final report

Project code: B.NBP.0555

Prepared by: Paul Jones, Richard Silcock, Joe Scanlan and Tim Moravek
Queensland Department of Agriculture and Fisheries

Date published: 30 June 2016

ISBN: <Delete if not required>

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

Spelling strategies for recovery of pasture condition

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

Abstract

Reduced condition of pasture and soil is common in pasture communities across northern Australia where desirable perennial grasses are the cornerstone for profitable and sustainable beef production. Spelling pasture from grazing over the summer growing season is a key grazing land management recommendation, however there is little hard evidence to underpin the recommendations on practical spelling regimes.

To address this information gap, trials to quantify the response of native pasture to differing spelling regimes were conducted at two sites in priority pasture communities in central and north Queensland. Detailed recordings were made on plant lifecycles, yield, composition and soil seed banks. The data collected has been used to refine the GRASP pasture growth model.

This project has generated a greater understanding of pasture responses to spelling. The results over a five year project life did not produce the significant differences expected in land condition that most Grazing Land Management recommendations imply. Indeed, this study has demonstrated that pasture recovery by spelling management is a longer term process than first thought. Bio-economic modelling was conducted on two co-operator properties providing key information on the outcomes of different spelling regimes. Continuing research on the population biology of *Bothriochloa ewartiana* and the impact of spelling regimes on key pasture species is recommended.

Executive Summary

Wet season spelling of grazing land is a key recommendation for maintaining or improving land condition. There is limited relevant information or experimental work on practical spelling strategies (McIvor 2011), although recent reviews by Scanlan *et al*. (2014) and O'Reagain *et al*. (2014) highlight principles for sustainable grazing land management and the role of spelling. This research project, funded by Meat and Livestock Australia, and Queensland Department of Agriculture and Fisheries, sought to improve the biological evidence base and modelling accuracy that underpin recommendations for use of wet season spelling to recover poor condition grazing land, and to design more reliable and cost-effective spelling options for producers. It assessed the effects of different spelling regimes on key pasture parameters of poor condition land at two sites in central and northern Queensland under both moderate and high stocking rates. Local networks of producers were engaged through on-property research, field days and group meetings.

Site 1, at Monteagle near Clermont, studied a combination of timing, duration and frequency of spelling within 'C' (poor) condition land. Two durations of spelling (early wet season or full wet season) were combined with two frequencies of spelling (annual or biennial), and each year there was an extra, once only full wet season spelling treatment, and all were compared against non-spelled areas in the same paddock. Site 2, at the Wambiana Grazing Trial, is 'C' condition land within an existing trial near Charters Towers (O'Reagain *et al*. 2014). Similar combinations of spelling duration and frequency, were compared against non-spelled areas at both a moderate and high stocking rate. At both sites, plots were 20 x 20m and replicated four times. Pasture yield, composition ground cover and soil surface characteristics were recorded, and land condition categorised. Population dynamics of the key perennial grasses *Bothriochloa ewartiana* and *Aristida* species were mapped in permanent quadrats. Soil cores were taken each spring to determine readily germinable seed reserves of pasture species.

In addition, two case studies were conducted with other co-operating producers based on their property level information. They incorporated bio-economic modelling to address key research questions around the interaction of stocking rates, spelling and land condition outcomes. This modelling was made possible by using the field trial data to improve the GRASP pasture growth model (McKeon *et al*. 2000). Land condition, animal production outputs and a full business analysis were generated for the scenarios on each property.

Five years of data from Site 1 in central Queensland showed a small, yet encouraging, response to spelling treatments on the pasture under a moderate stocking rate. However, pasture parameters and plant dynamics were more affected by seasonal conditions than the treatments. *B. ewartiana* is of particular interest in this study because of its palatable, productive and perennial (3P) characteristics. There was a small improvement in crown cover and pasture yield with spelling, driven by the increase in *B. ewartiana* crown cover and yield. Survival and crown cover of *B. ewartiana* recruits appear to have increased with spelling. Pasture yield, ground cover, crown cover and plant density all improved during the first two wet years of the trial and then decreased following a wildfire burn with three subsequent very dry summers. *Aristida* spp*.* are also of particular interest in this study because they have low palatability and forage productivity. *Aristida* spp. crown cover decreased following the burn and remained low for the next three dry summers. The *Aristida* spp. had a higher turnover of plants than *B. ewartiana*. There are very low numbers of germinable 3P grass seeds in the soil regardless of year or grazing management.

Three years of data from Site 2 in north Queensland has shown the importance of a moderate stocking rate to realise responses to spelling. Similar to Site 1, the pasture parameters and plant dynamics were more affected by seasonal conditions than treatments. While spelling increased pasture yields under a high stocking rate, the response was short lived (~3 months), and overall pasture yields were higher with a moderate stocking rate. Crown cover and composition of *B. ewartiana* and *Aristida* spp. were increased with spelling under a moderate stocking rate. While the first year of the trial had average rainfall and growing conditions the two subsequent dry years reduced the pasture yields, particularly under the high stocking rate. There were very low numbers of germinating 3P grass seeds in the soil in spring regardless of year or grazing management.

The project has generated a better understanding of the interaction of seasonal conditions, stocking rate, duration, timing and frequency of spelling for pasture recovery where the pasture is in poor condition. A viable seedbank of the desirable perennial grasses (mainly *B. ewartiana*) and a subsequent recruitment event are critical for land condition improvement (Orr and Phelps, 2013). Neither a seedbank of the required size nor suitable recruitment events occurred during the project at either site. This appears to be the underlying cause for the lack of a substantial improvement in land condition at both sites. Where an improvement in pasture parameters indicated an improvement in land condition with spelling, it was only recorded under the moderate stocking rate.

The benefits to industry come from an increased understanding of the responses of pasture in poor condition to different spelling regimes and through varying seasonal conditions. Spelling gives a small benefit to the crown cover of existing and germinating 3P grasses and the survival of 3P seedlings. Time frames in the order of 10 years are likely before spelling will have an obvious impact on land condition and productivity. Where a viable seedbank is present, and good seasonal conditions prevail for germination and establishment of 3P grasses, this timeframe may be considerably shorter. The ecological processes around episodic climatic events are not fully understood. However, the knowledge that a moderate stocking rate is necessary for these improvements to accrue is an important finding of this project. Modelling pasture growth has been improved so that the impacts of different spelling and stocking rate regimes on pasture condition at a multi-paddock scale is better understood over a range of pasture community types and seasons. The two case studies have generated information that producers can use to make the best decisions for their own property.

The lack of recruitment of *B. ewartiana* is the main reason that pasture condition has not improved. A lack of information on the population biology of *B. ewartiana*, particularly reproduction by seed and growing points, is seen as a major deficiency in understanding the current results. This lack of understanding hinders the explanation of the project results and the development of improved recommendations about the implementation of wet season spelling to recover poor land condition. This lack of clarity does not detract from the importance of 3P grasses for sustainability and profitability, nor the understanding that wet season spelling should be practised for the improvement and/or maintenance of land condition. There is strong confidence that land condition will improve with spelling and good grazing management, although it will take longer to measure than initially thought. Further monitoring and research on the impact of spelling on key pasture species to better understand land condition changes under conservative management practice is recommended.

Acknowledgments

We thank the four property owners, managers and their staff for cooperation, support and interest during the project, for sharing their records, experience and knowledge, and also for their generous hospitality which made the field work all the more enjoyable.

Technical assistance from Carly Harris, Jane Tincknell and Kaylea Paulger was integral to the success and completion of this project. Their dedication, enthusiasm and professionalism in what were often challenging conditions in the field, is greatly appreciated.

We thank Meat and Livestock Australia (MLA) and the Department of Agriculture and Fisheries (DAF) for contributing finance and facilities to the project team. We thank the many DAF staff who assisted with the field work and data processing throughout the project. Other staff from DAF also provided valuable guidance. The assistance and dedication of Bob Mayer and David Reid for the statistical analysis is especially acknowledged.

We thank the Technical Panel for their expertise and time as they met annually to review and guide the project. Members include, David Reid, Bob Mayer, Richard Silcock, David Orr, Joe Scanlan, Peter O'Reagain, John McIvor, Cameron Allan and Mick Quirk.

Table of Contents

List of Figures

List of Tables

1 Background

Reduced condition of pasture and soil is evident in most pasture communities across northern Australia (Queensland, Northern Territory, and Kimberley and Pilbara regions of Western Australia) and is demonstrated through a decline in density and growth of desirable perennial grasses. Extensive areas have been estimated as ‘C’ condition: around 50% of the Northern Gulf region, 40% of the Burdekin catchment and 20% of the Fitzroy Basin (using ‘ABCD’ condition ratings of Quirk and McIvor 2003), (Scarth *et al.* 2006, Beutel *et al.* 2009 and Karfs *et al.* 2009). These areas of ‘C’ condition pasture have effectively reduced their carrying capacity by 50% or more (McIvor *et. al*. 1995), and are also a major risk for erosion and downstream impacts on water quality (Bartley 2014). Spelling grazing land to maintain or improve land condition is a key recommendation for improved grazing management across northern Australia, especially for accelerating recovery of pasture that has declined in condition.

There is little reliable and relevant information on which to guide the design of cost-effective and practical spelling regimes for pasture condition recovery. There are few data on how quickly and effectively poor condition pasture will respond to variations in the timing, duration, and frequency of wet season spelling (McIvor 2011, Scanlan 2014). While Hunt (2014) has made general recommendations on pasture spelling, specific best management practice recommendations are lacking (Briske 2008, MacLeod 2009). In addition, modelling indicates that the net benefit of spelling a paddock, or group of paddocks, interacts strongly with both the overall stocking rate applied and the impact of any periods of heavy grazing associated with implementing the spelling strategy (Scanlan 2011).

The purpose of the study was to improve the evidence base underpinning recommendations for spelling pastures to recover poor condition grazing land. We report the response of native pasture in priority pasture communities to different timings, durations, and frequencies of pasture spelling. The primary studies were on the use of growing season, or ‘wet season’ spelling to recover the pasture and soil condition of paddocks of native pasture that are in poor condition in the Burdekin catchment. The interactions between seasonal conditions and the effect of spelling treatments under a moderate stocking rate, as well as a high stocking rate were examined. There were minimal benefits from spelling in our measured pasture parameters, however the increase in perennial grass basal area is an encouraging result. It appears that pasture recovery with spelling takes many years and is restricted by small, viable soil seed banks. A demonstration site in the Fitzroy catchment was also monitored for four years with similar results. We also conducted a monitoring program on two commercial operations that were using spelling to improve pasture condition.

Field trial data was used to improve the capacity of the GRASP model (McKeon *et al*. 2000) to simulate the impacts of different spelling and stocking rate regimes on pasture condition over a range of pasture community types and seasons. The modified GRASP model was then used to explore the best bet spelling options emerging from the field work at a multi-paddock scale, examining the effects of both overall stocking rate and any periods of heavy grazing associated with implementing the spelling strategy. This was incorporated into two case studies with co-operating producers.

The improved understanding and predictability of wet season spelling outcomes can be used to design more reliable and cost-effective spelling options for producers and thus contribute to more profitable and sustainable beef production in northern Australia.

2 Projective Objectives

The objectives are as per the original contract:

1. Improved understanding of the response of native pastures in poor condition to wet season spelling;

2. Quantified the impact of timing, duration, and frequency of pasture spelling on pasture and soil condition response in one major pasture community of Queensland;

3. Quantified the impact of overall stocking rate on the net benefit of pasture spelling in a second major pasture community of Queensland;

4. Identified practical plant-based indicators of (i) when a spelling period has been effective and (ii) how well pasture is responding to a spelling regime;

5. Developed improved capacity to realistically simulate the impacts of different wet season spelling regimes on the recovery of pasture and soil condition through refinement of models such as GRASP;

6. Explored, using GRASP, how the net benefit from spelling for a paddock, or group of paddocks, interacts with both the overall stocking rate applied and any periods of heavy grazing associated with the implementation of the spelling strategy;

7. Promoted engagement of local networks of producers and field staff in this research;

8. Developed improved recommendations for recovery of pasture and soil condition in each of the studied pasture communities.

3 Methodology

3.1 Site 1 and Site 2

3.1.1 Design

3.1.1.1 Site 1

Impacts of timing, duration and frequency of spelling on pasture recovery
The experimental plots were within a 'C' condition grazed paddock, 55 km west of Clermont in the Lennox land system (Gunn *et al*. 1967) which is described as 'plains; loamy red earths with *Eucalyptus melanophloia* woodland with *B. ewartiana* and *Aristida* spp.' The paddock is mainly box country land type (Whish, 2011), not cleared, with an even tree cover and predominantly native pasture with *B. ewartiana* and *Aristida* spp. as the main perennial grasses. The site was destocked over the 2012-13 summer following a wildfire in November 2012 and then very dry conditions followed. Ten treatments were applied over five years to plots (20 m by 20 m) within the selected paddock (Fig. 3-1).

Each treatment had four replicates. To account for a potential grazing pressure gradient each block was located so that each plot within the block was a similar distance to a permanent water point within the paddock. The site was destocked over the 2012/13 summer following a wildfire in November 2012 and then very dry conditions.

An extra set of recordings were taken in the adjacent commercial paddock (Comm.) where the owner had a rotational grazing system in place, as a comparison to the set stocking rate of the grazed treatment in the core spelled experiment. Four plots were established and pasture parameters were recorded as per the replicated trial. However, statistically valid comparisons cannot be made with the main trial as these plots were not part of the randomised treatment design. Additionally, stocking rates were deliberately varied in the commercial paddock so that comparisons cannot be made with the trial, where the stocking rate was relatively constant at about one beast to eight hectares.

Site 1 Treatments

Stocking rate	moderate (stable around long term carrying capacity)
Duration of spelling	nil, early wet season or full wet season
Frequency of spelling	annual or biennial
Timing of spelling	once in five years, with separate plots for each of years 1 to 5.

Four location replicates in one paddock

Duration	2010 to 2015
Total number of plots	40 (10 treatments x 4 reps = 40)

Treatments will be referred to by the below abbreviations herein:

- G – grazed + spell 2012-13
- EA – early wet season annual spelling
- FA – full wet season annual spelling
- EB – early wet season biennial spelling
- FB – full wet season biennial spelling

- FY1 – full wet season spell in year 1 only
- FY2 – full wet season spell in year 2 only
- FY3 – full wet season spell in year 3 only
- FY4 – full wet season spell in year 4 only
- FY5 – full wet season spell in year 5 only

S. D. indicates a significant difference within recordings ($P<0.05$).

Spelling involved the erection of a stock-proof fence around a plot in about November and then removing it about February (early wet season) or in April (full wet season). The nil spelling treatment (G) had to be spelled for six months over the 2012-13 summer, along with all other treatments, following the November 2012 wildfire.
Comm. refers to the plots monitored in the Commercial paddock.

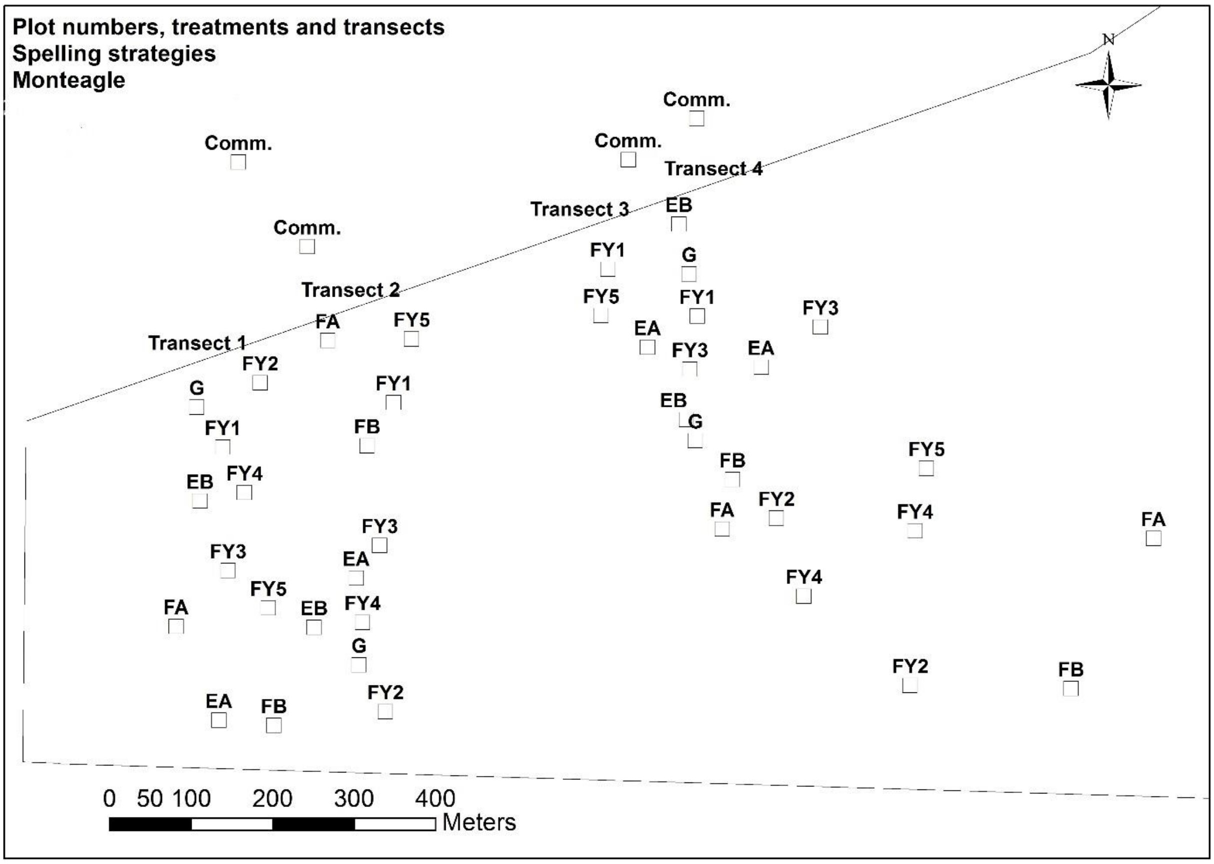


Fig. 3-1 Plot layout map at Site 1.

3.1.1.2 Site 2

<u>Impact of stocking rate on the benefits of spelling for pasture recovery</u>

An additional field research site was established within the Wambiana grazing trial 60 km south west of Charters Towers (O'Reagain *et al.* 2014). The site is an open eucalypt woodland with the dominant (~55%) vegetation being *E. brownii.* The soils are brown sodosols, moderately fertile and support a pasture layer containing *B. ewartiana, Aristida* spp*., Chrysopogon fallax*, and a variety of other perennial and annual grasses (Scanlan, 2013). Identical spelling strategies were tested in plots within two separate trials adjacent to the fence separating a paddock that has been heavily grazed for 14 years from one that has been moderately grazed over the same time. One trial remained within the heavily grazed paddock while the second trial was incorporated within the moderately grazed paddock by shifting the fence. This design provided insights into the interactions between spelling regime and overall stocking rate on pastures subjected to 14 years of heavy grazing pressure. A smaller combination of spelling regimes than at Site 1 was used. The grazing trial was destocked in June 2011 and burnt late October 2011. The whole site received an early wet season spell before cattle were reintroduced in February 2012.

The five treatments at each stocking rate were:

- Continuous grazing
- Early wet season annual spelling
- Full wet season annual spelling
- Early wet season biennial spelling
- Full wet season biennial spelling

Treatments were referred to by the below abbreviations for the two trials.

- G –grazed
- EA - early wet season annual spelling
- FA - full wet season annual spelling
- EB - early wet season biennial spelling
- FB - full wet season biennial spelling.

S. D. indicates a significant difference within recordings.

The heavy grazing pressure treatment is referred to as H and the moderate one as M (Fig. 3- 2). Thus combined codes were: HEB for ‘Heavy grazing pressure, Early wet season Biennial spelling’ and MG for ‘Moderate grazing pressure, continually Grazed’.

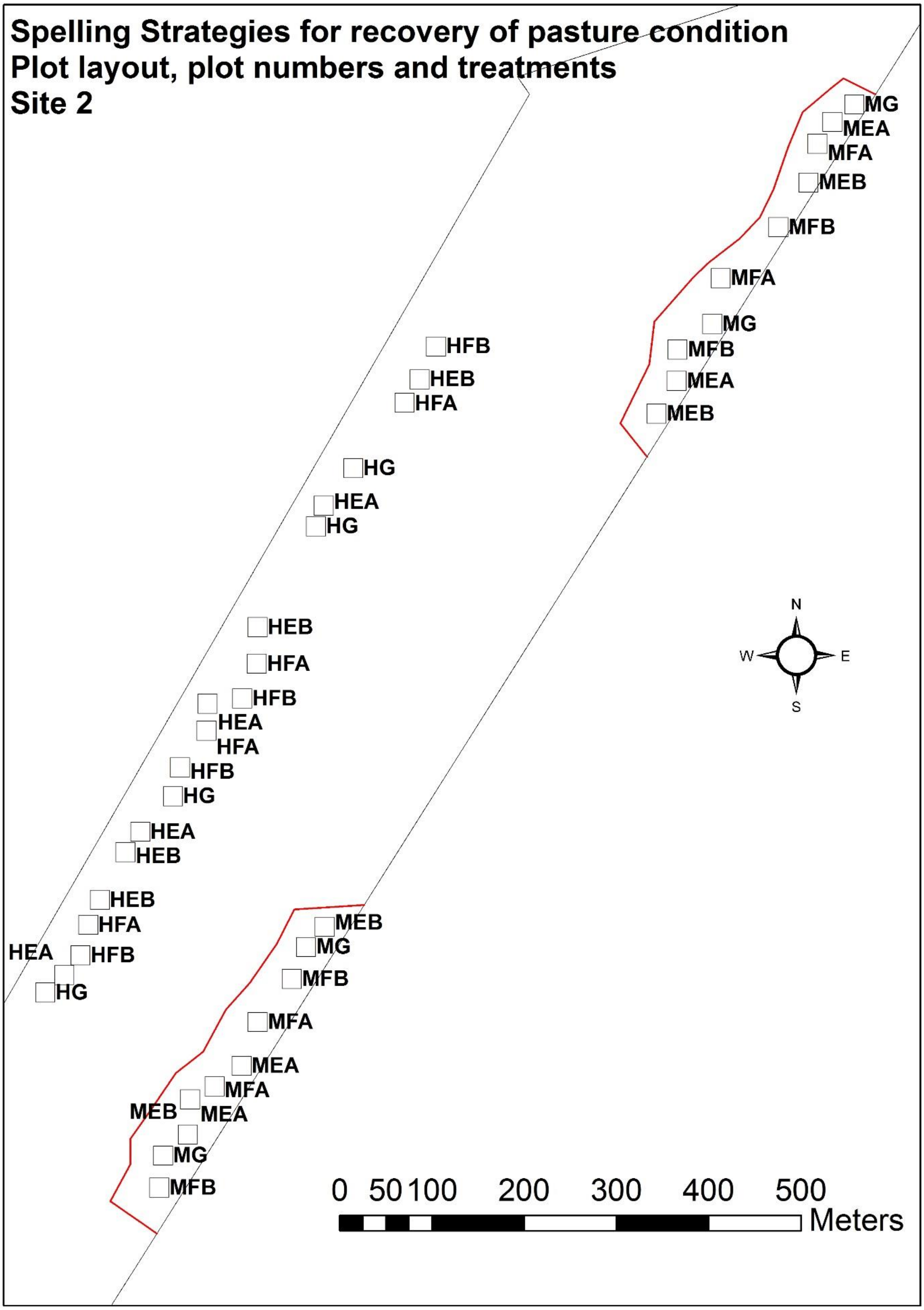


Fig. 3-2 Plot layout map at Site 2. Note M and H refer to moderate and high stocking rate respectively. The red lines indicate fencing modifications to the Wambiana grazing trial accommodating the spelling strategies research design.

3.1.2 Recordings

Twelve permanently located quadrats in each plot were recorded in detail to follow changes in plant dynamics and associated soil and pasture condition changes. These quadrats were specifically chosen to contain a reasonable number of the key perennial pasture grasses so that their population dynamics could be followed in detail and may not adequately reflect the overall changes occurring in the whole plot. Hence, additional measurements were recorded on a whole plot basis to ensure treatment effects on the whole plot such as recolonisation of very bare patches and changes in composition for particular plant species were identified. Whole plot data was collected on pasture yield and composition (Tothill *et al.* 1992), landscape function (Tongway and Hindley, 2004) and land condition (Corfield *et al.* 2006) as per the fixed quadrats.

The fixed quadrats were stratified based on the presence or absence of *B. ewartiana* at recording 1. Quadrats numbered 1 to 6 had 1 *B. ewartiana* plant present in the quadrat as well as 1 to many *Aristida* spp*.* plants. Quadrats numbered 7 to 12 did not have *B .ewartiana* present, but did have 1 to many *Aristida* spp*.* present.

Measurements included:

- pasture yield and composition (Tothill *et al.* 1992)
- ground cover (Anon, 2005)
- perennial grass basal area density and size (Orr, 1998)
- landscape function assessment (Tongway and Hindley, 2004)
- land condition (Corfield *et al.* 2006)
- perennial grass demography (Orr, 1998)
- Germinable soil seed banks in spring (Orr *et al*. 1996).

All plots were recorded before the trial started and at the end of each trial. The grazed plots, and any plots which were spelled in a particular year, were recorded three times in that year. The dates were usually in October, February and May corresponding to the end of the dry season, middle of the wet season and end of the wet season, respectively. These recording times were planned to coincide with perennial grass growth Phase 4 (October), Phases 2/3 (February) and Phase 3 (May).

3.1.3 Statistical analysis

The various pasture parameters at each sampling date were analysed by analysis of variance in several ways. Firstly, a randomised block (RB) analysis was conducted, using the plots as experimental units. If the block variance was less than the residual variance in any RB analysis, the block effect was then incorporated into the residual term to give a more stable estimate of error, with increased degrees of freedom and thus greater precision around statistical confidence.

In addition, initial values of the parameter being analysed (before treatments were applied) were used as covariates in a covariate analysis. Plots and quadrats were chosen to be as similar as possible on initial land condition, *B. ewartiana* and *Aristida* spp*.* density, and woody cover, but for other grasses the initial plot values varied considerably. This is why the initial mean values for treatments are included in the summary analyses tables. Covariate analyses were preferred whenever the test of significance of the covariate adjustment was significant at the 10% level. For the plot botanal (PB) data, initial values were not recorded, but corresponding fixed quadrat (FQ) values were used as covariates.

It should be noted that, especially for the earlier recordings, some treatments had not been fully implemented, so that some treatments were actually the same in each block. For example, at Site 1 a wildfire burnt the whole trial in November 2012 meaning that all plots then received a spell until June 2013. A consequence of this was that at the final recording in autumn 2015, the G (grazed + spell 2012-13) and the FY3 (full wet season spell in year 3 only) treatment were exactly the same. This was duly accounted for in the various statistical analyses (Appendix 2).

3.2 Adjustments to the GRASP model

GRASP was used to explore the best bet spelling options emerging from the field work at a multi-paddock scale, examining the effects of both overall stocking rate and any periods of heavy grazing associated with implementing of the spelling strategy.

Accurate estimation of pasture growth is a prerequisite for accurate estimates of pasture composition changes in the GRASP model. SWIFTSYND sites (Day and Philp, 1997) allow the estimation of many parameters in GRASP that drive pasture growth – in particular maximum nitrogen uptake, minimum nitrogen concentrations in green material and transpiration efficiency. From these parameters, we can estimate pasture growth under any seasonal conditions. A SWIFTSYND site was established in September 2013 at Site1. Measurements of soil moisture, green and dead plant cover, and dry matter yield (green and dead) for grass and forbs were conducted in December 2013, March 2014, June 2014 and September 2014. Rainfall was collected daily using an automatic weather station with pasture and tree basal area recorded once in mid-summer. Soil profile description and soil bulk density were estimated using the land systems information of Gunn *et al*. (1967).

Using the GRASP Calibrator program, a set of parameters was generated that reproduced the data closely. Soil moisture parameters were fine-tuned and then growth parameters were modified to reproduce the observed growth data (Scanlan *et al*. 2008). It was necessary to make some parameter changes from SWIFTSYND plots to longer term simulation in grazed areas. This was mainly to do with detachment rates, which are very low in SWIFTSYND plots, but are higher in grazed areas where there is some standover material from year to year. To get appropriate parameters for the rates of degradation and recovery, we used the percentage 3P grasses from the fixed quadrat data. Such existing parameters in GRASP have been validated from other experimental data which show that such a correlation is quite robust across many pasture communities.

GRASP estimates pasture utilisation in any particular combination of season and stocking rate throughout the year from records of animal numbers and calculated pasture growth. Cattle records from the Site 1 trial paddock allowed calculation of utilisation together with the recordings on pasture composition. Utilisation rate is a key driver of pasture composition change. The simulated change in pasture composition was compared with field observations in the trial. The model parameters were modified to give the best representation of the field data.

3.3 Case studies

Case studies provide simulated bio-economic outcomes from varying paddock management (involving spelling regimes) at a property level using the previous 30 years of climate data. They incorporated real world examples to provide information useful for graziers to help future decision making on their properties

Two case studies were initiated with two co-operating producers. The purpose of each case study was to capture property level information and document average measures of profitability and sustainability. This was done using current and past management data, and compared with outcomes from perceived improved management involving different spelling regimes. They were bio-economic studies with yearly physical outputs including pasture growth, land condition, stocking rates and live weight change calculated in GRASP. These were linked to an economic and cattle herd simulation model Breedcow and Dynama (Holmes 2005), which accepts the annual GRASP outputs as inputs for calculations of herd dynamics and profitability.

Property level information included land types and condition, tree and shrub cover, infrastructure layout, herd and enterprise structure, input costs and income. The process was run for between 10 and 30 years, depending on the property level information available. The co-operators nominated their area of interest with regard to spelling management for the comparison, and therefore had ownership of the exercise.

These simulations attempted to represent the management that was used on property.

This process:

- Identified knowledge gaps by engaging producers in the modelling.
- Extrapolated decades of grazing trial data to the property level and timeframe (10 – 30 years).
- Explored likely longer term trends without expensive on-ground studies.

The first case study was with Richard Hawkins at BonAccord, Anakie. The comparison used current management with regular spelling and reducing cattle numbers during drought, compared with a less aggressive destocking policy that included more supplementary feeding. The simulations were run from 2002 to 2015 which includes the 2002 to 2004 drought.

The second case study was with John Dunne at Oaklands, Duaringa. John had a two paddock rotation where preferential grazing was an issue in the more productive paddock. We examined varying his spelling and stocking rate management with the aim of improving land condition in the more productive paddock, while maintaining land condition in the less productive paddock.

3.3.1 BonAccord

BonAccord is a 5750 ha cattle property 10 km west of Anakie in central Queensland with mainly the brigalow/blackbutt land type. There are patches of silver-leaved ironbark, coolibah floodplains, downs country and lancewood/bendee ridges. About 75% of the property is cleared with buffel grass pastures established, and regrowth controlled by blade ploughing or Graslan herbicide. The majority of the property has very good (A) land condition. The predominant pasture species is the 3P grass *Cenchrus ciliaris*. The herd is self-replacing and turnoff from the property is mainly EU steers and cull heifers, with some cows and steers going to local markets. The cattle are a mix of breeds with a high *Bos indicus* content. Production is driven by seasonal conditions, which are generally divided into a typical wet season where the majority of rain falls between December and May and a dry season with very little rainfall from June to November the remainder of the time. Average annual rainfall is 652 mm.

An average of 1064 adult equivalents (AE) were carried on 5750 ha over the simulation period of 2003-2015. The simulated property commenced with 60% perennial grasses in three equally sized paddocks each of the same land type and area. The mean stocking rate (SR) was 18.5 AE/100 ha during the 2003-2015 period. This is an average AE of 1063, which is very close to the actual records. A moderately fertile box land type was selected to represent the property. The starting condition was set to represent 60% perennial grasses in 2003.

Simulations:

1. A fixed SR for all years of 18.5 AE/100 ha (referred to as fixed 18.5AE)
2. A fixed SR for all years of 15 AE/100 ha (fixed 15 AE)
3. A variable SR each year based on the actual yearly stock records for BonAccord but no spelling (variable 18.5AE)
4. A variable stocking with a spelling for one-third of the time. This spelling was achieved by having six months grazing followed by three months spell in a fixed rotation in all years. This is a representation of what was actually done on BonAccord. (variable+spell - referred to as BASELINE)
5. A variable stocking with spelling and a 5% heavier stocking rate than was actually used on BonAccord. (var+spell+^5%).

Simulations #2 and #5 were selected from multiple simulations with varying fixed SR. The 15 AE/100 ha simulation was used to produce a similar change in % perennials over the 2003 – 2015 period to that in the baseline treatment. This attempted to demonstrate the benefits of variable stocking. The var+spell+^5% simulation represented the amount that SR could be increased, yet still produced the same % perennial that would have occurred in the baseline, capturing the benefit of spelling that could be realised by increasing carrying capacity.

Overall, these simulations were not of the actual property in real terms. The attempt was to represent the management that was used on BonAccord for a single land type property with an overall carrying capacity similar to that of BonAccord.

BASELINE simulation (simulation #4)

The BASELINE in this work is a simplified version of what was done at BonAccord. Paddocks were spelled for three months and then grazed for the next six month period. This produced a spell for 33% of the time (compared to actual records of 35%). To accommodate the GRASP parameter sets, the spelling sequence was fixed. To do this, stocking rate in the grazed paddocks was 50% above the 'average' stocking rate for that year (for six months) and then ungrazed for three months. The timing of spelling differed for each paddock in each year in a three year cycle. After that time, the same sequence was repeated as for the first three year period (Table 3-1).

Table 3-1. Spelling sequence for BonAccord case study

Year	Dec-Jan-Feb	Mar-Apr-May	Jun-Jul-Aug	Sep-Oct-Nov
2003			spell	
2004		spell		
2005	spell			spell
2006			spell	
2005		spell		
2007	spell			spell
2009			spell	
2010		spell		
2011	spell			spell
2012			spell	
2013		spell		
2014	spell			spell
2015		spell		

3.3.2 Oaklands

Oaklands is a 10150 ha organic cattle property 60 km south of Duaringa in central Queensland. The cattle are a mix of breeds with a high *Bos indicus* content. Weaners are produced and then fattened at another property owned by the business. The main land types in order of magnitude are gum-topped box flats, bulloak, narrow-leaved ironbark woodland, box flats, bluegum river red gum flats, and silver-leaved ironbark on duplex. Roughly half of each land type is in a remnant vegetation state (Queensland Government, 2014). Land condition is predominantly 'B' or 'C' (Quirk and McIvor 2003) with an even distribution through land types, remnant and regrowth areas. 3P grasses (*B. ewartiana* and *Heteropogon contortus*) comprise about 50% of the pasture with the increasers (*Aristida* spp. and *Bothriochloa decipiens*) about 20%, and small contributions from 2P grasses (*P. effusum*) and annual grasses (*Eragrostis, Chloris, Sporobolus* and *Enneapogon* spp.). Production is driven by seasonal conditions with an average annual rainfall of 674 mm, mostly falling during the wet season.

The safe stocking rate for the two paddocks (Box Flats and Timbered) used in the simulation exercise was estimated by GRASP for 1991-2015. The paddocks were assumed to have 60% perennial grasses in the pastures at the start of the simulation. These results were similar to the safe carrying capacities estimated by the owners, with Box Flats having a slightly lower than estimated carrying capacity and the Timbered paddock a slightly higher estimate. The estimated total AEs for the two paddocks was set at 332 compared with an estimate of 350 from the owners.

Three simulations were done to identify the potential impacts of a number of stocking strategies, including spelling.

1. Assuming both paddocks were stocked at 14 AE/100 ha (referred to as Uniform).
2. Assuming both paddocks were stocked at a safe stocking rate i.e. 11.5 AE/100 ha for Timbered and 23 AE/100 ha for Box Flats (Safe).
3. A number of spelling regimes were tested with a view to maintaining the same total number of stock in both paddocks, but spelling Box Flats for six months over summer every second year. Thus for six months every two years, the Timbered paddock carried all livestock and the Box Flats paddock was ungrazed. Total stock numbers were kept the same for the whole simulation period (Spelled).

A variety of combinations of stocking rates for both paddocks was simulated.
Constraints were:

a. the total stock numbers had to be maintained over the whole simulation
b. the percentage of perennial grasses in the Timbered paddock had to be maintained
c. The percentage of perennial grasses in the Box Flats paddock had to improve.

3.3.3 Economic modelling

A bio-economic model for a breeding enterprise was developed in this project to assess the economic impact of wet season spelling against a range of alternative scenarios at both property locations. The model used a GRASP (McKeon, 2000) to Breedcow & Dynama (Holmes, 2005) process with results passed through a partial discounted cash flow analysis. Sensitivity analysis was conducted at discount rates of 2.5, 5.0, 7.5 and 10% with the baseline discount rate being 5%.

The breeding model started with the identification of a steady state herd based on property data and management input. The steady state analysis was performed with Breedcow and captured key variables including bull replacement and joining policies, selling policies, husbandry costs and prices (Table 3-2).

Table 3-2 Key variables identified by steady state analysis

Item	
5 in 1	$0.38 / dose
NLIS	$4.00 / tag
Management tag	$1.50 / tag
Hay (weaners), 5 days, 4kg/day	$4.80 / weaner
Sales commission	3.5% on live cattle (0% on cull cattle)
Transport costs	$19.89 / weaner to $33.65 / cow
Levy	$5.00 / animal
Price received	
- Weaner (female)	$3.00 / kg
- Weaner (male)	$3.56 / kg
- Heifers 1 year old	$2.95 / kg
- Heifers 2 year old	$2.80 / kg
- Cows 3+ years old	$2.30 / kg
Joining age (heifers)	12 – 24 months
Bull percentage	4 – 5%

The base herd was then applied to Dynama to inform the starting herd. Herd structure was then determined by live weight gains as identified by GRASP. Key variables such as weaning rate and mortalities were derived from the live weight gain data using the equations from Gillard and Moneypenny (1988):

Dry stock mortalities: 2+88*EXP (-0.03*LWG+50)/100
Wet stock mortalities: 6+94*EXP (-0.027*(LWG+50))/100
Weaning rate: (15.6+0.488*LWG)/100

The herd was then followed through time and balanced according to the Adult Equivalents (AE) used by GRASP for each scenario. Where discrepancies occurred between the modelled herd and the GRASP herd after automatic selling procedures had been performed, the model was manually adjusted to ensure the relationship between GRASP and Dynama was consistent. The manual adjustments followed the same rule set for each scenario. Firstly, if herd AEs exceeded GRASP AEs, a further sell down of two year old heifers to a level which would not impact older classes in following years was performed. If the herd model still exceeded AEs as measured by GRASP then older cows were sold down for each age group proportionally. Where GRASP AEs exceeded herd AEs, enough one year old heifers were purchased to ensure both GRASP and herd AEs were consistent. Fig. 3-3 shows the process flow that was followed. Economic outputs were passed through a discounted cash flow analysis and the Net Present Value (NPV) and Internal Rate of Return (IRR) reported on. The discount rate was 5%.

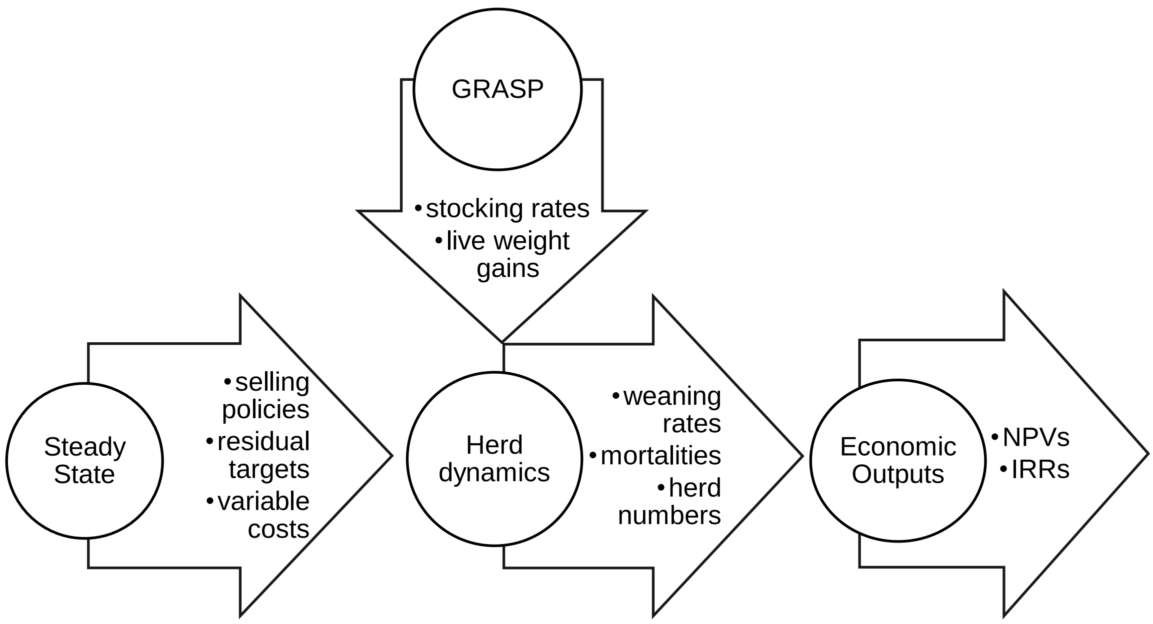


Fig. 3-3 Conceptual process flow for the bio-economic model

3.4 Oaklands demonstration site

The Oaklands Carbon Farming Project (Bray *et al*. 2016) is a demonstration site with the objectives of:

1. Understanding the impact of regrowth retention and pasture spelling on carbon stocks, livestock profitability and potential for carbon farming on poplar box woodland land type in central Queensland.
2. Engaging with the Mimosa landcare group and other landholders to understand the "carbon farming" options in the Mimosa Creek region.

The pastures were monitored to increase understanding of the effect of spelling on the above, as well as land condition maintenance and/or improvement. The demonstration site was not replicated, and therefore was not analysed for statistically significant differences. However, the pasture monitoring did add understanding to the processes occurring.

Treatments were:

1. Cleared and grazed
2. Suckers spelled
3. Cleared and spelled
4. Remnant and spelled
5. Suckers and grazed
6. Remnant and grazed
7. Graslan and spelled
8. Graslan and grazed

Pastures were assessed for each of the regrowth and spelling/grazing treatments from November 2012 to May 2015. Recordings were usually done in May and November. The ten year old suckers, remnant and Graslan plots were existing treatments. The cleared treatments had been subject to chaining in September 2012. The spelled treatments had fences erected and spelling began in December 2012 and continued to May 2015. Spelling involved destocking the treated area for the full summer wet season. The pasture data collected includes the starting conditions, and after one full wet season spell. Pastures were recorded in May and October each year until May 2015.

Pasture data for each plot was collected using a 50 x 50 cm quadrat on a 50 point grid across the treated area (Fig. 3-4). Data is presented for pasture yield, ground cover, crown cover and land condition index.

Data collected using the BOTANAL protocol includes species present and the amount of each, yield (kg/ha of dry matter), ground cover (%) and a range of soil surface condition parameters. This data allows a land condition index (1 = very good, 4 = very poor) to be generated (Corfield *et al.* 2006). The main determinants of the land condition index include the dominant species present, functional group (Table 3-3), crown cover and ground cover. Crown cover is the proportion of the ground covered by living crown material (at ground level) of all perennial grasses. Ground cover is the amount of ground covered by standing or detached organic material. Pasture data is summarised for each of these treatments.

Table 3-3 Functional groups recorded at Oaklands

Functional group	Description	Pasture plants recorded in this group
3P	**P**alatable, **P**erennial and **P**roductive grasses. These grasses respond well to rainfall and provide useful forage, however will decrease under heavy grazing pressure. They provide bulk for burning, ground cover and feed during dry times. They are abundant for land in good condition with usually >70% of the pasture composition.	Desert bluegrass, black speargrass, golden beardgrass, brigalow grass, kangaroo grass, forest bluegrass, buffel grass, Queensland bluegrass and silky browntop
Wire grasses and pitted bluegrass	These grasses are neither palatable nor productive and tend to increase in abundance with heavy grazing pressure. Pitted bluegrass can provide ground cover on scalded soils.	Wiregrasses pitted bluegrass
Annual grasses	These grasses are usually small and only live for one summer until setting seed. They provide a very short period of high quality, low quantity feed.	Lovegrasses, chloris, fairy grasses, bottlewashers, native couch, button grass, small burrgrass, and barnyard grass
2P	These grasses only exhibit two of the 3P characteristics	Hairy panic, windmill grasses, early spring grass, umbrella grasses, five minute grass, green couch, urochloa, Indian couch, tableland couch, red Natal grass
Other	These plants contribute very little to the pasture yield and do not fit the other categories.	Broadleaved forbs, sedges, native legumes, seca stylo and parthenium weed.

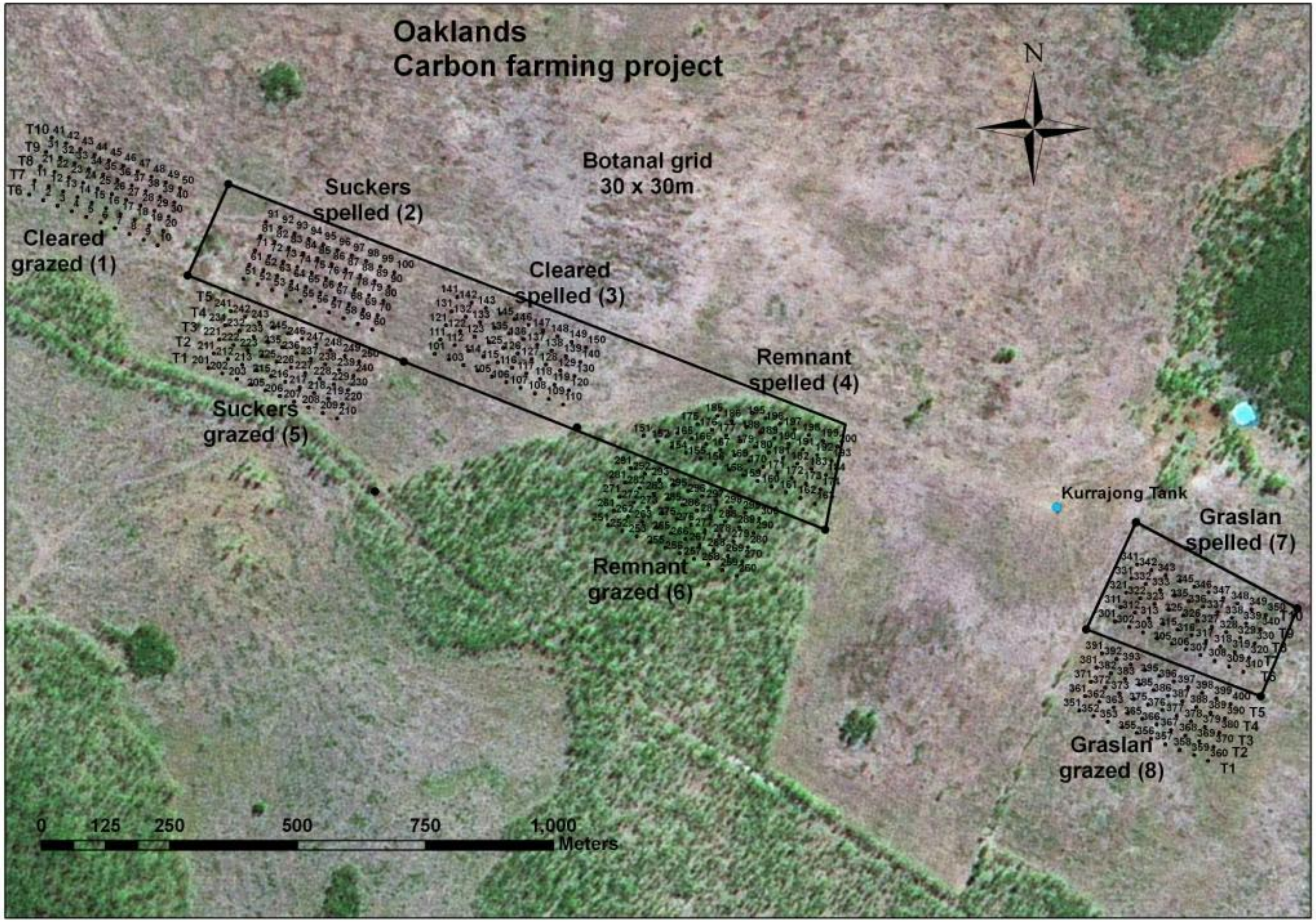


Fig. 3-4 Oaklands Carbon Farming Project map. Treatments and pasture sampling grid shown.

4 Results

4.1 Effect of spelling strategies on pastures and land condition at Site 1.

4.1.1 Rainfall and growing conditions at Site 1

The 12 years prior to trial establishment in October 2010 at Site 1 had been predominantly dry or very dry years. However, the three summers prior to trial establishment (2007-08, 2008-09 and 2009-10), had good growing conditions. The first two years of the trial (2010-11 and 2011-12) were considerably wetter than average, while the 2012-13, 2013-14 and 2014- 15 years were very dry (Table 4-1).

Table 4-1 Monthly rainfall (mm) at Site 1 from July 1998 to June 2014 and long term (91 years) average monthly rainfall (mm) at nearby Blair Athol

Month	Year 2006-07	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14	2014-15	Long term mean
Jul	22		75		10	8	34			25
Aug		9			44	23			26	20
Sep		31	22		202		1	1	54	15
Oct		43	14	36	10	22	2	4	9	34
Nov	6	126	81	48	107	105	18	106	2	55
Dec	72	133	20	32	235	228	12	8	166	93
Jan	165	174	174	162	48	223	46	114	149	107
Feb	100	162	139	160	38	152	62	61	31	112
Mar	20	5		43	134	97	34	86	29	65
Apr			51		150	49	66	5	6	33
May			4	8	38	60	28	2		30
Jun	137	3	25		35	28		12		27
Total	520	684	602	487	1052	995	302	399	472	619
Decile	4	7	6	4	10	10	1	3	4	

Immediately preceding the trial, the 2009-10 summer (October -March) had average rain and good growing conditions and the late winter (July-September) of 2010 received well above average rainfalls (256 mm). The start of the 2010-11 summer was very wet with good rainfall in November and December. Well distributed rainfall resulted in very good pasture growing conditions for the first and second years of the trial. The third year of the trial (2012-13) had a very dry spring, and a late start to pasture growth with a dry summer. Pasture growth over 2012-13 was very low due to the very dry spring and summer. The years 2013-14 and 2014-15 both had a very dry summer and autumn resulting in low pasture growth (Fig. 4.1 and 4.2).

Figure 4.2 shows a drought index for Site 1 which is a rolling average of the actual last 12 months rainfall compared to the long term average. The trial period has experienced two very wet years in 2010-11 and 2011-12 with very good growing conditions and strongly positive drought indices followed by three very dry years with very poor pasture growth and strongly negative indices.

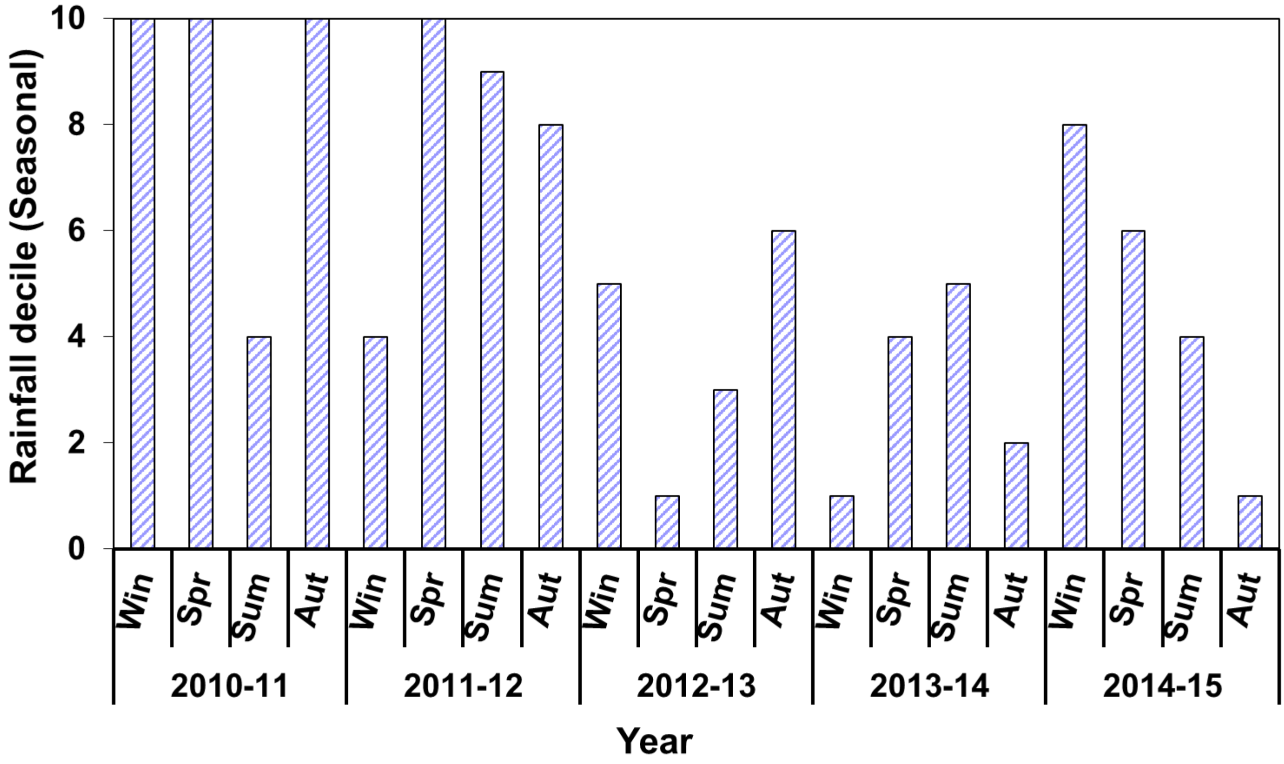


Fig. 4-1 Seasonal rainfall deciles at Site 1 (based on Blair Athol long-term data).

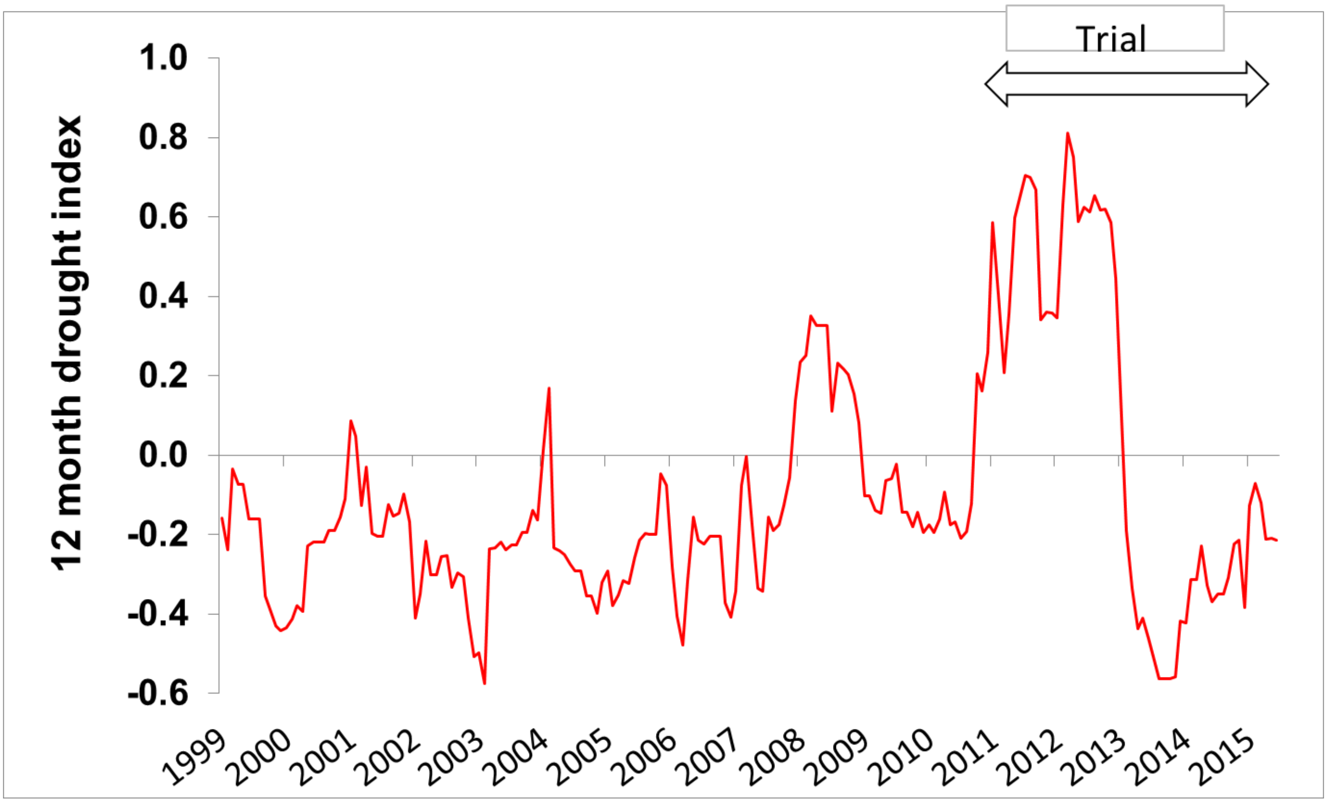


Fig. 4-2 A monthly drought index for Site 1 (∑last 12 months rainfall-∑12 months long-term average rainfall)/ average rainfall) based on Blair Athol long-term data. Note the trial operated from 2010 to 2015 and large consistently negative values indicate drought conditions.

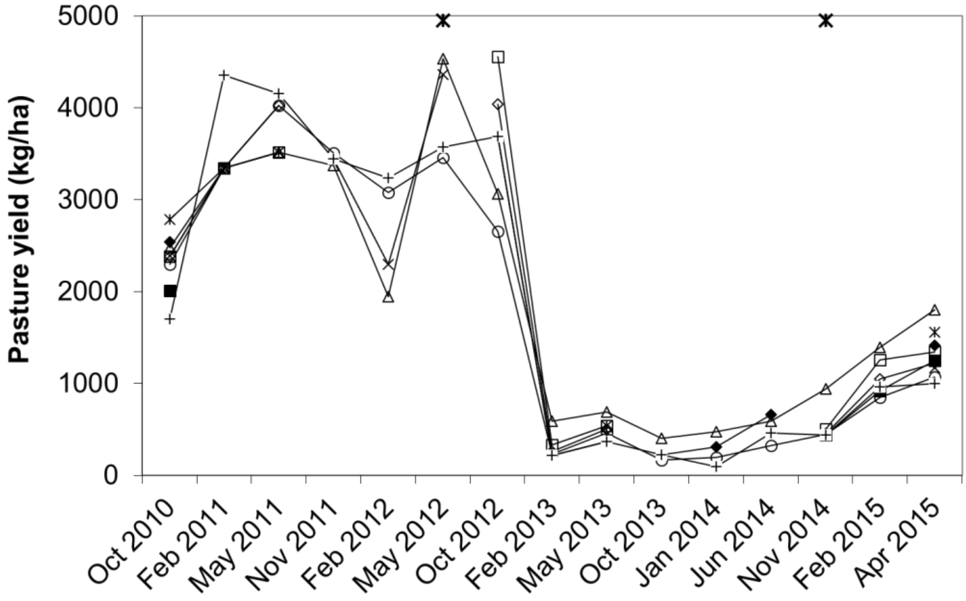
4.1.2 Fixed quadrat data

4.1.2.1 Pasture yield

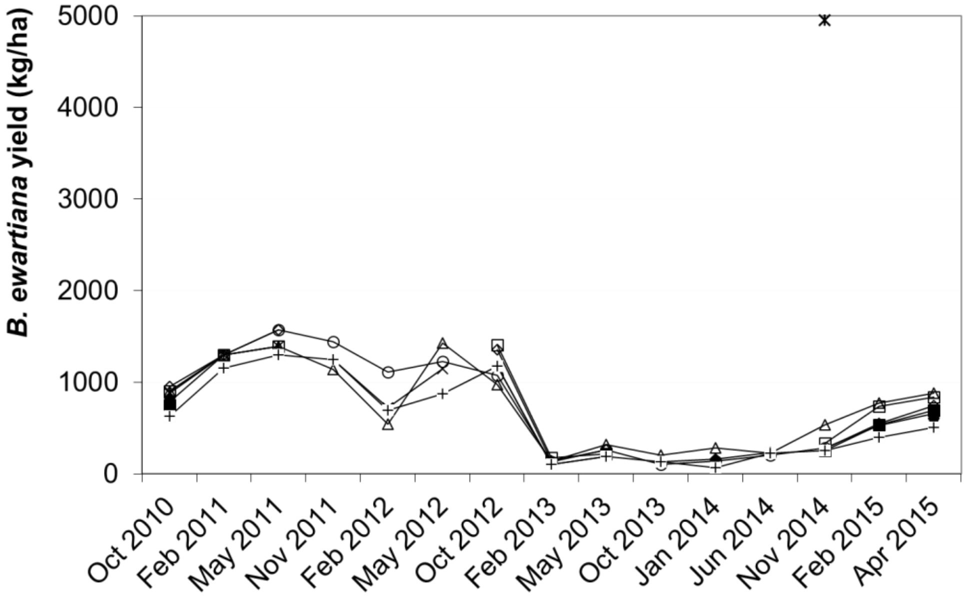
The pasture yield increased across all treatments through the first two years, with the increase being driven by growth of the key pasture taxa *B. ewartiana* and *Aristida* spp (Fig. 4-3a). High pasture yields were driven by the very wet conditions. During the second year of the trial growth may have been limited by available Nitrogen, more so than soil moisture. The burn, and then dry summers of 2012-13, 2013-14 and 2014-15, significantly reduced pasture yield. Treatment responses are only evident once during the first two wet years, and once during the following three dry years of the trial. In May 2012 FA increased pasture yield when compared to G and EA, and FY2 increased pasture yields compared to EA. In November 2014 FA increased pasture yields when compared to G, FY5, EA, EB, and FB.

The trend of increasing pasture yield under FA seems mainly driven by *B. ewartiana*. *B. ewartiana* had more pasture yield in November 2014 with FA when compared to G, FY5, EA, EB and FB (Fig. 4-3b). *Aristida* spp. yield increased in May 2012 by the FA, FY2 and G treatments when compared to EA (Fig. 4-3c). *P. effusum* yield increased in May 2013 by both FY2 and EB when compared with EA, FA, FB, FY1, FY3 and G. FY2 had more *P. effusum* yield than EB in May 2013 (Fig. 4-3d).

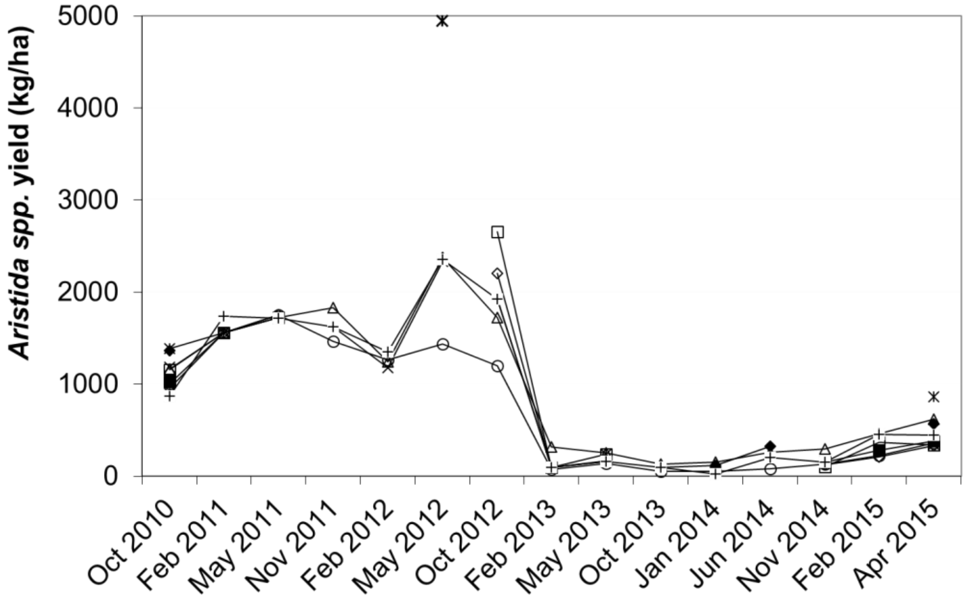
(a)


Pasture yield (kg/ha)
5000
4000
3000
2000
1000
0
Oct 2010
Feb 2011
May 2011
Nov 2011
Feb 2012
May 2012
Oct 2012
Feb 2013
May 2013
Oct 2013
Jan 2014
Jun 2014
Nov 2014
Feb 2015
Apr 2015

(b)


B. ewartiana yield (kg/ha)
5000
4000
3000
2000
1000
0
Oct 2010
Feb 2011
May 2011
Nov 2011
Feb 2012
May 2012
Oct 2012
Feb 2013
May 2013
Oct 2013
Jan 2014
Jun 2014
Nov 2014
Feb 2015
Apr 2015

(c)



(d)

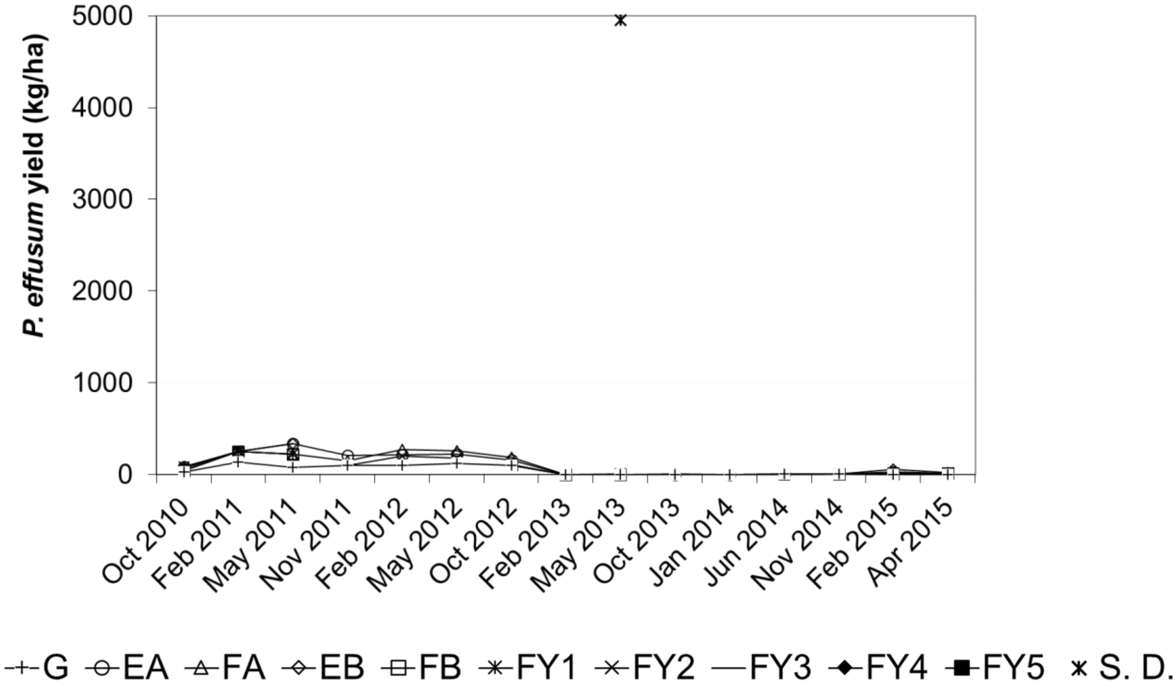


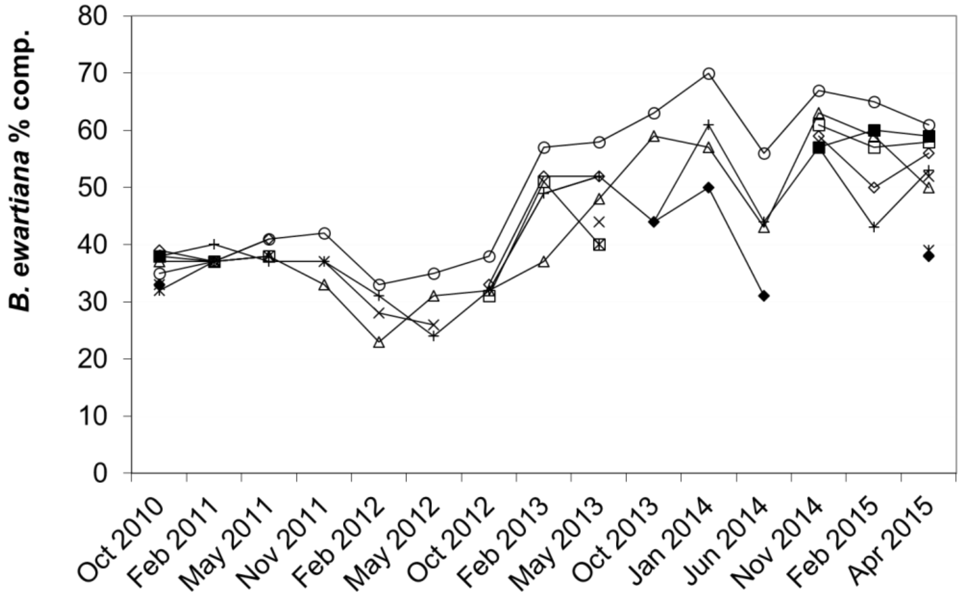
Fig. 4-3 Effect of spelling strategies on (a) Pasture yield, (b) *B. ewartiana* yield, (c) *Aristida* spp yield and (d) *P. effusum* yield in the fixed quadrats.

4.1.2.2 Composition

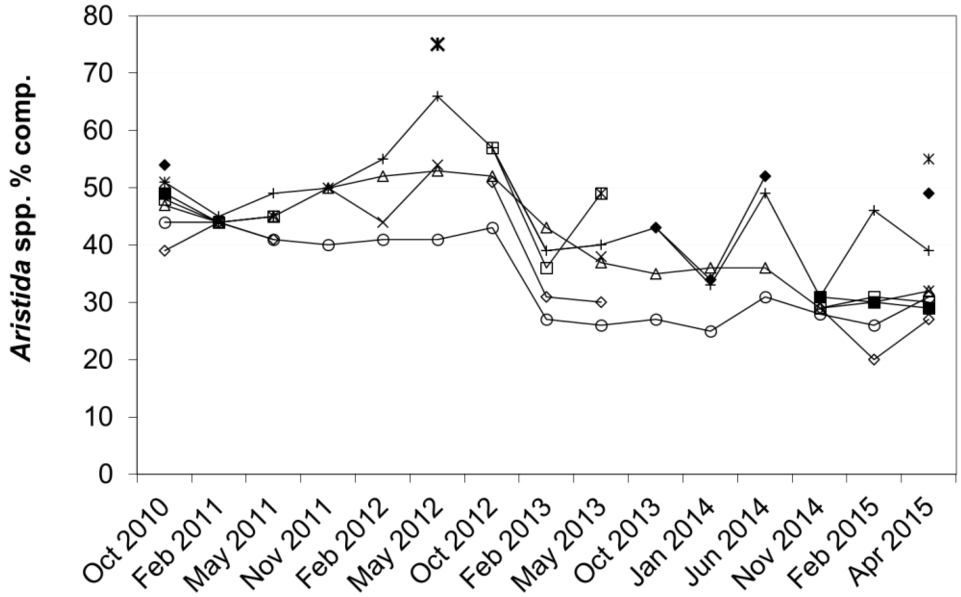
Pasture composition is dominated by the key pasture taxa *B. ewartiana* and *Aristida* spp. Overall, pasture composition has not varied greatly with treatments or recording dates however there is a trend for increasing *B. ewartiana* in the spelled treatments compared to the grazed, and over time. *B. ewartiana* composition was not affected by any treatment

(Fig. 4-4a). *Aristida* spp. composition was increased under the G treatment compared to EA in May 2012 (Fig. 4-4b). *P. effusum* had a greater composition under treatment FY2 compared to G, EA, EB, FA, FB, FY1 and FY3 in May 2013 (Fig. 4-4c). *B. ewartiana* increased noticeably since the fire in November 2012 with a subsequent decrease in *Aristida* spp. This trend has continued up to the last recording in April 2015. Pastures have been allocated to functional groups based on existing knowledge of their ecology (Table 4-2). For each recording, functional group composition was averaged across the three annual treatments – grazed, early wet season annual and full wet season annual spell (Figure 4-4d). There is a trend for increasing 3P while *Aristida* spp. are decreasing.

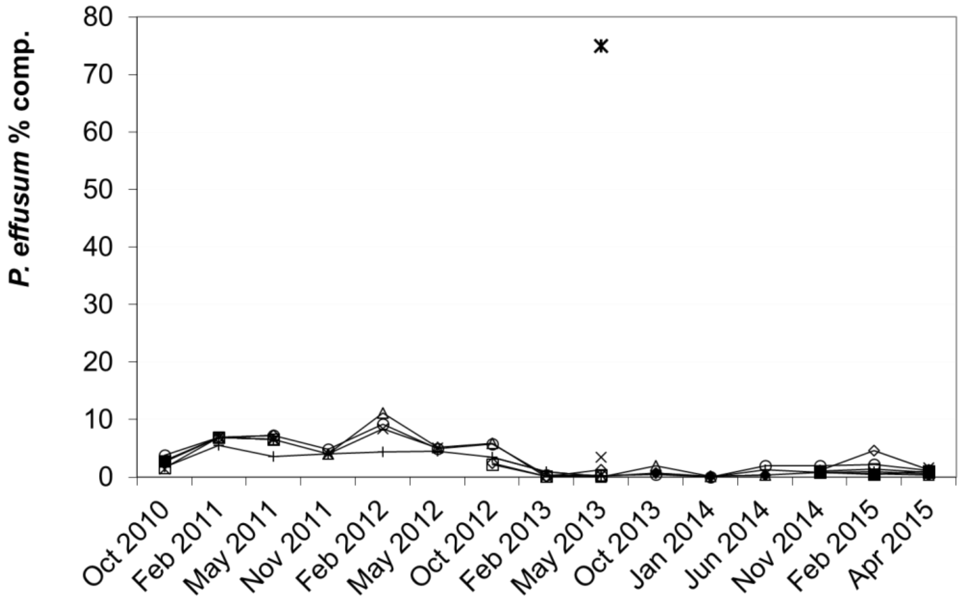
(a)



(b)



(c)



(d)

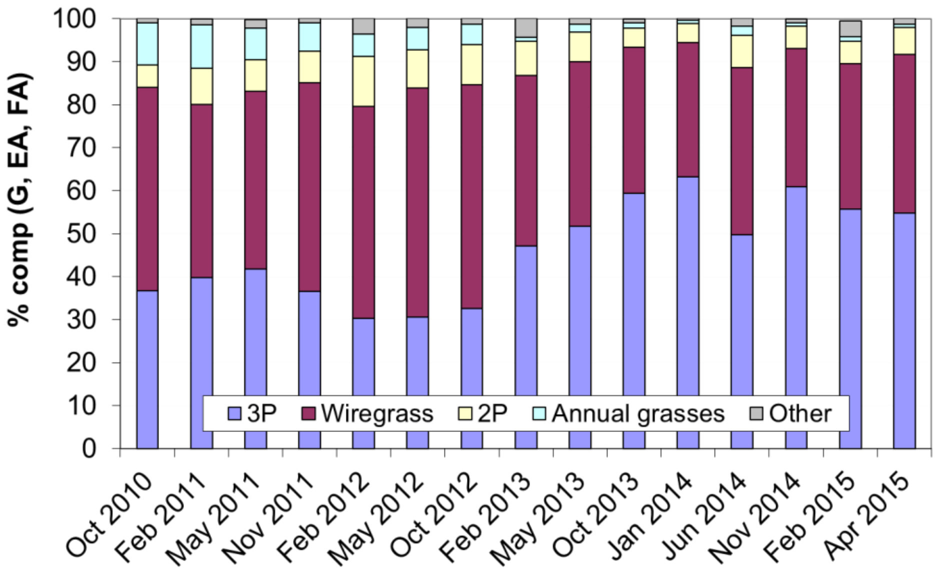


Fig. 4-4 Effect of spelling strategies on change in pasture composition for key taxa (a) *B. ewartiana* composition, (b) *Aristida spp* composition, (c) *P. effusum* composition and (d) Functional group composition averaged across the three annual treatments.

Table 4-2 Pasture functional groups and their constituents

Functional group	Taxon
3P	*Bothriochloa ewartiana, Cenchrus ciliaris, Dichanthium sericeum, Heteropogon contortus, Themeda triandra, Austrochloris dichanthioides*
2P	*Chrysopogon fallax, Digitaria spp, Eriachne mucronata, Melinis repens, Panicum effusum, Paspalidium spp, Themeda avenacea, Tripogon loliiformis, Unknown grass*
Wiregrass	*Aristida spp,*
Annual grasses	*Chloris spp, Enneapogon spp, Eragrostis spp, Perotis rara, Sporobolus spp, Tragus australianus, Urochloa panicoides*
Other	*Fimbristylis spp, forbs, Indigofera spp, native legumes, Rhynchosia minima, sedges, Stylosanthes scabra*

4.1.2.3 Ground cover and land condition

Ground cover improved across all treatments prior to the burn in November 2012, and has since remained at low levels with the dry conditions. Seasonal conditions have influenced ground cover more than spelling treatments. In May 2011 there was significantly more ground cover with treatments EA, EB, FA, FB, FY1 and FY2 compared to G (Fig. 4-5a). Land condition improved from October 2010 to February 2011 and was maintained until the burn in November 2012. In May 2012 there was better land condition with treatments EA, FA and FY2 compared to G. FA also had higher ground cover than FY2. Overall land condition is now similar to what it was when the project began, however there appears to be a trend for improving land condition with spelling treatments compared to grazing (Fig. 4-5b).

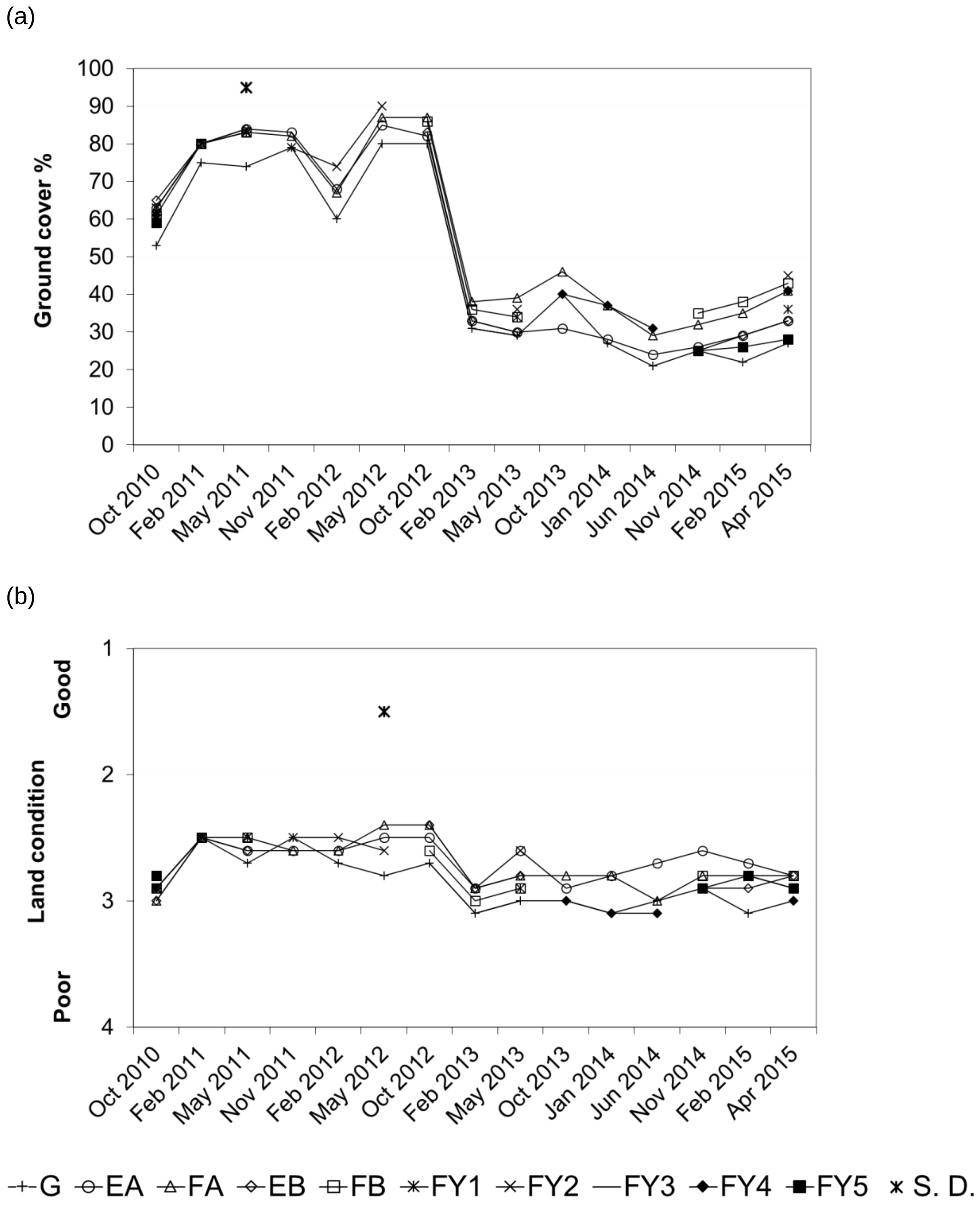
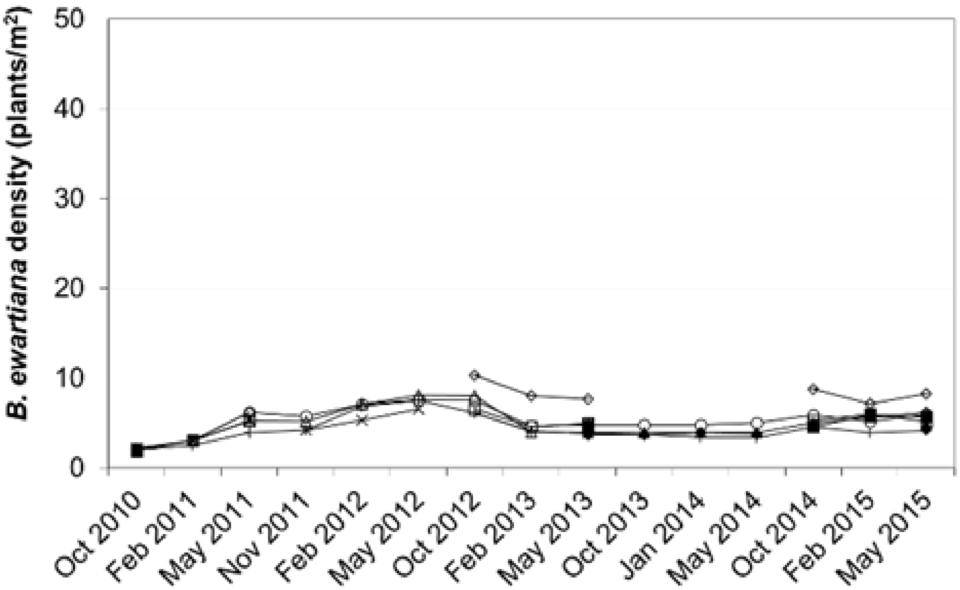


Fig. 4-5 Effect of spelling strategies on (a) ground cover %, and (b) land condition. Note: A higher land condition rating means poorer condition.

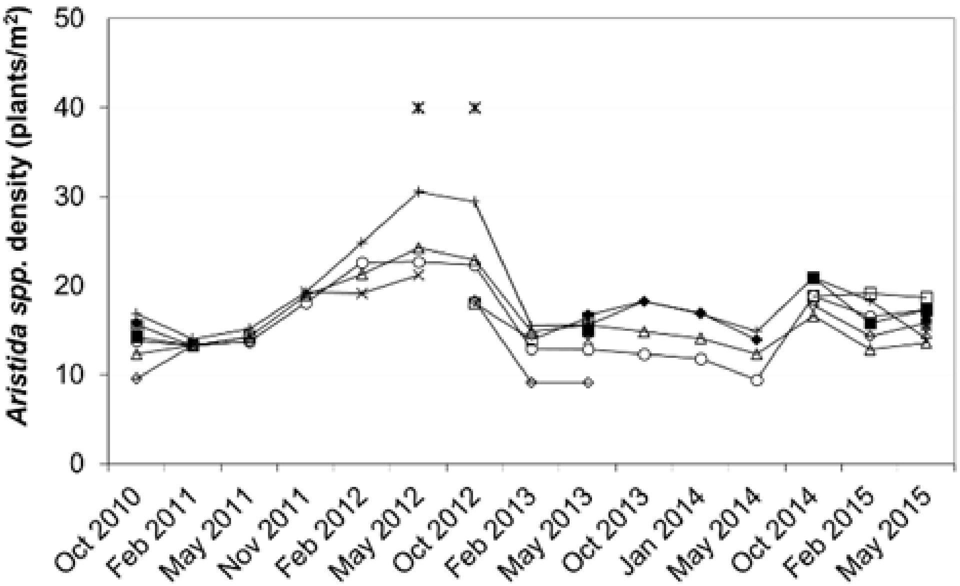
4.1.2.4 Density, recruitment, mortality and survival of perennial grasses

The density (plants/m^2) of *B. ewartiana*, *Aristida* spp. and *P. effusum* has increased and decreased with seasonal conditions. There was a small increase in density through the wet years, and then a decrease since the wildfire and following dry summers. Overall, *B. ewartiana* has had a small increase in density (Fig.4-6a). There was no treatment effect on *B. ewartiana* or *P. effusum* density. In May 2012 *Aristida* spp. had significantly higher density under treatment G than EA, FA and FY2, and FA had higher density than FY2 (Fig. 4-6b and c). In October 2012 *Aristida* spp. again had higher density under treatment G than EA, EB and FB, and treatment FY3 had higher density than EA, EB and FB.

(a)



(b)



(c)

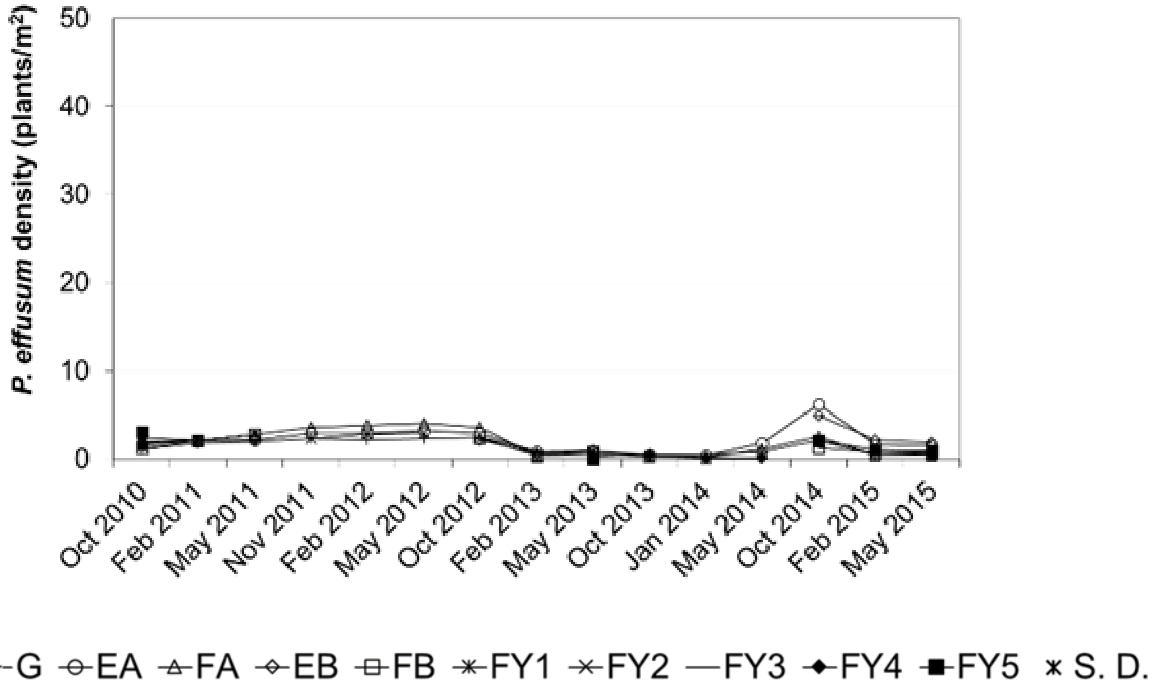
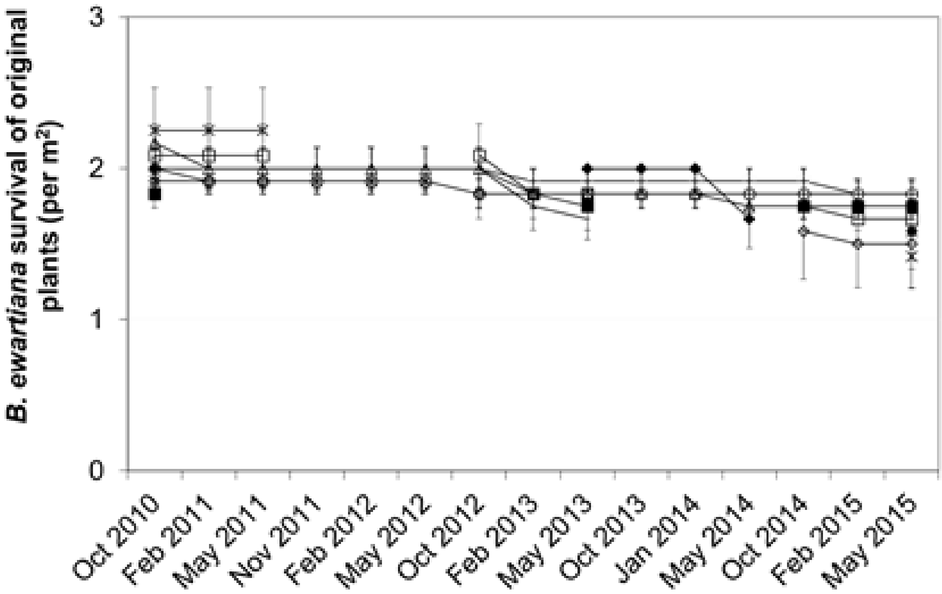


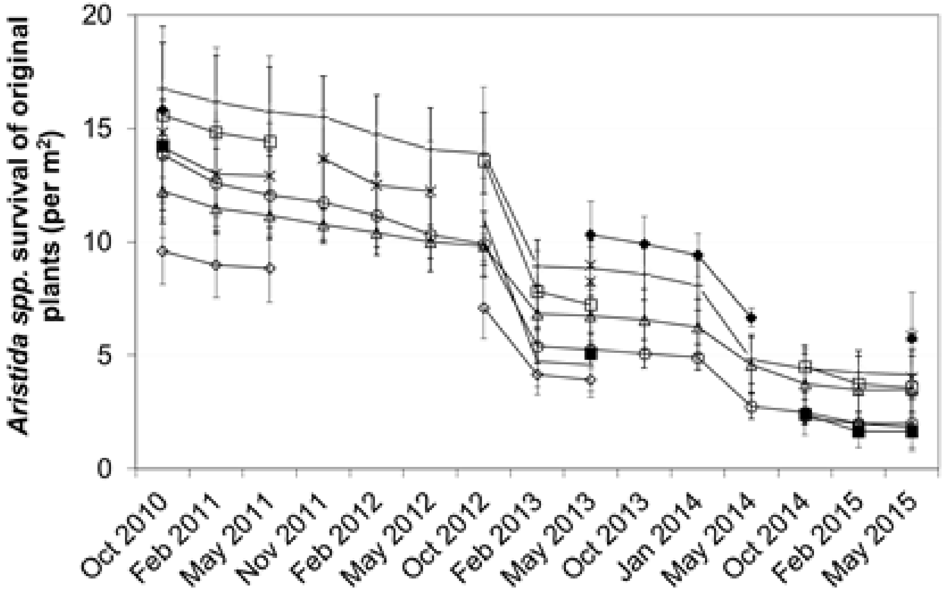
Fig. 4-6 Effect of spelling strategies on variation over time in (a) *B. ewartiana* density, (b) *Aristida* spp. density, and (c) *P. effusum* density.

The increased density for *B. ewartiana* was the result of high survival rates and recruitment. *B. ewartiana* had the highest survival rate from the original plants (Fig. 4-7a) while *Aristida* spp. had a low survival for original and recruiting plants to date (Fig. 4-7b). *P. effusum* has the lowest survival rate for both the original and recruiting plants, with almost none of the original plants surviving to May 2015 and very poor survival for all the seedling cohorts (Fig. 4-9c).

(a)



(b)



(c)

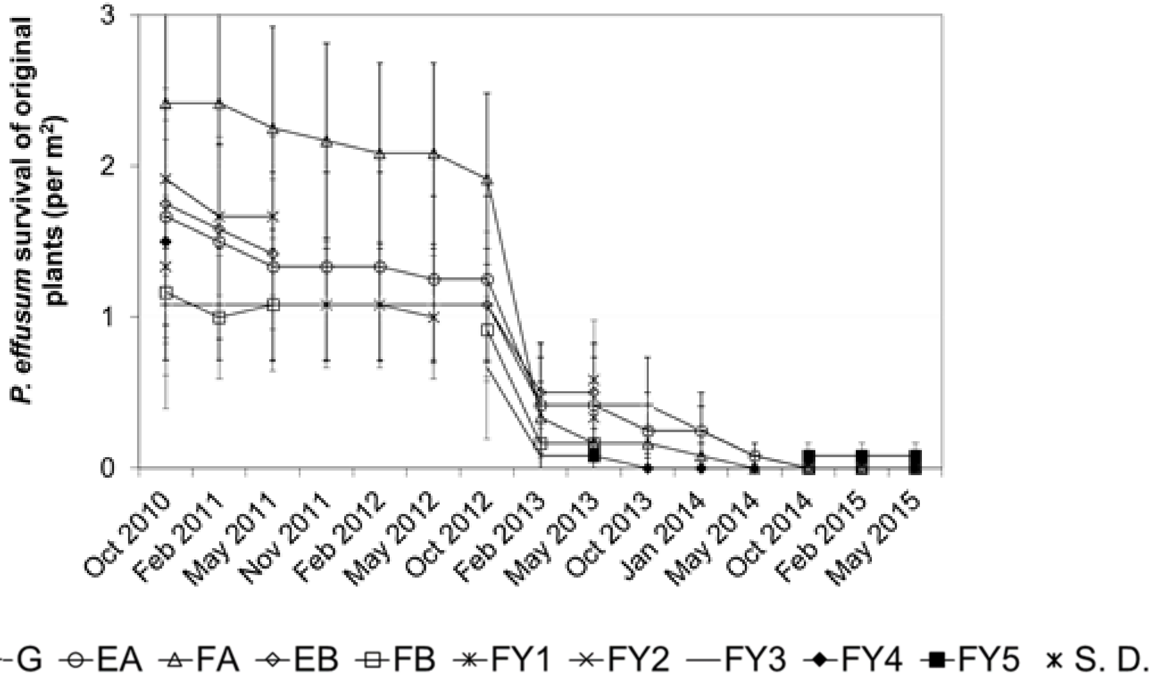


Fig. 4-7 Effect of spelling strategies on survival of original plants of (a) *B. ewartiana,* (b) *Aristida* spp and (c) *P. effusum* (note varying Y axis scale).

The February 2011 cohort for *B. ewartiana* had a high survival rate throughout the trial. While the burn and dry conditions affected some of the treatments, overall this cohort had a higher survival than all other cohorts and taxa. There appears to be a trend that all of the spelling treatments improved survival rates compared to the grazed treatment (Fig. 4-8) and this is also expressed in the crown cover of these seedlings (4.1.2.5). It should be noted that some treatments were the same in each block. For example, in February 2011 the EA, EB, FA, FB and FY1 treatments were all the same allowing the mean to be averaged across all these treatments. Therefore, some survival rates appear to be increasing over time. Comparison of treatments within a recording date is still valid.

Several of the annual and biennial spelled treatments had a higher survival rate of *B. ewartiana* than G and this was maintained until May 2015. In October 2012 the FB treatment had a higher survival than G, FA and FY3. In May 2013 the EA treatment had a higher survival than G, FY2, FY3, FY4 and FY5. In May 2015 the EA and FB treatments had a higher survival than G, FY1, FY2, FY3, FY4 and FY5.

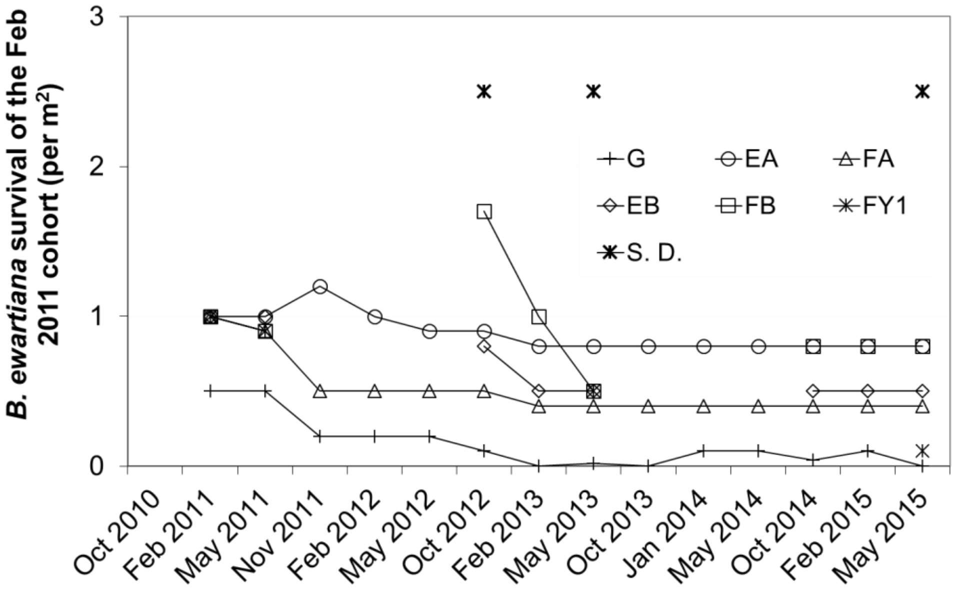


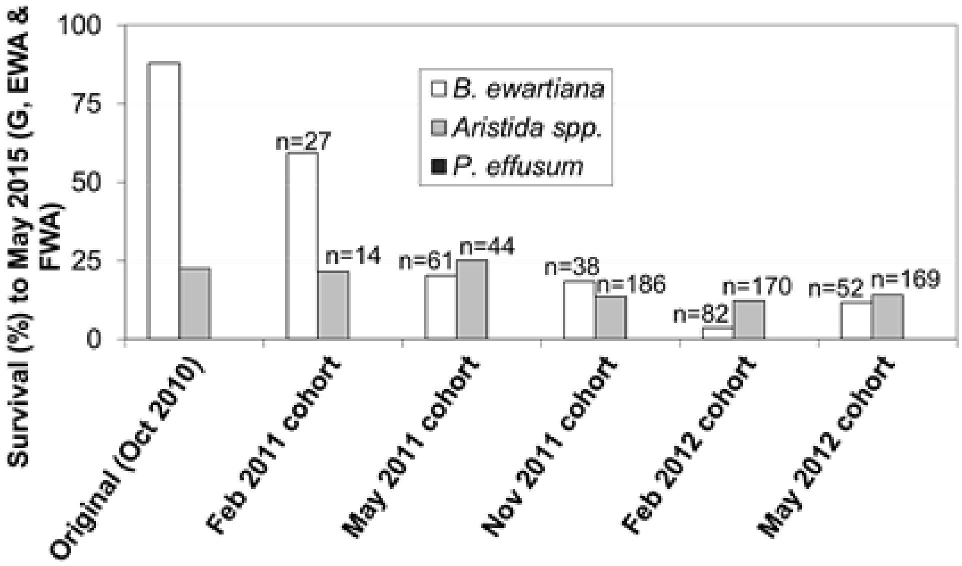
Fig. 4-8 Effect of spelling strategies on survival of the February 2011 *B. ewartiana* cohort.

The original plants of *Aristida* spp. and *P. effusum* decreased considerably in density from October 2012 to February 2013 while *B. ewartiana* was not affected. This period coincided with a dry spring and summer, and a wildfire that burnt the site in November 2012. The total density of each taxa decreased during this period due to the high mortality of cohorts that had established since the trial began. All cohorts of *B. ewartiana* prior to October 2012 were impacted by the dry spring and the burn. *P. effusum* had a very low survival of the original plants and zero survival for any cohorts by May 2015 with high mortalities caused by the fire. The dry conditions after the fire gave rise to very few recruits of all taxa for the next 12 months and high mortalities of those plants.

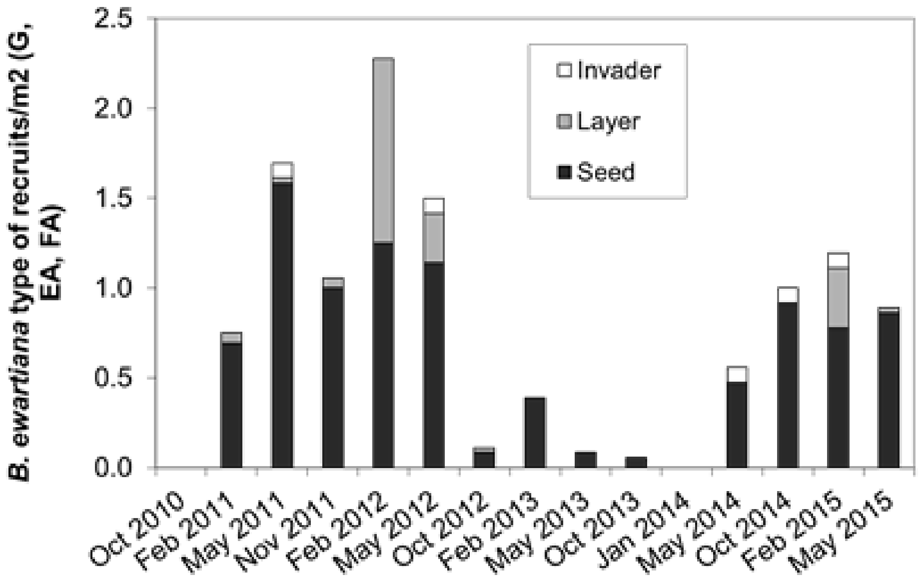
B. ewartiana recruited from seed and vegetatively. The vegetative recruits were from buds on tall stems that fell into contact with persistently wet soil and take root (layers), and from existing crowns invading the boundaries of the fixed quadrats (invaders). Layers did not survive through the fire and dry conditions (Fig. 4-9c). Layers contributed significantly to the number of recruits recorded in February and May 2012, and February 2015 (Fig.4-9b).
Fig. 4-9a includes five cohorts of these three taxa with numbers (n) ranging from 14 to 186. Cohorts recorded after May 2012 are not included due to low numbers and the shorter

length of assessment time. Neither the type of recruit, nor the total number of recruits was affected by spelling strategy (Fig. 4-9d).

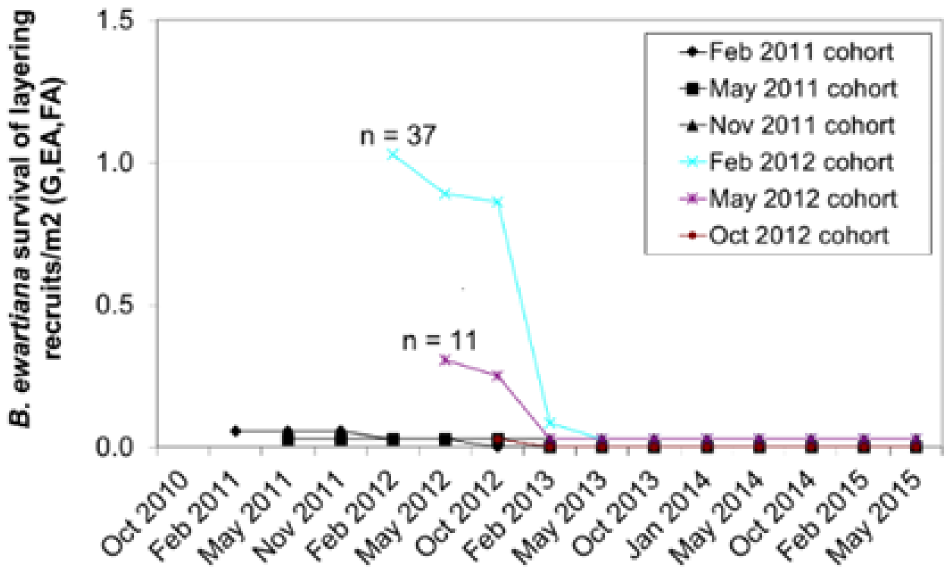
(a)



(b)



(c)



(d)

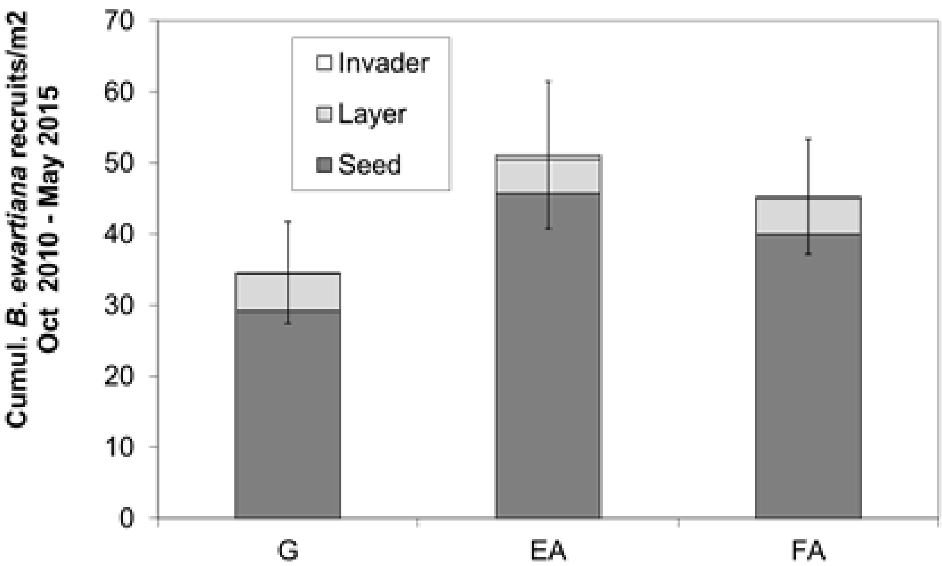
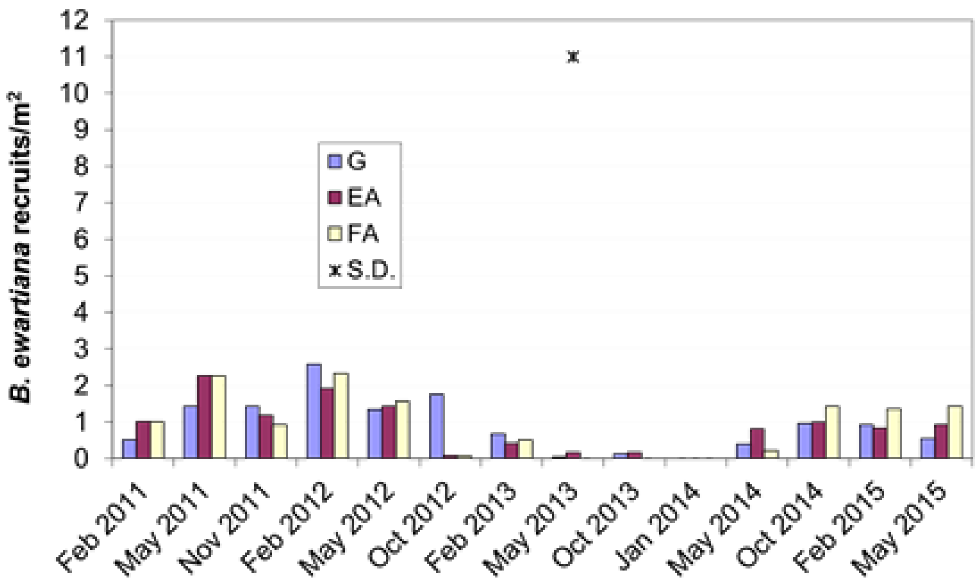


Fig. 4-9 (a) Survival of original plants and seedling cohorts of the three main taxa, (b) types of *B. ewartiana* recruits, (c) survival of *B. ewartiana* cohorts establishing from layering, and (d) effect of spelling strategy on *B. ewartiana* recruit type.

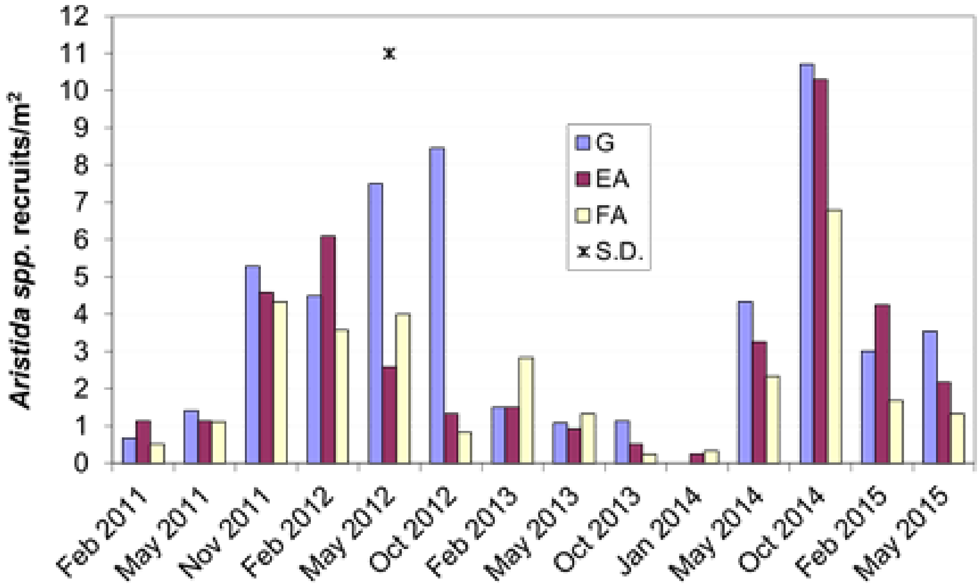
The number of recruits (Fig. 4-10) and mortalities (Fig. 4-11) are presented for each recording date subsequent to October 2010. The number of recruits at recording n+1 is those that have established between recording n and recording n+1. The number of mortalities at recording n+1 is the number of existing plants that have died or disappeared between recording n and recording n+1. These calculations allow better insights into the effect of seasonal conditions and spelling regimes on plant dynamics. Therefore, results are presented for G, EA and FA because these treatments were recorded at every recording date.

Appreciable recruitment rates (7-9 plants/m^2 in two years) and some survival of these recruits has occurred for all key taxa. High recruitment rates were found during the February 2011 to May 2012 period and again in May to October 2014. Most early recruits did not survive past October 2012 (Fig. 4-9 and 4-10) probably due to the fire and dry conditions. Despite dry conditions, high recruitment rates for *Aristida* spp*.* and *P. effusum* were recorded in October 2014. While *B. ewartiana* did have some recruits from May 2014 to May 2015 there were none in January 2014. Dry conditions prevailed leading up to January 2014. From May 2014 to May 2015 recruitment numbers were increased again for all three key taxa. Recruitments and mortalities for *Aristida* spp*.* were not affected by treatment meaning that the original relative order of plant density was maintained for the five years of the trial. Overall, spelling treatments did not greatly affect the number of recruits for any taxa. *B. ewartiana* had more recruits in treatment EA compared to G and FA in May 2013. *Aristida* spp*.* had more recruits in treatment G than EA or FA in May 2012. *P. effusum* had more recruits in treatment FA than G in February 2012.

(a)



(b)



(c)

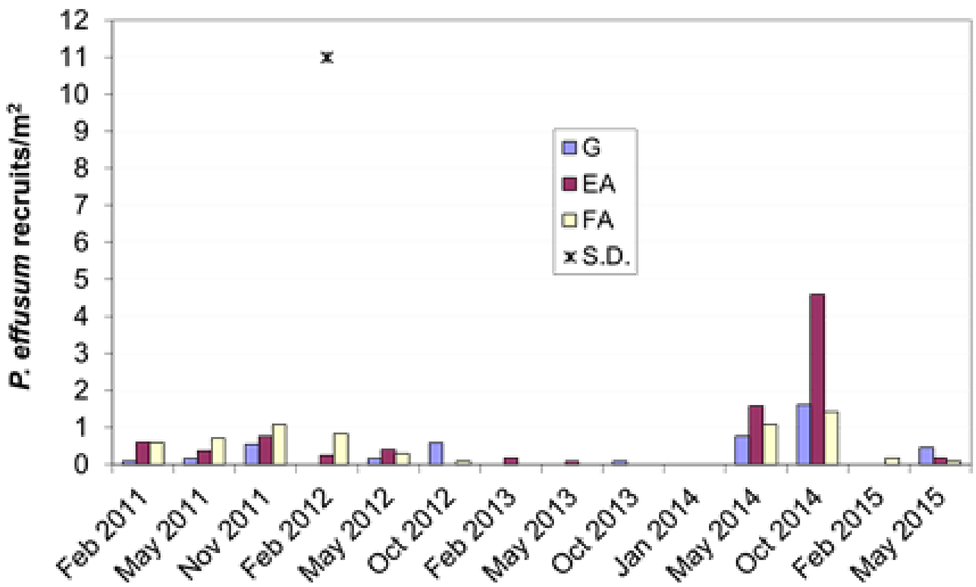
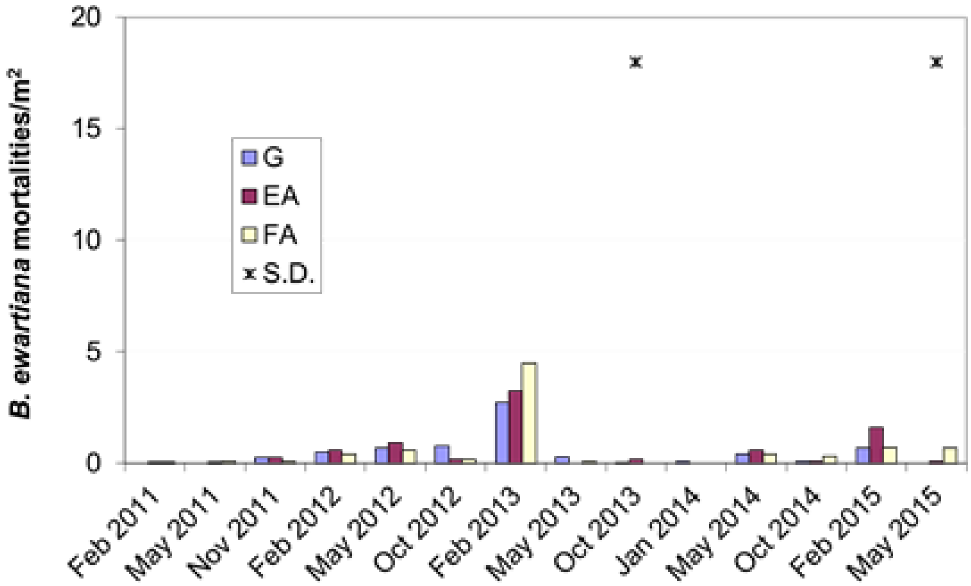


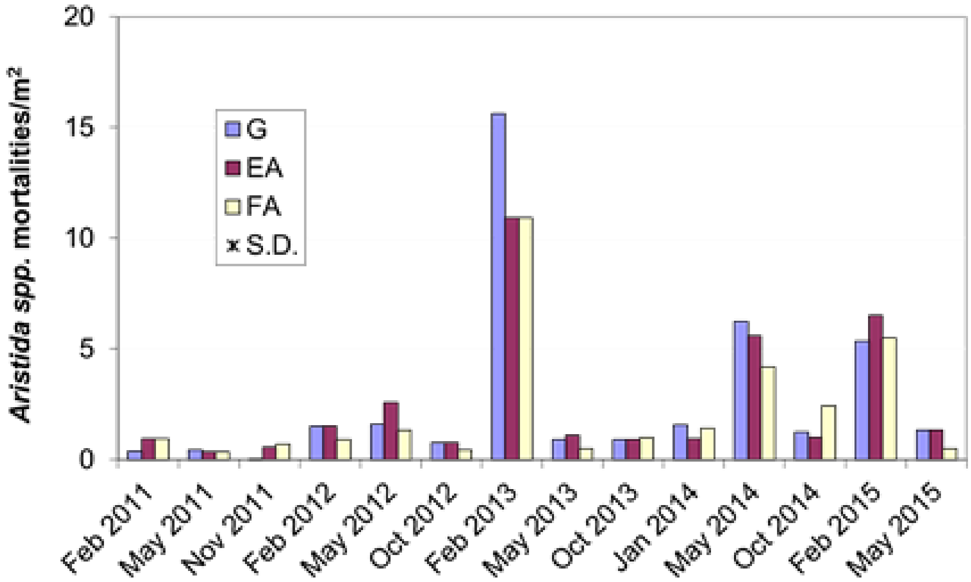
Fig. 4-10 Effect of spelling strategies on recruitment numbers at each recording date since 2010 for (a) *B. ewartiana*, (b) *Aristida* spp, and (c) *P. effusum* .

Mortalities occurred steadily for all key taxa. *B. ewartiana* had a high mortality rate only amongst the small recruiting plants. *Aristida* spp, and *P. effusum* had a high mortality rate for both the original and recruiting plants. Most mortalities were recorded at the February 2013 recording. *Aristida* spp. and *B. ewartiana* had a high mortality rate again at the May 2014 recording. *B. ewartiana* had a higher mortality in treatment EA compared to G in October 2013 and in FA compared to G in May 2015. The mortality of *Aristida* spp.and *P. effusum* was not affected by treatment in a consistent way (Fig. 4-11).

(a)


B. ewartiana mortalities/m²
20
15
10
5
0
G
EA
FA
S.D.
Feb 2011
May 2011
Nov 2011
Feb 2012
May 2012
Oct 2012
Feb 2013
May 2013
Oct 2013
Jan 2014
May 2014
Oct 2014
Feb 2015
May 2015

(b)


Aristida spp. mortalities/m²
20
15
10
5
0
G
EA
FA
S.D.
Feb 2011
May 2011
Nov 2011
Feb 2012
May 2012
Oct 2012
Feb 2013
May 2013
Oct 2013
Jan 2014
May 2014
Oct 2014
Feb 2015
May 2015

(c)

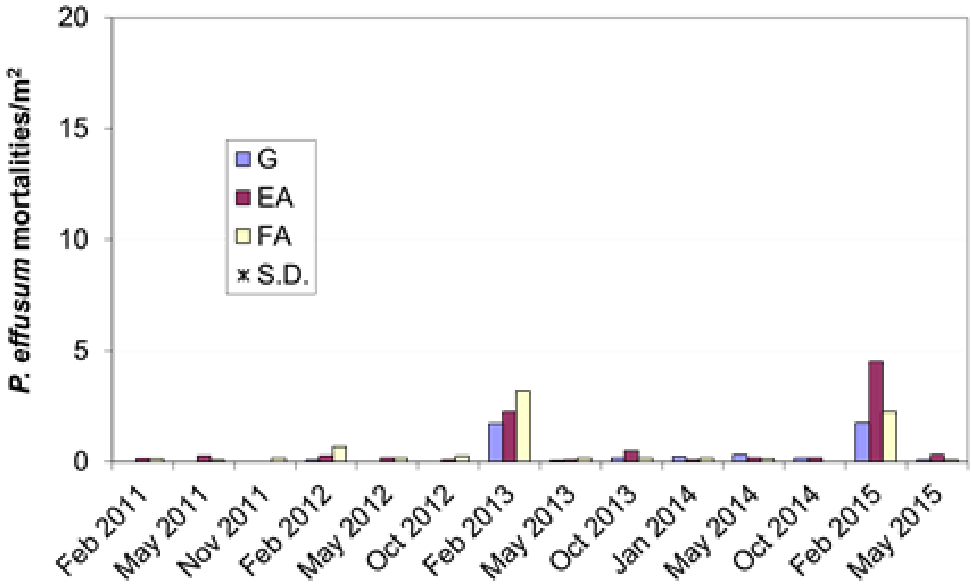


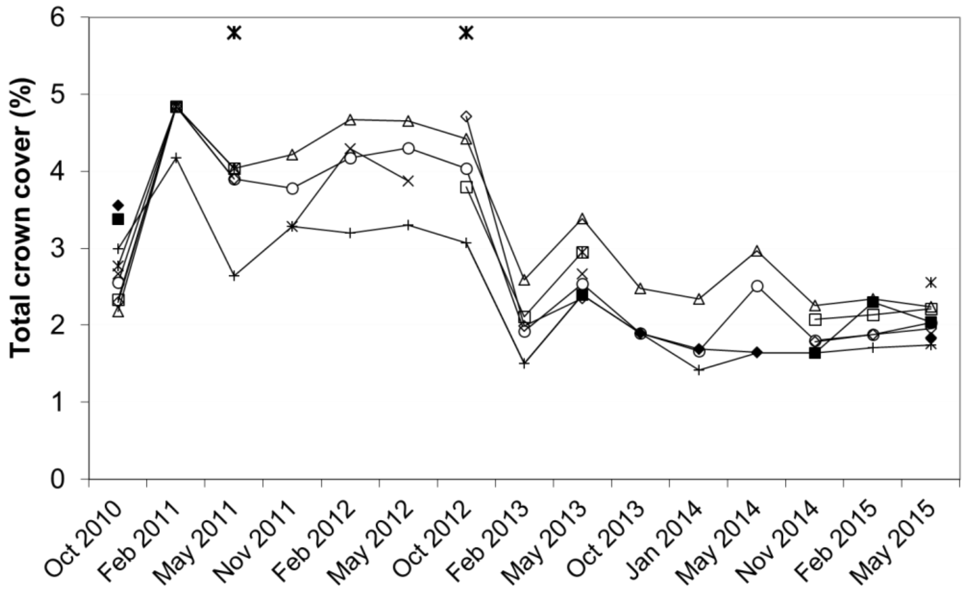
Fig. 4-11 Effect of spelling strategies on mortalities of (a) *B. ewartiana*, (b) *Aristida* spp, and (c) *P. effusum* plants of all ages combined.

4.1.2.5 Crown cover

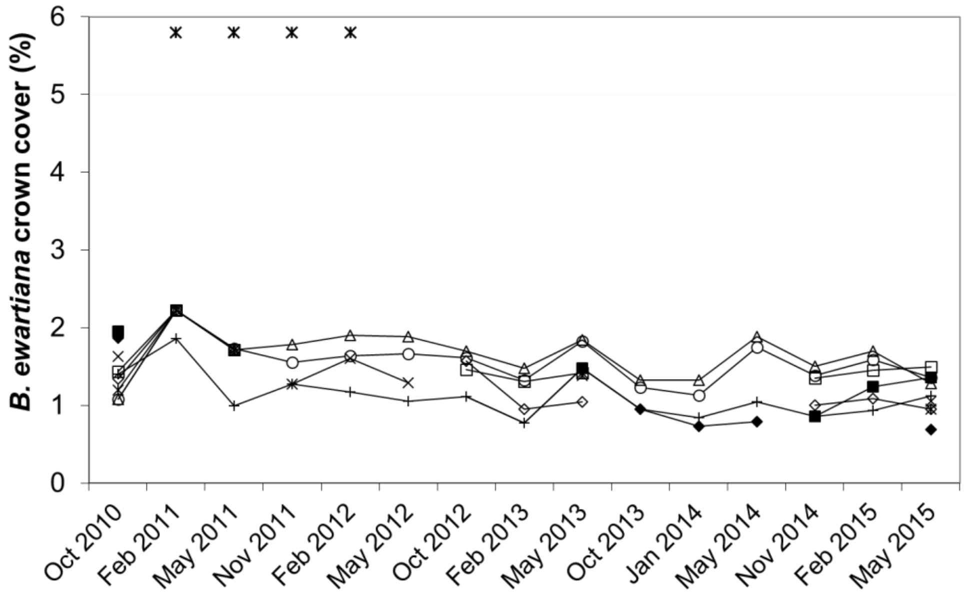
Crown cover varied with seasonal conditions across all treatments with both *B. ewartiana* and *P. effusum* at similar levels in May 2015 compared to the starting conditions for the trial. FA and EA increased total crown cover at May 2011 compared to G, while EA, EB and FA increased total crown cover at October 2012 compared to G (Fig. 4-12a). This change occurred during the first two growing seasons which were very wet. *B. ewartiana* crown cover was increased by EA, EB, FA, FB and FY1 compared to G at February and May 2011. At November 2011 FA had more crown cover than G and FY2 and at February 2012, EA, FA and FY2 had more crown cover of *B. ewartiana* than G (Fig.4-12b). *Aristida* spp. and *P. effusum* crown cover was not significantly affected by any treatment at any recording time (Fig. 4-12c and d).

The unplanned burn and dry summer of 2012-13 decreased total crown cover due to the decrease in *Aristida* spp. crown cover. *B. ewartiana* crown cover was stable through the burn and dry summer of 2012-13. The *P. effusum* crown cover, although very small (<0.25%) was not affected by treatments and had a large decrease following the burn and dry summer of 2012-13 (Fig. 4-12).

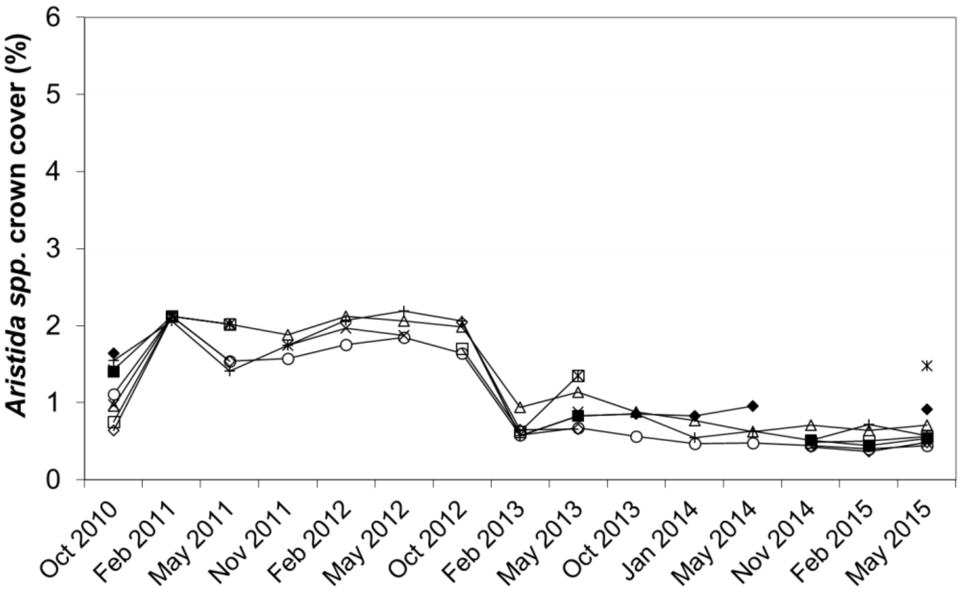
(a)


Total crown cover (%)
0
1
2
3
4
5
6
Oct 2010
Feb 2011
May 2011
Nov 2011
Feb 2012
May 2012
Oct 2012
Feb 2013
May 2013
Oct 2013
Jan 2014
May 2014
Nov 2014
Feb 2015
May 2015

(b)


B. ewartiana crown cover (%)
0
1
2
3
4
5
6
Oct 2010
Feb 2011
May 2011
Nov 2011
Feb 2012
May 2012
Oct 2012
Feb 2013
May 2013
Oct 2013
Jan 2014
May 2014
Nov 2014
Feb 2015
May 2015

(c)



(d)

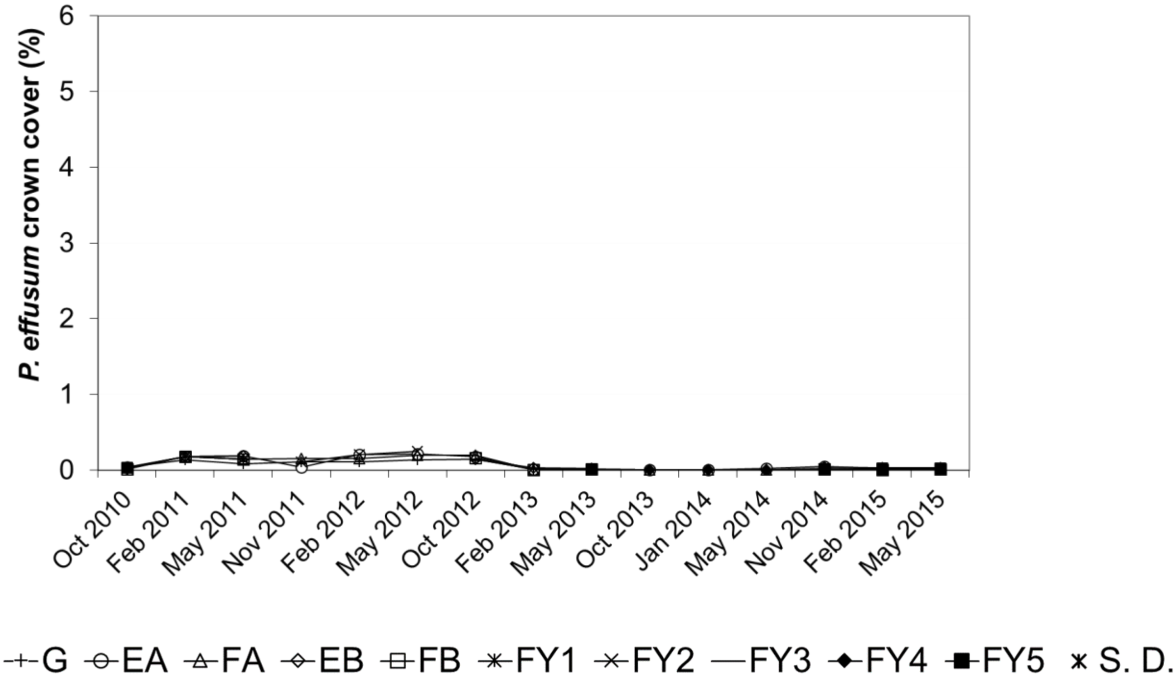
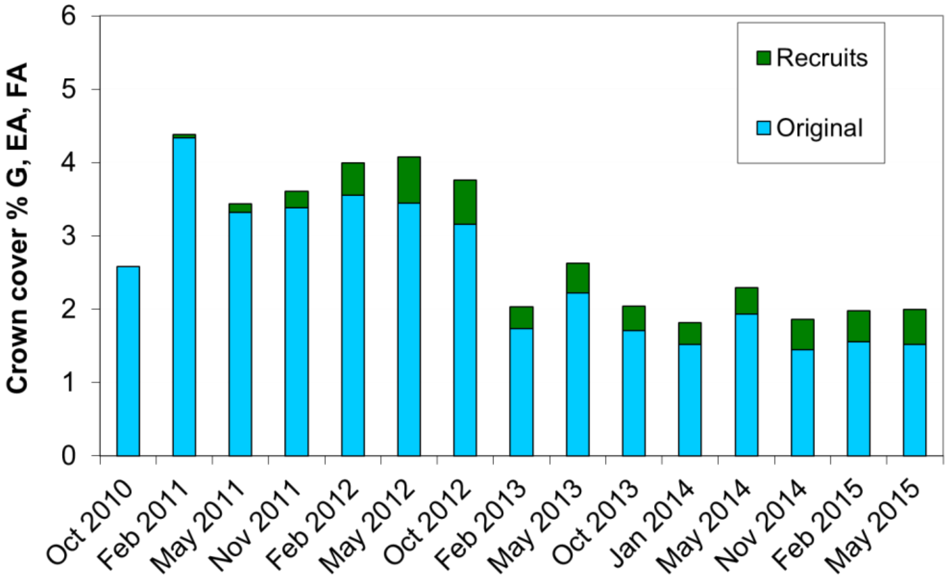


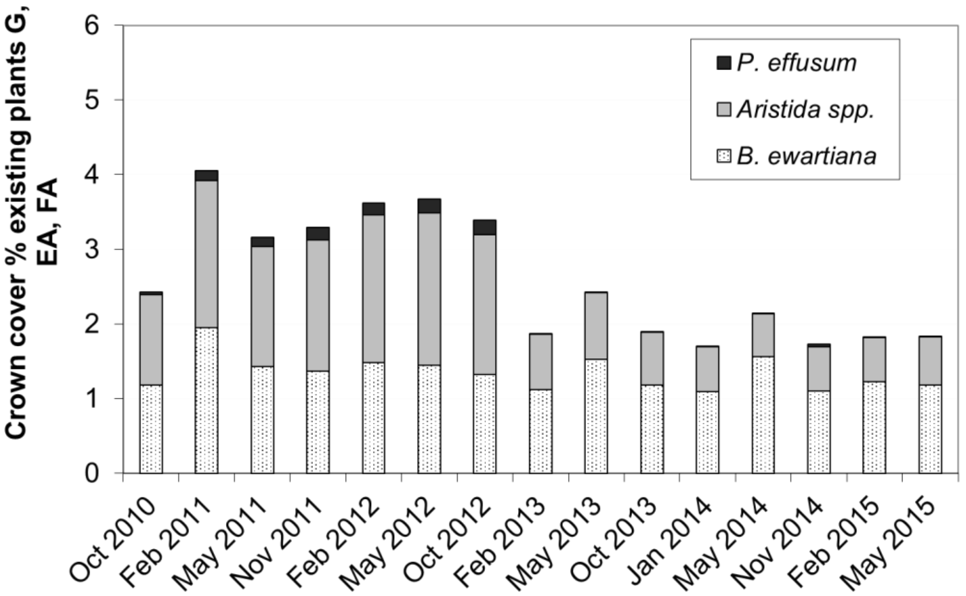
Fig. 4-12. Effect of spelling strategies on changes over time for (a) total crown cover, (b) *B. ewartiana* crown cover, (c) *Aristida* spp crown cover and (d) *P. effusum* crown cover.

The total crown cover since February 2012 always had a significant contribution from plants that recruited since trial establishment (~ 10%). Conversely, original plants provided most of the total crown cover (~ 90%) for all recordings (Fig. 4-13a). *Aristida* spp*.* and *B. ewartiana* contributed about half each to total crown cover until the November 2012 burn but thereafter the crown cover of *Aristida* spp was reduced considerably (Fig.4-13b). *P. effusum* had a very small contribution to total crown cover. *Aristida* spp*.* contributed about 70% of the crown cover of the recruits, while *B. ewartiana* contributed 20% and *P. effusum* 10% respectively (Fig. 4-13c and d).

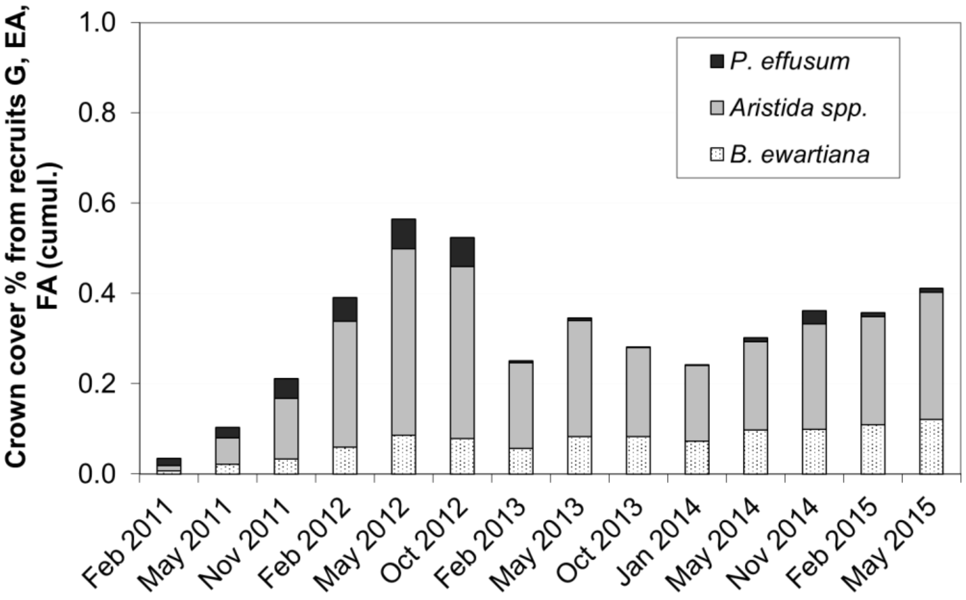
(a)



(b)



(c)



(d)

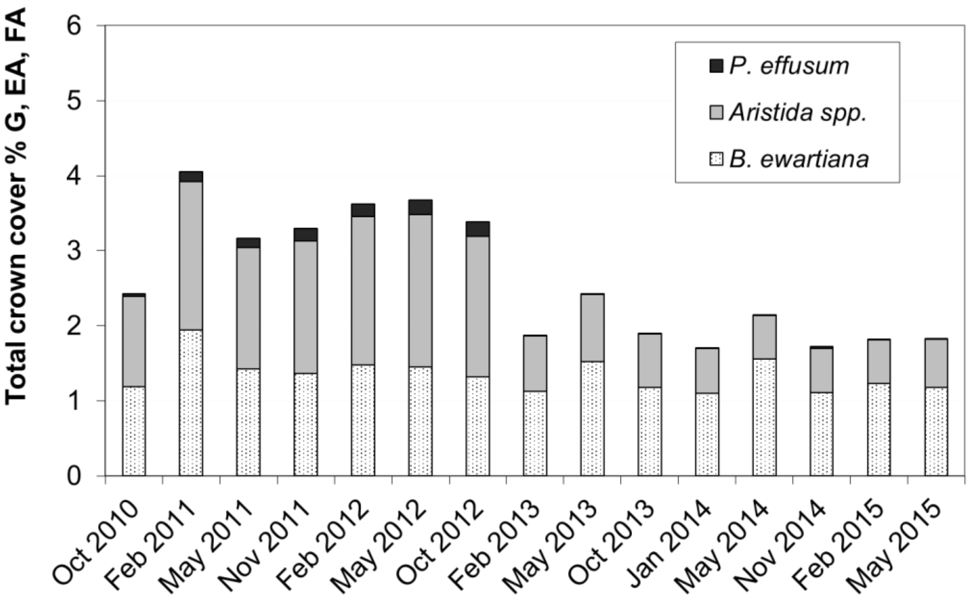


Fig. 4-13 Effect of spelling strategies on (a) Total crown cover with contributions from original and recruiting plants, (b) Crown cover contribution from surviving original plants, (c) Crown cover contributions from the recruits of *P. effusum, Aristida* spp and *B. ewartiana* and (d) Total crown cover. Note different Y axis scale.

The February 2011 *B. ewartiana* cohort had a high survival compared to other cohorts (Section 4.1.2.4). These surviving plants appear to have had a positive response to spelling and their crown cover compared to the G treatment. In February 2012 the EB treatment had significantly more crown cover than G, EA and FA. There appears to be a trend for increasing crown cover with the annual and biennial spelling treatments, particularly through the dry years in 2013-14 and 2014-15 (Fig. 4-14).

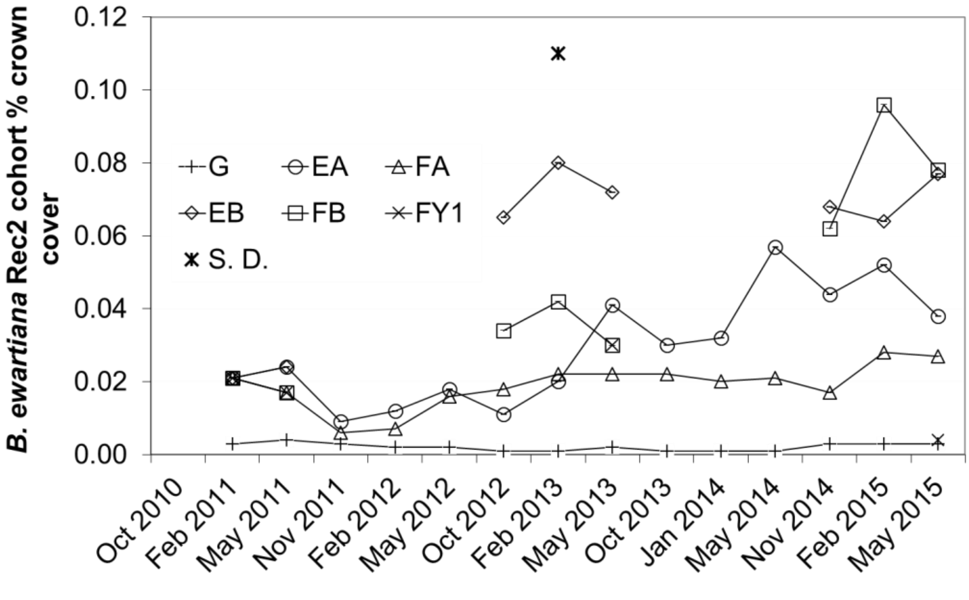


Fig. 4-14 Effect of spelling strategies on the crown cover of the February 2011 *B. ewartiana* cohort.

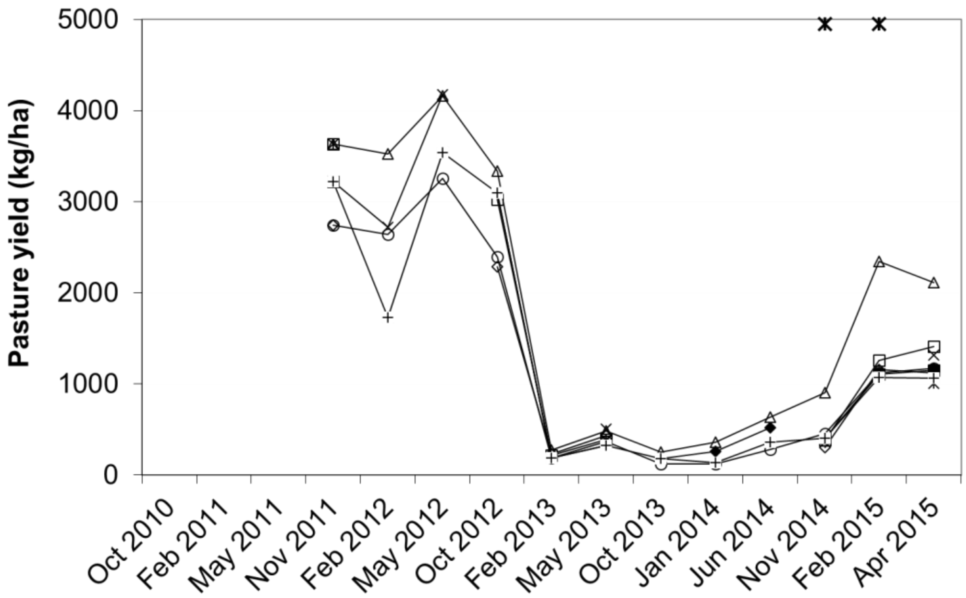
4.1.3 Plot BOTANAL data

Measurements were also recorded on a whole plot basis (PB) since November 2011 to ensure the capture of data that integrates treatment effects on the whole plot such as recolonisation of very bare patches and changes in composition for all major plant species. PB data is collected on pasture yield, composition, LFA and land condition as per the fixed quadrats. Spelling treatments measured in this way did not have a significant effect on these pasture parameters. Overall the PB and FQ data were in a similar range and follow a similar trend for pasture yield, composition, ground cover and land condition. Yield, composition and ground cover were slightly higher for the PB data compared to the FQ data. PB data is presented for the main pasture parameters from November 2011 to May 2014 (Fig. 4-15).

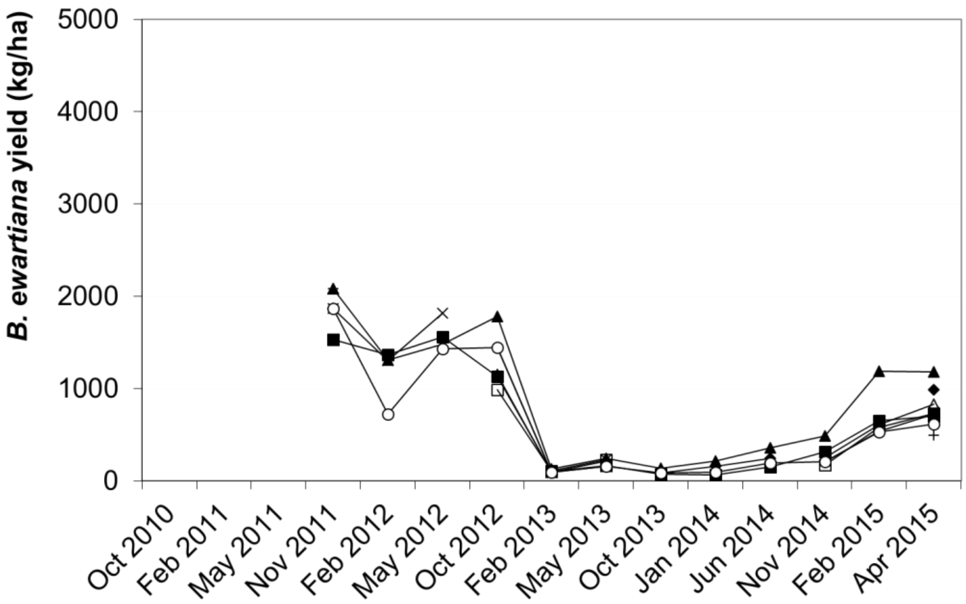
4.1.3.1 Pasture yield

By November 2014 pasture yield with FA spelling was significantly greater compared to EA, EB, FB, FY5 and G. This advantage was maintained in February 2015 and beyond (Fig. 4- 15a). However, *B. ewartiana* yield was not affected by treatment at any recording date (Fig. 4-15b). *Aristida* spp*.* yield increased with FA in November 2014 when compared to EA, EB, FB, FY5 and G (Fig. 4-15c). *P. effusum* yield increased with FA in October 2012 when compared to EA, EB, FB, FY3 and G (Fig. 4-15c).

(a)


Pasture yield (kg/ha)
5000
4000
3000
2000
1000
0
Oct 2010
Feb 2011
May 2011
Nov 2011
Feb 2012
May 2012
Oct 2012
Feb 2013
May 2013
Oct 2013
Jan 2014
Jun 2014
Nov 2014
Feb 2015
Apr 2015

(b)


B. ewartiana yield (kg/ha)
5000
4000
3000
2000
1000
0
Oct 2010
Feb 2011
May 2011
Nov 2011
Feb 2012
May 2012
Oct 2012
Feb 2013
May 2013
Oct 2013
Jan 2014
Jun 2014
Nov 2014
Feb 2015
Apr 2015

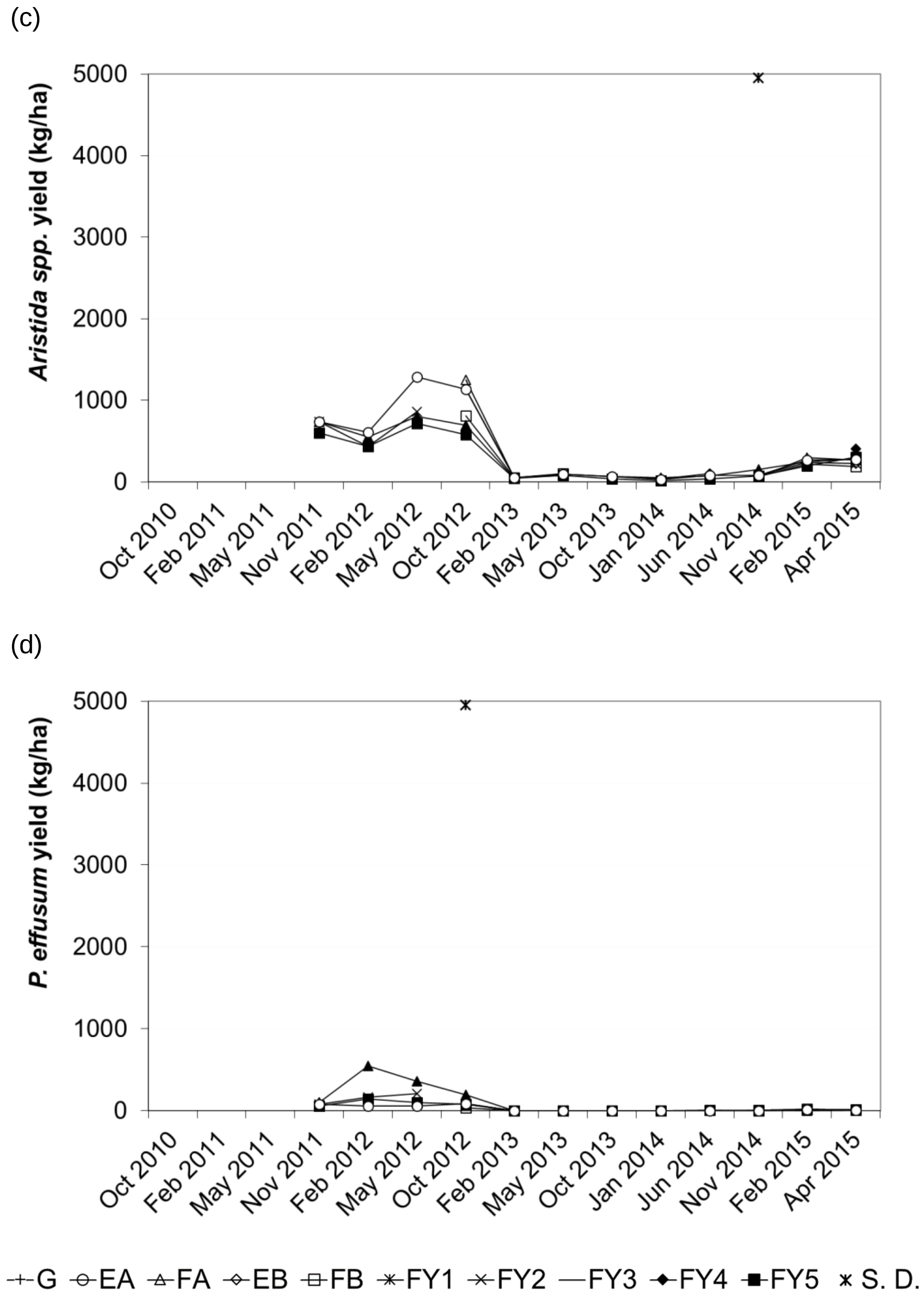


Fig. 4-15 Effect of spelling strategies on (a) Total pasture yield, (b) *B. ewartiana* yield, (c) *Aristida* spp yield and (d) *P. effusum* yield at the plot level.

4.1.4 Germinable soil seed data at Site 1

Soil sampling in the springs of 2011, 2012, 2013 and 2014 found very low numbers of germinable seeds of 3P grasses irrespective of the year or the grazing management being applied. While the *B. ewartiana* seedbank is very low there is a trend for an increase over time. *Aristida* spp. seedbank was also increasing (Table 4-3). The large diversity in the seedbank is considerably greater than that recorded by the BOTANAL sampling. Additionally, many perennial grasses recorded in the BOTANAL sampling were not recorded in the seedbank including *Cenchrus ciliaris, Chrysopogon fallax, Heteropogon contortus, Themeda avenacea, Eulalia aurea, Dichanthium sericeum* and *Tripogon loliiformis*. The sedges were very abundant and diverse (Appendix 7). There were no 3P grasses in the spring 2012 samples. *Eragrostis lacunaria* was consistently the main germinating perennial grass while *Aristida* spp. and *Eragrostis tenellula* were a significant proportion of the seed bank for the four sample dates. Very few legumes and tree species and no shrub species germinated, even of the ubiquitous *Carissa ovata*. The low biomass species *E. lacunaria, Fimbristylis* spp*., Cyperus* spp. and *Eragrostis* spp. were consistently found in significant numbers. Other species consistently found in low numbers include *Tragus australianus, P. effusum, Zornia* spp. and *Alysicarpus rugosus. B. ewartiana, Melinis repens, Bothriochloa pertusa* and *Austrochloris dichanthioides* were found in low numbers in some years (Appendix 7).

Table 4-3 Main species germinating (seeds/m^2) from Site 1 soil.

	Year			
	2011	2012	2013	2014
3P grasses				
Bothriochloa ewartiana	5	0	21	30
Themeda triandra	1	0	0	0
Other perennial grasses				
Eragrostis lacunaria	174	150	223	300
Aristida spp.	22	29	146	171
Eriachne mucronata	0	0	0	15
Melinis repens	8	7.5	0	0
Panicum effusum	3	1.5	21	8
Bothrichloa pertusa	0	0	2	9
Austrochloris dichanthioides	2	1.5	0	6
Annual grasses				
Eragrostis tenellula	64	62	85	49
Tragus australianus	4	3	8	6
Perotis rara	10	0	0	0
Digitaria ciliaris	14	4	0	0
Legumes				
Galactica tenuifolia	1	0	0	0
Sown stylos	4	0	0	0
Alysicarpus rugosus	9	2	4	2
Zornia spp.	9	9	2	1
Trees and shrubs				
Eucalyptus spp.	1	2	11	4.5

4.2 Effect of spelling strategies on pastures and land condition at Site 2

4.2.1 Rainfall and growing conditions at Site 2

The 14 years prior to trial establishment in December 2012 included runs of very wet years and very dry years. Very wet years with good growing conditions occurred from 1998-99 to 2000-01. Very dry conditions occurred from 2001-02 to 2004-05 with rainfall events being poorly distributed and poor pasture growth resulting. Conditions improved through 2007-08 and 2008-09 with well above average rainfall. The three years immediately prior to trial establishment (2009-10, 2010-11 and 2011-12) had well above average rainfall and good growing conditions. The 2012-13 summer had average rainfall and growing conditions after a wet July (Table 4-4). The second year (2013-14) had a dry winter, followed by below average and late summer rainfall and thus below average growing conditions. Very dry conditions continued throughout 2014-15 with a very poor pasture growth response.

Table 4-4 Monthly rainfall (mm) at Site 2 from July 1998 to June 2014 and long term (103 years) average monthly rainfall (mm) at nearby Trafalgar Station.

	Year									
Month	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14	2014-15	Long term mean
Jul	36		136		4	5	116			16
Aug					95		9		31	12
Sep	17	7	30		77		9		3	11
Oct		6			98	16	9	25	3	22
Nov	6	38	134	70	207		17	36		50
Dec	11	171	8	58	102	234	43	52	71	80
Jan	184	305	321	136	289	95	114	187	132	137
Feb	191	358	231	193	116	185	51	65	7	136
Mar	39	4	21	148	138	127	90	160	9	88
Apr		6	137	99	88	7	107	18		35
May	6		15	11	7	61	23			26
Jun	218	4			11	19	1	13	3	23
Total	708	898	1032	715	1232	749	589	555	257	647
Decile	7	9	10	7	10	7	5	4	1	

Figure 4-16 shows the same drought index for Site 2 (a rolling average of the actual last 12 months rainfall compared to the long-term average). The trial was established at the tail of some good rainfall and growing conditions which extended into the spelling periods of the first year. Rainfall and growing conditions quickly deteriorated thereafter and it was continuously dry for the last two years (Fig. 4-16). Site 2 experienced similar extremes in rainfall and growing conditions to Site 1.

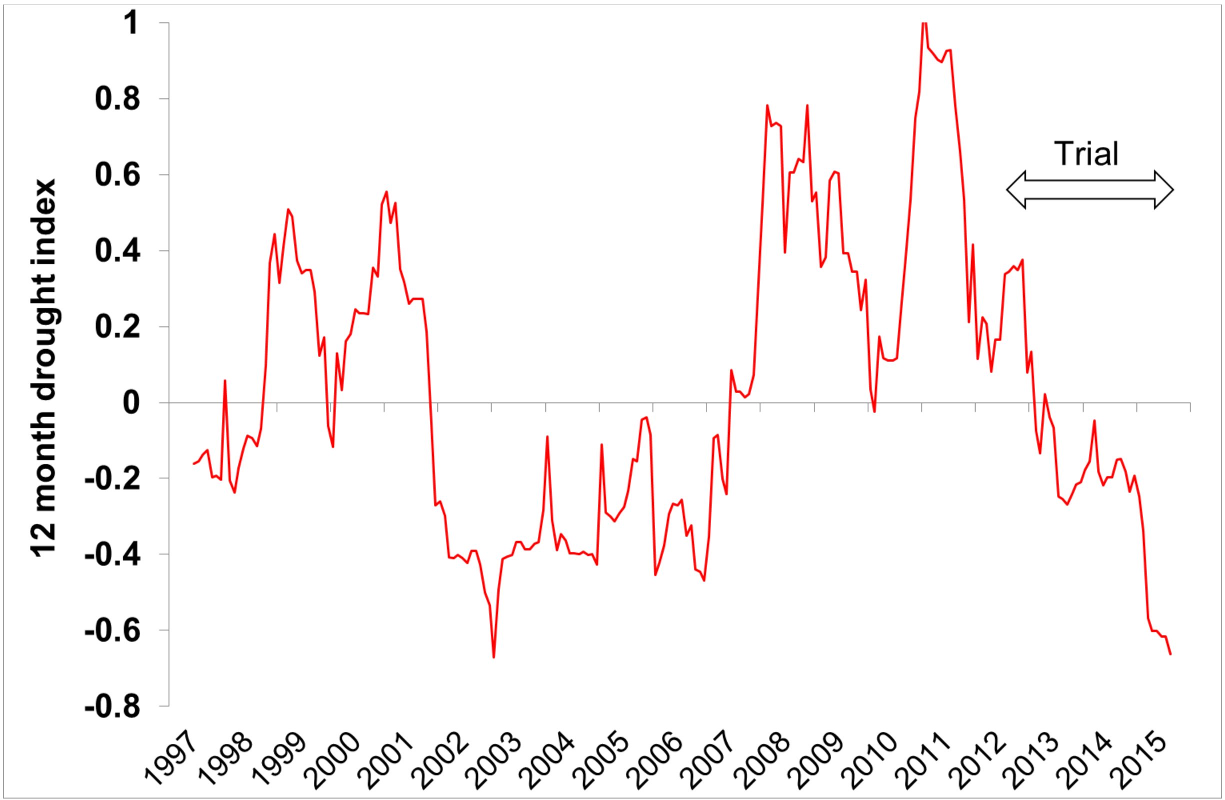


Fig. 4-16 A drought index for Site 2 (∑last 12 months rainfall-∑12 months average rainfall)/ average rainfall) based on Trafalgar long-term data. Note the trial operated from 2012 to 2015.

4.2.2 Fixed quadrat data

4.2.2.1 Pasture yield

Results were very similar from assessments done at the fixed quadrat and plot level (Fig. 4- 17). Total pasture yields were relatively low and there was a small overall increase at the moderate stocking rate until the dry conditions in 2014-15. Under high stocking rate, pasture yields increased when spelled for the full wet season, and then reverted to a low level when grazed again. Treatment effects are not apparent under the moderate stocking rate except for treatment G which had a smaller pasture yield than EA, EB, FA and FB in February 2013 (Fig. 4-17a).

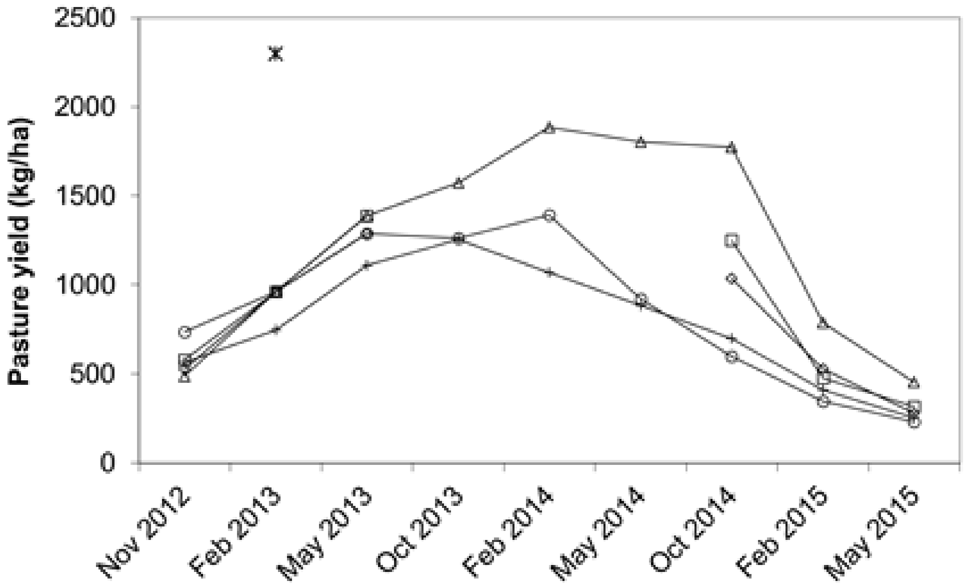
Under high stocking rate, spelling consistently increased pasture yield at the mid-summer and end of summer recordings. In February 2013, pasture yield was significantly less under treatment G compared to FA and FB, and under EA and EB compared to FA and FB. In

February 2015, treatments FA and FB had significantly greater pasture yield than G, and FA was also significantly greater than EA (Fig. 4-17b).

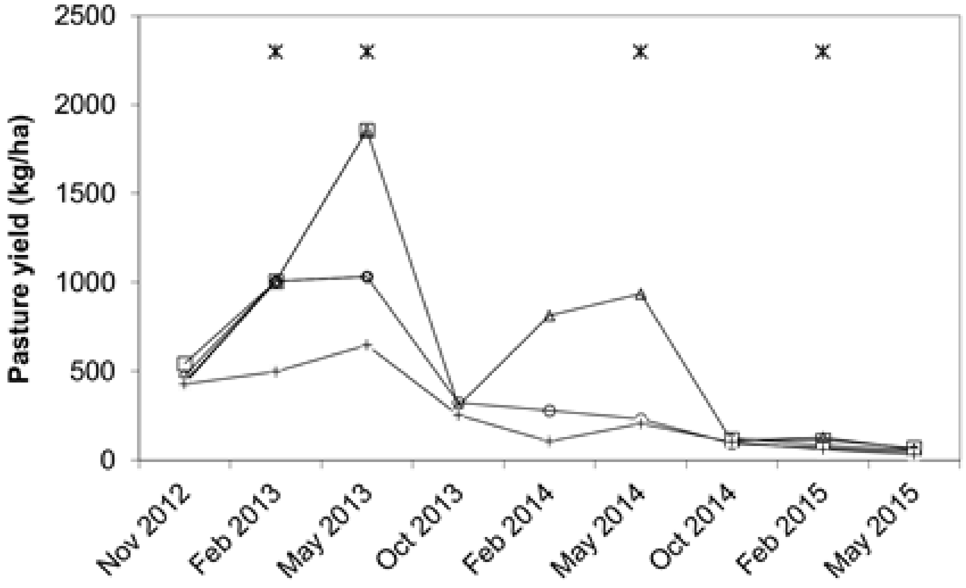
Similar results were found with *B. ewartiana* and *Aristida* spp. Under moderate stocking rate, *B. ewartiana* pasture yield was not affected by treatment. Under high stocking rate, treatment FA significantly increased *B. ewartiana* pasture yield in May 2013 when compared with G, EA and FB. In May 2014, treatment FA had a greater presentation yield than G and EA.

For *Aristida* spp. under moderate stocking rate treatment G pasture yield was only less compared to all spelling treatments in February 2013. Under high stocking rate treatment G had less pasture yield than all spelling treatments in both February and May 2013. In May 2015, treatments EB and FA had a greater pasture yield than both treatment G and FB.

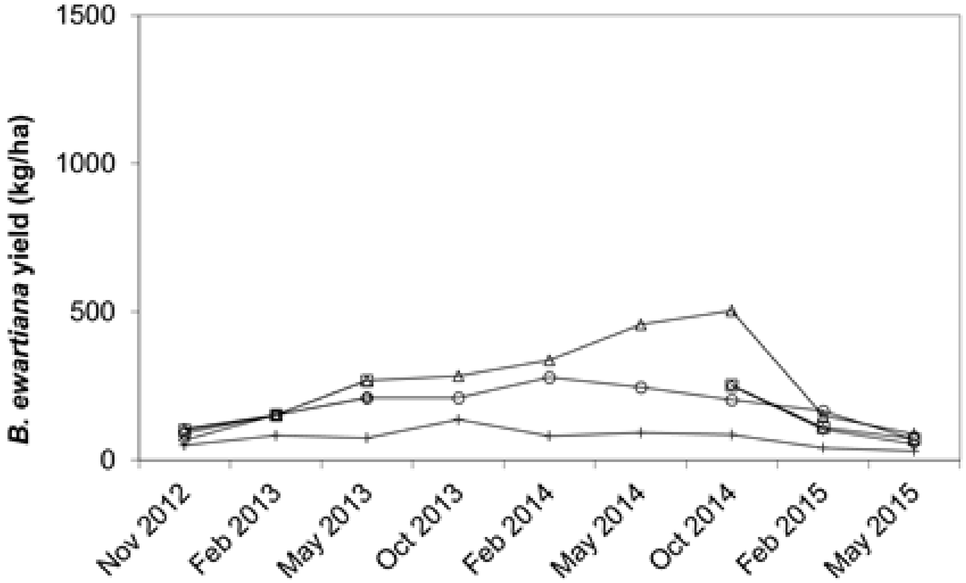
(a)



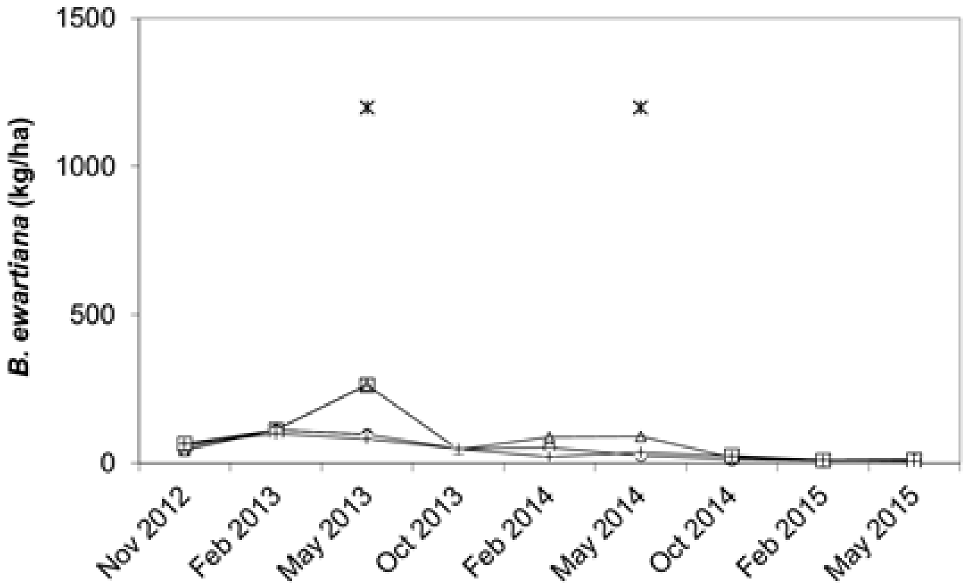
(b)


Pasture yield (kg/ha)
2500
2000
1500
1000
500
0
Nov 2012
Feb 2013
May 2013
Oct 2013
Feb 2014
May 2014
Oct 2014
Feb 2015
May 2015

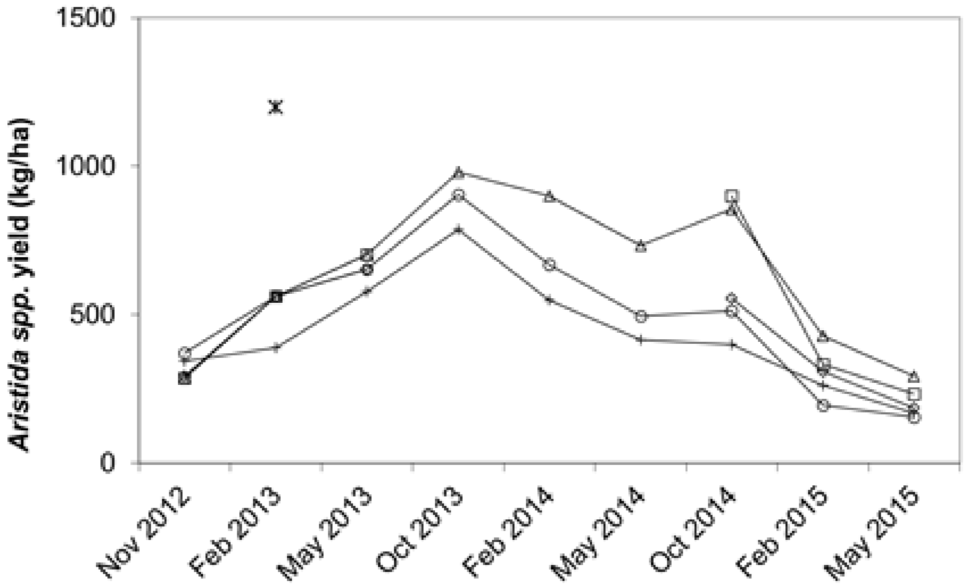
(c)


B. ewartiana yield (kg/ha)
1500
1000
500
0
Nov 2012
Feb 2013
May 2013
Oct 2013
Feb 2014
May 2014
Oct 2014
Feb 2015
May 2015

(d)


1500
1000
500
0
B. ewartiana (kg/ha)
Nov 2012
Feb 2013
May 2013
Oct 2013
Feb 2014
May 2014
Oct 2014
Feb 2015
May 2015

(e)


1500
1000
500
0
Aristida spp. yield (kg/ha)
Nov 2012
Feb 2013
May 2013
Oct 2013
Feb 2014
May 2014
Oct 2014
Feb 2015
May 2015

(f)

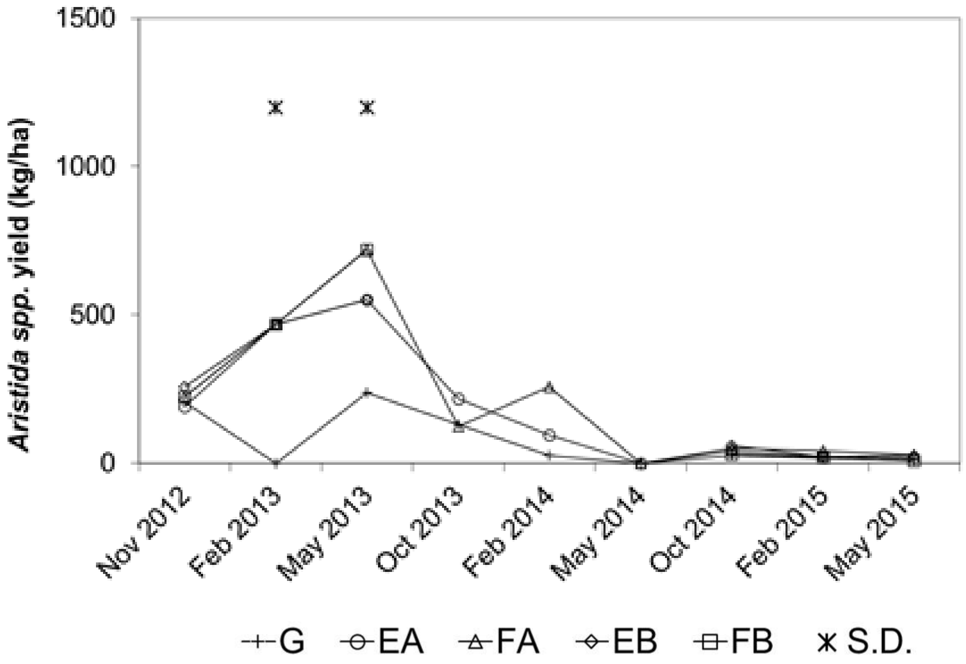
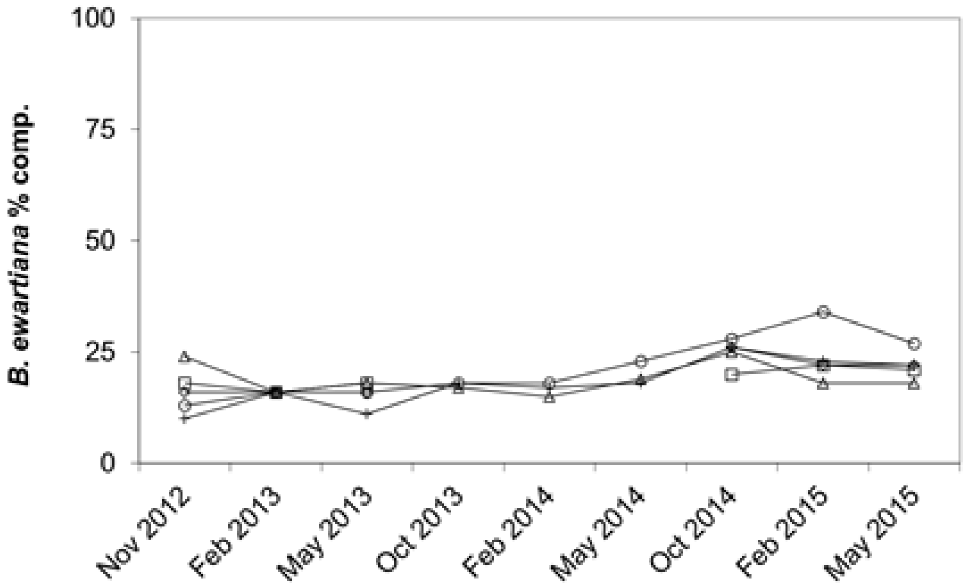


Fig. 4-17 Effect of spelling strategies on pasture yield for all pasture (a, b), *B. ewartiana* (c, d) and *Aristida* spp. (e, f) under moderate stocking rate (a, c and e) and high stocking rate (b, d and f). Note different Y axis scales.

4.2.2.2 Composition

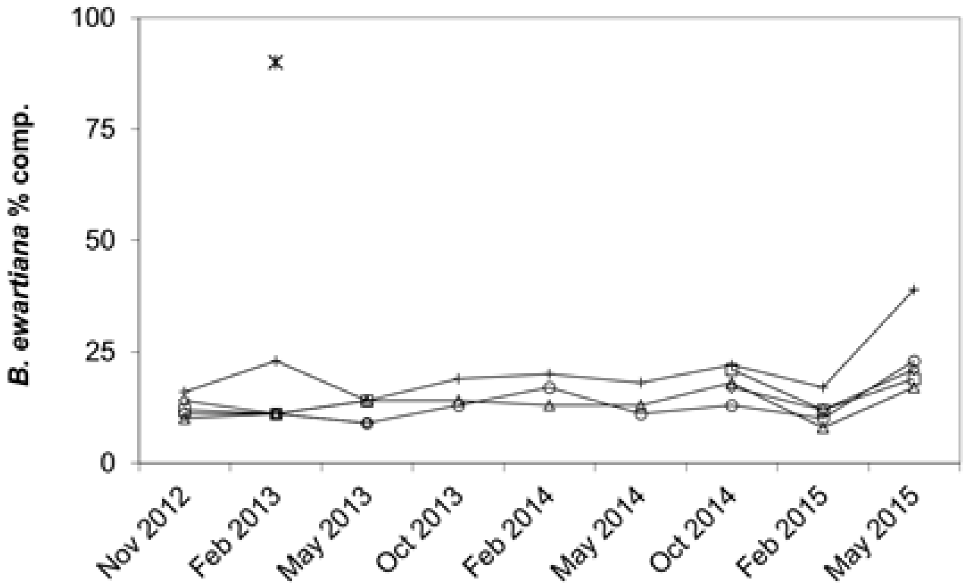
The plot level data is very similar to the fixed quadrat data for the key components of the pasture – *B. ewartiana* and *Aristida spp.* Spelling treatments had a minor impact on pasture composition (Fig. 4-18). Under moderate stocking rate neither *B. ewartiana* nor *Aristida* spp. were affected by any treatment. Under high stocking rate, *B. ewartiana* made up a greater percentage of the pasture composition in treatment G compared to EA, EB, FA and FB (Fig. 4-19d).

(a)



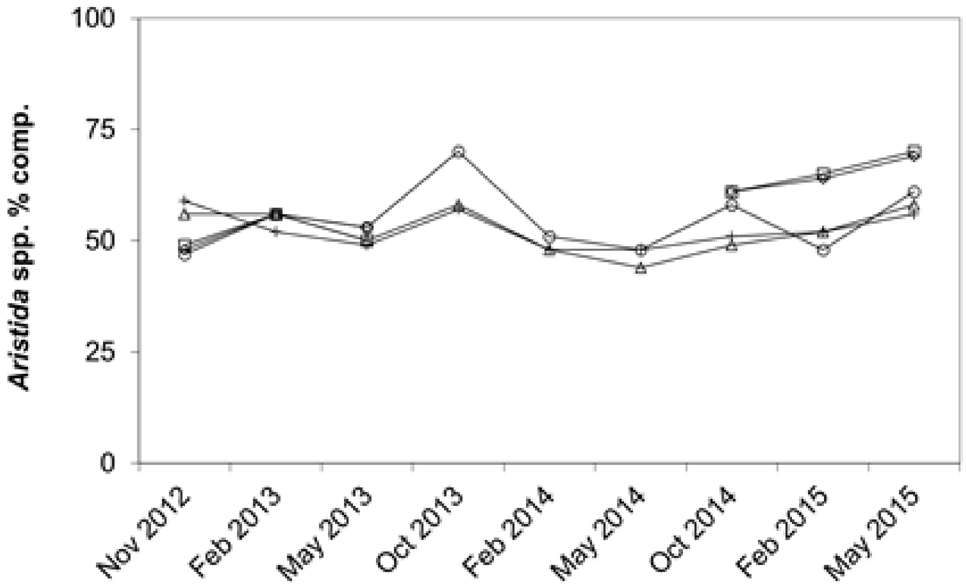
100
75
50
25
0
B. ewartiana % comp.
Nov 2012
Feb 2013
May 2013
Oct 2013
Feb 2014
May 2014
Oct 2014
Feb 2015
May 2015

(b)



100
75
50
25
0
B. ewartiana % comp.
Nov 2012
Feb 2013
May 2013
Oct 2013
Feb 2014
May 2014
Oct 2014
Feb 2015
May 2015

(c)



(d)

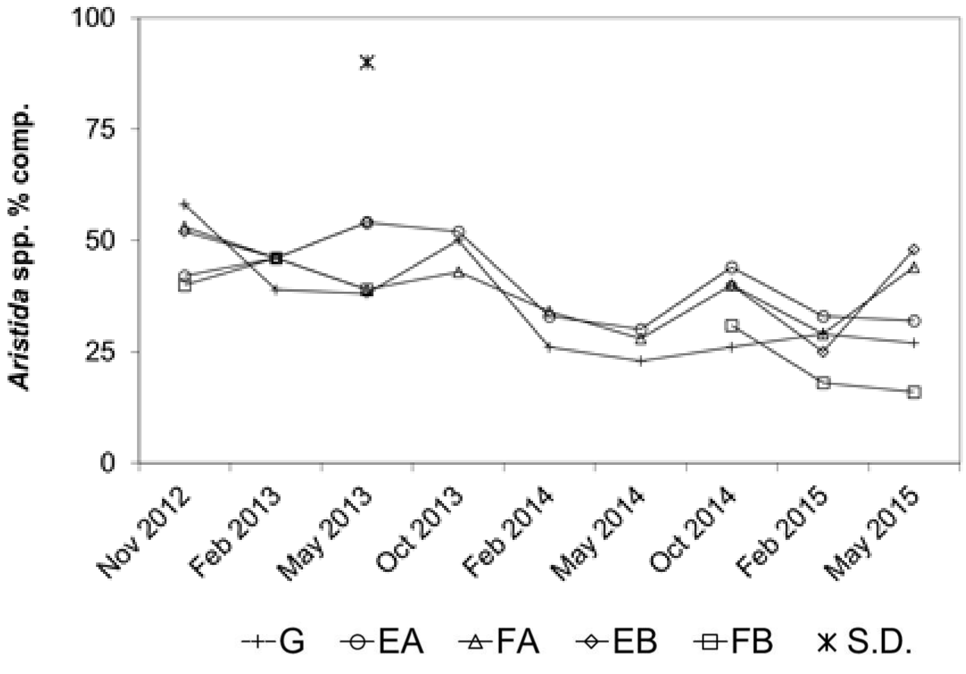


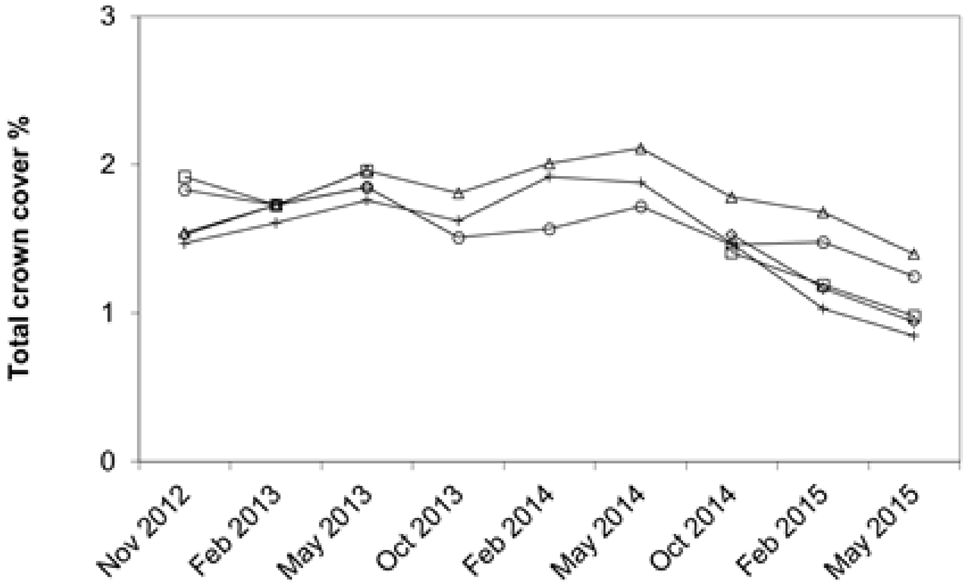
Fig. 4-18 Effect of spelling strategies on pasture composition for *B. ewartiana* and *Aristida* spp. under moderate stocking rate (a and c), and high stocking rate (b and d).

4.2.2.3 Crown cover

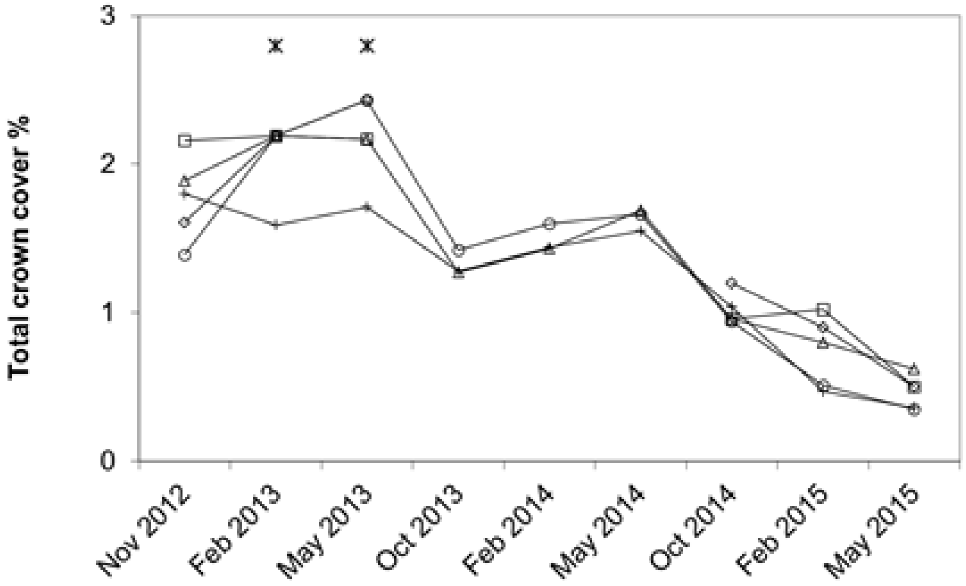
Total crown cover has decreased with the dry conditions under both moderate and high stocking rate irrespective of treatment. Under high stocking rate the decrease has been severe with a reduction from around 2% to below 1% crown cover over three years (Fig. 4- 19a and b). Spelling treatments have affected total crown cover but only under a high stocking rate. In February 2013, all high stocking rate spelling treatments had significantly more total crown cover than the G treatment. Also, in May 2013, the treatments EA and EB had more total crown cover than the G treatment (Fig. 4-19b).

There was minimal impact of spelling treatments on *B. ewartiana* crown cover regardless of stocking rate (Fig. 4-19c and d). Under moderate stocking rate the crown cover of *B. ewartiana* was increased in February 2013 with all the spelling treatments compared to G (Fig. 4-19c). The crown cover of *Aristida* spp. was not affected by any spelling treatment under a moderate or a high stocking rate.

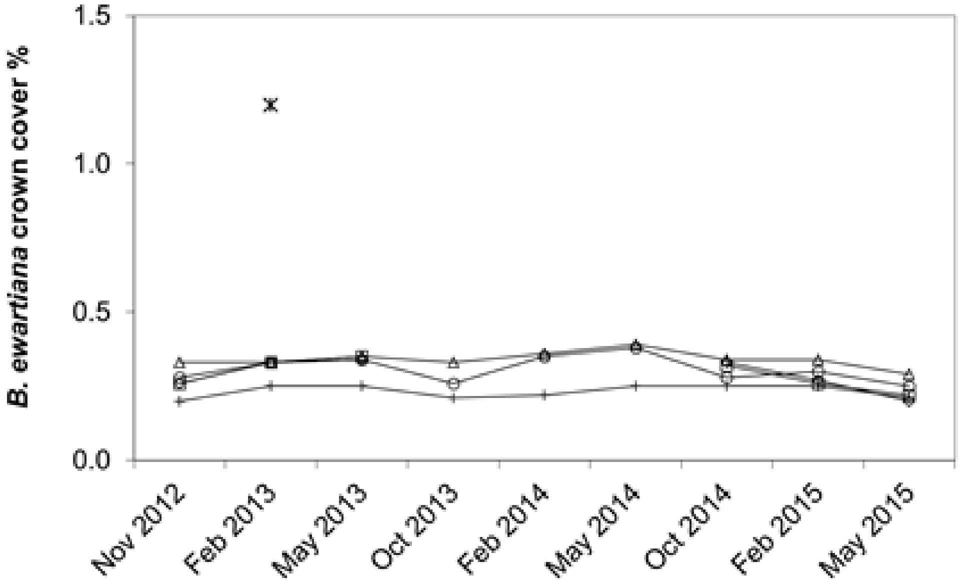
(a)



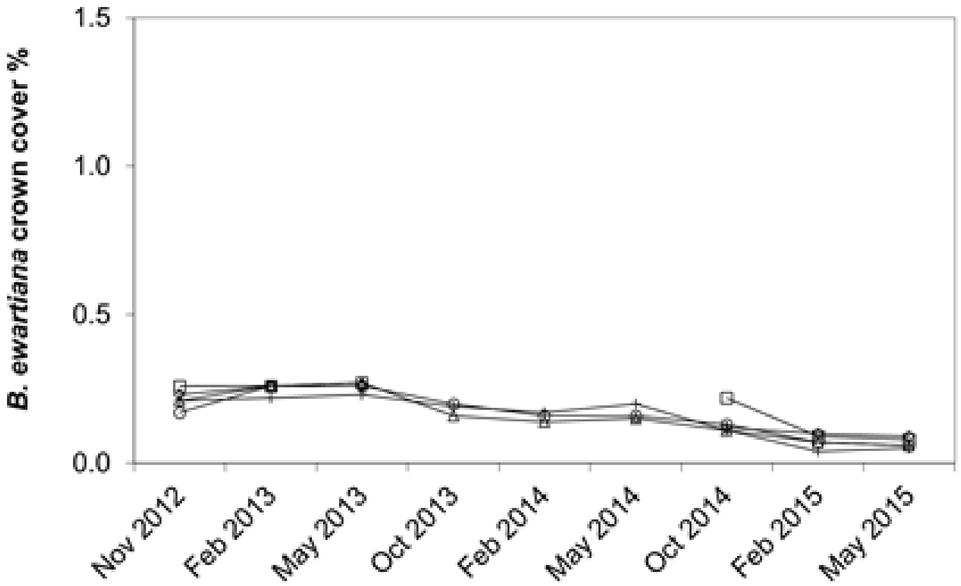
(b)



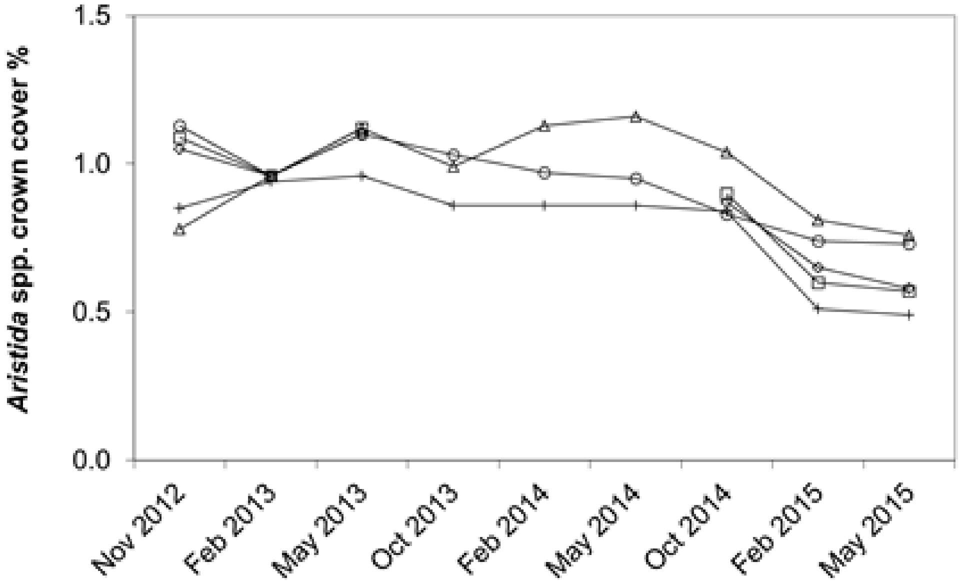
(c)


B. ewartiana crown cover %
1.5
1.0
0.5
0.0
Nov 2012
Feb 2013
May 2013
Oct 2013
Feb 2014
May 2014
Oct 2014
Feb 2015
May 2015

(d)


B. ewartiana crown cover %
1.5
1.0
0.5
0.0
Nov 2012
Feb 2013
May 2013
Oct 2013
Feb 2014
May 2014
Oct 2014
Feb 2015
May 2015

(e)



(f)

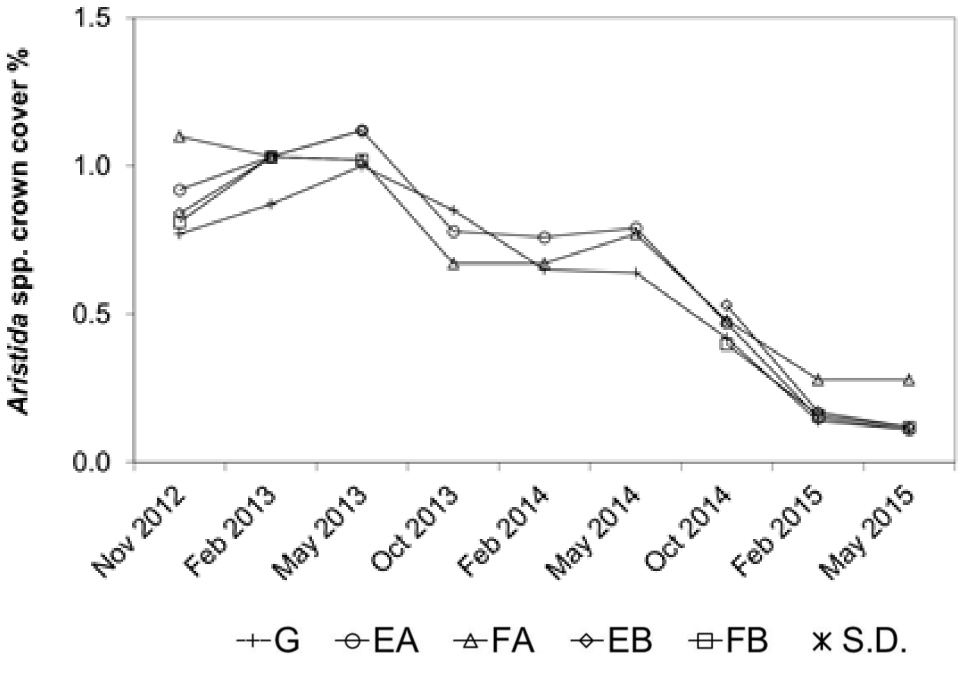
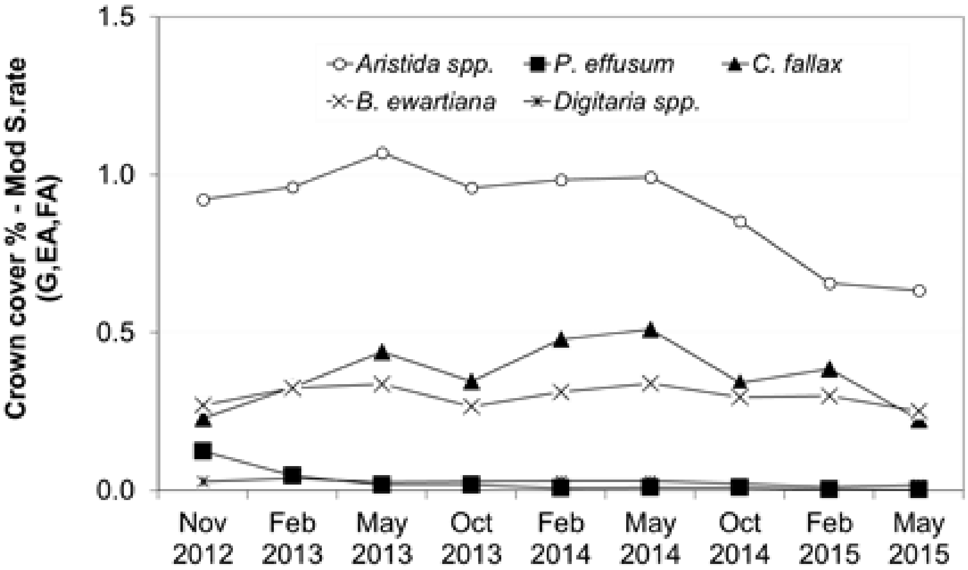


Fig. 4-19 Effect of spelling strategies under moderate or high stocking rate on - (a) and (b) total crown cover, (c) and (d) *B. ewartiana* crown cover, and (e) and (f) *Aristida spp* crown cover.

Aristida spp., *P. effusum, C. fallax, B. ewartiana* and *Digitaria spp* are the major taxa contributing to total perennial crown cover. *C. fallax* crown cover has been quite stable throughout the trial whether under a moderate or high stocking rate and does not appear to have decreased with the dry conditions. *B. ewartiana* crown cover has been stable when under a moderate stocking rate but has had a pronounced decrease when under a high stocking rate. The crown cover of *Aristida* spp., *P. effusum* and *Digitaria* spp. has decreased with the dry conditions with a greater decrease under a high stocking rate compared to a moderate stocking rate (Fig. 4-20a and b).

(a)



(b)

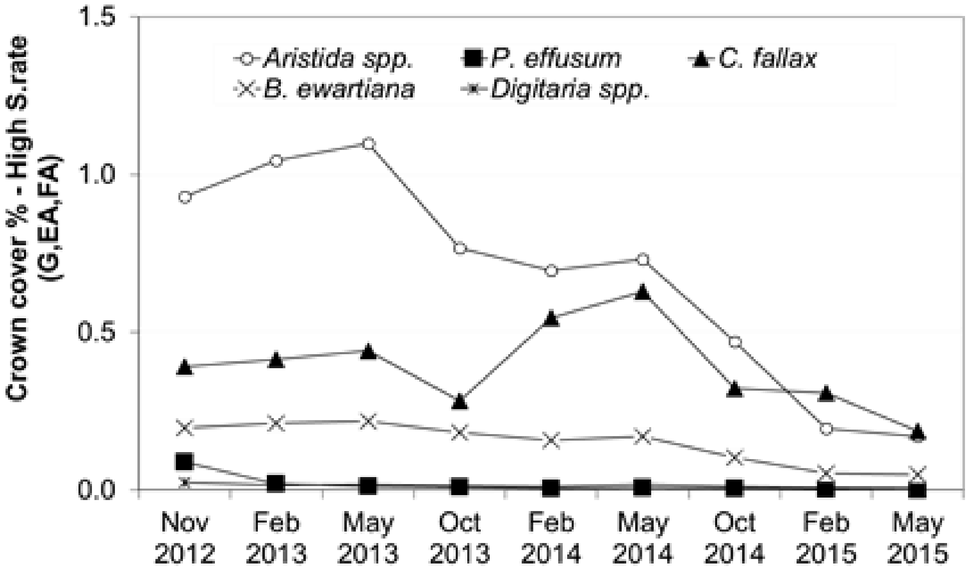


Fig. 4-20 Contributions from major taxa to crown cover under (a) moderate, and (b) high stocking rate. Note that the data is meaned across G, EA and FA treatments.

The November 2012 *B. ewartiana* cohort had a high survival compared to other cohorts when under a moderate stocking rate (Section 4.2.2.4) and these surviving plants appear to have had a positive response to spelling and their crown cover compared to the G treatment. There appears to be a trend for increasing crown cover with the FA, EA and FB spelling treatments compared to G particularly through the dry conditions in 2014-15 (Fig. 4- 21).

(a)

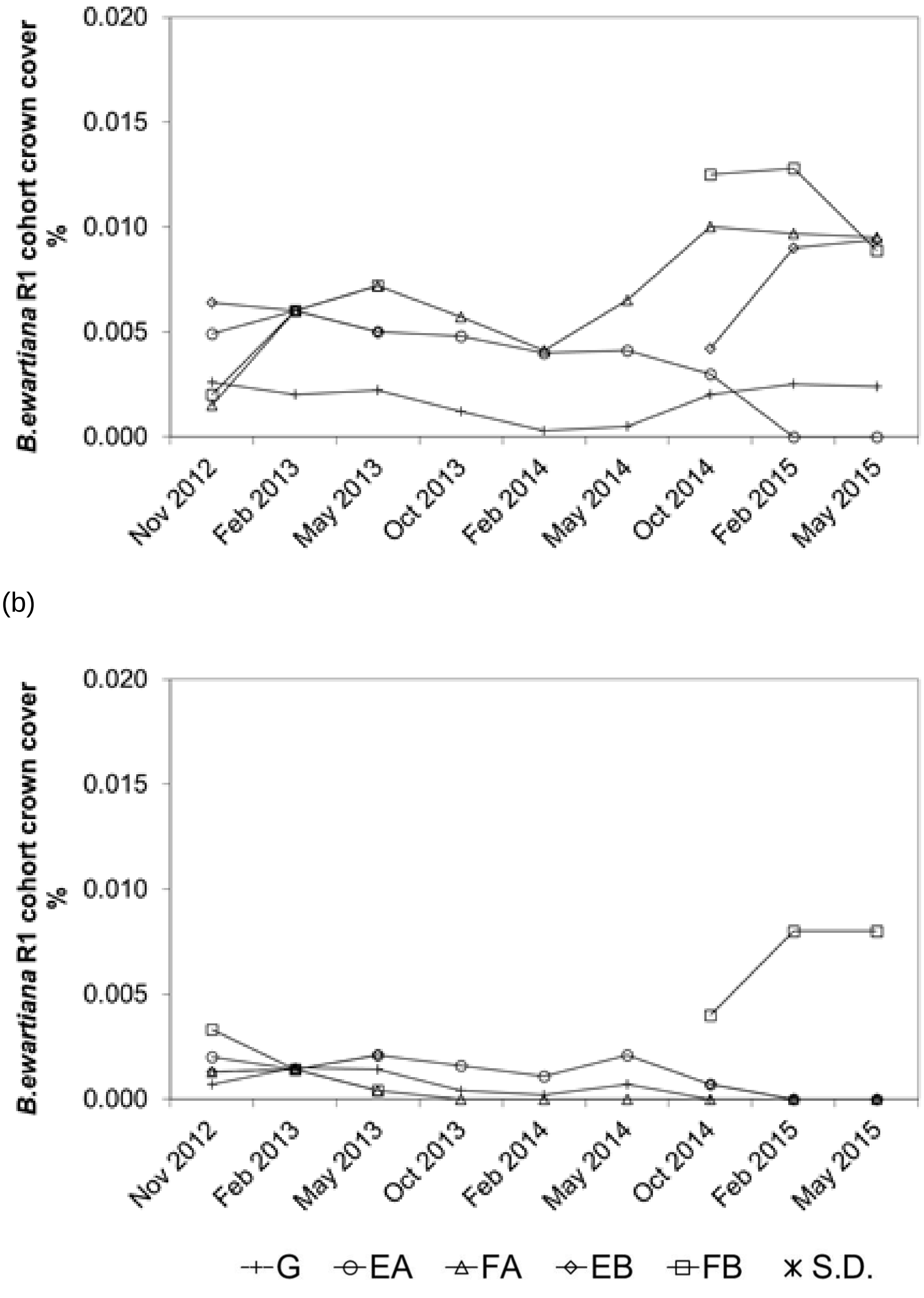
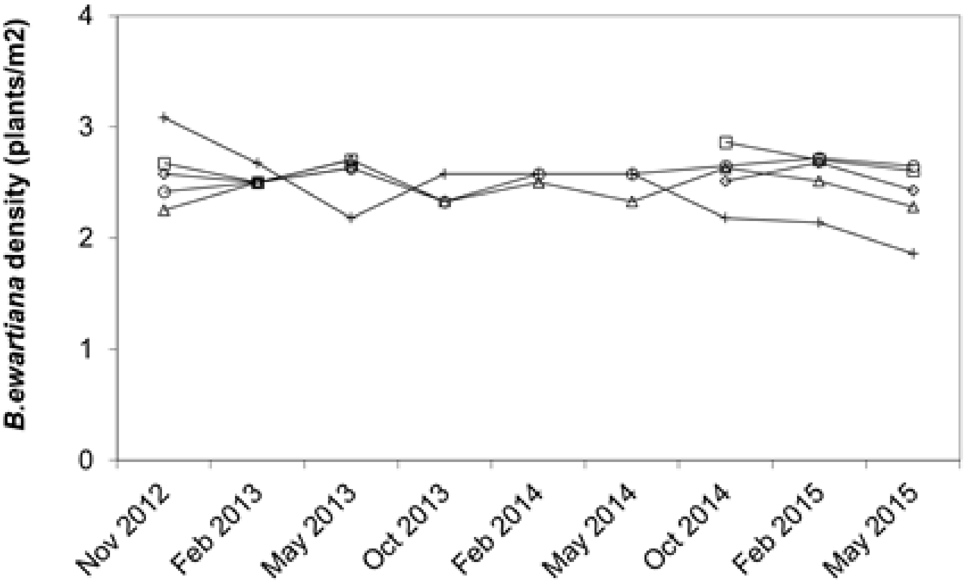


Fig. 4-21 Effect of spelling strategies on the crown cover of the November 2012 cohort of *B. ewartiana* under (a) moderate, and (b) high stocking rate.

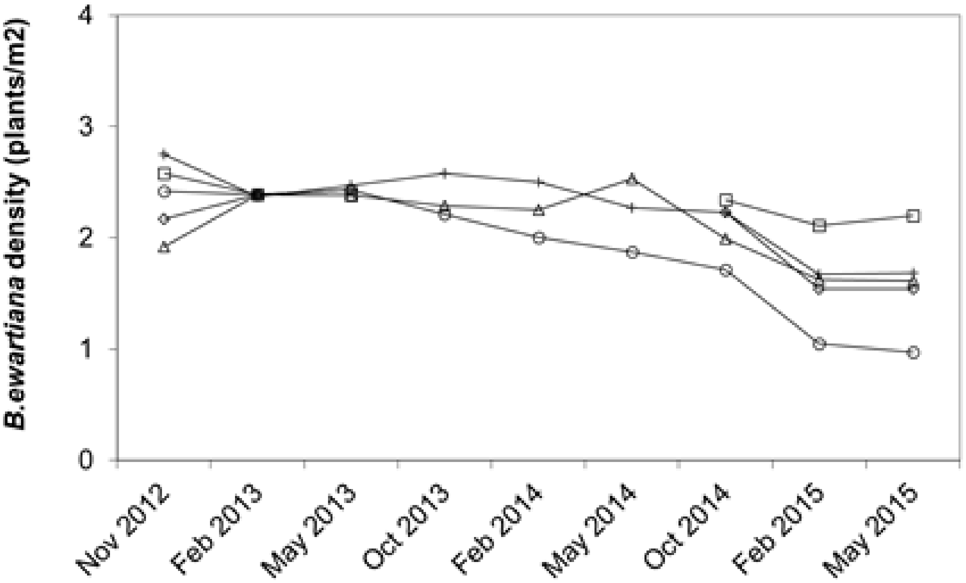
4.2.2.4 Density, recruitment, mortality and survival of perennial grasses

B. ewartiana and *Aristida spp.* density has been relatively stable regardless of the spelling treatments (Figure 4-22).

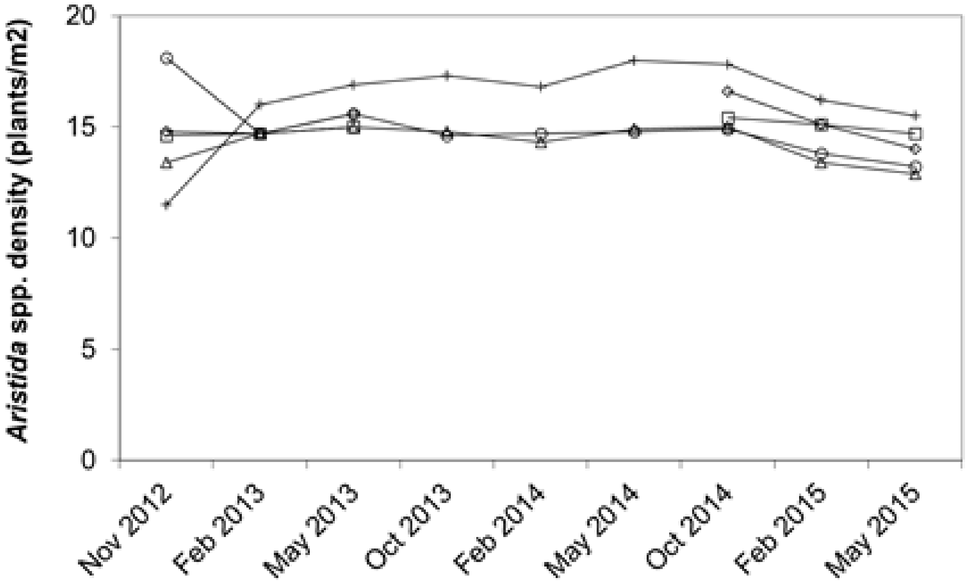
(a)


B.ewartiana density (plants/m2)
4
3
2
1
0
Nov 2012
Feb 2013
May 2013
Oct 2013
Feb 2014
May 2014
Oct 2014
Feb 2015
May 2015

(b)


B.ewartiana density (plants/m2)
4
3
2
1
0
Nov 2012
Feb 2013
May 2013
Oct 2013
Feb 2014
May 2014
Oct 2014
Feb 2015
May 2015

(c)



(d)

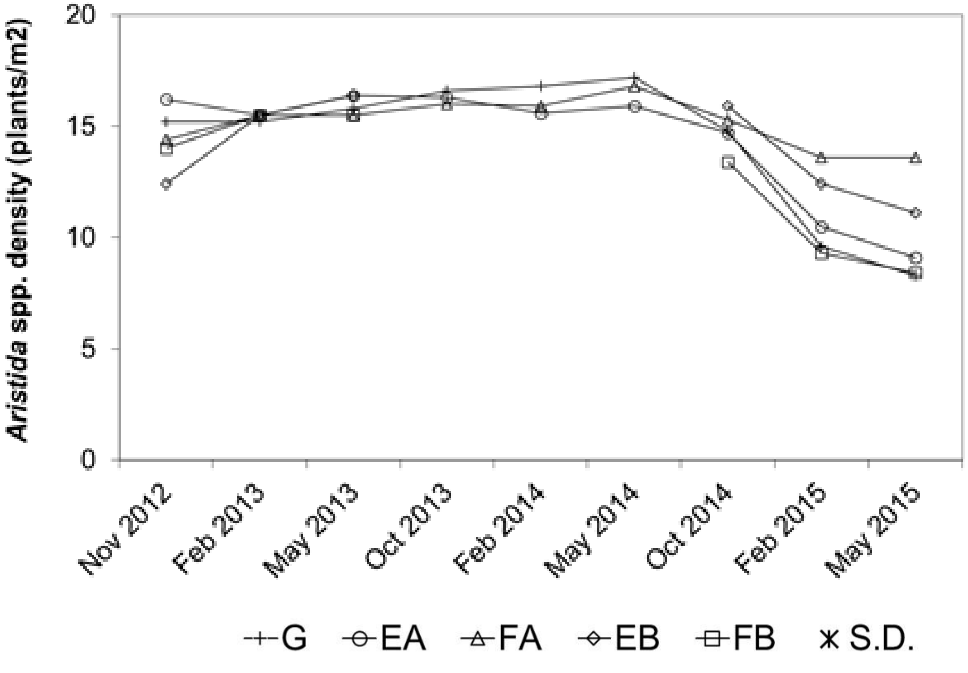
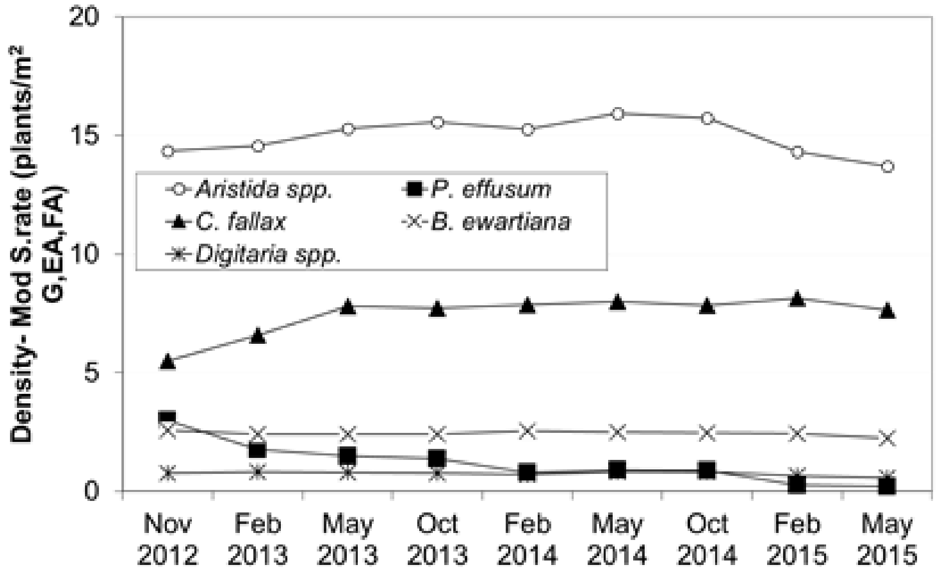


Fig. 4-22 Effect of spelling strategies under moderate or high stocking rate on - (a) and (b) *B .ewartiana* plant density, and (c) and (d), *Aristida spp.* plant density.

4.2.2.5 Under a high stocking rate *Aristida* spp. density decreased from October 2014 to May 2015 as a result of the dry conditions and there was a small decrease in *B. ewartiana* density (Fig.4-23). *P. effusum* density has decreased throughout the trial irrespective of stocking rate and *Digitaria spp.* has been quite stable (Fig. 4-23).

(a)



(b)

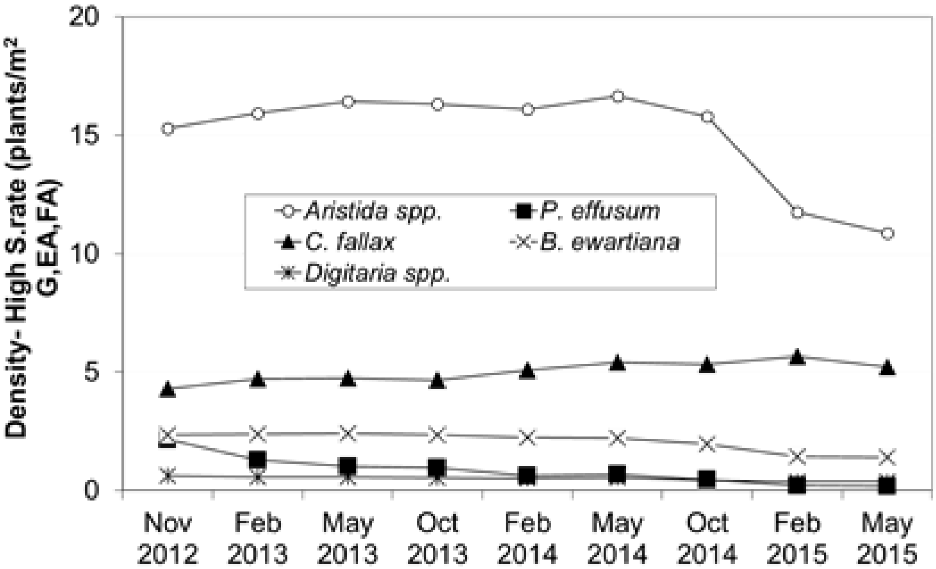
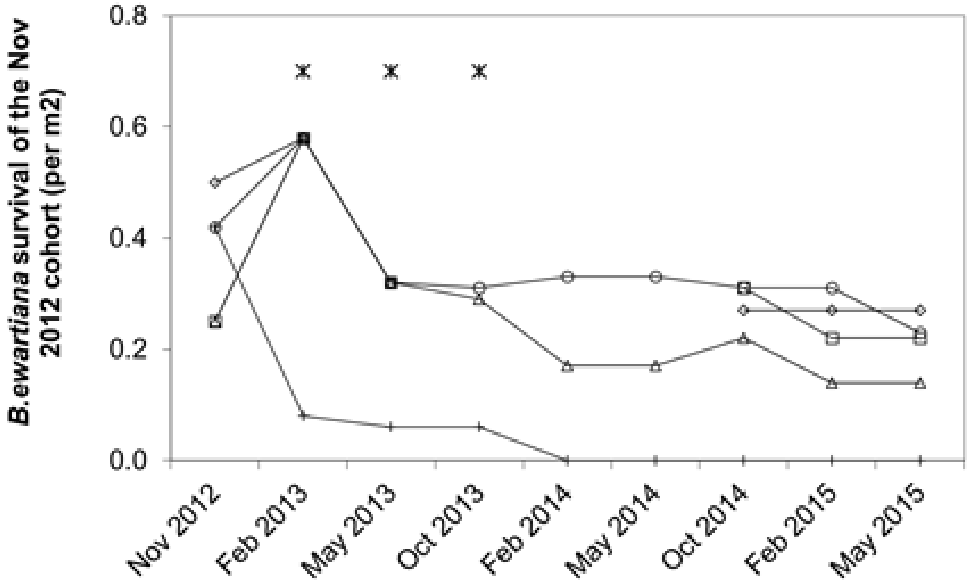


Fig. 4-23 Contributions from major taxa to density under (a) moderate, and (b) high stocking rate, meaned over all treatments. Note that the data is meaned across G, EA and FA treatments.

The November 2012 cohort for *B. ewartiana* has a higher survival than other cohorts and taxa. Under moderate stocking rate this cohort had a significantly higher survival with the treatments EA, EB, FA and FB compared to G in February 2013 and May 2013, and in October 2013 with EA and FA compared to G. Under a high stocking rate, none of the treatments affected the survival of the November 2012 cohort for *B. ewartiana* and survival was considerably less than under a moderate stocking rate (Fig. 4-24).

(a)



(b)

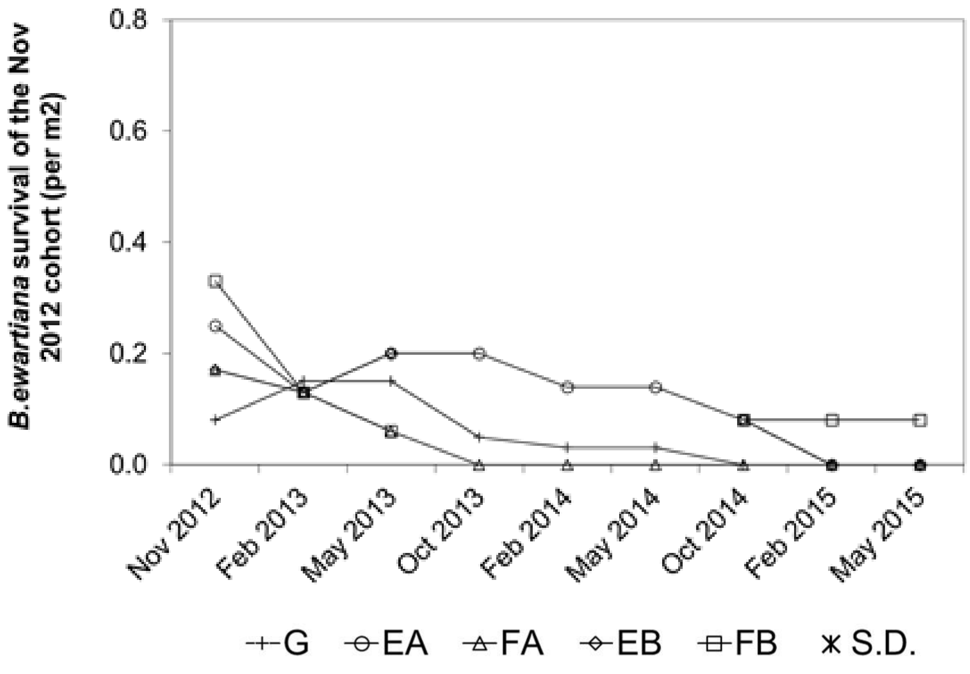


Fig. 4-24 Effect of spelling strategies on survival of the November 2012 *B. ewartiana* cohort under (a) moderate, and (b) high stocking rate.

4.2.3 Plot BOTANAL data

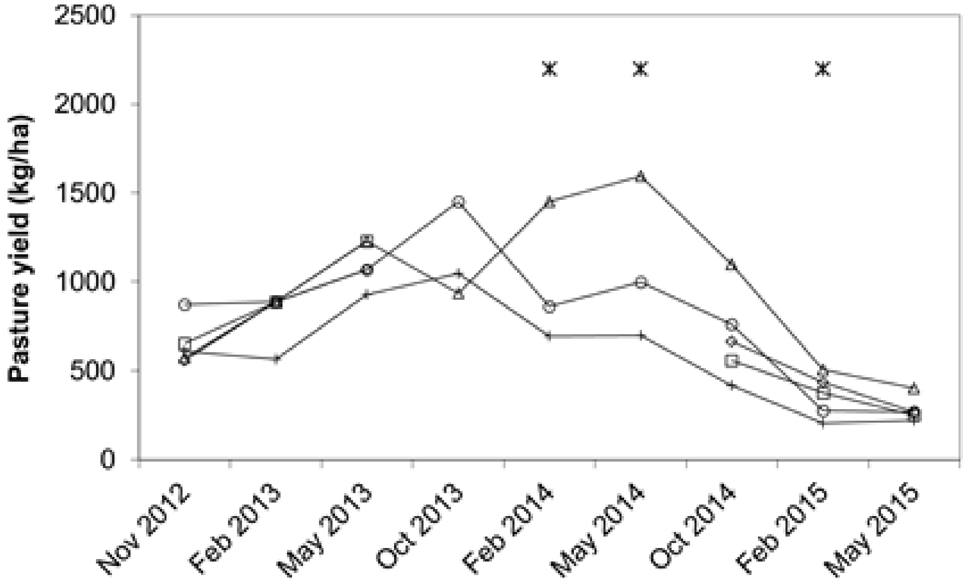
4.2.3.1 Pasture yield

Total pasture yields were low, however, overall they were higher under the moderate stocking rate. Under moderate stocking rate the treatment FA had greater pasture yield than

G in February 2014, May 2104 and February 2015. Pasture yield of FA was also greater than that of EA in February 2015 while treatment EB had more pasture yield than G in February 2015 (Fig. 4-25a and b).

Pasture yields under high stocking rate generally decreased over winter, and then recovered with a full wet season spell compared to the grazed plots (Fig. 4-25). Under high stocking rate most of the spelling treatments had higher pasture yields than the grazed treatment and the FA treatment was usually higher than all other treatments. In February 2013 the treatments EA, EB, FA and FB had higher pasture yield than G. In May 2013 the treatments FA and FB had higher pasture yields than EA, EB and G. In May 2014 the treatment FA had higher pasture yield than EA and G. In October 2014, the treatment EA had higher pasture yield than EB, FB and G. In February 2015 the treatment FA had higher pasture yield than EA, EB, FB and G.

(a)



(b)

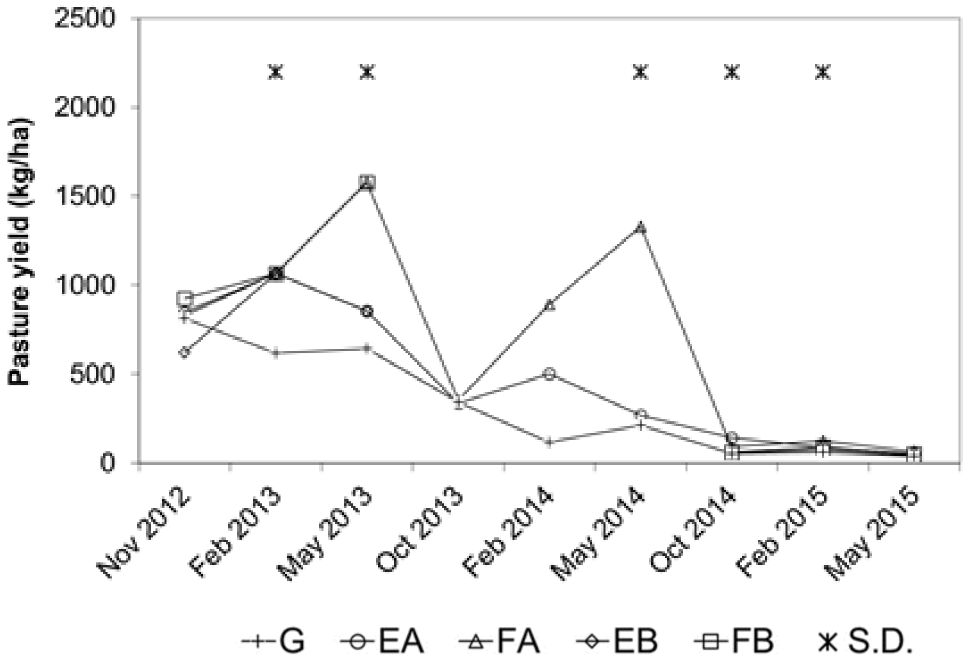
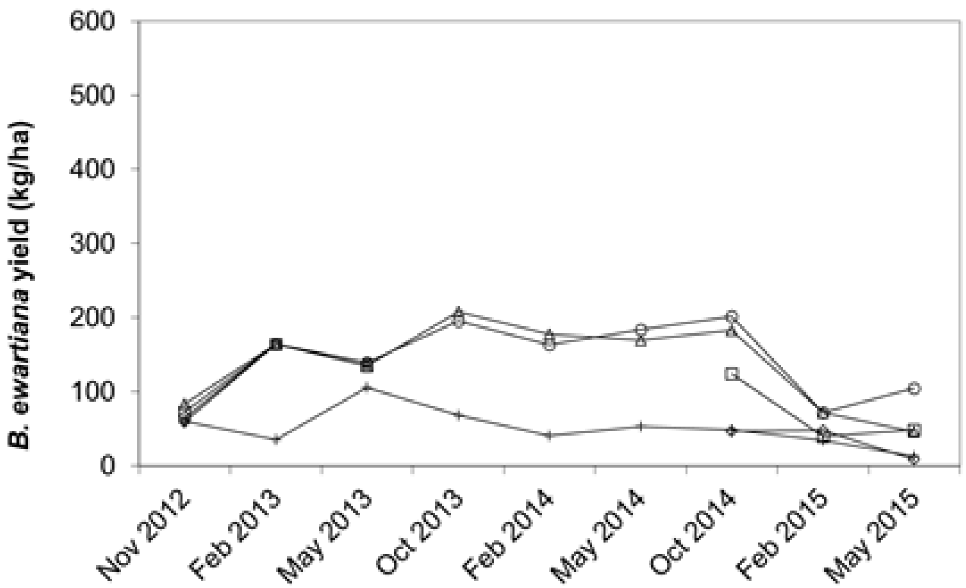


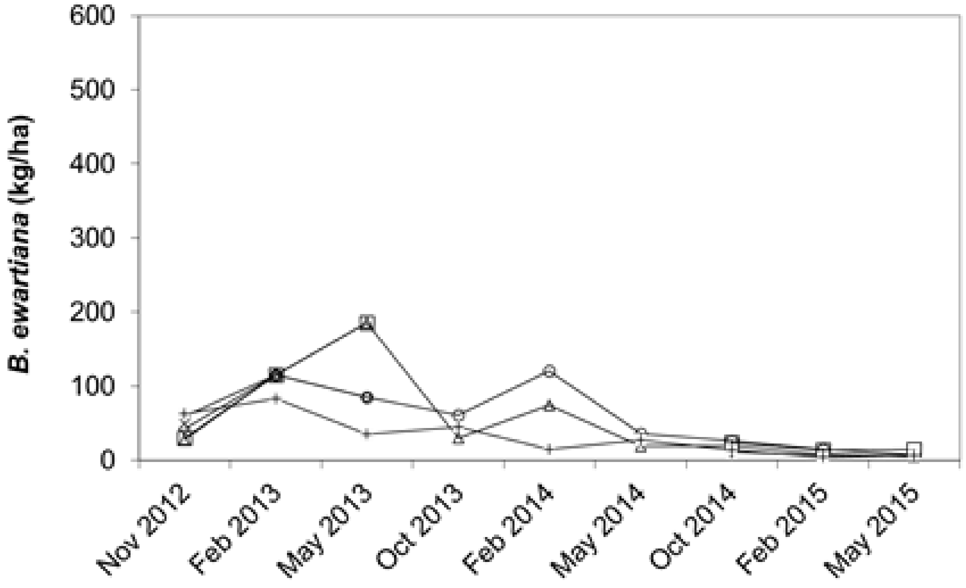
Fig. 4-25 Effect of spelling strategies on total pasture yield at the plot level under (a) moderate stocking rate and (b) high stocking rate.

The yield of *B. ewartiana* was not affected by treatment under the moderate or high stocking rate trial. The yield of *Aristida* spp. under high stocking rate increased with treatment FA compared to G and EA in May 2014 (Fig. 4-26).

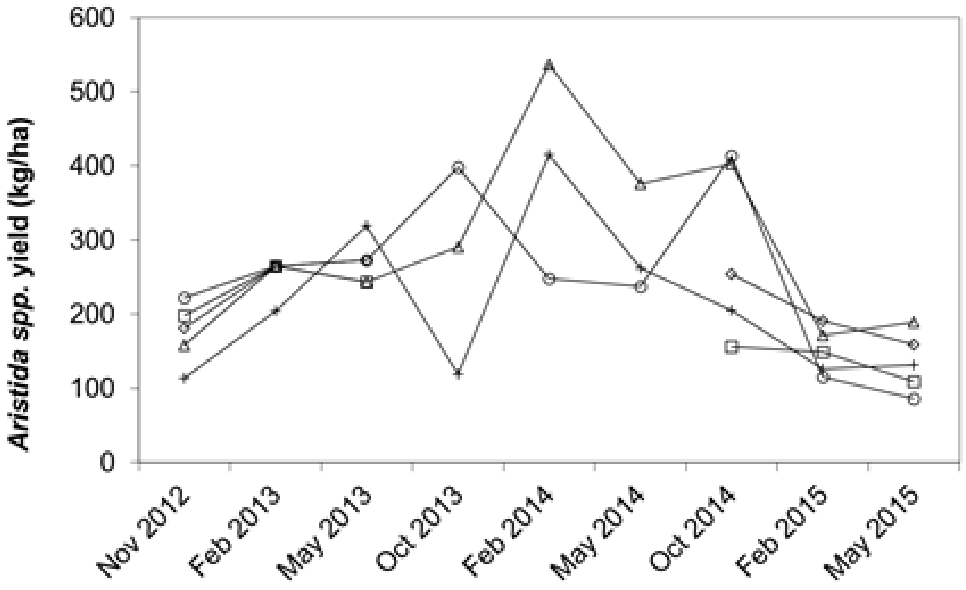
(a)



(b)


B. ewartiana (kg/ha)
600
500
400
300
200
100
0
Nov 2012
Feb 2013
May 2013
Oct 2013
Feb 2014
May 2014
Oct 2014
Feb 2015
May 2015

(c)


Aristida spp. yield (kg/ha)
600
500
400
300
200
100
0
Nov 2012
Feb 2013
May 2013
Oct 2013
Feb 2014
May 2014
Oct 2014
Feb 2015
May 2015

(d)

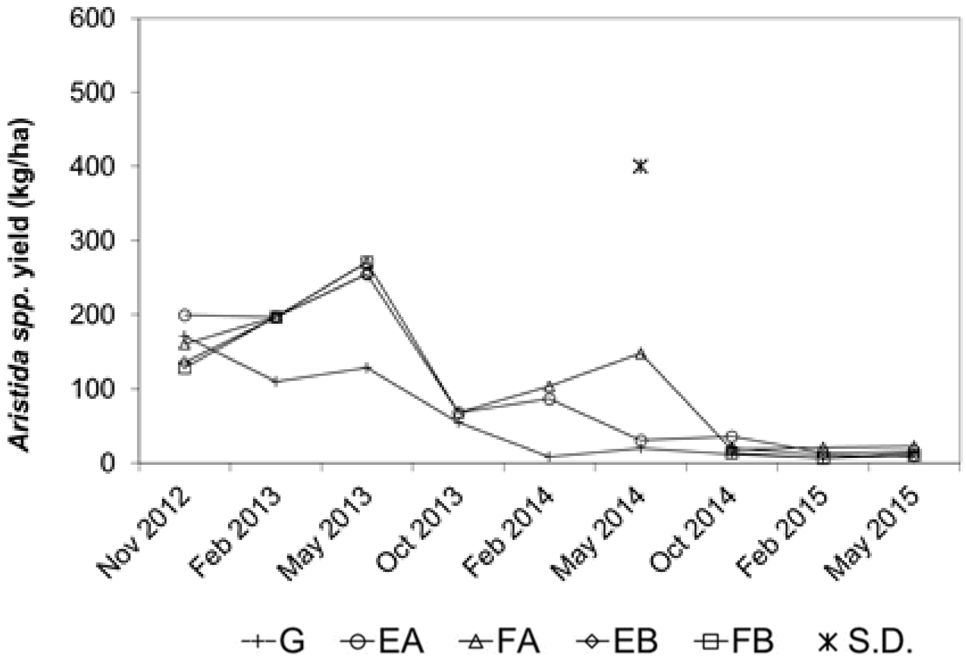
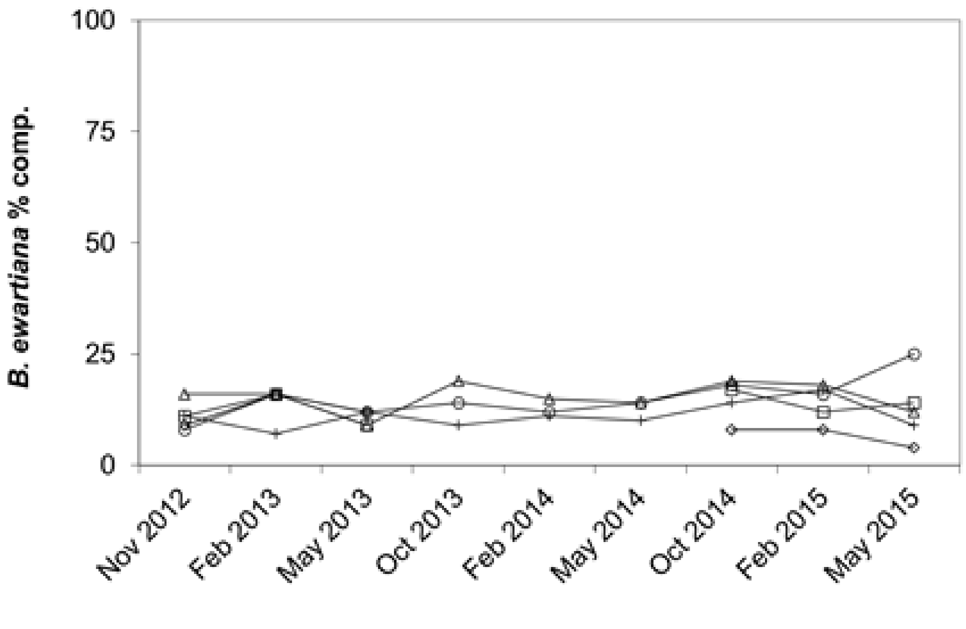


Fig. 4-26 Effect of spelling strategies on *B.* ewartiana and *Aristida* spp. total pasture yield at the plot level under moderate stocking rate (a and c) and high stocking rate (b and d).

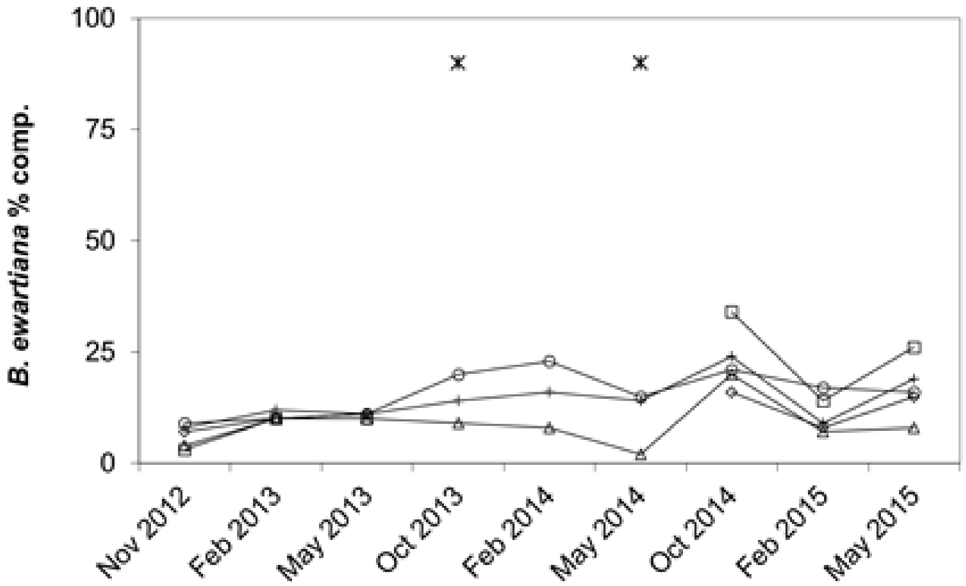
4.2.3.2 Composition

Spelling treatments had minimal effect on the composition of *B. ewartiana* and *Aristida* spp. in the pasture. Under high stocking rate *B. ewartiana* had a higher composition in October 2013 with the treatment EA compared to FA and in May 2014 with the treatments EA and G compared to FA (Fig. 4-27).

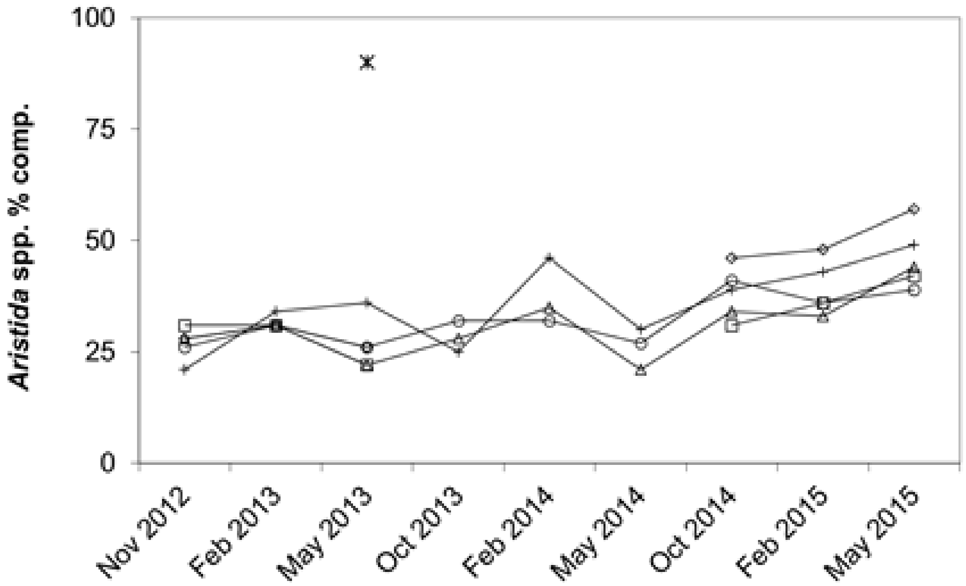
(a)



(b)


B. ewartiana % comp.
100
75
50
25
0
Nov 2012
Feb 2013
May 2013
Oct 2013
Feb 2014
May 2014
Oct 2014
Feb 2015
May 2015

(c)


Aristida spp. % comp.
100
75
50
25
0
Nov 2012
Feb 2013
May 2013
Oct 2013
Feb 2014
May 2014
Oct 2014
Feb 2015
May 2015

(d)

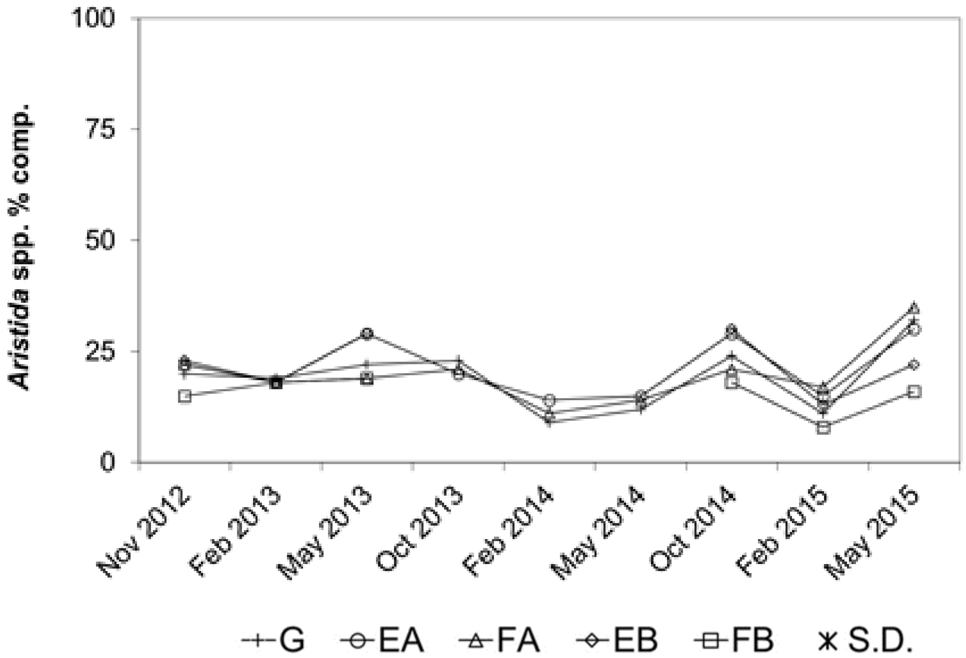


Fig. 4-27 Effect of spelling strategies on *B.* ewartiana and *Aristida* spp. composition at the plot level under moderate stocking rate (a and c) and high stocking rate (b and d).

4.2.4 Germinable soil seed data at Site 2

Germinable seeds of 3P grasses were very low irrespective of the year or grazing management applied and there were none in the spring 2012 samples. *B pertusa* and *E. lacunaria* were consistently the main germinating perennial grasses with *Aristida* spp. and *P. effusum* a significant proportion of the seedbank for the three sample dates (Table 4-5). The low biomass species *E. lacunaria, Fimbristylis* spp., *Cyperus* spp. and *Eragrostis* spp. were consistently found at Site 2 and at Site 1 (Appendix 8). The annual grasses *Schizachyrium* spp. and *Alloteropsis cimicina* had a high level of germinable seed in the spring of 2012. There were very few legumes except for *Zornia* spp. in the spring of 2012. Very few tree species emerged and no shrub species even of the dominant *Carissa ovata.* Other species which were usually found in low numbers include *Digitaria* spp., *Zornia* spp., *Alysicarpus rugosus*, *Tephrosea leptoclada* and *B. ewartiana. Dicanthium fecundum* had germinable seeds recorded only in 2014 despite being a common, perennial pasture component.

Table 4-5 Key species germinating seeds/m2 at Site 2

		Year		
		2012	2013	2014
3P grasses				
	B. ewartiana	0	4	2
	Dichanthium fecundum	0	0	11
Perennial grasses				
	B. pertusa	343	490	519
	Aristida spp.	23	65	44
	Chrysopogon fallax	1	2	0
	Eragrostis lacunaria	156	152	144
	Panicum effusum	30	21	21
Annual grasses				
	Schizachyrium spp.	1254	175	20
	Alloteropsis cimicina	136	28	19
	Digitaria ciliaris	41	4	0
Legumes				
	Sown stylos	1	0	1
	Alysicarpus rugosus	3	3.5	1
	Tephrosia leptoclada	6	1.5	2
	Vigna lanceolata	3	0	2
	Zornia spp.	67	32	13
Trees & shrubs				
	Eucalyptus spp.	1	0	0

4.3 Progress with GRASP modelling

4.3.1 Results and discussion

4.3.1.1 SWIFTSYND

Initial calibration efforts showed that the GRASP model could represent the observed data well (Fig.4-28). This is entirely expected as there are few data points and many parameters that can be altered to get a good fit. Further data became available after this initial analysis was done and early examination of the mid-year harvest data suggests that growth did not occur after the March harvest as suggested by GRASP. Further calibration will be necessary as more data from the SWIFTSYND sites become available.

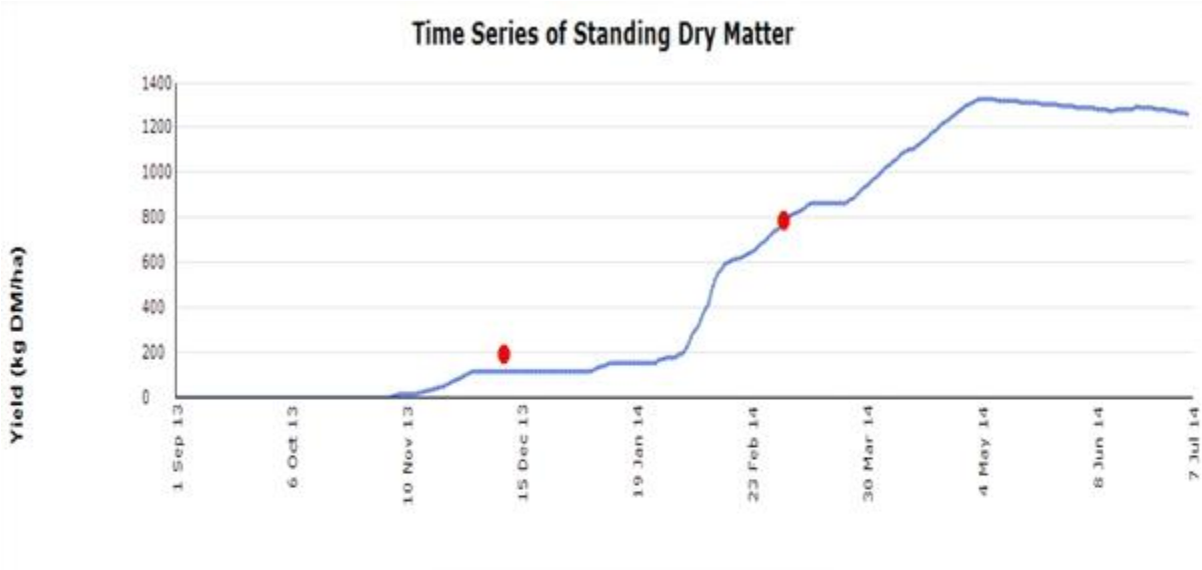


Fig. 4-28 Initial fit of pasture yield in SWIFTSYND plots and the modelled values at Site 1 using GRASP Calibrator.

4.3.1.1.1 Standing dry matter

The GRASP model was run to compare with the observed standing dry matter data reported for the three grazing treatments: continuously grazed; early wet season spelling and full wet season spelling. Initial assessment is that the data are well represented by the GRASP model using the parameters derived from the SWIFTSYND plots (Fig. 4-29). There was a major decline in December 2012 associated with the wildfire across the experimental site.

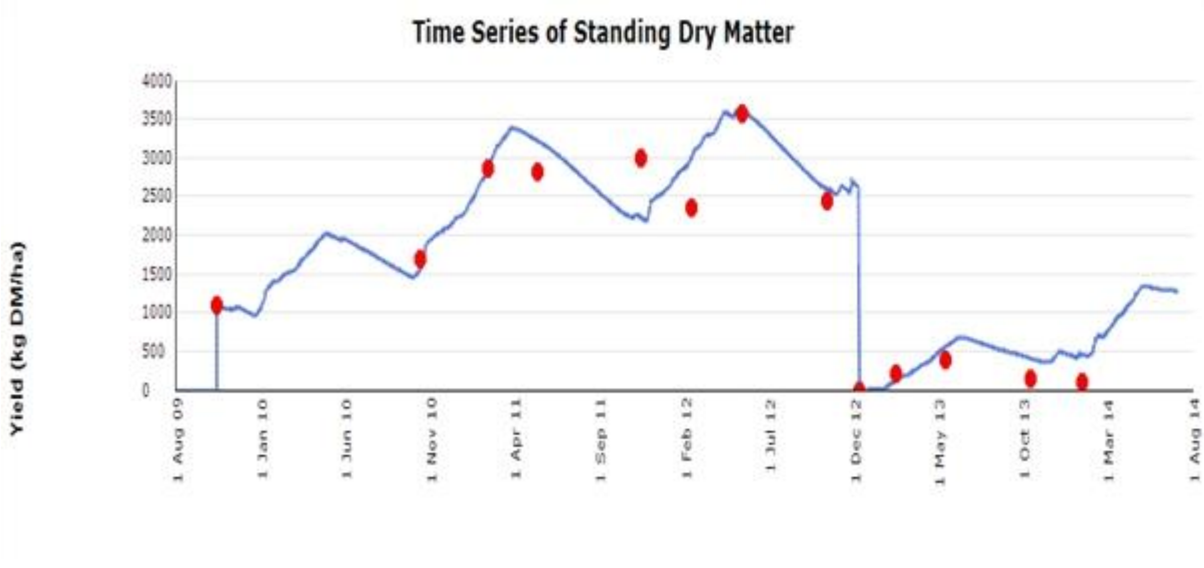


Fig. 4-29 Modelled and mean observed standing dry matter in the continuously grazed areas within Site 1.

One issue with assessing the 'goodness of fit' of modelled results to field observations is how closely the modelled points match the observations. Some critics point to values such as those at December 2011 and February 2012 to indicate that the model is not reproducing the data well. To put this in perspective, we plotted the modelled results along with the data from the four replicates (Fig. 4-30). There was a wide variation between replicates. Fig. 4-30 clearly shows that the modelled values were within the range of the observed data through to June 2013. The small differences after that time are often observed when GRASP is used to predict growth under poor growing conditions. This difference is not regarded as a major issue at this early stage of analysis. The same pattern is seen for the two pasture spelling treatments (Fig. 4-31).

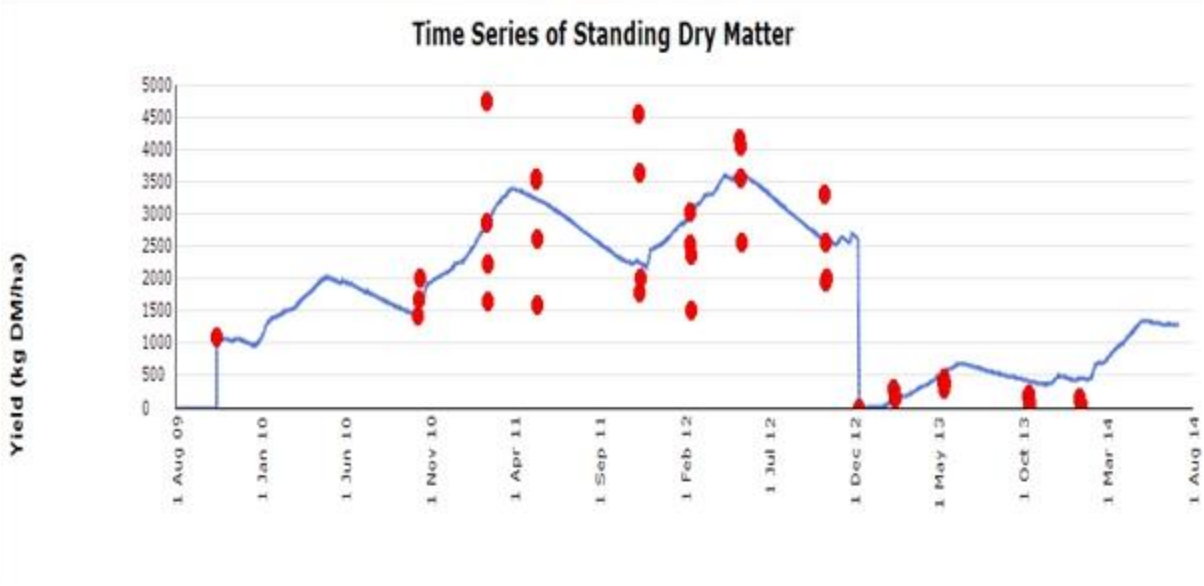
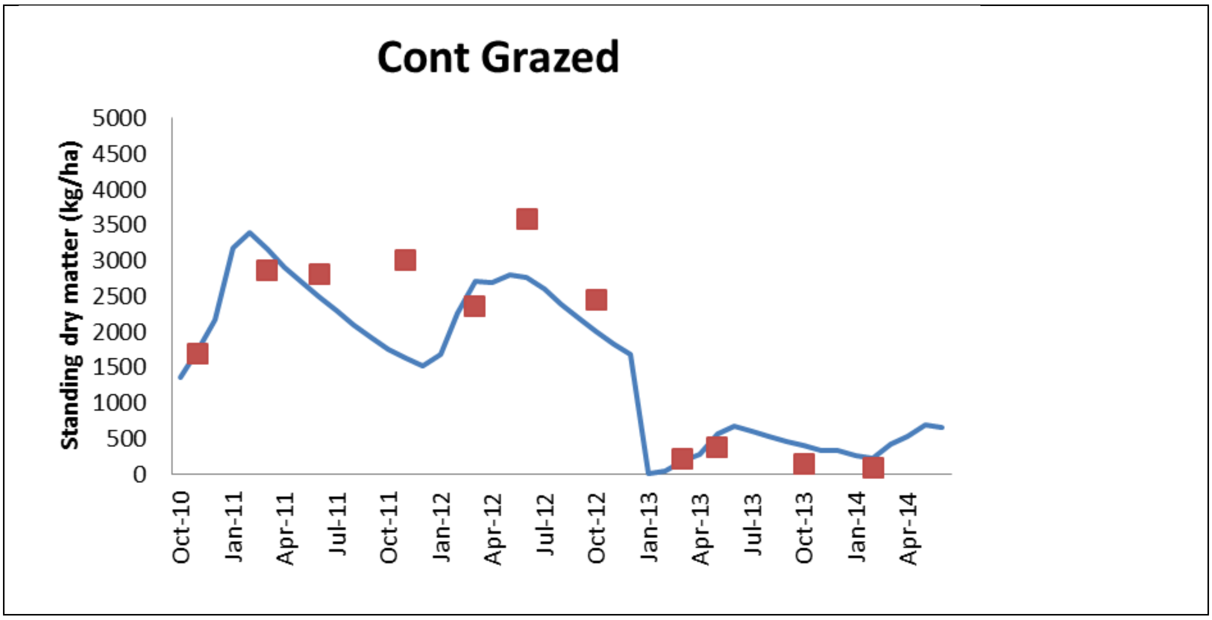


Fig. 4-30 Modelled and individual replicate observed standing dry matter in the common grazed areas within Site 1.



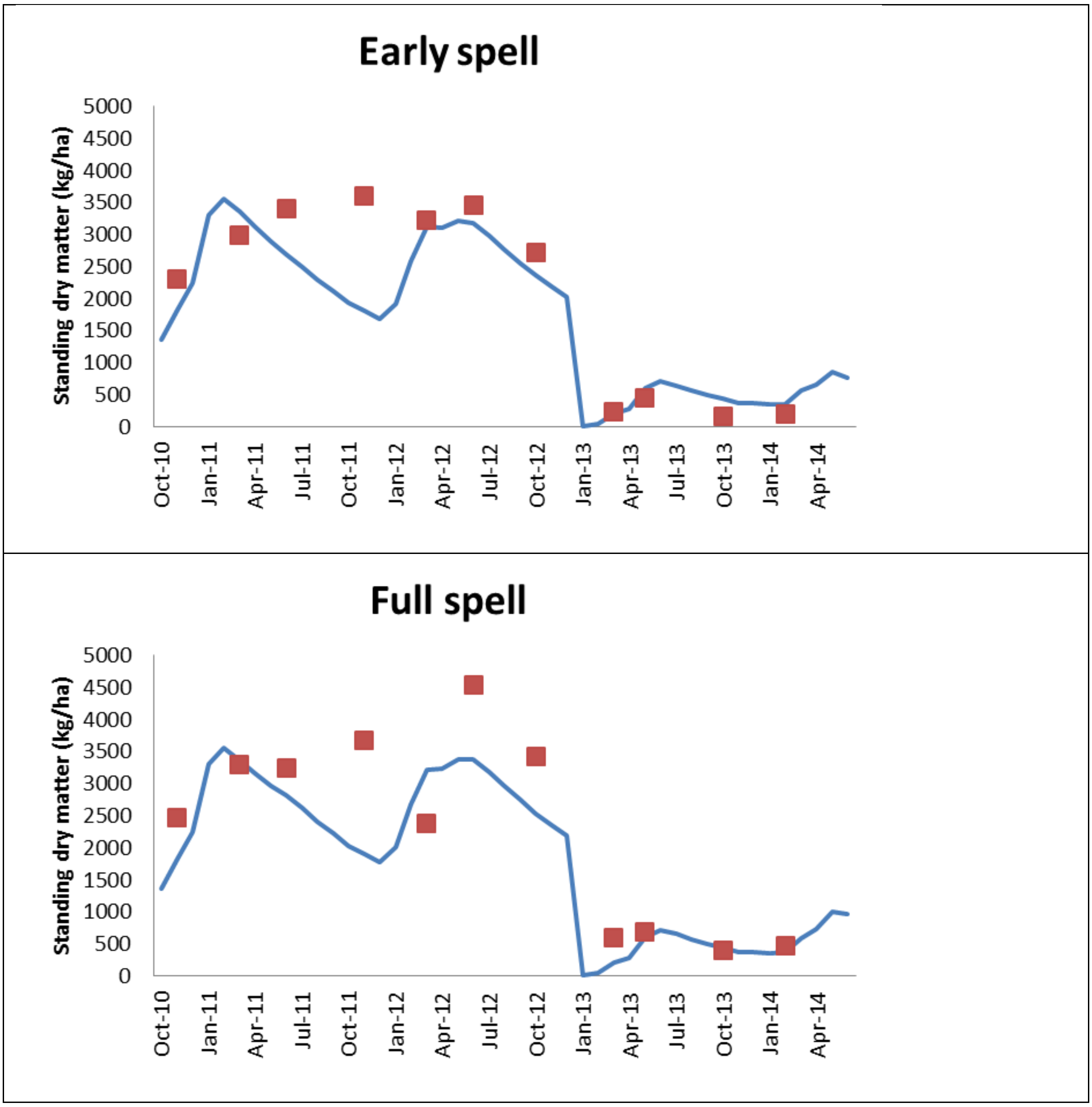


Fig. 4-31 Modelled and observed total standing dry matter (means of the four reps) in the continuously grazed (cont. grazed), early wet season spell (Early spell) and full wet season spell (Full spell) treatments at Site 1.

For all treatments, there was a reasonable fit between the observed and modelled data using the same core parameter file and merely changing the times that cattle grazed the pastures. The fourth sampling date (December 2011) shows a much higher observed yield than what the model predicts in all treatments. The reasons for this and some other differences need further investigation.

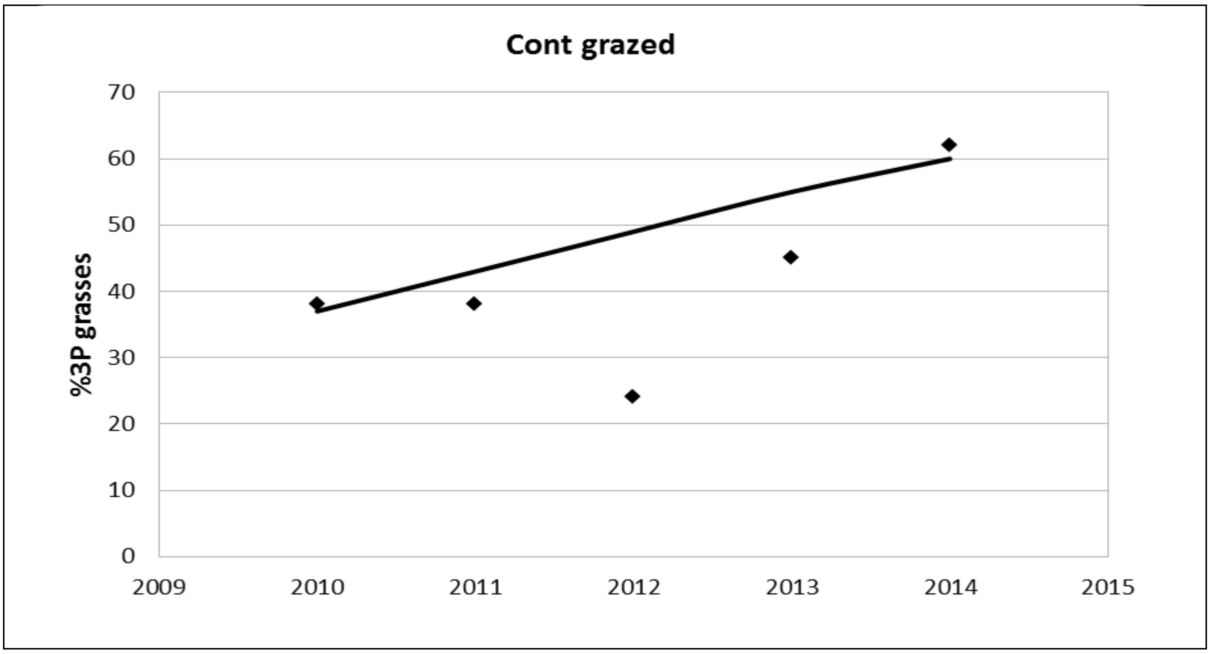
4.3.1.1.2 Percentage perennial grasses

The last aspect examined was the % 3P grasses. In the field data, this was primarily the percentage of *B. ewartiana* in the pasture. GRASP models changes in pasture condition by changes in the 12 'states', each with its associated percentage perennial grasses. The percentage of perennial grasses influences many parameter values within GRASP which in turn affect pasture production. Therefore it is necessary to adequately mimic changes in percentage perennials to ensure that pasture growth is accurately simulated in long-term simulations of various management options like pasture spelling.

The permanent quadrat data showed an improvement in %3P grasses in all treatments (Fig. 4-32). The GRASP simulations also produced an increase in percentage perennials, though there was much less variation than in the observations. Of particular note is the drop in %3P grasses observed in 2012 in all treatments. This was not reported by GRASP as the percentage utilisation during 2012 was always lower than the safe utilisation level which results in an improvement in percentage perennial grasses in the model. The reasons behind the different behaviour observed and simulated require further investigation.

It was necessary to have a slower rate of change than that used to simulate changes in the perennial grasses with related studies at Site 2 (Scanlan *et al*. 2013).

Data for the whole plots did not show the same improvement in %3P as was recorded for the fixed quadrat data. The reasons for this require further examination and could in part be caused by the random sampling of the whole plots compared with the repeated use of permanently marked plots in which *B. ewartiana* was present in half of the quadrats initially.



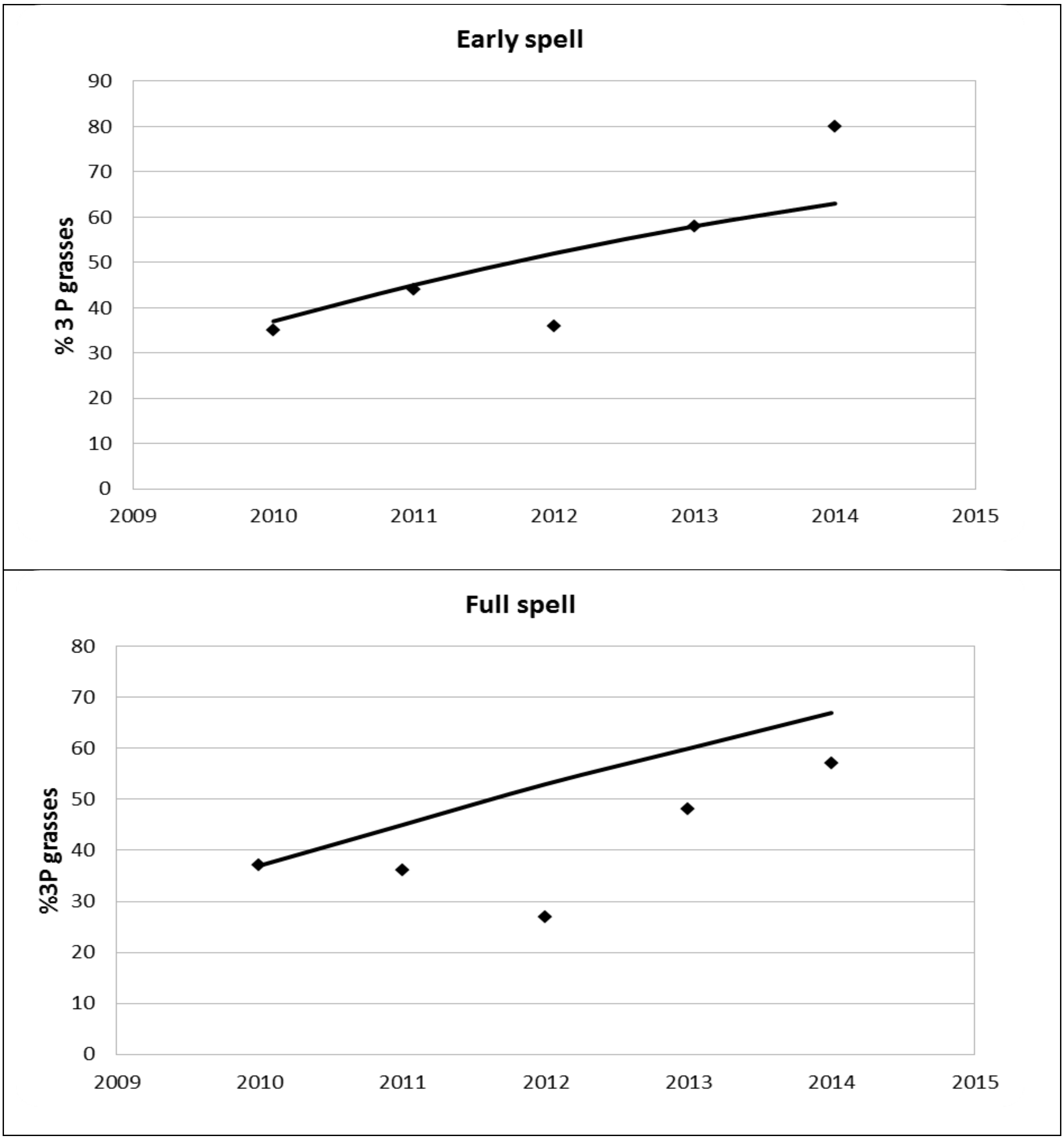


Figure 4-32 Modelled (Line) and observed (Diamonds) percentage of 3P grasses in the pastures in autumn of the continuously grazed (cont. grazed), early wet season spell (early spell) and full wet season spell (Full spell) treatments at Site 1. Data points are from the fixed quadrat sampling.

4.3.1.2 Key questions for applying GRASP to related scenarios analysis

There was common interest from all participants about the interaction of stocking rate, spelling and resultant land condition. Most producers thought the adjusted stocking rate information was a very meaningful way to present the data for production comparisons. They also thought that the one in four year spell was practical in terms of property management.

Several of the producers and agency staff were interested in the duration of spelling because of the importance of the animal production benefit over the wet season, particularly on low fertility soils. The producers wanted to know whether land condition improvement could occur, or at what rate, when spelling was only for part of the wet season.

Producers and agency staff were also interested in the problem of loading up other paddocks. This is commonly called the fourth paddock problem, or, the impact of higher short term stocking rates in paddocks which accept the cattle moved off the spelled paddock. This question was answered by the adjusted stocking rate information showing that the overall benefits from spelling management were only in the order of a 5 -10% improvement in productivity .

Key questions to be addressed by modelling outputs:

How important is:

- The interaction of stocking rate and resultant land condition for a one in four year, full wet season spell?
- The duration of spelling and resultant land condition?
- The effect of loading up other paddocks during a spelling system?

These questions have been addressed in Section 4.3.1.3.2, 4.5.1, 4.5.3 and Appendix 9

A series of related questions were also collected from co-operators and agency staff and these are presented in Appendix 4.

4.3.1.3 The interaction of spelling, stocking rate and starting land condition

4.3.1.3.1 Methods

To investigate the interaction between land condition and spelling, a simulation experiment was run with a wide range of stocking rates (from 5 AE/100 ha to 14 AE/100 ha) with and without spelling. This was done for 10 different climate windows of 30 years and the results meaned across those windows. This enables seven cycles of spelling as a spell was given every four years for a period of six months from 1 December. The growth parameters for the GRASP model were derived primarily from the SWIFTSYND sampling done at Monteagle with supplementary information on the rate of change of land condition derived from the spelling trial data. The growth parameters and the rate of change of land condition were lower/slower than those derived from the Wambiana grazing trial. Land condition is expressed as the 3P grass % (palatable, perennial and productive grass).

4.3.1.3.2 Results

At the lowest stocking rate of 5 AE/100 ha, the pastures in good and fair land condition (starting 3P% 84 and 50, representing A and B condition) showed an improvement in 3P%, irrespective of whether there was any spelling applied or not. For the C condition land (starting 3P% 20), spelling produced an improvement of over 30% for the 30 year simulation. When these C condition pastures were not spelled, there was little change in 3P% (Table 4- 6).

At a stocking rate of 6 AE/100 ha, spelling C condition pasture prevented further deterioration. B condition land without a spell tended to change little over the simulation period. At a stocking rate of 8 AE/100 ha, spelling prevented the decline of B condition land and gave a slight improvement in A condition. Spelling did not prevent the decline in land condition for C condition land at this stocking rate. At the high stocking rate of 10 AE/100 ha, spelling greatly slowed the decline of 3P grasses in A condition land. For B condition areas, spelling also slowed the decline for about 15 years but then the gap between spelled and non-spelled narrowed to virtually nothing at the end of 30 years. The C condition areas declined in condition at higher stocking rates whether spelled or not. At the very high stocking rate of 14 AE/100 ha, land condition decreased to very low levels regardless of spelling management or starting land condition.

Table 4-6 The interaction of spelling, stocking rate and starting land condition on the resultant land condition, expressed as 3P grass %. The figures presented are an average from 10 x 30 year climate windows.

	Starting land condition					
	'A' (84% 3P)		'B' (50% 3P)		'C' (20% 3P)	
Stocking rate (AE/100 ha)	Not spelled	Spelled	Not spelled	Spelled	Not spelled	Spelled
5	90	90	82	90	18	51
6	90	90	65	82	11	22
8	79	90	16	53	2	4
10	43	76	11	15	2	2
14	7	28	2	3	2	2

4.4 Pasture monitoring at the Oaklands Carbon Farming and Spelling demonstration site

4.4.1 Results and discussion

4.4.1.1 Summary

- 2012-13 summer was wetter than average
- 2013-14 summer wetter than average with a few large and poorly distributed falls of rain
- 2014-15 summer was also wetter than average with good growing conditions throughout this period
- Spelling consistently increased pasture yield although the benefit varies between years and between treatments
- Spelling did not change land condition (Fig. 4-33d)
- Results were very variable between plots
- The results are consistent with the Spelling Strategies research at Site 1 and Site 2

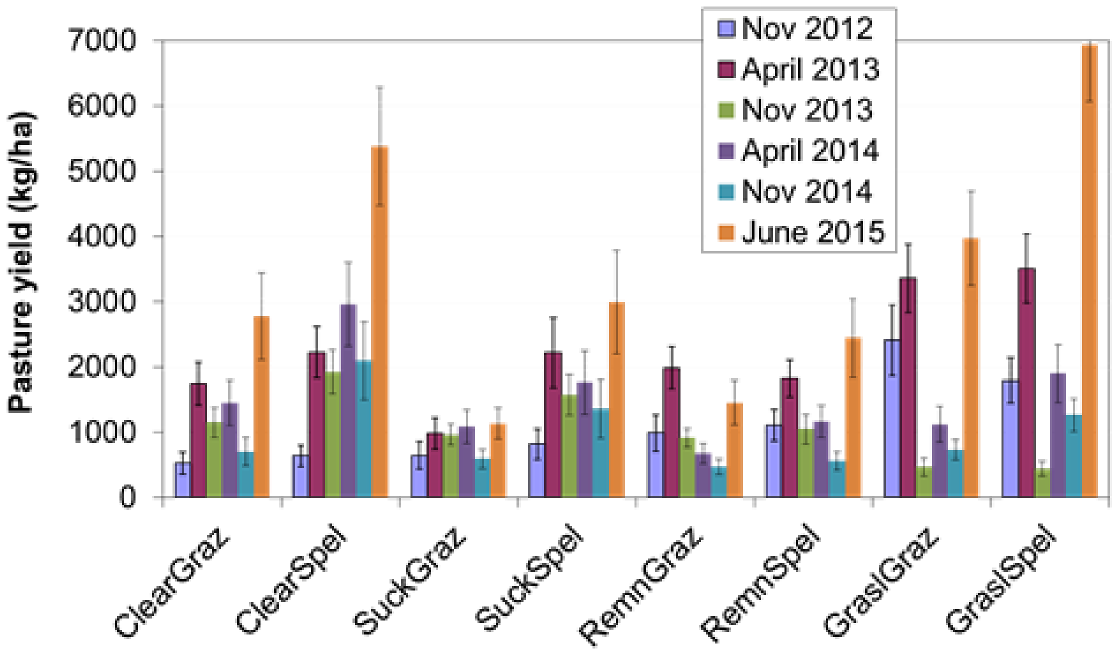
4.4.1.2 Pasture yield, ground cover, crown cover and land condition

Pasture yield has increased across all treatments in 2012-13. Pasture yields were least in 2013-14 but all plots then had a big increase in June 2015 particularly those spelled. The remnant treatments were the exception with low pasture yields and tree competition probably limiting pasture growth. The Graslan plots were burnt in early November 2013 and pasture yields did not recover until April 2014. Spelling improved pasture yield for all treatments at most recording dates. The biggest increase in pasture yield with spelling was realised in June 2015 and coincided with very good growing conditions.

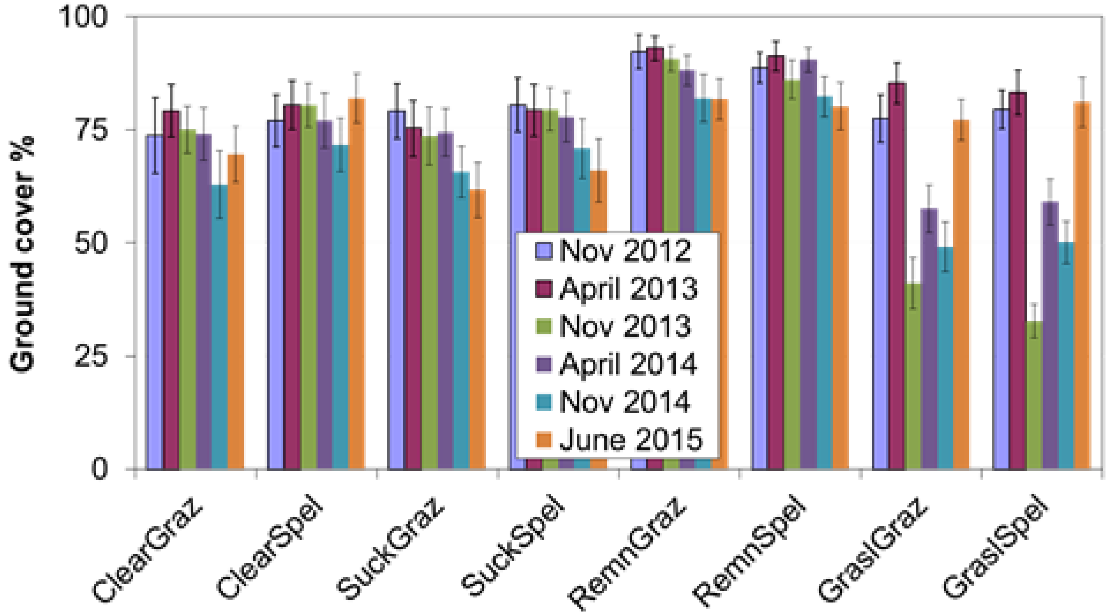
Ground cover decreased in the Graslan plots due to the early November 2013 burn and had recovered by June 2015. All other plots had high ground cover at all recording dates.

Land condition was generally rated as poor across the plots. The cleared plots appear to have an improving trend whether spelled or grazed due to improving pasture yield and crown cover (Fig. 4-33).

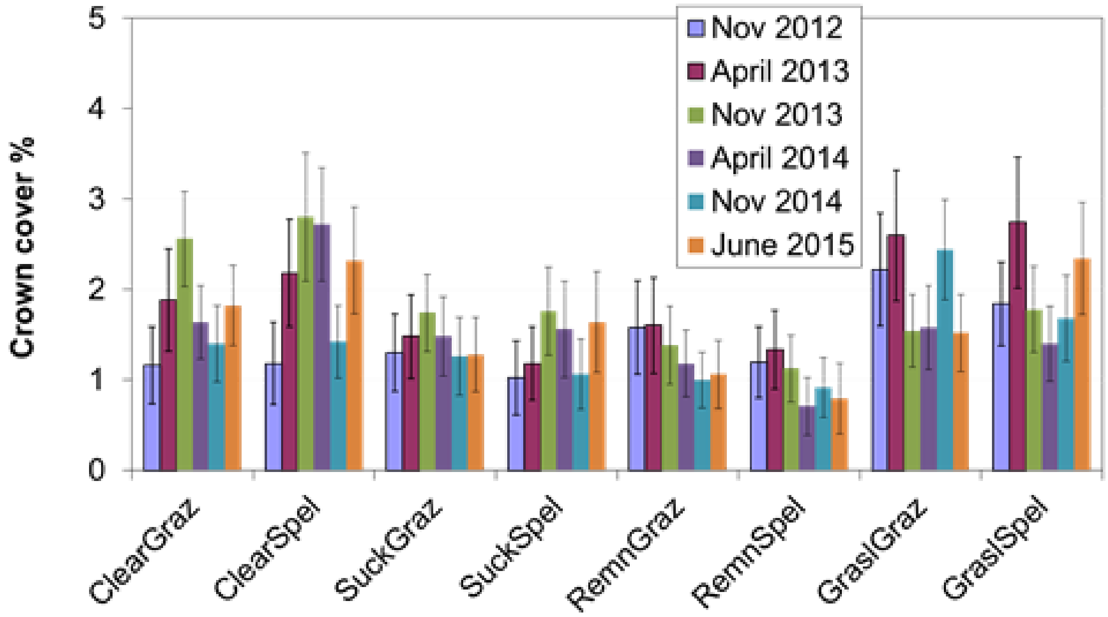
(a)



(b)


Ground cover %
100
75
50
25
0
Nov 2012
April 2013
Nov 2013
April 2014
Nov 2014
June 2015
ClearGraz
ClearSpel
SuckGraz
SuckSpel
RemnGraz
RemnSpel
GraslGraz
GraslSpel

(c)


Crown cover %
5
4
3
2
1
0
Nov 2012
April 2013
Nov 2013
April 2014
Nov 2014
June 2015
ClearGraz
ClearSpel
SuckGraz
SuckSpel
RemnGraz
RemnSpel
GraslGraz
GraslSpel

(d)

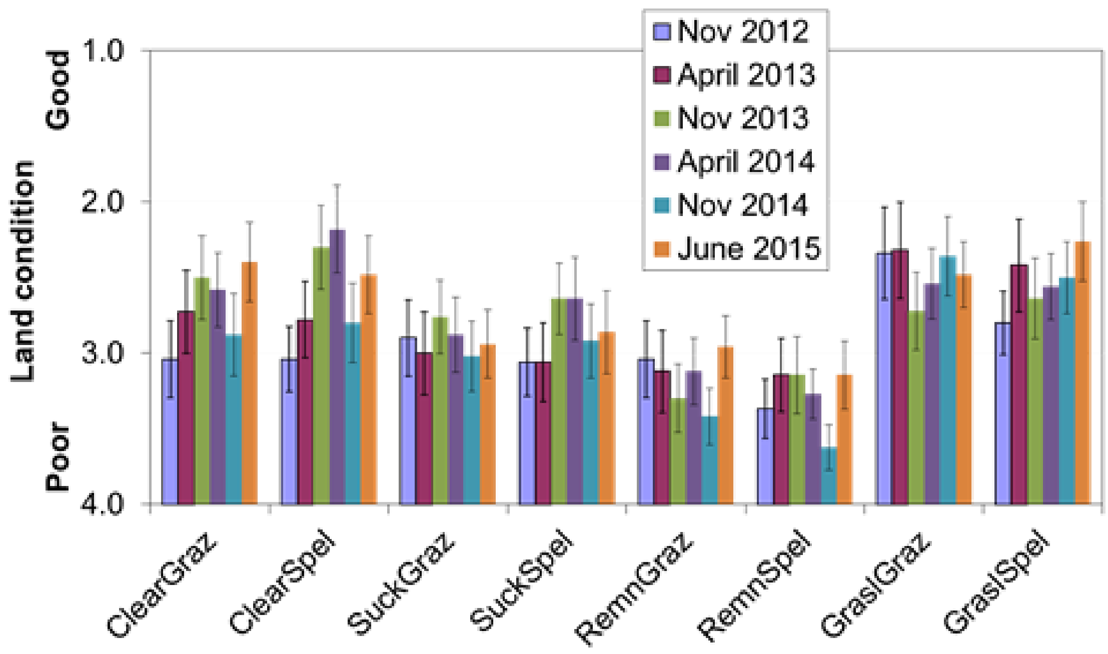


Fig. 4-33 Oaklands spelling and vegetation management demonstration site - (a) Pasture yield (kg/ha), (b) Ground cover %, (c) Crown cover, and (d) Land condition. Note: A higher land condition rating means poorer condition.

Good growing conditions over the 2012-13 summer resulted in large increases in pasture yield across all the treatments. 2013-14 growing conditions were not so good with a dry period mid-summer while 2014-15 growing conditions were very good. The Graslan treated plots were in a separate paddock stocked at a conservative stocking rate. All other plots were stocked at a higher rate than the owners consider to be desirable for the long term.

There was a consistent increase in pasture yield due to spelling over the trial for most treatments. The magnitude of this was quite variable across treatments and was not a strong effect until June 2015. The varying stocking rates across the trial may have masked some of the benefits of spelling. The Graslan plots had a big increase in yield due to spelling, which may have been realised due to the conservative stocking rate and better starting land condition.

Crown cover was variable across treatments and over time. There was a slight improvement in land condition particularly in the cleared plots driven by improved crown cover and pasture yield.

Research conducted under the Spelling Strategies Project at Site 1 and site 2, had similar results. During good seasons, spelling had minimal effects on pasture parameters when compared to grazing at a conservative stocking rate. Pasture composition also did not change with spelling. This is consistent with the Oaklands monitoring.

While the Graslan plots had decreased pasture yields, ground cover and crown cover following the fire, land condition was maintained at all recording dates. Ground cover was very good across most plots and reflects the recent good seasonal conditions. However, land condition is still poor across all plots and is due to a poor pasture composition and low crown cover. There is still a big potential for land condition improvement across all plots. This data, together with the Site 1 and Site 2 research shows that improvement of C land condition will take many years and the interactions of spelling, stocking rates and seasonal conditions are yet to be fully understood.

4.5 Case studies

4.5.1 BonAccord pasture growth modelling

4.5.1.1 FIXED versus SPELL stocking rate simulation

The baseline simulation (spelling for 1/3 of time plus variable stocking) produced the same change in perennial grasses as occurred in a lower fixed stocking rate simulation (18.5 AE/100 ha versus 15 AE/100 ha) but much greater than for a fixed stocking rate at the same overall stocking rate as for the baseline (both 18.5 AE/100 ha).The live weight gain per hectare was much higher in the baseline than for either of the fixed stocking rate simulations (21.1 kg/ha/year versus 16.4 and 16.7 kg/ha/year). The baseline was superior to both fixed stocking rate simulations for live weight gain per hectare and equal to or better than either treatment in terms of pasture condition as measured by perennial grass % (Fig. 4-34 and 4- 35).

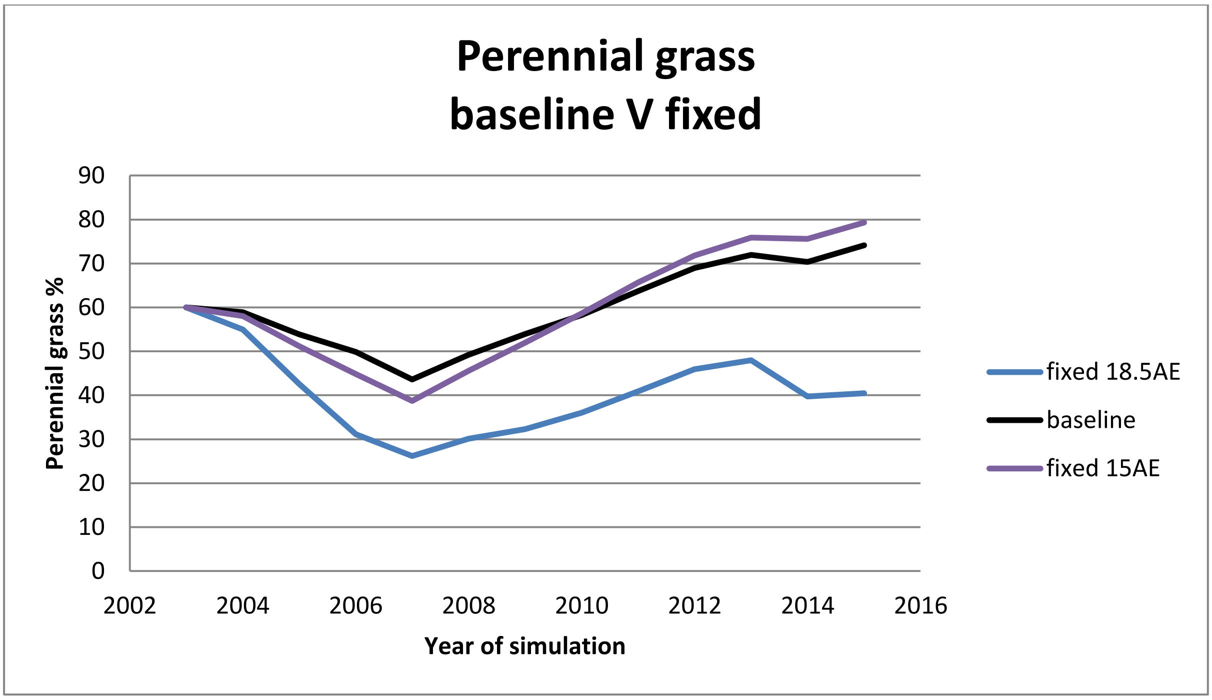


Fig. 4-34 The effect of two fixed stocking rates versus baseline (variable stocking plus spelling) on land condition (perennial grass %) at BonAccord.

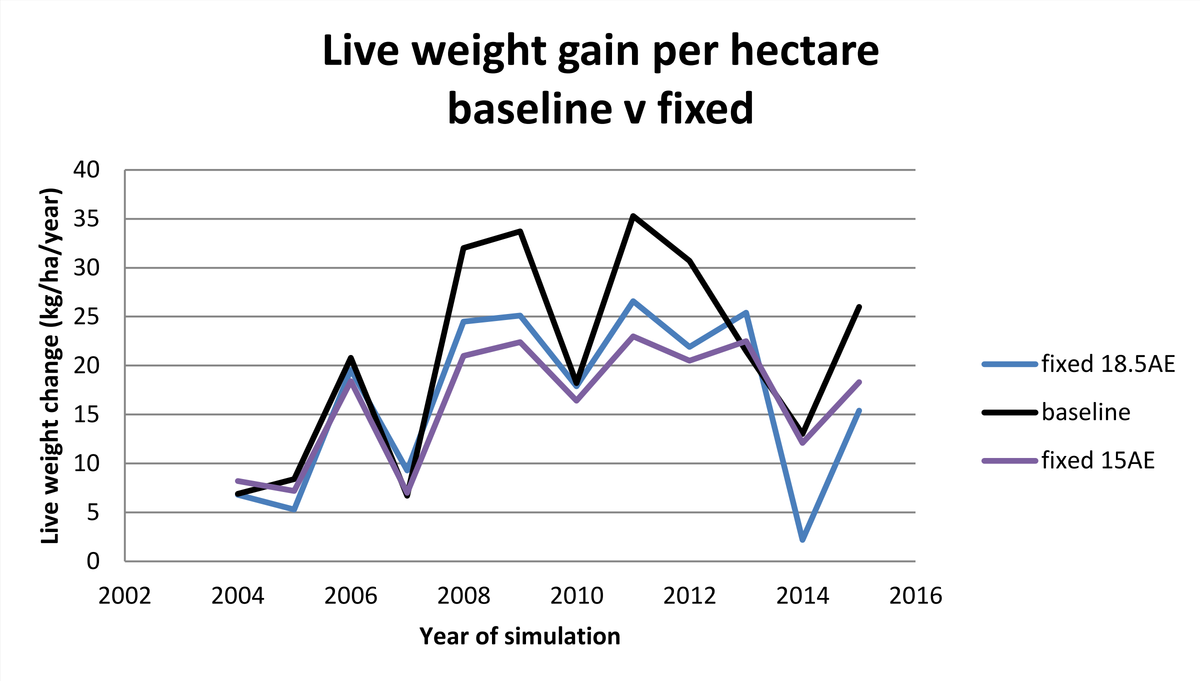


Fig. 4-35 The effect of two fixed stocking rates versus baseline (variable stocking plus spelling) on live weight gain/ha at BonAccord.

4.5.1.2 BASELINE versus VARIABLE stocking simulation

The variable stocking rate produced little overall change in the percentage perennial grass over the simulation period. It was intermediate between the two fixed stocking rates of the previous simulation. Adding spelling to the variable stocking rate (the baseline simulation) led to an increase in the perennial grasses with a difference of about 10% by the end of the 12 year simulation (Fig. 4-36). The mean live weight gain per hectare was 1.4 kg/ha/year (7%) higher in the baseline compared with the non-spelled variable stocking rate simulation. The baseline showed larger variation between years compared with the variable stocking with no spelling (Fig. 4-37).

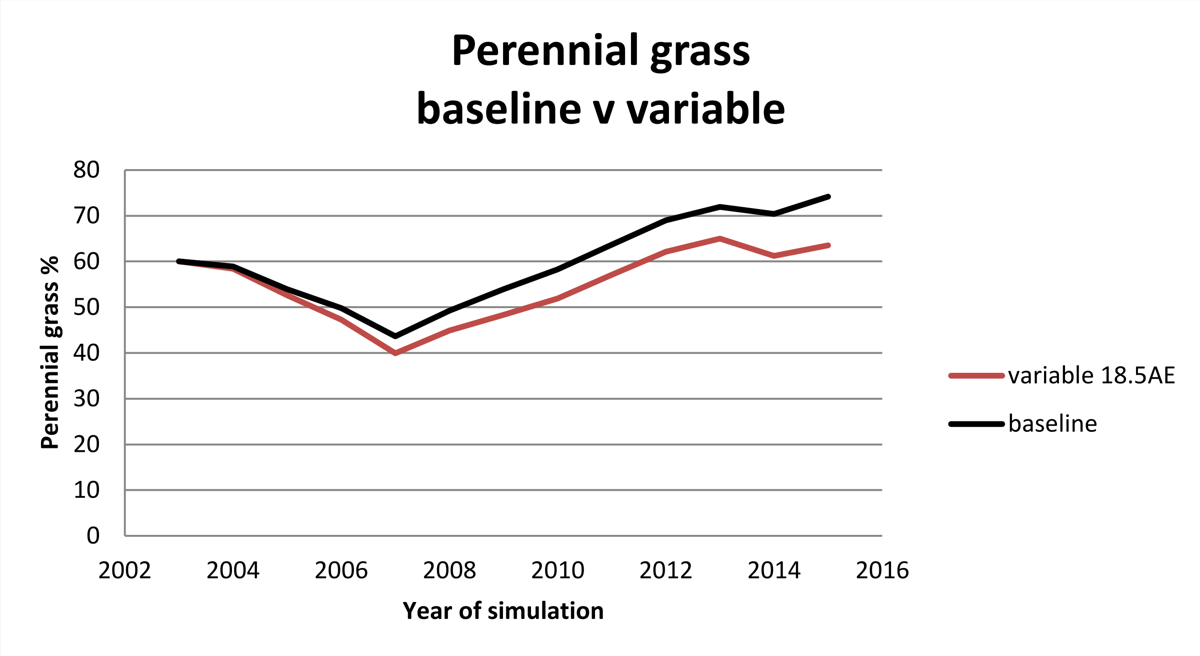


Fig. 4-36 The effect of variable stocking rates versus variable stocking plus spelling on land condition at BonAccord.

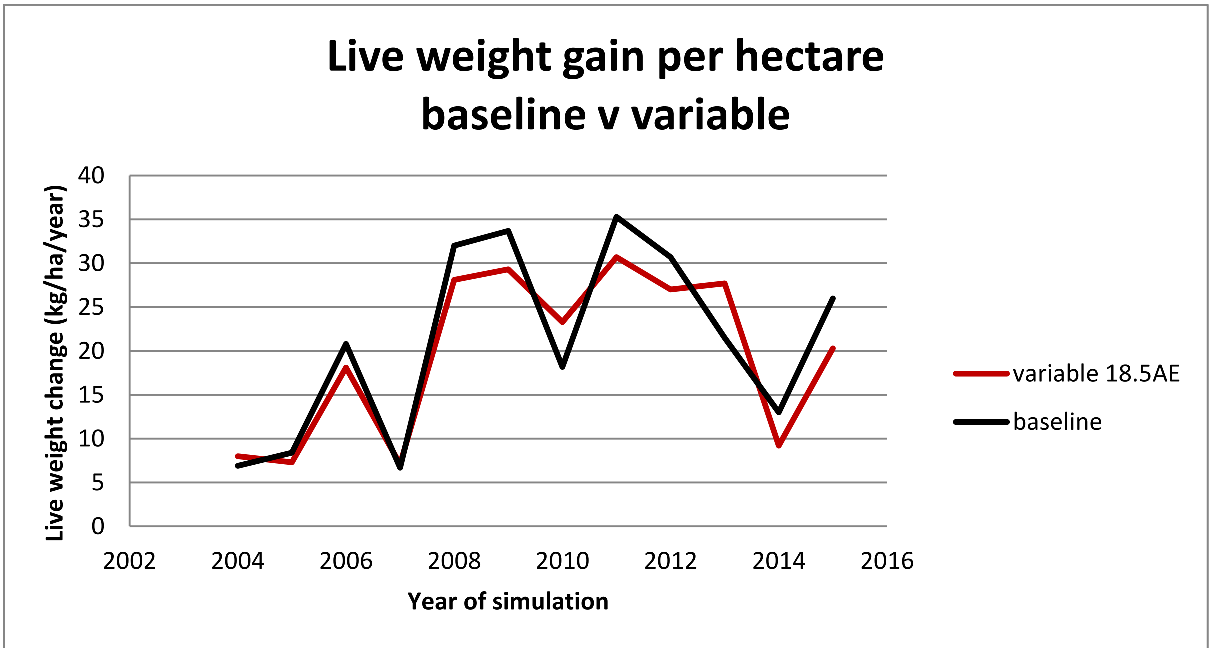


Fig. 4-37 The effect of variable stocking rates versus variable stocking plus spelling on live weight gain/ha at BonAccord.

4.5.1.3 Baseline versus increased SR

When the stocking rate was increased by 5% for all grazing periods, the percentage perennial grasses was slightly but consistently less than the baseline (Fig. 4-38). The baseline simulation increased the overall live weight produced per hectare by about 1.6% but with higher yearly variability. This was achieved at the expense of a slightly lower pasture condition – the percentage perennial grasses after 12 years was about 10% less in the simulation with increased stocking rate compared with the baseline simulation (Fig. 4-38 and 4-39).

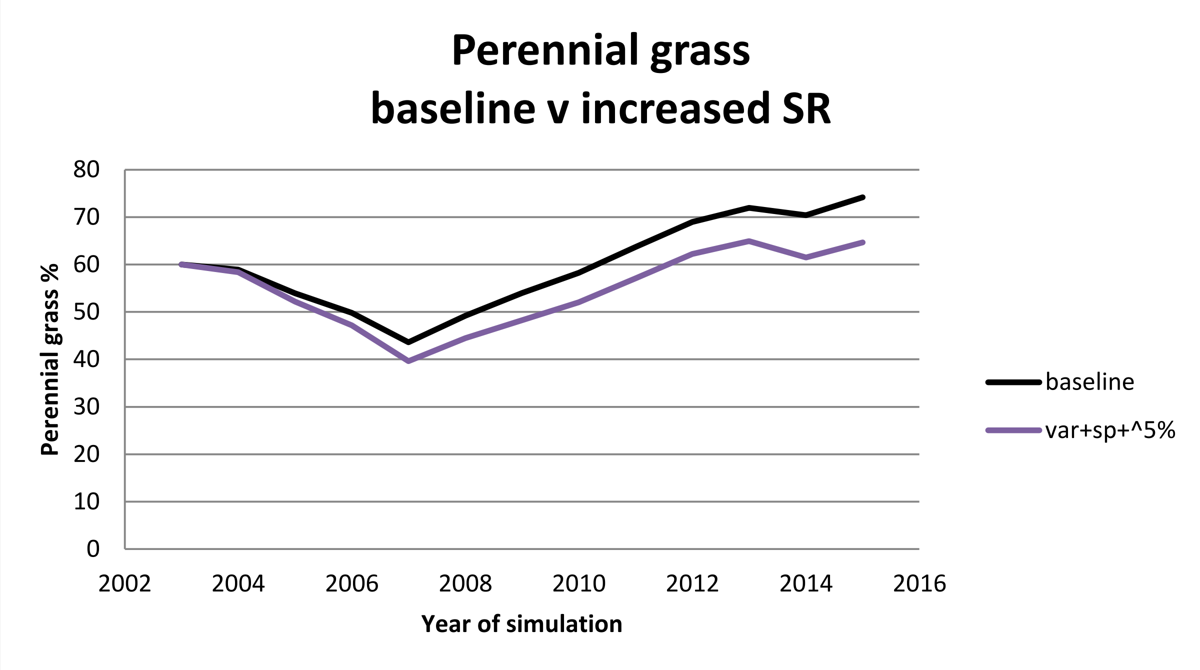


Fig. 4-38 The effect of a 5% increase in stocking rates with variable stocking rates plus spelling, compared to baseline on land condition at BonAccord.

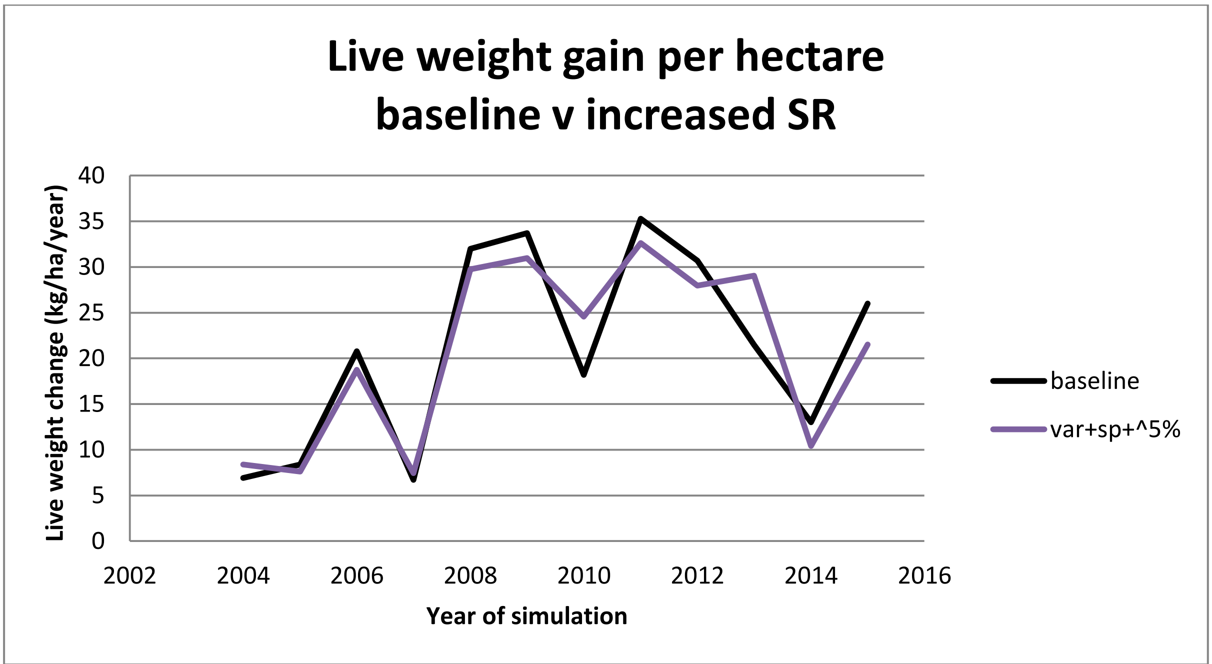


Fig. 4-39 The effect of a 5% increase in stocking rates with variable stocking rates plus spelling, compared to baseline, on simulated annual live weight gain/ha at BonAccord.

Overall a variable stocking rate that gave the same average stocking rate as the fixed stocking rate gave better land condition and animal production (Fig. 4-36 and 4-37). A lower fixed stocking rate could achieve the same pasture condition but this was at the expense of a 22% reduction in live weight gain (Fig. 4-35). Adding in a six month grazing and three month spelling regime on top of the variable stocking improved pasture condition as well as increased the animal production compared to all other simulations. A modest 5% increase in stock numbers could be imposed without adversely affecting the pasture condition compared with variable stocking with no spelling (Fig. 4-38). This gave about a 5% increase in live weight gain per hectare. However, this was still inferior to the baseline of variable stocking rate with spelling which had an average stocking rate of 18.5 AE/100ha.

4.5.2 BonAccord economic modelling

The modelling showed that, in terms of performance, no scenario was deemed to have crashed, but it should be noted that wet stock mortalities were close to the threshold, with a maximum mortality rate of 23.7% (Table 4-7). Weaning rates also showed that the “Fixed” (heavier) scenario had the lowest performance of any scenario.

Table 4-7 BonAccord wet stock mortalities and weaning rates for each scenario over 12 years

		Performance measure	
Scenario		Wet stock mortalities	Weaning rates
Variable	Average	8	66
(18.5 AE/100ha)	Minimum	7	37
	Maximum	14	87
Baseline	Average	7	69
(18.5 AE/100ha)	Minimum	6	39
	Maximum	13	89
Fixed 18.5 AE	Average	8	60
(18.5 AE/100ha)	Minimum	7	21
	Maximum	24	86
Fixed 15 AE	Average	7	69
(15 AE/100ha)	Minimum	6	38
	Maximum	13	90
Var+sp+5%	Average	8	66
(19.4 AE/100ha)	Minimum	6	37
	Maximum	14	88

Economic modelling results show that in terms of returns per dollar invested and wealth generation, the baseline (spelling) scenario and the variable with spelling and a 5% increase in stocking rate performed above the other scenarios (Table 4-8).

Table 4-8 BonAccord economic results for each scenario.

Scenario	IRR	NPV
Variable 18.5 AE	25.5%	$2,752,130
Baseline	26.3%	$2,861,205
Fixed 18.5 AE	22.6%	$2,405,771
Fixed 15 AE	25.3%	$2,373,377
Var+sp+5%	26.1%	$2,965,901

4.5.3 Oaklands pasture growth modelling

4.5.3.1 Simulation 1. Both paddocks stocked at 14 AE/100 ha

If both paddocks were stocked at the same stocking rate (14 AE/100 ha), the pasture condition improved in the Box Flats and deteriorated in the Timbered paddock (Fig. 4-40). This was expected as the safe stocking rate was exceeded in the Timbered paddock whereas the Box Flats paddock was stocked well below a safe stocking rate. This simulation demonstrates the importance of stocking to land type carrying capacity. While the overall stock numbers are correct for the two paddocks, the Timbered paddock soon became unsustainable due to high grazing pressure resulting in poor land condition (Fig. 4-40). Economic analysis of this simulation was taken no further.

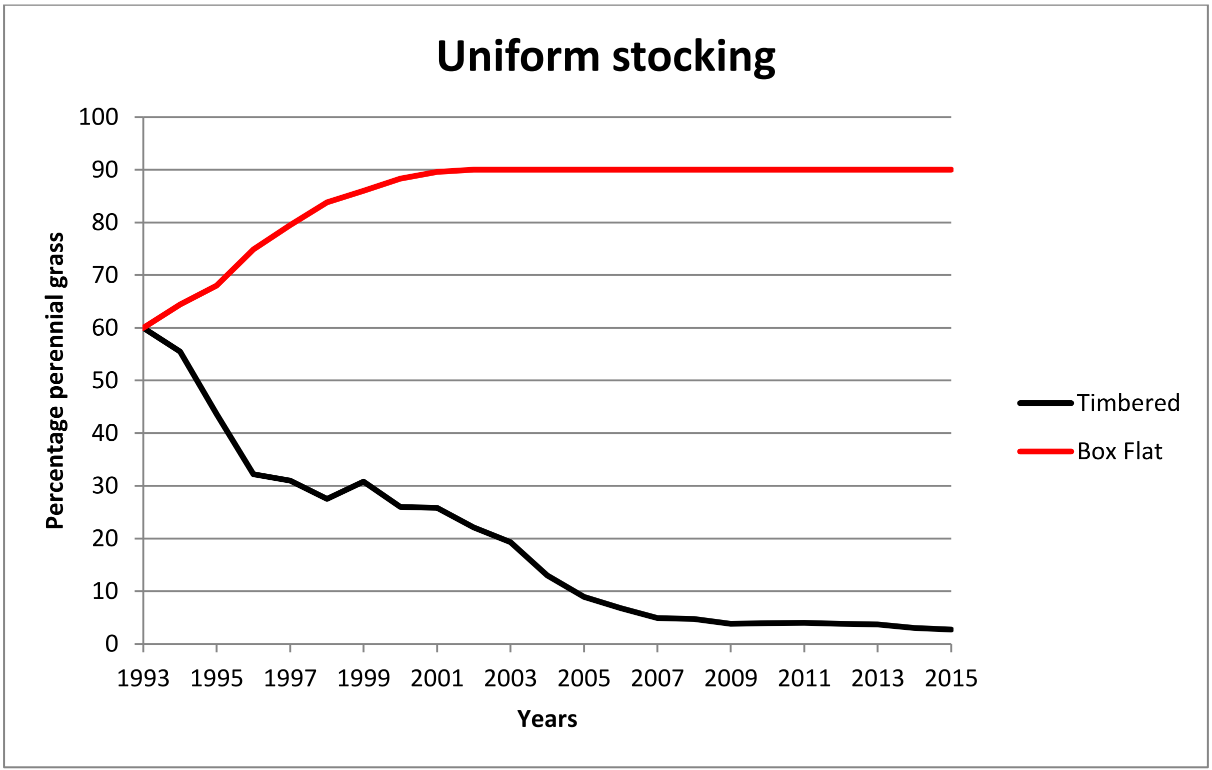


Fig. 4-40 The effect of uniform stocking rates (14 AE/100ha) on land condition at Oaklands.

4.5.3.2 Simulation 2. Both paddocks fixed, safe stocking rates

If both paddocks were stocked at fixed, safe long-term stocking rates, then the percentage of perennial grasses ended the simulation period at about the same level as at the start of the simulation. This essentially shows that the stocking rates that were selected form the modelling simulations (Section 3.3.2) were in fact safe stocking rates for this climate window (Fig. 4-41).

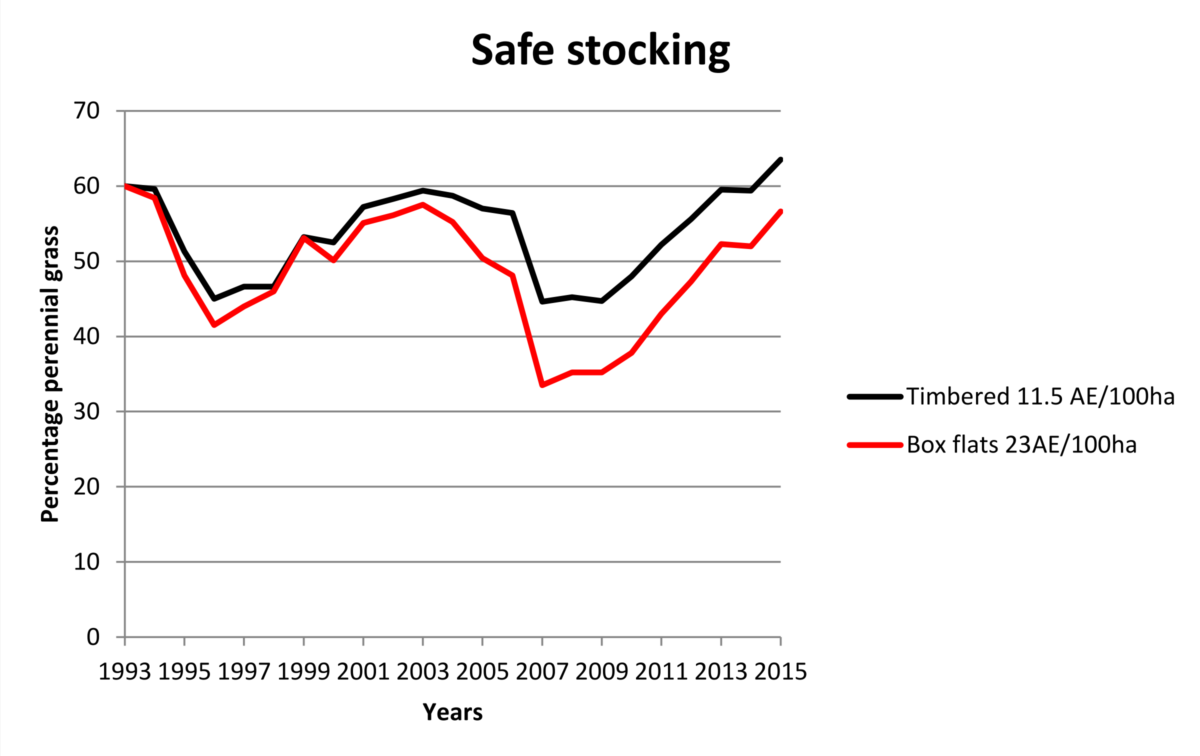


Fig. 4-41 The effect of safe long-term stocking rates on land condition at Oaklands.

4.5.3.3 Simulation 3. Best combination of stocking rates

The best combination of stocking rates that conformed to the constraints imposed was a base stocking rate of 10 AE/100 ha for the Timbered paddock and 33 AE/100 ha for the Box Flats. These were imposed for the beginning 18 months of each two year period. For the remaining six month period, all stock were in the Timbered paddock at a stocking rate of 14.5 AE/100 ha. This combination gave a total of 350 AE for the two paddocks. This was slightly higher than the 332 AEs that could be carried if both paddocks were stocked at their respective safe stocking rate.

Thus, the spelling enabled an additional 18 AEs to be carried in the paddock giving a modest 4-5 % increase (Table 4-9) while the condition of the Box Flats increased from a start of 60% perennial grasses to 90% perennial grasses by the end of the simulation (Fig. 4-42). This appears to be a win-win situation.

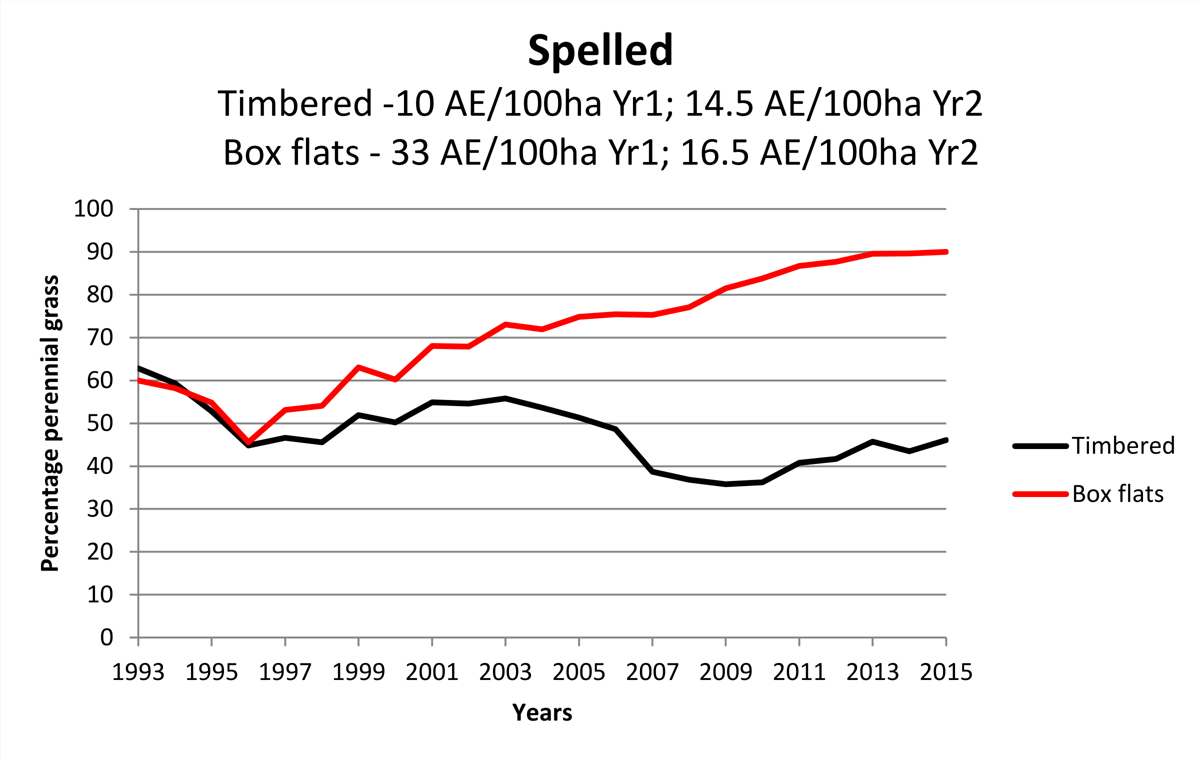


Fig. 4-42 The effect of safe stocking rates on land condition at Oaklands.

Table 4-9 Cattle numbers (AEs) at Oaklands for each spelling management simulation

Paddock	**Uniform SR**	**Safe SR**	**Spelled Yr1**		**Spelled Yr2**	
			Jun-Nov	**Dec-May**	**Jun-Nov**	**Dec-May**
Box Flat	69	113	160	160	160	0
Timbered	266	219	190	190	190	350
Total	**335**	**332**	**350**	**350**	**350**	**350**

Spelling can be done once every two years for the Box Flats paddock, allowing pasture condition to improve and animal production to increase. This also maintains the land condition in the Timbered paddock. The spelling allowed overall stock numbers to be increased by 4-5%. Part of the success of this specific simulation was the large size of the Timbered paddock (1900 ha) compared with the Box Flats (491 ha) which enables all the stock from the Box Flats to be put into the Timbered paddock for six months without increasing the stocking rate to such an extent that its condition was adversely affected.

4.5.4 Oaklands economic modelling

Two scenarios were modelled comparing breeding enterprise performance – the safe scenario and the spelled scenario. The simulated wet stock mortalities and weaning rates are presented in Table 4-10. The uniform treatment was still considered to have crashed and modelling was not undertaken on this scenario since results could not be interpreted.

Table 4-10 Oaklands wet stock mortalities and weaning rates for each scenario

Scenario		Performance measure	
		Wet stock mortalities	Weaning rates
Safe	Average	6	42
	Minimum	7	75
	Maximum	12	98
Spelled	Average	6	41
	Minimum	8	72
	Maximum	12	98

These results also show that there was very little, albeit some, difference between the safe and spelled scenarios in terms of economic performance. The safe scenario performed slightly better on all metrics owing to slightly better individual animal performance as modelled by GRASP. The economic results showed that despite better individual animal performance in the safe scenario, extra stock in the spelled scenario and better cash flow timing (Table 4-11) resulted in the spelled scenario having slightly better returns as measured by both IRR's and NPV's (Fig. 4-43). The extra stock in the spelled scenario resulted in an extra $88,830 in NPV, representing an 8% increase.

Table 4-11 Oaklands breeding enterprise modelling – economic outcomes

Scenario	IRR	NPV
Spelled	25.3%	$1,248,218
Safe	25.1%	$1,159,388

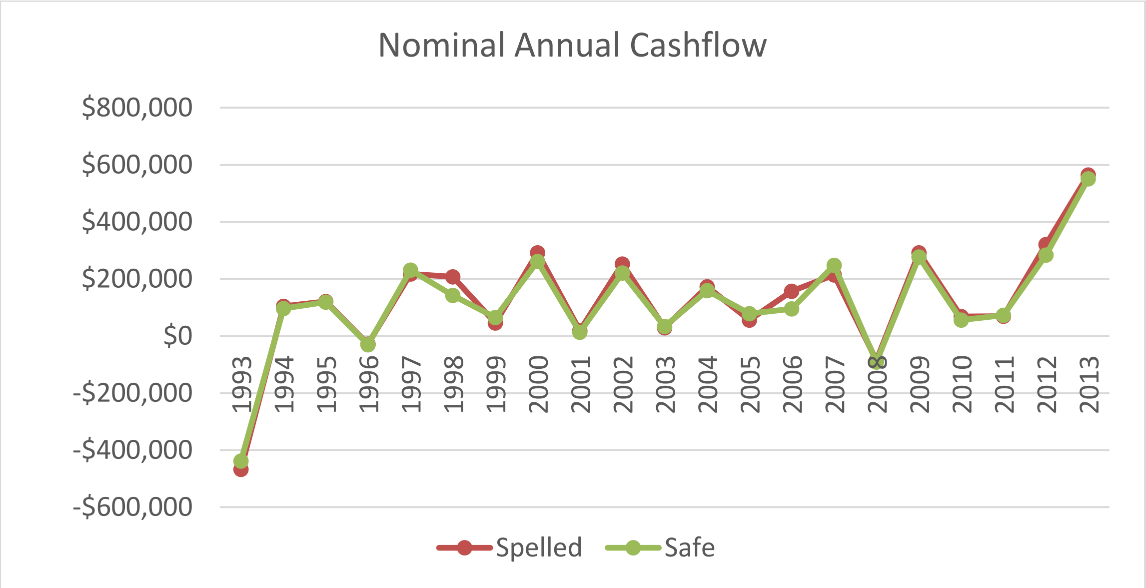


Fig. 4-43 Oaklands breeding enterprise modelling – nominal annual cash flow

4.6 Promoted engagement of local networks of producers and field staff in this research

4.6.1 Local networks of producers and field staff

The Spelling Strategies Project received publicity through linkages with the Northern Grazing Systems (NGS) project. In the Fitzroy catchment, there has been an increased awareness by approximately 1500 producers to management strategies that build resource resilience. This was achieved through presentations at field days, Beef-Up forums, consultations, presentations to various grazier groups, press releases, radio interviews, 7News segment and distribution of factsheets, case studies and booklets.

The Climate Savvy Grazing (CSG) field day held at Site 1 was one outcome of the NGS project in the Fitzroy catchment. The focus was on wet season spelling, land condition, burning and stocking rate management. Five of the CSG days were held across the Fitzroy basin. All of these field days were conducted by the staff in the Spelling Strategies Project.

Two hundred and fifty graziers in the Fitzroy basin attended presentations on stocking rates, grazing systems and their effects on land condition, animal production and profitability. While evaluations were not always possible, 60 of these graziers stated they had gained new knowledge after attending our field days. Evaluation sheets from 49 graziers who attended the CSG field days indicated that 37 gained new knowledge, predominantly on burning. Additionally, 14 of these graziers indicated they will implement new practices after attending the field day (mainly burning). An encouraging feedback was that many participants said they were currently practising best management based on the information presented. The CSG field days rated highly for the usefulness of the workshop, the information provided and the delivery of information.

Site 1 CSG Field Day

Average scores from evaluation sheets: (Scale 1 to 7)

Usefulness of the workshop	5.9
The information provided	6.0
The delivery of information	6.2

Two YouTube type videos were also developed. The first video has interviews with key speakers recorded at the Site 1 CSG field day including Paul Jones (DAF), Col Paton (EcoRich Grazing) and John Burnett, ‘Bendemeer’ Clermont. The focus was on land condition, burning, stocking rate management and wet season spelling. John Burnett gave a practical insight on how he incorporates these aspects of management to maintain and improve land condition. The second video focuses on managing for a variable and changing climate and has interviews from key speakers at the Alpha CSG field day, including David McRae (DSITIA) and Peter Whip, (PRW Agribusiness).

The videos are available at the following links:

Climate Savvy Grazing - Grazing management in the Fitzroy Woodlands http://www.youtube.com/watch?v=5wgtDUuYH7Y

Climate Savvy Grazing - Variable and Changing Climate

http://www.youtube.com/watch?v=1KUKAhBIzvU

At the Alpha CSG field day, an interview with the project leader on the Spelling Strategies Project was conducted with the ABC and aired on the Country Hour Segment. An audio recording is available at the following Country Hour audio link:

http://www.abc.net.au/rural/qld/content/2012/07/s3543570.htm

Project updates were published in the CQ BEEF Newsletter (Issue 13 Dec 2011, Issue 16 Dec 2012 and Issue 19 Dec 2013, Issue 23 Nov 2015), and Beeftalk Newsletter (Issue 37, Dec 2014) and are also available on the FutureBeef website:

http://futurebeef.com.au/resources/newsletters/queensland-newsletters/

A project brochure, factsheet and case study on wet season spelling was also published on the FutureBeef website.

http://futurebeef.com.au/topics/grazing-land-management/

Five articles were published in the CQBeef, Beetalk and Rural Weekly newsletters. Six poster papers and proceedings articles were published in Northern Beef Research Update Conference and Australian Rangeland Society conferences.

A secondary site was been established in Central Queensland through collaboration with a Carbon Farming Initiative (CFI) project led by Steven Bray of DAF. The Oaklands Carbon Farming Project is a demonstration site.

The project is based around the Mimosa Creek Landcare group providing an avenue to engage with the group on the topic of wet season spelling. This work, in conjunction with another DAF led project, exceeds MLA project milestone requirements.

The case studies exercise resulted from the engagement of local producer networks, the Technical panel and agency personnel. It was a positive step for gaining support for modelling work and for providing project updates. Stakeholders have quickly gained an understanding of the GRASP model and how outputs from the model can be targeted to answer key industry questions. The interactions of stocking rate, duration of spelling and resultant land condition were of common interest, together with the problem of increased short term stocking rates for non-spelled paddocks. The feedback has provided a clear direction for targeting modelling outputs with the case studies.

4.6.2 Technical Panel

A technical panel comprising experts in the fields of rangeland ecology, modelling and biometry was formed and met once a year to provide guidance and review project progress. The panel visited both Site 1 and Site 2 and met with the co-operating producers.

5 Discussion

5.1 Pasture responses to spelling treatments at Site 1

Seasonal conditions have had an overriding influence on pasture parameters for the first five years of the spelling strategies trial at Site 1. Exceptionally good seasonal conditions for the first two years, combined with a conservative stocking rate ensured that utilisation levels were very low whether grazed or not. Land condition improved slightly across all treatments during the initial wet period and was not affected by wet season spelling.

Because the first two years of the trial were exceedingly wet, pasture growth was quite likely more limited by soil nutrition than by soil moisture and thereby limited the potential of *B. ewartiana* to demonstrate enhanced growth compared to *Aristida* spp*.* The third year of the trial included a wildfire and dry conditions so that any potential lag effects of the spelling were less likely to be recognised. However, there appears to be a trend for a small increase in survival and crown cover of *B. ewartiana* seedlings with spelling. This only occurred in the February 2011 cohort, yet demonstrates the good seasonal conditions and time required for seedlings to establish, and survive the 2012 wildfire and subsequent dry conditions. Total crown cover was reduced by the burn and dry conditions in 2012/13 from 3% to 2%.

The contribution from *B. ewartiana* to crown cover and pasture composition may have improved by a small amount (10%) over that contributed by *Aristida* spp. and was sustained to the April 2015 recording (Section 2.3.1.7). This improved composition was only recorded at the fixed quadrat level, and is not reflected in the plot level data, highlighting the long term nature of land condition change and the prolonged time needed before significant changes are noted at the plot level.

The desirable characteristics of *B. ewartiana* were demonstrated by the maintenance of crown cover and density through the wildfire and very dry conditions. Similarly the undesirable, short lived nature of *Aristida* spp*.* was demonstrated with decreased crown cover following the burn which remained low for the next three dry summers. *B. ewartiana* has a lower turnover of plants than *Aristida* spp. This characteristic of *Aristida* spp. was demonstrated via recruiting plants having contributed about 10% to the total crown cover and being maintained through the wildfire and dry summers of 2012-15. This highlights the challenges involved when trying to improve pasture composition to a more desirable level with more *B. ewartiana*. Long timeframes will be involved to enable an improvement in land condition via wet season spelling when a moderate stocking rate is already in place, because there are only marginal improvements in crown cover of existing and seedling plants, and of survival of seedlings.

Grazing trials across northern Australia have had varied responses in land condition with wet season spelling. Hunt (2013), O'Reagain (2013) and Orr (2013) have all documented surprisingly slow or no response in land condition with wet season spelling for several years. However, the work of Ash (2011) and Orr (1997) has demonstrated considerable and rapid improvements in land condition with wet season spelling. The Virginia Park trials near Charters Towers had an estimated improvement from C to B land condition over ten years (A. Ash pers comm 2013) where composition of 3P grasses increased from ~ 7% to 20%. While the contribution from 3P grasses at Site 1 is higher at ~ 40%, there would still appear to be potential for a significant improvement.

We have used a Land Condition Index (Corfield *et al.* 2006) to extend the ABCD land condition concept in a more quantified way. Primary classifiers of the land condition index, in order of priority, are dominant pasture form, main functional group, perennial grass crown cover and then ground cover. Therefore large improvements in crown cover contribute only small improvements in land condition and changes in pasture composition are needed to improve land condition substantially. There is a trend for improving land condition with most of the spelling treatments compared to grazing.

B. ewartiana has been observed as being slow to increase its contribution to pasture composition under favourable management and good growing conditions in this study and that of (O'Reagain, 2013). Its expansion appears to be restricted by a small, viable seed bank and therefore slow to change plant density. The effect of the burn improving the contribution to crown cover and composition of *B. ewartiana* together with the decrease in *Aristida* spp*.* density during dry periods (Orr, 2011) are part of the processes needed for a land condition improvement. However, *Aristida* spp. regularly recruit many seedlings of very small size so it is the crown cover of them relative to that of *B. ewartiana* that is the critical issue rather than relative plant numbers and density.

5.2 Pasture responses to spelling treatments at Site 2

Site 2 plots were established with treatments implemented and recorded for the 2012-13, 2013-14 and 2014-15 years. Population dynamics measured at the fixed quadrat scale show that Site 1 had better crown cover than Site 2 in the order of 1%. *B. ewartiana* and *Aristida* spp*.* made a significant contribution to the total pasture yield at both sites. Land condition ratings are higher at Site 1 by about 0.25 of a rating on a 1-4 scale (C+ cf. C).

Full wet season annual spelling produced a significant increase in crown cover of *B. ewartiana* under moderate stocking rate. This is an important outcome, as this grass is a cornerstone for production and sustainability. While this improvement is not large enough to change the land condition index, it is encouraging. Additionally, this treatment has significantly increased the proportion of *B. ewartiana* in the pasture. Such improvements were not observed at Site 1. Past grazing history of the two sites is perhaps having an impact on recovery. Site 2 has been subject to high stocking rate for the previous 17 years during the grazing trial resulting in the current poor land condition. Before the Wambiana grazing trial commenced, land condition was good. By contrast, Site 1 was subjected to high grazing pressure for around 50 years, before the current owners took over in 2001. Possibly Site 1 is slower to show signs of recovery because it has had a longer period of high grazing pressure beforehand.

In the high stocking rate treatments, pasture yield significantly increased with full wet season annual spelling compared with the grazed treatment. This demonstrates the ability of the pasture to grow back from low yields in winter and spring season when followed by a full wet season spell. However, pasture yields in all other high stocking rate treatments were less than any of those recorded in the moderate stocking rate trial, highlighting the importance of setting a sustainable stocking rate that matches carrying capacity.

Recordings conducted in July 2011 (data not presented) show that the burn in November 2011 prior to our experiment did not affect perennial grass density or crown cover. Similar to Site1, Site 2 is demonstrating the long time needed to improve key pasture parameters when the underlying land condition is poor. Watson and Novelly (2012) have shown that a positive change in state in the Western Australian rangelands is possible. Over a 15 year period, with above average rainfall, nine sites recorded a significant increase in the density of *Chrysopogon fallax*. *C. fallax* is considered to be a desirable perennial grass. This study was unable to determine the factors contributing to the change but it does show that a land condition change through improved density of desirable perennial grass is possible within an acceptable management timeframe.

5.3 Germinable soil seed data

The soil seed load data from Site 1 demonstrates a large species diversity that is not reflected in the BOTANAL data. *B. ewartiana* (five seeds) and *Themeda triandra* (one seed) were the only 3P grasses to germinate from the 60 spring 2011 samples and none were recorded from the spring 2012 samples. *B. ewartiana* had 10 seeds recorded in 60 spring 2013 samples. Forbs, sedges and two species of Eragrostis were abundant in the soil seed bank. There were low numbers of germinating *Aristida* seeds in all four years, but considerably more than the 3P grass seeds. The 2013 data confirms there are low numbers of germinating 3P grass seeds in the soil after the dry season regardless of year or grazing management. This is consistent with soil seed bank data for *B. ewartiana* recorded by Orr (2011) at the Wambiana grazing trial. He found zero germinable seeds of this plant in two separate years of above average rainfall.

The soil seed load data from Site 2 also demonstrated a large diversity that is not reflected in the BOTANAL data, and there were low numbers of germinable 3P grass seeds regardless of the year or grazing management. However, there were large numbers of *B. pertusa* seedlings in all years. *D. fecundum* was only recorded in the final year. Interestingly, *Carissa ovata* seedlings were never recorded in the soil seed bank despite being abundant at the site.

Significant diversity was measured in the soil seed bank and is surprising given that both sites were rated as poor condition. The diversity held in the seedbanks was significantly different to the ground vegetation recorded in the BOTANAL data. Reasons include a lack of high level taxonomic skills in the operators, sampling techniques targeting higher yielding plants, time and resources (Silcock and Jones, 2012).

The diversity of *Aristida* species at both sites and the difficulty in confidently identifying many of them makes using them as an indicator of treatment effects problematic, both from seedbank tests and field sampling for biomass and density. If Aristida spp. data is amalgamated, as done here and often in BOTANAL samplings to overcome identification issues, there is the possibility that contrasting real responses by different species may mask important biological changes induced by treatments.

Many important perennial grasses such as *T. triandra* and *C. fallax* emerge so infrequently from soil samples and in such small numbers that assessing treatment effects on them in the medium term is impossible. The minor perennial grasses *Eulalia aurea, T. avenaceus* and *Cymbopogon* spp. never emerged from any of the soil samples.

With hindsight, testing for grazing treatment effects in the soil seed bank might be more definitive if only important species that are readily identifiable in the seedling stage are assayed and that the tests are run twice on each spring sample in the same summer. Young seedlings of key grasses like *B. pertusa* and *B. ewartiana* are almost identical and so too are many *Dichanthium*, *Eulalia* & other *Bothriochloa* species. This means that emergees have to be grown for months to obtain a reliable identification and daylength control of flowering in some species further extends the required time period. Hence, doing a second test in the same summer can be very time consuming and difficult to achieve.

5.4 Progress with GRASP modelling

As a result of this project, GRASP modelling is better simulating the recovery/degradation process at Sites 1 and 2. The improved fit of GRASP has been achieved by modification of weighting the impact of utilisation in each month, and the resultant changes in land condition state as measured by % perennial grasses. GRASP accurately represents pasture growth from a SWIFTSYND site, and the trend in standing dry matter for two spelling and one grazing treatment at Site 1. The modelled percentage of 3P grasses in the pasture requires further work. This includes incorporating more SWIFTSYND data and assessing data on changes in perennial grasses at other grazing trials.

Stocking rate is crucial to the success of spelling. If stocking rate is too high, then there will be little or no advantage to the practice of spelling. If the stocking rate is quite low, then improvement in 3P% will occur irrespective of whether or not any spelling is carried out. At intermediate stocking rates, spelling demonstrates a benefit. This may be to: a) improve 3P%, b) prevent decline in 3P%, or c) to slow any decline that would have occurred without the spelling.

All simulations used fixed, annual stocking rates as the GRASP model is unable to simulate spelling with flexible stocking rates. However, the principles derived from this work using fixed stocking rates will apply under any stocking strategies. If the overall utilisation of pasture within a growing season exceeds the safe level of utilisation, then 3P% will decline whether or not those pastures have previously or are subsequently spelled. Improvement will occur when the spelling allows the level of utilisation to fall below that threshold and allow 3P% to be maintained or to increase.

The work at Monteagle was useful as the analyses to date have shown that the rate of change of pasture condition is slower than that obtained from the detailed analyses of the Wambiana grazing trial (Scanlan *et al.* 2014). The SWIFTSYND site has enabled calibration of GRASP for another site in Queensland and will allow future work to be done on another land type which has been calibrated for change in 3P%. Both the Wambiana sites and the Monteagle site exhibit slower rates of change than was expected.

Information on the impact of length and frequency of spelling is published in Scanlan *et al.* (2014) based on simulations of the box land type from the Wambiana grazing trial. While the actual magnitude of responses will differ at Site 1, the pattern and implications will be the same. It is the length of spelling over a cycle that is the critical factor, provided spelling is carried out over summer. Similarly, early wet season spelling, when grasses are sensitive to grazing, should be more effective than late wet season spelling if the first part of the wet season receives rain. Full wet season spelling produced greater improvements in some pasture parameters but imposes a significant potential economic cost unless it is more beneficial than the average response that we have recorded.

Consultation with co-operating producers, the technical panel and agency personnel was a positive exercise for gaining support for modelling research and updating them on recent work. Stakeholders quickly gained an understanding of GRASP and how outputs can be targeted to answer key industry questions. The interactions of stocking rate, duration of spelling and resultant land condition were of common interest, and together with the fourth paddock problem (loading non-spelled paddocks) were the direction requested for targeting modelling outputs.

5.5 Case studies

The case studies were a logical progression from engagement with landholders, consultations over key research questions and incorporating Site 1 and Site 2 data to inform GRASP. The production of two case studies with biological and economic information incorporating practical spelling and stocking rate scenarios is a useful information product for industry. The case studies show the importance of stocking rate and varying animal numbers with seasonal conditions. There are some land condition and profitability benefits for the spelling regimes conducted on both case study properties compared to regimes without spelling. These results are specific for the seasonal conditions received over the previous 20 years.

In real terms, implementation of the spelling scenario at Oaklands would not be a rigid stocking rate, no matter what the growing conditions were like. If the total AEs in both paddocks were adjusted (within modest limits) depending on the season, it would be expected that the response would be quicker, that the condition of the Timbered paddock might improve or the total stock numbers carried might increase by a little more than the current 4-5% simulated.

The bio-economic model has several limitations that may affect the results and interpretation. Most importantly, the model is very specific for the climate sequence and properties that they represent. Extrapolation to other grazing businesses requires an understanding of the parameters and processes involved.

There are also specific technical limitations. Firstly, GRASP informs the herd modelling and dictates the grazing pressure that is applied in any particular year. This results in years where cattle are required to be purchased due to mortality and body weight issues to maintain grazing pressure. This may run contrary to reality where it is unlikely significant purchases are made during poor years. Secondly, the mortality and weaning rate equations, as derived from live weight gains, are not dynamic through time unlike the live weight gains themselves. This means that in years of similar annual live weight gain the weaning rate is similar, regardless of whether that year falls after three good years or after three bad years.

Another limitation of the modelling is that it cannot decide options, such as supplementary/production feed or changing markets depending on market opportunities (since price is assumed to remain static in real dollars). This does not represent commercial reality. The supplementation deficiency is driven through biological limitations and the inability of bio-economic models to incorporate the reduced or increased grazing pressure that supplementary feeding may induce. Modelled scenarios at this point, cannot be as adaptive or responsive as a real grazing enterprise to changes in seasons and markets.

Lastly, the choice to understock or overstock, even slightly, was not available. Otherwise it voids the biological modelling assumption. This is strongly linked to the first limitation of GRASP where it is the driver of stocking rates, not stocking rates driving the biological/GRASP outputs. To increase confidence in modelled results it is necessary that a *dynamic* bio-economic model be developed, which incorporates flexibility of management decisions in driving herd numbers and structures back to the biological data to regenerate outputs on a yearly and dynamic basis.

The results from two different commercial properties and scenarios show that wet season spelling can marginally improve performance and modelled profitability of grazing enterprises. However, the limitations to the current capability of bio-economic modelling causes an unknown amount of error. Given the rigid structure of bio-economic analysis, assuming the error relates equally to all scenarios, some key insights can be gained. The insights of the herd economic modelling are:

1) The heavier, inflexible, stocking rates perform poorly compared to the variable stocking rate scenarios for both profitability and performance.
2) There is very little profitability or performance difference between conservative variable stocking and set wet season spelling treatments.
3) Acceptable land condition outcomes were achieved with the spelling scenarios despite the additional grazing pressure on non-spelled paddocks.
4) High stocking rates that are fixed can cause significant land degradation, resulting in unacceptably low animal and economic performance. Even if this is overcome through supplementary feeding, there is a high economic and environmental risk.

5.6 Promoted engagement of local networks of producers and field staff in this research

The Spelling Strategies Project has received excellent publicity and engagement with producers through the Climate Savvy Grazing field days, producer involvement in the Technical Panel meetings, YouTube videos, factsheets and case studies on the FutureBeef website. The project received expert feedback and guidance annually from the Technical Panel. Five articles were published in the CQBeef, Beeftalk and Rural Weekly newsletters. Six poster papers and proceedings articles were published in Northern Beef Research Update Conference and Australian Rangeland Society conferences. Presentations were made at the Clermont Cattleman’s Challenge field day, Wambiana Field Day, Mimosa

Landcare meeting, BeefWeek 2015 tour to Oaklands and Central Queensland Beef Research Committee meeting.

Producers from the co-operating properties, the Technical Panel, key agency personnel and the Carbon Farming Project were consulted for the GRASP key research questions and scenarios analysis.

5.7 Extent to which each specific project objective was met

5.7.1 Improved understanding of the response of native pastures in poor condition to wet season spelling;

Objective 1 was addressed for five years at Site 1 under a moderate stocking rate, and for three years at Site 2 with both moderate and high stocking rate trials. There were only small improvements in pasture condition with spelling although only under moderate stocking rate. Within the seasonal conditions experienced, it appears that a small viable seed bank of desirable perennial grasses restricted the potential pasture recovery.

5.7.2 Quantified the impact of timing, duration, and frequency of pasture spelling on pasture and soil condition response in one major pasture community of Queensland;

Objective 2 was addressed as per Objective 1. Within the seasonal conditions experienced, only small improvements in pasture condition were achieved with full wet season annual spelling, and only with moderate stocking rate. Therefore the soil condition has not changed as it will take many years of improved pasture condition to change soil surface condition parameters.

5.7.3 Quantified the impact of overall stocking rate on the net benefit of pasture spelling in a second major pasture community of Queensland;

Objective 3 was addressed as per Objective 1. Within the seasonal conditions experienced, only small improvements in pasture condition were achieved with full wet season annual spelling, and only with moderate stocking rate. While full wet season annual spelling with high stocking rate increased pasture yield in autumn, the response was short lived (1 - 2 months). Increases in pasture yield with full wet season annual spelling were not realised during a very dry summer and with high stocking rate.

5.7.4 Identified practical plant-based indicators of (i) when a spelling period has been effective and (ii) how well pasture is responding to a spelling regime;

Objective 4 was not achieved. The spelling period experienced did not drive effective pasture recovery and pasture has not responded to any significant extent due to the slow rate of change for *B. ewartiana.*

5.7.5 Developed improved capacity to realistically simulate the impacts of different wet season spelling regimes on the recovery of pasture and soil condition through refinement of models such as GRASP;

Objective 5 has been addressed with the GRASP model better simulating the recovery/degradation process at Sites 1 and 2. GRASP accurately represents pasture growth from a SWIFTSYND site and the trend in standing dry matter for spelling and grazing treatments at Site 1.

5.7.6 Explored, using GRASP, how the net benefit from spelling for a paddock, or group of paddocks, interacts with both the overall stocking rate applied and any periods of heavy grazing associated with the implementation of the spelling strategy;

Objective 6 has been addressed with GRASP now able to simulate responses. Simulations show the importance of stocking rate and how it is crucial to the success of spelling. If the stocking rate is set too high, then there will be little or no advantage to the practice of spelling. If the stocking rate is too low, then improvement in 3P% will occur, irrespective of whether or not any spelling is carried out. GRASP was used to simulate case study scenarios examining varying stocking rate and spelling regimes based on real world examples. Full business analysis was conducted on the case studies generating practical examples with sustainability and profitability outcomes. This achievement is a significant additional outcome for this objective.

5.7.7 Promoted engagement of local networks of producers and field staff in this research;

Objective 7 has been addressed through comprehensive publicity and engagement with producers and agency personnel. Field days, industry meetings, electronic media, newsletters and conference proceedings have all been utilised to promote the project findings. The case studies and additional monitoring on co-operator properties are significant additional outcomes for this objective.

5.7.8 Developed improved recommendations for recovery of pasture and soil condition in each of the studied pasture communities;

Objective 8 has been addressed for the two studied key pasture communities in central and northern Queensland. The information generated from the project has informed key recommendations covering the importance of a moderate stocking rate, varying stock numbers with seasonal conditions, and regular wet season spelling.

5.8 Draft extension messages

5.8.1 The importance of a moderate stocking rate

The importance of a moderate stocking rate is critical given the small and slow responses to spelling. The trial findings show the lack of significant improvement in 3P crown cover under a high stocking rate. Our results reinforce the aim of stocking rate set around long term carrying capacity. Spelling, in conjunction with a moderate stocking rate, will maintain and/or improve land condition and also generate feed reserves. Modelling has replicated and confirmed this finding and recommendation.

5.8.2 Regular wet season spelling is critical, but be flexible depending on the seasonal conditions

The trial and modelling show the negative consequences, in terms of feedbase options and profitability, of a high stocking rate. Flexibility in management is required when spelling. During poor seasonal conditions if paddocks are subject to heavy grazing associated with the spelling of others, the net result can be negative. The case studies have shown the importance of stocking rate, and the need for flexibility in management to adjust stock numbers according to the amount of forage available. There was a small economic benefit from variable stocking rate management within the spelling regime while stocking around long term sustainable carrying capacity.

6 Conclusions/Recommendations

Our results support the belief that seasonal conditions have the main influence on pasture yield and land condition. Only small improvements in crown cover were measured with spelling. The improvement in crown cover occurred under moderate stocking rate and did not appear to be related to seasonal conditions. There was a trend for *B. ewartiana* seedlings which recruited during a wet summer to have better survival and crown cover than that of ones recruited in poorer summers. These small improvements in crown cover with spelling have not been reflected in pasture yield or condition rating measured in this trial. The expansion of *B. ewartiana* appears to be restricted by a small viable seed bank.

Managing for an improvement in land condition by implementing wet season spelling will require longer timeframes than previously thought. Essential guidelines for implementing this management includes: stocking around long term carrying capacity, adjusting stock numbers to the forage available and avoid high grazing pressure on the other paddocks associated with the spelling system.

A priority for future research and development is to address the lack of knowledge on the population biology of key perennial grass species. Seed and tiller ecology, together with the impacts of low utilisation levels on crown cover increase are key knowledge gaps. Extending the regular field measurements of the spelling treatments, and analysis of these results, in some form is strongly recommended.

7 Key Messages

Increases in the density and growth of desirable perennial grasses is necessary for extensive beef cattle production areas of northern Australia. Essential management to achieve these improvements includes: wet season spelling, stocking around long term carrying capacity, adjusting stock numbers to the forage available and avoiding excessively high grazing pressure on the other paddocks associated with the spelling system. Benefits to profitability and sustainability will accrue through better resilience to varying seasonal conditions and improvements to downstream water quality.

8 References

Anon (2005). QGraze. Monitoring the condition of Queensland's grazing lands. Queensland Government. Department of Primary Industry and Fisheries

Ash, A. J., Corfield, J. P., McIvor, J. G., and Ksiksi, T. S. (2011). Grazing management in tropical savannas: utilization and rest strategies to manipulate rangeland condition. Rangeland Ecology and Management 64, 223–239. doi:10.2111/REM-D-09-00111.1

Bartley, R., Corfield J. P., Hawdon, A. A., Kinsey- Henderson, A. E., Abbott, B. N., Wilkinson, S. N. and Keen, R. J. (2014) Can changes to pasture management reduce runoff and sediment loss to the Great Barrier Reef? The results of a 10-year study in the Burdekin catchment, Australia. The Rangeland Journal 36, p. 67–84.

Beutel TS, M Hoffmann and C. Holloway (2009). Extending rapid condition assessments in the Fitzroy Basin. Queensland Primary Industries and Fisheries.

Bray, S., Walsh, D., Phelps, D., Rolfe, J., Broad, K., Whish, G. and Quirk, M. (2016) Climate Clever Beef: options to improve business performance and reduce greenhouse gas emissions in northern Australia. The Rangeland Journal 38, p. 207–218.

Briske, D. D., Derner, J. D., Brown, J. R., Fuhlendorf, S. D., Teague, W. R., Havstad, K. M., Gillen, R. L., Ash, A. J., and Willms, W. D. (2008). Rotational grazing on rangelands: reconciliation of perception and experimental evidence. Rangeland Ecology and Management 61, p. 3-17.

Corfield, J.P., Abbott, B.N., Hawden, A. and Berthelsen, S. (2006). PATCHKEY: A patch classification framework for the upper Burdekin and beyond. Proceedings of the Australian Rangelands Conference, Renmark, South Australia. pp. 114-118.

Day, K.A. and Philp, M. W. (1997). Evaluating the risks of pasture and land degradation in native pasture in Queensland. Appendix 3 SWIFTSYND Methodology. Final report or Rural Industries and Research Development Corporation project DAQ124A.

Gillard, P. and Monypenny, R. (1988). A decision support approach for the beef cattle industry of tropical Australia. Agricultural Systems, 26, p. 179-190.

Gunn, R. H, Galloway, R. W., Pedley, L. and Fitzpatrick, E. A. (1967). Lands of the Nogoa-Belyando Area, Queensland, Land Research Series No.18, CSIRO, Australia.

Holmes, W. E. (2005). 'Breedcow and Dynama Herd Budgeting Software Package, Version 5.04. Training Series QE99002.' (Queensland Department of Primary Industries and Fisheries: Townsville.)

Hunt, L. P., Petty, S., Cowley, R., Fisher, A., White, A., MacDonald, N., Pryor, M., Ash, A. J., McCosker, K., McIvor, J. G., and MacLeod, N. D. (2013). 'Sustainable development of Victoria River District (VRD) grazing lands.' Final report Project B.NBP.0375. (Meat and Livestock Australia: North Sydney, NSW.)

NRM (2001). 'Weedy Sporobolus Grasses Strategy 2001–2006.'

Karfs, R. A., Abbott, B N., Scarth, P. F. and Wallace, J. F. (2009) Land condition monitoring information for reef catchments: a new era. The Rangeland Journal (31), 69–86.

MacLeod, N. D., Nelson, B. S., McIvor, J. G. and Corfield, J. P. (2009). Wet season resting – economic insights from scenario modelling. The Rangeland Journal 31, p. 143–150.

McIvor, J. G., Ash, A. J. and Cook, G. D. (1995). Land condition in the tropical tallgrass pasture lands: 1. Effects on herbage production. The Rangeland Journal 17, p. 69–85.

McIvor, J., Bray, S., Grice, T., Hunt L. and Scanlan, J. (2011) Grazing management options for improving profitability and sustainability. 1. New insights from experiments. Proceedings of the Northern Beef Research Update Conference, Darwin NT. pp 41-47.

McKeon, G. M., Ash, A. J., Hall, W. B., and Stafford Smith, M. (2000). Simulation of grazing strategies for beef production in north-east Queensland. In: 'Applications of Seasonal Climate Forecasting in Agricultural and Natural Ecosystems – The Australian Experience'. (Eds G. Hammer, N. Nicholls and C. Mitchell.). pp. 227–252. (Kluwer Academic Press: Dordrecht, The Netherlands.)

O'Reagain, P. and Bushell, J. (2013). Managing for a variable climate: long term results from the Wambiana grazing trial. Proceedings of the Northern Beef Research Update Conference. Cairns, August 2013.

O'Reagain, P., Scanlan, J., Hunt, L., Cowley, R., and Walsh, D. (2014). Sustainable grazing management for temporal and spatial variability in north Australian rangelands – a synthesis of the latest evidence and recommendations. The Rangeland Journal 36, p. 223–232.

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, 201–205.

Orr DM, Paton CJ, Lisle AT (1997) Using fire to manage species composition in Heteropogon contortus (black speargrass) pastures. 1. Burning regimes. Australian Journal of Agricultural Research 48, 795–802.

Orr, D. M. (1998). A life cycle approach to population ecology of two tropical grasses in Queensland, Australia. In: 'Population Biology of Grasses'. (Ed. G. Cheplick.) pp. 366–389. (Cambridge University Press: New York.)

Orr, D. M., and O'Reagain, P. J. (2011). Managing for rainfall variability: impacts of grazing strategies on perennial grass dynamics in a dry tropical savanna. The Rangeland Journal 33, 209–220.

Orr, D. M. and Phelps, D. G. (2013) Impacts of level of utilisation by grazing on an Astrebla (Mitchell grass) grassland in north-western Queensland between 1984 and 2010. 1. Herbage mass and population dynamics of *Astrebla* spp. The Rangeland Journal 35, p. 1–15.

Queensland Government (2014) https://publications.qld.gov.au/storage/f/2014-09-18T23%3A14%3A58.246Z/re-glossary-technical-descriptions.pdf

Quirk, M., and McIvor, J. (2003). 'Grazing Land Management: Technical Manual.' (Meat and Livestock Australia: North Sydney, NSW.)

Scanlan, J. C., Cowley, R. A., McKeon, G. M., Clewett, J., Fraser, G., Materne, C. M., and Pettit, C. L. (2008). 'Methods for Calibrating GRASP from the Literature and Field Data. Appendix 14: Improving Grazing Management using the GRASP Model.' (Meat & Livestock Australia Limited: Sydney.)

Scanlan, J.C., Cowley, R.A., Pahl, L.I., Whish, G.L. and MacLeod, N.D. (2011). The potential range of impacts of climate change on safe carrying capacities for extensive grazing lands of northern Australia. MODSIM 2011.

Scanlan, J. C., MacLeod, N. D., and O'Reagain, P. J. (2013). Scaling results up from a plot and paddock scale to a property – a case study from a long-term grazing experiment in northern Australia. The Rangeland Journal 35, p. 193–200.

Scanlan, J., McIvor, J., Bray, S., Cowley, R, Hunt, L., Pahl, L., MacLeod, N. and Whish, G. (2014). Resting pastures to improve land condition in northern Australia: guidelines based on the literature and simulation modelling. The Rangeland Journal 36, p. 429–443.

Scarth P, T Danaher, B Henry, R Hassett, J Carter and P Timmers (2006) State of the paddock: monitoring condition and trend in groundcover across Queensland. The 13th Australasian Remote Sensing Conference, Canberra

Silcock, R. G. and Jones, P. (2012). How well is land condition and biological diversity measured? Proc. 17th bienn. Conf., Aust. Rangeland Soc., Kununurra WA.

Star, M., Rolfe, J., Donaghy, P., Beutel, T., Whish, G. and Abbott, B. (2013). Targeting resource investments to achieve sediment reduction and improved Great Barrier Reef health. Agriculture, Ecosystems and Environment 180, p. 148-156.

Star, M., Rolfe, J. Long, P., Whish. G., Donaghy, P. (2015) Improved grazing management practices in the catchments of the Great Barrier Reef, Australia: does climate variability influence their adoption by landholders? The Rangeland Journal 37, p. 507-515.

Tongway, D.J. and Hindley, N.L. (2004). Landscape Function Analysis Manual: Procedures for monitoring and assessing landscapes. CSIRO Sustainable Ecosystems, ver. 3.1, May 2004, CD-Rom.

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 Division of Tropical Crops and Pastures. Tropical Agronomy Technical Memorandum No. 78, Brisbane.

Watson, I.W. and Novelly, P.E. (2012). Transitions across thresholds of vegetation states in the grazed rangelands of Western Australia. The Rangeland Journal 34, p. 231-238.

Whish, G. (Ed.) (2011). 'Land Types of Queensland.' Version 2.0. Prepared by the Grazing Land Management Workshop Team, Department of Employment, Economic Development and Innovation, Brisbane. PR07–3212. (Department of Employment, Economic Development and Innovation: Brisbane.)

9 Appendix

9.1 Germinable soil seed assessment method

In late winter/early spring each year, prior to any significant growing season rain, surface soil samples were taken from every plot that will have a spelling treatment imposed the next summer as well as from each continuously grazed (G) plot. A single core 5cm diameter and 5cm deep was taken from a spot adjacent to each of the 12 quadrats in each relevant plot. The six quadrats that had been originally chosen as having B. ewartiana plants growing in them were bulked into a single paper bag and the other six from that plot went together into another paper bag. In the first year at each site every plot was sampled, 44 at Monteagle and 40 at Wambiana.

Those samples were despatched shortly afterwards to Brisbane where they were individually broken into small crumbs and sieved through a 5 mm sieve. Stones, sticks, tree leaves and large debris was removed, care being taken to rub off any adhering soil and visible seeds. Thus any tiny seed that may have been accidentally removed would not have been that of a 3P grass or Aristida spp. because they are relatively large and visible to the naked eye. Fragments of the cryptic crowns of sedges and Tripogon loliiformis were left in the first year samples but in subsequent years they were removed as best as possible. However, some tiny pieces still remained in the soil to resprout when watering began but their speed of growth and size allowed them to be identified for what they were and they were not counted as seedlings. The processed soils were then placed in a sunny location in a glasshouse until early October when assessment of the germinability of the seeds they contained commenced as warm temperatures resumed there.

That assessment was done by spreading the entire contents of each bag over the surface of a 20cm diameter pot that was almost filled with damp vermiculite that had Aquasol general fertiliser solution added. The soil layer was about 1.5 cm deep depending on the quantity of soil material provided in each sample and was separated from the vermiculite by a layer of paper hand towel. The potted soils were then gently watered with a fine spray of town water so that a great deal of water percolated through the soil and the excess drained away. That watering regime was repeated several times each day for five days and then the frequency of watering declined to once or twice a day depending on the evaporative demand. The glasshouse had its minimum temperature controlled to 20^{o} C and cooling was used when the air temperature rose above 30^{o} C. Daily watering continued for another 3-4 weeks until moss and algae became evident on the surface of the soil. By this time the majority of seedlings that were going to emerge had done so.

Thereafter, pots were watered from below by standing them in trays that were filled with appropriate amounts of water to keep the soil near the soil surface moist but sufficiently dry that the moss, liverwort and algal growth was minimised. Pots were managed on their individual needs which varied with the degree of clay in the soil, the size and number of the growing plants, and the outside weather conditions -temperature, cloud, humidity and wind. Thus extra fertiliser was added on occasion in solution to the trays beneath to keep plants growing healthily until identified and removed.

Seedlings were removed as soon as a positive identification could be given or an adequate one for the purposes of the trial. Thus eucalypts were only identified to a genus as were

Enneapogon spp. and many Eragrostis spp. that came up in huge numbers sometimes. In many cases such identification was done for only one or a few plants that were allowed to grow to full seeding while others identified earlier as exactly the same species were removed at an early stage of maturity but linked by identity to that given to the mature plant by the Brisbane Herbarium. In most cases this process of identifying emerging seedlings was completed by mid-December but for those species with daylength sensitivity requirements for flowering, such as *Bothriochloa pertusa* and *Schizachyrium pseudeulalia*, this required them to be grown on into March. By then they were huge plants with high water and nutrient demands.

Usually no further surface rewatering of the soils occurred after the first phase which simulates the initial wet season flush that would be experienced in their natural environment. It is acknowledged that other dormant seeds remained in the soil and these could germinate on a later rainfall event, such as is common for some *Digitaria* and *Eragrostis* spp. but these are not species of major interest in this study. There was a major hailstorm that smashed the glasshouse room in late November 1914 which resulted in wetting of the soil surface in some pots and damage to some seedlings. The main species to emerge from those rewetted pots were Aristida spp. and sedges but in small numbers.

As a check of our methods, we allowed the soil of pots that had completed their initial germination and identification early to dry out fully and experience strong sunlight and warming for a few weeks. Then the soil layer above the paper towel, which had fully disintegrated by then, was removed virtually intact and placed in a bag. That soil was crushed up again with minimal force and respread in February 2015 over the surface of a new pot of vermiculite which had been infused with fertiliser solution in the same manner as the initial tests had been conducted. The pots were then steadily watered in the same manner as described before to see what seedlings would emerge. Emerging seedlings were identified and counted as before.

9.2 Statistical analysis

The following notation has been used for each ANOVA table:

[1] Probability test of treatment effect

[2] Standard error of means (maximum where number of reps varies)

[3] Treatment plots not measured at this recording

[4] Means in the same analysis followed by a similar letter do not differ significantly ($p>0.05$)

[5] Most efficient analysis type : CR=completely random, RB=randomised block, +C= covariate adjusted

[6] Analysis not applicable, since pre-treatment data. Means presented to show initial differences for possible later covariate adjustment

[7] Probability test of covariate effect

[8] Coefficient of covariate adjustment

[*] Means with this superscript at the same recording indicates they had the same spelling or grazing history up to that recording

Table 0-1 Site 1 total pasture yields (kg/ha) in the fixed quadrats

<table>
<tr><th></th><th colspan="15">Recording number</th></tr>
<tr><th>Treat.</th><th>R1</th><th>R2</th><th>R3</th><th>R4</th><th>R5</th><th>R6</th><th>R7</th><th>R8</th><th>R9</th><th>R10</th><th>R11</th><th>R12</th><th>R13</th><th>R14</th><th>R15</th></tr>
<tr><td>EA</td><td>2296</td><td rowspan="5">3345</td><td rowspan="2">4027</td><td>3511</td><td>3080</td><td>3456c</td><td>2652c</td><td>230</td><td>456</td><td>168</td><td>192</td><td>322</td><td>448b</td><td>848</td><td>1068</td></tr>
<tr><td>EB</td><td>2384</td><td>XXX</td><td>XXX</td><td>XXX</td><td>4037ab</td><td>261</td><td>505</td><td>XXX</td><td>XXX</td><td>XXX</td><td>452b</td><td>1050</td><td>1220</td></tr>
<tr><td>FA</td><td>2473</td><td rowspan="3">3518</td><td>3375</td><td>1942</td><td>4533a</td><td>3061bc</td><td>588</td><td>686</td><td>402</td><td>470</td><td>588</td><td>943a</td><td>1389</td><td>1800</td></tr>
<tr><td>FB</td><td>2381</td><td>XXX</td><td>XXX</td><td>XXX</td><td>4559a</td><td>333</td><td rowspan="2">536</td><td>XXX</td><td>XXX</td><td>XXX</td><td>505b</td><td>1255</td><td>1340</td></tr>
<tr><td>FY1</td><td>2782</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>1555</td></tr>
<tr><td>FY2</td><td>2391</td><td>XXX[7]</td><td>XXX</td><td>3443*</td><td>2299</td><td>4364ab</td><td>XXX</td><td>XXX</td><td>444</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>1167</td></tr>
<tr><td>FY3</td><td>2318</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>3687*abc</td><td>217*</td><td rowspan="4">369</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>995*</td></tr>
<tr><td>FY4</td><td>2538</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>226*</td><td>308</td><td>657</td><td>XXX</td><td>XXX</td><td>1412</td></tr>
<tr><td>FY5</td><td>2010</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td rowspan="2">438b</td><td>915</td><td>1248</td></tr>
<tr><td>G</td><td>1697</td><td>4354</td><td>4152</td><td>3443*</td><td>3233</td><td>3576bc</td><td>3687*abc</td><td>217*</td><td>226*</td><td>92</td><td>457</td><td>962</td><td>995*</td></tr>
<tr><td>Anova[1]</td><td>N.A.[5]</td><td>RB+C</td><td>RB+C</td><td>RB+C</td><td>RB+C</td><td>CR</td><td>RB+C</td><td>CR</td><td>RB</td><td>CR</td><td>CR</td><td>CR</td><td>RB</td><td>RB</td><td>CR</td></tr>
<tr><td>P(T)[1]</td><td></td><td>0.10</td><td>0.43</td><td>0.98</td><td>0.36</td><td>0.03</td><td>0.04</td><td>0.07</td><td>0.09</td><td>0.43</td><td>0.34</td><td>0.46</td><td>0.01</td><td>0.34</td><td>0.42</td></tr>
<tr><td>SEM[2]</td><td>358</td><td>534</td><td>294</td><td>349</td><td>537</td><td>268</td><td>310</td><td>100</td><td>95</td><td>130</td><td>146</td><td>153</td><td>103</td><td>188</td><td>226</td></tr>
<tr><td>P(C)[7]</td><td></td><td><0.01</td><td><0.01</td><td>0.10</td><td>0.06</td><td></td><td>0.01</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Coeff[8]</td><td></td><td>2.3</td><td>2.1</td><td>1.1</td><td>1.7</td><td></td><td>1.7</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

Table 0-2 Site 1 *B. ewartiana* pasture yields (kg/ha) in the fixed quadrats

<table>
<tr><th></th><th colspan="15">Recording number</th></tr>
<tr><th>Treat.</th><th>R1</th><th>R2</th><th>R3</th><th>R4</th><th>R5</th><th>R6</th><th>R7</th><th>R8</th><th>R9</th><th>R10</th><th>R11</th><th>R12</th><th>R13</th><th>R14</th><th>R15</th></tr>
<tr><td>EA</td><td>785</td><td rowspan="5">1296</td><td rowspan="2">1570</td><td>1442</td><td>1109</td><td>1226</td><td>1073</td><td>129</td><td>261</td><td>104</td><td>138</td><td>206</td><td>285b</td><td>527</td><td>659</td></tr>
<tr><td>EB</td><td>954</td><td>XXX</td><td>XXX</td><td>XXX</td><td>1357</td><td>136</td><td>264</td><td>XXX</td><td>XXX</td><td>XXX</td><td>277b</td><td>550</td><td>744</td></tr>
<tr><td>FA</td><td>905</td><td rowspan="3">1395</td><td>1139</td><td>542</td><td>1427</td><td>976</td><td>141</td><td>318</td><td>206</td><td>284</td><td>225</td><td>538a</td><td>773</td><td>879</td></tr>
<tr><td>FB</td><td>903</td><td>XXX</td><td>XXX</td><td>XXX</td><td>1408</td><td>178</td><td rowspan="2">217</td><td>XXX</td><td>XXX</td><td>XXX</td><td>330b</td><td>736</td><td>834</td></tr>
<tr><td>FY1</td><td>879</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>540</td></tr>
<tr><td>FY2</td><td>790</td><td>XXX</td><td>XXX</td><td>1245*</td><td>721</td><td>1145</td><td>XXX</td><td>XXX</td><td>208</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>612</td></tr>
<tr><td>FY3</td><td>836</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>1176*</td><td>106*</td><td>190*</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>508*</td></tr>
<tr><td>FY4</td><td>827</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>128*</td><td>162</td><td>233</td><td>XXX</td><td>XXX</td><td>608</td></tr>
<tr><td>FY5</td><td>754</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td rowspan="2">257b</td><td>537</td><td>692</td></tr>
<tr><td>G</td><td>625</td><td>1154</td><td>1297</td><td>1245*</td><td>693</td><td>876</td><td>1176*</td><td>106*</td><td>190*</td><td>128*</td><td>68</td><td>225</td><td>401</td><td>508*</td></tr>
<tr><td>P(T)</td><td></td><td>0.53</td><td>0.36</td><td>0.45</td><td>0.35</td><td>0.23</td><td>0.61</td><td>0.45</td><td>0.46</td><td>0.64</td><td>0.58</td><td>0.99</td><td><0.01</td><td>0.16</td><td>0.71</td></tr>
<tr><td>SEM</td><td>158</td><td>200</td><td>171</td><td>171</td><td>221</td><td>174</td><td>224</td><td>21</td><td>54</td><td>80</td><td>109</td><td>107</td><td>44</td><td>103</td><td>168</td></tr>
<tr><td>Anova</td><td>N.A.</td><td>RB</td><td>RB+C</td><td>RB+C</td><td>CR</td><td>RB</td><td>RB+C</td><td>CR</td><td>RB</td><td>CR+C</td><td>CR</td><td>CR</td><td>RB</td><td>RB</td><td>RB</td></tr>
<tr><td>P(C)</td><td></td><td></td><td><0.01</td><td>0.04</td><td></td><td></td><td>0.01</td><td></td><td></td><td>0.09</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Coeff</td><td></td><td></td><td>1.11</td><td>0.92</td><td></td><td></td><td>1.21</td><td></td><td></td><td>0.30</td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

Table 0-3 Site 1 *Aristida* spp. pasture yields (kg/ha) in the fixed quadrats

<table>
<tr><th></th><th colspan="15">Recording number</th></tr>
<tr><th>Treat.</th><th>R1</th><th>R2</th><th>R3</th><th>R4</th><th>R5</th><th>R6</th><th>R7</th><th>R8</th><th>R9</th><th>R10</th><th>R11</th><th>R12</th><th>R13</th><th>R14</th><th>R15</th></tr>
<tr><td>EA</td><td>1007</td><td rowspan="5">1519</td><td rowspan="2">1747</td><td>1463</td><td>1265</td><td>1437b</td><td>1200</td><td>71</td><td>137</td><td>51</td><td>49</td><td>81</td><td>126</td><td>223</td><td>361</td></tr>
<tr><td>EB</td><td>954</td><td>XXX</td><td>XXX</td><td>XXX</td><td>2206</td><td>95</td><td>162</td><td>XXX</td><td>XXX</td><td>XXX</td><td>121</td><td>208</td><td>333</td></tr>
<tr><td>FA</td><td>1160</td><td rowspan="3">1725</td><td>1829</td><td>1243</td><td>2374a</td><td>1720</td><td>315</td><td>253</td><td>130</td><td>154</td><td>257</td><td>297</td><td>462</td><td>615</td></tr>
<tr><td>FB</td><td>1153</td><td>XXX</td><td>XXX</td><td>XXX</td><td>2658</td><td>94</td><td rowspan="2">239</td><td>XXX</td><td>XXX</td><td>XXX</td><td>101</td><td>363</td><td>334</td></tr>
<tr><td>FY1</td><td>1387</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>864</td></tr>
<tr><td>FY2</td><td>1184</td><td>XXX</td><td>XXX</td><td>1619*</td><td>1177</td><td>2331a</td><td>XXX</td><td>XXX</td><td>153</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>342</td></tr>
<tr><td>FY3</td><td>1152</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>1923*</td><td>94*</td><td>155*</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>444*</td></tr>
<tr><td>FY4</td><td>1362</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>94*</td><td>117</td><td>325</td><td>XXX</td><td>XXX</td><td>569</td></tr>
<tr><td>FY5</td><td>1025</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td rowspan="2">150</td><td>282</td><td>382</td></tr>
<tr><td>G</td><td>866</td><td>1915</td><td>1716</td><td>1619*</td><td>1349</td><td>2355a</td><td>1923*</td><td>94*</td><td>155*</td><td>94*</td><td>21</td><td>202</td><td>453</td><td>444*</td></tr>
<tr><td>P(T)</td><td></td><td>0.32</td><td>0.99</td><td>0.72</td><td>0.97</td><td>0.03</td><td>0.10</td><td>0.27</td><td>0.23</td><td>0.59</td><td>0.31</td><td>0.37</td><td>0.30</td><td>0.38</td><td>0.25</td></tr>
<tr><td>SEM</td><td>219</td><td>355</td><td>425</td><td>314</td><td>241</td><td>228</td><td>361</td><td>87</td><td>46</td><td>53</td><td>53</td><td>96</td><td>69</td><td>105</td><td>150</td></tr>
<tr><td>Anova</td><td>N.A.</td><td>RB+C</td><td>CR+C</td><td>RB</td><td>CR</td><td>CR</td><td>CR+C</td><td>CR+C</td><td>CR+C</td><td>CR</td><td>CR</td><td>CR</td><td>RB+C</td><td>CR</td><td>CR+C</td></tr>
<tr><td>P(C)</td><td></td><td><0.01</td><td><0.01</td><td></td><td></td><td></td><td>0.04</td><td>0.07</td><td>0.04</td><td></td><td></td><td></td><td>0.04</td><td></td><td>0.04</td></tr>
<tr><td>Coeff</td><td></td><td>2.31</td><td>1.33</td><td></td><td></td><td></td><td>0.88</td><td>0.19</td><td>0.09</td><td></td><td></td><td></td><td>0.23</td><td></td><td>0.26</td></tr>
</table>

Table 0-4 Site 1 *P. effusum* pasture yields (kg/ha) in the fixed quadrats

	Recording number														
Treat.	**R1**	**R2**	**R3**	**R4**	**R5**	**R6**	**R7**	**R8**	**R9**	**R10**	**R11**	**R12**	**R13**	**R14**	**R15**
EA	86	251	337	167	171	182	161	1.0	0.9c	1.3	0	6.5	6.2	28	11
EB	51			XXX	XXX	XXX	110	0.3	6.6b	XXX	XXX	XXX	5.9	59	20
FA	72		220	132	251	237	190	0	0.3c	4.2	0.3	1.6	3.3	7	4
FB	45			XXX	XXX	XXX	108	0.3	1.7c	XXX	XXX	XXX	4.8	11	14
FY1	86			XXX	XXX	XXX	XXX	XXX		XXX	XXX	XXX	XXX	XXX	9
FY2	39	XXX	XXX	127*	229	206	XXX	XXX	12.5a	XXX	XXX	XXX	XXX	XXX	20
FY3	15	XXX	XXX	XXX	XXX	XXX	100*	1.6*	0.3c*	XXX	XXX	XXX	XXX	XXX	3*
FY4	79	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	2.8*	0.1	2.8	XXX	XXX	4
FY5	49	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	3.8	8	16
G	30	134	82	127*	139	163	100*	1.6*	0.3c*	2.8*	0	4.3		3	3*
P(T)		0.32	0.14	0.53	0.66	0.83	0.45	0.53	<0.01	0.71	0.31	0.46	0.88	0.48	0.26
SEM	29	105	102	28	72	60	43	0.9	1.9	1.7	0.2	2.2	2.5	22	6
Anova	N.A.	RB	CR	CR+C	RB+C	CR+C	RB	CR	RB	CR	CR	CR+C	CR+C	CR	RB
P(C)				<0.01	0.10	0.02						0.05	0.06		
Coeff				1.34	1.45	1.45						0.04	0.04		

Table 0-5 Site 1 *B. ewartiana* composition (%) in the fixed quadrats

<table>
<tr><th></th><th colspan="15">Recording number</th></tr>
<tr><th>Treat.</th><th>R1</th><th>R2</th><th>R3</th><th>R4</th><th>R5</th><th>R6</th><th>R7</th><th>R8</th><th>R9</th><th>R10</th><th>R11</th><th>R12</th><th>R13</th><th>R14</th><th>R15</th></tr>
<tr><td>EA</td><td>35</td><td rowspan="5">37</td><td rowspan="2">41</td><td>42</td><td>33</td><td>35</td><td>38</td><td>57</td><td>58</td><td>63</td><td>70</td><td>56</td><td>67</td><td>65</td><td>61</td></tr>
<tr><td>EB</td><td>39</td><td>XXX</td><td>XXX</td><td>XXX</td><td>33</td><td>52</td><td>52</td><td>XXX</td><td>XXX</td><td>XXX</td><td>59</td><td>50</td><td>56</td></tr>
<tr><td>FA</td><td>37</td><td rowspan="3">38</td><td>33</td><td>23</td><td>31</td><td>32</td><td>37</td><td>48</td><td>59</td><td>57</td><td>43</td><td>63</td><td>59</td><td>50</td></tr>
<tr><td>FB</td><td>38</td><td>XXX</td><td>XXX</td><td>XXX</td><td>31</td><td>51</td><td rowspan="2">40</td><td>XXX</td><td>XXX</td><td>XXX</td><td>61</td><td>57</td><td>58</td></tr>
<tr><td>FY1</td><td>32</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>39</td></tr>
<tr><td>FY2</td><td>33</td><td>XXX[3]</td><td>XXX</td><td>37*</td><td>28</td><td>26</td><td>XXX</td><td>XXX</td><td>44</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>52</td></tr>
<tr><td>FY3</td><td>35</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>32*</td><td>49*</td><td>52*</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>53*</td></tr>
<tr><td>FY4</td><td>33</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>44*</td><td>50</td><td>31</td><td>XXX</td><td>XXX</td><td>38</td></tr>
<tr><td>FY5</td><td>38</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td rowspan="2">57</td><td>60</td><td>59</td></tr>
<tr><td>G</td><td>38</td><td>40</td><td>37</td><td>37*</td><td>31</td><td>24</td><td>32*</td><td>49*</td><td>52*</td><td>44*</td><td>61</td><td>44</td><td>43</td><td>53*</td></tr>
<tr><td>P(T)[1]</td><td></td><td>0.35</td><td>0.66</td><td>0.34</td><td>0.24</td><td>0.23</td><td>0.85</td><td>0.49</td><td>0.43</td><td>0.25</td><td>0.55</td><td>0.52</td><td>0.77</td><td>0.26</td><td>0.38</td></tr>
<tr><td>SEM[2]</td><td>4</td><td>3</td><td>4</td><td>4</td><td>4</td><td>4</td><td>5</td><td>8</td><td>8</td><td>10</td><td>10</td><td>12</td><td>7</td><td>6</td><td>8</td></tr>
<tr><td>Anova[5]</td><td>N.A.[6]</td><td>RB+C</td><td>RB+C</td><td>RB</td><td>CR</td><td>RB</td><td>RB+C</td><td>RB</td><td>RB</td><td>RB</td><td>RB</td><td>CR</td><td>RB+C</td><td>RB+C</td><td>RB</td></tr>
<tr><td>P(C)[7]</td><td></td><td><0.01</td><td>0.02</td><td></td><td></td><td></td><td>0.01</td><td></td><td></td><td></td><td></td><td></td><td>0.02</td><td>0.02</td><td></td></tr>
<tr><td>Coeff[8]</td><td></td><td>0.5</td><td>0.4</td><td></td><td></td><td></td><td>0.7</td><td></td><td></td><td></td><td></td><td></td><td>0.9</td><td>0.9</td><td></td></tr>
</table>

Table 0-6 Site 1 *Aristida* spp. composition (%) in the fixed quadrats

<table>
<tr><th></th><th colspan="15">Recording number</th></tr>
<tr><th>Treat.</th><th>R1</th><th>R2</th><th>R3</th><th>R4</th><th>R5</th><th>R6</th><th>R7</th><th>R8</th><th>R9</th><th>R10</th><th>R11</th><th>R12</th><th>R13</th><th>R14</th><th>R15</th></tr>
<tr><td>EA</td><td>44</td><td rowspan="5">44</td><td rowspan="2">41</td><td>40</td><td>41</td><td>41b[4]</td><td>43</td><td>27</td><td>26</td><td>27</td><td>25</td><td>31</td><td>28</td><td>26</td><td>31</td></tr>
<tr><td>EB</td><td>39</td><td>XXX</td><td>XXX</td><td>XXX</td><td>51</td><td>31</td><td>30</td><td>XXX</td><td>XXX</td><td>XXX</td><td>29</td><td>20</td><td>27</td></tr>
<tr><td>FA</td><td>47</td><td rowspan="3">45</td><td>50</td><td>52</td><td>53ab</td><td>52</td><td>43</td><td>37</td><td>35</td><td>36</td><td>36</td><td>29</td><td>30</td><td>32</td></tr>
<tr><td>FB</td><td>48</td><td>XXX</td><td>XXX</td><td>XXX</td><td>57</td><td>36</td><td rowspan="2">49</td><td>XXX</td><td>XXX</td><td>XXX</td><td>29</td><td>31</td><td>30</td></tr>
<tr><td>FY1</td><td>49</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>55</td></tr>
<tr><td>FY2</td><td>51</td><td>XXX[3]</td><td>XXX</td><td>50*</td><td>44</td><td>54ab</td><td>XXX</td><td>XXX</td><td>38</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>32</td></tr>
<tr><td>FY3</td><td>51</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>57*</td><td>39*</td><td>40*</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>39*</td></tr>
<tr><td>FY4</td><td>54</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>43*</td><td>34</td><td>52</td><td>XXX</td><td>XXX</td><td>49</td></tr>
<tr><td>FY5</td><td>49</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td rowspan="2">31</td><td>30</td><td>29</td></tr>
<tr><td>G</td><td>51</td><td>45</td><td>49</td><td>50*</td><td>55</td><td>66a</td><td>57*</td><td>39*</td><td>40*</td><td>43*</td><td>33</td><td>49</td><td>46</td><td>39*</td></tr>
<tr><td>P(T)[1]</td><td></td><td>0.78</td><td>0.40</td><td>0.21</td><td>0.22</td><td>0.03</td><td>0.35</td><td>0.65</td><td>0.21</td><td>0.43</td><td>0.81</td><td>0.54</td><td>0.99</td><td>0.15</td><td>0.17</td></tr>
<tr><td>SEM[2]</td><td>5</td><td>6</td><td>5</td><td>5</td><td>5</td><td>5</td><td>8</td><td>12</td><td>9</td><td>12</td><td>9</td><td>12</td><td>9</td><td>6</td><td>10</td></tr>
<tr><td>Anova[5]</td><td>N.A.[6]</td><td>RB+C</td><td>RB+C</td><td>RB</td><td>CR</td><td>RB</td><td>RB</td><td>RB</td><td>RB</td><td>CR</td><td>RB</td><td>CR</td><td>RB+C</td><td>RB</td><td>RB</td></tr>
<tr><td>P(C)[7]</td><td></td><td>0.02</td><td>0.06</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>0.06</td><td></td><td></td></tr>
<tr><td>Coeff[8]</td><td></td><td>0.7</td><td>0.5</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>0.6</td><td></td><td></td></tr>
</table>

Table 0-7 Site 1 *P. effusum* composition (%) in the fixed quadrats

<table>
<tr><th></th><th colspan="15">Recording number</th></tr>
<tr><th>Treat.</th><th>R1</th><th>R2</th><th>R3</th><th>R4</th><th>R5</th><th>R6</th><th>R7</th><th>R8</th><th>R9</th><th>R10</th><th>R11</th><th>R12</th><th>R13</th><th>R14</th><th>R15</th></tr>
<tr><td>EA</td><td>3.8</td><td rowspan="5">6.9</td><td rowspan="2">7.2</td><td>4.8</td><td>9.2</td><td>4.9</td><td>5.7</td><td>0.4</td><td>0.2b</td><td>0.5</td><td>0.0</td><td>1.9</td><td>1.9</td><td>2.2</td><td>1.1</td></tr>
<tr><td>EB</td><td>2.6</td><td>XXX</td><td>XXX</td><td>XXX</td><td>2.4</td><td>0.1</td><td>1.3b</td><td>XXX</td><td>XXX</td><td>XXX</td><td>1.1</td><td>4.6</td><td>1.3</td></tr>
<tr><td>FA</td><td>2.9</td><td rowspan="3">6.5</td><td>4.0</td><td>11.1</td><td>5.2</td><td>5.8</td><td>0.0</td><td>0.0b</td><td>2.0</td><td>0.1</td><td>0.3</td><td>0.8</td><td>0.6</td><td>0.3</td></tr>
<tr><td>FB</td><td>1.6</td><td>XXX</td><td>XXX</td><td>XXX</td><td>2.2</td><td>0.1</td><td rowspan="2">0.4b</td><td>XXX</td><td>XXX</td><td>XXX</td><td>1.0</td><td>1.4</td><td>0.8</td></tr>
<tr><td>FY1</td><td>2.8</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>0.6</td></tr>
<tr><td>FY2</td><td>1.4</td><td>XXX[3]</td><td>XXX</td><td>4.0*</td><td>8.4</td><td>5.1</td><td>XXX</td><td>XXX</td><td>3.4a</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>1.6</td></tr>
<tr><td>FY3</td><td>0.6</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>3.5*</td><td>0.9*</td><td>0.1b*</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>0.6*</td></tr>
<tr><td>FY4</td><td>2.7</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>0.7*</td><td>0.1</td><td>0.4</td><td>XXX</td><td>XXX</td><td>0.3</td></tr>
<tr><td>FY5</td><td>2.7</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td rowspan="2">0.8</td><td>0.5</td><td>1.0</td></tr>
<tr><td>G</td><td>1.7</td><td>5.5</td><td>3.6</td><td>4.0*</td><td>4.4</td><td>4.5</td><td>3.5*</td><td>0.9*</td><td>0.1b*</td><td>0.7*</td><td>0.0</td><td>1.3</td><td>0.9</td><td>0.6*</td></tr>
<tr><td>P(T)[1]</td><td></td><td>0.57</td><td>0.46</td><td>0.87</td><td>0.54</td><td>0.98</td><td>0.12</td><td>0.54</td><td><0.01</td><td>0.26</td><td>0.58</td><td>0.25</td><td>0.69</td><td>0.48</td><td>0.65</td></tr>
<tr><td>SEM[2]</td><td>1.0</td><td>2</td><td>2</td><td>1</td><td>3</td><td>1</td><td>1</td><td>1</td><td>1</td><td>1</td><td>0.1</td><td>0.6</td><td>1</td><td>1.6</td><td>1</td></tr>
<tr><td>Anova[5]</td><td>N.A.[6]</td><td>CR+C</td><td>RB+C</td><td>CR+C</td><td>RB</td><td>CR+C</td><td>RB</td><td>CR</td><td>CR</td><td>CR</td><td>CR</td><td>CR+C</td><td>CR</td><td>CR+C</td><td>RB</td></tr>
<tr><td>P(C)[7]</td><td></td><td>0.01</td><td>0.03</td><td>0.04</td><td></td><td><0.01</td><td></td><td></td><td></td><td></td><td></td><td><0.01</td><td></td><td>0.05</td><td></td></tr>
<tr><td>Coeff[8]</td><td></td><td>1.3</td><td>1.2</td><td>0.7</td><td></td><td>1.0</td><td></td><td></td><td></td><td></td><td></td><td>0.4</td><td></td><td>0.7</td><td></td></tr>
</table>

Table 0-8 Site 1 ground cover (%) in the fixed quadrats

<table>
<tr><th></th><th colspan="15">Recording number</th></tr>
<tr><th>Treat.</th><th>R1</th><th>R2</th><th>R3</th><th>R4</th><th>R5</th><th>R6</th><th>R7</th><th>R8</th><th>R9</th><th>R10</th><th>R11</th><th>R12</th><th>R13</th><th>R14</th><th>R15</th></tr>
<tr><td>EA</td><td>63</td><td rowspan="5">80</td><td rowspan="2">84a[4]</td><td>83</td><td>68</td><td>85</td><td>82</td><td>33</td><td>30</td><td>31</td><td>28</td><td>24</td><td>26</td><td>29</td><td>33</td></tr>
<tr><td>EB</td><td>65</td><td>XXX</td><td>XXX</td><td>XXX</td><td>83</td><td>33</td><td>30</td><td>XXX</td><td>XXX</td><td>XXX</td><td>25</td><td>29</td><td>33</td></tr>
<tr><td>FA</td><td>63</td><td rowspan="3">83a</td><td>82</td><td>67</td><td>87</td><td>87</td><td>38</td><td>39</td><td>46</td><td>37</td><td>29</td><td>32</td><td>35</td><td>41</td></tr>
<tr><td>FB</td><td>61</td><td>XXX</td><td>XXX</td><td>XXX</td><td>86</td><td>36</td><td rowspan="2">34</td><td>XXX</td><td>XXX</td><td>XXX</td><td>35</td><td>38</td><td>43</td></tr>
<tr><td>FY1</td><td>63</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>36</td></tr>
<tr><td>FY2</td><td>63</td><td>XXX[3]</td><td>XXX</td><td>79*</td><td>74</td><td>90</td><td>XXX</td><td>XXX</td><td>36</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>45</td></tr>
<tr><td>FY3</td><td>67</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>80*</td><td>31*</td><td>29*</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>27*</td></tr>
<tr><td>FY4</td><td>61</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>40*</td><td>37</td><td>31</td><td>XXX</td><td>XXX</td><td>41</td></tr>
<tr><td>FY5</td><td>59</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td rowspan="2">25</td><td>26</td><td>28</td></tr>
<tr><td>G</td><td>53</td><td>75</td><td>74b</td><td>79*</td><td>60</td><td>80</td><td>80*</td><td>31*</td><td>29*</td><td>40*</td><td>27</td><td>21</td><td>22</td><td>27*</td></tr>
<tr><td>P(T)[1]</td><td></td><td>0.21</td><td><0.01</td><td>0.60</td><td>0.22</td><td>0.05</td><td>0.23</td><td>0.52</td><td>0.26</td><td>0.16</td><td>0.10</td><td>0.19</td><td>0.27</td><td>0.16</td><td>0.10</td></tr>
<tr><td>SEM[2]</td><td>3</td><td>3</td><td>2</td><td>3</td><td>4</td><td>2</td><td>3</td><td>3</td><td>4</td><td>5</td><td>4</td><td>3</td><td>4</td><td>4</td><td>5</td></tr>
<tr><td>Anova[5]</td><td>N.A.[6]</td><td>CR+C</td><td>RB</td><td>CR</td><td>CR</td><td>CR</td><td>RB</td><td>RB+C</td><td>CR+C</td><td>CR</td><td>CR</td><td>CR</td><td>RB</td><td>RB</td><td>CR</td></tr>
<tr><td>P(C)[7]</td><td></td><td>0.01</td><td></td><td></td><td></td><td></td><td></td><td>0.07</td><td>0.04</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Coeff[8]</td><td></td><td>0.5</td><td></td><td></td><td></td><td></td><td></td><td>0.4</td><td>0.4</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

Table 0-9 Site 1 land condition in the fixed quadrats

<table>
<tr><th></th><th colspan="15">Recording number</th></tr>
<tr><th>Treat.</th><th>R1</th><th>R2</th><th>R3</th><th>R4</th><th>R5</th><th>R6</th><th>R7</th><th>R8</th><th>R9</th><th>R10</th><th>R11</th><th>R12</th><th>R13</th><th>R14</th><th>R15</th></tr>
<tr><td>EA</td><td>2.9</td><td rowspan="5">2.5</td><td rowspan="2">2.6</td><td>2.6</td><td>2.6</td><td>2.5bc</td><td>2.5</td><td>2.9</td><td>2.6</td><td>2.9</td><td>2.8</td><td>2.7</td><td>2.6</td><td>2.7</td><td>2.8</td></tr>
<tr><td>EB</td><td>3.0</td><td>XXX</td><td>XXX</td><td>XXX</td><td>2.4</td><td>2.9</td><td>2.8</td><td>XXX</td><td>XXX</td><td>XXX</td><td>2.9</td><td>2.9</td><td>2.8</td></tr>
<tr><td>FA</td><td>3.0</td><td rowspan="3">2.5</td><td>2.6</td><td>2.6</td><td>2.4c</td><td>2.4</td><td>2.9</td><td>2.8</td><td>2.8</td><td>2.8</td><td>3.0</td><td>2.8</td><td>2.8</td><td>2.9</td></tr>
<tr><td>FB</td><td>2.9</td><td>XXX</td><td>XXX</td><td>XXX</td><td>2.6</td><td>3.0</td><td rowspan="2">2.9</td><td>XXX</td><td>XXX</td><td>XXX</td><td>2.8</td><td>2.8</td><td>2.8</td></tr>
<tr><td>FY1</td><td>2.9</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>2.9</td></tr>
<tr><td>FY2</td><td>2.9</td><td>XXX[3]</td><td>XXX</td><td>2.5*</td><td>2.5</td><td>2.6b</td><td>XXX</td><td>XXX</td><td>2.6</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>2.9</td></tr>
<tr><td>FY3</td><td>2.9</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>2.7*</td><td>3.1*</td><td>3.0*</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>3.0*</td></tr>
<tr><td>FY4</td><td>2.9</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>3.0*</td><td>3.1</td><td>3.1</td><td>XXX</td><td>XXX</td><td>3.0</td></tr>
<tr><td>FY5</td><td>2.8</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td rowspan="2">2.9</td><td>2.8</td><td>2.9</td></tr>
<tr><td>G</td><td>2.9</td><td>2.5</td><td>2.7</td><td>2.5*</td><td>2.7</td><td>2.8a</td><td>2.7*</td><td>3.1*</td><td>3.0*</td><td>3.0*</td><td>3.1</td><td>3.0</td><td>3.1</td><td>3.0*</td></tr>
<tr><td>P(T)[1]</td><td></td><td>0.99</td><td>0.14</td><td>0.78</td><td>0.58</td><td><0.01</td><td>0.27</td><td>0.49</td><td>0.06</td><td>0.31</td><td>0.24</td><td>0.34</td><td>0.46</td><td>0.37</td><td>0.79</td></tr>
<tr><td>SEM[2]</td><td>0.1</td><td>0.1</td><td>0.1</td><td>0.1</td><td>0.1</td><td>0.05</td><td>0.1</td><td>0.1</td><td>0.1</td><td>0.1</td><td>0.1</td><td>0.1</td><td>0.1</td><td>0.1</td><td>0.1</td></tr>
<tr><td>Anova[5]</td><td>N.A.[6]</td><td>CR+C</td><td>RB+C</td><td>CR</td><td>RB</td><td>RB</td><td>RB+C</td><td>RB</td><td>CR</td><td>CR+C</td><td>CR</td><td>CR</td><td>RB</td><td>RB</td><td>RB</td></tr>
<tr><td>P(C)[7]</td><td></td><td><0.01</td><td>0.01</td><td></td><td></td><td></td><td>0.09</td><td></td><td></td><td>0.07</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Coeff[8]</td><td></td><td>0.8</td><td>0.5</td><td></td><td></td><td></td><td>0.4</td><td></td><td></td><td>0.6</td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

Table 0-10 Site 1 total crown cover %

<table>
<tr><th></th><th colspan="15">Recording number</th></tr>
<tr><th>Treat.</th><th>R1</th><th>R2</th><th>R3</th><th>R4</th><th>R5</th><th>R6</th><th>R7</th><th>R8</th><th>R9</th><th>R10</th><th>R11</th><th>R12</th><th>R13</th><th>R14</th><th>R15</th></tr>
<tr><td>EA</td><td>2.56</td><td rowspan="5">4.84</td><td rowspan="2">3.90a[4]</td><td>3.78</td><td>4.17</td><td>4.30</td><td>4.04a</td><td>1.92</td><td>2.54</td><td>1.90</td><td>1.67</td><td>2.51</td><td>1.80</td><td>1.88</td><td>2.03</td></tr>
<tr><td>EB</td><td>2.30</td><td>XXX</td><td>XXX</td><td>XXX</td><td>4.71a</td><td>1.99</td><td>2.35</td><td>XXX</td><td>XXX</td><td>XXX</td><td>1.79</td><td>1.88</td><td>1.96</td></tr>
<tr><td>FA</td><td>2.18</td><td rowspan="3">4.04a</td><td>4.22</td><td>4.67</td><td>4.65</td><td>4.42a</td><td>2.59</td><td>3.39</td><td>2.48</td><td>2.34</td><td>2.97</td><td>2.26</td><td>2.34</td><td>2.24</td></tr>
<tr><td>FB</td><td>2.33</td><td>XXX</td><td>XXX</td><td>XXX</td><td>3.80ab</td><td>2.11</td><td rowspan="2">2.95</td><td>XXX</td><td>XXX</td><td>XXX</td><td>2.08</td><td>2.14</td><td>2.21</td></tr>
<tr><td>FY1</td><td>2.77</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>2.56</td></tr>
<tr><td>FY2</td><td>2.67</td><td>XXX[3]</td><td>XXX</td><td>3.28*</td><td>4.29</td><td>3.87</td><td>XXX</td><td>XXX</td><td>2.67</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>1.76</td></tr>
<tr><td>FY3</td><td>3.69</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>3.07*b</td><td>1.50*</td><td rowspan="4">2.39</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>1.74*</td></tr>
<tr><td>FY4</td><td>3.56</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>1.90*</td><td>1.69</td><td>1.65</td><td>XXX</td><td>XXX</td><td>1.84</td></tr>
<tr><td>FY5</td><td>3.38</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td rowspan="2">1.64</td><td>2.30</td><td>2.04</td></tr>
<tr><td>G</td><td>2.99</td><td>4.17</td><td>2.64b</td><td>3.28*</td><td>3.20</td><td>3.30</td><td>3.07*b</td><td>1.50*</td><td>1.90*</td><td>1.42</td><td>1.64</td><td>1.71</td><td>1.74*</td></tr>
<tr><td>P(T)[1]</td><td></td><td>0.22</td><td><0.01</td><td>0.20</td><td>0.13</td><td>0.24</td><td>0.03</td><td>0.27</td><td>0.44</td><td>0.43</td><td>0.34</td><td>0.06</td><td>0.38</td><td>0.36</td><td>0.73</td></tr>
<tr><td>SEM[2]</td><td>0.50</td><td>0.48</td><td>0.28</td><td>0.39</td><td>0.38</td><td>0.44</td><td>0.37</td><td>0.38</td><td>0.46</td><td>0.38</td><td>0.35</td><td>0.34</td><td>0.26</td><td>0.23</td><td>0.35</td></tr>
<tr><td>Anova[5]</td><td>N.A.[6]</td><td>RB+C</td><td>RB+C</td><td>CR+C</td><td>RB+C</td><td>CR+C</td><td>RB+C</td><td>CR</td><td>CR+C</td><td>CR</td><td>CR</td><td>CR+C</td><td>RB</td><td>RB</td><td>RB</td></tr>
<tr><td>P(C)[7]</td><td></td><td><0.01</td><td><0.01</td><td>0.01</td><td>0.02</td><td>0.05</td><td><0.01</td><td></td><td>0.09</td><td></td><td></td><td>0.07</td><td></td><td></td><td></td></tr>
<tr><td>Coeff[8]</td><td></td><td>1.49</td><td>0.91</td><td>0.65</td><td>0.74</td><td>0.55</td><td>0.69</td><td></td><td>0.28</td><td></td><td></td><td>0.32</td><td></td><td></td><td></td></tr>
</table>

Table 0-11 Site 1 *B. ewartiana* crown cover %

<table>
<tr><td></td><td colspan="15">Recording number</td></tr>
<tr><td>Treat.</td><td>R1</td><td>R2</td><td>R3</td><td>R4</td><td>R5</td><td>R6</td><td>R7</td><td>R8</td><td>R9</td><td>R10</td><td>R11</td><td>R12</td><td>R13</td><td>R14</td><td>R15</td></tr>
<tr><td>EA</td><td>108</td><td rowspan="5">2.22a</td><td rowspan="2">1.73a</td><td>1.55ab</td><td>1.64a</td><td>1.66</td><td>1.61</td><td>1.32</td><td>1.82</td><td>1.23</td><td>1.13</td><td>1.75</td><td>1.38</td><td>1.59</td><td>1.36</td></tr>
<tr><td>EB</td><td>1.34</td><td>XXX</td><td>XXX</td><td>XXX</td><td>1.57</td><td>0.95</td><td>1.04</td><td>XXX</td><td>XXX</td><td>XXX</td><td>1.00</td><td>1.09</td><td>0.95</td></tr>
<tr><td>FA</td><td>1.08</td><td rowspan="3">1.71a</td><td>1.78a</td><td>1.90a</td><td>1.88</td><td>1.70</td><td>1.48</td><td>1.84</td><td>1.32</td><td>1.32</td><td>1.88</td><td>1.50</td><td>1.70</td><td>1.28</td></tr>
<tr><td>FB</td><td>1.43</td><td>XXX</td><td>XXX</td><td>XXX</td><td>1.46</td><td>1.31</td><td rowspan="2">1.42</td><td>XXX</td><td>XXX</td><td>XXX</td><td>1.35</td><td>1.45</td><td>1.49</td></tr>
<tr><td>FY1</td><td>1.20</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>0.95</td></tr>
<tr><td>FY2</td><td>1.63</td><td>XXX[3]</td><td>XXX</td><td>1.27*b</td><td>1.60a</td><td>1.29</td><td>XXX</td><td>XXX</td><td>1.38</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>1.05</td></tr>
<tr><td>FY3</td><td>1.68</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>1.11*</td><td>0.77*</td><td rowspan="4">1.48</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>1.12*</td></tr>
<tr><td>FY4</td><td>1.87</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>0.95*</td><td>0.73</td><td>0.79</td><td>XXX</td><td>XXX</td><td>0.69</td></tr>
<tr><td>FY5</td><td>1.95</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td rowspan="2">0.86</td><td>1.24</td><td>1.36</td></tr>
<tr><td>G</td><td>1.40</td><td>1.86b</td><td>0.99b</td><td>1.27*b</td><td>1.17b</td><td>1.05</td><td>1.11*</td><td>0.77*</td><td>0.95*</td><td>0.84</td><td>1.04</td><td>0.93</td><td>1.12*</td></tr>
<tr><td>P(T)[1]</td><td></td><td>0.04</td><td><0.01</td><td>0.02</td><td>0.02</td><td>0.07</td><td>0.26</td><td>0.84</td><td>0.66</td><td>0.55</td><td>0.51</td><td>0.38</td><td>0.55</td><td>0.61</td><td>0.69</td></tr>
<tr><td>SEM[2]</td><td>0.36</td><td>0.15</td><td>0.15</td><td>0.13</td><td>0.14</td><td>0.20</td><td>0.22</td><td>0.30</td><td>0.38</td><td>0.29</td><td>0.30</td><td>0.18</td><td>0.34</td><td>0.35</td><td>0.31</td></tr>
<tr><td>Anova[5]</td><td>N.A.[6]</td><td>RB+C</td><td>RB+C</td><td>CR+C</td><td>CR+C</td><td>CR+C</td><td>RB+C</td><td>CR+C</td><td>CR+C</td><td>RB</td><td>CR</td><td>RB</td><td>CR+C</td><td>CR+C</td><td>RB</td></tr>
<tr><td>P(C)[7]</td><td></td><td><0.01</td><td><0.01</td><td><0.01</td><td><0.01</td><td>0.01</td><td><0.01</td><td>0.06</td><td>0.01</td><td></td><td></td><td></td><td>0.05</td><td>0.02</td><td></td></tr>
<tr><td>Coeff[8]</td><td></td><td>1.4</td><td>1.0</td><td>1.0</td><td>0.8</td><td>0.7</td><td>0.7</td><td>0.5</td><td>0.5</td><td></td><td></td><td></td><td>0.7</td><td>0.9</td><td></td></tr>
</table>

Table 0-12 Site 1 *Aristida* spp. crown cover %

<table>
<tr><th></th><th colspan="15">Recording number</th></tr>
<tr><th>Treat.</th><th>R1</th><th>R2</th><th>R3</th><th>R4</th><th>R5</th><th>R6</th><th>R7</th><th>R8</th><th>R9</th><th>R10</th><th>R11</th><th>R12</th><th>R13</th><th>R14</th><th>R15</th></tr>
<tr><td>EA</td><td>1.11</td><td rowspan="5">2.12</td><td rowspan="2">1.54</td><td>1.57</td><td>1.75</td><td>1.85</td><td>1.64</td><td>0.58</td><td>0.67</td><td>0.56</td><td>0.47</td><td>0.48</td><td>0.44</td><td>0.40</td><td>0.44</td></tr>
<tr><td>EB</td><td>0.64</td><td>XXX</td><td>XXX</td><td>XXX</td><td>2.04</td><td>0.65</td><td>0.66</td><td>XXX</td><td>XXX</td><td>XXX</td><td>0.43</td><td>0.37</td><td>0.49</td></tr>
<tr><td>FA</td><td>0.96</td><td rowspan="3">2.02</td><td>1.88</td><td>2.12</td><td>2.06</td><td>1.98</td><td>0.94</td><td>1.14</td><td>0.88</td><td>0.77</td><td>0.62</td><td>0.71</td><td>0.64</td><td>0.71</td></tr>
<tr><td>FB</td><td>0.75</td><td>XXX</td><td>XXX</td><td>XXX</td><td>1.70</td><td>0.62</td><td rowspan="2">1.35</td><td>XXX</td><td>XXX</td><td>XXX</td><td>0.49</td><td>0.50</td><td>0.56</td></tr>
<tr><td>FY1</td><td>1.43</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>1.48</td></tr>
<tr><td>FY2</td><td>0.97</td><td>XXX[3]</td><td>XXX</td><td>1.74*</td><td>1.97</td><td>1.87</td><td>XXX</td><td>XXX</td><td>0.88</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>0.48</td></tr>
<tr><td>FY3</td><td>1.97</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>2.06*</td><td>0.57*</td><td rowspan="4">0.83</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>0.57*</td></tr>
<tr><td>FY4</td><td>1.64</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>0.85*</td><td>0.83</td><td>0.96</td><td>XXX</td><td>XXX</td><td>0.91</td></tr>
<tr><td>FY5</td><td>1.40</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td rowspan="2">0.51</td><td>0.44</td><td>0.54</td></tr>
<tr><td>G</td><td>1.55</td><td>2.06</td><td>1.41</td><td>1.74*</td><td>2.07</td><td>2.19</td><td>2.06*</td><td>0.57*</td><td>0.85*</td><td>0.55</td><td>0.63</td><td>0.72</td><td>0.57*</td></tr>
<tr><td>P(T)[1]</td><td></td><td>0.90</td><td>0.12</td><td>0.62</td><td>0.42</td><td>0.70</td><td>0.43</td><td>0.53</td><td>0.18</td><td>0.37</td><td>0.34</td><td>0.66</td><td>0.83</td><td>0.73</td><td>0.14</td></tr>
<tr><td>SEM[2]</td><td>0.35</td><td>0.40</td><td>0.30</td><td>0.22</td><td>0.16</td><td>0.23</td><td>0.21</td><td>0.18</td><td>0.27</td><td>0.13</td><td>0.16</td><td>0.27</td><td>0.18</td><td>0.19</td><td>0.26</td></tr>
<tr><td>Anova[5]</td><td>N.A.[6]</td><td>RB+C</td><td>RB+C</td><td>CR</td><td>RB</td><td>RB</td><td>RB</td><td>CR</td><td>RB</td><td>CR</td><td>CR</td><td>CR</td><td>CR</td><td>CR</td><td>CR</td></tr>
<tr><td>P(C)[7]</td><td></td><td><0.01</td><td><0.01</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Coeff[8]</td><td></td><td>1.29</td><td>0.86</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

Table 0-13 Site 1 *P. effusum* crown cover %

<table>
<tr><th></th><th colspan="15">Recording number</th></tr>
<tr><th>Treat.</th><th>R1</th><th>R2</th><th>R3</th><th>R4</th><th>R5</th><th>R6</th><th>R7</th><th>R8</th><th>R9</th><th>R10</th><th>R11</th><th>R12</th><th>R13</th><th>R14</th><th>R15</th></tr>
<tr><td>EA</td><td>0.038</td><td rowspan="5">0.175</td><td rowspan="2">0.186</td><td>0.036</td><td>0.206</td><td>0.211</td><td>0.182</td><td>0.016</td><td>0.013</td><td>0.004</td><td>0.003</td><td>0.018</td><td>0.050</td><td>0.018</td><td>0.020</td></tr>
<tr><td>EB</td><td>0.032</td><td>XXX</td><td>XXX</td><td>XXX</td><td>0.140</td><td>0.034</td><td>0.022</td><td>XXX</td><td>XXX</td><td>XXX</td><td>0.042</td><td>0.029</td><td>0.028</td></tr>
<tr><td>FA</td><td>0.029</td><td rowspan="3">0.140</td><td>0.151</td><td>0.151</td><td>0.194</td><td>0.198</td><td>0.008</td><td>0.013</td><td>0.007</td><td>0.003</td><td>0.009</td><td>0.020</td><td>0.003</td><td>0.003</td></tr>
<tr><td>FB</td><td>0.012</td><td>XXX</td><td>XXX</td><td>XXX</td><td>0.164</td><td>0.006</td><td rowspan="2">0.016</td><td>XXX</td><td>XXX</td><td>XXX</td><td>0.012</td><td>0.008</td><td>0.011</td></tr>
<tr><td>FY1</td><td>0.021</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>0.008</td></tr>
<tr><td>FY2</td><td>0.019</td><td>XXX[3]</td><td>XXX</td><td>0.109*</td><td>0.203</td><td>0.247</td><td>XXX</td><td>XXX</td><td>0.015</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>0.020</td></tr>
<tr><td>FY3</td><td>0.007</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>0.147*</td><td>0.013*</td><td rowspan="4">0.006</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>0.007*</td></tr>
<tr><td>FY4</td><td>0.016</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>0.005*</td><td>0.001</td><td>0.004</td><td>XXX</td><td>XXX</td><td>0.003</td></tr>
<tr><td>FY5</td><td>0.033</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td rowspan="2">0.017</td><td>0.020</td><td>0.019</td></tr>
<tr><td>G</td><td>0.039</td><td>0.133</td><td>0.085</td><td>0.109*</td><td>0.107</td><td>0.137</td><td>0.147*</td><td>0.013*</td><td>0.005*</td><td>0.002</td><td>0.005</td><td>0.004</td><td>0.007*</td></tr>
<tr><td>P(T)[1]</td><td></td><td>0.66</td><td>0.34</td><td>0.10</td><td>0.50</td><td>0.56</td><td>0.89</td><td>0.46</td><td>0.73</td><td>0.82</td><td>0.78</td><td>0.34</td><td>0.18</td><td>0.43</td><td>0.36</td></tr>
<tr><td>SEM[2]</td><td>0.013</td><td>0.085</td><td>0.057</td><td>0.042</td><td>0.051</td><td>0.053</td><td>0.049</td><td>0.012</td><td>0.010</td><td>0.003</td><td>0.002</td><td>0.005</td><td>0.013</td><td>0.010</td><td>0.008</td></tr>
<tr><td>Anova[5]</td><td>N.A.[6]</td><td>RB</td><td>RB+C</td><td>RB+C</td><td>RB+C</td><td>CR+C</td><td>CR+C</td><td>CR+C</td><td>CR</td><td>RB+C</td><td>CR+C</td><td>RB+C</td><td>CR</td><td>CR</td><td>CR</td></tr>
<tr><td>P(C)[7]</td><td></td><td></td><td>0.08</td><td><0.01</td><td>0.02</td><td>0.01</td><td><0.01</td><td>0.07</td><td></td><td>0.01</td><td>0.07</td><td>0.08</td><td></td><td></td><td></td></tr>
<tr><td>Coeff[8]</td><td></td><td></td><td>1.76</td><td>2.88</td><td>2.53</td><td>2.49</td><td>2.29</td><td>0.32</td><td></td><td>0.16</td><td>0.05</td><td>0.19</td><td></td><td></td><td></td></tr>
</table>

Table 0-14 Site 1 *B. ewartiana* crown cover % ($x10^{-3}$) of the surviving February 2011 cohort

<table>
<tr><td></td><td colspan="14">Recording number</td></tr>
<tr><td>Treat.</td><td>R2</td><td>R3</td><td>R4</td><td>R5</td><td>R6</td><td>R7</td><td>R8</td><td>R9</td><td>R10</td><td>R11</td><td>R12</td><td>R13</td><td>R14</td><td>R15</td></tr>
<tr><td>EA</td><td rowspan="5">21</td><td rowspan="2">24</td><td>9</td><td>12</td><td>18</td><td>11</td><td>20b[4]</td><td>41</td><td>30</td><td>32</td><td>57</td><td>44</td><td>52</td><td>38</td></tr>
<tr><td>EB</td><td>XXX</td><td>XXX</td><td>XXX</td><td>65</td><td>80a</td><td>72</td><td>XXX</td><td>XXX</td><td>XXX</td><td>68</td><td>64</td><td>77</td></tr>
<tr><td>FA</td><td rowspan="3">17</td><td>6</td><td>7</td><td>16</td><td>18</td><td>22b</td><td>22</td><td>22</td><td>20</td><td>21</td><td>17</td><td>28</td><td>27</td></tr>
<tr><td>FB</td><td>XXX</td><td>XXX</td><td>XXX</td><td>34</td><td>42ab</td><td rowspan="2">30</td><td>XXX</td><td>XXX</td><td>XXX</td><td>62</td><td>96</td><td>78</td></tr>
<tr><td>FY1</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>4</td></tr>
<tr><td>G</td><td>3</td><td>4</td><td>3</td><td>2</td><td>2</td><td>1</td><td>1b</td><td>2</td><td>1</td><td>1</td><td>1</td><td>3</td><td>3</td><td>3</td></tr>
<tr><td>P(T)[1]</td><td>0.24</td><td>0.40</td><td>0.62</td><td>0.49</td><td>0.41</td><td>0.08</td><td>0.04</td><td>0.16</td><td>0.45</td><td>0.44</td><td>0.33</td><td>0.11</td><td>0.23</td><td>0.07</td></tr>
<tr><td>SEM[2]</td><td>13</td><td>11</td><td>4</td><td>5</td><td>9</td><td>15</td><td>16</td><td>19</td><td>16</td><td>17</td><td>25</td><td>19</td><td>28</td><td>21</td></tr>
<tr><td>Anova[5]</td><td>RB</td><td>RB</td><td>CR</td><td>RB</td><td>CR</td><td>RB</td><td>RB</td><td>RB</td><td>CR</td><td>CR</td><td>CR</td><td>RB</td><td>RB</td><td>RB</td></tr>
</table>

Table 0-15 Site 1 *B. ewartiana* survival (plants/m^2) of the February 2011 cohort

<table>
<tr><th></th><th colspan="14">Recording number</th></tr>
<tr><th>Treat.</th><th>R2</th><th>R3</th><th>R4</th><th>R5</th><th>R6</th><th>R7</th><th>R8</th><th>R9</th><th>R10</th><th>R11</th><th>R12</th><th>R13</th><th>R14</th><th>R15</th></tr>
<tr><td>EA</td><td rowspan="5">1.0</td><td rowspan="2">1.0</td><td>1.2</td><td>1.0</td><td>0.9</td><td>0.9ab[4]</td><td>0.8</td><td>0.8a</td><td>0.8</td><td>0.8</td><td>0.8</td><td>0.8</td><td>0.8</td><td>0.8a</td></tr>
<tr><td>EB</td><td>XXX</td><td>XXX</td><td>XXX</td><td>0.8ab</td><td>0.5</td><td>0.5abc</td><td>XXX</td><td>XXX</td><td>XXX</td><td>0.5</td><td>0.5</td><td>0.5ab</td></tr>
<tr><td>FA</td><td rowspan="3">0.9</td><td>0.5</td><td>0.5</td><td>0.5</td><td>0.5b</td><td>0.4</td><td>0.4abc</td><td>0.4</td><td>0.4</td><td>0.4</td><td>0.4</td><td>0.4</td><td>0.4ab</td></tr>
<tr><td>FB</td><td>XXX</td><td>XXX</td><td>XXX</td><td>1.7a</td><td>1.0</td><td rowspan="2">0.5ab</td><td>XXX</td><td>XXX</td><td>XXX</td><td>0.8</td><td>0.8</td><td>0.8a</td></tr>
<tr><td>FY1</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>0.1b</td></tr>
<tr><td>FY2</td><td>XXX[3]</td><td>XXX</td><td>0.2*</td><td>0.0</td><td>0.0</td><td>XXX</td><td>XXX</td><td>0.0bd</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>0.0b</td></tr>
<tr><td>FY3</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>0.1b*</td><td>0.0*</td><td rowspan="4">0.02cd</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>0.0b*</td></tr>
<tr><td>FY4</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>0.0*</td><td>0.0</td><td>0.0</td><td>XXX</td><td>XXX</td><td>0.0b</td></tr>
<tr><td>FY5</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td rowspan="2">0.04</td><td>0.0</td><td>0.0b</td></tr>
<tr><td>G</td><td>0.5</td><td>0.5</td><td>0.2*</td><td>0.2</td><td>0.2</td><td>0.1b*</td><td>0.0*</td><td>0.0*</td><td>0.1</td><td>0.1</td><td>0.1</td><td>0.0b*</td></tr>
<tr><td>P(T)[1]</td><td>0.38</td><td>0.67</td><td>0.23</td><td>0.31</td><td>0.38</td><td>0.02</td><td>0.10</td><td>0.03</td><td>0.13</td><td>0.27</td><td>0.26</td><td>0.14</td><td>0.25</td><td>0.04</td></tr>
<tr><td>SEM[2]</td><td>0.5</td><td>0.5</td><td>0.4</td><td>0.4</td><td>0.4</td><td>0.4</td><td>0.3</td><td>0.2</td><td>0.3</td><td>0.3</td><td>0.3</td><td>0.3</td><td>0.3</td><td>0.2</td></tr>
<tr><td>Anova[5]</td><td>RB</td><td>RB</td><td>RB</td><td>RB</td><td>RB</td><td>RB</td><td>RB</td><td>RB</td><td>RB</td><td>RB</td><td>CR</td><td>RB</td><td>RB</td><td>RB</td></tr>
</table>

Table 0-16 Site 1 *B. ewartiana* plant density (plants/m^2)

<table>
<tr><th></th><th colspan="15">Recording number</th></tr>
<tr><th>Treat.</th><th>R1</th><th>R2</th><th>R3</th><th>R4</th><th>R5</th><th>R6</th><th>R7</th><th>R8</th><th>R9</th><th>R10</th><th>R11</th><th>R12</th><th>R13</th><th>R14</th><th>R15</th></tr>
<tr><td>EA</td><td>2.00</td><td rowspan="5">3.05</td><td rowspan="2">6.21</td><td>5.75</td><td>7.08</td><td>7.58</td><td>7.50</td><td>4.67</td><td>4.83</td><td>4.83</td><td>4.83</td><td>5.00</td><td>5.92</td><td>5.17</td><td>6.00</td></tr>
<tr><td>EB</td><td>1.92</td><td>XXX</td><td>XXX</td><td>XXX</td><td>10.33</td><td>8.00</td><td>7.67</td><td>XXX</td><td>XXX</td><td>XXX</td><td>8.75</td><td>7.17</td><td>8.25</td></tr>
<tr><td>FA</td><td>2.17</td><td rowspan="3">5.25</td><td>5.17</td><td>7.08</td><td>8.08</td><td>8.00</td><td>4.00</td><td>3.92</td><td>3.92</td><td>3.92</td><td>3.92</td><td>5.00</td><td>5.58</td><td>6.17</td></tr>
<tr><td>FB</td><td>2.08</td><td>XXX</td><td>XXX</td><td>XXX</td><td>6.58</td><td>4.58</td><td rowspan="2">4.96</td><td>XXX</td><td>XXX</td><td>XXX</td><td>5.33</td><td>6.00</td><td>5.17</td></tr>
<tr><td>FY1</td><td>2.25</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>5.08</td></tr>
<tr><td>FY2</td><td>1.92</td><td>XXX[3]</td><td>XXX</td><td>4.21*</td><td>5.33</td><td>6.58</td><td>XXX</td><td>XXX</td><td>4.25</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>4.67</td></tr>
<tr><td>FY3</td><td>2.00</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>6.13*</td><td>4.08*</td><td>3.83*</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>4.12*</td></tr>
<tr><td>FY4</td><td>2.00</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>3.67</td><td>3.71*</td><td>3.92</td><td>3.75</td><td>XXX</td><td>XXX</td><td>4.25</td></tr>
<tr><td>FY5</td><td>1.83</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>4.58</td><td>XXX</td><td>XXX</td><td>XXX</td><td rowspan="2">4.58</td><td>5.92</td><td>5.67</td></tr>
<tr><td>G</td><td>2.00</td><td>2.50</td><td>3.92</td><td>4.21*</td><td>6.83</td><td>7.50</td><td>6.13*</td><td>4.08*</td><td>3.83*</td><td>3.71*</td><td>3.42</td><td>3.33</td><td>3.92</td><td>4.12*</td></tr>
<tr><td>P(T)[1]</td><td></td><td>0.36</td><td>0.36</td><td>0.18</td><td>0.21</td><td>0.34</td><td>0.27</td><td>0.10</td><td>0.08</td><td>0.17</td><td>0.33</td><td>0.32</td><td>0.14</td><td>0.33</td><td>0.30</td></tr>
<tr><td>SEM[2]</td><td>0.13</td><td>0.53</td><td>0.81</td><td>0.65</td><td>0.62</td><td>0.55</td><td>1.52</td><td>1.14</td><td>0.93</td><td>0.45</td><td>0.52</td><td>0.62</td><td>1.25</td><td>0.95</td><td>1.19</td></tr>
<tr><td>Anova[5]</td><td>N.A.[6]</td><td>RB</td><td>RB</td><td>RB</td><td>RB</td><td>RB</td><td>CR</td><td>RB</td><td>RB</td><td>RB</td><td>RB</td><td>CR</td><td>RB</td><td>RB</td><td>RB</td></tr>
<tr><td>P(C)[7]</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Coeff[8]</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

Table 0-17 Site 1 *Aristida* spp. plant density (plants/m^2)

<table>
<tr><th></th><th colspan="15">Recording number</th></tr>
<tr><th>Treat.</th><th>R1</th><th>R2</th><th>R3</th><th>R4</th><th>R5</th><th>R6</th><th>R7</th><th>R8</th><th>R9</th><th>R10</th><th>R11</th><th>R12</th><th>R13</th><th>R14</th><th>R15</th></tr>
<tr><td>EA</td><td>13.8</td><td rowspan="5">13.3</td><td rowspan="2">13.7</td><td>18.1</td><td>22.6</td><td>22.7bc[4]</td><td>22.3b</td><td>12.9</td><td>12.8</td><td>12.3</td><td>11.8</td><td>9.4</td><td>18.8</td><td>16.5</td><td>17.3</td></tr>
<tr><td>EB</td><td>9.6</td><td>XXX</td><td>XXX</td><td>XXX</td><td>18.3b</td><td>9.1</td><td>9.1</td><td>XXX</td><td>XXX</td><td>XXX</td><td>17.8</td><td>14.3</td><td>15.8</td></tr>
<tr><td>FA</td><td>12.3</td><td rowspan="3">14.2</td><td>18.9</td><td>21.3</td><td>24.2b</td><td>22.9ab</td><td>14.8</td><td>15.6</td><td>14.8</td><td>14.1</td><td>12.3</td><td>16.6</td><td>12.8</td><td>13.6</td></tr>
<tr><td>FB</td><td>15.6</td><td>XXX</td><td>XXX</td><td>XXX</td><td>18.0b</td><td>13.9</td><td rowspan="2">16.4</td><td>XXX</td><td>XXX</td><td>XXX</td><td>18.8</td><td>19.1</td><td>18.7</td></tr>
<tr><td>FY1</td><td>14.2</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>15.5</td></tr>
<tr><td>FY2</td><td>14.8</td><td>XXX[3]</td><td>XXX</td><td>19.3*</td><td>19.1</td><td>21.2c</td><td>XXX</td><td>XXX</td><td>13.9</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>14.8</td></tr>
<tr><td>FY3</td><td>12.2</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>29.4*a</td><td>15.5*</td><td>15.6*</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>14.1*</td></tr>
<tr><td>FY4</td><td>15.8</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>16.7</td><td>18.2*</td><td>16.9</td><td>13.9</td><td>XXX</td><td>XXX</td><td>16.2</td></tr>
<tr><td>FY5</td><td>14.3</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>15.0</td><td>XXX</td><td>XXX</td><td>XXX</td><td rowspan="2">20.9</td><td>15.8</td><td>17.3</td></tr>
<tr><td>G</td><td>16.8</td><td>14.0</td><td>15.1</td><td>19.3*</td><td>24.8</td><td>30.5a</td><td>29.4*a</td><td>15.5*</td><td>15.6*</td><td>18.2*</td><td>16.8</td><td>14.8</td><td>18.3</td><td>14.1*</td></tr>
<tr><td>P(T)[1]</td><td></td><td>0.10</td><td>0.29</td><td>0.82</td><td>0.22</td><td><0.01</td><td>0.01</td><td>0.56</td><td>0.59</td><td>0.29</td><td>0.59</td><td>0.41</td><td>0.80</td><td>0.57</td><td>0.91</td></tr>
<tr><td>SEM[2]</td><td>2.5</td><td>0.37</td><td>0.65</td><td>1.66</td><td>1.8</td><td>0.8</td><td>2.6</td><td>3.1</td><td>2.9</td><td>2.9</td><td>3.0</td><td>2.3</td><td>3.0</td><td>2.7</td><td>2.8</td></tr>
<tr><td>Anova[5]</td><td>N.A.[6]</td><td>RB+C</td><td>CR+C</td><td>CR+C</td><td>RB+C</td><td>RB+C</td><td>RB+C</td><td>RB</td><td>RB</td><td>RB</td><td>CR</td><td>CR</td><td>RB</td><td>RB</td><td>RB</td></tr>
<tr><td>P(C)[7]</td><td></td><td><0.01</td><td><0.01</td><td><0.01</td><td><0.01</td><td><0.01</td><td>0.02</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Coeff[8]</td><td></td><td>0.9</td><td>0.9</td><td>1.1</td><td>1.0</td><td>1.1</td><td>0.7</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

Table 0-18 Site 1 *P. effusum* plant density (plants/m²)

<table>
<tr><th></th><th colspan="15">Recording number</th></tr>
<tr><th>Treat.</th><th>R1</th><th>R2</th><th>R3</th><th>R4</th><th>R5</th><th>R6</th><th>R7</th><th>R8</th><th>R9</th><th>R10</th><th>R11</th><th>R12</th><th>R13</th><th>R14</th><th>R15</th></tr>
<tr><td>EA</td><td>1.67</td><td rowspan="5">2.11</td><td rowspan="2">2.16</td><td>2.94</td><td>2.94</td><td>3.19</td><td>2.89</td><td>0.82</td><td>0.92</td><td>0.42</td><td>0.33</td><td>1.75</td><td>6.17</td><td>1.67</td><td>1.50</td></tr>
<tr><td>EB</td><td>1.75</td><td>XXX</td><td>XXX</td><td>XXX</td><td>2.18</td><td>0.61</td><td>0.97</td><td>XXX</td><td>XXX</td><td>XXX</td><td>4.92</td><td>2.17</td><td>1.83</td></tr>
<tr><td>FA</td><td>2.42</td><td rowspan="3">2.79</td><td>3.59</td><td>3.81</td><td>4.00</td><td>3.58</td><td>0.34</td><td>0.40</td><td>0.29</td><td>0.12</td><td>1.08</td><td>2.50</td><td>0.42</td><td>0.42</td></tr>
<tr><td>FB</td><td>1.17</td><td>XXX</td><td>XXX</td><td>XXX</td><td>2.40</td><td>0.34</td><td rowspan="2">0.80</td><td>XXX</td><td>XXX</td><td>XXX</td><td>1.25</td><td>0.75</td><td>0.75</td></tr>
<tr><td>FY1</td><td>1.92</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>0.42</td></tr>
<tr><td>FY2</td><td>1.33</td><td>XXX[3]</td><td>XXX</td><td>2.28*</td><td>2.83</td><td>2.93</td><td>XXX</td><td>XXX</td><td>0.79</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>0.92</td></tr>
<tr><td>FY3</td><td>0.83</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>2.47*</td><td>0.78*</td><td>0.72*</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>0.67*</td></tr>
<tr><td>FY4</td><td>1.50</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>0.31</td><td>0.44*</td><td>0.11</td><td>0.17</td><td>XXX</td><td>XXX</td><td>0.33</td></tr>
<tr><td>FY5</td><td>3.08</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>0.00</td><td>XXX</td><td>XXX</td><td>XXX</td><td rowspan="2">2.08</td><td>1.00</td><td>0.92</td></tr>
<tr><td>G</td><td>1.08</td><td>1.79</td><td>1.91</td><td>2.28*</td><td>2.18</td><td>2.30</td><td>2.47*</td><td>0.78*</td><td>0.72*</td><td>0.44*</td><td>0.44</td><td>0.83</td><td>0.42</td><td>0.67*</td></tr>
<tr><td>P(T)[1]</td><td></td><td>0.29</td><td>0.13</td><td>0.21</td><td>0.42</td><td>0.36</td><td>0.25</td><td>0.35</td><td>0.16</td><td>0.86</td><td>0.24</td><td>0.54</td><td>0.17</td><td>0.27</td><td>0.48</td></tr>
<tr><td>SEM[2]</td><td>0.67</td><td>0.26</td><td>0.42</td><td>0.56</td><td>0.62</td><td>0.61</td><td>0.45</td><td>0.23</td><td>0.31</td><td>0.23</td><td>0.13</td><td>0.75</td><td>1.61</td><td>0.60</td><td>0.52</td></tr>
<tr><td>Anova[5]</td><td>N.A.[6]</td><td>CR+C</td><td>CR+C</td><td>CR+C</td><td>CR+C</td><td>CR+C</td><td>CR+C</td><td>BR+C</td><td>RB+C</td><td>CR+C</td><td>CR+C</td><td>CR</td><td>CR</td><td>CR</td><td>CR</td></tr>
<tr><td>P(C)[7]</td><td></td><td><0.01</td><td><0.01</td><td><0.01</td><td><0.01</td><td><0.01</td><td><0.01</td><td><0.01</td><td><0.01</td><td>0.01</td><td><0.01</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Coeff[8]</td><td></td><td>1.1</td><td>1.3</td><td>1.5</td><td>1.4</td><td>1.5</td><td>1.5</td><td>0.5</td><td>0.4</td><td>0.3</td><td>0.2</td><td></td><td></td><td></td><td></td></tr>
</table>

Table 0-19 Site 1 *B. ewartiana* recruitments (plants/m^2)

	Recording number														
Treat.	**R1**	**R2**	**R3**	**R4**	**R5**	**R6**	**R7**	**R8**	**R9**	**R10**	**R11**	**R12**	**R13**	**R14**	**R15**
EA	2.00	1.02	2.25	1.17	1.92	1.42	0.08b[4]	0.42	0.17b	0.17	0.00	0.82	1.00	0.83	0.92
EB	1.92			XXX	XXX	XXX	5.25a	1.17	0.17b	XXX	XXX	XXX	2.75	1.07	1.33
FA	2.17		2.25	0.92	2.33	1.58	0.08b	0.50	0.00cd	0.00	0.00	0.22	1.42	1.36	1.42
FB	2.08			XXX	XXX	XXX	1.67b	0.50	0.88bc	XXX	XXX	XXX	0.92	1.01	0.25
FY1	2.25			XXX	XXX	XXX	XXX	XXX		XXX	XXX	XXX	XXX	XXX	1.42
FY2	1.92	XXX[3]	XXX	1.42*	1.92	1.42	XXX	XXX	0.25cd	XXX	XXX	XXX	XXX	XXX	1.50
FY3	2.00	XXX	XXX	XXX	XXX	XXX	1.75*b	0.67*	0.04*d	XXX	XXX	XXX	XXX	XXX	0.54*
FY4	2.00	XXX	XXX	XXX	XXX	XXX	XXX	XXX	1.67b	0.13*	0.11	0.48	XXX	XXX	0.75
FY5	1.83	XXX	XXX	XXX	XXX	XXX	XXX	XXX	2.83a	XXX	XXX	XXX	0.96	1.30	0.00
G	2.00	0.50	1.42	1.42*	2.58	1.33	1.75*b	0.67*	0.04*d	0.13*	0.00	0.40		0.92	0.54*
P(T)[1]		0.38	0.54	0.70	0.65	0.96	0.03	0.42	<0.01	0.47	0.20	0.28	0.30	0.92	0.36
SEM[2]	0.13	0.53	0.67	0.49	0.44	0.34	1.16	0.30	0.37	0.10	0.04	0.20	0.70	0.42	0.53
Anova[5]	N.A.[6]	RB	RB	RB	RB	RB	CR	CR	RB	RB	CR	RB+C	RB	RB+C	RB
P(C)[7]												0.05		0.06	
Coeff[8]												1.59		1.83	

Table 0-20 Site 1 *Aristida* spp. recruitments (plants/m^2)

	Recording number														
Treat.	**R1**	**R2**	**R3**	**R4**	**R5**	**R6**	**R7**	**R8**	**R9**	**R10**	**R11**	**R12**	**R13**	**R14**	**R15**
EA	13.8	0.50	1.13	4.58	6.08	2.58b	1.33	1.50	0.92bc	0.50	0.25	3.25	10.3	4.25	2.17bc
EB	9.6			XXX	XXX	XXX	7.08	0.92	0.33c	XXX	XXX	XXX	12.8	3.33	2.25bc
FA	12.3		1.11	4.33	3.58	4.00b	0.83	2.83	1.33bc	0.25	0.33	2.33	6.8	1.67	1.33c
FB	15.6			XXX	XXX	XXX	4.25	3.33	4.96bc	XXX	XXX	XXX	10.7	5.33	1.08c
FY1	14.2			XXX	XXX	XXX	XXX	XXX		XXX	XXX	XXX	XXX	XXX	5.58ab
FY2	14.8	XXX[3]	XXX	5.29*	3.83	3.00b	XXX	XXX	0.83c	XXX	XXX	XXX	XXX	XXX	8.83a
FY3	12.2	XXX	XXX	XXX	XXX	XXX	8.46*	1.50*	1.08*c	XXX	XXX	XXX	XXX	XXX	3.54*bc
FY4	15.8	XXX	XXX	XXX	XXX	XXX	XXX	XXX	6.33ab	1.12*	0.42	2.25	XXX	XXX	4.33bc
FY5	14.3	XXX	XXX	XXX	XXX	XXX	XXX	XXX	9.92a	XXX	XXX	XXX	10.7	3.33	1.75c
G	16.8	0.67	1.42	5.29*	4.50	7.50a	8.46*	1.50*	1.08*c	1.12*	0.00	4.33		3.00	3.54*bc
P(T)[1]		0.53	0.78	0.81	0.49	0.01	0.28	0.08	<0.01	0.11	0.35	0.53	0.58	0.43	<0.01
SEM[2]	2.5	0.24	0.39	1.31	1.20	0.85	3.31	0.66	1.90	0.34	0.16	1.10	2.6	1.21	1.31
Anova[5]	N.A.[6]	RB	RB	RB	RB	RB	CR	CR	RB	CR	CR	RB	RB	RB	RB
P(C)[7]															
Coeff[8]															

Table 0-21 Site 1 *P. effusum* recruitments (plants/m^2)

	Recording number														
Treat.	**R1**	**R2**	**R3**	**R4**	**R5**	**R6**	**R7**	**R8**	**R9**	**R10**	**R11**	**R12**	**R13**	**R14**	**R15**
EA	1.67	0.60	0.36	0.75	0.25ab	0.41	0.00	0.17a	0.08	0.00	0	1.58	4.58	0.00	0.17
EB	1.75			XXX	XXX	XXX	1.00	0.00b	0.25	XXX	XXX	XXX	4.67	0.33	0.25
FA	2.42		0.71	1.08	0.83a	0.30	0.08	0.00b	0.00	0.00	0	1.08	1.42	0.17	0.08
FB	1.17			XXX	XXX	XXX	0.17	0.00b	0.04	XXX	XXX	XXX	1.25	0.17	0.08
FY1	1.92			XXX	XXX	XXX	XXX	XXX		XXX	XXX	XXX	XXX	XXX	0.33
FY2	1.33	XXX[3]	XXX	0.54*	0.58ab	0.29	XXX	XXX	0.08	XXX	XXX	XXX	XXX	XXX	0.92
FY3	0.83	XXX	XXX	XXX	XXX	XXX	0.58*	0.00*b	0.00*	XXX	XXX	XXX	XXX	XXX	0.46*
FY4	1.50	XXX	XXX	XXX	XXX	XXX	XXX	XXX	0.17	0.08*	0	0.17	XXX	XXX	0.25
FY5	3.08	XXX	XXX	XXX	XXX	XXX	XXX	XXX	0.17	XXX	XXX	XXX	1.62	0.08	0.00
G	1.08	0.08	0.16	0.54*	0.00b	0.16	0.58*	0.00*b	0.00*	0.08*	0	0.75		0.00	0.46*
P(T)[1]		0.06	0.09	0.54	0.05	0.53	0.25	0.03	0.65	0.65		0.58	0.11	0.24	0.62
SEM[2]	0.67	0.24	0.23	0.39	0.18	0.12	0.35	0.04	0.11	0.09		0.72	1.21	0.10	0.32
Anova[5]	N.A.[6]	RB	CR+C	RB	RB	RB+C	RB	RB	RB	RB		RB	RB	RB	RB
P(C)[7]			<0.01			0.04									
Coeff[8]			0.27			0.15									

Table 0-22 Site 1 *B. ewartiana* mortalities (plants/m^2)

<table>
<tr><td></td><td colspan="15">Recording number</td></tr>
<tr><td>Treat.</td><td>R1</td><td>R2</td><td>R3</td><td>R4</td><td>R5</td><td>R6</td><td>R7</td><td>R8</td><td>R9</td><td>R10</td><td>R11</td><td>R12</td><td>R13</td><td>R14</td><td>R15</td></tr>
<tr><td>EA</td><td>2.00</td><td rowspan="5">0.05</td><td rowspan="2">0.04</td><td>0.25</td><td>0.58</td><td>0.92</td><td>0.17</td><td>3.25</td><td>0.00</td><td>0.18a</td><td>0.00</td><td>0.58</td><td>0.08</td><td>1.58</td><td>0.08c</td></tr>
<tr><td>EB</td><td>1.92</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>3.50</td><td>0.50</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>2.69</td><td>0.33bc</td></tr>
<tr><td>FA</td><td>2.17</td><td rowspan="3">0.08</td><td>0.08</td><td>0.42</td><td>0.58</td><td>0.17</td><td>4.50</td><td>0.08</td><td>0.00b</td><td>0.00</td><td>0.42</td><td>0.33</td><td>0.70</td><td>0.68ab</td></tr>
<tr><td>FB</td><td>2.08</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>2.50</td><td>0.08</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>0.31</td><td>1.00a</td></tr>
<tr><td>FY1</td><td>2.25</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td></tr>
<tr><td>FY2</td><td>1.92</td><td>XXX[3]</td><td>XXX</td><td>XXX</td><td>0.25</td><td>0.17</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td></tr>
<tr><td>FY3</td><td>2.00</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>2.71*</td><td>0.29*</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td></tr>
<tr><td>FY4</td><td>2.00</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>0.08</td><td>0.58</td><td>XXX</td><td>XXX</td><td>XXX</td></tr>
<tr><td>FY5</td><td>1.83</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>0.97</td><td>0.41bc</td></tr>
<tr><td>G</td><td>2.00</td><td>0.00</td><td>0.00</td><td>0.25</td><td>0.50</td><td>0.67</td><td>0.75</td><td>2.71*</td><td>0.29*</td><td>0.02b</td><td>0.08</td><td>0.42</td><td>0.08</td><td>0.67</td><td>0.00c</td></tr>
<tr><td>P(T)[1]</td><td></td><td>0.55</td><td>0.77</td><td>0.30</td><td>0.66</td><td>0.30</td><td>0.38</td><td>0.42</td><td>0.27</td><td>0.03</td><td>0.59</td><td>0.93</td><td>0.62</td><td>0.12</td><td>0.01</td></tr>
<tr><td>SEM[2]</td><td>0.13</td><td>0.08</td><td>0.10</td><td>0.08</td><td>0.19</td><td>0.26</td><td>0.31</td><td>0.82</td><td>0.18</td><td>0.05</td><td>0.06</td><td>0.25</td><td>0.20</td><td>0.61</td><td>0.18</td></tr>
<tr><td>Anova[5]</td><td>N.A.[6]</td><td>CR</td><td>RB</td><td>RB</td><td>RB</td><td>RB</td><td>RB</td><td>RB</td><td>CR</td><td>CR+C</td><td>CR</td><td>RB</td><td>CR</td><td>CR+C</td><td>CR+C</td></tr>
<tr><td>P(C)[7]</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>0.08</td><td></td><td></td><td></td><td>0.06</td><td>0.01</td></tr>
<tr><td>Coeff[8]</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>0.33</td><td></td><td></td><td></td><td>2.3</td><td>0.95</td></tr>
</table>

Table 0-23 Site 1 *Aristida* spp. mortalities (plants/m^2)

<table>
<tr><td></td><td colspan="15">Recording number</td></tr>
<tr><td>Treat.</td><td>R1</td><td>R2</td><td>R3</td><td>R4</td><td>R5</td><td>R6</td><td>R7</td><td>R8</td><td>R9</td><td>R10</td><td>R11</td><td>R12</td><td>R13</td><td>R14</td><td>R15</td></tr>
<tr><td>EA</td><td>13.8</td><td rowspan="5">0.94</td><td rowspan="2">0.33</td><td>0.54</td><td>1.50</td><td>2.58</td><td>0.75</td><td>10.9</td><td>1.08</td><td>0.92</td><td>0.95</td><td>5.58</td><td>1.00</td><td>6.50</td><td>1.33</td></tr>
<tr><td>EB</td><td>9.6</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>9.7</td><td>0.33</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>6.83</td><td>0.83</td></tr>
<tr><td>FA</td><td>12.3</td><td rowspan="3">0.33</td><td>0.69</td><td>0.92</td><td>1.33</td><td>0.42</td><td>10.9</td><td>0.50</td><td>1.00</td><td>1.41</td><td>4.17</td><td>2.42</td><td>5.50</td><td>0.50</td></tr>
<tr><td>FB</td><td>15.6</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>7.7</td><td>0.75</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>5.08</td><td>1.50</td></tr>
<tr><td>FY1</td><td>14.2</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td></tr>
<tr><td>FY2</td><td>14.8</td><td>XXX[3]</td><td>XXX</td><td>XXX</td><td>2.00</td><td>0.83</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td></tr>
<tr><td>FY3</td><td>12.2</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>15.6*</td><td>0.92*</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td></tr>
<tr><td>FY4</td><td>15.8</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>1.17</td><td>5.25</td><td>XXX</td><td>XXX</td><td>XXX</td></tr>
<tr><td>FY5</td><td>14.3</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>8.58</td><td>0.33</td></tr>
<tr><td>G</td><td>16.8</td><td>0.38</td><td>0.42</td><td>0.02</td><td>1.50</td><td>1.58</td><td>0.75</td><td>15.6*</td><td>0.92*</td><td>0.92</td><td>1.55</td><td>6.25</td><td>1.25</td><td>5.33</td><td>1.33</td></tr>
<tr><td>P(T)[1]</td><td></td><td>0.12</td><td>0.95</td><td>0.39</td><td>0.76</td><td>0.24</td><td>0.79</td><td>0.26</td><td>0.62</td><td>0.98</td><td>0.62</td><td>0.72</td><td>0.56</td><td>0.71</td><td>0.29</td></tr>
<tr><td>SEM[2]</td><td>2.5</td><td>0.31</td><td>0.23</td><td>0.32</td><td>0.71</td><td>0.58</td><td>0.39</td><td>3.0</td><td>0.39</td><td>0.32</td><td>0.34</td><td>1.30</td><td>0.96</td><td>1.71</td><td>0.42</td></tr>
<tr><td>Anova[5]</td><td>N.A.[6]</td><td>RB+C</td><td>CR</td><td>CR+C</td><td>CR</td><td>CR</td><td>CR</td><td>CR+C</td><td>CR</td><td>RB</td><td>CR+C</td><td>RB</td><td>CR</td><td>RB</td><td>RB</td></tr>
<tr><td>P(C)[7]</td><td></td><td>0.04</td><td></td><td>0.10</td><td></td><td></td><td></td><td>0.06</td><td></td><td></td><td><0.01</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Coeff[8]</td><td></td><td>0.06</td><td></td><td>0.09</td><td></td><td></td><td></td><td>0.6</td><td></td><td></td><td>0.14</td><td></td><td></td><td></td><td></td></tr>
</table>

Table 0-24 Site 1 *P. effusum* mortalities (plants/m^2)

<table>
<tr><th></th><th colspan="15">Recording number</th></tr>
<tr><th>Treat.</th><th>R1</th><th>R2</th><th>R3</th><th>R4</th><th>R5</th><th>R6</th><th>R7</th><th>R8</th><th>R9</th><th>R10</th><th>R11</th><th>R12</th><th>R13</th><th>R14</th><th>R15</th></tr>
<tr><td>EA</td><td>1.67</td><td rowspan="5">0.15</td><td rowspan="2">0.25</td><td>0.00</td><td>0.25</td><td>0.17</td><td>0.08</td><td>2.23</td><td>0.08</td><td>0.50</td><td>0.08</td><td>0.17</td><td>0.17</td><td>4.50</td><td>0.33</td></tr>
<tr><td>EB</td><td>1.75</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>1.56</td><td>0.00</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>3.08</td><td>0.58</td></tr>
<tr><td>FA</td><td>2.42</td><td rowspan="3">0.08</td><td>0.17</td><td>0.67</td><td>0.17</td><td>0.25</td><td>3.20</td><td>0.17</td><td>0.17</td><td>0.16</td><td>0.15</td><td>0.00</td><td>2.25</td><td>0.08</td></tr>
<tr><td>FB</td><td>1.17</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>2.08</td><td>0.00</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>0.67</td><td>0.08</td></tr>
<tr><td>FY1</td><td>1.92</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td></tr>
<tr><td>FY2</td><td>1.33</td><td>XXX[3]</td><td>XXX</td><td>XXX</td><td>0.00</td><td>0.17</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td></tr>
<tr><td>FY3</td><td>0.83</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>1.72*</td><td>0.04*</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td></tr>
<tr><td>FY4</td><td>1.50</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>0.10</td><td>0.11</td><td>XXX</td><td>XXX</td><td>XXX</td></tr>
<tr><td>FY5</td><td>3.08</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>XXX</td><td>1.08</td><td>0.08</td></tr>
<tr><td>G</td><td>1.08</td><td>0.00</td><td>0.00</td><td>0.00</td><td>0.08</td><td>0.00</td><td>0.00</td><td>1.72*</td><td>0.04*</td><td>0.17</td><td>0.24</td><td>0.33</td><td>0.17</td><td>1.75</td><td>0.08</td></tr>
<tr><td>P(T)[1]</td><td></td><td>0.19</td><td>0.16</td><td>0.10</td><td>0.28</td><td>0.74</td><td>0.18</td><td>0.21</td><td>0.58</td><td>0.43</td><td>0.84</td><td>0.61</td><td>0.27</td><td>0.29</td><td>0.54</td></tr>
<tr><td>SEM[2]</td><td>0.67</td><td>0.10</td><td>0.11</td><td>0.06</td><td>0.24</td><td>0.13</td><td>0.08</td><td>0.51</td><td>0.08</td><td>0.20</td><td>0.13</td><td>0.12</td><td>0.08</td><td>1.20</td><td>0.23</td></tr>
<tr><td>Anova[5]</td><td>N.A.[6]</td><td>RB</td><td>CR</td><td>CR</td><td>RB</td><td>CR</td><td>RB</td><td>CR+C</td><td>CR</td><td>CR</td><td>RB+C</td><td>RB+C</td><td>CR</td><td>RB</td><td>CR</td></tr>
<tr><td>P(C)[7]</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td><0.01</td><td></td><td></td><td>0.07</td><td>0.03</td><td></td><td></td><td></td></tr>
<tr><td>Coeff[8]</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>1.04</td><td></td><td></td><td>0.12</td><td>0.14</td><td></td><td></td><td></td></tr>
</table>

Table 0-25 Site 1 total pasture yields (kg/ha) at the plot level

	Recording Number											
Treat.	**R1(FQ)**	**R4**	**R5**	**R6**	**R7**	**R8**	**R9**	**R10**	**R11**	**R12**	**R13**	**R14**	**R15**
EA	2296	2744	2641	3259	2393	190	370	124	118	278	454*b[4]	1118b	1173
EB	2384		XXX	XXX	2289	228	430	XXX	XXX	XXX	302b	1158b	1123
FA	2473	3631	3521	4161	3334	271	481	253	361	635	903a	2343a	2114
FB	2381		XXX	XXX	3023	217	387	XXX	XXX	XXX	385b	1257b	1410
FY1	2782		XXX	XXX	XXX	XXX		XXX	XXX	XXX	XXX	XXX	1005
FY2	2391	3218	2721	4176	XXX	XXX	507	XXX	XXX	XXX	XXX	XXX	1313
FY3	2318		XXX	XXX	3093*	186*	327*	XXX	XXX	XXX	XXX	XXX	1062*
FY4	2538		XXX	XXX	XXX	XXX	XXX	178*	256	516	XXX	XXX	1174
FY5	2010		XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	403b	1106b	1150
G	1697		1726	3537	3093*	186*	327*	178*	137	359		1069b	1062*
P(T)[1]		0.43	0.19	0.16	0.25	0.24	0.33	0.39	0.18	0.05	0.03	0.01	0.09
SEM[2]	358	529	536	323	390	30	71	64	82	86	125	239	272
Anova[5]	N.A.[6]	CR	CR	CR	CR	RB	RB	RB	CR	CR	RB	RB	RB
P(C)[7]													
Coeff[8]													

Table 0-26 Site 1. *B. ewartiana* pasture yields (kg/ha) at the plot level

	Recording Number												
Treat.	**R1(FQ)**	**R4**	**R5**	**R6**	**R7**	**R8**	**R9**	**R10**	**R11**	**R12**	**R13**	**R14**	**R15**
EA	785	1532	1365	1560	1132	98	166	73	66	151	316	655	701
EB	954		XXX	XXX	988	110	227	XXX	XXX	XXX	172	577	733
FA	905	2082	1309	1478	1783	126	246	139	216	355	488	1189	1183
FB	903		XXX	XXX	1154	96	212	XXX	XXX	XXX	249	606	830
FY1	879		XXX	XXX	XXX	XXX		XXX	XXX	XXX	XXX	XXX	496
FY2	790	1866	1302	1819	XXX	XXX	233	XXX	XXX	XXX	XXX	XXX	742
FY3	836		XXX	XXX	1447*	94*	160*	XXX	XXX	XXX	XXX	XXX	619*
FY4	827		XXX	XXX	XXX	XXX	XXX	83*	159	242	XXX	XXX	989
FY5	754		XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	206	538	722
G	625		726	1430	1447*	94*	160*	83*	97	193		530	619*
P(T)[1]		0.61	0.47	0.71	0.09	0.64	0.66	0.25	0.08	0.21	0.07	0.06	0.44
SEM[2]	158	428	315	255	211	18	51	29	38	67	81	152	207
Anova[5]	N.A.[6]	RB	RB	CR	CR	RB	RB	RB	RB	CR	RB	RB	RB
P(C)[7]													
Coeff[8]													

Table 0-27 Site 1 *Aristida* spp*.* pasture yields (kg/ha) at the plot level

	Recording Number												
Treat.	**R1(FQ)**	**R4**	**R5**	**R6**	**R7**	**R8**	**R9**	**R10**	**R11**	**R12**	**R13**	**R14**	**R15**
EA	1007	600	438	720	580	42	81	35	16	41	70*b[4]	195	305
EB	954		XXX	XXX	810	51	101	XXX	XXX	XXX	68b	221	192
FA	1160	737	547	803	697	46	93	68	52	74	156a	245	281
FB	1153		XXX	XXX	1252	50	80	XXX	XXX	XXX	62b	295	272
FY1	1387		XXX	XXX	XXX	XXX		XXX	XXX	XXX	XXX	XXX	313
FY2	1184	738	438	861	XXX	XXX	97	XXX	XXX	XXX	XXX	XXX	226
FY3	1152		XXX	XXX	1136*	52*	97*	XXX	XXX	XXX	XXX	XXX	278*
FY4	1362		XXX	XXX	XXX	XXX	XXX	66*	38	103	XXX	XXX	405
FY5	1025		XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	80b	238	223
G	866		608	1288	1136*	52*	97*	66*	31	79		271	278*
P(T)[1]		0.72	0.87	0.16	0.38	0.96	0.91	0.51	0.45	0.16	0.02	0.86	0.70
SEM[2]	219	152	176	170	290	11	19	22	15	18	19	60	73
Anova[5]	N.A.[6]	RB	CR	RB	RB	CR+C	CR+C	RB	CR	CR	RB+C	RB+C	RB+C
P(C)[7]						0.05	0.03				0.06	0.05	0.02
Coeff[8]						0.03	0.04				0.06	0.2	0.2

Table 0-28 Site 1 *P. effusum* pasture yields (kg/ha) at the plot level

	Recording Number												
Treat.	**R1(FQ)**	**R4**	**R5**	**R6**	**R7**	**R8**	**R9**	**R10**	**R11**	**R12**	**R13**	**R14**	**R15**
EA	86	58	145	100	77b[4]	0.2	2	0.5	0.1	6	2	23	9
EB	51		XXX	XXX	39b	1.2	3	XXX	XXX	XXX	7	11	14
FA	72	98	544	361	197a	0.5	3	0.7	0.1	2	4	2	4
FB	45		XXX	XXX	79b	0	3	XXX	XXX	XXX	4	15	5
FY1	86		XXX	XXX	XXX	XXX		XXX	XXX	XXX	XXX	XXX	7
FY2	39	76	167	205	XXX	XXX	4	XXX	XXX	XXX	XXX	XXX	11
FY3	15		XXX	XXX	89*b	0.3*	2*	XXX	XXX	XXX	XXX	XXX	7*
FY4	79		XXX	XXX	XXX	XXX	XXX	1.1*	0	1	XXX	XXX	2
FY5	49		XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	3	16	12
G	30		58	54	89*b	0.3*	2*	1.1*	0.1	1		12	7*
P(T)[1]		0.32	0.05	0.07	<0.01	0.44	0.95	0.87	0.37	0.24	0.42	0.58	0.81
SEM[2]	29	21	117	78	26	0.3	2	0.9	0.05	2	2	8	5
Anova[5]	N.A.[6]	RB+C	CR	CR	RB	RB	CR	RB	RB	CR	CR	RB+C	RB
P(C)[7]		0.10										0.02	
Coeff[8]		0.3										0.2	

Table 0-29 Site 2 total pasture yields (kg/ha) in the fixed quadrats

S.R.	Treat.	R 1[0]	R 2	R 3	R 4	R 5	R 6	R 7	R 8	R 9
Med.	MEA	736	963 a[7]	1289	1264	1394	922	600	347	231
	MEB	530			XXX[8]	XXX	XXX	1037	529	279
	MFA	487		1387	1575	1884	1803	1773	787	454
	MFB	582			XXX	XXX	XXX	1250	478	317
	MG	567	747 b	1111	1254	1070	884	699	412	254
	Anov[1]	N.A.[6]	RB+C	RB+	CR+	RB+	RB+	RB+	RB+	CR+
	P(T)[2]		0.012	0.14	0.33	0.33	0.13	0.25	0.16	0.11
	SEM[3]		67	106	157	380	299	364	113	57
	P(C)[4]		<0.01	<0.0	0.04	0.10	0.09	0.03	<0.0	<0.0
	Coeff[5]		1.7	1.7	1.7	2.9	2.4	2.8	1.3	0.4
High	HEA	440	1008 a	1032 b	325	281	233 b	97	68 bc	47
	HEB	478			XXX	XXX	XXX	125	85	59
	HFA	428		1855 a	307	813	938 a	111	130 a	61
	HFB	543			XXX	XXX	XXX	119	112	68
	HG	430	501 b	649	255	107	205 b	101	62 c	32
	Anov	N.A.	CR+C	RB+	RB+	CR	RB	RB	CR	CR
	P(T)		<0.01	<0.0	0.69	0.08	0.03	0.69	0.04	0.17
	SEM		106	192	58	201	158	15	16	10
	P(C)		<0.01	<0.0 1	0.01					
	Coeff		2.5	2.7	1.3					

Table 0-30 Site 2 *B. ewartiana* pasture yields (kg/ha) in the fixed quadrats

S.R.	Treat.	R 1[0]	R 2	R 3	R 4	R 5	R 6	R 7	R 8	R 9
Med.	MEA	91	153	211	210	280	247	204	165	70
	MEB	68			XXXX[3]	XXXX	XXXX	251	103	56
	MFA	107		268	283	337	458	503	151	88
	MFB	101			XXXX	XXXX	XXXX	253	111	72
	MG	51	84	74	138	82	93	87	41	30
	P(T)[1]		0.13	0.05	0.30	0.15	0.19	0.36	0.32	0.37
	SEM[2]	24	20	41	60	87	123	140	43	20
	Anov[5]	N.A.[6]	RB	RB	RB	CR	RB	CR	CR	CR
	P(C)[7]									
	Coeff[8]									
High	HEA	45	113	98b[4]	49	52	26b	12	9	10
	HEB	57			XXXX[3]	XXXX	XXXX	19	10	12
	HFA	44		264a	47	89	91a	20	11	11
	HFB	66			XXXX	XXXX	XXXX	25	11	13
	HG	66	99	81b	48	21	37b	23	11	7
	P(T)[1]		0.78	0.04	0.99	0.27	<0.01	0.49	0.99	0.68
	SEM[2]	15	22	49	21	27	11	5	4	3
	Anov[5]	N.A.[6]	CR	CR	CR	RB	CR	CR	CR	RB
	P(C)[7]									
	Coeff[8]									

Table 0-31 Site 2 *Aristida* spp*.* pasture yields (kg/ha) in the fixed quadrats

S.R.	Treat.	R 1[0]	R 2	R 3	R 4	R 5	R 6	R 7	R 8	R 9
Med.	MEA	371	561a	653	905	669	496	512	194	155
	MEB	293			XXX	XXX	XXX	555	308	187
	MFA	286		703	980	901	733	855	428	292
	MFB	287			XXX	XXX	XXX	899	332	233
	MG	343	388b	578	786	548	416	400	262	169
	P(T)[1]		0.02	0.31	0.44	0.47	0.42	0.54	0.39	0.17
	SEM[2]	114	148	63	101	196	166	240	81	42
	Anov[5]	N.A.[6]	RB+C	RB+	RB+	RB+	RB+	RB+	CR+	CR+
	P(C)[7]		<0.01	<0.0	0.02	0.01	0.04	0.03	<0.0	<0.0
	Coeff[8]		1.3	1.3	1.7	1.7	1.1	2.0	0.9	0.5
High	HEA	190	468a	551a	217	94	62b	41	21	18ab
	HEB	257			XXX	XXX	XXX	59	21	26a
	HFA	224		720a	123	257	258a	50	41	28a
	HFB	224			XXX	XXX	XXX	30	19	8b
	HG	206	193b	237b	130	25	47b	27	16	10b
	P(T)[1]		<0.01	<0.0	0.17	0.07	0.03	0.38	0.13	<0.0
	SEM[2]	54	61	92	35	63	54	12	7	3
	Anov[5]	N.A.[6]	CR+C	RB+	CR+	CR	CR	RB	RB+	RB+
	P(C)[7]		<0.01	<0.0	<0.0				0.08	<0.0
	Coeff[8]		1.7	1.5	1.3				0.1	0.1

Table 0-32 Site 2 *B. ewartiana* pasture composition (%) in the fixed quadrats

S.R.	Treat.	R 1[0]	R 2	R 3	R 4	R 5	R 6	R 7	R 8	R 9
Med.	MEA	13	16	16	18	18	23	28	34	27
	MEB	16			XXXX[3]	XXXX	XXXX	26	22	22
	MFA	24		18	17	15	19	25	18	18
	MFB	18			XXXX	XXXX	XXXX	20	22	21
	MG	10	16	11	18	17	18	26	23	22
	P(T)[1]		0.84	0.06	0.96	0.88	0.56	0.85	0.31	0.74
	SEM[2]	5	2	2	3	5	4	5	5	5
	Anova[5]	N.A.[6]	RB+C	RB+C	RB+C	RB+C	CR+C	CR+C	RB+C	RB+C
	P(C)[7]		<0.01	<0.01	0.02	0.06	<0.01	<0.01	<0.01	0.01
	Coeff[8]		1	1	1	1	1	1	1	1
High	HEA	11	11b	9	13	17	11	13	10	23
	HEB	14			XXXX[3]	XXXX	XXXX	17	12	21
	HFA	10		14	14	13	13	18	8	17
	HFB	12			XXXX	XXXX	XXXX	21	12	19
	HG	16	23a	14	19	20	18	22	17	39
	P(T)[1]		<0.01	0.16	0.41	0.62	0.33	0.56	0.67	0.58
	SEM[2]	3	4	2	3	5	3	4	4	10
	Anova[5]	N.A.[6]	CR+C	CR+C	RB	RB	RB	CR+C	CR	CR
	P(C)[7]		0.04	0.07				0.05		
	Coeff[8]		1	0.3				1		

Table 0-33 Site 2 *Aristida* spp. pasture composition (%) in the fixed quadrats

S.R.	Treat.	R 1[0]	R 2	R 3	R 4	R 5	R 6	R 7	R 8	R 9
Med.	MEA	47	56	53	70	51	48	58	48	61
	MEB	48			XXXX[3]	XXXX	XXXX	61	64	69
	MFA	56		50	58	48	44	49	52	58
	MFB	49			XXXX	XXXX	XXXX	61	65	70
	MG	59	52	49	57	48	48	51	52	56
	P(T)[1]		0.23	0.59	0.12	0.92	0.79	0.28	0.36	0.32
	SEM[2]	13	3	3	4	6	5	5	7	6
	Anova[5]	N.A.[6]	CR+C	RB+C	CR+C	CR+C	CR+C	CR+C	CR+C	CR+C
	P(C)[7]		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	Coeff[8]		1	1	1	1	1	1	1	1
High	HEA	42	46	54a	52	33	30	44	33	32
	HEB	52			XXXX[3]	XXXX	XXXX	40	25	48
	HFA	53		39b	43	34	28	40	29	44
	HFB	40			XXXX	XXXX	XXXX	31	18	16
	HG	58	39	38b	50	26	23	26	29	27
	P(T)[1]		0.14	<0.01	0.41	0.71	0.32	0.11	0.24	0.06
	SEM[2]	8	4	3	5	7	3	5	5	7
	Anova[5]	N.A.[6]	CR+C	CR+C	CR+C	CR	CR+C	RB+C	RB+C	CR+C
	P(C)[7]		<0.01	<0.01	<0.01		<0.01	<0.01	0.05	0.09
	Coeff[8]		1	0.5	1		0.5	1	0.3	0.4

Table 0-34 Site 2 total crown cover (%)

S.R.	Treat.	R 1[0]	R 2	R 3	R 4	R 5	R 6	R 7	R 8	R 9
Med.	MEA	1.83	1.73	1.85	1.51	1.57	1.72	1.46	1.48	1.25
	MEB	1.53			XXXX[3]	XXXX	XXXX	1.53	1.17	0.94
	MFA	1.54		1.96	1.81	2.01	2.11	1.78	1.68	1.40
	MFB	1.92			XXXX	XXXX	XXXX	1.41	1.19	0.98
	MG	1.47	1.61	1.76	1.62	1.92	1.88	1.47	1.03	0.85
	P(T)[1]		0.48	0.69	0.61	0.46	0.60	0.53	0.16	0.06
	SEM[2]	0.29	0.14	0.20	0.21	0.24	0.26	0.16	0.19	0.14
	Anova[5]	N.A.[6]	RB+C	CR+C	RB+C	CR+C	CR+C	CR+C	CR+C	CR+C
	P(C)[7]		<0.01	<0.01	0.05	<0.01	0.02	<0.01	0.02	<0.01
	Coeff[8]		0.7	0.9	1.0	1.5	1.2	0.8	0.4	0.4
High	HEA	1.39	2.19a	2.43a	1.42	1.60	1.66	0.94	0.51	0.35
	HEB	1.61			XXXX[3]	XXXX	XXXX	1.20	0.90	0.50
	HFA	1.89		2.17ab	1.27	1.43	1.69	0.96	0.80	0.62
	HFB	2.16			XXXX	XXXX	XXXX	0.96	1.02	0.50
	HG	1.80	1.59b	1.71b	1.28	1.44	1.55	1.04	0.47	0.36
	P(T)[1]		<0.01	0.03	0.75	0.63	0.78	0.65	0.07	0.28
	SEM[2]	0.39	0.18	0.20	0.15	0.13	0.16	0.14	0.14	0.10
	Anova[5]	N.A.[6]	RB+C	RB+C	RB+C	RB+C	RB+C	RB+C	RB+C	RB+C
	P(C)[7]		<0.01	<0.01	0.01	<0.01	0.02	<0.01	0.08	0.04
	Coeff[8]		1.1	1.1	0.7	0.7	0.6	0.4	0.2	0.2

Table 0-35 Site 2 *B. ewartiana* crown cover (%)

S.R.	Treat.	R 1[0]	R 2	R 3	R 4	R 5	R 6	R 7	R 8	R 9
Med.	MEA	0.28	0.33a	0.34	0.26	0.35	0.38	0.28	0.30	0.25
	MEB	0.26			XXXX[3]	XXXX	XXXX	0.33	0.27	0.20
	MFA	0.33		0.35	0.33	0.36	0.39	0.34	0.34	0.29
	MFB	0.26			XXXX	XXXX	XXXX	0.32	0.26	0.22
	MG	0.20	0.25b	0.25	0.21	0.22	0.25	0.25	0.25	0.21
	P(T)[1]		0.05	0.09	0.06	0.12	0.13	0.46	0.68	0.66
	SEM[2]	0.09	0.04	0.03	0.02	0.04	0.04	0.04	0.05	0.05
	Anova[5]	N.A.[6]	RB+C	RB+C	RB+C	RB+C	RB+C	RB+C	RB+C	CR+C
	P(C)[7]		<0.01	<0.01	<0.01	0.03	0.05	<0.01	<0.01	<0.01
	Coeff[8]		0.9	1.1	0.7	0.8	0.6	1.0	0.9	0.7
High	HEA	0.17	0.26	0.26	0.20	0.16	0.16	0.13	0.07	0.06
	HEB	0.23			XXXX[3]	XXXX	XXXX	0.12	0.10	0.09
	HFA	0.21		0.27	0.16	0.14	0.15	0.11	0.07	0.06
	HFB	0.26			XXXX	XXXX	XXXX	0.22	0.09	0.08
	HG	0.21	0.22	0.23	0.19	0.17	0.20	0.11	0.04	0.05
	P(T)[1]		0.14	0.62	0.71	0.89	0.72	0.23	0.36	0.46
	SEM[2]	0.08	0.03	0.03	0.04	0.04	0.04	0.04	0.02	0.02
	Anova[5]	N.A.[6]	RB+C	RB+C	CR+C	RB	RB	RB+C	CR+C	CR+C
	P(C)[7]		<0.01	<0.01	0.02			<0.01	<0.01	<0.01
	Coeff[8]		1.2	1.1	1.2			0.7	0.5	0.4

Table 0-36 Site 2 *Aristida* spp. crown cover (%)

S.R.	Treat.	R 1[0]	R 2	R 3	R 4	R 5	R 6	R 7	R 8	R 9
Med.	MEA	1.13	0.96	1.10	1.03	0.97	0.95	0.83	0.74	0.73
	MEB	1.05			XXXX[3]	XXXX	XXXX	0.87	0.65	0.58
	MFA	0.78		1.12	0.99	1.13	1.16	1.04	0.81	0.76
	MFB	1.09			XXXX	XXXX	XXXX	0.90	0.60	0.57
	MG	0.85	0.94	0.96	0.86	0.86	0.86	0.84	0.51	0.49
	P(T)[1]		0.83	0.52	0.23	0.17	0.17	0.50	0.39	0.32
	SEM[2]	0.22	0.09	0.12	0.07	0.09	0.11	0.09	0.11	0.10
	Anova[5]	N.A.[6]	RB+C	CR+C	RB+C	CR+C	CR+C	CR+C	CR+C	CR+C
	P(C)[7]		<0.01	<0.01	0.09	<0.01	<0.01	<0.01	<0.01	<0.01
	Coeff[8]		0.8	1.0	0.5	1.0	0.9	0.9	0.5	0.5
High	HEA	0.92	1.03	1.12	0.78	0.76	0.79	0.47	0.15	0.11b
	HEB	0.84			XXXX[3]	XXXX	XXXX	0.53	0.17	0.12b
	HFA	1.10		1.02	0.67	0.67	0.77	0.48	0.28	0.28a
	HFB	0.81			XXXX	XXXX	XXXX	0.40	0.16	0.12b
	HG	0.77	0.87	1.00	0.85	0.65	0.64	0.42	0.14	0.11b
	P(T)[1]		0.10	0.34	0.21	0.73	0.63	0.73	0.15	0.04
	SEM[2]	0.21	0.08	0.07	0.06	0.11	0.11	0.07	0.04	0.04
	Anova[5]	N.A.[6]	RB+C	RB+C	RB+C	CR+C	CR+C	RB+C	RB+C	CR+C
	P(C)[7]		<0.01	<0.01	<0.01	<0.01	<0.01	0.01	0.07	0.10
	Coeff[8]		1.1	1.2	1.0	0.6	0.6	0.4	0.1	0.1

Table 0-37 Site 2 *B. ewartiana* density (plants/m^2)

S.R.	Treat.	R 1[0]	R 2	R 3	R 4	R 5	R 6	R 7	R 8	R 9
Med.	MEA	2.42	2.50	2.63	2.33	2.58	2.58	2.65	2.72	2.65
	MEB	2.58			XXXX[3]	XXXX	XXXX	2.51	2.68	2.43
	MFA	2.25		2.70	2.33	2.50	2.33	2.63	2.51	2.28
	MFB	2.67			XXXX	XXXX	XXXX	2.86	2.70	2.61
	MG	3.08	2.67	2.18	2.58	2.58	2.58	2.18	2.14	1.86
	P(T)[1]		0.13	0.25	0.50	0.96	0.63	0.47	0.52	0.30
	SEM[2]	0.41	0.19	0.25	0.16	0.24	0.21	0.26	0.26	0.27
	Anova[5]	N.A.[6]	CR+C	CR+C	RB	CR	RB	CR+C	CR+C	CR+C
	P(C)[7]		<0.01	<0.01				<0.01	<0.01	<0.01
	Coeff[8]		0.8	0.8				0.8	0.7	0.8
High	HEA	2.42	2.39	2.43	2.21	2.00	1.87	1.71	1.05	0.97b
	HEB	2.17			XXXX[3]	XXXX	XXXX	2.23	1.54	1.54ab
	HFA	1.92		2.38	2.29	2.25	2.53	1.99	1.62	1.61ab
	HFB	2.58			XXXX	XXXX	XXXX	2.34	2.11	2.20a
	HG	2.75	2.37	2.47	2.58	2.50	2.27	2.23	1.67	1.68ab
	P(T)[1]		0.94	0.94	0.52	0.75	0.55	0.44	0.18	0.04
	SEM[2]	0.36	0.22	0.22	0.24	0.46	0.43	0.25	0.29	0.24
	Anova[5]	N.A.[6]	CR+C	CR+C	CR+C	CR	CR+C	RB+C	CR+C	CR+C
	P(C)[7]		<0.01	<0.01	0.02		0.07	<0.01	<0.01	<0.01
	Coeff[8]		0.8	0.7	0.6		0.8	0.7	0.6	0.6

Table 0-38 Site 2 *Aristida* spp*.* density (plants/m^2)

S.R.	Treat.	R 1[0]	R 2	R 3	R 4	R 5	R 6	R 7	R 8	R 9
Med.	MEA	18.1	14.7	15.6	14.6	14.7	14.8	14.9	13.8	13.2
	MEB	14.8			XXXX[3]	XXXX	XXXX	16.6	15.1	14.0
	MFA	13.4		15.0	14.8	14.3	14.9	15.0	13.4	12.9
	MFB	14.6			XXXX	XXXX	XXXX	15.4	15.1	14.7
	MG	11.5	16.0	16.9	17.3	16.8	18.0	17.8	16.2	15.5
	P(T)[1]		0.31	0.42	0.34	0.26	0.12	0.48	0.69	0.61
	SEM[2]	2.0	1.1	1.2	1.3	1.2	1.1	1.3	1.5	1.3
	Anova[5]	N.A.[6]	CR+C	CR+C	CR+C	CR+C	CR+C	CR+C	RB+C	RB+C
	P(C)[7]		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	Coeff[8]		1.1	1.2	1.3	1.3	1.4	1.3	1.3	1.3
High	HEA	16.2	15.5	16.4	16.3	15.6	15.9	14.7	10.5	9.1
	HEB	12.4			XXXX[3]	XXXX	XXXX	15.9	12.4	11.1
	HFA	14.4		15.5	16.0	15.9	16.8	15.3	13.6	13.6
	HFB	14.0			XXXX	XXXX	XXXX	13.4	9.3	8.4
	HG	15.2	15.2	15.8	16.6	16.8	17.2	14.8	9.6	8.3
	P(T)[1]		0.65	0.46	0.87	0.72	0.66	0.29	0.28	0.17
	SEM[2]	2.5	0.6	0.7	0.8	1.1	1.0	0.8	1.6	1.7
	Anova[5]	N.A.[6]	RB+C	RB+C	RB+C	RB+C	RB+C	RB+C	CR+C	CR+C
	P(C)[7]		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	Coeff[8]		1.1	1.0	1.3	1.2	1.2	1.0	0.7	0.6

Table 0-39 Site 2 *B. ewartiana* recruitments (plants/m^2)

S.R.	Treat.	R 1[0]	R 2	R 3	R 4	R 5	R 6	R 7	R 8	R 9
Med.	MEA	0.42	0.15	0.08	0.00	0.25	0.00	0.00	0.25	0.08
	MEB	0.50			XXXX[3]	XXXX	XXXX	XXXX	0.17	0.08
	MFA	0.25		0.08	0.00	0.25	0.00	0.00	0.08	0.00
	MFB	0.25			XXXX	XXXX	XXXX	XXXX	0.08	0.00
	MG	0.42	0.17	0.08	0.08	0.08	0.00	0.00	0.17	0.00
	P(T)[1]		0.88	-	0.40	0.52	-	-	0.79	0.57
	SEM[2]	0.21	0.12	-	0.05	0.11	-	-	0.11	0.05
	Anova[5]	N.A.[6]	RB	-	CR	CR	-	-	CR	CR
	P(C)[7]									
	Coeff[8]									
High	HEA	0.25	0.21	0.00	0.00	0.08	0.00	0.00	0.00	0.00
	HEB	0.17			XXXX[3]	XXXX	XXXX	XXXX	0.08	0.00
	HFA	0.17		0.04	0.00	0.33	0.00	0.00	0.17	0.08
	HFB	0.33			XXXX	XXXX	XXXX	XXXX	0.17	0.17
	HG	0.08	0.17	0.08	0.17	0.08	0.11	0.00	0.08	0.00
	P(T)[1]		0.84	0.42	0.10	0.59	0.15	-	0.83	0.16
	SEM[2]	0.12	0.18	0.05	0.06	0.19	0.04	-	0.11	0.05
	Anova[5]	N.A.[6]	CR	CR	CR	RB	RB+C	-	RB	RB
	P(C)[7]						0.08			
	Coeff[8]						0.3			

Table 0-40 Site 2 *Aristida* spp. recruitments (plants/m^2)

S.R.	Treat.	R 1[0]	R 2	R 3	R 4	R 5	R 6	R 7	R 8	R 9
Med.	MEA	6.50	1.78	1.17	0.42	0.63	0.58	0.00	1.33	0.17
	MEB	4.00			XXXX[3]	XXXX	XXXX	XXXX	1.25	0.25
	MFA	4.67		0.81	0.75	0.56	0.67	0.19	0.17	0.17
	MFB	4.67			XXXX	XXXX	XXXX	XXXX	1.67	0.08
	MG	4.00	2.28	0.96	0.42	0.40	1.08	0.31	0.42	0.17
	P(T)[1]		0.43	0.46	0.30	0.15	0.56	0.18	0.44	0.95
	SEM[2]	1.09	0.55	0.28	0.16	0.07	0.34	0.10	0.64	0.14
	Anova[5]	N.A.[6]	CR+C	RB+C	RB	RB+C	CR	RB+C	RB	CR
	P(C)[7]		<0.01	0.03		<0.01		0.08		
	Coeff[8]		0.4	0.2		0.1		0.1		
High	HEA	3.67	1.69	0.75	0.25	0.85	0.67	0.17	0.33	0.33
	HEB	3.83			XXXX[3]	XXXX	XXXX	XXXX	1.67	0.00
	HFA	4.17		0.58	0.17	0.56	0.92	0.17	0.92	0.58
	HFB	4.75			XXXX	XXXX	XXXX	XXXX	1.17	0.17
	HG	3.92	1.75	0.75	0.67	1.17	1.33	0.00	0.08	0.08
	P(T)[1]		0.92	0.73	0.62	0.09	0.22	0.27	0.20	0.08
	SEM[2]	0.93	0.57	0.23	0.37	0.15	0.25	0.08	0.48	0.14
	Anova[5]	N.A.[6]	CR	CR	RB	RB+C	CR	CR	RB	RB
	P(C)[7]					<0.01				
	Coeff[8]					0.4				

Table 0-41 Site 2 *B. ewartiana* mortalities (plants/m^2)

S.R.	Treat.	R 1[0]	R 2	R 3	R 4	R 5	R 6	R 7	R 8	R 9
Med.	MEA	0.17	0.13b	0.04	0.00	0.00	0.00	0.08	0.17	0.17
	MEB	0.42			XXXX[3]	XXXX	XXXX	XXXX	0.00	0.33
	MFA	0.17		0.00	0.00	0.08	0.17	0.00	0.17	0.25
	MFB	0.25			XXXX	XXXX	XXXX	XXXX	0.25	0.08
	MG	0.08	0.58a	0.17	0.08	0.08	0.00	0.00	0.25	0.25
	P(T)[1]		<0.01	0.06	0.40	0.42	0.10	0.40	0.43	0.83
	SEM[2]	0.14	0.12	0.05	0.05	0.05	0.06	0.05	0.10	0.16
	Anova[5]	N.A.[6]	RB	RB	CR	RB	CR	CR	CR	CR
	P(C)[7]									
	Coeff[8]									
High	HEA	0.50	0.19	0.00	0.08	0.33	0.08	0.17	0.67	0.08
	HEB	0.50			XXXX[3]	XXXX	XXXX	XXXX	0.75	0.00
	HFA	0.25		0.00	0.17	0.08	0.08	0.50	0.50	0.08
	HFB	0.17			XXXX	XXXX	XXXX	XXXX	0.42	0.08
	HG	0.75	0.16	0.00	0.08	0.42	0.00	0.08	0.67	0.00
	P(T)[1]		0.86	-	0.75	0.15	0.42	0.42	0.87	0.72
	SEM[2]	0.29	0.15	-	0.09	0.11	0.05	0.22	0.25	0.06
	Anova[5]	N.A.[6]	CR+C	-	CR	RB	RB	RB	RB	RB
	P(C)[7]		0.03							
	Coeff[8]		0.3							

Table 0-42 Site 2 *Aristida* spp. mortalities (plants/m^2)

S.R.	Treat.	R 1[0]	R 2	R 3	R 4	R 5	R 6	R 7	R 8	R 9
Med.	MEA	2.50	1.50	0.38	0.00	0.92	0.08	0.50	2.50	0.67
	MEB	1.00			XXXX[3]	XXXX	XXXX	XXXX	2.67	1.42
	MFA	0.75		0.46	0.58	1.00	0.08	0.17	1.75	0.67
	MFB	1.17			XXXX	XXXX	XXXX	XXXX	1.92	0.50
	MG	0.75	0.83	0.17	0.17	0.58	0.17	0.42	1.92	1.00
	P(T)[1]		0.36	0.46	0.17	0.56	0.42	0.37	0.83	0.39
	SEM[2]	0.47	0.63	0.19	0.21	0.28	0.05	0.16	0.67	0.34
	Anova[5]	N.A.[6]	RB	CR	CR	RB	RB	CR	RB	RB
	P(C)[7]									
	Coeff[8]									
High	HEA	1.75	0.69	0.21	0.25	1.50	0.33b	0.75	5.17	1.75
	HEB	1.83			XXXX[3]	XXXX	XXXX	XXXX	4.42	1.25
	HFA	2.17		0.17	0.50	0.75	0.00c	0.67	2.58	0.58
	HFB	1.17			XXXX	XXXX	XXXX	XXXX	5.08	1.08
	HG	0.83	1.00	0.17	0.67	1.00	0.92a	1.50	5.67	1.33
	P(T)[1]		0.32	0.89	0.53	0.35	<0.01	0.33	0.55	0.71
	SEM[2]	0.85	0.27	0.09	0.25	0.35	0.09	0.41	1.35	0.57
	Anova[5]	N.A.[6]	CR	RB	RB	CR	RB	CR	RB	RB
	P(C)[7]									
	Coeff[8]									

Table 0-43 Site 2 *B. ewartiana* crown cover % (x10^{-3}) of the surviving November 2012 cohort

<table>
<tr><th>S.R.</th><th>Treat.</th><th>R 1[0]</th><th>R 2</th><th>R 3</th><th>R 4</th><th>R 5</th><th>R 6</th><th>R 7</th><th>R 8</th><th>R 9</th></tr>
<tr><td rowspan="10">Med.</td><td>MEA</td><td>4.9</td><td rowspan="4">6.0</td><td rowspan="2">5.0</td><td>4.8</td><td>4.0</td><td>4.1</td><td>3.0</td><td>0.0</td><td>0.0</td></tr>
<tr><td>MEB</td><td>6.4</td><td>XXXX[3]</td><td>XXXX</td><td>XXXX</td><td>4.2</td><td>9.0</td><td>9.4</td></tr>
<tr><td>MFA</td><td>1.5</td><td rowspan="2">7.2</td><td>5.7</td><td>4.1</td><td>6.5</td><td>10.0</td><td>9.7</td><td>9.5</td></tr>
<tr><td>MFB</td><td>2.0</td><td>XXXX</td><td>XXXX</td><td>XXXX</td><td>12.5</td><td>12.8</td><td>8.9</td></tr>
<tr><td>MG</td><td>2.6</td><td>2.0</td><td>2.2</td><td>1.2</td><td>0.3</td><td>0.5</td><td>2.0</td><td>2.5</td><td>2.4</td></tr>
<tr><td>P(T)[1]</td><td></td><td>0.13</td><td>0.16</td><td>0.20</td><td>0.31</td><td>0.30</td><td>0.43</td><td>0.60</td><td>0.68</td></tr>
<tr><td>SEM[2]</td><td>2.0</td><td>2.3</td><td>2.0</td><td>1.7</td><td>2.0</td><td>2.6</td><td>4.6</td><td>6.8</td><td>6.2</td></tr>
<tr><td>Anova[5]</td><td>N.A.[6]</td><td>RB+C</td><td>CR+C</td><td>RB+C</td><td>CR+C</td><td>RB+C</td><td>CR+C</td><td>CR+C</td><td>CR+C</td></tr>
<tr><td>P(C)[7]</td><td></td><td><0.01</td><td><0.01</td><td>0.01</td><td>0.07</td><td>0.08</td><td><0.01</td><td><0.01</td><td><0.01</td></tr>
<tr><td>Coeff[8]</td><td></td><td>1.5</td><td>1.7</td><td>1.4</td><td>0.7</td><td>1.1</td><td>2.2</td><td>2.9</td><td>2.7</td></tr>
<tr><td colspan="11"></td></tr>
<tr><td rowspan="10">High</td><td>HEA</td><td>2.0</td><td rowspan="4">1.4</td><td rowspan="2">2.1</td><td>1.6</td><td>1.1</td><td>2.1</td><td>0.7</td><td>0.0</td><td>0.0</td></tr>
<tr><td>HEB</td><td>1.3</td><td>XXXX[3]</td><td>XXXX</td><td>XXXX</td><td>0.7</td><td>0.0</td><td>0.0</td></tr>
<tr><td>HFA</td><td>1.3</td><td rowspan="2">0.4</td><td>0.0</td><td>0.0</td><td>0.0</td><td>0.0</td><td>0.0</td><td>0.0</td></tr>
<tr><td>HFB</td><td>3.3</td><td>XXXX</td><td>XXXX</td><td>XXXX</td><td>4.0</td><td>8.0</td><td>8.0</td></tr>
<tr><td>HG</td><td>0.7</td><td>1.5</td><td>1.4</td><td>0.4</td><td>0.2</td><td>0.7</td><td>0.0</td><td>0.0</td><td>0.0</td></tr>
<tr><td>P(T)[1]</td><td></td><td>0.93</td><td>0.08</td><td>0.12</td><td>0.12</td><td>0.15</td><td>0.51</td><td>0.44</td><td>0.44</td></tr>
<tr><td>SEM[2]</td><td>1.0</td><td>1.0</td><td>0.7</td><td>0.5</td><td>0.3</td><td>0.8</td><td>1.8</td><td>3.6</td><td>3.6</td></tr>
<tr><td>Anova[5]</td><td>N.A.[6]</td><td>CR+C</td><td>CR+C</td><td>CR+C</td><td>RB+C</td><td>CR</td><td>RB</td><td>CR</td><td>CR</td></tr>
<tr><td>P(C)[7]</td><td></td><td><0.01</td><td><0.01</td><td><0.01</td><td>0.05</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Coeff[8]</td><td></td><td>0.8</td><td>0.7</td><td>0.6</td><td>0.3</td><td></td><td></td><td></td><td></td></tr>
</table>

Table 0-44 Site 2 *B. ewartiana* density (plants/m^2) of the surviving November 2012 cohort

S.R.	Treat.	R 1[0]	R 2	R 3	R 4	R 5	R 6	R 7	R 8	R 9
Med.	MEA	0.42	0.58a	0.32a	0.31a	0.33	0.33	0.31	0.31	0.23
	MEB	0.50			XXXX[3]	XXXX	XXXX	0.27	0.27	0.27
	MFA	0.25		0.32a	0.29a	0.17	0.17	0.22	0.14	0.14
	MFB	0.25			XXXX	XXXX	XXXX	0.31	0.22	0.22
	MG	0.42	0.08b	0.06b	0.06b	0.00	0.00	0.00	0.00	0.00
	P(T)[1]		<0.01	0.02	0.02	0.10	0.10	0.26	0.33	0.48
	SEM[2]	0.21	0.07	0.08	0.06	0.10	0.10	0.11	0.12	0.12
	Anova[5]	N.A.[6]	CR+C	CR+C	CR+C	CR	CR	CR+C	CR+C	CR+C
	P(C)[7]		<0.01	<0.01	<0.01			<0.01	<0.01	<0.01
	Coeff[8]		0.6	0.6	0.4			0.5	0.4	0.5
High	HEA	0.25	0.13	0.20	0.20	0.14	0.14	0.08	0.00	0.00
	HEB	0.17			XXXX[3]	XXXX	XXXX	0.08	0.00	0.00
	HFA	0.17		0.06	0.00	0.00	0.00	0.00	0.00	0.00
	HFB	0.33			XXXX	XXXX	XXXX	0.08	0.08	0.08
	HG	0.08	0.15	0.15	0.05	0.03	0.03	0.00	0.00	0.00
	P(T)[1]		0.78	0.14	0.12	0.12	0.12	0.72	0.44	0.44
	SEM[2]	0.12	0.08	0.07	0.06	0.04	0.04	0.06	0.04	0.04
	Anova[5]	N.A.[6]	CR+C	RB+C	CR+C	RB+C	RB+C	RB	CR	CR
	P(C)[7]		<0.01	<0.01	<0.01	0.05	0.05			
	Coeff[8]		0.6	0.6	0.6	0.3	0.3			

Table 0-45 Site 2 total pasture yield (kg/ha) at the plot level

S.R.	Treat.	R 1[0]	R 2	R 3	R 4	R 5	R 6	R 7	R 8	R 9
Med.	MEA	874	887	1069	1452	864 ab[4]	999ab	762	275bc	270
	MEB	560			XXXX[3]	XXXX	XXXX	665	435ab	269
	MFA	574		1231	935	1450a	1598a	1099	506a	404
	MFB	656			XXXX	XXXX	XXXX	558	376abc	252
	MG	611	566	928	1048	694b	699b	419	208c	220
	P(T)[1]		0.08	0.22	0.59	0.03	0.02	0.07	0.03	0.11
	SEM[2]	124	154	143	364	164	167	156	62	48
	Anova[5]	N.A.[6]	CR+C	CR+C	CR	RB+C	RB+C	RB+C	RB+C	CR+C
	P(C)[7]		0.02	<0.01		0.01	0.04	<0.01	<0.01	<0.01
	Coeff[8]		0.7	1.5		2.2	1.6	1.5	0.8	0.3
High	HEA	848	1066a	854b	336	502	270b	144a	87bc	55
	HEB	622			XXXX[3]	XXXX	XXXX	58b	75bc	44
	HFA	829		1577a	355	891	1329a	92ab	124a	65
	HFB	925			XXXX	XXXX	XXXX	62b	92b	51
	HG	813	617b	645b	345	117	212b	55b	62c	40
	P(T)[1]		<0.01	<0.01	0.99	<0.01	0.01	0.03	<0.01	0.29
	SEM[2]	153	102	96	90	86	188	19	8	8
	Anova[5]	N.A.[6]	RB+C	RB+C	CR	RB+C	RB	RB	RB	CR
	P(C)[7]		<0.01	<0.01		0.02				
	Coeff[8]		1.1	0.8		0.6				

Table 0-46 Site 2 *B. ewartiana* pasture yield (kg/ha) at the plot level

S.R.	Treat.	R 1[0]	R 2	R 3	R 4	R 5	R 6	R 7	R 8	R 9
Med.	MEA	65	164	139	195	163	184	202	72	105
	MEB	59			XXXX[3]	XXXX	XXXX	47	48	9
	MFA	83		135	208	178	170	183	72	46
	MFB	73			XXXX	XXXX	XXXX	124	40	49
	MG	60	35	106	68	41	53	49	34	13
	P(T)[1]		0.41	0.79	0.46	0.32	0.33	0.21	0.62	0.36
	SEM[2]	31	68	40	84	65	62	57	22	35
	Anova[5]	N.A.[6]	CR	CR+C	CR	CR	RB	CR	CR+C	CR
	P(C)[7]			<0.01					0.01	
	Coeff[8]			1.6					0.5	
High	HEA	59	115	85	61	121	36	26	15	8
	HEB	42			XXXX[3]	XXXX	XXXX	11	7	7
	HFA	28		186	30	74	19	19	9	5
	HFB	30			XXXX	XXXX	XXXX	24	14	15
	HG	63	83	35	45	15	27	14	4	7
	P(T)[1]		0.48	0.17	0.15	0.14	0.23	0.19	0.10	0.35
	SEM[2]	19	20	65	10	33	6	5	3	3
	Anova[5]	N.A.[6]	RB	CR+C	CR	CR	RB	RB	RB+C	CR+C
	P(C)[7]			0.02					<0.01	0.09
	Coeff[8]			2.2					0.2	0.1

Table 0-47 Site 2 *Aristida* spp. pasture yield (kg/ha) at the plot level

S.R.	Treat.	R 1[0]	R 2	R 3	R 4	R 5	R 6	R 7	R 8	R 9
Med.	MEA	222	265	273	398	248	237	413	115	86
	MEB	181			XXXX[3]	XXXX	XXXX	254	191	159
	MFA	158		243	291	537	376	403	171	189
	MFB	198			XXXX	XXXX	XXXX	156	149	109
	MG	114	204	319	119	415	262	205	126	131
	P(T)[1]		0.18	0.28	0.24	0.23	0.27	0.33	0.15	0.20
	SEM[2]	71	39	38	104	110	73	104	23	31
	Anova[5]	N.A.[6]	RB+C	CR+C	RB	CR+C	RB+C	CR+C	CR+C	CR+C
	P(C)[7]		<0.01	<0.01		<0.01	0.03	<0.01	<0.01	<0.01
	Coeff[8]		1.1	1.6		3.2	2.5	1.4	1.0	0.7
High	HEA	200	197	255	68	87	31b	36	14	17
	HEB	136			XXXX[3]	XXXX	XXXX	20	11	9
	HFA	161		271	68	104	148a	18	21	23
	HFB	129			XXXX	XXXX	XXXX	14	7	10
	HG	171	110	129	55	9	20b	12	7	14
	P(T)[1]		0.06	0.14	0.30	0.36	<0.01	0.19	0.14	0.15
	SEM[2]	51	38	57	6	47	11	7	4	4
	Anova[5]	N.A.[6]	CR+C	RB+C	RB+C	CR	RB+C	CR+C	RB	RB
	P(C)[7]		<0.01	0.01	<0.01		0.02	0.02		
	Coeff[8]		0.8	1.0	0.2		0.3	0.1		

Table 0-48 Site 2 *B. ewartiana* composition (%) at the plot level

S.R.	Treat.	R 1[0]	R 2	R 3	R 4	R 5	R 6	R 7	R 8	R 9
Med.	MEA	8	16	12	14	12	14	18	16	25
	MEB	9			XXXX[3]	XXXX	XXXX	8	8	4
	MFA	16		9	19	15	14	19	18	12
	MFB	11			XXXX	XXXX	XXXX	17	12	14
	MG	11	7	12	9	11	10	14	17	9
	P(T)[1]		0.37	0.49	0.50	0.68	0.61	0.57	0.61	0.35
	SEM[2]	5	8	3	5	4	3	5	5	7
	Anova[5]	N.A.[6]	CR+C	CR+C	CR	RB	RB	CR	RB	RB
	P(C)[7]		0.07	<0.01						
	Coeff[8]		0.9	0.7						
High	HEA	9	10	11	20a[4]	23	15a	21	17	16
	HEB	7			XXXX[3]	XXXX	XXXX	16	8	15
	HFA	4		10	9b	8	2b	20	7	8
	HFB	3			XXXX	XXXX	XXXX	34	14	26
	HG	8	12	11	14ab	16	14a	24	9	19
	P(T)[1]		0.53	0.96	0.02	0.23	0.04	0.24	0.25	0.15
	SEM[2]	3	3	3	2	6	3	5	3	5
	Anova[5]	N.A.[6]	RB	CR+C	RB	CR	RB	RB	RB+C	RB+C
	P(C)[7]			0.01					0.05	0.06
	Coeff[8]			0.7					0.8	1.0

Table 0-49 Site 2 *Aristida* spp. composition (%) at the plot level

S.R.	Treat.	R 1[0]	R 2	R 3	R 4	R 5	R 6	R 7	R 8	R 9
Med.	MEA	26	31	26b[4]	32	32	27	41	36	39
	MEB	28			XXXX[3]	XXXX	XXXX	46	48	57
	MFA	28		22b	28	35	21	34	33	44
	MFB	31			XXXX	XXXX	XXXX	31	36	42
	MG	21	34	36a	25	46	30	39	43	49
	P(T)[1]		0.55	0.01	0.71	0.55	0.25	0.52	0.33	0.34
	SEM[2]	8	4	3	6	9	4	7	5	6
	Anova[5]	N.A.[6]	RB+C	CR+C	CR+C	CR+C	CR+C	CR+C	CR+C	CR+C
	P(C)[7]		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	Coeff[8]		0.9	1.1	1.2	1.5	1.1	1.0	1.2	1.5
High	HEA	22	18	29	20	14	15	29	15	30
	HEB	23			XXXX[3]	XXXX	XXXX	30	13	22
	HFA	22		19	21	11	14	21	17	35
	HFB	15			XXXX	XXXX	XXXX	18	8	16
	HG	20	19	22	23	9	12	24	11	32
	P(T)[1]		0.90	0.14	0.94	0.63	0.88	0.24	0.31	0.10
	SEM[2]	5	4	5	6	4	4	4	3	5
	Anova[5]	N.A.[6]	CR+C	CR+C	CR+C	CR	CR+C	RB	RB	RB
	P(C)[7]		<0.01	<0.01	0.04		0.01			
	Coeff[8]		0.8	1.0	0.8		0.7			

9.3 GRASP development

Joe Scanlan

Plan for using field data to improve GRASP

SWIFTSYND to parameterise GRASP for pasture growth

Accurate estimates of pasture growth is a prerequisite for accurate estimates of pasture composition changes. SWIFTSYND sites allow the estimation of parameters in GRASP that drive pasture growth – in particular maximum nitrogen uptake, minimum nitrogen concentrations in green material and transpiration efficiency. From these parameters, we can estimate pasture growth under any seasonal conditions. The site was established in August 2013. Measurements were conducted in Nov-Dec 2013, Feb-Mar 2014, May-June 2014 and Aug-Sep 2014 and also include soil moisture, green and dead plant cover, dry matter yield (green and dead) for grass and forbs. Rainfall is collected daily and pasture basal area in mid-summer. Tree basal area and soil profile description were collected once.

Use animal numbers to estimate utilisation

From records of animal numbers and pasture growth, the GRASP model estimates the pasture utilisation in any particular combination of season and stocking rate throughout the year. Cattle records are collected from the Site 1 trial paddock and allowed calculation of utilisation together with the recordings on pasture composition. Utilisation is a key driver of pasture composition change.

Determine pasture composition changes

In any year when pasture utilisation is less than the safe utilisation, pasture condition improves. This is measured by a change in ‘state’ with state 0 being in excellent condition and state 11 being very poor condition. So an improvement in condition is represented by a decrease in state number. A decrease in state is accompanied by an increase in percent perennials.

Compare with field data

The simulated change in pasture composition was compared with field observations. The figure below (Fig. 9-1) shows results for one paddock at Wambiana where simulated results were compared with field observations. This is the first time that pasture composition has been modelled for this long-term grazing trial using the new formulation of the pasture composition sub-model.

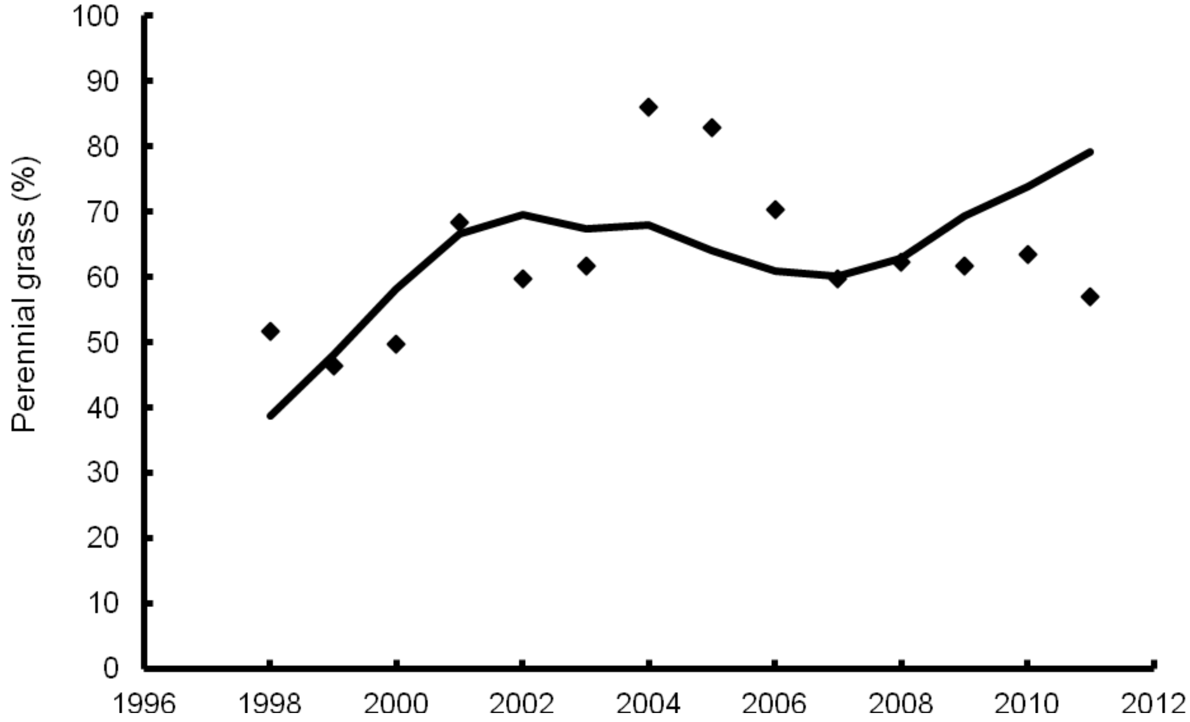


Fig. 0-1 Predicted (——) and observed (◆) perennial grass percentage for one of the moderate stocking rate paddocks (paddock 5) in Wambiana grazing trial, Charters Towers.

Modify parameters of the pasture composition sub-model as needed

It is quite possible that the parameters in the pasture composition sub-model derived from the initial Wambiana study do not adequately represent the pasture composition changes at Site 1. Model parameters were modified to give the best representation of the field data.

It is also possible that the current formulation of the model does not give a good representation of the field data derived from this study. If that were the case, then consideration would be given to deriving a different representation of the process. This would have to be considered site-specific until or if support from other studies or analyses

Plan for applying GRASP to selected scenarios analysis

GRASP will be used to explore the best bet spelling options emerging from the field work at a multi-paddock scale, examining the effects of both overall stocking rate and any periods of heavy grazing associated with the implementation of the spelling strategy. Three applications of the modified GRASP will be tested.

The first study deals with the pasture response to different frequencies and lengths of rest periods, under different stocking rates, with this information being averaged across 20 different climate windows (each 30 years). This overcomes the possibility that a particular climatic period produced an unusual response.

The second study covers the change in pasture condition for a recommended resting regime where animals are agisted off property. The third is a variant of the second application with the displaced animals being distributed across the other paddocks involved in the rotational resting regime. Stocking rates are constant for each climate window, with the starting stocking rates being considered safe for the 20 year climate window being studied.

Consultations with industry were conducted to generate questions to be answered within the capabilities of the GRASP modelling. Scenarios were developed to answer these questions. Consultations were conducted via teleconference with members of the Technical Panel and co-operating producers. Scenario analysis was conducted.

Changes in percent perennials

The original version of GRASP was unable to model the full impacts of pasture resting as the utilisation of growth was not sensitive to the season of that utilisation. As a result of this formulation, grazing during the summer growth period had the same impact as grazing during the winter period when the dominant pasture species are dormant. Mott *et al*. (1985) have shown that excessive grazing during the growing season decreases pasture condition, depending on the degree of utilisation of growth in the growing season. This necessitated modification of the model to account for the known biological response to grazing during the growing season.

The major modification involved weighting the impact of utilisation depending on the month in which that utilisation occurred (Fig. 9-2a). At one extreme, the impact of grazing in each month is equal (as may be the case in aseasonal locations) and at the other extreme, 100% of the impact occurs during the summer growing season of northern Australia.

Utilisation is used to estimate the change in pasture condition state (Fig. 9-2b). There are several critical parameters: the magnitude of change at 0% and 100% utilisation; the utilisation rate at which there is no change in condition (the safe utilisation rate where the line crosses the X-axis), and utilisation rate at which the rate of change increases from being low close to the safe utilisation to being more pronounced at high or low utilisation rates. This differs from the original GRASP model in which the change of state was 0 around the safe utilisation level and 1 (or a larger integer) above or below the thresholds.

In the original GRASP model, pasture condition state was represented as an integer value from 0 (excellent condition) and 11 (very poor condition) (Figure 1 in McKeon *et al.* 2000). In the revised model, state can be represented by any real value between 0 and 11 and the relationship between state and percentage perennial grasses is shown in Fig. 9.2c. In an ungrazed pasture (0% utilisation) the state can decrease (i.e. improve) by a specified maximum (usually between 1.2 and 1.5); at 100% utilisation the state can increase (i.e. degrade) by a specified maximum as shown in Fig. 9.2b. State does not change when utilisation is at the specified safe level (30% in Fig. 9.2b). Percent perennial grass is used as the indicator of condition and varies between a maximum of 90% and a minimum of 1%. While some land types may not have 90% perennial grass even when in excellent condition, in this representation of condition, pasture in its maximum possible condition will be represented as 90% perennial grass.

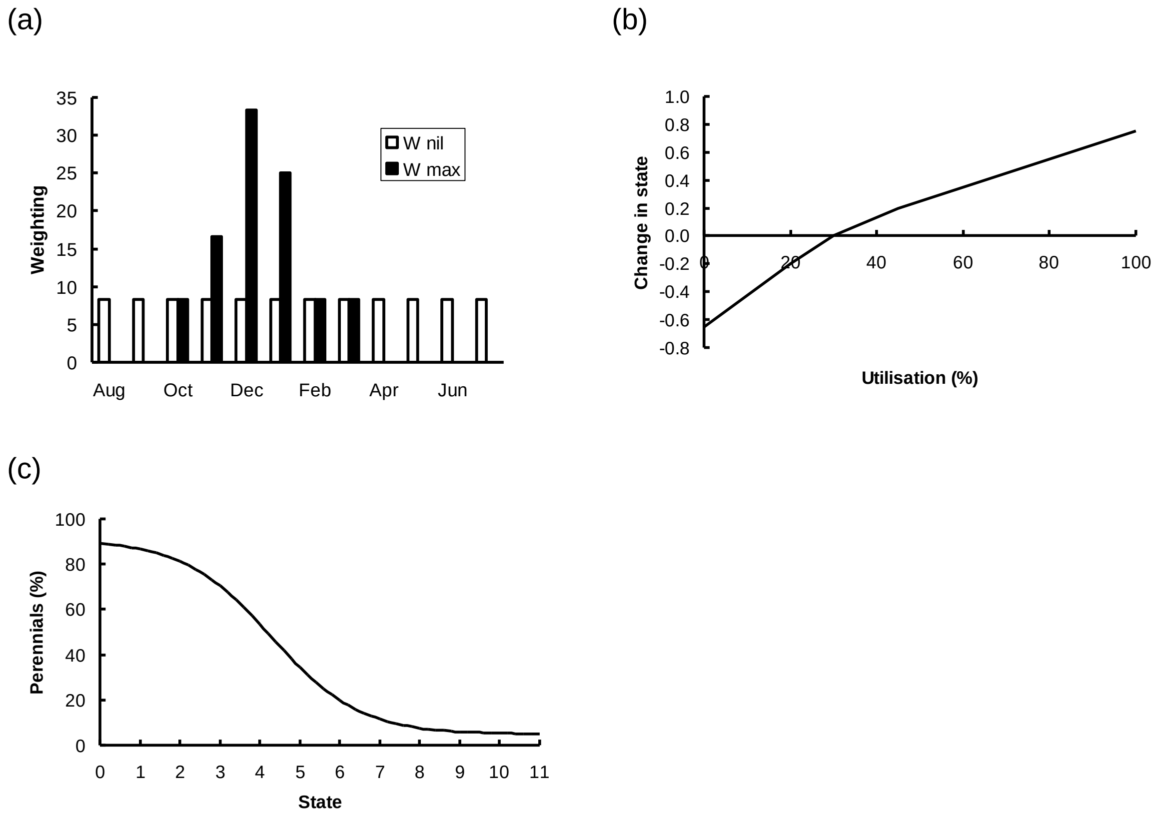


Fig. 0-2 Elements in calculation of perennials (%) within GRASP (a) monthly weighting applied to utilisation per month showing W Nil (nil weighting) where all months contribute 8%, and W max (maximum weighting) where the six months shown contribute a total of 100% to utilisation calculation; (b) change in state as a function of utilisation (%) showing specific parameters from Wambiana, and (c) perennials (%) as a function of state.

Effect of changes in perennials

Within GRASP, there is a set of parameters that represents pasture in excellent condition (state 0) and another set that represents degraded pasture (state 11). Not all parameters differ between the two states. Those that do are shown in Table 9-50.

Between these two extremes, GRASP uses a linear interpolation based on % perennials to estimate the parameter values.

Table 0-50 Parameters that are considered in representing the best and worst pasture conditions in simulation runs, showing relationships between these used in this work.

Parameter name	**Parameter number in State 0 (range shown)**	**Relationship between values in State 0 & 11**
Initial pasture condition	p(194) (0 to 11)	na
Recovery rate – maximum increase in condition during one year under 0% utilisation	P(195) (1 to 3)	na
Degradation rate – maximum decrease in condition in one year under 100% utilisation	P(196) (1 to 3)	na
Can condition recover from state 11	P(197) (0 or 1)	na
% utilisation for an increase in condition by one state	P(198) (typical values from 10 to 25%)	na
% utilisation for a decrease in condition by one state	P(199) (typical values from 25 to 45%)	na
% utilisation when condition does not change	P(83)	na
Maximum nitrogen uptake	P(99)	p(181) = p(99)*0.7
Green cover when transpiration is 50%	P(45)	p(182) = p(45)*0.75
Height (cm) of 1000 kg/ha	p(96)	p(183) = p(96)*0.75
% N at zero growth	p(101)	p(184) = p(101)+0.2
% N at maximum growth	p(102)	p(185) = p(102)+0.2
Prop of dead leaf detached per day from 1 Dec to 30 April	p(128)	p(186) = p(128)+0.00
Prop of dead stem detached per day from 1 Dec to 30 April	p(129)	p(187) = p(129)+0.002
Prop of Dead leaf detached per day from 1 May to 30 November	p(130)	p(188) = p(130)+0.002
Prop of Dead stem detached per day from 1 May to 30 November	p(131)	p(189) = p(131)+0.002
Soil water index at which above-ground growth stops.	p(149)	p(190) = 0.9
Yield (kg/ha) at which intake restriction no longer operates	p(144)	p(192) = p144
Soil water index for maximum green cover	p(009)	p(193) = 0.9
Growth index for green day/frost	p(056)	p(200) = p056

The net results of the above changes in parameters varies considerably depending on the actual climate and land type. Typically, state 11 (very poor condition) has about a 40-60% reduction in pasture growth compared with that of state 0 (excellent condition).

9.4 Other key questions from co-operators and agency staff for applying GRASP

Other questions from the co-operators which were not common themes:

- What is the effect of not loading up paddocks for the first four years of a spelling cycle?
- How to grow more grass?
- How much does a different starting land condition affect recovery?
- How much does different initial seasonal conditions affect recovery?
- After a major drought, how does spelling compare to set stocking affect recovery?
- How much do seasonal conditions during spelling cycles affect recovery?
- How much do El Niño and La Niña years affect recovery?

Other questions from the agency staff which were not common themes:

- How long does it take to recover C condition land to A/B condition?
- What circumstances speed up recovery of land condition?
- How effective is opportunistic spelling when seasonal conditions are good?
- How do growing conditions affect recovery e.g. starting in 1964 versus 1974?
- What proportion of years is it OK to load up other paddocks during a spelling cycle?
- When and how should opportunistic spelling occur?
- What duration and frequency of spelling is required to recover C versus maintaining A land condition?
- How effective is opportunistic spelling when done in conjunction with an above-average rainfall forecast based on the SOI?
- How does the abundance of Indian couch affect recovery with spelling?
- For a given time in the wet season, what is the probability of growing different amounts of grass and what is the best management if it has not rained by this date?

9.5 Thoughts on plant physiological aspects and slow response to spelling

Richard Silcock

Any recovery to a high proportion of 3P species is driven by an increase of crown cover of remaining 3P plants AND recruitment of new 3P plants. An increase in crown cover of existing plants can occur under reasonable seasonal conditions provided utilisation rates on those plants is relatively light. 'Safe' utilisation levels will probably only allow the maintenance of current basal cover levels in fair seasons. To get an increase will require well above average seasons or well below safe utilisation levels of those species while they are actively growing. We do not have a figure for this level and this project aims to give insights to that.

If there is a large density of other perennial non-3P grasses in competition with them, the chances of basal cover improvement will be lowered in line with classic competition theory. Hence a high proportion of *Eriachne mucronata*, *Aristida pruinosa*, *Bothriochloa pertusa* and *Chrysopogon fallax* will slow the potential increase of crown cover of the 3P grasses. The reasons vary with the species – *Aristida* because they are mostly ungrazed, *B. pertusa* because it spreads by stolons and produces masses of highly germinable seeds, *E. mucronata* because plants have a very long lifespan and are unpalatable while *C. fallax* too is very long lived and, despite being very palatable, has a massive rhizome system below-ground that resists the ingress of any other grass.

Increase in crown cover from seedling recruitment is a much more hazardous process in a perennial pasture than expansion of existing crowns. Classic competition theory says that if seedlings have the same growth rhythm as existing perennial plants, that they will struggle to access nutrients and sufficient moisture to survive in close association with existing plants. Added to that, grasses become etiolated from light starvation and lack tillers that provide enhanced rooting volume, strength and secondary meristems. So they are easily uprooted by grazers or eaten off by herbivores of all sorts – stock, marsupials, lepidopterous larvae, locusts etc. As well, they then usually fail to flower and set any seed to replace those from which they came. Documented survival rates of <1% of germinated seeds of perennial grasses is normal and 5% survival to adulthood is a very good result.

Then there is the issue of the relative numbers of viable seeds of the 3P grasses from which seedling recruitment can occur when good summer rains come. Most large perennial pasture grasses do not have large persistent seedbanks and that is well documented (Orr, Phelps, McIvor, Silcock, O'Connor, Hyder). *B. pertusa* and *H. contortus* are exceptions which this project has confirmed but the desirability of the former is in dispute. This project has demonstrated that in some spring seasons there is almost no germinable seed of the 3P grasses in the soil, unlike the other 2 grasses just named. So no amount of light grazing will allow seedling recruitment of those 3P grasses in those situations. However, a good summer season may allow a high level of seedset in preparation for the next summer. It must also be recognised that the rate of growth of seedlings of *B. ewartiana* in the first summer of establishment is very slow, especially the number of tillers developed. This project has provided extra data to underpin that information found from earlier seed production plots (Loch and Silcock). In this it is a much poorer re-establisher than

H. contortus which Orr and others have documented to be able to develop sizeable crowns by the end of their first growing season in an existing pasture.

There are other issues in very good summer seasons like have been recently experienced – poor flowering under exhausted soil nitrogen supplies and high levels of ergot attack of flowers of *Bothriochloa* species in wet summers. In the case of exhaustion of available soil nitrogen, it was very evident in exclosures at Keilambete during the A/B project that very few seedheads were put up by all 3P grasses at the end of a very wet summer that followed a wet winter. This applied to *H. contortus*, *Themeda triandra*, *B. ewartiana* and *Cenchrus ciliaris* and has also been documented by Orr for *Astrebla* species in western Qld. This is again quiet readily explained by basic grass physiology although the *Bothriochloa* genus is normally regarded as less demanding of nitrogen for growth than most other common C_4 grasses. Reasons for this are sometimes put in terms of mycorhizal associations around the root systems of such plants but I cannot recall any specific publication on this topic for *Bothriochloa.* Flowering may also be more severely reduced than total biomass growth but I cannot think of a citation for this.

With regard to the parasitising of the florets of *Bothriochloa* by ergots, Loch and Silcock in separate situations have found seedset of *Bothriochloas* to be severely reduced by ergot infestations in abnormally wet and humid summers. The closely related *Dichanthium* genus does not seem to suffer from this problem to anywhere near the same extent and may be a feature correlated with the abundance of *Dichantium* species in the monsoonal tropics of Australia and other wet tropical regions. Hence at Wambiana, *D. fecundum* may not suffer in wet summers while *B. ewartiana* does. I would seek confirmation of these ideas from others who have done intensive studies of these plants in northern Australia but cannot think of anyone.

At both Wambiana and Monteagle, there is only a small population of *H. contortus* and *D. sericeum* from which to make comparisons and at Monteagle there is no *D. fecundum*. To date I have not found *D. sericeum* or *H. contortus* in the seed bank at either site and only an occasional *T. triandra*. (less than *Eucalyptus* spp.). I have yet to confirm any *D. fecundum* from Wambiana soil over 2 spring samplings. What we have recorded is a few *B. ewartiana* seeds in spring 2011 and 2013 but none in 2012 at Monteagle. At Wambiana there were no *B. ewartiana* seeds germinable in spring 2012 but there may be a few in 2013 (results pending). Hence, with a relatively low sampling intensity such as we are using, recording germinable seeds of *B. ewartiana* when the average seed population is under 50 per sq metre may not occur from a sample area of only about 1 square metre despite that area coming from over 400 individual cores 5cm in diameter. By comparison, the recorded density of germinable *B. pertusa* seeds at the Wambiana trial site is in excess of 300 /sqm (range 0 – 2290) and is just reaching observable numbers at Monteagle where its presence in the pasture is still very low.

In the absence of any knowledge or information about the underground traumas due to root-eating insects, diseases, nematodes etc such controlling factors of seedling recruitment and crown expansion can only be mentioned as speculative at this time but not to be dismissed out of hand.

If the rainfall data from Monteagle is reviewed, there were below average summers prior to the trial commencement and then consecutive decile 10 years for the first 2 summers followed by a decile 4 summer and fire in 2012-13. Under those conditions, crown enlargement and seedling recruitment just prior to the trial commencement may have been limited. During the trial, crown enlargement was to be expected if competition from existing perennial grasses was not too great. Trial data shows that there was a major population of perennial wiregrasses there to compete. We have no data about seedset of *B. ewartiana* but under the very wet conditions, it could have been quite low due to lack of available Nitrogen and high levels of ergot infestation of the seedheads, but this is unproven and I think undocumented.

The issue of crown carbohydrate reserves is speculative as is that about low number of tiller buds from which to expand the existing crowns. My personal view is that carbohydrates reserves are not the main issue as that should only apply where moisture and nutrients are non-limiting and seems to be a cool temperate climate phenomenon where low temperatures allow such accumulation. There has been no notable review of this topic for many years now. If a plant has large rhizomes, such as *C. fallax*, then those organs should be involved in feeding new tillers to emerge once the rains return because there is no above-ground plant left. By comparison, the crown of *B. ewartiana* and *B. pertusa* is completely exposed and early regrowth of leaves possibly feeds the new tillers with nutrients along with renewed uptake of soil minerals by surviving roots. Both put out bunches of aerial leaves and small shoots on marginal rainfall and probably derive some carbohydrates from the living stem below. I acknowledge that many tropical grasses do have a certain amount of plant crown beneath the soil surface that could be a carbohydrate store but I think of that part of the plant as being mainly a sheltered source of meristems of roots and shoots.

There are many different crown structures amongst tropical grasses and so a general theory about how they initiate regrowth at the start of the wet season seems improbable. There will be several strategies but some energy source is obviously needed until adequate photosynthesis takes over. Where that source is needs to be determined as well as what chemical form it is in during the dry season. We know that live pieces crown of many grasses can survive moderate dehydration and complete lack of green leaf and live roots and then resprout and grow if soil moisture is returned. Wiregrasses and black speargrass are not good at doing this while buffel, *C. fallax* and *Digitaria divaricatissima* regrow fairly readily (Silcock unpublished data). A couple of PhDs could work on this and the manner of crown development of major tropical grasses to provide real data to enhance the broader field studies currently and recently undertaken.

I have not addressed the obvious question of control mechanisms that enhance or restrict germination of seeds of the main pasture species. That is another series of studies in itself that involves innate seed dormancy mechanisms and light x temperature effects on germination of non-dormant seed. In general, seed of most of the perennial species involved can be germinated quite readily after any initial dormancy is lost in the first 6-9 months. However, the degree to which constancy of available moisture interacts with temperature and light intensity is a major complication that we have no data for. Suffice to say that, many times, very few non-dormant grass seeds germinate after early wet season rains for reasons we cannot yet describe. Only *H.contortus* and *D. sericeum* have, to my knowledge, been studied in sufficient detail to provide credible information about such germination control.

9.6 Issues and knowledge gaps relating to plant physiological responses to spelling

Issue or Knowledge Gap (I or KG)	Importance (1-5)	Outcome potential (1-5)	Priority to further develop (Imp. x Out.Pot.)
KG - lowest level of utilisation and seasonal requirements to get improved crown cover	5	3	15
KG - competition from non-3P grasses for 3P crown cover increase	5	3	15
I - survival of perennial grass seedlings with competition from existing plants	5	2	10
I – *B. ewartiana* seedling growth in first summer is very slow	4	2	8
I – poor flowering and decreased growth of *B. ewartiana* in good rainfall years	4	3	12
I – seedset of *B. ewartiana* decreased by Ergot in wet summers	4	3	12
I – low sampling intensity for soil seed studies	3	3	9
KG – underground traumas during wet summers	2	2	4
I – crown enlargement expected in 1st year of trial	4	3	12
I – tiller and bud ecology is more important than crown carbohydrate reserves	4	2	8
KG – where and what is the carbohydrate energy source to start growth at the beginning of the wet season	3	2	6
KG – control mechanisms (including soil moisture, light and temperature) that enhance or restrict germination of seeds	3	4	12

Note – higher numbers have greater value

9.7 Soil seed bank at Site 1

Table 0-51 Site 1 germinable seed density (seeds/1.0367 m2)

	Year			
Taxonomic unit	2011	2012	2013	2014
Abutilon otocarpum				0
Alloteropsis cimicina	3	2		3
Alternanthera nana	1			0
Alternanthera repens	1			0
Alysicarpus rugosus	9	2	4	2
Ammannia multiflora	168	69		16
Aristida acuta				0
Aristida benthamii var. benthamii	5	9	2	105
Aristida calycina	1	6	13	3
Aristida calycina var. calycina			48	0
Aristida holathera	3	3		2
Aristida holathera var. holathera			6	0
Aristida	15		11	
Aristida jerichoensis var. subspinulifera	2		2	11
Aristida latifolia			15	5
Aristida muricata			4	11
Aristida pruinosa	4	3	11	17
Aristida spp.	7	8	13	11
Austrochloris dichanthioides	2	2		6
Bergia trimera	700	283	79	99
Blumea integrifolia			6	3
Bothriochloa ewartiana	5		18	31
Bothriochloa pertusa			2	9
Bulbostylis barbata	361	110	37	60
Centipedia minima	9	8	4	2
Chamaesyce drummondii	3			0
Commelina benghalensis	1			0
Cyperus casteneus				0
Cyperus difformis			2	0
Cyperus fulvus	16	9	33	25
Cyperus squarrosus	25	16	15	17
Digitaria ammophila			2	2
Digitaria bicornis		3		5
Digitaria brownii	1	2	6	11
Digitaria ciliaris	14	3		
*Digitaria ciliaris**				0
Digitaria spp.		2		0
Drosera spp.	3	17	7	3
Dysphania glomulifera	104	38		
Dysphania	88		129	
Eleusine indica		8		0
Enneapogon	3		2	5
	Year			

Taxonomic unit	2011	2012	2013	2014
Enneapogon avenaceus	6	8		0
Enneapogon pallidus	1	2		0
Enneapogon polyphyllus		2		
Enneapogon virens				0
Enteropogon acicularis			6	0
Epaltes australis	45	19	20	3
Eragrostis lacunaria	180	156	193	311
Eragrostis sp.		2	2	0
Eragrostis tenellula	67	64	73	50
Eriochloa pseudoacrotrica	2		4	0
Eucalyptus melanophloia	1			0
Eucalyptus populnea		2	9	5
Evolvulus alsinoides	8	8	2	2
Fimb ramets		3		0
Fimbristylis dichotoma	38	19	15	19
Fimbristylis microcarya	44	212	72	64
Galactia tenuiflora	1			0
Heliotropium cunninghamii			4	0
Heliotropium spp.		2		
Hybanthus enneaspermus	4	16	4	
Hypericum gramineum			2	
Indigofera linnaei		2		
Melhania oblongifolia		2		
Melinis repens	8	8		
Monocot		2		
Panicum effusum	3		18	
Paspalidium constrictum	1		2	
Perotis rara	10			
Phyllanthus virgatus	1			
Polycarpaea spp. aff. P. corymbosa	6	8	7	
Polymeria calycina	5			
Portulaca filifolius	1			
Portulaca oleracea		2		
Portulaca pilosa			2	
Pterocaulon spp.	1			
Schenkia australis			2	
Sedge	4	30	2	
Senecio spp.		3		
Sida sp. aff. brachypoda CHA456	1			
Sida spinosa	1			
Spermacoce spp. aff. brachystemma	6	8	4	
Sporobolus australasicus	5	3	9	
Sporobolus caroli	1		4	
Stylosanthes hamata cv. Verano	3			
Stylosanthes scabra cv. Seca	1			
Synaptantha tillaeacea var. tillaeacea	2			
	Year			
Taxonomic unit	2011	2012	2013	2014

Themeda aff. triandra	1		
Tragus australianus	4	3	7
Tripogon loliiformis		3	6
Urochloa panicoides	2		
Wahlenbergia spp.	7	2	18
Waltheria indica	1	3	
Zornia muriculata	9	9	
Zornia muriculata subsp. angustata			2

9.8 Soil seed bank at Site 2

Table 0-52 Site 2 germinable seed density (seeds/0.9425 m2)

Taxonomic unit	Year 2012	2013	2014
Alloteropsis cimicina	128	27	18
Alternanthera denticulata			7
Alternanthera denticulata var.	30	27	3
Alternanthera nana		3	2
Alysicarpus rugosus	3	3	1
Ammannia multiflora	28	10	5
Aristida benthamii var. benthamii	7	7	0
Aristida calycina var. calycina	8	33	16
Aristida calycina var. praealta		2	0
Aristida jerichoensis subsp.	2	2	6
Aristida muricata	2	0	4
Aristida pruinosa		13	0
Aristida sciuroides			9
Aristida spp.	3	5	6
Bacopa floribunda	7	0	1
Blumea integrifolia	43	30	17
Bothriochloa decipiens var. cloncurrensis			1
Bothriochloa ewartiana		3	2
Bothriochloa pertusa	323	462	489
Brachyachne convergens	1	0	0
Bulbostylis barbata	6	3	1
Centipedia minima		2	0
Chloris lobata	1	0	0
Chloris pectinata ?	3	0	0
Chloris pumilio	14	3	1
Chloris scariosa	1		
Chrysopogon fallax	1	2	0
Crotalaria montana	2	2	0
Cyanotis axillaris	1	0	0
Cyperaceae	16	0	0
Cyperus difformis	6	2	3
Cyperus fulvus	17	2	3
Cyperus nervulosus	20	0	0
Cyperus pulchellus	43	8	17
Cyperus pulchellus Resprout		2	2
Cyperus squarrosus	70	33	31
Dactyloctenium radulans	1	2	1
Dichanthium fecundum			10
Digitaria brownii	1	2	0

Taxonomic unit	Year 2012	2013	2014
Digitaria ciliaris	23	5	0
Digitaria imbricata	1	2	3
Echinochloa colona	1	0	0
Eleusine indica	1	0	0
Enneapogon polyphyllus	2	3	0
Enneapogon spp.			1
Epaltes australis	80	52	43
Eragrostis cumingii	43	48	31
Eragrostis elongata	52	8	9
Eragrostis lacunaria	147	143	136
Eragrostis parviflora	18	3	3
Eragrostis sororia	2	0	0
Eragrostis speciosa			1
Eragrostis tenellula	1	8	3
Eriachne obtusa		2	0
Eriachne squarrosa?	1	0	0
Eriochloa pseudoacrotricha	3	3	2
Eucalyptus brownii			1
Eucalyptus crebra	1	0	0
Evolvulus alsinoides	7	12	8
Fimbristylis depauperata	2	0	0
Fimbristylis dichotoma	215	113	91
Fimbristylis dichotoma Respt		18	0
Fimbristylis microcarya	1034	320	387
Goodenia cycloptera	6	0	0
Heliotropium cunninghamii	3	3	0
Hybanthus enneaspermus	7	3	4
Ipomoea coptica	1	0	0
Ipomoea plebeia	1	0	0
Lindernia scapigera	54	23	23
Lipocarpha microcephala	27	2	0
Ludwigia perennis	1	0	1
Mitrasacme prolifera	7	0	0
Mnesithea formosa	56	15	10
Oldenlandia galioides	224	113	79
Oldenlandia mitrasacmoides subsp.		2	1
Oxychloris scariosa		0	0
Panicum decompositum var. tenuius	1	0	0
Panicum effusum	28	20	20
Paspalidium clementii	1	0	0
Paspalidium criniforme			2
Paspalidium spp.	1	0	0
Perotis rara	1	0	1
Phyllanthus virgatus	19	27	28
Poaceae	6		
Portulaca pilosa	6	5	1

Taxonomic unit	Year 2012	2013	2014
Pterocaulon spp.	7	0	2
Rotala maxixana			1
Ruellia australis	1	0	0
Sauropus trachyspermus	1	0	0
Schizachyrium pseudeulalia	1182	165	19
Sedge Dead	4	3	2
Sedge Resprout		22	0
Sida spinosa	3	0	0
Spermacoce spp. aff.	4		
Spermococe aff. S. brachystem		5	0
Sporobolus australasicus	6	3	2
Sporobolus caroli	6	3	0
Striga sp.	7	0	1
Stylosanthes scabra	1		1
Tephrosia leptoclada	6	2	2
Themeda triandra		3	0
Tripogon loliiformis	32	18	3
Typha sp.	1		
*Urochloa subquadripara**	2	0	0
Vernonia cinerea			1
Vigna lanceolata	3		2
Zornia muriculata subsp. angustata	38		
Zornia spp.		30	12

9.9 BonAccord case study brochure

Case study 1: The interactions of spelling, stocking rates and seasonal conditions on BonAccord, Anakie Qld

Summary

Stocking around the long term carrying capacity, varying stocking rates with seasonal conditions and wet season spelling was found to give superior land condition, cattle production and profitability when compared to other stocking rate and spelling management on BonAccord. Bio-economic modelling was conducted on a simulated property with similar land types and management to that on BonAccord for the period 2003 to 2015. The actual cattle numbers on BonAccord for this period were used for the study. Richard Hawkins (owner) has always stocked conservatively and reduced cattle numbers during dry conditions. Richard has questioned whether he could have run a few more cattle to increase profit and still maintain land condition. He also questioned the value of his spelling management compared to a more fixed stocking management. The simulations were conducted to answer these key questions around the interactions of stocking rate, spelling and seasonal conditions.

Background

BonAccord is a commercial cattle property 10 km south of Anakie with mainly the brigalow/blackbutt land type. There are patches of silver-leaved ironbark, coolibah floodplains, downs country and lancewood/bendee ridges. About 75% of the property is cleared with buffel pastures established, and regrowth controlled by blade ploughing or Graslan herbicide. The majority of the property has very good land condition with predominantly buffel grass. The herd is self-replacing and turnoff from the property is mainly EU steers and cull heifers, with some cows and steers going to local markets. The cattle are a mix of breeds with a high *Bos indicus* content. Production is driven by seasonal conditions which is generally divided into a typical wet season where the majority of rain falls between December and May and a dry season with very little rainfall the remainder of the time. Average annual rainfall is 652 mm.

An average of 1064 adult equivalents (AE) were carried over the simulation period of 2003-2015 giving an average stocking rate (SR) of 18.5 AE/100 ha based on actual BonAccord records. A moderately fertile box land type was selected to represent the property.

Richard Hawkins on BonAccord has questioned the effectiveness of his spelling management and whether he could run more cattle

Simulations include:

1. A fixed SR for all years of 18.5 AE/100 ha (**fixed 18.5AE**)

2. A fixed SR for all years of 15 AE/100 ha (**fixed 15AE**)

3. A variable SR each year based on the actual yearly stock records for BonAccord but no spelling (**variable 18.5AE**)

4. A variable stocking with a spelling for one third of the time. This spelling was achieved by having 6 months grazing followed by 3 months of spelling in a fixed rotation in all years for each paddock. This is a representation of what was actually done on BonAccord. (**Baseline**)

5. A variable stocking with spelling and a 5% heavier stocking rate than was actually used on BonAccord. (**var+spell+^5%)**.

Findings

Overall, the baseline management gave the best land condition and profitability. The fixed 15AE has good land condition but profitability is reduced due to lower cattle production. The Var+sp+5% gave an increase in profitability at the expense of decreased land condition. Fixed 18.5AE compromised both profitability and land condition. While the variable 18.5AE and the baseline had the same overall stocking rate, the benefit from spelling gave a small increase in profitability and land condition. These examples demonstrate the benefits obtained when varying stocking rates with seasonal conditions and also wet season spelling (Figure 1 and Table 1).

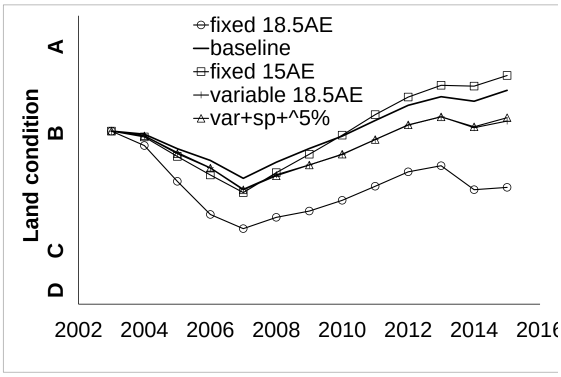


Figure 1 Modelled land condition from 2003 to 2015 at BonAccord

Economic modelling results show that in terms of returns per dollar invested and wealth generation, the baseline (spelling) scenario and the variable with spelling and a 5% increase in stocking rate performed above the other scenarios (Table 1).

Table 1 Modelled economic performance at BonAccord.

Scenario	Internal rate of return (%)	Net present value ($)
Variable 18.5 AE	25.5	2,752,130
Baseline	26.3	2,861,205
Fixed 18.5 AE	22.6	2,405,771
Fixed 15 AE	25.3	2,373,377
Var+sp+5 %	26.1	2,965,901

Conclusions

This case study shows the importance of stocking around the long term carrying capacity, varying cattle numbers with seasonal conditions and incorporating wet season spelling management. The results are specific to the climatic conditions received at BonAccord from 2003 to 2015 and while the actual cattle numbers were used for the baseline management, the land types and spelling management is a representation of what was actually done on BonAccord. This case study gives a good idea of the magnitude of the benefits to be obtained and relative profitability when management is aimed at maintaining and/or improving land condition.

9.10 Appendix 10 Oaklands case study brochure

Case study 2: The interactions of spelling, stocking rates and seasonal conditions on Oaklands, Duaringa Qld

Summary

There are small land condition and profitability benefits for a spelling regime involving a two paddock rotation. The management involves spelling a paddock with box flats every second year and moving these cattle into an adjoining paddock with the less productive bulloak land type. This management was compared with a no spell scenario where both paddocks were run at safe carrying capacity. Bio-economic modelling was conducted on a simulated property with similar land types and management to that on Oaklands for the period 1993 to 2015.

John Dunne has been burning for woody weed management and spelling on Oaklands since taking ownership in 1997. He has now focussed this management to improve the land condition on the favoured box flats along the creeks. These are the key areas on this breeding property to enhance the reproductive levels and profitability. Any gains in body condition score are critical for the breeders so John is very interested in an optimised management to favour these areas.

Background

Oaklands is an organic cattle property 60 km south of Duaringa. The cattle are a mix of breeds with a high *Bos indicus* content. Weaners are produced and then fattened at another property owned by the business. The main land types in order of magnitude are gum-topped box, bulloak, narrow-leaved ironbark, box flats and bluegum, and silver-leaved ironbark with roughly half of each land type in a remnant state. Land condition is predominantly 'B' or 'C' with an even distribution through land types, remnant and regrowth areas. Production is driven by seasonal conditions which is generally divided into a typical wet season where the majority of rain falls between December and May and a dry season with very little rainfall the remainder of the time. Average annual rainfall is 674 mm.

John Dunne on Oaklands has questioned the effectiveness of a two paddock rotation with breeders on creek flats to optimise production and land condition

John does not like to move breeders during the summer peak calving period so a rotation with two adjoining paddocks was examined. Box flats paddock is mainly the more productive box land type and joins the less productive Timbered paddock. The safe carrying capacity for the two paddocks was estimated. The simulation examined a six month summer spell every second year on the Box flats paddock. The cattle from this paddock were put in the Timbered paddock. A number of simulations were run for the two paddocks. The aim is to maintain the safe carrying capacity for the two paddocks, maintain land condition in the Timbered paddock and improve land condition in the Box flats paddock.

Findings

If both paddocks were stocked at fixed, safe stocking rates, then land condition was maintained for the simulation period. The safe stocking rates were 11.5 AE/100ha for the Timbered paddock and 23 AE/100ha for the Box flats paddock.

The best combination of stocking rates was a base stocking rate of 10 AE/100 ha for the Timbered paddock and 33 AE/100 ha for the Box Flats. These were imposed for the beginning 18 months of each 2-year period. For the remaining 6-month period, all stock were in the Timbered paddock at a stocking rate of 14.5 AE/100 ha. The spelling management gave a 5% increase in cattle numbers compared to the safe stocking rate management (Table 1 and Figure 1). Part of the success of the spelling management is the large size of the Timbered paddock (1900 ha) compared with the Box Flats (491 ha) which enables all the stock from the Box Flats to be put into the Timbered paddock without increasing the stocking rate to such an extent that its condition was adversely affected.

Table 1 Simulated cattle numbers for the spelling and safe stocking rate comparison

Paddock	Safe SR	Spelled Yr1		Spelled Yr2	
		Jun-Nov	Dec-May	Jun-Nov	Dec-May
Box Flat	113	160	160	160	0
Timbered	219	190	190	190	350
Total	**332**	**350**	**350**	**350**	**350**

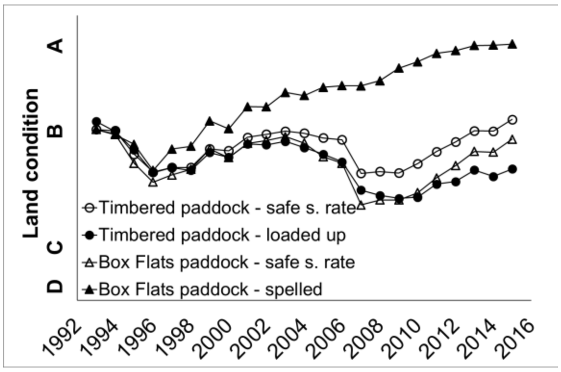


Figure 1 Modelled land condition from 1993 to 2015 at Oaklands

There was a small economic benefit to the spelling management compared to the safe stocking rate management when measured by the Internal Rate of Return (IRR) and the Net Present Value (NPV). This was driven by slightly better individual animal performance and increased cattle numbers (Table 2).

Table 2 Modelled economic performance at Oaklands.

Scenario	Internal rate of return (%)	Net present value ($)
Spelled	25.3%	$1,248,218
Safe SR	25.1	$1,159,388

Conclusions

There are small land condition and profitability benefits for a spelling regime involving a two paddock rotation. This was achieved because the best combinations of stocking rates were found that would maintain the land condition in the Timbered paddock and also improve land condition in the Box flats paddock.

In reality the implementation of the spelling scenario at Oaklands would not be a rigid stocking rate no matter what the growing conditions were like. If the total AEs in the whole paddock were adjusted (within modest limits) depending on the season, it would be expected that the response would be quicker, that the condition of the Timbered paddock might improve or the total stock numbers carried might increase a little more than the 5% calculated in this example.