DEPARTMENT OF CONSERVATION AND LAND MANAGEMENT

Using Fire to Rehabilitate Areas Disturbed by Mining Exploration in the Rudall River Region.

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1. BACKGROUND

Fire, wind and water are powerful agents that have moulded life in Australian deserts since the last ice age. In a remote part of the Great Sandy Desert, CALM, CSIRO, a local Aboriginal community and CRA Exploration Pty Ltd (CRAE) are cooperating in a unique study to harness fire for environmental rehabilitation.

Ever since European settlement, the remote and harshly beautiful deserts of Western Australia have lured explorers in search of pastures and precious metals. In the 1800s, Giles, Warburton, Carnegie, Forrest and other hopefuls led expeditions on horses and camels into the unknown and inhospitable interior. Since the 1950s, explorers using helicopters, bulldozers and trucks have searched the desert for tell-tail signs of oil and minerals. Abandoned seismic lines and exploration tracks crisscross the sand plains and dune fields, taking decades to revegetate. Most of the exploration in the Great Sandy Desert pre-dates the declaration of nature conservation reserves and national parks, and while some of the exploration tracks are useful for land managers and park visitors, many are ecological intrusions and a hazard to wandering outback motorists who can become lost in the maze of tracks.

In 1972, CRAE began exploring for a range of mineral commodities in ancient metamorphic rocks along the Rudall River system in the Great Sandy Desert. This large and spectacular desert drainage system was declared a national park in 1977 to conserve its unique landscape and wildlife. The Rudall River National Park of 1.6 million hectares is the second largest national park in Australia, Kakadu being larger. It stretches from Hanging Rock in the west to Lake Dora in the northeast and embraces the headwaters of the Yandagooge Creek and the entire drainage basin of the Rudall River. It was opened for exploration and mining in the year it was declared a national park, with strict safeguards to protect the environment. In 1985, CRAE discovered the Kintyre uranium deposit straddling the northern boundary of the Park. Other important mineral discoveries have also been made in the region, including the giant Telfer gold mine and the rich Nifty copper deposits north of the National Park. Along with other important geological clues, these discoveries indicate an emerging world-class mineral province that will contribute substantial mineral wealth for many years to come. Careful management of mining developments is required so that the environmental integrity of the region is maintained and enhanced and to ensure that the desires and aspirations of local Aboriginal communities are able to be realised. CRAE recognises the importance of these values and, in consultation with CALM and local communities, operates a multiple land use approach that caters for exploration, the environment and Aboriginal concerns.

During mineral exploration, actual physical intrusion on the environment caused by tracks and grids is confined to very small areas. This is achieved by deliberately phased work programs that use satellite, airborne and other remote techniques to dramatically reduce the size of areas for exploration. In the past 10 years, drilling in the Rudall River National Park has disturbed less than 1% of the 13,000 square kilometres of the National Park. When exploration is completed, CRAE aims to return the land to its original condition, both within and outside national parks. Rehabilitation within the national park is monitored by CALM.

Once exploration work is completed and tracks are closed and rehabilitated using various techniques such as ripping, regeneration of ephemeral plants can be rapid, depending on rainfall. However, regeneration of woody shrubs and the return of the disturbed areas to a climax community can take many years. This is particularly the case in areas of spinifex and acacia sand plain.

CALM and CSIRO scientists, supported by CRAE and local Aboriginal communities, are investigating new techniques for rehabilitating exploration tracks. Fire has the potential to accelerate the return of the climax community. CRAE geologists and CALM scientists observed that in some instances exploration tracks in areas burnt by wildfire quickly revegetated after rain, and within a relatively short time, had virtually returned to a pristine condition. Scientists believed that this was due to the combined effects of the elemental agents fire, wind and water.

CALM, CSIRO, local Aboriginal people and CRAE have joined forces in a collaborative experiment to investigate the role of fire in rehabilitating old exploration tracks in the Rudall River area. When the processes are scientifically understood, the potential exists to use controlled fire to restore disturbed areas to a climax community. As well as conservation benefits, managing fire in this manner provides an opportunity for Aboriginal communities to participate in an economic activity on their own terms while at the same time ensuring that important connections with the land and traditional skills are fostered and maintained.

Assisted by people from a nearby Aboriginal community, several small experimental fires were set in September 1992 to rehabilitate old exploration tracks. The structure and composition of the vegetation was measured prior to burning. Immediately after the fires, sand traps and erosion pins were established on the burnt areas, on the exploration tracks within the burnt areas, and on adjacent unburnt areas to measure the movement of soil and seed blown around by the strong desert winds. The regeneration of vegetation on and off the exploration tracks is being monitored.

Fire has been a natural component of desert ecosystems for thousands of years, brought on by lightning and, until recently, by the traditional burning practices of Aborigines who used fire for a myriad of purposes. In the past, much of the desert landscape was an interlocking mosaic of vegetation at different stages of regeneration; from recently burnt through to long unburnt patches. Desert flora have evolved a wide range of adaptive traits to survive and regenerate in a fire-prone environment. Many species are able to re-sprout following fire while others regenerate from seeds buried in the soil or encased in protective woody fruits.

Sand plains and dune fields of the Great Sandy Desert are covered with dome shaped hummocks of flammable spinifex which trap sand and seed carried by the wind. Fire temporarily denudes the land of vegetation and strong desert winds blow sand and seed once held beneath the hummocks. Heat from the fire is also important in preparing some seeds for germination by cracking the hard, protective seed coat.

The spinifex hummocks which cover the desert sands are important for reducing wind erosion. When fire removes the vegetation, the wind speed experienced near the soil surface increases significantly, exposing the soil to erosion.

In the first few weeks after the small experimental fires set to rehabilitate the exploration tracks (see Hart Simpson and Associates 1993), hundreds of tonnes of sand, ash, and thousands of seeds which had accumulated beneath the spinifex hummocks, were re-distributed by the wind. There was virtually no soil or seed movement on the unburnt areas. Wind-blown soil and seed accumulated on the exploration tracks and the level of the soil surface on the tracks increased by up to 5 centimetres. The extent of sand drift following the fires varied depending on the clay content of the soil with most soil and seed movement occurring on the sandy soils. Within a short time, a firm crust developed over the soil surface, preventing any further wind erosion of soil.

Seeds blown by the wind and prepared for germination by the heat of the fire lay buried in the sand awaiting the third and most critical element - water.

Rainfall in the Great Sandy Desert is erratic and undependable and although the annual average is about 200 mm, long periods of drought are not uncommon. The timing and the amount of rain is critical to the germination and development of seedlings. An annual assessment of seedlings on the exploration tracks in both burnt and unburnt areas revealed that in the unburnt area there was no established seedlings of spinifex and shrubs but in the burnt area, there were numerous seedlings of these species. The density and diversity of seedlings on the tracks in the burnt area was not as high as was anticipated, but the low summer rainfall probably contributed to this.

This unique experiment has demonstrated that fire can play an important role in rehabilitating areas disturbed by mining in the arid zone. Future research will examine in more detail, the processes of soil movement and seed dispersal on different soil and vegetation types.

2. FIRE RESEARCH

If fire is to be used in the arid zone in a safe and controlled manner to provide habitat diversity, to break up the run of wildfires or to rehabilitate exploration tracks, then it is essential that fire behaviour under different conditions of weather and fuel is well understood and can be predicted within reasonable limits.

Spinifex (species of *Triodia* and *Plechtrachne*), the dominant ground cover, forms a discontinuous or patchy fuel (30-60% cover) throughout the sand plains and dune fields of the arid zone. The behaviour of fire in the highly flammable spinifex fuel, like any other bushland fuel, is affected by fuel structure and loading, fuel dryness, weather and topography.

2.1 Study aims:

i) To determine threshold conditions for the start and spread of fire. Being a patchy fuel, conditions of fuel, weather and topography need to be such that flames are able to integrate, or bridge the bare patches between the hummocks.

ii) To predict fire rate of spread and flame size

3. To link fire behaviour, factors affecting heat transfer and acute (immediate, physical) fire impact on plants and on the soil. Acute fire impacts give rise to ecological effects and the severity of impact will depend on the temperature history experienced at the locale of interest.

2.2 Methods

A series of experimental fires were set and closely monitored in the Rudall River National Park. Individual plots were not be constructed, rather the expectation was that fires would be contained by natural barriers such as stony hills, by recently burnt areas and by using the existing network of tracks. Each fire was set using a 100-200 m line of fire and allowed to run for 100-500 m. In most instances, tongues of fire emerged from the line and spread rather than a 200 m headfire as is the case in continuous fuels. The dependent variables measured were;

i) Fire rate of spread (m/h)
ii) Flame length and flame height (m)
iii) Temperature histories at various heights above the soil and below the soil surface (not reported here)

Fire rate of spread is dependent on;

A. FUEL FACTORS:
- cover
- patchiness and distribution
- load
- height
- bulk density or packing ratio
- degree of curing or moisture content

B. WEATHER FACTORS
- wind speed
- temperature
- relative humidity

C. TOPOGRAPHY
- slope

2.2.1 Measuring fuels

2.2.1.1 Structure

Cover, patchiness and distribution of fuel were measured using continuous line transects. For each experimental fire, line transects were about 200 m (or the anticipated length of fire run) x 50 m . The continuous lengths of fuel patches and of bare patches were measured. The fuel was then described by:

i) % cover
ii) mean bare patch size and fuel patch size
iii) median bare patch size and fuel patch size
iv) modal bare patch size and fuel patch size
v) fuel patch and bare patch patchiness ratio (Mean/variance ratio)

Fuel height was measured by measuring the top height of hummocks intercepted by the line transects described above.

2.2.1.2 Fuel load

Biomass samples (all material < 4 mm diameter) were collected, oven dried and weighed to determine fuel load (t ha^{-1}). 10-20 samples, each 1 m x 1 m, were collected from each experimental fire site. Sampling was stratified if there was a measured or visual difference in fuel structure within an experimental fire

2.3 Preliminary Results and Discussion

2.3.1 Post-fire soil movement

Figures 1 and 2 below show the rate of soil movement with time for both unburnt (control) plots and for burnt plots at the Sand Dune study site. This represents the quantity of soil which was mobilised by the wind and trapped in "erosion pitfall traps". The effects of removal of vegetation by fire and the subsequent transport of topsoil by wind are clearly evident. The quantity of soil deposited in the sand traps on the burnt site in the first 30 days after fire is in the order of 200-300 times more than in the unburnt site. The rate of soil movement on the burnt sites declined with time after fire and by about 277 days after fire was similar to the unburnt (control) sites.

Figure 1: Soil movement on unburnt sand plains as measured by the amount of soil in pit traps.

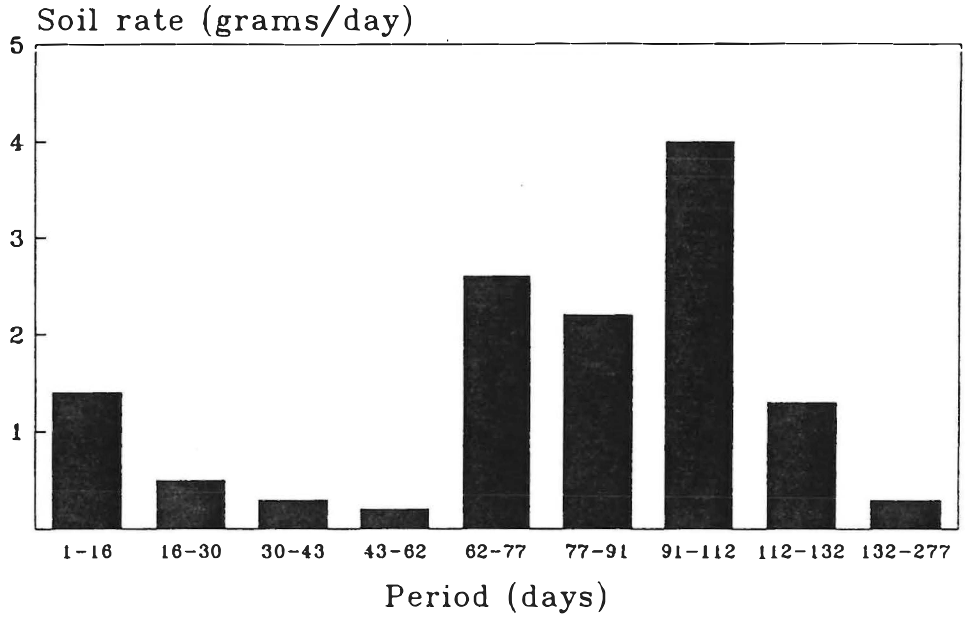
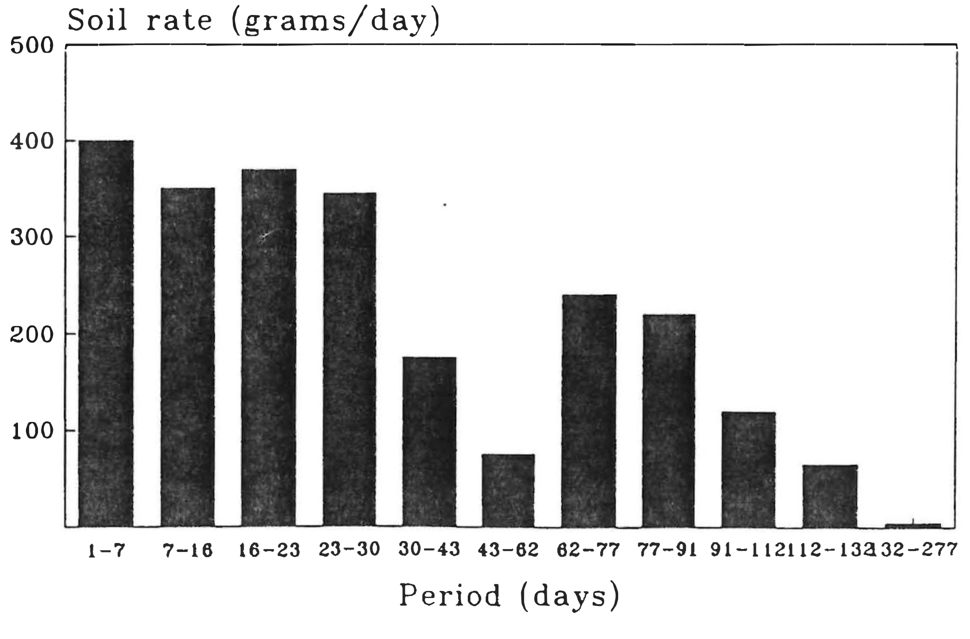


Figure 2: Soil movement on burnt sand plains as measured by the amount of soil in pit traps.

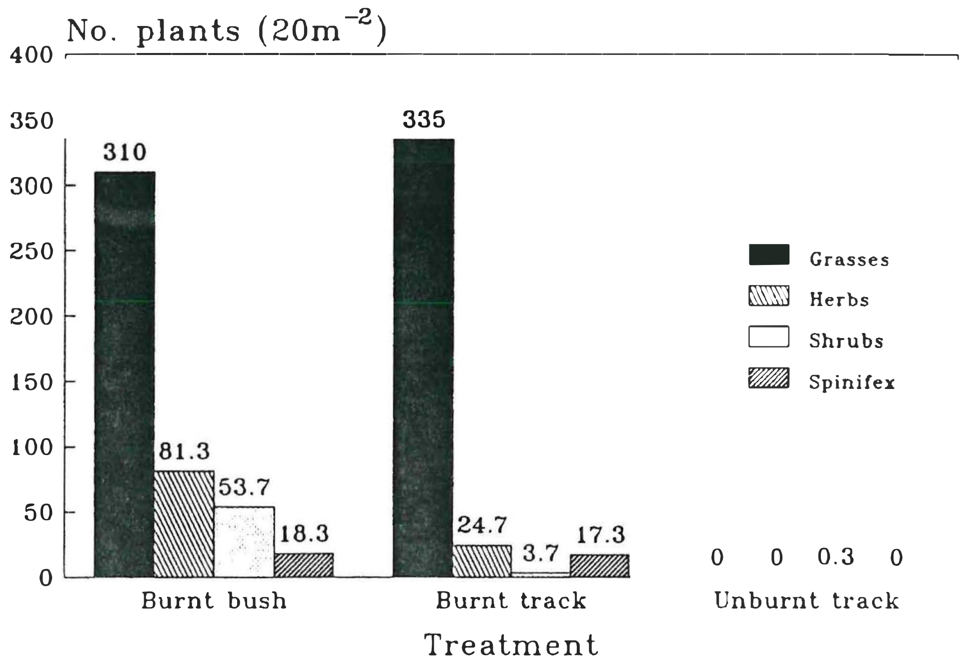


The topsoil on the burnt site stabilised well before the vegetation cover had returned. By 277 days after fire, regeneration on the burnt site was well advanced but the cover was <10% and the mean height of the vegetation was < 10 cm. The mean cover and height of vegetation on the unburnt site was about 37% and 35 cm respectively. The soil surface on the burnt site had deflated by up to 10 mm but soil actually accumulated on the exploration tracks where the soil surface had elevated by as much as 10 cm in some instances due to this accretion.

2.3.2 Post-fire regeneration

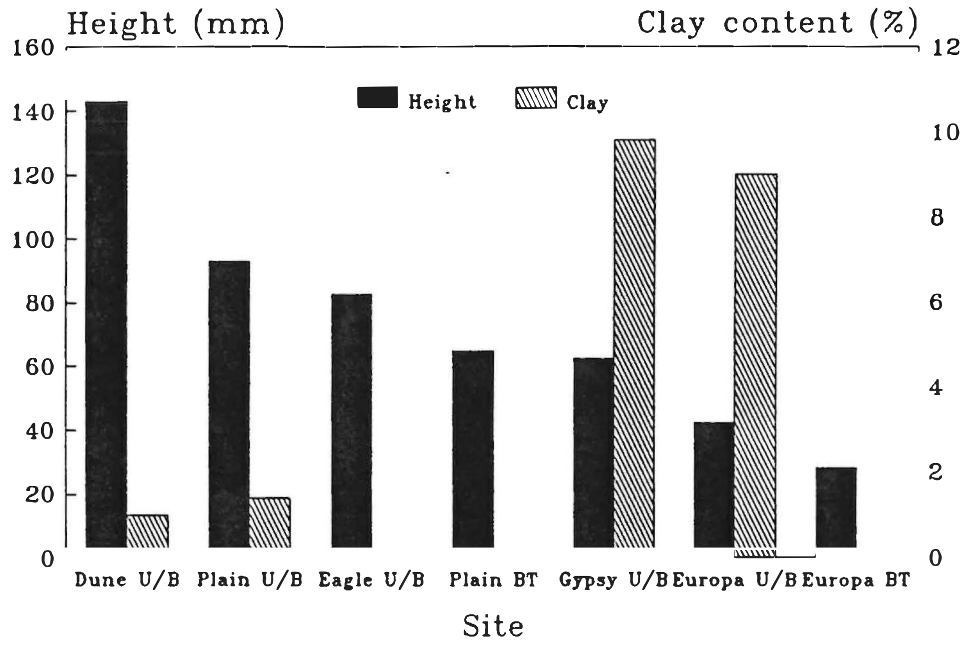
In addition to soil being mobilised after burning the vegetation, there was clearly an amount of soil stored seed which was also transported by wind and deposited on the tracks. Details of early regeneration on the tracks has been reported by Hart (1993) who was responsible for monitoring this component of the research project. Hart (1993) reported that the post-fire regeneration on the tracks following the small scale experimental burns was of mixed success. Figure 3 below shows that grasses, herbs and spinifex successfully established on the tracks following fire at this site. The difference in the density of woody shrubs on the burnt bush (off tracks) and the burnt track can be partially explained by the fact that many of the woody shrubs in the bush (off tracks) were established plants which had re-sprouted following fire. However, the post-fire regeneration on the track at this study site could be characterised as very successful. These experimental fires were small (about 4 ha), patchy and of low-moderate intensity (400-100 kWm^{-1}). Larger and more intense fires resulting in a greater removal of vegetation would probably increase the volume of soil and associated seed accretion onto the exploration tracks, thereby improving the regeneration. Clearly, in desert environments, antecedent rainfall is critical to the successful establishment of regeneration. Hart's post-fire regeneration data are summarised in Figure 3 below.

Figure 3: Post-fire regeneration on and off exploration tracks (ex Hart 1993).



As this rehabilitation technique depends on the post-fire transport and deposition of soil and seed, it is likely to be most successful on soils which are more predisposed to wind erosion, i.e., soils with low clay content, and soils with significant seed quantities. The quantity of soil which builds up beneath the mature spinifex hummocks is probably a reliable field indicator of the "erodibility" of soil at a site. Soils on a number of landform units were assessed for there "erodibility" by measuring the distance between the top of these soil accretions and the inter-clump pavement. In addition, soil samples were taken for physical and chemical analysis, including clay content of the upper layers (see Appendix 1). These data are shown below in Figure 4 for both long unburnt and recently burnt sites. As expected, there is an inverse relationship between surface soil clay content and the height of accretions beneath the hummocks for the long unburnt sites. The deflation of these accretions by wind erosion following fire is also clearly evident from Figure 4. More detailed analysis of soil structures is currently underway and will be reported on in the final report.

Figure 4: Mean height of hummock soil accretions above pavement.



U/B = unburnt, BT = burnt

2.3.3 Soil seed bank

As discussed above, the location and quantity of soil stored seed is critical to the establishment of post-fire regeneration. Reported here (Table 1) are very preliminary findings of the location of seed and germination responses to heat treatment. Soil samples (10 cm diam. x 5 cm deep) were taken from soil accretions beneath spinifex hummocks (mounds) and from the pavements between hummocks. More detailed studies have been carried in the CSIRO laboratories in Canberra since these data were gathered and will be reported on in the final report. From the data presented in Table 1, the significantly more seed germinated following heat treatment at all sites except the Europa site. The other trend to emerge is that more seed is found beneath the spinifex hummocks than between the hummocks, again with the exception of the Europa site. As these data are preliminary, one must be cautious with interpretation, but it is most likely that soil as well as seed is stripped from the inter-hummock areas and trapped beneath the hummocks. The Europa site has a substantially lower erosion potential because of the relatively high clay content in the soil (Figure 4) so perhaps it is not surprising that there is a high seedling density in the inter-mound soil. The very high density for the Europa heat treatment may reflect inadequate sample size, as the high seedling count was due to only two of the six soil samples.

These data, together with the data shown in Figure 4, suggest that, all else being equal, some landform units are likely to respond more positively to fire as a rehabilitation technique than others. The sandier soils (dunes and sand plains) are more likely to respond well to this treatment. Analysis of additional data collected in 1995 will provide a clearer picture of this. As discussed by Hart (1993), it may be necessary to rip exploration tracks which have been severely compacted prior to burning to enable the establishment of deep root systems.

To supplement this, there is an unequalled opportunity to survey a range of exploration tracks across a range of geomorphological units for regeneration following the wildfire in 1995.

Table 1: Preliminary observations of mean seed density (m^{-2}) based on seedling germination, location and germination response to heat treatment, Rudall River.

	Mound	Inter-mound
Gleneagles site		
Heat treatment	191	64
No heat	95	64
Gypsy site		
Heat	254	64
No heat	95	64
Sand dune site		
Heat	191	95
No heat	64	32
Europa site		
Heat	254	1367
No heat	286	382

2.3.4 Fuels

In all, some 20 experimental fires were set to develop an understanding of fire behaviour in these fuel types. A capacity to predict when fires will spread, when they will self extinguish and rates of spread is vital to managing fire, as described in the methods section. Because spinifex fuels are patchy or discontinuous, it is essential that flames are of sufficient dimensions to breach the inter-hummock gap if fire is to spread. Thus, factors critical to the spread of fire are factors which describe the patchiness of the fuel (height, cover, bare patch sizes, patchiness ratio) and factors which effect flame size and angle (fuel quantity, fuel moisture, wind speed).

Detailed descriptions of fuel structure, quantity and moisture content, factors which affect fire behaviour, were made over several years and during experimental burning at the Rudall River study site. Table 2 summarises general fuel characteristics for common landform/geomorphic units within the Rudall River study area. These data were gathered in 1994.

Table 2: Summary of means of fuel characteristics for major fuel types in the Rudall River study area (1994).

Variable	Plateau	Ravine	Scree slope	Plain	Creek
Spinifex cover (%)	20.9	65.3	30.6	42.7	42.2
Other species cover (%)	0.9	1.2	1.8	4.1	2.1
Spinifex ht. (cm)	23.9	36.8	23.0	28.1	28.8
Spinifex patch size (m)	0.58	1.34	0.48	0.70	0.85
Bare patch size (m)	2.18	0.79	1.05	0.88	1.47
% bare patches > 2m	38.8	4.2	16.3	6.7	20.4
Dry fuel wt. (t/ha)	2.34	12.06	4.15	7.96	7.23
Spinifex clump bulk density (kg/m^3)				15.55	17.80
Spinifex leaf/stem wt ratio				1.85	2.34
Bare patch ratio	2.25	0.70	0.61	0.65	1.35
Spinifex patch ratio	0.20	1.11	0.20	0.28	0.41

Plateaus, or stony hill tops, carried a relatively light covering of small, clumped spinifex. Despite this, and much to our surprise, this fuel type, when fully "cured" (straw coloured moisture content < 15%) was capable of carrying fire under fairly severe weather conditions (Temp. 37-40° C, wind speed >25 Km/h), although fires tended to run in narrow tongues, many (but not all) of which eventually burnt out. Ravines or erosional gullies within the hills and leading onto the plains, although often no more than 5-20 m wide, were highly flammable on account of the quantity and continuity of fuels and their steep slopes. These act as wicks for fires burning on the plains to burn up onto and often across hills. The scree slopes or hillsides also carry light fuels but due to their steepness, fires under severe conditions are able to burn very rapidly and up these slopes. Both the vegetation regeneration experiments and the fire behaviour experiments were conducted on the sand plains, as these constitute most of the area affected by mining exploration tracks.

Fuel details for the experimental fires set to regenerate exploration tracks are presented in Table 3. The Europa site, situated on clayey soils in a low lying drainage basin unlike the other sites which were situated on sand plain, supported a different, more resinous spinifex species with significantly different fuel properties. Noticeable differences included the higher fuel loading, the clumps were about twice as dense and the higher proportion of dead leaves intermixed with live leaves. Spinifex clumps on the sandy plains were sparse (lower clump density), and contained very little dead material. Presumably the dead material was quickly removed by termites on these sites.

Table 3: Summary of fuel characteristics for the Rudall River rehabilitation burning trials. Measurement made 1992 with the exception of the Europa site (1994).

Variable	Gleneagles	Gypsy	Sand dune	Europa
Spinifex cover live (%)	30.5	36.7	36.8	34.5
Spinifex cover dead (%)	10.8	1.8	1.6	7.7
Other species (%)	4.3	4.0	5.3	2.1
Dry fuel wt. (t/ha)	4.94	6.19	4.47	7.96
Spinifex ht. (cm)	25.5	33.0	34.5	28.1
Spinifex patch size (m)	1.25	1.06	1.08	0.7
Bare patch size (m)	1.52	1.26	1.23	0.88
% bare patches > 2 m	15.1	9.7	10.5	6.7
Spinifex clump density (kg/m^3)	7.77	8.82	7.58	15.55
Leaf/stem ratio	1.16	0.62	0.88	1.85
Stem thickness (mm)	1.5			
Leaf thickness (mm)	0.75			

As the fuel for a bushfire is live and dead vegetation, it is not surprising that in hummock grasslands the amount of fuel available for combustion is largely influenced by time since last fire and rainfall. Good rains fell over the study site over the period 1992-1995, stimulating growth of the spinifex. While there was additional growth of spinifex, there was also growth of herbs and soft grasses between the clumps which contributed to increased fuel load and cover. This change in the structure and abundance of fuels over this period is shown in Figure 5. The relationship between spinifex cover and dry weight for the Rudall River area (clump ht. 25-35 cm) is shown in Figure 6.

Figure 5: Changes in fuel load and cover at the Europa site following good rains.

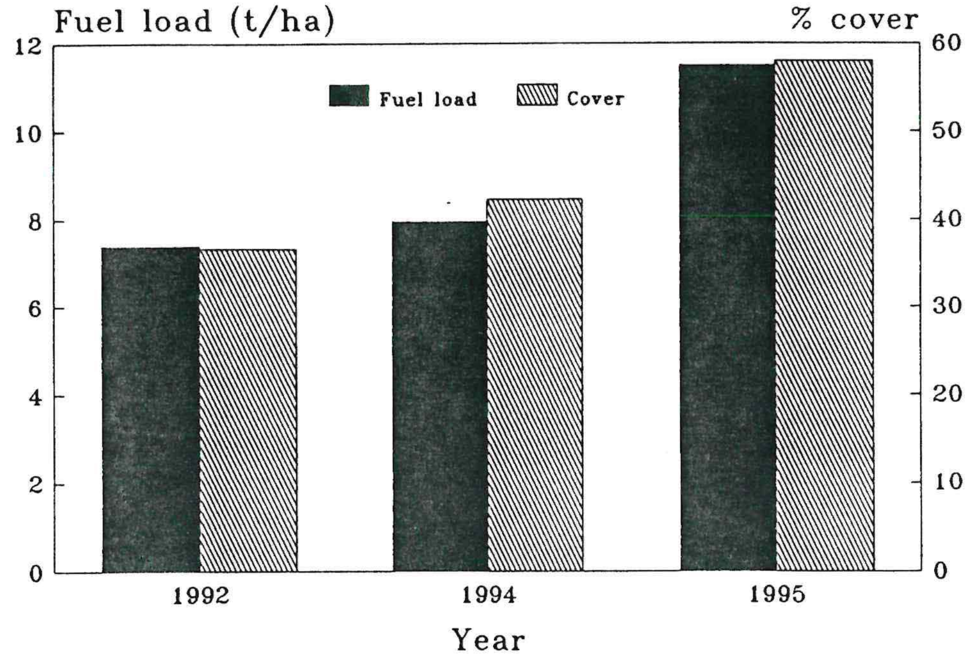
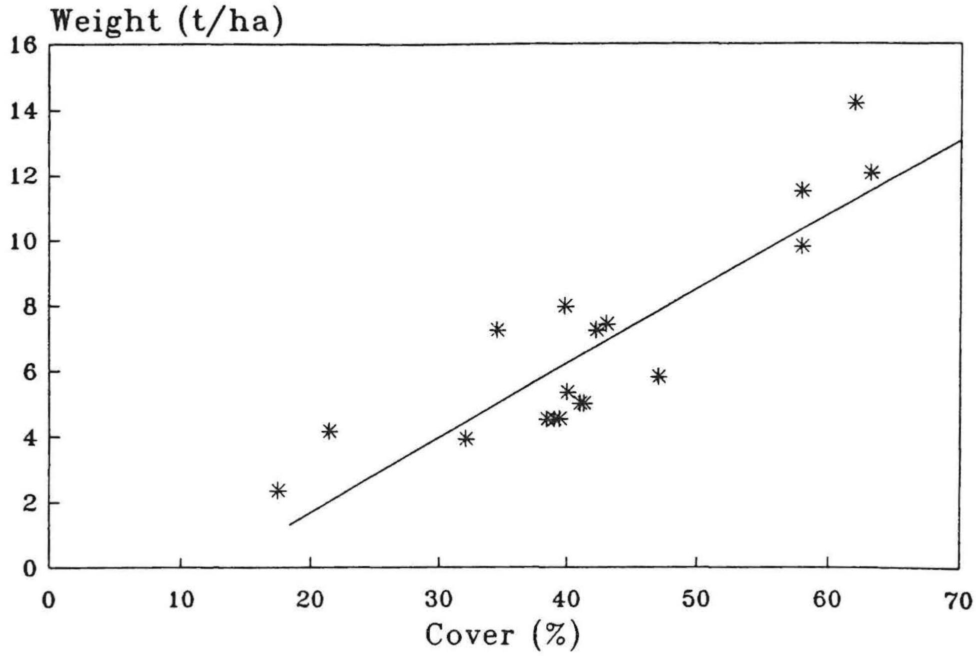


Figure 6: Relationship between spinifex cover and dry weight (fuel load).



The moisture content of vegetation also affects its property as a fuel. The dominant fuel, spinifex hummocks, consist of a mixture of live and dead vegetation at varying ratios depending on the age of the plant, species, seasonal conditions and activity of termites (as discussed above). Dead vegetation can either consist of old, dead portions of the hummock or actual dead material within live hummocks. The former source is often found on the inside of large old spinifex rings. The amount of this material varies, as shown in Table 3 above. The amount of dead material within live clumps (sheaths, dead stalks, dead leaves et.) varies from 10 - 25%, depending on the factors described above. The proportion of dead material can have a significant influence on the combustion properties of the fuel. Because spinifex clumps consist of live and dead material, and of leaves and stems, initially it was not clear what portion of the clump should be measured to provide a meaningful and reliable characterisation of the moisture content of the clump in relation to its fuel properties. Eventually we decided to take a sample through the entire profile of the clump to determine moisture content.

From the limited diurnal moisture content sampling undertaken, there appeared to be little variation in moisture content throughout the day. The moisture content of live material (which makes up about 75-80% by weight) varied seasonally but the moisture content of dead material varied diurnally. It was common for dead material to dry out to 3-4% on many occasions. The highest clump profile moisture content measured was 52.% taken from green clumps in a drainage line soon after good rains. The lowest clump profile moisture content measured was 13.3% taken from straw yellow clumps stony hilltops. On the plains, clump profile moisture content was commonly 16-20% (greenish-yellow). When moisture content exceeded 20-25%, fires were reluctant to spread. Hummocks became difficult to light at moisture contents above 35%.

2.3.5 Fire behaviour

Fire behaviour, fuel and weather conditions for the 20 experimental fires (including data from wildfires) are summarised in Table 4. As described above, one of the main objectives with regard to fire behaviour is to reliably predict under what conditions of fuel and weather fires are likely to spread and when they are likely to self-extinguish. Further detailed analysis will be carried out on fire behaviour data; the following is preliminary.

Table 4: Summary of fuels, weather and fire behaviour for Rudall River study site. T1, T2 etc.

Location	Date	Wind speed 2m (km/h)	Temp. (°C)	RH (%)	Profile moisture content (%)	Dry fuel wt. (t/ha)	Cover (%)	Rate of spread (m/h)	Flame ht. (m)	Comments
Sand dune	21/8/92	9-16	26-28	18-20	30.0	4.47	38.4	0	clumps 1-1.5 m	Fires lit with 200 m lines. Ignition moderate but fire did not spread. Fuels too moist and too light for wind conditions.
Gleneagles	24/8/92	16-30	28-31	26-30	20.5	4.94	41.3	0	clumps 1-1.5m	As above. Fire did not spread even at higher wind speeds. Fuels too light and too moist for winds.
Sand dune	30/10/92	10-15	32-35	20-25	24.6	4.52	39.4	0	clumps 1-1.5m	As above. Winds too light, fuels too light and too moist for winds.
Gleneagles	30/10/92	15-20	35-37	20-25	22.4	4.94	41.3	0	clumps 1-1.5m	Fire spread initially, then extinguished after 7.5 minutes. Fuels too light, too moist for winds.
Gleneagles	1/10/93	15-20	30-35	20-25	19.4	4.94	41.3	0	as above	As above.
Europa creek	1/10/93	15-25	32-35	20-25	18.7	7.23, patchy	42.2 patchy	320-350 (x=336)	1.5-2.0	Fire ignited readily. Several tongues spread initially while winds were 20-25 kph. Fire extinguished when winds <16. Fuels too moist for winds <16, but o.k 20-25 kph.
Europa creek	5/10/93	T1:	31-33	15-20?	18.4	7.23	42.2	T1:975 T2:1040 T3:754 T4:2013 T5:2160 T6:1080	1.5-2.5 1.5-2.5 1.5-2.5 3.0-4.0 3.0-4.5 1.5-2.5	Spinifex ignited readily. Fire spread rapidly down heavy fuel corridors, broke up in lighter fuels. Clumps contained high proportion of dead, dry leaves (3-4% mc). Flame angles 40-60°, depth up to 15 m at high spread rates. Crossed 4m track. Spotting 15-20 m from low shrubs. Self-extinguished when ran into light fuels and wind dropped.
Europa Valley	26/10/94	T1: 15-18 gusting 22 T2:16-20 gusting 25 T3: 16-20 gusting 25 T4: 18-22 gusting 26	30-32 33-35 37-38 39-40	13-15 12-14 9-10 7-9	17.3 17.3 17.3 16.6	5.33 5.33 5.33 5.33	40.0 40.0 40.0 40.0	1200 1450 1350 1450 (2000 @ 25 kph wind)	1.5-2.5 2.0-3.0 2.0-3.0 2.5-3.0	Very active fire behaviour under dry SE winds. Burnt across plains, little or no flank/backfire. Burnt rapidly up ravines and slopes into hill tops where most fires burnt out in the sparse spinifex. Fire readily crossed 3-4 m track at 2,000 m/h, winds 25kph..
Europa 1	25/10/95	T1: 6-11 T2: 10-15 (x=13.6)	32	10	20.0	11.5	58.0	750 1125	2.0-3.0	100 m ignition line fragmented under light E winds (6-11kph). 2-3 tongues picked up under NE gust. Fire out when wind dropped 6-11 kph.
Europa 2	25/10/95	10-15 gusting to 24	33	7	20	11.5	58.0	1500	3.0-4.0	Winds variable, gusting to 24, but mostly 10-15. Fire spread sustained along entire length of line.

Europa 3	25/10/95	T1: 2-6 T2: 11-13	34 34	7 7	20 20	14.2 14.2	62.0 62.0	150-0 800 (x=375)	1.0-2.0 2.0-3.0	T1:Very light winds initially. Fire staggering and fragmenting. T2: Winds picked up, several tongues spread.
Europa 4	26/10/95	6-10, gusting to 16	25	9	17.5	14.2	62.0	300-500	1.5-2.0	Winds light. Fire fragmented, staggering and after 6 mins., one tongue still spreading, most of line gone out.
Europa 5	26/10/95	T1: 5-10 T2: 15-20 gusting to 23.	36	6	16.6	14.2	62	128-0 2100	1.0-2.0 2.5-3.5	T1: Winds very light and variable, flames erect, fire fragmented and reluctant to spread. T2: Winds picked up, fire spread rapidly for short burst.
North Bore 6	26/10/95	3-6, gusts to 8.	37	5	13.6	3.9	32	0	clumps 1.0-1.5	Fire did not spread. Winds too light, fuels too light.
North Bore 7	27/10/96	8-12, gusting to 16	38	5	13.6	3.9	32	0	clumps 1.0-1.5	As above.
Airport 8	27/10/95	2-5	37	5	18.7	5.8	47	0	clumps 1.0-2.0	Fire did not spread. Winds too light.
Airport 9	27/10/95	T1: 8-10, gusts to 15 T2: 10-13, gusts to 18.	37	5	18.7	5.8	47	300-0 480	1.0-1.5	T1: Winds light, fire staggering, mostly out. T2: Winds picked up for short burst. Winds too light.
Airport 10	28/10/95	2-5	24	15	18.6	9.8	58	0	clumps 1.5-2.0	Calm early morning conditions. Winds too light for sustained fire spread. Burnt out after 8-10 mins.
Airport 11	28/10/95	3-8 gusts to 10	27	13	18.6	9.8	58	600	2.0-3.0	Winds mostly steady at 5-8 kph. Fire spread maintained.
North Bore 12	28/10/96	10-15, lulls to 5	36	6	17.7	3.9	32	0	1.0-1.5	Winds 18 kph at ignition then dropped. Fire went out - winds too light for light fuel.
North Bore 13	28/10/96	15-20 gusts to 23, lulls to 10	37	6	17.7	3.9	32	600-0	1.5-2.0	Fire fragmented, mostly out. Some tongues spreading with stronger wind gusts in light fuels. Threshold wind about 19-20 kph.

As expected, fire spread was dependent on wind speed, fuel load and fuel moisture. Ambient temperature and relative humidity appeared to have an effect on fire spread aside from its effect on moisture content but this could not be demonstrated. The threshold wind speed for fire spread decreased with increasing fuel load and cover (Figure 7) and increased with increasing moisture content. It was not possible to accurately determine the threshold wind speed for spread without carrying out numerous experiments and the data shown in Figure 7 are estimates based on limited number of field observations and "expert" assessment. During the "life" of an experimental fire, wind speed was never constant, hence the ranges given in the table above. Spinifex fires are very sensitive to wind shifts and lulls or short wind gusts can have a profound influence on fire behaviour.

The importance of fuel load on reducing the wind speed threshold for spread was clearly evident during the course of these experiments (Figure 7). Precedent rainfall has an important effect on fuel quantity and structure, as described above.

When conditions of fuel moisture and load were conducive for fire spread, then rate of spread was controlled by wind speed as shown in Figure 8. Data shown include all fires so no allowance is made for variations in fuel moisture or load.

Figure 7: Estimated threshold wind speed (at 2m) for fire spread in spinifex with fuel load and moisture content.

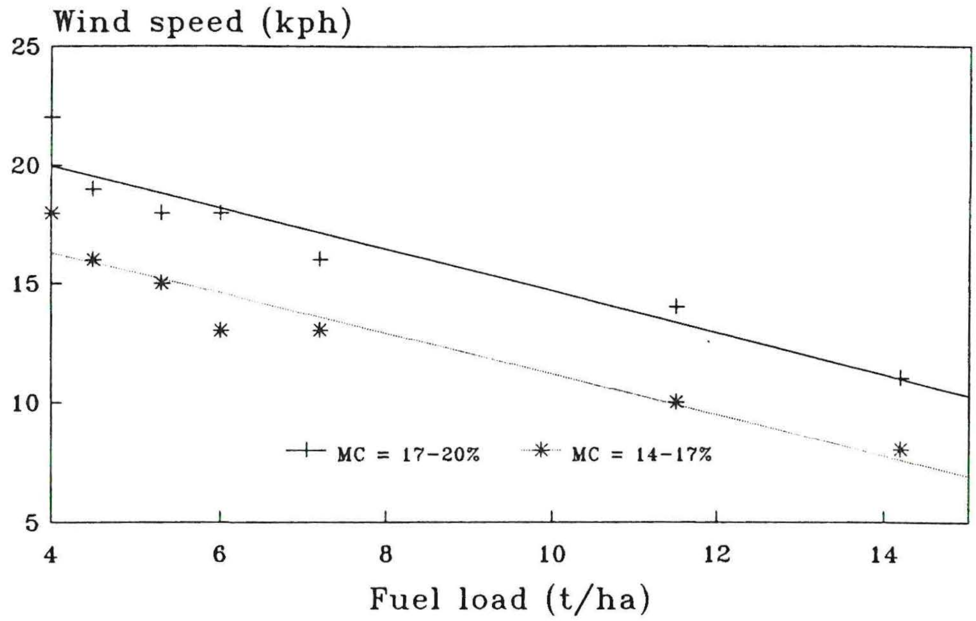
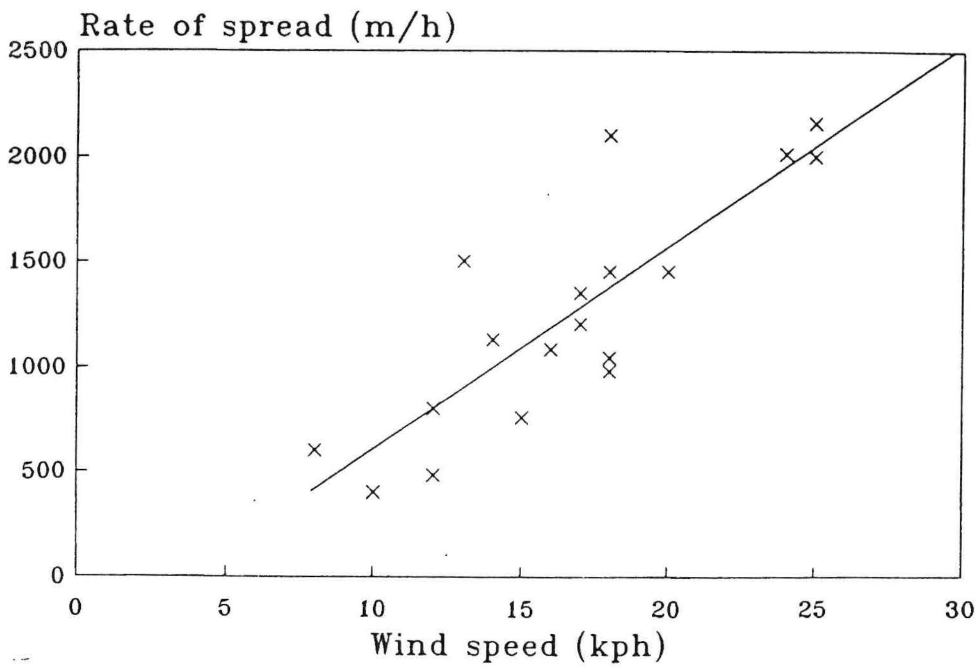


Figure 8: Rate of spread with wind speed (2m) for all spreading fires.



Conclusions

This is an interim report; further data analysis and interpretation is underway so conclusions drawn here are tentative. Notwithstanding this, we have demonstrated that prescribed fire can be used effectively and efficiently to rehabilitate areas disturbed by mining exploration. This unique technique has not been used operationally before. The advantage of this technique over traditional techniques of ripping and seeding is that it uses natural factors (fire, wind and water) and natural processes of seed and soil redistribution. Appropriate fire regimes can also enhance the biodiversity of the broader landscape as well as break up the run of major wildfires. There is also the exciting potential to provide meaningful employment to local Aboriginal people, most of whom have a profound empirical understanding of fire. However, the technique is not fail-proof. Regeneration success depends on the nature of the site (soil type, soil-stored seed bank), the size and intensity of the fire, follow-up rains and the extent of compaction of tracks. This work provides guidelines for selecting sites which are likely to lend themselves to this form of rehabilitation. Compacted tracks should, ideally, be ripped prior to burning.

This study has demonstrated that there is a risk associated with using fire in an area where there are inadequate suppression forces or fire breaks. This can and has been reduced by improved understanding of fire behaviour, especially conditions for fire start and stop, and by taking precautions prior to ignition. The fire behaviour information provided in this report can be used to better plan and implement operational prescribed burns. It is recommended that fires are not set without consolidated edges, which can be natural fire breaks, areas recently burnt by wildfire or buffer burns deliberately set in advance of rehabilitation burns and under conditions when fire spread is marginal.

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