final report

Enhancing adoption of improved grazing and fire management practices in northern Australia: Bio-economic analysis and regional assessment of management options

Abstract

In this project we enhanced two existing simulation models, GRASP and ENTERPRISE, and used these alone and in combination to evaluate current and candidate 'best practice' management options for extensive grazing lands across 6 regions in Queensland and the Northern Territory. The main management options of interest were stocking rate, pasture spelling and fire management. Regions included the Victoria River District, Burdekin woodlands, Fitzroy woodlands, Mitchell grasslands of western Queensland, Mitchell grasslands of the Barkly region, and the Maranoa-Balonne woodlands. Regional workshops with local technical specialists and producers guided and evaluated model outputs. Modelled scenarios of different degrees of stocking rate variability over time suggested that annual increases and decreases of around 10-25% per year in total stock numbers per property, in line with changing pasture availability, give improved financial outcomes as well as ensuring good pasture condition. Simulations within specific climate windows can produce results where fixed stocking rates perform better than some degree of variation, but these do not appear to be common. Testing of various wet season spelling regimes suggested that spelling for at least 6 months in a four-year period provided accelerated improvement in pasture condition on the spelled paddocks. If animals from the spelled paddocks were accommodated on other paddocks, however, adverse impacts could occur on these stocked-up paddocks if they experienced successive years of higher than safe utilisation levels. Net benefits of spelling regimes for the whole property can therefore be less than expected. Testing of various fire regimes suggested that use of fire to manage unwanted woody vegetation is economic when woody cover is sufficient to be impacting pasture production but not so dense as to be preventing its regular use (through lack of fine fuel).

Executive summary

Guidelines were identified and evaluated for four management practices in six regions across the grazing lands of northern Australia: managing stocking rate; use of fire; pasture spelling or resting; and development of infrastructure. The six regions were the Victoria River District, Burdekin woodlands, Fitzroy woodlands, Mitchell grasslands of western Queensland, Mitchell grasslands of the Barkly region, and the Maranoa-Balonne woodlands. For each region, a series of two workshops was completed. The output from the first workshop in each region was collated information on current and best practices (the latter informed by a separate project (B.NBP.0579) that reviewed the relevant evidence base) as well as documentation of a representative property on which to undertake simulations and economic analyses for that region. The second workshop for each region discussed and evaluated modelled information on the biophysical and economic impacts of implementing current and best management practices (identified at the first workshop in each region) on the representative property.

To adequately simulate the biophysical impacts of variations in practice (eg, varying degrees of stocking rate flexibility; frequency and duration of wet season spelling), algorithms within the GRASP model were significantly enhanced with respect to pasture condition and its relationship to utilisation rates, tree basal area changes over time, and annual stocking rate flexibility in relation to available pasture. In addition, the ENTERPRISE model was modified to handle multiple paddocks and mobs and to permit reallocation of grazing pressure across paddocks associated with the spelling of other paddocks.

Variations in practice were evaluated by 2 types of scenario analysis for each region. Firstly, component analysis using GRASP tested variations and combinations of stocking rate management, pasture spelling and burning for several major land types and for 20 different climate windows of 30 years each. This enabled generalisations to be made and avoided misinterpretations associated with starting simulations in one climatic period. This process, combined with input from each region about the practice variations of particular interest, identified the subset of scenarios that were investigated by the second type of analysis, property-level analysis using both GRASP and ENTERPRISE. Property-level analyses were conducted over one climate window only.

Based on component and property-level analyses, the key inferences for the management practices included:
For stocking rate management. Some degree of flexibility between years was generally better (in terms of pasture condition and livestock production) than a fixed stocking rate when the total stock number for the property was at or near the safe carrying capacity (equivalent in general terms to long-term carrying capacity as in the Grazing Land Management workshop). This was also generally associated with a better economic outcome at the property level. A high degree of flexibility produced higher revenue in a majority of cases, but gave increased risk and in some cases, the negative impacts of poorer years were greater than the benefits of the good years. There were regional variations in the modelled responses, with the Burdekin and Fitzroy catchments in north Queensland exhibiting decreased productivity and profitability from flexible stocking rates relative to fixed stocking at safe carrying capacity. This appeared to be due to the run of years in the property model runs, with a number of poor years following a number of very good years, during which time animal numbers built up in the flexible stocking regime options. This resulted in damage to the pasture in the transition to poorer years and this damage remained apparent for the duration of the simulation. These situations appear to be relatively uncommon. Interestingly though, these simulations match measured pasture, animal and economic data at the Wambiana grazing trial during the same climate window.

For use of fire. There was interest in use of fire in several regions, and modelling indicated that fire had benefits for production in some regions (Burdekin Woodlands, Victoria River District) for managing unwanted woody vegetation. In drier areas it was generally seen as not applicable

(Qld Mitchell grasslands) or important only with respect to prevention of the adverse impacts of wildfire (Barkly). As expected, modelling indicated that the opportunities to use fire are strongly related to rainfall, land type fertility, presence of trees and stocking rate. Lower fertility land types and lower rainfall areas produced fewer opportunities to get successful burns, particularly if trees were present or the areas were grazed in the growing season before burning.

For pasture spelling There was considerable interest in this practice as a means of improving land in poor condition. Modelling indicated that the more frequent the spells and the longer each spell was, the better the pasture response was (at least until pastures had recovered). A major issue was the management of stock from the spelled paddocks. In all regions, and especially in the more remote ones, there was an overwhelming view that stock had to be moved onto other paddocks within the same property. This meant that benefits of spelling could be reduced or negated by the heavier grazing pressure imposed on those areas carrying the extra stock from the spelled paddocks. Modelling showed major impacts of the sequence of years experienced on the net benefit of spelling regimes. The main issue in a four-paddock rotation was that the last paddock to receive a spell usually showed serious pasture decline because of the three consecutive growing seasons during which its effective stocking rate was increased by 33%. Options to overcome this problem need to be examined.

In more extensive areas there was significant interest in spelling country by shifting the pattern of grazing with water point management rather than with additional fencing. There was significant uncertainty about the effectiveness of this approach and how best to implement it. No modelling was done to investigate this issue.

The practical issue of moving stock during the wet season meant that in areas with heavy clay soils, spelling would most likely be applied for the whole growing season rather than for part there-of. Spelling for a short period (2-3 months) every four years may enable a slightly higher stocking rate to be carried for the remaining period, thereby giving a greater total grazing time per unit area compared with carrying a lower number of animals all the time. However, achieving this increased stocking rate when stock from spelled paddocks need to be accommodated on other areas could be problematic. Further work on this aspect is warranted.

There are still a number of model limitations that prevent simulations of the impact of spelling on a whole property basis when combined with a flexible stocking rate. This should be remedied in future work.

For infrastructure development. This was of interest mainly to the regions within the Northern Territory/WA. Guides as to the maximum numbers of animals per watering point (~300) and maximum paddock size (one water point per 20-25 km^2) were developed from examination of the literature. There was some regional variation in these figures. Limited economic modelling was done and no biophysical modelling was applicable for this issue. There is a need for some simple economic modelling to assist producers to decide on the most appropriate intensity of infrastructure development consistent with their objectives.

A related project (B.NBP.0579) has drawn together the existing information relevant to these four topics identified as the most important management-related activities in extensive grazing systems in northern Australia. This has been complemented by new, property-level modelling and analyses of some of the management options at a regional level. As such, the guidelines developed for each region provide the best available information on these management options for the six regions studied. These guidelines will be used as a resource to inform any management-related documents, workshops or field days. The project's findings should point the way forward for new research or demonstration activities within northern Australia (in relation to these four management areas).

Contents

1 Background

This project is part of the Northern Grazing Systems (NGS) program which aims to increase adoption of innovative best-practice grazing management by beef producers throughout Queensland, Northern Territory and the Kimberley and Pilbara regions of Western Australia. These practices have potential to benefit up to 3 million km^2 of northern Australia.

This project will improve understanding of interactions and trade-offs, and identify cost effective grazing land management strategies for:
- improving animal production and economic performance;
- improving and maintaining land condition (vegetation, soil health and water quality); and
- improving risk management in relation to climate variability.

The importance of infrastructure development (fencing, waters), stocking rate management, pasture spelling, and prescribed burning have been demonstrated at various field study sites. However, researchers and practitioners were unable to predict how variations and combinations of these practices will affect the productive capacity and resource condition of grazing land in particular situations. In addition, the economic and practical implications of implementing these strategies at an enterprise scale were unclear. This limited the rate of adoption of practices to improve grazing and fire management across northern Australia. The NGS program will integrate, enhance and extend key findings and knowledge generated from completed grazing and fire research funded by MLA and other research organisations across northern Australia.

NGS will be undertaken in two phases:

Phase 1 was completed in July 2010 for five targeted regions:

- Victoria River District and east-Kimberley;
- Burdekin-Fitzroy[1] woodlands;
- Mitchell grasslands - western Queensland;
- Mitchell grasslands - Barkly Tablelands; and
- Maranoa-Balonne woodlands.

Three activities were undertaken in each region, being:
1. Regional assessment - Source, collate and report region-specific research data and herd and pasture management practices, and facilitate the input of producers and other regional specialists in identifying and assessing best-bet management guidelines. [reported elsewhere as part of B.NBP.0578]]

2. Synthesis - Review, analysis and synthesis of data and outputs from completed field research studies across northern Australia to develop additional insights, produce relationships that assist extrapolation to a range of environments and starting conditions, and to generate a suite of best-bet management guidelines and strategies for different environments and scales of operation. [reported in B.NBP.0579 Final Report]

3. Bio-economic modelling – Modify, link and apply existing simulation models to evaluate best-bet guidelines and strategies in terms of their impacts on the productive capacity of grazing land, water quality, soil health, risk profile and economic performance.

Phase 2 commenced after the completion of Phase 1 and will implement, test and increase adoption of these practices through on-property demonstration sites, field days, forums, training workshops and MLA/DEEDI producer publications. It will also roll out the bio-economic modelling

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[1] In the original proposal, this was regarded as one region. In this report, results are reported separately for the Burdekin and Fitzroy catchments.

framework, for evaluating best-practice management strategies, across other regions of northern Australia.

2 Project objectives

1. Documented current (range and relative occurrence) and best-bet strategies and practices related to infrastructure development, managing stocking rate, pasture spelling and prescribed burning for each of the five study regions:
    *   Savannas of the Victoria River District (NT) and east-Kimberley (WA)
    *   Woodlands of the Burdekin and Fitzroy catchments (north-east and central Qld)
    *   Mitchell grasslands of western Queensland
    *   Mitchell grasslands of the Barkly Tablelands (NT)
    *   Woodlands of the Maranoa-Balonne region (southern Qld).

2. Developed and defined representative grazing enterprises and required parameters for use in bio-economic modelling for each of the five study regions.

3. Contributed regional input to B.NBP.0579 for the synthesis and analysis of research and publications and development of key principles, response curves and best-bet guidelines for grazing land management relating to infrastructure development, managing stocking rate, pasture spelling and prescribed burning.

4. Developed a bio-economic modelling framework that evaluates biophysical and economic impacts of management strategies and practices (infrastructure development, managing stocking rate, pasture spelling and prescribed burning).

5. Used the bio-economic modelling framework to quantify the impacts and trade-offs associated with current and best-bet grazing land management strategies (infrastructure development, managing stocking rate, pasture spelling and prescribed burning), derived from Objective 1 and from B.NBP.0579, on measures of animal production, enterprise profit, land condition, water quality and risk in each of the five study regions.

6. Validated and refined with producers and other local specialists the best-bet guidelines (infrastructure development, managing stocking rate, pasture spelling and prescribed burning) from the bio-economic modelling for each region.

7. Using output from Objectives 5 & 6 and in conjunction with B.NBP.0579, contributed to the development of a revised set of best-bet guidelines for infrastructure development, managing stocking rate, pasture spelling and prescribed burning for each of the five study regions.

8. In conjunction with B.NBP.0579, contributed to the selection of a sub-set of best-bet guidelines for each region to be extended via regional producer demonstration sites.

9. In conjunction with B.NBP.0579, contributed to the identification of priority grazing land management research questions, and their justification, for each study region.

3   Methodology for bio-economic modelling

3.1   Changes to the GRASP model

GRASP is the most widely tested and used pasture-grazing model in northern Australia, and has been well documented in Rickert *et al.* (2000) and McKeon *et al.* (2002). After an analysis of the features required to undertake this study, a number of changes to the GRASP model were required to enable the simulation of the various management strategies proposed in this study. These changes were made to the FORTRAN developer's code after initial prototyping in STELLA® simulation software (from iseee systems - http://www.iseesystems.com/).

The major changes are described below. Examples of the effects of these changes to model output are given. In many situations, the changes produced by the new model routines were relatively minor and these situations are not discussed here.

3.1.1   Pasture condition

In the original model (pre 1990), the percent perennials was used only as an indicator of pasture 'condition'. In the mid 1990s, the percent perennials was dynamically linked directly to several parameters i.e. these parameters were altered during the simulation rather than being fixed. For example, when the percentage perennials decreased, the maximum nitrogen uptake was reduced. Essentially there are a set of parameters which represents the pasture when it is in excellent condition (90% perennials; A condition, represented in the model as State 0). At the other extreme, there are parameters which represent the poorest state that the modeller wishes to use in the simulation (1% perennials; C- condition or State 11). Table 1 shows what parameters change with a change of state. It is possible to allow the model to stay in state 11 once it reaches that state, or to allow the simulated pasture condition to improve after state 11 has been reached. The relationship between state and the percentage of perennials in the pasture dry matter is shown in Figure 1.
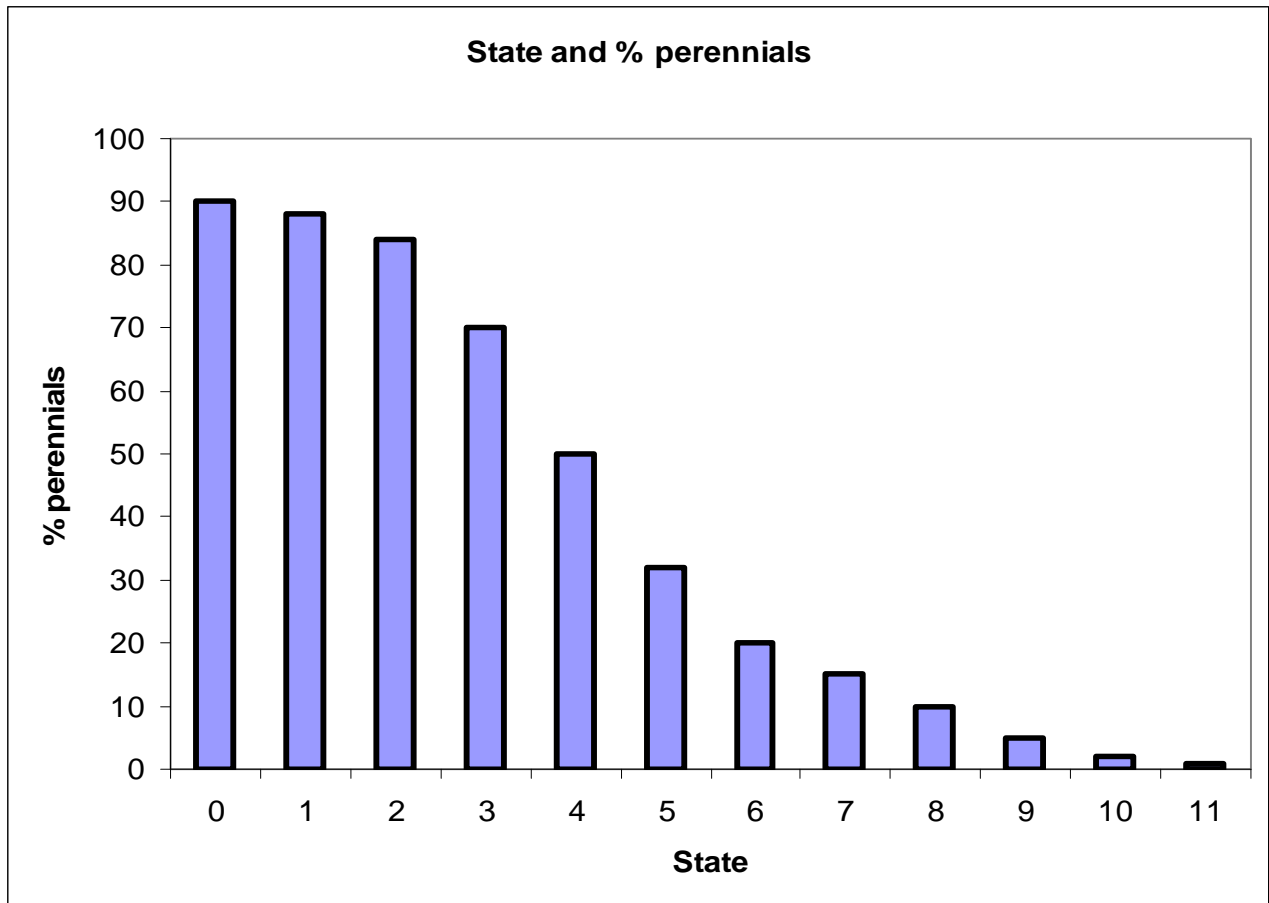
Figure 1. Relationship between percent perennials and state as used in the GRASP degradation model.

The parameters that are represented in the best and worst conditions are then used to calculate a parameter value by a linear interpolation between the two extremes. The relationship between the parameters in excellent and very poor condition is shown in Table 1.

Table 1. Parameters that are considered in representing the best and worst pasture conditions in simulation runs, showing relationships between these used in this work.

Parameter name	Parameter number in State 0 (range shown)	Relationship between values in State 0 & 11
Initial pasture condition	p(194) (0 to 11)	na
Recovery rate – maximum increase in condition during one year under 0% utilisation	P(195) (1 to 3)	na
Degradation rate – maximum decrease in condition in one year under 100% utilisation	P(196) (1 to 3)	na
Can condition recover from state 11	P(197) (0 or 1)	na
% utilisation for an increase in condition by one state	P(198) (typical values from 10 to 25%)	na
% utilisation for a decrease in condition by one state	P(199) (typical values from 25 to 45%)	na
% utilisation when condition does not change	P(83)	na
Maximum nitrogen uptake	P(99)	p(181) = p(99)*0.7
Green cover when transpiration is 50%	P(45)	p(182) = p(45)*0.75
Height (cm) of 1000 kg/ha	p(96)	p(183) = p(96)*0.75
% N at zero growth	p(101)	p(184) = p(101)+0.2
% N at maximum growth	p(102)	p(185) = p(102)+0.2
Prop of dead leaf detached per day from 1 Dec	p(128)	p(186) = p(128)+0.00

to 30 April		
Prop of dead stem detached per day from 1 Dec to 30 April	p(129)	p(187) = p(129)+0.002
Prop of Dead leaf detached per day from 1 May to 30 November	p(130)	p(188) = p(130)+0.002
Prop of Dead stem detached per day from 1 May to 30 November	p(131)	p(189) = p(131)+0.002
Soil water index at which above-ground growth stops.	p(149)	p(190) = 0.9
Yield (kg/ha) at which intake restriction no longer operates	p(144)	p(192) = p144
Soil water index for maximum green cover	p(009)	p(193) = 0.9
Growth index for green day/frost	p(056)	p(200) = p056

In the original model, the states were represented as integers i.e. there were 12 states including state 0 and state 11. The change of state could only occur as an integer change (Figure 2). If the utilisation rate for the year was higher than p(199), then the condition would decrease by one state; if below p(198), then condition would improve by one state. Between p(198) and p(199), condition did not change. This step function can lead to anomalous situations where pasture utilisation rates were close to these thresholds for a large proportion of the time, but because they did not exceed the threshold, condition did not vary.

The new formulation of this part of the model represents state as a real variable and allows this to change by any amount between +p(195) and -p(196) in any one year. Results from this project suggested that the simulated rate of change of pasture condition was too high in many cases using the new formulation. As a result of this, a proposed model has been developed (Figure 2). This will be extensively tested; initial indications are that it is more realistic in its rate of change (as judged by experienced researchers and practitioners).

In addition, the histogram shown in Figure 1 is represented as a continuous non-linear regression (rather than as a set of discrete intervals).
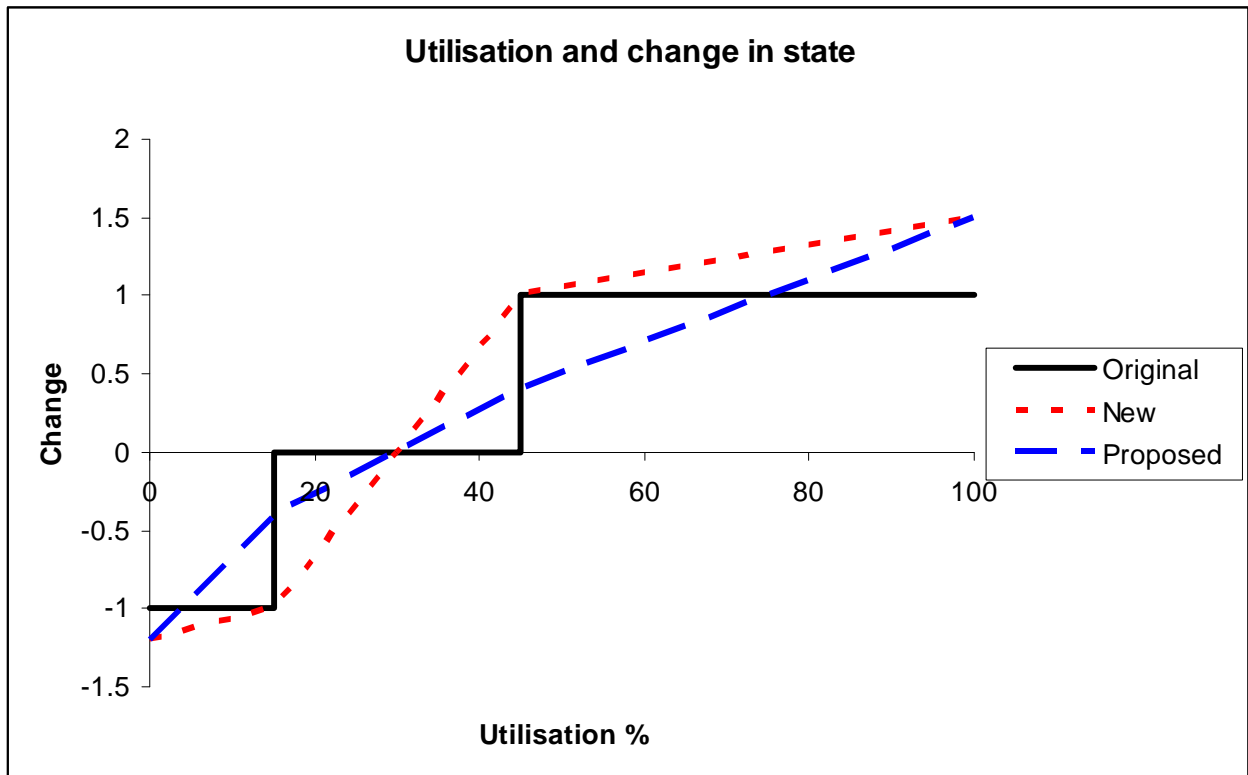
Figure 2. The original (step function) and new (piecewise linear function) models of the change in state as influenced by utilisation. (The proposed model has now been tested and appears to represent the expectations of technical experts to a greater degree than the first improvement to the original model.)

3.1.2 Percentage perennials

The major change for the percentage perennial calculations is that this is now a continuous variable rather than the 12 levels which corresponded to the states. The linear interpolation of the variables listed in Table 1 still applies as in the original model, however, there are a whole range of values which these variables can take on, not simply the 12 steps that were possible under the original formulation. In addition, the utilisation is a weighted value as described in 3.1.3 (which was also used to estimate grass basal area change).

Example: The Goldfields (no trees) land type (moderate fertility, neutral red duplex soil) in poor condition was set-stocked at 12 AE/100 ha. Three simulations were compared: the original degradation option; the new method; and finally the proposed method. In the first case, the percentage perennials changes but this does not influence any of the growth parameters within the model: for the other methods, growth parameters were linked to the percentage perennials.

In Figure 3, the percent perennials differ quite markedly between the three simulations. When the original model was used, the pasture utilisation level was less than the safe level, but not sufficiently low that it allowed pasture condition to improve. Thus the simulated pasture condition remained poor, leading to poor growth and under a fixed stocking rate regime; this ensured that condition did not improve. By contrast, the new model allowed pasture condition to improve in the mid-1970s, thereby giving good growth and enabling the fixed stocking rate to be carried through some of the poor years following the 1970s. Over time, pasture condition improved to the maximum of 90% perennials.

When utilisation rates are outside the central range (above the upper or below the lower threshold values) for most years, there will be little difference between the original and new models. However, it is more common for the utilisation to be between these values. This causes the original model to indicate no change in condition whereas the new models do produce some change (in some cases quite small) unless the utilisation is exactly equal to the long-term safe

utilisation level. The proposed model gives a rate of change which appears slower and more realistic than the 'new' model.
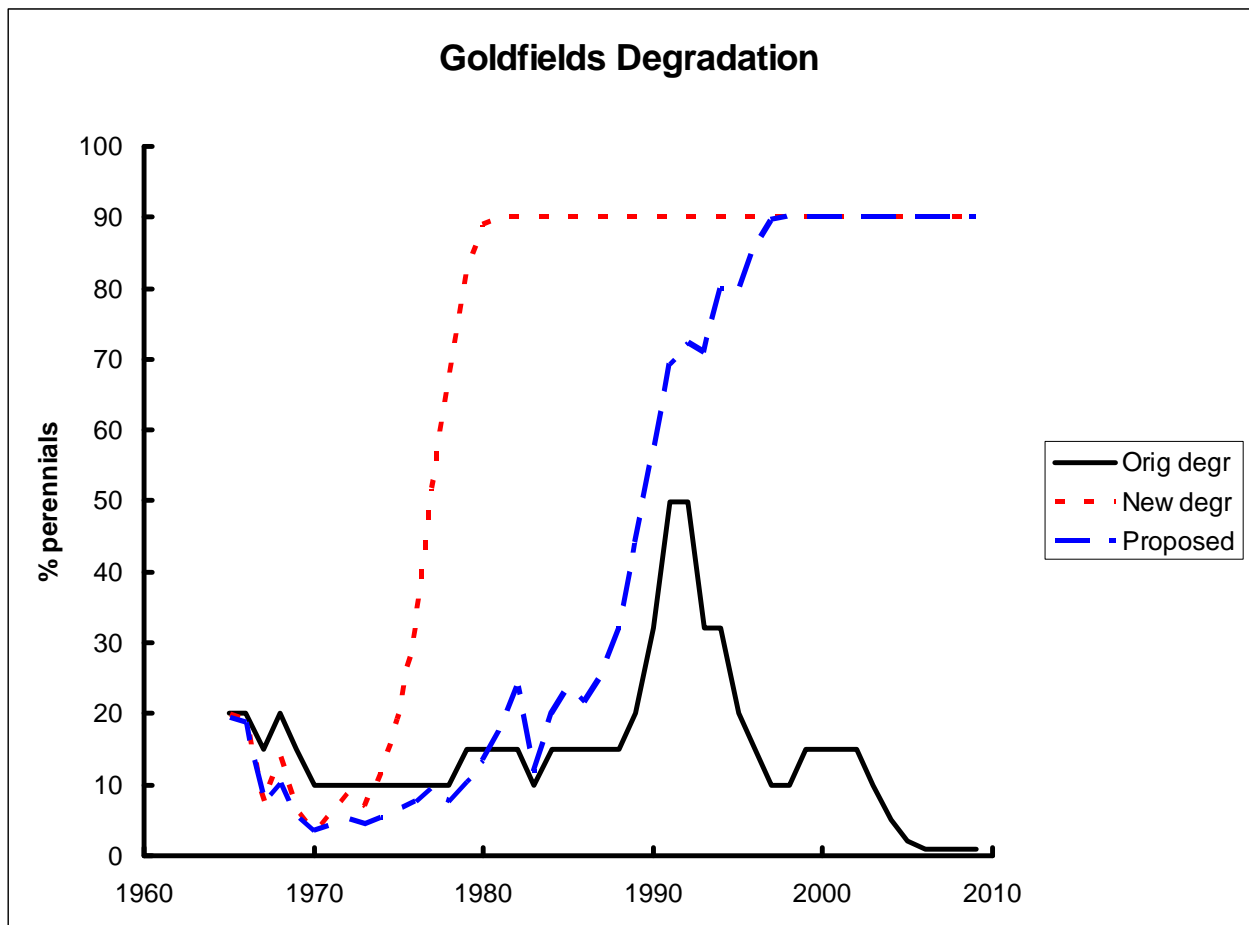

Figure 3. Percent perennials for Goldfields land type for simulations using the original degradation option, the new model and the proposed model.

3.1.3 Weighted grazing impact

Within northern Australia, perennial grasses are known to be sensitive to grazing during the early growing period. The original version of GRASP did not differentiate between utilisation that occurred at different times of the year e.g. heavy grazing in Dec-Feb had the same effect on grass basal area and percentage perennials as the same level of grazing in Jun-Aug.

In the revised model, a weighting was applied to the utilisation that occurs during each month of the year (Figure 4). That weighting can vary from all months being equal at one extreme to all grazing impact occurring during the six months of the growing season at the other extreme. The month of peak impact is a parameter as is the total weighting/effect over the six months of the growing season. This change impacts on grass basal area and percent perennials which both have affects on pasture growth estimates.

A limitation is that the same weighting factors are applied each year, irrespective of the growing conditions in that particular year. Thus, a high utilisation rate (say 40% compared to a safe level of 25%) would produce the same change in a very dry year as in a year with very good growing conditions. This applies to the majority of management-related parameters within GRASP.
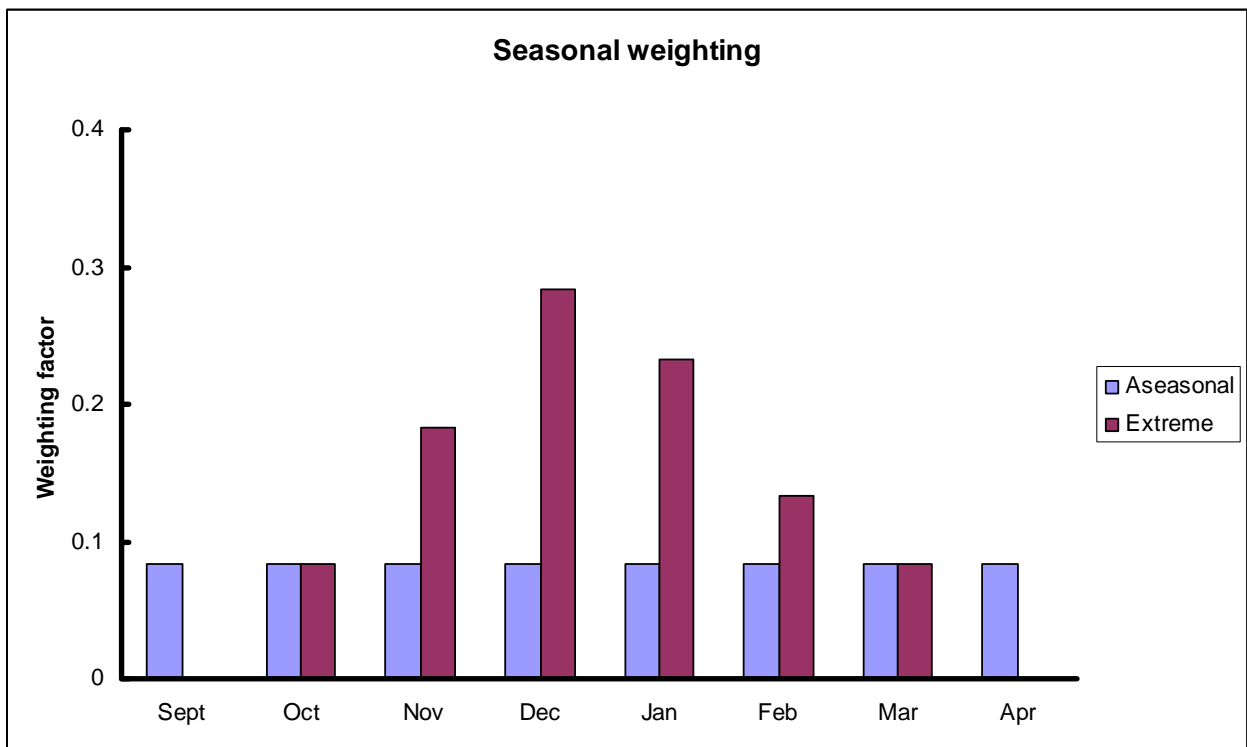
Figure 4. The weighting factor applied to utilisation to simulate the degree of seasonality in the effect of utilisation on grass basal area and percent perennials. For *Aseasonal*, all months are equal in their effect; for *Extreme*, maximum monthly weighting is 28% for selected peak month (Dec in this case).

3.1.4 Grass basal area

Field observations indicate that the dry matter yield that can be grown at a certain grass basal area is partly dependent upon the pasture species and partly on the environment. For example, in central and southern Queensland, a grass basal area of 5% could support a growth of about 2500 kg/ha. This was used to estimate a monthly figure of 80 kg/ha/month/unit of basal area. In some areas of the Northern Territory, monthly growth may exceed 150kg/ha, based on extensive pasture productivity studies. The utilisation and the growth during the growing season (both cumulative) impact on the monthly grass basal area, with higher utilisation and lower growth leading to decreased grass basal area. These monthly changes are constrained by user-defined parameters. These observations are used when determining the appropriate parameters in the new grass basal area sub-model.

Example of effect on simulations: The Goldfields land type was grazed at a fixed stocking rate of 5 AE/100 ha for pasture with 20% perennial grasses and a tree basal area of 2.5 m^2/ha. In the original model, the grass basal area varied between 2.1 and 6.4 whereas with the new model, it was generally lower and varied between 0.3 and 5.1 (Figure 5). The major differences occurred during poorer years, when the new model simulates marked declines in grass basal area due to the heavy grazing of early growing season growth. The major affect of grass basal area in the simulations is to influence growth in the early growing season period with a lower grass basal area producing lower growth. As this is the period when the pasture is most sensitive to high utilisation rates, the feedback is quite marked.

The more seasonal is the climate, the higher the weighting value that should be used in the simulations to reflect the greater damage that can occur by grazing early in the growing season.
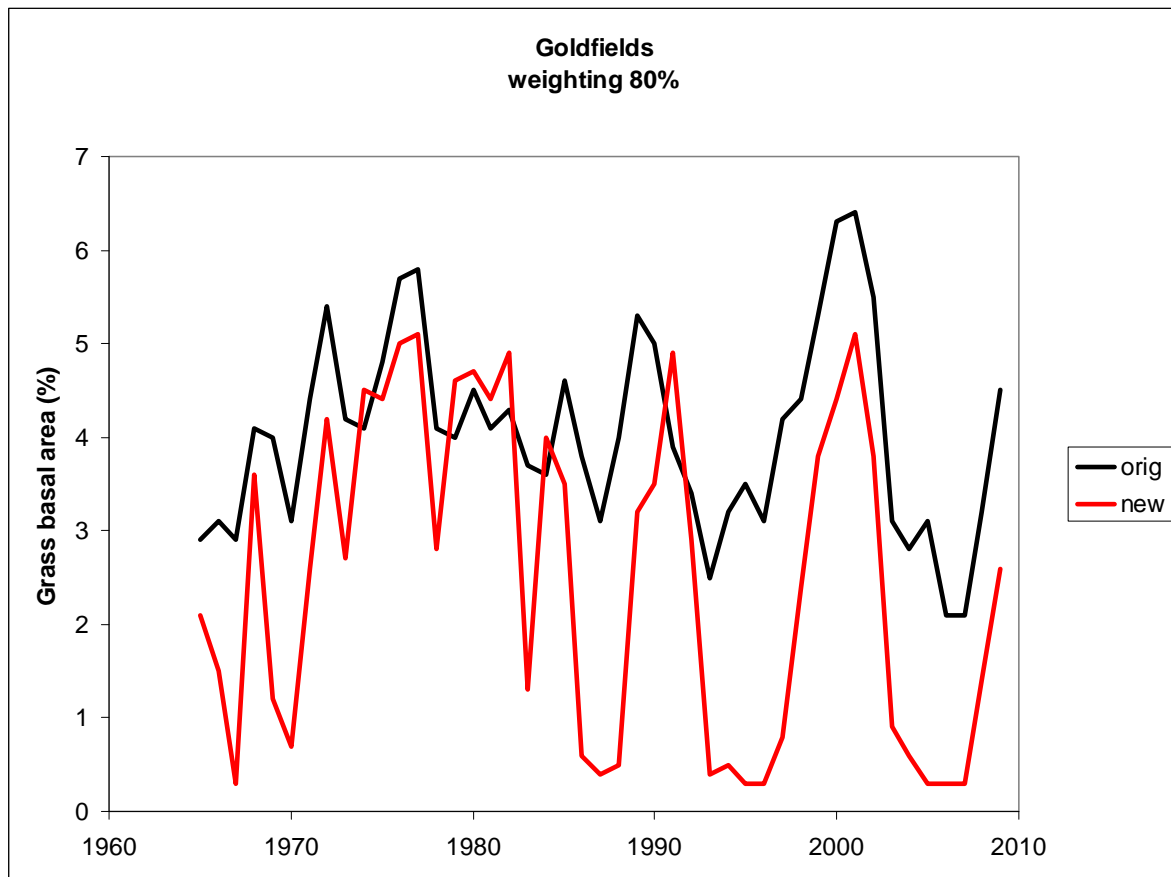
Figure 5. Grass basal area changes comparing the original and new model of utilisation effects on GBA. (A weighting of 50% is equivalent to no monthly weighting; a weighting of 100% represents no grazing impact outside the Oct-Mar growing season).

3.1.5   Tree basal area change

The original developer's version of GRASP used a fixed tree basal area (TBA), although it was possible to specify a tree basal area for each year using the management code methodology. This required specifying a date and a new tree basal area prior to the commencement of simulations.

A very simple tree growth model was developed and included in this version of GRASP. The starting tree basal area is a parameter and the annual rate of increase is another parameter. This would result in exponential growth, so a third parameter is required to specify a maximum possible TBA. The rate of increase is fixed for the duration of the simulation. Specifically, there are no differences between good and poor years.

The TBA can be reduced if there are fires. Below the dry matter yield threshold at which fires can be carried, there is no effect of fire (Figure 6). At a high fuel load, the effect of fire is at a maximum. The reduction in TBA from a fire with > upper threshold of fuel loads is specified as a parameter, with a linear increase in effectiveness between the lower and upper threshold values. Thus the change in effectiveness depends on the dry matter present, and is not influenced by any other feature. To represent regrowth (rather than mature woodlands), we use a higher annual rate of increase and a higher decrease in tree basal area at maximum fire effectiveness.

3.1.6 Flexible stocking rates

The stocking rate options available in the original developer's code within GRASP were fixed stocking rate or fully responsive stocking rate. For fixed, the stocking rate was a constant number of animals (of a specified starting weight) per unit area for the whole simulation period. For the fully flexible option, the number of animals was set at the end of the growing season (a user defined date) when a certain proportion of the available forage (utilisation rate) was set to be eaten over the ensuing 12 months. These are the extremes of what is actually done in the real world by land managers with very few producers practising moderate to high flexibility. To enable GRASP to model some of these situations, another option was developed. This enables a cap to be placed on the annual changes in stocking rate and the absolute changes that may occur over a simulation period. By making these allowable changes very small, a fixed stocking rate is mimicked; by making the changes very large, a fully flexible strategy can be represented (see Figure 7 for examples of the three stocking rate models). From the first series of workshops that were run, it appeared that common practice is about 10-20% annual change and 25 to 50% change over a simulation period (usually 25-30 years).
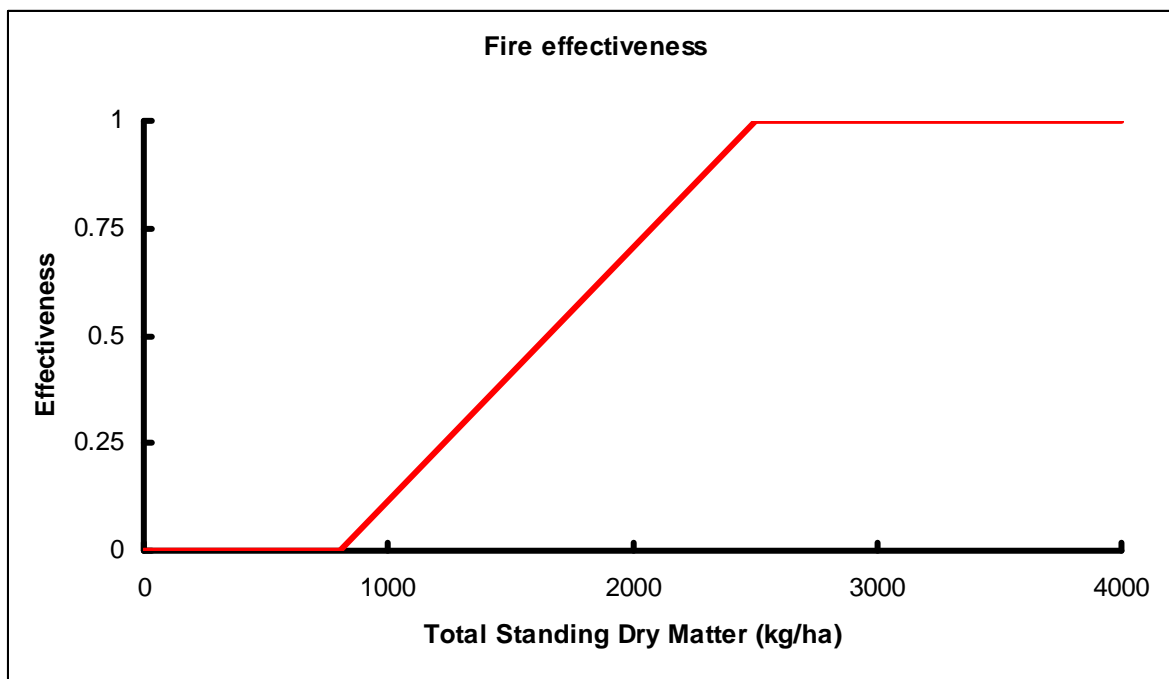

Figure 6. Relative effectiveness of fire in reducing tree basal area as a function of standing dry matter. [The maximum reduction in TBA is a parameter set in GRASP}.

Example: Figure 7 shows the stocking rate management options for a Goldfields land type where the pasture was initially in C condition (~20% perennials): fixed (14.9 head/100ha); moderate flexibility (20% increase and decrease per year and 40% maximum variation over the simulation period) and fully flexible (no constraints on year-to-year variation). Figure 8 has the yearly variation in percent perennials.

The fixed stocking rate leads to a further deterioration of pasture condition (see Fig. 8). The fully flexible option leads to wide variation in stocking rate. During the early 1980s, pasture decline is observed as the annual change in stocking rate is higher than the pasture can support, and further damage occurs. In this example, the pasture cannot recover, even though the stocking rates are adjusted each year. In comparison, the moderate flexibility did not damage pastures. In this case, the stocking rate during the 1970s did not increase as much as in the fully flexible treatment. Consequently, the poor years in the 1980s, mid 1990s and 2000s did not adversely impact condition, as the pasture condition at the start of the poor years was better, enabling it to withstand the poor periods better. The perennials continue to improve but the stocking rate can

only improve to the 40% limit imposed by the user. In simulations where it is anticipated that pasture improvement will occur, the user should have a high upper limit to allow the stocking rate to increase as condition increases.
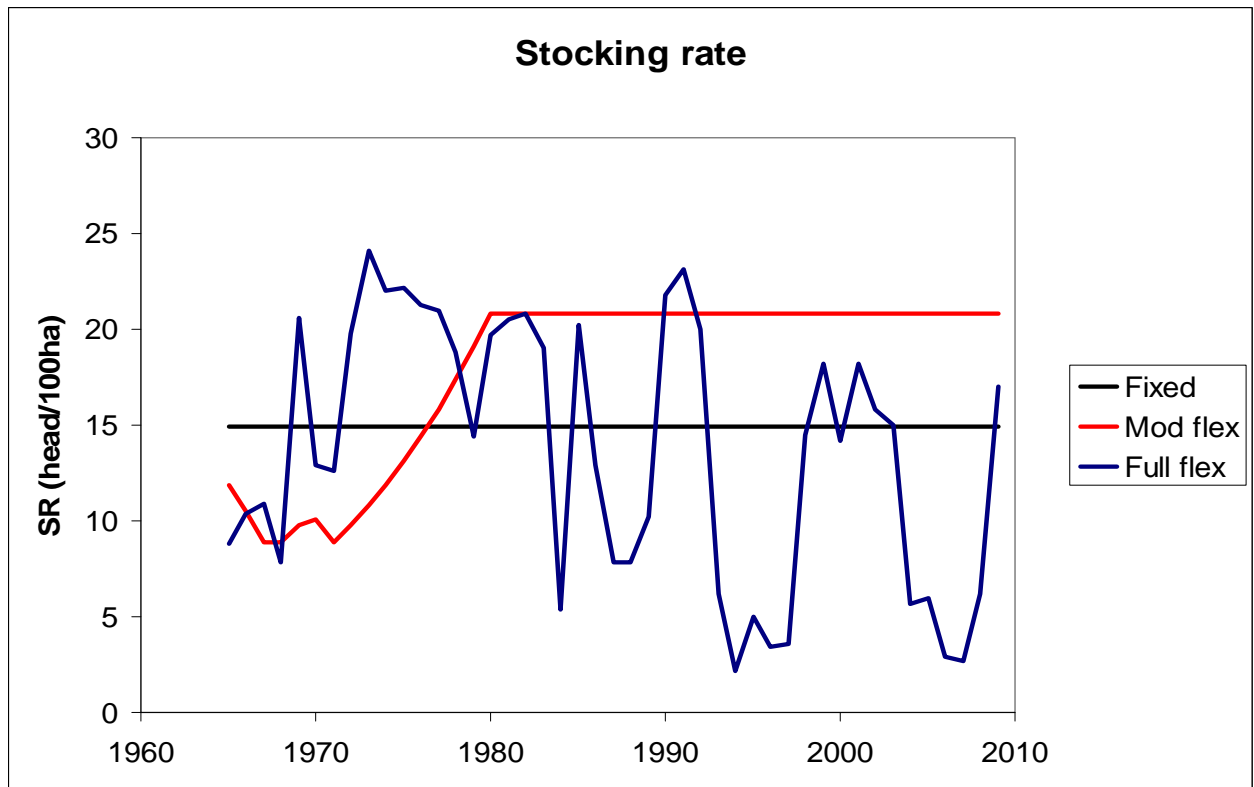

Figure 7. Annual stocking rates under the three stocking rate strategies (fixed, fully flexible and moderate flexibility). (Annual changes are limited to +/- 20% and +/- 40% over the whole simulation period, compared with the fixed stocking rate.)
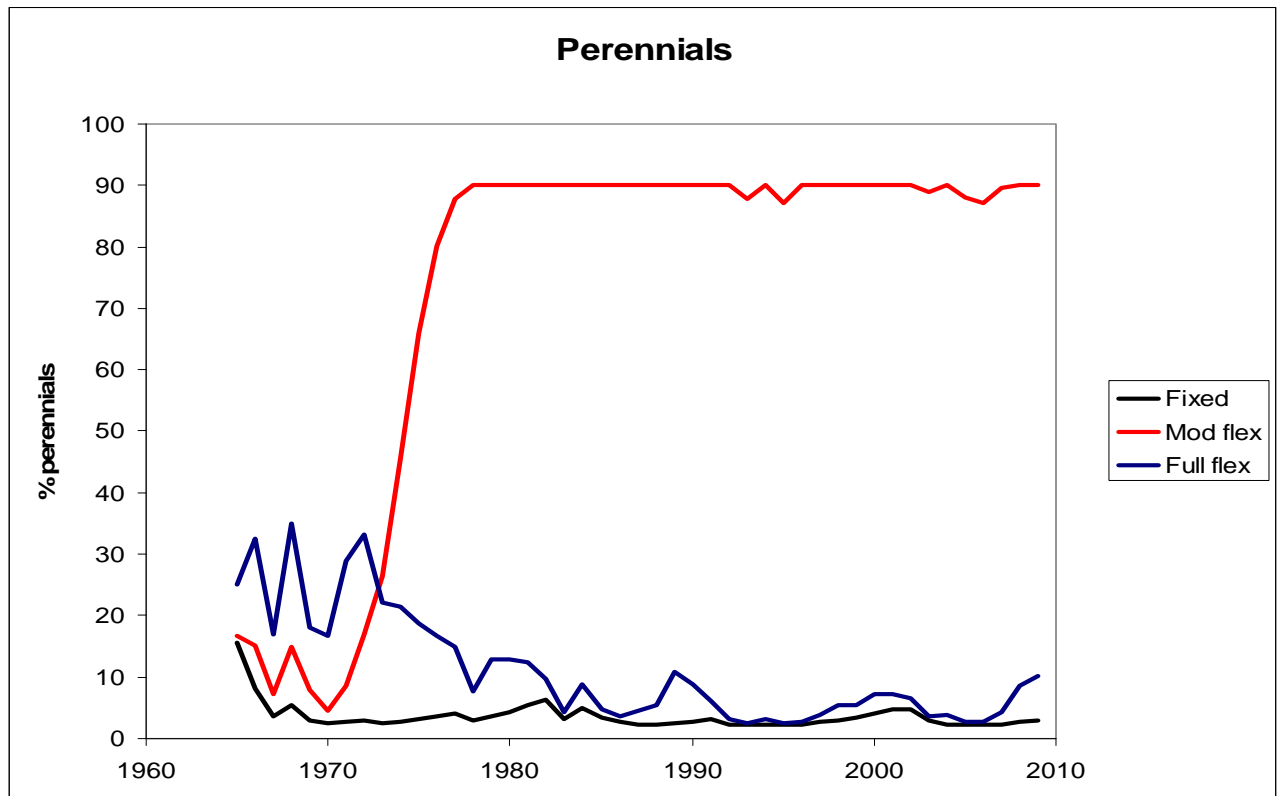
Perennials

Figure 8. Percent perennials for the three stocking rate strategies shown in Figure 7.

3.1.7 Monthly liveweight gain

An initial investigation of the feasibility of developing a monthly liveweight gain model was undertaken. Data from two fixed stocking rate treatments in the Wambiana grazing trial was used for model development.

The general approach was to build upon the current annual liveweight gain model in GRASP which uses a multiple regression in which the independent variables are % utilisation of growth and % green days (i.e. those days with a growth index > 0.05). To this, we added another term – month. This was necessary as it appeared that for a given utilisation and % green days, there was a different liveweight gain depending on the month of the year. This is likely to be related to pasture quality (which is not explicitly modelled in GRASP).

The response surface developed using these three variables accounted for about 66% of observed variation in the actual data – for both supplemented and unsupplemented data. Results are shown in Figure 9. This change was not incorporated into the version of GRASP used to model property-level management practices. Further work on this is needed and is planned.

3.2   Modelling stocking rate, spelling and fire impacts

The following sections address the GRASP modelling known as component analysis, which was completed as part of the bio-economic modelling for the NGS project. Component analysis refers to detail analysis of stocking rates, pasture spelling and burning, done individually on several land types within each region and for 20 different climate windows of 30 years. This enabled generalisations to be made and avoided misinterpretations associated with starting simulations in one climatic period. Simulations at the representative property are reported in section 4.2.

The component analysis was conducted for each of the six NGS regions, being:
- Woodlands of the Maranoa-Balonne region (southern Qld).
- Mitchell grasslands of western Queensland

- Woodlands of the Burdekin catchment (north-east Qld)
- Savannas of the Victoria River District (NT) and east-Kimberley (WA)
- Mitchell grasslands of the Barkly Tablelands (NT)
- Woodlands of the Fitzroy catchment (central Qld).

The purpose of the component analyses was to simulate the outcomes of a range of grazing land management strategies concentrating on managing stocking rate, pasture spelling and prescribed burning, over 20 different climatic periods, each of 30 years duration. The results of the component analyses, combined with what was regarded by the regions as priority grazing land management practices, were then used to identify the grazing land management scenarios that would be investigated by the property level analyses.

The focus of investigations by component analysis was the extent to which a range of stocking rate, pasture spelling and prescribed burning strategies impacted pasture condition and livestock productivity. These are described in the methodology section that follows.

METHODOLOGY
The component analysis occurred at the level of individual land types. Two to three land types were selected in each of the six regions, representing levels of fertility - low, moderate and high. The land types modelled for each region are shown in Table 3.

The component analysis was confined to the grazing land management factors that have been identified as priorities for the NGS project, being:
1. Management of stocking rate;
2. Pasture spelling; and
3. Prescribed burning.

Figure 9. Modelled monthly liveweight gain for Wambiana grazing trial for two stocking rates and with and without supplementation.
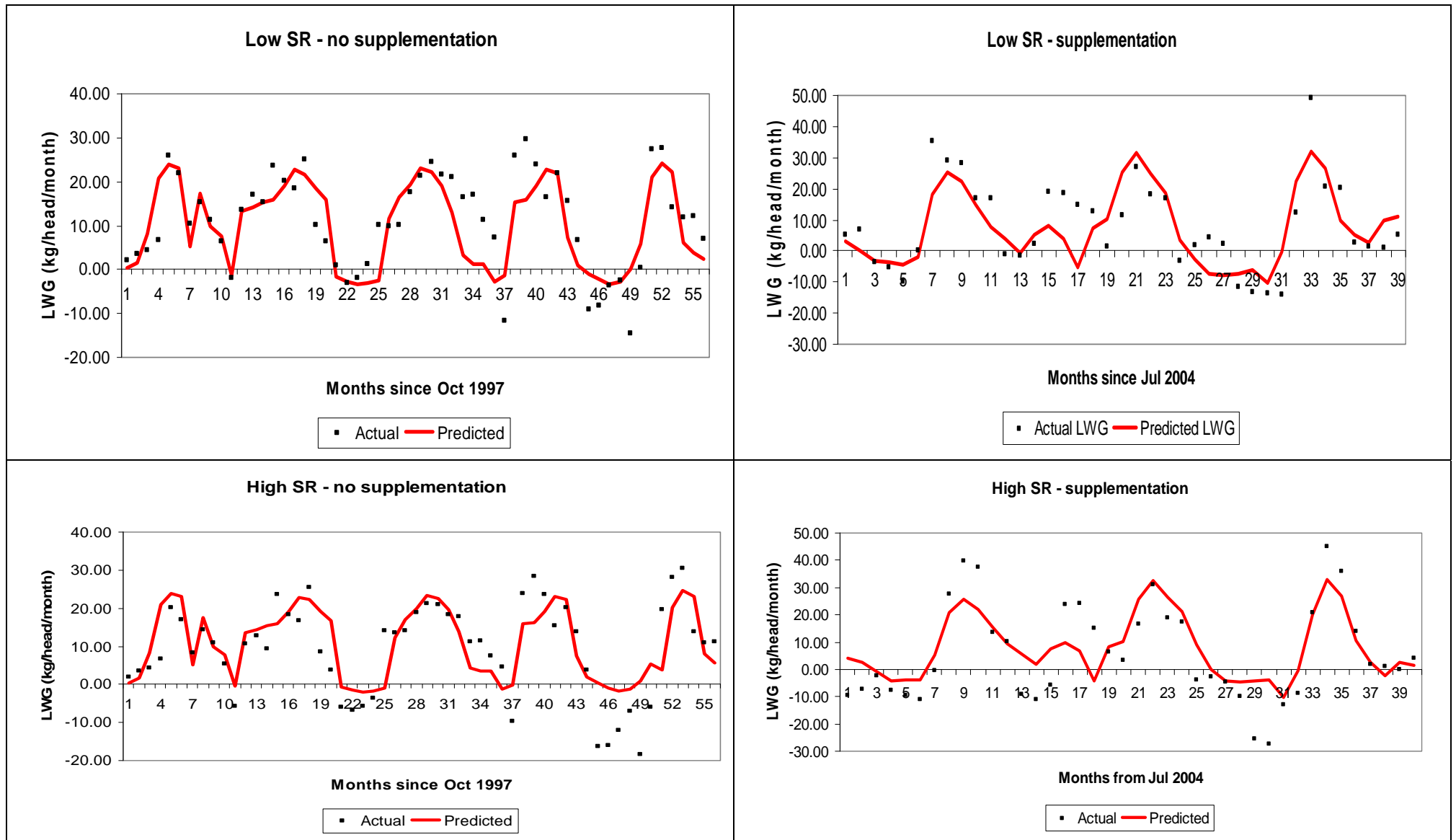
Table 2. Summary of simulations done for component analyses.

Region	Land types	Stocking rates[2]	Spelling	Burning
Woodlands of Maranoa-Balonne, region, Qld	Brigalow/belah Poplar box on alluvial plains Soft mulga	Fixed Current practice (±20% ±40%) Highly flexible (±50% ±90%) Fully responsive	2, 3 and 6 month spells with stock agisted	Frequency of cool and hot fires
Mitchell grasslands of Western Qld	Open downs Open alluvia Soft mulga sandridges	Fixed Current practice (±20% ±40%) Highly flexible (±50% ±90%) Fully responsive	2, 3 and 6 month spells with stock agisted	Frequency of cool and hot fires
Woodlands of Burdekin catchment, Qld	Black basalt Goldfields red duplex Yellowjacket on sandy soils	Fixed Current practice (±20% ±40%) Highly flexible (±50% ±90%) Fully responsive	2, 3 and 6 month spells with stock agisted	Frequency of cool and hot fires
Savannas of Victoria River District, NT	Black cracking clay Good red soils Poor red soils Spinifex hills	Fixed Current practice (±10% ±20%) Highly flexible (±40% ±40%) Fully responsive	2, 3 and 6-month spell with stock moved to other paddocks on property	Frequency of cool and hot fires
Mitchell grasslands of Barkly Tableland, NT	Grey cracking clay Gravelly red earth	Fixed Current practice (±10% ±20%) Highly flexible (±40% ±40%) Fully responsive	2, 3 and 6-month spell with stock moved to other paddocks on property	Frequency of cool and hot fires
Woodlands of Fitzroy catchment, Qld	Alluvial brigalow Poplar box Narrow-leaved ironbark with rosewood	Fixed Current practice (±10% ±20%) Highly flexible (±40% ±40%) Fully responsive	2, 3 and 6 month spells	Frequency of cool and hot fires

Table 3. The land types, representing a range of fertility levels (high to low), which were modelled in each of the six NGS regions.

Region	Land types
Maranoa/Balonne, Qld	Brigalow/belah Poplar box on duplex Soft mulga on sandplains
Mitchell grasslands of Western Qld	Open downs Soft mulga sandridges
Burdekin rangelands, Qld	Black basalt Goldfields red duplex Yellowjacket on sandy soils
Victoria River District, NT	Black cracking clay Good basalt red soil Poor calcareous red soil Spinifex plains
Barkly Tableland Mitchell grasslands, NT	Grey cracking clay Gravelly red earth
Fitzroy rangelands, Qld	Alluvial brigalow Box flats Narrow-leafed ironbark with rosewood

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[2] Twelve stocking rate flexibility options were simulated with the ones shown here being of most interest.

Assessing appropriate set stocking rates

The simulations associated with each management factor were undertaken with four different stocking rates. For each land type referred to above, four stocking rates were selected, representing light, light to moderate, moderate (approximately safe long-term carrying capacity) and moderate to heavy.

Safe stocking rates are often presented as safe utilisation rates e.g. 25% of annual growth can be safely consumed in a year in many native pasture communities. While this is generally accepted and can be useful in running simulation models, it is not a good way of communicating to land managers. A better way is to give a sustainable/safe stocking rate (number of head per area)
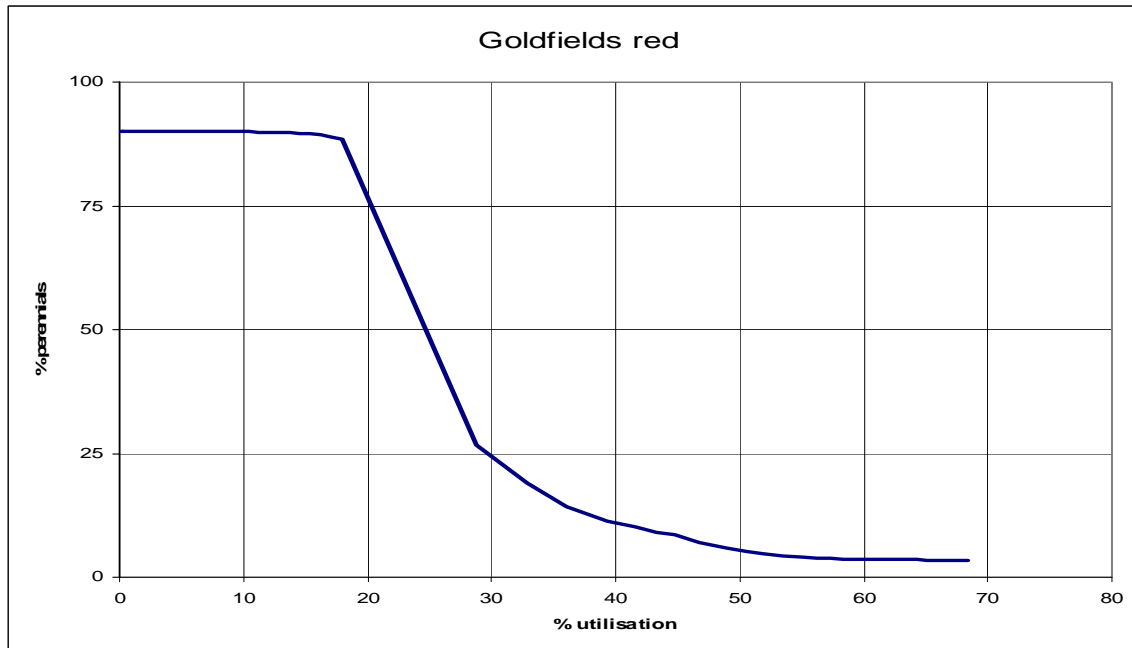

Figure 10. Percent perennials and utilisation for Goldfields land type (Burdekin catchment, north Queensland) where safe utilisation is 25% of annual growth. At 25% utilisation, the percent perennials is 50%, which is part of the definition of safe stocking rate used here.

We developed a method of estimating safe set-stocking rates. Initially, it is important to define what is meant by 'safe'. We defined safe as that set or fixed stocking rate that ensured that the percent perennials over the simulation period exceeded 50%[3]. Inherently there is a time-frame for safe stocking rate – is it safe over 10 years, 30 years or 100 years? The longer the period of interest, the lower is the safe stocking rate because there is a greater chance of experiencing a moderate period of poor seasons. During these periods, a fixed stocking rate leads to high utilisation and pasture decline, which in turn results in lower pasture growth. As the stocking rate is fixed, irrespective of growth in any one year, this leads to further decline in condition as a lower amount of pasture is available for the same number of livestock. A period of about 30 years seems to be a useful compromise.

GRASP was run at a wide range of stocking rates for the same climatic window which produced output showing the mean values over a simulation period for % utilisation, percent perennials and stocking rate. Initially, the degradation parameters (p198, p199, p628 and p628) were adjusted to ensure that percent perennials were at least 50% at the nominated safe utilisation

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[3]   If the 50% perennials was the mean of many of the starting years being very high and the majority of years at the end of the simulation being very low, then this was not regarded as a safe stocking rate and a lower stocking rate which did not exhibit this pattern was chosen.

rate (see Figure 10). Once this was done, the stocking rate that gave at least 50% perennials was used as the safe stocking rate for that land type for that climatic window (see Figure 11).
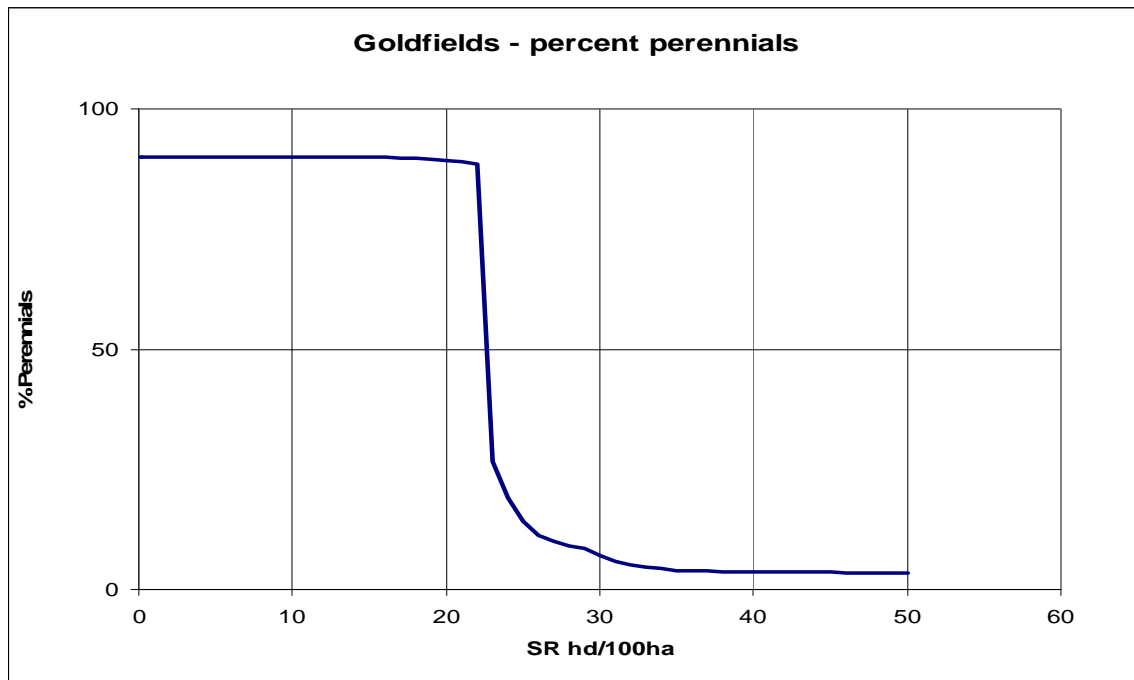

Figure 11. Percent perennials at a range of stocking rates for the Goldfields land type (Burdekin catchment, north Queensland). Note the very sharp drop in perennials when stocking rate exceeds 22 head/100 ha.
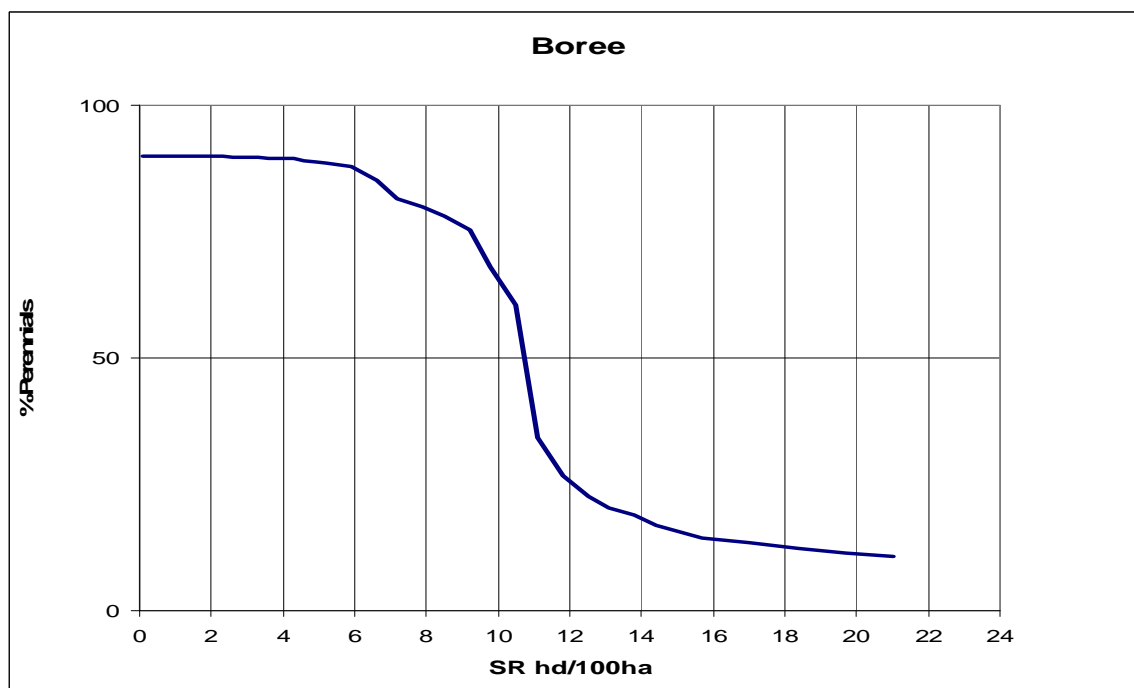
Figure 12. Percent perennials at a range of stocking rates for the Boree land type (Mitchell grasslands, western Queensland). Note the less dramatic decline in perennials when stocking rate exceeds 6 head/100 ha compared with the steep decline after the initial drop for the Goldfields land type.

In the various analyses used in this project, we required a range of stocking rates, not only the safe stocking rates. When studying the representative property, we required a safe stocking rate for each of the initial land conditions that we were interested in. This was done using different

initial conditions (as represented by different values of p194) and using the approach above, with the same degradation parameters being used for all simulations. When studying the effects of stocking rates, we required a range of stocking rates from quite conservative to one that was above the long term safe value, to demonstrate the principles of managing stocking rate. To do this, we examined the graph of stocking rate and percent perennials. In general we selected four stocking rates – very low (~20% below safe); low (~10% below safe); safe; above safe (~10% higher than safe). At the very low stocking rate, a poor pasture should show some improvement; at the above safe stocking rate, a pasture in very good condition will eventually show some decline.

There were regional differences between the shapes of the curves relating percent perennials and stocking rate (compare Figures 11 and 12). It appears that in higher or more reliable rainfall conditions, the steeper is the decline in perennials as SR increases, though more work needs to be done to confirm this..

The four stocking rates selected for each land type modelled during the component analysis are shown in Table 4. These same four stocking rates were used for the stocking rate management, pasture spelling and prescribed burning simulations for the property-level analyses.

Table 4. The four stocking rates (AE/100 ha)[4] used for each land type modelled in each of the six NGS regions.

Region	Land types	Stocking rates (AE/100ha)			
Maranoa/Balonne, Qld	Brigalow/belah	27.1	33.7	38.8	46.8
	Poplar box on alluvial plains	13.2	14.4	16.8	19.3
	Soft mulga	4.6	5.4	6.1	7.2
Mitchell grasslands of Western Qld	Open downs	7.0	10.0	12.0	15.0
	Open alluvia	4.0	4.5	5.0	5.5
	Soft mulga sandridges	2.0	2.5	2.9	3.3
Burdekin rangelands, Qld	Black basalt	30.0	33.0	36.0	40.0
	Goldfields red duplex	13.0	17.0	21.0	23.0
	Yellowjacket on sandy soils	5.0	7.5	11.0	13.0
Victoria River District, NT	Black cracking clay	7.0	9.0	11.0	18.0
	Good basalt red soil	2.0	3.0	4.0	7.0
	Poor calcareous red soil	0.5	0.8	2.0	3.0
	Spinifex plains	0.2	0.5	0.6	2.0
Barkly Tableland Mitchell grasslands, NT	Gravelly red earth	1.0	2.0	2.5	4.0
	Black cracking clay	4.0	7.0	9.0	12.0
Fitzroy rangelands, Qld	Alluvial brigalow	30.0	37.0	42.0	50.0
	Box flats	18.0	22.2	25.8	31.2
	Narrow-leaved ironbark with rosewood	3.0	4.0	5.0	6.0

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[4] An adult equivalent (AE) was defined as a 455 kg animal. This was modelled by commencing the simulation year with an animal of 400 kg allowing for an annual liveweight gain of approximately 120kg, giving a yearly 'average' of an AE.

Managing stocking rate

The stocking rate management strategies investigated were a combination of the four selected stocking rates with 12 stocking rate flexibility options, giving rise to 48 different stocking rate scenarios. Each of these 48 stocking rate scenarios were then simulated for the 20 different 30-year climate windows, occurring between 1900 and 2000, and for four different starting pasture conditions (approximating the A, B, C, and D pasture condition ratings). This resulted in 3840 stocking rate simulations for each of the 18 regional land types. Each of these 3840 simulations contained output or results for each year of the 30-year climate window for outputs such as actual stocking rate, % utilisation rate, % perennials, and liveweight gain (LWG) per head and per hectare.

Each stocking rate flexibility option sets maximum and minimum limits for changes in stocking rates that are allowable over time. The percent change in stocking rate that is allowable over time is calculated once each year when the stocking rate is reset during the modelling, which for the NGS project was the 31st May. The stocking rate is changed at this time in accordance with the total standing dry matter (TSDM) available, the safe utilisation rate for that particular land type, and the extent of change allowable that has been dictated by the stocking rate flexibility option chosen. If the stocking rate flexibility option allowed stocking rates to change fully in accordance with the TSDM available at the end of May (known as the fully responsive strategy), then the number of head in the paddock could conceivably double or triple if the recent growing season was considerably better than the previous, or it could be halved or quartered if the recent growing season was relatively poor. The stocking rate flexibility options limit the extent that the stocking rate can be increased and decreased at the time stocking rate is reset (end of May). However, rather than the stocking rate flexibility options specifying a single rate of increase and a single rate of decrease in stocking rate, users can specify different rates of change depending on whether the current stocking rate is above or below the long-term average stocking rate set for the paddock (see Figure 13). In this respect, they are defined by a set of six numbers, representing the percent change that is allowable in relation to a particular long-term stocking rate from one year to the next, and over the entire simulation period (usually around 30 years). The first pair of numbers dictates the percent increase and decrease respectively that is allowable from one year to the next when the current stocking rate is higher than the long-term stocking rate set for the paddock. The next pair of numbers does the same, except that they apply when the current stocking rate is lower than the long-term stocking rate. The last pair of numbers dictates the percent increase and decrease respectively that are allowable over the entire simulation period.

For example, the stocking rate flexibility option of 10, 30; 20, 30; and 30, 40; allows the annual stocking rate to:

- increase by up to 10% or decrease by up to 30% from one year to the next if the stocking rate at the 31st May is higher than the long-term stocking rate set for the paddock;
- increase by up to 20% or decrease by up to 30% from one year to the next if the stocking rate at the 31st May is lower than the long-term stocking rate set for the paddock; and
- increase by up to 30% or decrease by up to 40% over the entire simulation period relative to the long-term stocking rate set for the paddock.

Figure 13 shows how the number of AE in a paddock may change over time in accordance with this particular stocking rate flexibility option (10, 30; 20, 30; and 30, 40), assuming that the long-term stocking rate set for the paddock results in that paddock carrying 1000 AE. When cattle numbers are above 1000 AE, increases of up to 10% (100 AE) are allowable annually, to a maximum of 30% (1300 AE) over 30 years. Conversely, when the number of AE in the paddock is below 1000, the AE can increase by 20% (200 AE) and decrease by up to 30% (300 AE) annually, until the maximum decrease of 40% (400 AE) is reached.

The 12 stocking flexibility options used during component analysis were:
1.   0.1, 0.1; 0.1, 0.1; 0.1, 0.1; (approximating a fixed stocking rate)
2.   5, 5; 5, 5; 10, 10;
3.   10, 10; 10, 10; 20, 20;
4.   20, 20; 20, 20; 40, 40;
5.   30, 30; 30, 30; 60, 60;
6.   20, 50; 50, 20; 80, 90;
7.   40, 40; 40, 40; 80, 80;
8.   50, 50; 50, 50; 90, 90;
9.   60, 60; 60, 60; 100, 95;
10.   70, 70; 70, 70; 150, 95;
11.   80, 80; 80, 80; 200, 95; and
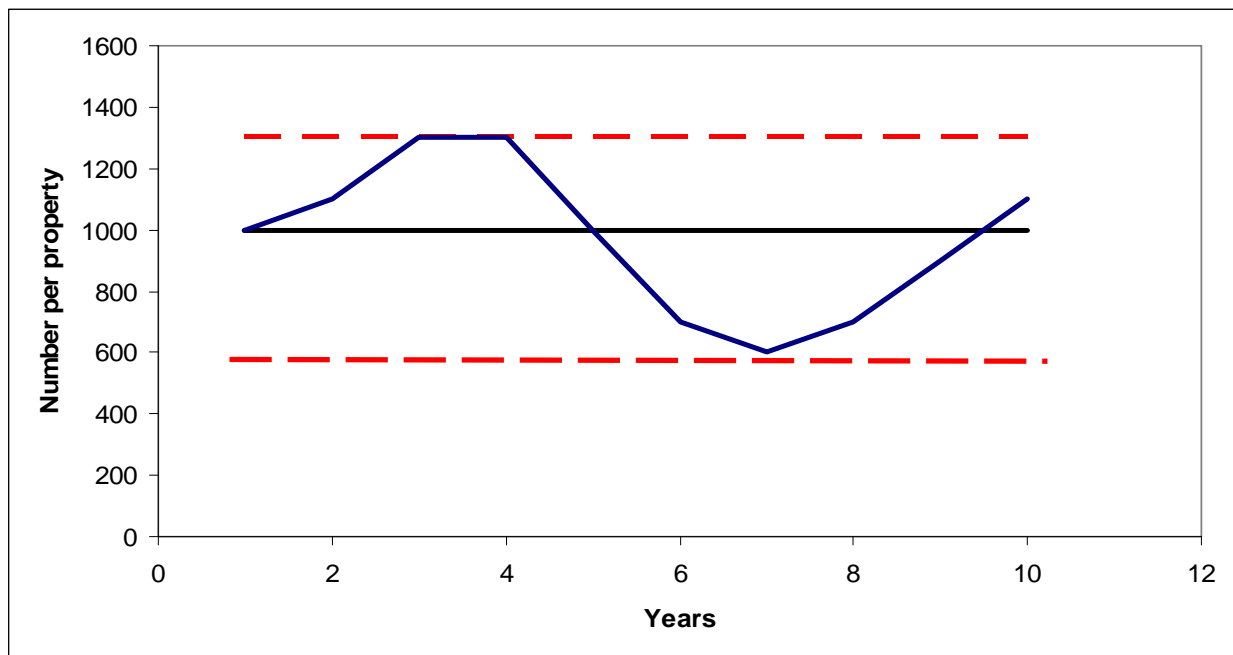12.   900, 90; 900, 90; 900, 90 (approximating a fully responsive strategy).

Figure 13. Changes in the number of cattle (AE) that are allowable using the stocking rate flexibility option of 10, 30; 20, 30; and 30, 40.

These results were collated in two ways. First of all, two FORTRAN programs were written that calculated the means for the 30-year climate windows. In doing so, these programs put a floor in the liveweight gains of 50 kg/yr, effectively not allowing liveweight gain to fall below this for any of the stocking rate management strategies. This was done to prevent very large negative liveweight changes giving rise to unrealistic means. In the real world, animals are not allowed to lose weight or to put on only small gains, as they are supplemented. The results represent the individual management strategies arising from the combinations of four stocking rates x four starting conditions x 12 flexibility options. These results for factors such as % perennials and LWG per head were imported into Excel spreadsheet templates that summarised these data in the form of pivot tables and graphs.

In addition to this, a number of graphs were generated showing the changes in factors such as % perennials or LWG per hectare which occurred over selected 30-year climate windows in response to particular stocking rate strategies. These graphs show how these factors respond annually to particular stocking rate strategies, as opposed to the averages or final outcomes of applying these strategies over 30-year or longer time frames (described above).

Pasture spelling
The pasture spelling management strategies that were simulated arose from the factorial which was the same four stocking rates x 19 spelling strategies x 20 climate windows (each 30 years). The spelling scenarios were three spelling durations (two, three and six months) x six frequencies of spelling (every year, three years out of four, three forms of spelling equivalent to spelling every second year, and one year out of four) plus no spelling. The commencement of spelling always occurred on the 1st of December, and continued for two, three or six months.

This resulted in 1520 simulations that were run separately for each of the four pasture condition ratings (equivalent to A, B, C and D), for each of the regional land types. In total, 6080 individual pasture spelling simulations were run for each of the 18 land types.

Again, the results were collated in two ways. First of all, two FORTRAN programs were written that calculated the means for the climate windows, giving 76 sets of means for each starting pasture condition for each land type. As for the stocking rate component analyses, these programs put a floor in the liveweight gains of 50 kg/head/yr, effectively not allowing liveweight gain to fall below this for any of the spelling management strategies. These results for factors such as % perennials and LWG per head were imported into Excel spreadsheet templates that summarised these data in the form of pivot tables and graphs.

As occurred for stocking rate analysis, a number of graphs were generated showing the changes in factors such as % perennials or LWG per hectare which occurred over selected climate windows in response to particular spelling strategies. These graphs show how these factors respond annually to particular spelling strategies, as opposed to the averages or final outcome of applying these strategies over the whole simulation period.

With the pasture spelling strategies investigated above, no consideration was given to where stock were sent (and the impacts of this on that paddock) when the land type was rested, as it was assumed that they were either agisted or sold. Given that stock from spelled paddocks are likely to be held in other paddocks on the property, a second form of component spelling analysis was conducted. Five paddocks were simulated to start in C condition. These were stocked so that the pasture condition would remain essentially the same over the simulated 30-year climate window if no spelling was to be undertaken (as was done in one of the paddocks). The remaining four paddocks were spelled on a rotating basis, with a 6-month spell every 4 years (irrespective of any seasonal condition considerations). During the period of spelling, the extra animals were evenly distributed across the other 3 paddocks, essentially increasing their stocking rate by 33% during the growing season and by 16.7% on an annual basis.

Prescribed burning
Prescribed burning was investigated in three ways during component analysis. The first of these calculated the percent of years that two types of fires could be achieved over a simulation period of 100 years (1900 to 2000). The two types of fires were a cool fire, when TSDM reached 800 kg/ha, and a hot fire, when TSDM reached 2000 kg/ha. The total fuel load would be much higher than these figures (approximately double) as the grass and tree-leaf litter also contribute to the fire fuel load. The percent of years in which these fires could be achieved were calculated for each land type for each of the four stocking rates plus a stocking rate of zero (no grazing), with a zero or low tree basal area (TBA), and with a 'typical' TBA value. This resulted in 20 burning simulations concerning the incidence of cool and hot fires being run for each land type.

The second way in which prescribed burning was investigated was to calculate the percent of years in which a particular burning regime was successful (i.e. achieved a cool fire), again over the same 100 year simulation period. The burning regimes that were investigated were burning on a nominated year every 10th year, every 5th year, every 3rd year, every 2nd year, and every year. Again, this was done for each land type with four stocking rates plus a zero stocking rate, and with two TBAs (zero or low, and higher). An exception to this occurred for the Fitzroy region,

where burning on a nominated year every 4th rather than 5th year was investigated. This produced 50 simulations on the percent of years that a variety of burning regimes achieved burns, under a range of stocking rate and TBA conditions.

Thirdly, the percent of years in which a cool fire was achieved with a burning regime of burning on a nominated year (e.g. every 5th year) was further investigated with the addition of an 18-month spell (one year prior to burning and six months post-burning). This was done for each land type, using four stocking rates and one TBA (zero or the average for each land type). This produced four simulations, showing the percent of years that this particular burning regime produced a cool burn, under four different stocking rates.

Some minor changes were made for the Fitzroy region – calculated the percent of years in which a 1 in 4 year (rather than 1 in 5) burn was successful, with and without an 18 month rest period, for both cool and hot fires.

The results of these three forms of investigation into prescribed burning were imported into an Excel spreadsheet template, and were summarised using pivot tables and graphs.

3.3 Changes to the ENTERPRISE model

The original ENTERPRISE model
Economic projections for a range of land resource management strategies were derived from the application of a highly modified version of an existing herd economic model (ENTERPRISE). The original model was designed to mimic the economic performance of a user-specified beef representative cattle enterprise for simulation runs of 100 years. Using a range of user-defined herd management and marketing parameters, the model captures the structure of the initial herd and projects this through time as set by the simulation run length. The herd population dynamics are highly dependent on projections of pasture annual carrying capacity and animal growth, and herd reproduction and mortality rates. Carrying capacity and animal growth projections for each year of a simulation run are derived from the GRASP pasture production simulation model. Parameter values for the key economic driving variables of reproduction, breeder and steer mortality, and supplementary feeding requirements to limit annual growth loss are generated through linear regressions with annual liveweight gain per head values (provided by the GRASP simulations).

The original ENTERPRISE model is relatively versatile in terms of the types of cattle enterprise structures that can be configured, but is necessarily restricted in how precisely it can represent a specific real-world beef herd. For example, it is centred on breeding and fattening enterprises and does not handle trading operations or store production structures particularly well - the annual link to GRASP does not allow feedback between the projected actual numbers of stock on hand and the next season's stocking rate used for input to GRASP. The original model also represented the entire herd as being carried on a single homogeneous tract of rangeland with no allowance for variation of pasture resources across the landscape and no consideration given to the implications of a multiple paddock structure for the herd structure that might exist both across space and within the restraints of variable land resource conditions within paddocks that are associated with different herd and landscape management regimes. The 100 year fixed simulation length of the original model was also a source of constraint when either regional climate data was limited or simulations of shorter periods were required to explore a particular strategy.

The modified ENTERPRISE model
The modified model allowed for a property to be composed of up to 20 paddocks. Each paddock consisted of only one land type with only one pasture condition and only one tree basal area. This enabled each paddock to be represented by one model run in GRASP. There is capability

for each paddock to be composed of up to 3 classes (representing different conditions or tree densities) but this feature was not tested and used in the present study.

Each paddock normally carried one class of livestock. This enabled the simulation of situations where a limited area of good grazing land to 'finish off' cattle could restrict the make up and sales strategy of the whole property. This feature could be over-ridden to avoid unwanted/unintended situations. For example, it would be possible for the whole herd size to be constrained by the size of the paddock that contained replacement heifers. In this case, the constraint is an artificial or nonsensical constraint whereas the previous constraint relating to the bullock paddocks is real.

Extensive changes were required to represent what the groups indicated was the 'typical production system' for the representative property. This ranged from a standard breeding/fattening operation to one which produced store cattle only and to the extreme where all young cattle were moved off-property and the heifers were returned to the property when they were old enough to breed. Such changes were complex to implement in the spreadsheet structure on which ENTERPRISE was built.

3.3.1 Modelling representative properties

Examining the impacts of the components of grazing management for individual land types demonstrates the impacts of these on a single land type at a time. This is essentially the same as running simulations for one (uniform) paddock on a property. While this has some value, we required an understanding of the impacts of these at a property level, considering both the biophysical and economic aspects.

To do this we developed a representative property for each of the six regions. This was done at the first workshops in each region. These representative properties were simplifications of a real property to enable the simulations to be run. The maximum number of paddocks was 20, with each paddock made up of only one land type which was uniform in condition. Each paddock was assigned an animal class, consistent with the stated enterprise type for the property e.g. paddocks were for breeders, or weaners, or bullocks, or replacement heifers. To enable simulations of the whole property to be done, we had to generate biophysical outputs (from GRASP) which were then analysed (using ENTERPRISE).

For GRASP, we first aligned each paddock and land type with a similar land type from the Grazing Land Management project. This enabled us to use a set of parameters (specified in a base MRX file) which described most soil and pasture parameters. Parameters specific to the particular paddock as specified in the workshops were added including parameters defining tree density, stocking rate and other management actions. The final step was to calculate the set of parameters which defined the 'degraded' state. Because we were doing such a large number of simulations, we developed an automated way of doing this (as described in Table 1).

It was decided to examine only one management aspect (stocking rate, pasture resting, burning) in each analysis. To model a mix of different aspects became quite complex and more importantly, it became more difficult to determine which changed practice contributed to any simulated changes.

For stocking rate, we generally simulated fixed stocking rates, fully flexible stocking (where annual rates were set solely on the amount of forage available at the end of the growing season and the safe utilisation level), and two moderately flexible stocking rate changes. These flexible stocking strategies included a 'current practice' strategy and on with slightly more flexibility. These involved an annual assessment of the appropriate stocking rate, but the changes that were allowed each year were specified/limited by the user. In addition, the maximum changes allowed over the whole simulation period were also specified by the user. In several regions, the current practice could be approximated by annual limits of +/- 20% changes and longer term

limits of +/- 40% relative to the initial stocking rate specified. (see section 3.2 for a detailed explanation).

For spelling, we examined a four-paddock, fixed-rotation system where the paddocks started in poor condition (state 6 or 7) and paddocks received a six-month spell every 4 years. This was done for both fixed stocking rates and for any of the flexible stocking rate options. [Note: with the current model, spelling for less than six months is possible only for fixed stocking rates].

When examining the effects of burning, a four-paddock fixed-rotation system was used. The woody plant layer was either regrowth (with high annual rates of increase and high rates of reduction due to fire) or large trees with a shrubby understorey (with generally lower rates of increase and damage due to fire).

For all simulations, we chose the period from 1980 to 2006 as the climate window to use, as this would be meaningful to the majority of land managers involved in the workshops.

The grazing and land resource management scenarios that have been subject to simulation include - (1) an array of stocking rate strategies ranging from fixed through increasing levels of annual flexibility to a stocking regime that is totally responsive to available seasonal dry matter, (2) wet season resting of individual paddocks for 6 months on a 1 year in 4 years rotation, and (3) use of prescribed fire for individual paddocks on a 1 year in 4 years burning regime. These strategies were based the output of a synthesis of literature and relevant trials and ensuing discussion with producers at first round regional workshops.

The general structure of the ENTERPRISE model and its connection to the GRASP pasture simulation model is presented in Figure 14.

Regions[5]
Various management scenarios have been explored for the following regions in Queensland and the Northern Territory:

1. Mitchell grasslands of western Queensland
2. Woodlands of the Burdekin catchment Queensland
3. Woodlands of the Fitzroy Catchment Queensland
4. Savannas of the Victoria River District (NT)
5. Mitchell grasslands of the Barkly Tablelands (NT)

The grazing and land resource management scenarios that have been canvassed do vary between the regions to some degree due to differences between regions and due to learnings from previous workshops and their associated simulation results. For example, while the effect of the adoption of an array of fixed and variable stocking rate strategies is explored in all regions, the extent to which some scenarios allow the annual stocking rates to vary alters. Also, the impact of applying prescribed fire to manage timber and shrubby regrowth is only examined in the regions for which this was seen to be a significant management issue. The general scenarios that were considered are summarised by region in Table 5.

Simulation modelling results are initially presented by region in the following sub-sections. General conclusions that might be drawn from across the 5 regions are presented in a concluding section. The simulation runs use the actual climatic sequence experienced in the regional reference site commencing 1980-81 season.

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[5] ENTERPRISE modelling was not done for Maranoa Balonne region.
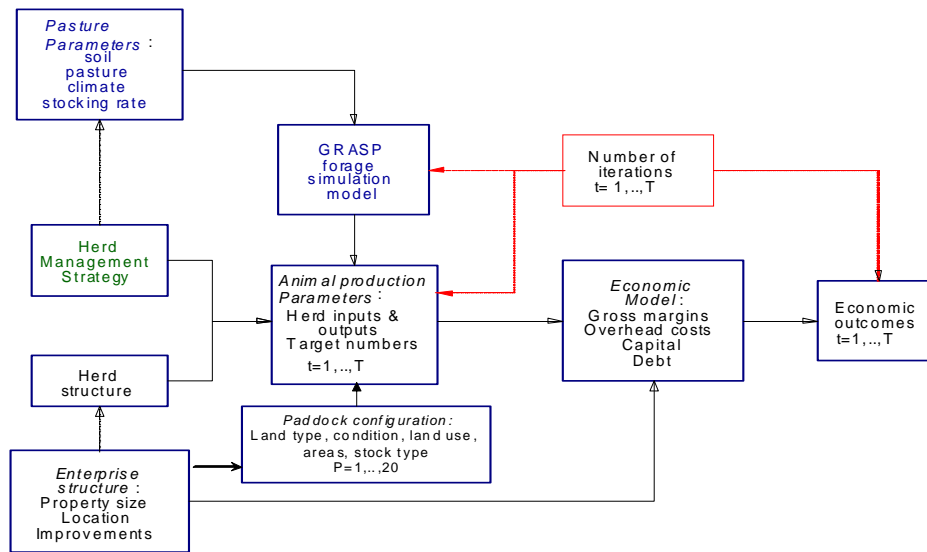
Model structure

Figure 14. General structure of the ENTERPRISE herd economic simulation model.

Table 5. General indication of what property-level simulations were done for each region.

Region	Stocking rates	Spelling	Burning
Mitchell grasslands of Western Qld	All paddocks have varying levels of flexibility. Current practice was +/- 20% change per year.	Four paddocks start in poor [C] condition with fixed stocking rate and 6-month spell, compared with no spelling	Not applicable – burning not practiced in region
Woodlands of Burdekin catchment, Qld	All paddocks have varying levels of flexibility. Current practice was +/- 20% change per year.	Four paddocks start in poor [C] condition with fixed stocking rate and 6-month spell, compared with no spelling	Four paddocks start with moderate level of unwanted woody vegetation.
Savannas of Victoria River District, NT	All paddocks have varying levels of flexibility. Current practice was +/- 10% change per year.	Four paddocks start in poor [C] condition with fixed stocking rate and 6-month spell, compared with no spelling	Four paddocks start with moderate level of unwanted woody vegetation.
Mitchell grasslands of Barkly Tableland, NT	All paddocks have varying levels of flexibility. Current practice was +/- 20% change per year.	Four paddocks start in poor [C] condition with fixed stocking rate and 6-month spell, compared with no spelling	Four paddocks start with moderate level of unwanted woody vegetation.
Woodlands of Fitzroy catchment, Qld	All paddocks have varying levels of flexibility. Current practice was +/- 10% change per year.	Four paddocks start in poor [C] condition with fixed stocking rate and 6-month spell, compared with no spelling	Four paddocks start with moderate level of unwanted woody vegetation.

3.4   Regional guidelines

Representative regional grazing enterprises
Each region requires representative enterprises to be specified in terms of herd structure and dynamics, production system, production parameters, and biophysical resources. Existing herd/property models used in regional versions of EdgeGLM, the Beef CRC (Bill Holmes), or other sources were considered in this process. Information based on local experience and observations from the first series of regional workshops was also critical to ensure regional credibility and relevance.

Review of best-practice recommendations before, and after bio-economic analyses
The project undertook regional assessment and consultation with beef producers, researchers, extension officers and others in each region via two series of workshops and out-of-session reviews.

The first series of regional workshops documented current and best-bet grazing management practices, identified regional data, and defined representative grazing enterprises that will be parameterised in the bio-economic model.

The second series of regional workshops validated and refined best-practice guidelines from the bio-economic modelling for each region. The pros and cons of implementing draft best-practice guidelines were evaluated in a whole enterprise systems framework.

4   Results and discussion

4.1   Biophysical modelling with GRASP

Below is a summary of the component analysis results presented at the workshops in each NGS region. Again, these results are confined to the priority grazing land management factors, being management of stocking rate, pasture spelling, and prescribed burning.

4.1.1   Stocking rate

Key overall findings for managing stocking rate
The key findings from the component analyses of managing stocking rate are described below, along with some illustrations as examples. These are broken up into two parts, the first based on the means of 20 different climate windows (each 30 years) to illustrate the magnitude of changes, and the second considers selected 30-year climate windows to illustrate the pattern of changes.

Findings based on the means of 20 different climate windows
The findings below are drawn from the analyses of five of the six NGS regions, being Maranoa-Balonne, western Queensland Mitchell grass, Fitzroy Basin, VRD and Barkly Tablelands. The outcomes of the different stocking rate strategies in these regions were relatively similar compared with those from the Burdekin; the results for the Burdekin are reported separately.

Maranoa-Balonne, western Queensland Mitchell grass, Fitzroy Basin, VRD and Barkly Tableland
On land in good condition (A and B), percent perennials, pasture growth, and liveweight gain per head (LWG/hd) and liveweight gain per hectare (LWG/ha) are maintained or improved when fixed stocking rates are low to moderate, whereas these decline when under fixed higher stocking rates.

For this reason, flexible stocking rate strategies are not needed to maintain land in good condition if set stocked at low to moderate levels, but the higher LWG/ha achieved with higher stocking rates can only be achieved by maintaining good land condition by using flexible stocking

rate strategies. Figure 15 below shows that for the black cracking clay land type in A condition in the VRD, % perennials can be maintained at high levels when set stocked (stocking rate flexibility number 1) at 7 and 9 AE/100ha. While % perennials were maintained by set stocking at low stocking rates, a comparison of Figures 15 and 16 shows that with more flexible stocking strategies the same % perennials can be achieved but with a higher LWG/ha.
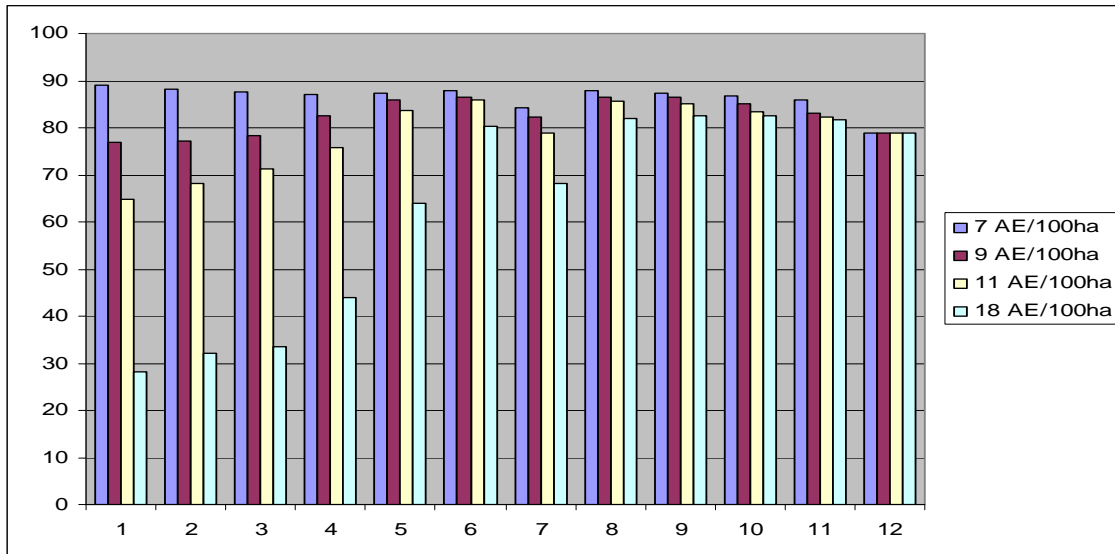

Figure 15. Percent perennials for the black cracking clay land type in A condition from the VRD, for four stocking rates and 12 stocking rate flexibilities.
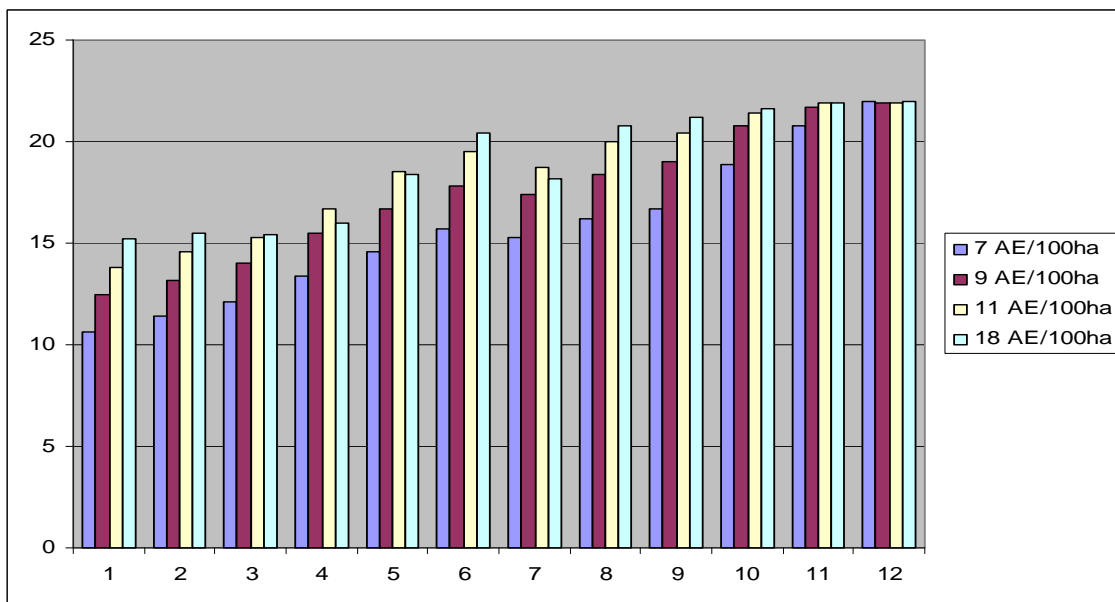
Figure 16. LWG/ha for the black cracking clay land type in A condition from the VRD, for four stocking rates and 12 stocking rate flexibilities. Note that the stocking rates are those at the start of the simulation: by the end of simulations with high flexibility, all stocking rates would be comparable.

When set-stocking land in poor condition (C and D), pastures remain in a degraded state and LWG/ha is mostly low, even at a moderate stocking rate. This point is illustrated in Figure 17, where % perennials on the VRD black cracking clay land type in C condition remain low when set stocked (option 1) at the moderate stocking rate of 11 AE/100ha.

For land in poor condition, a responsive stocking rate strategy was needed to improve pasture and livestock parameters. A low set stocking rate also improved % perennials. Figure 17 shows an improvement in % perennials as stocking rate flexibility increases, and Figure 18 shows a similar level of improvement for LWG/ha.
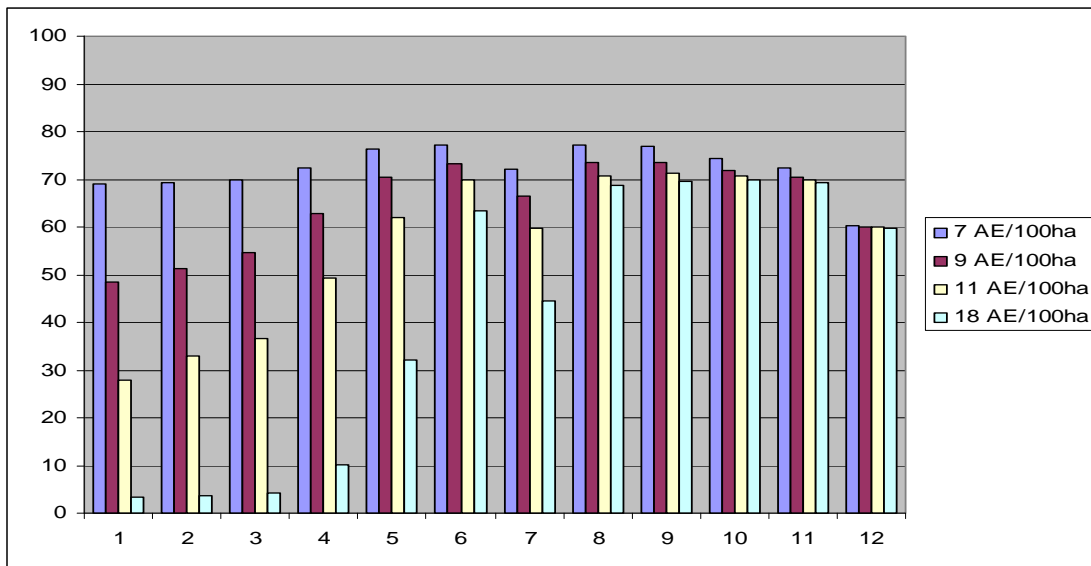

Figure 17. Percent perennials on the VRD black cracking clay in C condition for four stocking rates and 12 stocking rate flexibilities.
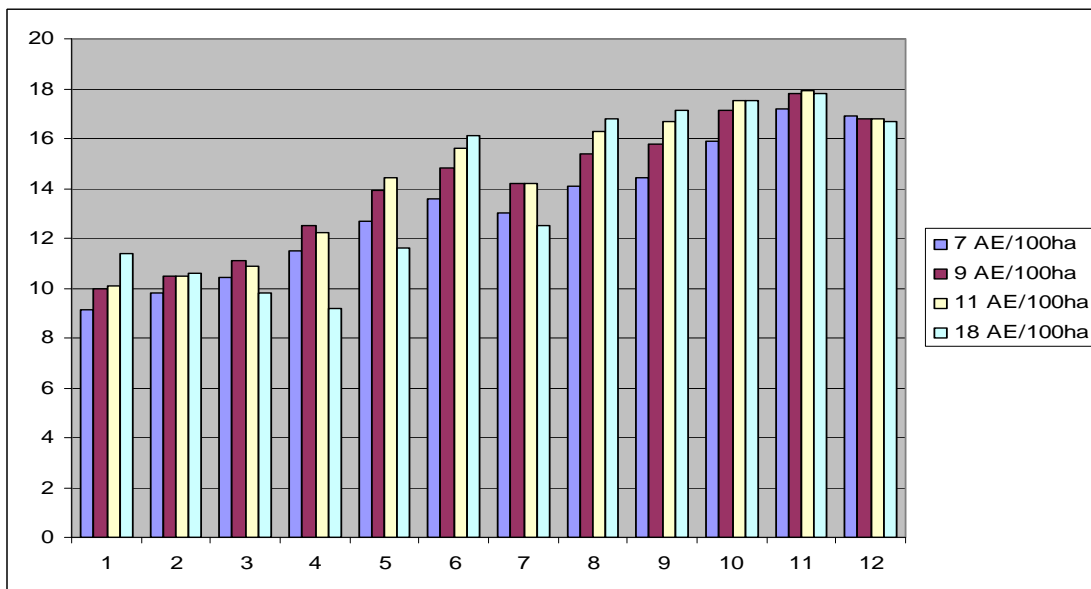

Figure 18. LWG/ha on the VRD black cracking clay in C condition for four stocking rates and 12 stocking rate flexibilities.

Flexible stocking rate strategies ensure that land remains in good condition and improve land in poor condition, with the latter appearing more effective at moderate rather than high starting stocking rates. Figure 19 shows the inability of fixed stocking to improve % perennials on poplar box land type in C condition in the Maranoa-Balonne, even at moderate stocking rates. Figure 20 shows that a fully flexible stocking rate strategy is capable of improving % perennials on the same land type when stocking rate is moderate, but was not able to significantly restore % perennials at the high stocking rate.

Flexible stocking rate strategies on land in good condition will maintain or improve percent perennials, pasture growth and LWG/ha, even with high starting stocking rates (see % perennials and LWG/ha in Figures 15 and 16).
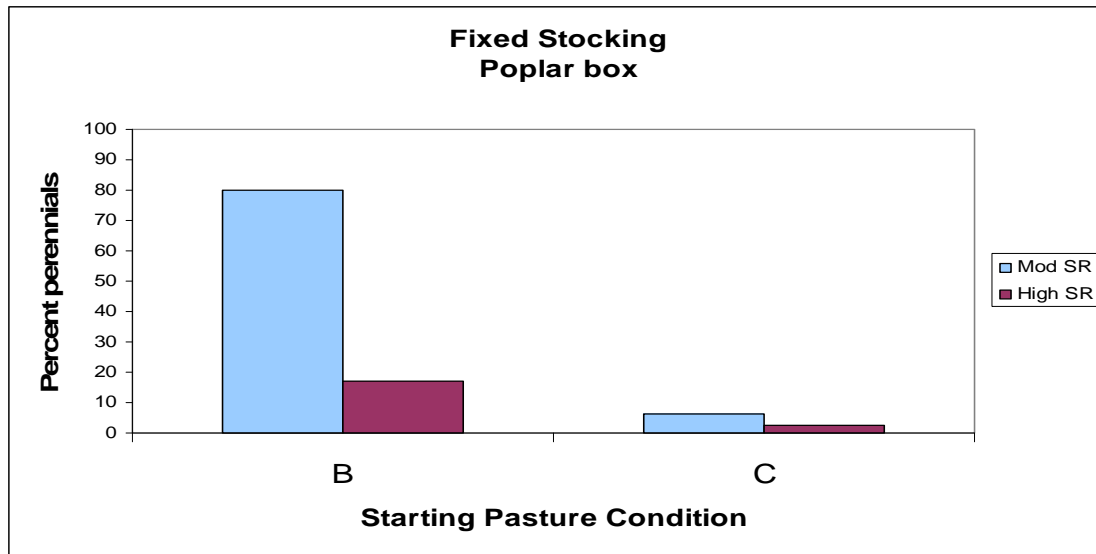

Figure 19. Percent perennials in the poplar box land type with B and C starting conditions in the Maranoa-Balonne, with a fixed stocking rate strategy and two stocking rates.
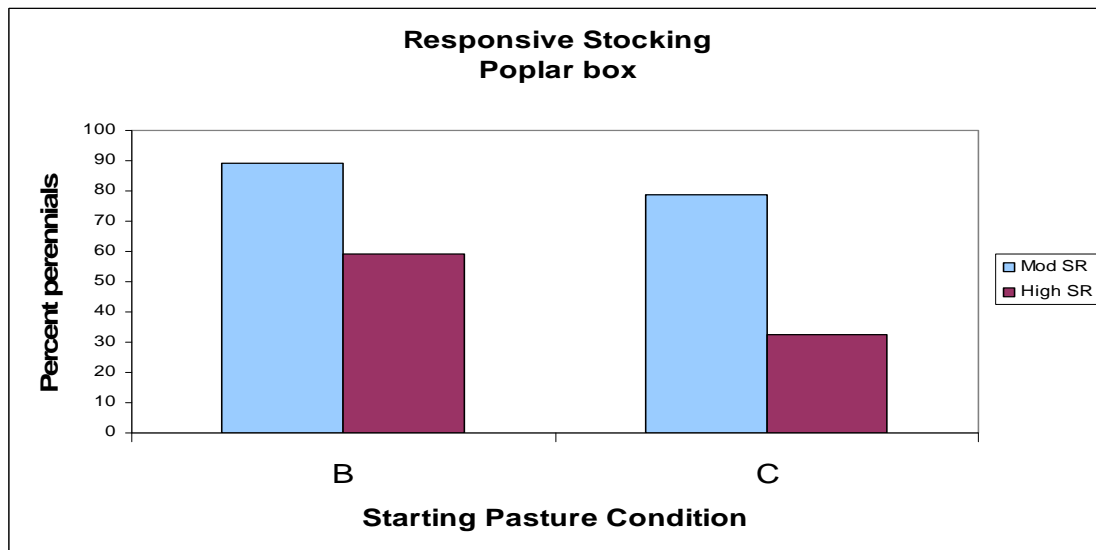

Figure 20. Percent perennials in the poplar box land type with B and C starting conditions in the Maranoa-Balonne, with a fully responsive stocking rate strategy and two stocking rates.

In general, as stocking rate flexibility increases, so does pasture growth, % perennials, LWG/hd and LWG/ha. With increasing stocking rate flexibility, the adverse impacts of higher starting stocking rates are decreased, with the degree of flexibility required increasing as the starting stocking rate increases (see % perennials and LWG/ha in Figures 15 and 16). Note that at moderate to high flexibility, the ending stocking rate can be very different from starting values and indeed the final stocking rates may be very similar for all initial stocking rates.
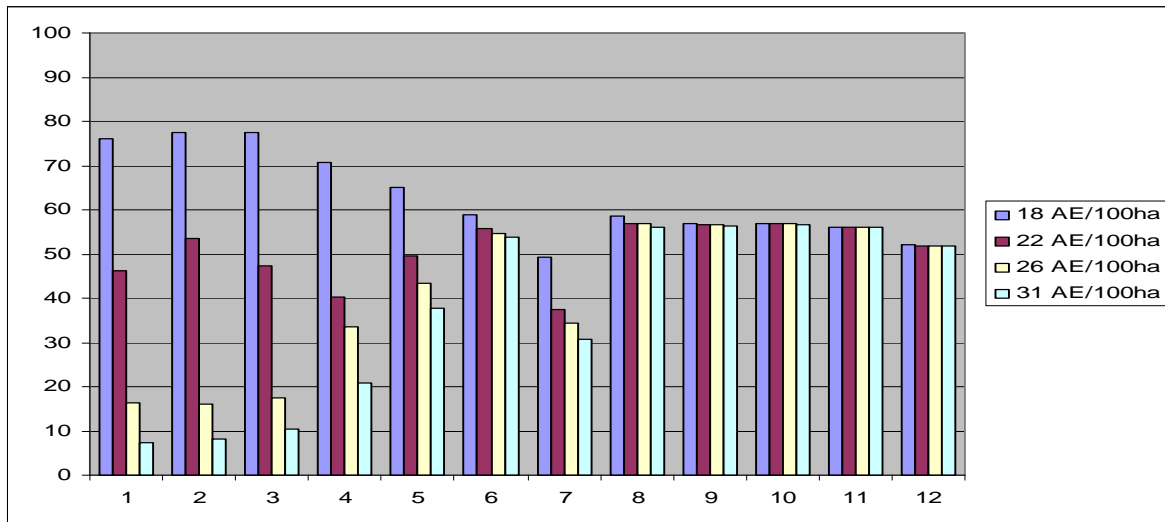
Figure 21. Percent perennials on box flats in B condition in the Fitzroy Basin, for four stocking rates and 12 stocking rate flexibilities.
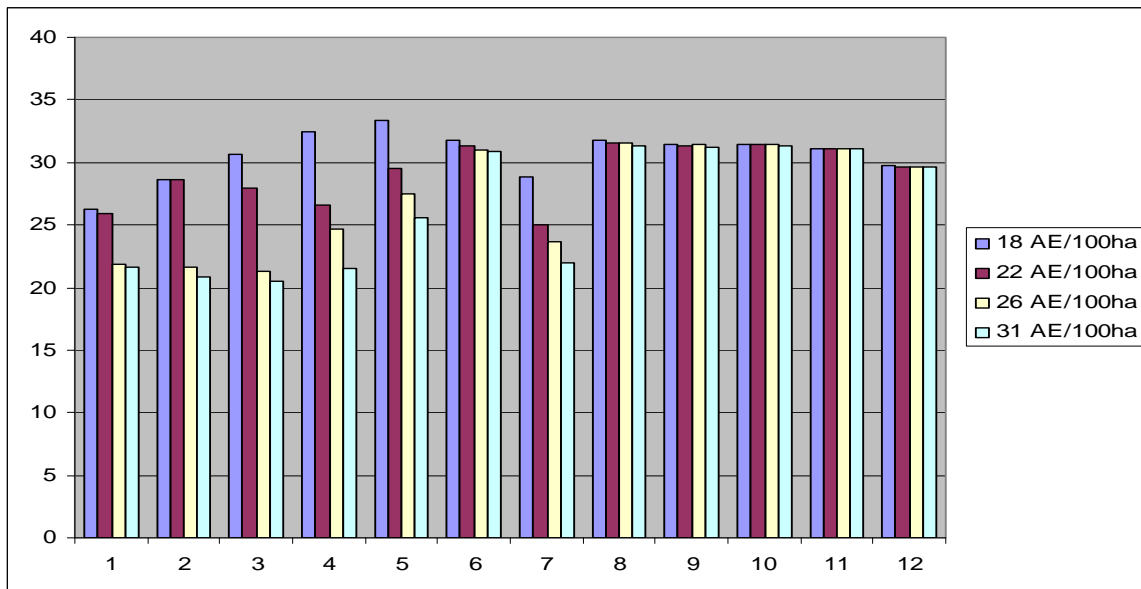

Figure 22. LWG/ha on box flats in B condition in the Fitzroy Basin, for four stocking rates and 12 stocking rate flexibilities.

When starting stocking rates are moderate to high on land in good condition, a high flexibility strategy (in the order of 40, 40, 40, 40, 80, 80) is needed to maintain good pasture condition together with high LWG/ha. Figure 21 shows that the % perennials do not reach 50% for the higher stocking rates until the stocking rate flexibility increases to level 6, being 40, 40, 40, 40, 80, 80%. Similarly, Figure 22 shows that LWG/ha also attains maximum rates for the higher stocking rates when stocking rate flexibility reaches level 6.

High flexibility stocking rate strategies may be better suited to managing climate risk than are fixed or low flexibility strategies unless very conservative fixed stocking rates are used. Flexible stocking strategies may be even more effective if stocking rates were adjusted on more than one occasion each year. The rules that might be used and the practicality of such adjustments require study.

Additional preliminary investigations for poplar box woodland in the Fitzroy Basin (post-workshop at Emerald) indicate that a relatively low flexibility strategy with the allowable extent of stocking rate reductions exceeding increases, may have some potential to maintain good condition and

achieve good animal production. This stocking rate flexibility option appears to perform well with regard to % perennials, LWG/ha, and the proportion of years when supplementary feeding is needed, and may be more achievable at the property level than the more flexible strategies described above. Figure 23 shows the % perennials in B condition box flats in the Fitzroy Basin at the original four stocking rates and 12 new levels of stocking rate flexibility. These range from set stocked (1) to a high flexibility of 50, 70, 50, 70, 60, 70 (option 12). The flexibility strategy of 10, 30, 20, 30, 30, 40 (option 6), combined with the lowest stocking rate, appears to perform well, considering the results for % perennials (Figure 23), LWG/ha (Figure 24), and proportion of years when supplementary feeding is required (Figure 25).
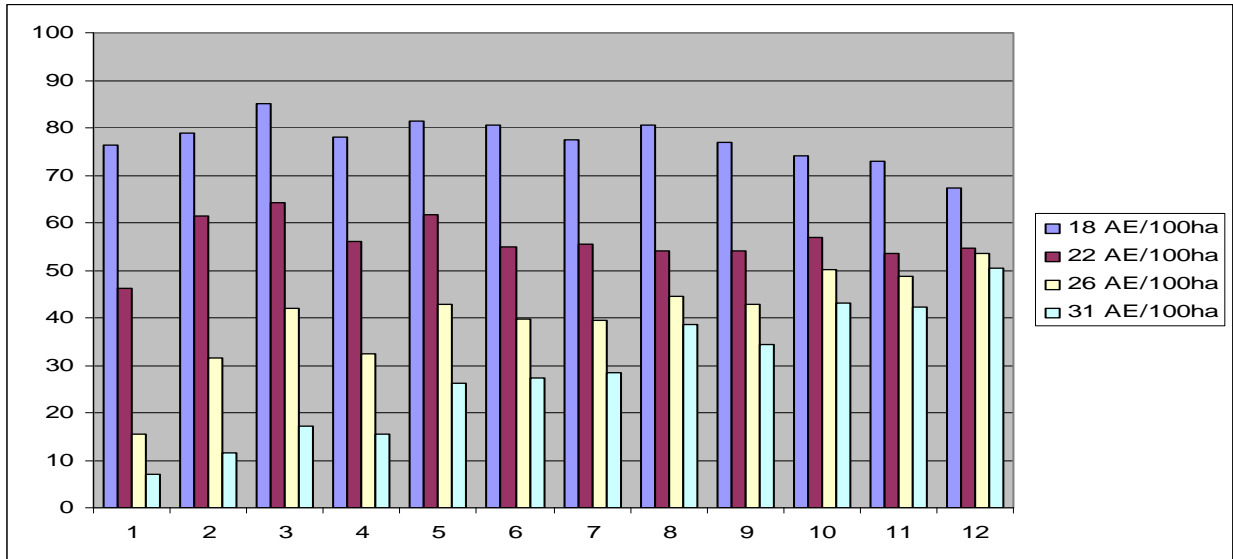

Figure 23. Percent perennials in B condition box flats in the Fitzroy Basin that occur under four stocking rates and 12 levels of stocking rate flexibility.
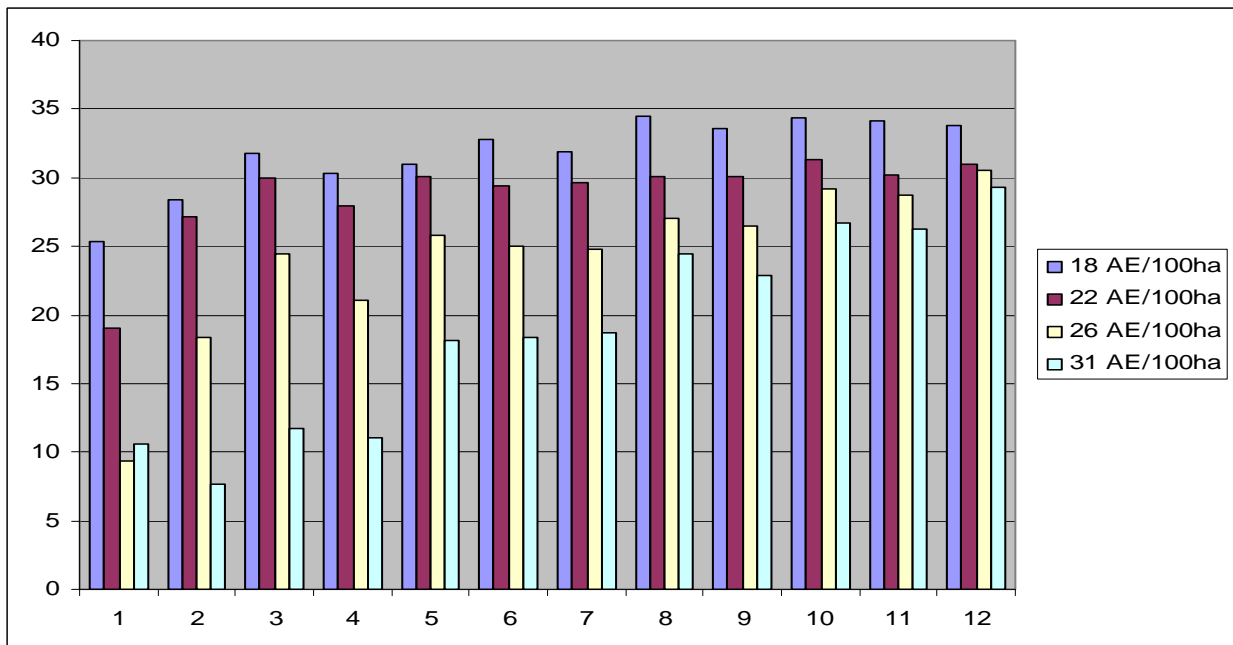

Figure 24. LWG/ha in B condition box flats in the Fitzroy Basin that occur under four initial stocking rates with 12 levels of stocking rate flexibility.

This analysis needs to be repeated for the other regions before more can be concluded about the efficacy of this 10, 30, 20, 30, 30, 40 stocking rate flexibility option.
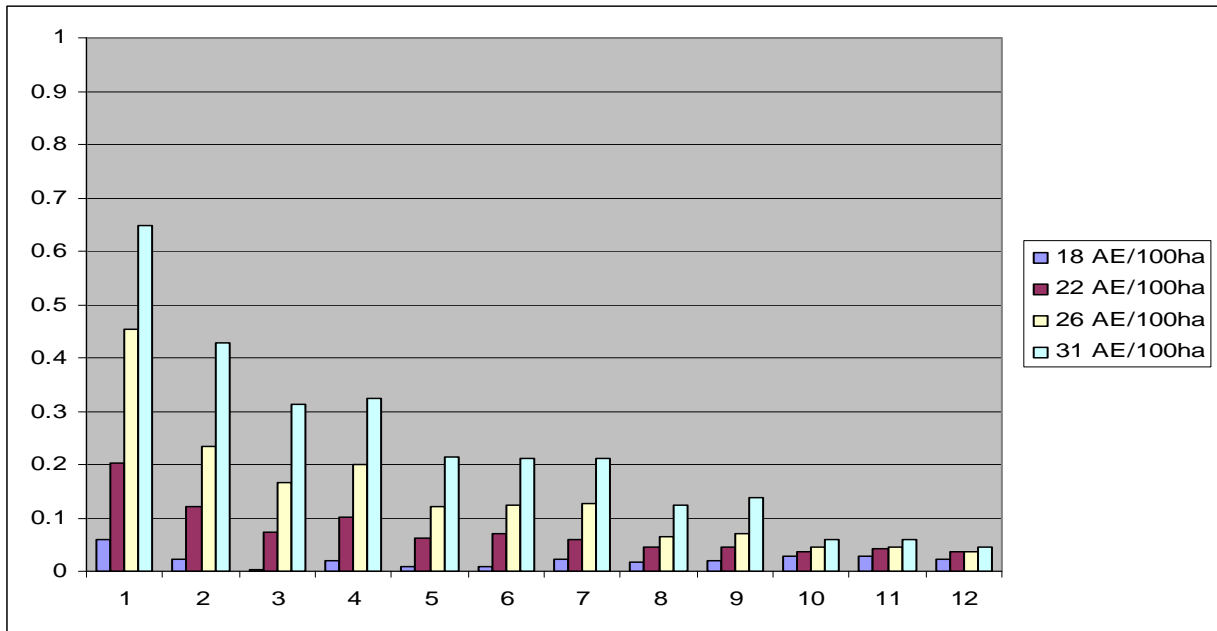

Figure 25. Proportion of years supplementary feeding was necessary in B condition box flats in the Fitzroy Basin that occur under 4 stocking rates and 12 levels of flexibility.

Burdekin region
The response of % perennials on three land types in B condition in the Burdekin region to the 12 levels of stocking rate flexibility were the opposite to those reported above for the other five NGS regions. Generally, the higher % perennials were obtained with fixed stocking, and then declined as flexibility increased (see Figures 26, 27 and 28).
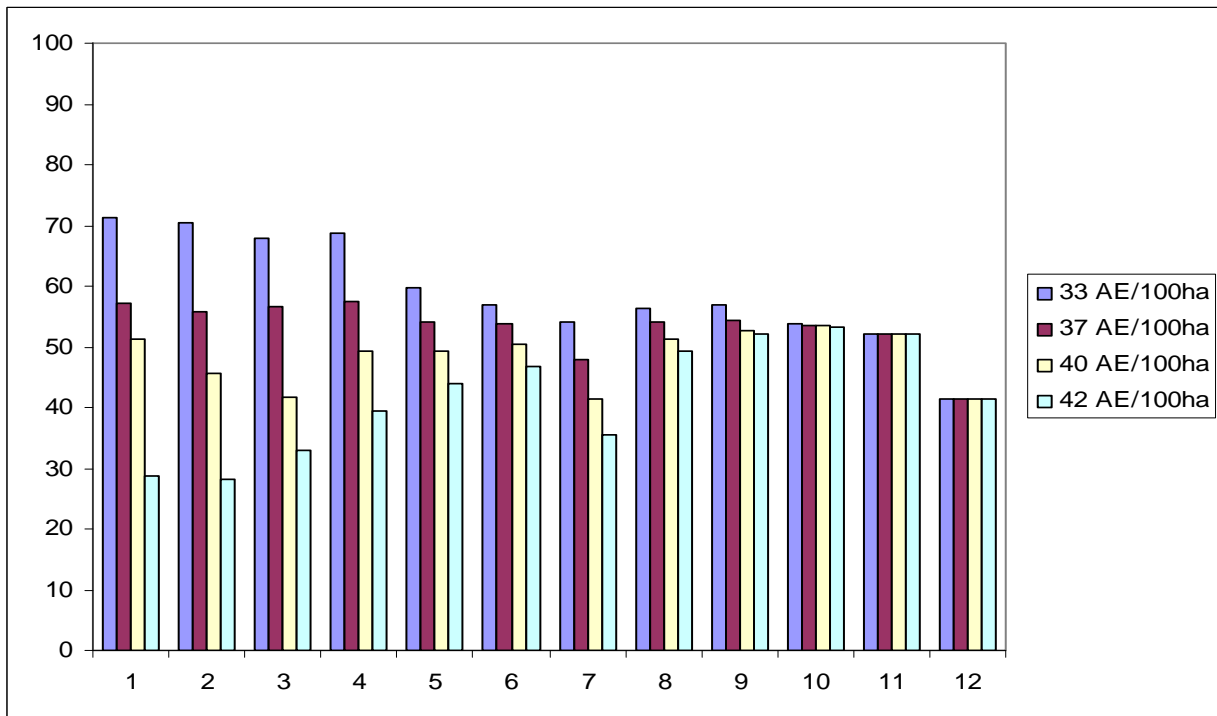

Figure 26. Percent perennials for black basalt land type in the Burdekin region in B condition, for four starting stocking rates with 12 levels of stocking rate flexibility.
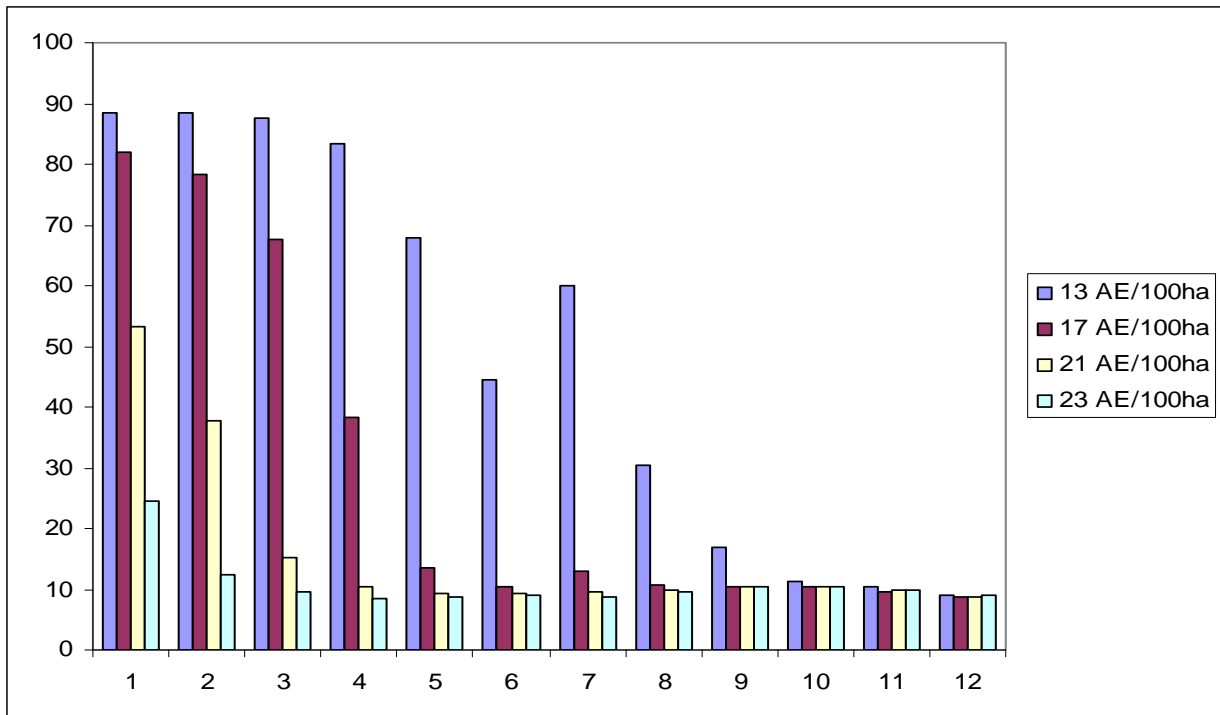
Figure 27. Percent perennials for goldfields land type in the Burdekin region in B condition, for four starting stocking rates with 12 levels of stocking rate flexibility.
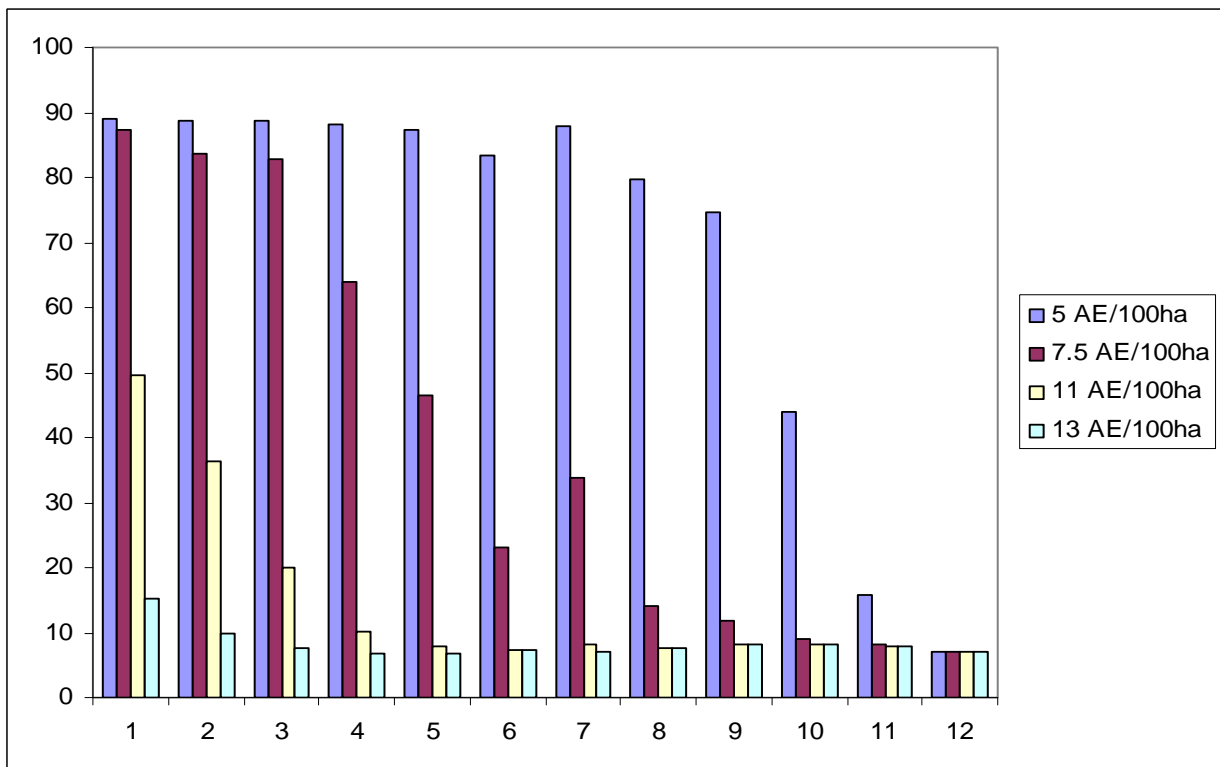

Figure 28. Percent perennials for yellowjacket land type in the Burdekin region in B condition, for four starting stocking rates with 12 levels of stocking rate flexibility.
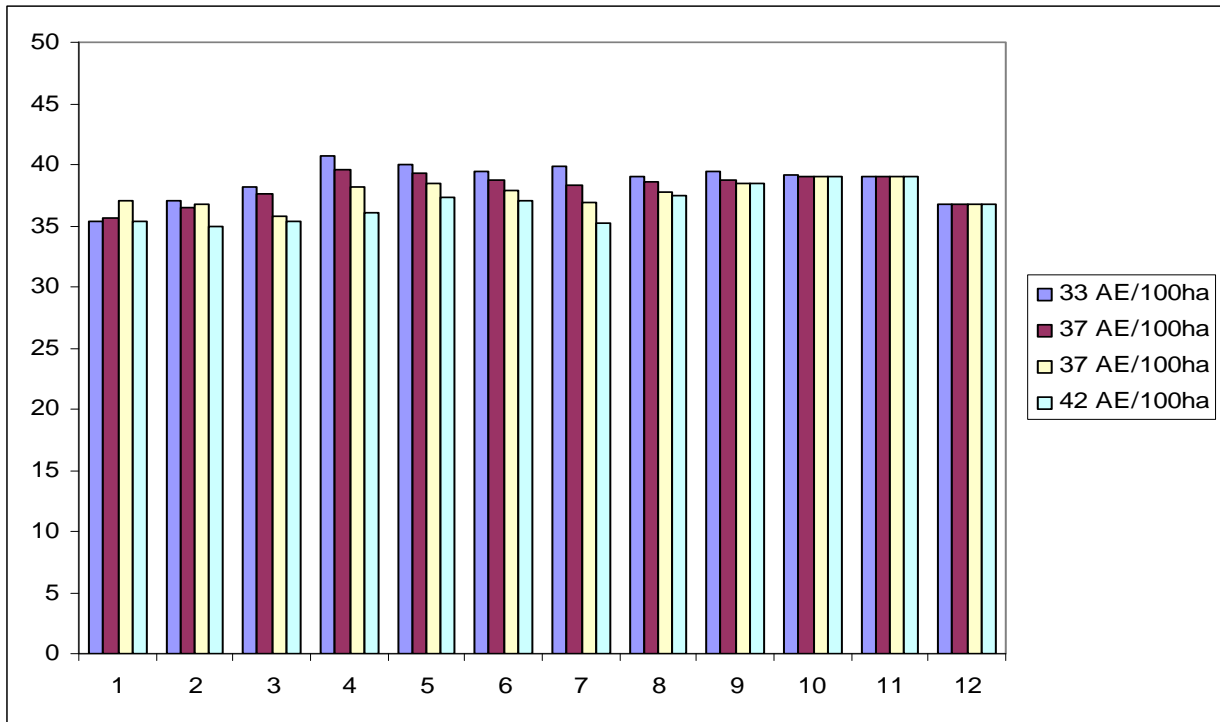
Figure 29. LWG/ha for the black basalt land type in the Burdekin region in B condition, for four starting stocking rates with 12 levels of stocking rate flexibility.
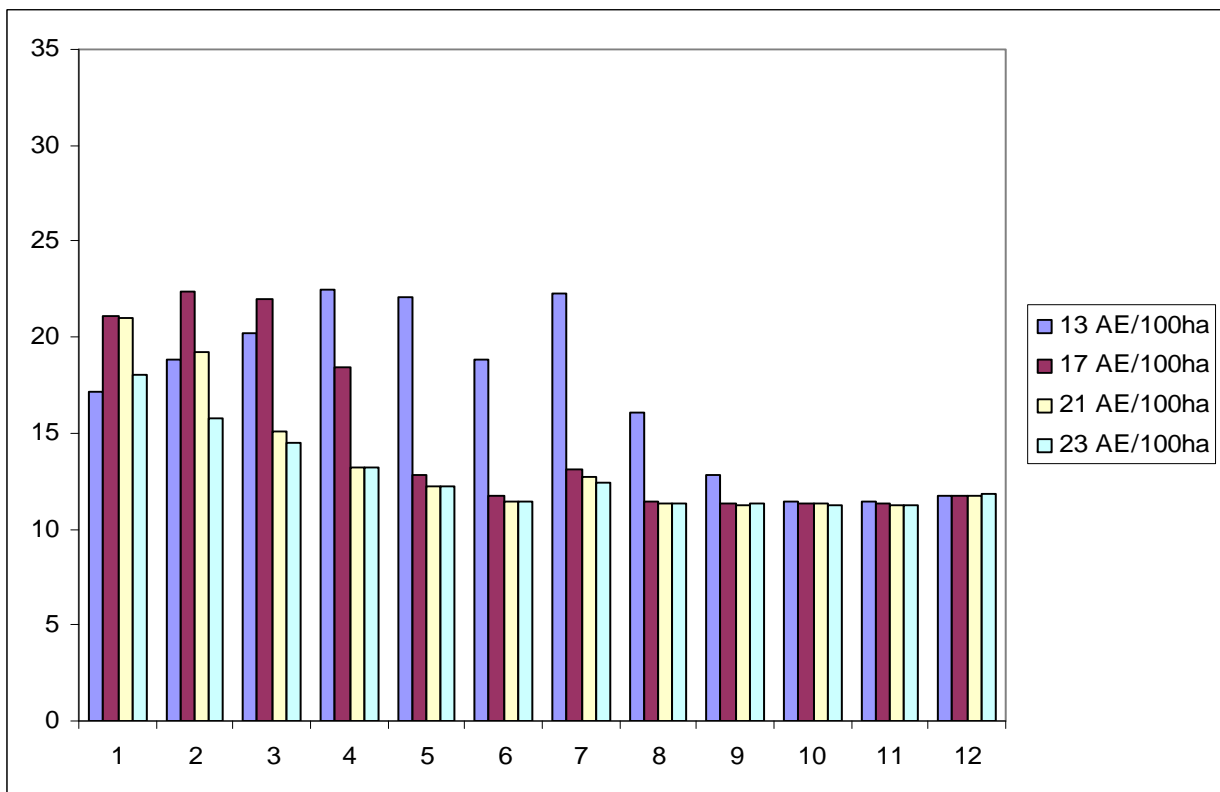

Figure 30. LWG/ha for the goldfields land type in the Burdekin region in B condition for four starting stocking rates with 12 levels of stocking rate flexibility.
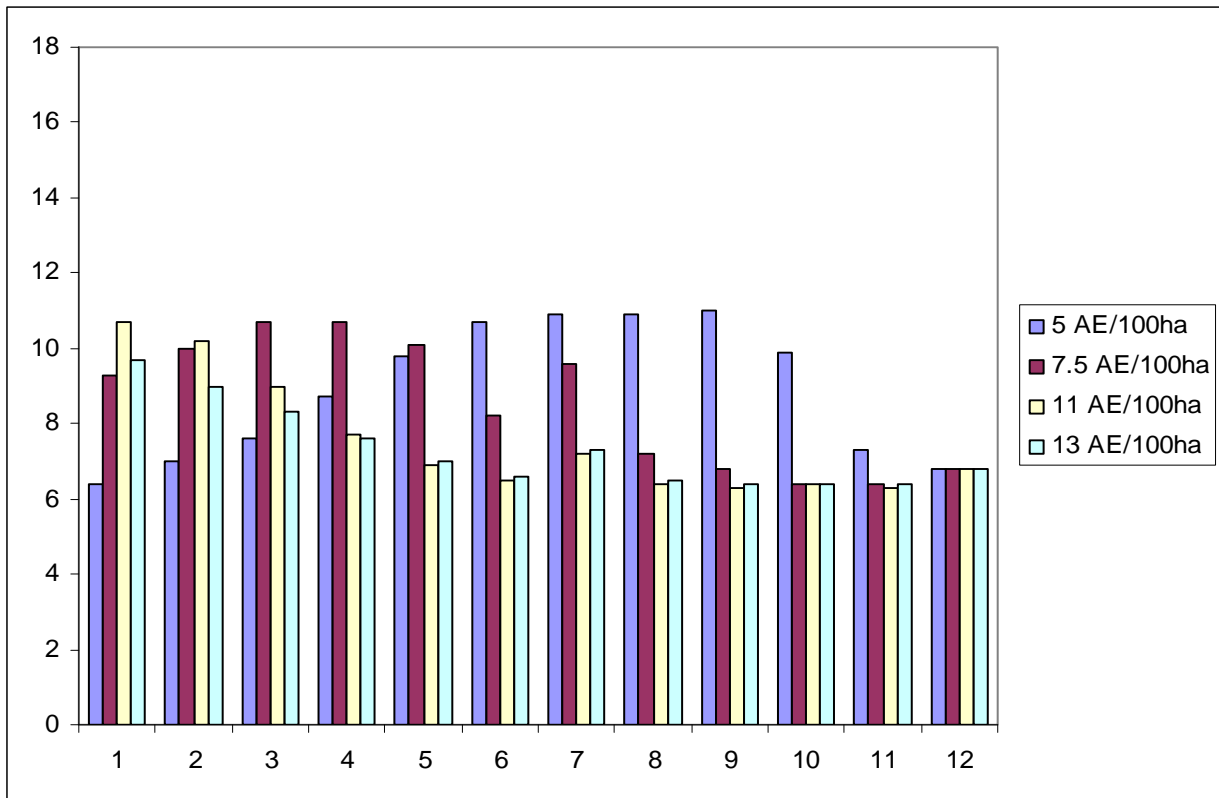
Figure 31. LWG/ha for the yellowjacket land type in the Burdekin region in B condition, for four starting stocking rates with 12 levels of stocking rate flexibility.

Similarly, set stocking also produced similar or higher LWG/ha than did the flexible stocking rate strategies, as seen in Figures 29, 30, and 31.

The different response to the 12 flexibility options in the Burdekin cannot be explained at the moment, and may be due to inconsistencies in the way the model runs were set up. This requires further investigation.

Findings based on individual 30-year time periods
Again, the responses observed on the land types in the Burdekin to the 12 stocking rate flexibilities were different to those from the other five NGS regions, and are reported separately below.

Pasture condition, LWG/hd and LWG/ha generally decline to very low levels under moderate set stocking rates during years of low rainfall, and may not recover. This is due to the high utilisation rate that occurs during years of low pasture growth, which causes a decline in grass basal area and the proportion of the pasture which is perennial grasses (% perennials) in subsequent years. This decline in pasture condition further lowers pasture growth rates, and because stocking rate is fixed, the actual utilisation rates increase, causing more deterioration of pasture condition. The ongoing feedback between increasing utilisation rates and decreasing pasture growth means that these pastures are not able to recover. Figure 32 shows how % perennials decline to, and remain at, very low levels when poplar box in the Fitzroy Basin is set stocked at 3.9 ha/AE. In comparison, the flexible stocking rate strategies are able to maintain % perennials at higher levels over most of the period.

Pasture condition and LWG/hd and LWG/ha can also decline markedly under moderately high and high stocking rate flexibility strategies. This occurs when dry years immediately follows one or more above average rainfall years, due to the high utilisation rate experienced during the following dry year. This is illustrated in the VRD in Figure 33, where large declines in %

perennials occur even with fully flexible and highly flexible (±30% change annually and ±60 change of the longer term) strategies.
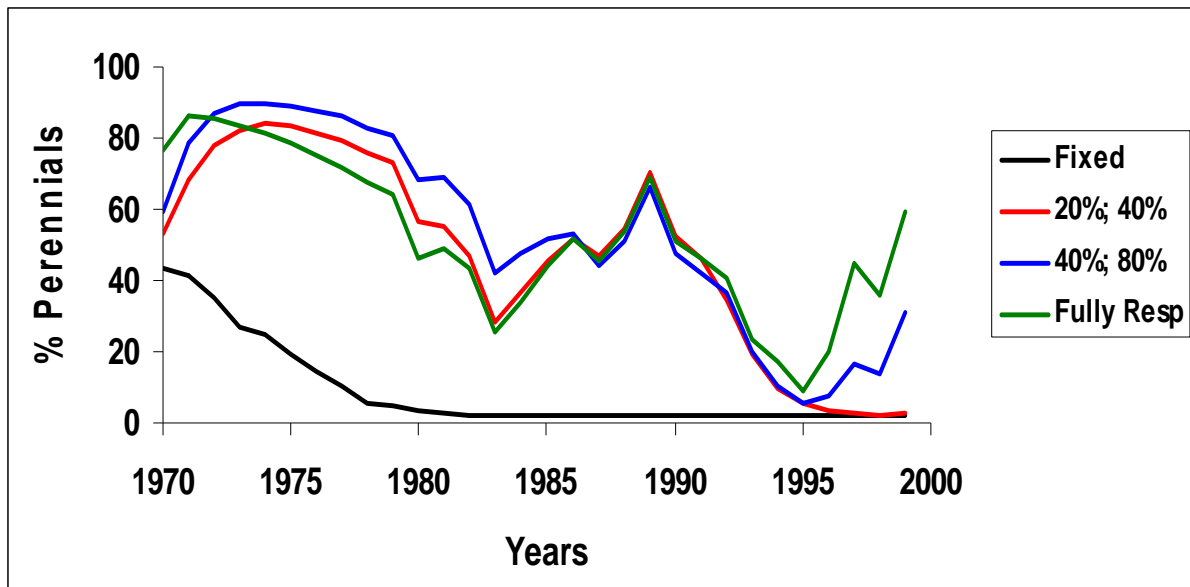

Figure 32. Change in % perennials for poplar box in the Fitzroy Basin under set stocking and three levels of stocking rate flexibility, starting in B condition.
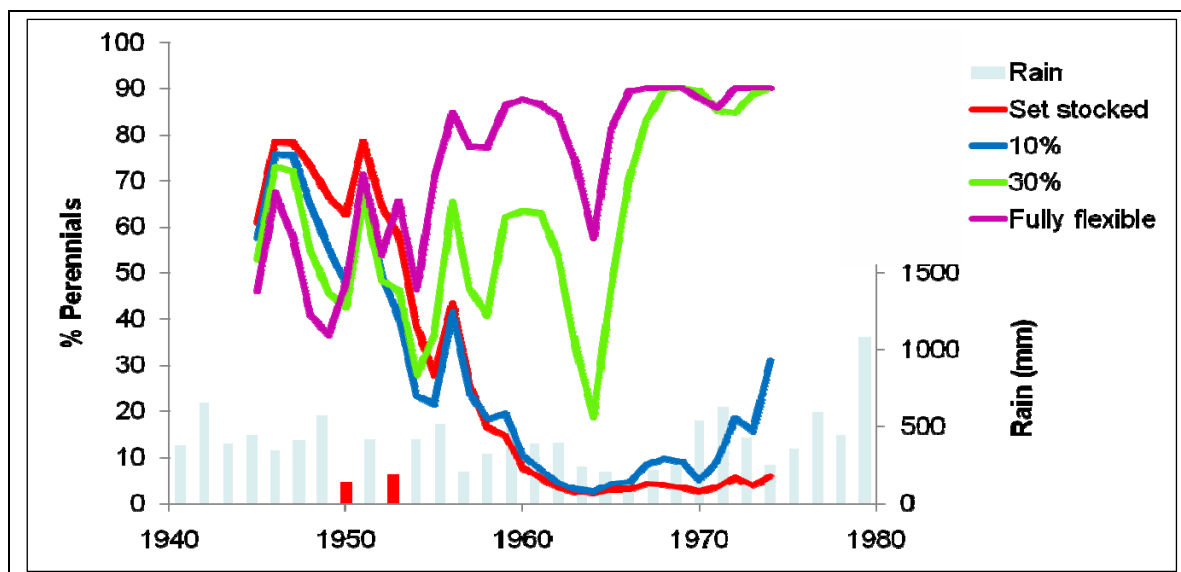

Figure 33. Change in % perennials occurring with set stocking and three levels of stocking rate flexibility, on black cracking clays in the VRD, starting in B condition.

However, these values often recovered quickly under the flexible stocking rate strategies due to the low stocking rates and associated low utilisation rates during the subsequent years when rainfall increased, whereas they took much longer to recover or did not recover at all under the less flexible strategies (where utilisation rate remained higher).

Generally, the recovery and maintenance of % perennials (see Figures 32 and 33) and LWG/ha was improved with increasing stocking rate flexibility.

There were few if any occasions when high and fully flexible stocking rate strategies resulted in declines in % perennials greater than those observed with current practice (less flexibility) and set stocking.

Burdekin region
The changes in % perennials, LWG/hd and LWG/ha that occur between 1975 and 2005 for the goldfields land type are shown below. Figures 34 and 35 show changes in % perennials and LWG/hd respectively, at four stocking rates. Fixed stocking performs quite well at the two lower stocking rates, but poorly at the two higher rates.
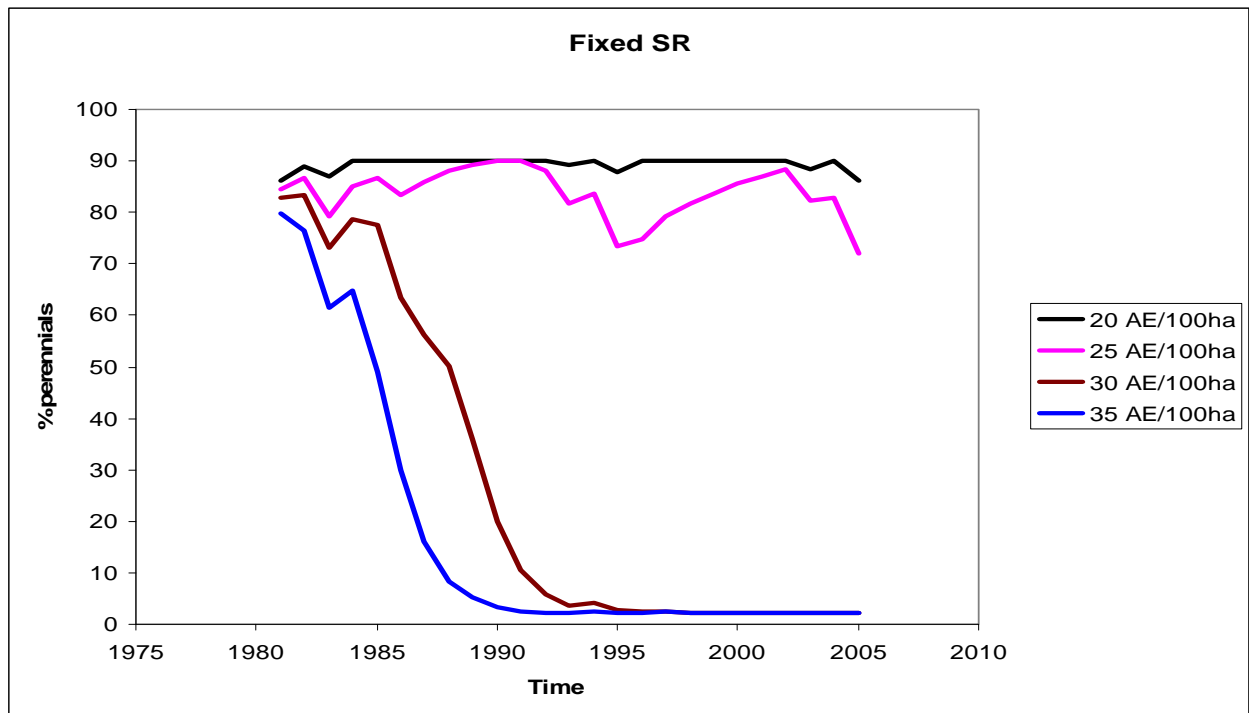

Figure 34. Changes in % perennials that occur between 1975 and 2005 using a fixed stocking rate strategy and four stocking rates for goldfields land type in the Burdekin.

The response of % perennials and LWG/hd to current practice stocking rate flexibility, being +20% change in stocking rate annually and +40% change over the longer term, is generally poorer than what was observed for fixed stocking rate (Figures 36 and 37). Percent perennials declined to very low levels at all four starting stocking rates, and LWG/hd was often negative for the three higher stocking rates. During these years, destocking would have to occur.

The response of this Burdekin land type to the range of stocking rate flexibility options differs to land types from other regions. Investigations after the end of the project indicated that this was due to the climate window examined; other climate windows produced similar results to other regions..

When LWG/ha over the same time period was compared for fixed stocking rate, current practice flexibility and fully flexible, fixed stocking rate again appeared to produce the best results (Figure 38).
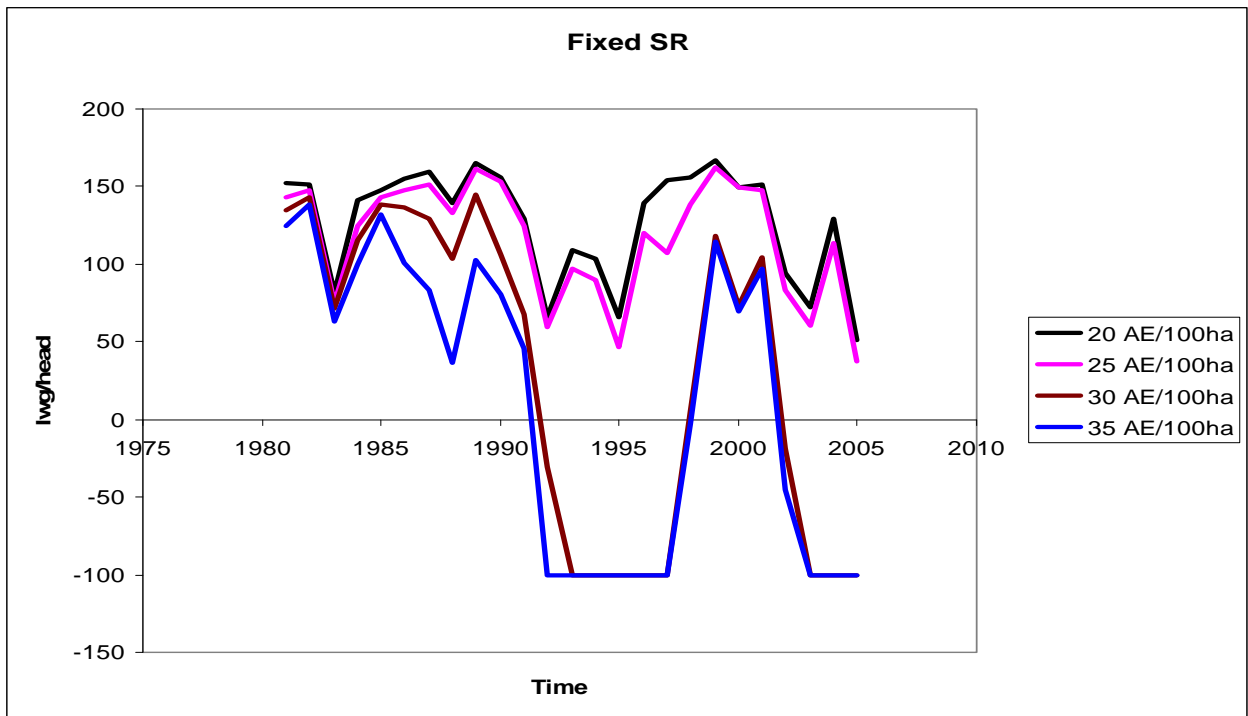
Figure 35. Changes in LWG/hd using a fixed stocking rate strategy and four starting stocking rates for the goldfields land type in the Burdekin. The large negative LWGs are an indication of how many days in the year that liveweight was lost and should not be interpreted as actual liveweight change.
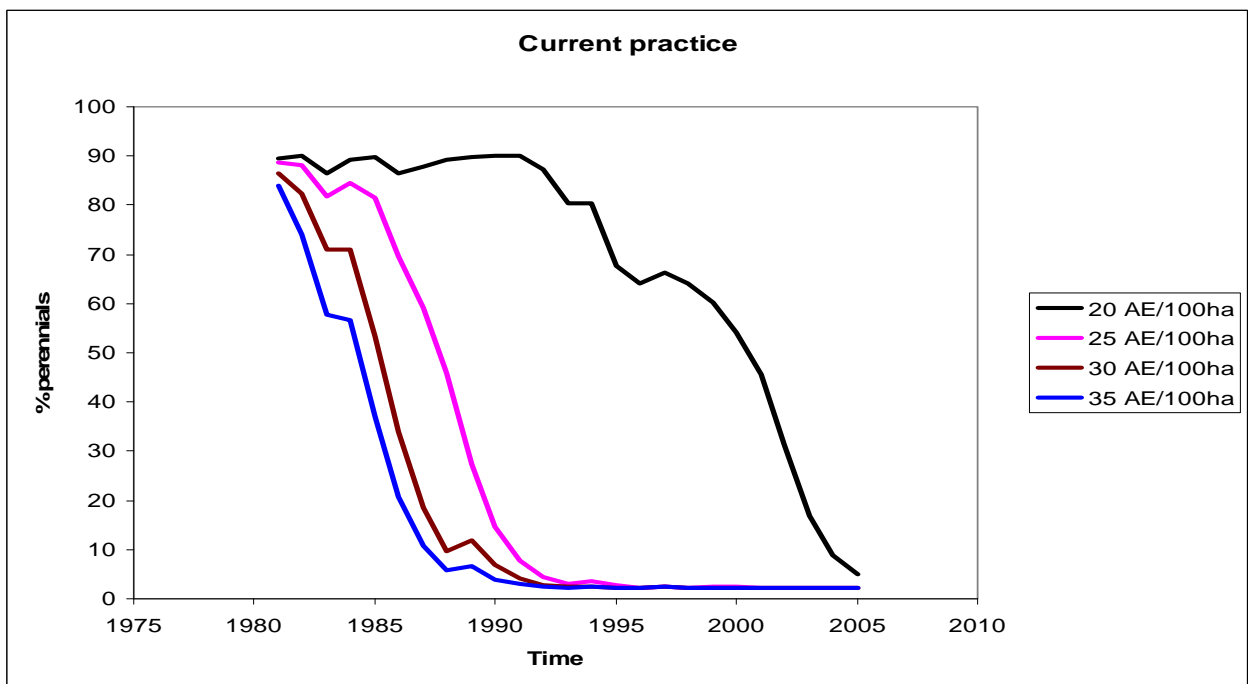
Figure 36. Changes in % perennials between 1975 and 2005 using current practice flexibility (+20% annual and +40% over the longer term) and four starting stocking rates for the goldfields landtype in the Burdekin.
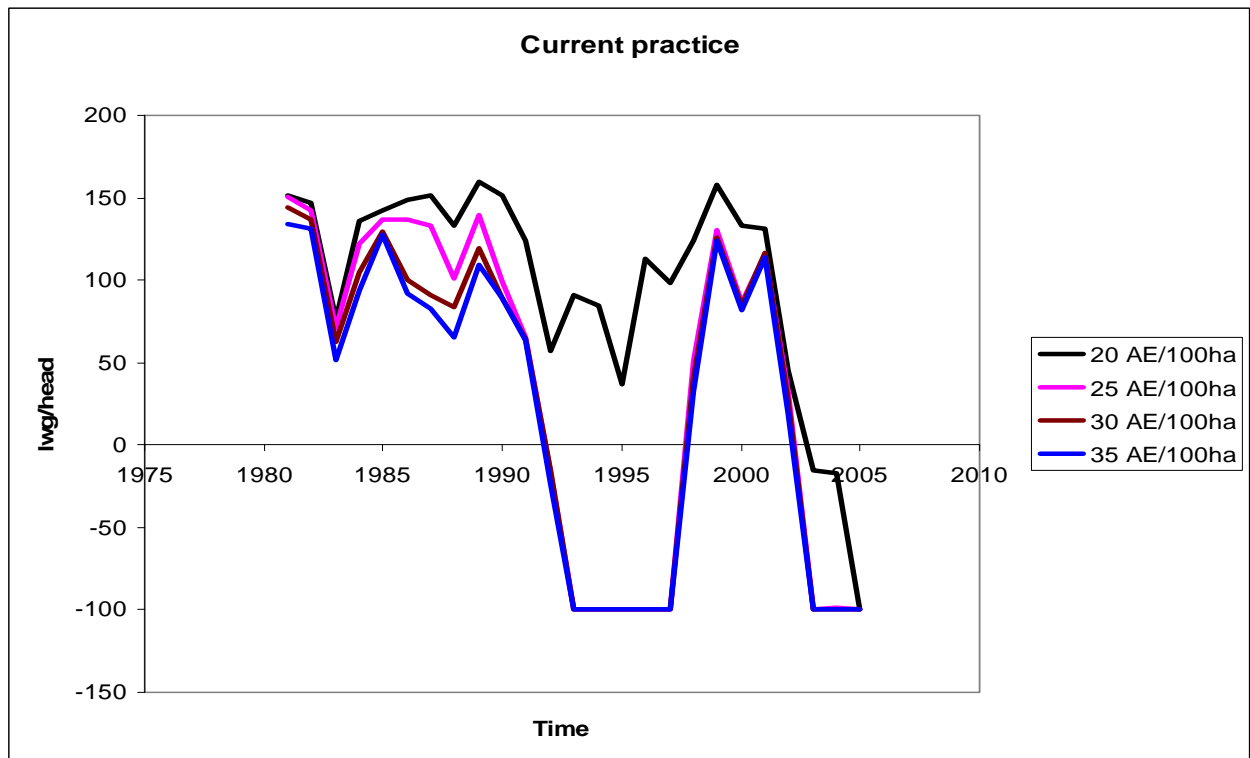
Figure 37. Changes in LWG/hd that occur between 1975 and 2005 using current practice flexibility (+20% annually and +40% over the longer term) and four starting stocking rates.
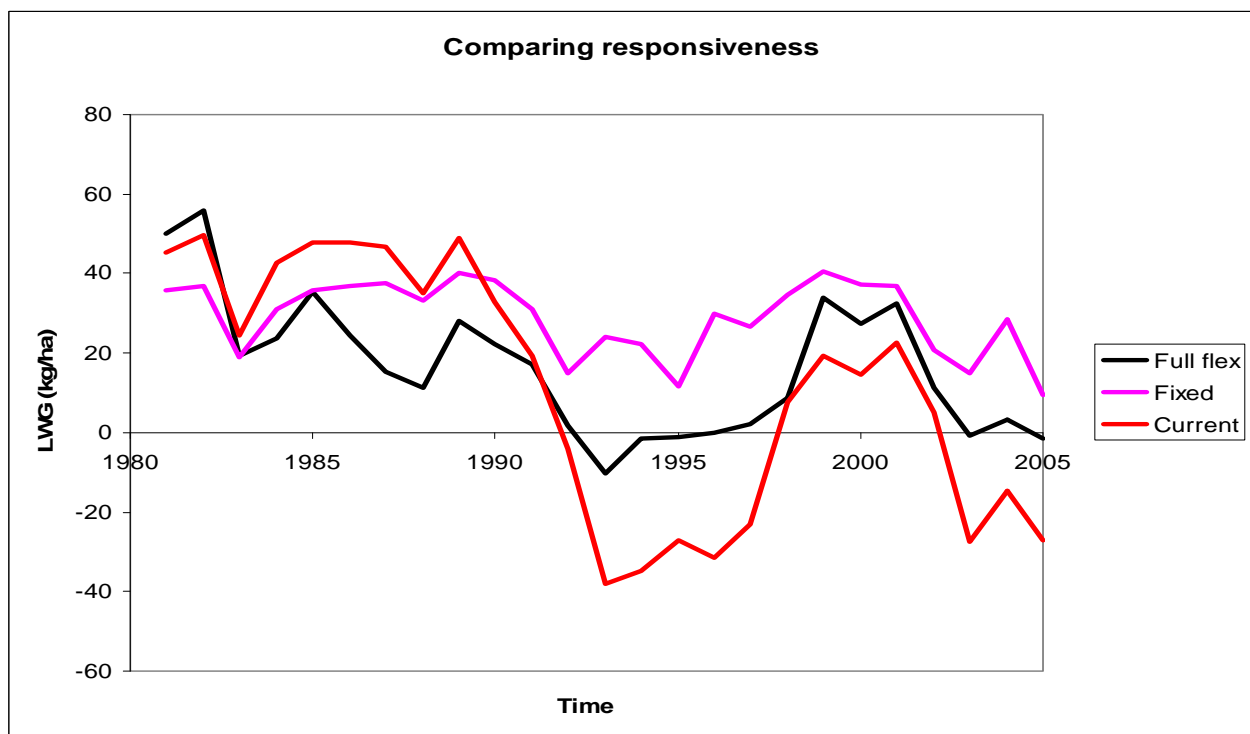
Figure 38. Comparison of LWG/ha for fixed stocking (25 AE/100 ha), current practice flexibility, and full flexibility for the goldfields land type in the Burdekin.

4.1.2 Pasture resting

This section identifies and discusses the key findings for pasture resting presented at the workshops in each of the NGS regions.

Key overall findings for pasture spelling

The component analysis of pasture spelling was confined to spelling during the growing season, commencing at the 1st of December, to align with the period when spelling pastures is known to be most effective.

Analyses of pasture spelling were also carried out in two ways. First of all, the modelling assumed that stock from the rested paddock were agisted or sold, and that there was no increase in stocking rate or utilisation rate associated with placing these animals in other paddocks during the spell period. Secondly, a four-paddock rotational-spell system was investigated, where animals from the spelled paddock were distributed in equal proportions across each of the other three paddocks.

Spelling in combination with agistment

Generally, pasture spelling will maintain or improve pasture condition, LWG/hd and LWG/ha, but the effectiveness of a particular spelling regime will depend on starting land condition, land type, stocking rate, length and frequency of spell, prevailing seasonal conditions, and sequences of seasonal conditions over time.

As stocking rate increases and land condition decreases, spelling is increasingly important in maintaining and improving land condition, with longer duration and more frequent spells required.

On more fertile land types, such as open downs and alluvial brigalow, which are in A condition, and where seasonal conditions are reasonable, spelling is not needed to maintain good pasture condition and high LWG/hd with low to moderate stocking rates. Figure 39 below demonstrates that, at low and moderate stocking rates, only a minor increase in % perennials arose from the implementation of a six-month spell every four years on A condition open downs (Note that 90% perennials is the maximum value in the model). A similar trend for LWG/hd is demonstrated in Figure 40.
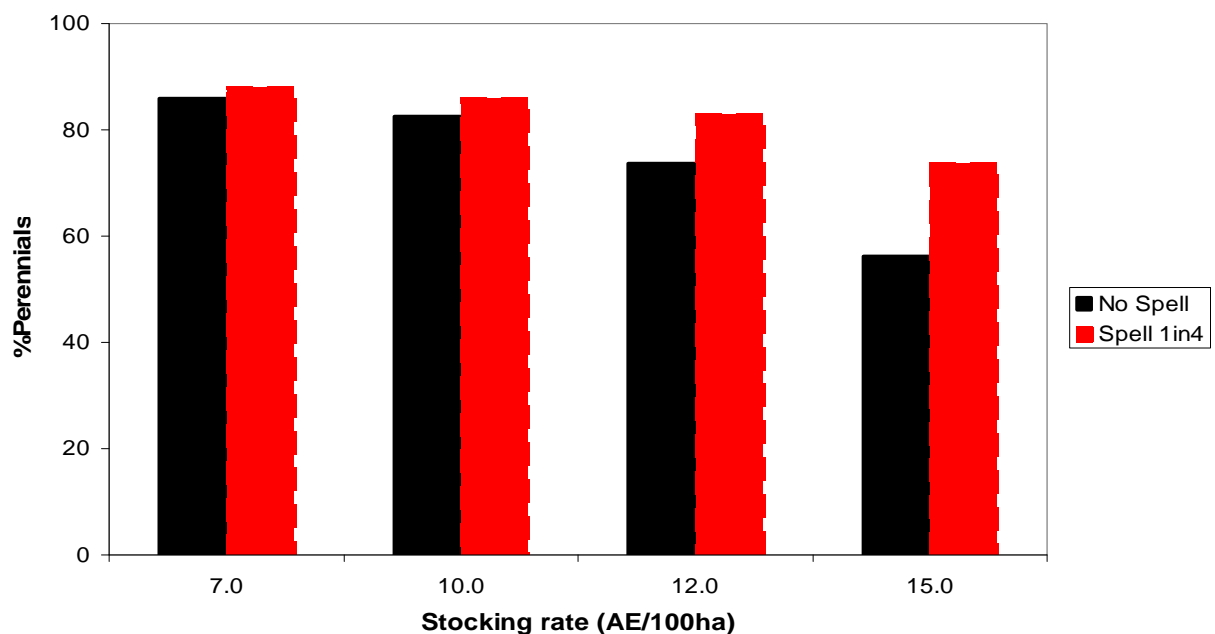
Figure 39. Changes in % perennials that occur with and without a six-month spell every four years, at four stocking rates, on open downs in A condition, in the western Queensland Mitchell grass downs.
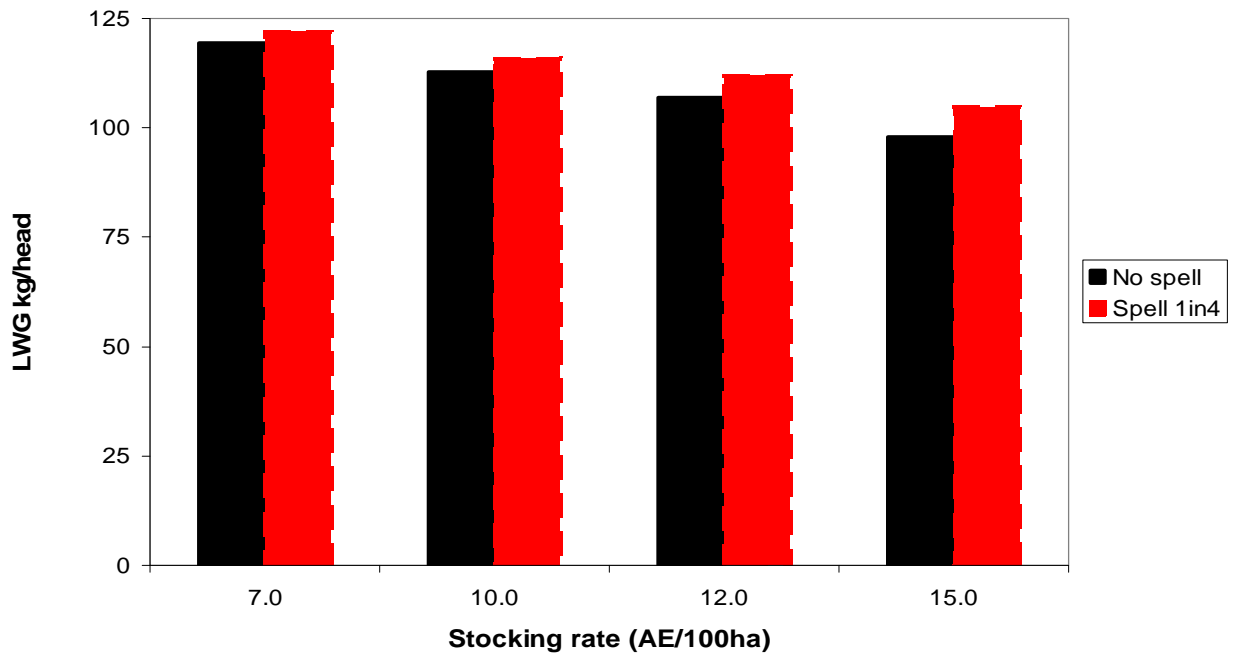
Figure 40. Changes in LWG/hd that occur with and without a six-month spell every four years, at four stocking rates, on open downs in A condition, in the western Queensland Mitchell grass downs.
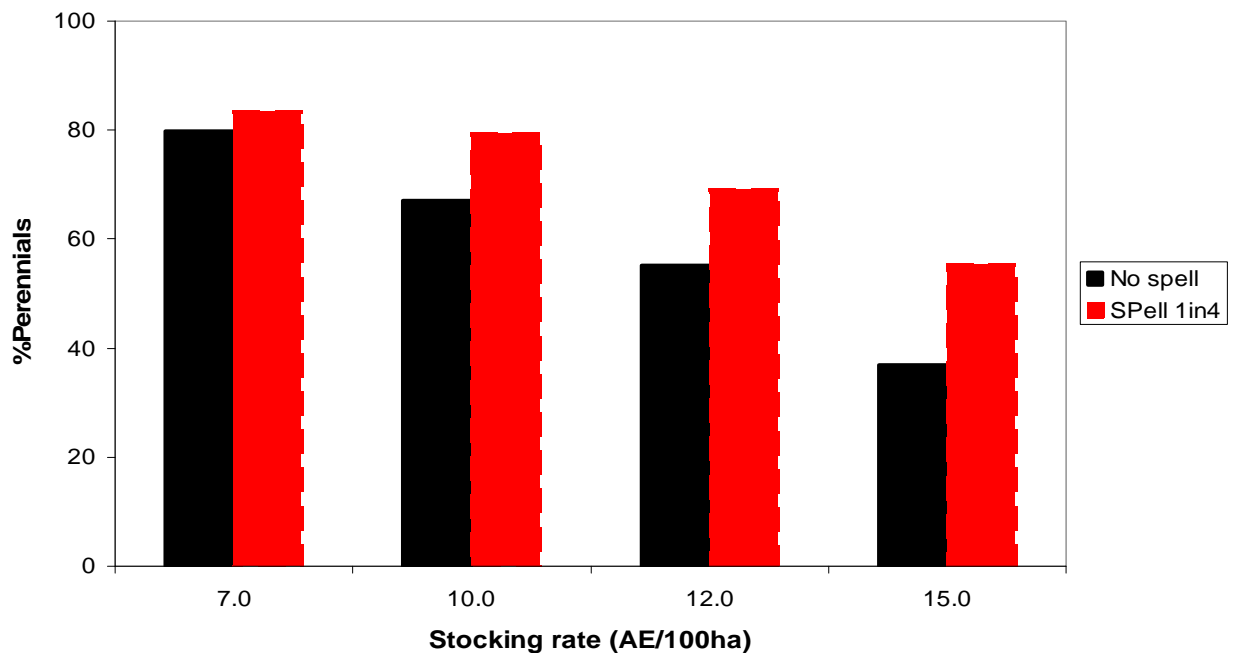
Figure 41. Changes in % perennials that occur with and without a six-month spell every four years, at four stocking rates, on open downs in B condition, in the western Queensland Mitchell grass downs.

When these more fertile land types are in B condition, and stocked at medium to high rates, then a six-month spell every four years is needed to maintain % perennials. This is illustrated by Figure 41, where % perennials decline on B condition open downs at the higher stocking rates, with these being restored to more than 50% with a six-month spell every four years.

Similar results were observed for the less fertile land types, such as soft mulga and poplar box, which again were in good condition. Figure 42 shows that at a moderate stocking rate, a spell every four years is not needed to maintain % perennials in B condition poplar box. However, at a

high stocking rate, % perennials decline to low levels, and in this case a six-month spell every four years improves pasture condition significantly.
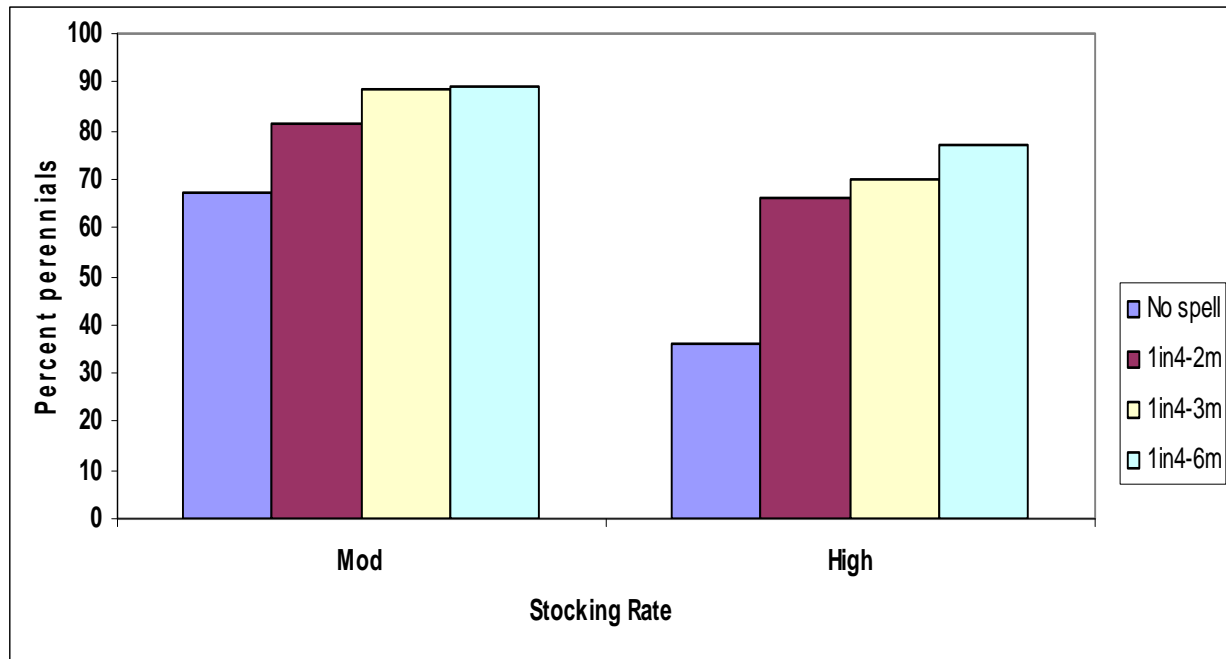
Figure 42. Changes in % perennials on B condition poplar box land type in the Maranoa-Balonne, that occur with moderate (15 AE/100ha) and high (20 AE/100ha) stocking rates, and with two, three and six-month duration spells that occur every four years.

When the more fertile land types are in poor condition (C), a six-month spell every four years in conjunction with reducing stocking rate is needed to improve pasture condition (% perennials). In this case, reducing stocking rate and spelling appear to be of equal importance in recovering pasture condition. This point is illustrated in Figure 43, where % perennials on C condition black cracking clays in the VRD recover with a six-month spell every four years at the lower stocking rate, but not at the higher rate. If it was necessary to maintain a higher stocking rate, then at least a three month spell every year would be needed to sufficiently improve % perennials on the same land type (see Figure 44).

With less fertile land types in poor condition, recovery relies more on a six-month spell every four years than it does on reducing stocking rate, but both are required for improvement in % perennials and LWG/hd. For the very low fertility land types, lower stocking rates and more frequent spelling may be needed for their recovery. Figure 45 shows changes in % perennials on C condition soft mulga in the western Queensland Mitchell grass downs. Reductions in stocking rate alone are not sufficient to recover % perennials (Figure 45) and LWG/hd (Figure 46), and must be combined with a six-month spell every four years before reasonable % perennials are obtained.
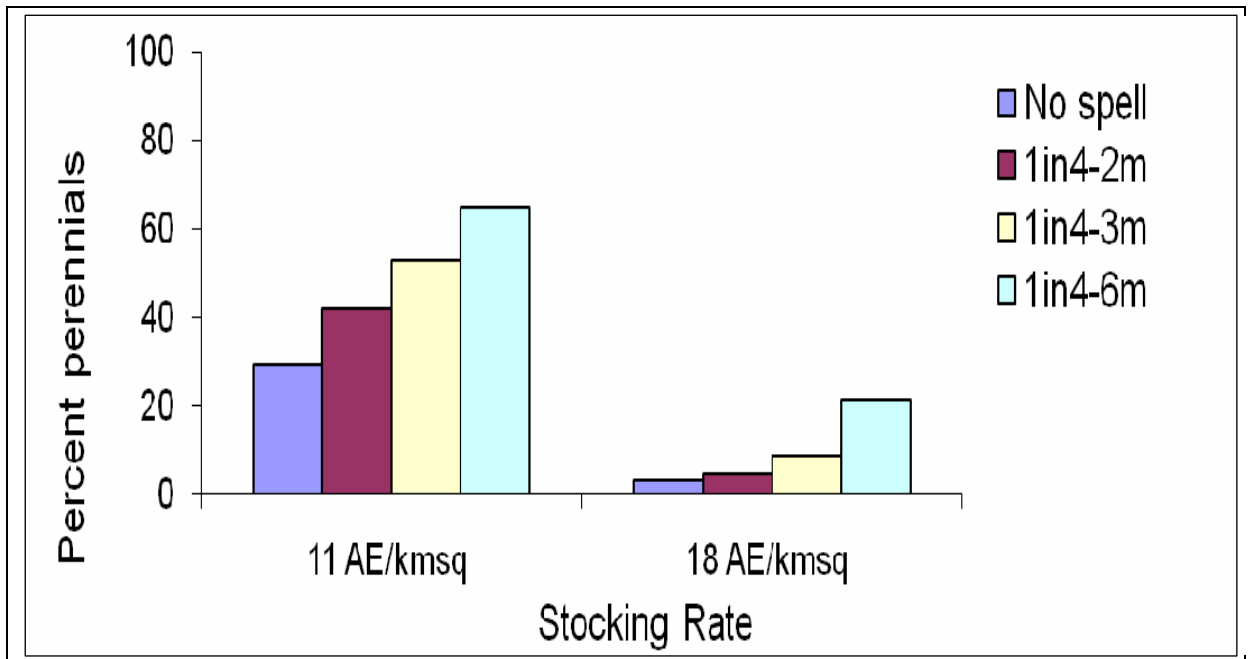
Figure 43. Change in % perennials on C condition black cracking clays in the VRD, at two stocking rates, and with a range of spell durations, repeated every four years.
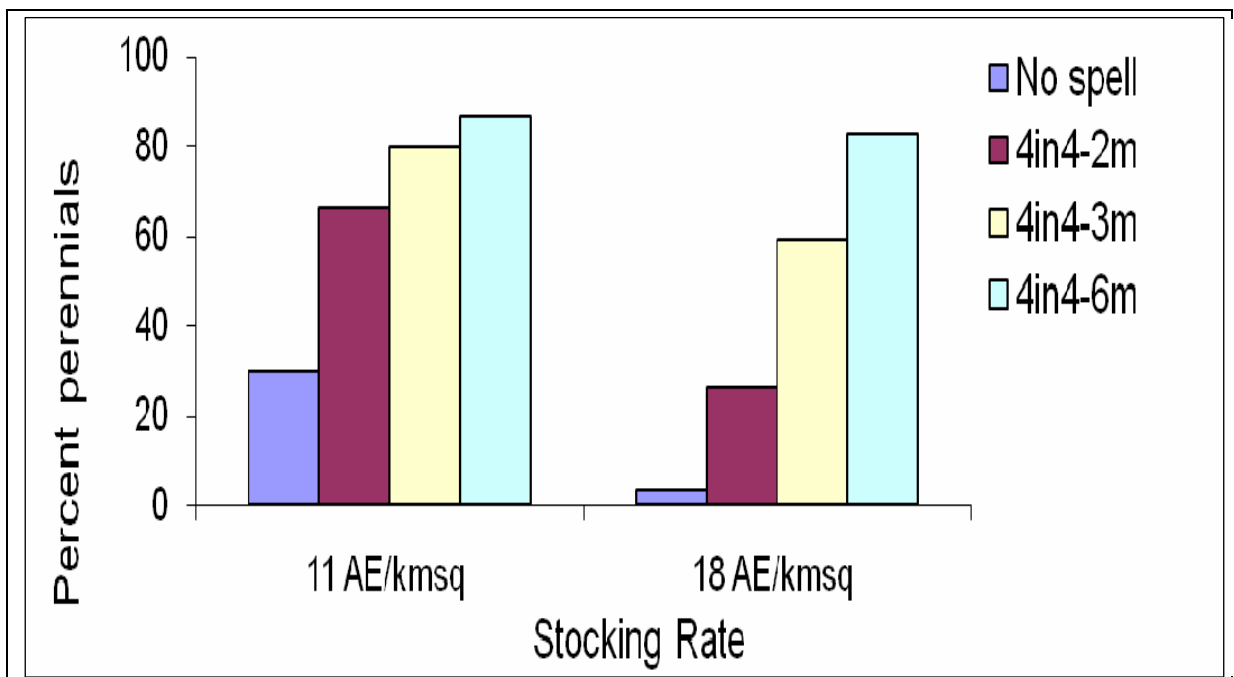
Figure 44. Change in % perennials on C condition black cracking clays in the VRD, at two stocking rates, and with a range of spell durations, repeated every year.
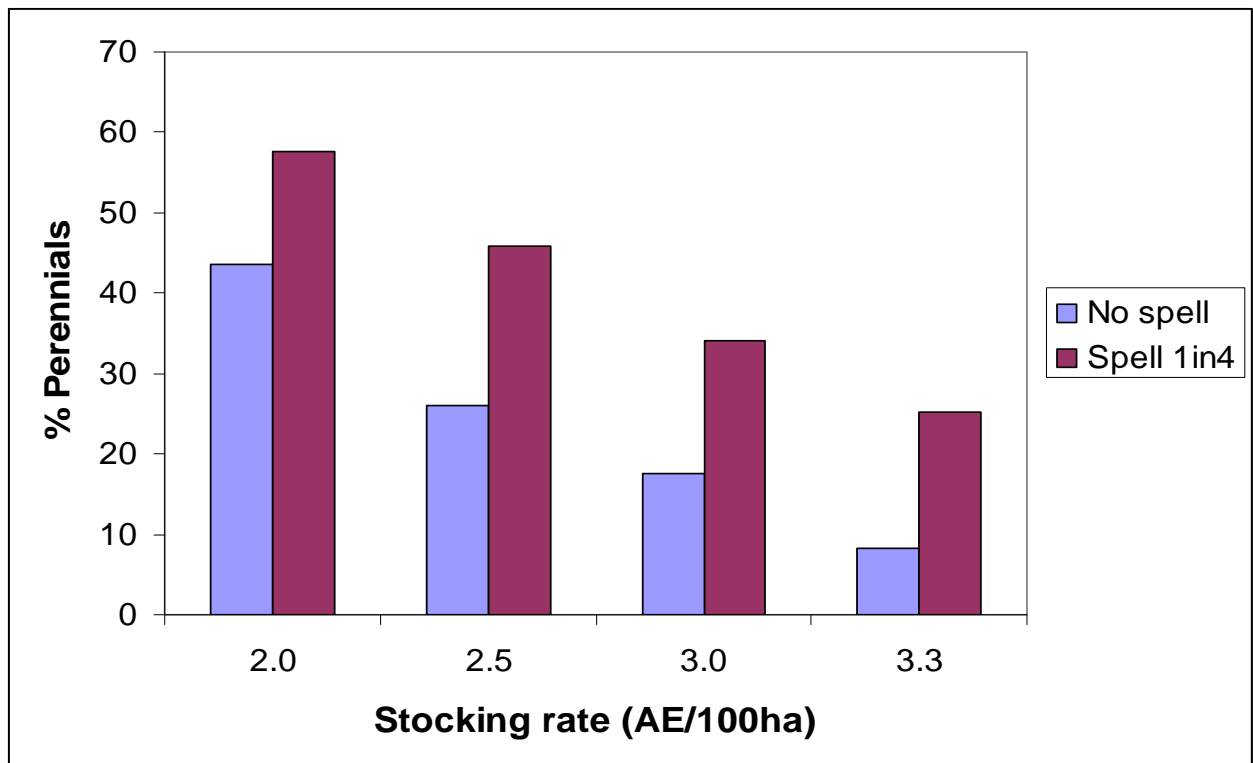
Figure 45. Changes in % perennials for C condition soft mulga in the western Queensland Mitchell grass downs occurring with variation in stocking rate, and with and without a six-month spell every four years.
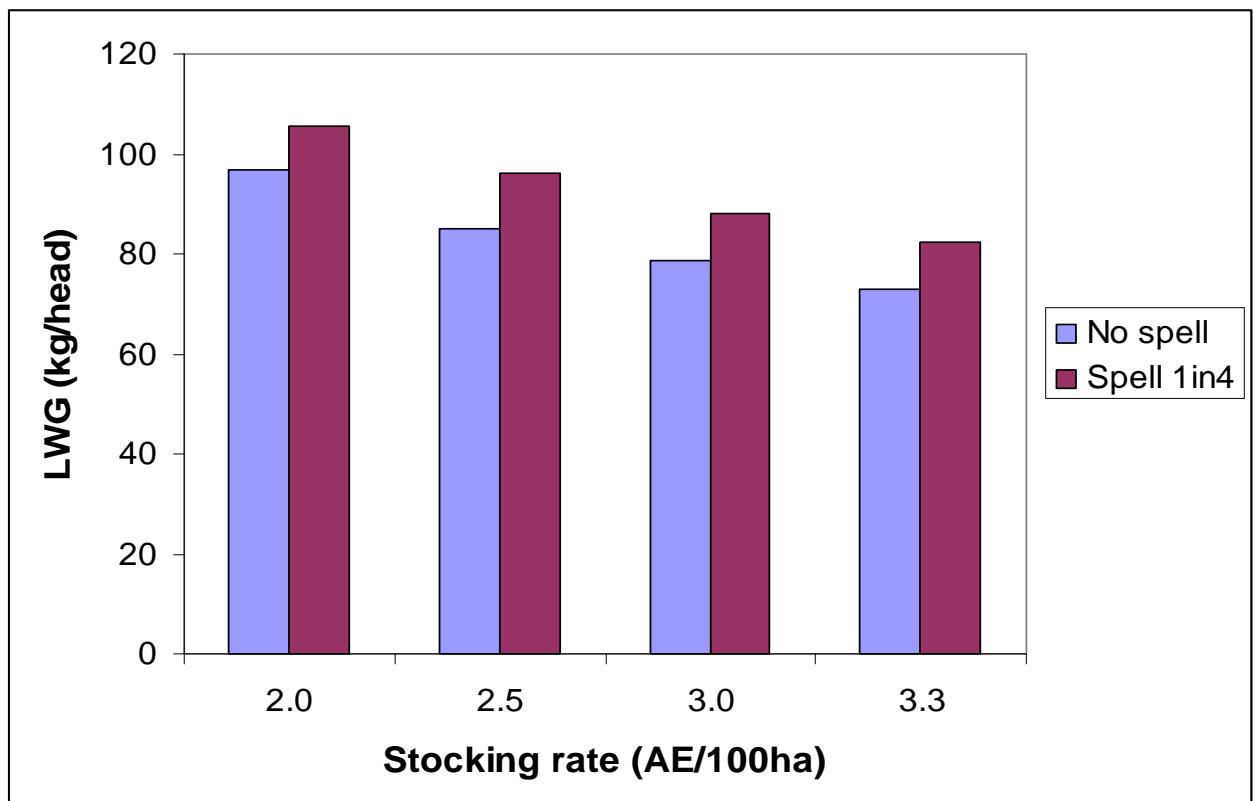
Figure 46. Changes in LWG/hd for C condition soft mulga in the western Queensland Mitchell grass downs occurring with variation in stocking rate, and with and without a six-month spell every four years.

On all land types in poor condition, spelling for six months every four years may recover % perennials to around 50% or more, provided the stocking rate is low. More frequent spelling will be needed to recover perennials as stocking rate increases, with a six-month spell every year

needed to recover % perennials and LWG/hd at high stocking rates. In this case, the high stocking rate is used for only 6 months in the year, effectively halving the stocking rate. In Figure 47 below for goldfields land type in the Burdekin, % perennials are improved with a six-month spell at the low stocking rate, but the same spelling regime has little impact at the higher stocking rate. In this case, at least a three-month spell every year is needed to significantly improve % perennials (Figure 48). Figures 49 and 50 show the same trend for LWG/hd.

Figure 47. Percent perennials for C condition goldfields land type in the Burdekin, at two stocking rates, and with and without a spell of variable duration every four years.

While reductions in stocking rate alone are capable of recovering poor condition pastures, this may be at the expense of livestock productivity. A six-month spell in conjunction with a moderate stocking rate may achieve the same level of pasture recovery as stocking at a low rate alone, but the simulations indicate that former may produce higher LWG/ha. Figure 51 shows that the recovery of % perennials in C condition black cracking clays in the Barkly Tablelands occurs equally well with either a low stocking rate of 7 AE/km^2 on its own, or a higher stocking rate of 9 AE/ km^2 in combination with a six-month spell every four years. However, the higher stocking rate plus spelling strategy provides a better LWG/ha, being 5kg/ha for the low stocking rate approach, compared with 7kg/ha or the latter strategy (Table 6). A monthly time-step liveweight gain model would enable us to investigate this more thoroughly. These results should be regarded as preliminary.
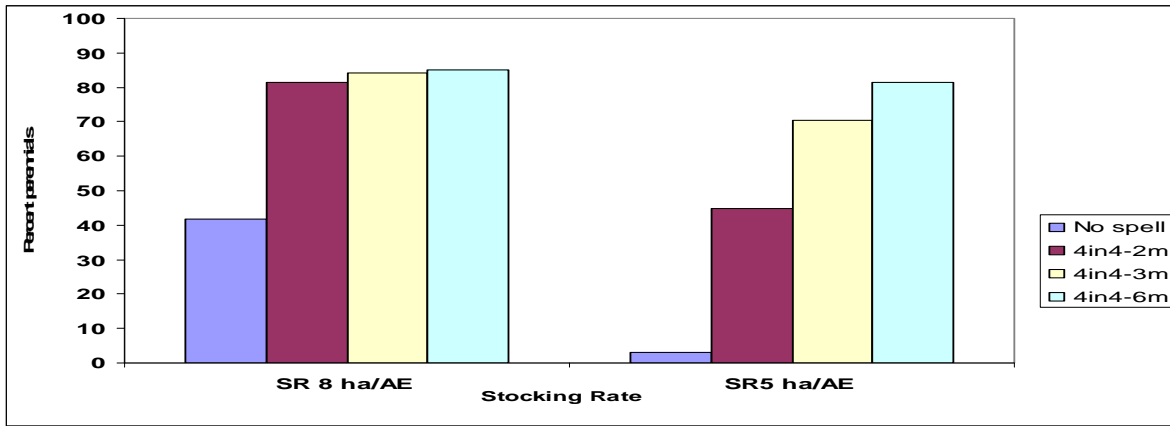
Figure 48. Percent perennials for C condition goldfields land type in the Burdekin, at two stocking rates, and with and without a spell of variable duration every year.
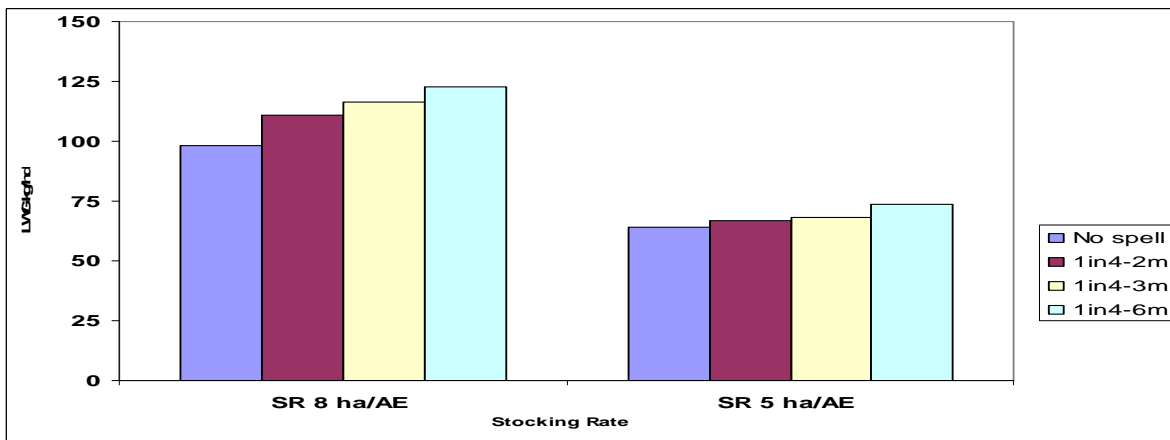

Figure 49. LWG/hd for C condition goldfields land type in the Burdekin, at two stocking rates, and with and without a spell of variable duration every four years.

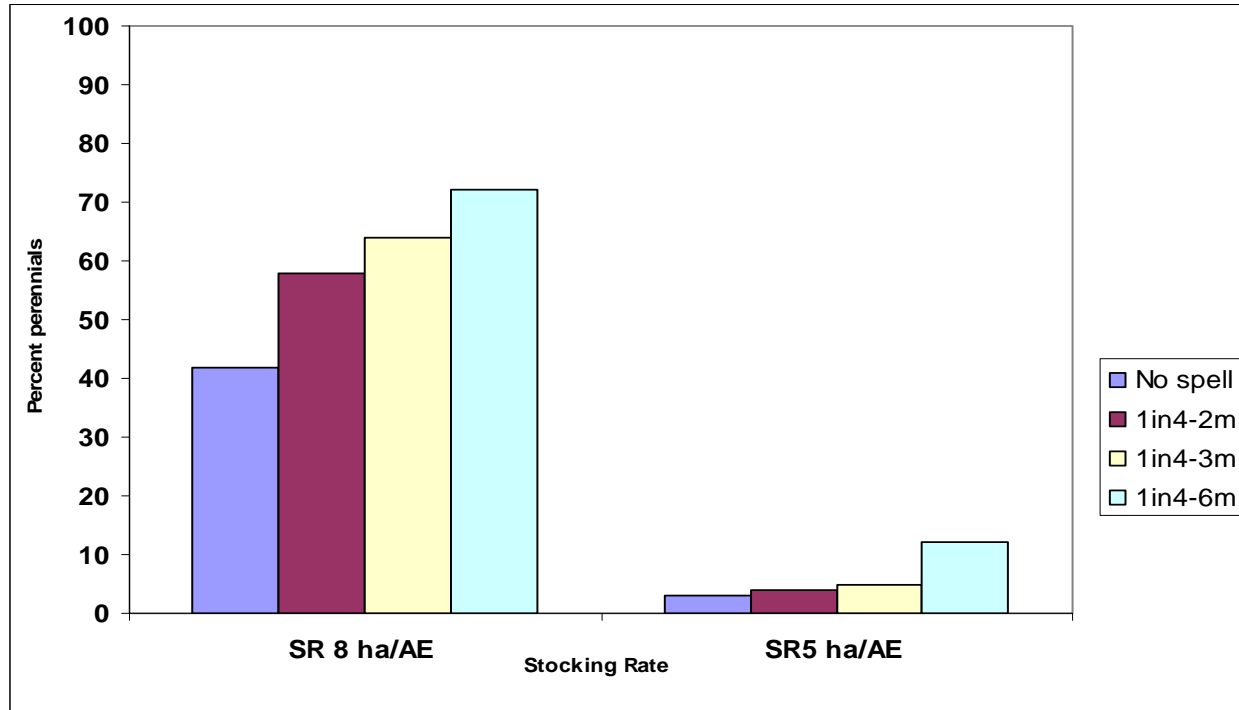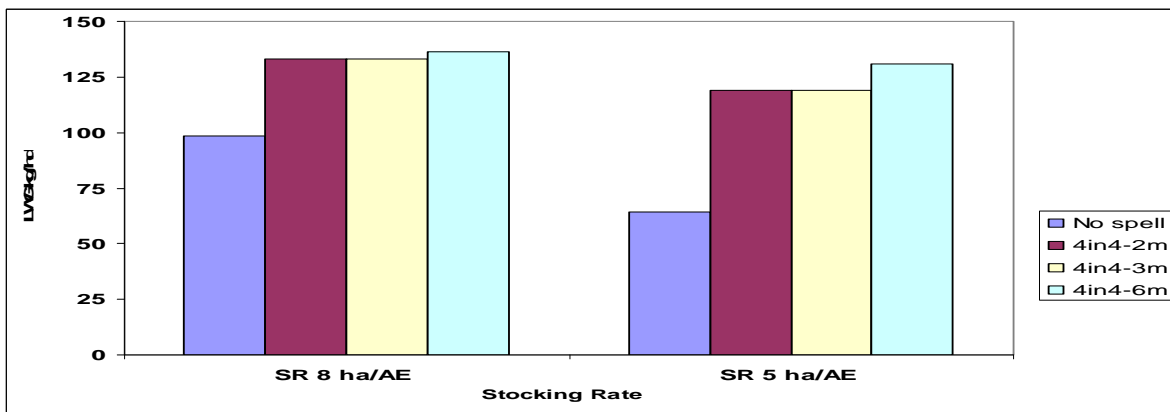**Figure 50.** LWG/hd for C condition goldfields land type in the Burdekin, at two stocking rates, and with and without a spell of variable duration every year.
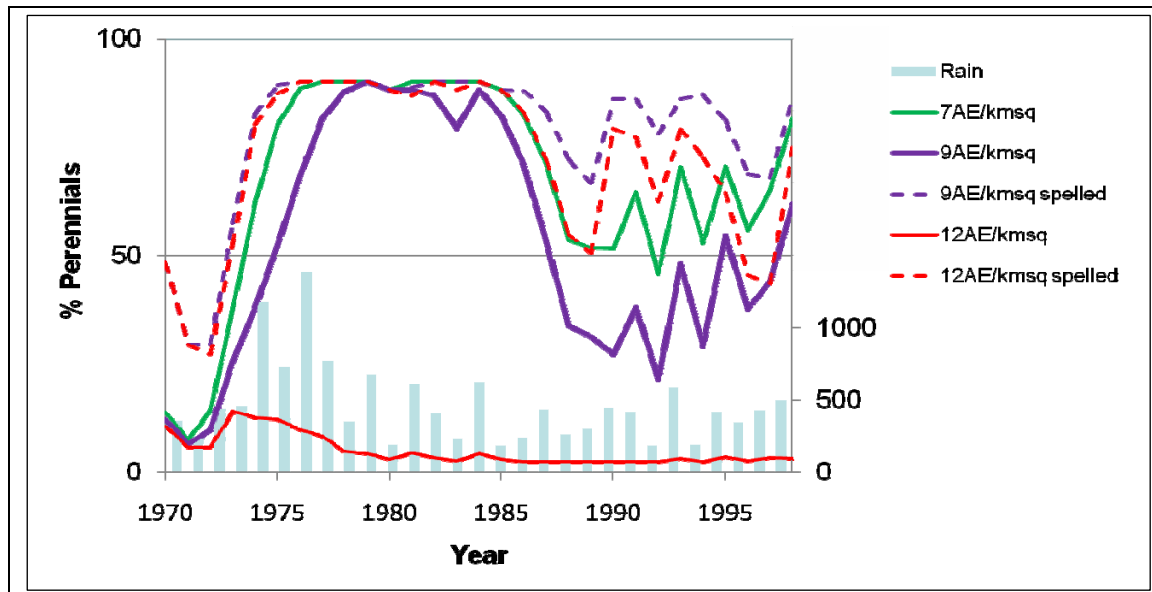
Figure 51. Level of % perennials in C condition black cracking clays in the Barkly Tablelands, at different stocking rates, with and without a six-month spell every four years.

Table 6. The LWG/ha for different combinations of stocking rate (AE/100ha), with and without a six-month spell every four years, for C condition black cracking clay in the Barkly Tablelands.

Stocking rate ± spell	Average LWG/ha
7AE	5
9AE	3
9AE + spell	7
12AE	-8
12AE +spell	5

Conversely, if the stocking rate is too high, then even spelling every year for six months over the growing season will not be sufficient to recover pasture condition. This is shown in Figure 52, where % perennials in C condition poplar box in the Maranoa-Balonne do not fully recover at a high stocking rate, even when spelled for six months every year.

The outcomes of spelling are very sensitive to stocking rate. Longer duration and higher frequency spelling are required as stocking rates increase, but only to a point. When this upper limit of stocking rate is reached, even spelling for six months every year will not result in pasture recovery.

The above durations and frequencies of spelling that the modelling suggests are required to maintain or recover pasture condition may be over-estimated because the modelling applies inflexible rules, year after year. If spelling could be better matched to the prevailing seasons, with more aggressive spelling strategies practised when seasonal growing conditions are good, and curtailed when seasons are poor, then the duration and frequency of effective spells required may be lower than presented here. Potentially, a two-month spell every four years could be very

effective if timed to coincide with very good seasonal growing conditions but the practicalities of this option may limit its use in more extensive rangelands.
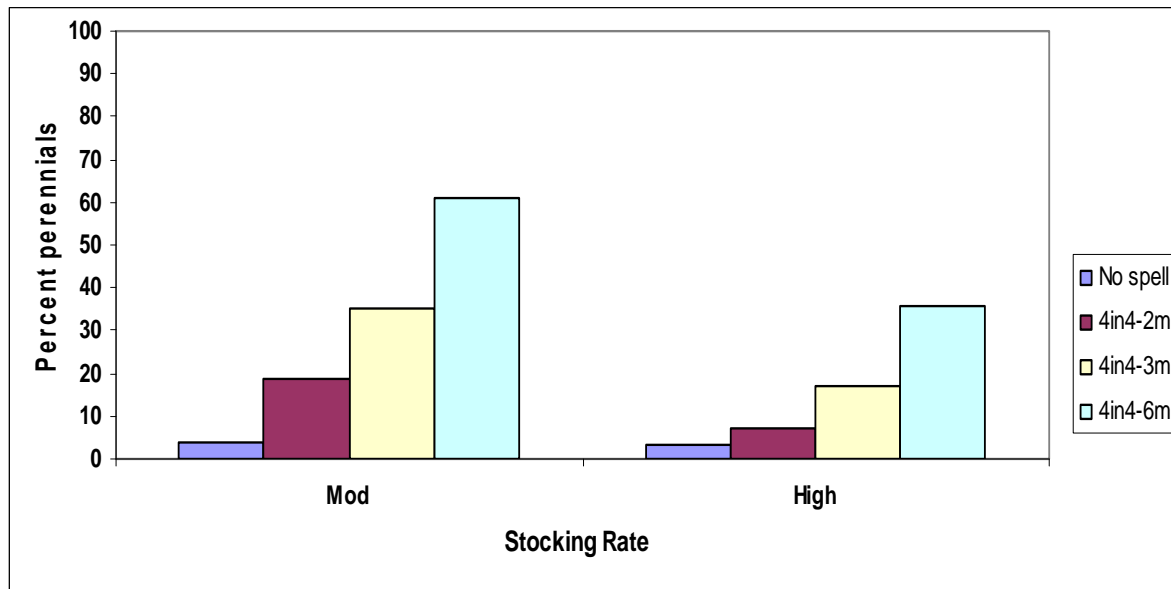
Figure 52. Percent perennials in C condition poplar box in the Maranoa-Balonne, at moderate (15 AE/100ha) and high (20 AE/100ha) stocking rates, with and without a spell of 2-6 months every year.

Component spelling - Four-paddock rotational spelling system
As part of the component modelling, we simulated a range of spelling options. These covered variable length of spells (2, 3 and 6 months) and differing frequencies (from annual to 1 in 4 years). Conceptually, the cattle from the spelled paddocks were agisted, and this is exactly how the economic models were evaluated.

Among many groups, there was concern expressed about the agistment option – either through lack of availability, concerns about practicality or because of high cost. To overcome this, we developed a way of moving the cattle from the agisted paddock onto the other paddocks in the spelling regime. Typically, we examined a four-paddock system where one paddock was spelled each year for a 6-month period commencing in December. This was derived from recommendations made by the synthesis activities in the accompanying parts of this project. The effect of this is that the paddocks that are not spelled have a stocking rate that is 33.3% higher during the summer growing period than would be the case if there was no spelling or the cattle from the spelled paddock were agisted off-property. Clearly the capacity of the non-spelled paddocks to tolerate this increased stocking pressure had to be weighed up against the benefits to the spelled paddock.

With the current version of the model, it is only possible to run simulations of this aspect of spelling with a constant stocking rate. It is hoped that a variable stocking rate option can be developed in future to overcome this limitation.

Effect of stocking rate on effectiveness of spelling
As shown from the component analysis of stocking rate, spelling will not lead to improved pasture condition if the stocking rates used are too high. In environments where the peak yield is reached in the majority of years (where the system is limited by the maximum nitrogen uptake variable, for example in coastal Queensland speargrass communities), this stocking rate is critical, as exceeding this safe long-term stocking rate by only a small amount (<5%) leads to a decline in percentage perennials and therefore pasture productivity (~ 22 head/100 ha - Figure 11). This sharp decline occurs despite the relationship between utilisation and percent perennials being as expected (Figure 10). Under a constant stocking regime, this leads to chronic

overgrazing and the system will not recover. Spelling in these circumstances will not improve the situation. In systems where the major limitation is rainfall (e.g. western Queensland Mitchell grasslands), the threshold does not appear to have the same effect and the dramatic decline when the threshold is exceeded by a small amount is not as evident as in the case mentioned before.

At the other extreme, a very low stocking rate will lead to improvement in pasture condition (assuming it is not in A condition to begin with) whether or not any spelling regime is used. Between these extremes, there is opportunity for spelling over summer to have a beneficial impact on pasture condition.

The 4th paddock problem
Achieving benefits from spelling requires that the overall stocking rate is appropriate. If the stocking rate is too high, then spelling does not lead to improve4d pasture condition. If stocking rate is low, then pastures will recover without spelling being undertaken.

When undertaking spelling with stocking rates between these two categories, the last paddock to get spelled (the 4th paddock) ends up in poor condition (in most of the simulations undertaken to date). This is because it is 'overgrazed' for three consecutive summers. An example is shown in Figure 53. In some simulations, the third paddock also declines in condition (lower % perennials) and in still other examples, the unspelled paddock improves while the 4th paddock declines in condition. These behaviours are particularly sensitive to the choice of stocking rate and in this respect are somewhat of an artefact of the rigid, fixed stocking rates used in these simulations. However, the 4th paddock problem is real and some considerations of how to overcome this need investigation.

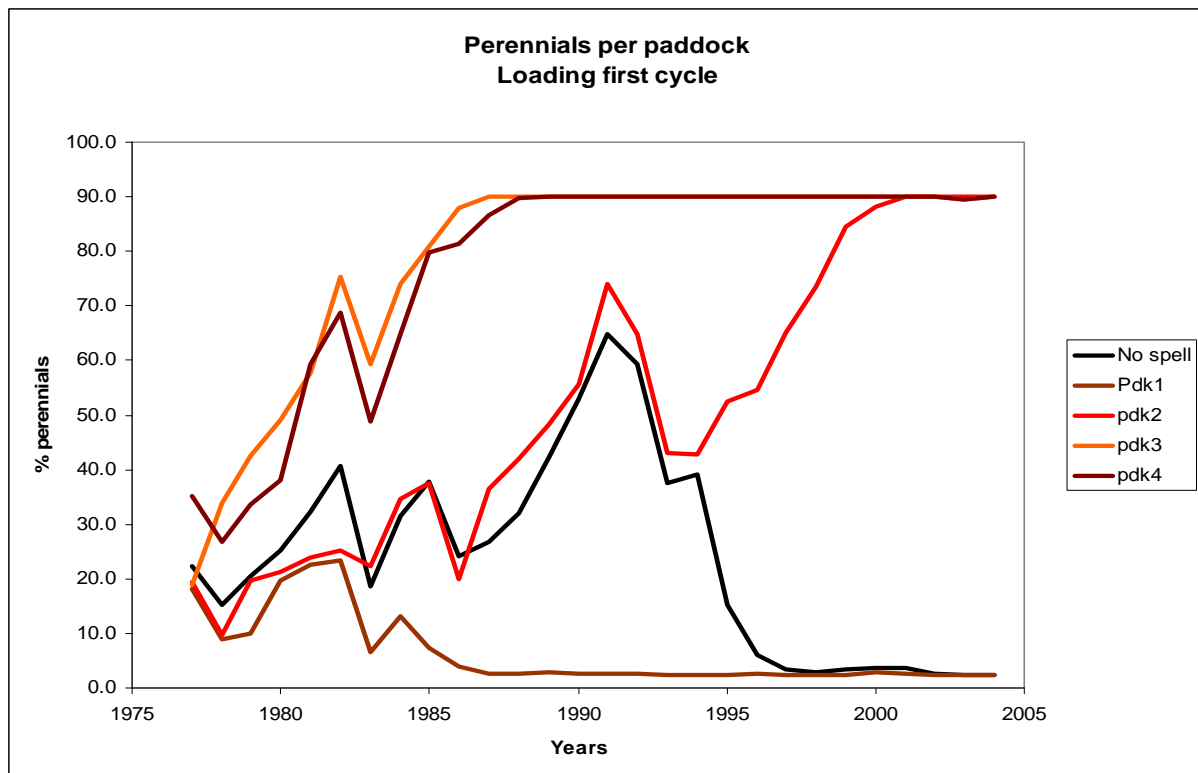**Figure 53.** Percent perennials in four spelled paddocks in a rotational 1 in 4 year spelling system compared with an unspelled paddock for a goldfields land type in Burdekin region of north Queensland.

There are two main ways of addressing the 4th paddock problem. The first is to differentially load up the other three paddocks so that the paddock that has the longer period of overgrazing during

the summer before it gets the first spell actually gets less than its proportional share of the cattle from the spelled paddocks.

The other potential solution is to reduce or eliminate the loading up of the other three paddocks for a period during the initial setting up of the spelling regime for the first 4-year cycle. Some simulations were done along these lines to see if there was scope for using this approach. In VRD and Barkly, landholders use poorer country (that is not usually use much) during the wet to spell black soil. So there is spare capacity in the system, to a degree. This is less likely to be applicable as regions become more intensified and have fewer undeveloped areas.

A study was done in which the stock from the spelled paddocks were agisted for the first four years of the spelling regime, and thereafter the stock were allocated to the remaining three paddocks. The rationale for this was that this should give the maximum response to this general approach (other than by continuing the agistment for a longer period). All paddocks commenced in C condition and during the first 4 years, there should have been an increase in condition (and percentage perennials). Due to the current limitations of the model, the stocking rate was fixed for the duration of the study. It is likely that in reality, the land manager would increase the stocking rate to take advantage of the improvement in condition (and therefore increased production). The results in Figure 54 indicate that spelling associated with agistment of cattle from the spelled paddocks during the first 4-year cycle improves all paddocks compared with the unspelled control. This may not occur in all land types as others have yet to be studied.
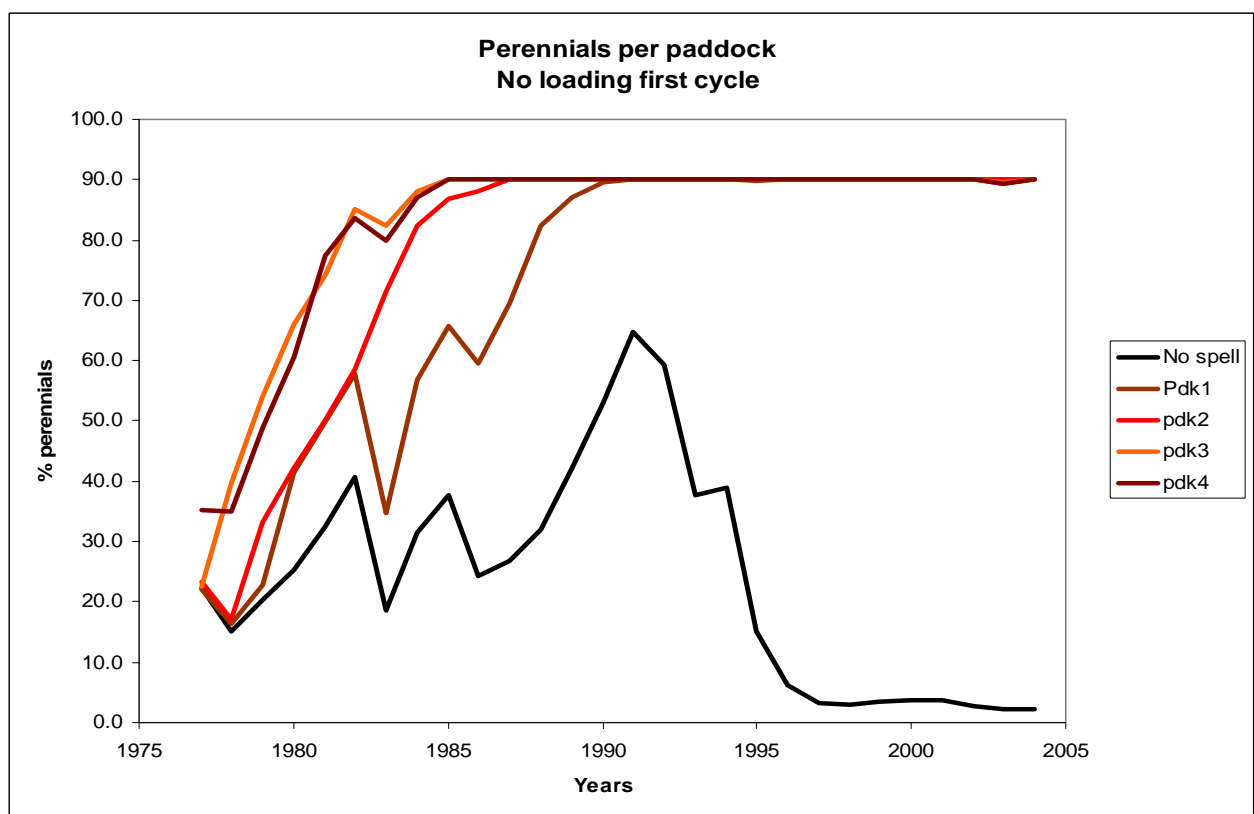
Figure 54. Percent perennials for 4 spelled paddocks compared with an unspelled control (as in Figure 53) with the exception that cattle from the spelled paddock were agisted rather than being placed into the remaining 3 paddocks during the first 4-year cycle.

4.1.3 Use of fire

Key overall findings for prescribed burning
The success of burning depends on stocking rate, the fertility of land types, extent of tree and shrub cover, and climate.

For all land types, low stocking rates significantly improve the chances of achieving any form of burn. Generally, the proportion of years that cool and hot fires can be achieved decreases as stocking rate increases. This point is illustrated in Figure 55 for the yellowjacket land type in the Burdekin, showing the decline in the percent of years in which cool and hot fires occur as stocking rate progressively increases.
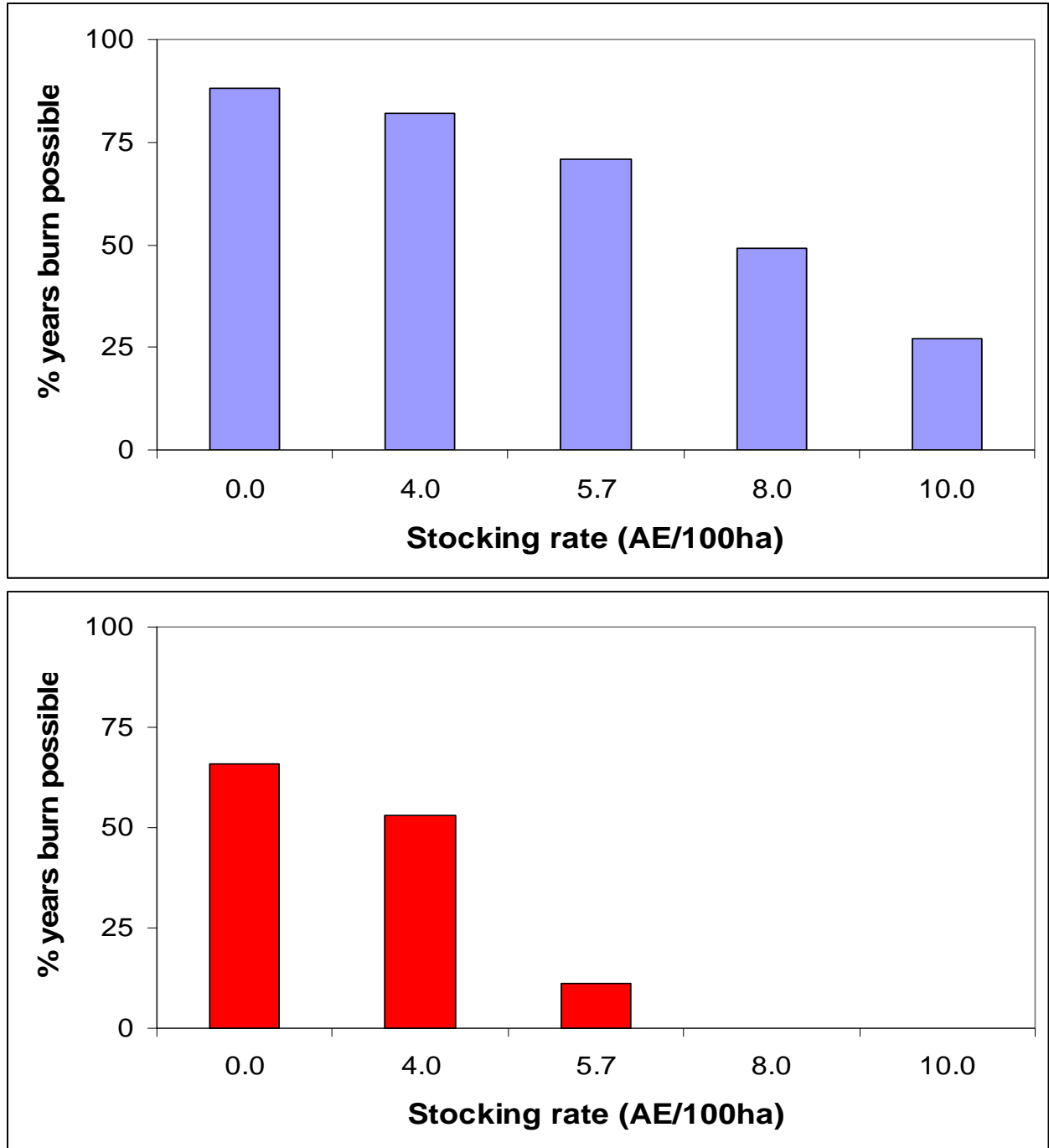
Figure 55. The percent of years that cool fires (blue) and hot fires (red) can be achieved for five stocking rates in the yellowjacket land type of the Burdekin.

For low fertility land types (especially in low rainfall areas), such as soft mulga and poplar box, the proportion of years in which cool burns can be achieved is small. This may be in the order of 25% when grazed at low to moderate rates, and only 10% at high stocking rates. In these low

fertility land types, hot fires are uncommon, occurring in about 10% of years when stocking rate is low, and not at all at higher stocking rates.

For the more fertile land types (especially in higher rainfall areas), such as alluvial brigalow and black basalt, cool fires can be achieved in the majority of years, and particularly at low to moderate stocking rates. At high stocking rates, the achievement rates for cool fires declines markedly, to as low as 10%. Hot fires can be achieved in far fewer years, usually less than 50% of years when stocking rate is low, and may not be possible when stocking rate is high.

Similarly for low fertility land types, the success rate for achieving cool burns on a specified year, every five years, is quite small. When stocking rate is low, the success rate for cool fires every five years is in the range of 25 to 50%, but declines at higher stocking rates to 5 - 30%. If attempts to burn every five years are accompanied by an 18 month spell, the success rate can be significantly improved, doubling in some cases when stocking rates are high. This is illustrated below in Figure 56.
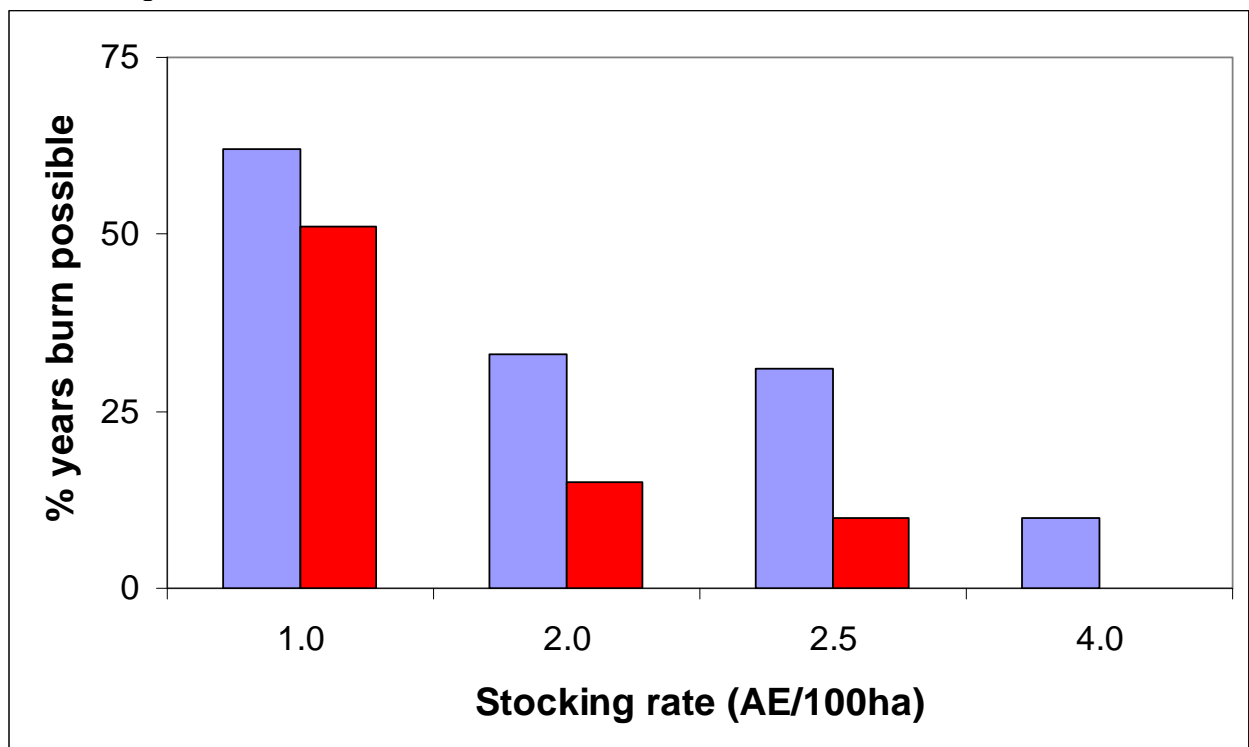
Figure 56. The percent of years in which cool fires can be achieved at four stocking rates, with and without spelling, on the Wonorah land type of the Barkly Tablelands.

On the more fertile land types, the success rate for achieving cool burns on a specified year, every five years, is very high, often approaching 100% when stocking rate is low. At high stocking rates, the success rate ranges from 10 to 50%, and when accompanied by a spell, this range improves from 40-100%.

Trees also significantly impact the proportion of years cool and hot fires can be achieved. For poplar box in the Fitzroy Basin, a TBA of 4 m^2/ha reduced the incidence of cool fires from around 70% to 20%, and hot fires from 50% to 10%. See Figures 57 and 58.
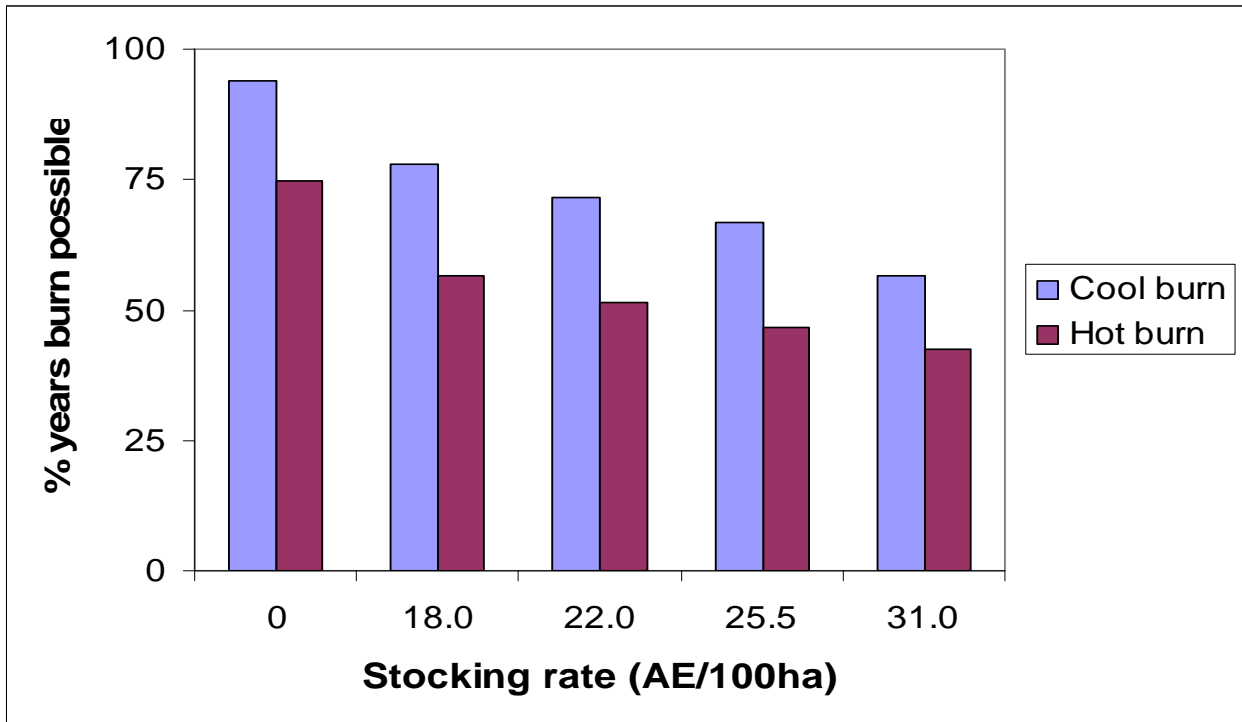
Figure 57. The percent of years in which cool and hot fires occur in poplar box without trees, at five stocking rates in the Fitzroy.

Similarly, the success rate of achieving a fire every four years was markedly reduced by trees, and particularly in association with high stocking rates. Without trees, and at the two highest stocking rates, attempts to achieve cool and hot fires every four years were successful on 75% of occasions. With trees, and at the same two stocking rates, the success rates dropped to around 40% for cool fires and 20% for hot fires. Figure 59 below shows the decline in the success of achieving a hot fire in poplar box with trees as stocking rate increases, with and without spelling.
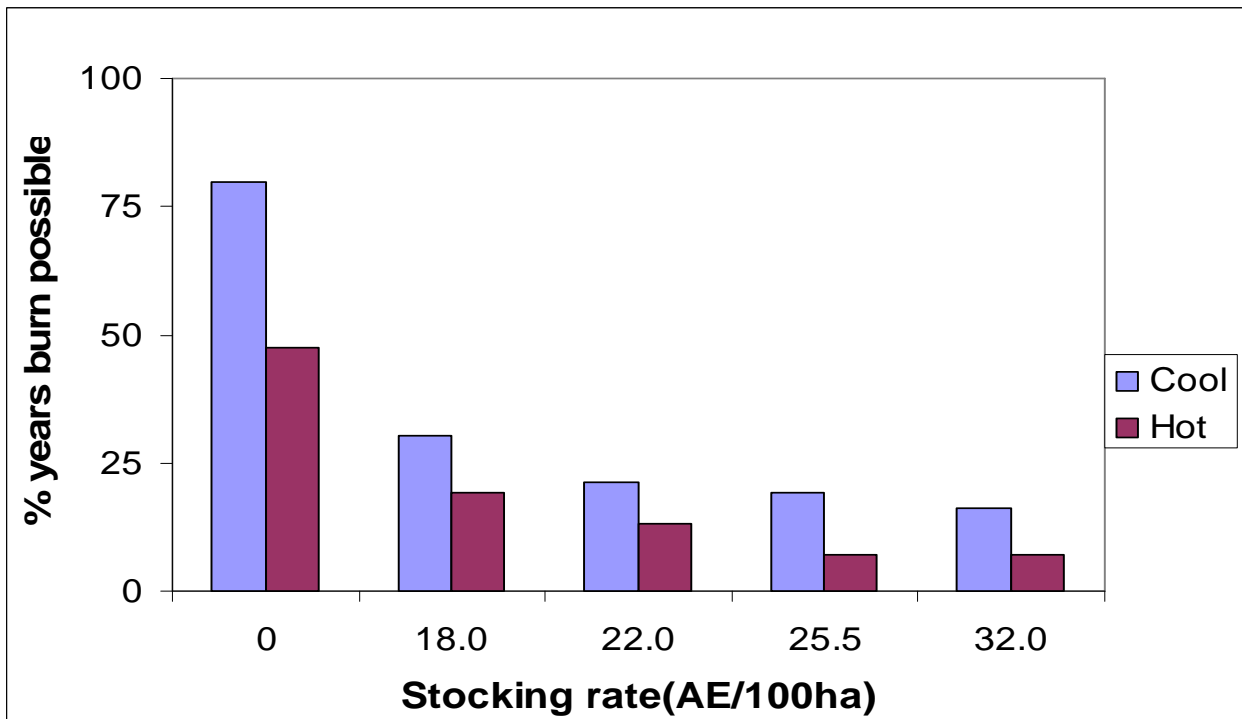
Figure 58. The percent of years in which cool and hot fires occur in poplar box with trees (TBA=4), at five stocking rates.
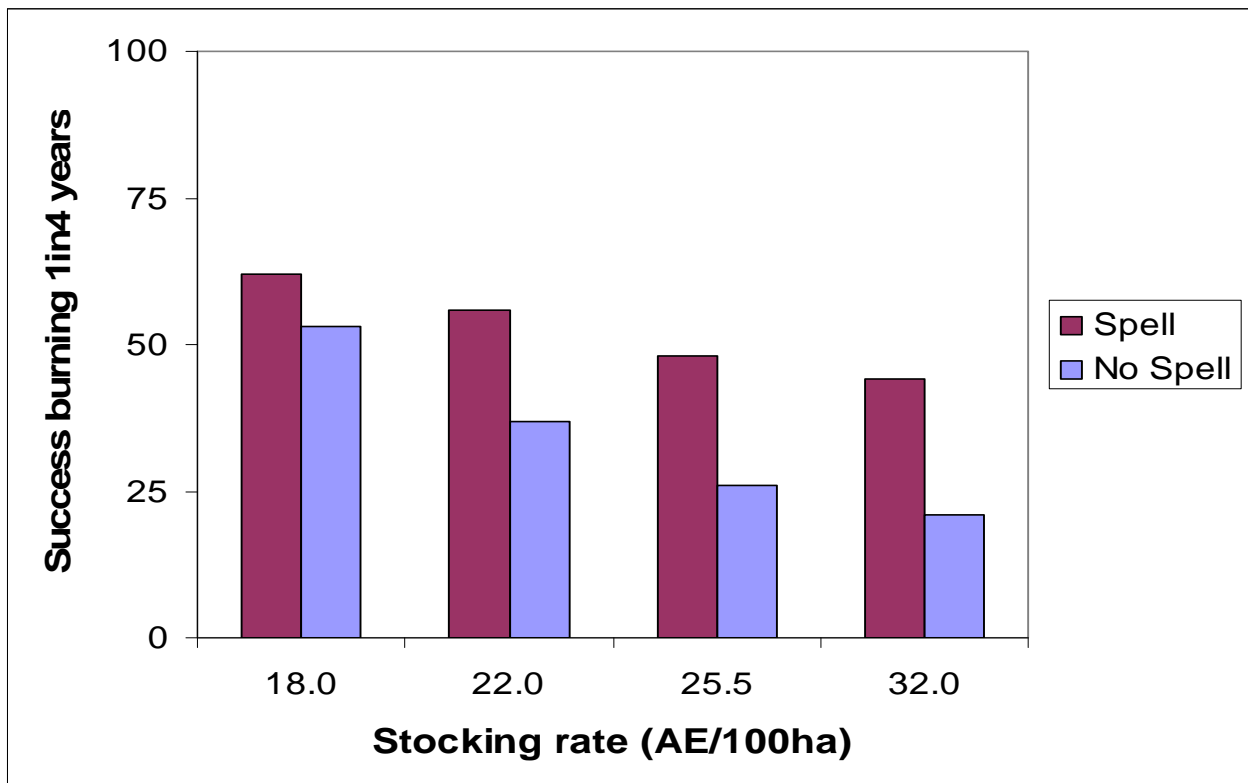
Figure 59. The success rate of achieving a hot fire at four stocking rates with and without a spell in poplar box woodland in the Fitzroy Basin.

The reductions in the incidence of fire caused by higher stocking rates and TBA can be countered to some extent through spelling. As mentioned above, the success rate of achieving a hot fire every four years in poplar box with trees at the higher stocking rates was 20%. When accompanied by an 18 month spell, this success rate improved to near 50%. Similar increases in the success rate of achieving cool fires every five years in other land types when stocking rate was high occurred when burning was also done in combination with an 18 month spell.

Overall, there are few opportunities to burn pastures when grazed at moderate to high stocking rates, and this is especially so for the less fertile land types, land types with trees and in areas of low rainfall. If a prescribed hot fire every four to five years is needed to control woody regrowth, then spelling will be required to regularly produce the fuel loads necessary for a hot fire of this frequency. Regular burning requires the design and implementation of a burning plan, which is likely to incorporate spelling.

The key findings above generally apply equally well to all six NGS regions. One possible exception is the Maranoa-Balonne, where there is a poor chance of achieving burns in all three land types at any stocking rate other than low, including the more fertile brigalow belah. In this region, it would appear that spelling would play a more important role in a burning plan compared with other regions. However, the choice of stocking rate has a strong effect on results and not all stocking rates called 'low SR' are equivalent in terms of their affect, so some results could be an artefact of the choice of stocking rates. Comparisons should be made within the one land type and comparisons across land types and regions should be done with caution.

4.2 Economic modelling with ENTERPRISE

Simulation modelling results are initially presented by all regions (except Maranoa Balonne) in the following sub-sections. General conclusions that might be drawn from across the regions are presented in a concluding section. The simulation runs use the actual climatic sequence experienced in the regional reference site commencing 1980-81 season.

4.2.1 Mitchell grasslands of western Queensland.

The Western Queensland Mitchell grasslands case study enterprise is 16,200 ha and assumed to be located at approximately 500 km and 215 km respectively from selling centres in Roma and Longreach. Blackall was the rainfall station used in simulations. The enterprise is comprised of a breeding herd producing weaner steers which are sold at approximately 240 kg liveweight in Roma. Cull breeders are sold in saleyards at Longreach. There are 11 paddocks of which the breeding herd is run in 8 paddocks, all or a subset of which form the basis of the different herd and land resource management strategies that are explored.

Scenario 1 - Fixed versus flexible stocking rates.
The first scenario examines the affect of managing annual stocking rates in either a fixed or flexible manner. Four strategies are considered including:

- fixed stocking - set on the basis of safe carrying capacity with nil annual variation in target stock numbers,
- limited annual flexibility - possible variation of 20% up or down each season in accordance with available dry matter subject to a total upper or lower limit of 40% (regarded as current practice in this region),
- high flexibility - annual variation within 50% up or down subject to a 90% upper or lower limit, and
- fully responsive – annual stocking rate can be varied without limit to consume the specified safe utilisation percentage of the end of season standing dry mater (depending on land type, but usually 25 or 30%).

Each of the 8 breeder paddocks commence the simulation in the condition (variable) specified at the initial workshop held in Longreach. Projected breeder numbers for the four stocking rate strategies are presented in Figure 60.
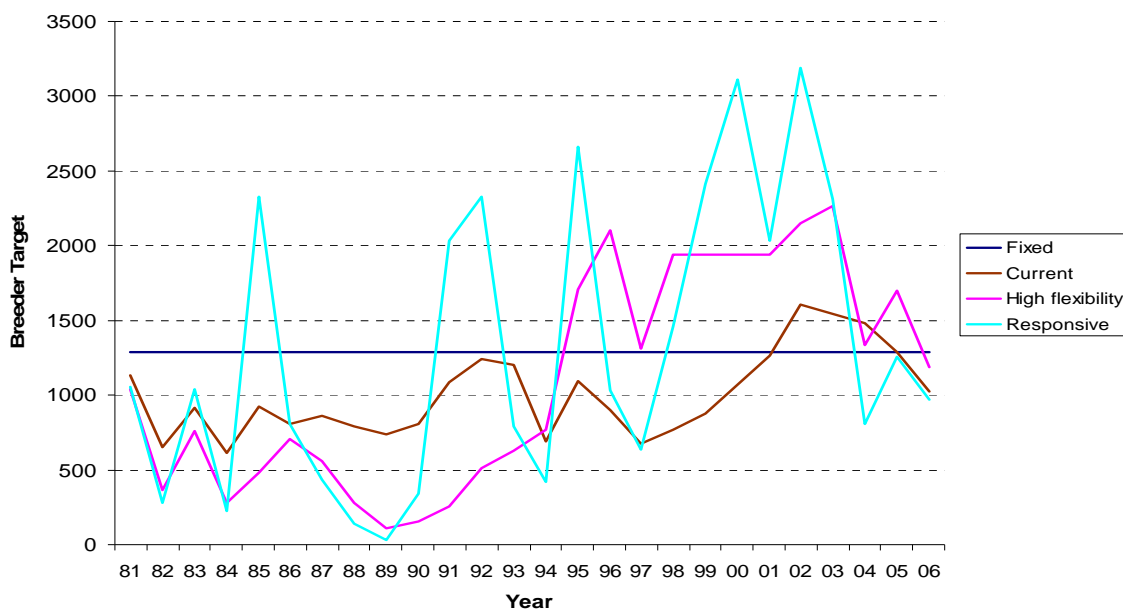
Figure 60. Target breeder numbers for four stocking rate strategies–Mitchell grasslands.

Despite the considerable year-to-year variation in the target numbers under the three flexible stocking rate strategies, the general trend is to increase breeder numbers over time in light of generally favourable climatic conditions in the later part of the sequence.

The projected annual gross margins per hectare for the simulation is presented in Figure 61 with the results summarised in Table 7. The annual profitability of the four strategies as applied to the Blackall case study and as illustrated by the gross margin is clearly influenced by the particular strategy employed. The largest variation between years is clearly shown for the completely responsive strategy with the least variation applying to the fixed stocking rate strategy.
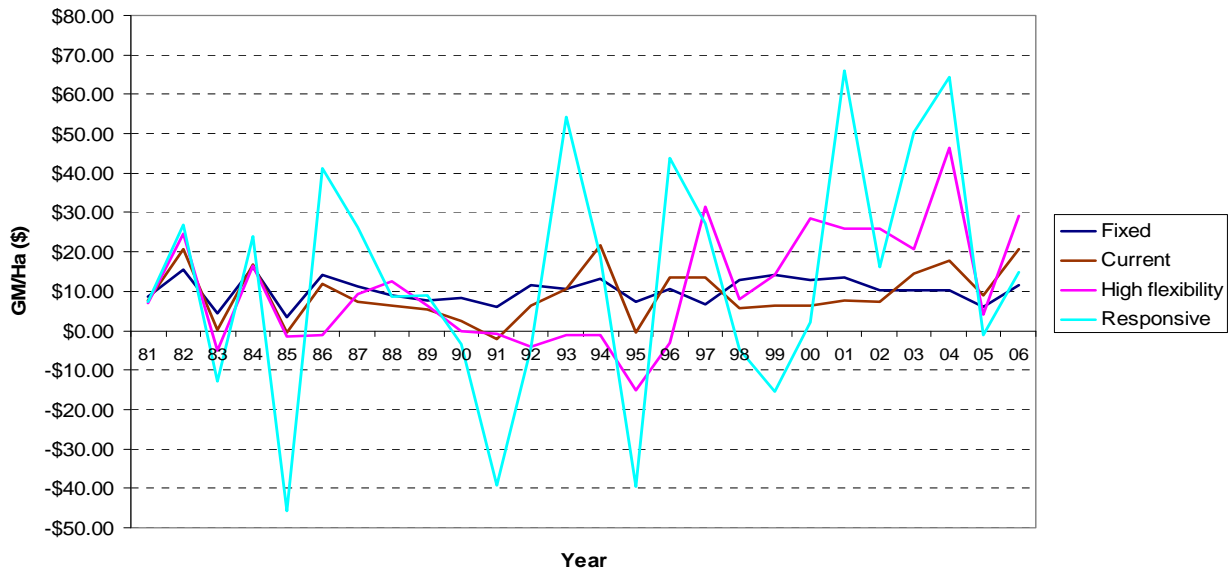
Figure 61. Projected GM/Ha for four stocking rate strategies – Mitchell grasslands.

For the climatic sequence applying from 1980-81 to 2005-06, the average gross margin/ha progressively increased with increasing flexibility in stocking rate strategies. However, the increasing average is accompanied by increasing annual variation with the two most flexible stocking rate strategies also having the highest proportion of years in which the projected gross margin is actually negative - between 35-40% of years with a negative result.

Table 7. Average, minimum, and maximum values of GM/Ha for the four stocking rate strategies – Mitchell grasslands.

	Fixed SR	Current (20%+/-)	High flexibility	Responsive
Average	$10.25	$9.12	$10.66	$12.88
Minimum	$3.32	-$2.27	-$15.27	-$45.73
Maximum	$16.11	$21.53	$46.39	$65.95
Years with –ve values	0	3	10	9

Scenario 2 – short duration wet season resting and increasing stocking rate.
The second scenario assumes that the 11 paddocks are in the condition specified by the initial workshop and that three are in good condition and do not warrant spelling. The remaining eight paddocks are subject to a 2-month seasonal spelling regime each 4th year with two lots of four paddocks undergoing the sequential 1 in 4 year spelling rotation. The stocking rate for the paddocks is annually fixed. Five different fixed stocking rates were used: a base rate and increments of 8%, 16%, 24% and 32% above the base rate. This was an attempt to equate the

anticipated benefit of spelling to an increase in stocking rate, and to see what, if any, economic implications this had. (does this include agistment costs?)

Projected target breeder numbers for the 2-month wet season spelling and five stocking rate regimes are presented in Figure 62. By assumption the annual variation is nil.

Figure 62. Target breeder numbers under 2-month wet season spell and five stocking rate strategies – Mitchell grasslands.

Consistent with the fixed stocking rate projections for Scenario 1, the inter-annual variation in target breeder numbers is not extreme across the simulation period. The increasing levels of stocking rate are evident in the increasing total breeder herd size associated with the five regimes. The projected gross margin per hectare for the simulation is presented in Figure 63 with the results summarised in Table 8.

Figure 63. Projected GM/Ha under 2-month wet season spell and five stocking rate regimes – Mitchell grasslands.

The profitability of the spelling strategy as measured by the gross margin projections is subject to considerable annual variability due largely to the fixed stocking rate regimes preventing destocking when declining climatic conditions warrant it, thereby imposing feeding penalties to offset stock weight losses and reducing the availability of surplus sale animals.

Under the climate sequence from 1980-81 to 2005-06, the spelling strategy was potentially profitable and increased on average with increasing levels of stocking rate. As for Scenario 1, there were no years in which these fixed stocking rates generated negative gross margins and the variation between minimum and maximum values increased with increasing stock numbers carried.

Table 8. Average, minimum, and maximum values of GM/Ha for 2-month wet season spell and five stocking rate regimes – Mitchell grasslands.

	0%	8%	16%	24%	32%
Average	$9.61	$10.27	$10.94	$11.24	$11.72
Minimum	$4.37	$4.77	$4.88	$3.27	$3.13
Maximum	$17.18	$17.83	$19.27	$19.77	$21.14
Years -ve	0	0	0	0	0

Scenario 3 - Whole of wet season spelling plus fixed versus flexible stocking rates.
The third scenario is a variation of the first and second scenarios - 8 of the 11 paddocks are in C condition and warranted being included in a spelling strategy, while the condition of the remaining three is judged to be in A condition. The spelling regime is for spells of 6 months from the commencement of the wet season involving two sets of 4 paddocks undergoing a rotation cycle of one seasons spell with a three-year return cycle. The same four stocking rate strategies that were employed in the first scenario are also examined in this scenario - viz. (a) fixed stocking - set on the basis of safe carrying capacity with nil annual variation in target stock numbers, (b) limited annual flexibility – annual variation +/- 20% subject to a +/- 40% absolute limit, (c) high flexibility - annual variation +/- 50% subject to a +/- 90% absolute limit, and (d) fully responsive - annual stocking rate varies without limit to utilise 25-30% (depending on land type) of the end of season standing dry mater.

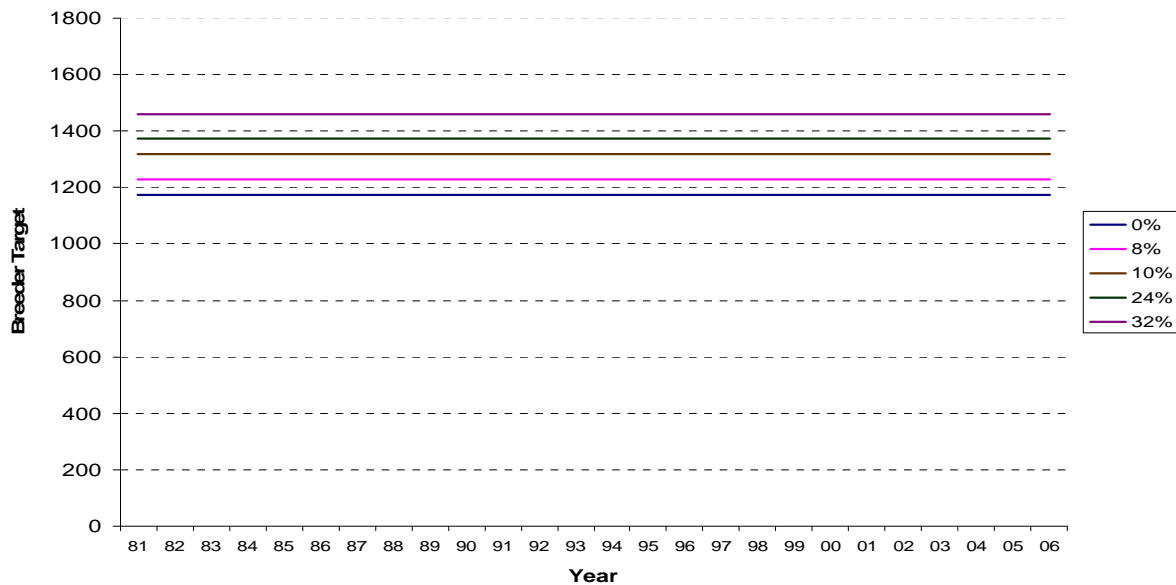Projected breeder numbers for the four stocking rate strategies are presented in Figure 64.
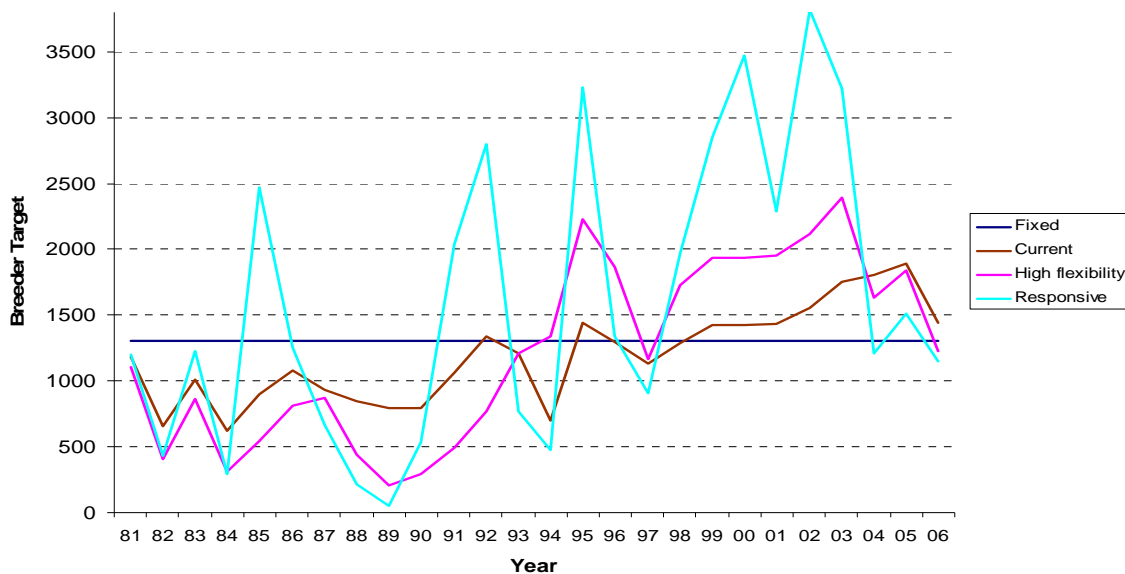
Figure 64. Target breeder numbers under 6-month wet season spell and four stocking rate strategies – Mitchell grasslands.

The number of breeders carried follows a similar pattern to those for each of the stocking rate strategies employed in the first scenario. The scenario assumes that the breeders that would normally be carried in a given paddock that is due to be rested as part of the rotation are held on agistment for 26 weeks at another property located at a distance of 100 km from the model property and subsequently returned to the treated paddock. In this way, the main impact of the spelling regime is on operating expenses with total stock numbers varying according to projected changes (if any) in subsequent productivity of the spelled paddocks. The projected annual gross margins per hectare for the simulation is presented in Figure 65 with the results summarised in Table 9.
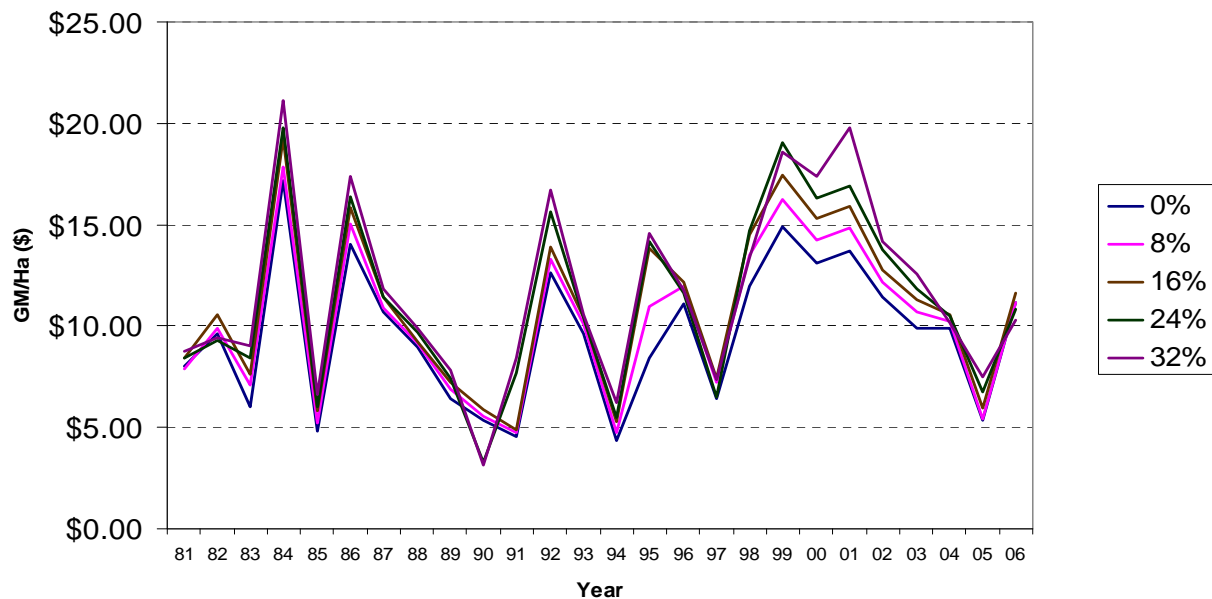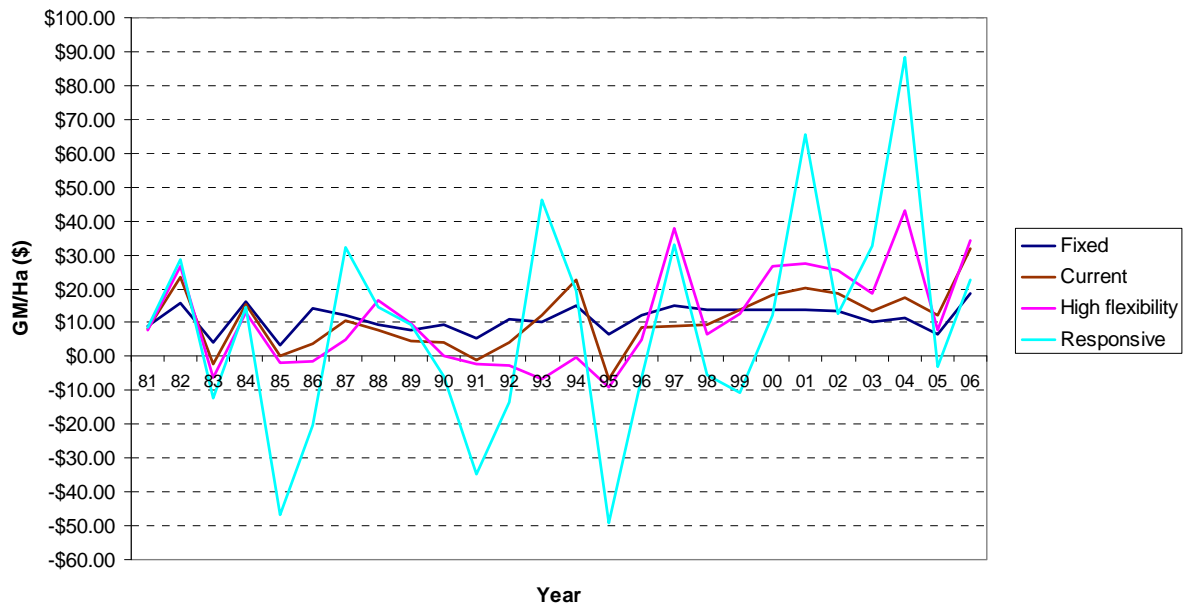

Figure 65. Projected GM/Ha under 6-month wet season spell and four stocking rate strategies – Mitchell grasslands.

As was the case with the first scenario, the annual profitability of the 6-month spelling and four stocking rate strategies as illustrated by the gross margin/ha projections is clearly influenced by the particular stocking rate strategy employed. The largest variation between years is again associated with the completely responsive strategy with the least variation applying to the fixed stocking rate strategy. Because the GRASP simulation generally projected an increased level of productivity after spelling, the actual range of the gross margin/ha projections has increased as shown in Table 9.

Table 9. Average, minimum, and maximum values of GM/Ha for 6-month wet season spell and 4 SR strategies – Mitchell grasslands.

	Fixed SR	Current (20%+/-)	High flexibility	Responsive
Average	$11.25	$10.77	$11.25	$8.97
Minimum	$3.50	-$6.63	-$9.21	-$49.31
Maximum	$18.77	$31.76	$43.08	$88.49
Years -ve	0	3	8	11

Under the climate sequence from 1980-81 to 2005-06, the 6-month spelling strategy was potentially profitable for each of the stocking rate strategies, although the fully responsive strategy is no longer generating the highest average gross margin/ha for the simulation period. For the first three stocking rate strategies, the spelling strategy has generated a modest increase

in gross margin/ha over the projections for Scenario 1 (Table 7). For the fully responsive stocking strategy, the increased annual variation in projected gross margins has increased the number of years that this measure is actually negative in the simulation period – as a result of herd numbers building up in good seasons and having to be liquidated in subsequent poor seasons - thereby giving an average projection one third below that of Scenario 1 (Table 7).

Scenario 4 - Whole of wet season spelling - 50% of breeder paddocks in poor (C) condition.

The fourth scenario assumes that four of the eight breeder paddocks are in good (A) condition and the remaining four paddocks are in poor (C) condition. This is a variant of Scenario 3, employing a smaller set of paddocks requiring treatment. However, for this scenario the spelling sequence for treated paddocks is more rigid involving two consecutive 6-month spells for each paddock with a six-year gap before re-treatment. The scenario compares results for two management strategies - (a) nil spelling and (b) spelling. There is only one grazing strategy employed for this scenario - viz. limited annual flexibility grazing regime - annual variation +/- 20% subject to a +/- 40% absolute limit. As for the previous scenario, the breeders in a paddock due for spelling are sent on agistment to another property at a distance of 100 km for the duration of the spell.

Projected breeder numbers for the four stocking rate strategies are presented in Figure 66.

Despite the projected increase in carrying capacity (Figure 66), the two-year spelling requirement and the penalty of agisting the breeders off the property for the spelling duration has rendered the spelling strategy marginally less profitable than the nil spelling strategy (Table 10).
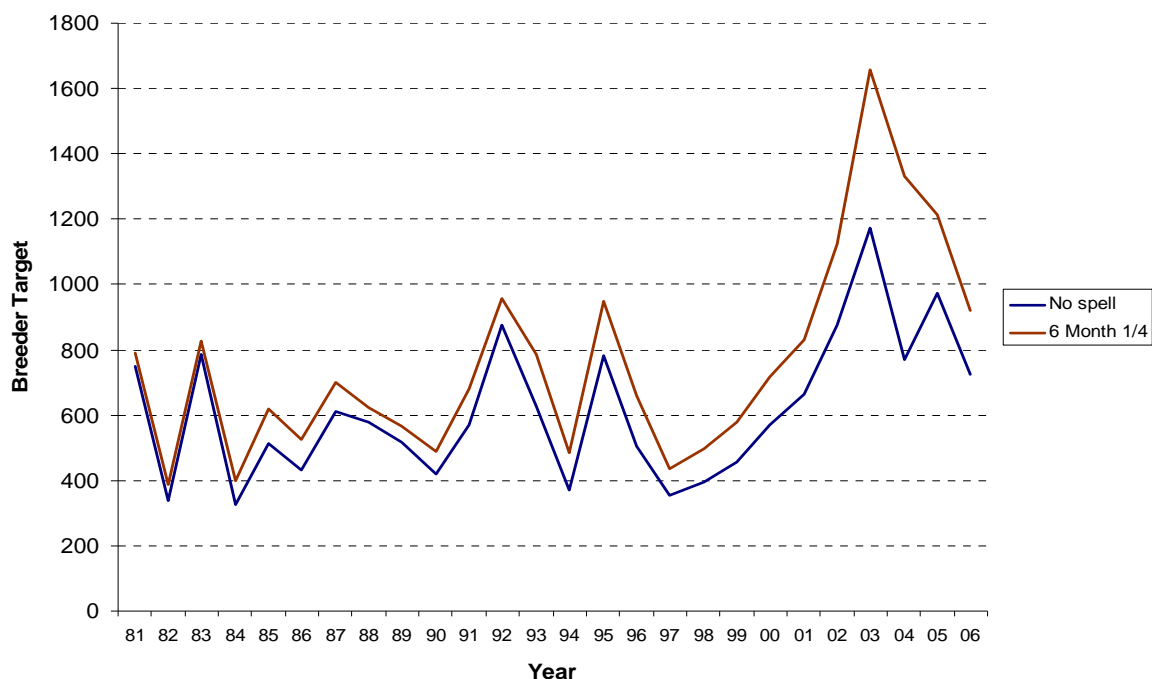
Figure 66. Target breeder numbers under nil and 6-month wet season spell and current practice stocking strategy – Mitchell grasslands.

The number of breeders carried follows a generally similar pattern to that for the same limited flexibility stocking rate strategy that was employed in Scenario 1 - although not exactly the same because the eight paddocks in this simulation have a different assumed starting condition for these two respective scenarios. For this fourth scenario, once the wet season spelling rotation becomes established across the four paddocks, there is an increasing (and positive) divergence between the projected breeder numbers for the nil spell and spelling strategies.
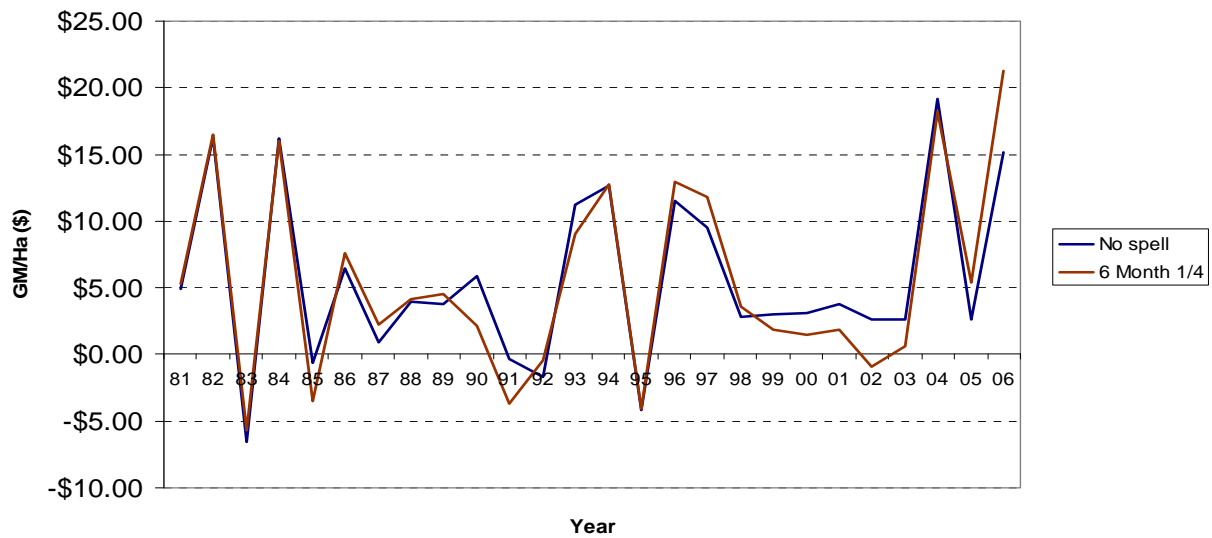
Figure 67. Projected GM/Ha under nil and 6-month wet season spell and one stocking rate strategy – Mitchell grasslands.

The projected gross margin per hectare for the simulation is presented in Figure 67 with the results summarised in Table 10.

**Table 10.** Average, minimum, and maximum values of GM/Ha under nil and 6-month wet season spell and one stocking rate strategy – Mitchell grasslands.

	No spell	6-month 1/4
Average	$5.57	$5.42
Minimum	-$6.56	-$5.70
Maximum	$19.15	$21.25
Years -ve	5	6

The relatively low average value of gross margin/ha for the nil spelling strategy relative to that for the same stocking rate regime in Scenario 1 is a consequence of the different assumed starting states of the eight breeder paddocks between the two scenarios and the fact that the four paddocks targeted for treatment under this fourth scenario continue to deteriorate under the nil spelling option.

Conclusion.
For the Western Queensland Mitchell grasslands case study, a range of grazing and land management options have been reviewed. For the particular seasonal sequence that was experienced between 1980-81 to 2005-06, stocking rate strategies that involved considerable flexibility in varying stock numbers between seasons were generally more profitable on average than more restrictive or fixed stocking rate strategies. These more flexible strategies also involved higher risks of being caught with excessive numbers of animals and the need to rapidly adjust them to meet changing seasonal circumstances. Wet season spelling strategies show promise, especially for strategies that do not require high spelling frequencies and for which the proportion of paddocks that urgently require treatment is not high. The spelling strategies explored here assumed that stock in treated paddocks would be agisted elsewhere off the property for the duration of the spell. If it were possible to redistribute the stock to other parts of the property and avoid the agistment penalties, then the economic potential of the spelling strategy would invariably improve. Nevertheless, caution is required to prevent the redistribution of stock causing excessive numbers to be held in other paddocks during the critical wet season,

and leading to serious longer term damage to the recipient paddocks. This particular issue was not explored for this region (see Fitzroy Region).

4.2.2 Woodlands of the Burdekin Catchment - Pajingo.

The Burdekin case study enterprise is 24,000 ha and assumed to be located in the Desert Uplands region approximately 330 km from Townsville. Pajingo was the rainfall location used for simulations. The enterprise centres on a breeding cattle herd producing weaner steers that are sent to agistment located 120 km distant and sold for live export. The breeding herd is run in eight paddocks all, or a subset, of which form the basis of the different herd and land resource management strategies that are explored.

Scenario1 - Fixed versus flexible stocking rates.
The first scenario examines the effect of employing fixed or flexible stocking rate strategies. As was the case for the Western Queensland Mitchell grasslands case study, four strategies are considered including: (a) fixed stocking - set on the basis of safe carrying capacity, (b) limited annual flexibility - +/- 20% annual variation subject to +/- 40% total limit (local current practice), (c) high flexibility - +/- 50% annual variation subject to +/- 90% total limit, and (d) fully responsive - varied without limit to utilise 25-30% of the end of season standing dry mater.

Each of the eight breeder paddocks commence the simulation in the condition (variable) specified at the initial workshop held in Charters Towers. One divergence from the assumptions that were employed for the West Queensland case study is that paddocks are destocked and the animals agisted off-property if the end of wet season dry matter is less than 250 kg/ha. This change was necessary as the low rainfall years in mid-90s led to long-term poor pasture condition at all but the lowest stocking rates, if destocking was not undertaken and had adverse long-term impacts that masked the treatment effects we were studying. Projected breeder numbers for the four stocking rate strategies are presented in Figure 68.
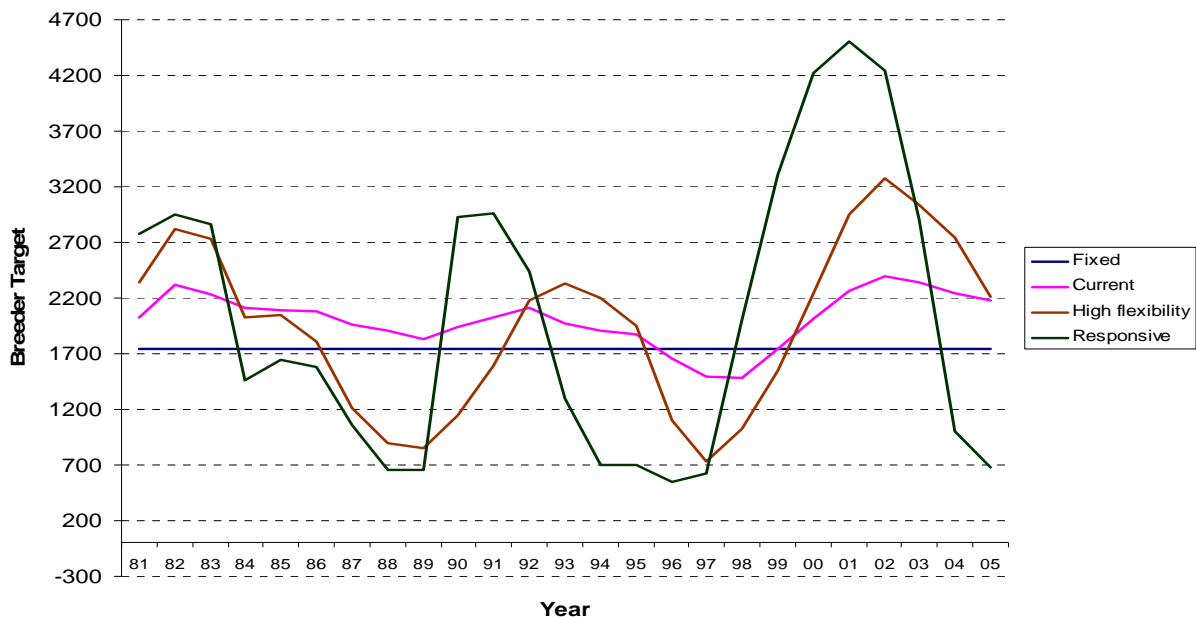
Figure 68. Target breeder numbers under four stocking rate strategies - Burdekin.

Despite the considerable year-to-year variation in the target numbers under the three flexible stocking rate strategies, there is a slight trend to increase breeder numbers over time. This occurred although poor seasonal conditions experienced in the mid-80s and again in the mid-90s required significant downward adjustments in stock numbers, which were more easily achieved by the more flexible stocking rate strategies.

The projected gross margin per hectare for the simulation is presented in Figure 69 with the results summarised in Table 11.
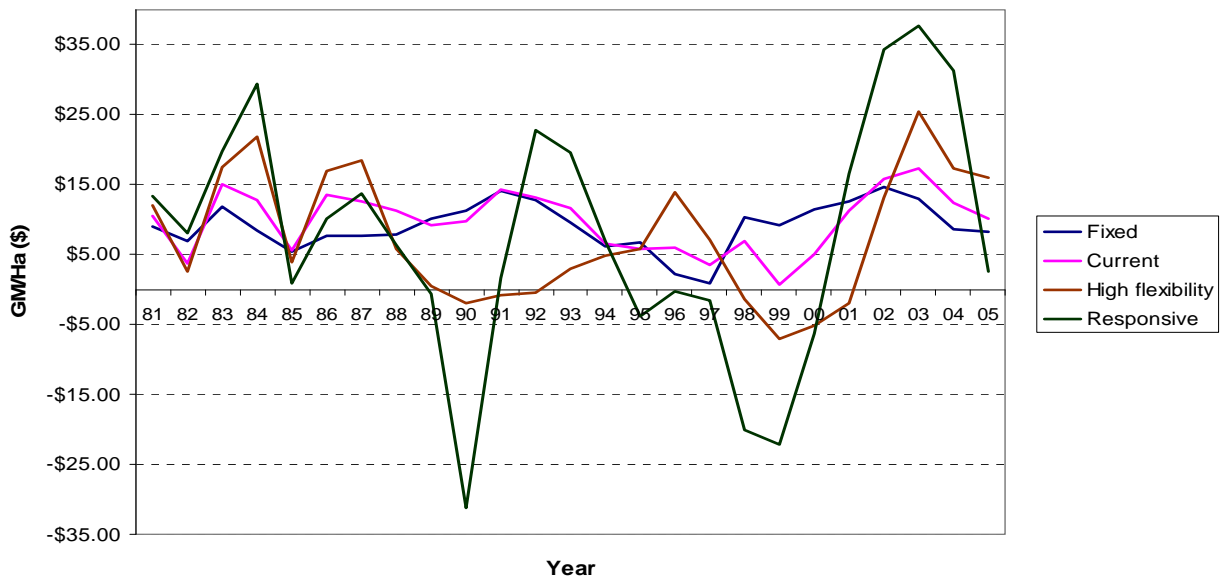
Figure 69. Projected GM/Ha under four stocking rate strategies - Burdekin.

The projected annual profitability of the four strategies as applied to the Burdekin Woodlands case study and as illustrated by the gross margin/ha is clearly influenced by the particular stocking rate adjustment strategy that is employed. The largest variation between years is clearly shown for the completely responsive strategy, with the least variation obviously applying to the fixed stocking rate strategy.

Table 11. Average, minimum, and maximum values of GM/Ha for four stocking rate strategies - Burdekin.

	Fixed	Current	High flexibility	Responsive
Average	$9.06	$9.79	$7.50	$7.58
Minimum	$0.88	$0.63	-$7.03	-$31.14
Maximum	$4.66	$17.30	$25.45	$37.82
Years - negative	0	0	7	8

For the climatic sequence applying from 1980-81 to 2004-05, the average gross margin/ha was positive for each of the four stocking rate strategies. The limited ability to alter stock numbers to exploit projected increases in forage availability and to reduce numbers when conditions deteriorated gave the limited flexibility strategy a small advantage over the fixed stocking strategy. While the two most flexible stocking strategies offered some opportunities to exploit favourable seasonal conditions reflected in the increasing maximum values for gross margin/ha, they also substantially increased the risk of incurring negative returns giving lower average outcomes for the simulation period than either of the fixed or limited variability stocking strategies. This was apparently due to the adverse impacts of poor years following good years.

Scenario 2 - Whole wet season rest - half breeder paddocks in poor condition and increasing stocking rate.
The second scenario assumes that of the eight breeder paddocks, four paddocks are in good condition and do not warrant spelling. The remaining four paddocks are subject to a 6-month seasonal spelling regime each 4th year through a sequential 1 in 4 year spelling rotation. There are five strategies simulated for this scenario - (a) nil spelling applied - essentially a baseline with a fixed stocking rate based on estimated safe carrying capacity, (b) spelling plus a fixed stocking rate, and (c) through (e) which are spelling and a flexible stocking rate applied each year within

+/-5%, 10% and 20% annual limits respectively and total limits of +/-10%, 20% and 40% respectively for the duration of each simulation.

Projected target breeder numbers for the nil spell and various 6-month spelling and fixed or flexible stocking rate strategies are presented in Figure 70.

The projected target breeder numbers necessarily follow a similar pattern across the simulation period to those for the fixed and limited variability strategies considered in Scenario 1. However, the different assumptions concerning the respective starting conditions of the eight breeder paddocks, with the four non-spelled paddocks all being in good condition, has raised the overall target levels for the present strategies. The main impact of the flexible stocking strategies has been to allow greater downward flexibility in numbers in response to the relatively poor seasonal conditions in the mid-80s and mid-90s, exacerbated to some extent by further pasture decline in response to increased stock numbers overshooting longer-term capacity associated with the most flexible stocking rate strategy.

The projected annual gross margins per hectare for the simulation is presented in Figure 71 with the results summarised in Table 12.

The spelling strategy offers an increase in gross margin/ha over the fixed baseline, but only for the fixed stocking rate strategy. Reduced flexibility under these circumstances associated with the 5% and 10% limits on annual variation does improve the overall performance of these strategies (Table 12), but not enough to exceed the more conservative set-stocked strategy. The divergence between these results and those for Scenario 1 is again attributed to the differential starting conditions for the eight breeder paddocks that have been applied to the two scenarios.
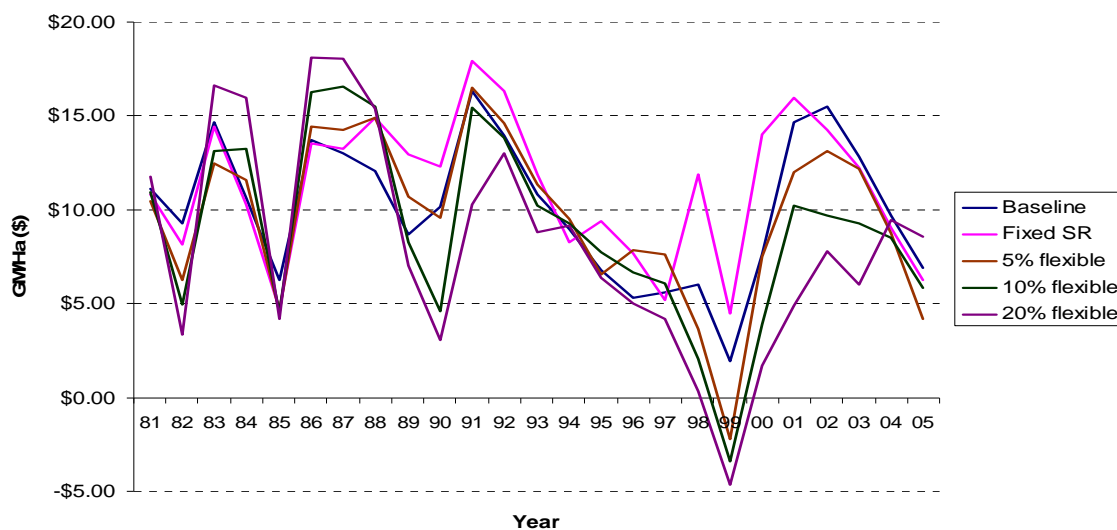
Figure 70. Target breeder numbers under nil and 6-month wet season spell and four stocking rate strategies - Burdekin.
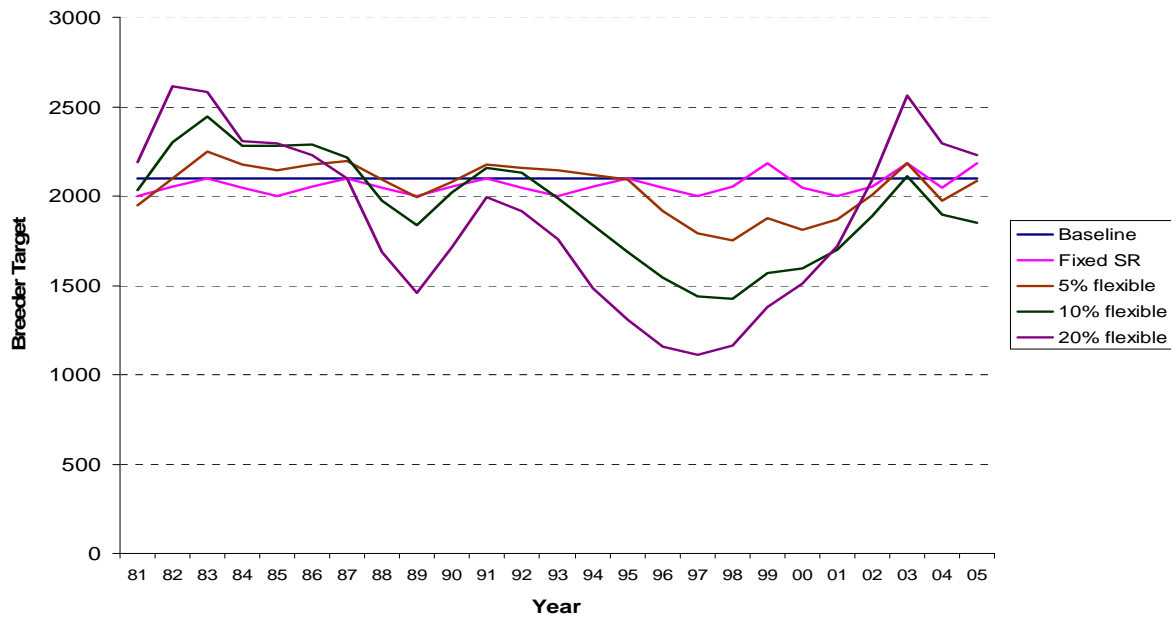
Figure 71. Projected GM/Ha under nil spelling and spelling with four fixed and variable stocking rate strategies - Burdekin.

Table 12. Average, minimum, and maximum values of GM/Ha under nil spelling and spelling with four fixed and variable stocking rate strategies - Burdekin.

	Baseline	Fixed SR	5% flexible	10% flexible	20% flexible
Average	$10.10	$11.20	$9.69	$8.94	$8.28
Minimum	$1.92	$4.45	-$2.21	-$3.41	-$4.67
Maximum	$16.36	$17.91	$16.50	$16.57	$18.11
Years -ve	0	0	1	1	1

Scenario 3 - Prescribed fire with breeder paddocks in good and/ or poor condition.
The third scenario is essentially comprised of two sub-scenarios involving the use of fire to control woody regrowth in a sub-set of four of the eight breeder paddocks.

The first sub-scenario assumes that all eight paddocks are in good condition, but under the present grazing regime, four paddocks will exhibit some degree of deterioration through excess woody regrowth. A comparison is made of (a) nil burning, and (b) burning, both cases including a fixed stocking rate strategy.

The second sub-scenario assumes that four of the eight breeder paddocks are in poor condition and will further deteriorate without effective control of the regrowth. A comparison is made of (a) nil burning, and four alternative burning and stocking rate strategies including (b) burn + fixed stocking rate, (c) burn + variable stocking rate subject to +/- 5% annual change and 10% total limit, and (d) burn + variable stocking rate subject to +/-10% annual change and 20% total limit. These sub-scenarios are examined separately in the following sub-sections.

3.1 Nil burn cf. burn, four paddocks in good condition.

Projected target breeder numbers for the nil burn and burn and fixed stocking rate strategies applied to 4 good condition paddocks are presented in Figure 72.

Figure 72. Target breeder numbers under nil burn and burn strategies applied to four good condition paddocks - Burdekin.

The target breeder numbers are held constant across the simulation period for both strategies with a modest reduction for the burning strategy due to the way the burning regime was set up in the model. It is assumed that the stock are temporarily removed from a paddock prior to burning and returned soon after with no significant grazing impact on the paddocks to which they are relocated.

The projected gross margin per hectare for the simulation is presented in Figure 73 with the results summarised in Table 13.

The annual gross margin/ha for the burn strategy lags the nil burn strategy for most of the first half of the simulation period - presumably as a result of the limited impact that the timber is initially having on the pastures given the good condition of the paddocks and because the poor seasonal conditions in the mid-80s and fixed stocking rates would have reduced the effectiveness of the burning treatment. In the second half of the simulation period, the burn strategy generates higher annual gross margin/ha in the majority of years. Overall, the economic value of the burning strategy when the treatment paddocks are already in good condition is quite limited, offering only a marginal increase in average gross margin/ha over the nil burning strategy (Table 13).

Figure 73. Projected GM/Ha under nil burn and burn strategies applied to four good condition paddocks - Burdekin.

Table 13. Average, minimum, and maximum values of GM/Ha under nil burn and burn strategies applied to four good condition paddocks - Burdekin.

	Nil burn + fixed SR	Burn + fixed SR
Average	$11.71	$11.78
Minimum	$4.30	$4.84
Maximum	$17.33	$16.33
Years - negative	0	0

3.2 Nil burn versus burn, four paddocks in poor condition.

Projected target breeder numbers for the nil burn and burn/stocking rate strategies applied to four poor condition paddocks are presented in Figure 74.
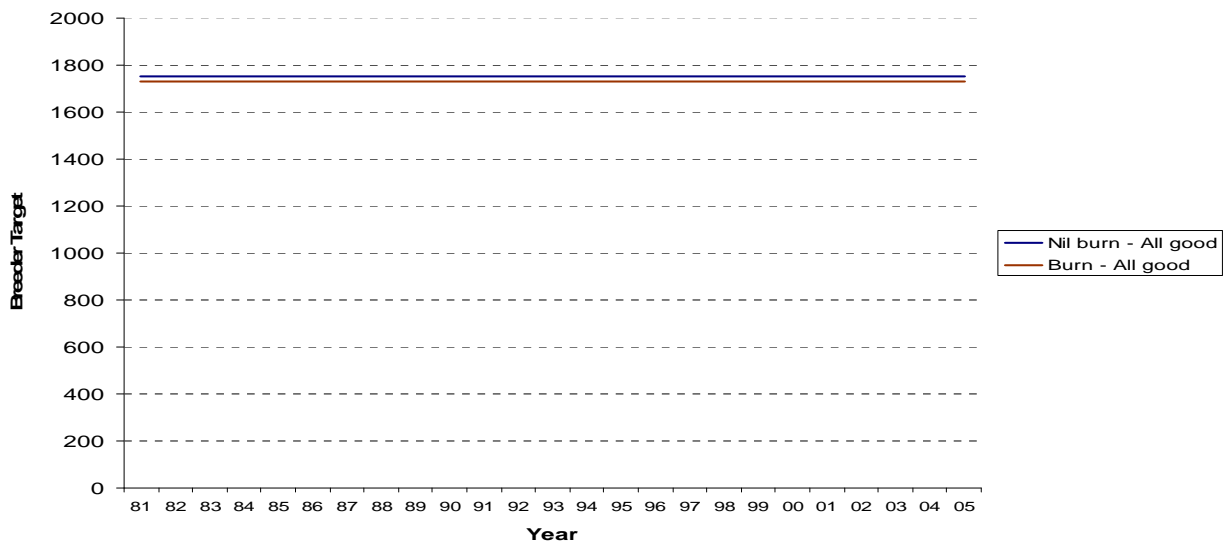
The target breeder numbers are held constant across the simulation period for the nil burn and burn strategies with fixed stocking rate regimes. The burning strategies accompanied by variable stocking rates follow quite different trajectories with the +/- 20% annual variation strategy significantly increasing annual breeder targets in the initial five years of the simulation run before reaching a plateau and declining sharply in the 90s.

The projected annual gross margins per hectare for the simulation is presented in Figure 75 with the results summarised in Table 14.

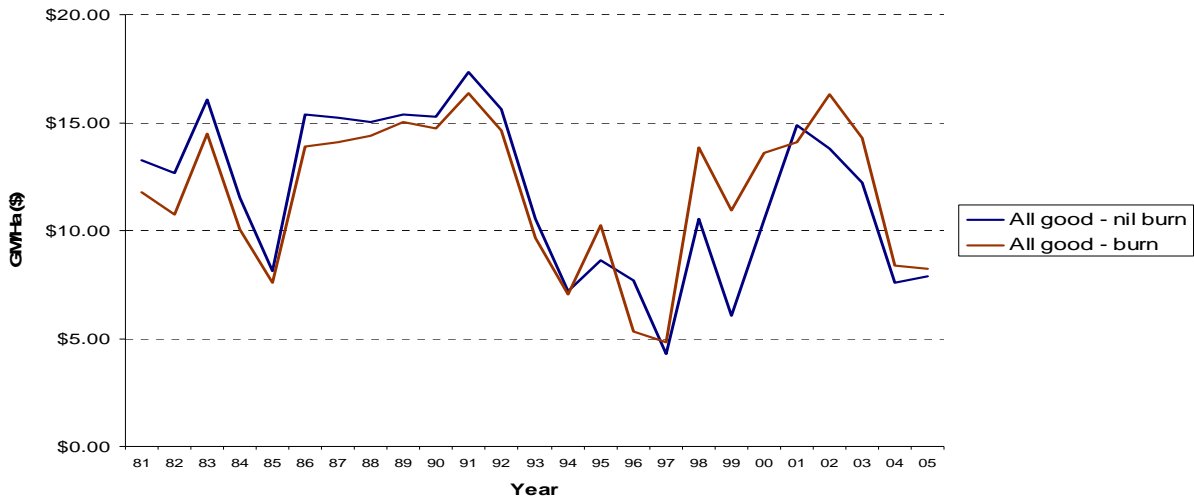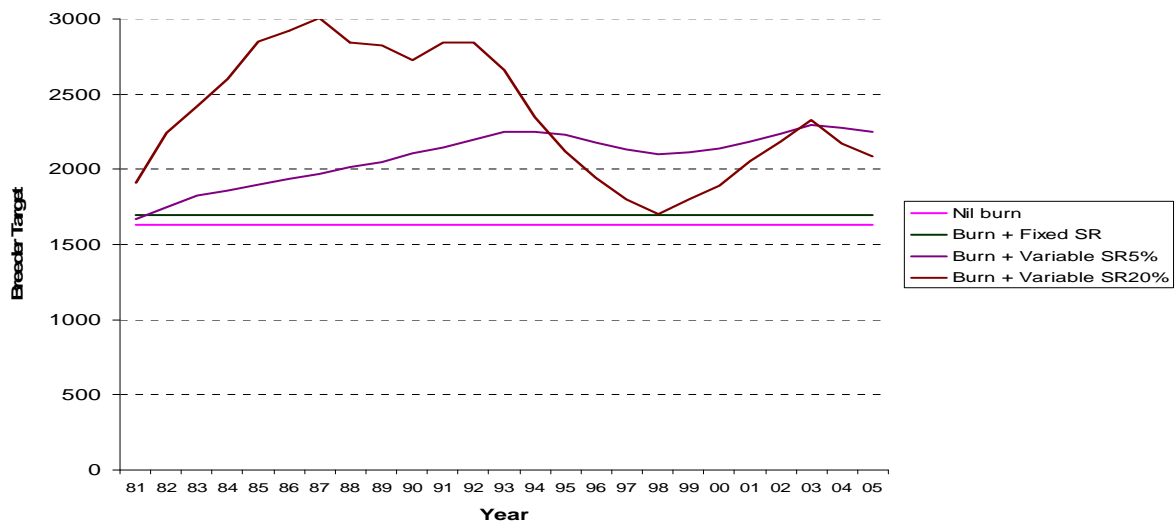**Figure 74.** Target breeder numbers under nil burn and burn strategies applied to four poor condition paddocks - Burdekin.
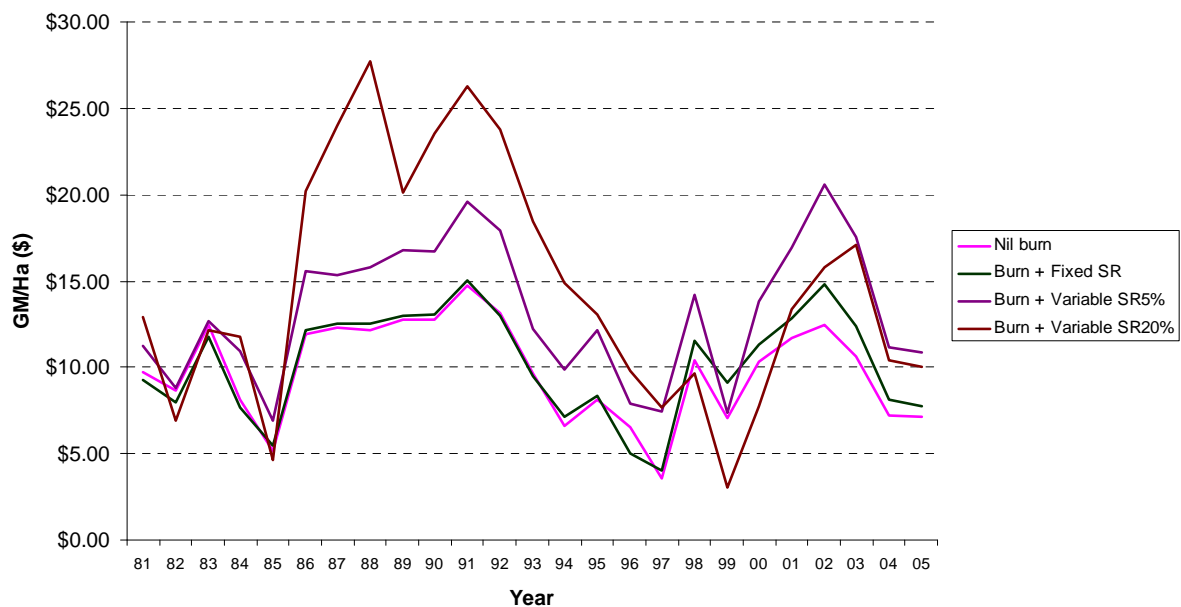
Figure 75. Projected GM/Ha under nil burn and burn strategies applied to four poor condition paddocks - Burdekin.

The annual gross margin/ha for each burn strategy and stocking rate regime generally tracks the nil burn strategy for the first seven years of the simulation period. Beyond that period each of the burn and stocking rate strategies yield a higher annual gross margin/ha than the nil burning strategy, with the exception of the +/- 20% annual variation of stocking rate from 1998 to 2001. Nevertheless, the variable stocking rate regimes exhibited the greatest divergence from the nil burning strategy, especially from the mid 1980s through to the late 1990s. On average, the economic value of the burning strategy exceeds that of taking nil action for all of the stocking rate regimes, although the difference is greatest when variable stocking rate regime are applied to take advantage of improving pasture conditions or to reduce grazing pressure when seasons deteriorate (Table 14). Compared to the outcome of the sub-scenario examining good initial paddock conditions (3.1), when stocking rates are fixed the average gross margin/ha for poor initial conditions is slightly less than that for the good condition sub-scenario reflecting the poorer productivity of the treated paddocks. However, the average gross margin/ha is greater than that of the good condition scenario when advantage is taken of the variable stocking rate option. This

is counter to the outcome of Scenario 1 and is best explained by the better overall initial condition of the four untreated paddocks and improvement in the treated paddocks preventing the extreme crash in stock numbers in 1998 and 1999 observed for that particular scenario.

Table 14. Average, minimum, and maximum values of GM/Ha under nil burn and burn strategies applied to four poor condition paddocks - Burdekin.

	No burn+Fixed SR	Burn+Fixed SR	Burn+Var SR5%	Burn+Var SR20%
Average	$9.81	$10.21	$13.22	$14.60
Minimum	$3.59	$4.03	$6.93	$3.03
Maximum	$14.76	$15.00	$20.58	$27.70
Years - negative	0	0	0	0

Conclusion.

A range of grazing and land management options have been reviewed for the Burdekin Woodlands case study. For the particular seasonal sequence that was experienced between 1980-81 to 2004-05, stocking rate strategies that involved considerable flexibility in varying stock numbers between seasons were generally less profitable on average than more restrictive or fixed stocking rate strategies. In the main, these more flexible strategies typically involve producers facing elevated risks of having animal numbers build up during favourable seasonal sequences and subsequently being caught with excessive numbers of animals and the need to rapidly liquidate them when adverse seasonal conditions emerge.

Wet season spelling strategies show promise, although the seasonal conditions experienced in this region over the simulation period did not favour flexibility in setting stocking rates. These strategies allowed animal numbers to build up in sequential favourable seasons that are followed by a marked deterioration in seasonal conditions in the mid 1980s and mid 1990s, requiring destocking paddocks in some years.

Prescribed fire to manage woody regrowth also prospectively offers economic advantages over the alternative option of doing nothing, although the absolute advantage is relatively modest when the paddocks targeted for treatment are already in good condition. While relative gains are greater for a context of treatment paddocks being in poor condition, for this case study the greatest advantage was reaped when some flexibility was applied to stocking rates in conjunction with burning.

4.2.3 Woodlands of the Fitzroy Catchment - Duaringa.

The Fitzroy Woodlands case study enterprise is based on an 11,500 ha property located approximately 170 km from Rockhampton and Biloela equally. Duaringa was the rainfall location used for simulations. The enterprise centres on a breeding cattle herd and is seeking to produce and finish heavy steers for the north Asian market (esp. Japan Ox). The combined breeding and fattening herd is run in 18 paddocks - of which 11 are generally used by the breeders and heifers - all or a subset of which form the basis of the different herd and land resource management strategies that are explored.

Scenario 1 - Fixed versus flexible stocking rates.
The first scenario examines the effect of employing fixed or flexible stocking rate strategies. Similar to the case for both the Western Queensland Mitchell grasslands and Burdekin Woodlands case studies, four strategies are considered, including: (a) fixed stocking - set on the basis of safe carrying capacity, (b) limited annual flexibility - +/- 20% annual variation subject to +/- 40% total limit, (c) high flexibility - +/- 40% annual variation subject to +/- 80% total limit, and (d) fully responsive - varied without limit to utilise 25-30% of the end of season standing dry mater. The second strategy (+/-20%, 40% limit) has been suggested as approximating local practice, and the actual limits attached to the third strategy differ slightly from those used for Western Queensland Mitchell grasslands and the Burdekin Woodlands (i.e. +/- 50% annual, 90%

absolute). Each of the 18 paddocks commences the simulation in the condition (variable) that was specified at the initial workshop that was held in Emerald.

Projected breeder numbers for the four stocking rate strategies are presented in Figure 76. While there is considerable year-to-year variation evident in the target numbers under the three flexible stocking rate strategies, there is no significant trend to either increasing or decreasing breeder numbers over time. Extremely poor seasonal conditions were experienced in the region during the mid-90s and again to a lesser extent in 2002-03, resulting in significant downward adjustments in stock numbers which was possible to a greater or lesser extent only under the more flexible stocking rate strategies.

In Figure 76, the target numbers for the current flexibility decreased by much more than the 40% maximum decrease imposed within the GRASP modelling. This is partly because the LWG values in the mid 1990s are low, and that produced low branding rates and high mortality rates, resulting in the inability of the herd (as modelled in ENTERPRISE) to reach the numbers used in GRASP. This is a good example of the need to dynamically link GRASP and ENTERPRISE, particularly for extreme situations. In the majority of situations this 'disconnect' is minimal and can be ignored.
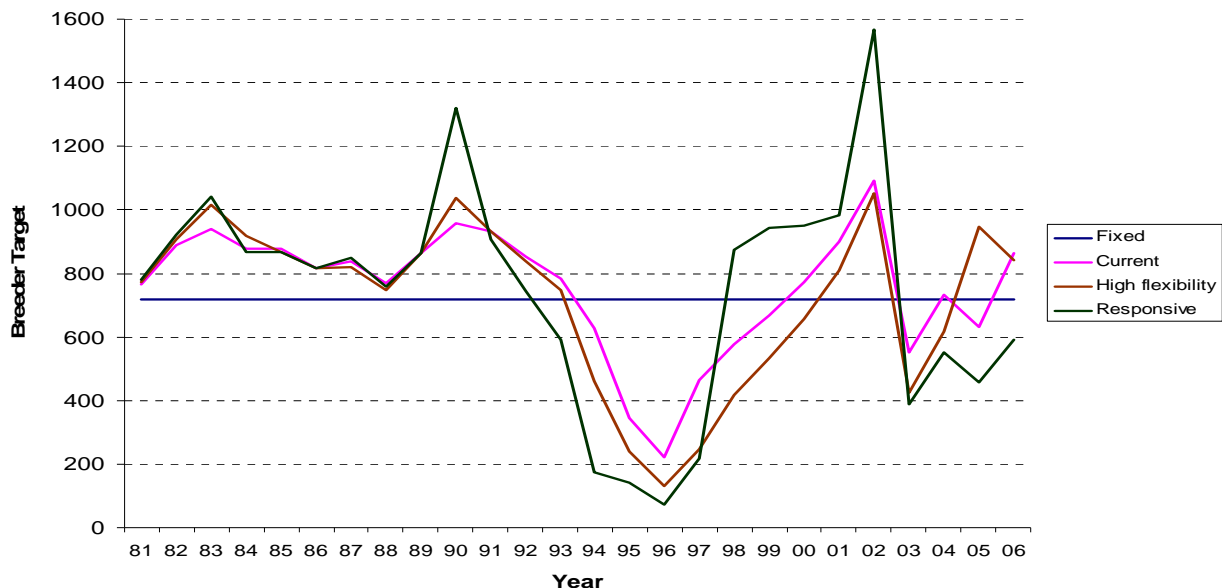
Figure 76. Target breeder numbers under four stocking rate strategies - Fitzroy.

The projected annual gross margins per hectare for the simulation is presented in Figure 77 with the results summarised in Table 15.

The annual profitability of the four strategies as applied to the Fitzroy Woodlands case study and as illustrated by the gross margin/ha is clearly influenced by the particular stocking rate strategy that has been employed. For the first half of the simulation period, the largest annual variation in gross margin/ha is associated with the completely responsive strategy, while the least variation applies to the fixed stocking rate strategy. This ranking of variability changes in the second half of the simulation period where, after all of the strategies experience a significant decline in gross margin/ha after 1992-93, the fixed stocking rate strategy shows a greater level of variation than the flexible stocking rate strategies - in particular the totally responsive strategy which essentially collapsed following a rapid build up of stock numbers in the early 1990s before seasonal conditions worsened after 1992-93 and thresholds for largely irreversible pasture damage were exceeded.
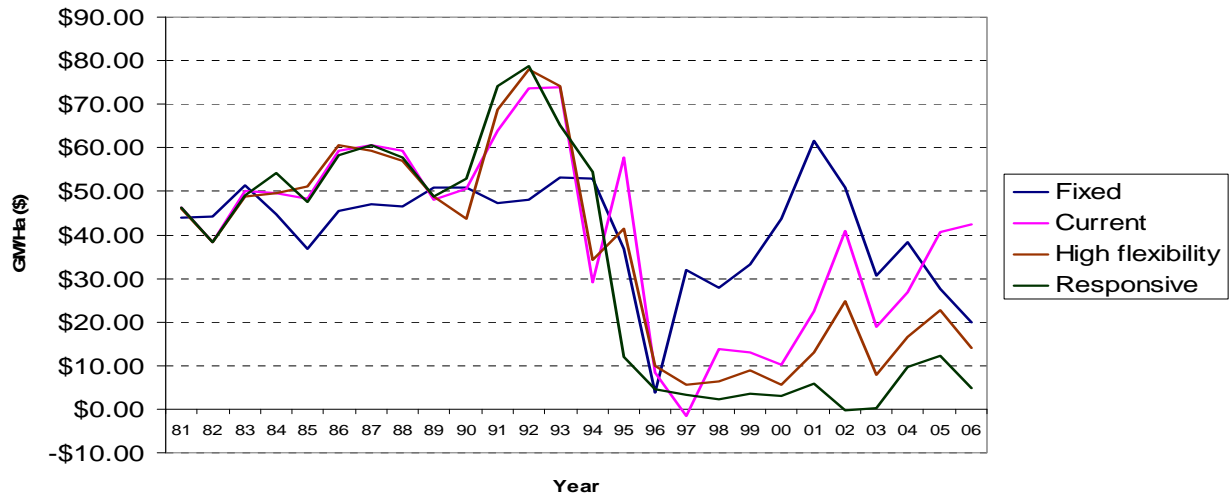
Figure 77. Projected annual GM/Ha under four stocking rate strategies- Fitzroy.

Table 15. Average, minimum, and maximum values of GM/Ha for four stocking rate strategies- Fitzroy.

	Fixed	Baseline	High flexibility	Responsive
Average	$41.15	$40.20	$35.98	$32.60
Minimum	$3.94	-$1.49	$5.68	-$0.19
Maximum	$61.65	$73.88	$77.96	$78.71
Years -ve	0	1	0	1

Largely as a result of the sharp decline in gross margin/ha after 1992-93 and subsequent failure to return to former levels, the average gross margin/ha of each of the flexible stocking rate strategies is lower than that for the fixed stocking rate strategy. This is similar to the scenario for the Burdekin Woodlands case study and counter to the outcome for the Western Queensland Mitchell grasslands case study. It highlights the interaction between stocking rate regimes and specific climatic sequences in influencing pasture condition and subsequent carrying capacity and productivity of grazing enterprises. This needs further investigation.

Scenario 2 – Whole-of- wet season resting four of 11 breeder paddocks that are in poor (C) condition, remaining paddocks in mixed condition.
The second scenario assumes that seven of the 11 breeder paddocks on the property are in mixed condition as defined at the initial workshop in Emerald, but the remaining four breeder paddocks are defined to be in poor (C) condition. Results are compared between two management strategies - (a) nil spelling and (b) spelling for 6 months within a 1 year spell in 4 year rotation. There is only one grazing strategy employed for this scenario - viz. limited annual flexibility grazing regime - annual variation +/- 20% subject to a +/- 40% absolute limit. The scenario assumes that the breeders that would normally be carried in a given paddock that is due to be rested as part of the rotation are held on agistment for 26 weeks at another property located at a distance of 100 km from the model property, which are subsequently returned to the treated paddock. In this way, the main impact of the spelling regime is on operating expenses with total stock numbers varying according to projected changes (if any) in subsequent productivity of the spelled paddocks. The pasture condition in the four paddocks targeted for treatment will remain poor or deteriorate in the absence of spelling at the stocking rates used.

Projected breeder numbers for the nil spelling and spelling strategies are presented in Figure 78. The number of breeders carried follows a generally similar pattern to that for the same limited flexibility stocking rate strategy that was employed in Scenario 1 - although not exactly the same because the four breeder paddocks in the spelling regime have a different assumed starting

condition for these two respective scenarios. For this spelling scenario, once the wet season spelling rotation became established across the four paddocks, there was an increasing (and positive) divergence between the projected breeder numbers for the nil spell and spelling strategies for most of the remaining years in the simulation period. The poor seasonal conditions experienced in the mid-1990s have had a marked impact on projected carrying capacity for both the nil spelling and spelling strategies.
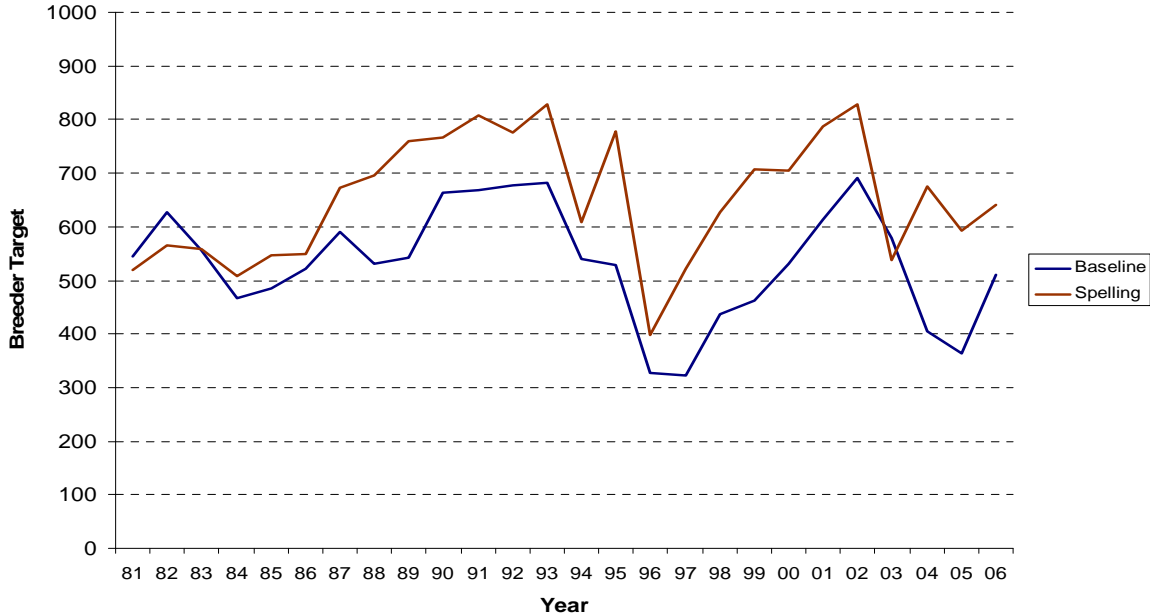

Figure 78. Target breeder numbers under nil and 6-month wet season spell (scenario s2) and one stocking rate strategy- Fitzroy.
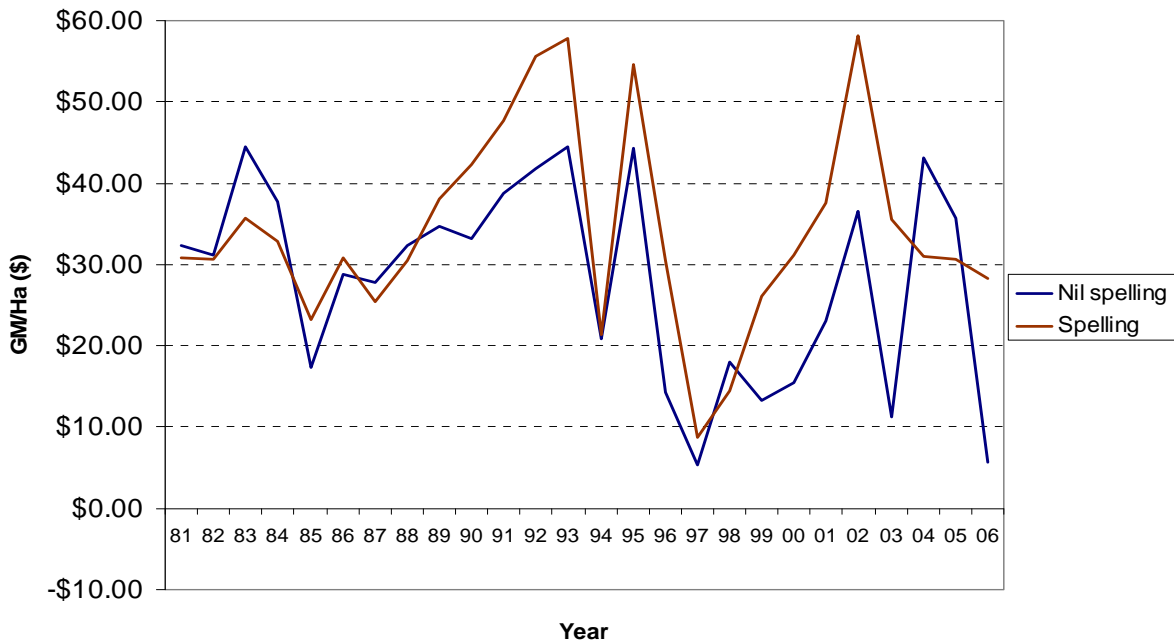

Figure 79. Projected GM/Ha under nil and 6-month wet season spell (scenario 2) and one stocking rate strategy- Fitzroy.

The projected annual gross margins per hectare for the simulation is presented in Figure 79 with the results summarised in Table 16.

The carrying capacity increased over most of the simulation period (Figure 78), despite the decline of the mid 1990s. Despite the penalty of agisting the breeders off the property for the spelling duration, the spelling strategy showed improved profitability over the nil spelling strategy (Table 16).

Table 16. Average, minimum, and maximum values of GM/Ha under nil and 6-month wet season spell (scenario 2) and one stocking rate strategy- Fitzroy.

	Baseline	Spelling
Average	$28.16	$34.22
Minimum	$5.27	$8.70
Maximum	$44.56	$58.13
Years - negative	0	0

Scenario 3 - Whole of wet season resting four of 11 breeder paddocks which are in poor (C) condition, remaining paddocks in good (A/B) condition.
The third scenario assumes that seven of the 11 breeder paddocks on the property are in good (A/B) condition and four breeder paddocks are defined to be in poor (C) condition. Results are compared between two management strategies - (a) nil spelling and (b) spelling for six months within a 1 year spell in 4 year rotation. There is only one grazing strategy employed for this scenario - viz. limited annual flexibility grazing regime - annual variation +/- 20% subject to a +/- 40% absolute limit. The scenario, like Scenario 2, assumes that the breeders that would normally be carried in a given paddock that is due to be rested as part of the rotation are held on agistment for 26 weeks at another property located at a distance of 100 km from the model property and subsequently returned to the treated paddock. In this way, the main impact of the spelling regime is on operating expenses with total stock numbers varying according to projected changes (if any) in subsequent productivity of the spelled paddocks. The paddock condition in the four paddocks targeted for treatment will remain poor or deteriorate in the absence of spelling at the stocking rate used.
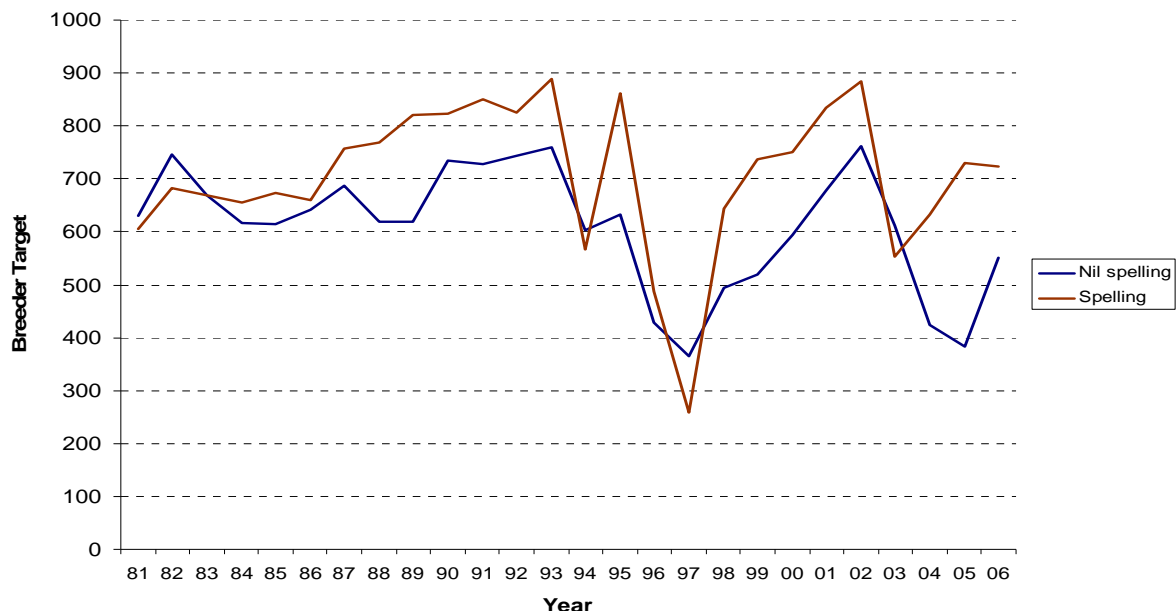

Figure 80. Target breeder numbers under nil and 6-month wet season spell (scenario 3) and one stocking rate strategy- Fitzroy.

Projected breeder numbers for the nil spelling and spelling strategies are presented in Figure 80. For this third scenario, once the wet season spelling rotation becomes established across the four paddocks, there is also an increasing (and positive) divergence between the projected breeder numbers for the nil spell and spelling strategies for most of the remaining years in the simulation period. As for the second scenario, the poor seasonal conditions experienced in the mid-1990s have had a marked impact on projected carrying capacity for both the nil spelling and spelling strategies.

The projected annual gross margins per hectare for the simulation is presented in Figure 81 with the results summarised in Table 17.
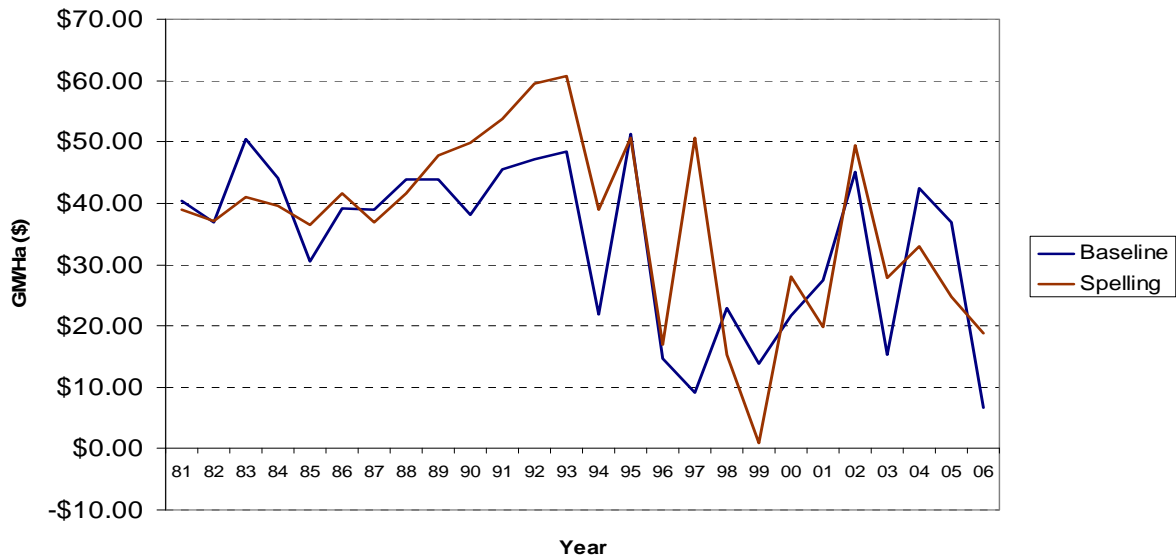
Figure 81. Projected annual GM/Ha under nil and 6-month wet season spell (scenario 3) and one stocking rate strategy- Fitzroy.

The projected increase in carrying capacity (Figure 80) over most of the simulation period, (despite the substantial decline of the mid 1990s) and the penalty of agisting the breeders off the property for the spelling duration, has increased the profitability of the spelling strategy over the nil spelling strategy (Table 17). In this case, where the seven breeder paddocks that were not subject to spelling were assumed to all be in good rather than mixed condition, the average gross margin/ha for both strategies was naturally higher than for the previous scenario in which the paddock condition varied. Moreover, while there is a gain from spelling the poor condition paddocks, the relative size of the advantage is less than that for Scenario 2.

Table 17. Average, minimum, and maximum values of GM/Ha under nil and 6-month wet season spell (scenario 3) and one stocking rate strategy- Fitzroy.

	Baseline	Spelling
Average	$33.71	$36.93
Minimum	$6.65	$0.85
Maximum	$51.38	$60.79
Years - negative	0	0

Scenario 4 - Prescribed fire on four breeder paddocks in good condition.
The fourth scenario involves the use of fire in a 1 year in 4 year sequential rotation to control woody regrowth in a sub-set of four of the eight breeder paddocks. The four target paddocks are assumed to be in good (B) condition and fire is intended to suppress woody regrowth encroachment that is likely to occur with no intervention. A comparison is made of (a) nil burning,

and (b) burning, with both strategies following a variable stocking rate regime allowing +/-20% annual change and 40% total limit. It is assumed that the stock are temporarily removed from a paddock prior to burning and returned soon after with no significant grazing impact on the paddocks to which they are relocated.

Projected target breeder numbers for the nil burn and burn strategies applied to four good condition paddocks are presented in Figure 82.
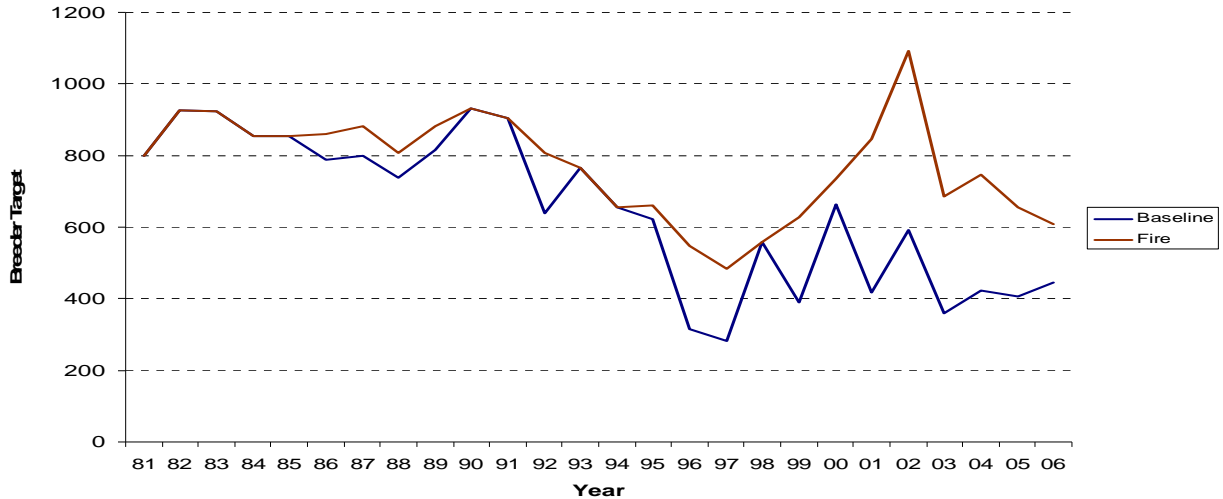
Figure 82. Target breeder numbers under nil burn and burn strategies applied to four good condition paddocks- Fitzroy.

The projected breeder numbers begin to diverge between the no burn and burning strategies once all four of the treated paddocks have been included in the rotation. The impact of the poor seasonal conditions in the mid-1990s on projected carrying capacity is evident, but numbers increase significantly during the return to more favourable seasons in the early 2000s.

The projected annual gross margins per adult equivalent for the simulation is presented in Figure 83 with the results summarised in Table 18.
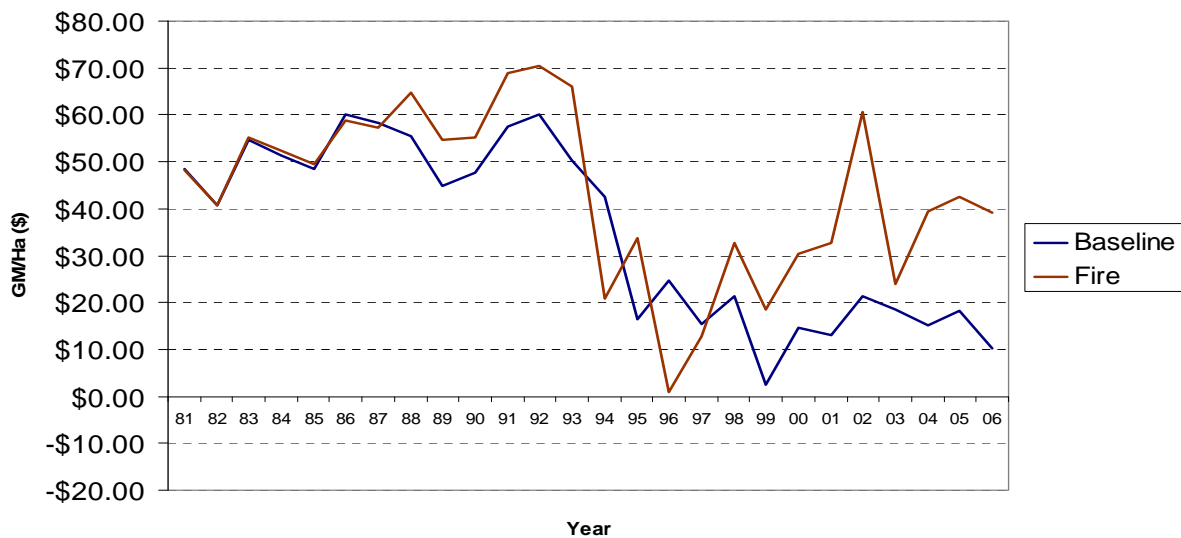
**Figure 83.** Projected GM/Ha under nil burn and burn strategies applied to four good condition paddocks- Fitzroy.

Once all of the four paddocks have entered the rotational burning sequence, the annual gross margin/ha for the burn strategy exceeds that of the nil burn strategy for most of the first half of the simulation period. While the build up of stock on both the nil burning and burning paddocks in the early 1990s required a downwards adjustment for both strategies in the mid-1990s, the burning strategy continued to outperform the nil burning strategy through the second half of the simulation period. Overall, the economic value of the burning strategy for this case study is quite positive offering an advantage in excess of 20% over the simulation period (Table 18).

Table 18. Average, minimum, and maximum values of GM/Ha under nil burn and burn strategies applied to four good condition paddocks- Fitzroy.

	Baseline	Fire
Average	$35.06	$43.48
Minimum	$2.42	$0.92
Maximum	$60.20	$70.52
Years - negative	0	0

Conclusion.
A range of grazing and land management options have been reviewed for the Fitzroy Woodlands case study. For the particular seasonal sequence that was experienced between 1980-81 to 2005-06, the various flexible stocking rate strategies - limited through to fully responsive - were generally less profitable on average than the fixed stocking rate strategy. The more flexible strategies typically involve producers facing elevated risks of having animal numbers build up during favourable seasonal sequences and subsequently being caught with excessive numbers of animals and the need to rapidly liquidate them when adverse seasonal conditions emerge, as happened in the mid 1990s. Both scenarios involving wet season spelling strategies generated higher levels of projected profitability, although the relative advantage was greater when the non-treatment paddocks are in mixed condition rather than good condition. Prescribed fire to manage woody regrowth also prospectively offers economic advantages over the alternative option of not pursuing a control strategy with the magnitude of the gain heavily influenced by the starting condition of the treated paddocks relative to the non-treated paddocks.

4.2.4 Savannas of the Victoria River District (NT).

The Victoria River District case study enterprise is 4,594 km^2 and assumed to be located at approximately 750 km from Darwin. The enterprise is comprised of a breeding herd producing steers which are sold at approximately 320 kg liveweight for live export to Asia. There are 20 paddocks of which the breeding and heifer herd is run in 16 paddocks of variable condition, all or a subset of which form the basis of the different herd and land resource management strategies that are explored. Because the absolute size of pastoral enterprises varies widely within and between regions in the Northern Territory, gross margin per adult equivalent (GM/AE) is used as the profitability metric rather than gross margin per hectare for each of the scenarios in this case study.

Scenario1 - Fixed versus flexible stocking rates.
The first scenario examines the effect of fixed or flexible stocking rate strategies. As for the other case studies, four strategies are considered including: (a) fixed stocking - set on the basis of safe carrying capacity, (b) limited annual flexibility (referred to as baseline)- +/- 10% annual variation subject to +/- 30% total limit (local current practice), (c) high flexibility - +/- 40% annual variation subject to +/- 80% total limit, and (d) fully responsive - varied without limit to utilise 5-15% of the end of season standing dry mater, depending on land type. Each of the 16 breeder and heifer paddocks commence the simulation in the condition (variable) specified at the initial workshop

held in Katherine. Projected breeder numbers for the four stocking rate strategies are presented in Figure 84.
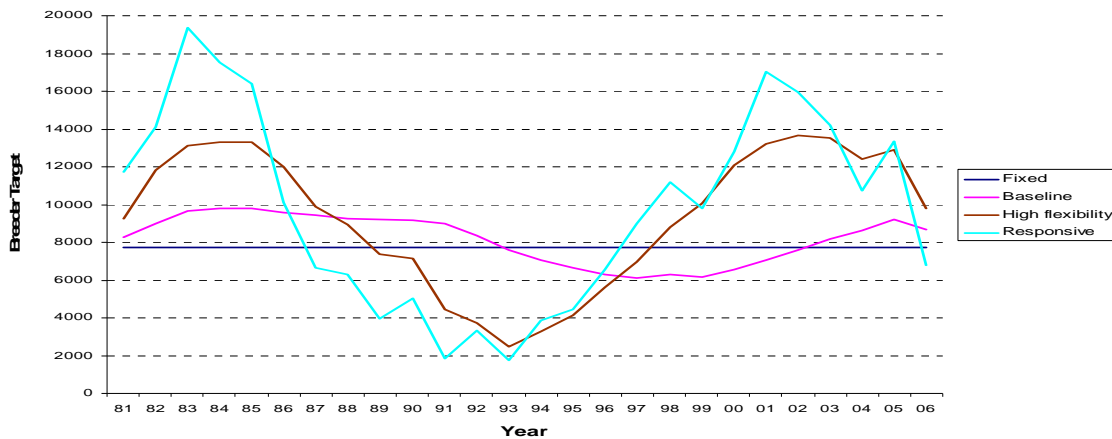
Figure 84. Target breeder numbers under four stocking rate strategies - VRD.

The simulation period for the VRD case study was characterised by relatively favourable seasonal conditions at the commencement and finishing quarters. The projected target breeder numbers reflect this seasonal pattern, with progressively greater fluctuations in stock numbers associated with the increased levels of stocking rate flexibility embodied in the baseline, high flexibility and totally responsive strategies.

The projected annual gross margins per adult equivalent for the simulation is presented in Figure 85 with the results summarised in Table 19.

The simulation reveals considerable variability in the annual gross margins per adult equivalent in the first half of the simulation period, especially associated with the more flexible stocking rate strategies (Figure 85). There is considerably less variability between the strategies in the second half of the simulation period despite the projected increase in carrying capacity (Figure 84) for the more flexible strategies. The principal reason for this lagged response of profitability to apparent carrying capacity is because the need to rapidly reduce stock numbers in the middle of the simulation period left the model enterprise with a very small core herd with limited numbers of animal classes. The model was set to not allow stock purchases to augment herd numbers in rebuilding phases, thereby requiring the herd to slowly rebuild itself from within its own structure. This was achieved largely through retaining the maximum number of available replacements, limiting dry culling and holding on to older animal classes, each of which reduced the annual availability of sale females from an already small herd. Nevertheless, the flexible stocking rate strategies remained more profitable over the whole simulation period than the fixed stocking rate strategy (Table 19).
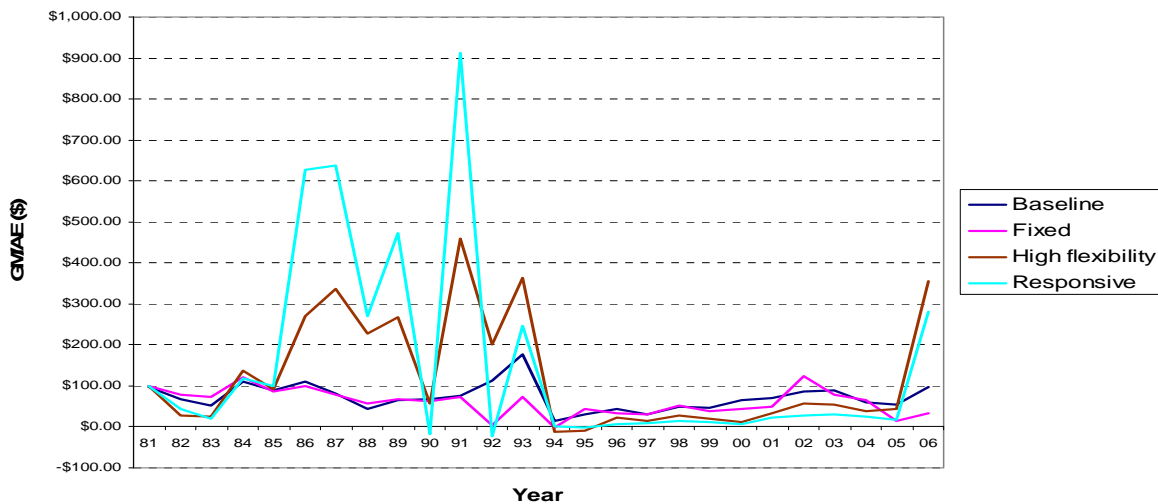
Figure 85. Projected GM/AE under four stocking rate strategies - VRD.

Table 19. Average, minimum, and maximum values of GM/AE under four stocking rate strategies - VRD.

	Fixed	Baseline/current	Fixed	High flexibility	Responsive
Average	$60.86	$72.72	$60.86	$123.84	$152.22
Minimum	-$1.37	$15.08	-$1.37	-$12.81	-$22.39
Maximum	$124.41	$177.53	$124.41	$458.94	$913.22
Years - negative	1	0	1	2	3

Scenario 2 - Whole of wet season resting four of 16 heifer and breeder paddocks which are in poor (C) condition, remaining paddocks in good (A/B) condition.
The second scenario assumes that 12 of the 16 heifer and breeder paddocks are in good (A/B) condition and four of these paddocks are in poor (C) condition. Results are compared between two management strategies - (a) nil spelling and (b) spelling for 6 months within a 1 year spell in 4 year rotation. There is only one grazing strategy employed for this scenario - viz. limited annual flexibility grazing regime - annual variation +/- 10% subject to a +/- 30% absolute limit. The scenario assumes that the animals that are normally carried in a rested paddock are agisted for 26 weeks at another property located 250 km from the property and subsequently returned to the treated paddock. The main impact of the spelling regime is on operating expenses with total stock numbers varying according to projected changes in productivity of the spelled paddocks. The paddock condition will remain poor or deteriorate without spelling at the stocking rate used.

Projected breeder numbers for the nil spelling and spelling strategies are presented in Figure 86. Once each of the four paddocks has entered the spelling rotation and the impact begins to take hold on pasture response, the projected breeder numbers begin to exceed those for the nil spelling strategy. As also occurred for the flexible stocking strategies of the first scenario, the poor seasonal conditions through the middle of the simulation period required substantial destocking under both strategies. Recovery in numbers actually carried was relatively slow.

The projected annual gross margins per adult equivalent for the simulation is presented in Figure 87 with the results summarised in Table 20.

Figure 86. Target breeder numbers for nil and 6-month wet season spell and one stocking rate strategy - VRD.
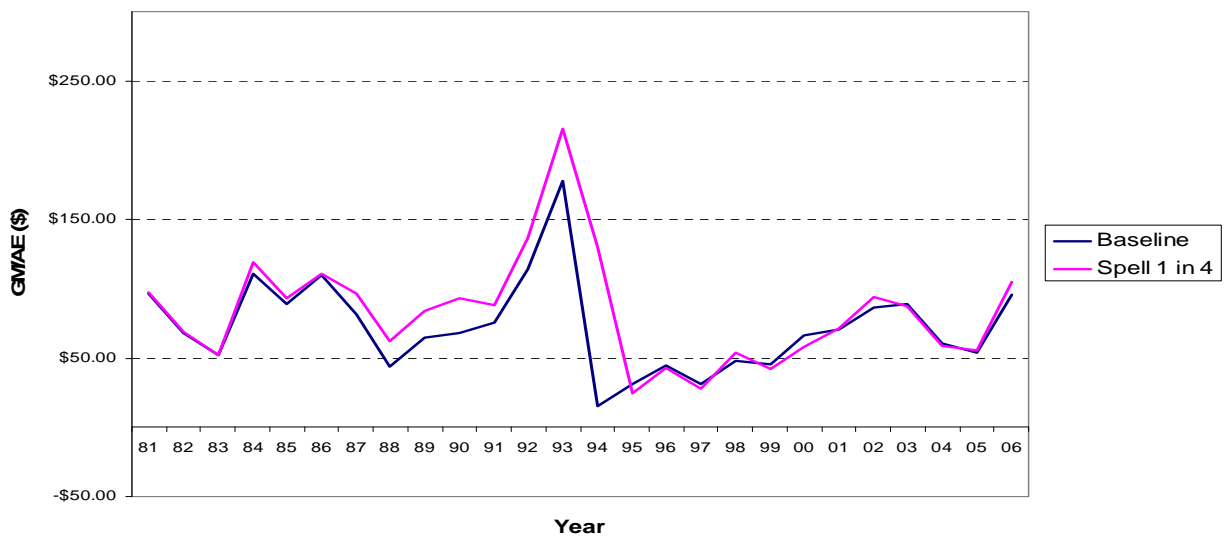
Figure 87. Projected GM/AE under nil and 6-month wet season spell and one stocking rate strategy - VRD.

The annual projected gross margin per adult equivalent generally follow the pattern of projected stock numbers (Figure 86) through the simulation period - the sharp peak observed through 1991-92 and 1993-94 resulted from a series of forced sales of breeders required to reduce stock numbers during that period. Overall, the spelling strategy was more profitable than the nil spelling strategy (Table 20) although most of the gain was a result of the improved carrying capacities from the spelling regime that occurred in the earlier stage of the simulation period.

Table 20. Average, minimum, and maximum values of GM/AE under nil and 6-month wet season spell and one stocking rate strategy - VRD.

	Baseline	Spelling
Average	$72.72	$83.34
Minimum	$15.08	$24.67
Maximum	$177.53	$215.80
Years - negative	0	0

Scenario 3 - Prescribed fire with eight breeder paddocks in poor condition and 25% or 50% of the area treated.

This third scenario assumes that eight of the 12 breeder and heifer paddocks are sufficiently poor condition due to regrowth encroachment to warrant treatment. The prescribed burning regime involves two sets of four paddocks undergoing a 1 year in 4 year rotational sequence of fire. Two separate prescribed burning strategies are examined, viz 25% and 50% respectively of the area in a treated paddock is burnt. Therefore, the strategies that are covered are (a) nil burn and (b) burn respectively 25% and 50% of the area of a treated paddock. The stocking rate regime applied for each strategy involves either the current baseline stocking strategy (+/-10% annual change, +/-30% absolute limit) or the high flexibility stocking strategy (+/- 40% annual change, +/-80% absolute limit). An assumption is made that paddock condition in the eight treatment paddocks will continue to deteriorate without burning.

Projected breeder numbers for the nil burning and 2 burning X 2 stocking rate strategies are presented in Figure 88.
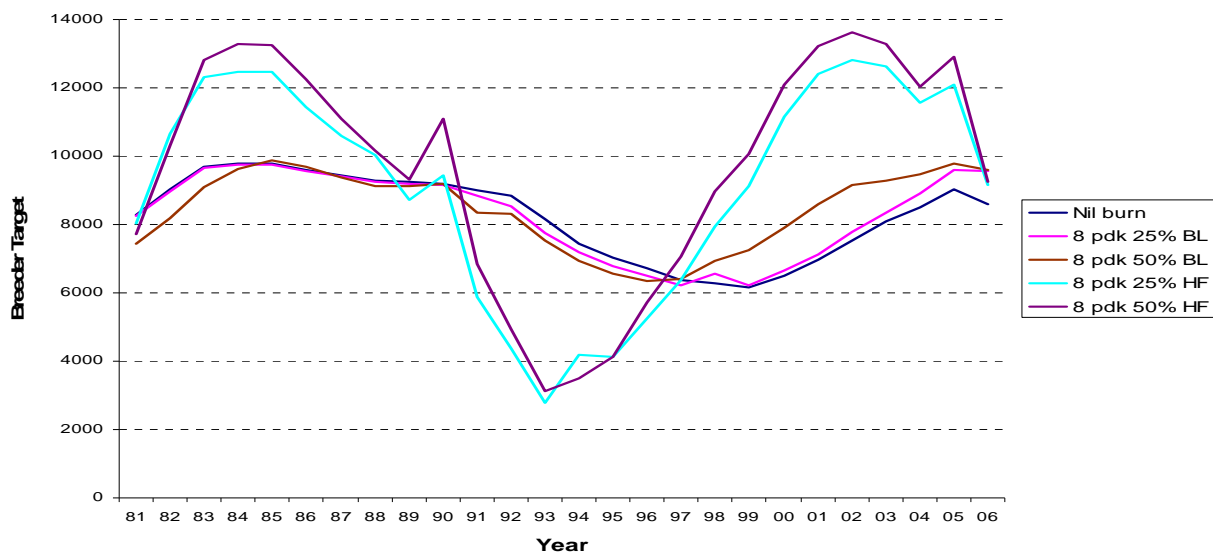
Figure 88. Target breeder numbers under nil burn and 25% or 50% burn X two stocking rate strategies - VRD.

Similar to the case for Scenario 1, the variability in projected breeder numbers is much greater for the high flexibility stocking rate strategy than for the limited flexibility (+/-10% annual, 30% absolute) strategy, with or without burning. There is a lesser difference in projected breeder numbers between the 25% and 50% burn strategies, but for both stocking rate regimes the projected divergence is naturally greater for the high flexibility stocking strategy.

The projected annual gross margins per adult equivalent for the simulation is presented in Figure 89 with the results summarised in Table 21.
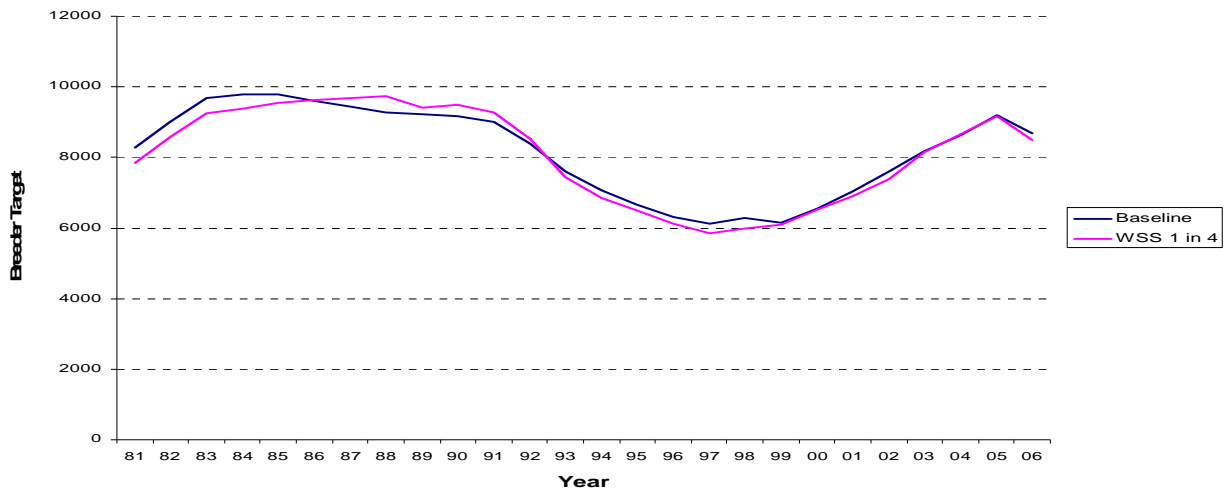
The annual projected gross margin per adult equivalent results generally follows a pattern not dissimilar to that for Scenario 2 through the simulation period. The annual average gross margin per adult equivalent is usually higher for each of the burning strategies than the nil burning strategy. There is considerably more year-to-year variation when the high flexibility stocking rate regime is applied. The sharp peak observed through 1991-92 and 1993-94 for these regimes again resulted from a series of forced sales of breeders required to reduce stock numbers during that period. Overall, the burning strategy was more profitable than the nil burning strategy (Table 21) although most of the gain occurred in the earlier stage of the simulation period. In all cases the average gross margin per adult equivalent was higher when a larger proportion (in this case 50%) of the paddock is treated. As was the case for Scenario 1, the high flexibility stocking regime also contributed to the highest average gross margin per adult equivalent.
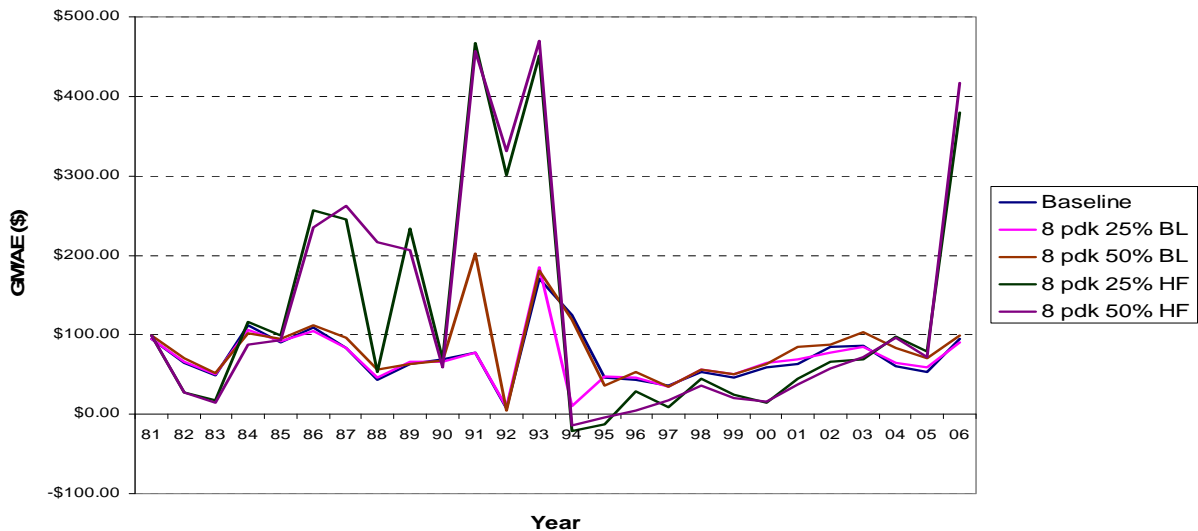
Figure 89. Projected GM/AE under nil burn and 25% or 50% burn X two stocking rate strategies - VRD.

Table 21. Average, minimum, and maximum values of GM/AE under nil burn and 25% or 50% burn X two stocking rate strategies - VRD.

	+/-10%, 30% - nil burn	+/-10%, 30% - 25% burn	+/-10%, 30% - 50% burn	+/-40%, 80% - 25% burn	+/-40%, 80% - 50% burn
Average	$72.39	$69.42	$82.43	$125.46	$130.28
Minimum	$7.45	$9.51	$5.15	-$20.64	-$14.63
Maximum	$170.45	$185.09	$202.68	$466.92	$469.57
Years - ve	5	5	4	5	4

Conclusion.

A range of grazing and land management options have been reviewed for the VRD case study. For the particular seasonal sequence that was experienced between 1980-81 to 2005-06, the various flexible stocking rate strategies - limited through to fully responsive - were generally more profitable on average than the fixed stocking rate strategy. The more flexible strategies typically involve producers facing elevated risks of having animal numbers build up during favourable seasonal sequences and subsequently being caught with excessive numbers of animals and the need to rapidly liquidate them when adverse seasonal conditions emerge, particularly as happened in the mid 1990s. The scenario involving a wet season spelling strategy generated higher levels of projected profitability, although the bulk of the gain occurred from responses in the first half of the simulation period. Prescribed burning to manage woody regrowth also prospectively offers economic advantages over the alternative option of not pursuing a control strategy, with the magnitude of the gain heavily influenced by the proportion of the targeted paddocks that are treated.

4.2.5 Mitchell grasslands of the Barkly Tablelands.

The Barkly Tableland case study enterprise is 6,000 km^2 and is comprised of a breeding herd producing steers of approximately 300 kg which are transferred for growing out on another property located at a distance of 750 km. For modelling purposes these transfers are treated as sales with an imputed value placed on the steers at point of delivery. There are 20 paddocks of

which the breeding and heifer herd is run in 14 paddocks of variable condition, all or a subset of which form the basis of the different herd and land resource management strategies that are explored. Because the absolute size of pastoral enterprises varies widely within and between regions in the Northern Territory, gross margin per adult equivalent (GM/AE) is used as the profitability metric rather than gross margin per hectare for each of the scenarios in this case study. Unlike the other case studies, this case study only examined two management strategies - fixed versus flexible stocking rate strategies and wet season spelling. There was no perceived interest in exploring the prescribed use of fire for woody regrowth control for the Barkly Tableland region.

Scenario 1 - Fixed versus flexible stocking rates.
The first scenario examines the effect of employing either fixed or flexible stocking rate strategies. As was the case for the other case studies, four strategies are considered - for this case including: (a) fixed stocking - set on the basis of safe carrying capacity, (b) limited annual flexibility - +/- 20% annual variation subject to +/- 40% total limit (local current practice), (c) high flexibility - +/- 30% annual variation subject to +/- 60% total limit, and (d) fully responsive - varied without limit to utilise 5-15% of the end of season standing dry mater, depending on land type. Each of the 14 breeder and heifer paddocks commences the simulation in the condition (variable) specified at the initial workshop held in Tennant Creek.

Projected breeder numbers for the four stocking rate strategies are presented in Figure 90.
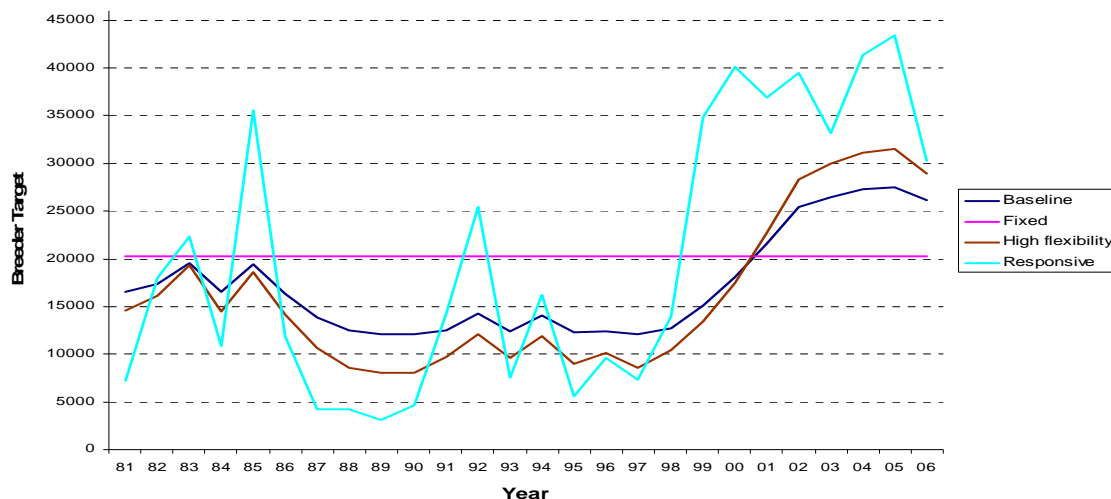
Figure 90. Target breeder numbers under four stocking rate strategies - Barkly.

The simulation period for the Barkly Tableland case study was characterised by relatively favourable seasonal conditions at the early stage and exceptionally favourable conditions again towards the end of the period. The projected target breeder numbers reflect this seasonal pattern with progressively greater fluctuations in stock numbers associated with the increased levels of stocking rate flexibility embodied in the baseline, high flexibility and totally responsive strategies. The projected annual gross margins per adult equivalent for the simulation is presented in Figure 91 with the results summarised in Table 22.

The simulation reveals considerable variability in the annual gross margin per adult equivalent measure, particularly in the first half of the simulation period for the more flexible stocking rate strategies. There is generally less variability between the various strategies in the second half of the simulation period despite the projected increase in carrying capacity (Figure 90) for the more flexible strategies. The principal reason for this lagged response of profitability to apparent carrying capacity (as for the VRD case study), is because the need to reduce stock numbers in the middle of the simulation period. This left the model property with a relatively small herd with limited numbers of animal classes thereby requiring the herd to slowly rebuild itself from within its own structure which reduced the annual availability of sale animals from an already small herd.

Nevertheless, the flexible stocking rate strategies remained more profitable over the whole simulation period than the fixed stocking rate strategy (Table 22).
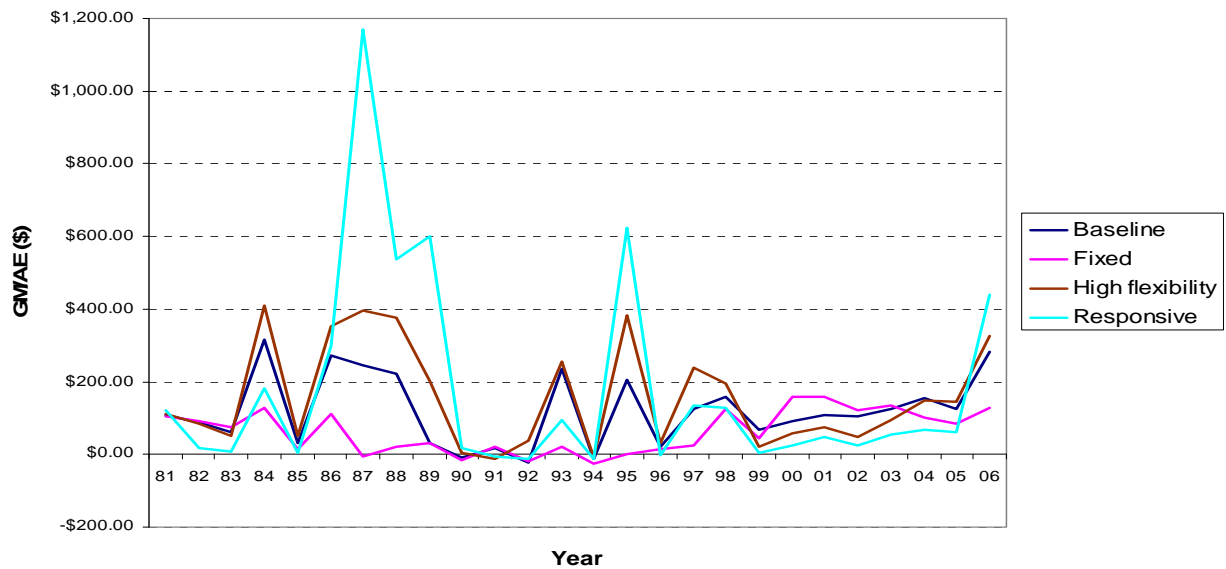
Figure 91. Projected GM/AE under four stocking rate strategies - Barkly.

Table 22. Average, minimum, and maximum values of GM/AE under four stocking rate strategies - Barkly.

	Baseline	Fixed	High flexibility	Responsive
Average	$121.42	$63.61	$156.73	$178.18
Minimum	-$22.03	-$25.64	-$11.01	-$13.45
Maximum	$315.59	$160.04	$411.16	$1,169.85
Years - negative	3	4	2	4

Scenario 2 - Whole of wet season resting four of 14 heifer and breeder paddocks which are in poor (C) condition, remaining paddocks mixed condition.
The second scenario assumes that four of the 14 heifer and breeder paddocks are in poor (C) condition - the four paddocks are predominantly comprised of black soils. Results are compared between two management strategies - (a) nil spelling and (b) spelling for 6 months within a 1-year spell in 4-year rotation. There is only one grazing strategy employed for this scenario - viz. a limited annual flexibility grazing regime - annual variation +/- 20% subject to a +/- 40% absolute limit. The scenario assumes that the animals that are normally carried in a rested paddock are agisted for 26 weeks at another property that is located at a distance of 250 km from the property and subsequently returned to the treated paddock. The main impact of the spelling regime is on operating expenses with total stock numbers varying according to projected changes in productivity of the spelled paddocks. A further assumption is made that the condition of the targeted paddocks will remain poor or deteriorate without spelling.

Projected breeder numbers for the nil spelling and spelling strategies are presented in Figure 92.
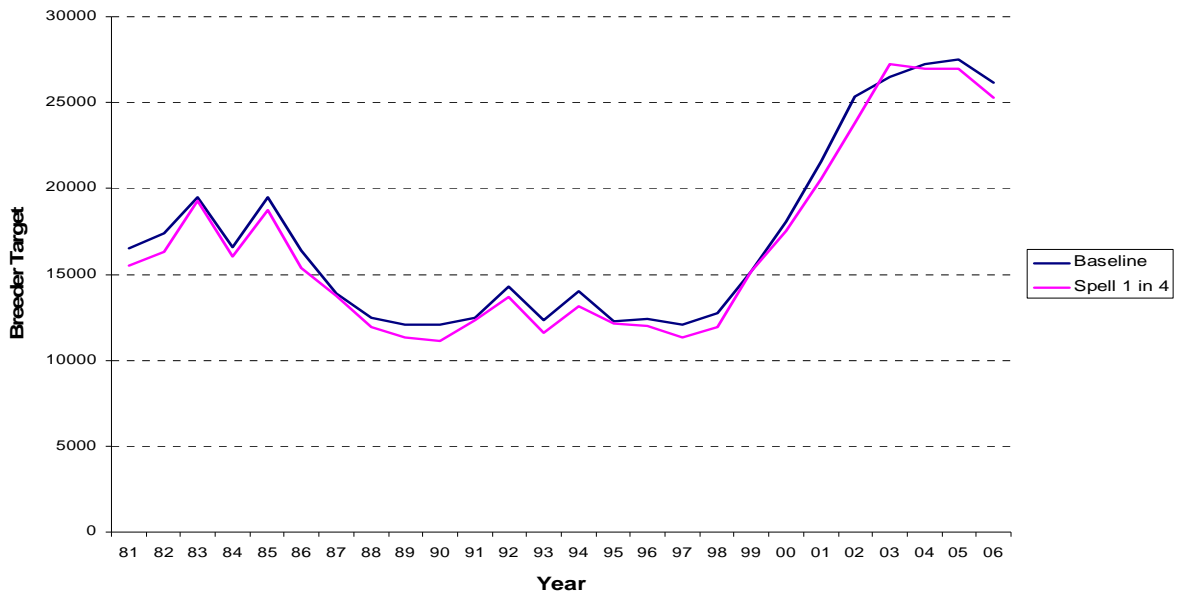
Figure 92. Target breeder numbers under nil and 6-month wet season spell and one stocking rate strategy - Barkly.

The projected breeder numbers follow a similar trajectory to that of the equivalent stocking rate regime from Scenario 1. For much of the simulation period the target numbers under the spelling strategy actually track below that of the nil spelling strategy.

The projected gross margin per adult equivalent for the simulation is presented in Figure 93 with the results summarised in Table 23.
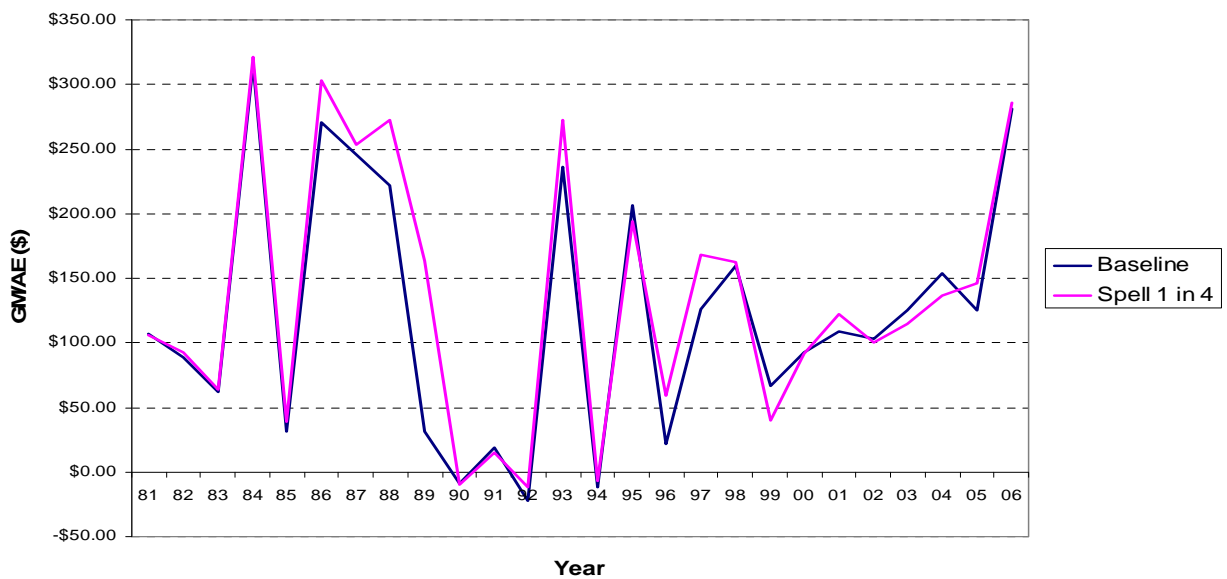
Figure 93. Projected GM/AE under nil and 6-month wet season spell and one stocking rate strategy - Barkly.

The annual projected gross margin per adult equivalent results show a high degree of inter-annual variation, with the spelling strategy showing an advantage for approximately a third of the years in the simulation period. Most of the advantage occurred in the second half of the 1980s and mid-1990s. Overall, the spelling strategy was more profitable than the nil spelling strategy (Table 23).

Table 23. Average, minimum, and maximum values of GM/AE under nil and 6-month wet season spell and one stocking rate strategy - Barkly.

	Nil-spelling	Spelling
Average	$121.42	$134.27
Minimum	-$22.03	-$11.95
Maximum	$315.59	$321.35
Years - negative	3	3

Conclusion.

A range of grazing and land management options have been reviewed for the Barkly Tableland case study. For the particular seasonal sequence that was experienced in this region (1980-81 to 2005-06), the various flexible stocking rate strategies - limited through to fully responsive - were more profitable on average than the fixed stocking rate strategy, with the fully responsive strategy offering the greatest relative advantage. The more flexible strategies typically involve producers facing elevated risks of having animal numbers build up during favourable seasonal sequences and subsequently being caught with excessive numbers of animals and the need to rapidly liquidate them when adverse seasonal conditions emerge. The scenario involving a wet season spelling strategy generated higher levels of projected profitability, although the bulk of the gain occurred from responses in the second half of the 1980s and mid-1990s. Prescribed burning to manage woody regrowth was not examined as this management issue was not seen to be a priority at the Tennant Creek workshop.

4.2.6 Overview.

This report has briefly described the procedure and outcomes of the bio-economic modelling component of the Northern Grazing Systems project as applied to five case study regions in Queensland (three) and the Northern Territory (two), viz:

1. Mitchell grasslands of western Queensland
2. Woodlands of the Burdekin Catchment
3. Woodlands of the Fitzroy Catchment - Duaringa
4. Savannas of the Victoria River District (NT)
5. Mitchell grasslands of the Barkly Tablelands (NT)

The scenario modelling was largely confined to variations on three general herd and land management strategies - fixed versus flexible stocking rates, wet season pasture spelling and prescribed burning for woody regrowth control. While there was a good deal of overlap in the specific assumptions underpinning each practice for the various case study regions, there were also differences such as the actual stocking rate applied, assumed starting condition of treatment paddocks, duration and frequency of spelling regimes, proportion of paddocks subject to fire etc.

A major observation from the simulation results is that seasonal context and starting condition are important factors influencing simulation outcomes, and have a similar importance as treatment extent and response. For example, while each of the case studies identified a potential difference between the prospective values of fixed versus flexible stocking rate strategies, this was not consistent across strategies or regions - the variable stocking rate regimes were definitely favoured for the Western Queensland Mitchell grasslands and two Northern Territory case studies, but not for the Burdekin or Fitzroy regions.

The first group experienced particularly favourable seasonal conditions at either or both the commencement or latter part of the simulation periods, while the Burdekin and Fitzroy experienced severe seasonal conditions at either the beginning and/or middle part of the

simulation period, which led to declining pasture and animal performance under the higher numbers of stock carried under the flexible stocking rate strategies.

Regardless of context, the wet season spelling and prescribed burning strategies appeared to offer scope for economic advantage across all of the case studies for which they were examined. Nevertheless, the context did influence both the relative and absolute advantage attributed to the management strategy. For example, for the regions in which the flexible stocking rate strategies performed better than fixed strategies this flowed through to either wet season spelling or prescribed fire strategies that also employed flexible stocking rate regimes. While wet season spelling and prescribed fire were generally economic management options, the relative gain over a nil action baseline was inevitably greater when the treatment paddocks were in poor rather than good condition - i.e. there was more to be gained from rehabilitation. However, the absolute level of performance as might be measured by average gross margin per hectare or per adult equivalent was typically higher when the treated paddocks were already in good condition - i.e. the higher potential productivity of good land will always stand out against that of rehabilitated poor land. Finally, unless rehabilitation costs are punitive, a treatment regime that seeks to rehabilitate a larger proportion of a potential treatment paddock will generally be favoured over a regime that operates on a lesser area.

5   Success in achieving objectives

5.1   Document current and best practice

The six regional workshops undertaken documented the practices that were considered current and best practice. Some of the workshops had a limited number of producers. However, the documents produced drew on experience of agency staff as well as the producers, and upon previous documentation. Indeed, the Burdekin region has had many such documents produced recently. For other regions, this exercise proved to be very useful in drawing together all relevant information.

5.2   Develop representative grazing enterprises

At each workshop, two representative properties were developed. Given the project's resources, it was possible only to model one of these properties for each region. These properties spanned a wide range of enterprise types – wider than the project team thought would have been developed. This was useful as it highlighted the need to consider more than the standard breeding/fattening properties that are often used.

The range of enterprise types meant that the ENTERPRISE model had to be modified for each of the five properties modelled. Property-level modelling could not be done for Maranoa-Balonne region during this project. While this was a difficult task (given the model is spreadsheet-based), it has resulted in a wide range of models that should represent much of the range of property enterprise mixes likely to be encountered across northern Australia. To modify these to new regions would require new cost structures and also different property configurations which are smaller adjustments than are required to represent new stock management regimes.

5.3   Input to B.NBP.0579 synthesis

Regional groups contributed to the synthesis study by providing source documents as well as reviewing the actual synthesis document. Some of the bio-economic modelling analyses were used to inform part of the synthesis document, however as these two projects were run in parallel, it was not possible for all the bio-economic modelling results to be incorporated into the synthesis document. However, there were no cases where major differences existed between the two approaches, and each supported and/or extended the results/insights from the other.

5.4 Developed a bio-economic modelling framework

The changes to GRASP and ENTERPRISE and their linkage enable bio-economic analyses of extensive beef properties across northern Australia to be done. This was a pre-requisite for the whole project. While this development was successful, a few major issues arose. Firstly, the number of changes required to GRASP meant that there was only sufficient time to do preliminary assessment of the enhancements made. In some cases (e.g. pasture condition modelling), the improvement to the model was useful, but further modifications would have been desirable and have actually been undertaken subsequently. In addition, the project highlighted the need to be able to run GRASP and ENTERPRISE interactively so that herd dynamic changes made in ENTERPRISE are incorporated into GRASP for subsequent years. At present, the information flow is uni-directional from GRASP to ENTERPRISE. Monthly liveweight gain and a woody component model would also be desirable.

5.5 Use the bio-economic modelling framework to quantify trade-offs

This was done for five representative properties. The Maranoa-Balonne property was not modelled during this project as the model modification had not been completed at the time of the workshops and the commitments to other regions precluded the work being done at a later stage. Property-level modelling has since been undertaken for this region.

Stocking rate
All groups recognised the overall importance of stocking rate. There were few, if any, contentious issues on this aspect. In some workshops, landholders indicated *'we know how to look after land in good condition'*. This stemmed from the audience being mainly composed of those producers who were already undertaking good (if not 'best') management practices on their properties. Many had also been to GLM workshops and/or similar activities focused on grazing management. There was recognition that not all landholders were actually doing this – for a variety of reasons. At least one of those reasons was a perceived benefit by having 'as many cattle as possible' rather than focussing on whole-property economic performance.

Having some flexibility in terms of year-to-year variation in stock numbers was seen as essential, especially to deal with a failed wet season or a series of poorer years. At the first workshop, producers appeared comfortable with the idea of a modest degree of flexibility – up to around 20% change per year in most years but with larger decreases during a very poor season or a run of poorer years. Interestingly, at the second series of workshops, there appeared to be some level of discomfort with stocking rate flexibility as portrayed in the model runs. This may have been due to the rigid modelling rules used to represent flexibility on a year-to-year basis (simply based on variation in pasture growth) versus being flexible in particular years based on significant changes in pasture supply and other factors. Stocking rate management involving varying numbers between years (and within years) require more study and on-ground testing (as in the next phase of the Wambiana grazing trial).

There was no interest in the fully flexible stocking strategy, largely due to logistics and problems associated with the sale or purchase of a large proportion of their herd, and the associated spikes and troughs in cash flow. In the NT regions, the degree of acceptable year-by-year flexibility appeared to be lower than other regions at around 10% per year. This is likely a reflection of the distance to markets or agistment and the inflexibility inherent in breeder herds, but may also reflect the lower climate variability in these regions compared to those in drier parts of Queensland.

Pasture spelling
All regions showed a lot of interest in this topic. The more closely settled areas (Maranoa-Balonne, Longreach and Burdekin) were interested in the different lengths of spell, although the difficulty of moving stock around during the growing season on heavy clay soils was acknowledged as a limitation.

The most common reaction to this work was that there was a need to move the cattle onto other paddocks on the property rather than moving them onto agistment. The latter was done in the simulations as the GRASP model could initially not easily be calibrated to represent the changing stock numbers at frequent and regular intervals. Towards the end of the project, a method to work around this limitation was derived in conjunction with Dr Greg McKeon. When this information was presented, it received much better acceptance and stimulated more discussion that at previous workshops.

Two key points stand out. Firstly, spelling for a period of three months once in every four years gave rise to a greater improvement in pasture condition than lowering stocking rates by one quarter. (This work was completed for Burdekin and NT regions only). At the same time, this gave an increase in the total grazing days available for the paddock (approximately a 15% increase). This is an example of a win-win – better pasture condition and increased number of stock that can be carried. By contrast, this did not always happen when the other paddocks were 'loaded up' with the cattle from the spelled paddocks. In that case, where the 'loaded up' paddocks were in excess of their safe utilisation levels for more than one year, they suffered long term damage.

The other key point is that the climate window used can have a major impact on all the stocking rate and spelling results, ranging from all paddocks in a spelling system recovering condition (even the fixed SR control) to all spelled paddocks being in poorer condition than the fixed SR control. Therefore, the implementation of pasture spelling must be carried out with continual reassessment of condition of the paddocks within the spelling regime, and overall stocking rates must be managed so that the paddocks that receive the 'extra animals' during the spell of neighbouring paddocks are not damaged. Another idea is to avoid spelling in lighter seasons as these times give relatively small response to spelling and the risk of damage from increased grazing pressure on other paddocks is high.

Burning
Even though several regions had little interest in using burning as a management tool, there was a lot of interest in the likely frequency of burning given different land type productivities and different stocking rates. The key message to come from this simulation work was that the best chance of a hot fire was in the more productive land types, in higher rainfall areas and at lower stocking rates. For less productive land types and for heavier stocking rates, a spell of 12 months before and six months after the burn increased the chance of success. If woody plants were allowed to increase, they reached a level where it was no longer possible to carry a fire (even with very low stocking rates). This was particularly the case for drier regions and for less productive land types within a region.

5.6   Contribute to revised set of best-bet guidelines

The results from the bio-economic modelling were presented at all workshops. These results were discussed with regional staff developing the guidelines. Insights from the bio-economic analyses as well as the synthesis of information (from B.NBP.0579) were incorporated into the final set of guidelines.

5.7   Contribute to future research and demonstration projects

During the final stages of this project, a number of formal and informal workshops/meetings were held to discuss and plan future work that MLA would consider funding/commissioning. During these events, the input from the bio-economic modelling team was sought and the results were used to inform decisions as to what future work should be done. The recovery of pasture in poor condition using various spelling options was a major one of these projects and benefitted greatly from the work done within the project. This related to the frequency and length of spells that

should be examined. The results of that project when completed will be valuable in refining the present bio-economic modelling framework.

5.7.1 Research

The following priority grazing land management research questions, and their justification, for each study region have been identified (in collaboration with B.NBP.0579).
 a) Frequency and duration of spelling trade-offs – all regions
 b) Effects of loading up other paddocks during pasture spelling – all regions
 c) Most profitable and practical level of stocking rate flexibility
 d) Impacts of stocking at 5-10% above the recommended long-term carrying capacity.

5.7.2 Demonstration

The appropriate strategies that may be considered for demonstration on-ground differ between regions. Below are some preliminary proposals:

 a) Woodlands of the Maranoa-Balonne region –
  i) spelling up to six months to recover poor land condition. Implementation to ensure net property benefits remains problematic
  ii) stocking flexibility – moderate to high flexibility may be the best option; possible to do on small places but not larger ones; specific implications for on-ground management need sorting out.
  iii) burning – not generally required except in smaller areas where unwanted woody vegetation is causing an issue; frequency of burning is adequate on cleared and more productive areas; if woody vegetation is already dense or productivity is low, then burning is not an option without mechanical intervention.

 b) Mitchell grasslands of western Queensland
  i) Spelling for up to six months to recover poor condition country; logistics of moving around on heavy clay soils during the summer may be an issue. Implementation to ensure net property benefits remains problematic.
  ii) Economic modelling seemed to suggest that high but not fully responsive stocking rate strategy was best. This gave intermediate pasture condition and was a reasonable compromise. Implications for on-ground improvement of stocking rate management require sorting out.
  iii) Burning was not seen as a desirable or required practice except, perhaps, for very small areas of woody plant encroachment onto open downs. It has a role in managing feathertop but implementation and net benefits are uncertain.

 c) Woodlands of the Burdekin and Fitzroy catchments
  i) Spelling for three or six months appeared the most promising and most practical options. Implementation to ensure net property benefits remains problematic.
  ii) Relatively constant stocking rates appeared to be the more financially rewarding than using high levels of stocking rate flexibility and also better than what might be regarded as current practice. While this is broadly consistent with the practical outcomes seen in Wambiana grazing trial, it differs markedly from the other regions within the project. One possible explanation concerns the influence of trees. The presence of trees is known to increase year-to-year variability in this location. While some trees were present in all regions, these catchments has a mixture of cleared areas and remnant vegetation – more so than in other regions where all or at least a substantial part of the area was either naturally treeless, essentially uncleared or had been extensively cleared previously. Another explanation may be that these results are specific to the particular sequence of years examined.
  iii) Burning simulations showed that woody vegetation could be maintained at current levels with a regime of 1 year in 4 burning where there was a relatively rapid increase

in woody vegetation (fast growing shrubs), provided sufficient fuel could be maintained.

d) Savannas of the Victoria River District and Barkly regions
   i) Spelling for the whole growing season was considered the only practical spelling option with livestock moved onto other paddocks on the same property. Issues associated with how to commence a spelling regime need to be addressed. Also the way in which to cope with wide year to year variation in potential stocking rate need to be developed. Implementation to ensure net property benefits remains problematic.
   ii) Use of fire was generally seen as necessary to prevent damaging wildfires (especially in the Barkly Tableland) rather than as a livestock or grazing management tool.
   iii) The sequence of good years over the last 10-20 years made generalisations more problematic in these regions.

6 Impact on meat and livestock industry – Now and in five years time

6.1 Bio-economic modelling

The ability to analyse whole-of-property impacts of suggested management practices has given an assessment of the competing needs of economic performance in the short-mid term and pasture condition in the mid-long term. While recommendations for individual producers have not been made, the analyses of what would happen on a representative property should provide a good base upon which to assess decisions. As the capability of bio-economic modelling continues to improve, the applicability of the analyses to individual circumstances will improve.

6.2 Documentation of management practices

The development of regional guidelines has provided a solid foundation for future extension programs and also identified knowledge and information gaps that are suitable topics for future research. The combination of bio-economic modelling, information and experience from the regional groups and synthesis of scientific information has provided guidelines for grazing land management that are scientifically sound and practically relevant. In the short-term this will ensure that any grazing land management programs undertaken in northern Australia have access to the best available information.

7 Conclusions and recommendations

7.1 Recommendations

7.1.1 Better modelling capacity

Improvements to the modelling framework are suggested in the following areas:
   i) Better representation of woody component in GRASP;
   ii) Better LWG model (ideally at a weekly/monthly timeframe) to reflect regional variation and impacts of supplementation and enable the finer timescale management options to be evaluated correctly;
   iii) Continued modification of ENTERPRISE; convert to programming language to fully integrate with GRASP – to allow appropriate feedback between herd and property constraints to the pasture production modelling;
   iv) Dynamic allocation of stock numbers to paddocks in proportion to production and condition – taking a whole property view rather than a paddock-by-paddock view.
   v) Evaluate spelling with variable stocking rate through improvements to the modelling framework; and

vi) Adjustment of livestock numbers at more than one time per year.

7.1.2 Research/demonstration gaps

i) Demonstration of spelling with loading other paddocks and issues associated with varying seasonal conditions as well as issue associated with commencing a spell; and

ii) Demonstration of altering stock numbers at different times of year – what are the options?

7.1.3 Priority grazing land management research questions

i) Frequency and duration of spelling trade-offs – all regions;

ii) Effects of loading up other paddocks – all regions;

iii) Most profitable and practical level of stocking rate flexibility; and

iv) Impacts of stocking at 5-10% above the recommended long-term carrying capacity.

8 Relevant references

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