kg/hd**
Tree Competition																
Treeless	68.7	151.0	79.5	171.0	50.1	109.1	156.2	288.1	70.9	157.4	65.9	152.6	70.7	151.0	80.3	168.6
Treed	37.2	120.6	35.3	118.7	22.5	77.2	70.8	274.3	30.2	122.4	32.1	126.5	22.8	103.8	35.8	134.8
LSD (P=0.05)	10.09	22.74	3.25	23.78	6.62	16.66	8.68	ns	17.02	24.00	10.59	23.63	14.18	19.39	6.28	16.20
Significance	**	*	***	**	***	**	***	ns	***	*	**	*	***	**	***	**
% Treeless/treed	184.7	125.2	224.9	144.0	222.7	141.4	220.5	105.0	234.7	128.6	205.6	120.6	310.1	145.4	224.0	125.1
Grazing Pressure																
Low	37.1	172.8	38.9	181.7	25.4	119.5	88.8	302.7	48.9	152.3	39.2	141.7	43.3	145.1	45.9	173.7
Medium	58.0	137.3	66.1	153.2	44.0	100.7	118.9	283.0	44.6	137.3	47.4	142.5	47.7	128.1	60.9	154.6
High	63.7	97.2	67.2	99.7	39.5	59.2	132.8	257.9	58.0	130.0	60.5	134.4	49.2	109.0	67.3	126.8
LSD (P=0.05)	12.35	27.85	3.98	29.12	8.11	20.40	10.63	ns	ns	ns	12.98	ns	ns	23.74	7.70	19.84
Significance								ns	ns	ns		ns	ns			
Tree Comp. * Graz Press																
Treeless																
Low	49.6	198.3	51.9	207.5	32.7	130.8	112.6	298.2	71.2	171.0	55.3	156.2	69.2	166.0	63.2	189.7
Medium	73.2	146.5	90.0	180.0	62.3	124.7	147.5	295.0	59.9	142.4	62.0	147.1	71.2	147.1	80.9	169.0
High	83.2	108.2	96.5	125.5	55.3	71.8	208.5	271.0	81.4	158.7	80.5	154.5	71.7	139.7	96.7	147.1
Treed																
Low	24.6	147.3	26.0	155.8	18.0	108.2	65.0	307.2	26.6	133.6	23.1	127.2	17.4	124.2	28.6	157.6
Medium	42.7	128.2	42.2	126.5	25.6	76.8	90.3	271.0	29.4	132.2	32.7	138.0	24.2	109.0	41.0	140.2
High	44.3	86.3	37.9	73.8	23.8	46.5	57.2	244.7	34.6	101.2	40.4	114.2	26.7	78.2	37.8	106.4
LSD (P=0.05)	ns	ns	5.63	ns	11.47	ns	15.04	ns	ns	ns	ns	ns	ns	ns	10.88	ns
Significance	ns	ns		ns		ns		ns	ns	ns	ns	ns	ns	ns		ns
Site mean	52.9	135.8	57.4	144.86	36.30	93.14	113.50	281.20	50.52	139.88	49.00	139.56	46.73	127.38	58.06	151.69

APPENDIX O. Sample time details, Ironbark and Poplar box sites

Appendix O1. Summary of experimental activities plus recording and sampling times at Glentulloch grazing and burning trials done by Roma staff

Location: 250 45.35.9' S, 1480 25.13.3' E at Weather Station (Paddock 7)

Research Activity	***Dates***							
Cattle Liveweight Weighing							Source of cattle	
Herd 1	30-Nov-1994	17-Feb-1995	19-Apr-1995	29-Jun-1995	21-Aug-1995	Cattle sold	Wallaroo	
Herd 2	25-Oct-1995	23-Mar-1996	14-Jun-1996	11-Sep-1996	25-Oct-1996	Cattle sold	Rostock	
Herd 3	28-Nov-1996	06-Feb-1997	13-May-1997	17-Jul-1997	17-Sep-1997	05-Nov-1997	Rostock	
Herd 4	10-Nov-1997	13-Jan-1998	17-Mar-1998	12-May-1998	02-Jul-1998	17-Aug-1998	Swans Lagoon	
	02-Nov-1998	15-Dec-1998	15-Feb-1999	30-Mar-1999	25-May-1999	28-Jun-1999		
Herd 5	01-Jul-1999	31-Aug-1999	13-Oct-1999	15-Dec-1999	01-Feb-2000	15-Mar-2000	Swans Lagoon	
	03-May-2000	15-Jun-2000	01-Aug-2000					
Herd 6	01-Aug-2000	14-Sep-2000	15-Nov-2000	14-Dec-2000	24-Jan-2001	21-Mar-2001	Swans Lagoon	(kept Herd 5)
	27-Apr-2001	06-Jun-2001						
Herd 7	6-Nov-2001	30-Jan-2002	27-Mar-2002	02-May-2002	12-Jun-2002		Swans Lagoon	
BOTANAL Pasture Sampling	Jan-1995	13 - 16 May 1996	14 - 18 Apr 1997	6 - 9 Apr 1998	12 - 14 Apr 1999	27-30-Mar 2000	10-18 Apr 2001	29 Apr - 2 May 2002
Grazing/Burn/R'off/Exclosures Composition, Yield, Green, /Cover								
Burning off - Burn site	3-Nov-94	05-Oct-1995 part burn - 2 plots	19-Sep-96	14-Oct-97	no burn wet winter/spring	24-Aug-1999	26-Oct-2000	16-Oct-2001
Burning off exclosures	Pdk 3	Pdk 6 totally exclosed	Pdk 6 wallaby grazed	Pdk 12	Pdk 7 east	Pdk 7 west	Pdk 9	
	26-Oct-2000	26-Oct-2000		26-Oct-2000	26-Oct-2000		26-Oct-2000	
Burning (Pdk 8 wildfire)	17-Nov-1999							
TRAPS Tree Recording	Oct-1995	Oct-1996	Sep-1997	10-12 &15 August 1999	Burn Site 17&18-Aug-1999	16-21 Apr 2002		
Tree Basal Area	1995	08-Jan-1997	Jun-2002	Bitterlich				
Original tree 1920 Basal diameter	28-Jun-2002							

Pasture Basal Area	Jun-1995	Nov-1996	Nov-1997	Oct-1998	2-Jun-1999 in BT	6 &7 Sept 2000 in GT	15 & 16 May 2001 GT	28&29 May 2002 in GT
					18-20 Oct 1999 in GT	7 Sept 2000 in BT	17 May 2001 BT	30 May 2002 in BT
Charting fixed plots	May-1995	Mar-1996	6 - 8 May 1997	17 - 19 June 1998	10 - 18 May 1999	5-7 June 2000		
Soil Seed Loads		16-Oct-1996	28-Aug-1997	24-Sep-1998	7-Sept 1999 in GT	23-Aug-2000 in GT		
					17 Aug 1999 in BT	24-Aug-2000 in BT		
Swiftsynd Pasture Growth Sites	**GE1- Pdk 1 Enteropogon**	**GD2-Pdk 7 Dichanthium**	**GC3-Pdk 4/CB1 Chrysopogon**	**GA4-Pdk 7 Aristida**	**GB5-BS (CB3) Bothriochloa**	**GB5T-TNB1 Bothriochloa (trees)**		
Mown off 1995	02-Mar-1995	02-Mar-1995	02-Mar-1995	07-Feb-1995	02-Mar-1995			
	27-Apr-1995	26-Jun-1995	22-Jun-1995	22-Jun-1995	22-Jun-1995			
	22-Jun-1995	16-Feb-1996	21-Feb-1996	16-Feb-1996	21-Feb-1996			
	21-Feb-1996	28-Apr-1996	20-May-1996	21-May-1996	20-May-1996			
	28-Apr-1996	21-May-1996	21-Jul-1996	20-Jul-1996	21-Jul-1996			
	21-May-1996	21-Jul-1996	23-Sep-1996	23-Sep-1996	17-Sep-1996			
	20-Jul-1996	17-Sep-1996						
	24-Sep-1996							
Mown off 1996	18-Sep-1996	17-Sep-1996	17-Sep-1996	17-Sep-1996	17-Sep-1996	22-Oct-1996		
	03-Jan-1997	03-Jan-1997	06-Jan-1997	17-Dec-1996	17-Dec-1996	06-Jan-1997		
	04-Mar-1997	04-Mar-1997	03-Mar-1997	04-Mar-1997	03-Mar-1997	03-Mar-1997		
	13-May-1997	13-May-1997	12-May-1997	13-May-1997	12-May-1997	12-May-1997		
	13-Aug-1997	13-Aug-1997	13-Aug-1997	13-Aug-1997	13-Aug-1997	13-Aug-1997		
	15-Oct-1997	14-Oct-1997		15-Oct-1997	14-Oct-1997	14-Oct-1997		
Mown off 1997	16-Oct-1997	14-Oct-1997	14-Oct-1997	16-Oct-1997	14-Oct-1997	16-Oct-1997		
	15-Jan-1998	15-Jan-1998	15-Jan-1998	15-Jan-1998	16-Jan-1998	16-Jan-1998		
	06-Jun-1998	06-Jun-1998	07-Jun-1998	06-Jun-1998	08-Jun-1998	08-Jun-1998		
Mown off 1998	02-Sep-1998	08-Sep-1998	08-Sep-1998	02-Sep-1998	08-Sep-1998	08-Sep-1998		
	22-Jan-1999	22-Jan-1999	22-Jan-1999	22-Jan-1999	22-Jan-1999	22-Jan-1999		
	24-May-1999	5/99 TH, Hassett	5/99 TH, Hassett	5/99 TH, Hassett	5/99 TH, Hassett	5/99 TH, Hassett		
Mown off 1999	20-Oct-1999	20-Oct-1999	20-Oct-1999	20-Oct-1999	20-Oct-1999	20-Oct-1999		
	09-May-2000	09-May-2000	10-May-2000	09-May-2000	10-May-2000	10-May-2000		
Mown off 2000	11-Oct-2000	11-Oct-2000	burnt off 26/10/2000	11-Oct-2000	burnt off 26/10/2000	burnt off 26/10/2000		

		22-May-2001	23-May-2001	22-May-2001	23-May-2001	22-May-2001	22-May-2001
Native pasture Chem. analysis		9/11-Apr-2002					
Pasture nutrient yields		9/11-Apr-2002					
NIRS - Faecal Sampling		05-Nov-1997	23-Nov-1997	16-Dec-1997	30-Dec-1997	13-Jan-1998	28-Jan-1998
	Herd 4	16-Feb-1998	02-Mar-1998	17-Mar-1998	01-Apr-1998	20-Apr-1998	30-Apr-1998
		12-May-1998	02-Jun-1998	15-Jun-1998	02-Jul-1998	15-Jul-1998	03-Aug-1998
		17-Aug-1998	02-Sep-1998	14-Sep-1998	29-Sep-1998	16-Oct-1998	02-Nov-1998
		17-Nov-1998	30-Nov-1998	15-Dec-1998	06-Jan-1999	18-Jan-1999	03-Feb-1999
		15-Feb-1999	05-Mar-1999	15-Mar-1999	30-Mar-1999	14-Apr-1999	03-May-1999
		13-May-1999	01-Jun-1999	16-Jun-1999	28-Jun-1999		
	Herd 5	14-Jul-1999	29-Jul-1999	16-Aug-1999	30-Sep-1999	13_Oct-1999	01-Nov-1999
		15-Nov-1999	01-Dec-1999	15-Dec-1999	06-Jan-2000	17-Jan-2000	01-Feb-2000
		18-Feb-2000	01-Mar-2000	15-Mar-2000	30-Mar-2000	17-Apr-2000	03-May-2000
		16-May-2000	30-May-2000	30-May-2000	15-Jun-2000	29-Jun-2000	15-Jul-2000
	Herd 6	01-Aug-2000	16-Aug-2000	30-Aug-2000	14-Sep-2000	02-Oct-2000	16-Oct-2000
		01-Nov-2000	15-Nov-2000	30-Nov-2000	14-Dec-2000	04-Jan-2001	16-Jan-2001
		30-Jan-2001	08-Mar-2001	15-Mar-2001	02-Apr-2001	18-Apr-2001	27-Apr-2001
Runoff - Soil/Water - Rainfall							
	1994	1-Oct-1994	3-Nov-1994	21-Nov-1994			
	1995	20-Jan-1995	6-Feb-1995	4-Oct-1995	16-Nov-1995	6-Dec-1995	
	1996	30-Jan-1996	21-May-1996	1-Nov-1996	13-Dec-1996		
	1997	21-Feb-1997	17-Mar-1997	5-Jun-1997	3-Oct-1997	14-Oct-1997	10-Nov-1997
		1-Dec-1997	16-Dec-1997	30-Dec-1997			
	1998	28-Jan-1998	16-Feb-1998	2-Mar-1998	12-Mar-1998	20-Apr-1998	27-Apr-1998
		12-May-1998	30-Jun-1998	23-Jul-1998	31-Jul-1998	12-Aug-1998	18-Sep-1998
		29-Sep-1998	29-Oct-1998	17-Nov-1998	30-Nov-1998	22-Dec-1998	
	1999	6-Jan-1999	3-Feb-1999	15-Feb-1999	25-Feb-1999	5-Mar-1999	23-Mar-1999
		7-Apr-1999	13-May-1999	16-Jun-1999	30-Jun-1999	29-Jul-1999	7-Oct-1999
		31-Oct-1999	11-Nov-1999	14-Dec-1999			
	2000	06-Jan-2000	12-Jan-2000	20-Jan-2000	31-Jan-2000	18-Feb-2000	15-Mar-200
		09-May-2000	6-Aug-2000	1-Nov-2000	15-Nov-2000	24-Nov-2000	19-Dec-2000
	2001	4-Jan-2001	12-Jan-2001	30-Jan-2001	08-Feb-2001	08-Mar-2001	15-Mar-2001
		27-Apr-2001	03-Aug-2001		30-Oct-2001	07-Nov-2001	14-Nov-2001
		19-Nov-2001	28-Nov-2001	12-Dec-2001	18-Dec-2001		

2002	09-Jan-2002	18-Jan-2002	24-Jan-2002	21-Feb-2002	23-Feb-2002	27-Feb-2002
	03-Apr-2002	18-Apr-2002	12-Jun-2002			
Runoff water- Nurient analysis	24-Nov-2000					
	30-Jan-2001	14-Nov-2001	19-Nov-2001	28-Nov-2001		
	27-Feb-2002	03-Apr-2002	12-Jun-2002			
Runoff - Nurient analysis - Soil	30-Jan-2001	14-Nov-2001	19-Nov-2001	28-Nov-2001		
	27-Feb-2002	3-Apr-2002	12-Jun-2002			
LFA - Grazing trial	16-Oct-2000	Pdks 5 & 8 (50 m transect)				
Landscape Function Analysis	19-Dec-2000	Pdks 4, 7, 9, 12 (50m)				
Soil surface stability	21/28-Feb-2002					
LFA - Burning trial	8/9-Apr-2002					
LFA - Runoff sites (9)	10-Apr-2002					
LFA - Exclosures (7)	11-Apr-2002					
Tree Canopy Cover	21-Jul-1999	(Grazing trial recorded)				
Tree Root yield - Poplar box	13/16-Aug-2002	Pdk 5 Traps				
Tree leaf fall litter	01-Aug-2000	01-Dec-2000	Pdk 5			
Tree total biomass	2-4 June 2003	Burning trial site	TNb1, TB2, TNb3			
Grass Repeated defoliation	**Enteropogon ramosus**	**Dichanthium sericeum**	**Aristida ramosa**	**Bothriochloa bladhii**	**Chloris divaricata**	
Mowed off sites	**Pdk 1**	**Pdk 7**	**Pdk 7**	**(lane)**	**Pdk 8**	
	14-Dec-1999	14-Dec-1999	14-Dec-1999	14-Dec-1999	14-Dec-1999	
	17-Jan-2000	17-Jan-2000	17-Jan-2000	17-Jan-2000	17-Jan-2000	
	06-Mar-2000	06-Mar-2000	06-Mar-2000	06-Mar-2000	06-Mar-2000	
	16-Mar-2000	16-Mar-2000	16-Mar-2000	16-Mar-2000	16-Mar-2000	
	06-Dec-2000	30-Nov-2000	06-Dec-2000	06-Dec-2000	06-Dec-2000	
		21-Mar-2001	21-Mar-2001	21-Mar-2001	21-Mar-2001	
Recording Defoliation sites	15-May-2002					
Grass root yields	6-Dec-2000	12 grazing paddocks				
Soil Profile Characterisation	01-Aug-1996	Descriptions				

Soil Profile Chem/Phys Analysis	02-Aug-1996	Chem & Physical Analysis				
Soil profile moisture capacity						
Soil Surface Chem anal Grazing	22-Nov-2001					
Soil Surface Chem anal Burning	28-Nov-2001					
Soil Profile Salinity Analysis	23/24-May-2002	Descriptions, Chem analysis				
Photographs	06-Nov-1994					
(Fixed Point)	21-Apr-1995	01-Aug-1995				
	09-May-1996	08-Sep-1996	15-Aug-1996 P6			
	21-Feb-1997	20-Mar-1997	01-Aug-1997	23-Nov-1997		
	16-Feb-1998	01-Apr-1998	03-Aug-1998	16-Oct-1998		
	15-Feb-1999	21-Apr-1999	15-Aug-1999	13-Sep-1999	16-Nov-1999 P8	
	6-1-2000 P8	18-Feb-2000	10-May-2000	07-Sep-2000	16-Oct-2000	01-Nov-2000 P13
	12-Jan-2001	15-Mar-2001	18-Apr-2001	15-Jul-2001		07-Nov-2001
	19-Dec-2001	02-May-2002				

Group Meetings & Field days

"Maintop" group meeting 1994
"Glentulloch" Core group meeting 11-Apr-1995
Field day 26-Apr-1995
Core group field day 19-Jun-1996
Landcare field day 1-July-1997
Soils / Runoff field day 26-May-1998
Core group field day 31-Mar-1999
Field day 30-Aug-2000 -Core group, MLA, Agforce, SQBRC
Private tours of site - MLA, Producers, Students, Texas A&M staff, UQ, QDPI

Appendix O2. Keilambete Botanal pasture sampling dates 1994–2001

Burning trial	Grazing trial
1994 CNs 12/7/94 & 25/7/94 CBs 12/7/94 & 25/7/94 TNs 12/7/94 & 25/7/94 TBs 12/7/94 & 25/7/94	**1994** CH1 14/6/94 & 19/7/94 CH2 8/7/94 & 19/7/94 CL1 14/6/94, 30/6/94 & 7/7/94 CL2 8, 19 & 20/7/94 CM1 8/7/94 & 19/7/94 CM2 14/6/94 & 19/7/94 TH1 11/7/94 & 20/7/94 TH2 11/7/94 & 20/7/94 TL1 11/7/94 & 20/7/94 TL2 12, 20 & 22/7/94 TM1 11/7/94 & 20/7/94 TM2 11/7, 12/7, & 20/7/94
1995 CBs 7/4/95 CNs 10/4/95	**1995** CL1 10/495; CL2 11/4/95 CM1 10/4/95; CM2 10/4/95 CH1 10/4/95; CH2 10/4/95 TH1 6/4/95; TH2 6/4/95 TL1 5/4/95; TL2 7/4/95 TM1 6/4/95; TM2 6/4/95
1996 18/4/95 & 19/4/95	**1996** 16/4/95 – 19/4/95
1997 CBs 14/5/97 CNs 15/5/97	**1997** 21/4/97 – 24/4/97
1998 30/3/98 – 2/4/98	**1998** 30/3/98 – 2/4/98 Stock Pdk 6/5/98 Runoff plots 1/4/98
1999 12/4/99 – 16/4/99	**1999** 12/4/99 – 16/4/99 Stock Pdk 21/4/99 Runoff plots 16/4/99
2000 3/4/00 – 6/4/00	**2000** 3/4/00 – 6/4/00 Stock Pdk 10/5/00 Runoff plots 6/4/00
2001 30/4/01 – 2/5/01	**2001** 30/4/01 – 2/5/01 Stock Pdk 30/04/01

APPENDIX P. Spring burn conditions at Poplar box site

Table P1. Burn Experiment fire history (Swamp paddock), Glentulloch

Poplar box country ***Burn area of 6 blocks of 1 ha - 2 cleared/treed * burn * 3 reps***

Conditions	1994	1995	1996	1997	1998
Fire No.	1	2 (plots 1 and 9 only)	3	4	No Burn
Date	3/11/1994	5/10/1995	19/09/1996	14/10/1997	wet winter/spring
Time of Day	12 - 3.00 pm	12 - 4.00 pm		12-2.00 pm	fire wouldn't carry
Grass Condition	Dry and short	Green in Grass	Dry	Dry to Green tinges	Green grass and Calotis
Wind Speed (km/hr)	0 (nil)	0 (nil)	Gusty	5 - 10 km/hr gusty	
Wind Direction	-	-	West - North West	North West	
Air Temperature	Warm	Cool	Warm	Warm	
Relative Humidity					high
Rate of Spread	Very Slow	Slow - Nil	Good	5 km/hr and gusty	nil
Danger Index	Low	Low	moderate to high	moderate to high; wide breaks	nil
Flame height (m)	2 m in cleared	Low	4 m in cleared	4 m in cleared	no fire
Fuel Load- Trees	Low; estm 600 kg/ha	see Botanal DM yields	see Botanal DM yields	see Botanal DM yields	see Botanal DM yields;
-Cleared	Low; extra tree leaf litter				additional green growth
Litter	Tree leaf significant cover	Negligible	Negligible	Some in Cleared	
Fire assistance	Fuel fire lighter Bug	Fuel fire lighter	Fuel lighter in trees mainly	Fuel lighter in trees mainly	
Ease of burning- Trees	Constant assistance	Constant assistance; abandoned	Patchy to good fire in trees;	Patchy to good fire in trees;	
- Cleared	Frequent assistance	Frequent assistance	Very good fire in cleared	Very good fire in cleared	
Type of Fire	Cool; slow. Very difficult to burn. Walked back & forth over whole site using fire dripper. Tree litter carried fire betweengrass tussocks	Very Cool; slow. Couldn't get a burn in trees. Only burnt reps 1 & 3, mostly by hand dripper	Warm. slow burn under trees	Warm. slow burn under trees. good burn across cleared with gusts of wind	nil

Table P1 (contd). Burning conditions in 1999 – 2001 at the Glentulloch burning trial site

Poplar box country

	1999	2000	2001
Fire No.	5	6	7
Date	24/08/1999 (early)	26/10/2000 (after rain); followed by 50 mm	16/10/2001 (after light rain and rain predicted)
Time of Day	12-1 pm	11 - 1 pm	10 - 3 pm
Grass Condition	Dry, insignificant green	Dry, small amount green at base	Dry, sm amount green tinge at base some tussocks
Wind Speed (km/hr)	NE 25 km/hr	NE to 20 km/hr	N - NW to 30 km/hr
Wind Direction	NE	NW - NE; gusts from SW	N - NW; strong gusty
Air Temperature	Cool Max 23°C	Cool breeze, Max 30°C (with no wind)	Max 28°C (constant wind)
Relative Humidity	Low	High - heavy storm clouds to north, 88 mm last week	High clouds leading a rain front from west
Rate of Spread	Good	v fast CB1, Good all cleared; drippers in strips in trees	Fast north half of CB1; slow back burn other plots
Danger Index	moderate to high; good wide breaks	moderate to high; good wide breaks	High, strong gusty wind towards unburnt plots
Flame height (m)	4 m in wind in cleared, 0.30 -1 m treed	5 m in wind CB1, to 4 m cleared, 0.30 -1 m treed	5 m in wind CB1, to 4 m cleared, 0.30 -1.5 m treed
Fuel Load- Trees	see Botanal DM yields	Spaced to sparse grass tussocks, cover of tree leaves	Spaced grass tussocks, cover of tree leaves
-Cleared		Good, dry grass - see botanal DM yields	Good, dry grass - see botanal DM yields
Litter	Moderate, excellent in Cleared	Moderate, tree leaf mainly, almost carpet under trees	Moderate, tree leaf only; wind blown leaf strips.
Fire assistance	Fuel fire Bug	Fuel fire Bug, strips in trees	Fuel fire Bug, strips in trees, backburn against wind
Ease of Burning- Trees	Patchy	Patchy to poor strips	Patchy due to back burn for safety
- Cleared	Excellent	Excellent	Exclt; bark of dead trees burning @ base; falling over
Type of Fire	Cool, quick. Slow burn under trees excellent in cleared Better fire with wind gusts Burnt around edges (initially back burn)	Cool, quick in cleared, slow in trees Slow burn under trees excellent in cleared Better fire with wind gusts Burnt around edges (initially back burn)	Slow backburn; few quick spots in open; slow in trees Slow back burn under trees, small patches left. Excellent in cleared. Better fire with wind gusts. All back burnt from south, some strips across site. South edges first lit on changes in wind to north. Dense buffel along track edge gives risk of fire escape

APPENDIX Q. Charting experimental methods

Appendix Q1. Glentulloch sampling designs and layouts

PADDOCKS

See Appendix A

Note: The paddock numbering system for the Burn site was possibly inconsistent in the first year but the treatment meanings were always correct.

TRANSECTS

In the grazing trial, the 3 transects in each paddock were roughly aligned N-S. Transects were numbered from **East to West** in each paddock. The eastern transect was nbr 1 and the western one was nbr 3. Posts were numbered from north to south, the northernmost post was nbr 1 and the southernmost one was nbr 4. This numbering system applied all the time for whatever purpose the transects were used.

There were no transects in paddock 13, the commercial paddock.

In the burn site, the transects were arranged in a St Andrews Cross with a central peg. Numbering of the posts was 0 for the central one and then 1 to 4 clockwise from the most northern post in each plot. Hence transects run from post 1 to post 3 (through post 0) and post 2 to 4 (Transect 2).

SOIL SEED SAMPLES

Soils were sampled in the grazing and burn trials at the end of each winter. In the grazing trial, a set of 4 cores was taken at posts 2, 3 and 4 on each permanent transect. On the burn site, the samples were taken from around the central post of the crossed transects of each 1ha plot. Cores were 5cm diameter and to 4cm depth. They were taken at least 2 metres away from the post, between plants and so as not to be right on the basal area transects between posts.

The 4 cores at a post were bulked in the field into a paper bag. Roots and litter were separated out later, prior to putting the soil into pots.

TREES

An initial tree basal area for each paddock was done using a Bitterlich stick in March 1995, mostly along the marked N-S transects in each paddock. Readings were taken near posts 2 and 3, making sure the observer stayed away from the fences. In Pdk 13, 4 readings were taken in a grid over the western one-third of the paddock.

All trees, dead or alive were counted in a complete circle because the Tordon had only recently been applied and we needed to get an original tree density for each paddock.

The exercise was repeated in 1996 but at a much greater detail. The burn site was first recorded by this method a week later.

PERMANENT CHARTING QUADRATS

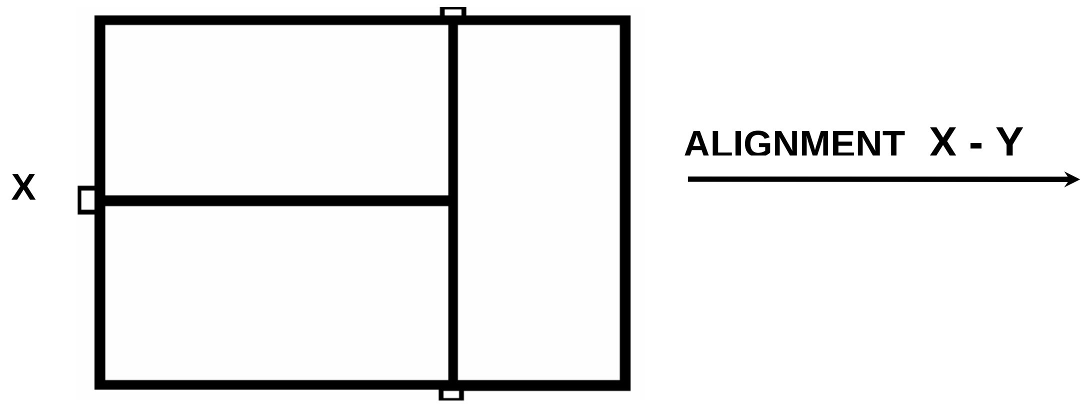
There were 3 sets of 3 x 0.5 sq m quadrats near the steel peg at one end of each of the permanent transects in each grazed paddock. The steel peg was either post 1 or 4. In the burn site, the quadrats are located around the central steel peg (post 0). This gave a total area in each paddock of 13.5 sq metres in which to locate the desired number of key plants.

To get 50 plants of each key species per paddock requires an average occurrence of 5-6 plants per set of 3 quadrats. At suitable spots, the three 0.5m quadrats were placed together as shown below and 3 small, wooden pegs driven into the ground. The peg arrangement provided a unique orientation for the quadrats. A description of where each set of quadrats was located in relation to the post was written in a separate file and the orientation of the long axis noted eg. 12 paces NE of post 1, aligned N-S. [Initially, a small scale map was drawn of the location of each set of 3 quadrats for each post used as a reference marker. This graphic was later deleted from this file.]

Key plant species selected at Glentulloch were
Bothriochloa decipiens
Aristida ramosa
Enteropogon ramosus
Dichanthium sericeum
and *Chrysopogon fallax.*

Aristida calycina was a subsidiary species where *A. ramosa* was rare, especially at the burn site. Key species were chosen on the basis of the BOTANAL frequency & DM yield data as well as perenniality. Thus *Enneapogon gracilis* was excluded because it is too ephemeral and concentrated where there are few perennial plants. *Tragus* and *S.birchii* were left out for similar reasons.

Glentulloch Permanent Quadrat Layout



It was uncommon to encompass all key species in a Set of 3 0.5m^2 quadrats, so each group tended to be dominated by 2-3 of the key species. To compensate, other quadrat groups were dominated by the other species.

The field drawings were done at a 1:10 scale on 5mm grid paper, ie. a 5mm grid side represented 5cm on the ground (See App. Q2).

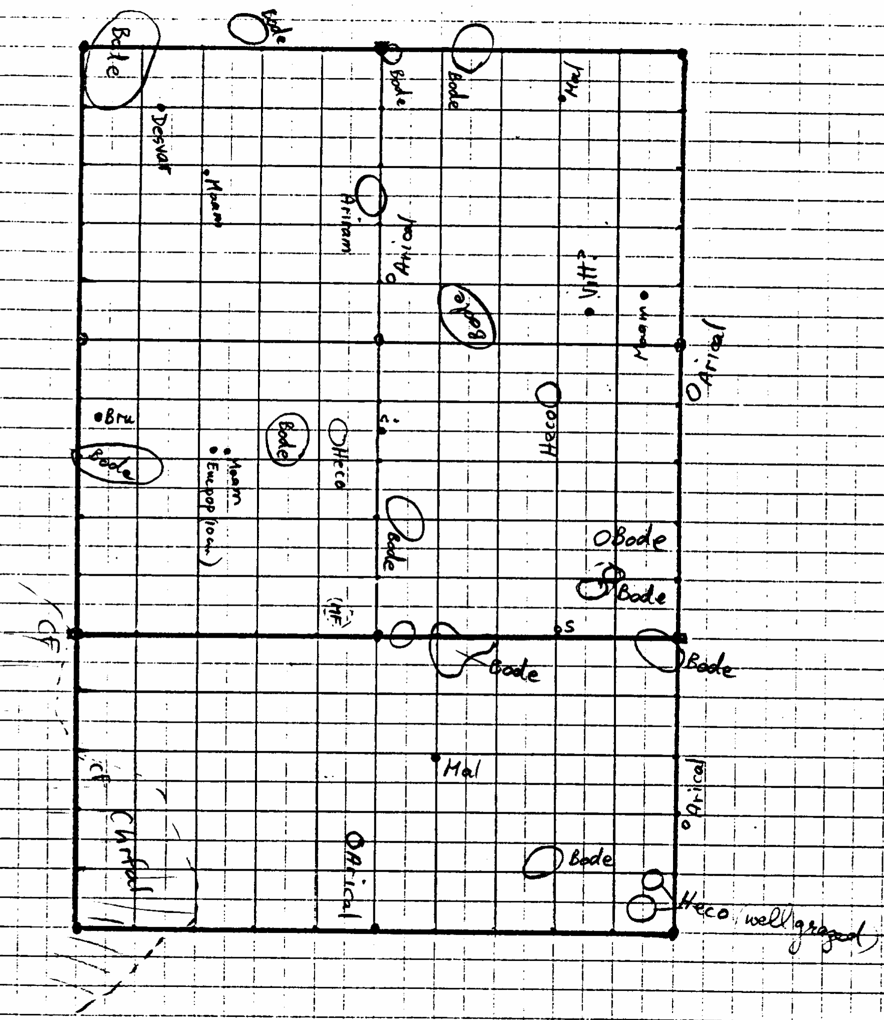
<u>Burn Site Quadrat Locations</u>

Quadrats were located around the central transect peg (Nbr 0) of each plot and were installed in exactly the same manner as in the grazing areas. [The other steel posts are numbered 1 to 4 clockwise from the most northern post in each plot.]. Where quadrat sets are described as 'aligned' x-y, the alignment refers to the longer axis of the 3-quadrat set. The direction should run from the peg X at one end along the join of the 2 parallel quadrats and across the middle of the third quadrat placed at right angles to the other two.

Appendix Q2. Typical raw quadrat charting sheet from Glentulloch

GLENTULLOCH

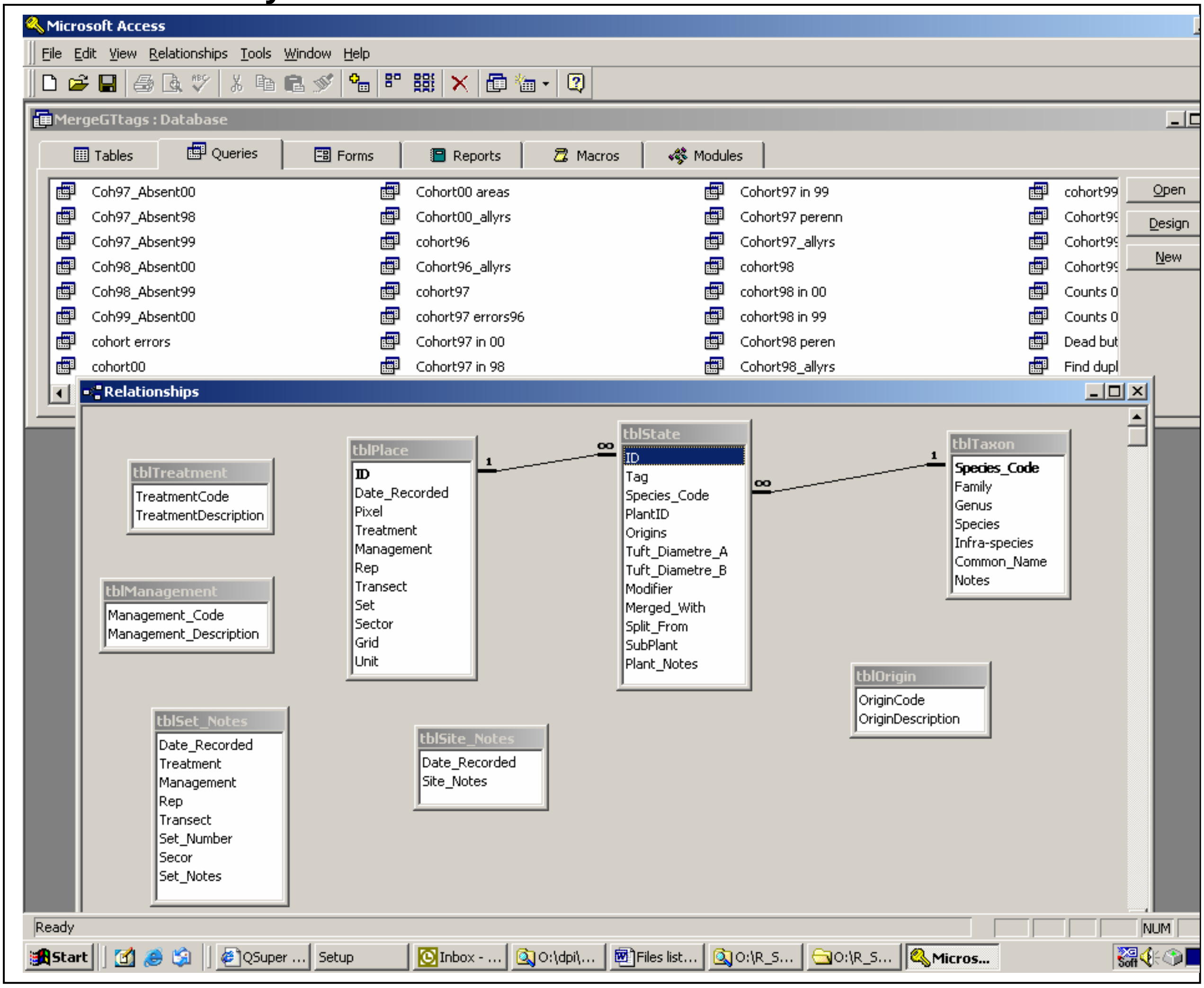
SET	PEG	TRANSECT	PADDOCK	DATE
2	4	2	6	12-4-95



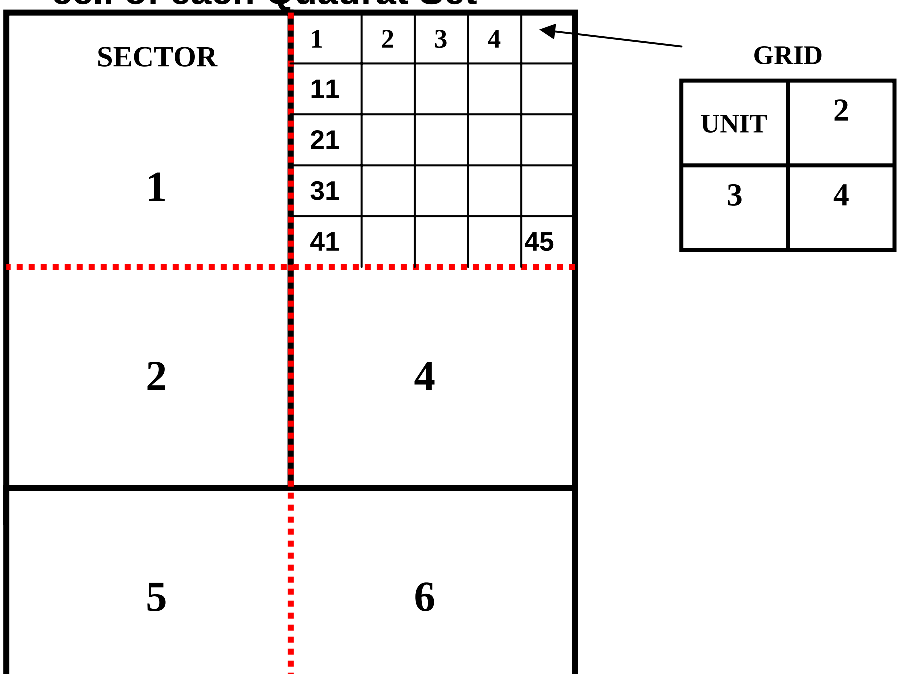
Counts:

Spp	Nbr
Enneap. spp.	0
Brun. aust.	1
Tripogon	0
Glycine spp.	0
Galv. burr.	0
Sclerolaena	0
Malvastrum	4
Calotis lapp	2
Einadia polyg.	0

Appendix Q3. Main table relationships of the Glentulloch Charting Analysis Database

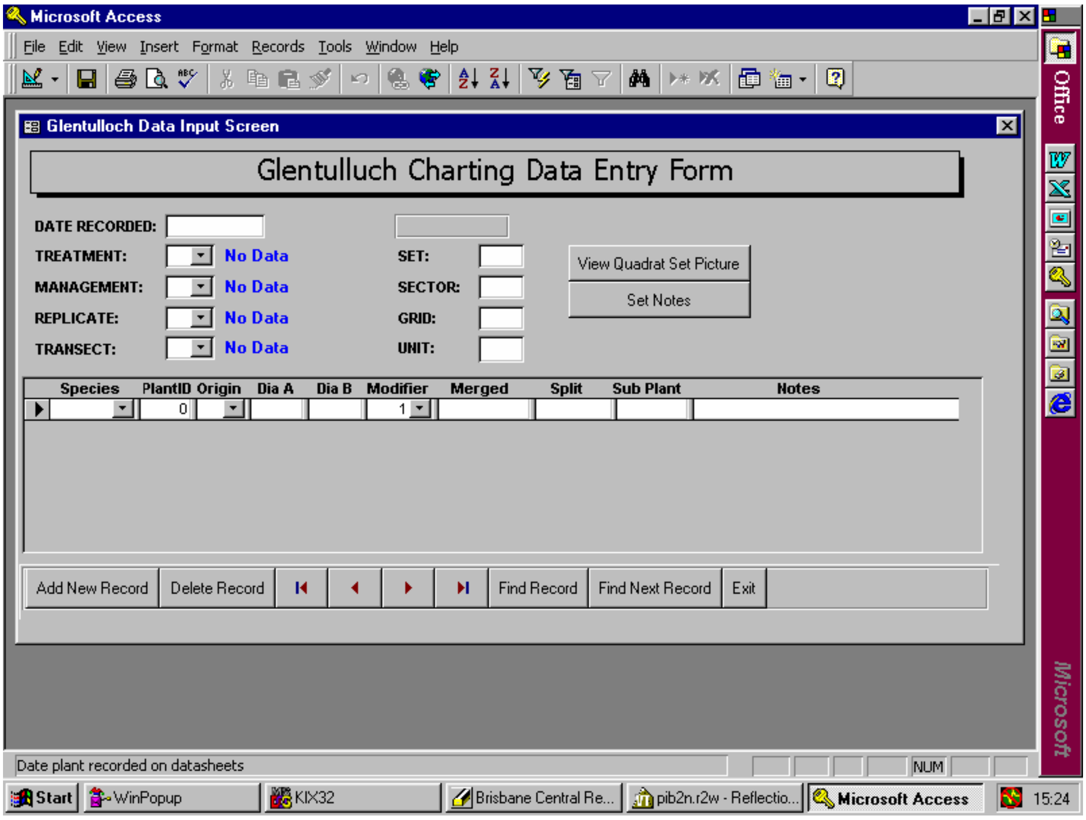


Appendix Q4. Numbering system used to identify each 10cmx10cm cell of each Quadrat Set

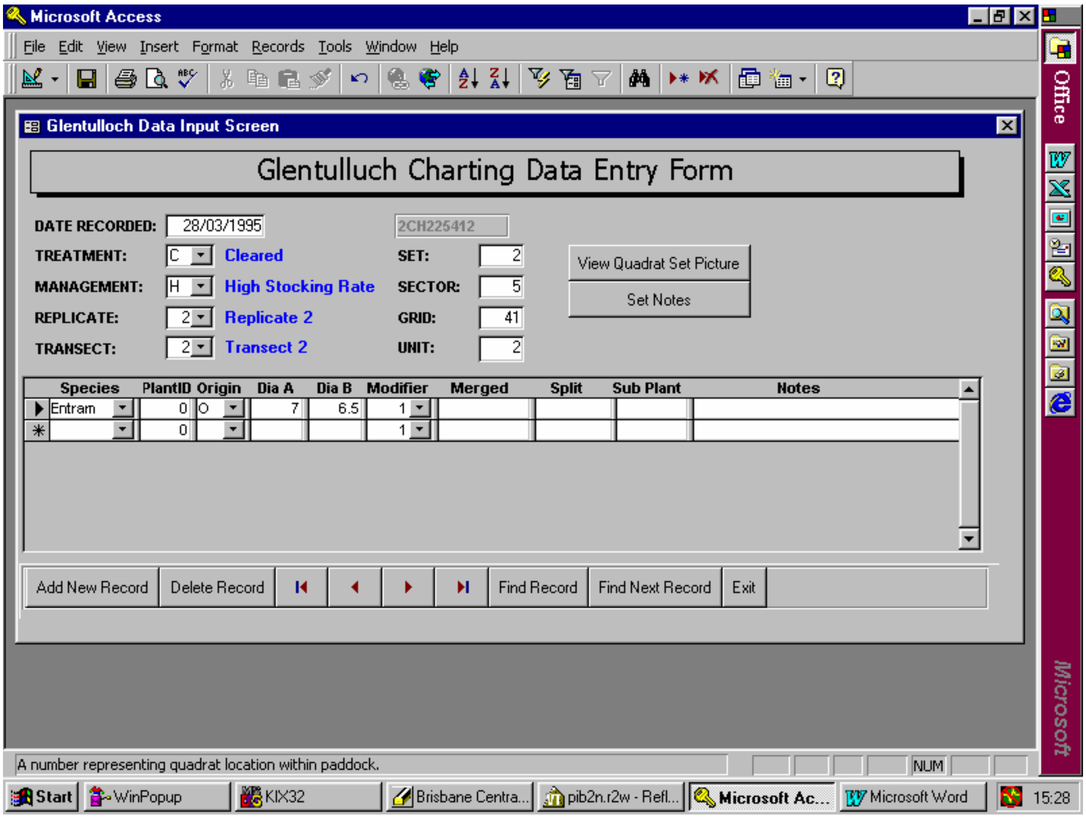


Appendix Q5. Access Data entry system forms for Charting data from field sheets

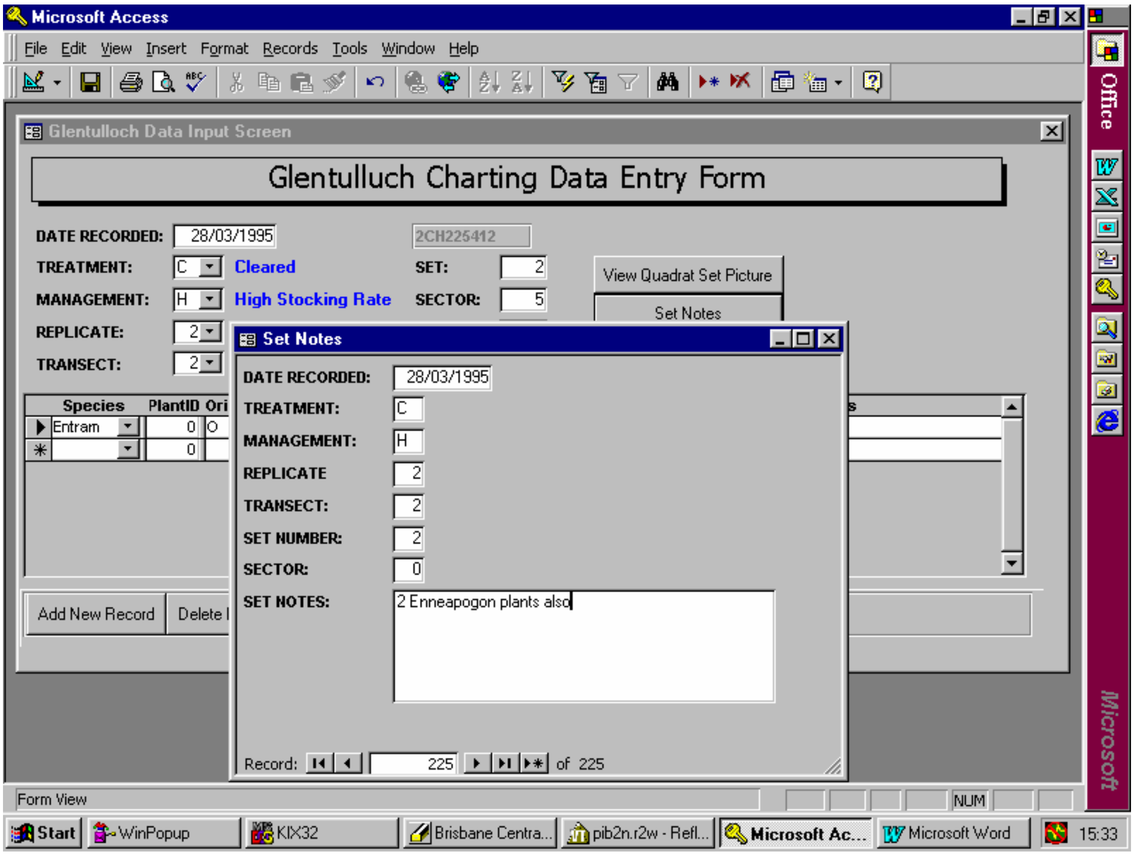
(A) Empty form



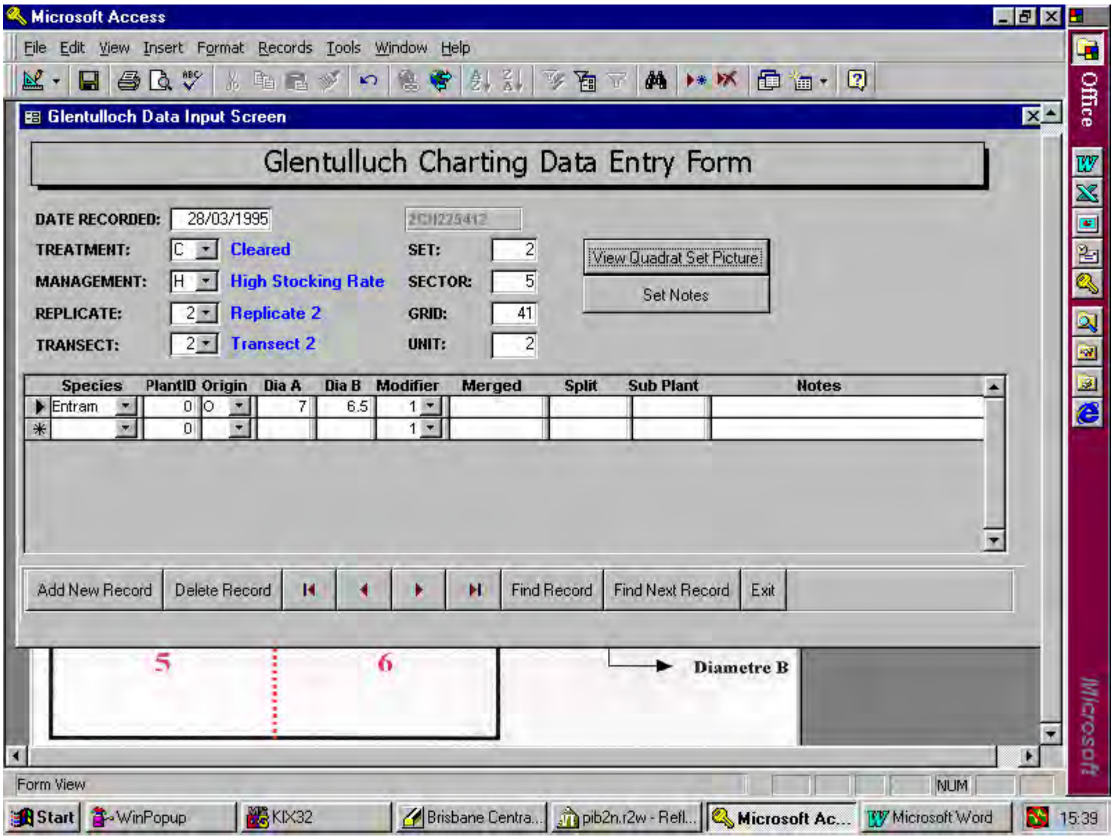
(B) Form with the location (2CH225412) & dimensions (mm) of a single *E. ramosus* plant entered



(C) Appearance of the Set Notes sub-window for adding general notes about a Set



(D) Another view showing how the grid numbering system diagram can lie visible below



The MSAccess database used an autonumbering system to assign a unique number to each record as it was created. Each record was also given a unique location ID, generated automatically during data entry, for each plant's location, eg. 2CH225412 in Figure Q5(B). The location ID was coupled with the species code, eg. Entram and a supplementary PlantID number to give a logical-looking code to each plant that a researcher could mentally interpret. The PlantID was for the rare occasion when there was more than one plant of the same species within a 10x10cm cell of the Set matrix.

The plant location ID was an alphanumeric string formed from
Rep, Trtmt, Mgmnt, Trsct, Set, Sector, Grid, Unit

– hence 2CH225412 in the example shown.

Each set in a paddock (say CH2 – Rep2 of the Treeless (C) High Grazing Pressure (H) paddock) was divided into 6 Sectors. There were 25 Grid cells (10x10cm) per sector (numbered 1-5, 11-15, 21-25, 31-35 & 41-45) and 4 Units (5x5cm) per Grid cell. All were numbered in the strict spatial sequence shown in Figure Q4 so that each year the same plant should have the same locationID (if it does not move much).

Later a unique numeric Tag (between 1 and 13,000) was assigned manually to each plant as it appeared for the first time, because the original auto-created index did not handle split or migrating plant crowns adequately. The Tag number was carried forward into each subsequent year that the plant or its vegetative derivatives persisted.

The database also had fields for noting whether crowns split up or merged together with adjacent plants of the same species, but the computer interrogation logic for incorporating and tracking such changes was never developed adequately. Hence the later use of tag numbers.

The two tuft diameters (A and B) refer to the plant crown (as drawn on the sheets) in 2 directions perpendicular to each other. They were used to calculate the circumscribed area via the formula for the area of an ellipse, $A = (\pi * A * B)/4$. The modifier field was designed to deal with *C. fallax* which often grew as a sward over areas of 0.5 to 5 square metres. For a tussock grass the modifier was 1.0 (the default) but for *C. fallax* and sometimes *E. ramosus*, this was a proportion to indicate how densely the individual tillers or tiller groups occupied the total area delineated on the chart. Typical modifiers used were 0.3, 0.1 and 0.05, indicating an operator-estimated 30%, 10% and 5% real basal/crown area at ground level had a point frame or line intercept method been used.

APPENDIX R. Plant lifespan calculations, Ironbark site

Population flux data used to calculate grass lifespans and death rates at Keilambete. Column headings (a) to (k) are used in the main report text to refer to each parameter

Keilambete trial Trmt	Graz	Rep	Species	(a) No. of plants in 1994 (a)	(b) No. of plants in 2000 (b)	(c) Net change (b-a)	(d) Rate of increase (b/a)	(e) No. of plants recruited between 1994 and 2000	(f) No. plants lost between 1994 and 2000	(g) 1994 plants still present in 2000	(h) % survival of plants in (a) (g/aX100)	(i) Expected time for original plants to die (years) (no. yrs/(100-h))X100	(j) Total plants (a+e)	(k) Plant flux - % ann. mortality of all plants (f/jX100)
C	H	1	Botewa	63	123	60	1.95	169	107	36	57.14	14.0	232	46.1
C	H	1	Chrfal	67	85	18	1.27	59	41	45	67.16	18.3	126	32.5
C	H	1	Hetcon	64	301	237	4.70	474	233	22	34.38	9.1	538	43.3
C	H	2	Botewa	62	57	-5	0.92	110	113	22	35.48	9.3	172	65.7
C	H	2	Chrfal	77	103	26	1.34	72	45	55	71.43	21.0	149	30.2
C	H	2	Hetcon	61	266	205	4.36	529	321	17	27.87	8.3	590	54.4
C	L	1	Botewa	63	96	33	1.52	97	64	47	74.60	23.6	160	40.0
C	L	1	Chrfal	92	108	16	1.17	63	47	58	63.04	16.2	155	30.3
C	L	1	Hetcon	67	167	100	2.49	436	333	20	29.85	8.6	503	66.2
C	L	2	Botewa	67	83	16	1.24	43	27	55	82.09	33.5	110	24.5
C	L	2	Chrfal	87	89	2	1.02	27	23	67	77.01	26.1	114	20.2
C	L	2	Hetcon	60	173	113	2.88	262	149	40	66.67	18.0	322	46.3
C	M	1	Botewa	64	97	33	1.52	118	84	42	65.63	17.5	182	46.2
C	M	1	Chrfal	78	70	-8	0.90	37	45	41	52.56	12.6	115	39.1
C	M	1	Hetcon	86	183	97	2.13	301	204	12	13.95	7.0	387	52.7
C	M	2	Botewa	63	86	23	1.37	82	59	49	77.78	27.0	145	40.7
C	M	2	Chrfal	80	94	14	1.18	59	44	55	68.75	19.2	139	31.7
C	M	2	Hetcon	67	222	155	3.31	467	311	31	46.27	11.2	534	58.2
T	H	1	Botewa	70	164	94	2.34	220	126	40	57.14	14.0	290	43.4
T	H	1	Chrfal	60	62	2	1.03	36	32	36	60.00	15.0	96	33.3
T	H	1	Hetcon	81	152	71	1.88	261	190	3	3.70	6.2	342	55.6
T	H	2	Botewa	71	95	24	1.34	115	89	43	60.56	15.2	186	47.8
T	H	2	Chrfal	85	102	17	1.20	47	30	67	78.82	28.3	132	22.7
T	H	2	Hetcon	57	221	164	3.88	467	303	20	35.09	9.2	524	57.8
T	L	1	Botewa	66	69	3	1.05	28	24	50	75.76	24.8	94	25.5
T	L	1	Chrfal	79	82	3	1.04	22	19	64	81.01	31.6	101	18.8
T	L	1	Hetcon	72	116	44	1.61	250	206	38	52.78	12.7	322	64.0
T	L	2	Botewa	77	98	21	1.27	71	48	53	68.83	19.3	148	32.4
T	L	2	Chrfal	87	75	-12	0.86	32	43	49	56.32	13.7	119	36.1
T	L	2	Hetcon	65	137	72	2.11	214	140	19	29.23	8.5	279	50.2
T	M	1	Botewa	83	133	50	1.60	113	63	61	73.49	22.6	196	32.1
T	M	1	Chrfal	79	95	16	1.20	55	39	49	62.03	15.8	134	29.1
T	M	1	Hetcon	67	129	62	1.93	224	161	16	23.88	7.9	291	55.3
T	M	2	Botewa	80	94	14	1.18	102	84	47	58.75	14.5	182	46.2
T	M	2	Chrfal	79	77	-2	0.97	43	41	51	64.56	16.9	122	33.6
T	M	2	Hetcon	70	183	113	2.61	552	437	22	31.43	8.8	622	70.3

APPENDIX S. Soil seedload germination methods, Poplar box site

Appendix S1. Soil Seed Load - pot setup & watering procedure

Aim: To estimate the number and diversity of germinable seeds in the soil.

0. The germination runs should be done in late spring and repeated (on the same soil sample) in late summer if needed. Early November and late March are best so that temperatures are warm and early flowering is possible for most natives. Heatwaves are avoided and so is Xmas/New Year. Do in a glasshouse if possible to reduce insect attacks.
1. Collect the surface soil in early spring (September). Collect 4 cores at each site and bulk them. Individual cores are often 5cm diam and 3-5cm deep.
2. Use 15cm rigid plastic pots with drainage holes. Normally 120 are needed for Glentulloch. Wash them.
3. Place a 15x15cm piece of paper handtowel or kitchen paper in the bottom so as to cover the drainage holes.
4. Almost fill each pot with washed river sand of medium grain size (0.5 - 1.5 mm diam). Leave enough room to place 1-1.5cm of soil on top plus a 0.5-1cm lip at the top where water can briefly pond.
5. Irrigate all pots as a group with a rose spray on a tap connected to good (low E.C.) water so the sand is thoroughly wetted. Then leave them to drain for a day.
6. While the surface sand is still wet, spread 100ml of concentrated Aquasol solution (double normal strength) over the surface of each pot using a small beaker or measuring cylinder.
7. Allow all pots to dry out in the surface layer before adding the soil collected from the field.
8. The soil samples from the field should be air dry and then sieved through a 5mm brass sieve to break up clods, to remove clean stones and to remove large pieces of litter & sticks. The objective is to lose no soil but to remove all things that cannot harbour seeds.
9. After sieving and breaking up clods, the soil is either returned to its bag or placed immediately on a pot of sand with its plastic identification label at the side of the pot. (See Figure S1)
10. Smooth out the soil to a level, smooth surface.
11. Make a note of the colour, texture and amount of free litter of each pot.
12. On a Monday, water-up all the pots at early morning, soaking all pots so that water ponds on top of the soil where possible. Rewater a number of times for about 30 minutes but do not overflow the pot and possibly lose seeds in that way. Overhead watering has been shown to promote much more seedling emergence than subsurface watering (Orr *et al.* 1996).
    [Automated watering systems can be used but, if soils differ greatly in texture, you can have severe over- or under-watering of individual pots which will affect the results.]
13. For the first 5 days, rewater well every 2 hours so that the seeds are exposed to leaching and frequent free water for 5 days. The aim is to simulate a very wet week but this will only occur if overcast, mild days and nights prevail at the same time.
14. Every morning record the max/min temperatures for the previous 24 hrs using a max/min thermometer lying on the bench amongst the pots. Also make notes about the sunniness of the morning and any other environmental conditions that could impinge on the germination of the seeds or the drying/wetting of the pots. Note which pots drain rapidly or very slowly.
15. After 5 days, reduce watering to 3 times a day and reduce the volume applied to that needed to just keep the soil visibly wet at all times. Try not to swamp emerging seedlings for too long.
16. Place a small pin with a large coloured, plastic head in the centre of each pot. This, in relation to the plastic label saying where the soil came from, defines 4 quadrants over the soil surface. These quadrants are useful for counting and relocating seedlings. See Figure S1.
17. Draw up a recording sheet for the whole experiment on which short notes can be made about each pot. [See Table S1.] This sheet can cater for notes on drainage, colour, texture, moss growth etc that applies to the whole pot.
18. Draw up another recording sheet for each pot like that shown in Table S2. Place date of recording down the LHS as a Y-axis and 4 quadrants plus a comments field across the top as an X-axis. Ensure the header of each sheet identifies the sample run, trial site and pot/sample number. This sheet is to record seedling data and numbers emerging. All sheets are punched and clipped together in a ring binder.

19. After 10 days watering, only water the pots enough in the morning and evening to keep the soil surface damp. Excessive watering from here on will only encourage moss and algal growth plus increase the likelihood of damping-off of seedlings.
20. You need not start counting or identifying seedlings until about 2 weeks after first watering them up. Initially count the total number of monocots and dicots in each pot using Table S1 format. In this way, if something disastrous happens to a pot, there has been a basic count done.

N.B. If you are doing this for the first time, you should compile a progressive record of the seedling features of each species. Record the size and disposition of each early leaf, plus features such as hairs, glands, stem colour etc. In this way, you will have an early identity of each main species in future and that will speed-up this work in later years.
A database of seedling features would enhance searches in the future.

21. Procure a large, bound ledger book into which examples of seedlings can be stuck and pressed for reference. Each preserved seedling should be labelled with its presumed name, the pot & quadrant from which it came and the date of harvest.
22. Keep the surface soil wet for 3-4 weeks. Thereafter, water only to keep seedlings growing as fast as possible. Where feasible, water down the side of a pot or up from the base so that algal growth is restricted.
23. After a month (less on sandy soils), you will need to infuse more nutrients to keep the seedlings growing well.
Do this by making up a single strength solution of Aquasol and standing each remaining pot in that solution for about a minute until the drying sand has absorbed all it can hold. In this way the bigger plants that have used most water since last watering get the most extra nutrients. Avoid putting nutrients on the surface as that will just encourage algal growth. If appropriate, the nutrient solution can be carefully squirted or pipetted down the gaps that develop at the side of each pot.
24. Once seedlings are identifiable, they should be removed carefully (by tweezers or sharp scalpel) so as not to disturb the soil surface. The date of removal, the pot and quadrant number and the plant identity should be recorded on the Table S2 data sheets. Appropriate comments should be made where something different is seen.
[Put an ‘R’ before the count to indicate removal eg. R 2 Eramol.]
25. Once all seedlings have been identified and removed from a pot, watering of that pot ceases and it is put aside for a possible second run. Allow it to dry out completely but keep an eye on it to see if any overlooked new or resprouting plant appears. Watch that ants do not nest in the dry sand and that the dry sand does not seep out through drainage holes where the paper layer has rotted away.
26. Any plant that dies or withers should be recorded as dying, the date noted, and by what cause. Identify it to the lowest level possible eg. family or genus.
27. If there are species that cannot be quickly identified but for which several plants exist, transplant 1 or 2 into a bigger pot with potting mix in it. If the plants are very young (2-4 leaves) and the soil very wet, they usually pull up easily with plenty of root to enable them to re-establish in the new pot. Take great care during transplanting. Dig a deep hole in the new pot and get roots down as far as possible but keep the crown at or just below the soil surface. Trim large leaves to 30% size.
28. The new pot must be kept very moist on top until the seedlings have clearly struck and are showing secondary growth eg. tillers in grasses. Each such transplanted seedling needs to be identified with a coloured pin as well as the quadrant of the pot and the parent pot from which it originally came. Use data sheets like Table S2 to record progress of these transplants or write on the back of the adjacent sheet in the ring-binder. Note the transplantation on the original pot datasheet and to where it went, eg. “R1 grass -> V3 Q1 R pin” as shown in Table S2. Fertilizer will be needed after plants have re-established and start growing rapidly.
29. By following this system, you can probably confidently identify the species earlier next time. Often 8-10 seedlings can be transplanted from various original pots into a single 25cm diam pot to save space. Nutrients need to be given to theses pots, - in proportion to the size of the plants growing.
30. Some species can only be positively identified from ripe fruit or seeds. In that case, only 1-2 plants need be taken right through to seeding - the others can be removed as small plants but have their final identity linked to those plants which were grown out to seed
(or positively identified).
31. Some groups of plants are very hard to identify to a species level and a genus name is acceptable. In some cases, all species of a genus can be lumped together for ecological purposes, eg. *Enneapogon* and so identification to genus is all that is needed.

32. Not all viable seeds emerge from 1 watering but the vast majority of the perennial grasses do. To find out how much has been missed, do another run next spring or autumn on the same soil. The best way to do that is to let the pot dry out once all emergent seedlings have been identified and removed. Keep the pot in a greenhouse away from rain and hoses.
[Then, to initiate a new run, gently break-up the soil layer with a scalpel or knife without removing the soil from the pot and with minimal mixing of the soil with the sand below. When all pots are ready like this, resume the watering regime used before. You may have to add nutrients a bit earlier, depending on how well the seedlings grow.]
33. The majority of seedlings emerging in subsequent runs will be those from species with small, hardseeded seeds such as sedges, Malvaceae, *Sporobolus*, *Eragrostis* and *Wahlenbergia* and medics.
34. In autumn, a much greater proportion of dicots emerge, particularly Bluebells, Stonecrop (*Crassula*), cudweeds and *Centauria* spp.
35. Where possible, remove seedlings so as to achieve a minimal number of pots to water eg. save seedlings of several species in 1 pot rather than 1 seedling per pot & several pots with the same species in them. However, try to keep 2-3 examples of each for as long as possible in case some die of rootrot or are eaten by insects (grasshoppers are the worst culprit).
36. There is always the risk that seedlings that look similar are from different species and that the difference takes weeks or months to show up. Hence, until experienced with the species commonly found at a site, err on the side of caution initially, until a reliable seedling key or descriptor set is constructed.
37. Leaf hairs are a mixed blessing for identification- in some genera they give an early clue eg. *Digitaria* spp. while in others they are no help eg. *Chloris* spp.
38. Some plants will not flower for 6-12 months and will need to be kept growing that long before getting an identity.

Figure S1. POT LAYOUT

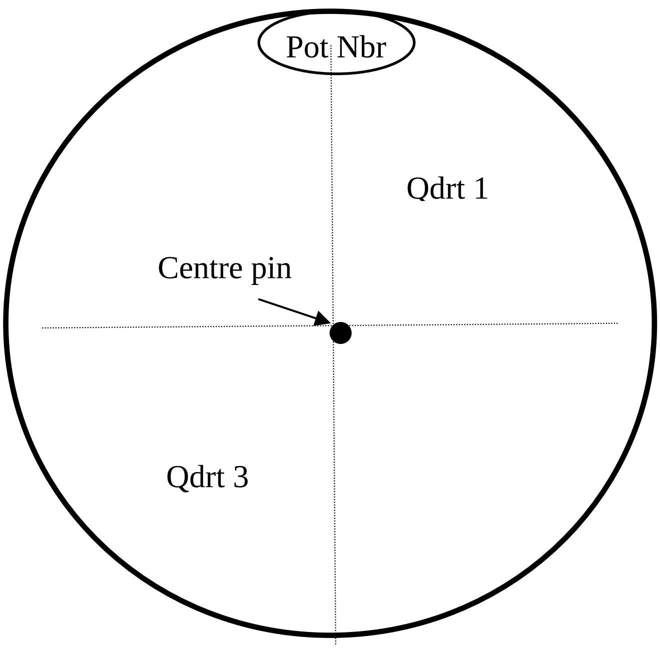


Table S1. Suggested soil information and early seedling count format for each pot

Glentulloch Soil Seed Loads

Pot	Monocots Dicots	Pot	Monocots Dicots	Pot	Monocots Dicots
C B 1		P4 T1 3		P8 T2 4	
C B 2		P4 T1 4		P8 T3 2	
C B 3		P4 T2 2		P8 T3 3	
C N 1		P4 T2 3		P8 T3 4	
C N 2		P4 T2 4		P9 T1 2	
C N 3		P4 T3 2		P9 T1 3	
T B 1		P4 T3 3		P9 T1 4	
T B 2		P4 T3 4		P9 T2 2	
T B 3		P5 T1 2		P9 T2 3	
T N 1		P5 T1 3		P9 T2 4	
T N 2		P5 T1 4		P9 T3 2	
T N 3		P5 T2 2		P9 T3 3	
P1 T1 2		P5 T2 3		P9 T3 4	
P1 T1 3		P5 T2 4		P10 T1 2	
P1 T1 4		P5 T3 2		P10 T1 3	
P1 T2 2		P5 T3 3		P10 T1 4	
P1 T2 3		P5 T3 4		P10 T2 2	
P1 T2 4		P6 T1 2		P10 T2 3	
P1 T3 2		P6 T1 3		P10 T2 4	
P1 T3 3		P6 T1 4		P10 T3 2	
P1 T3 4		P6 T2 2		P10 T3 3	
P2 T1 2		P6 T2 3		P10 T3 4	
P2 T1 3		P6 T2 4		P11 T1 2	
P2 T1 4		P6 T3 2		P11 T1 3	
P2 T2 2		P6 T3 3		P11 T1 4	
P2 T2 3		P6 T3 4		P11 T2 2	
P2 T2 4		P7 T1 2		P11 T2 3	
P2 T3 2		P7 T1 3		P11 T2 4	
P2 T3 3		P7 T1 4		P11 T3 2	
P2 T3 4		P7 T2 2		P11 T3 3	
P3 T1 2		P7 T2 3		P11 T3 4	
P3 T1 3		P7 T2 4		P12 T1 2	
P3 T1 4		P7 T3 2		P12 T1 3	
P3 T2 2		P7 T3 3		P12 T1 4	
P3 T2 3		P7 T3 4		P12 T2 2	
P3 T2 4		P8 T1 2		P12 T2 3	
P3 T3 2		P8 T1 3		P12 T2 4	
P3 T3 3		P8 T1 4		P12 T3 2	
P3 T3 4		P8 T2 2		P12 T3 3	
P4 T1 2		P8 T2 3		P12 T3 4	

Table S2. Seedling Emergence and Identification Recording Sheet example

<u>Glentulloch AB - Soil Seed</u> *Run: November 1997*

POT Nbr: P6 2/3 **Date Soil Collected:** *September 1997*

Date	Q1	Q2	Q3	Q4	Notes
12/11		R 2 Eramol	R 1 Callap	R 3 Arissp = P4 3/4 Q2	
		R 1 Porole	R 1 Eramol	R 1 grass -> V3 Q1 R pin	Hairy SLB; erect
		R 5 Wahlsp			
21/11	R 1 Digsan				

Note: 'R 5 Wahlsp means 5 *Wahlenbergia* spp. were removed on the date shown from Quadrant 2

Table S3. Major features used to distinguish species in the seedling stages. In any case, look to see if there is a seed or fruit capsule partially visible on the soil surface at the point where the seedling appeared. If so, note its characteristics eg. awns, hairs, size, shape.

Monocots	**Dicots**
Leaf 1 length : width ratio	Cotyledon shape
Leaf 1 length	Length of coty petioles
Leaf 1 abruptness of taper to apex	Hair type and shape
Adaxial hairs	Later leaf shape
Sheathing leafbase (SLB) hairs	Opposite or alternate leaf arrangement on stem
Small knobs on leaf margins	Prickles
Rolled vs. folded emerging leaves	Adaxial/abaxial hairs
Later leaf length & width	Flowerbud position
All early leaves in 1 vertical plane or not	Fleshiness
General hairiness	Stemminess
General colour and waxiness	Glands under leaves
Flattened vs. round cross-section of SLBs	Presence of stipules
Erectness & number of tillers	Simple or compound leaves
Prickle hairs on leaf margins	Growth habit / stolons / rhizomes
Purple colour of SLB	Flower size, shape and colour
Seedhead type	Fruit shape & size
Seed type / shape	Stem colour
	Germination type - epigeal or hypogeal

NOTE: Some species have features of both groups and need to be treated with a modified logic.

APPENDIX T. Calculating cattle numbers for each paddock

Appendix T1

Calculating animal numbers for a particular paddock

Background

In western Qld, utilisation is **"percentage of the end of summer standing forage that is to be consumed in the next 12 months"**. There is no uncertainty factor – droughts are expected and adjustments are only made for extremely good seasons once each year after an end-of-summer pasture assessment. To calculate animal numbers, Grasscheck uses the annual intake of a DSE (50kg dry sheep), which is about 450kg of dry matter. Rates of 20-30% are considered optimal in large paddocks.

In subcoastal Qld, the formula seems to be **"percentage of summer growth"**. The amount of summer growth is apparently calculated in hindsight or as a prediction based on historical rainfall records and maybe recent SOI values. There seems to be no 'point-in-time' reading taken of the existing pasture. No animal size or type is specified but a 450kg steer eating 2560kg of DM/year seems assumed as a AE conversion factor. A 30% utilisation rate calculated in this way has been shown to be sustainable in the long term (Scanlan *et al*. 1994).

Our method

In our A/B trial, we wish to impose high, moderate and low rates of utilisation. We trialled the following way of calculating animal numbers for each paddock. We defined utilisation as the **"percentage consumption over 12 months of the standing forage at late spring or autumn by animals of known starting weight"**. We use historical peaks and troughs in daily liveweight gain on that country, over a range of grazing pressures, to predict DM intake extremes. We measured the standing forage in each paddock, we weighed the cattle and then calculated the kilos of animal LWt that each paddock could run for the next year using Dennis Minson's table linking intake to rate of LWt gain (Minson & McDonald 1987).
The formulae used for calculating forage consumption are as follows –

Forage DM intake $I = (1.185 + 0.00454\mathbf{L} - 0.0000026\mathbf{L}^2 + 0.315\mathbf{G})^2$

where **L** = LWt of beast at time **X** and **G** = LWt gain/day at that time

For Keilambete in the LOW grazing pressure paddocks $G = \sin\mathbf{X}$;
MED " " $G = -0.3 + 1.1 \sin\mathbf{X}$;
and HIGH " " $G = -0.5 + 1.2 \sin\mathbf{X}$

where $\mathbf{X} = \pi$*(day nbr/365)
Calculations of the intake were done in 10 day blocks before LWt was incremented.

For Glentulloch in the LOW grazing pressure paddocks $G = 1.1\sin X$
MED $G = -0.2 + 1.1\sin X$;
HIGH $G = -0.4 + 1.1\sin X$

The assumption that we make to smooth the calculations is that the rate of LWt gain follows a wave shape over 12 months, like a sine curve. The historical data sets the amplitude of the curve and we tally the results in 10-day increments for a year. Thus for Keilambete LOW, annual intake was based upon a maximum allowable gain/hd/day of 1.0kg in mid-summer and winter gains which never fell below zero. For the MED treatments, intake was framed around a maximum allowable gain of 1.1kg/hd/day, but in winter, weight loses of as much as 0.3kg/hd/day were envisaged. This gave an effective best gain of about 0.8kg/hd/day (1.1 – 0.3) compared to 1.0kg/day for the LOW and 0.7kg/day for the HIGH (by the same logic). The calculation is the same irrespective of tree cover because only the standing pasture biomass is considered to be grazed.

We use 50% utilisation as a moderate figure for small paddocks because animals use them more evenly and predictably than most commercial-sized paddocks and because extra, unmeasured pasture growth is expected during the ensuing summer.

We initially aimed to carry 3 weaner steers per paddock, starting at 200kg LWt, and calculated paddock sizes from known Swiftsynd results. We allowed for a 50% reduction in pasture growth due to trees in the treed paddocks. In practice, our paddock size has been reasonable but sometimes we have to take 1 or more animals out of the 75% utilisation paddocks during dry winters.

After the extremely good 1996-97 summer at Keilambete, we used the formula and had up to 5 animals in some 75% utilisation paddocks and 10 head in 25% utilisation ones to achieve the desired consumption. This meant that the HIGH paddocks had very little left in them a year later in April 1998 and they could not sustain 2 head in those paddocks for the next year on the available feed. So 2 steers were put into the 2 adjoining HIGH grazing pressure paddocks with an open gate linking them so as to maintain grazing pressure on the pastures. There was then good winter and summer rain but numbers were left unchanged until autumn 1999. That excellent 1998/99 summer resulted in a large bulk of uneaten pasture in all paddocks by autumn 1999. So extra animals were put into most paddocks, using the projected intake formulae that were based on standing dry matter yield alone. This proved to be detrimental to animal growth (see Section 8) because no account was taken of the protein content of the feed and no adjustment in numbers was made for another year, despite poor 2000 summer rains.

In summary, this approach is a hybrid of concepts. We wish to base utilisation levels on real standing pasture weights and real animal size during the year but are reliant on historical animal growth rate data. By doing Botanals in autumn and early summer, we could adjust numbers twice a year to cater for recent seasonal extremes. In any event, we were still keeping the relative utilisation levels comparable at Heavy, Moderate and Light. Selective grazing in the Light paddocks sees some species regularly heavily grazed and others ignored. Ecologically the effect is usually good and animal growth rates tell us the effect is good agriculturally also. The economics of very light stocking seem poor by Australian standards.

Appendix T2

Table T1. Forage consumption calculator

Example
Glentulloch High Grazing Pressure Pdk

Start date = 29-Jun-99
Initial liveweight (kg) = 155
Max rate of gain (kg/d) = 1.1
Min LWT gain rate (kg/d) = -0.4

LWt gain formulae

Keilambete	LO =sinX	MED = -0.3 + 1.1sinX	HI = -0.5 + 1.2sin(pi*day/365)
Glentulloch	LO = 1.1sinX	MED = -0.2 + 1.1sinX	HI = -0.4 + 1.1sinX

Forage eaten eqn I = (1.185 + 0.00454L - 0.0000026L^2 + 0.315G)^2

Results incremented every 10 days

Date	Day	LWt change	LWt @ start	Feed consumed in 10d	Feed consumed Total	LWt chnge 10 day	LWt GAIN Total
29-Jun-1999	305	0.14	**155**	31.7	32	1.4	1.4
09-Jul-1999	315	0.06	156	32.9	65	0.6	2.0
19-Jul-1999	325	-0.03	157	34.0	99	-0.3	1.7
29-Jul-1999	335	-0.12	157	35.0	134	-1.2	0.5
08-Aug-1999	345	-0.21	156	35.9	169	-2.1	-1.6
18-Aug-1999	355	-0.31	153	36.7	206	-3.1	-4.6
28-Aug-1999	365	-0.40	150	37.4	244	-4.0	-8.6
07-Sep-1999	10	-0.31	146	35.7	279	-3.1	-11.7
17-Sep-1999	20	-0.21	143	34.2	314	-2.1	-13.8
27-Sep-1999	30	-0.12	141	32.8	346	-1.2	-15.0
07-Oct-1999	40	-0.03	140	31.6	378	-0.3	-15.3
17-Oct-1999	50	0.06	140	30.6	409	0.6	-14.7
27-Oct-1999	60	0.14	140	29.8	438	1.4	-13.3
06-Nov-1999	70	0.22	142	29.1	467	2.2	-11.0
16-Nov-1999	80	0.30	144	28.6	496	3.0	-8.0
26-Nov-1999	90	0.37	147	28.2	524	3.7	-4.3
06-Dec-1999	100	0.43	151	28.0	552	4.3	0.0
16-Dec-1999	110	0.49	155	27.9	580	4.9	4.9
26-Dec-1999	120	0.54	160	28.0	608	5.4	10.4
05-Jan-2000	130	0.59	165	28.2	636	5.9	16.3
15-Jan-2000	140	0.63	171	28.5	665	6.3	22.5
25-Jan-2000	150	0.66	178	29.0	694	6.6	29.1
04-Feb-2000	160	0.68	184	29.5	723	6.8	35.9
14-Feb-2000	170	0.69	191	30.2	754	6.9	42.8
24-Feb-2000	180	0.70	198	31.0	785	7.0	49.8
05-Mar-2000	190	0.70	205	31.9	817	7.0	56.8
15-Mar-2000	200	0.69	212	32.9	849	6.9	63.7
25-Mar-2000	210	0.67	219	34.0	883	6.7	70.4
04-Apr-2000	220	0.64	225	35.1	918	6.4	76.8
14-Apr-2000	230	0.61	232	36.3	955	6.1	82.9
24-Apr-2000	240	0.57	238	37.6	992	5.7	88.6
29-Apr-2000	245	0.54	244	38.6	1031	5.4	94.0
09-May-2000	255	0.49	249	40.0	1071	4.9	99.0
19-May-2000	265	0.43	254	41.4	1112	4.3	103.3
29-May-2000	275	0.37	258	42.8	1155	3.7	107.0
08-Jun-2000	285	0.30	262	44.2	1199	3.0	110.0
18-Jun-2000	295	0.22	265	45.6	1245	2.2	112.2
28-Jun-2000	305	0.14	267	47.0	1292	1.4	113.7

Table T2. Calculating animal numbers for each paddock to achieve the desired utilisation level

Steers enter : 30-Apr-1999

GLENTULLOCH

Treatmt	Autumn '99 DMY(kg/ha)	Pdk Area (ha)	Unavailable Residue (kg/ha)	Avail. Forage/ha	Utilisn %	Total feed eaten (kg)	Weaner Start LWt (kg)	Kgs 1 beast eats in 365 days	Theor. animals per pdk	**Best options re nbrs**	Pdk Grazing Days avail.	Date feed runs out	**Propn of steer wgt terciles**
CL1	2539	12	150	2389	25	7167	165	1508	4.75	*5*	347	10-Apr-2000	2A,3L
CL2	2709	12	150	2559	25	7677	165	1508	5.09	5	372	05-May-2000	4H,1L
CM1	1955	6	150	1805	50	5415	165	1430	3.79	*4*	346	09-Apr-2000	2A,2L
CM2	1753	6	150	1603	50	4809	165	1430	3.36	**3**	409	12-Jun-2000	1H,2A
CH1	674	3.9	150	524	75	1533	165	1342	1.14	*2*	208	24-Nov-1999	2A
CH2	797	3.9	150	647	75	1892	165	1342	1.41	*2*	257	12-Jan-2000	2A
TL1	1409	18	150	1259	25	5666	165	1508	3.76	*4*	343	06-Apr-2000	1H,3L
TL2	729	18	150	579	25	2606	165	1508	1.73	*2*	315	10-Mar-2000	1A,1L
TM1	613	12	150	463	50	2778	165	1430	1.94	2	355	18-Apr-2000	2A
TM2	636	12	150	486	50	2916	165	1430	2.04	2	372	06-May-2000	2A
TH1	704	6	150	554	75	2493	165	1342	1.86	*2*	339	03-Apr-2000	2A
TH2	501	6	150	351	75	1580	165	1342	1.18	*2*	215	30-Nov-1999	2A

A = middle third, H = heavy one-third, L = lightest one-third of mob

Don't use below average weight animals in high utilisation pdks. They suffer enough already!

Red values are of concern

italics means relatively light animals should be used

Bold numbers mean heavier than avge weights can be included

Basically you have to -

1. Assess how much feed you have.
2. Know what the starting weight of your cattle is.
3. Estimate the likely range of daily cattle weight gains for that country.
4. Marry the starting date of grazing with the pattern of weight gain at that time of year.
5. Calculate the forage consumption per head over the next year or part thereof that you plan to graze the paddocks.
6. Set a forage utilisation rate for each paddock based on current standing feed. [You may set these to reflect the likelihood of more rain during the grazing period. The more rain you expect, the higher the utilisation rate of the existing forage.]
7. Calculate the number of head that can be run on each paddock at those utilisation rates.
8. Adjust numbers to round up or down from the theoretical number of animals. NOTE: if theoretical numbers are between n.5 and n.8 head for a paddock, use n+1 lighter than average cattle. If number is between n.2and n.5, use n heavier than average cattle. n+/- 0.1 is left as n head.
9. Never have less than 2 animals per paddock.

Appendix T3

A/B project stocking rate calculations

Background

When working out the relative stocking rates (and thus grazing pressure) of different trials, the actual time that the stock were grazing and the intensity of grazing/defoliation must both be considered. Any gaps in the residency of animals in a paddock is a spell for the pasture and an opportunity for it to regain strength and to accumulate biomass before grazing resumes. The size of the individual animals also has a bearing on how intense the grazing is. Animal productivity is then a closely tied combination of production per head and the number of head per hectare.

The easiest thing to measure & the least changeable is the area of the paddock. In this theoretical example we do not take into account the evenness of grazing within a paddock. That varies in space and time and has compensatory feedbacks, provided that the animals can physically walk to all parts of the paddock comfortably. That is usually a given in trials on small research paddocks like ours.

Methods

1. Measure the area of each paddock accurately.

2. Work out the number of animal grazing-days imposed on each paddock. That is the number of animals multiplied by the number of days that those animals were always in that paddock. If animal numbers in a paddock change at any time during the research year, the grazing-days calculation is done for each period that animal numbers were constant. Then the grazing days for each period are summed to give a total for the research period. To do this step properly, we need to know each individual's weight when it goes in and comes out of a paddock. In this way, the cumulative mass of grazing pressure can be calculated and expressed in terms of a common or defined unit such as adult cow or AE or DSE. If an animal dies or escapes, the date of its death/escape is estimated and its weight at the time calculated by some logical method.

3. The length of the research period is then calculated by subtracting the start date from the final date on which a given mob of stock were used in the trial. A new research period might be triggered by the removal of an existing mob of fat bullocks from all treatments and their replacement by new weaner animals. The replacement may be partial, eg. 1 or 2 from a group of 3-4 in each paddock, as long as the swap is consistent for all treatments at this time.
4. If there is a time lag between when the existing animals are removed and the new ones go in, then that period has to be accounted for by adding it to the time of the existing mob. We use the term grazing period to describe the time during which some animals were always in the paddock and we talk of mobtime as the time in days between when the latest mob first went in and when the next mob eventually replaces them. Grazing period can equal mobtime if there is not delay in replacing one mob with the next. Both these periods may be different from a classic year of 365 days that economists often use when doing economic analyses

5. The stocking rate can be expressed in a number of ways.
   Firstly it can be done on the basis of head of stock, irrespective of their size, sex or age. This is not a sophisticated measure of stocking rate.
   Secondly it can be done on the basis of the number of Adult beasts (450kg LWt) that are equivalent to the actual average weight per head. For instance, 2 weaners of 225 kg equal only 1 AE of 450kg. Southern Australia often use 400kg as their AE. It is also possible to use another conversion so as to allow comparison with sheep & goat grazing. They normal term used is Dry Stock Equivalent (DSE) to standardise the livestock unit to an adult wether of 50kg. Thus it is vital to explain exactly which standard you are using when doing these calculations.

6. The next consideration is what time the stocking rate applies to. Time when animals are not in the paddock must be allowed, eg. in rotational grazing strategies, as it amounts to a rest for the pasture. Such rest will be beneficial to the pasture and to the next lot of animals who conceivably will have a bonus supply of fodder that would not have been there had the other animals been removed on the same day that the new mob went in. We can think of 6 different ways to express grazing pressure for our experimental work, -

   2 animal size measures X 3 possible time periods –

   AEs or head X 365 day years or grazing period or mobtime

   From grazing pressure flows the more commonly used term of stocking rate, which is really grazing pressure per unit area or its inverse, area per unit grazing pressure.

7. **Mobtime stocking rate is probably the best to use** when the data will be accumulated over a number of years in an attempt to gauge a long term carrying capacity for different pastures. The other 2 measures are more useful for short term studies where cumulative effects of the stocking pressure are not being measured. Mobtime can be shorter or longer than a year.

8. Adult equivalents (AEs) are calculated by using the mean of the animal liveweights between consecutive weighings and dividing by 450. A refinement, when animal numbers varied during the study period, can work out the weighted mean AE by taking into account the proportion of the total grazing days to which each average AE applies during the entire study period.

Table T4 uses several of these approaches to calculate the ‘average stocking rate’ over 7 years for each treatment. It is important to note that these calculations must initially be done for each paddock individually. Serious errors can arise if average paddock areas are used with average animal numbers when paddock size for different treatments varies greatly.

Appendix T4

Table T4. Calculation spreadsheet and summary of the time animals spent in a paddock and the resultant Stocking Rate measures calculated

	Glentulloch			Calculator for grazing days & stocking rates			Area(ha)	12				
Year	**Events**	DATES	Cattle Nbr	Grazing days	TOTAL Beast days	Weight (kg) at swapover	NOTES	Parameter	Value	Units	Calcns by 450kg AE value	units
1994-95	Datein1	30/11/94	3	792		187						
1	Datechge11	21/08/95		0				Ttl days	264	mob days		
	Datechge12			0				Avge hd/365dyr	2.17	head	1.38	AE
	Datend1	21/08/95	3		792	386		Av S/rate/365d	5.53	ha/beast	8.69	ha/AE
	Grazed period	264						Av nbrs/grz day	3.00	hd/day	1.91	AE/grz day
mobtime	329				Av Lwt AEs	0.64[#]		Av SR/grz day	4.00	ha/hd/grz day	6.28	ha/AE/gd
								Av hd/mobtime	2.41	hd/period	1.53	AE/period
								Av SR/mobtime	4.98	ha/hd/period	7.83	ha/AE/period
1995-96	Datein2	25/10/1995	3	1098		145						
2	Datechge21	25/10/1996		0				Ttl days	366	mob days		
	Datechge22			0				Avge hd/365dyr	3.01	head	1.65	AE
	Datend2	25/10/1996	3		1098	350		Av S/rate/365d	4.00	ha/beast	7.25	ha/AE
	Grazed period	366						Av nbrs/grz day	3.00	hd/day	1.65	AE/grz day
mobtime	400				Av Lwt AEs	0.55		Av SR/grz day	4.00	ha/hd/grz day	7.27	ha/AE/gd
								Av hd/mobtime	2.75	hd/period	1.51	AE/period
								Av SR/mobtime	4.37	ha/hd/period	7.95	ha/AE/period
1996-97	Datein3	28/11/1996	3	1026		175						
3	Datechge31	5/11/1997		0				Ttl days	342	mob days		
	Datechge32			0				Avge hd/365dyr	2.81	head	1.53	AE
	Datend3	5/11/1997	3		1026	315		Av S/rate/365d	4.30	ha/beast	7.84	ha/AE
	Grazed period	342						Av nbrs/grz day	3.00	hd/day	1.63	AE/grz day
mobtime	347				Av Lwt AEs	0.54		Av SR/grz day	4.00	ha/hd/grz day	7.35	ha/AE/gd
								Av hd/mobtime	2.96	hd/period	1.61	AE/period
								Av SR/mobtime	4.06	ha/hd/period	7.45	ha/AE/period

Year	Events	DATES	Cattle Nbr	Grazing days	TOTAL Beast days	Weight (kg) at swapover	NOTES	Parameter	Value	Units	Calcns by 450kg AE value	Calcns by 450kg AE units
1997-98	Datein4	10/11/1997	3	702		160						
4.1	Datechge41	2/07/1998	4	184		295		Ttl days	280	mob days		
	Datechge42	17/08/1998		0		285		Avge hd/365dyr	2.43	head	1.20	AE
	Datend4	17/08/1998	4		886	285		Av S/rate/365d	4.90	ha/beast	10.00	ha/AE
	Grazed period	280						Av nbrs/grz day	3.16	hd/day	1.56	AE/grz day
mobtime	280				Av Lwt AEs	0.49		Av SR/grz day	3.79	ha/hd/grz day	7.67	ha/AE/gd
					Alt AE Avg	0.53*		Av hd/mobtime	3.16	hd/period	1.56	AE/period
								Av SR/mobtime	3.79	ha/hd/period	7.67	ha/AE/period
1998-99	Datein5	17/08/1998	4	1260		285						
4.2	Datechge51	28/06/1999		0				Ttl days	315	mob days		
	Datechge52			0				Avge hd/365dyr	3.45	head	2.84	AE
	Datend5	28/06/1999	4		1260	455		Av S/rate/365d	3.50	ha/beast	4.23	ha/AE
	Grazed period	315						Av nbrs/grz day	4.00	hd/day	3.29	AE/grz day
mobtime	319				Av Lwt AEs	0.82		Av SR/grz day	3.00	ha/hd/grz day	3.65	ha/AE/gd
								Av hd/mobtime	3.95	hd/period	3.25	AE/period
								Av SR/mobtime	3.04	ha/hd/period	3.69	ha/AE/period
1999-00	Datein6	2/07/1999	5	1745		140						
6	Datechge61	15/06/2000		0				Ttl days	349	mob days		
	Datechge62			0				Avge hd/365dyr	4.78	head	2.39	AE
	Datend6	15/06/2000	5		1745	310		Av S/rate/365d	2.50	ha/beast	5.02	ha/AE
	Grazed period	349						Av nbrs/grz day	5.00	hd/day	2.50	AE/grz day
mobtime	349				Av Lwt AEs	0.50		Av SR/grz day	2.40	ha/hd/grz day	4.80	ha/AE/gd
								Av hd/mobtime	5.00	hd/period	2.50	AE/period
								Av SR/mobtime	2.40	ha/hd/period	4.80	ha/AE/period

Year	**Events**	DATES	Cattle Nbr	Grazing days	TOTAL Beast days	Weight (kg) at swapover	NOTES	Parameter	Value	Units	Calcns by 450kg AE value	units
2000-01	Datein7	15/06/2000	5	235		308						
6.2	Datechge71	1/08/2000	4	1076		324		Ttl days	316	mob days		
	Datechge72	27/04/2001		0		485		Avge hd/365dyr	3.59	head	3.16	AE
	Datend7	27/04/2001	4		1311	485		Av S/rate/365d	3.30	ha/beast	3.79	ha/AE
	Grazed period	316						Av nbrs/grz day	4.15	hd/day	3.66	AE/grz day
mobtime	316				Av Lwt AEs	0.88		Av SR/grz day	2.89	ha/hd/grz day	3.28	ha/AE/gd
					Alt AE Avg	0.86		Av hd/mobtime	4.15	hd/period	3.66	AE/period
								Av SR/mobtime	2.89	ha/hd/period	3.28	ha/AE/period
										Alternative calculations	**1**	**2**
TOTALS	Grazing time	2232		Bst-days	8118	285		Avge nbrs/365dyr	3.18			
								Mean S/rate/365d	4.01			
Altve 2 >	2340	Ttl days	2232	< Altve 1				Av nbrs/grz day			3.64	
Mobtime								Mean SR/grzday	3.44		3.30	
								Av nbrs/mobtime				3.47
								Mean SR/mobtime	3.65			3.46

AE calculated as the mean of the animal weights upon entry and final exit from a paddock. These values were used in the stocking rate calculations shown.

* Alt AE is the weighted average AE that allows for the proportion of the total grazing days that occurred between each weighing listed

APPENDIX U. Ironbark site steer feedlot performance after Year1 on trial

Table U1. Keilambete Grazing Trial 1994 - 95 Cattle: Performance in a Feedlot after removal from the trial paddocks

PDK	I.D.	Ear Tag	Paddock weight at .. 4/11/94	3/02/95	25/04/95	14/08/95	Feedlot weights (kg) 13/09/95	18/10/95	24/11/95	overall	Feedlot weight gains (kg/d) 13/09/95	18/10/95	24/11/95	overall	Cond Score 24/11/95 1 to 5 scale	1 – 9 scale
Area (ha)			Day nbr	91	81	111	30	65	102	385	30	65	102	385		
CL1	1	213	236	296	396	412	450	516	572	336	1.27	1.60	1.57	0.87	4.5	8
O G	2	217	264	310	411	436	412	450	488	224	-0.80	0.22	0.51	0.58	4	7.5
	3	228	278	323	414	456	492	542	592	314	1.20	1.32	1.33	0.82	4.5	8
10.4	Avg Wt		259	310	407	435	451	503	551	291	0.56	1.05	1.14	0.76	4.33	7.83
CL2	1	201	286	350	416	436	468	516	558	272	1.07	1.23	1.20	0.71	4.5	8
O Y	2	207	272	321	430	470	496	546	580	308	0.87	1.17	1.08	0.80	4.5	8.5
	3	(239)?	286	351	482	M	418	456	M	-	-	-	-	-	M	M
10.5	Avg Wt		281	341	443	453	**461**	**506**	**569**	**290**	**0.97**	**1.20**	**1.14**	**0.75**	**4.50**	**8.25**
	mean CL		**270**	**325**	**425**	**444**	**456**	**504**	**560**	**291**	**0.76**	**1.12**	**1.14**	**0.75**	**4.42**	**8.04**
CM1	1	209	264	289	410	430	434	474	488	224	0.13	0.68	0.57	0.58	4	7.5
O O	2	235	230	255	363	384	426	484	546	316	1.40	1.54	1.59	0.82	4	7
	3	197	236	250	370	384	430	480	510	274	1.53	1.48	1.24	0.71	4.5	8
5.7	Avg Wt		243	265	381	399	430	479	515	271	1.02	1.23	1.13	0.70	4.17	7.50
CM2	1	214	220	265	365	398	432	474	520	300	1.13	1.17	1.20	0.78	4	7
O P	2	226	228	266	393	390	426	468	536	308	1.20	1.20	1.43	0.80	4	8
	3	224	246	293	384	412	442	476	512	266	1.00	0.98	0.98	0.69	4.5	8
5.4	Avg Wt		231	275	381	400	433	473	523	291	1.11	1.12	1.20	0.76	4.17	7.67
	mean CM		**237**	**270**	**381**	**400**	**432**	**476**	**519**	**281**	**1.07**	**1.17**	**1.17**	**0.73**	**4.17**	**7.58**
CH1	1	200	240	266	380	368	400	450	M	-	1.07	1.26	-	-	M	M
O W	2	203	194	198	310	296	334	372	408	214	1.27	1.17	1.10	0.56	4	7
	3	231	210	240	357	366	396	454	508	298	1.00	1.35	1.39	0.77	4.5	8
3.7	Avg Wt		215	235	349	343	377	425	458	256	1.11	1.26	1.25	0.66	2.83	5.00
CH2	1	212	216	241	353	342	372	418	476	260	1.00	1.17	1.31	0.68	4.5	8.5
O B	2	208	238	233	345	308	366	420	M	-	1.93	1.72	-	-	M	M
	(3 day)3	225	212	218	252	284	316	380	440	228	1.07	1.48	1.53	0.59	4	6.5

PDK	I.D.	Ear Tag	Paddock weight at ..				Feedlot weights (kg)				Feedlot weight gains (kg/d)				Cond Score 24/11/95	
			4/11/94	3/02/95	25/04/95	14/08/95	13/09/95	18/10/95	24/11/95	overall	13/09/95	18/10/95	24/11/95	overall	1 to 5 scale	1 – 9 scale
3.5	Avg Wt		222	231	317	311	351	406	458	244	1.33	1.46	1.42	0.63	2.83	5.00
mean CH			**218**	**233**	**333**	**327**	**364**	**416**	**458**	**250**	**1.22**	**1.36**	**1.33**	**0.65**	**2.83**	**5.00**
TL1	1	206	232	311	392	422	496	544	578	346	2.47	1.88	1.53	0.90	4.5	8
G G	2	233	238	311	373	412	454	508	538	300	1.40	1.48	1.24	0.78	4	6.5
	3	222	260	308	380	414	466	490	510	250	1.73	1.17	0.94	0.65	4.5	8
21	Avg Wt		243	310	382	416	472	514	542	299	1.87	1.51	1.24	0.78	4.33	7.50
TL2	1	234	200	262	342	388	448	500	530	330	2.00	1.72	1.39	0.86	4	8
G Y	2	236	234	284	386	402	430	462	500	266	0.93	0.92	0.96	0.69	4	8
	3	216	236	310	395	440	450	518	564	328	0.33	1.20	1.22	0.85	4	7
19.7	Avg Wt		223	285	374	410	443	493	531	308	1.09	1.28	1.19	0.80	4.00	7.67
mean TL			**233**	**298**	**378**	**413**	**457**	**504**	**537**	**303**	**1.48**	**1.39**	**1.21**	**0.79**	**4.17**	**7.58**
TM1	1	194	198	247	320	354	390	456	482	284	1.20	1.57	1.25	0.74	4	7.5
G O	2	237	204	273	361	384	406	448	488	284	0.73	0.98	1.02	0.74	4	7.5
	3	211	190	249	338	374	354	418	462	272	-0.67	0.68	0.86	0.71	4	8
10	Avg Wt		197	256	340	371	383	441	477	280	0.42	1.08	1.05	0.73	4.00	7.67
TM2	1	227	228	302/274	420	438	438	478	514	286	0.00	0.62	0.75	0.74	4	8
G P	2	230	242	275	364	418	472	538	590	348	1.80	1.85	1.69	0.90	4	8
	3	238	228	261	330	368	400	458	480	252	1.07	1.38	1.10	0.65	4	8
9.9	Avg Wt		233	270	371	408	437	491	528	295	0.96	1.28	1.18	0.77	4.00	8.00
mean TM			**215**	**263**	**356**	**389**	**410**	**466**	**503**	**288**	**0.69**	**1.18**	**1.11**	**0.75**	**4.00**	**7.83**
TH1	1	229	254	272	367	350	390	450	504	250	1.33	1.54	1.51	0.65	4	7.5
G W	2	198	212	239	320	340	396	468	M	-	1.87	1.97	-	-	M	M
	3	205	228	263	351	372	374	426	M	-	0.07	0.83	-	-	M	M
6.6	Avg Wt		231	258	346	354	387	448	504	250	1.09	1.45	1.51	0.65	1.33	2.50
TH2	1	202	226	268	350	366	416	472	534	308	1.67	1.63	1.65	0.80	4	8
G B	2	232	236	265	370	380	420	480	518	282	1.33	1.54	1.35	0.73	4	8
	3	215	200	217	280	316	370	418	440	240	1.80	1.57	1.22	0.62	4	7.5
7.2	Avg Wt		221	250	333	354	402	457	497	277	1.60	1.58	1.41	0.72	4.00	7.83
	Mean TH		**226**	**254**	**340**	**354**	**394**	**452**	**501**	**263**	**1.34**	**1.51**	**1.46**	**0.68**	**2.67**	**5.17**

M = Missing data - means no applicable data for calculation

APPENDIX V. Beef market specifications and calculations

Table V1. Notes on market specifications used for cattle marketing analyses

Notes:	Nbr perm incisors	Age (mths)	
	0	<25	Ox = either female with fewer than 7 teeth OR no secondary sex chars
	2	20 - 30	Steer = castrate or entire male with no secondary sexual chars
	4	25 - 35	Cow = female with 8 permanent incisors
	6	30 - 45	Bull = entire or castrate male showing secondary sexual chars
	8	>40	

Grassfed steers	Age/teeth	LWt range (kg)		
Domestic	12 - 24	300 -450		
Korean P1	< 42	490 - 580		
Jap grassfed	> 36	530 - 750		
EC	< 30 / 2-4	450 - 620		
Feeders	20-30 / 2	400 - 450		
Feeders	26-33	420 - 480	Jap short feed B1	Note; B2 & B3 have to be Euro breeds
Feeders	-	240 - 310	Domestic 70d for S'marts	
Feeders	< 15	300 - 430	HRI trade 60-100d feed	
Feeders	< 39	300 - 340	Korea KI >100d feed	

Table V2. Excel Worksheet for calculating marginal economics of intensified grazing management

Worksheet for calculating marginal economics of intensified grazing management

	Treatment	Stocking rate ha/head	LWt gain per head kg	Avge steers per 100ha nbr	LWt gain / 100ha kg	Extra wgt cf. lower intensity kg	Extra steers cf. lower intensy nbr	Beef value $ / kg	**Extra $** per extra steer $	Profit / extra steer $	Profit/ha per extra steer $	Triple bottom line
Result												
	Destocked	0	0	0	0	0	0	0	-	-	-	
	LOW	5.5	155	18.18	2818	2818	18.2	$1.60	$248.00	$188.00	$34.18	
	MED	3.2	136	31.25	4250	1432	13.1	$1.50	$142.78	$82.78	$25.87	
	HIGH	2.3	112	43.48	4870	620	12.2	$1.25	-$23.56	-$83.56	-$36.33	
	TREED	4.6	121	21.74	2630	2630	21.7	$1.40	$169.40	$109.40	$23.78	
	TREELESS	2.7	148	37.04	5481	2851	15.3	$1.50	$296.75	$236.75	$87.68	

Inputs		**S/Rate**	**LWG/hd**		**Beef value**	**Cost/hd**
	Low	5.5	155	**Green cells**	$1.60	$60.00
	Med	3.2	136	**take data**	$1.50	$60.00
	High	2.3	112	**inputs**	$1.25	$60.00
	Treed	4.6	121		$1.40	$60.00
	Treeless	2.7	148		$1.50	$60.00

APPENDIX W. Runoff and Soil Loss field methods

Appendix W1. Runoff and soil loss study operational strategies

Service interval and time required

It is anticipated the sites will be inspected every 2 to 4 weeks or as soon as possible after significant falls of rain. The field time for these activities is anticipated at 1 day per fortnight per site in the field, once the site is established. The lab and associated computer and office time is expected to be similar to the field time. This gives a total of around 5 man-days per fortnight on the project.

Field site check list-

Don't leave home without the following:
Drinking water and lunch
Field site key
Laptop computer with Monitor, Boss and Dataflow software and cables.
Field sheets and this check list
Baby oil
Tool box (including small screw driver, silastic, portable drill, drill bits and metal screws, and pliers, and electronic wire trimmers)
Scales, Bucket or Plastic box to weigh sediment in, and shovel
Oven bags
Marking pen
Sample bottles
Neutron Moisture Meter (NMM)
Camera and Boom

Operations

(1) Weather Station
Dump out and check Monitor weather station

- Check the manual rainguage and record any rainfall
- Unlock the logger housing
- Check that the loggers light is flashing and the logger and sensors for any signs of physical damage
- Turn the computer on.
- Connect the MONITOR cable between laptop and logger.
- Get into the MONITOR directory containing the software to retrieve the data.
- Type START and check that the computer time and date are correct as the logger will use these for re-initialising after dumping out the data (If you have to update, use a 24hr clock).
- Check the serial communications section to see that the BAUD rate is set at 1200. You must respond Y to save the changes. (it can help to check again to see that the changes have been saved).
- Retrieve the data from the logger using the file naming system described below.

After retrieving the data:

- Check the logger time and record any significant differences in times between the computer and the logger. Update the time if necessary
- Reset the logger. This will wipe any data from the logger's memory but will not reset the time. Be sure you have retrieved the data before you do this.

(2) Flume sites
Service Gerlach trough/Flume sites.

- Check the pits and troughs for spiders, snakes etc.
- Collect and weigh and record any sediment in the gerlach trough (using scales, bucket and shovel). A sample of the soil may be required to determine soil moisture content (oven bag)
- Collect and record a 1.0 litre sample of any runoff in the collection drum. (Using the sample bottle)
-

Service the Gerlach trough/Flume DATAFLOW logger and Capacitance to Frequency sensor.

- Check the manual rainguage and record any rainfall
- Check the logger and sensor for signs of physical damage.
- Turn the computer on
- Connect the DATAFLOW cable between laptop and logger.
- Put the DATAFLOW disk into the A drive (with the data disk in B drive and directory B:\dataflow on disk).
- Type DF to run the software
- READ the data from the logger using the file naming system described below.

After successfully retrieving the data:

- Reset the logger. This will wipe any data from the loggers memory but will not reset the time. Be sure you have retrieved the data before you do this.
- Quit from DATAFLOW. You may have to change between disks in the A drive to do this.
- Read NMM tubes (NMM), take 0-10 cm moisture sample (oven bag) and take OH cover photos (boom and camera)

(3) Tipping Bucket sites
Service Gerlach trough/tipping bucket sites.

- Unlock the tipping bucket pit and open the lids to the Gerlach troughs.
- Check the pits and troughs for spiders, snakes etc.
- Record the reading on the manual counter on the tipping bucket and note any loose connections and equipment (fix only if confident).
- Collect and weigh and record any sediment in the gerlach trough (using scales, bucket and shovel). A sample of the soil may be required to determine soil moisture content (oven bag)
- Collect and record a 1.0 litre sample of any runoff in the collection drum in the pit. (Using the sample bottle)

Service Gerlach trough /Tipping bucket Boss logger

- Check the manual rainguage and record any rainfall
- Check that the logger's light is flashing about once every 10 seconds, or for signs of physical damage.
- Clean any dust and debris out of the tipping bucket raingauge funnel (and the small one inside).
- Turn the computer on
- Connect the BOSS cable between laptop and logger.
- Get into the BOSS directory containing the software to retrieve the data.
- Type BOSS to run the software
- READ the data from the logger using the file naming system described below.

After successfully retrieving the data:

- Check the parameters on the logger (important that the log interval is set to 5 and the Change for each channel is set to 1.)
- Reset the logger. This will wipe any data from the loggers memory but will not reset the time. Be sure you have retrieved the data before you do this.
- After resetting the logger be sure to check that the light is flashing once every 10 secs.
- Quit from BOSS.
- Run BOSSDATA
- Read the file you just retrieved into BOSSDATA. This will allow you to quickly look at the data in the file and to compare gross counts with the manual counters on the tipping buckets. If you divide the counts on channel 0 by 2 you will get the number of millimetres recorded by the Tipping bucket rainguage. (Channel 1 is the exclosure, channel 2 is the medium grazing pressure plot, and Channel 3 is the high grazing plot.).

- If all OK

  (ie each channel is recording and agrees with the manual counts reasonably)

  Then quit and move on.

- If not OK

  Record the problem, check for any disconnected wires and reconnect if necessary. Reset logger, and ensure light is flashing. Tip the bucket in the pit (noting the number of tips and any changes to the counters etc.). Wait 5 mins and read the logger as described above but using a file name such as test.bos (you should delete any existing test.bos files in the data directory you are using prior to running the program).

  Look at test.bos with BOSSDATA and see if the recorded tips agree with what you did. If they do, move on. If they don't, record the problem and move on.

- Lock up the pits and the logger housing.
- Read NMM tubes (NMM), take 0-10 cm moisture sample (oven bag) and take OH cover photos (boom and camera)

Appendix W2. Naming conventions for Botanal & others assessments of Glentulloch runoff plots

Botanal files:
Groff98.in and Groff98.out
Groff99.in and Groff99.out

Pdk	Data	Analysis	Treat name	File code	Paddock code
2 grazed	21	1	Rep 1 Med Grz	r1m-b	2 CM G
2	22	2	Rep 1 Med Exc	r1e-c	2 CM E
3	3	3	Rep 1 High	r1h-a	3 CH
4 trees	4	4	Trees Excl	et	4 TL
5 flume	5	5	Flume Medium	tfm-h	5 TM
8 grazed	81	7	Rep 2 Med Grz	r2m-e	8 CM
8	82	8	Rep 2 Med Exc	r2e-f	8 C M
9	9	9	Rep 2 High	r2h-d	9 CH
12 flume	12	6	Flume High	tfh-g	12 TH

APPENDIX X. Economic extras

Table X1. Economic scenario for poplar box country based on the mean of 7 years of our research data, for a good and a poor price option

Treatment	Stocking rate ha/head	LWt gain per head kg	Avge steers / 100ha nbr	LWt gain / 100ha kg	Extra wgt cf. lower intensity kg	Extra steers cf. lower inty nbr	Beef value $ / kg	**Extra $** per extra steer $	Profit / extra steer $	Profit/ha per extra steer $	Triple bottom line
Glentulloch - 7 yr avge		**Good prices**									
Destocked	0	0	0	0	0	0	0	-	-	-	
LOW	5.5	155	18.2	2818.2	2818.2	18.2	$1.60	$248.00	$188.00	$34.18	V. good
MED	3.2	136	31.3	4250.0	1431.8	13.1	$1.50	$142.78	$82.78	$25.87	Good
HIGH	2.3	112	43.5	4869.6	619.6	12.2	$1.25	-$23.56	-$83.56	-$36.33	Bad
TREED	4.6	121	21.7	2630.4	2630.4	21.7	$1.40	$169.40	$109.40	$23.78	Good
TREELESS	2.7	148	37.0	5481.5	2851.0	15.3	$1.50	$296.75	$236.75	$87.68	Excellent
Glentulloch - 7 yr avge		**Low prices**									
Destocked	0	0	0	0	0	0	0	-	-	-	
LOW	5.5	155	18.2	2818.2	2818.2	18.2	$1.20	$186.00	$126.00	$22.91	Good
MED	3.2	136	31.3	4250.0	1431.8	13.1	$1.00	$66.43	$6.43	$2.01	Poor
HIGH	2.3	112	43.5	4869.6	619.6	12.2	$0.90	$10.84	-$49.16	-$21.37	Bad
TREED	4.6	121	21.7	2630.4	2630.4	21.7	$0.90	$108.90	$48.90	$10.63	Fair
TREELESS	2.7	148	37.0	5481.5	2851.0	15.3	$1.15	$257.31	$197.31	$73.08	Excellent

Table X2. Economic scenario for silverleaf ironbark country based on the mean of 7 years of our research data, for a good and a poor price option

Treatment	Stocking rate ha/head	LWt gain per head kg	Avge steers per 100ha nbr	LWt gain / 100ha kg	Extra wgt cf. lower intensity kg	Extra steers cf. lower inty nbr	Beef value $ / kg	**Extra $** per extra steer $	Profit / extra steer $	Profit/ha per extra steer $	Triple bottom line
Keilambete 7 yr avge	**Low price range**										
Destocked	0	0	0	0	0	0	0 -	-	-		
LOW	4.5	150	22.2	3333.3	3333.3	22.2	$1.20	$180.00	$120.00	$26.67	Good*
MED	2.7	137	37.0	5074.1	1740.7	14.8	$1.00	$72.50	$12.50	$4.63	Poor
HIGH	2.6	119	38.5	4576.9	-497.2	1.4	$0.90	-$670.30	-$730.30	-$280.88	Disaster
TREED	4	132	25.0	3300.0	3300.0	25.0	$0.90	$118.80	$58.80	$14.70	Fair
TREELESS	2.6	139	38.5	5346.2	2046.2	13.5	$1.15	$236.09	$176.09	$67.73	Excellent
Keilambete 7 yr avge	**Good price range**										
Destocked	0	0	0	0	0	0	0 -	-	-		
LOW	4.5	150	22.2	3333.3	3333.3	22.2	$1.60	$240.00	$180.00	$40.00	V. good
MED	2.7	137	37.0	5074.1	1740.7	14.8	$1.50	$153.75	$93.75	$34.72	V. good
HIGH	2.6	119	38.5	4576.9	-497.2	1.4	$1.25	-$1,326.75	-$1,386.75	-$533.37	Disaster
TREED	4	132	25.0	3300.0	3300.0	25.0	$1.40	$184.80	$124.80	$31.20	V. good
TREELESS	2.6	139	38.5	5346.2	2046.2	13.5	$1.50	$252.51	$192.51	$74.04	Excellent

* Triple bottom line rating is compared to ABS economic data for beef enterprises compiled for Statistical regions of Qld (B. Bartholomew 1996)

APPENDIX Y. List of Figures and Tables

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