BEST-BET PRACTICES FOR MANAGING GRAZING LANDS IN THE VICTORIA RIVER DISTRICT OF THE NORTHERN TERRITORY

A technical guide to options for optimising land condition, animal production and profitability

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March 2014

Bibliography:

Walsh, D. and Cowley, R. A. (2014). Best-bet Practices for Managing Grazing Lands in the Victoria River District of the Northern Territory. Northern Territory Government, Australia. Technical Bulletin No. 352.

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Technical Bulletin No. 352
ISBN: 978-0-7245-4762-3

Table of Contents

1 INTRODUCTION

This technical guide has been written to help inform and improve grazing management in the Victoria River District (VRD) of the Northern Territory (NT). It focuses on four major themes: managing stocking rates, spelling pastures, prescribed burning and property infrastructure development. The guide is intended as a technical resource for use by those working with producers to improve the management of grazing lands.

The guide is a product of the Northern Grazing Systems (NGS) initiative, which was developed and implemented in a partnership between Meat and Livestock Australia (MLA), CSIRO, the NT Department of Resources (now the Department of Primary Industry and Fisheries (DPIF)), the Queensland (Qld) Department of Employment, Economic Development and Innovation and the Western Australia (WA) Department of Agriculture and Food. This initiative was designed to ensure that the beef cattle industry in the NT, Qld and northern WA derives the full benefit from research on how best to manage grazing country for beef production.

The information in this guide has been derived from various sources, including a review of research reports, biological and economic modelling of different management options, and the input of producers and technical specialists from the region.

Future work in the region will focus on working with producers and their advisors to increase awareness, understanding and uptake of improved grazing practices. The technical guide will be a key reference for extension activities and will continue to be improved by new information and experiences shared by producers, their advisors and researchers.

2 HOW THE GUIDE WAS DEVELOPED

This technical guide was developed by combining information from three major sources:

1. A review of publications from completed research on grazing land management relevant to northern Australia (Qld, the NT, and the northern rangelands of WA). This review focused on four themes – managing stocking rates, pasture spelling, prescribed burning and intensifying property infrastructure with more fences and water points (see McIvor et al. 2010).

2. Outputs from testing different management options via computer simulation models. The effects of stocking rates, pasture spelling and prescribed burning on pasture and animal productivity were simulated with the GRASP model. Grazing trial data and pasture growth studies have been used to develop GRASP, which can be run for specific land types and over any sequence of years where climate data exists. The pasture and animal productivity output from GRASP was subsequently used in an economics spreadsheet model called ENTERPRISE to assess how various management practices affect the economics of a beef enterprise with a herd and paddock structure typical of the region. This testing of options with GRASP and ENTERPRISE provided a way of extrapolating responses to grazing management measured in grazing trials to a wider range of land types and climate conditions. It also provided a way to test many variations in grazing management that would be expensive and time-consuming to test on the ground. This helped to identify the practices that have the most impact and narrowed down the most cost-effective ways of implementing these practices (see Scanlan 2010).

3. Knowledge and experience of producers and technical specialists from the region, including their assessment of the most relevant and useful outputs from the review of research and the modelling. This was done during two workshops and via direct input to reports, including this guide. This local input also identified and prioritised research gaps in the region.

Not all practices (or the many variations of these practices) have been objectively evaluated in every region of northern Australia. Even where there is solid data on a practice, it often represents only one land type and a particular sequence of seasonal conditions. Furthermore, information from grazing trials or other sources of hard data needs to be considered in the context of the whole property. Local knowledge and experience combined with the modelling have therefore been very important in helping form the guidelines and ideas in this guide. As there will be some degree of uncertainty about what practices (and variation of these practices) will work best in any particular situation, it is important to see the guidelines and ideas as input to the decision-making process and not as set prescriptions or “recipes”.

3 USE OF THE TECHNICAL GUIDE

The information in the guide has been developed around the major issues common to most regions of northern Australia. These are:

- How to best manage stocking rates over time to keep pastures in good condition and optimise beef production (Section 5.2).
- How to most cost-effectively recover pasture that has declined to poor (or ‘C’) condition (Section 5.3).
- How to manage woody vegetation thickening (Section 5.4).
- How to most cost-effectively bring under-utilised pastures into production (Section 5.5).

For each issue, information is presented on:

- Signs (what the issue looks like on the ground).
- Underlying causes.
- Management responses – the key practices and their rationale.
- The specific management actions that can contribute to achieving better practice and the evidence-base for these.
- How to implement these actions.
- Trade-offs, caveats and uncertainties.

The guide is designed to be technical and comprehensive so that it captures the information, insights, ideas and uncertainties that arose from the research findings, modelling output and the views of producers and technical specialists in the region.

The guide can be used in several ways:

- For people working with producers, as:
  - a means of improving their understanding of key grazing management practices and their awareness of the evidence base that underpins these practices
  - a source of ideas for management strategies that will most cost-effectively address a particular issue or objective
  - a guide to which issues/practices, and variations of these, deserve additional extension activity via demonstration sites or other processes
  - a guide to which issues/practices, and variations of these, require more research and/or on-property testing.
- As a source of new information and examples for extension activities and information products, including Grazing Land Management (GLM) workshop materials.
- As a means of capturing new insights and information from interactions with producers, property case studies and demonstrations.
- As a framework for capturing the results of future research trials and modelling.

4 THE VICTORIA RIVER DISTRICT

The VRD is about 85 700 km² in size and is situated south-west of Katherine in the NT. The region has a semi-arid monsoonal climate and experiences two distinct seasons. The wet season occurs from October to April and the dry season from May to September. Rainfall is highly variable from year to year, but there is a distinct gradient of decreasing mean annual rainfall ranging from 1000 mm in the north to 400 mm in the south of the district (Kraatz 2000). Mean daily temperature maximums range from about 27 ºC in July to almost 40 ºC in November (Kraatz 2000).

The main vegetation types in the region include *Eucalyptus* woodlands with tall-grasses, cracking black clays supporting productive grasslands, shrublands and open woodlands, and uplands and rugged stone country with spinifex and arid short-grasses (Kraatz 2000). In the north of the district, the country tends to be rugged and hilly, with valleys of tropical tall-grass and bluegrass plains (Oxley 2004). The mid to southern parts of the district have large areas of gently undulating country supporting productive Mitchell grass plains.

Pastoral settlement began in the late 1880s. Today, the average property size in the VRD is about 3300 km² (with a range of about 1000 to 12 000 km²) and herd sizes range from several hundred to more than 20 000 head (Kraatz 2000; Oxley 2004). When producers were asked to nominate a current carrying capacity for their property in 2004, the average in the VRD was about 21 500 adult equivalents (AEs) (Oxley 2004). Many producers felt that there was capacity to increase herd sizes on their properties with further infrastructure development.

The majority of properties in the VRD are breeder operations turning off young stock (at about two years of age) to the live export trade, but some of the larger properties also finish cattle. Since environmental conditions demand that cattle need to have a high *Bos indicus* content, Brahmans are the dominant breed (Oxley 2004). There is an ongoing trend towards improving animal performance through genetics, cross-breeding and improved husbandry practices. The predominant market targeted by producers in the VRD is feeder steers for the live export market to Indonesia. Spayed cows and export heifers are also significant turn-off classes whilst a small number of producers sell cattle directly to abattoirs, re-stockers or backgrounders (Oxley 2004).

Properties in the VRD have relatively large paddocks (average 130 km²) and the average number of paddocks per property is about 20 (Oxley 2004). The average number of man-made water points per property is about 50 (Oxley 2004). In 2004, it was estimated that about 68% of the total area was within 5 km of water. Over 70% of producers surveyed in 2004 thought that the ideal maximum distance that cattle should have to walk to water was between 3 km and 5 km (Oxley 2004). Water point development and paddock subdivision are high priorities for many producers; however, costs are constraining the rate of development.

Continuous grazing is the most common grazing strategy in the VRD; but other approaches, such as rotational systems and opportunistic spelling, are also used (Oxley 2004). The typical approach to managing stocking rates is through trial and error and experience rather than formal assessments of carrying capacity or forage budgeting.

Some producers in the VRD conduct prescribed burning. The reasons for burning include wildfire prevention, removing rank pasture, moving cattle to green pick, controlling woody vegetation thickening and managing pasture composition (Oxley 2004). Woody vegetation thickening is an issue for many producers in the region, with the main impacts being reduced pasture growth, increased mustering costs, erosion due to poor pasture cover and damage to fences (Oxley 2004). A significant number of producers suppress fire at all costs in order to protect their pasture resource.

5 GUIDELINES FOR GRAZING MANAGEMENT AND PRESCRIBED BURNING

5.1 INTRODUCTION

The following sections specifically address four key issues facing grazing land managers in the region, with information structured so that it targets the specific characteristics and causes of each issue. The key issues, and their signs and causes, are summarised in Table 1. Figure 1 shows how the information related to these issues is structured in each section of the guide.

Table 1. Key grazing land management issues for the Victoria River District

Issue	Sign(s)	Underlying cause(s)
1. The challenge of matching animal demand to pasture supply on land in generally good land condition	• Pastures are mainly in good (A or B* condition. • Such pastures will change in appearance depending on seasons, with ample feed for the whole year in above-average rainfall years, adequate feed for the whole year in average seasons and possible feed shortages in below-average rainfall years. • There may be a few overgrazed patches with low ground cover and less desirable species (C condition).	• Spatial and temporal variability in pasture growth between years, during years and on different parts of the property. • Cattle grazing preferences. • Limited flexibility to vary cattle numbers within and between years, especially for breeder enterprises.
2. Managing pastures in poor (C) land condition	• Most of the paddock or preferred land type(s) are in C condition. • There are still some preferred perennial grasses but they are small, widely spaced and have low vigour. • Persistent patch grazing is occurring. • Ground cover is generally poor with some erosion and significant loss of moisture through run-off. • In some cases, there is a high proportion of undesirable species, such as unpalatable grasses and forbs. • Highly nutritious feed may be available for short periods but feed shortages can develop quickly during dry periods.	• Chronic overgrazing of paddocks. • Selective use of land type or area of a paddock. • Exacerbated by drought and/or intense/frequent wildfire events.
3. Managing woody vegetation thickening	• Increased density of shrubs and trees, particularly on productive soil types. • Reduced pasture growth when woody vegetation is dense.	• Sequences of very wet years. • Reduced competition from grasses due to heavy grazing. • Reduced frequency and/or intensity of effective fires. • Fire-induced germination events. • Disruption of natural drainage patterns and hydrology.
4. Bringing under-utilised pastures into production	• Significant areas of the paddock receive little or no grazing pressure. • Old, rank pasture with limited vigour, even after rain.	• Inadequate number and/or location of water points in relation to paddock size. • The distance of pasture from water is too great for cattle to access it. • Sometimes strong avoidance of particular areas (e.g. poor water quality).

*Land condition conventions follow Chilcott et al. (2005) where A=good, B=fair, C=poor and D=degraded

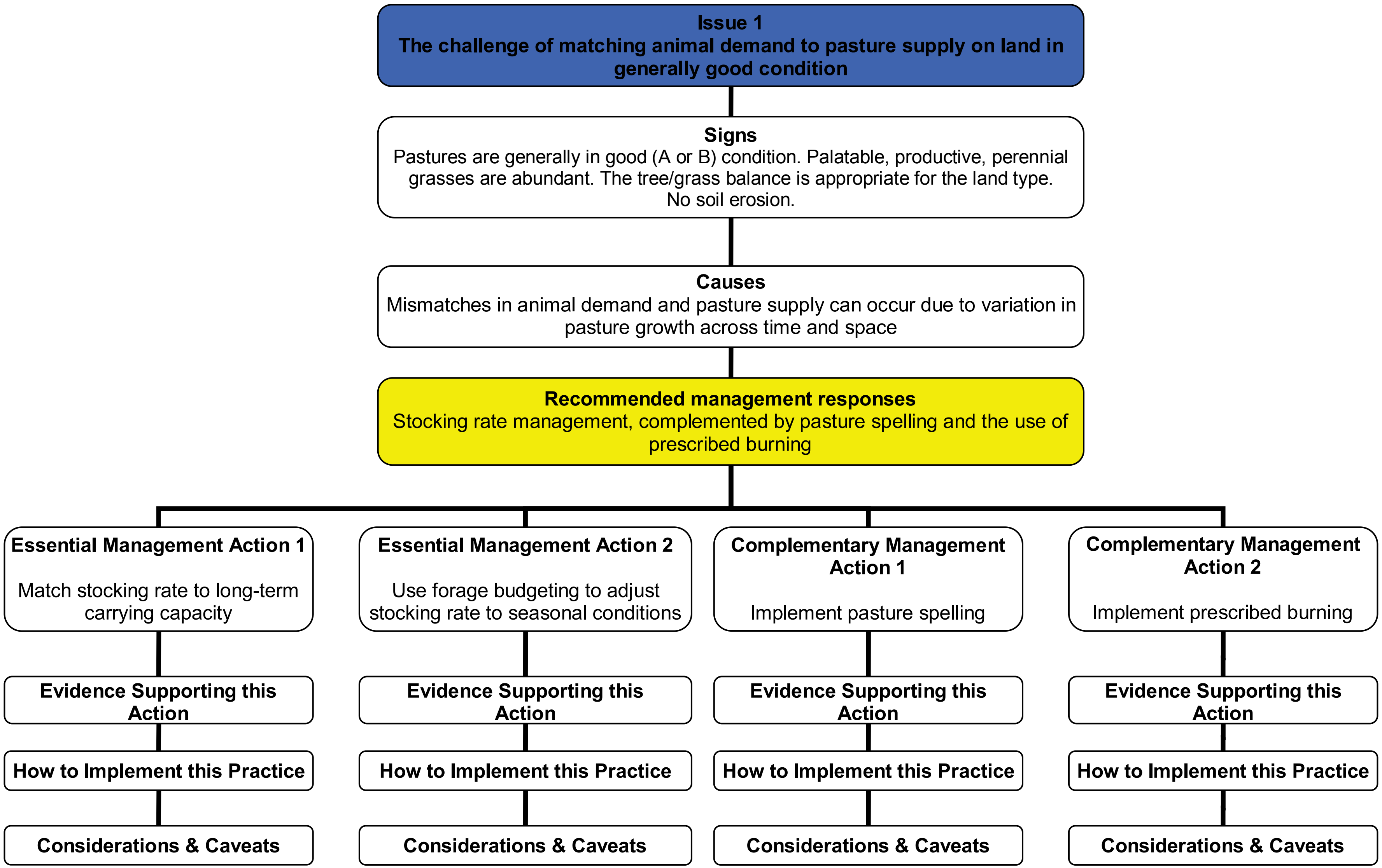


Figure 1. Diagrammatic representation of how this technical guide is structured, using "The challenge of matching animal demand to pasture supply on land in generally good condition" as an example issue

5.2 ISSUE 1: THE CHALLENGE OF MATCHING ANIMAL DEMAND TO PASTURE SUPPLY ON LAND IN GENERALLY GOOD CONDITION

Much of the grazing land in northern Australia is considered to be in good land condition and a recent analysis confirmed that this is true for the VRD (Karfs and Trueman 2005). NT Pastoral Land Board figures indicate that about 93% (n=130) of Tier 1 monitoring sites in the VRD were in good or fair land condition in 2007-08 (Pastoral Land Board 2010). A major challenge facing producers is how to optimally use this feed for animal production while at the same time maintaining good land condition. In good years, high stocking rates can increase animal production per hectare, but in poor years high stocking rates can result in poor animal production outcomes and degraded pastures.

The amount of feed grown each year can vary widely due to the timing and amount of rainfall, so the appropriate number of animals to utilise the feed also varies widely. In theory, it would be desirable to change animal numbers each year so that the feed demand by animals matches the feed supply from the pasture. In this way, overgrazing and subsequent pasture deterioration during periods when pasture growth is low, are avoided and animal production increases in years with high pasture growth. However, this is not easy to do because the feed supply is not known in advance, and there are practical limitations to how much and how often animal numbers can be altered, particularly in breeding enterprises.

5.2.1 Signs

The pastures in this scenario are generally in A or B condition. This suggests the pastures have not been overgrazed in the past or, if some overgrazing has occurred, the pastures have been allowed to recover. Such pastures will change in appearance depending on seasons, with ample feed for the whole year in good years, adequate feed for the whole year in average seasons and possibly inadequate feed towards the end of the year in poor years. Even in pastures that are predominantly in A or B condition, there may be some overgrazed patches with low ground cover and the presence of less desirable species (C condition). It is the continued overgrazing of these C condition patches that leads to them increasing in size and frequency. If continued over a period of years, the average land condition moves from A/B to C.

5.2.2 Causes

By definition, producers with pastures in A/B condition successfully match supply and demand most of the time. The major cause of mismatches in feed supply and demand for these producers is the temporal variability in pasture growth. Pasture growth can vary widely between years, during years and on different parts of the property. This is compounded by the production system of extensive beef enterprises, in which most animals tend to stay on the property for more than one year and, in the case of breeders, up to 10 to 12 years. Changing cattle numbers within or between years will have immediate and ongoing impacts on herd structure and cash flow, as well as exposing the business to risks in the market (which also varies within and between years). Hence, many rangeland beef enterprises have limited flexibility to vary cattle numbers within and between years and breeder enterprises have the least flexibility of all.

However, this is not to say that cattle numbers stay fixed. In any given year, variation in numbers (and particularly AEs) comes about from selling animals (sale of steers, surplus heifers, cull cows), producing calves, buying animals (e.g. bulls), and from changes in live-weight and/or physiological status of individual animals. On a typical breeder property, these factors may result in a variation in AEs in the order of 10% to 20% a year (McIvor et al. 2010). The total AEs will vary between years due to variations in the breeding, mortality, retention and selling rates, and the timing of sales. For example, delaying the sale of steers and cull heifers by just two or three months can increase the average AEs carried in a year by 10%.

Given the variability in pasture supply through time and the limited capacity to adjust cattle numbers, the management questions that arise for pastures in A/B land condition include:

a. What combinations of stocking rate and pasture spelling will deliver the best animal production, economic and land condition outcomes?

b. What are the best options for managing stocking rate to reduce the risk of overgrazing in below-average rainfall years?

c. How do producers best take advantage of the extra feed in above-average rainfall years?

5.2.3 Management responses: stocking rate management, complemented by pasture spelling and the use of prescribed burning

Although changes in growing conditions are a major cause of mismatches between feed supply and demand, they are largely outside the control of producers; the most effective management response therefore is to adjust the stocking rate (the demand side of the equation). Pastures can also benefit from complementary practices, such as spelling and/or prescribed burning. Spelling can be used to increase the quantity of the pasture and/or alter when it is consumed. Prescribed burning can be used to modify animal behaviour and eliminate the contrast in pasture growth caused by patch-grazing. Burning can also improve the overall availability and quality of feed by removing old, rank growth (e.g. in spinifex country). The following pages explain in detail how these practices can be used to match animal demand to pasture supply on land in good condition.

5.2.4 Essential management action 1: match stocking rate to long-term carrying capacity

There are three broad approaches to the management of stocking rate. The first approach is to stock at a relatively low level year-in, year-out so that the level of pasture utilisation is not excessive in any given year (or at least in most years). This approach avoids overgrazing in below-average years but forgoes the extra animal production that could be achieved in above-average years and hence may incur a financial penalty. However, research has shown that this approach avoids losses in below-average years and can lead to enhanced financial performance over the long-term (Buxton and Stafford Smith 1996; O'Reagain et al. 2009, 2011). When forage growth exceeds demand, it provides a buffer against subsequent poor growth periods, allowing cattle numbers to remain more constant in the medium term. It also allows perennial species to regenerate and become well established and can also provide producers with opportunities for prescribed burning.

The second approach is to adjust animal numbers seasonally so that animal demand closely matches current and/or anticipated feed supply (i.e. a trading approach). This practice should theoretically minimise periods of overgrazing and feed deficit while making good use of feed in above-average years. Although this approach can minimise pasture "going to waste", there is a risk of overgrazing if animal numbers are not reduced quickly when the pasture supply is declining. If left too late, there is a risk of being caught with excess animals and insufficient feed, leading to forced sales (perhaps at a loss), loss of animal condition, production penalties, additional feed costs, increased mortalities and/or land degradation (O'Reagain et al. 2011).

The third approach is to also adjust stock numbers in response to feed supply, but in a way that maintains stocking rates close to the long-term recommended average most of the time. In contrast to the approach described above (where action to reduce high stock numbers needs to be done promptly to avoid feed shortages), a moderately stocked property can often afford to take a "wait and see" approach before decisions become critical.

Risk-averse approaches to stocking rate management have generally proven to be the most successful for optimising land condition and profitability in the rangelands. Stocking at close to the long-term carrying capacity of the land in most years is generally the most profitable in the medium to long-term and the least risky economically and ecologically (Buxton and Stafford Smith 1996; Landsberg et al. 1998; O'Reagain et al. 2009, 2011).

Whilst stocking rates in excess of the long-term carrying capacity can be very profitable in the short term, they are less profitable over the longer term because of the effect of poor pasture growth years and subsequent declines in land condition and pasture productivity. Maintaining high stocking rates during poor growth years is the primary cause of land degradation and can reduce production for several years or increase variability in production. High stocking rates (especially on poor condition land or in below-average seasons) result in weight-for-age penalties at market and/or increased supplement costs, both of which can reduce profit (O'Reagain et al. 2009, 2011).

There is a perception in the northern beef industry that "more cattle" equals "more animal production" and that stocking at close to the long-term carrying capacity is not economically viable. However, using stocking rates in line with recommended carrying capacities does not necessarily equate to lower overall herd production. In fact, in conjunction with high quality stock, the opposite is often the case. When stocking rates are sustainable, animals have more opportunity to selectively graze and achieve optimum nutrition. The subsequent live weight gain and body condition score benefits can lead to increased production per head. For example, a breeder in good body condition has a much higher chance of re-conceiving, and weaners can reach target weights faster (Schatz et al. 2008). Stocking at close to the long-term carrying capacity provides the best option for successfully balancing pasture productivity, good land condition and profitability for most enterprises in the rangelands.

The long-term carrying capacity of paddocks and properties can be determined using safe pasture utilisation rates and historical pasture growth data for each land type (Johnston et al. 1996). Walsh and Cowley (2011) used cattle records and modelled pasture growth from commercial paddocks in good land condition to retrospectively calculate safe pasture utilisation rates in the NT. The assumption for this technique was that commercial paddocks in good land condition have been well managed and the computed long-term average pasture utilisation rate can thus be considered 'safe' for that land type. In the VRD region, stocking rates that achieve up to 20% utilisation of yearly pasture growth on black soils, 10% to 15% on red soils and 5% on spinifex-based pastures are considered to be ecologically sustainable. Grazing studies in Qld and the higher rainfall areas of the NT show that declines in pasture condition occur when high utilisation rates (>30%) coincide with average to below-average rainfall seasons.

In regions where rainfall is relatively predictable (such as the VRD and the Barkly), the safe pasture utilisation rate for a given land type is typically applied to the pasture growth that would be expected in at least 50% of years (i.e. the long-term median growth). This approach implies that animal demand will exceed pasture supply half the time; however, in more reliable rainfall zones, below-average years do not tend to occur over many successive years and so any loss in land condition may be readily restored in subsequent above-average seasons. However, when this approach is applied in less productive regions and where rainfall is more variable and unpredictable (e.g. Central Australia) there is a higher risk that overgrazing will occur for several consecutive years. Applying the safe utilisation rate to the annual pasture growth expected in at least 70% of years helps reduce the potential impact of overgrazing during extended periods of below-average rainfall (Scanlan et al. 1994; Ash and Stafford Smith 1996; O'Reagain et al. 2009, 2011). This approach is also recommended for more risk-averse producers (Chilcott et al. 2005) and would be useful in situations where it is desirable to retain stable stock numbers because it is based on a level of pasture growth that is likely to occur more often (≥70% of years).

5.2.4.1 Evidence supporting this management action

Two key grazing studies have helped to establish sustainable utilisation rate recommendations in the VRD region. In the Mt Sanford trial, utilisation rates of up to 23% were found to be sustainable over the medium term on fertile black cracking clays in small, evenly-grazed paddocks in fair to good condition (Cowley et al. 2007; Hunt et al. 2010). At Mt Sanford, the stocking rates that achieved a utilisation rate of 23% on black soils ranged between 19 and 23 AE/km², depending on the season.

The second grazing study, at Pigeon Hole Station in the VRD, was also conducted on fertile black cracking clay soils. The Pigeon Hole paddocks tended to be in C land condition and the optimum utilisation rate for balancing land condition and animal production targets was found to be 19% (Hunt et al. 2010). The stocking rates required to achieve a 19% average utilisation rate ranged between 9 and 17 AE/km² depending on season. Average utilisation rates between 13% and 17% had positive or stable trends in plant species composition and cover whilst an average utilisation rate of 24% failed to meet some important yield and cover targets at Pigeon Hole Station (Hunt et al. 2010). A higher average utilisation rate (32%) resulted in the greatest decline in land condition, negative trends in species composition and an increased risk of unacceptably low ground cover levels (Hunt et al. 2010).

The considerable variation in the stocking rates required to achieve a desired utilisation rate at Pigeon Hole and Mt Sanford reflects the effect of seasons and land condition on carrying capacity (Hunt et al. 2010). The results of the two trials support the current recommended utilisation rates of 20% for pastures on fertile black cracking clays in the VRD (Hunt et al. 2010).

Impact of stocking rate management on animal production and profitability

International and Australian literature shows that as stocking rate is increased, animal production per head declines, and animal production per unit area increases initially to a maximum and then declines. Most studies on intensively-managed sown pastures have shown a linear decline in animal production per head with an increase in stocking rate (Figure 2; Jones and Sandland 1974) but Ash and Stafford Smith (1996) suggested that animal production in rangelands is less sensitive to this trend due to much greater spatial and temporal variability. There is some evidence to suggest that the stocking rates applied in northern Australian grazing trials have not been high enough to identify the peak and subsequent decline in production per hectare. This may reflect the seasons experienced during the studies or the relative insensitivity of animal production to stocking rate in extensive native pastures.

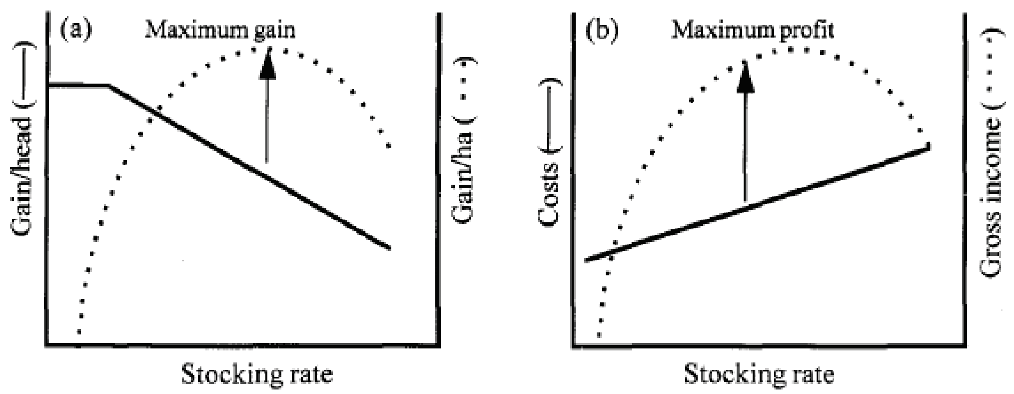


Figure 2. (a) The Jones-Sandland model relating livestock performance to stocking rate, (b) the relationship between stocking rate and economic performance based on the Jones-Sandland model (from Ash and Stafford Smith 1996)

These observations are supported by the results of the Mt Sanford and Pigeon Hole trials. Despite declines in individual animal performance at Mt Sanford, earnings before interest and tax per unit area were still higher in the high utilisation rate paddocks due to increased turnoff (Hunt et al. 2010). At first glance, the Mt Sanford data suggests that there is little incentive to run conservative stocking rates. However, the Mt Sanford trial was conducted during a run of above-average rainfall years. Production results after the one poor wet season of the trial (2002-3) indicate that the higher utilisation rates were not environmentally or economically sustainable. Weaning percentage declined at higher utilisation rates after the poor wet season and took two years to recover (Hunt et al. 2010). Production was also more variable through time at higher utilisation rates. Production indices that performed better at lower utilisation rates included breeder weight, inter-calving interval and kilograms of weaners produced per unit area (Hunt et al. 2010). Thus, breeder herds in the VRD can maintain high weaning rates at high utilisation rates provided seasonal conditions are favourable. However, once seasonal conditions deteriorate, breeders may be unable to maintain calf output, resulting in lower weaning rates.

In the Pigeon Hole trial, there was a 14% decline in individual animal production with a doubling of utilisation rate (Hunt et al. 2010). Like at Mt Sanford, however, the decline in per head production was offset by increased per hectare production (and thus profit) at higher stocking rates. Inter-calving interval, steer live-weight gain, branding rate and weaning rate were not correlated with utilisation rate. Only weaner weight (which directly influences weight weaned per hectare) responded to utilisation rate at Pigeon Hole Station (Hunt et al. 2010). At a utilisation rate of 13%, the proportion of cows pregnant and lactating was slightly higher, and calf losses were lower than at higher utilisation rates. So, whilst there appeared to be little production penalty in implementing higher stocking rates over the relatively good seasons experienced during the trial, the lower weaner weights may have a hidden cost in that turn-off times for steers may be longer and heifers may take longer to reach joining weight. Furthermore, the negative impacts on land condition described above would be expected to have negative production impacts over the longer term, particularly during poorer seasons. In the Pigeon Hole Station trial, stocking rates were adjusted to reflect the forage supply in May each year. This annual adjustment of stocking rate to track forage supply is likely to have dampened the impacts of higher utilisation rates on animal performance compared with a set-stocked regime at similar stocking rates (R. Cowley, pers. comm.).

The VRD results support the findings of the Wambiana trial in Qld (O'Reagain et al. 2009) where over a ten-year period, constant moderate stocking (average 25% utilisation) gave better financial returns and pasture condition than constant heavy stocking (average 50% utilisation). The latter gave good returns during the early years of the trial, which experienced average to above-average pasture growth, but not during subsequent poor seasons when returns were very poor. Heavy stocking also led to poor pasture condition and an ongoing penalty to production, especially in years of limited soil moisture.

Impact of stocking rate management on land condition

Notably, the grazing research as a whole does not provide a consistent message in relation to stocking rate management and its impact on profit and land condition. In part, this is probably because most trials have been run for too short a time (<10-15 years), and pasture systems probably have a certain degree of resilience to change. Some trials did not trigger much change in land condition even at their highest level of grazing pressure (which varied over time in many cases). Several trials have shown that higher-than-recommended utilisation rates can result in greater productivity and profitability, although this appears to only hold for sequences of above-average rainfall years. One exception to this pattern has been observed at the Galloway Plains trial in Qld (Orr 2005) which inferred that relatively heavy stocking (up to 50% average annual utilisation) generated the most profit even during a series of below-average years and with only modest declines in pasture and soil condition.

Given the uncertainty surrounding stocking rate management, and the economic temptation to run higher stock numbers, it is not surprising that producers in the VRD have recently asked whether it is fine to "stock up" for short periods (one to two years) to generate extra cash-flow to meet financial commitments. The available evidence suggests that if the area in question is in good condition and the usual stocking rates are close to the long-term carrying capacity, then some flexibility in stocking rate is possible, and even desirable. Modelling simulations for the VRD (using the GRASP model) indicate that for producers wanting to move from low to moderate stocking rates, some level of annual stocking rate adjustment to match pasture supply will be needed in order to maintain good land condition and maximise animal production. Figure 3 shows that the higher the target stocking rate, the greater the annual flexibility in numbers has to be to maintain good land condition. Increasing flexibility also generally led to increased live-weight gains per hectare for a given stocking rate (Figure 4). Live-weight gains per head tended to be maximised at lower target stocking rates regardless of flexibility (Figure 5).

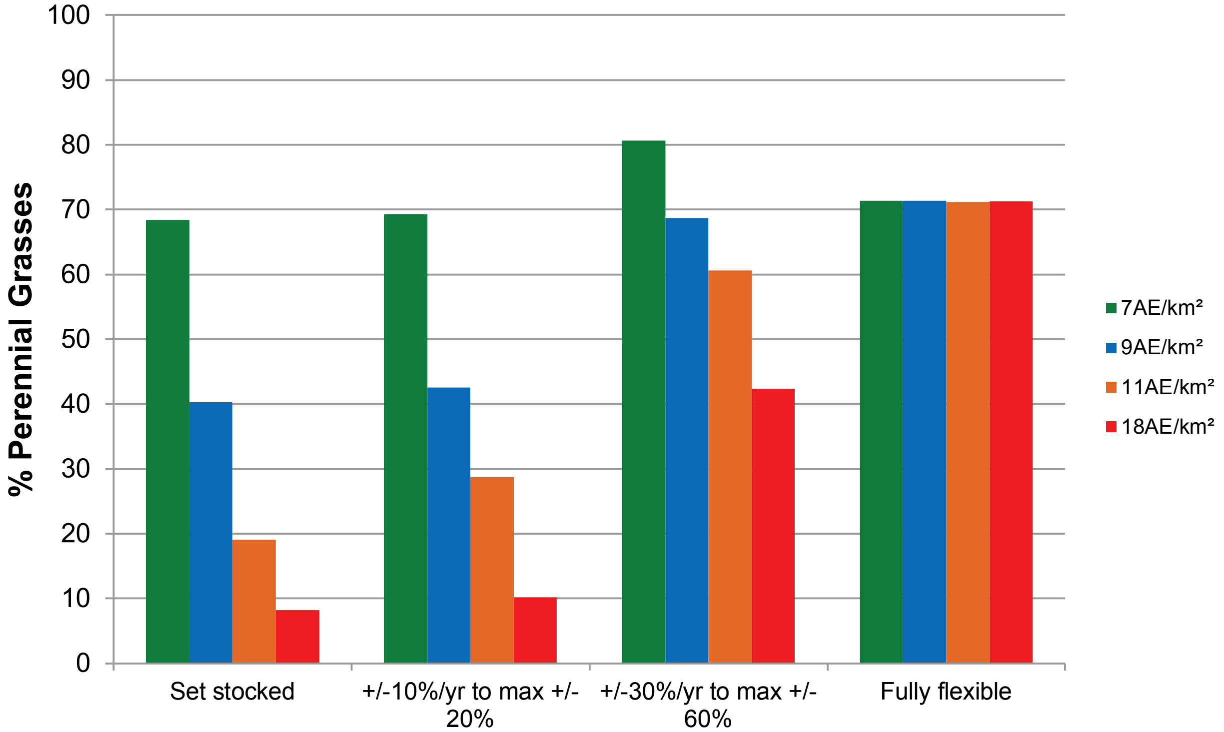


Figure 3. GRASP simulation showing the impact of stocking rate strategy on land condition for a basalt black cracking clay in the VRD starting in B land condition. Percentage perennial grasses is used as a proxy for land condition (A condition ≥84%, B=32-83%, C=6-31%, D ≤ 5%). Target stocking rates are shown in the legend, with 7 AE/km² considered low, 9 low-moderate, 11 'safe' and 18 high. Note that the 'safe' stocking rate is defined as the stocking rate which achieved an average of no less than 50% perennials over the long-term simulation period. This may or may not be indicative of a safe stocking rate on actual properties. The flexibility scenarios shown on the x-axis are no flexibility (set stocked), +/-10% per year to a maximum of +/-20% over the simulation period, +/-30% per year to a maximum of +/60% over the simulation period and fully flexible (stocking rates could vary as much as needed to closely track the pasture supply).

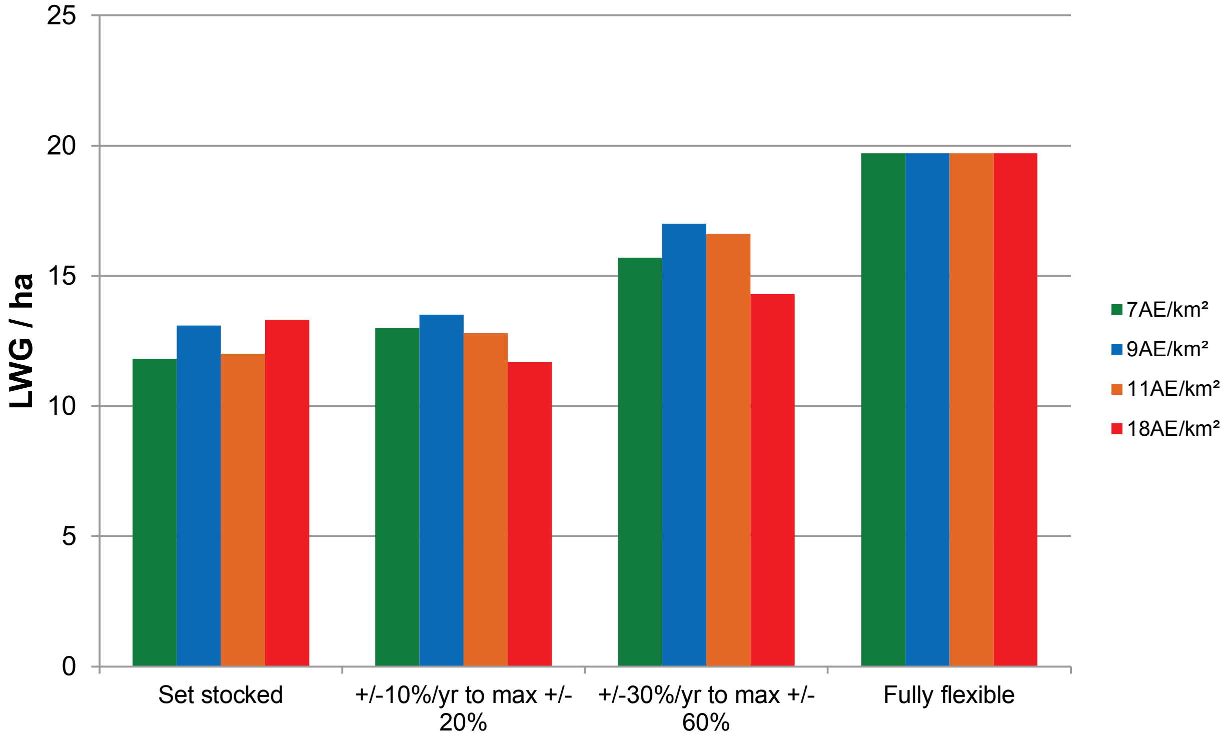


Figure 4. GRASP simulation showing the impact of stocking rate strategy on live-weight gain <u>per hectare</u> on a basalt black cracking clay land type in the VRD starting in B land condition. Stocking rate and flexibility scenarios are as in the previous figure.

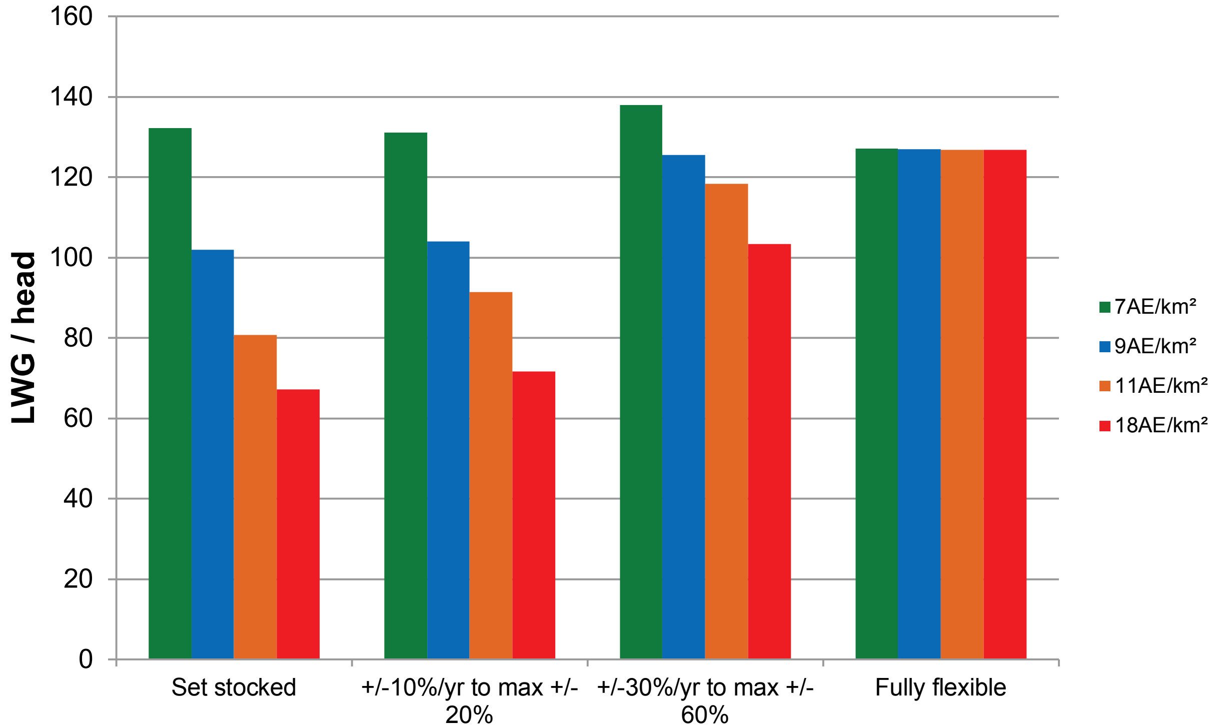


Figure 5. GRASP simulation showing the impact of stocking rate strategy on live-weight gain <u>per head</u> on a basalt black cracking clay land type in the VRD starting in B land condition. Stocking rate and flexibility scenarios are as in the previous figures.

Research trials and bio-economic modelling show that the transition from a good year to a poor year is the most critical time for impacting on long-term land condition, so stock numbers may have to be reduced quickly if the season is poor under a higher stocking rate strategy.

It should be noted that in order to implement a short-term increase in stocking rates on country in C condition, a program of wet season spelling will probably be required in order to improve land condition and maximise animal performance (see Section 5.3.4).

5.2.4.2 The implementation of this practice

In the VRD and Barkly regions, where the timing and amount of rainfall is relatively predictable, sustainable carrying capacities are typically based on the pasture growth that would be expected in at least 50% of years.

DPIF has calibrated several parameter sets to model pasture growth in the VRD region using the GRASP model. As a result, it is possible to produce median pasture growth estimates for several land types with a high degree of confidence. Together with evidence-based recommendations for sustainable utilisation rates, carrying capacities can be calculated for properties in the VRD region. Producers can ask DPIF to calculate carrying capacities at the paddock and property level. Alternatively, producers can learn how to calculate these figures by attending a Katherine region GLM course.

One common mistake when setting stocking rates is to calculate the number of stock a paddock can carry based on the total area of the paddock. In practice, many paddocks have areas beyond 5 km from water. These areas are rarely used by stock and should not be included in the area calculations. In the VRD and the Barkly, actual stocking rates should be calculated based on the carrying capacity of the land within 5 km of water.

When matching animal demand to feed supply, producers need to be aware of the relative feed demand of different classes of livestock. Animals of different weights and nutritional demand require different amounts of feed (Chilcott et al. 2005). Furthermore, urea supplementation increases feed intake during the dry season by as much as 20% (Winks et al. 1970; Winks and Laing 1972; NT Government 2009) and must be taken into consideration when determining feed demand. Once again, DPIF can provide advice on calculating AEs from raw stock numbers or producers can learn how to do this by attending a GLM course.

Finally, the grazing pressure from feral and native herbivores needs to be taken into account when calculating stocking rates (see Chilcott et al. 2005 for appropriate conversions).

5.2.4.3 Considerations/caveats

Care needs to be taken if the land types within the paddock vary widely in the palatability of their pasture species, land condition and/or productivity. Small areas of preferred country can be subjected to stocking rates orders of magnitude higher than the average for the paddock. Producers need to monitor these preferred patches to ensure that they are not being degraded. Strategies for sustainably managing small areas of preferred land types include:

- Fencing the preferred areas with land types of similar attractiveness.
- Positioning water points more than 5 km from grazing-sensitive land types.
- Setting stocking rates based on the carrying capacity of the most preferred land type in the paddock.
- Using patch burning and/or supplements in other parts of the paddock to draw animals away from the preferred patches.
- Spelling paddocks to recover land condition on preferred patches.

5.2.5 Essential management action 2: use forage budgeting to adjust stocking rate to seasonal conditions

If stock numbers are rigidly applied based on the long-term carrying capacity of the paddock/property (i.e. set stocking at the carrying capacity), there will be years where potential additional production will be forgone (i.e. in good seasons) and years when animal production and land condition declines could occur (i.e. in poor seasons). Model simulations indicate that stocking rates can be increased above the long-term carrying capacity in good seasons to take advantage of above-average pasture growth with lower risk of harming the pasture, but prompt action is required to reduce stocking rates as pasture availability and seasonal conditions decline. The model simulation in Figure 6 shows that for the fully flexible stocking rate option, land condition improvements tended to coincide with good rainfall years. In these years, stocking rates were allowed to rise to track the forage supply but when a poor wet season followed good seasons, major declines in land condition occurred (Figure 6). Such declines in land condition can persist for many years and impact negatively on pasture productivity and profitability.

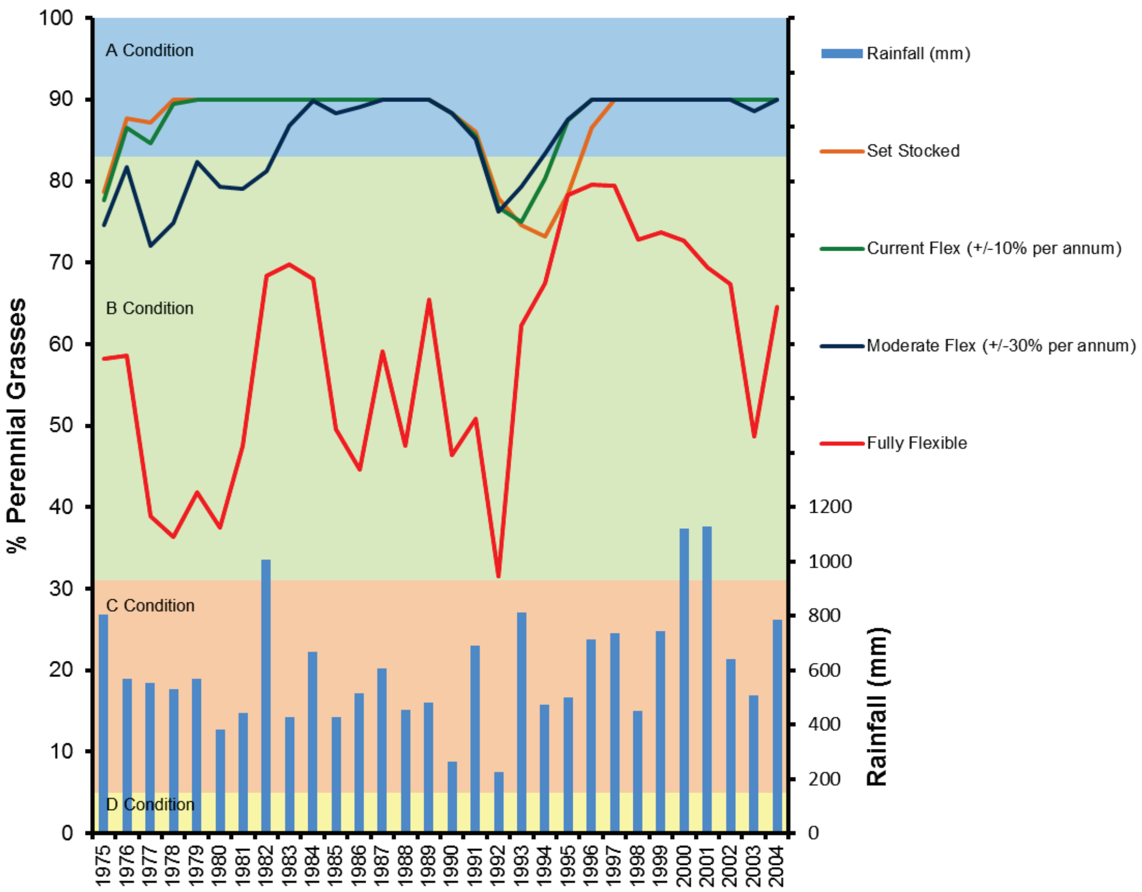


Figure 6. GRASP simulation of the impact of various flexible stocking rate strategies on land condition for a black cracking clay in the VRD, starting in B condition for the period 1975-2005. During this run of relatively favourable seasons, the lower flexibility options maintained good land condition because they tended to have lower average stocking rates. The percentage of perennials in the pasture under the fully flexible strategy was very variable and a decline in land condition occurred in poor wet seasons in the late 1970s and the early 1990s because stock numbers had built up during good seasons. Because the model adjusts stock numbers at the end of the wet season, high stocking rates negatively impacted on land condition when a poor wet season followed these good seasons. Thus, whilst a higher flexibility approach can have production benefits, it can also increase risk in the transition between good seasons and poor seasons.

If stocking rates are allowed to “creep up” over a period of favourable seasons, a below-average wet season can lead to overgrazing of the preferred perennial grasses and a decline in ground cover levels. In this situation, stocking rates will need to be reduced back to levels consistent with the long-term carrying capacity. In the case of a total failure of the wet season or consecutive poor years, stocking rates may need to be reduced below the long-term carrying capacity in order to protect pastures from long-term damage. Plans for a progressive reduction in stocking rates during deteriorating seasonal conditions should be developed to avoid crisis management. Adjust stocking rates at least twice a year if necessary (i.e. at the start of the dry season and then again later in the dry season during normal mustering operations). Where it is feasible, reducing stocking rates during the wet season if rains are poor can help protect land condition.

Stocking rate decisions should be based on an assessment of current pasture conditions. This should consider patterns of grazing distribution within paddocks. Where they have been developed, plant and soil indicators should be used to inform decisions about the need to reduce stocking rates to avoid land degradation as pasture availability and seasonal conditions decline. The condition of perennial grass tussocks (such as the amount of residual biomass or stubble height) are important indicators of future plant survival and pasture productivity.

Seasonal forecasts can be used in areas where they have good reliability to aid stocking rate decisions for the coming wet season. In the VRD, producers have little confidence in seasonal forecasting (White and Walsh 2010) and estimates of expected pasture production based on historical records are typically used instead (e.g. Dyer et al. 2003; Chilcott et al. 2005; Cowley et al. 2007). Regardless of the method used, the limitations of seasonal forecasts and historical records should be acknowledged and producers must be prepared to adjust stock numbers if conditions do not turn out as anticipated.

5.2.5.1 Evidence supporting this management action

The Wambiana trial in Qld tested the economic and land management implications of variable stocking rates where animal numbers were changed each year at the end of the growing season. The variable stocking regime did not perform any better financially than set stocking and experienced problems (both financial and land condition) in the transition from good to poor years. Bio-economic modelling from the VRD indicates that a variable stocking regime can result in higher profits than a set-stocked regime, but large losses can occur in transition years and annual economic performance is more variable with increasing flexibility (Figure 7 and Table 2).

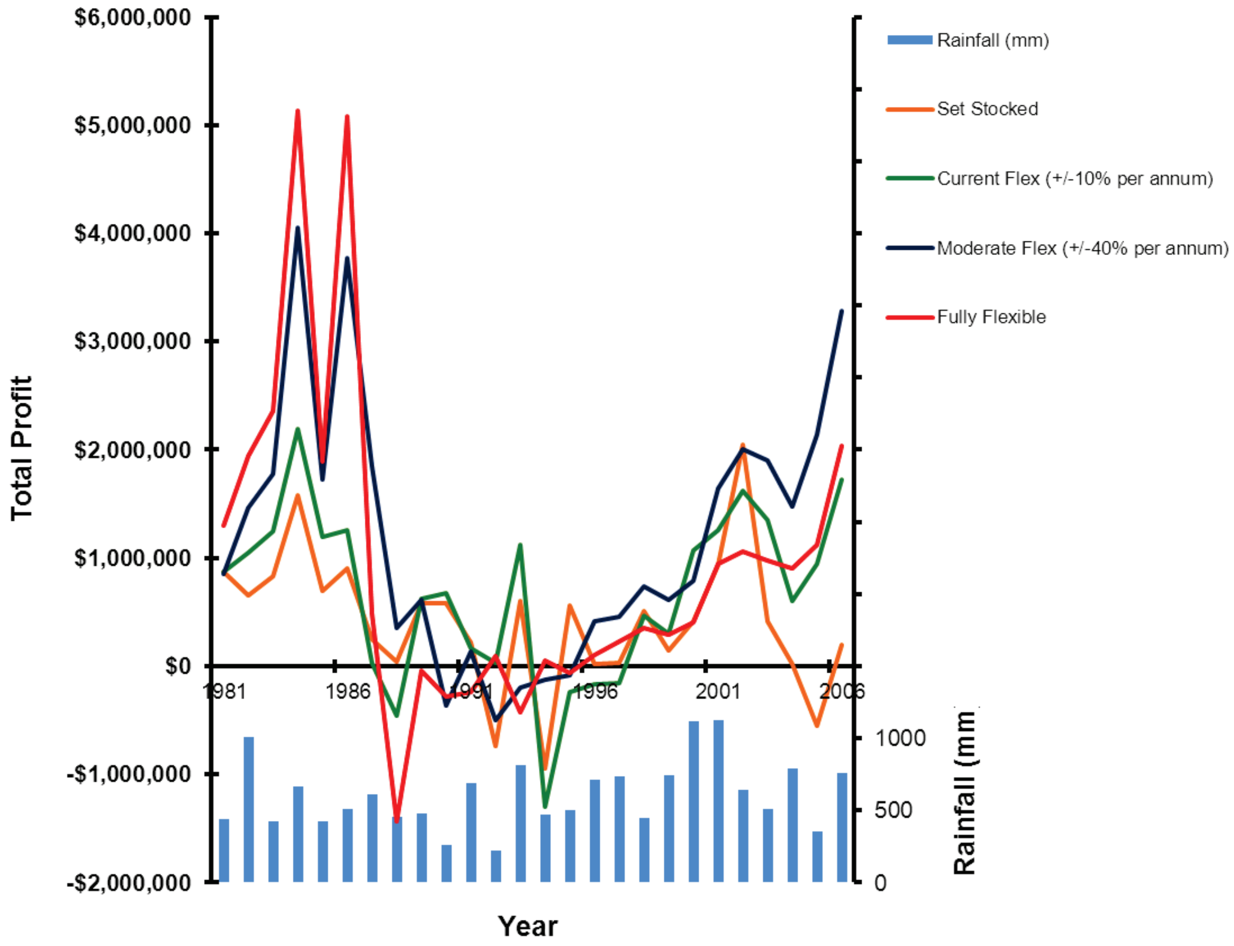


Figure 7. ENTERPRISE simulation of total profit versus stocking rate flexibility options for a southern VRD representative property of 4600 km² running about 14 700 AEs (1981-2006). The flexibility options shown are: set stocked (same stocking rate for whole simulation regardless of season), current industry flexibility (+/-10% per year to a ceiling of +/-30% across the simulation), moderate flexibility (+/-40% adjustment of stock numbers per year to a ceiling of +/-80% across the simulation) and fully flexible (unlimited flexibility to track the seasons).

Table 2. A summary of simulated total profit for the above southern VRD representative property under various stocking rate flexibility scenarios (1981-2006). In the fully flexible scenario, economic losses occurred in more years due to the cost of feeding animals and lost income from retaining heifers to facilitate the build-up of stock numbers after poor seasons.

	Stocking rate flexibility strategy			
Profit measures	**Set stocked**	**Current industry flexibility**	**Moderate flexibility**	**Fully flexible**
Average	$416 675	$671 358	$1 183 113	$932 796
Minimum	-$948 449	-$1 296 903	-$500 759	-$1 436 190
Maximum	$2 043 541	$2 196 585	$4 053 775	$5 135 221
No. years negative	3	5	5	8
Net present value @ 4%	$7 474 151	$10 939 166	$19 361 872	$17 266 561

Although the Wambiana trial showed there was potential to make more money by taking advantage of a run of above-average seasons, there was no indication of how this approach would work when one above-average year occurs in isolation amongst average to below-average years. Given that it is not possible for a producer to know whether they are experiencing an isolated good year or the beginning of a sequence of good years, it is difficult to confidently recommend a fully flexible stocking strategy, particularly for breeder operations. Moderate levels of stocking rate flexibility appear to provide the best compromise between land condition, animal production and profit outcomes and are practical to implement.

The Mt Sanford and Pigeon Hole utilisation rate trials also provide some information on the issue of adjusting stocking rates to closely match pasture growth. Considerable adjustment of stocking rates was required to achieve target utilisation rates in these trials due to seasonal and land condition effects. For example, at Mt Sanford (B condition), annual stocking rates in the optimal utilisation treatment (23%) ranged between 12 and 23 AE/km² (average 18 AE/km²). At Pigeon Hole (C condition), stocking rates in the best performing utilisation treatment (19%) ranged between 13 and 20 AE/km². At times, the researchers involved in the Mt Sanford and Pigeon Hole trials found it challenging to achieve set utilisation rates within treatments due to practical issues. At Mt Sanford, adjusting stock numbers following forage budgeting in April was more successful than the approach used at Pigeon Hole. At Pigeon Hole, stock numbers were adjusted following pasture growth modelling, rather than field-based forage budgeting and this sometimes led to insufficient cattle being added to the paddocks (Hunt et al. 2010). Sometimes there were also delays in adding cattle following good seasons, which meant that target utilisations were sometimes not achieved in high rainfall years. It is likely that producers would also face practical limitations in adjusting stock numbers to closely match forage supply. Achieving clean musters in heavily-timbered paddocks and ensuring adequate paddock security are obvious ones. Due to the practical limitations described above, annual fluctuations around a target utilisation rate will occur. The goal is therefore to maintain a long-term average utilisation rate that is sustainable for the land type in question. Annual deviations away from the target utilisation rate are probably not critical so long as high utilisation rates are not maintained when seasonal conditions continue to deteriorate.

5.2.5.2 The implementation of this practice

In the VRD and Barkly regions, which have a fairly reliable wet season, forage budgets are best prepared at the end of the wet season (i.e. April/May). This timing coincides well with the first round musters on many properties in the north which is when paddock stock numbers can be adjusted. Producer feedback from regional workshops indicated that stocking rate adjustments of 20% to 30% per annum are typical of what is achieved via normal station management (i.e. weaning and turning off steers/growers/culls). Additional adjustments in stocking rates come from retaining more heifers (if building numbers) or selling more aggressively in response to a poor season.

A forage budget should be developed at the start of the dry season for the coming 12 months (i.e. until the following year round one muster). This should allow for adequate pasture residue at the start of the next wet season and for the possibility of a poor wet season. In the VRD, the recommended end-of-dry season targets are ~1000 kg/ha residue and 40% cover in October in most years to minimise erosion and maximise infiltration when the first wet season rains occur (Post et al. 2006; McIvor et al. 1995; Scanlan et al. 1996). To maximise nutrient and water retention, at least 70% ground cover in October in most years is recommended (Post et al. 2006). Estimates of standing forage biomass at the end of the wet season, together with recommended sustainable utilisation rates, can be used to determine stock numbers for the coming 12 months.

Standing biomass (kg/ha) is normally estimated in several areas of the paddock/property. This can be done using visual estimates, photo standards or cutting actual samples. Several standing biomass estimates should be made for each land type within the paddock. The estimates for each land type can then be averaged and multiplied by the area of the land type within 5 km of water in the paddock. It should be noted that the total biomass does not represent the total amount of pasture available for grazing. The pasture available for grazing is determined by adjusting the total biomass for such factors as the safe utilisation rate for the land type, the desired level of residual biomass at the beginning of the next growing season and an estimate of pasture detachment rates. Producers can ask DPIF for advice on calculating a forage budget. Alternatively, producers can learn how to do forage budgeting by attending one of the Katherine region GLM courses.

When matching animal demand to feed supply, producers need to be aware of the relative feed demand of different classes of livestock. Animals of different weights and nutritional demand require different amounts of feed (see Chilcott et al. 2005 for appropriate conversions). For example, removing weaners as early as possible in the dry season significantly reduces the feed demand of the breeder when feed quality and quantity is declining, which in turn helps her to retain body condition and increase her chances of future reproductive success. Such a management practice has the dual benefits of managing stocking rate (and thus land condition) as well as improving breeder performance. As mentioned previously, urea supplementation increases feed intake during the dry season by as much as 20% and must be taken into consideration when determining feed demand. The grazing pressure from feral and native herbivores also needs to be included when calculating the number of animals to be placed back into a paddock. DPIF can provide advice on calculating AEs from stock numbers or producers can learn how to do this by attending a GLM course.

Once cattle are put into a paddock, the pasture should be checked regularly to ensure that overgrazing is not occurring, particularly on preferred land types. If the feed supply is deteriorating faster than expected, stock numbers should be reduced. Another feed budget can be conducted to determine how many cattle to remove in order to meet end-of-dry-season targets.

5.2.5.3 Considerations/caveats

Using forage budgeting in isolation to calculate potential increases in stocking rate is problematic given that it is usually based on what pasture has grown rather than on what will grow. Furthermore, there are many other factors that affect the practicality, desirability and risk associated with short to long-term increases in stocking rate (i.e. forage quality, future pasture growth, production system, market risk, freight costs and weed invasion).

As an alternative to increasing stock numbers, good growing seasons provide an opportunity to improve individual animal performance, spell pastures to improve land condition (see Section 5.3.4) and/or build up fuel loads to use fire to manage woody plant populations (see Section 5.4).

5.2.6 Complementary management action 1: implement pasture spelling

Spelling pastures can increase the amount of pasture grown and/or reduce the amount consumed. This strategy can be used to increase the total feed supply or defer when it is consumed. Pasture spelling also has a role to play in restoring and maintaining good land condition.

5.2.6.1 Evidence supporting this management action

Whilst there has been considerable research on using pasture spelling to improve land condition, there have been few studies on the effects of pasture spelling on land in good condition. The Ecograze project at Charters Towers showed that spelling paddocks for eight weeks in the early growing season each year, combined with 50% utilisation, gave similar pasture performance to 25% utilisation without pasture rest. Both these treatments maintained good land condition during the seasons experienced during the trial.

Palatable perennial grass species in northern Australia are particularly sensitive to defoliation early in the growing season (Ash et al. 1997). Pasture spelling during the early growing season (i.e. the first six to eight weeks of the wet season) allows preferred perennial grasses to replenish their root reserves and grow enough leaf to withstand grazing later in the year.

Cattle tend to return repeatedly to preferred patches. If pastures are not spelled, these preferred patches become chronically overgrazed, less palatable species increase and declines in land condition occur. By allowing patches to regrow under early wet season rest, they become more like the remainder of the pasture and animals are less likely to overgraze these patches, especially if spelling is combined with fire.

As an alternative to early wet season spelling, spelling for the entire wet season allows pasture species to replenish their root reserves and allows them to set seed. A practical method for achieving early wet season spelling or full wet season spelling is to remove cattle from the paddock during the second round muster.

Many producers are aware of the positive effects of spelling from their observations of holding paddocks and laneways. These areas, which tend to get very heavily grazed for short periods during the dry season, are usually destocked during the wet season. Under this regime, the paddocks and laneways respond very well to rainfall and rest and are often in better land condition and have a larger amount of feed than nearby paddocks that are grazed continuously.

In terms of frequency, a general conclusion from South African studies was that pastures in good condition should be spelled one year in four (and more often for pastures in poor condition). In the VRD, experience suggests that to maintain good land condition, paddocks should be spelled every three to four years during the wet season. Figure 8 shows some GRASP modelling output that looked at the impact of stocking rate and spelling combinations on land condition. The scenario was developed for the purposes of demonstrating improvements in poor (C) condition land, but also highlights the benefits of spelling for maintaining pastures in good condition. At a moderate stocking rate, a whole-of-wet season spell once every four years improved land condition and kept it there. Without spelling, land condition took much longer to improve under the moderate stocking rate and was very dependent on good seasons for improvement.

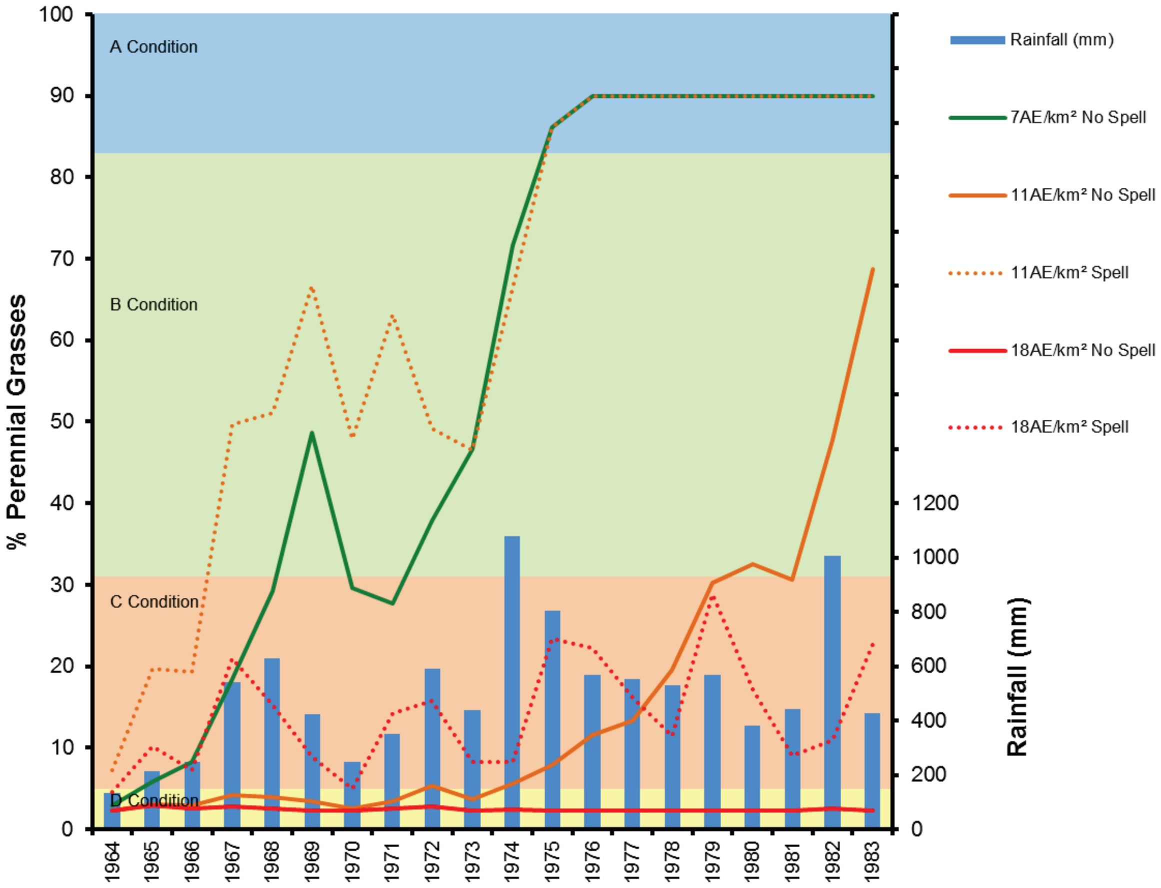


Figure 8. GRASP simulation of wet season spelling and stocking rate management for a basalt cracking black clay in the southern VRD. Percentage of perennial grasses in the pasture is used as a proxy for land condition. A low stocking rate (without spelling) maintained good land condition after the late 1970s. At a higher (but still safe) stocking rate of 11 AE/km² good land condition was reached earlier and then maintained if a whole wet season spell was included every four years. Without the spell, the percentage of perennials in the pasture took much longer to improve at the moderate stocking rate. At a high stocking rate (18 AE/km²) land condition never recovered, even when spelling was implemented.

5.2.6.2 The implementation of this practice

In practice, to achieve either early or full wet season spelling, most producers will probably need to remove cattle from the paddock at the second round muster. In many cases, these paddocks might only be re-stocked during the next first round muster due to access issues.

Another common practice is to turn off bores and troughs in the wet season when cattle have access to surface waters in other parts of the paddock. This encourages cattle to graze away from bores and troughs, gives the areas around the bores a spell and allows cattle to make use of under-utilised feed in outer areas of the paddock.

Where the aim is to grow more feed, spelling will need to occur during the growing season. If, however, the aim is to retain feed for later in the year, then spelling can be planned for any time. However, many producers are wary of “saving” large bodies of feed because they are a significant fire risk late in the dry season.

Where preferentially-grazed patches are obvious, rotational burning can help to “re-set” these patches and increase the even-ness of grazing after spelling (see Section 5.3.6).

5.2.6.3 Considerations/caveats

Two common problems are seen in the implementation of pasture spelling. One problem occurs when the animals removed from the paddock to be spelled are put into other paddocks without regard to the increase in stocking rate in those paddocks. Overgrazing some paddocks in order to achieve spelling in another defeats the purpose of the exercise. To overcome this problem, spelling should be done during good seasons (where there is more pasture available), animals should only be put into paddocks with spare grazing capacity, or excess animals should be sold or agisted. Some paddocks may have capacity for additional livestock during the wet season due to the extra watered area provided by semi-permanent surface waters. Such paddocks can provide a temporary home for stock from paddocks that are being spelled.

The other problem commonly seen is that some producers consider that destocking paddocks during failed wet seasons or droughts is the same as spelling. Destocking during periods of little to no pasture growth can protect the grass tussocks and soils but does not allow pasture plants to increase their root reserves or produce seed. Spelling thus needs to occur during periods of active pasture growth to maximise its benefits.

5.2.7 Complementary management action 2: implement prescribed burning

Fire can be used to influence where animals graze and encourage them to leave grazed patches and graze elsewhere. This is because animals prefer to graze the fresh “green pick” that is produced after burning when soil moisture is present.

5.2.7.1 Evidence supporting this management action

There is both experimental evidence (e.g. Andrew 1986) and a lot of practical experience to show that animals prefer burnt areas that are regrowing, to unburnt areas.

In a burning trial at Mt Sanford, burning appeared to alter the pattern of grazing in a rotationally-burnt paddock. Cattle were attracted to burnt areas of the paddock, even when the burnt areas were a long way from water (Dyer et al. 2003). The attractiveness of the burnt areas was highest straight after burning but declined within two years.

5.2.7.2 The implementation of this practice

Experience in the Katherine region indicates that rotational burning (every four to five years) can “re-set” the pasture and improve the even-ness of grazing. In the VRD, 25% is considered to be the minimum area of the paddock to burn. Any less than that and animals will concentrate on small burnt areas and may do more harm than good through overgrazing. The placement of fires in relation to preferred parts of the paddock is also important. For example, in the Mt Sanford trial, burnt areas close to water were heavily overgrazed and became degraded.

Animals do not graze exclusively on the burnt areas; so there will be some grazing (and possibly continuing deterioration) on the non-burnt areas. A rotational strategy through time helps to overcome this issue. Dyer et al. (2003) noted several factors that should be taken into account when rotational burning:

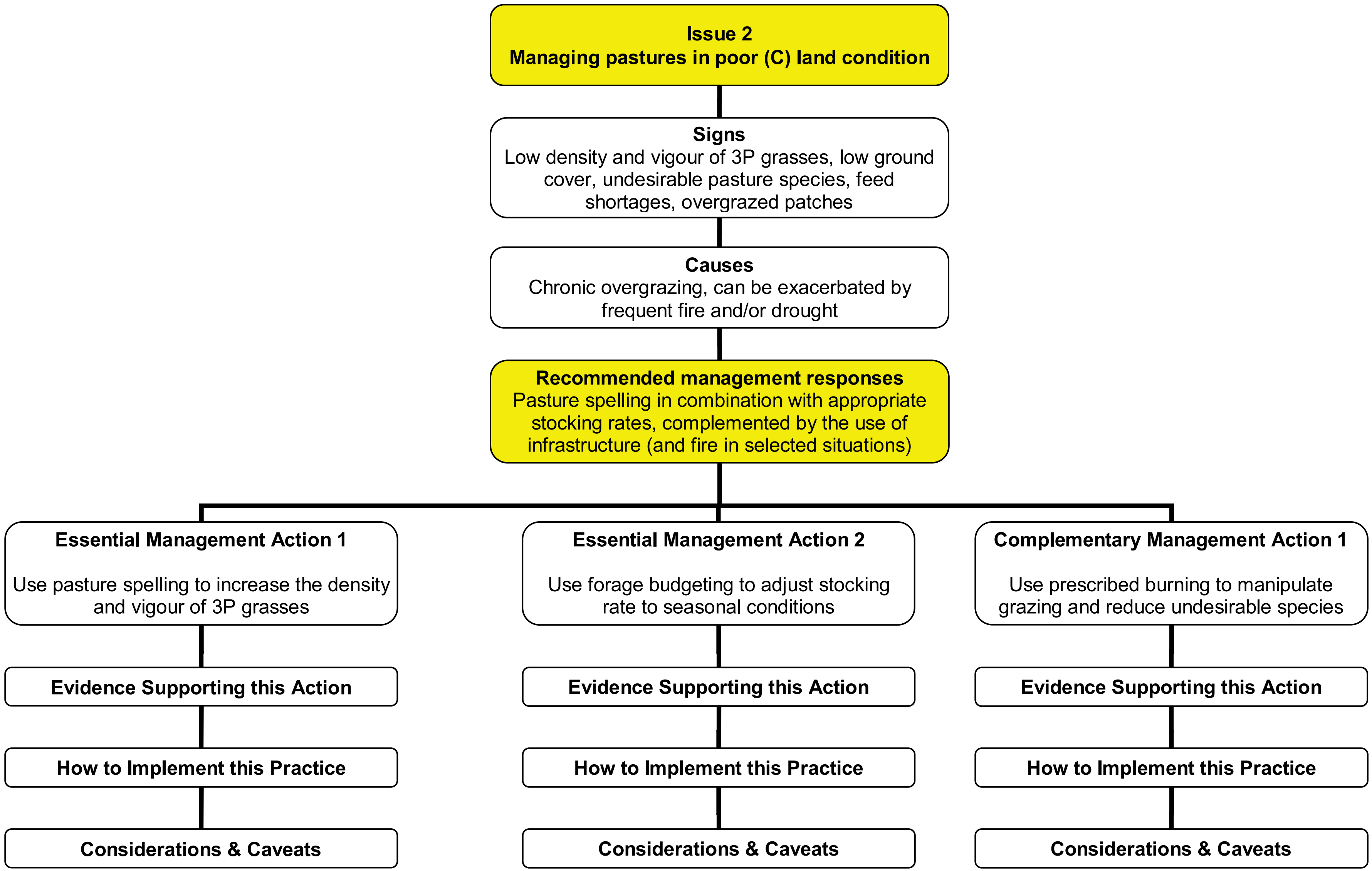
- Match the stocking rate to the new level of pasture available after burning.
- Do not re-burn areas for four to five years after burning.
- Be aware of the location of waters and preferred land types when burning.
- Do not burn areas that are already preferred by cattle as this can lead to excessive overgrazing after burning.
- Where possible, do not burn immediately adjacent to last year’s burn as this can lead to overgrazing along the “edges”.

5.2.7.3 Considerations/caveats

Obviously, stocking rates need to be adjusted to account for the lower pasture availability in the paddock if a large percentage is burnt. This can be achieved by calculating a forage budget. Feral animals and native herbivores also need to be kept off the burnt country as much as possible.

Burning can increase or decrease the incidence of native woody species (see Section 5.4) and exotic weeds. Advice can be sought from DPIF, Bushfires NT and DLRM's Weeds Branch when planning a burning regime.

This section of the guide has provided information on how to maintain land in good condition. The next section outlines practices to improve land in poor condition.


Issue 2
Managing pastures in poor (C) land condition
Signs
Low density and vigour of 3P grasses, low ground cover, undesirable pasture species, feed shortages, overgrazed patches
Causes
Chronic overgrazing, can be exacerbated by frequent fire and/or drought
Recommended management responses
Pasture spelling in combination with appropriate stocking rates, complemented by the use of infrastructure (and fire in selected situations)
Essential Management Action 1
Use pasture spelling to increase the density and vigour of 3P grasses
Evidence Supporting this Action
How to Implement this Practice
Considerations & Caveats
Essential Management Action 2
Use forage budgeting to adjust stocking rate to seasonal conditions
Evidence Supporting this Action
How to Implement this Practice
Considerations & Caveats
Complementary Management Action 1
Use prescribed burning to manipulate grazing and reduce undesirable species
Evidence Supporting this Action
How to Implement this Practice
Considerations & Caveats

5.3 ISSUE 2: MANAGING PASTURES IN POOR (C) LAND CONDITION

Section 5.2 covered the situation where a paddock or property is in good overall condition but there may be some patches in poorer condition. This section deals with pastures that have deteriorated and the paddock or property is now in poor condition. Note that land condition issues related to woody vegetation thickening are covered in Section 5.4.

NT Pastoral Land Board figures indicate that about 7% (n=130) of Tier 1 monitoring sites in the VRD were in poor land condition in 2007-08 (Pastoral Land Board 2010).

The dilemma for producers with land in C condition is how to manage animal numbers to minimise periods of feed shortage while using pasture spelling (and sometimes fire) to improve land condition and productivity.

5.3.1 Signs

Most of the paddock or particular parts of the paddock (e.g. preferred land type(s)) are in C condition. A common scenario for a paddock in C condition is that the amount of useful pasture growth is low, but there are still some palatable, productive and preferred (3P) grasses (but they are small, widely spaced and have low vigour), less palatable species are common; ground cover is generally poor with deteriorating soil surface condition, with some erosion and significant loss of moisture through runoff. In some cases, there is a high proportion of undesirable species, such as unpalatable perennial grasses and forbs. Although highly nutritious pasture may be available for short periods after rain, feed shortages can develop quickly.

5.3.2 Causes

The primary cause of poor land condition is usually chronic and continuing overgrazing, which may be exacerbated by drought and/or intense/frequent wildfire events. Frequent and severe defoliation can have deleterious effects on both individual plants by reducing their vigour and on soils and pastures by reducing land condition (lower cover and more bare ground, lower infiltration and more run-off, altered botanical composition, increased patchiness). Drought and intense wildfire can sometimes exacerbate damage to an already weakened pasture. High fire frequency can lead to the loss of fire sensitive species and prevent preferred pasture species from replenishing their root and seed reserves.

The 3P grasses are typically selectively grazed within the pasture leading to them being weakened, resulting in a reduction in size and vigour, and eventually death. Seed production of 3P grasses may be prevented and recruitment of new 3P grass seedlings will be minimal.

With the decline of 3P grasses, other plants which have strategies to survive the grazing pressure tend to increase. These may be quick-growing and prolific seeding species (e.g. native sorghum) or species with unpalatable traits that livestock avoid (e.g. wiregrasses, rattlepods). Unpalatable traits may include tough leaf blades and stems, chemical deterrents or prickles and spines.

The management questions that arise for pastures in C land condition are:

a. What combination of stocking rate and pasture spelling will minimise feed shortages and improve land condition?

b. Could infrastructure development improve the even-ness of use of pastures and spread the grazing pressure?

c. Does prescribed burning have a role in improving pasture composition and the vigour of preferred species on C condition land?

5.3.3 Management responses: use pasture spelling in combination with appropriate stocking rates, complemented by the use of infrastructure (and fire in highly selected situations)

The main objectives in this situation are to encourage the 3P grasses to increase in the pasture and minimise the loss of soil and moisture in runoff. Experimental and anecdotal evidence suggests that the most effective actions will be pasture spelling combined with stocking rate management. Installing additional infrastructure may be useful to move stock away from preferentially overgrazed land types or to enable the application of pasture spelling. Fire is not usually a recommended action unless a particular species is known to be significantly encouraged by fire or you wish to alter grazing patterns to benefit particular species or areas of the paddock. In many cases, fire will actually exacerbate poor land condition by killing annual species, removing organic matter and ground cover and increasing grazing pressure on preferred species. The lack of perennial grass tussocks protecting the soil leaves it particularly vulnerable to erosion following the removal of ground cover by fire.

5.3.4 Essential management action 1: use pasture spelling to increase the density and vigour of 3P grasses

A general recommendation for improving pasture condition is to have a planned but flexible regime to spell target paddocks for the whole growing season commencing from the first rain event sufficient to initiate new growth (e.g. 50 mm in three days). Spelling regimes can be described by their timing, duration and frequency or number of rest periods. In effect, a spelling regime is applying a number of growing season rest days over a period of years. This raises questions about how the stage of the growing season, duration of discrete rest periods and frequency influence the effectiveness of each rest day applied. Data on these questions is very limited but some clues can be derived from completed grazing and exclosure trial work and bio-economic modelling (see below).

5.3.4.1 Evidence supporting this management action

Wet season spelling, and particularly spelling during the early growing season, has been widely recommended across many regions, though often with little local data on which to base cost-effective strategies. The existing experimental data from a limited number of regions indicates that spelling during the wet season, and particularly during the early growing season when grasses are most susceptible to heavy defoliation, is important for managing 3P grasses (Ash and McIvor 1998; Hunt et al. 2010).

At the individual 3P grass scale, the grass needs time to grow a leaf canopy (often from low root reserves), re-build root reserves for the following dry season and future wet season leaf flush and produce seed. Seedlings require time to grow and store root reserves to survive the following dry season. Consequently, longer rest periods may have advantages over shorter periods in terms of accumulated benefit.

The required frequency of spelling or number of rest periods to achieve a certain goal will be determined by both initial land condition (spelling alone is unlikely to be sufficient to restore D condition land) and growing conditions experienced during the rest period (pasture maintenance and recovery are boosted by good seasonal conditions). Establishment of seedlings from the seed set during an earlier rest period may be enhanced by a subsequent rest period. Exploratory bio-economic modelling for the VRD shows that the best and most practical option for improving land condition from C to B, is to wet season spell for six months once every four years, in combination with safe stocking rates. In the model simulations this spelling regime led to improved pasture composition (increases in perennial grasses to >50%) and higher cattle live-weight gains (Figure 9 and Table 3). The modelling also demonstrated that spelling is ineffective for improving land condition if stocking rates are too high, and that low stocking rates (without spelling) can also lead to improved land condition, but with lower per hectare animal performance than spelling in combination with safe stocking rates (Figure 9 and Table 3).

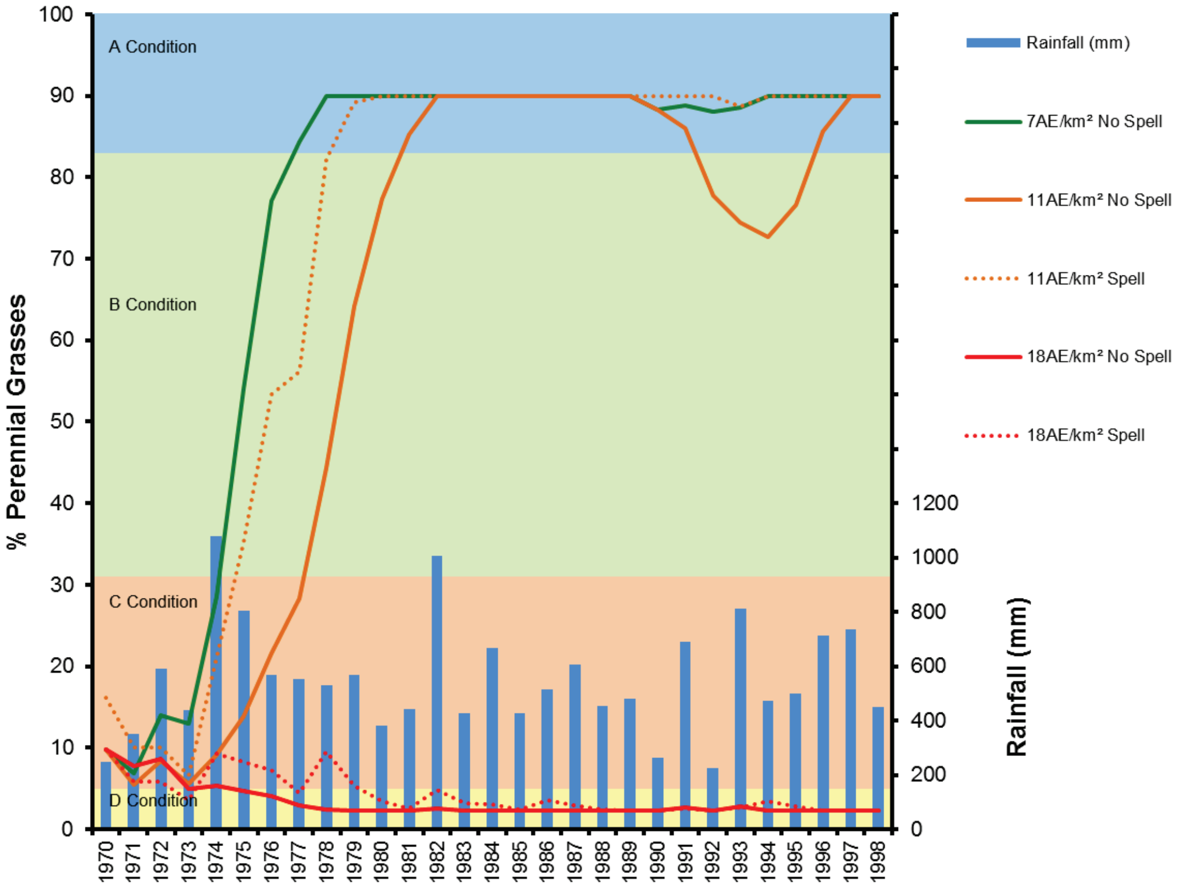


Figure 9. GRASP simulation of wet season spelling and stocking rate management for a basalt cracking black clay in the southern VRD. Percentage of perennials in the pasture is used as a proxy for land condition. At a low stocking rate of 7 AE/km² (no spell) land condition improved the quickest. At a higher (but still safe) stocking rate of 11 AE/km² with a wet season spell every four years, land condition improved at almost the same rate as the lower stocking rate, but the total live-weight gain over the period was better. At 18 AE/km², land condition never improved, even when a spelling regime was implemented (lines superimposed at bottom of graph). Note that the starting year can have a large impact on the results – in this case the early 1970s were good seasons which helped to improve land condition very quickly in the lower stocking rate scenarios.

Table 3. GRASP simulation results for average live-weight gain per hectare for the above stocking rate and spelling scenarios (1970-98) for a basalt cracking black clay in the southern VRD

Stocking rate and spelling scenarios	Average live-weight gain (kg/ha)
7 AE/km² (no spelling)	10
11 AE/km² (no spelling)	14
11 AE/km² + six month wet season spell every four years	13
18 AE/ km² (no spelling)	0
18 AE/km² + six month wet season spell every four years	1

Increasing the number of rest periods can be expected to give a greater pasture response but represents a trade-off as grazing is foregone during the rest period. There are no experiments in northern Australia dealing explicitly with comparisons of the frequency of rest periods but a number of trials provide useful information indicating that as land condition declines, pasture rests need to be more frequent if land condition is to be improved (McIvor et al. 2010). Minimal gains will be made with spelling if stocking rates are not matched to feed supply following the rest period and ongoing overgrazing occurs.

There is some limited evidence that rest during the dry season may also be useful for retaining ground cover and improving rainfall infiltration for the following growing season.

5.3.4.2 The implementation of this practice

Most response to spelling seems to occur in the early part of the growing season; so the duration of the rest period for poor condition pastures should be a minimum of eight weeks from the start of effective growth. However, a full wet season spell may be more practical to manage and perhaps more cost-effective in some situations. Pasture responses to spelling are much lower in below-average rainfall years compared with average or good years; so cost-effectiveness is likely to be better in better rainfall years.

A common question is how to prioritise paddocks for spelling. Bio-economic modelling for the VRD found that the results of spelling were very variable depending on which paddock was spelled and the seasonal conditions experienced during the spelling period. The modelling indicated that recovery from C to B land condition can take between five and 15 years. Where there are several paddocks in C condition that are to be spelled in some type of rotation (and the cattle are kept on property rather than sold or agisted), the paddock that is spelled last may suffer long-term declines in condition as a consequence of the extended duration of increased stocking rate it has suffered if sequences of poor seasons are experienced (Figure 10).

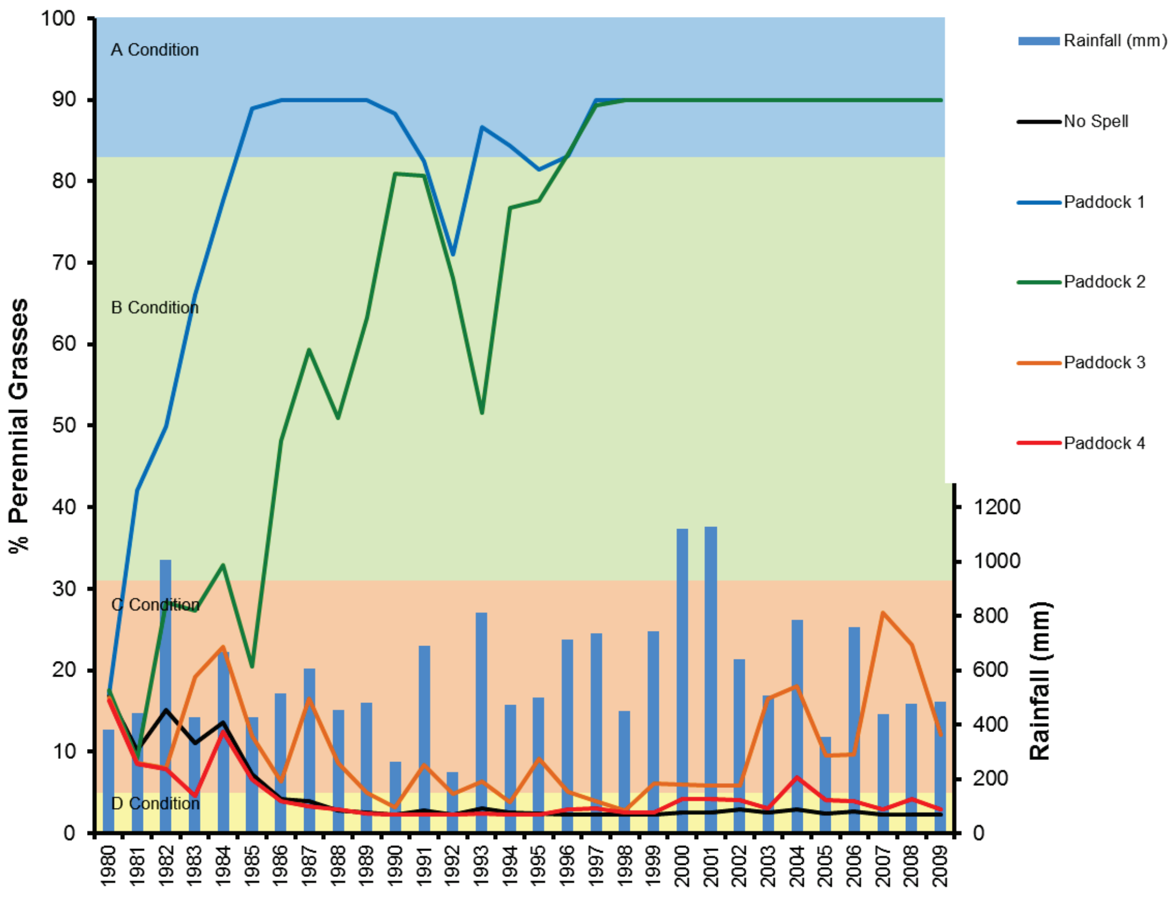


Figure 10. GRASP simulation of a six month spell every four years achieved via a four paddock rotation system, where the cattle from the paddock being spelled are spread evenly amongst the other three paddocks. A non-spelled paddock is included for comparison. Percentage of perennials in the pasture is used as a proxy for land condition. In the early part of this time window, the seasons were good and Paddocks 1 and 2 improved in land condition and maintained this good land condition, even during the less favourable seasons. Paddock 4, which was the last in the sequence to be spelled, never improved in condition and performed similarly to the paddock that was never spelled.

The modelling also indicates there is potentially a large effect of the year during which the spelling occurs. In a good growth year, the higher stocking rates in the 'loaded-up' paddocks may still be within safe utilisation rates; so no damage occurs and land condition will stay the same or slightly improve. In a poorer growth year, the spelled paddock may improve slightly but the 'loaded-up' paddocks could well be damaged and may take even longer to recover. This suggests that the paddock with the most area of C condition patches should be spelled first to minimise further damage.

Producers in the VRD who are interested in spelling are adamant that spelling regimes need to be applied flexibly rather than rigidly, so that seasonal conditions can be taken into account. Spelling is likely to achieve the best result in good seasons; so the cattle from the paddock to be spelled might well be retained and put into other paddocks because the feed supply is able to support them. In average or poorer seasons, the other paddocks may not be able to support these additional cattle and they may need to be sold or agisted to achieve the spell. Sometimes financial or seasonal constraints mean that a paddock earmarked for spelling is required for production. Other options for minimising adverse outcomes in a rotational spelling regime are to reduce overall cattle numbers before initiating the spelling, or distributing the cattle from the spelled paddock to other paddocks on the basis of their relative land condition and forage supply (rather than just spreading them evenly across the other paddocks).

5.3.4.3 Considerations/caveats

See Section 5.2.6.3.

5.3.5 Essential management action 2: use forage budgeting to adjust stocking rate to seasonal conditions

Minimal gains will be made with spelling if stocking rates following the rest period are not matched to feed supply and ongoing overgrazing occurs. Section 5.2 describes how to match animal demand and pasture supply.

5.3.6 Complementary management action 1: use prescribed burning to manipulate grazing patterns and reduce undesirable pasture species

Fire is considered to be a supplementary tool for improving land condition and is less important than spelling and stocking rate management. Fire can be used to attract cattle away from areas to be spelled because animals prefer to graze recently-burnt areas in preference to non-burnt areas, due to the higher quality pasture. Fire can also be used to remove dry, rank pasture from under-grazed patches and "re-set" patches that have been overgrazed. Some undesirable pasture species can be manipulated using prescribed burning.

5.3.6.1 Evidence supporting this management action

Fire can be used to spell other parts of paddocks because animals prefer to graze recently-burnt areas in preference to non-burnt areas. This will give some spelling to the non-burnt areas and has been effective under experimental conditions but its effectiveness under commercial conditions is unknown. Animals do not graze exclusively on the burnt areas so there will be some grazing (and possibly continuing deterioration) on the non-burnt areas. Where only small areas are burnt, the concentration of grazing on this small area may also do more harm than the benefit derived on the non-burnt area.

Fire can be used to remove old patches of dry mature herbage so that all young material is equally accessible. This can improve the even-ness grazing and prevent continued selective grazing of existing poor condition patches. However, burning removes the feed supply and if seasons are poor, can lead to heavy grazing and the need for additional rest.

Fire can also be used to manipulate undesirable species in the pasture. The most effective action will depend on the undesirable species being targeted and whether or not they are sensitive to fire. Local knowledge will be required to determine the likely response of individual species in a specific region. Undesirable species can be split into three categories based on their response to management actions:

Managing species that are sensitive to fire

Some undesirable grass species are sensitive to fire (e.g. annual sorghum can be reduced in pastures in the VRD if it is burnt before it seeds). Fire can be used to manipulate herbaceous species composition by killing plants, influencing recruitment or altering grazing preferences. Local knowledge should be sought to determine the expected impact of individual fires or particular fire regimes on the specific targeted unpalatable grass species. Some unpalatable grass species may be encouraged by fire. The fire regime may also encourage other desirable species.

Managing species that are sensitive to grazing management and competition from other pasture species

Some unpalatable species cannot be managed with fire but may be sensitive to grazing management through competition from 3P grasses (e.g. in the Pigeon Hole trial, *Wedelia asperimma* declined in the low utilisation treatment).

Overgrazing for long periods and ongoing selective grazing reduces the vigour of 3P grasses and may allow other grasses and forbs to establish and dominate. In this situation, matching stocking rates to the 3P grass forage and spelling may be useful to allow the 3P grasses to recover and compete successfully with undesirable species (see Section 5.2 on matching stocking rates to carrying capacity, and pasture spelling).

Managing species that are insensitive to grazing management or fire

Some introduced and native undesirable species are insensitive to grazing management and fire (e.g. in the VRD, such species as *Aristida latifolia, Eulalia aurea, Sehima nervosum, Flemingia pauciflora*, *Tephrosia* spp. and *Trichodesma zeylanicum*).

In this situation, management actions are limited, especially in rangeland situations. In more productive country, herbicides and mechanical removal can be effective and profitable with some species.

The best management action in extensive, lower productivity country may be to match stocking rates to palatable feed supply so the desirable species are not further overgrazed and the undesirable species is not further encouraged.

5.3.6.2 The implementation of this practice

The implementation of a fire regime will require planning to ensure adequate fuel is available. This may mean adjusting stocking rates or spelling to preserve fuel, followed by conservative stocking in the post-fire period to encourage the recovery of desirable pasture species. Additional infrastructure may be useful for enabling smaller areas to be burnt at one time.

Producers have to determine the fire regime required to manage the target species (a fire regime over many years may be required, not just a single fire). The intensity of fire for changing the composition of the herbaceous layer appears to be less important than for managing woody species. However, an important consideration prior to burning is to ensure there are adequate fuel loads and appropriate weather conditions to carry the fire. Land type, soil type and land condition will influence the capacity for effective fires (see Section 5.4.4.2).

Post-fire spelling and stocking rates will be critical for maximising any benefits of using fire to manage herbaceous species. Where there are few desirable plants, there may be little positive response to prescribed burning in the short to the medium term.

Utilising fuel accumulation in above-average seasons will minimise the opportunity cost of spelling prior to burning. Look for opportunities to address two or more ‘purposes’ with the same fire regime (e.g. manage a woody plant and an unpalatable grass whilst improving the even-ness of grazing and pasture quality). The risk of a poor season must also be considered and appropriate strategies put in place if the season following burning has low rainfall.

5.3.6.3 Considerations/caveats

There are some important considerations when contemplating the use of fire to improve C land condition. The first is that there is a high risk that fire can further damage an already weakened pasture, reduce cover to unacceptable levels and leave soils exposed to erosion. High fire frequency can lead to the loss of fire-sensitive species and prevent preferred pasture species from replenishing their root and seed reserves. Prescribed burning also comes at a cost to animal production. Costs will be associated with any spelling of pastures that is required in order to build up fuel loads so that an effective fire can be achieved. Burning when fuel loads are inadequate to achieve the purpose of the fire is obviously counter-productive. Likewise, it is important that pastures are not grazed too soon after the fire. Grazing in the immediate post-fire period hinders the recovery of desirable pasture species. In particular, it is ideal that palatable, perennial grasses are allowed to set seed in the post-fire period and this may require destocking or, at least, very low stocking densities. If pre- or post-fire destocking is necessary, forage must be available for livestock on other parts of the property or they will have to be agisted or sold.

Fire can promote germination of some woody species, notably acacias. It is important to monitor the area in the post-fire period in order to be able to respond appropriately to large-scale germination events. If large recruitment events are triggered by a fire, a second fire may be useful. Conducting a second prescribed fire before the plants set seed can reduce the build-up of seed-banks of species such as acacias.

Issue 3
Managing woody vegetation thickening

Signs
Evidence that woody vegetation densities are higher than in the past and large numbers of seedlings or saplings are establishing

Causes
Sequences of very wet years, reduced competition from grasses due to heavy grazing, reduced intensity or frequency of fire, rising carbon dioxide levels

Recommended management responses

Prescribed burning, stocking rate management and pasture spelling

Essential Management Action 1

Use prescribed burning to kill or suppress woody plants

- **Evidence Supporting this Action**
- **How to Implement this Practice**
- **Considerations & Caveats**

Essential Management Action 2

Match stocking rate to long-term carrying capacity

- **Evidence Supporting this Action**
- **How to Implement this Practice**
- **Considerations & Caveats**

Essential Management Action 3

Implement pasture spelling

- **Evidence Supporting this Action**
- **How to Implement this Practice**
- **Considerations & Caveats**

5.4 ISSUE 3: MANAGING WOODY VEGETATION THICKENING

Most pastoral enterprises in northern Australia are underpinned by native vegetation, which almost always includes a tree and shrub component. This woody vegetation varies greatly both within and between vegetation types in terms of the overall density and biomass of woody plants, the structure of the woody strata and the species composition.

Woody species vary in their growth form, mode of reproduction, reproductive output, mode of seed dispersal, recruitment patterns and longevity. They also differ in their palatability to different types of herbivores (including livestock) and their responses to different types of disturbance. Browsing and fire, as well as other kinds of shoot damage, will influence different species, or even different individuals of a species, in different ways. All these factors make for enormous spatial and temporal variation in the woody component of northern Australian vegetation.

Although the woody components of northern Australian pastoral lands are naturally dynamic, in many areas there is concern that since pastoral settlement, there has been a trend of increasing density. This increase comes from three sources: (i) thickening of native understorey (shrub) species; (ii) increased density of native overstorey (tree) species; and (iii) invasion of non-native trees, shrubs and woody vines. Different species are involved in different locations and often there are multiple species involved.

Woody plants can be problematic for pastoral production reliant on natural or semi-natural vegetation. The following are the major issues, though their importance certainly varies from one situation to another:

- Woody plants can compete with more palatable or more nutritious forage and so reduce livestock carrying capacity.
- Some woody plants are toxic to livestock.
- Dense stands of woody plants can inhibit livestock access to water.
- Dense woody vegetation can interfere with efficient animal husbandry (e.g. mustering).
- Woody vegetation may provide habitat for pest animals, such as feral pigs.

It is also true that some species of woody plants, both native and exotic, can provide shade and useful browse (which may contribute significantly to livestock diets in some land types and climatic conditions).

Many pastoral areas of northern Australian include some woody species that are not native. Examples in the VRD include parkinsonia (*Parkinsonia aculeata*) and rubber bush (*Calotropis procera*). However, the proliferation of various native woody species is also of great concern to pastoralists. In the VRD, these species include rosewood (*Terminalia volucris*), conkerberry (*Carissa lanceolata*), bauhinia (*Bauhinia cunninghamii*) and *Vachellia farnesiana*.

5.4.1 Signs

In general, the biomasses of woody and herbaceous components of the vegetation are inversely related to one another: all else being equal, higher woody plant biomass is associated with lower herbaceous biomass. The size, number and distribution of woody plants can all be useful indicators of the impact that woody plants are having on the herbaceous layer. A low density of large scattered trees and shrubs is likely to have little deleterious effect on a pastoral production system and may, in fact, be beneficial.

Historical recollections of previous vegetation states (lower tree and shrub densities, for example) can be unreliable. Importantly, the change in woody plant biomass may be gradual and imperceptible so photographic records, including aerial photographs and satellite imagery provide useful and more reliable evidence. Darrell Lewis' book "Slower than the Eye Can See" is a good example of using repeat photography to document woody vegetation change in the VRD (Lewis 2002). Another important sign of current or impending problems can come from an examination of tree and shrub population structures. A large proportion of small plants (seedlings, saplings) may indicate a growing population, though caution is necessary when making such interpretations because other causes (such as frequent fire) can produce similar results. The presence of such species as rubber bush (*Calotropis procera*), prickly acacia (*Acacia nilotica*), mesquite (*Prosopis* spp.) and parkinsonia (*Parkinsonia aculeata*), which are known invasives, indicates a threat of increasing non-native woody weeds.

5.4.2 Causes

Many factors drive tree and shrub populations. Some of the important ones are indicated in Figure 11, which portrays the dynamic balance between woody and herbaceous (mainly grasses) components of the vegetation. The main drivers of the dynamic are rainfall as a promoter of germination and growth, drought or poor wet seasons as a cause of mortality, competition between grasses and woody species (for water, nutrients and/or light), grazing and browsing differentially affecting biomass and possibly survival, and fire as a remover of herbaceous biomass and a cause of top-kill and mortality of woody species. Some of these factors can be managed; some cannot. Among the factors driving observed or quantified increases in populations of woody plants include sequences of very wet years, reduced competition from grasses due to heavy grazing, reduced frequency and/or intensity of fire because of lack of fuel or active fire suppression or, as suggested in some literature, rising CO_2 levels. One important relationship is between plant size and susceptibility to fire. For many species, small plants are more susceptible to fire than large plants. This means that increasing "woodiness" associated with a lack of fire can create a positive feedback in which effective fire becomes less likely. This feedback loop is exacerbated by the negative effect of increasing woodiness on fuel loads.

The management questions that arise for managing woody vegetation thickening are:

a. What combination of prescribed burning and grazing management will minimise woody vegetation thickening?

b. What are the best prescribed burning regimes to manage woody vegetation?

5.4.3 Management responses: prescribed burning and grazing management

Fire and grazing/browsing are the key manageable factors that influence the woody components of northern Australian vegetation. Critically, these two factors interact with one another (Figure 11) because herbivores and fire compete for herbaceous material. Prescribed burning thus constitutes a management response to increasing woodiness of northern Australian vegetation.

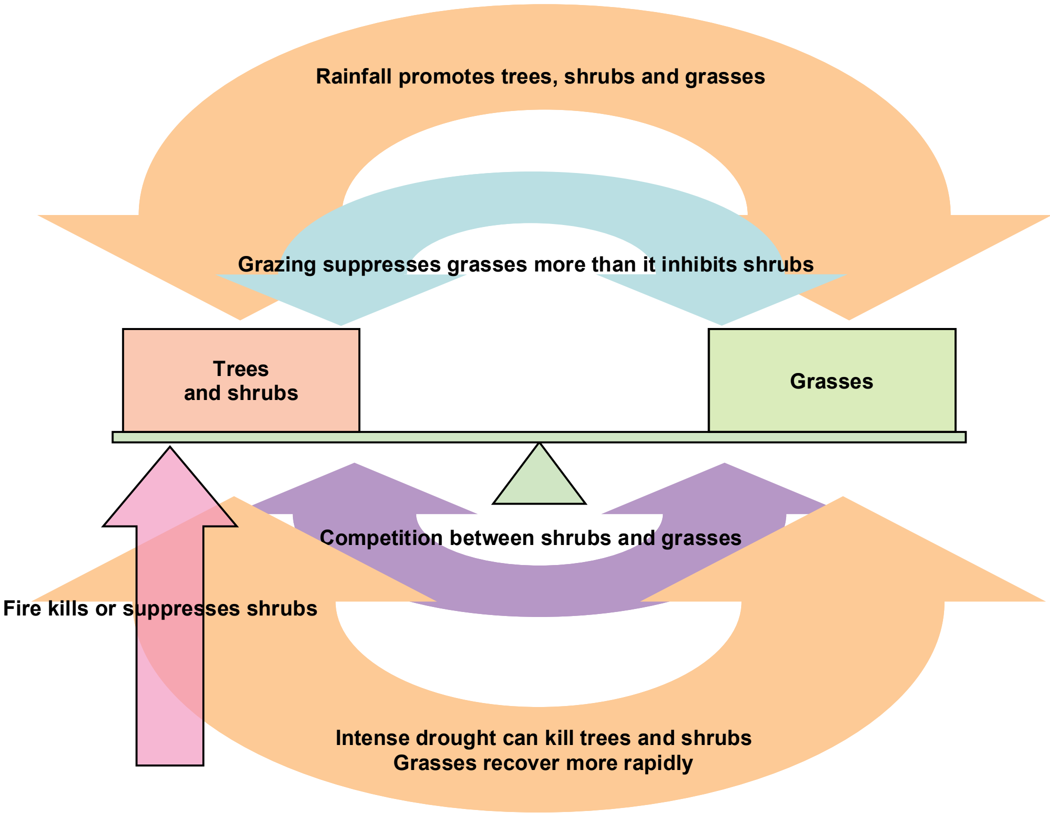


Figure 11. Factors that affect tree and shrub populations

5.4.4 Essential management action 1: use prescribed burning to kill or suppress woody plants

If woody plants are reaching densities or a biomass that is deleterious, prescribed burning is one of the options open to land managers. The most useful burning regime will depend on the woody species present, their density and the size class structure of their populations. More intense fires may be useful for species that are more tolerant of fire, where tree and shrub densities are high and where plants are large. Less intense fires may be suitable for fire-susceptible species or where the purpose is to reduce or suppress a cohort of recently-established (i.e. small) shrubs.

5.4.4.1 Evidence supporting this management action

Much of the fire research that has been conducted in northern Australia has focused on the ecology and management of the woody plant strata of the vegetation. This work has included research on native plant communities in the Top End and the VRD of the NT and the northern Gulf savannas and Cape York Peninsula woodlands in Qld, as well as on invasive woody species in the Burdekin woodlands of north-east Qld. Research is lacking for many regions and vegetation communities.

Evidence from the Katherine region confirms that woody species compete with grasses for both nutrients (such as nitrogen) and moisture during the growing season. Woody thickening thus has a negative impact on pasture yield and/or quality (Dyer et al. 2003). In higher rainfall areas (e.g. the northern VRD), pasture growth is constrained more by nutrients than by moisture in most years due to rapid dilution of soil nitrogen. In lower rainfall areas (e.g. the southern VRD), soil moisture is a bigger constraint to grass growth than nutrient dilution (Dyer et al. 2003). This means that in the northern VRD, increased woody vegetation is likely to reduce pasture quality (due to nitrogen dilution) before it impacts on pasture yield. The opposite is true in the southern VRD.

When the costs and benefits of various burning regimes were compared using modelling, the results indicated that late dry season burning gave the best economic outcome over the long-term, and that early dry season burning was more economically beneficial than not burning at all (Dyer et al. 2003). The costs associated with burning (e.g. mustering, de-stocking, wildfire control and implementing a prescribed burn) were highest for wildfire and late dry season burning and lowest for biennial early dry season burning. The long-term suppression of fires led to the highest mustering costs due to the increase in tree cover making it difficult to locate and move cattle. Even though the costs associated with late dry season burning were high, the improvements in average live-weight gain, branding rate and mortality rates resulted in higher livestock turn-off and revenue for this scenario (Dyer et al. 2003).

5.4.4.2 The implementation of this practice

Woody plant mortality rates in the VRD are determined mainly by vegetation height, with smaller plants being more susceptible to burning (Dyer et al. 2003). However, regardless of height, outright mortality rates for most woody species are relatively low (<5%). Fires are thus best used to suppress the cover and size of woody plants (through canopy "top kill") and by preventing further increases in plant density. The taller the vegetation, the higher are the fuel loads and the wind speeds needed to achieve a successful top kill. Thus, there is a greater likelihood of having the minimum required combination of fuel loads and wind speeds to achieve a successful fire if woody vegetation is burned when it is small (e.g. <2 m). The most effective conditions for reducing woody cover are fuel loads above 2500 kg/ha and cover >60% during high temperature, low humidity and constant breeze conditions late in the dry season (Dyer et al. 2003).

In most cases, perennial grass pastures in good land condition are resilient and benefit from periodic dry season burning (Dyer et al. 2003). On black-soil ribbon-grass/bluegrass pastures in the VRD, burning every four to six years is recommended to control woody vegetation cover and remove the accumulation of rank pasture. In arid short grass pastures in the VRD, where there is a higher risk of negative impacts on land condition after burning, less frequent burns (e.g. every five to six years) during periods of above-average rainfall and under low to moderate grazing pressure are recommended. This provides a good balance between maintaining pasture composition and woody vegetation management (Dyer et al. 2003). High burning frequencies (e.g. fires three years in five) in arid short grass pastures in the VRD favour annual grasses over perennials and leave soils exposed to erosion. There is some evidence to suggest that less frequent fires (every five to 10 years) of higher intensity may achieve a similar result as more frequent fires of lower intensity. A fire regime such as this is also less disruptive to the grazing enterprise. Twenty five per cent is considered to be the minimum paddock area to burn in the VRD. Any less than that and animals will concentrate on small burnt areas and may negatively impact on preferred pasture species through overgrazing.

The implementation of a regime of prescribed burning to manage woody plant populations requires planning. The emphasis should be on a fire regime rather than on individual fires. Fires should be timed to suit the purpose for which they are intended rather than following a simple schedule. This will generally mean waiting for years in which fuel loads are adequate.

GRASP modelling for the VRD illustrates how stocking rates can impact on potential fuel loads (Figures 12 and 13). The modelling indicates that over the past 100 years, there were very few years where fuel loads would have been adequate (>2000 kg/ha) to achieve a hot (i.e. late dry season) fire on a productive red soil, particularly at higher stocking rates. There were more opportunities for hot fires on black soils; but again, the number of years of adequate fuel loads decreased with increasing stocking rates. At the heaviest stocking rates, there were virtually no opportunities for a hot fire.

The modelling confirms that there will be more opportunities to reach the minimum fuel loads required to carry a cool fire (800 kg/ha); but once again, high stocking rates reduce the number of years when fuel loads will be adequate (Figures 12 and 13). For productive red soils, stocking rates above 3 AE/km² greatly reduce the number of years that fuel loads are adequate to conduct a cool burn and on black cracking clays, stocking rates above 7 AE/km² reduce the opportunities to ≤20% of years. These simulations suggest that lower stocking rates and/or pasture spelling will be required to maximise opportunities to accumulate adequate fuel loads to conduct prescribed burns.

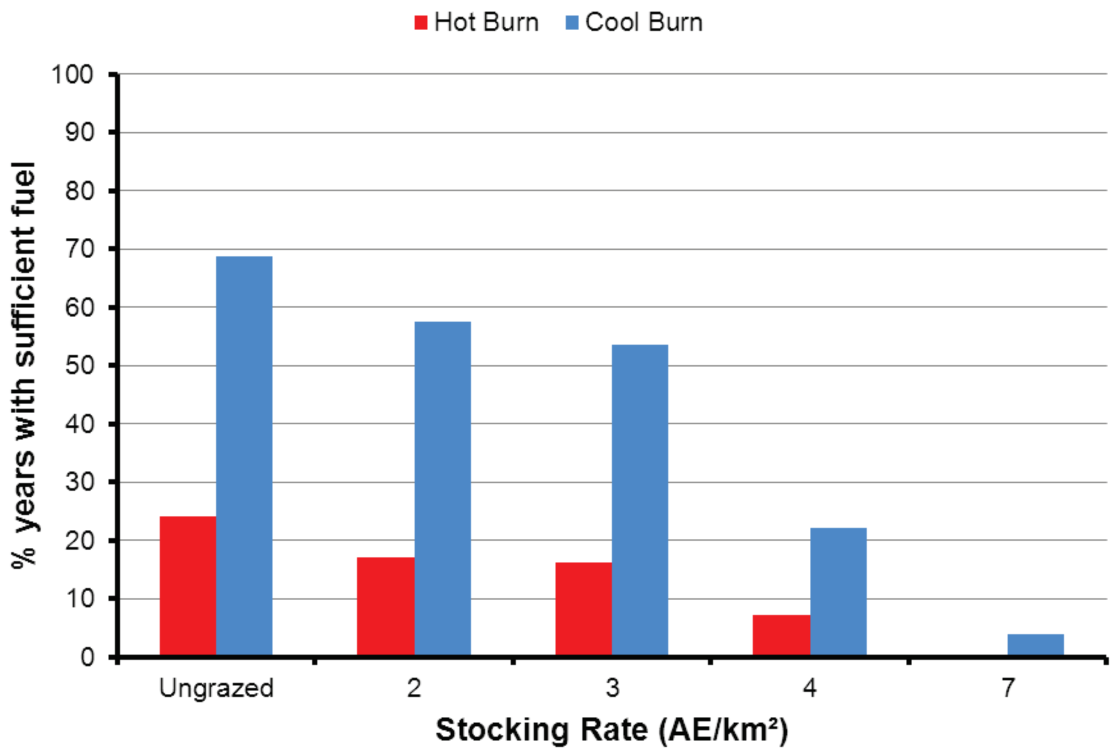


Figure 12. GRASP simulation showing the interaction between stocking rate and fuel load for a productive red soil (Antrim land system) in the VRD. The figure indicates the number of years that fuel loads would have been adequate to achieve a cool fire (>800 kg/ha) or a hot fire (>2000 kg/ha) in the last 100 years.

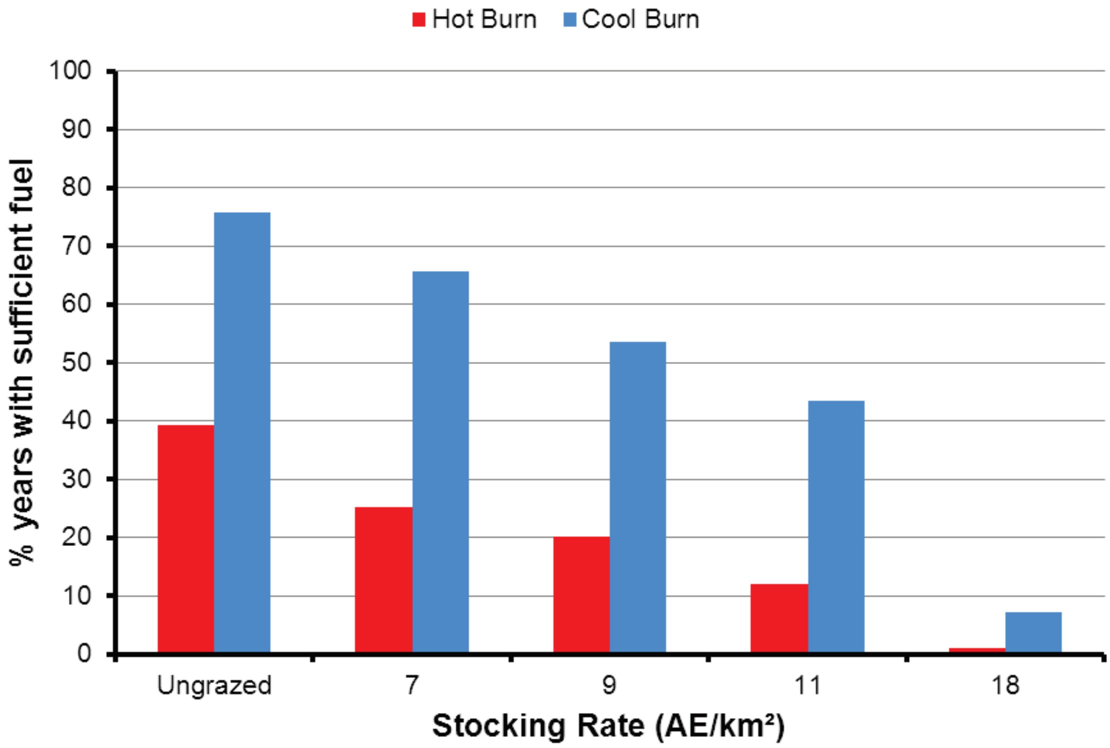


Figure 13. GRASP simulation showing the interaction between stocking rate and fuel load for a black cracking clay soil in the VRD. The figure indicates the number of years that fuel loads would have been adequate to achieve a cool fire (>800 kg/ha) or a hot fire (>2000 kg/ha) in the last 100 years.

5.4.4.3 Considerations/caveats

There are some important considerations when contemplating the use of fire to manage woody plant populations. The first is that prescribed burning comes at a cost. Costs will be associated with any spelling of pastures that is required in order to build up fuel loads so that an effective fire can be achieved. Burning when fuel loads are inadequate to achieve the purpose of the fire is obviously counter-productive. Likewise, it is important that pastures are not grazed too soon after the fire. Grazing in the immediate post-fire period hinders the recovery of desirable pasture species. In particular, it is important that palatable perennial grasses are allowed to set seed in the post-fire period and this may require destocking or, at least, very low stocking densities. If pre- or post-fire destocking is necessary, forage must be available for livestock on other parts of the property or else they will have to be agisted or sold.

Modelling from the VRD shows that the economic benefits of prescribed burning may take more than 20 years to become apparent (Dyer et al. 2003). For producers who are under pressure to achieve short-term animal production improvements, this time-frame may be a barrier to the implementation of a prescribed burning strategy.

Fire can promote germination of some woody species, notably acacias. It is important to monitor the area in the post-fire period in order to be able to respond appropriately to large-scale germination events. If large recruitment events are triggered by a fire, a second fire may be useful. Conducting a second prescribed fire before recruits set seed can reduce the build-up of seed-banks of such species as acacias.

5.4.5 Essential management action 2: match stocking rate to long-term carrying capacity

For systems in which the incorporation of fire is the preferred option for managing woody plants, it is critical to integrate grazing and fire regimes. Heavy grazing over long periods may facilitate an increase in woody plants by reducing the competition that woody seedlings face from palatable herbaceous perennials. As outlined above, it also reduces the opportunity for conducting prescribed fires. Matching stocking rate to long-term carrying capacity increases the window of opportunity for incorporating effective fire into the management system.

5.4.5.1 Evidence supporting this management action

Fire and grazing clearly compete for grass biomass. The general relationship between stocking rate and herbaceous biomass is well established though the specifics vary between land types and climatic zones. In the VRD, 2500 kg/ha is considered to be the minimum fuel load for an effective fire for woody plant management; this threshold will be reached more frequently in higher rainfall zones and where stocking rates are lower. Grazing by feral and native herbivores influences herbage availability in the same ways as domestic stock.

The Mt Sanford and Pigeon Hole trials in the VRD showed that pasture utilisation rates exceeding ~24% resulted in end-of-dry-season fuel loads that were insufficient for achieving an effective fire to manage woody vegetation in most seasons on black soil country.

5.4.5.2 The implementation of this practice

A fire regime requires the parallel implementation of a stocking strategy that allows for fuel build up before burning and pasture recovery afterwards. It may be facilitated if contiguous areas requiring similar fire regimes are fenced together. The intensity of a fire will be affected by the amount of fuel available but also by weather conditions and the state of the fuel at the time of burning. Low fuel moisture (for example <35%), high atmospheric temperatures, low relative humidity and high wind speeds will lead to higher intensity fires. Lower intensity, or just slower moving fires, with longer residence times may actually lead to higher mortality rates in some trees and shrubs.

5.4.5.3 Considerations/caveats

Matching stocking rates to long-term carrying capacities increases the prospects for incorporating fire into a management system. Consideration must be given to whether fire is the most appropriate tool for a particular location or system. If the main purpose of burning is to manage woody plants, the costs and benefits of fire must be weighed against those of mechanical and chemical methods of tree and shrub control. It is important to burn when conditions are suitable, which will mean waiting for the appropriate season, thus reducing the costs of burning in terms of lost animal production.

5.4.6 Essential management action 3: implement pasture spelling

Pasture spelling is a means of managing both fuel build up and post-fire recovery. Spelling a pasture during all or part of the growing season prior to burning facilitates the accumulation of grass fuel. This is one way of increasing the likelihood of being able to conduct an effective fire for woody plant management. A spell during the post fire period should be designed to allow palatable perennial grass tussocks to recover from having been burnt and, ideally, to set seed.

5.4.6.1 Evidence supporting this management action

See Section 5.3.4.

5.4.6.2 The implementation of this practice

The length of a pre-fire rest period necessary to facilitate fuel accumulation depends on soil moisture levels which are, of course, dependent on rainfall received. In poorer growing seasons and in lower rainfall zones, a longer period of spelling is required in order for a target threshold of herbaceous biomass to be reached. Thus there will be great temporal and spatial variation in what constitutes appropriate pre-fire and post-fire rest periods. In highly favourable seasons, it will be possible to conduct an effective prescribed fire without a pre-fire rest period as herbaceous production will exceed off-take by livestock.

5.4.6.3 Considerations/caveats

See Sections 5.2.6.3.

Issue 4
Bringing under-utilised pastures into production

Signs
Significant areas in larger paddocks receive little or no grazing and accumulate ungrazed pasture. Areas close to water may be overgrazed if stocking rates are based on total paddock area instead of watered area

Causes
Large paddocks with insufficient or poorly located water points

Recommended Management Responses

Develop water and/or paddock infrastructure

Essential Management Action 1

Install more water points in large paddocks

Evidence Supporting this Action

How to Implement this Practice

Considerations & Caveats

Essential Management Action 2

Reduce paddock size

Evidence Supporting this Action

How to Implement this Practice

Considerations & Caveats

5.5 ISSUE 4: BRINGING UNDER-UTILISED PASTURES INTO PRODUCTION

Considerable areas of ungrazed palatable forage often occur in large paddocks. In 2001, it was estimated that 22% of the VRD was beyond 5 km from water (Fisher 2001). This figure is similar to a recent study of 12 properties in the VRD which showed that 27% of the land was beyond 5 km (Hunt et al. 2010). Hunt et al. (2010) estimated that about 2000 km² of productive land across the 12 properties was effectively unwatered. This unused pasture represents livestock production that is forgone by pastoral businesses, whilst areas near water often become degraded through overgrazing. Management options that create the opportunity for cattle to use pastures distant from water have the potential to increase returns to the livestock enterprise by allowing more cattle to be carried (where paddocks are currently stocked below the carrying capacity) or to spread the current grazing pressure more evenly. Where cattle numbers are increased, improvements in returns will come from increases in production per hectare. Where current grazing pressure is spread more widely, increased returns are likely to come from increased production per head.

Developing the water point and fencing infrastructure on a property to improve grazing distribution is the primary management option to address this issue, although fire may sometimes have a role (to remove accumulations of old forage and improve grazing distribution), and spelling may aid the recovery of previously overgrazed areas.

5.5.1 Signs

In large paddocks (e.g. >100 km² in the VRD), significant areas of the paddock distant from water points receive little or no grazing and accumulate masses of ungrazed herbage. The areas near the water points that are subject to very high utilisation can be large and/or expanding quickly if stocking rates are based on total paddock area rather than the carrying capacity of the watered area of the paddock.

5.5.2 Causes

The problem of having ungrazed areas distant from water principally arises in large paddocks with few water points where animals are unable to reach the distant parts of the paddock during daily foraging activities. Because cattle need to drink regularly (usually once a day) under the hot conditions experienced in northern Australia, 80% to 90% of grazing activity occurs within 5 km of water, with 55% to 60% of this occurring within 3 km of water (Fisher 2001). This places a limit on the distance from water that animals can graze and can result in large amounts of pasture beyond the usual foraging distance from water being left ungrazed. There is also a production benefit to be gained from minimising the amount of energy that cattle expend because walking diverts energy away from growth and the maintenance of body condition. In addition to having insufficient water points, poorly located water points (in relation to factors that influence grazing distribution such as topography, shade or favoured areas) can also contribute to these problems.

If stocking rates for a paddock are based on paddock size but there are too few water points to fully water the paddock, there will be an excessive number of cattle per water point. This will contribute to the development of large, expanding areas of overgrazed country and land degradation around water points.

The management questions that arise for pastures distant from water are:

a. What infrastructure development will give me the best bang for my buck?

b. Do I need to build fences or can I just put in water points to improve grazing distribution?

c. When does it become cost-prohibitive to develop more infrastructure?

5.5.3 Management responses: develop water and paddock infrastructure

The most important management response involves making the areas of palatable forage accessible to cattle (i.e. all areas are within walking distance of water for the cattle) by establishing more water points. Improving the control over cattle grazing distribution by reducing paddock size is also an important response. This helps minimise the extent to which large numbers of cattle congregate in favoured areas of pasture or use favoured water points. If developing new water points and reducing paddock size increases the pasture available to cattle, it may be possible to increase the number of stock carried (provided the long-term carrying capacity of a paddock is not exceeded). If a paddock is already stocked at or above its safe carrying capacity, installing additional water points will not allow more stock to be carried in the paddock, but should help to distribute grazing pressure more evenly within the paddock. In turn, this can lead to increases in individual animal production due to the increased quality and quantity of forage available per animal.

5.5.4 Essential management action 1: install more water points in large paddocks

Establishing additional water points in or near areas of unused palatable forage will increase the extent to which cattle graze those areas. It is the most important management action to implement. Ideally, the maximum distance from water to palatable forage should not exceed about 3 km. Thus, to ensure reasonable levels of use in a large paddock, water points need to be separated by no more than about 5 to 6 km. A good rule of thumb is to allow one water point per 20 to 25 km^2 of land area.

5.5.4.1 Evidence supporting this management action

The notion that establishing more water points in ungrazed areas will increase the use of those areas is self-evident and practical experience bears this out. However, understanding the optimum number and distribution of water points to make best use of available forage and the associated response of livestock, productivity and land condition for a region can be informed by existing research. Most research on these issues has occurred in extensive regions (e.g. Central Australia and the VRD). Research in rangelands in the USA has also demonstrated that establishing new water points in under-utilised areas can increase grazing in those areas and reduce pressure on previously frequently used areas.

Although a number of studies have reported the maximum distance cattle will walk from water to forage in northern Australia (e.g. up to 11 km on the Barkly Tableland and usually no further than 5-8 km from water in Central Australia), most grazing by cattle occurs much closer to water. Grazing pressure usually declines markedly beyond about 3 km from water, although where water points are sparse, cattle will use areas further from water. For example, on the Barkly Tableland (where water points are often separated by as much as 10 km or more) an assessment over a number of properties showed that about 55% to 60% of cattle activity occurred within 3 km of water and 80% to 90% occurred within 5 km of water (Fisher 2001). Although some cattle activity occurred further from water, this was low, particularly at the extreme distances.

In the Pigeon Hole project, where additional water points were established in a large paddock, approximately 90% of cattle activity (assessed using GPS collars) occurred within 3 km of water. After infrastructure development, a large proportion of this paddock fell within 3 km of water (the average distance to water in this paddock was 2.1 km). As a result, there were fewer areas where ungrazed forage accumulated. Establishing new water points in large paddocks at Pigeon Hole Station allowed more cattle to be carried because more of the country was accessible for grazing. Thus, a general recommendation to improve the effective use of available pasture and minimise the size of areas of ungrazed pasture in the more extensive grazing regions is for most of a paddock to be within 3 km of water and the distance between water points not to exceed approximately 6 km (Hunt et al. 2010). GIS data analysed from the VRD in 2007 showed that 71% of black soils and 55% of red earths (i.e. the better soil types) were within 3 km of man-made and natural waters (Hunt et al. 2010). Two thirds of the pastoral land that was classified as unwatered (i.e. >5 km from water) had relatively low productivity ($\leq$3 AE/km^2). Producers at recent workshops in the region felt that it is not economically viable to develop water points at the recommended maximum distance of 6 km. GIS data from Hunt et al. (2010) indicates the current economic threshold for industry appears to be somewhere closer to 10 km for productive land types (92% of black soils and 84% of red earths were within 5 km of water in 2007) and greater than this for less productive land types. This is backed by recent producer opinion gathered in the region (Walsh 2009; White and Walsh 2010).

Pasture utilisation rates have recently been derived for 12 properties across the VRD (Hunt et al. 2010). The properties were chosen to represent the geographical range across the region. Using station cattle numbers, modelled pasture growth and GIS analysis, actual utilisation rates were calculated for each property and compared with the estimated safe utilisation rate (based on the area of each land type on the station multiplied by the current recommendations of 20% for black soils, 15% for good red soils, 10% for poor red soils and 5% for spinifex-based pastures). Half the case study properties were found to have current utilisation rates equal to, or greater than, the recommended safe utilisation rate calculated for their station. The remainder of the stations had utilisation rates that were, on average, 5% lower than their recommended rates. When the watered area was taken into account, the average utilisation rate within 5 km of water across the case study area was 18%. Whilst this is within the recommended sustainable utilisation rate for black soils, it exceeds the sustainable rates for the other soil types. In fact, the utilisation rate within 5 km of water was 1.4 times higher than 'safe' levels when soil type was taken in account, suggesting that utilisation rates may be exceeding recommended levels on many properties (Hunt et al. 2010).

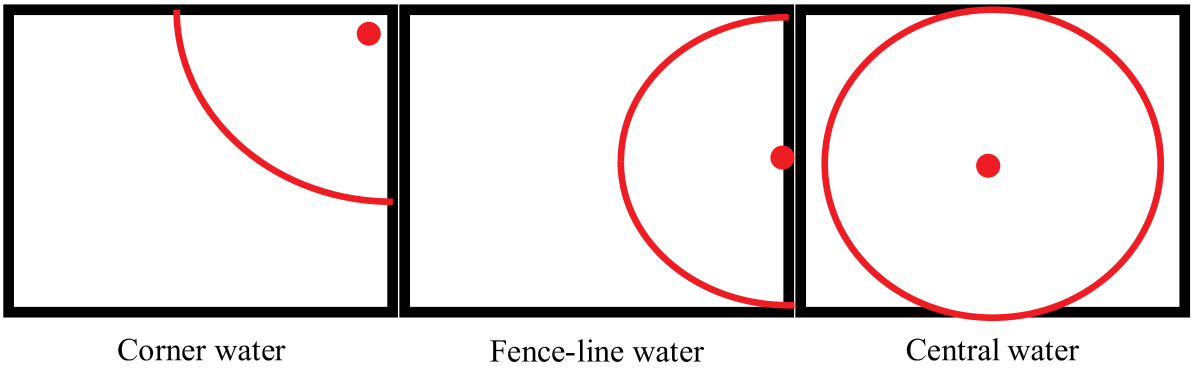
As highlighted above, the most productive land types were found to be better watered. About 2000 km² of productive land was found to be unwatered across the study region. Thus, the study suggests that there is some potential to sustainably increase stock numbers with additional infrastructure on those properties that have low utilisation rates and productive soil types that are not fully watered. For many, further infrastructure development should be seen as an opportunity to spread current grazing pressure rather than to increase numbers. For some properties, where only poorer land types are undeveloped, further infrastructure development to increase carrying capacity may not be economically viable.

Thus, whilst the experimental data is limited, the available evidence suggests that in order to maximise carrying capacity, water points should be placed about 6 km apart (i.e. a 3 km grazing radius). Whether it is economically viable to do so in extensive areas such as the VRD and the Barkly is still a matter of debate. Some producers argue that the need to balance additional carrying capacity with the high cost of development means that it is currently more realistic to place water points 10 km apart (i.e. a 5 km grazing radius), starting with the most productive land types first. The high costs of water point installation and maintenance, and the productive potential of under-developed country are the main constraints to more intensive development (White and Walsh 2010).

5.5.4.2 The implementation of this practice

Water points should be sited away from fence lines and areas that cattle favour (e.g. creek lines, riparian areas, shady sites) whenever possible as this may help in reducing the extent to which cattle congregate around the water for lengthy periods and reduce the possibility for these areas to be overgrazed. They should also be sited away from sensitive parts of the landscape, such as soils that are highly erodible. Studies in semi-arid rangelands in South Australia and WA have shown that grazing use within paddocks is more evenly distributed if water points are located away from fences. Although corner and paddock boundary locations for waters are preferred from a cost perspective, they create problems because they concentrate cattle in a smaller area and increase the effective stocking rate close to water (Table 4). This creates large sacrifice areas around the water and can negatively impact on production because animals need to walk further to access feed. A centrally located water point dramatically increases the watered area of the paddock and results in lower effective stocking rates within 5 km of water (Table 4). If existing water sources (bores or dams) have sufficient capacity, water can be piped to tanks and troughs to provide water in areas without suitable dam or bore sites.

Table 4. An example of the impact of water point placement on effective grazing area and stocking rate



	Corner water	Fenceline water	Central water
Total paddock area (km²)	100	100	100
Number of head in paddock	300	300	300
Area within 5 km of water (km²)	20	39	79
Stocking rate within 5 km of water (head/km²)	15	8	4

5.5.4.3 Considerations/caveats

There will be regional differences in how many water points are needed and how far apart they should be placed. These differences will be influenced by the productivity and heterogeneity of the land, the presence of permanent and semi-permanent surface waters, changes in land values and by management/maintenance considerations. In the more developed regions (e.g. central Qld) water points are usually already closer than the recommendations. This is not so true in the VRD where the high costs of drilling and equipping water points has constrained development.

Obviously, the cost of developing new water points must be considered. Where installing new water points ‘opens up’ new country to grazing, the investment is more likely to be worthwhile. The quality of the land in ungrazed areas should also be considered prior to installing additional water points. As demonstrated by the VRD study above, some land may be ungrazed because of its low pasture value, and installing a new water point to make this area more readily accessible to cattle may not be financially worthwhile.

In a paddock that has multiple water points cattle will not necessarily distribute themselves evenly amongst them. In very large paddocks carrying many animals, this can result in large congregations of cattle on certain water points. In the VRD and the Barkly, the maximum number of animals using a water point should be limited to about 300 head for the most productive land types (if grazed under a continuous grazing strategy) in order to balance land condition and animal production outcomes (McIvor et al. 2010).

It is also important to note that despite having improved access to water, cattle will continue to graze paddocks unevenly to some extent. Other techniques to attract cattle to under-utilised areas should thus be implemented. A recent trial conducted at Rockhampton Downs Station in the Barkly region found that cattle could be trained to use alternate water points in order to achieve more even use of the paddock (Scott et al. 2009). The strategic location and regular re-location of supplements, and strategically burning patch grazed areas or areas with an accumulation of old senescent pasture may also help to distribute grazing more evenly.

If fire is used to remove accumulations of old feed, careful management is required after burning. It is generally considered important that perennial grasses in burnt areas be allowed to re-grow so there is a reasonable body of feed before they are grazed again after burning. Feral animals and native herbivores will need to be kept off the burnt country as much as possible. Burning in the early dry season will effectively mean the paddock cannot be used for the remainder of the dry season since the cattle will concentrate on these areas and potentially kill re-shooting perennial grasses.

Having more than one water point in a paddock can increase options for prescribed burning because cattle can be moved to an alternative water point to allow sufficient fuel to accumulate in another area. Additional water points may also allow unburnt parts of the paddock to be used after others have been burnt. In large paddocks that only have one water point, stock have to be removed to accumulate fuel and then have to be kept out of the paddock to allow pasture recovery. The development of new water points in a paddock also provides options for spelling overgrazed areas around older water points.

The effect of installing additional water points on the natural biodiversity of an area should also be considered. Many grazing-sensitive species of native fauna and flora now only exist in areas that are remote from water. Installing additional water points so that few water-remote areas remain may pose a risk to the persistence of this biodiversity. Where important biodiversity resources exist, some areas should remain remote from water (or fenced to exclude grazing) to protect these resources. A general recommendation is that up to 10% of a property should be set aside to conserve biodiversity.

5.5.5 Essential management action 2: reduce paddock size

Subdividing large paddocks to create smaller paddocks will provide better control over where cattle graze and can thus improve the use of previously ungrazed areas and help reduce overgrazing of favoured areas. This is a much more effective way of managing and improving grazing distribution than simply adding more water points to a paddock. However, because the financial cost involved can be substantial, it is often considered by local producers to be less attractive than just establishing additional water points.

5.5.5.1 Evidence supporting this management action

Although installing more water points to make ungrazed areas in a paddock more readily accessible to cattle can increase the use of these areas, some areas in large paddocks may still not be grazed much because of cattle preferences. Some water points may also be preferred so a large proportion of the herd may graze in areas near those water points. Reducing the size of large paddocks provides better control over where cattle graze and improves the effective use of available forage, potentially allowing an increase in the number of stock carried with reduced risk of land degradation due to large concentrations of livestock in favoured areas.

Again, there is limited evidence from formal research on the effect of paddock size on grazing distribution and pasture use. The Pigeon Hole project in the VRD is the only one to have specifically investigated the effect of different paddock sizes. Using GPS collars to record cattle distribution in paddocks over six-month periods, the research at Pigeon Hole indicated that individual cattle (and the mob as a whole) generally use a greater proportion of a paddock if paddock size is reduced. Confining cattle to smaller paddocks appears to have some effect in ‘forcing’ them to use areas they may not use if paddocks were larger (although they still may not use areas that contain few palatable plants). This effect means that having smaller paddocks results in grazing being distributed more widely across the landscape as a whole, and should improve the effective use of available forage. It is also obvious that fences control where cattle can go at the landscape scale, thus preventing too many animals congregating on preferred parts of the landscape.

Reducing paddock size to that which approximates the usual grazing radius of cattle (i.e. the distance from water that encompasses the majority of cattle grazing) could be considered the ideal for many of the more extensive regions as it will mean most areas in a paddock are accessible to cattle. Assuming a grazing radius of 3 km this would translate to a paddock size of about 36 km^2. In paddocks of this size at Pigeon

Hole the herd generally used 80% or more of the paddock area compared with approximately 70% in larger paddocks where additional watering points had been established. The research showed that reducing paddock size did not substantially improve the uniformity of grazing at smaller scales (e.g. patch scales) within paddocks. This suggests there is little value in reducing paddock size below that where all parts are accessible to cattle (i.e. no smaller than 30-40 km^2) in the more extensive regions of northern Australia. However, some producers in the VRD believe that it is not currently economic to develop commercial paddocks below a size of 50 km^2, particularly on poorer soil types.

5.5.5.2 The implementation of this practice

To better manage grazing impacts, paddocks should be designed to separate minor land types that are sensitive to grazing (e.g. riparian zones, frontage country) where possible. In many situations this will not be practical due to the relatively small size or irregular shapes of such areas. However, an understanding of how cattle use the landscape (e.g. their tendency to avoid steep or rugged country) can be used to inform paddock design.

In other parts of Australia, fencing highly different land types into different paddocks is often recommended as a strategy to minimise preferential grazing. However, in the VRD, having black soils and red soils together in the same paddock is desirable for animal performance. In the wet season, cattle prefer to stay off the boggy black soils and spend their time on higher red soil country. However, because red soil pastures typically have lower carrying capacity, care needs to be taken to ensure that stocking rates are managed to prevent overgrazing on these areas.

Creating smaller paddocks will often also require the establishment of additional water points to provide water in all paddocks. Where possible, it is recommended that the smaller paddocks contain at least two water points (particularly if the paddocks are around 30-40 km^2) since this would further increase the extent of the area grazed, reduce the potential for excessive overgrazing around water points (by reducing the number of cattle per water point), and provide some safety and flexibility should one water point fail. Allowing one water point per 20-25 km^2 of land area is recommended to maximise the area accessible to cattle.

5.5.5.3 Considerations/caveats

Installation and maintenance costs are a major consideration when reducing paddock size. Fencing costs escalate rapidly for paddocks smaller than about 30 km^2, and paddocks smaller than this may be hard to justify solely on the grounds of improving grazing management. The development of new paddocks should occur on the most productive land first, where increased returns from development are most likely, or to protect sensitive areas of the landscape.

For more productive areas with higher carrying capacities, smaller paddock sizes are likely to be warranted in order to better manage stocking rates, have mobs of a manageable size and minimise the occurrence of high concentrations of livestock within paddocks. Smaller paddocks facilitate the use of other management options and in some circumstances may reduce operating costs. For example, having a larger number of smaller paddocks will increase the opportunities for pasture spelling, can make mustering easier and can facilitate the use of prescribed burning.

As mentioned earlier, smaller paddocks do not result in completely even use within a paddock. Some areas may still not receive much use, and some areas will be heavily used. However, the rate at which overgrazed areas grow will be slower. As well as reducing paddock size, the use of other tools such as the strategic placement of supplements or prescribed fire should also be considered to improve grazing distribution in paddocks (see Sections 5.2.7 and 5.3.6).

6 KNOWLEDGE GAPS

Several activities undertaken during the NGS project (2009-2012) have identified knowledge gaps related to the science and management of stocking rates, pasture spelling, prescribed burning and infrastructure development. The following needs relevant to the VRD were identified via a comprehensive literature review (McIvor et al. 2010), the bio-economic modelling (Scanlan 2010) and two workshops held in the region (Walsh 2009; White and Walsh 2010):

6.1 STOCKING RATES

1. Practical, robust pasture and soil indicators to allow producers to recognise when stocking rates need to be reduced to avoid lasting damage to pastures and soils.

2. A better understanding of the pros and cons of conservative set-stocking versus variable stocking rate strategies in terms of economic performance and land condition in the VRD.

3. A long-term demonstration site investigating the practical aspects of matching stocking rate to carrying capacity.

4. Cost-effective options for managing feral and native herbivores.

5. An analysis of the impact of the trend of increasing animal size on food intake and conversion efficiency and its effect on the number of cattle that can be run.

6. Practical options for increasing production efficiency (i.e. managing stocking rates to improve nutrition per head, using tropically adapted *Bos taurus*).

7. The development of more reliable seasonal forecasting tools.

6.2 PASTURE SPELLING

1. Research to predict the pasture growth and recovery responses that can be achieved using the most promising pasture spelling regime(s) identified for the region, particularly to recover C condition country. One promising option identified is a four-paddock rotation with wet season spelling whereby additional cattle are either removed or allocated to non-spelled paddocks based on forage budgeting.

2. Determining the relative contributions of grass regrowth and seedling recruitment to pasture recovery under spelling in order to improve the modelling of responses in GRASP.

3. Practical, robust indicators to allow producers to assess when pastures have been adequately spelled and grazing can re-commence.

4. An increased understanding of the benefits and costs of spelling during the early growing season, the whole growing season and the non-growing season.

5. An assessment of the relative performance of destocking versus wet season spelling versus conservative set stocking for improving land condition.

6. Reliable information on the costs and benefits of various grazing and spelling strategies.

7. Investigating whether large herds (>1000 head) can be managed using rotational grazing and minimal additional infrastructure development in the region.

8. Post-fire grazing and spelling management options for improving land condition in Mitchell grass country.

It should be noted that a demonstration site exploring aspects of points 1 to 3, in combination with a prescribed burning regime, has recently commenced on Delamere Station.

6.3 PRESCRIBED BURNING

1. An improved understanding of the interactions between grazing, fire and rainfall and their impact on pre-fire and post-fire pasture dynamics, animal production and business performance.
2. Clearer guidelines on how far from water and what percentage of the paddock should be burnt in order to minimise heavy grazing of burnt patches.
3. Recommendations on the best pre-fire and post-fire management actions under different seasonal conditions.
4. Detailed analyses of the impact of fire on organic matter and nutrient cycles at different time scales.
5. The economic costs and benefits of using burning versus other strategies to achieve particular outcomes.
6. How to best manipulate grazing distribution using fire to improve the even-ness of use of paddocks.
7. How to better manage feral and native herbivore grazing on burnt areas.
8. Research on the trade-offs between land condition improvement and greenhouse gas emissions when using fire.

6.4 INFRASTRUCTURE DEVELOPMENT

1. How to improve the uniformity of grazing within paddocks without the need for more fencing – e.g. using tools such as prescribed burning and the strategic placement of supplements to manipulate grazing behaviour.
2. Research on the pros and cons of new technologies (e.g. telemetry, walk-over weighing, rotational grazing strategies) on animal behaviour and production performance.
3. Determining the appropriate level of infrastructure development for the region to optimise animal production and profitability.
4. An economic analysis of the costs, handling efficiencies and animal performance benefits of using laneways to muster and move cattle.
5. Improved understanding of the impact of infrastructure development on per head and per hectare productivity.
6. Behavioural aspects of cattle in relation to water points – e.g. understanding their fidelity to specific water points and how to increase the use of alternative water points whilst minimising production penalties and management costs to keep them on specific waters.
7. How to best manage grazing distribution using multiple water points and less fencing.

8. Tools to help producers develop plans for paddock subdivision and/or new water points which include likely outcomes for animal production, economic performance, break-even timelines and land condition.

7 ACKNOWLEDGEMENTS

This technical guide has been produced with the support of the Australian Government's Caring for our Country Program and MLA through the project 'Enhancing adoption of improved grazing and fire management practices in northern Australia: Bio-economic analysis and regional assessment of management options', a component of the NGS initiative.

Many industry members and technical experts gave generously of their time and experience during the development of this guide through regional workshops and related activities. These contributors included Allan Andrews, Consolidated Pastoral Company; Keith Holzwart, Avago Station, KPIAC Chairman; Michael and John Underwood, Riveren Station; John and Helen Armstrong, Gilnockie Station; Adam Northey, VRDCA, Andrew Craig and Michael Jeffery, DAFWA; Ellena Hannah, Neil MacDonald, Trudi Oxley, Tim Schatz, Simone Parker, David Ffoulkes and Kieren McCosker, DPIF.

Sections 1 to 3 of the guide were originally written by Michael Quirk. A significant amount of the background information presented in Section 5 was compiled by John McIvor, Leigh Hunt, Steven Bray and Tony Grice (see McIvor et al. 2010). The bio-economic modelling outputs were prepared by Robyn Cowley, Joe Scanlan, Lester Pahl, Neil MacLeod and Giselle Whish (see Scanlan 2010).

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