Spinifex Fuel Survey - Karijini National Park

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Introduction

Spinifex (*Triodia* and *Plectrachne spp*.) grassland occupies ~27% of the Australian continent and ~43% of Western Australia, making it a most predominant vegetation type. Spinifex grasslands are restricted to the semi-arid and arid parts of central and northern Australia where they occupy a variety of soil types and landforms. Mature spinifex grasslands are highly flammable and together with soils and climate, fire has played an important role in shaping the biodiversity of these ecosystems. However, there is evidence that the fire regime has changed dramatically since European settlement. For thousands of years, Aboriginal people deliberately burnt much of the spinifex grasslands for a myriad of reasons, and together with lightning ignitions, the landscape was maintained as a relatively fine-grain, stable mosaic of different seral stages. With the cessation of traditional Aboriginal burning across most of the spinifex-dominated landscapes, the fire regime quickly changed to one of predominantly large hot/dry season wildfires, most ignited by lightning.

Proactive fire management across much of the arid region is virtually absent, despite the frequency of large wildfires. The region is large, remote and sparsely populated so the wildfire threat to human life and property is low, resulting in a low commitment to fire management. However, there is growing evidence that the regime of large, intense summer wildfires is adversely impacting the biota and while there is some debate about the most appropriate fire regime for protecting and maintaining biodiversity, most fire managers are agreed that frequent large summer wildfires are undesirable.

Whatever the management objective, a firm knowledge of fire behaviour and ecology is necessary for implementing appropriate, risk-based fire management. To this end, a spinifex fire behaviour model has been developed, based largely on a series of experimental fires in the Great Sandy and Gibson Deserts (Western Desert). Complementing the development of the fire behaviour model has been the ongoing development of spinifex fuel models, which characterise and quantify the various formations of spinifex in the Western Desert in terms of fuel properties with time since fire and rainfall. Retrospective (space-for-time) fuel surveys to achieve this have been systematically carried out in the Great Victoria, Gibson, Little Sandy and Great Sandy Deserts. A notable bioregional exception to the spinifex fuel surveys was the Pilbara region, which has a significantly different climate and geomorphology to the Western Desert. To overcome this knowledge gap, a first step in surveying the diversity of landsystems in the Pilbara region was to survey spinifex fuels in Karijini National Park for which there exists a reasonable documented fire history.

Methods

The fuel survey, conducted 3-5th August 2014, focussed on sites in and adjacent to Karijini National Park that were accessible by vehicle. The sampling procedure was stratified according to time since last fire, which was determined from fire history maps prepared by

Tim Hunt (DPaW) based on interpretation of Landsat satellite imagery dating back to 1999 (see series Figure 1 below).

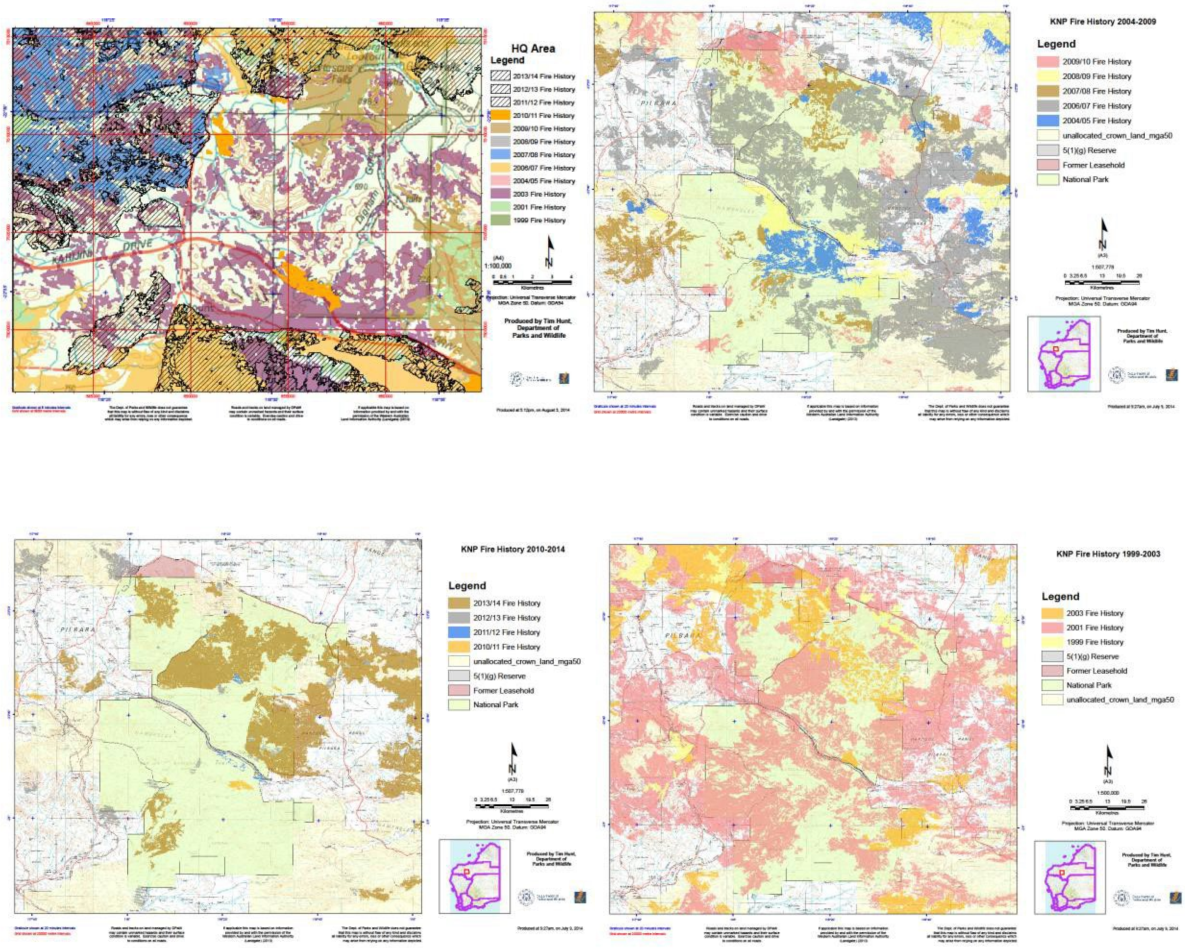


Figure 1: Series of fire history maps 1999-2014 for Karijini NP based on interpretation of Landsat satellite imagery (Courtesy Tim Hunt, DPaW)

Nineteen (19) locations (KJ1-19) in mostly known but different fuel ages were selected for survey (see Figure 2) as an initial study to assess the variability and diversity of fuel complexes in and around the Park. At each survey site, two survey lines each 50 m long were assessed. Vegetation fuel cover (%), categorised as either live spinifex, dead spinifex, soft grass, herb or woody shrub <1.5 m was determined by measuring the linear, vertically projected distance occupied by that category along the transect, to the nearest cm. The proportion (%) of bare ground was measured similarly. The height of intercepted vegetation was measured and in the case of spinifex clumps, the shape or form/architecture of the clump was allocated to one of five developmental categories shown in Figure 3. These were derived from studies of spinifex in the Western Desert (predominantly *T. basedowii* with some occurrences of *T. melvillei* and *T. schinzii*), so one of the aims of this survey was to test the applicability of these forms to *Trioda spp*. in Karijini NP. Clump 'bulk density' was categorised from a visual estimate according to whether the soil surface could be seen or was blocked from view when looking through the clump from above.

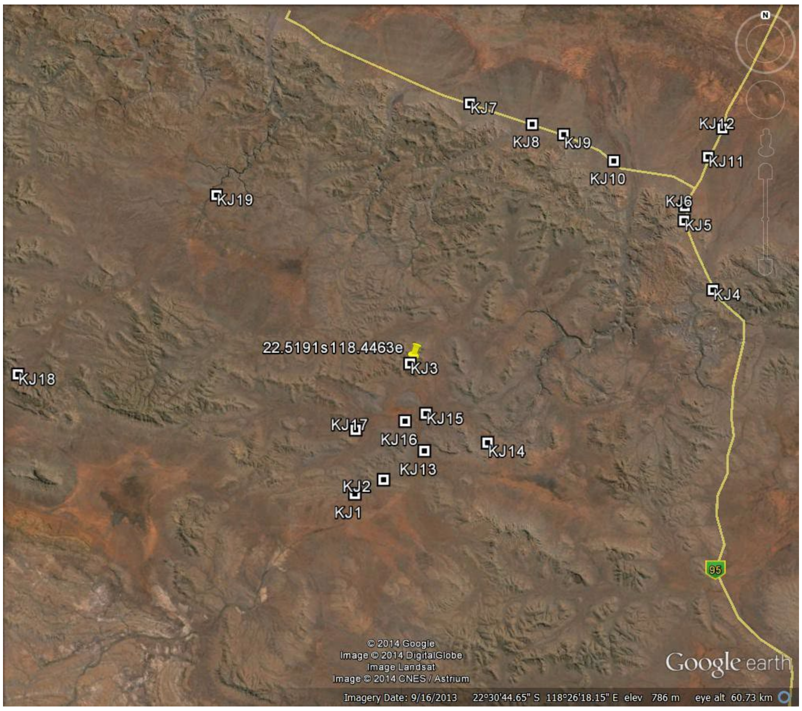
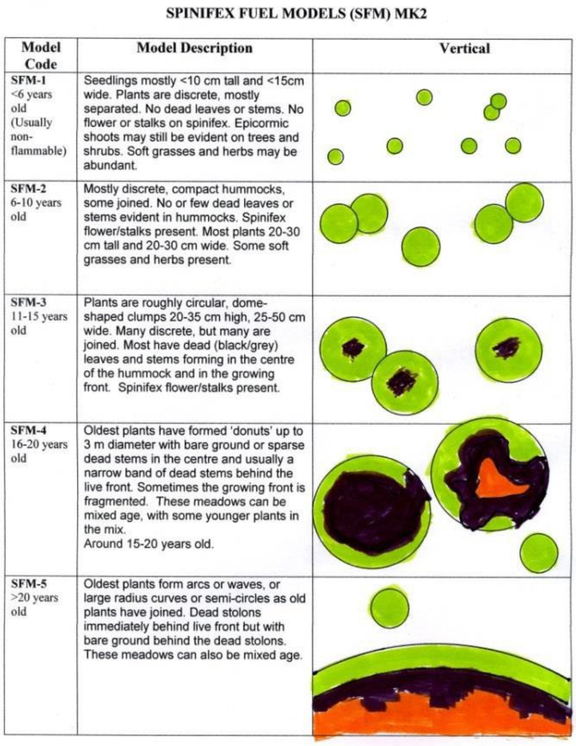


Figure 2: Location of fuel survey sites in and adjacent to Karijini National Park



SPINIFEX FUEL MODELS (SFM) MK2

Model Code	Model Description	Vertical
SFM-1 <6 years old (Usually non-flammable)	Seedlings mostly <10 cm tall and <15cm wide. Plants are discrete, mostly separated. No dead leaves or stems. No flower or stalks on spinifex. Epicormic shoots may still be evident on trees and shrubs. Soft grasses and herbs may be abundant.	
SFM-2 6-10 years old	Mostly discrete, compact hummocks, some joined. No or few dead leaves or stems evident in hummocks. Spinifex flower/stalks present. Most plants 20-30 cm tall and 20-30 cm wide. Some soft grasses and herbs present.	
SFM-3 11-15 years old	Plants are roughly circular, dome-shaped clumps 20-35 cm high, 25-50 cm wide. Many discrete, but many are joined. Most have dead (black/grey) leaves and stems forming in the centre of the hummock and in the growing front. Spinifex flower/stalks present.	
SFM-4 16-20 years old	Oldest plants have formed 'donuts' up to 3 m diameter with bare ground or sparse dead stems in the centre and usually a narrow band of dead stems behind the live front. Sometimes the growing front is fragmented. These meadows can be mixed age, with some younger plants in the mix. Around 15-20 years old.	
SFM-5 >20 years old	Oldest plants form arcs or waves, or large radius curves or semi-circles as old plants have joined. Dead stolons immediately behind live front but with bare ground behind the dead stolons. These meadows can also be mixed age.	

Figure 3: Spinifex growth/development models derived from T. basedowii and T. melvillei in the Western Desert. Some but not all species encountered in Karijini displayed these growth characteristics.

Plate 3: Typical SFM4 (see Figure 3 above) development stage for a Triodia sp. in Karijini NP.

Dry fuel biomass (fuel load) was determined for each site by harvesting all vegetation fuel (dead < 6mm diam., live < 4mm diam.) from 1 m^2 quadrats placed at 10 m intervals along the survey lines, giving a total of 10 x 1 m^2 samples per survey point. The 'green', or air dry biomass in each quadrat was weighed in the field. Samples were taken for moisture content determination by oven drying later, enabling dry fuel load to be calculated and expressed in tonnes per hectare (t/ha). Each survey point was geocoded and photographed. Where available, stems of mallee and other tree coppice/regrowth from the last fire were cross-sectioned and growth rings counted to obtain an estimate of time since last fire. This was important for fires that occurred before 1999 for which there was no recorded year of fire occurrence.

Plate 1: Growth rings on mallee coppice and other stems were used to estimate time since last fire.

Results and Discussion

Since 1999 (and probably earlier), the Park has experienced a fire regime dominated by large, frequent lightning-caused wildfires. Large fires occurred in 2001 (~280,000 ha or ~40% of the Park), 2006/07 (~140,000 ha or ~ 22% of the Park) and 2013/14 (~230,000 ha or ~35% of the Park). This pattern is consistent with the contemporary unmanaged fire regime in the spinifex deserts, although the frequency of fires in Karijini is higher, probably due to the higher rainfall and higher fuel productivity. To what extent the current regime is a deviation from the pre-historical (natural) regime is unknown, as are the long term ecological and environmental effects, although there is some evidence that fire sensitive species such as mulga communities are being adversely impacted/extirpated.

In general terms, a most striking difference between the spinifex meadows sampled in Karijini NP and those sampled in the Western Desert was the fine-scale variability of soil/site/habitat types in Karijini NP and the consequent variability in the composition, structure and biomass of spinifex meadows. Surface soils at the survey sites were mostly rocky with the proportion and dimensions of rock material varying depending on local geomorphology. Spinifex species associated with rocky soils on slopes (run-off areas) included *T. wiseana* and *T. pungens*(?), while *T. melvillei* (?) most often occurred on alluvial sand plains (run-on areas). Fuel ages ranging from 3 years to 24 years post-fire across a variety of site types were sampled (See Appendix 1 for details).

Another broad difference between Karijini and Western Desert spinifex meadows is the relatively high ground cover of spinifex at Karijini even on stony, 'poor' (low productivity) sites. Fuel biomass and height on these sites was low, but cover was relatively high, increasing the potential for these sites to carry fire under low wind speed conditions.

Plate 2: Spinifex meadow on a poor site (stony, shallow soils, north aspect) with a low fuel load and fuel height but with a relatively high ground cover (~65%), making these fuel complexes flammable even under low wind conditions.

As mentioned, there was no recorded fire history pre-1999 available, so estimates of fuel age pre-1999 were based on ring counting of mallee coppice and other woody stems, where such material was available. Growth rings, which were assumed to be annual, were not always clear and required a level of interpretation by experienced dendrochronologists, with some assumptions being made. For example, the clarity of growth rings varied within a stem section – where growth rings were diffuse and uninterpretable, a constant rate of growth was assumed based on rings that were clear. A good relationship existed between fuel age (time since last fire) determined from ring counting and known fuel age (Figure 4), although the ring counting technique slightly, but consistently, over-estimated actual fuel age.

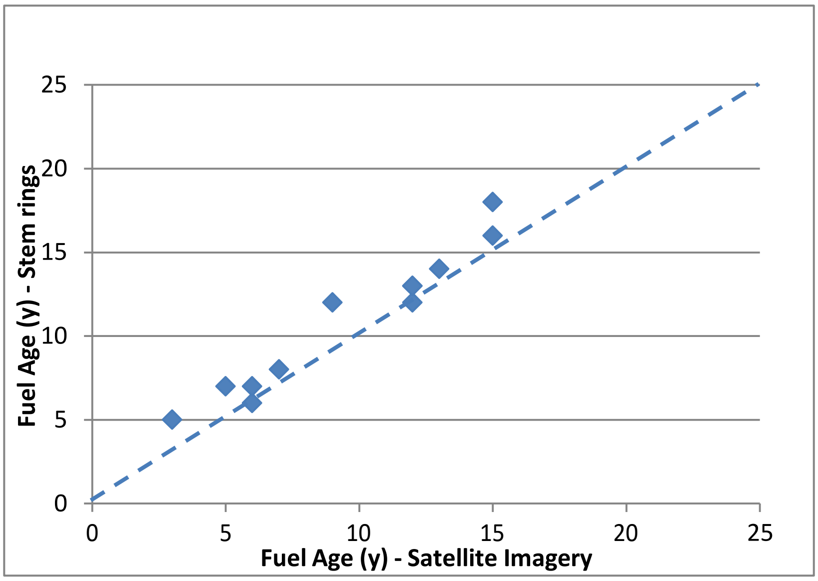


Figure 4: The relationship between actual fuel age determined from satellite imagery of fire history and fuel age determined from coppice stem ring counting. Line of perfect agreement shown.

As expected, the spinifex meadow fuel properties were a function of site type (site productivity) and time since last fire. Figure 5 shows the relationship between dry fuel load and time since last fire for three 'site types' visually identified in the field based on surface soil texture, landform position and aspect. The most productive site surveyed was *T. melvillei* growing on sandy loam soils on plains low in the profile. This site type appeared restricted in area and atypical of spinifex meadows in the Park. As shown in Figure 5, only one sample was obtained for this type and the relationship between time since fire and fuel load for this type is speculative. The KNP landscape mostly comprised spinifex (*T. wiseana and T. pungens?)* growing on very stony soils with varying soil depth, and on a variety of slopes and aspects (see Plate 3 and Figure 5).

Plate 3: L-R: Site type 1: T. melvillei on a sandy-loam. Site type 2: T. wiseana (?) on a stony soil run-on site. Site type 3: T. wiseana/pungens? On a stony soil run-off site (See Figure 5).

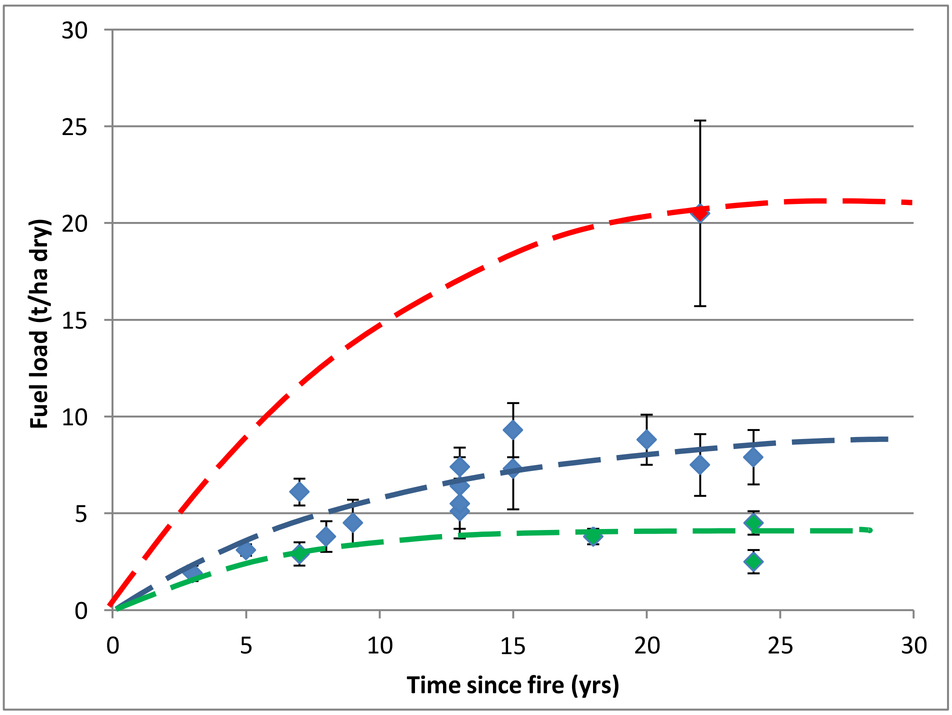


Figure 5: The relationship between dry fuel load and time since fire (fuel age) for three spinifex-dominated site-types in Karijini NP. Site type 1(red): T. melvillei on a sandy-loam. Site type 2(blue): T. wiseana (?) on a stony soil, run-on site. Site type 3(green): T. wiseana/pungens? on a stony soil, run-off site. With only one sample point, Site type 1(red) model is highly speculative.

With the exception of the most productive (Site type 1) and least productive (Site type 3) sites, the relationship between fuel load and time since fire for most of the spinifex meadows surveyed in KNP fell within the range of that for the various Western Desert sites (Figure 6).

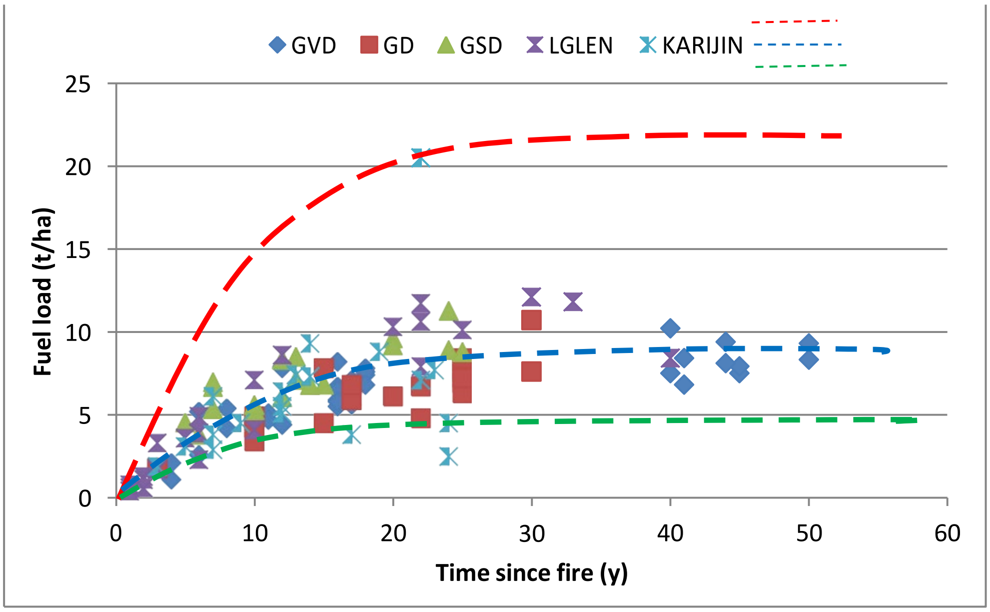


Figure 6: Relationship between dry fuel load and fuel age (time since fire) for Great Victoria Desert (GVD IBRA), Gibson Desert (GD IBRA), Great Sandy Desert (GSD IBRA), Lorna Glen (LG – Murchison IBRA) and three Karijini NP sites (Pilbara IBRA).The 'red' model is speculative.

As discussed, a noticeable feature of the KNP spinifex meadows was the relatively high ground cover, even on ‘poor’ sites with low biomass and low clump height. This is illustrated in Figure 7, which shows the relationship between fuel age (time since fire) and spinifex fuel cover. This has significant fire behaviour prediction implications. The current spinifex fire behaviour model developed from experimental fires in the Gibson and Great Sandy Deserts uses fuel load as the key fuel characteristic model input. In the Western Desert, fuel cover and height are correlated with fuel load, but this is not the case for KNP because of the site variability and the relatively high cover levels associated with low fuel loads on ‘poor’ sites. Therefore, the current model is likely to under-predict the potential rate of spread of spinifex growing on ‘poor’ sites with low fuel load (2-3 t/ha), low fuel height (15-20 cm) but high fuel cover (55-65%). Further work on the spinifex fire behaviour model is needed to take account of the fuel structural differences encountered in KNP.

From Figure 7, it is evident that the mean height of spinifex/fuel is a function of time since fire and of site quality, with taller fuels occurring on the better sites (deeper soils, better moisture regime).

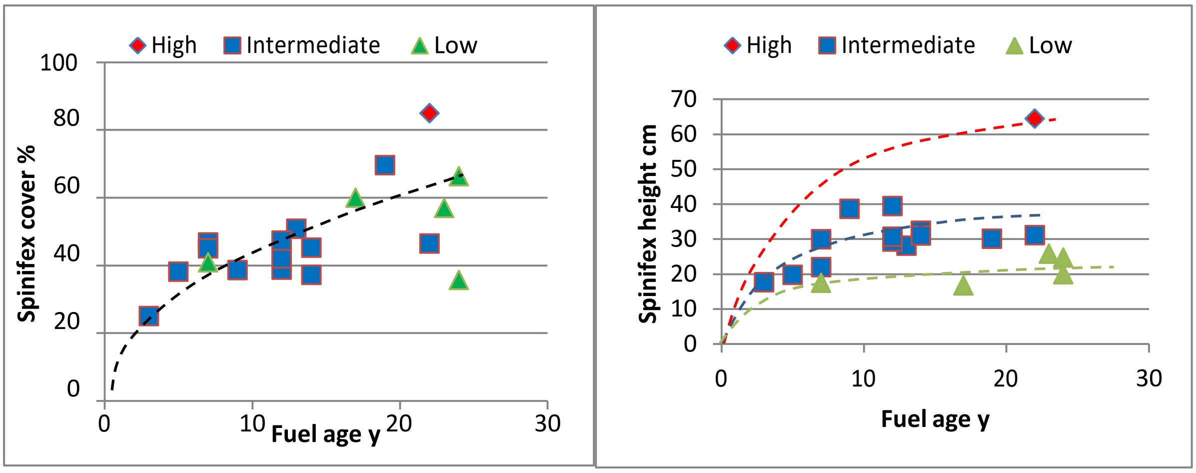


Figure 7: Relationships between time since fire and (L) fuel (spinifex) cover and (R) fuel height for three ‘site types’ in KNP.

The mean linear fuel patch size and bare patch size for KNP is shown in Figure 8 with data from the Western Desert sites. The mean bare patch size is at the lower end of the range compared to the other sites, but the mean patch size of fuel is significantly higher, reflecting the higher level of ground cover and the overall higher flammability of KNP fuels.

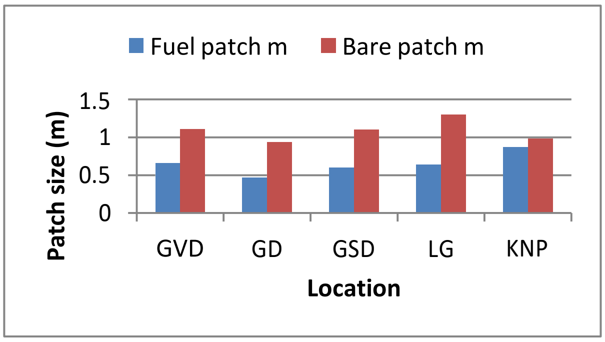


Figure 8: Mean fuel patch and bare patch sizes for spinifex landscapes in various regions (see Fig. 6).

As with other sites in the Western Desert, there was a relationship between the age of the spinifex and the profile moisture content of the clump at a given time – older spinifex was drier than younger spinifex because of the higher proportion of dead fuel in the clump (Figure 9). In KNP there was also a significant difference in moisture content associated with the various sites – the drier fuels occurred on the harsher sites (stony, shallow soils, run-off, north aspect – 'Low' in Fig. 9). This has implications for prescribed burning and for wildfire suppression – given this site-based moisture differential, there exists the potential for carrying out prescribed burning when some sites (e.g., run-on areas, alluvial plains) are at a relatively high moisture content and are reluctant to carry fire under cool, calm conditions, while other sites (ridges, steep stony slopes on north aspects) are drier and will readily carry fire. This is visually evident in Plate 3 above.

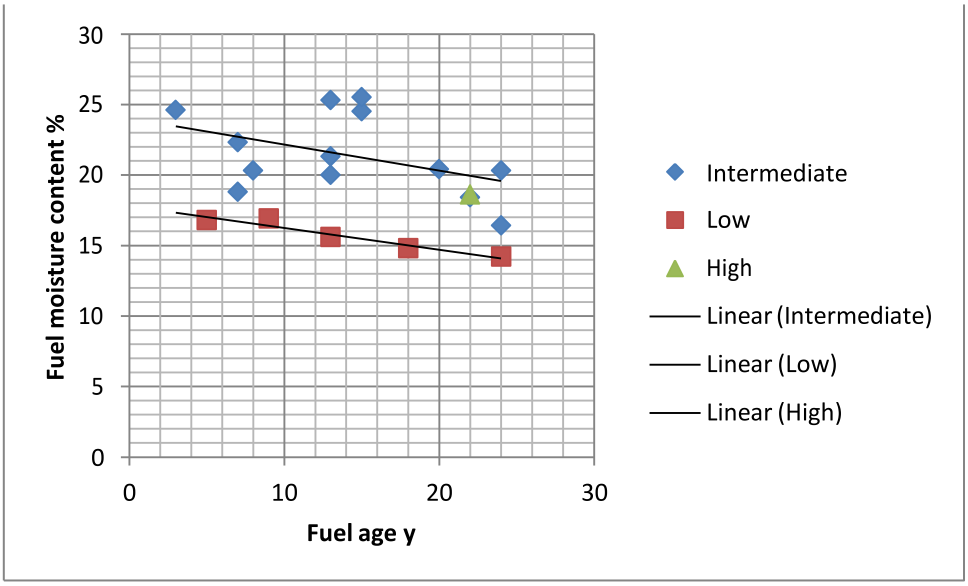


Figure 9: The profile moisture content of spinifex clumps at any point in time was related to fuel age and site condition (High, Intermediate, Low site quality).

Conclusions

In KNP, spinifex occurs on a variety of sites with variable soil, slope, drainage and aspect characteristics, so site quality and time since last fire are both important factors affecting the characteristics of spinifex as fuel, including fuel load, height and moisture content. Fuel cover is generally higher than other spinifex landscapes and while it increases in the early post-fire period, it is unrelated to site quality. For this reason, mature but poor quality (low productivity) sites carrying low fuel biomass and short spinifex are capable of carrying rapidly spreading fires at low wind speeds. The current spinifex fire spread model will likely under- predict the rate of spread on these sites.

Flammability differentials associated with fuel moisture content gradients in various landforms could be exploited to safely carry out prescribed burning under cool, damp conditions soon after rainfall to reduce the risk of large, intense wildfires.

Further work is needed to calibrate and validate the current spinifex fire behaviour model for Pilbara spinifex fuel types.

Appendix 1: Spinifex Fuel Structure Summary. LOCATION: Karijini NP IBRA: Pilbara ASSED: August 2014

Plot	Fuel age plan (y)	Fuel age stem (y)	$\bar{x}$ spini clump shape	$\bar{x}$ Fuel load (t/ha)	Live spini cover (%)	Dead spini cover (%)	Soft grass/ herb cover (%)	Low Shrub cover (%)	Total fuel cover (%)	$\bar{x}$ Fuel ht. (cm)	$\bar{x}$ Fuel patch size (m)	$\bar{x}$ Bare (%)	$\bar{x}$ Bare Patch size (m)
KJ1 **22.6196** **118.4003**	N/A	20	2.2	8.8	69.60	0	0	1.2	70.8	30.1	1.27	30.0	0.57
KJ2 **22.6085** **118. 4241**	N/A	18	3.3	3.8	59.5	0.45	0.45	2.2	62.6	16.7	0.81	39.9	0.54
KJ3 **22.5191** **118.4463**	15	18	3.4	7.3	35.8	1.41	0.2	2.6	40.0	32.4	0.99	63.0	1.75
KJ4 **22.4597** **118.7063**	13	13	3.0	7.4	50.2	0	0	8.5	58.7	28.1	0.76	47.9	0.67
KJ5 **22.4039** **118.6839**	7	8	2.1	3.8	46.7	0	0	3.3	50.0	21.9	0.72	51.8	0.82
KJ6 **22.3928** **118.6847**	12	13	2.0	6.4	38.7	0	0	6.3	45.0	29.3	0.74	57.6	1.12
KJ7 **22.3076** **118.4988**	14	16	2.8	9.3	45.2	0	0	6.6	51.8	31.0	0.72	50.4	0.81
KJ8 **22.3247** **118.5534**	9	14	3.0	4.5	38.6	0	0	1.8	40.4	38.3	1.37	60.5	2.16
KJ9 **22.3333** **118.5808**	13	13	2.1	5.1	42.0	0	1.5	4.8	48.3	39.4	1.27	64.9	1.75
KJ10 **22.3551** **118.6240**	N/A	24	3.8	7.7	40.4	16.5	0.2	2.3	59.4	25.8	0.84	46.1	1.09
KJ11 **22.3513** **118.7074**	7	7	1.8	2.9	40.4	0.5	0.5	0.9	42.3	24.4	0.69	59.7	1.01
KJ12 **22.3273** **118.7206**	13	13	2.9	5.5	43.0	4.3	0	0	46.3	30.6	0.97	52.4	1.31
KJ13 **22.5857** **118.4583**	N/A	23	2.8	7.1	44.5	1.9	0.8	0.1	47.3	31.1	0.83	48.3	0.92
KJ14 **22.5805** **118.5113**	3	5	1.5	1.9	24.6	0.4	1.25	0.5	26.7	17.6	0.41	76.0	1.17
KJ15 **22.5581** **118.4599**	N/A	24	1.9	2.5	35.7	0	3.8	0	39.5	19.9	.53	60.8	0.93
KJ16 **22.5634** **118.4420**	N/A	24	3.0	4.5	58.3	8.0	0	0.5	66.8	24.7	1.14	31.0	0.64
KJ17 **22.5700** **118.4009**	N/A	22	3.0	20.5	40.7	1.0	17.5	0	59.2	64.4	1.58	40.8	1.24
KJ18 **22.5275** **118.1153**	7	6	1.9	6.1	45.0	0	0	0.9	45.9	29.9	0.59	55.4	0.73
KJ19 **22.3841** **118.2793**	5	7	1.7	3.1	38.1	0	0	9.7	47.7	19.7	0.52	56.7	0.78

Appendix 2: Photographs of Karijini NP survey sites

KJ1

KJ2

KJ3

KJ4

KJ5

KJ6

KJ7

KJ8

KJ9

KJ10

KJ11

KJ12

KJ13

KJ14

KJ15

KJ16

KJ17 KJ18

KJ19