A REVIEW OF FIRE AS A PASTORAL MANAGEMENT TOOL IN CENTRAL AUSTRALIA

August 2001

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Technical Bulletin No. 290

ISBN 0 7245 3079 7

CONTENTS

EXECUTIVE SUMMARY

Fire as a pastoral management tool is still in its infancy in arid Central Australia (CA) despite a general acceptance that some type of fire management is essential. The long intervals between fire events due to recurrent drought conditions is the main reason why attempts to gather information and conduct research were limited during the 20th century.

The project "Fire as a pastoral management tool" 1998-2002 aims to develop more knowledge within DPIF about fire, so as to better advise the pastoral industry on its use and outcomes. This Technical Bulletin attempts to gather and collate what research and anecdotal evidence already exists about fire in CA.

The review attempts to identify the major gaps in our understanding of using fire for various purposes on pastoral properties, and it is hoped that this can be used to support future research directions. Some topics for future research consideration include a better economic understanding of the different types of fire; for example burning to reduce wildfire risk, as opposed to burning to reduce shrub seedlings. Specific species and vegetation types like witchetty bush and ironwood have little information in regard to fire effects. The use of integrated approaches to scrub control, with fire as the primary treatment, is also discussed.

An extension booklet has been produced from the main findings of this Technical Bulletin "Burning for Profit 1st edition", which utilises some of the time-series photography accumulated by DPIF over several decades. It is hoped that this guidebook will encourage CA land managers to think in terms of different types of fire for different outcomes.

There remains on most properties the intractable problem of trying to instigate a fire management plan over vast areas with very limited labour resources. However, by developing a good understanding of the effects and outcomes of using fire, it may be possible to more strategically apply fire within the confines of labour and resources available.

1 INTRODUCTION

There is a continuing interest from the Central Australian pastoral industry to better understand the role of fire, particularly in terms of averting destructive wildfire and managing tree and shrub populations. Trees, shrubs, and dead timber are vital contributors to sustainable production from arid woodlands. However, in certain areas of Central Australia (CA), juvenile trees and shrubs established in large numbers in wet seasons after the 1957-1966 drought broke. This understorey of shrubs competes with pasture grasses and herbage for limited water and nutrients and makes cattle mustering difficult.

This Technical Bulletin deals with fire as a pastoral management tool. Fire management for maintaining biodiversity is not discussed purposefully, but pastoral and conservation outcomes using fire as a tool may often be compatible. This multi-outcome use of fire may become more common in the future with increasing demands for sustainable production to also include maintaining biodiversity on pastoral land (James 1999; Duguid 1999).

The use of fire on spinifex hummock grasslands is discussed. However, an ongoing concern in CA is whether it is beneficial or detrimental to burn the more productive rangelands upon which the industry is largely based. There are several unresolved issues regarding fire in non-spinifex vegetation, which are discussed in terms of what research has been done and where, and how well what is known fits into the local context of low-input, extensive beef cattle properties.

1.1 Geographical Setting

Geomorphologically, CA encompasses the MacDonnell and associated ranges and the areas fed by watercourses flowing from these ranges (Latz 1995). This area occupies the southern half of the Northern Territory and spills over into Western Australia and into northern South Australia. Land occupied by pastoral leases tends to be associated with the mountain ranges and major rivers and creeks. While pastoral activity has centred on these relatively small fertile areas, most leases also have large tracts of mulga (*Acacia aneura*) shrublands and hummock grasslands dominated by unpalatable spinifex (*Triodia* spp.) (Wilson et al. 1990).

Several systems have been used and continue to be used to classify land and vegetation into discrete units in CA (e.g. Shaw and Bastin 1987; Pickup 1985; Foran 1984). It is possible to use these classifications to identify areas requiring different fire prescriptions. For instance, certain combinations of soil, landform, and vegetation in CA are more likely to harbour rabbits (Foran 1986), or be favoured by grazing cattle (Low et al. 1973). Similarly, certain vegetation types seem to be prone to tree and shrub increase after a run of wet seasons (Friedel 1981). The characteristics of particular land types can greatly influence the fire regime that is present as well as the fire prescription that may be required by land managers.

1.2 The Pastoral Industry

The CA pastoral industry began with the construction of the overland telegraph line from Darwin to Adelaide in the 1870s. It had a slow beginning because of distance to markets and the vagaries of erratic seasonal conditions and limited water availability. Horse breeding for military customers was common before motorised transport. The early push north by the South Australian railway ensured Adelaide as the main market for CA pastoral enterprises.

Since the Second World War, the pioneer families and newcomers have developed a very low-input beef cattle industry based on the gradual accumulation of knowledge about cattle raising and land management. Improved herds and better transport facilities have created opportunities in new markets. Disease control programs over several decades have led to improved infrastructure and more flexible range management. Cattle prices, operating costs, and recurrent droughts continue to be the major determinants of profitability.

Cattle are grazed on natural pastures based around (mostly) artificial water sources (sub-artesian bores and dams). A few artesian bores exist in the east and far south east of the region. The dependence on artificial waters reduces mustering costs as the cattle can be more readily trapped into holding paddocks and yards using one-way spear trap gates.

Cattle graze the rangeland unevenly, having definite preferences for particular land types and plant species according to seasonal conditions, although most land types are utilised to some degree at some time (Low et al. 1973).

More detailed descriptions of how the industry operates can be found in Shaw and Bastin (1996) and Bertram and Oliver (1996).

1.3 The Attitudes of Pastoralists Towards the Use of Fire

Attitudes towards the use of fire as a pastoral management tool vary widely amongst the 60-70 families currently running CA cattle properties. It is impossible to find a consensus of opinion on this issue but there are some published reports and anecdotes available.

An early 1990s survey of property management practices based on producer experience reveals some general opinions. The region was divided into six pastoral districts and between six and 10 properties contributed to each district's property management guide through a workshop process (DPIF 1993/94). The only area to not have a definite fire prescription for spinifex was the southern district. This perhaps reflects the lower mean rainfall of the southern area. One southern producer would not recommend fire in spinifex at any time. Apart from spinifex, no district would conclusively recommend burning mulga, each having some reservations about regrowth of young mulga after fire and the loss of top feed and grass. One district suggested more research was needed on burning mulga. The survey suggests that for all the other, more productive, range types the current fire prescription is one of suppression. One group did support burning high rank grass in creeks but "only as a last resort".

This confirms that CA pastoralists do not generally believe that fire is a useful land management tool except in spinifex. Breaking up the spinifex, however, is the key to averting wildfire and this seems to be acknowledged in the property guides. It is a lesson that pastoralists have learnt from periodic wildfire events in the 20th century. Wildfire continues to occur on extensive tracts of non-pastoral land. In 2000, 80,000 km^2 were burnt in the Tanami region between July and October (Grant Allan pers.comm.).

The possibility of temporarily improving pastures after burning spinifex is a bonus that pastoralists do not particularly count on, but which is welcomed when the right post-fire rains occur (Griffin 1990, O'Reilly 1998a).

There are individual pastoralists who actively burn in non-spinifex vegetation in CA (e.g. Purvis 1986) but their knowledge of the practicalities and outcomes of using fire is not widely publicised at this time.

2 FIRE RECORDS

2.1 Natural Fires

An analysis of information from 1970 to 1980 showed that the vast majority of fires in CA are started by dry lightning storms, most often in the month of November (Griffin et al. 1983). This has enormous significance to wildfire management because it means that if fuels are allowed to build up, then wildfire is more or less inevitable. Lightning storms and relatively high fuel loads combined to create wildfires in CA during the 1920s, 1950s, and 1970s (Ralph 1984).

2.2 Aboriginal Fire Management (pre 1870)

It is believed that fire was the desert Aborigines' single most important survival ‘tool’ (Latz 1995). It was used for cooking, warmth, signalling, as an aid in hunting and warfare, in rituals, and to increase run-off. A most important use was to increase the yield of food plants. Of the 12 plants considered most important to the traditional Aboriginal economy, five are ‘fire weeds’, three are fire tolerant, and four are fire intolerant. To ensure maximum production of these plants, it is likely that different fire treatments were deliberately applied and were ‘vegetation type’ specific (Latz 1995). The degree to which Aboriginal burning affected the vegetation now being grazed by cattle cannot be underestimated.

2.3 Historic Fire Records (1870-1970)

Pastoralism and European settlement began in CA in the 1870s. It is known that the seasons of inland Australia in the 1870s were, in general, exceptionally good (Meinig 1962) and this assisted the rapid expansion of farming and pastoralism during this period.

Invariably, each explorer in CA at this time encountered smoke or recently burnt country on a daily basis. In 1873, W.C. Gosse found different aged fire scars, some of which were “beautifully green”, compared to the surrounding unburnt country (Ralph 1984). The Telegraph Station recorded only 230 mm of rain in 1874 but good seasons followed in 1875 (429 mm), 1877 (518 mm), and 1879 (695 mm). The long term mean annual rainfall is 275 mm. The years 1876 and 1878 had 160 mm and 276 mm, respectively.

Exploration journals suggest that fires helped explorers to know where water could be found during the 1870s (Giles 1926). This suggests that burning was not practised just in spinifex-based vegetation. Aboriginal burning was possibly breaking up fuel distributions and suppressing large-scale wildfires in 1879/1880. This run of seasons was not experienced again for 40 years.

There was 1000 mm of rain recorded at Alice Springs between July 1920 and June 1921, which is the highest financial year rainfall on record. Fires in inland Australia during this period probably burnt out an area the size of NSW (700,000km^2) (McArthur and Luke 1977). Rabbits had become prevalent in CA by this time and large tracts of mulga in the southern Alice Springs area never recovered after these fires. The burnt stems still stand today. Anecdotal evidence suggests that the 1921 fires burnt more or less from Oodnadatta (SA) to the Gulf of Carpentaria (NT) (Ralph 1984).

2.4 Contemporary Fire Records (post 1970)

In 1974-75 another exception to normal conditions developed in inland Australia when a combination of heavy fuels induced by two good seasons resulted in widespread and costly wildfires (McArthur and Luke 1977, Griffin et al. 1983). By November 1974, fires had moved south to about the latitude of Alice Springs, and it was in this region that the fire season reached its peak in December and extended into January and February 1975.

During the fire period in 1974-75, up to 15 fires were being reported each day in CA. It is estimated that 1,000,000 km^2 or 13% of the Australian continent was burnt (Ralph 1984). Up to 80% of the Uluru (Ayers Rock) National Park was burnt. As a consequence, Government agencies made a determined effort to develop and implement a wildfire aversion strategy for the park (Saxon 1984). The knowledge generated by this fire management plan then provided a model for how spinifex vegetation could be managed in other CA parks and reserves (Preece et al. 1989).

The total area burnt in the Northern Territory by bushfires during 1974-75 has been estimated at 450,000 km^2. From a production viewpoint, wildfire in the 1970s destroyed 10,000km of fencing and cost $4 million dollars to CA (Griffin et al. 1983).

Fire records up until recently were anecdotal and even steeped in legend because of the enormous areas burnt and the low population densities of the outback. There are now satellite-based methods available to the NT Bushfires Council which, for instance, readily sourced, tracked, and mapped the large fires in the Tanami region of CA in 2000 (Grant Allan pers. comm.). Officers of the Bushfires Council were able to electronically mail details of the fire path to cattle properties that may have been affected. These satellite-based methods promise to help promote better fire management for the vast spinifex sand plains of Australia (Griffin 1988).

2.5 Lessons from non-pastoral fires in CA

Despite the obvious close ties between the Aboriginal economy and the use of fire, there was no scientific research into the role of fire in the CA ecosystem prior to the 1970s (Maconochie 1971).

The onset of good seasons in the 1970s led to more interest in fire research in CA. This early research was ecological rather than production based and centred on promoting the concept of patch or mosaic burning in spinifex (Bolton and Latz 1978, Latz and Griffin 1978). The extinction and reduction of medium-sized mammal fauna was perhaps exacerbated by the discontinuation of mosaic burning in spinifex.

Even by the early 1980s, little effort had yet been directed at mastering the use of prescription burning in CA, both for hazard reduction or landscape management purposes (Griffin et al. 1983). By the 1990s it was considered that “Fire is an essential component in the maintenance of most arid and semi-arid ecosystems.” (Preece et al. 1989). Without fire some vegetation tends to become a closed tree and shrub dominated system rather than more open grassland (Hodgkinson and Griffin 1982).

A 1987 fire workshop involving CA conservation land managers revealed some of the same concerns about using fire that the pastoral industry had in 1993 (see section 1.3). These concerns were that fires might escape onto adjoining pastoral land upsetting neighbourly relations and that fires might actually damage fire sensitive areas within their parks (Morton 1987).

Since then guidelines have been developed for using fire for managing CA parks and reserves (Preece et al. 1989) and fire has now been used even on pastoral land to reduce wildfire hazards in areas where fire sensitive rare species occur (Duguid 1999).

3 FIRE AND SPINIFEX

Spinifex (hummock grasslands of mostly unpalatable *Triodia* spp.) is the largest and perhaps most characteristically Australian ecosystem (Griffin 1992). In CA the response of spinifex to fire is well documented (Griffin 1990). Immediately after fire some species are able to re-sprout from buds, roots and rhizomes prior to any rainfall. Following rains a large variety of short-lived forbs and grasses establish. Major rains initiate establishment of seed-regenerating trees and shrubs. Spinifex and other perennials begin to replace short-lived species. Compositional diversity declines as the flora becomes more dominated by perennials (5,000-10,000 mm cumulative rainfall after fire).

It is known that after fire, spinifex in Western Australia (WA) can be almost entirely replaced by woollybutt grass (*Eragrostis eriopoda*) for a few years (Burbidge 1943). Also in WA, Suijendorp (1969) described the practice of burning ‘soft’ spinifex[1] every five to six

[1] Spinifex (*Triodia* spp.) can be separated into hard prickly species and softer less prickly species

years to encourage establishment of other species and to promote palatable spinifex regrowth.

From a pastoral perspective, a study in CA described the pasture response of burning hard spinifex (*Triodia basedowii*) (O'Reilly 1998a). The year following the burn (1996) was very dry and sand drift occurred. Excellent summer rains in early 1997 produced good germination of woollybutt (*Eragrostis eriopoda*) and other grasses. It is known that woollybutt germinates best in moist soil over 40^{o}C (i.e. good summer rains)(Mott 1972). The 19.7 km^2 area burnt in 1995 had a conservative useful pasture plant yield of 880 tonnes DM[2] (500 kg/ha) in 1998. An equivalent area on adjacent unburnt spinifex could only yield 5 tonnes DM of pasture plants (24 kg/ha). The fire produced an additional 875 tonnes of edible grass over 20 km^2. The measured response is probably a best-case scenario in pastoral terms. Actual post-fire pasture response in spinifex alliances depends on cumulative rainfall, time-since-fire, and proximity of non-spinifex alliances contributing to a greater assortment of species (Griffin 1990). Another CA study in hard spinifex (White unpub. report) showed that post-fire response was related to edaphic factors; in particular, the existence of paleo-drainage channels.

In WA coastal spinifex rangeland, it has been shown that no common grass species which may grow after fire (including *Eragrostis eriopoda*) is any more palatable or nutritious than the soft spinifex (*Triodia schinzii*) which was burnt. There is therefore little to be gained from burning this type of 'softer' spinifex if the purpose is only to encourage alternative grass species (Holm and Allen 1988). Although burning spinifex in WA can produce large quantities of nutritious forage for the wet season, the modified pasture cannot support livestock during long dry spells. Livestock remain dependent on unburnt soft spinifex for dry season maintenance (Stretch 1996).

3.1 Fire Prescription for Spinifex

It is clear that of all the vegetation types in CA, spinifex has been studied most and much practical information has been gathered (Burbidge 1943, Suijendorp 1969, Griffin 1984, Griffin and Allan 1986, White 1993, O'Reilly 1998a). Furthermore, it is the single vegetation type in CA about which there seems to be a general agreement among land managers on a best practice fire prescription. Regular patch or mosaic burning of spinifex reduces the risk of wildfire, promotes biodiversity, and sometimes improves pastures for a short time.

Spinifex has low to negligible value in terms of pastoralism in CA; yet pastoralists recognise that it requires active management in the form of regular patch burning, both to break up fuel loads at the landscape level and to improve what little pastoral value it has.

Another aspect to prescribed fire in spinifex relates to timing of burns. Spinifex accumulates fuel more like a shrub than a grass. Although it builds up fuel according to seasonal conditions it is perhaps not as attuned to current seasonal conditions as fuel loads in other vegetation. It may well be worth considering burning spinifex only at times when more valuable adjacent pastures are less likely to burn (Grant Allan pers. comm.).

Given the accumulated knowledge now available, policies on managing spinifex are slowly being implemented (e.g. Burrows and van Didden 1991). It is likely that the use of satellite imagery to identify paleo-drainage areas and assess fuel loads, along with the use of aerial incendiary ignition is the best way of implementing a fire prescription over large tracts of Aboriginal and Crown land in Australia (Griffin 1992). Pastoralists may also be interested in using these technologies to reduce the costs of managing spinifex on their properties. However, it is likely that individual pastoralists will continue lighting spinifex on the ground using roads and natural features as fire breaks.

[2] Dry Matter (weight after all moisture is removed)

4 FIRE AND CENTRAL ARID WOODLANDS

4.1 Pasture Communities of Central Arid Woodlands

Central arid woodlands are a collection of eight range types, each with characteristic tree and shrub species and soils, which occur in and around the CA ranges (Foran 1984)(Table 1). These non-spinifex range types vary in their pastoral value and wildfire frequency and each may require a different fire prescription based on susceptibility to scrub increases and the impact of rabbits.

Of the eight woodland communities described by Foran (1984) and detailed below in Table 1, four have a low wildfire frequency while four have a moderate to high wildfire frequency. It is these four high-fire-risk woodland communities which are discussed further in this Technical Bulletin because as well as having a high wildfire frequency, each community is also moderately to highly susceptible to scrub increase.

The four woodland types requiring management for scrub increase and wildfire in CA are:

- Open woodlands occurring on alluvial plains at the bases of hills and ranges. These have a mix of woody species such as whitewood *(Atalaya hemiglauca*), supplejack (*Ventilago viminalis*), corkwoods (*Hakea* spp.), and witchetty bush (*Acacia kempeana*), which is a species of high woody weed potential in CA (White 1997).

- Sandy, open woodlands occurring on coarse sandy alluvial soils and often dominated by ironwood (*Acacia estrophiolata*). Ironwood can form dense thickets of juvenile trees and is regarded as an increasing species (Griffin 1981, Cassidy 2001). Broombush (*Senna artemisioides* subsp. *filifolia*) is another ‘increasing’ species (Friedel 1985) commonly found in sandy open woodlands.

- Mulga-annual grassland which can have relatively high value for pastoralism in CA, has a moderate susceptibility to scrub increase, and a moderate wildfire frequency. The main woody species is mulga (*Acacia aneura*) which is a decreasing or an increasing species in CA depending on the presence of rabbits and/or changed fire regimes (Friedel 1985).

- Mulga-perennial grassland is also dominated by *Acacia aneura* but the ground-storey is dominated by less palatable perennial grasses, predominantly woollybutt (*Eragrostis eriopoda*). Cattle will preferentially graze mulga-annual pastures before mulga-perennial pastures.

Table 1. Characteristics of central arid woodland types (Foran 1984, p302)

Central arid woodland type	Value to pastoralism	Value as drought forage reserve	Wildfire frequency	Susceptibility to scrub increase	Impact of rabbit grazing
Open woodland	High	Moderate	Moderate	High	Low
Sandy, open woodland	Moderate	Low	High	High	Low
Mulga-annual grassland	High	Moderate	Moderate	Moderate	Low
Mulga-perennial grassland	Low	Moderate	Moderate	Moderate	Low
Calcareous, shrubby grassland	High	Low	Low	Low	High
Open, gidyea woodland	Moderate	Low	Low	Moderate	Moderate
Perennial, gidyea woodland	High	Moderate	Low	Low	Low
Eucalypt floodplain	Very high	Low	Low	High	Low

4.2 Scrub increase

Before discussing the role of fire in the pastorally important (non-spinifex) central arid woodlands of CA, it is necessary to outline the important issue of scrub increase, also known as the woody weed problem or woodland thickening. For a complete history of this issue in Australia, as well as a summary of research done, refer to Noble (1997). For a CA perspective on the issue, refer to Friedel (1985), White (1997) and O'Reilly (2000a).

Increased density of woody plants occurs throughout the world in semi-arid environments that are grazed (Humphrey 1958, Noble 1997). Any permanent solution to the problem requires changes in pastoral management, particularly grazing management, which recognise the basic biological processes that control the balance of shrubs and grasses in semi-arid and arid woodlands (Hacker 1993).

Figure 1. Areas of Australia where trees and/or shrubs have increased significantly since pastoralism began. Reproduced with permission from J. Noble (1997)

4.2.1 Impact of shrubs on pasture production

It has been clearly shown during efforts to revegetate with Australian woody vegetation in arable regions, that reducing the competition of forbs and grasses (herbage) is beneficial and sometimes vital for successful establishment and growth of trees and shrubs (Venning 1988; Agriculture WA 1998; Schirmer and Field 2000).

Conversely, it has been shown that production of herbage is inversely related to tree density in two semi-arid woodlands of eastern Australia (Beale 1973, Walker et al. 1972). It has been suggested that as little as 10% tree and shrub cover can reduce pasture potential in mulga (Jones 1996).

There is an alternative view on the key mechanism driving woody plant effects on grasses. Based on CSIRO research in semi-arid mulga woodlands of eastern Australia, it is suggested that grass does not thin when the shrubs build up. However grasses in thick scrub are more susceptible to drying out earlier. The combined stress of early drought and grazing can then kill off grasses prematurely (Hodgkinson 1998a). Interestingly, mulga trees can apparently also die if the grasses are overgrazed, because the grass tussocks act as wicks to channel water deeper into the soil (Hodgkinson 1998b).

In terms of arid CA, the theory that thick scrub can cause earlier drought stress in grasses could be a useful area for future investigation.

There have been no specific experiments in CA to see what effect thickening scrub has had on pasture production. Scrub control trials in CA suggest that trees and shrubs do impact substantially on ground storey pasture growth. There were fourfold increases in pasture production (to 1,400 kg/ha) on sites where the trees and shrubs were removed by chemicals (White 1997).

4.2.2 The mechanics of scrub increase

Major germination events of native trees and shrubs occur in years of particularly favourable rainfall (Hacker 1993), the best conditions being after significant cool season (winter) rainfalls (Booth et al. 1996). Competition between perennial grasses and shrub seedlings is intense in the following summer months, particularly when conditions are less than favourable, and this accounts for the mortality of many seedlings in their first year. If good summer rains occur during the seedlings' first year, most will survive (Booth 1996), but they are susceptible to being killed by fire at this time (Noble 1997). In the absence of fire, there may occur a progressive increase in shrub cover over the following years (Hacker 1993).

Summer growing perennial grasses are best able to provide the competition needed to suppress shrub seedlings (Hacker 1993). The removal or over-depletion of these grasses by total grazing pressure is therefore a significant factor contributing to scrub increases.

The abnormally high rainfalls from 1973 to 1978 in CA led to several species of woody plants gaining large numbers of recruits, in far greater numbers than was needed to maintain former population levels (Griffin 1981, Friedel 1981). Many of these young trees and shrubs have persisted through subsequent dry periods and have gone on to pose a serious problem in otherwise productive pastoral land. The three most important ‘increaser’ species in CA are all *Acacia* spp. They are *A. aneura* (mulga), *A. kempeana* (witchetty bush), and *A. estrophiolata* (ironwood) (Cassidy 2001). The various species of *Senna artemisioides* are shorter-lived smaller shrubs, some of which are also ‘increasers’ in CA (Friedel 1985).

4.3 The Open Pastoral State

It is common sense that old trees and shrubs are valuable to arid woodland pastoralism, and not just for shade and browse. Soil, seed and litter accumulate under old trees and shrubs and their dead timber. In these woodlands there is often more perennial grass under mature canopies and amongst dead timber than in open or ‘inter-grove’ areas. Old trees tend to occur in the ‘fertile patches’ or run-on areas in a landscape where nutrients and water are in short supply (Tongway and Ludwig 1990). The harsher ‘run-off’ conditions in the inter-grove zones tend to lose water, nutrients, and litter, into niches associated with dead timber and old trees and shrubs.

We need to make the distinction between old and dead trees and shrubs, which are useful, if not vital, and young and active trees and shrubs, which are detrimental in excessive numbers.

The most useful pastoral situation for arid woodland range types is probably to have a good cover of mature trees and dead timber, combined with good visibility and openness in the understorey. This vegetation structure allows for easier mustering and observation of cattle, and maximises availability of light, water and nutrients to growing forbs and grasses. Photographic series of known localities in CA often show that the landscape was much more open prior to the 1970s. By the 1990s, it was common to find that the original well-spaced canopy of mature trees still existed, but that the understorey was often 'choked' with the progeny of the over-storey trees.

The most likely way of achieving an 'open pastoral state' in excessively woody pastoral country is probably to periodically and strategically 'clean up' excessive tree and shrub seedlings and juveniles with prescribed grass fires while they are still young enough to die from a single burn.

While the process of scrub increase is well documented from the 1970s (e.g. Friedel 1981, White 1997), another scrub increase danger period unfolded after April 2000. Over 200 mm of rain was recorded in both February and April 2000 over the CA ranges. Significant numbers of shrubs were recorded as having germinated in 2000 in one paddock being studied by DPIF (G. O'Reilly unpublished data). With excellent summer follow-up rains in 2001, conditions were suitable for seedling survival and growth. There would appear to be a significant risk of scrub increases from this cohort of trees and shrubs from 2000. The 1970s increases went largely unnoticed in the early stages. In 2001, ongoing research may not only record a large germination event, but may show how fire can control tree and shrub seedlings when conditions are otherwise suitable for their continued growth.

4.4 Soil and Landscape Function

It is sometimes thought that burning can leave the land exposed and vulnerable to erosion and that cryptogam cover (mosses, lichens, fungi, algae) are adversely affected. Although studies have shown that cryptogams do offer protection against erosion, only minor changes were recorded in rangeland soils where burns had been conducted (Greene et al. 1990). Cryptogam recovery was complete within four years of fire.

While fires every five years or less could pose an erosion risk, the slow or erratic fuel build-up in arid rangelands makes such a fire regime unlikely. A prescribed fire regime based on 10-20 year intervals is unlikely to damage rangeland soils (Kinnell et al. 1990). There is also evidence from semi-arid grasslands in the USA that using prescribed fire to reduce woody perennials has no greater impact on erosion and site degradation than does drought and normal weather fluctuations (White and Loftin 2000).

4.5 Grasses and Forbs (herbage)

A valid concern of CA pastoralists is sacrificing feed for fuel in a capricious rainfall zone, both in terms of quantity of feed, but also with the quality of feed that returns after fire.

The best local information available regarding the effects of fire on herbage comes from the fires studied in the late 1970s by Griffin and Friedel (1984a). They found that a winter burn was preferable for pasture production. Composition of pasture plants palatable to cattle was generally maintained or improved. Summer burning significantly decreased the grass component. In an open woodland vegetation type, grasses recovered to pre-burn yields within six months. It took 12 months in mulga groves and inter-groves. In all cases, palatable grass biomass on burnt plots eventually exceeded that on unburnt plots. Rainfall, season of burning, and reduction of cover, appeared to be important factors in determining the composition of post-fire herbage.

Studies in semi-arid mulga in south-west Queensland have shown that pasture regeneration and botanical composition are not affected by infrequent fire (Sullivan and Pressland 1986), but that *Aristida* spp., an undesirable component of pastures, may be favoured by fire at certain times in some areas.

Buffel grass (*Cenchrus ciliaris*), a common pasture species in fertile areas of CA, responds favourably to fire. In Sonora, Mexico, irrespective of temperature and precipitation, buffel grass produced new growth 5-10 days after fire (Martin-R et al. 1999). Plants began to grow rapidly five days after 20 mm or greater of storms, and reached full leaf elongation in 25-30 days (Martin-R et al. 1995).

DPIF fire studies investigating the effect of fire on *Acacia farnesiana* reported a complete recovery of native perennial grasses (mostly *Bothriochloa ewartiana*, *Themeda triandra* and *Enteropogon ramosus*) 18 months after burning (G. O'Reilly unpublished data).

A general rule of thumb might be that in the arid zone it could be two or more years before enough rainfall has accumulated to restore grasses and herbage after fire (P. Latz pers. comm.). However there should be no long-term adverse effects on yield or quality once enough rain has fallen to rejuvenate pastures.

4.6 Specific Vegetation

4.6.1 Mulga

Mulga (*Acacia aneura*) covers about 20% of the Australian continent (Partridge 1996). There are 25,600 km^2 of mulga lands in CA representing 23% of the useable rangelands (Perry et al. 1962).

Managing mulga shrublands for pastoralism is complex because of poor acidic soils, low and unreliable rainfall, and because of the interactions between grasses, trees and shrubs, as well as the presence of domestic, feral, and native herbivores (Partridge 1996).

In mulga lands of NSW and Queensland, it is usually the understorey shrubs that are considered the woody weed problem, with mulga itself being traditionally regarded as useful drought fodder (Beale et al. 1986; Pressland et al. 1986; Soil Conservation Service of NSW 1988). An analysis of impacts on CA tree and shrub populations (Friedel 1985) showed that mulga itself (along with *Senna* spp.) was the most common 'increaser' species in CA. Changed fire regimes were suggested as an important cause of this increase. It was also found that in rabbit-prone areas of CA, mulga was actually a 'decreaser' species. Rabbits are known suppressants of arid zone trees and shrubs (Lange and Graham 1983).

Jones (1996) suggests that in south-west Queensland, for mulga, a fuel load of 1,000 kg/ha DM is the minimum necessary to carry a fire and kill a substantial number of target shrubs.

The best local information on fire and mulga comes from the CSIRO fire studies from the late 1970s (Griffin and Friedel 1984b). Two range types were burnt; mulga and open woodland. It was found that summer and winter fire treatments caused a similar level of mortality in mulga (*Acacia aneura*) and the understorey shrubs, *Eremophila gilesii* and *Cassia* (now *Senna* spp.). Another shrub, *Eremophila latrobei*, was more susceptible to summer burning. *Acacia aneura* had enhanced germination following the hot (summer) fire. There were no important effects on available nutrients from either type of fire.

Survival of mulga after a single fire seems to vary. Wilson and Mulham (1979) reported 16% survival after wildfire in western NSW, while a cool winter burn in CA reported 36% survival (O'Reilly 2000b). Griffin and Friedel (1984b), also in CA, reported 33% and 31% survival of mulga after a winter and summer burn, respectively. However, in WA 100% mortality has been reported with all trees succumbing to the effects of fire within a few years of burning (Fox 1986).

Mulga in CA is often associated with a scattering of understorey shrubs such as turpentine (*Eremophila sturtii*), crimson turkey bush (*E. latrobei*), and Charleville turkey bush (*Eremophila gilesii*). In the 450 mm average yearly rainfall areas of south-west Queensland (Partridge 1996), these understorey shrubs of mulga can become serious woody weeds (Burrows 1973) capable of returning to pre-burn densities within four years of fire (Jones 1996). *Eremophila latrobei* and *E. sturtii* regenerate from basal shoots but *E. gilesii* is easily killed by fire and regenerates from seed. Controlled fire after winter germination events of these shrubs has been shown to be effective in their control (Pressland et al. 1986).

In CA, *E. gilesii* has been shown to be very susceptible to fire (O'Reilly 2000b). However in the lower rainfall mulga of CA it is not uncommon to observe cohorts of this shrub also succumbing to drought. Along with *E. sturtii*, it is not regarded as the serious woody weed threat in CA that it is in south-west Queensland.

A common argument against burning mulga is that it will simply promote even more germination and establishment of the shrub. Hodgkinson and Oxley (1990) using seed of mulga trees from near Alice Springs tested the effects of fire on germination. They found that post-fire germination probably only occurs where there is a litter build-up, that is next to logs or at the base of trees etc. The burning of fine fuels (grass and forbs) did not promote germination of mulga except where the soil surface remained moist. It was found that if the soil was dry after fire, then germination of mulga remained unchanged. Even without fire treatment, 17% of mulga seeds germinated in moist soil (i.e. non-dormant percentage). Fire-promoted germination is never widespread and is usually confined to areas of high fire intensity or areas where there is a large number of seeds (e.g. beneath parent plants)(Soil Conservation Service of New South Wales 1988). This is supported by Griffin and Friedel (1984b) who found greater mulga regrowth after a summer burn than after a winter burn.

4.6.2 Ironwood

Ironwood (*Acacia estrophiolata*) is a CA tree species occurring on coarse alluvial soil plains and river frontages. It tends to produce dense stands or thickets of juveniles in and around well-spaced parent plants (Cassidy 2001).

Griffin (1981) burnt two plots of juvenile ironwood near Alice Springs. The fire reduced the population but basal re-sprouting was common. It was concluded that the probability of getting enough fuel for a second fire in a reasonable time was low and that it was likely that productivity would be reduced from the 1970s increase of this species in CA. It was noted that seedlings and very small ironwoods were susceptible to fire so that early identification of major germination events could be critical for effective control.

It is hoped that planned DPIF studies on the effects of multiple burning on this species will produce further useful information regarding its management (Cassidy 2001).

4.6.3 Witchetty bush

Witchetty bush (*Acacia kempeana*) is a mid-sized to large shrub occurring in a variety of alluvial and calcareous habitats of CA, either as the dominant over-storey species or in mixed woodland situations (Wilson et al. 1990). There is little published material describing experimental burning of witchetty bush. Experienced observers report that a hot fire is needed to kill adult shrubs (Bastin 1989). O'Reilly (2000b) reported 29% mortality of witchetty bush after a cool winter burn.

There is a need for more information regarding this species, as it is one of the main contributors to scrub increase in CA. DPIF studies (G. O'Reilly unpublished data) involve burning mature, young adult, juvenile and seedling witchetty bush. It is hoped that this research leads to more facts being published on the effects of fire on this species.

4.6.4 Acacia farnesiana

This introduced shrub is normally found as scattered plants along creeks and around water-points and occasionally forms dense thickets which have considerable nuisance value when mustering. It has increased in some areas of CA, often where rabbit warrens have been 'ripped' (O'Reilly 1999; Will Dobbie pers comm.).

A recent fire study involved burning *Acacia farnesiana* along a creekline in CA (G. O'Reilly unpublished data). Shrub densities varied from 27 to 2,215 shrubs per hectare. Pasture yields in and amongst shrubs averaged 2,500 kg/ha providing plenty of fuel for the first burn carried out in April 1999. The fire was relatively hot and completely scorched the shrub canopy in most areas. By June, all shrubs of all age/size classes were showing fresh basal regrowth, despite there having been dry conditions and negligible rainfall since the burn. This species is known to exhibit basal regeneration after fire in wetter climates (Rasmussen et al. 1983).

Canopy recovery was near complete for all age classes when heavy summer rains fell (approximately 200 mm in February 2000). There were another 200 mm in April 2000. When next visited, in August, all burnt shrubs, regardless of age class, had died back. All post-fire regrowth had fallen or withered on the basal regrowth 'canes'. It could not be determined if the cause of this dieback was competition from the perennial grasses; which grew back vigorously after the rain, or that the grasses made conditions conducive for frost to kill off the shrub regrowth. Unburnt individuals remained healthy at this time.

The following summer (2000/2001) was also exceptionally wet and, when next visited in May 2001, all *Acacia farnesiana* shrubs, regardless of whether burned or not, were dead or dying. Insect damage appeared to be the main cause of this dieback.

A second fire is planned for these shrubs in 2001. Camels may also be part of an integrated approach to controlling this species, it being one of their most preferred browse shrubs (Dörges and Heucke 1995).

4.6.5 Broombush

Broombush (*Senna artemisioides* subsp *filifolia*) is a short-lived shrub which, along with other subspecies of *Senna artemisioides*, has become excessively dense in some CA woodlands (Friedel 1985) There is some evidence suggesting that fire is effective against this species (Griffin and Friedel 1984b, Hodgkinson and Oxley 1990). Its status as a pasture-suppressing shrub, and its response to fire, could be better quantified in CA.

5 TOWARDS A FIRE PRESCRIPTION FOR CA RANGELANDS

5.1 Preventative and Remedial Fires in Scrub Country

There may be two paths to scrub increase in arid woodlands of CA. If there is little or no perennial grass competition, then germinated shrub seedlings are more likely to survive dry spells during their early growth and scrub increase can result. However even if good grass cover is maintained, shrub seedlings can still grow in large numbers on rare occasions when there is a run of good seasons. Before they get too big and while there is grass fuel to burn they may be brought under control with a cool preventative burn. 'Cool' because there is likely to be lots of continuous grass fuel about and because only the seedlings are being targeted. Based on rainfall records, this type of burn may be needed every 20-30 years in CA woodland vegetation.

If the scrub already got away during a wet spell years ago, perhaps when there was more grazing pressure, but there is grass fuel available these days, then a remedial burn may be the preferred option. This fire would need to open up the thick scrub canopy, and because there is likely to be less continuous grass fuel available, a remedial burn may be better applied under hot windy conditions to get it to carry through the scrub. If the remedial burn is successful then the land manager can go back to occasionally applying preventative burns when good seasons follow on from good seasons.

In some cases, where an excessive scrub problem has been allowed to develop through the 1980s and 1990s, the young adult trees and shrubs are now so dense that they suppress ground pasture, and therefore fuel, for a remedial burn. In these cases, fire alone may be no longer possible in the short to medium term, and it may be necessary to incorporate some type of mechanical or chemical control to provide a fuel build-up and frontage for burning into the adjoining thick scrub.

5.2 Three Types of Fire on CA Cattle Properties

Apart from the preventative and remedial fires described above, a third category of fire is needed on most stations. Spinifex needs to be patch burned on a 5-10 year rotation to prevent wildfire and encourage biodiversity. There are therefore three types of fire used on stations to both manipulate vegetation and to prevent destructive wildfire.

In arid woodlands, seasons are directly responsible for the germination of tree and shrub seedlings, but grazing management of perennial grasses is linked to seedling survival. During rare ‘wet’ periods, cooler preventative fires may be needed to kill seedlings regardless of grass competition. Where scrub increases have occurred in the past and are well established, hot fires may be needed as a primary treatment to return existing scrubs back to more open woodland. A third type of fire involves large tracts of spinifex, which should be regularly broken up with patch or mosaic burning, preferably in years when adjoining non-spinifex vegetation will not carry fire.

6 ECONOMICS OF PRESCRIBED BURNING

Any fire prescription developed for use on CA pastoral properties needs to be justified in terms of profitability to the overall enterprise, although a sense of land stewardship can also be a strong motivation which most often results in improved profitability (e.g. Purvis 1986).

Pastoralists are likely to readily accept the ecological rationale of scrub increase and of using fire for scrub management. They are likely to be more concerned with the costs and benefits to the enterprise of doing so, keeping in mind the low-input basis of these enterprises in the arid zone. There has been a decision support system (DSS) developed to assist planning prescribed fires and projecting the costs and benefits of burning out to 20 years after fire (Ludwig 1991). This DSS has been adapted for generating a fire management plan for Uluru National Park in CA (Saxon 1984). The use of this or an adapted DSS for pastoral fire management could be an area for further investigation in CA.

6.1 Costs of Scrub Increase

Economic analysis of severe shrub encroachment in western NSW showed that a typical pastoral property could lose $40,000 of potential income each year, which translated to $25 million to $42 million for the whole state annually (Ralph 1991). Although this analysis was for sheep rangelands, it did consider mustering time based on two men working from motorcycles three times per year, which has some relevance to CA. It was concluded that in ‘open’ country, it would take 3.75 hours per 1,000 ha to muster efficiently. This figure increased to 4.75 hours for mustering with a moderate shrub increase, and took up to six hours in country with a severe shrub problem.

6.2 Costs of Different Control Methods

MacLeod and Johnston (1990) compared the costs and benefits of seven rangeland restoration techniques for western NSW and concluded that prescribed fire was the only economically viable option when repayments of interest and principal were included in the analysis. The relatively low cost of applying fire (approximately $50/km^2) helped to offset the costs of foregone grazing associated with sacrificing pasture for fuel. The least economical rangeland restoration methods were blade ploughing and water ponding, both of which are used in CA.

The major costs of using fire include the construction of firebreaks, labour and vehicles to conduct the burn and importantly, the risk that the fire may get away and burn valuable feed on the property or on adjoining properties (Cann 1991). Even allowing for these costs, the cost of fire is in the order of hundreds of dollars per km^2, rather than in the thousands (Cann 1991), making it by far the cheapest method of controlling scrub increases.

6.3 Opportunity Costs of Spelling and Burning Feed

The erratic seasons of CA are likely to play a large part in how long the burn and recovery cycle takes. It is likely that at times it is vital to allow pastures to recover after fire in the absence of grazing. However at the times when fire is most likely to be achievable, cattle are likely to be grazing alluvial fans and footslopes rather than thick scrub (Low et al. 1973). On the other hand green pick produced soon after a fire is likely to attract cattle if other areas are hayed-off.

Some observers suggest a general rule of thumb is that cattle must be kept off regenerating pastures for two or more years after fire (Peter Latz pers. comm.). In one CA fire of 1999, native perennial grasses returned to pre-burn yields 18 months after burning, during which time small numbers of cattle were grazed continuously (G. O'Reilly unpublished data). Griffin and Friedel (1984a) reported pastures returning to pre-burn yields within 12 months in ungrazed mulga groves in CA. Cattle were allowed onto green 'pick' for a short time after a cool winter fire in mulga in CA (O'Reilly 2000b).

An economic analysis of prescribed burning in western NSW showed that all the outcome scenarios investigated returned a positive dollar return within a reasonable timeframe (Burgess 1987). The best case scenario was that stock could be returned to a paddock in 6-12 months and that there was an increase in production resulting from the burn. This scenario produced a discounted dollar return of $16,777 after four years for a 2,000 ha paddock stocked with a self-replacing merino flock. The worst case scenario assumed that the paddock needed to be spelled for 18-24 months after a fire due to insufficient rainfall and that the fire did not increase livestock production at all. In this worst case scenario it would take 13 years for the burn to 'pay for itself'. However the study concluded that for a rural development project, the rate of return is quite acceptable for all the scenarios described.

The question of whether grazing can continue during fire treatment in extensive paddocks of the arid zone might be a useful topic for further investigation in CA. The strong patterning of landscapes within paddocks and cattle preferences for each landscape could provide a basis for applying fire concurrent with grazing. The effect of grazing on post-fire recovering pastures could also be better quantified.

Cooler preventative burns are most likely to be undertaken at times when feed is abundant. It is possible on the extensive properties of CA that, in some circumstances, there is no grazing foregone as a result of sacrificing pasture for fuel. Grazing value is only foregone if it becomes necessary to sell stock, or if animal performance suffers. During good seasonal conditions in CA neither scenario is likely unless wildfire destroys large areas of a property.

It would not be unusual for many CA properties to have paddocks, or parts of paddocks, which are spelled for two years or more. If an area was being spelled for two years or more, then applying a fire treatment to that area should not affect the grazing potential of the property as a whole. There may be scope for significantly reducing the costs associated with foregone grazing by incorporating fire treatments into a system of spelling or extended-rest grazing.

6.4 Costs of Doing Nothing

There is sometimes a belief among CA pastoralists that excessive scrub increases will eventually thin themselves out through natural pests and diseases, competition, and the effects of drought. While this may well occur over an extended time period, the cost of not doing anything to speed up this process in the short to mid-term remains unquantified.

Buxton (1997) looked at a hypothetical sheep property with a low woody weed cover of only 0.11%. The financial gains of controlling the woody weeds at this low level were compared with two scrub increase scenarios over the next twenty years. This was the 'do nothing' approach, with canopy cover increasing to 2% and 5% over that time. Controlling the woody weeds before they increased realised only a minimal benefit in cash surplus ($829 per year). However, where nothing was done about controlling the current woody weed population, cash flow decreased by between $6,192 and $16,044 per year over the next twenty years.

Another cost of 'doing nothing' is the damage to fencing and infrastructure caused by wildfire. Wildfire in the 1970s cost the CA pastoral industry $4 million (Griffin et al. 1983).

7 INTEGRATED MANAGEMENT USING HERBICIDES

It has been found that repeated autumn fires can reduce densities of fire resistant species like budda (*Eremophila mitchellii*) and turpentine (*E. sturtii*), but the opportunities for consecutive fires are very rare in Australia's rangelands (Noble et al. 1992; Griffin 1981). An approach has been developed which involves applying chemical defoliants at low concentrations to post fire regrowth to mimic leaf scorching by fire (Noble et al. 1991). The results of this research are that the herbicide glyphosate gave promising results when applied at concentrations as low as 12.5% of that recommended for killing adult shrubs. A preliminary cost/benefit analysis suggests that this treatment could be aerially applied the year after a prescribed burn at a cost of $850/km^2$. When compared with blade ploughing (up to $6,500/km^2$) this cost is at the upper limit to be an economically viable option for most pastoral leases in NSW (Noble 1997). The cost of getting a suitable aircraft to CA would increase the cost of applying this treatment locally.

The use of low dose chemical defoliants with prescribed fire may be a useful area for further research and testing in CA, particularly for fire resistant species like ironwood (*Acacia estrophiolata*), witchetty bush (*Acacia kempeana*) and mimosa wattle (*Acacia farnesiana*).

8 PRACTICAL ASPECTS OF PRESCRIBED BURNING

Conducting a prescribed burn is not a particularly difficult task. The ingredients for success are commonsense, good preparation and experience (Soil Conservation Service of New South Wales 1988). It is desirable to develop a plan for conducting a prescribed burn six months before the event. Neighbours and authorities (i.e. NT Bushfires Council) need to be informed, and if appropriate, insurance arranged.

8.1 Fuel and Wind

Wind speeds of up to 20 km/h may be required for fire to carry in spinifex vegetation (Stretch 1996). Where fuel loads are heavy, light winds are preferred. Light winds are no guarantee that a spinifex burn can be contained. Patchy fuel loads sometimes result in localised whirlwinds (willy willys) because of the irregular advance of the fire front (Stretch 1996). These winds can carry burning material over firebreaks.

CSIRO research into grassland firebreaks (Lehane 1999) showed that a 10 m wide break had a 99% chance of holding a fire travelling at five kilometres per hour in a well-grassed paddock with four tonnes of fuel per hectare. It is rare to have this much fuel in Central Australia but buffel grass, spinifex, and native perennial grasses along creek lines can reach these fuel loads. Reducing the firebreak width to 5 m nearly halved the chances of holding a fire. If the wind was blowing strongly (more than 25 km/h) no firebreak of practical width was effective. In strong wind, burning material was blown along the ground, with some finding its way across firebreaks. Trees near a firebreak were a major hazard. Trees within 20 m of a firebreak greatly reduced its chances of holding the fire.

Fuel tends to be very patchy in arid rangelands depending on the distribution of scarce water and nutrients. Areas with low fuel can be used as natural firebreaks for controlled burning during normal seasons. The manager needs to know where these natural firebreaks are in relation to wind directions on the day of the fire. Research and practical experience of how fuel is distributed in different arid rangeland vegetation types, both in average and exceptional seasons, could be a useful area for further investigation.

DPIF has a vehicle-based ‘rapid-assessment’ technique for estimating ground-storey biomass in CA, which could be adapted for use in planning fires and fire control at the paddock or property scale (O’Reilly 1998b). Satellite imagery may be the most efficient way of determining patterns of vegetation cover as a measure of fuel load over extensive tracts of largely unoccupied land (Griffin 1992).

Managers planning a burn should check with the Bureau of Meteorology and avoid periods when steep pressure gradients or rapidly changing weather conditions are forecast (Stretch 1996).

8.2 Gaining Practical Experience

There is considerable scope for further research into fire/weather relationships and other practical considerations regarding conducting safe and effective prescribed burns in CA. This is particularly important for pastoralists to develop confidence and expertise in handling woodland fires that may only occur once or twice in 20-30 years.

One way of getting more experience would be to undertake controlled burns in areas where critical fuel loads can be achieved in years when widespread fires would not be possible. Smaller pockets of ‘run-on’ country, areas with introduced buffel and couch grasses, and spinifex may burn more frequently than once every 20-30 years. These fires could be used to give pastoralists the opportunity to work with fire, and gain more first-hand experience for those years when more widespread fires would be possible. The resources to train people in working with fire (staff of the NT Bushfires Council) are going to be more readily available in years with an overall low wild fire risk.

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