final report

Project code:	B.NBP.0405
Prepared by:	Dr David Phelps Ian Houston
	Department of Employment, Economic Development and Innovation
Date published:	March 2014
ISBN:	9781740361842

PUBLISHED BY
Meat & Livestock Australia Limited
Locked Bag 991
NORTH SYDNEY NSW 2059

A guide to the recovery of Mitchell grass

Meat & Livestock Australia acknowledges the matching funds provided by the Australian Government to support the research and development detailed in this publication.

Abstract

Research sites were monitored within commercial paddocks in 2006 and again in 2009 to determine drought impacts on Mitchell grass and potential management actions to ease these impacts and to hasten recovery. Drought conditions which began in 2001 had eased by 2009. Low rainfall coupled with high evaporation during prolonged drought can kill Mitchell grass despite its drought tolerance. Management leading up to and during drought may improve the chances of Mitchell grass survival—especially wet season spelling to promote Mitchell grass root growth. Land in good condition going into drought is more likely to recover quickly through a high density of plants and seed in the soil. Land in poor condition needs time to recover from a smaller number of plants, which must be encouraged to produce seed to establish the next generation of Mitchell grass.

Executive summary

In western Queensland, severe drought conditions began in late 2001 and did not generally ease until the 2008/09 summer. Despite the ability of Mitchell grass plants to become dormant during drought, a large proportion of plants appeared to be dead rather than drought-dormant by the end of the 2002/03 summer. Tillers and remaining leaves were blackened and unpalatable to livestock. The term ‘Mitchell grass dieback’ was coined by producers and other observers to describe what had occurred, although most were confident that the grass would recover with the breaking of the drought.

Mitchell grass plants generally failed to respond to widespread average summer rains in early 2004 (> 250 mm). Observation suggested that moisture had penetrated to a soil depth of about 60 cm and a response from plants was expected. When there was no general response, research into the reasons for this was initiated (NBP.348 'Mitchell grass death in Queensland: extent, economic impact and potential for recovery'; 2005-07). This included an investigation of discrete areas of pasture that had responded to the 2003-04 summer rain. Further declines in condition of Mitchell grasslands occurred between winter 2005 and winter 2006 and, by 2006, field surveys indicated that 53% of this pasture community was in poor (C) condition, primarily due to dieback. Measurements at some sites suggested practices such as wet season spelling and burning can pre-condition Mitchell grass pasture for greater resistance to drought-induced dieback. However, the casual mechanisms and the effective timing and frequency of these practices remained unclear.

The aim of the current project was to better understand the factors affecting the rate of recovery of Mitchell grass pasture. It commenced in 2009, following above average rains, and re-measured sites (first measured in 2006) which had paired plots representing contrasting levels of dieback. Measurements of Mitchell grass health and land condition were conducted in the field and soil samples collected for germination studies.

The majority of the 49 sites revisited had greater dry matter yields in 2009, as would be expected following improved summer rainfall. Established Mitchell grass plants increased in size and vigour between 2006 and 2009. There was limited evidence of any increase in the density of mature Mitchell grass plants. Land condition improved at only 26% of sites. Mitchell grass seedlings were present at some sites indicating the potential for improvement in density over the 2009/10 summer.

There was very little Mitchell grass seed in the 2009 soil seed bank—especially poor condition sites—suggesting further summers are needed to re-build the reserves. This further suggests that recovery from drought and poor land condition is conditional on the recovery of existing Mitchell grass plants to set seed and provide a seed source for germination and further recovery.

Management to accelerate pasture recovery after drought needs to concentrate on the existing, residual plants of Mitchell grass - rather than relying on seed in the soil - to ensure improvement in land condition and a return to full productivity.

Table of Contents

List of Tables

List of Figures

1 Background

Queensland's Mitchell grasslands represent 19% of the state's native pasture area—some 33,800,000 ha—and support approximately 15% of Queensland's cattle herd and more than 40% of its Merino sheep flock. Between 2500-3000 people depend on employment generated by the production of beef, sheep meat and wool based on Mitchell grass country (ABS 2005). Mitchell grass provides the bulk of the pasture yield within the open grassland landscape (Orr and Holmes 1984; Weston 1988), intrinsically linking the ability to carry stock with Mitchell grass growth over summer and carry-over forage into winter.

Rainfall variability is high within the Mitchell grasslands—as in most arid and semi-arid rangelands of the world—and droughts occur frequently. Under the best estimate climate change predictions, drought frequency is likely to increase across the Mitchell grasslands as rainfall declines and evaporation increases (DERM 2009). The soils of the Mitchell grasslands are heavy cracking clays which become extremely dry (moisture levels of 4–5%) by the end of the winter dry season and during drought. The high water holding capacity of these soils coupled with the low soil moisture levels mean that initial rains of at least 100 mm are needed to wet the soils to 30 cm depth. Such rainfall events occur infrequently, suggesting a generally slow recovery from drought. Deep (>60 cm) soil moisture can be replenished through rain water flowing down the vertical cracks of the soil, although this process is not well understood.

Mitchell grass is a tropical (summer growing) tussock grass with adaptations to dry conditions. Tussocks become drought dormant to escape desiccation and death during extended dry periods (Whalley and Davidson 1968; 1969), and roots extend beyond 100 cm to tap into deeper soil moisture reserves (Everist 1964). However, the mechanisms involved in the breaking of drought dormancy are poorly understood, and only one published account of Mitchell grass root structure exists (Everist 1964).

Severe drought conditions began in late 2001 and did not generally ease until the 2008/9 summer—it has been colloquially termed the 'millennium drought'. Despite the ability of Mitchell grass plants to become dormant during drought, a large proportion of plants appeared to be dead rather than drought-dormant by the end of the 2002/03 summer. Tillers and remaining leaves were blackened and unpalatable to livestock. The term 'Mitchell grass dieback' was coined by pasture scientists and industry to describe what had occurred, although most were confident that the grass would recover with the breaking of the drought.

Mitchell grass plants generally failed to respond to widespread average summer rains in early 2004 (> 250 mm). Observations suggested that moisture had penetrated to a soil depth of about 60 cm and a response from plants was expected. When there was no general response, research into the underlying reasons, and the clues for management in areas that had responded, was initiated (NBP.348 'Mitchell grass death in Queensland: extent, economic impact and potential for recovery'; 2005-07). A major decline in condition occurred between winter 2005 and winter 2006 and by 2006 this research had estimated that 53% of the Mitchell grasslands were in poor (C) condition due to dieback. This research was concluded in 2006 and found instances where some specific timing of grazing or burning practice prior to the drought appeared to help reduce or prevent dieback (Phelps *et al*. 2007a, b).

Wide-scale death and dieback of Mitchell grass tussocks has been recorded on three previous occasions: the 1900s, 1930s and 1960s (e.g. Forrest 1988; Everist 1935; 1939). It appears that pastures eventually recovered but there is no information on the extent of tussock mortality, the speed of recovery or if recovery occurred from low-vigour remnant tussocks or from seedlings. Understanding the process of recovery can help identify management options that will hasten a return to full productivity.

2 Project objectives

By 31 March 2011, the research organisation will have:

1. Provided updated management guidelines for accelerating the recovery of Mitchell grass pastures following severe drought, including the relative importance of new plants and surviving tussocks.
2. Refined management guidelines for responding to variable climatic conditions.
3. Published a fact sheet updating current knowledge of Mitchell grass recovery from severe drought.

3 Methodology

This project re-measured paired sites with contrasting levels of dieback established in 2006—a subset of the five areas of activity undertaken within the previous project. These sites were considered to have the best potential for improving understanding of Mitchell grass recovery.

Adjacent sites demonstrating contrasting Mitchell grass response were identified in the previous project through the assessment of land condition, remote sensing techniques, discussions with the steering committee, industry liaison; and discussions with GLM workshop participants. Broad criteria for site selection were allowed, with the data set to be used for the identification and exploration of trends and hypothesis generation. The criteria were that sites:

- must be within Open Downs, Ashy Downs or Wooded Downs land types
- should visually demonstrate a difference in response
- should primarily be due to management across fence lines, burn lines or along an identifiable grazing or rainfall gradient.

The 49 sites (22 paired sites and one set of 5 sites within a long-term grazing experiment, Orr and Phelps 2004) of contrasting response were reassessed in August-September 2009, as a follow-up to the base-line measurements in June-December 2006. Pasture yield, botanical composition (Tothill *et al.* 1992) and *Astrebla* spp. density, vigour and basal area (Orr 1998) were measured within 30 quadrats of 1x1 m^2 size along two 75 m transects for each site. Tussock density and basal area were grouped into 'dead' and 'living' categories, to allow previous and current basal area to be assessed. Photographs were taken of general site conditions and of each quadrat.

The ability to link to remote sensing data in the future was made by ensuring:

- recording of site waypoints to an accuracy of +/- 5 m
- that sites were within an area representative of the aspect being measured (e.g. burnt or unburnt areas)

- each site would cut across at least two LandSat pixels (by having two 75 m long transects, at 45 degree angles, with their respective starting point spaced 40 m apart)
- paired sites were between 200 and 1000 m distance from each other to avoid sites overlapping within pixels.

Potential botanical composition was estimated through assessment of the soil seed bank at each site. Ten soil samples, each comprising four cores of 5 cm diameter and 5 cm depth, were collected along the same 75 m transects providing sufficient sampling intensity for small plots (Jones and Bunch 1988). Samples from one transect were germinated in a shade-house at Longreach and counts conducted as each species became identifiable (Orr *et al.* 1996). The second set of samples was retained as duplicates.

General observations of grazing pressure, pasture response, pasture condition and land type were recorded, and site history (grazing, burning and site specific rainfall) was obtained through semi-structured interviews with the owner/manager of each property in 2006. Rainfall data were estimated for each site using Silo DataDrill (Jeffrey *et al.* 2001).

A rainfall/evaporation ratio (R/E index, see Hodgkinson and Müller 2005) was used as a guide to the severity of soil moisture deficit, with any summer period (October-March) where the moving average of the ratio failed to exceed 0.15 (15%) deemed to be a failed summer and likely to increase perennial grass mortality.

Raw data were analysed through ANOVA, correlation and multiple regression to identify major trends. Discriminant Analysis (DA) was used to estimate level of significance (95% confidence interval) between paired sites (GenStat 2007) based on similarity groupings in PCA (Phelps *et al*. 2007a). Square root transformed data of *Astrebla* seedling density, *Astrebla* tussock density and size (both live and dead) and soil seed bank functional groups (*Astrebla*, other 3P grasses, other perennial grasses, annual grasses, desirable forbs and undesirable forbs) were used for DA. This mix of datasets differed slightly from the DA reported by Phelps *et al*. (2007a) using 2006 data—the corresponding 2006 site data was re-analysed and did not affect the significant differences between sites reported in 2007. The 2006 data are re-presented in the Results and Discussion section with detail of data and analyses in the Appendices (9.1, 9.2, and 9.3).

4 Results and discussion

The 49 sites were dominated by Open Downs land types (32 sites) with 13 Ashy Downs and four Wooded Downs sites (Table 1). Seventeen sites were in poor (C) condition in 2006, of which ten were Ashy Downs sites (76% of the Ashy Downs sites). Four of the Ashy Downs sites had improved in condition by 2009 but three sites declined to poor condition. All three sites were near McKinlay (Redland Park and the McKinlay common adjacent to Redland Park). The 2006 good condition assessment was based on a high density of Mitchell grass seedlings (2.4-18.4 seedlings/m^2) which set seed following good growing conditions over the 2005/06 summer. The high seedling density in 2006 did not translate into a high density of mature tussocks in 2009 and so land condition declined. Rapid response of seedlings has been observed on previous occasions in the Ashy Downs (Phelps unpublished).

No wooded downs sites were in poor condition in either 2006 or 2009. Only 22% (seven) of Open Downs sites were in poor condition in 2006 and 2009.

It is possible that Mitchell grass tussocks in Ashy Downs—which has deeper, more strongly self-mulching soils with deeper and wider cracks—are less able to withstand the drying conditions associated with drought. The soils of the Ashy Downs require more rain to re-fill the moisture profile than Open or Wooded Downs soils (Phelps *et al*. 2007a). Mitchell grass tussocks do not seem to be as well anchored in the loose surfaced Ashy soils—potentially being pulled out during grazing (Phelps unpublished).

There were seven burnt/unburnt pairs, 28 sites that were never rested and 13 spelled opportunistically in the dry or the wet season—three which had been spelled in the dry season and five spelled in the wet season. Of these sites only Dundonald Lane has received regular annual spelling in the long-term (20-30 years). Overall, 13 (26%) sites were estimated to have improved in condition and seven (14%) to have declined in condition.

Table 1. A general description of the 49 sites recorded in 2006 and 2009 and the corresponding trend in pasture condition

Site name	**Site condition**[1]				**Land Type**	**Burning**	**Grazing system between 1999 and 2007**	**Number of failed wet seasons**[2]
	pre-2006	**‘06**	**‘09**	**direction**				
Accord Access	B	C	C	↔	Ashy Downs	Not burnt	Conservative, Wet season spell (WSS)	1
Accord Bendigo	B	C	B	↑	Ashy Downs	Not burnt	Conservative, WSS	1
Accord Outback	B	C	C	↔	Ashy Downs	Not burnt	Conservative, occasional spell	1
Accord Railway	B	C	C	↔	Ashy Downs	Not burnt	Heavy summer, then spelled	1
Arrowfield burn	A	B	B	↔	Wooded Downs	Burnt in January 1999	Opportunistic rotational	1
Arrowfield unburn	A	B	B	↔	Wooded Downs	Not burnt	Opportunistic rotational	1
Beeantha #1	A	A	A	↔	Ashy Downs	Not burnt	Heavy summer, then spelled	0
Beeantha #2	A	B	B	↔	Open Downs	Not burnt	Consistently heavy	0
Camara burnt	B	B	A	↑	Open Downs	Burnt in January 2001	Conservative, occasional spell	1
Camara unburnt	B	B	C	↓	Open Downs	Not burnt	Conservative, occasional spell	1
Dundonald Lane	A	A	A	↔	Open Downs	Not burnt	WSS, annual dry season heavy grazing	0

---

[1] Estimated from *Astrebla* basal area and density and soil seed bank species density; pre-2006 condition inferred from total tussock density (live plus dead) in 2006 (Phelps *et al*. 2007).

[2] Number of failed wet seasons between April 1999 and April 2009.

Site name	**Site condition[1]**				**Land Type**	**Burning**	**Grazing system between 1999 and 2007**	**Number of failed wet seasons[2]**
	pre-2006	**'06**	**'09**	**direction**				
Dundonald Paddock	A	B	A	↑	Open Downs	Not burnt	Conservative continuous	0
E/ Bandon Grove Hvy Graze	B	C	B	↔	Open Downs	Not burnt	Consistently heavy	1
E/ Bandon Grove Lt Graze	A	B	B	↔	Open Downs	Not burnt	Conservative continuous	1
Glenferrie burnt	B	B	A	↑	Ashy Downs	Burnt in December 2002	Opportunistic rotational	1
Glenferrie unburnt	B	C	B	↑	Ashy Downs	Not burnt	Opportunistic rotational	1
Kaloola burn	A	B	B	↔	Wooded Downs	Burnt in February 2000	Opportunistic rotational	1
Kaloola unburn	A	B	B	↔	Wooded Downs	Not burnt	Opportunistic rotational	1
Kaloola wether 1	B	C	B	↑	Ashy Downs	Not burnt	Opportunistic rotational	1
Kaloola wether 2	A	B	B	↔	Open Downs	Not burnt	Opportunistic rotational	1
Langdale burn	A	C	C	↔	Ashy Downs	Burnt in January 1992	Conservative, occasional spell	2
Langdale unburn	A	C	C	↔	Ashy Downs	Not burnt	Conservative, occasional spell	2
Langdale No rain	B	C	B	↑	Ashy Downs	Not burnt	Conservative, occasional spell	2
Langdale Rain	A	B	B	↔	Open Downs	Not burnt	Conservative, occasional spell	2
Loongana laneway	A	C	B	↑	Open Downs	Not burnt	Occasional heavy grazing	1
Loongana paddock	A	C	B	↑	Open Downs	Not burnt	Conservative, WSS	1
Malakoff 1	B	B	B	↔	Open Downs	Not burnt	Conservative, occasional spell	0
Malakoff 2	B	B	B	↔	Open Downs	Not burnt	Conservative, occasional spell	0
Norwood Waterford	B	B	B	↔	Open Downs	Not burnt	Conservative continuous	0
Norwood Wilsons	A	A	B	↓	Open Downs	Not burnt	Regular spelling	0
Redland Park Common 1	A	A	B	↓	Open Downs	Not burnt	Consistently heavy	0
Redland Park Common 2	A	A	C	↓	Open Downs	Not burnt	Consistently heavy	0
Redland Park Coomara	A	A	C	↓	Open Downs	Not burnt	Conservative, occasional spell	0
Redland Park Landsborough	A	A	C	↓	Open Downs	Not burnt	Heavy summer, then spelled	0

Site name	**Site condition**[1]				**Land Type**	**Burning**	**Grazing system between 1999 and 2007**	**Number of failed wet seasons**[2]
	pre-2006	**‘06**	**‘09**	**direction**				
Rodney Downs Burnt	A	B	A	↑	Ashy Downs	Burnt in April 2001	Opportunistic rotational	0
Rodney Downs Unburnt	A	C	C	↔	Ashy Downs	Not burnt	Opportunistic rotational	0
Rosebank #1	A	B	B	↔	Open Downs	Not burnt	Conservative continuous	0
Rosebank#2	B	B	B	↔	Open Downs	Not burnt	Conservative continuous	0
Strathmore 1	A	A	A	↔	Open Downs	Not burnt	Conservative continuous	0
Strathmore 2	A	C	C	↔	Open Downs	Not burnt	Consistently heavy	0
Toorak 10%	A	A	B	↓	Open Downs	Not burnt	Very light grazing	0
Toorak 20%	A	B	B	↔	Open Downs	Not burnt	Very light grazing	0
Toorak 30%	A	B	B	↔	Open Downs	Not burnt	Conservative continuous	0
Toorak 50%	B	C	B	↑	Open Downs	Not burnt	Conservative continuous	0
Toorak 80%	B	B	A	↑	Open Downs	Not burnt	Very heavy winter, then spelled	0
Whitehill fire site burnt	A	C	C	↔	Open Downs	Burnt in March 2003	Conservative, occasional spell	1
Whitehill fire site unburnt	A	C	C	↔	Open Downs	Not burnt	Conservative, occasional spell	1
Whitehill holding pdk	A	B	B	↔	Open Downs	Not burnt	Occasional moderate grazing	1
Whitehill ungrazed	B	B	B	↔	Open Downs	Not burnt	Conservative, occasional spell	1

Growing conditions

Growing conditions improved considerably at most sites during the summer of 2008/09 (Figure 1), providing a reprieve from the drought conditions of the previous seven years. Total pasture yield was higher in 2009 than in 2006 (1450 kg/ha cf 760 kg/ha, $P<0.001$) in response to the improved growing conditions and pastures looked much healthier and more productive. Total pasture yield was also correlated ($P<0.05$) with live tussock basal area and hence with land condition. This relationship is already well understood and forms the basis of land condition discounting of pasture growth tables in Grazing Land Management training materials (e.g. Chilcott *et al*. 2007).

Most sites had little, if any, increase in *Astrebla* density between 2006 and 2009 indicating a lack of overall improvement in land condition. This suggests that widespread drought recovery had not yet occurred in the Mitchell grasslands by winter 2009. Some sites did have Mitchell grass seedlings present indicating the potential for improvement over the 2009/10 summer. The Dundonald continuous grazing and Glenferrie unburnt sites both improved from C to B condition. At Dundonald this improvement coincided with a change in fencing resulting in more control of grazing pressure. There were no management changes at Glenferrie. The improvements appeared to be from the recovery of existing tussocks as basal area increased.

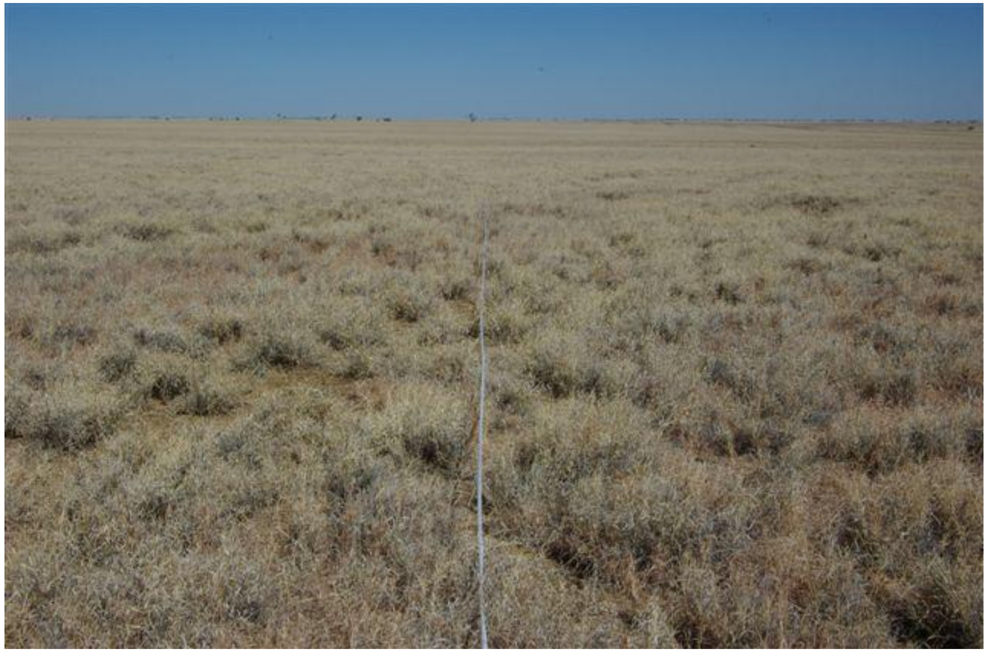
The general lack of land condition change suggests that historical land management and rainfall have a strong influence over land condition in the Mitchell grasslands. This is contrary to conventional industry wisdom, and to previously reported studies, which suggest that drought recovery can occur quickly with one above-average wet season. It may also suggest that industry is not reporting improved land condition, but rather improvement in pasture yield, or perhaps improvement in vigour of isolated tussocks but in the absence of increased tussock density.

Figure 1. Photographs of selected sites showing the increased pasture yield but not necessarily land condition improvement from 2006 to 2009

Site in 2006

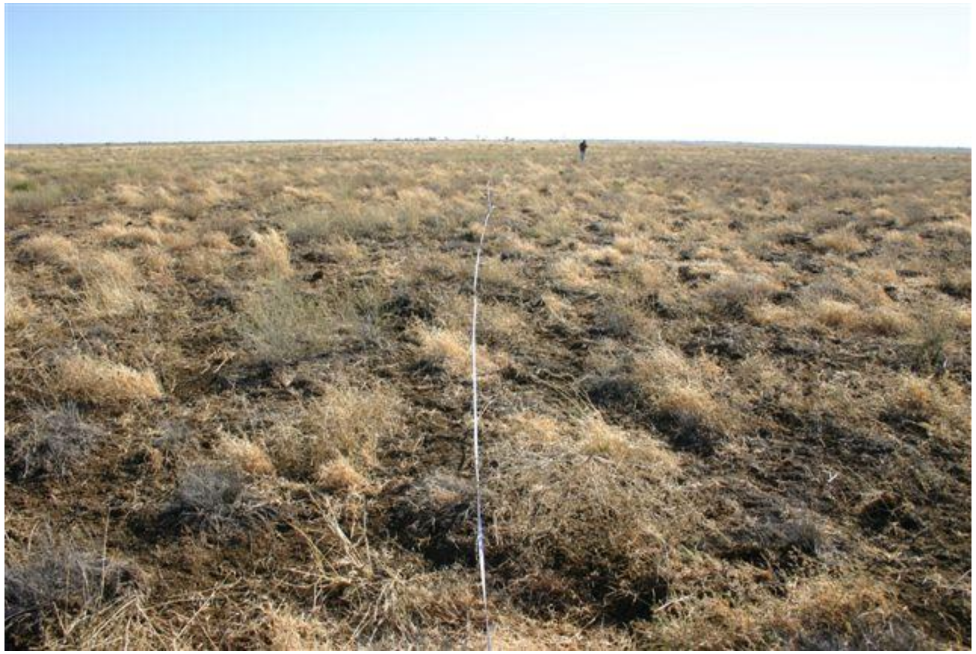
Rodney Downs burnt site in 2006: land condition is B, with Mitchell grass tussocks about 1.5 m apart. The pasture is dominated by Mitchell grass with unpalatable forbs present.

Same site in 2009



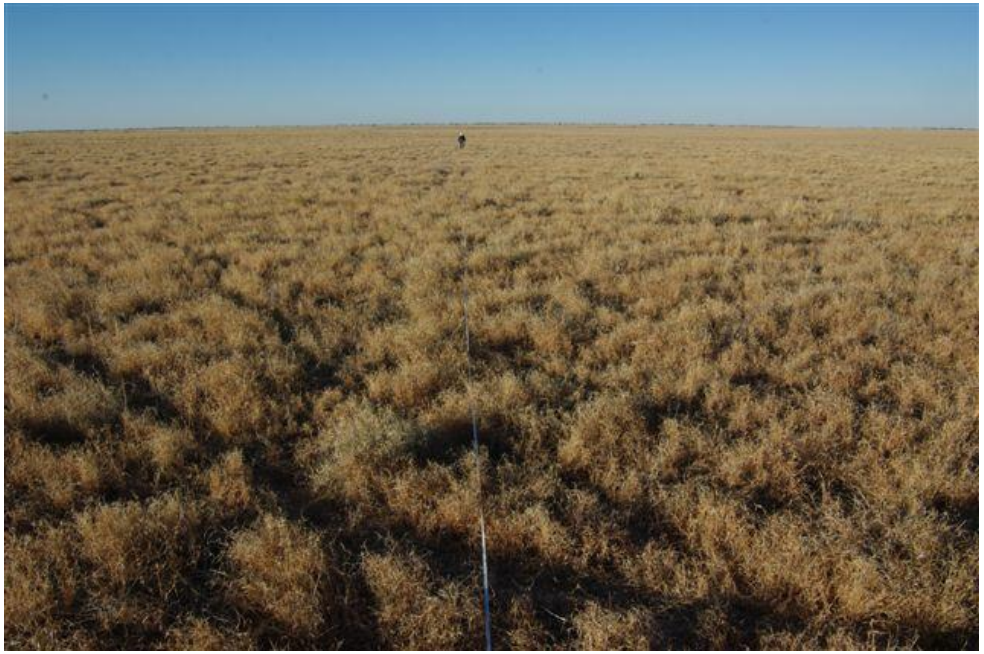
Rodney Downs burnt site in 2009: land condition is B, with Mitchell grass tussocks about 1 m apart. The pasture is dominated by Mitchell grass and includes Flinders grass.

Site in 2006



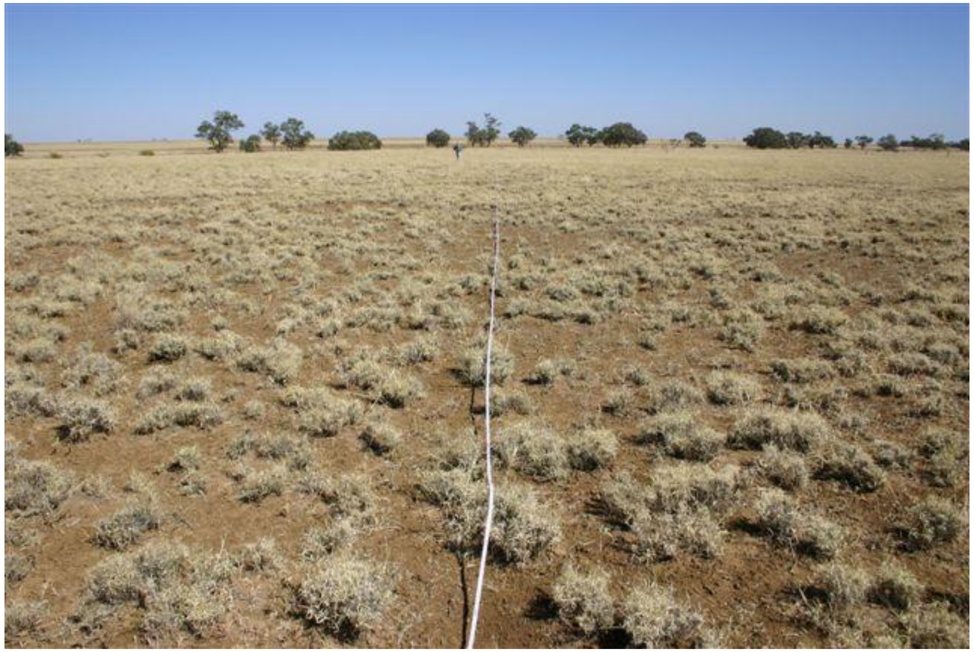
Rodney Downs unburnt site in 2006: land condition is C, with Mitchell grass tussocks about 10–20 m apart. The pasture is a dominated by Flinders grass and unpalatable forbs.

Same site in 2009



Rodney Downs unburnt site in 2009: land condition is C, with Mitchell grass tussocks about 10–20 m apart. The pasture is a dominated by Flinders grass. The lack of improvement in land condition was typical of most sites.

Site in 2006



Dundonald wet season-spell (laneway) site in 2006: land condition is B, with Mitchell grass tussocks about 1.5 m apart. The pasture is dominated by Mitchell grass.

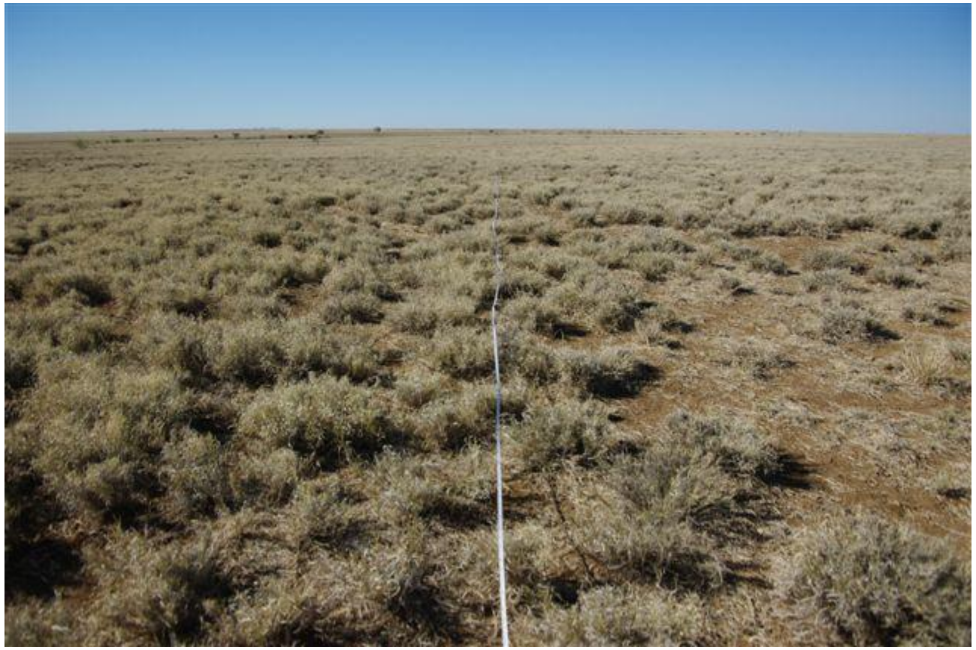
Same site in 2009

Dundonald wet season-spell (laneway) site in 2009: land condition is B (or B/A), with Mitchell grass tussocks about 1 m apart. The pasture is dominated by Mitchell grass and includes other 3P grasses such as brown top and blue grass.

Site in 2006

Dundonald continuous graze (paddock) site in 2006: land condition is C, with Mitchell grass tussocks about 5–10 m apart. The pasture yield is dominated by Mitchell grass as there is little else growing.

Same site in 2009



Dundonald continuous graze (paddock) site in 2009: land condition is B, with Mitchell grass tussocks about 2–5 m apart. The pasture yield is dominated by Mitchell grass. This was one of the few sites to improve in land condition. Grazing management had changed since 2006, with the area being fenced into a new paddock and grazed more consistently than leading up to 2006.

The summer Rainfall/Evaporation Index (where a low R/E Index represents dry and desiccating conditions and a high R/E represents wet and humid conditions) increased from 0.07-0.13 during 2002/03 to >0.25 in 2008/09. Not all monitoring sites had a reprieve from low R/E conditions. The paired sites at Arrowfield and East Bandon Grove (both south of Longreach) had low R/E ratios over the 2007/08 and 2008/09 summers prior to re-sampling in 2009.

A low R/E Index (below 0.15 for any 3 month period) was correlated with a high density of dead Mitchell grass tussocks in 2006 (Phelps *et al*. 2007a). This finding was consistent with Hodgkinson and Müller (2005) who found that increased perennial grass death in western NSW was related to a reduced R/E Index.

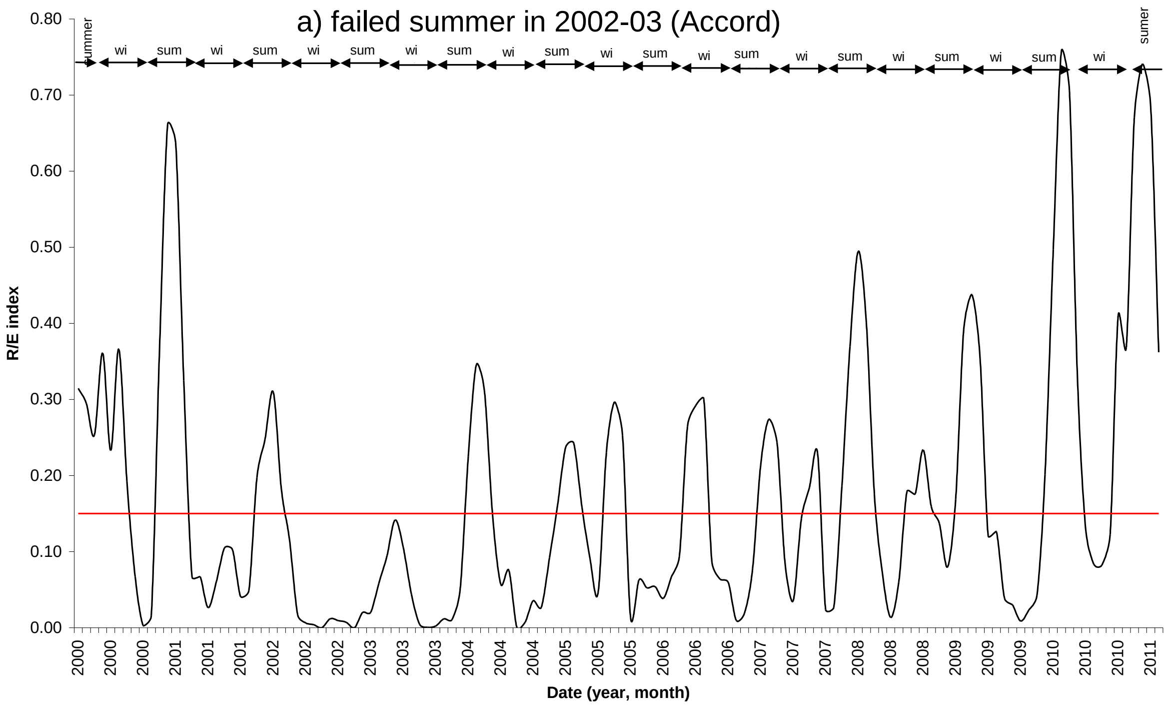
In the current project, increasing R/E leading up to monitoring in 2009 resulted in dead tussocks decaying and disappearing and the remaining live tussocks expanding at the base ($P<0.05$). As dead tussocks decay and disappear it becomes more difficult to tell what the pre-drought tussock density may have been like and difficult to determine historical land condition. During drought the dead tussocks remain standing due to the dry conditions.

At Arrowfield and East Bandon Grove, the density and size of dead tussocks continued to increase—and live tussock size declined—between 2006 and 2009 as R/E stayed relatively low. Management may have had an impact at these sites, as the increase in dead tussock size was less in burnt and low-grazing pressure sites ($P<0.05$).

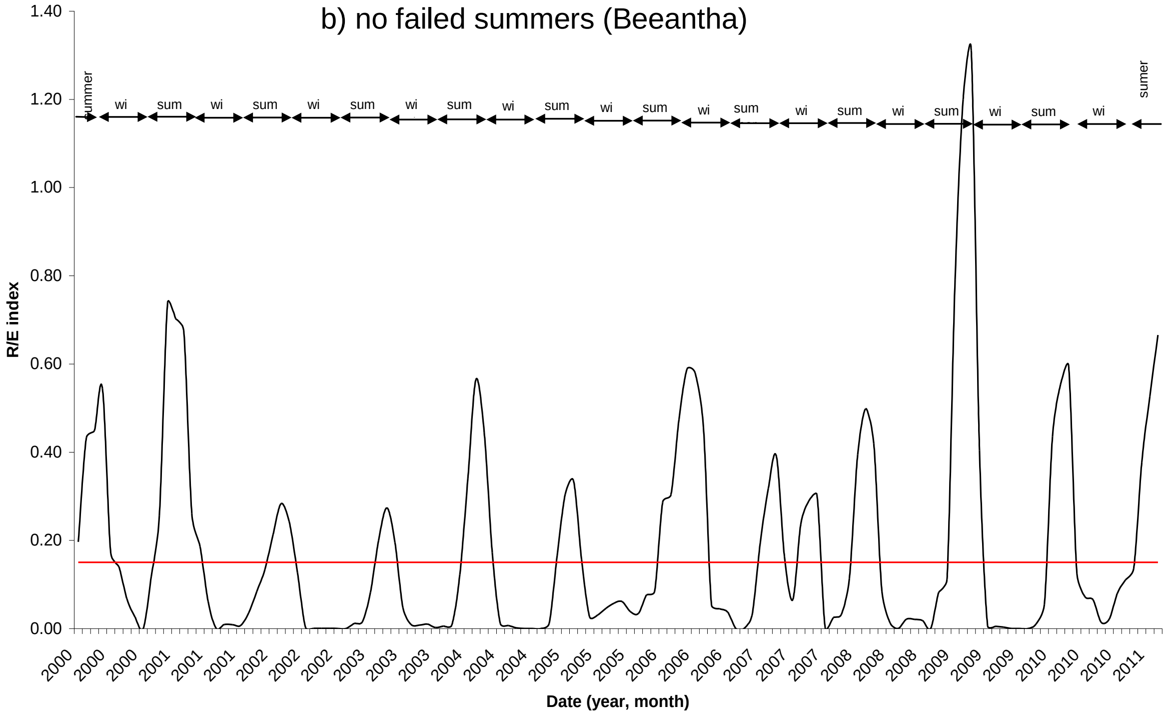
Phelps *et al*. (2007a) reported sites which had experienced at least one failed summer (where the R/E remains below 0.15, e.g. Figure 2a) had significantly reduced density and basal area of live *Astrebla* plants than sites with no failed summers. With the addition of monitoring data from 2009 it is also clear that live tussock density and size will decrease within a season when R/E is low ($P<0.05$, see correlation table in Appendix 9.4). The R/E index during the ‘normal’ growing season is therefore a useful way to represent the degree of dryness or desiccating conditions. The more severe the drought conditions e.g. more failed wet seasons, the greater the desiccating conditions (lower R/E index), and the greater the reduction in density and size of live tussocks.

Winter R/E is typically low (<0.10) due to the general lack of winter rain, even though evaporation rates are low across the Mitchell grasslands. The winter of 2006 was an exception—especially in the Longreach area. Individual live tussock size was positively correlated ($P<0.05$) with the 2006 R/E index in both 2006 and 2009 recordings, as was a decline in dead tussock basal area between 2006 and 2009. This suggests that winter rain has a role to play in maintaining live Mitchell grass tussock health during drought. It further suggests that spelling of Mitchell grass may be effective when the tussocks are actively growing regardless of season. Observations during the 2006 winter were that Mitchell grass responded to the rain due to above average winter air temperature and even set seed in some areas. During drought, opportunities to rest country to maintain good—or improve poor—land condition over winter may be as important as resting country over summer so long as *Astrebla* tussocks are actively growing.

Early Grasp modelling of the long-term grazing study at Gilruth Plains, in Mitchell grasslands at Cunnamulla suggests *Astrebla* spp can survive 680 cumulative days with a soil moisture index less than 0.3 and *Dichanthium sericium* 250 days (McKeon pers. comm). It would be worth exploring soil moisture output from Grasp within an analysis of drought management (discussed later).



a) failed summer in 2002-03 (Accord)



b) no failed summers (Beeantha)

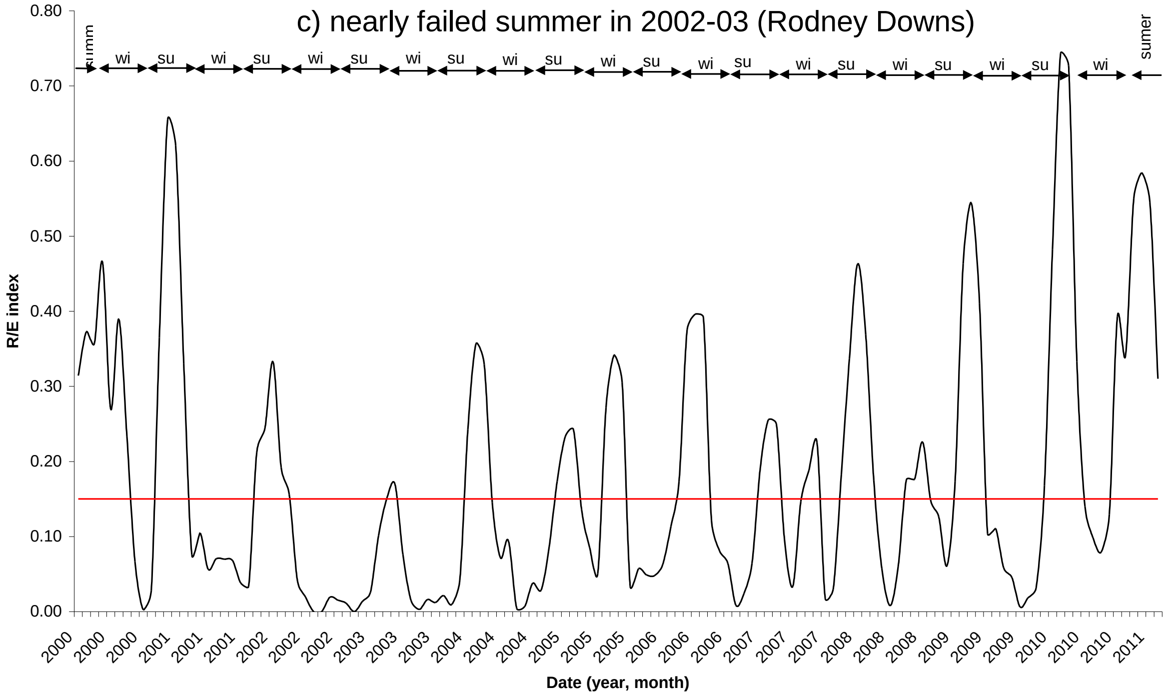


Figure 2. Examples of a) failed b) not-failed and c) nearly failed summers from selected sites. R/E index is the ratio of rainfall to evaporation, derived from SILO data

Sites which had been exposed to the longest period of low R/E and had experienced at least one failed summer had significantly lower living *Astrebla* spp. density and basal area (BA, Table 2) in 2006. This effect did not carry forward into 2009 as *Astrebla* live density increased more in sites with at least one failed summer. Sites which did not experience a failed summer (e.g. Figure 2b) had a high live Mitchell grass basal area (Table 2). Conversely, sites with high dead plant density and basal area had experienced at least one failed summer. There was no difference in total (live plus dead) plant density or in seedling density. Reduced basal area under extended dry conditions is consistent with other published accounts of the dynamics of the pastures of the Mitchell grasslands (Orr and Holmes 1984). Sites on the threshold of a failed summer (e.g. Figure 2c) tended towards low *Astrebla* survival (data not presented).

Where there was improvement in *Astrebla* basal area between 2006 and 2009, this arose from vegetative growth as existing tussocks increased in size, broke into segments and expanded to form new plants or grew from dormant rhizomes.

There was a tendency for more seedlings to be present at sites with no failed summers in both 2006 and 2009 recordings (P=0.152 and P=0.232). It is possible that the *Astrebla* soil seed bank declined during the drought, leaving fewer viable seeds to germinate. This has been noted previously by Orr (1991) who also observed that the best recruitment occurs following good seed production by established tussocks. For drought recovery—especially for areas in poor condition and with associated low *Astrebla* tussock density—remnant tussocks must first grow sufficiently to produce seed and the seed be incorporated in the soil seed bank before land condition can improve. Given that *Astrebla* seed has a dormancy of 6-12 months, a fast recovery would still take two growing seasons. Management actions would be required in the first summer to encourage *Astrebla* seed production and in the second summer to encourage germinating seedlings to establish. If the conditions in the second summer were inadequate to promote germination, recovery would be further delayed.

Table 2. The impact on *Astrebla* spp. of at least one failed summer in terms of dead and live plant density (plants/m^2), dead and live plant basal area (BA, cm^2/m^2) and seedling density (plants/m^2) at 49 sites

Factor	At least one failed summer	No failed summer	significance level (ANOVA)
Live density in 2006	1.2	3.1	0.020
Live plant BA in 2006	27.8	63.4	0.023
Dead density in 2006	1.6	0.7	< 0.001
Dead plant BA in 2006	74.4	42.4	0.006
Seedling density in 2006	1.7	2.6	0.207
Live density in 2009	2.6	2.9	0.640
Live plant BA in 2009	31.2	58.8	0.070
Dead density in 2009	0.5	0.2	0.010
Dead plant BA in 2009	14.4	9.6	0.135
Seedling density in 2009	0.6	1.9	0.232
No. of observations	26	23	

Far fewer Mitchell grass seedlings germinated from the 2009 soil seed bank samples than from the 2006 samples. The 2009 samples—which were potted up and watered from January 2010—took considerably longer to germinate and to grow into identifiable plants than usual. In 2006, for instance, all plants from seed had been identified by May 2007 following the start of watering in January 2007. The 2009 samples were grown through to March 2011 before all plants could be identified and no Mitchell grass had gone to seed. This led to delays in data analysis and reporting and also created concerns over the accuracy of the 2009 soil seed bank data. The duplicate soil samples from five sites were sieved and checked for *Astrebla* spikelets and a sub-sample of seeds tested for viability (via tetrazolium). Four out five locations had more spikelets than were found in the germinable soil seed banks (Table 3)) and all spikelets had high viability (75-100%).

The presence viable *Astrebla* spikelets at sites previously thought to have no or little *Astrebla* seed based on the standard growing out of samples is of concern. The remaining duplicate samples should be processed to check the validity of the earlier findings, although the management recommendations are not likely to change.

Table 3. *Astrebla* spikelet count and viability from five sites compared with site germinable seed bank

Site	Spikelet count	Viability (%)	Average viable spikelet count	Germinated *Astrebla*
Dundonald Lane	0	N/a	0	0
Glenferrie burnt	1.9	75	1.4	0
Dundonald paddock	2.1	80	1.6	0.1
Arrowfield Burn	0.4	100	0.4	0
Rosebank #1	1.9	80	1.5	0

4.1 Land condition relationships

Astrebla soil seed bank density was higher ($P<0.001$) in good condition sites than poor condition sites in 2006 with a similar trend in 2009 (Table 4). *Astrebla* live tussock density and basal area was higher in good condition sites ($P<0.001$) in both 2006 and 2009 whilst dead tussock density and basal area were higher in poor condition sites in 2006. There was no land condition difference in dead tussock basal area in 2009 following the decay of dead tussocks from above average rainfall.

Table 4. The relationship between good (A and B) and poor (C) land condition and *Astrebla* spp. dead and live plant density (plants/m^2), dead and live plant basal area (BA, cm^2/m^2), seedling density (plants/m^2) and soil seed bank density (plants/m^2) at 49 key sites

Factor	A condition	B condition	C condition	significance level (ANOVA)
Live density in 2006	5.1	2.4	0.4	<0.001
Live plant BA in 2006	251.9	158.4	20.5	<0.001
Dead density in 2006	0.5	1.1	1.7	<0.001
Dead plant BA in 2006	78.1	112.5	186.2	0.001
Seedling density in 2006	4.3	2.9	0.5	0.001
Soil seed bank density in 2006	216.4	159.9	32.2	<0.001
No. of observations	9	23	17	
Live density in 2009	6.0	3.5	0.6	<0.001
Live plant BA in 2009	486.0	127.5	24.1	<0.001
Dead density in 2009	0.1	0.5	0.3	0.090
Dead plant BA in 2009	30.4	35.8	22.0	0.611
Seedling density in 2009	0.3	1.8	0.6	0.328
Soil seed bank density in 2009	14.3	5.0	0.0	0.093
No. of observations	8	28	13	

The *Astrebla* soil seed bank levels in good condition sites in 2006 were comparable with soil seed banks of 200 seeds/m^2 recorded in 1982 and 1988 at Gilruth Plains near Cunnamulla (Orr 1991) and Toorak Research Station near Julia Creek (Orr 1998). Recruitment of 15 and 30 seedlings/m^2, respectively, over the following summer led to recovery of *Astrebla* density and basal area following drought (Orr and Phelps 2010). The high soil seed bank in the current study in 2006 did not appear to translate into new tussocks or widespread improvement in land condition by 2009. Further analysis of site data is needed to determine if this was due to poor timing of rainfall, potential competition from annual plants or another reason.

The *Astrebla* soil seed bank levels in 2009—even in good condition sites—were inadequate to promote a seedling led recovery from drought and poor land condition. As a generalisation, 10% of the seed in the soil seed banks can establish as seedlings, and 10% of these seedlings can survive through to mature tussocks. This gives a potential of about 0.01 new tussocks/m^2 at good condition sites. Poor condition sites had no detectable *Astrebla* seed in the soil in 2009.

Annual grasses dominated the 2009 soil seed bank, especially in poor condition sites (P=0.012; A=570; B=1940; C=3575 seeds/m^2). The high annual grass seed levels in poor condition sites indicate that annual grass seedlings would compete strongly with *Astrebla* seedlings for moisture and nutrients and reduce their chance of survival, even if there was adequate seed in the soil (Orr and Evenson 1993).

Higher *Astrebla* density and basal area in good condition sites in both 2006 and 2009 indicate a much better ability to respond to rain and recover quickly from drought. This is reinforced by the higher yields at good condition sites, especially in 2009 following rain.

Pre-drought land condition may have affected the risk of declining to poor condition during the drought. Pre-drought land condition was estimated during the 2006 measurements based on site visual assessments, total *Astrebla* density and basal area and soil seed bank data—31 were in A condition and 18 in B condition. No sites were in C condition before the drought started. During drought, *Astrebla* tussocks are clearly visible as raised areas with standing dead tillers or clearly defined crowns, and generally do not break down and disappear until the drought breaks. Livestock tend to avoid these remnant tussocks during grazing and so trampling does not hasten their break-down, unless stock numbers are high. Poor condition sites are readily recognisable through the absence of these remnant *Astrebla* tussocks, although visually distinguishing between A and B condition may be imprecise.

Of the A condition sites, 45% declined to B condition in 2006 and 26% to C condition. Of the B condition sites, 50% declined to C condition in 2006. It appears that sites in A condition had greater drought resilience presumably due to better living *Astrebla* and better soil seed banks.

Considering that all sites were in good (A or B) condition before the drought, it is apparent that good condition sites are susceptible to the negative impacts of drought and failed summers. In particular, 14 of the 26 sites (54%) with at least one failed summer declined to poor condition whilst only 2 (9%) without a failed summer declined to poor condition.

A successful drought management strategy will aim to keep land in good condition to reduce the risk of declining land condition during drought—unfortunately it does not eliminate the risk entirely.

4.2 Management impacts

Of the 49 sites measured, 24 (12 pairs) demonstrated differences ($P<0.05$) in 2006 due to burning or grazing, based on the factors of *Astrebla* seedling density, *Astrebla* tussock density and size (both live and dead) and soil seed bank functional groups. These differences persisted into 2009 (Table 5, Phelps *et al*. 2007a, Appendices 9.2 and 9.3). Four burnt pairs and one wet season spell pair failed to show differences in either 2006 or 2009.

The three burnt sites with superior pasture condition, relative to their paired sites, were in the Longreach district. One site was burnt in January 1999 (Arrowfield), one in March/April 2001 (Rodney Downs) and one in December 2002 (Glenferrie). Each site was rested over the summer following burning and did not experience significant grazing pressure from kangaroos.

Of the four sites where burning made no difference, one was an historical burn scar from January 1992 (Langdale) where a hot summer fire impacted land condition, one site burnt in February 2000 (Kaloola) and received subsequent heavy grazing pressure from kangaroos, one burnt during January 2001 (Camara) and one burnt in March 2003 during the drought (Whitehill). The lack of difference at these sites can be explained through a) the burnt area being restored in the 14 years since the fire (Langdale), b) heavy grazing pressure associated with adjacent wooded areas (Kaloola) and c) burning during drought associated with a low R/E Index (Whitehill). The lack of difference in the paired site at Camara is perplexing. Visually, there was an obvious difference with the burnt area judged to be in A condition and the un-burnt area in C condition in 2009. Pasture yield, live *Astrebla* density and basal area were higher in the burnt site in both 2006 and 2009 than in the un-burnt site. In this instance the Discriminant Analysis (DA) appears to have grouped the sites based on soil seed bank composition and the differences in other measures were undetectable.

Burning can stimulate *Astrebla* spp. tillering, seed production and yield, at least when fire is followed by above average rainfall (Scanlan 1980; 1983). In another study, *Astrebla* spp. tillering, basal area and survival was not affected by burning at the start of a below-average growing season (Phelps 2006). It is possible that a single burn sometime prior to drought conditions could promote *Astrebla* spp. survival during drought, perhaps through the promotion of new tillers and root growth. When burning is coupled with high grazing pressure over the subsequent summer, however, the interaction is generally detrimental to perennial grass survival (Orr *et al.* 1991; Orr and Paton 1993; 1997; Orr 2004). The range of responses found in the current study suggests that fire in the period before the onset of drought can reduce extent of drought-induced dieback, but the mechanisms are not clear. Our understanding of the timing of fire, the type of fire and the precedent and the antecedent soil moisture levels required to successfully use fire as a drought management tool are inadequate to make any management recommendations at this stage.

The wet-season spell site which demonstrated a superior density of surviving *Astrebla* spp. tussocks was within a laneway which has been grazed heavily by sheep for 3-6 weeks every winter during shearing for at least the last 20 years. The laneway is ungrazed for the rest of the year. Discussions with the land-holder suggest that residual stubble height is generally less that 10cm. The state of this pasture, relative to other areas on the property, during the height of the drought was spectacular. Mitchell grass tussocks had grown new tillers from the crown, set seed and pasture yield was estimated to range between 800 and 2000 kg/ha of dry matter. In contrast, tussocks in the adjacent paddock failed to tiller, and hence did not set seed, and yields ranged from 150 to 500 kg/ha. This strong difference was not as apparent in 2009—suggesting that above-ground assessment during improved growing conditions may not be a reliable indicator of resilience to drought.

There was a positive correlation between greater frequency and duration of spelling and live *Astrebla* basal area in 2009 (Appendix 9.4). This is consistent with bio-economic modelling which demonstrated greater perennial grass increase over time with more frequent and longer-duration wet season spelling (J Scanlan, unpublished).

Table 5. Paired sites with significant differences (P<0.05) due to management factors

Site name	***Burning***	***Grazing system***
Arrowfield burn	Burnt in January 1999	Opportunistic rotational
Arrowfield unburn	Not burnt	Opportunistic rotational
Dundonald Lane		Wet season spell with annual heavy grazing in winter
Dundonald Paddock		Conservative continuous
E/ Bandon Grove Hvy Graze		Consistently heavy
E/ Bandon Grove Lt Graze		Conservative continuous
Glenferrie burnt	Burnt in December 2002	Opportunistic rotational
Glenferrie unburnt	Not burnt	Opportunistic rotational
Kaloola wether 1		Opportunistic rotational
Kaloola wether 2		Opportunistic rotational
Langdale No rain		Conservative, occasional spell
Langdale Rain		Conservative, occasional spell
Malakoff 1		Conservative, occasional spell
Malakoff 2		Conservative, occasional spell
Rodney Downs Burnt	Burnt in April 2001	Opportunistic rotational
Rodney Downs Unburnt	Not burnt	Opportunistic rotational
Rosebank #1		Conservative continuous
Rosebank#2		Conservative continuous
Strathmore 1		Conservative continuous
Strathmore 2		Consistently heavy
Toorak 10-50%		Very light to heavy grazing
Toorak 80%		Very heavy, spelled in 1997/98 wet season
Whitehill holding pdk		Occasional moderate grazing
Whitehill ungrazed		Conservative, occasional spell

General discussion

Country which remains in good condition during drought has a greater chance of recovering quickly. Drought-affected Mitchell grass pastures can only recover through improvement in the density and size of surviving *Astrebla* tussocks. In drought-affected pastures where land condition is still good, this may occur rapidly with the onset of improved growing conditions as drought-dormant tussocks respond to rain. Where land is in poor condition live *Astrebla* tussocks are sparse. Individual tussocks may recover rapidly but overall land condition can only improve with an increase in *Astrebla* density. A key question for the current project to answer was if this recovery could occur from seedlings establishing from seed in the soil or if recovery was dependent on existing tussocks responding, seeding and replenishing the seed in the soil ready for germination.

The re-assessment of the 49 sites of contrast in 2009 showed limited improvement in land condition as the drought started to break over the 2008/09 summer. Live *Astrebla* basal area had increased from 2006 as existing tussocks grew in size or separated into new plants which then increased in size. Pasture yield was much higher in 2009 than in 2006 as would be expected with improved growing conditions.

There was no evidence of mass recruitment of *Astrebla* seedlings promoting recovery and no evidence of a large reserve of *Astrebla* seed in the soil to promote recovery from seedling establishment. The recovery pathway was thus dominated by vegetative reproduction and suggests that the key management action during drought recovery is to ensure individual *Astrebla* tussocks are protected from overgrazing. In situations where land condition is poor during drought, protecting individual *Astrebla* tussocks may be crucial to ensuring effective drought recovery. This is consistent with the findings of Orr (1991) who report that *Astrebla* soil seed banks persist for only 3-4 years and that a fresh crop of seed is needed to recharge the soil seed bank before mass-germination is possible.

Whilst good growing conditions (i.e. a high Rainfall/Evaporation Index) are a prerequisite of recovery from drought and improved land condition there was evidence that management plays a crucial role. The processes involved in selective grazing of *Astrebla* have been well documented (e.g. Orr 1975; 1978; 1980a; 1980b; Orr and Holmes 1984; Orr 1998) and high grazing pressure during drought are likely to exacerbate mortality and lead to declining land condition. Conversely, light grazing pressure and/or spelling whilst *Astrebla* tussocks are actively growing will help promote the survival of these tussocks ready for drought recovery.

Land type may interact strongly with drought and management, although the current study sites were not established in a way to specifically explore this aspect. The few Wooded Downs sites in the study retained good condition from 2006 to 2009; the Open Downs sites tended to be in good condition but the Ashy Downs sites were dominated by poor condition in both 2006 and 2009. The management required—and pasture dynamics—within the Ashy Downs land type appears to be different enough to warrant further investigation, especially given the predominance of poor condition country on Ashy Downs reported by Phelps *et al* (2007a). A useful starting point would be to conduct a desktop spatial analysis to explore rainfall and evaporation patterns (using SILO data) in relation to MODIS greenness, site location and land types. This would also provide additional data relating to the R/E Index and failed summers and allow this to be coupled with the length of the growing season and ground cover indices at sites.

The current study reinforced two elements of uncertainty in assessing drought-related land condition in the Mitchell grasslands:

- Simple techniques for distinguishing dead from drought-dormant tussocks (e.g. the tussock tug/kick to determine anchorage, root stripping to detect moisture and butt squeeze to check if rhizomes are living or dead, Phelps and Rolfe 2005) are just guides. Where even a single *Astrebla* rhizome remains alive within a tussock, recovery can be rapid once growing conditions improve.

- The decay of dead tussocks precludes the accurate assessment of pre-drought land condition once the drought breaks. Other studies (e.g. Phelps 2006) also suggest the breakdown and disappearance of dead tussocks is more rapid under heavy grazing pressure.

The land condition measures we are currently using may not be good indicators of drought resilience. For instance the paired wet season spelling sites in Dundonald Paddock and Lane were judged to both return to good condition in 2009 despite the spelled Lane being obviously better in pasture yield and *Astrebla* tussock health and seed set than the continuously grazed paddock during the drought.

A simple field technique to better indicate drought resilience may be possible based on brushing soil away from *Astrebla* crowns and counting the exposed roots. Phelps (unpublished data) determined separate relationships between the number of crown-initiated roots and total root weight ($P<0.001$), crown weight ($P<0.001$) and tiller weight ($P<0.001$) in a study where 18 Mitchell grass plants were grown under differing moisture and defoliation levels. Crown weight was also a predictor ($P<0.001$) of root weight. Good Land Condition is strongly associated with high live *Astrebla* basal area and hence high crown weight, and the positive relationship between root mass and a grass's ability to seek moisture and nutrients is well understood. The relationship between the number of roots visible after brushing soil away from the crown and total roots would first need to be determined by extracting whole plants from the field.

Rainfall variability is recognised as extreme across the Mitchell grasslands with the most recent extended drought being a case in point. Predictions under climate change scenarios (DERM 2009) include reduced rainfall falling in fewer—yet more intense—events and evaporation increasing as temperatures increase. The risk of drought or at least longer dry seasons—and shorter pasture growing seasons—would increase as a result.

The best predictions by 2030 are:

- Annual and seasonal temperature: annual mean temperature (the average of all daily temperatures within a given year) is projected to increase by 1.1°C. There is little variation in projections across the seasons.
- Annual and seasonal rainfall: annual rainfall (the total rainfall received within a given year) is projected to decrease by three per cent (-11 mm). The largest seasonal decrease of eight per cent (-5 mm) is projected for spring.
- Annual and seasonal potential evaporation: across all seasons the annual 'best estimate' increase is projected to be around three per cent (87 mm), with some models projecting up to a six per cent increase in autumn (39 mm) and winter (25 mm).

There is no clear indication at this stage if these changes would lead to more failed wet seasons where the R/E Index remains below 0.15 for the summer. However, this seems to be a distinct possibility and industry will need the management tools to both hasten the recovery from drought and to prevent drought contributing to poor land condition. DERM (2009) suggest that deep soil cracking will increase with more frequent or intense droughts—this may be exacerbated in the Ashy Downs. They also suggest that the net impact of a lower moisture regime and higher atmospheric CO_2 is likely to be reduced quantity and quality of pasture resulting in lower carrying capacities, animal production and enterprise viability.

There are challenges ahead for grazing management in the Mitchell grasslands—even if the climate change predictions are overstated. The current project has reinforced the need to adjust stocking rates to match the feed on offer and to implement growing season spelling.

Recent bio-economic modelling (Scanlan, McLeod unpublished) suggest there are few economic advantages in adjusting stock numbers beyond 40% of the long-term carrying capacity. Mitchell grass country may well need stock reductions in the order of 60-90% of pre-drought numbers to preserve land condition. The modelling has not been used to explicitly explore drought management and so has not included reductions of such magnitude. If the frequency of drought increases as climate change progresses, drought management will become increasingly important. Key questions to be addressed include:

- What role does spelling have during drought years, and how crucial is timing of rest compared with the duration?
- What level of de-stocking is required to maintain land condition through safe utilisation levels?
- What are the financial and land condition risks associated with failing to adequately reduce stock numbers?

4.3 Refined management guidelines for responding to variable climatic conditions

There are three stages in managing for drought in Mitchell grass country:

1. building resilience ready for drought
2. managing during drought
3. promoting recovery from drought.

4.3.1 Building drought resilience

Maintaining land in good condition is the best option to build drought resilience. Whilst having country in good condition going into drought does not prevent a failed summer from killing *Astrebla*, it does maximise the chances of retaining country in good condition as the drought breaks. Country in poor condition going into a drought has very little chance of a quick recovery as *Astrebla* density is low, basal area is low, seed production is restricted and soil seed banks are low. There is no opportunity to improve land condition during drought.

The key management action to maintain Mitchell grass country in good condition is to vary stock numbers around the safe long-term carrying capacity to stay within the safe utilisation rate. This may be supplemented by wet season spelling to maximise tussock size and—presumably—encourage root growth and hence maximise infiltration rates whilst maximising soil seed reserves. Phelps (unpublished) has demonstrated that spelling establishing *Astrebla* seedlings for five months promotes root and crown growth compared with heavily defoliated seedlings—even when defoliation is delayed by six weeks. There have been no studies of the role of spelling in encouraging the root growth of mature *Astrebla* tussocks.

4.3.2 Managing during drought

Retaining as high a density of live tussocks as possible maximises the potential for recovery. This is likely to occur more from remnant tussocks than from new seedlings—even with tussocks that appear to have low plant vigour. When conditions are right for mass germination of seedlings, the amount of available seed is greater when country is in good condition. It may be possible to maximise rainfall infiltration during drought by maintaining live basal cover. Transient ground cover in the inter-tussock spaces is likely to be low during drought regardless of management.

The key management action to maintain Mitchell grass country in good condition during drought is to reduce stock numbers well below the safe carrying capacity, preferably to a level consistent with the safe utilisation rate. A failed wet season may still lead to *Astrebla* death and reduced land condition during drought but the evidence that overgrazing will further reduce land condition is incontrovertible.

The theory associated with wet season spelling suggests it to be an essential management action during drought to protect already stressed *Astrebla* tussocks. One site (Dundonald Lane) adds weight to this theory, as do case studies of the benefits of de-stocking during drought (e.g. Phelps 2008 p17). During drought it may be important to spell whenever conditions suit Mitchell grass growth, such as the flush of growth in the winter of 2006.

4.3.3 Promoting drought recovery

The management to promote drought recovery differs for country in good compared with poor condition. In each case drought breaking rains are a prerequisite for recovery to occur and management needs to concentrate on allowing remnant Mitchell grass plants—often of low vigour—to take advantage of rains to expand in size, promote root growth and go to seed. This is best achieved by spelling or keeping stock numbers at low levels until recovery has occurred.

The key management action for country in good condition is to keep the stocking rate low for the first few months of the wet season until the majority of Mitchell grass plants in the pasture have gone to seed. Delaying an increase in stock numbers will ensure a low utilisation rate during the crucial early growth phases and allow Mitchell grass to re-build energy reserves, re-establish roots and replenish the soil seed bank. This may be supplemented by early wet season spelling to further promote root growth and seedling establishment. Good condition country will recover faster from tussock regrowth than poor condition country and may recover over a single summer as tussock density and basal area increase.

Poor condition country needs the combination of maintaining low stocking rates and implementing full wet season spelling over a number of wet seasons. The scattered living *Astrebla* tussocks need to be encouraged to increase in size and produce seed to re-build soil seed banks so that seedlings can establish in subsequent summers. Once seedlings germinate, spelling for 5-6 months over the wet season will encourage crown and root development to promote survival during the following dry season. With adequate soil moisture seedlings may mature and set seed over a single wet season (Phelps, unpublished). Overall, this recovery process may take 3-5 years: 1-2 years for established tussocks to replenish the soil seed banks and 2-3 years for seedlings to become established tussocks able to survive the next drought. Bio-economic modelling (Scanlan, McLeod unpublished) suggests that improving land condition through wet season spelling provides better returns than allowing the country to remain in poor condition.

If the drought has been short (1-2 years) recovery may occur through seedling establishment—especially in good condition country where soil seed banks are replenished through existing tussocks producing seed. If the drought has been prolonged (more than 3-5 years) then *Astrebla* soil seed banks are likely to be almost fully depleted due to the decay of seed in the soil and the lack of new seed being added to the soil seed bank. Recovery from prolonged drought appears to be dependent on existing tussock density alone.

4.4 Future research and extension direction

The recommendation that poor condition *Astrebla* country cannot recover from prolonged drought though soil seed banks alone is confounded by stories of bare paddocks recovering after decades, and by the early suggestion of Everist (1934) that viable *Astrebla* seed can remain buried at depth for decades before rising to the surface and germinating. There has always been an assumption that Mitchell grass country can recover based on viable soil seed banks persisting. The current study suggests that a persistent soil seed bank is unlikely to exist. Low-cost seed burial experiments to follow *Astrebla* buried seed longevity and field sampling and sieving for *Astrebla* spikelets are required to clarify these ‘management myths’ after 70 years of speculation.

There is inadequate understanding of how the timing and regime of fire/grazing prior to drought may influence resistance to dieback. The results suggest there is a complex process involved, which may be better understood through small scale pot or plot studies. This could be the subject of an MLA supported postgraduate student project.

There would be benefits in remeasuring the sites of contrast in 2011 or 2012, following the exceptionally wet period from July 2010 through to March 2012. This would clarify if:

- land condition has generally improved following a second above average wet season
- existing contrasts in land condition have persisted following the well above-average rains
- the *Astrebla* soil seed bank has increased
- the *Astrebla* soil seed bank is greater in good condition compared with poor condition country.

The collection of duplicate samples of the soil seed bank is recommended, with one set used for counting *Astrebla* spikelet density on collection (to provide immediate results) and the other for germinating out (to provide overall species results for analysis). This knowledge would provide additional insights or caveats to improve the current management recommendations.

The management recommendations from the current study should be linked with Northern Grazing Systems (NGS) initiative on-property demonstration and extension activities. The fact sheet publication from the current study will have greater impact if integrated with and delivered through NGS.

The potential root count technique to assess drought resilience is especially relevant to current NGS projects on managing for a variable and changing climate and could be field tested on the Mitchell grassland demonstration property.

Desktop modelling of drought specific management options and responses should be undertaken within Grasp and Enterprise using the existing NGS Mitchell grassland representative property parameters. In particular, it would be worth exploring more variable stocking rates and spelling during drought periods independent of other rainfall windows. It would also be beneficial to explore the difference in starting wet season spelling within a drought window and at the start of a drought recovery window and to explore potential benefits of spelling when Mitchell grass growth occurs in any season.

There would be benefits in a spatial desktop analysis to further tease out the rainfall and evaporation patterns based on MODIS greenness and the ground cover index to investigate the possible differential impact of drought on the Ashy Downs land type. If the suspected differences are identifiable, then different management actions will need to be developed to reduce the risk of further degradation across the Ashy Downs.

5 Success in achieving objectives

The objectives of this project have been successfully achieved:

1. Updated management guidelines for accelerating the recovery of Mitchell grass pastures following severe drought, including the relative importance of new plants vs. surviving tussocks, have been determined. It is in now clear that recovery from seed in the soil cannot be relied on and that reducing utilisation levels and wet season spelling are crucial for promoting recovery from drought.
2. Management guidelines for responding to more variable climatic conditions concentrate on promoting *Astrebla* tussock health – and with a view to promote and monitor root growth.
3. A fact sheet updating current knowledge of Mitchell grass recovery from severe drought will be published by June 2011 once integrated with NGS activities and publications.

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

Economic modelling suggests that the value of cattle production from Queensland's Mitchell grasslands is reduced by $58.5 to $92.4 million per annum for each year that poor land condition persists (Phelps *et al*. 2007a). Despite increases in pasture yield with increased rainfall, only 26% of sites improved in condition, and the long-term carrying capacity at the majority of sites remains compromised in 2009.

The first phase of this research increased industry's understanding of the severity, extent and economic impact of drought dieback in Mitchell grass and encouraged debate over the need to change management practices for sustainability.

The second phase suggests that drought resilience is maximised by maintaining good land condition—with an obvious link to the Northern Grazing Systems (NGS) initiative on managing for a variable and changing climate, including on-property demonstrations and extension activities.

7 Conclusions and recommendations

Recovery of drought-affected Mitchell grass pastures from seed in the soil cannot be relied upon, and the population of residual healthy tussocks determines the rate of recovery. This reinforces the need for managing utilisation and employing wet season spelling during and after extended drought conditions.

Additional field and desktop research is needed to confirm and further develop the management recommendations derived from the monitoring data to date:

- Desktop spatial studies to determine if different management actions are needed for Ashy Downs
- Desktop bio-economic modelling
- Field collection of soils to check for the viability of *Astrebla* seed at depth, and to estimate the persistence of the *Astrebla* soil seed bank
- A third measurement of the sites of contrast following the well above-average rains of 2010/11
- Development of a drought resilience field technique based on visible *Astrebla* crown root density.

This work has advanced our knowledge of the recovery processes of drought affected Mitchell grasslands and consolidated the importance of keeping country in good condition.

8 Bibliography

ABS (2005). Agriculture Survey, 2001-2004. Area and Production of all Commodities, Australia. Queensland total and Queensland by Statistical Division, Australian Bureau of Statistics. **2006**.

Chilcott, C.R., Milson, J.A. and Phelps, D.G. (2007). "Grazing Land Management Education Package Workshop Notes - Mitchell Grasslands", Meat and Livestock Australia Limited, Sydney.

DERM (2009) (http://www.climatechange.qld.gov.au/pdf/regionsummary-cwq.pdf accessed 29th March 2011)

Everist, S.L. (1935). Inland Pastures. Part II. Response during 1934 season of Mitchell and other grasses in western and central Queensland. *Queensland Agricultural Journal* **43**: 274-87.

Everist, S.L. (1939). Some notes on the Springsure and Clermont districts, July 1938.

Everist, S.L. (1964). The Mitchell grass country. *Queensland Naturalist* **17**: 45-50.

Forrest, P. (1988). "A Rush for Grass", Murranji Press. Ilfracombe Shire Council.

GenStat (2007). GenStat for Windows. Release 9.2, Lawes Agricultural Trust (Rothamsted Experimental Station).

Hodgkinson, K.C. and Müller, W.J. (2005). Death model for tussock perennial grasses: a rainfall threshold for survival and evidence for landscape control of death in drought. *The Rangeland Journal* **27**: 105-15.

Jeffrey, S.J., Carter, J.O., Moodie, K.B. and Beswick, A.R. (2001). Using spatial interpolation to construct a comprehensive archive of Australian climate data. *Environmental Modelling Software* **16**: 309-30.

Jones, R.M. and Bunch, G.A. (1988). A Guide to Sampling and Measuring the Seed Content of Pasture Soils and Animal Faeces, CSIRO Australia Division of Tropical Crops & Pastures**:** 13.

Orr, D.M. (1975). A review of *Astrebla* (Mitchell grass) pastures in Australia. *Tropical Grasslands* **9**: 21-36.

Orr, D.M. (1978). Effects of sheep grazing *Astrebla* spp. grassland in central western Queensland. Department of Agricultural Science. Brisbane, University of Queensland.

Orr, D.M. (1980a). Effects of sheep grazing *Astrebla* grassland in central-western Queensland I. Effect of grazing pressure and livestock distribution. *Australian Journal of Agricultural Research* **31**: 797-806.

Orr, D.M. (1980b). Effects of sheep grazing *Astrebla* grassland in central-western Queensland II. Effects of seasonal rainfall. *Australian Journal of Agricultural Research* **31**: 807-20.

Orr, D.M. (1991). Trends in the recruitment of *Astrebla* spp. in relation to seasonal rainfall. *Rangeland Journal* **13**: 107-17.

Orr, D.M. (1998). A life cycle approach to the population ecology of two tropical grasses in Queensland, Australia. *In* "Population Biology of Grasses". G.P. Cheplick. Cambridge, University of Cambridge Press**:** 366-89.

Orr, D.M. (2004). Dynamics of plant populations in *Heteropogon contortus* (black speargrass) pastures on a granite landscape in southern Queensland. 4. The effects of burning on *H. contortus* and *Aristida* spp. populations. *Tropical Grasslands* **38**: 77-87.

Orr, D.M. and Evenson, C.J. (1993). A glasshouse study of competition between *Astrebla lappacea* (curly Mitchell grass) and two associate species. *Rangeland Journal* **15**: 298-301.

Orr, D.M. and Holmes, W.E. (1984). Mitchell Grasslands. *In* "Management of Australia's Rangelands". G.N. Harrington, M.D. Young and A.D. Wilson. Melbourne, CSIRO**:** 241-54.

Orr, D.M., McKeon, G.M. and Day, K.A. (1991). Burning and exclosure can rehabilitate degraded black speargrass (*Heteropogon contortus*) pastures. *Tropical Grasslands* **25**: 333-6.

Orr, D.M. and Paton, C.J. (1993). Fire and grazing interact to manipulate pasture composition in *Heteropogon contortus* (black speargrass) pastures. Proceedings of the XVII International Grasslands Congress, Palmerston North, New Zealand and Rockhampton, Australia.

Orr, D.M. and Paton, C.J. (1997). Using fire to manage species composition in *Heteropogon contortus* (black speargrass) pastures 2. Enhancing the effects of fire with grazing management. *Australian Journal of Agricultural Research* **48**: 803-10.

Orr, D.M., Paton, C.J. and Blight, G.W. (1996). An improved method for measuring the germinable soil seed banks of tropical pastures. *Tropical Grasslands* **30**: 201-5.

Orr, D.M. and Phelps, D.G. (2004). Long term responses of *Astrebla* spp. (Mitchell grass) tussocks to rainfall in north-western Queensland. Proceedings 13th Australian Rangelands Conference, Alice Springs, Australia.

Orr, D. M. and Phelps, D.G. (2010). The occurrence and causes of episodic recruitment of *Astrebla* spp. Proceedings of the Australian Rangeland Society Conference, Bourke September 2010.

Phelps, D.G. (2006). Controlling *Aristida latifolia* (feathertop wiregrass) in *Astrebla* spp. (Mitchell grass) grasslands with fire and grazing. The Sciences (Agronomy and Rural Science). Armidale, University of New England**:** 238.

Phelps, D.G. (2008). Gaining from training-stories from successful graziers DPI&F Brisbane PR08-4129.

Phelps, D.G., Orr, D.M. and Houston, I. (2007a). "Mitchell grass death in Qld: extent, economic impact and potential for recovery ". North Sydney, Meat and Livestock Australia**:** 57.

Phelps, D.G., Orr, D.M., Rolfe, L. and Houston, I. (2007b). "Rain waiter or decision maker? Managing Mitchell grass during drought". Longreach, Department of Primary Industries & Fisheries.

Phelps, D.G. and Rolfe, L. (2005). "Mitchell grass response and suggested management guidelines based on research and grazier experience". Longreach, Department of Primary Industries & Fisheries.

Phelps, D.G., Rolfe, L. and Houston, I. (2005). "Drought recovery. Tillers, to be grazed or saved?" Longreach, Department of Primary Industries & Fisheries.

Scanlan, J.C. (1980). Effects of spring wildfires on *Astrebla* (Mitchell grass) grasslands in north-west Queensland under varying levels of growing season rainfall. *Australian Rangeland Journal* **2**: 162-8.

Scanlan, J.C. (1983). Changes in tiller and tussock characteristics of *Astrebla lappacea* (curly Mitchell grass) after burning. *Australian Rangeland Journal* **5**: 13-9.

Tothill, J.C., Hargreaves, J.N.G., Jones, R.M. and McDonald, C.K. (1992). "BOTANAL - A comprehensive sampling and computing procedure for estimating pasture yield and composition 1. Field sampling", CSIRO Australia Division of Tropical Crops & Pastures, Tropical Agronomy Technical Memorandum No.78.

Weston, E.J. (1988). Native pasture communities. *In* "Native pastures in Queensland". W.H. Burrows, J.C. Scanlan and M.T. Rutherford. Brisbane, Queensland Department of Primary Industries. Information Series QI87023**:** 21-33.

Whalley, R.D.B. and Davidson, A.A. (1968). Physiological aspects of drought dormancy in grasses. *Proceedings of the Ecological Society of Australia* **3**: 17-9.

Whalley, R.D.B. and Davidson, A.A. (1969). Drought dormancy in *Astrebla lappacea*, *Chloris acicularis* and *Stipa arisitglumis*. *Australian Journal of Agricultural Research* **20**: 1035-42.

9 Appendices

9.1 Table of sites of contrast including statistical summary from Discriminant Analysis for 2006 and 2009 data

Site name	Site condition pre-2006	Site Condition 2006	Site Condition 2009	Land Type	Burning	Grazing system	Number of failed wet seasons	Multivariate group	Paired difference (2009)	Paired difference (2006)
Accord Access	B	C	C	Ashy Downs	Not burnt	Conservative, WSS	1	1	NS	NS
Accord Bendigo	B	C	B	Ashy Downs	Not burnt	Conservative, WSS	1	1	NS	NS
Accord Outback	B	C	C	Ashy Downs	Not burnt	Conservative, occasional spell	1	1	NS	NS
Accord Railway	B	C	C	Ashy Downs	Not burnt	Heavy summer, then spelled	1	1	NS	NS
Arrowfield burn	A	B	B	Wooded Downs	Burnt in January 1999	Opportunistic rotational	1	4	P<0.05	P<0.05
Arrowfield unburn	A	B	B	Wooded Downs	Not burnt	Opportunistic rotational	1	3	P<0.05	P<0.05
Beeantha #1	A	A	A	Ashy Downs	Not burnt	Heavy summer, then spelled	0	3	N/S	N/S
Beeantha #2	A	B	B	Open Downs	Not burnt	Consistently heavy	0	3	N/S	N/S
Camara burnt	B	B	A	Open Downs	Burnt in January 2001	Conservative, occasional spell	1	1	N/S	N/S
Camara unburnt	B	B	C	Open Downs	Not burnt	Conservative, occasional spell	1	1	N/S	N/S
Dundonald Lane	A	A	A	Open Downs	Not burnt	Occasional heavy grazing	0	3	P<0.05	P<0.05
Dundonald Paddock	A	B	A	Open Downs	Not burnt	Conservative continuous	0	2	P<0.05	P<0.05
E/ Bandon Grove Hvy Graze	B	C	B	Open Downs	Not burnt	Consistently heavy	1	4	P<0.05	P<0.05

Site name	Site condition pre-2006	Site Condition 2006	Site Condition 2009	Land Type	Burning	Grazing system	Number of failed wet seasons	Multivariate group	Paired difference (2009)	Paired difference (2006)
E/ Bandon Grove Lt Graze	A	B	B	Open Downs	Not burnt	Conservative continuous	1	3	P<0.05	P<0.05
Glenferrie burnt	B	B	A	Ashy Downs	Burnt in December 2002	Opportunistic rotational	1	3	P<0.05	P<0.05
Glenferrie unburnt	B	C	B	Ashy Downs	Not burnt	Opportunistic rotational	1	1	P<0.05	P<0.05
Kaloola burn	A	B	B	Wooded Downs	Burnt in February 2000	Opportunistic rotational	1	1	N/S	N/S
Kaloola unburn	A	B	B	Wooded Downs	Not burnt	Opportunistic rotational	1	1	N/S	N/S
Kaloola wether 1	B	C	B	Ashy Downs	Not burnt	Opportunistic rotational	1	1	P<0.05	P<0.05
Kaloola wether 2	A	B	B	Open Downs	Not burnt	Opportunistic rotational	1	3	P<0.05	P<0.05
Langdale burn	A	C	C	Ashy Downs	Burnt in January 1992	Conservative, occasional spell	2	1	N/S	N/S
Langdale unburn	A	C	C	Ashy Downs	Not burnt	Conservative, occasional spell	2	5	N/S	N/S
Langdale No rain	B	C	B	Ashy Downs	Not burnt	Conservative, occasional spell	2	1	P<0.05	P<0.05
Langdale Rain	A	B	B	Open Downs	Not burnt	Conservative, occasional spell	2	4	P<0.05	P<0.05
Loongana laneway	A	C	B	Open Downs	Not burnt	Occasional heavy grazing	1	1	N/S	N/S
Loongana paddock	A	C	B	Open Downs	Not burnt	Conservative, WSS	1	1	N/S	N/S
Malakoff 1	B	B	B	Open Downs	Not burnt	Conservative, occasional spell	0	1	P<0.05	P<0.05
Malakoff 2	B	B	B	Open Downs	Not burnt	Conservative, occasional spell	0	2	P<0.05	P<0.05

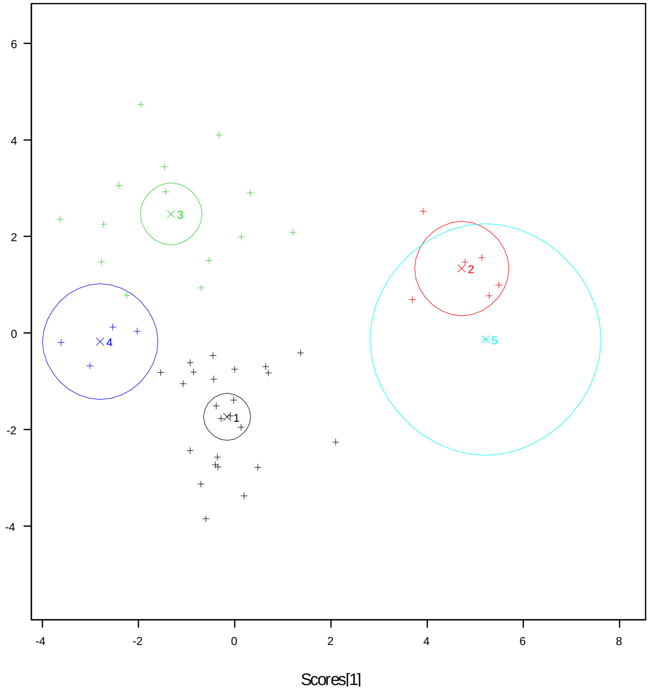
Site name	Site condition pre-2006	Site Condition 2006	Site Condition 2009	Land Type	Burning	Grazing system	Number of failed wet seasons	Multivariate group	Paired difference (2009)	Paired difference (2006)
Norwood Waterford	B	B	B	Open Downs	Not burnt	Conservative continuous	0	3	N/S	N/S
Norwood Wilsons	A	A	B	Open Downs	Not burnt	Regular spelling	0	3	N/S	N/S
Redland Park Common 1	A	A	B	Open Downs	Not burnt	Consistently heavy	0	1	N/S	N/S
Redland Park Common 2	A	A	C	Open Downs	Not burnt	Consistently heavy	0	1	N/S	N/S
Redland Park Coomara	A	A	C	Open Downs	Not burnt	Conservative, occasional spell	0	1	N/S	N/S
Redland Park Landsborough	A	A	C	Open Downs	Not burnt	Heavy summer, then spelled	0	1	N/S	N/S
Rodney Downs Burnt	A	B	A	Ashy Downs	Burnt in April 2001	Opportunistic rotational	0	3	$P<0.05$	$P<0.05$
Rodney Downs Unburnt	A	C	C	Ashy Downs	Not burnt	Opportunistic rotational	0	1	$P<0.05$	$P<0.05$
Rosebank #1	A	B	B	Open Downs	Not burnt	Conservative continuous	0	4	$P<0.05$	$P<0.05$
Rosebank#2	B	B	B	Open Downs	Not burnt	Conservative continuous	0	3	$P<0.05$	$P<0.05$
Strathmore 1	A	A	A	Open Downs	Not burnt	Conservative continuous	0	3	$P<0.05$	$P<0.05$
Strathmore 2	A	C	C	Open Downs	Not burnt	Consistently heavy	0	1	$P<0.05$	$P<0.05$
Toorak 10%	A	A	B	Open Downs	Not burnt	Very light grazing	0	2	N/S	N/S
Toorak 20%	A	B	B	Open Downs	Not burnt	Very light grazing	0	2	N/S	N/S
Toorak 30%	A	B	B	Open Downs	Not burnt	Conservative continuous	0	2	N/S	N/S
Toorak 50%	B	C	B	Open Downs	Not burnt	Conservative continuous	0	2	N/S	N/S
Toorak 80%	B	B	A	Open Downs	Not burnt	Very heavy winter, then spelled	0	3	$P<0.05$	$P<0.05$

Site name	Site condition pre-2006	Site Condition 2006	Site Condition 2009	Land Type	Burning	Grazing system	Number of failed wet seasons	Multivariate group	Paired difference (2009)	Paired difference (2006)
Whitehill fire site burnt	A	C	C	Open Downs	Burnt in March 2003	Conservative, occasional spell	1	1	N/S	N/S
Whitehill fire site unburnt	A	C	C	Open Downs	Not burnt	Conservative, occasional spell	1	1	N/S	N/S
Whitehill holding pdk	A	B	B	Open Downs	Not burnt	Occasional moderate grazing	1	1	P<0.05	P<0.05
Whitehill ungrazed	B	B	B	Open Downs	Not burnt	Conservative, occasional spell	1	3	P<0.05	P<0.05

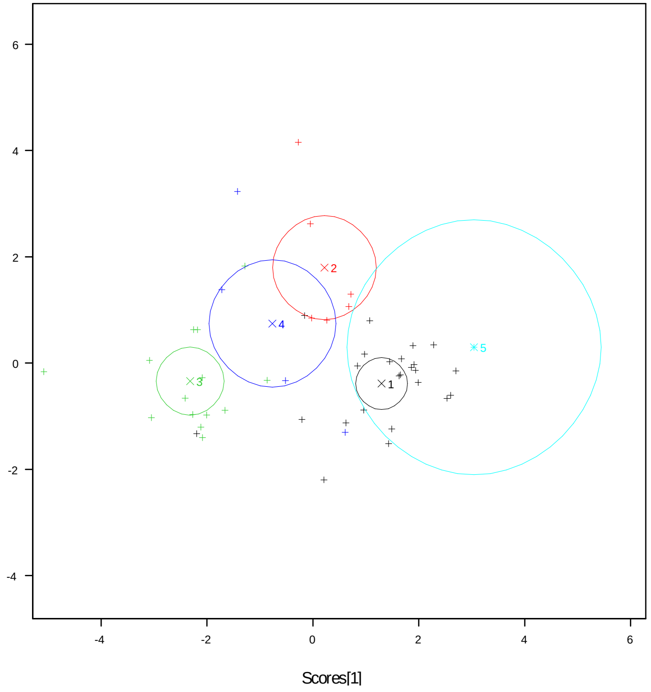
9.2 Table of PCA group statistical differences from Discriminant Analysis for 2006 and 2009 data

Comparison of PCAgroup	**2006**	**2009**
1 vs 2	P<0.05	P<0.05
1 vs 3	P<0.05	P<0.05
1 vs 4	P<0.05	P<0.05
1 vs 5	P<0.05	N/S
2 vs 3	P<0.05	P<0.05
2 vs 4	P<0.05	N/S
2 vs 5	N/S	N/S
3 vs 4	P<0.05	P<0.05
3 vs 5	P<0.05	P<0.05
4 vs 5	P<0.05	P<0.05

9.3 Figure of PCA group statistical differences (95% confidence intervals) from Discriminant Analysis for 2006 and 2009 data



2006 DA



2009 DA based on multivariate groupings

9.4 Correlation table of major factors recorded at the sites of contrast

Correlation table of major factors where: Astr = *Astrebla* spp.; BA = basal area (cm^2/m^2); sling=seedling density (no/m^2); tsk = tussock density (no/m^2); SSB = germinable soil seed bank (density no/m^2) functional groups (O3PG = desirable perennial grasses, excluding *Astrebla* spp.; OPG = undesirable perennial grasses; AG = Annual grasses; forb des. = desirable forbs; forbsundes. = undesirable forbs); GP = grazing pressure (C = cattle, K = kangaroo, S = sheep, T = total) for the period or summer (S) or winter (W) periods as indicated; RE index = ratio of rainfall to evaporation. Analysis based on raw data.

	Bot_Astr_BA_Tdead_cm_06	Bot_Astr_BA_Tdead_cm_09	Bot_Astr_BA_Tdead_cm_ch	Bot_Astr_BA_Tlive_cm_06	Bot_Astr_BA_Tlive_cm_09	Bot_Astr_BA_Tlive_cm_ch	Bot_Astr_BA_deadP_cm_06	Bot_Astr_BA_deadP_cm_09	Bot_Astr_BA_deadP_cm_ch	Bot_Astr_BA_dead_cm_06	Bot_Astr_BA_dead_cm_09	Bot_Astr_BA_dead_cm_ch	Bot_Astr_BA_liveP_cm_06	Bot_Astr_BA_liveP_cm_09	Bot_Astr_BA_liveP_cm_ch	Bot_Astr_BA_live_cm_06	Bot_Astr_BA_live_cm_09	Bot_Astr_BA_live_cm_ch	Bot_Astr_RBA_dead_cm_06	Bot_Astr_RBA_dead_cm_09	Bot_Astr_RBA_dead_cm_ch	Bot_Astr_RBA_live_cm_06	Bot_Astr_RBA_live_cm_09	Bot_Astr_RBA_live_cm_ch	Bot_Astr_Tsling06	Bot_Astr_Tsling09	Bot_Astr_Tslingch	Bot_Astr_Ttsk_live06	Bot_Astr_Ttsk_live09	Bot_Astr_Ttsk_livech	Bot_Astr_gt1sling09	Bot_Astr_gtsling06	Bot_Astr_gtslingch	Bot_Astr_lt1sling09	Bot_Astr_ltsling06
Bot_Astr_BA_Tdead_cm_06																																			
Bot_Astr_BA_Tdead_cm_09	0.0356																																		
Bot_Astr_BA_Tdead_cm_ch	-0.9195	0.36																																	
Bot_Astr_BA_Tlive_cm_06	-0.547	0.309	0.6321																																
Bot_Astr_BA_Tlive_cm_09	-0.3952	-0.1386	0.3145	0.6874																															
Bot_Astr_BA_Tlive_cm_ch	-0.0314	-0.4805	-0.1597	0.009	0.7324																														
Bot_Astr_BA_deadP_cm_06	0.0862	0.2784	0.029	0.3122	0.1751	-0.0516																													
Bot_Astr_BA_deadP_cm_09	-0.1649	0.8153	0.4745	0.3699	0.0222	-0.3162	0.2863																												
Bot_Astr_BA_deadP_cm_ch	-0.2104	0.4517	0.374	0.0498	-0.1275	-0.2222	-0.5945	0.6002																											
Bot_Astr_BA_dead_cm_06	0.962	-0.0412	-0.9143	-0.6247	-0.4375	-0.0168	-0.1891	-0.241	-0.0444																										
Bot_Astr_BA_dead_cm_09	0.2423	0.7667	0.0753	0.1062	-0.2561	-0.4522	0.1478	0.2533	0.0892	0.1983																									
Bot_Astr_BA_dead_cm_ch	-0.9188	0.2362	0.9506	0.6634	0.3809	-0.0974	0.2301	0.3097	0.0678	-0.9687	0.0512																								
Bot_Astr_BA_liveP_cm_06	-0.0128	0.291	0.1264	0.5192	0.4124	0.0811	0.8239	0.3377	-0.4044	-0.2384	0.1118	0.2712																							
Bot_Astr_BA_liveP_cm_09	-0.1624	0.732	0.4395	0.3203	-0.0302	-0.3419	0.2884	0.9415	0.5493	-0.2391	0.1791	0.289	0.3761																						
Bot_Astr_BA_liveP_cm_ch	-0.1662	0.6201	0.399	0.0548	-0.2601	-0.4096	-0.1476	0.8177	0.8095	-0.1234	0.1293	0.1584	-0.1514	0.859																					
Bot_Astr_BA_live_cm_06	-0.5635	0.2998	0.6439	0.9984	0.6829	0.0042	0.268	0.3597	0.0782	-0.6289	0.102	0.6666	0.4704	0.3063	0.0668																				
Bot_Astr_BA_live_cm_09	-0.379	-0.1969	0.2763	0.6574	0.9967	0.7561	0.1506	-0.0541	-0.1711	-0.4148	-0.2689	0.3545	0.3795	-0.111	-0.3281	0.654																			
Bot_Astr_BA_live_cm_ch	-0.0127	-0.52	-0.1927	0.0039	0.7259	0.9958	-0.0332	-0.3832	-0.2939	-0.0034	-0.4438	-0.1089	0.0941	-0.4121	-0.4916	-0.002	0.7552																		
Bot_Astr_RBA_dead_cm_06	0.9017	-0.0891	-0.8768	-0.6312	-0.4521	-0.0307	-0.1454	-0.2194	-0.0628	0.9286	0.0944	-0.9223	-0.206	-0.2007	-0.1003	-0.6378	-0.4323	-0.0189																	
Bot_Astr_RBA_dead_cm_09	0.4127	0.6454	-0.1315	-0.077	-0.307	-0.3505	0.1322	0.1535	0.0184	0.3705	0.9079	-0.1476	0.0744	0.1541	0.1233	-0.0845	-0.3173	-0.3462	0.2702																
Bot_Astr_RBA_dead_cm_ch	-0.8245	0.2676	0.875	0.6347	0.3863	-0.0632	0.1868	0.2695	0.0702	-0.8639	0.1483	0.9178	0.2342	0.2503	0.1376	0.6395	0.3629	-0.0743	-0.9653	-0.0093															
Bot_Astr_RBA_live_cm_06	-0.4638	0.2264	0.522	0.868	0.5746	-0.0226	0.2938	0.3307	0.0323	-0.5377	0.0116	0.5508	0.4401	0.3282	0.1069	0.8675	0.5446	-0.0318	-0.5551	-0.1186	0.5443														
Bot_Astr_RBA_live_cm_09	-0.2856	-0.2019	0.1872	0.5228	0.8546	0.6866	0.0987	-0.0446	-0.1198	-0.3086	-0.2878	0.2415	0.208	-0.1076	-0.2297	0.5262	0.8586	0.679	-0.3381	-0.3167	0.2653	0.6275													
Bot_Astr_RBA_live_cm_ch	0.2257	-0.4964	-0.4059	-0.4357	0.2869	0.8035	-0.2359	-0.4418	-0.1738	0.2871	-0.3394	-0.3785	-0.2855	-0.5101	-0.3864	-0.4312	0.327	0.8058	0.2743	-0.2179	-0.344	-0.4734	0.3888												
Bot_Astr_Tsling06	-0.3344	-0.0422	0.2956	0.3591	0.1157	-0.1774	0.3635	-0.0125	-0.3139	-0.4292	-0.0566	0.423	0.296	-0.03	-0.1955	0.3502	0.1167	-0.1492	-0.4266	-0.1559	0.4007	0.3257	0.0478	-0.3314											
Bot_Astr_Tsling09	-0.1616	-0.1743	0.0823	-0.0793	-0.1034	-0.068	-0.0016	-0.2273	-0.1894	-0.1588	-0.0392	0.1519	-0.0658	-0.2248	-0.2034	-0.0778	-0.0879	-0.0488	-0.1736	-0.0983	0.1536	-0.0762	-0.1293	-0.0562	0.2241										
Bot_Astr_Tslingch	0.2617	-0.0361	-0.2585	-0.3946	-0.1621	0.1468	-0.3641	-0.0896	0.2287	0.3577	0.039	-0.3546	-0.3255	-0.0711	0.1041	-0.3851	-0.1562	0.1272	0.3484	0.1116	-0.3316	-0.3599	-0.1059	0.306	-0.899	0.2253									
Bot_Astr_Ttsk_live06	-0.6124	0.1994	0.6501	0.677	0.5365	0.104	0.2724	0.2819	0.0092	-0.6783	0.0205	0.6963	0.3537	0.2308	0.0507	0.6752	0.5145	0.0951	-0.6612	-0.1574	0.644	0.4157	0.3208	-0.1289	0.3906	-0.021	-0.3999								
Bot_Astr_Ttsk_live09	-0.5353	0.1648	0.5645	0.6165	0.4338	0.0192	0.2599	0.1978	-0.051	-0.5988	0.056	0.6243	0.3384	0.1475	-0.0297	0.6138	0.419	0.022	-0.5982	-0.0742	0.6011	0.3763	0.1785	-0.2433	0.3761	0.0443	-0.3561	0.7178							
Bot_Astr_Ttsk_livech	-0.232	0.0621	0.241	0.2917	0.1534	-0.0623	0.1341	0.0379	-0.0802	-0.2654	0.0618	0.2861	0.1755	0.0106	-0.0857	0.2894	0.1514	-0.0507	-0.2793	0.0303	0.2983	0.1759	-0.0229	-0.2341	0.1972	0.0809	-0.1608	0.1573	0.8005						
Bot_Astr_gt1sling09	-0.1536	-0.1761	0.0742	-0.102	-0.1121	-0.0587	-0.0387	-0.2117	-0.1453	-0.1408	-0.0595	0.1284	-0.0941	-0.2111	-0.1732	-0.0993	-0.0977	-0.0432	-0.1616	-0.1121	0.1375	-0.0838	-0.1233	-0.0403	0.1955	0.9854	0.2473	-0.0446	0.0124	0.0559					
Bot_Astr_gtsling06	-0.1296	0.1796	0.1916	0.1589	0.075	-0.0457	0.4353	0.1193	-0.2633	-0.247	0.1679	0.2942	0.3999	0.0436	-0.1745	0.1356	0.0708	-0.0239	-0.219	0.0855	0.2506	0.0781	0.0271	-0.0617	0.5511	0.069	-0.5199	0.3392	0.3155	0.1556	0.0401				
Bot_Astr_gtslingch	-0.0865	-0.2389	-0.0132	-0.1617	-0.1352	-0.0347	-0.2211	-0.2459	-0.0218	-0.0246	-0.1264	-0.0069	-0.2571	-0.2132	-0.0854	-0.1493	-0.1203	-0.0296	-0.0558	-0.1397	0.02	-0.1106	-0.1252	-0.0108	-0.0545	0.8792	0.4495	-0.1855	-0.123	-0.0147	0.9049	-0.3889			
Bot_Astr_lt1sling09	-0.1035	-0.0465	0.0783	0.0981	0.0145	-0.072	0.2015	-0.1585	-0.3013	-0.1573	0.098	0.1851	0.1326	-0.1463	-0.2293	0.0922	0.0254	-0.0463	-0.1274	0.0428	0.144	0.0188	-0.0737	-0.1057	0.2308	0.4151	-0.0443	0.1233	0.1893	0.1624	0.2544	0.1806	0.1576		
Bot_Astr_ltsling06	-0.3406	-0.0856	0.2843	0.3612	0.1111	-0.1856	0.3066	-0.0398	-0.2894	-0.4198	-0.0989	0.4027	0.2399	-0.0427	-0.1781	0.3564	0.1132	-0.1592	-0.423	-0.1906	0.3876	0.3418	0.0467	-0.3517	0.9836	0.2322	-0.879	0.3573	0.3462	0.1834	0.207	0.3917	0.024	0.2156	
Bot_Astr_ltslingch	0.3367	0.0828	-0.2818	-0.358	-0.1115	0.1821	-0.2935	0.0263	0.2671	0.4123	0.1091	-0.3925	-0.2319	0.0304	0.1606	-0.3537	-0.1126	0.1575	0.4182	0.1973	-0.3808	-0.3454	-0.0539	0.3477	-0.9783	-0.199	0.8886	-0.3518	-0.3347	-0.1719	-0.1876	-0.3817	-0.0104	-0.1304	-0.9963
Bot_Astr_tsk_dead06	0.6175	-0.141	-0.6319	-0.6418	-0.4336	0.0046	-0.3281	-0.3173	0.0076	0.6986	0.1162	-0.6824	-0.3878	-0.3111	-0.1176	-0.6366	-0.4055	0.0156	0.5358	0.2382	-0.4918	-0.5868	-0.3308	0.3201	-0.4718	-0.0209	0.4622	-0.53	-0.5388	-0.308	-0.0075	-0.3438	0.1395	-0.0848	-0.4452
Bot_Astr_tsk_dead09	0.196	0.4778	0.0049	-0.0031	-0.2761	-0.3772	0.1297	0.0389	-0.0756	0.1576	0.755	0.0306	0.0703	-0.0497	-0.0918	-0.0082	-0.2703	-0.3502	0.0841	0.6183	0.0804	-0.1113	-0.2777	-0.1825	-0.103	0.04	0.121	0.0431	0.1014	0.1068	0.0096	0.1985	-0.0756	0.1788	-0.1566
Bot_Astr_tsk_deadch	-0.4899	0.3645	0.6007	0.6061	0.2771	-0.1867	0.3734	0.3193	-0.0437	-0.5852	0.255	0.6608	0.4012	0.2706	0.0669	0.5987	0.2532	-0.1841	-0.4666	0.0734	0.5045	0.5017	0.1789	-0.3913	0.3968	0.0391	-0.3791	0.5227	0.5591	0.3432	0.0118	0.4214	-0.1686	0.1667	0.3458
Bot_Astr_tsk_live06	-0.6337	0.1627	0.6556	0.6631	0.5433	0.1265	0.1793	0.2448	0.0558	-0.6738	0.0004	0.6866	0.2848	0.192	0.0475	0.6653	0.5245	0.1168	-0.6599	-0.1787	0.6369	0.4007	0.3324	-0.0982	0.3607	-0.0295	-0.3738	0.9945	0.7062	0.1455	-0.0499	0.3121	-0.1789	0.1031	0.3301
Bot_Astr_tsk_live09	-0.4904	-0.0943	0.4208	0.5159	0.4636	0.1546	0.1708	-0.085	-0.2139	-0.5302	-0.0633	0.5242	0.2468	-0.1193	-0.2636	0.516	0.4702	0.1744	-0.5434	-0.1475	0.5244	0.2912	0.2165	-0.0996	0.3827	0.1152	-0.3308	0.6192	0.9525	0.818	0.0766	0.2621	-0.041	0.2484	0.365
Bot_Astr_tsk_livech	-0.1284	-0.2473	0.0227	0.1379	0.165	0.0979	0.0771	-0.2997	-0.3159	-0.1477	-0.0808	0.1301	0.0913	-0.302	-0.3726	0.1362	0.1881	0.1307	-0.1754	-0.0479	0.1692	0.0571	0.0155	-0.05	0.2049	0.1697	-0.1286	0.01	0.6599	0.9274	0.1365	0.0894	0.0877	0.2355	0.2062
Bot_Astr_tsk_part06	0.1049	0.3754	0.0497	0.2345	0.0183	-0.1946	0.9152	0.3911	-0.4357	-0.1475	0.1935	0.1993	0.7003	0.3994	0.0391	0.1961	-0.0146	-0.1891	-0.1147	0.1788	0.1676	0.2037	-0.0599	-0.3089	0.3405	0.0756	-0.3064	0.205	0.2196	0.1351	0.0421	0.3065	-0.0918	0.2086	0.3092
Bot_Astr_tsk_part09	-0.1929	0.84	0.5104	0.3783	-0.0542	-0.4292	0.308	0.9186	0.5138	-0.2745	0.3848	0.3772	0.3235	0.863	0.7418	0.3691	-0.1236	-0.4832	-0.2304	0.2266	0.3008	0.3062	-0.1041	-0.4801	0.0144	-0.2215	-0.1139	0.3814	0.2451	0.0193	-0.2032	0.1997	-0.2724	-0.1702	-0.0274
Bot_Astr_tsk_partch	-0.2294	0.8138	0.5342	0.352	-0.0619	-0.4153	0.1252	0.8944	0.6461	-0.2605	0.368	0.3586	0.1897	0.8331	0.7839	0.3507	-0.1288	-0.4742	-0.2206	0.2023	0.284	0.2818	-0.0979	-0.4442	-0.0605	-0.2535	-0.0535	0.3618	0.2129	-0.0094	-0.2265	0.1451	-0.2706	-0.2283	-0.0982
Bot_SSB_AG06	0.1047	-0.0186	-0.105	0.0262	0.1956	0.2447	0.2797	0.1761	-0.0857	0.0265	-0.2262	-0.0843	0.3078	0.1983	0.0415	0.0072	0.1788	0.2301	0.0593	-0.1656	-0.1065	-0.044	0.0993	0.1644	-0.2139	-0.1417	0.1501	0.0661	-0.0398	-0.1134	-0.1788	-0.0337	-0.1505	0.1475	-0.2286
Bot_SSB_AG09	0.2377	-0.1496	-0.2808	-0.3465	-0.3008	-0.0894	-0.0824	-0.0515	0.0256	0.2569	-0.1928	-0.3106	-0.1884	0.0004	0.1045	-0.3456	-0.2982	-0.0948	0.3775	-0.068	-0.4105	-0.3029	-0.2067	0.1245	-0.1356	-0.2519	0.0224	-0.2877	-0.361	-0.2643	-0.2191	0.014	-0.208	-0.263	-0.1527
Bot_SSB_AGch	0.2181	-0.1507	-0.2629	-0.3686	-0.3689	-0.1624	-0.1651	-0.1035	0.051	0.2602	-0.1369	-0.2998	-0.2835	-0.0558	0.0972	-0.3623	-0.3615	-0.1639	0.3766	-0.024	-0.3977	-0.3032	-0.2436	0.0832	-0.0808	-0.2224	-0.0192	-0.3186	-0.3649	-0.2434	-0.1777	0.0241	-0.1742	-0.3159	-0.0944
Bot_SSB_Astr06	-0.1257	0.2644	0.2214	0.403	0.2842	0.0135	0.4778	0.3542	-0.1016	-0.2549	0.049	0.2721	0.3866	0.3506	0.1603	0.3909	0.2546	-0.0021	-0.2886	-0.0082	0.2975	0.3869	0.2626	-0.1608	0.2178	-0.2126	-0.3133	0.3509	0.3514	0.1963	-0.2398	0.0753	-0.2531	0.0772	0.2238
Bot_SSB_Astr09	-0.1101	0.0203	0.1108	0.1804	0.1507	0.0384	0.1825	0.0779	-0.0869	-0.1585	-0.0525	0.1482	0.2958	0.0516	-0.1084	0.1666	0.1455	0.048	-0.1193	-0.1405	0.0858	0.0407	0.0264	-0.0183	0.033	0.115	0.0187	0.286	0.2996	0.1788	0.0375	0.2428	-0.0688	0.4535	-0.0161
Bot_SSB_Astrch	0.108	-0.2548	-0.2011	-0.3688	-0.257	-0.0081	-0.4414	-0.3347	0.0876	0.2275	-0.0546	-0.2456	-0.3377	-0.3346	-0.1704	-0.3588	-0.2289	0.0083	0.2654	-0.0104	-0.2785	-0.3715	-0.2523	0.1542	-0.2078	0.2222	0.3076	-0.3042	-0.3029	-0.1678	0.2384	-0.0415	0.2375	-0.0157	-0.2201
Bot_SSB_O3PG06	0.0322	-0.1198	-0.0771	0.1937	0.5112	0.5222	0.0357	-0.0618	-0.0817	0.0219	-0.1316	-0.0557	0.2227	-0.1069	-0.2371	0.1853	0.5172	0.5231	0.0546	-0.1425	-0.0953	0.037	0.3507	0.353	-0.0139	-0.1229	-0.0413	0.2279	0.0333	-0.149	-0.1145	0.1235	-0.1582	-0.0851	-0.0418
Bot_SSB_O3PG09	0.341	-0.1476	-0.3764	-0.3032	-0.1762	0.0416	-0.1549	-0.206	-0.0436	0.3785	-0.0182	-0.3903	-0.2093	-0.1715	-0.0673	-0.299	-0.1616	0.0455	0.325	0.0219	-0.3316	-0.2877	-0.1671	0.1514	-0.1693	0.105	0.2164	-0.2605	-0.2885	-0.185	0.1157	-0.2043	0.1937	-0.0212	-0.1426
Bot_SSB_O3PGch	0.3328	-0.1253	-0.36	-0.3354	-0.2657	-0.0514	-0.1601	-0.1935	-0.0287	0.3719	0.0053	-0.3776	-0.2473	-0.1513	-0.0248	-0.3297	-0.2522	-0.0477	0.313	0.047	-0.3123	-0.2922	-0.2282	0.0876	-0.1656	0.1261	0.2222	-0.2991	-0.2924	-0.1572	0.1352	-0.2247	0.2204	-0.0059	-0.1342
Bot_SSB_OPG06	-0.0802	-0.0505	0.055	-0.0058	-0.0024	0.0022	0.1092	0.0963	-0.0104	-0.109	-0.1911	0.0627	0.0532	0.0972	0.0743	-0.01	-0.0096	-0.004	-0.0334	-0.1998	-0.0195	0.0971	0.0828	-0.0212	0.1398	-0.1932	-0.2265	-0.0469	0.0221	0.0717	-0.1838	0.2353	-0.2696	-0.1119	0.1034
Bot_SSB_OPG09	0.1435	-0.2461	-0.2308	-0.194	-0.137	-0.0067	-0.276	-0.1885	0.0722	0.2171	-0.2022	-0.2724	-0.1937	-0.1861	-0.0915	-0.187	-0.1218	0.0011	0.2327	-0.1679	-0.2872	-0.1501	-0.0646	0.1046	-0.0994	0.1989	0.1888	-0.3089	-0.2186	-0.0441	0.241	-0.2794	0.3412	-0.1599	-0.0494
Bot_SSB_OPGch	0.1491	-0.1051	-0.1805	-0.11	-0.0791	-0.0057	-0.2506	-0.1885	0.051	0.2156	0.0335	-0.2112	-0.1572	-0.1879	-0.1136	-0.1025	-0.0643	0.0039	0.1643	0.0607	-0.1542	-0.1665	-0.1045	0.0788	-0.1707	0.2723	0.293	-0.1451	-0.1469	-0.0835	0.2896	-0.3537	0.4177	-0.0049	-0.112
Bot_SSB_forb_des06	0.165	0.1079	-0.1116	0.0103	-0.0378	-0.0617	-0.0344	-0.1769	-0.1197	0.1721	0.3763	-0.08	0.0108	-0.296	-0.3217	0.01	-0.0132	-0.026	0.1594	0.2516	-0.0973	-0.1987	-0.2012	0.0076	-0.1617	-0.0669	0.1315	0.0351	0.2702	0.353	-0.0644	-0.0203	-0.0507	-0.0382	-0.1742
Bot_SSB_forb_des09	0.2112	-0.0751	-0.2267	-0.1315	-0.1565	-0.0922	-0.0234	-0.3305	-0.2578	0.2146	0.2409	-0.1577	-0.0811	-0.3665	-0.3461	-0.1307	-0.126	-0.0533	0.1836	0.2994	-0.1095	-0.221	-0.2562	-0.0283	-0.0494	0.137	0.1109	-0.1924	0.1031	0.3118	0.1228	0.082	0.0783	0.1193	-0.0725
Bot_SSB_forb_desch	0.1209	-0.1542	-0.1735	-0.1507	-0.1459	-0.0596	-0.0027	-0.2433	-0.202	0.1198	0.0122	-0.119	-0.0959	-0.2031	-0.1637	-0.1496	-0.129	-0.0409	0.0944	0.1594	-0.0548	-0.109	-0.1459	-0.036	0.054	0.1945	0.0334	-0.2338	-0.0677	0.1053	0.1773	0.1032	0.1195	0.156	0.037
Bot_SSB_forb_undes06	0.0867	-0.2258	-0.1697	-0.1651	-0.128	-0.0214	-0.1892	-0.3106	-0.1028	0.1373	-0.0328	-0.1482	-0.2209	-0.3269	-0.2267	-0.1555	-0.1009	0.0014	0.0933	-0.0503	-0.1106	-0.2735	-0.217	0.0781	-0.0158	0.1259	0.0724	-0.0555	-0.1191	-0.1212	0.1149	-0.2485	0.2117	0.0993	0.0367
Bot_SSB_forb_undes09	0.0535	0.0909	-0.0142	-0.1135	-0.1364	-0.0814	-0.1163	-0.0473	0.0574	0.0846	0.2043	-0.0344	-0.1618	-0.0774	0.0069	-0.1071	-0.13	-0.0791	0.0319	0.2069	0.023	-0.1052	-0.1477	-0.0427	0.1899	0.1989	-0.1004	-0.0926	-0.0376	0.0264	0.2125	0.1312	0.14	-0.0033	0.1809
Bot_SSB_forb_undesch	-0.0084	0.215	0.0924	0.0062	-0.0359	-0.0552	0.0186	0.1511	0.1113	-0.0133	0.1917	0.0621	-0.0001	0.1359	0.1451	0.0057	-0.0472	-0.0673	-0.0306	0.2046	0.0872	0.0798	0.0093	-0.0838	0.1691	0.0897	-0.1288	-0.0436	0.0416	0.0966	0.1078	0.2628	-0.0125	-0.0638	0.1292
Bot_tot_yield06	-0.4554	0.1666	0.4906	0.6124	0.345	-0.099	0.1754	0.3546	0.1512	-0.4969	-0.1149	0.4772	0.2882	0.4417	0.3119	0.6132	0.3076	-0.1247	-0.4803	-0.1609	0.4552	0.7965	0.4652	-0.4162	0.2298	-0.2365	-0.336	0.3855	0.2033	-0.0436	-0.2131	0.1449	-0.2582	-0.2017	0.2217
Bot_tot_yield09	-0.2946	-0.2379	0.1814	0.15	0.2892	0.2577	0.0201	0.0494	0.0246	-0.2958	-0.4521	0.187	0.0447	0.1701	0.1567	0.1518	0.2743	0.231	-0.1026	-0.4042	-0.0031	0.2502	0.3534	0.1037	0.0244	-0.1876	-0.1086	0.2246	0.0515	-0.1202	-0.1975	0.0549	-0.2055	-0.0066	0.0147
Bot_tot_yieldch	0.0998	-0.4227	-0.2594	-0.4092	-0.0018	0.3812	-0.1427	-0.2789	-0.1149	0.1375	-0.397	-0.2406	-0.2215	-0.226	-0.1187	-0.408	0.0168	0.3757	0.3378	-0.3002	-0.4323	-0.4706	-0.0433	0.5079	-0.1893	0.0132	0.1951	-0.1122	-0.1339	-0.0933	-0.02	-0.0752	0.0136	0.1827	-0.1925
Condition_change_%	0.3558	-0.1786	-0.4024	-0.395	-0.3058	-0.0507	-0.4007	-0.1789	0.1844	0.4605	-0.1001	-0.4946	-0.4307	-0.1508	0.0771	-0.3793	-0.2909	-0.0558	0.4168	0.0233	-0.4266	-0.3371	-0.2602	0.1045	-0.2081	-0.1997	0.1183	-0.3673	-0.3724	-0.2121	-0.1894	-0.2683	-0.0603	-0.1363	-0.1713
GP_DSS_99_07	-0.0724	-0.0288	0.0563	0.2599	0.378	0.2769	0.0594	-0.1563	-0.1808	-0.0877	0.1251	0.121	0.1144	-0.2413	-0.3206	0.2606	0.3953	0.2968	-0.0757	0.0681	0.097	0.2794	0.4333	0.1596	-0.0619	-0.02	0.0529	0.0596	0.0524	0.023	0.0197	0.1096	-0.0285	-0.2171	-0.0921
GP_No_spells_99_07	0.0258	0.0413	-0.0078	0.16	0.3409	0.3193	-0.0279	-0.0545	-0.0224	0.033	0.1294	-0.0009	0.0609	-0.1657	-0.2105	0.1611	0.3524	0.3262	0.0545	0.0861	-0.0333	0.0972	0.3239	0.2514	-0.1674	-0.0503	0.1447	0.0585	0.0809	0.0644	-0.011	0.0802	-0.0443	-0.2244	-0.202
GP_WSS_99_07	0.1093	0.0939	-0.0651	0.0182	0.2021	0.2612	-0.1007	0.057	0.1319	0.1353	0.0937	-0.1141	-0.0074	-0.0447	-0.0436	0.0191	0.2046	0.2539	0.1591	0.0765	-0.1445	-0.1021	0.1229	0.2599	-0.2144	-0.0631	0.186	0.0397	0.0827	0.0832	-0.0363	0.0284	-0.0455	-0.1626	-0.2425
GP_dist_to_water_km	0.1278	-0.1744	-0.1879	-0.158	-0.2323	-0.1718	-0.1409	-0.2848	-0.1214	0.1646	0.0245	-0.1615	-0.2463	-0.2234	-0.1022	-0.1471	-0.2124	-0.1532	0.1557	0.0575	-0.1461	-0.1149	-0.2064	-0.0976	0.1663	-0.0522	-0.1897	-0.1888	-0.1008	0.0195	-0.0872	-0.0139	-0.0744	0.1627	0.1864
GP_rest_durn_mnth	-0.0665	0.137	0.1159	0.3135	0.4693	0.3523	0.1034	0.0702	-0.0274	-0.0939	0.1509	0.1339	0.1922	-0.0451	-0.1544	0.3109	0.4705	0.3525	-0.1294	0.0818	0.1566	0.2944	0.4711	0.1846	-0.0997	-0.1179	0.0467	0.1389	0.1827	0.1395	-0.0983	0.1501	-0.1546	-0.1415	-0.1426
RE_FWS_3mnth_av	0.4073	-0.0731	-0.4089	-0.3672	-0.3479	-0.1347	-0.0329	-0.2937	-0.219	0.4104	0.2035	-0.3667	-0.1529	-0.3306	-0.2682	-0.3692	-0.3183	-0.1008	0.3397	0.29	-0.2742	-0.3794	-0.3364	0.0684	-0.0839	-0.107	0.0358	-0.3421	-0.1525	0.0782	-0.1227	-0.0117	-0.1081	0.0392	-0.0897
RE_FWS_3mnth_av0_20	0.4077	-0.123	-0.429	-0.3054	-0.2643	-0.0776	-0.0578	-0.3798	-0.2705	0.4177	0.2156	-0.371	-0.1157	-0.4189	-0.3829	-0.3078	-0.2284	-0.0352	0.3425	0.3089	-0.272	-0.3737	-0.3245	0.0752	-0.0141	-0.002	0.0132	-0.3554	-0.1091	0.1512	-0.0177	0.018	-0.024	0.0739	-0.0194
RE_FWS_6mnth_av	0.3156	-0.1082	-0.3372	-0.2758	-0.1841	0.0051	-0.0075	-0.2225	-0.1804	0.3132	0.0659	-0.3024	-0.0494	-0.2464	-0.2356	-0.2816	-0.1629	0.0287	0.2062	0.2035	-0.159	-0.3504	-0.2803	0.0975	0.0364	0.0309	-0.0225	-0.2716	-0.1382	0.0378	0.0131	0.0176	0.0046	0.0943	0.0365
RE_daily_rain	-0.4704	-0.0095	0.4354	0.3129	0.3547	0.195	-0.0694	0.2358	0.2558	-0.4446	-0.2774	0.3828	0.0674	0.2748	0.256	0.319	0.33	0.1598	-0.3237	-0.3724	0.2352	0.4077	0.4316	0.0058	-0.1195	-0.0065	0.1166	0.2828	0.1145	-0.0811	0.016	-0.1397	0.0743	-0.1128	-0.1017
RE_index_S00_01	-0.4177	0.1066	0.4319	0.328	0.3103	0.1197	0.0286	0.3828	0.2973	-0.4196	-0.2462	0.3652	0.118	0.435	0.3989	0.3314	0.2733	0.074	-0.3077	-0.3131	0.2346	0.4826	0.435	-0.0789	-0.1645	-0.1314	0.1054	0.2417	0.0746	-0.1023	-0.1123	-0.1582	-0.0361	-0.138	-0.1473
RE_index_S01_02	0.063	0.0915	-0.0229	0.0662	0.1762	0.1806	0.1073	0.1212	0.0122	0.0327	0.0185	-0.0287	0.1116	0.1361	0.0835	0.0615	0.165	0.1649	0.1508	0.016	-0.1523	0.0544	0.1727	0.131	-0.3676	-0.2732	0.2448	0.0068	0.0662	0.088	-0.28	-0.1596	-0.1902	-0.0497	-0.3713
RE_index_S02_03	-0.3007	0.1868	0.3542	0.2095	0.138	-0.0064	0.1328	0.4589	0.2742	-0.3328	-0.1967	0.2893	0.1061	0.5083	0.4836	0.2093	0.0959	-0.0546	-0.282	-0.2552	0.2236	0.3392	0.2612	-0.1059	0.0428	-0.0896	-0.083	0.3157	0.0137	-0.2524	-0.0698	0.0423	-0.0824	-0.1289	0.0383
RE_index_S03_04	-0.386	0.0843	0.3935	0.3152	0.2805	0.0908	0.0182	0.3426	0.2723	-0.3854	-0.239	0.3322	0.0982	0.3962	0.3684	0.3196	0.2461	0.0484	-0.2947	-0.3084	0.2225	0.5035	0.4011	-0.142	-0.1786	0.0582	0.2047	0.1308	0.0532	-0.0372	0.0898	-0.2508	0.1896	-0.1412	-0.1431
RE_index_S04_05	-0.3973	-0.2426	0.2755	0.1038	0.3177	0.3402	-0.182	0.0786	0.2178	-0.3418	-0.4924	0.2235	-0.0966	0.1613	0.2255	0.1141	0.3028	0.3014	-0.199	-0.4389	0.0876	0.2086	0.3914	0.1959	-0.1906	-0.0884	0.1508	0.1098	-0.1011	-0.2379	-0.0608	-0.3003	0.0719	-0.174	-0.1454
RE_index_S05_06	-0.3396	0.1182	0.3635	0.2968	0.2422	0.0552	0.0631	0.4208	0.3005	-0.352	-0.2691	0.2905	0.1053	0.5169	0.4932	0.3	0.1989	0.003	-0.2853	-0.2486	0.2289	0.5824	0.4497	-0.1805	-0.0849	-0.1659	0.0103	0.1308	-0.0806	-0.2269	-0.1382	-0.1782	-0.0515	-0.2014	-0.0552
RE_index_S06_07	-0.2007	0.0504	0.2072	-0.0527	0.0427	0.1082	0.0224	0.4296	0.3418	-0.204	-0.392	0.1086	-0.0508	0.4904	0.5512	-0.051	0.0028	0.0479	-0.0795	-0.3148	-0.0028	0.0494	0.155	0.1169	-0.1308	-0.1684	0.0551	0.1333	-0.1231	-0.2893	-0.1272	-0.0609	-0.0914	-0.2736	-0.1312
RE_index_S07_08	-0.3773	-0.2963	0.2357	0.1151	0.3421	0.3632	-0.2529	-0.1968	0.046	-0.3025	-0.2768	0.2381	-0.0799	-0.1863	-0.1546	0.1243	0.3547	0.3611	-0.1822	-0.3282	0.1002	0.1149	0.3411	0.2499	-0.2438	0.1076	0.2921	0.1213	0.0818	0.0117	0.1381	-0.1591	0.1951	-0.1238	-0.2346
RE_index_S08_09	-0.2995	0.1352	0.3327	0.2105	0.2001	0.0781	0.09	0.4725	0.3214	-0.3198	-0.2979	0.2504	0.0939	0.5567	0.5419	0.2116	0.1543	0.0206	-0.2395	-0.26	0.1782	0.4245	0.3733	-0.08	-0.1147	-0.2775	-0.01	0.1787	-0.0957	-0.2896	-0.2591	-0.1396	-0.1794	-0.1887	-0.0963
RE_index_S99_00	-0.3872	-0.1042	0.3205	0.0987	0.1963	0.1777	-0.174	0.0157	0.1584	-0.3339	-0.1914	0.2918	-0.0792	0.0179	0.0629	0.1072	0.1941	0.1637	-0.2882	-0.2875	0.2213	0.0735	0.2258	0.1685	-0.0782	-0.1292	0.0202	0.358	0.0763	-0.1999	-0.1328	-0.0663	-0.0942	-0.0165	-0.071
RE_index_W00	-0.157	-0.2809	0.036	-0.0449	0.0919	0.1687	-0.2448	-0.3911	-0.1239	-0.0876	-0.0357	0.0802	-0.1274	-0.4403	-0.3994	-0.0385	0.1257	0.1996	-0.0618	-0.1123	0.0337	-0.2226	-0.0465	0.2108	0.0422	0.4113	0.1426	0.0643	0.1922	0.2173	0.4381	0.1342	0.3468	-0.0044	0.0172
RE_index_W01	-0.0816	-0.2711	-0.0304	-0.0326	0.1309	0.2108	-0.2693	-0.3795	-0.0937	-0.0066	-0.0321	-0.0014	-0.1009	-0.4191	-0.3914	-0.0269	0.1637	0.2397	0.068	-0.0706	-0.0898	-0.1435	0.0463	0.2222	-0.2051	0.1555	0.2749	-0.0901	0.0631	0.1671	0.1686	-0.1066	0.2009	-0.0163	-0.2035
RE_index_W02	-0.1714	-0.1443	0.1033	0.0775	0.1716	0.1637	-0.1266	-0.1799	-0.0453	-0.1342	-0.0416	0.1263	0.0058	-0.2243	-0.2425	0.0796	0.1878	0.1793	-0.0851	-0.146	0.0487	-0.0126	0.1041	0.1327	-0.1825	0.2854	0.3107	0.0582	0.0628	0.0389	0.317	0.0282	0.2803	-0.0709	-0.2076
RE_index_W03	0.2963	0.0247	-0.2669	-0.1783	-0.3032	-0.2503	-0.0127	-0.3327	-0.2686	0.2955	0.4101	-0.1972	-0.0475	-0.4155	-0.417	-0.1818	-0.2681	-0.1969	0.1725	0.342	-0.0863	-0.3127	-0.3823	-0.0624	0.2465	0.2198	-0.1476	-0.0753	0.1023	0.2099	0.2008	0.3213	0.0483	0.1729	0.2026
RE_index_W04	-0.1104	-0.2612	0.0003	-0.0401	0.1816	0.2876	-0.2107	-0.3777	-0.1411	-0.0511	-0.0176	0.0476	-0.0775	-0.4596	-0.4475	-0.0364	0.2175	0.3191	0.0171	-0.0938	-0.0432	-0.3356	-0.0357	0.3568	-0.1751	0.1289	0.2329	0.0978	0.2032	0.204	0.1252	0.0179	0.1078	0.0645	-0.197
RE_index_W05	0.1234	-0.4097	-0.2764	-0.2004	-0.0172	0.1643	-0.3228	-0.6305	-0.2596	0.2101	0.0145	-0.2104	-0.2337	-0.6549	-0.5695	-0.1915	0.0354	0.2127	0.178	0.0539	-0.1702	-0.3721	-0.193	0.2219	0.106	0.2947	0.0264	-0.2011	0.0021	0.1761	0.2853	-0.1396	0.3225	0.1466	0.147
RE_index_W06	-0.3579	-0.0754	0.3044	0.2338	0.3984	0.3294	-0.0542	0.2283	0.2368	-0.3379	-0.3791	0.2482	0.0763	0.2912	0.2685	0.237	0.3727	0.2873	-0.1902	-0.348	0.1031	0.3331	0.4558	0.1216	-0.2621	-0.1682	0.1865	0.1247	-0.0029	-0.1115	-0.145	-0.2275	-0.0368	-0.1772	-0.2403
RE_index_W07	-0.2809	0.0047	0.264	-0.0175	0.0928	0.1441	0.0323	0.3598	0.275	-0.2857	-0.3911	0.192	-0.044	0.4226	0.4752	-0.0152	0.0577	0.0894	-0.1865	-0.3497	0.0989	0.0878	0.203	0.1259	-0.0889	-0.0582	0.0627	0.2201	-0.0853	-0.3104	-0.016	-0.01	-0.0105	-0.243	-0.0958
RE_index_W08	0.0389	-0.4125	-0.1985	-0.1787	0.0633	0.2547	-0.3178	-0.5692	-0.2124	0.1255	-0.0581	-0.1425	-0.2061	-0.6121	-0.5391	-0.1708	0.1119	0.296	0.1633	-0.0554	-0.1846	-0.3566	-0.0968	0.3125	-0.0926	0.2673	0.2127	-0.1667	0.0407	0.2013	0.2737	-0.126	0.3061	0.0543	-0.0751
RE_index_W09	-0.1088	-0.1562	0.0402	-0.0446	0.0845	0.1581	-0.1261	-0.1986	-0.0614	-0.0727	-0.0408	0.0638	-0.061	-0.2667	-0.2508	-0.042	0.1045	0.1745	-0.0362	-0.1344	0.0012	-0.1832	-0.0333	0.1791	-0.2465	0.3239	0.392	-0.0222	0.146	0.2263	0.3509	-0.0616	0.3497	-0.0336	-0.2586
RE_index_W99	0.0881	-0.2441	-0.1782	-0.15	-0.1048	-0.0037	-0.2242	-0.4754	-0.2118	0.1483	0.1192	-0.1209	-0.168	-0.5201	-0.462	-0.1443	-0.0632	0.0415	0.1534	0.0698	-0.1404	-0.2383	-0.166	0.0941	0.1004	0.3931	0.0763	-0.1413	0.0714	0.223	0.4167	0.1274	0.3299	0.0056	0.0827
RE_total_rain	-0.4739	0.0063	0.4449	0.3067	0.3441	0.1863	-0.0587	0.2577	0.2652	-0.451	-0.2751	0.3899	0.0657	0.2955	0.279	0.3127	0.3178	0.1492	-0.3389	-0.3732	0.2508	0.399	0.419	0.0018	-0.1312	-0.0119	0.1258	0.2922	0.1221	-0.0784	0.0095	-0.1513	0.0732	-0.108	-0.112

	Bot_Astr_ltslingch	Bot_Astr_tsk_dead06	Bot_Astr_tsk_dead09	Bot_Astr_tsk_deadch	Bot_Astr_tsk_live06	Bot_Astr_tsk_live09	Bot_Astr_tsk_livech	Bot_Astr_tsk_part06	Bot_Astr_tsk_part09	Bot_Astr_tsk_partch	Bot_SSB_AG06	Bot_SSB_AG09	Bot_SSB_AGch	Bot_SSB_Astr06	Bot_SSB_Astr09	Bot_SSB_Astrch	Bot_SSB_O3PG06	Bot_SSB_O3PG09	Bot_SSB_O3PGch	Bot_SSB_OPG06	Bot_SSB_OPG09	Bot_SSB_OPGch	Bot_SSB_forb_des06	Bot_SSB_forb_des09	Bot_SSB_forb_desch	Bot_SSB_forb_undes06	Bot_SSB_forb_undes09	Bot_SSB_forb_undesch	Bot_tot_yield06	Bot_tot_yield09	Bot_tot_yieldch	Condition_change_%	GP_DSS_99_07	GP_No_spells_99_07	GP_WSS_99_07
Bot_Astr_ltslingch																																			
Bot_Astr_tsk_dead06	0.4445																																		
Bot_Astr_tsk_dead09	0.1748	0.1421																																	
Bot_Astr_tsk_deadch	-0.3364	-0.8781	0.3489																																
Bot_Astr_tsk_live06	-0.3261	-0.5115	0.026	0.4968																															
Bot_Astr_tsk_live09	-0.3486	-0.447	0.0567	0.4506	0.6187																														
Bot_Astr_tsk_livech	-0.1885	-0.1688	0.0518	0.1849	0.0051	0.7888																													
Bot_Astr_tsk_part06	-0.2955	-0.2551	0.1665	0.322	0.1017	0.0999	0.0477																												
Bot_Astr_tsk_part09	0.0127	-0.3428	0.1518	0.3979	0.3448	-0.0618	-0.3485	0.4017																											
Bot_Astr_tsk_partch	0.0794	-0.3094	0.1251	0.3534	0.3458	-0.0883	-0.3829	0.2064	0.979																										
Bot_SSB_AG06	0.2452	-0.0518	-0.2897	-0.091	0.0388	-0.09	-0.1449	0.2664	0.156	0.1073																									
Bot_SSB_AG09	0.1318	0.0939	-0.2743	-0.2215	-0.2884	-0.3901	-0.2709	-0.037	0.059	0.0712	0.2819																								
Bot_SSB_AGch	0.0679	0.1126	-0.2038	-0.2051	-0.3116	-0.3811	-0.2413	-0.114	0.0173	0.0438	0.0105	0.9624																							
Bot_SSB_Astr06	-0.2204	-0.2802	-0.0207	0.2553	0.3012	0.253	0.0864	0.5199	0.3462	0.2541	0.2598	-0.141	-0.2205																						
Bot_SSB_Astr09	0.0565	-0.1513	0.1388	0.2104	0.2772	0.2725	0.1301	0.1264	0.1143	0.0939	0.3708	-0.1907	-0.3038	-0.1347																					
Bot_SSB_Astrch	0.2221	0.253	0.0383	-0.221	-0.257	-0.2106	-0.0671	-0.4897	-0.3222	-0.2352	-0.2044	0.1123	0.1749	-0.9915	0.2623																				
Bot_SSB_O3PG06	0.0349	-0.1036	-0.1023	0.0486	0.232	0.0473	-0.1213	-0.0035	-0.0414	-0.0434	0.1816	0.2377	0.1963	0.0418	0.0728	-0.0312																			
Bot_SSB_O3PG09	0.1429	0.3679	-0.126	-0.4093	-0.2471	-0.2354	-0.1063	-0.1653	-0.1963	-0.1729	-0.0807	0.1338	0.1623	-0.2708	-0.0008	0.2636	0.0491																		
Bot_SSB_O3PGch	0.1357	0.3837	-0.1069	-0.415	-0.2866	-0.2421	-0.084	-0.1636	-0.1876	-0.164	-0.1124	0.0906	0.1263	-0.2763	-0.0138	0.2673	-0.1288	0.9842																	
Bot_SSB_OPG06	-0.1149	-0.1544	-0.182	0.0582	-0.0626	-0.0293	0.0117	0.1395	0.1655	0.1457	0.1185	0.5486	0.5382	0.0436	-0.034	-0.047	0.2462	-0.1432	-0.1859																
Bot_SSB_OPG09	0.036	0.2067	-0.1797	-0.2826	-0.2863	-0.1747	0.0016	-0.2611	-0.1601	-0.1129	-0.1518	0.1745	0.2249	-0.3423	0.016	0.3354	-0.0061	0.32	0.3188	-0.0097															
Bot_SSB_OPGch	0.1133	0.2458	0.0395	-0.2136	-0.1191	-0.0799	-0.0085	-0.2661	-0.2272	-0.1835	-0.1846	-0.3361	-0.298	-0.2373	0.0367	0.2359	-0.2008	0.3038	0.3373	-0.8065	0.599														
Bot_SSB_forb_des06	0.1735	0.1043	0.415	0.1019	0.0487	0.3029	0.3475	-0.122	-0.079	-0.0572	-0.0958	-0.1953	-0.1765	-0.1785	0.1836	0.1979	-0.0573	0.0068	0.017	-0.2407	-0.1129	0.126													
Bot_SSB_forb_des09	0.0842	0.1479	0.3188	0.0141	-0.1816	0.2125	0.4125	-0.1312	-0.3385	-0.3324	-0.1705	-0.2293	-0.1907	-0.2503	-0.1414	0.2252	-0.2266	-0.0559	-0.0153	-0.2658	-0.0562	0.1797	0.4396												
Bot_SSB_forb_desch	-0.0237	0.0921	0.0715	-0.0527	-0.2311	0.0301	0.2191	-0.0621	-0.3175	-0.3254	-0.1225	-0.1204	-0.0907	-0.1546	-0.2773	0.1142	-0.2095	-0.0658	-0.0281	-0.13	0.0139	0.1123	-0.187	0.8001											
Bot_SSB_forb_undes06	-0.0285	0.475	0.1258	-0.3889	-0.0389	-0.0207	0.0041	-0.1636	-0.3243	-0.3101	-0.0912	-0.0889	-0.0668	-0.349	0.0837	0.3509	0.0156	0.4626	0.4565	-0.2173	0.1678	0.2732	0.1569	0.135	0.0429										
Bot_SSB_forb_undes09	-0.1839	-0.0296	0.0853	0.0693	-0.0824	-0.0162	0.0439	-0.1098	-0.0717	-0.0522	-0.1215	-0.093	-0.0625	-0.1158	0.0023	0.113	0.0756	0.0817	0.0677	-0.0983	-0.1553	-0.0131	-0.0098	0.1014	0.1175	0.0795									
Bot_SSB_forb_undesch	-0.1369	-0.3167	-0.0057	0.297	-0.0453	-0.0008	0.0344	0.0083	0.1391	0.1467	-0.046	-0.0235	-0.0115	0.1173	-0.0495	-0.1207	0.0539	-0.2156	-0.2237	0.051	-0.2335	-0.1789	-0.1047	0.0022	0.0723	-0.5476	0.7905								
Bot_tot_yield06	-0.243	-0.4648	-0.2724	0.3084	0.3826	0.0871	-0.1885	0.0864	0.389	0.3963	0.0102	0.0171	0.0149	0.3287	-0.086	-0.3314	0.0176	-0.2489	-0.2502	0.3042	-0.1116	-0.3095	-0.4502	-0.3303	-0.0606	-0.3138	-0.1206	0.0916							
Bot_tot_yield09	-0.0155	-0.3847	-0.5497	0.0984	0.2328	0.0199	-0.1568	-0.0428	0.1055	0.1222	0.2781	0.3901	0.3278	0.1105	0.0282	-0.1039	0.2276	-0.0985	-0.1382	0.4734	-0.0549	-0.4115	-0.4698	-0.4624	-0.192	-0.2363	-0.036	0.115	0.5397						
Bot_tot_yieldch	0.2116	0.008	-0.3577	-0.1805	-0.1003	-0.0598	0.0024	-0.1293	-0.2485	-0.2367	0.3012	0.4198	0.3522	-0.1861	0.1126	0.196	0.2378	0.1244	0.0813	0.2425	0.0438	-0.1683	-0.101	-0.2057	-0.1575	0.0316	0.0734	0.0422	-0.3389	0.6092					
Condition_change_%	0.1619	0.3966	-0.2404	-0.4917	-0.3309	-0.3295	-0.1604	-0.3979	-0.1717	-0.0948	0.1481	0.4228	0.3987	-0.3245	-0.239	0.2847	0.0145	0.1934	0.1894	0.102	0.0847	-0.0316	0.0325	0.1466	0.1386	0.2441	-0.026	-0.1718	-0.1467	-0.0083	0.1289				
GP_DSS_99_07	0.0743	-0.2078	0.1987	0.2928	0.0683	0.0936	0.0656	-0.0733	-0.1261	-0.1184	-0.1877	-0.1999	-0.1551	-0.0007	-0.0638	-0.0077	0.0971	-0.0718	-0.0886	-0.0863	0.0307	0.0873	0.2557	0.1555	-0.0007	-0.0497	-0.2008	-0.138	0.1031	-0.1247	-0.2365	-0.2317			
GP_No_spells_99_07	0.1852	-0.1259	0.2348	0.2327	0.0699	0.1058	0.08	-0.098	-0.0716	-0.0547	-0.2403	-0.2406	-0.1827	-0.0734	-0.0764	0.0615	0.1675	-0.0926	-0.1216	-0.0772	-0.05	0.0323	0.3135	0.2313	0.0436	-0.0139	-0.2279	-0.1828	-0.0769	-0.1471	-0.092	-0.2318	0.8288		
GP_WSS_99_07	0.2318	-0.0111	0.1966	0.1055	0.05	0.0848	0.0689	-0.0911	0.001	0.0213	-0.2159	-0.205	-0.1525	-0.1187	-0.0647	0.1071	0.1817	-0.0836	-0.1152	-0.0451	-0.1098	-0.0288	0.2714	0.2312	0.0716	0.0236	-0.1836	-0.1686	-0.2209	-0.1229	0.0708	-0.161	0.416	0.8536	
GP_dist_to_water_km	-0.1749	0.0891	-0.0104	-0.0893	-0.1752	-0.0232	0.1076	-0.1537	-0.2567	-0.2401	-0.1201	0.2627	0.3079	-0.0265	-0.2648	-0.0089	-0.0566	0.1993	0.2079	0.1525	-0.0922	-0.1767	0.1287	0.057	-0.0236	0.2065	-0.1927	-0.2886	-0.0867	0.0146	0.098	0.441	0.0043	0.003	0.0008
GP_rest_durn_mnth	0.1322	-0.1929	0.2214	0.2896	0.1377	0.1809	0.1226	0.0318	0.0227	0.0171	-0.1512	-0.359	-0.3313	0.1062	-0.0234	-0.1064	0.1477	-0.1248	-0.1501	-0.0162	-0.163	-0.0834	0.2899	0.1914	0.0157	-0.082	-0.1831	-0.1033	0.0636	-0.1524	-0.2303	-0.3197	0.7674	0.8522	0.6706
RE_FWS_3mnth_av	0.0945	0.5078	0.204	-0.3821	-0.3361	-0.0621	0.184	-0.1064	-0.3023	-0.2993	-0.1378	0.0425	0.0833	-0.1941	-0.1815	0.1653	-0.2673	0.0996	0.1463	-0.1831	-0.0191	0.1354	0.4962	0.4888	0.2033	0.3082	-0.2705	-0.4164	-0.4361	-0.5169	-0.1669	0.4386	0.0362	0.0882	0.1096
RE_FWS_3mnth_av0_20	0.0263	0.3895	0.1936	-0.2752	-0.345	0.0163	0.2906	-0.1503	-0.4094	-0.4039	-0.1126	-0.0061	0.0255	-0.307	-0.1062	0.285	-0.2288	0.1207	0.1605	-0.3003	0.0135	0.2484	0.5765	0.5529	0.2197	0.2926	-0.138	-0.2957	-0.5309	-0.5518	-0.1165	0.3977	0.083	0.1235	0.1234
RE_FWS_6mnth_av	-0.0287	0.4568	-0.0421	-0.4528	-0.268	-0.0417	0.1566	-0.0717	-0.3202	-0.3261	0.1242	0.0277	-0.0063	-0.2368	-0.0392	0.2255	-0.1177	0.0672	0.0876	-0.2965	-0.0245	0.223	0.3232	0.3411	0.1572	0.3842	-0.0071	-0.242	-0.4343	-0.4233	-0.0639	0.4453	-0.1372	-0.1346	-0.091
RE_daily_rain	0.0933	-0.457	-0.2354	0.3189	0.2931	0.0307	-0.1902	-0.0559	0.2773	0.3087	0.0238	-0.0758	-0.0858	0.1718	0.1065	-0.1533	0.1339	-0.2151	-0.2373	0.212	0.1033	-0.1087	-0.4036	-0.4488	-0.2213	-0.3907	0.0357	0.27	0.4975	0.5739	0.1728	-0.3994	0.0544	0.0219	-0.0151
RE_index_S00_01	0.1373	-0.4488	-0.236	0.3108	0.2403	-0.0504	-0.2522	0.0474	0.4047	0.4219	0.0891	-0.0136	-0.0394	0.2895	0.0716	-0.2726	0.0926	-0.2405	-0.2553	0.2507	0.0425	-0.1757	-0.4794	-0.4932	-0.2193	-0.4545	-0.0638	0.2257	0.6034	0.5767	0.0761	-0.3309	0.024	-0.0258	-0.0642
RE_index_S01_02	0.3726	-0.3198	0.0737	0.3383	-0.0053	0.0185	0.0277	0.1137	0.158	0.1435	0.0964	0.0851	0.0614	0.1829	0.0477	-0.1719	0.1098	0.0293	0.0096	0.143	-0.0774	-0.1603	0.0618	-0.0456	-0.0912	-0.4965	-0.3057	0.0485	0.0002	0.1666	0.186	-0.2005	0.1906	0.2705	0.2622
RE_index_S02_03	-0.0503	-0.2545	-0.2165	0.1363	0.2952	-0.141	-0.4104	0.2398	0.4938	0.4742	0.1419	0.1641	0.1308	0.3619	0.0139	-0.3506	0.2278	-0.0563	-0.0963	0.4311	-0.0626	-0.3822	-0.6612	-0.6127	-0.2286	-0.2413	0.0413	0.183	0.5973	0.55	0.052	-0.2444	-0.1482	-0.1975	-0.1831
RE_index_S03_04	0.1328	-0.4605	-0.2629	0.3088	0.1263	-0.0486	-0.1607	0.0602	0.3289	0.338	0.06	-0.1552	-0.1788	0.2423	0.0305	-0.232	-0.0184	-0.1845	-0.1799	0.1234	0.0758	-0.054	-0.3733	-0.4125	-0.2018	-0.4686	0.0232	0.3073	0.5157	0.4539	0.0215	-0.3738	0.04	-0.017	-0.0649
RE_index_S04_05	0.1322	-0.3474	-0.5633	0.0566	0.1326	-0.1247	-0.2625	-0.1986	0.0656	0.1144	0.1727	0.2067	0.1665	-0.0379	-0.03	0.033	0.1165	-0.1871	-0.2065	0.2018	0.1933	-0.0473	-0.4873	-0.5	-0.2215	-0.324	-0.1108	0.106	0.3844	0.7168	0.439	-0.0517	-0.0598	-0.0891	-0.0892
RE_index_S05_06	0.0382	-0.3484	-0.418	0.1278	0.127	-0.2087	-0.365	0.0558	0.4003	0.4152	0.1406	0.1401	0.1061	0.2207	-0.0685	-0.2239	0.0354	-0.1994	-0.2042	0.3104	0.0308	-0.2304	-0.5995	-0.5799	-0.2339	-0.3791	-0.0995	0.1493	0.7559	0.6333	-0.0043	-0.0476	-0.0726	-0.1992	-0.2562
RE_index_S06_07	0.109	-0.2474	-0.4622	0.0108	0.123	-0.2597	-0.4267	0.117	0.4232	0.4261	0.2904	0.4243	0.3599	0.1886	-0.0539	-0.1908	0.1961	-0.1512	-0.1849	0.4095	0.0508	-0.2979	-0.6366	-0.5845	-0.2142	-0.3982	-0.0119	0.2347	0.3828	0.6574	0.3741	-0.0391	-0.2671	-0.2544	-0.1648
RE_index_S07_08	0.2273	-0.3494	-0.2262	0.2215	0.1636	0.1269	0.0336	-0.3796	-0.1359	-0.0606	-0.0088	-0.0931	-0.0945	-0.2184	0.0733	0.2223	0.0004	-0.2593	-0.2575	-0.0021	0.1839	0.1104	0.1121	-0.0716	-0.1532	-0.3556	-0.0916	0.1416	0.0867	0.3598	0.3205	-0.1994	0.2076	0.2063	0.142
RE_index_S08_09	0.081	-0.2636	-0.4115	0.0506	0.1692	-0.2424	-0.4409	0.1161	0.458	0.4635	0.232	0.2548	0.1998	0.2849	-0.0349	-0.282	0.127	-0.1917	-0.2128	0.3727	-0.0023	-0.2998	-0.6817	-0.6303	-0.2341	-0.3325	-0.1481	0.0799	0.6862	0.6606	0.0918	-0.0244	-0.1538	-0.2358	-0.24
RE_index_S99_00	0.0706	0.0897	-0.0896	-0.1282	0.3815	0.0478	-0.2376	-0.168	0.0978	0.142	-0.0665	-0.0538	-0.0373	0.0875	0.062	-0.0771	0.1627	-0.1378	-0.1657	0.2193	0.007	-0.1715	-0.3084	-0.3396	-0.1655	0.1541	-0.0575	-0.1429	0.2954	0.3776	0.1437	-0.1675	-0.056	-0.0458	-0.0223
RE_index_W00	-0.0178	-0.204	0.085	0.2342	0.0988	0.302	0.307	-0.3147	-0.3314	-0.284	-0.1298	-0.1884	-0.1595	-0.3366	0.1016	0.3412	-0.0154	-0.1021	-0.0986	-0.1962	0.1234	0.2301	0.4267	0.3002	0.0434	-0.127	0.2729	0.3071	-0.3672	-0.1095	0.2235	-0.2375	0.1614	0.199	0.1732
RE_index_W01	0.2052	-0.147	0.0776	0.1767	-0.05	0.1716	0.2575	-0.3906	-0.3392	-0.2754	-0.1512	-0.2433	-0.2108	-0.3357	0.0866	0.3383	-0.1513	-0.1757	-0.1476	-0.2795	0.2282	0.3588	0.4494	0.361	0.0947	-0.2042	-0.0277	0.1022	-0.324	-0.12	0.1711	-0.1725	0.2718	0.3251	0.2753
RE_index_W02	0.2045	-0.2371	0.0821	0.2642	0.0818	0.1055	0.0703	-0.213	-0.13	-0.0914	0.0041	-0.3086	-0.3228	-0.1792	0.1323	0.1919	-0.0831	-0.1956	-0.1794	-0.1905	0.0987	0.211	0.2885	0.1745	-0.0018	-0.2718	0.0379	0.1988	-0.1322	-0.0251	0.0965	-0.3479	0.2903	0.324	0.2563
RE_index_W03	-0.1904	0.3686	0.5191	-0.0981	-0.0725	0.1925	0.3017	-0.0373	-0.2777	-0.2884	-0.3197	-0.2106	-0.1289	-0.1622	-0.0264	0.1545	-0.1222	0.1469	0.1675	-0.1843	-0.0797	0.1005	0.5418	0.5706	0.2622	0.3661	0.1814	-0.0726	-0.4538	-0.646	-0.2944	0.0473	0.0775	0.109	0.105
RE_index_W04	0.2058	-0.115	0.161	0.1867	0.1316	0.3061	0.2867	-0.3018	-0.3086	-0.2625	0.0046	-0.1789	-0.1877	-0.2932	0.255	0.319	0.0542	-0.1142	-0.123	-0.2683	0.0918	0.2692	0.5331	0.3091	-0.0179	-0.0231	-0.0129	0.0034	-0.5052	-0.1472	0.3114	-0.1959	0.2368	0.3487	0.3463
RE_index_W05	-0.1363	0.2137	-0.0007	-0.2026	-0.1664	0.2084	0.3954	-0.3561	-0.6564	-0.622	-0.2307	-0.16	-0.1014	-0.5158	-0.0176	0.5	-0.0657	0.2265	0.2366	-0.3671	0.1943	0.4089	0.4729	0.4025	0.1244	0.4083	0.1944	-0.0877	-0.6084	-0.3338	0.2001	0.1467	0.056	0.1024	0.1142
RE_index_W06	0.2283	-0.4841	-0.4352	0.2479	0.1383	-0.0691	-0.1962	-0.1094	0.2105	0.2493	0.2461	0.1224	0.0579	0.0615	0.1	-0.0468	0.1303	-0.2659	-0.2872	0.1451	0.1155	-0.0479	-0.3602	-0.4369	-0.2373	-0.4917	-0.1319	0.1914	0.4173	0.6405	0.3227	-0.1456	0.0465	0.0166	-0.0164
RE_index_W07	0.0758	-0.2645	-0.463	0.0266	0.2124	-0.2079	-0.4308	0.1056	0.3824	0.3851	0.2941	0.4015	0.3352	0.1805	-0.072	-0.1853	0.2137	-0.1416	-0.1785	0.4641	0.0076	-0.3672	-0.6026	-0.5947	-0.248	-0.4076	-0.0226	0.2315	0.419	0.6742	0.3587	-0.0651	-0.2494	-0.2704	-0.2072
RE_index_W08	0.081	0.0336	0.0155	-0.0243	-0.1266	0.2187	0.3774	-0.4015	-0.5627	-0.5118	-0.1598	-0.1924	-0.1553	-0.4743	0.0478	0.4682	-0.0827	0.0502	0.0645	-0.3536	0.2048	0.4043	0.5614	0.4131	0.0769	0.1308	0.0735	-0.0186	-0.5813	-0.2323	0.288	0.0018	0.1977	0.2874	0.283
RE_index_W09	0.2596	-0.1312	0.1074	0.1762	-0.0048	0.206	0.266	-0.1677	-0.1773	-0.152	0.0039	-0.351	-0.3669	-0.1463	0.1379	0.1606	-0.1345	-0.1314	-0.1065	-0.3042	0.0582	0.278	0.5005	0.2865	-0.0209	-0.1681	0.0544	0.1489	-0.3802	-0.2182	0.1143	-0.2963	0.218	0.3058	0.294
RE_index_W99	-0.0835	-0.062	0.2088	0.1596	-0.1123	0.2035	0.3469	-0.2938	-0.4137	-0.3766	-0.3245	-0.1712	-0.0865	-0.3979	-0.053	0.3805	-0.1511	0.0387	0.0652	-0.1959	0.1692	0.257	0.5392	0.4837	0.1689	-0.0507	0.2061	0.2042	-0.4278	-0.301	0.0666	-0.0949	0.2174	0.2559	0.2135
RE_total_rain	0.1041	-0.4244	-0.229	0.2911	0.3001	0.033	-0.1928	-0.0317	0.2949	0.3222	0.0338	-0.0899	-0.1033	0.2063	0.1043	-0.1873	0.132	-0.2078	-0.2298	0.2107	0.0764	-0.1236	-0.4136	-0.4617	-0.2288	-0.3639	0.0352	0.2532	0.4965	0.558	0.1559	-0.4033	0.0321	0.0029	-0.0252

	GP_dist_to_water_km	GP_rest_durn_mnth	RE_FWS_3mnth_av	RE_FWS_3mnth_av0_20	RE_FWS_6mnth_av	RE_daily_rain	RE_index_S00_01	RE_index_S01_02	RE_index_S02_03	RE_index_S03_04	RE_index_S04_05	RE_index_S05_06	RE_index_S06_07	RE_index_S07_08	RE_index_S08_09	RE_index_S99_00	RE_index_W00	RE_index_W01	RE_index_W02	RE_index_W03	RE_index_W04	RE_index_W05	RE_index_W06	RE_index_W07	RE_index_W08	RE_index_W09	RE_index_W99	RE_total_rain
GP_dist_to_water_km																												
GP_rest_durn_mnth	-0.1038																											
RE_FWS_3mnth_av	0.5114	-0.0036																										
RE_FWS_3mnth_av0_20	0.5113	0.0058	0.926																									
RE_FWS_6mnth_av	0.3601	-0.1752	0.783	0.846																								
RE_daily_rain	-0.5472	0.0905	-0.8426	-0.8866	-0.86																							
RE_index_S00_01	-0.4985	0.0725	-0.7766	-0.8768	-0.828	0.9567																						
RE_index_S01_02	-0.138	0.2291	-0.2587	-0.2721	-0.5931	0.4222	0.4621																					
RE_index_S02_03	-0.3522	-0.0592	-0.7539	-0.9237	-0.7241	0.7141	0.779	0.1676																				
RE_index_S03_04	-0.4816	0.1178	-0.7385	-0.7797	-0.7641	0.9041	0.9203	0.4384	0.6408																			
RE_index_S04_05	-0.319	-0.1415	-0.6016	-0.595	-0.476	0.7683	0.7511	0.3105	0.4729	0.6838																		
RE_index_S05_06	-0.2266	-0.0629	-0.5468	-0.6676	-0.4957	0.6986	0.8246	0.1685	0.7207	0.7729	0.7188																	
RE_index_S06_07	-0.3372	-0.2175	-0.6305	-0.7309	-0.4801	0.6234	0.6945	0.2111	0.7849	0.5723	0.7103	0.7083																
RE_index_S07_08	-0.2499	0.1304	-0.2916	-0.2003	-0.3465	0.5807	0.4496	0.3721	-0.043	0.537	0.6651	0.2786	0.1671															
RE_index_S08_09	-0.2869	-0.1349	-0.5664	-0.7347	-0.5025	0.6828	0.824	0.1897	0.8233	0.6688	0.7207	0.9382	0.8352	0.1359														
RE_index_S99_00	-0.3759	-0.0473	-0.3994	-0.6032	-0.4641	0.585	0.5266	-0.0286	0.5833	0.3002	0.4103	0.3284	0.3545	0.1796	0.4756													
RE_index_W00	-0.0845	0.1139	-0.0929	0.1585	-0.009	0.05	-0.1862	0.0248	-0.4279	0.0002	0.0238	-0.4173	-0.2588	0.6143	-0.554	-0.2178												
RE_index_W01	-0.1771	0.1795	0.0704	0.2465	-0.0348	0.1509	-0.0194	0.2923	-0.5386	0.1196	0.1956	-0.2873	-0.3117	0.7828	-0.4215	-0.1363	0.7899											
RE_index_W02	-0.2199	0.242	-0.1614	-0.0085	-0.1991	0.274	0.1117	0.2245	-0.2395	0.3174	0.1885	-0.1314	-0.1314	0.7594	-0.2857	-0.1066	0.8067	0.8179										
RE_index_W03	0.3231	0.1072	0.5971	0.6244	0.4668	-0.7078	-0.7951	-0.4093	-0.5689	-0.7185	-0.9018	-0.8073	-0.7679	-0.4126	-0.841	-0.2746	0.2735	0.0588	0.0161									
RE_index_W04	-0.1491	0.1556	0.0439	0.2422	0.0289	0.0286	-0.1685	0.265	-0.5265	-0.113	0.0841	-0.5216	-0.3125	0.6164	-0.5341	-0.053	0.8017	0.8621	0.7201	0.14								
RE_index_W05	0.1963	-0.0471	0.3572	0.5957	0.4819	-0.4373	-0.6381	-0.2397	-0.7686	-0.5006	-0.2163	-0.6755	-0.6295	0.1621	-0.7618	-0.281	0.6001	0.5369	0.2468	0.4598	0.5939							
RE_index_W06	-0.3838	0.0047	-0.6166	-0.5807	-0.5201	0.7927	0.8149	0.4782	0.4261	0.7672	0.9264	0.7357	0.6617	0.6896	0.7069	0.2506	0.0392	0.267	0.2696	-0.9191	0.1337	-0.3304						
RE_index_W07	-0.2573	-0.2017	-0.6064	-0.7159	-0.4856	0.6133	0.6604	0.1877	0.7892	0.5836	0.6908	0.7162	0.9473	0.2612	0.7949	0.3602	-0.1546	-0.2854	-0.0138	-0.6926	-0.296	-0.6096	0.6111					
RE_index_W08	0.0718	0.1023	0.2646	0.5026	0.2824	-0.1985	-0.4068	0.0445	-0.7536	-0.2355	-0.0187	-0.5751	-0.5068	0.5403	-0.6931	-0.2847	0.8174	0.8567	0.6352	0.2853	0.8594	0.8635	-0.0373	-0.4711				
RE_index_W09	-0.1873	0.2468	0.0167	0.1625	-0.0323	0.1035	-0.05	0.2215	-0.4075	0.1995	0.0199	-0.3214	-0.2502	0.6473	-0.4606	-0.2243	0.8134	0.8069	0.9077	0.1345	0.7728	0.3644	0.123	-0.1613	0.7283			
RE_index_W99	0.169	0.1669	0.2291	0.441	0.135	-0.2271	-0.4239	-0.0048	-0.6208	-0.1915	-0.2682	-0.5483	-0.5176	0.4115	-0.7404	-0.442	0.878	0.733	0.6771	0.5385	0.6313	0.6672	-0.2499	-0.4034	0.8055	0.7051		
RE_total_rain	-0.5593	0.0835	-0.8417	-0.906	-0.8598	0.9961	0.9603	0.4081	0.7462	0.9018	0.7462	0.6986	0.6319	0.5349	0.697	0.6222	0.0048	0.0971	0.2344	-0.7018	-0.007	-0.4682	0.7648	0.621	-0.2439	0.0803	-0.2786	