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Natural Resource Management

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Developing, implementing and evaluating fire management of woody vegetation in the Gulf region

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Abstract

This project tested the potential for using fire to manage woody vegetation in the northern Gulf savannas. It addressed the problem of increasing woody vegetation as a cause of declining cattle carrying capacities. The work looked at a wide range of tree and shrub species but focussed on two, in particular, that are widely recognised by Gulf graziers and others as being the species of greatest concern in many parts of the region. The project demonstrated that burning in the October-January period can kill a proportion of the targeted species, notably gutta percha and breadfruit. Repeated burning had a greater impact than single fires. Burning also altered the structure of shrub and tree populations, reducing the sizes of individuals, resulting in more open woodland. The work demonstrated the importance of adequate fuel before effective fires can be achieved. This highlights the importance of considering the factors that drive above-ground grass biomass when developing a regime of prescribed burning and especially of integrating fire and grazing management.

Executive summary

As in many vegetation types in Australian and other rangelands, the tropical woodlands of the northern Gulf region are perceived to have experienced increasing densities of trees and shrubs. While there is still debate about the causes of such increases, burning presents a possible option for countering them. This project was undertaken as a preliminary test of this option for the northern Gulf savannas.

Its objectives were to:

1. Devise management guidelines and practices for the use of fire for the management of the woody vegetation and pastures of the Gulf savannas;
2. Ensure that 50% of graziers in the northern and southern Gulf savannas of Queensland are aware of these guidelines and practices for the use of fire.

Researchers and extension officers from CSIRO and Queensland Department of Primary Industries and Fisheries worked directly with pastoralists from the northern Gulf Savannas in an area stretching from Mt Surprise through to Karumba. The approach was to establish a small number of “core” sites and a larger number of “satellite” sites and to impose prescribed fires at these sites. Changes in tree and shrub populations on burned areas were compared with those on nearby unburned plots. The research was originally planned for the period 2003-2006. However, low fuel loads, as a result of drier than average conditions during the 2003-2004 and 2004-2005 wet seasons, meant that fires in the subsequent dry seasons were of low intensity. The effect of these dry years on the prospects for burning and on the intensity of fires that were conducted, were exacerbated at several sites by the fact that the sites were stocked, in accordance with the needs of the various co-operating land-holders. For this reason, further resources were obtained in order to take advantage of the relatively wet season of 2005-2006.

Where fuel loads permitted sites were burned each year between 2003 and 2005. Decisions about whether to burn were made following discussions between researchers and land-holders. Effects were quantified at five core sites and photographic records made at twelve satellite sites. All five core sites and seven out of twelve satellite sites were burned during the initial experimental period (2003-2006). At unburned sites, fuel loads were inadequate to carry effective fires during this period. Most sites were burned only once during 2003-2006, two sites were burned twice, and three were burned three times. One site had been burned immediately prior to the beginning of the study in 2002. In 2006, four core sites were burned.

The study found that:

- Fuel loads during the study period were generally below 2000 kg/ha.
- Single fires resulted in increased mortality of a range of tree and shrub species, including two species considered increasers of greatest concern, gutta percha (*Excoecaria parvifolia*) and breadfruit (*Gardenia vilhelmii*). Mortality rates due to burning were up to three times those recorded in unburned plots though they were highly variable between sites and species.
- Shrubs at the few sites that were subject to more than one fire experienced higher mortality than sites subject to a single fire.
- A large proportion of trees and shrubs that were subject to fire sprouted from the base after the fire
- Fires reduced the average size of living trees and shrubs.

- There was a widespread acceptance of the principle of using fire to manage tree and shrub populations but a significant challenge in applying this principle is to incorporate into property management a capacity to manage fuel grass loads.

The principal recommendations emerging from this study are:

- Fire can be used to manage populations of important shrub species even though fire-induced mortality of shrubs is modest.
- There is a need for a better understanding of the interactions between rainfall, grazing and burning as determinants of grass and other fuel loads. This could be derived from a combination of rigorous research and adaptive management.
- The integration of fire and grazing management is absolutely critical if there is to be an efficient and effective application of fire to the management of shrub densities.

The results are relevant to graziers and other land managers of the tropical woodlands of the Gulf savannas and similar woodland types in Western Australia, the Northern Territory and other parts of Queensland. A small number of land holders in the Gulf savannas have had close and direct contact with this project through their involvement with individual sites. These individuals have had input into decision-making in relation to particular sites and practical involvement with prescribed burning. All graziers in the Northern and Southern Gulf Savannas have had the opportunity to learn of the project and its results through mass media and targeted workshops (e.g. $avannaPlan).

In this image of the site at Foresthome, the area to the right of the track has been burned twice in recent years (in 2002 and 2003). It illustrates the effect of burning in opening up the mid-storey, which, at this site, was dominated by breadfruit. The eucalypt overstorey was not greatly altered.

Contents

1 Background

An increasing density of woody plants has been reported in many of the world's rangelands. This is an issue in rangelands used for livestock grazing because of the known relationships between woody plant density and herbage production. Dense woody vegetation can also increase mustering costs. This means that, all else being equal, rangelands with dense stands of woody plants are less productive for grazing industries than are more open rangelands. Various explanations have been advanced and tested to account for observed trends toward higher densities of woody plants. These include increased dispersal capacity as a result of new dispersal vectors, changing fire regimes, and changing concentrations of atmospheric CO_2. Any links between woody plant density and fire regimes suggests that burning could be used to counter trends to higher densities of trees and shrubs. Indeed fire has been tested for this application and is exploited in various rangeland situations. Little fire research has been conducted in the northern Gulf savannas of Queensland, though increasing tree and shrub densities are of concern to pastoralists of the region.

The northern Gulf savannas are diverse. They support various types of grasslands and woodlands and concern is expressed that the density of woody plants in general is increasing in the woodlands. Some species are seen as being more important than others. The species of greater concern include gutta percha (*Excoecaria parvifolia*) and breadfruit (*Gardenia vilhelmii*). These are widespread species. Gutta percha occurs from north-west Queensland across to north-eastern Western Australia, while breadfruit is found in north Queensland and the northern part of the Northern Territory. We know of no research conducted on the general ecology of these two species.

2 Project objectives

This project aimed to develop and test recommendations for the use of fire for management of woody vegetation in the gulf savannas through a collaborative effort between landholders and woodland ecologists.

Its specific objectives were to:

1. Devise management guidelines and practices for the use of fire for the management of the woody vegetation and pastures of the Gulf savannas;
2. Ensure that 50% of graziers in the northern and southern Gulf savannas of Queensland are aware of these guidelines and practices for the use of fire.

3 Methodology

This project involved working with pastoralists of the northern Gulf region to determine, apply and test the effects of producer-determined fires on native woody species. This collaboration was facilitated by the formation of a Project Steering Group in consultation with the Northern Gulf Resource Management Group and other stakeholders. The Steering Group identified three focus districts for the project centred on Georgetown, Croydon and Normanton.

The Project Steering Group also identified primary target species for the project. While there is a perception that woody species in general have been increasing in density in the Northern Gulf savannas, most concern is expressed about increasing populations of certain species. The Project

Steering Group identified breadfruit (*Gardenia vilhelmii*) and gutta percha (*Excoecaria parvifolia*) as the species that should be the primary targets of the research.

Once focus districts and target species were chosen, the project team identified prospective study sites. These were of two types, hereafter referred to as “core” sites and “satellite” sites. At core sites, detailed quantitative data were collected by documenting the woody species present along belt transects. Although transects at these sites were chosen to target breadfruit and gutta percha, all woody species present along transects were documented. At a small number of satellite sites, neither of the main target species was present. A complete list of species present at core and satellite sites is presented in Table 1. Prior to the imposition of any prescribed fires, the following data were collected from each individual tree or shrub present on transects:

(i) location, as distance along and distance away from mid-line of transect

(ii) diameter of each stem, measured 30 cm above the ground

(iii) number of stems

(iv) height of each stem, measured to the highest living leaf

At satellite sites, the effects of fires were documented qualitatively. The satellite sites provided an opportunity (i) to document the effects of fire on woody species growing under a greater range of circumstances; and (ii) for a larger number of pastoralists to have a more direct involvement in the work. At these sites, the effects of fires were documented photographically.

The timing of fires was determined in discussions with the Project Steering Group and individual property owners. These determinations depended strongly on fuel availability. The times of fires at each core and satellite site are shown in Table 2. Prior to burning, the biomass of fine fuel was estimated for each core site using the BOTANAL technique. At satellite sites, fuel loads were estimated visually.

Within two weeks of burning, the immediate impacts of the fires at core sites were evaluated by measuring the “scorch” and “char” heights on trees and shrubs at intervals along each transect. These were defined as the maximum heights to which the individual tree or shrub was scorched or charred respectively, and were taken as measures of fire intensity.

All data are securely stored on the CSIRO server at the Davies Laboratory, Townsville.

Table 1 - Species of trees and shrubs recorded at core and satellite sites
A = Abingdon Downs; DD = Delta Downs; F = Foresthome; OP = Oakland Park; W = Woodview;
BH = Beverley Hills; B = Blanncourt; D = Dumas; H = Huonfels; S = Springfield; T = Tabletop;
N = Narrawa; P = Prestwood; R = Reigate Station; SL = Shady Lagoon; W = Woodstock
NB. Only the most common species are listed for the satellite sites.

Species	**A**	**DD**	**F**	**OP**	**W**	**BH**	**B**	**D**	**H**	**S**	**T**	**N**	**P**	**R**	**SL**	**W**
Acacia farnesiana Mimosa bush										✔						
Acacia holosericea Silver-leaved wattle				✔												
Acacia victoriae Prickly wattle												✔				
Acacia spp.			✔	✔		✔		✔			✔		✔	✔	✔	✔
Archidendropsis basaltica Dead finish			✔													
Alphitonia excelsa				✔												
Atalaya hemiglauca Whitewood		✔		✔								✔				
Brachychiton paradoxus Red-flowered kurrajong				✔												
Carissa ovata Currant bush				✔								✔				
Cryptostegia grandiflora Rubbervine		✔								✔		✔				
Erythrophleum chlorostachys Cooktown ironwood	✔		✔	✔		✔	✔								✔	
Eucalyptus miniata Darwin woollybutt	✔															
Eucalyptus polycarpa Long-fruited bloodwood	✔															
Eucalyptus tessallaris Morton Bay ash	✔	✔	✔		✔											
Eucalypytus erythrophloia Gum-topped bloodwood	✔		✔	✔												
Excoecaria parvifolia Guttapercha		✔			✔										✔	
Flueggea virosa White currant bush			✔													
Gardenia vilhelmii Breadfruit	✔		✔			✔	✔		✔		✔		✔		✔	
Grevilllea striata Beefwood		✔														
Lysiphyllum cunninghamii Bauhinia				✔												
Maytenus cunninghamii Yellowberry bush	✔		✔									✔				
Melaleuca bracteata River teatree		✔														
Melaleuca spp.				✔		✔					✔			✔	✔	
Species	**A**	**DD**	**F**	**OP**	**W**	**BH**	**B**	**D**	**H**	**S**	**T**	**N**	**P**	**R**	**SL**	**W**
Melaleuca viridiflora Broad-leaved paperbark				✔											✔	

Petalostigma pubescens Quinine tree	✔										✔					
Planchonia careya				✔												
Santalum lanceolatum Sandalwood		✔														
Terminalia platyphylla Wild plum; yellow-wood	✔	✔	✔				✔		✔				✔			

Table 2 - Times of burning at core and satellite sites
NB: The Foresthome site was burned prior to any measurements being taken. The site thus lacks an unburned control.

Site / Year	**2002**	**2003**	**2004**	**2005**	**2006**
Core Sites					
Abingdon Downs	-	January	November	December	December
Delta Downs	-	-	-	January	December
Foresthome	August	October	-	-	-
Oakland Park	December	October	-	-	November
Woodview	December	-	November	December	November
Satellite Sites					
Beverley Hills	-	-	November	-	-
Blanncourt	-	October	-	October	-
Dumas	-	-	-	-	-
Foresthome	-	-	-	-	-
Huonfels	-	-	-	-	-
Springfield	-	-	November	-	-
Tabletop	-	-	October	-	-
Narrawa	-	-	November	-	-
Prestwood	-	October	-	-	-
Reigate Station	-	-	-	-	-
Shady Lagoon	-	-	November	-	-
Woodstock	-	-	-	-	-

The longer term effects of the prescribed fires were documented during revisits to sites at intervals after burning. At each visit, all previously recorded trees and shrubs on transects were relocated and the heights and diameters of each stem were measured. Woody plants not previously recorded were also measured at these times. The times of visits during which each individual plant was measured/remeasured were: November 2002, August 2003, May 2004, June 2005, June 2006 and June 2007.

4 Results and discussion

4.1 Core sites

4.1.1 Rainfall

Rainfall during the study period is shown in Figure 1. In general, the study period was somewhat drier than average in terms of monthly, seasonal and annual rainfalls. Although there were individual months that received above-average rainfall, the general pattern was of below-average rainfalls in most months.

4.1.2 Fuel loads

Fuel loads throughout the course of the project ranged from 870 kg/ha to 2900 kg/ha. At most sites, and on most occasions on which estimates were made, fuel loads were less than 2000 kg/ha (Figure 2). There was a general trend for sites that had been burned to have higher herbaceous biomass in the year following burning. This was the case at Abingdon Downs and Woodview in 2004 and 2006 but not 2005; at Oakland Park in 2004, 2005 and 2006; and at Delta Downs in 2004 and 2006 but not in 2005.

4.1.3 Fire intensity – scorch and char heights

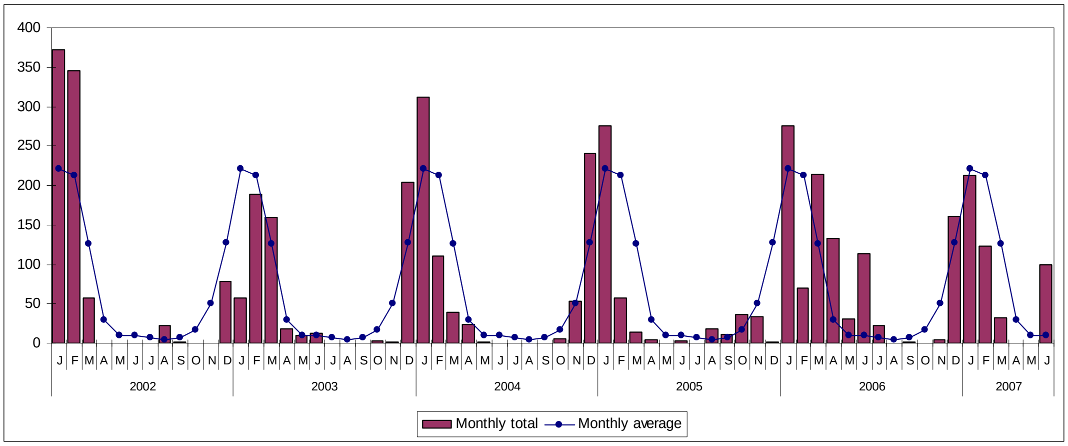
Fires were generally of low intensity as indicated by measured scorch and char heights. Char heights were consistently less than 1 m and mostly below 50 cm (Figure 3a). Scorch heights were mostly below 5m (Figure 3b).

4.1.4 Plant density and woodland composition

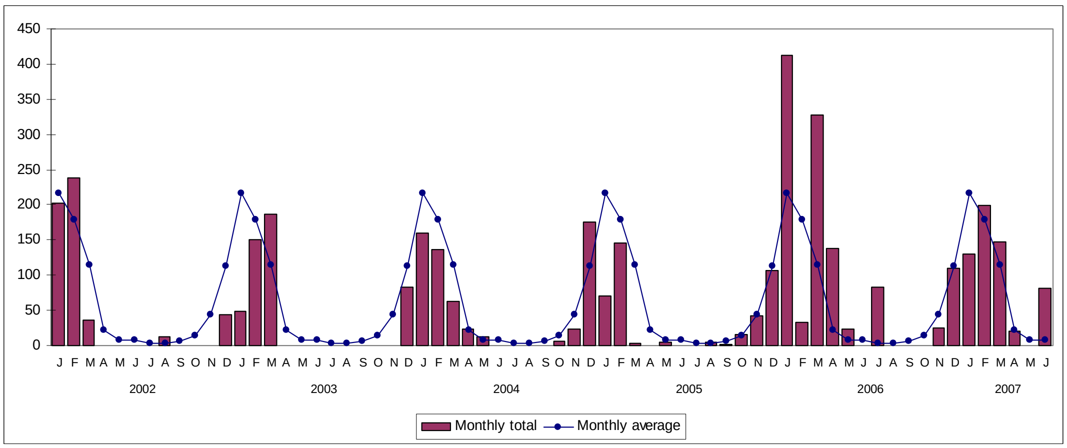
Overall tree and shrub densities at the core sites ranged from 1683 plants/ha to 2454 plants/ha. These densities are modest compared with some of those recorded in other areas where the proliferation of native trees and shrubs or invasion by introduced trees and shrubs are an issue. For example, in semi-arid woodlands of western NSW, shrub populations reach densities "which generally exceed 1000 and may be as high as 10,000 shrubs per ha." (Harrington *et al.* 1984). *Dodonaea attenuata* (hopbush) and *Eremophila sturtii* (turpentine) were reported at densities ranging from 600 to 19,000 shrubs per ha in north-western NSW (Booth *et al.* 1996). Total woody plant densities in the upper Burdekin catchment in north-east Queensland ranged from 500 to 1500 plants/ha. (Scanlan *et al.* 1996). Shrub densities were mostly less than 200 plants/ha and tree densities less than 600 plants/ha in a semi-arid tropical savanna in the Northern Territory where there was a trend toward higher densities over a thirty year period (Bastin *et al.* 2003).

The densities of individual species ranged up to 1222 plants/ha for breadfruit and 1730 plants/ha for gutta percha.

(a) Georgetown



(b) Croydon



(c) Normanton

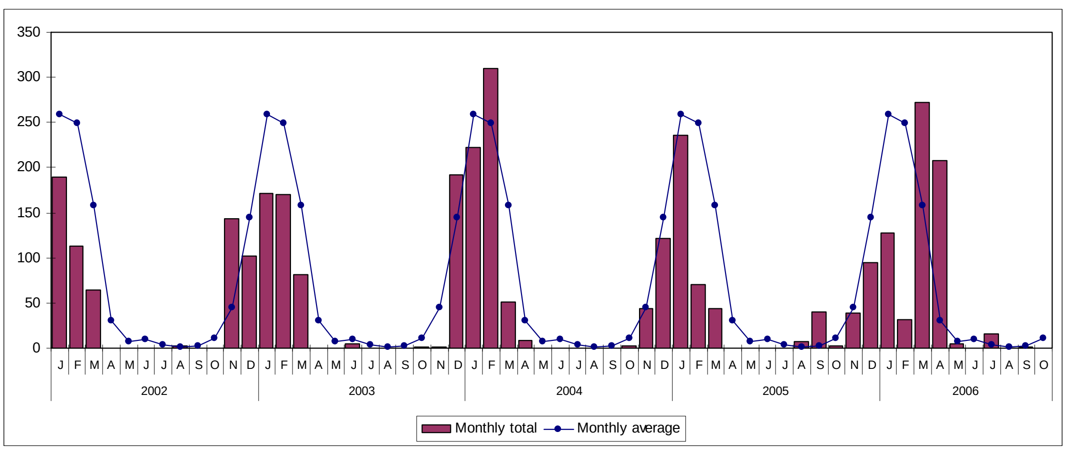


Figure 1 - Monthly and average monthly rainfalls (mm) for (a) Georgetown, (b) Croydon and (c) Normanton between January 2002 and October 2006 (Georgetown and Croydon) and October 2007 (Normanton).

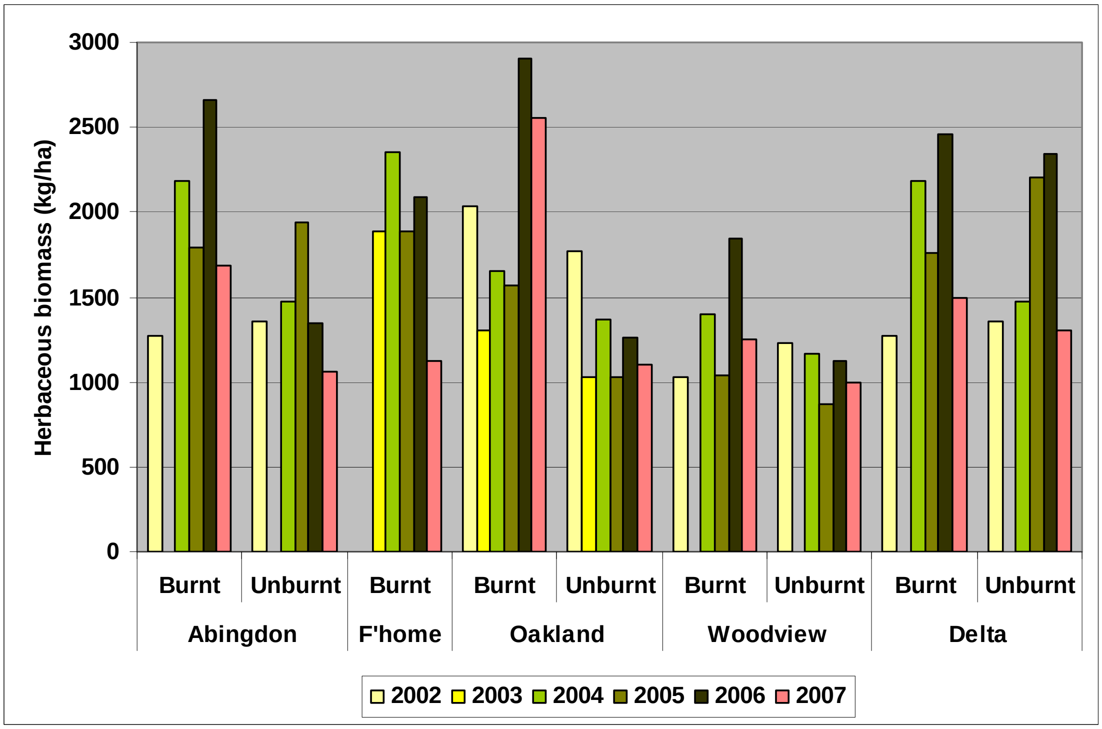
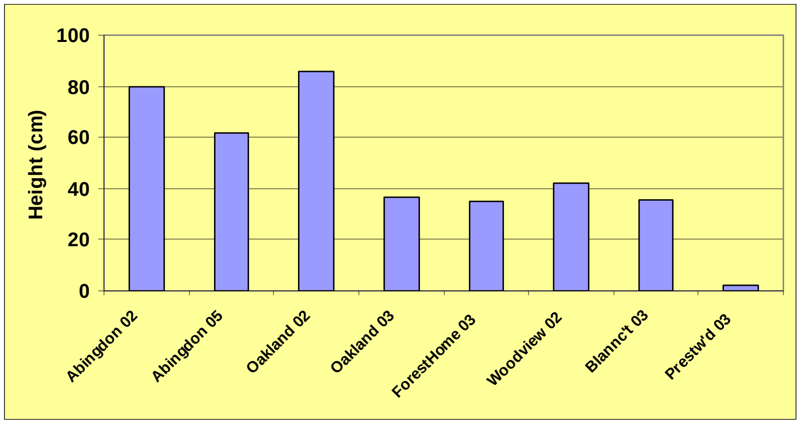


Figure 2 - Herbaceous fuel loads at core sites. Data were not available for Abingdon Downs, Woodview and Delta Downs in 2003.

(a)



(b)

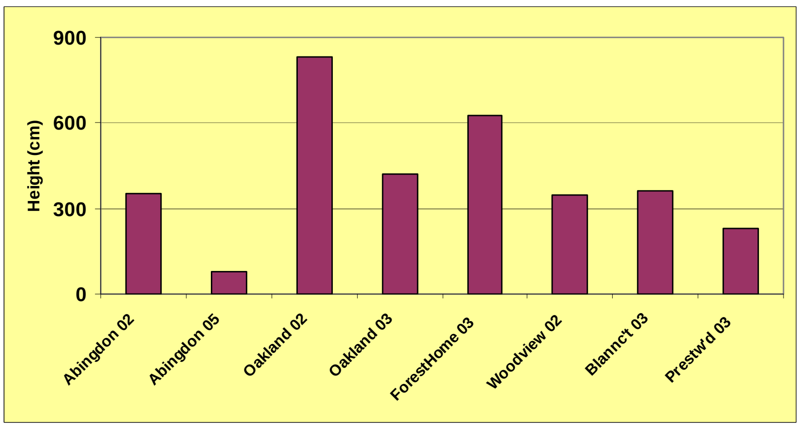


Figure 3 - Mean (a) char and (b) scorch heights measured at selected sites within two weeks of burning

4.1.5 Woody plant survival

Transect data allowed us to compare woody plant mortality rates between burned and unburned sites. Mortality rates varied a great deal and the patterns in this variation indicate both species and site effects. Site affects are probably influenced by fire intensity and frequency.

Mortality rates on unburned plots ranged from 4% to 86% though, in most cases, mortality rates of unburned plants were less than 25%. The highest rates of mortality recorded for plants on unburned plots were for *Acacia* spp. at Oakland Park (86%) and eucalypts at Woodview (50%).

Mortality rates of plants on burned plots were consistently higher than those for plants on unburned plots. They ranged from 6% to 89% with a high proportion of site-species combinations having mortality rates over 25%.

Mortality rates for all species combined averaged 29-68% on burned plots compared with 7-24% on unburned plots. The only exception was for Delta Downs where the mortality rate of burned plants was only 8%.

Gardenia vilhelmii (breadfruit) exhibited mortality rates of 32-76% on burned plots compared with 4-11% on unburned plots. Likewise, burned *Excoecaria parvifolia* (gutta percha) on Woodview (the main study site for this species) had a mortality rate more than three times that of unburned representatives of the same species.

Eucalypts (*Eucalyptus* spp., *Corymbia* spp.) showed variable but, overall, surprisingly high mortality rates in both burned and unburned plots. This is attributable to the high proportion of small plants in the populations initially recorded at the sites and a presumed high rate of turnover in the juvenile phases of the life cycles of these species.

An important aspect of a species' response to burning involves the interaction with plant size. Typically, a plant's response to burning is size-dependent. For example, *Cryptostegia grandiflora* and *Ziziphus mauritiana*, both of which are invasive shrubs in northern Australia, show a size-dependent response to burning (Grice 1996). In general, smaller plants are more susceptible than larger plants.

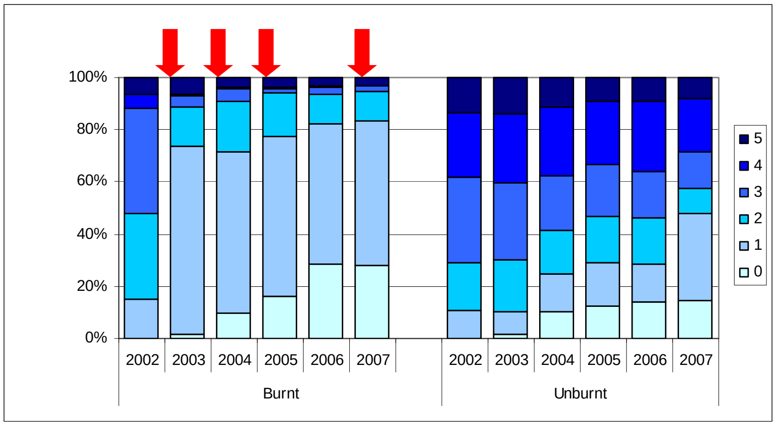
4.1.6 Structure of woody plant populations

Shrub population structures were investigated by first categorising plants into size-classes. Size-classes were based on plant height (H cm). The same categories were used for each species and site. These were:

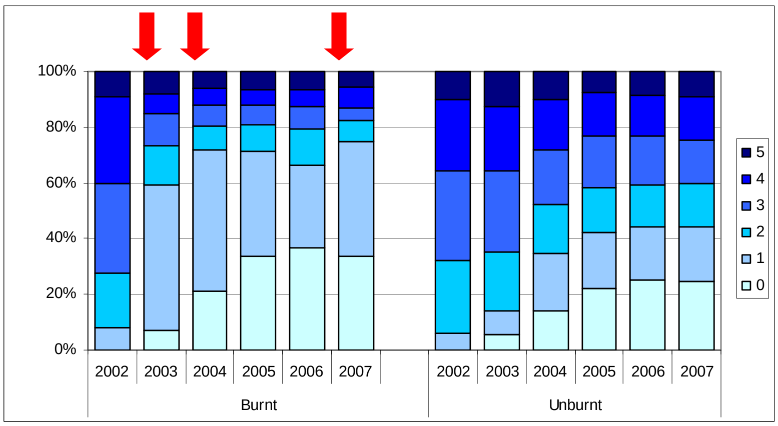
Class 1: $0 < H \leq 50$ cm
Class 2: $51 < H \leq 150$ cm
Class 3: $151 \leq H \leq 250$ cm
Class 4: $251 \leq H \leq 500$ cm
Class 5: $H > 500$ cm.

At four of the five sites, the proportions of the total tree and shrub populations in Classes 4 and 5 declined substantially with burning (Figure 4). These declines corresponded to increases in the proportions of the populations in Classes 1-3 and the proportions of plants recorded as being dead. At the fifth site, Delta Downs, the difference between burnt and unburnt plots was less dramatic.

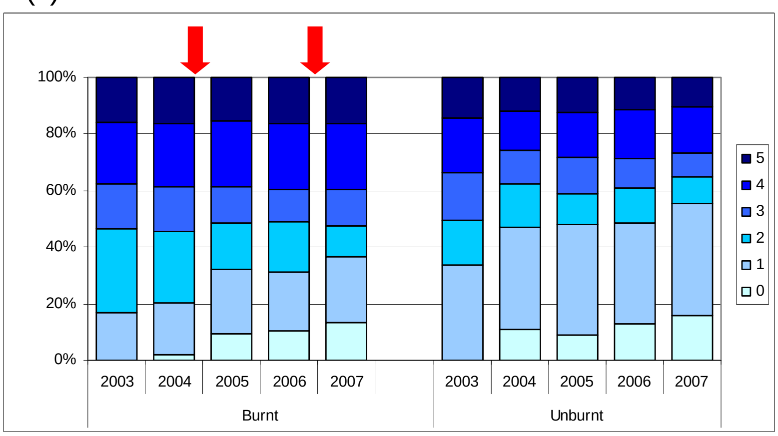
(a) Abingdon Downs



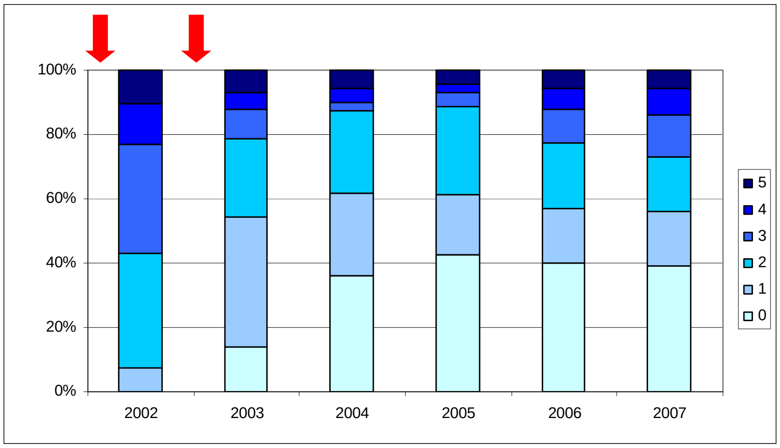
(b) Oakland Park



(c) Delta Downs



(d) Foresthome



(e) Woodview

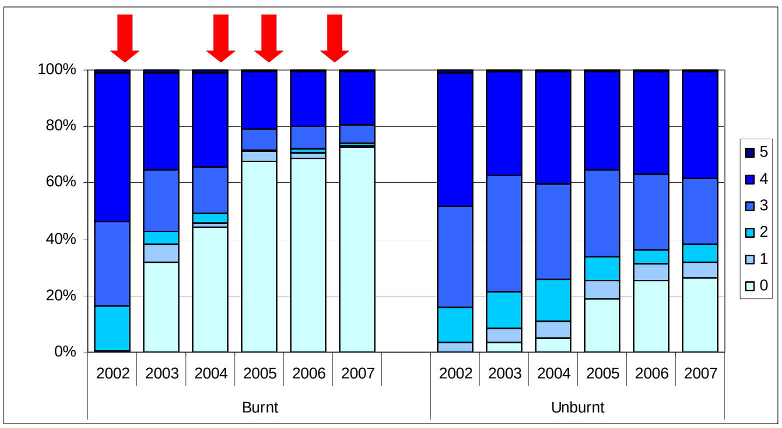


Figure 4 - Changes in structure of populations of all woody plants in burnt and unburnt plots at each core site. See text above for quantitative limits of size-classes. Class 0 (pale blue) represents dead plants. Arrows indicate approximate times of fires.

The population structures of some individual species were more affected by burning. At Abingdon Downs, the structure of burnt populations of *Gardenia vilhelmii* diverged from that of unburnt populations. After two fires, 34% of the original population were dead and, of the surviving plants, 96% were in the lowest size-class. The corresponding values for the adjacent unburned population were 5% dead and 15% in the lowest size-class (Figure 5a). The shifts in population structure recorded for the burned population of *G. vilhelmii* at Oakland Park were in a similar direction but less extreme (Figure 5b). Over the course of the work, the structure of the population of *G. vilhelmii* at Foresthome shifted strongly toward dominance by smaller individuals (Figure 5c).

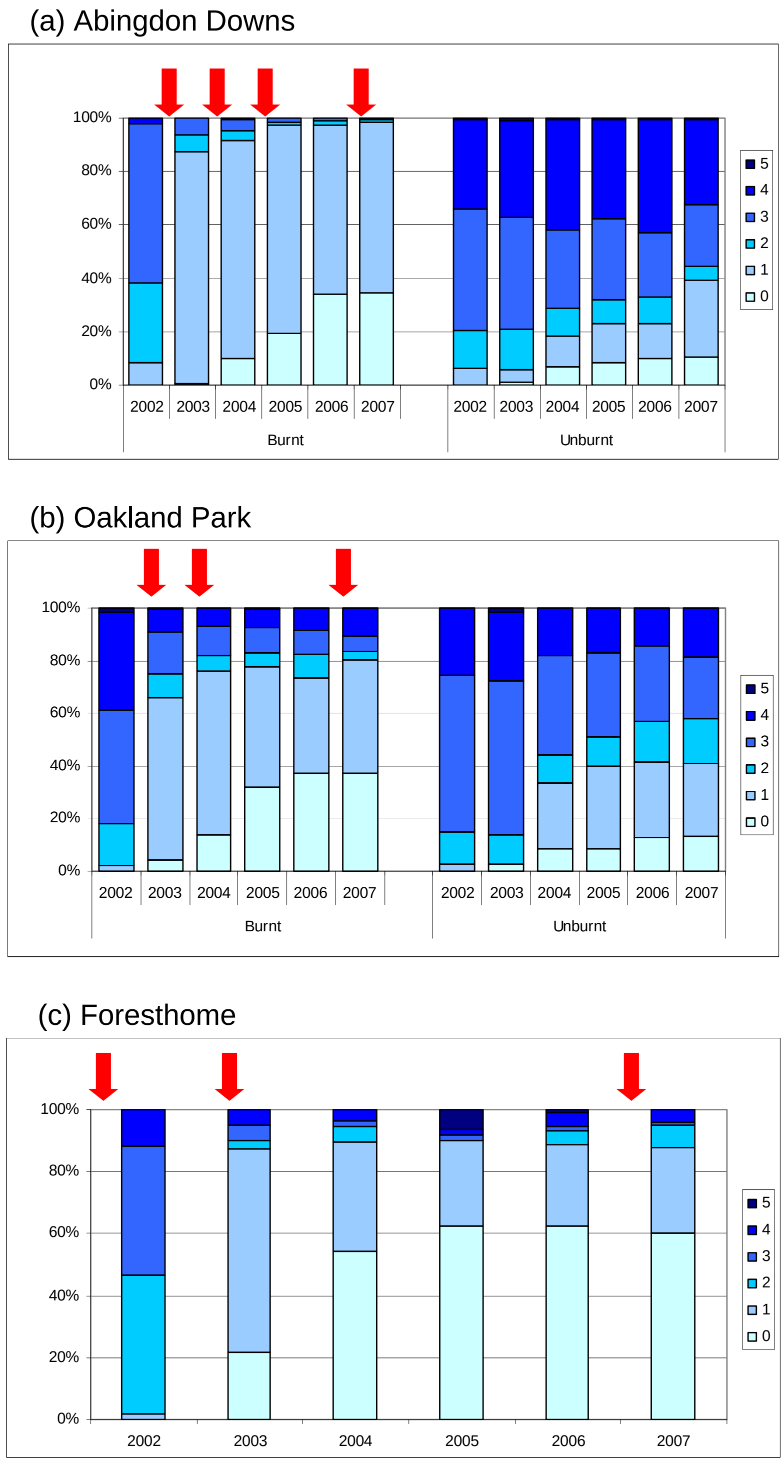


Figure 5 - Changes in structure of populations of *Gardenia vilhlemii* (breadfruit) in burnt and unburnt plots at each core site. See text above for quantitative limits of size-classes. Class 0 (pale blue) represents dead plants. Arrows indicate approximate times of fires.

The results for the other main target species, *Excoecaria parvifolia*, were more variable, probably as a result of differing fire intensities between the sites at which this species was found. At Delta Downs, where the burned treatment was subject to only one fire and that being of low intensity, there was no significant change in the structure of the population (Figure 6a). However, at Woodview the proportion of the population in classes 2-5 declined markedly up to 2006. While 25% of unburned plants died during the study period, the corresponding value for burned plots was 75%. A wildfire burned some transects in the control plots of Woodview (Figure 6b).

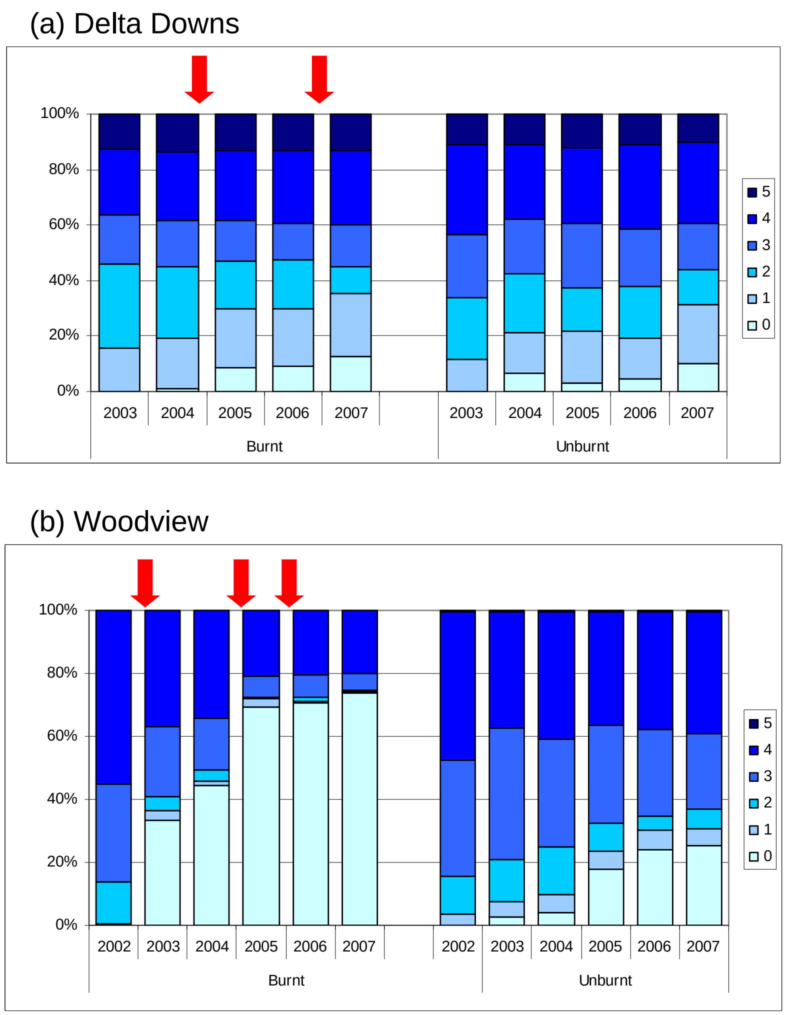


Figure 6 - Changes in structure of populations of *Excoecaria parvifolia* (gutta percha) in burnt and unburnt plots at two core site. See text above for quantitative limits of size-classes. Class 0 (pale blue) represents dead plants. Arrows indicate approximate times of fires.

Population structures of *Eucalyptus* spp. did change as a result of burning (Figure 7). The proportion of plants in upper and medium size-classes declined more in burned than in unburned plots with corresponding increases in the proportion of the population in the lower size-classes.

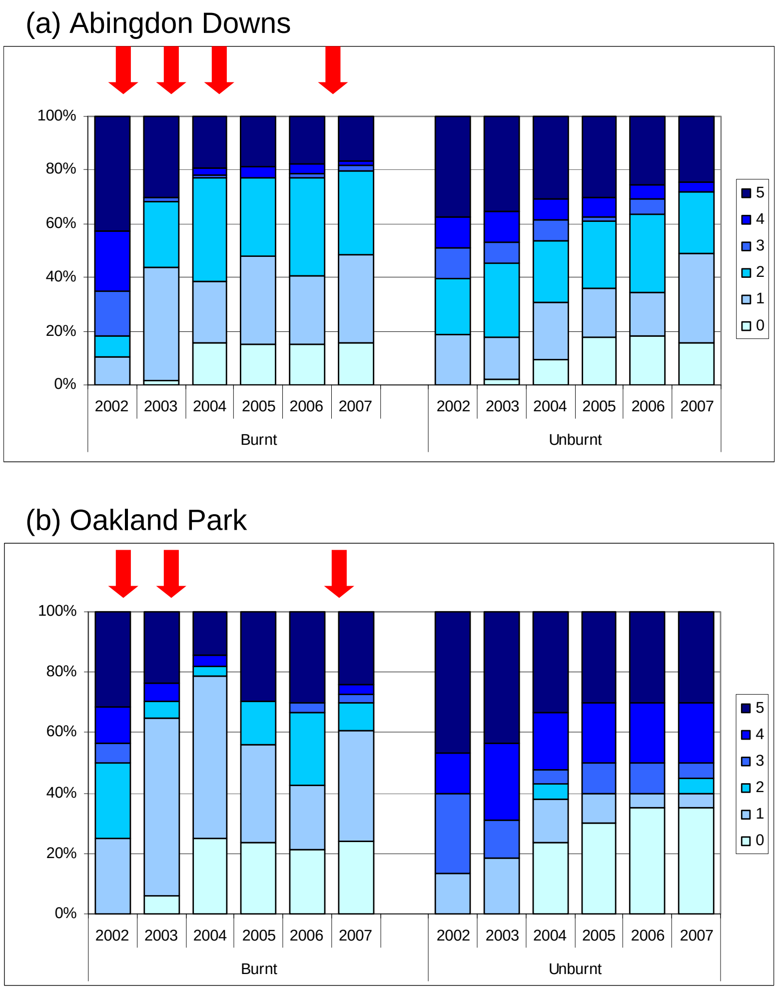


Figure 7 - Changes in structure of populations of *Eucalyptus* spp. in burnt and unburnt plots at two core site. See text above for quantitative limits of size-classes. Class 0 (pale blue) represents dead plants. Arrows indicate approximate times of fires.

4.2 Satellite sites

Table 3 provides information on the status of satellite sites. In general, fuel loads were estimated as low, mostly below 1500 kg/ha. These fuel loads yielded mostly low-intensity fires though there were some exceptions to this. Of the twelve satellite sites, five could not be burned during the project due to low fuel loads.

The results from satellite sites are most effectively shown pictorially as a series of “before and after” photographs. These indicate that apparent changes in woody plant stands as a result of burning vary from negligible to quite dramatic. Examples are provided in Figure 8. The relatively low intensity fire at Beverley Hills had little apparent effect on the population of woody species, though there may have been some thinning of the mid-storey (Figure 8a). The results were similar at Prestwood where sparse and discontinuous fuel loads resulted in a low-intensity fire and little change in the populations of trees or shrubs (Figure 8b). By contrast there was a high intensity fire at the Tabletop site in October 2004. It resulted in widespread top-kill of trees and shrubs followed by basal sprouting of both *Acacia* spp. and *Petalostigma pubescens* (Figure 8c). The main problem species at Springfield was the introduced rubber vine. The intense fire there led to complete top-kill of many rubbervine plants and apparently to significant mortality (Figure 8d).

Table 3 - Status of satellite sites

Property	Paddock	Fuel	Result
Beverley Hills	2000 ha Spelled 12 mo prior to burning	*Themeda triandra* *Heteropogon contortus* 1000-1500 ka/ha	Relatively low intensity fire
Tabletop	280 ha Spelled 12 mo prior to burning	*Hyptis suaveolens* 1600-1800 kg/ha	Very hot fire; widespread top-kill of trees and shrubs; post-fire sprouting of *Acacia* spp. and *Petalostigma pubescens*
Narrawa	530 ha Spelled 10 mo prior to burning	1000-1500 kg/ha	Fire intensity variable
Shady Lagoon	8000 ha Very light stocking for 12 mo prior to burning	N/A	Lightning initiated hot wild-fire but some areas lightly burnt or unburnt; widespread top-kill especially of *Acacia* spp.
Springfield	675 ha. Not spelled before planting, but lightly grazed	1500-2000 kg/ha	Hot fire
Blanncourt	Relatively open woodland; very lightly grazed for 12 mo prior to burning	*Aristida* spp. and leaf litter 500-850 kg/ha	Low intensity fire in 2003 despite high air temperatures; hot fire in 2005
Prestwood	Spelled 12 mo prior to burning and only light grazing in previous year	*Aristida* spp., *Heteropogon contortus* and annual grasses 500-900 kg/ha	Fire intensity variable but generally low and many unburned sections due to low wind speed and discontinuous fuel loads
Foresthome	Spelled in preparation for burning but forage required for cattle	1500 kg/ha in August 2004 but subsequently lower	Not burned due to insufficient fuel
Huonfels	1300 ha (subsequently sub-divided) and generally in poor condition	Fuel loads low and discontinuous	Fire not possible due to low fuel loads
Woodstock	-	1500 kg/ha	Fire not possible due to low fuel loads
Dumas	-	N/A	Fire not possible due to low fuel loads
Reigate	-	N/A	Fire not possible due to low fuel loads

(a) Beverley Hills

November 2004

December 2004

May 2005

(b) Prestwood

October 2003

August 2004

December 2006

(c) Tabletop

September 2004

December 2004

May 2005

(d) Springfield

October 2004

November 2004

April 2005

Figure 8 - Sequences of photographs of representative areas of satellite sites

5 Success in achieving objectives

This project aimed to develop and test recommendations for the use of fire for management of woody vegetation in the gulf savannas through a collaborative effort between landholders and woodland ecologists.

Its specific objectives were to:

1. Devise management guidelines and practices for the use of fire for the management of the woody vegetation and pastures of the Gulf savannas;
2. Ensure that 50% of graziers in the northern and southern Gulf savannas of Queensland are aware of these guidelines and practices for the use of fire.

In this project, researchers and extension staff have worked with local pastoralists to test the effects of burning on some of the important native increaser shrubs of the northern Gulf region. This work has provided a basis for recommendations about the practical use of fire in the management of these woody species.

The outcomes from the project were constrained to some degree by the below-average rainfalls experienced during the study period (Figure 1). The low rainfalls meant that fuel loads and, so fire intensities, were low; at most sites it was not possible to conduct acceptable prescribed fires in successive years; and at some satellite sites no fires were conducted. The effects of low rainfalls on fuel loads were compounded by the effects of cattle grazing and trampling. At some sites, paddocks destined for burning were stocked in the period leading up to the planned time of burning.

5.1.1 Development of management guidelines

The project was able to identify shrub species that are of greatest concern to the pastoralists of the region. The two species that were perceived to have increased most in the Northern Gulf savannas are breadfruit (*Gardenia vilhelmii*) and gutta percha (*Excoecaria parvifolia*). These are widespread though not always dominant species that have not previously been the subject of research.

In spite of the effects of seasonal conditions and cattle grazing on fuel availability, most of the sites established by this project were burned at least once during the period of the research. The remoteness of the sites precluded making formal measurements of fire intensity. However, in general, the fires were of low intensity. The guidelines relate to the application and effects of such fires.

Each satellite site was burned only once during the study period. Two core sites were burned only once each, one was burned twice each and two were burned three times each. One site (Foresthome) was burned immediately prior to the experimental period. This gave some limited capacity to report on the effects of multiple fires.

5.1.2 Grazier awareness

A strength of this work was that the research was conducted with a large number of collaborating land-holders. They were involved in identifying target species, offering properties for potential study sites, selecting study sites and helping determine fire regimes. A weakness corresponding to this collaborative approach was the lack of co-ordination between sites, particularly in relation to the timing of fire, and indeed, whether a site was burned at all. Land-holder collaborators also had control over stocking of the experimental paddocks. Given that seasonal conditions during the study period were drier than average, there was demand for the forage on experimental plots and capacity to burn was compromised at some sites. The broad geographic spread of sites gave an opportunity to observe responses under a wide range of circumstances and also for scientists involved in the work to have contact with land-holders across the region. Various communication methods were used to make land-holders from across the Northern and Southern Gulf Savannas aware of the work and its conclusions.

6 Impact on meat and livestock industry

6.1 Current impact

This project has drawn attention to the possibilities for using fire to manage tree and shrub populations in Gulf savannas. The alliance with land-holders, particularly those involved with satellite sites, has pointed to the barriers to the use of fire, including dealing with the competing demands on grass as fuel versus forage, and the logistical and social challenges of conducting prescribed fires over extensive areas.

The project:

- demonstrated the impacts of individual fires on tree and shrub populations
- provided practical experience in conducting prescribed fires
- provided opportunities to discuss the benefits and challenges of using fire as a tool.

The project had contact with a large number of land-holders spread broadly across the Northern Gulf savannas, an area stretching from Mt Surprise to Karumba. A small number of graziers had a more intensive interaction through their involvement with core sites. Even those involved with satellite sites were involved in the decision-making about the possibility and timing of fires and in fire management. This facilitated a two-way exchange of information.

6.2 Future impact

The experience of Northern Gulf graziers with this project has laid a foundation for subsequent changes in their use of fire. Prescribed burning to control the density of shrub populations will only be effective when it is integrated with other aspects of property management, most notably grazing management. As land managers recognise the benefits of burning, build their skills in fire management, and devise ways of managing fuel loads, the targeted use of fire as a shrub management tool will increase. It will be useful to document changes in the use of fire, including attitudes, extent, geographical spread, and fire frequency, as well as responses to those fires in terms of shrub density and pasture resources.

7 Conclusions and recommendations

A general principle to emerge from this project is that burning is a demonstrably useful tool for managing populations of native trees and shrubs in the Northern Gulf savannas. Important species that are perceived to have increased in density on pastoral land can be thinned by prescribed burning in the late dry season. Thinning results from both fire-induced death of individuals and changes in population structure related to basal sprouting following top-kill.

Gutta percha and breadfruit, both of which are important amongst the woody species perceived to have increased in density in Gulf savannas, can be killed by fire. The death rates achieved with gutta percha were higher than those seen in breadfruit but the difference between the species was confounded with differences in fire intensity. Generally, the very low-intensity fires at some sites did not result in greatly elevated mortality rates relative to unburned sites. **Land managers attempting to reduce shrub densities with fire should prescribe fires at times of relatively high grass fuel loads.** This requires a level of planning and management that has not always been evident during the current project. Destocking may be required in order to allow an accumulation of grass fuels. A longer period of destocking or lighter stocking rates will be required to achieve this under low rainfall conditions, where the area to be targeted has a history of heavy grazing, or where a dense woody stratum itself suppresses grass production. Premature burning (i.e. burning before adequate fuel is available) imposes the cost of reduced forage availability without any benefits of woody plant control.

It is extremely important to examine the principle that fire can be used to manage woody plants in Gulf savannas in the light of the multiple forces that are likely to be driving the abundance of woody species in tropical woodlands. These will include rainfall, the direct and indirect effects of grazing by livestock, fire and competition between woody plants. Rainfall will influence recruitment of trees and shrubs by driving seed production, germination and seedling survival. Grazing is important because it may directly affect the survival and growth of at least some species of trees and shrubs. Indirectly, grazing will affect tree and shrub populations via its effects on grasses. Grasses, in particular perennial grasses, potentially provide competition for recently emerged seedlings of trees and shrubs and fuel for fires that can kill a proportion of woody plants and shift the population structure. This project has quantified only some of these interactions and then, only in a preliminary way. Nevertheless, it has particularly highlighted the importance of the rainfall-grazing-fire interactions.

This work has provided a foundation for a more refined understanding of the role of fire in governing tree and shrub populations in Gulf savannas. It is important to build on the findings of this initial work. **One important way for this to happen is for graziers themselves to test the application of prescribed burning to their own situations.** Unlike in some other parts of northern Australia, there appears to be fairly widespread acceptance of fire as a tool and a willingness to use that tool. The main practical challenge in this regard is to more effectively manage the rainfall-grazing-fire interaction.

Any testing of the use of fire by graziers should be backed by further research that takes a more rigorous approach than has been possible during the current study. In part this is required in order to manage fuel loads to ensure timely experimental fires of an appropriate intensity, but also to examine the broader ecological and management context of fire as a tool. Effort should be directed at shrub species that it is agreed are important across a wide geographical area. This does not deny the fact that many tree and shrub species contribute to the issue of woody plant management in the Gulf savannas. Any further research on the role and management potential of fire should consider not simply how fire affects the growth and survival of the trees and shrubs present but also: (i) fuel dynamics and how it is influenced by rainfall, grazing and fire; (ii) the impacts of trees and shrubs in suppressing perennial grasses; (iii) the patterns of tree and shrub recruitment. The trade-off of a more comprehensive approach to the use of fire in woody plant management is in the capacity to take geographical variation into account and to address the multi-species nature of woody plant dynamics. Any further fire research in the region should also consider how the timing of fires influences the outcome.

This research has operated on a very different time-frame from that of the “natural events” that drive northern Australian rangelands. The results must be assessed with this in mind. They suggest that two or three fires in close succession are more effective than a single fire in reducing shrub density. However, while this is consistent with the conclusions of other research, we have few data for the Gulf savannas that cover responses to multiple fires. Extrapolation to the longer term to predict the consequences of particular fire regimes is even more tentative. **Research and management should consider the impacts of fire in relation to medium-long term variation in rainfall, fuel loads and shrub recruitment.** From the research perspective this could perhaps be done using spatial information as a surrogate for temporal information.

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