Spinifex fuel moisture survey, Great Victoria Desert

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Neil Burrows[1], Agnes Kristina[2], Ana Negreiros[2], Errol Thoomes[3]

[1]DBCA Research Associate; [2]DFES Technical Services; [3]DBCA Volunteer

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Summary

A survey of soil and spinifex moisture content was undertaken, primarily in the Great Victora Desert, to evaluate the efficacy of previously determined relationships between modelled root zone soil moisture ($AWRA_{RZ}$), and spinifex and actual soil moisture content. Many meadows were severely drought affected with plants containing a high proportion (30-90% by volume) of dead leaves, making soil moisture and $AWRA_{RZ}$ irrelevant for predicting live plant moisture content. For other meadows not affected by drought, there were good relationships between profile soil moisture content (0-30cm depth), $AWRA_{RZ}$ and live spinifex clump moisture content. The data gathered from this survey were reasonably consistent with data from the earlier Wubin longitudinal study. However, the relationships developed from the Wubin study were a poor predictor of the moisture content of spinifex meadows sampled during this survey. Generally, the models under-predicted moisture content. Possible explanations are provided in this report.

Because of the shortcomings of using $AWRA_{RZ}$ to spatially and temporally predict spinifex moisture content in remote areas, we recommend a concerted effort be made to evaluate the efficacy of high resolution satellite-derived NDVI. In the interim, and in the absence of a better alternative, we recommend persisting with the $AWRA_{RZ}$ -based models to predict spinifex fire behaviour and fire danger rating.

Introduction

Fuel moisture content is an important input to predicting fire danger rating and fire behaviour in spinifex deserts. Spinifex meadows comprise a mix of live and dead fine fuels, making their moisture content difficult to predict or model. Dead fuel can exist as dead plants, dead foliage behind the active growing front of live plants, or as dead foliage within live clumps. There are a number of factors affecting the live-to-dead fuel ratio in a spinifex meadow, but time since last fire and moisture regime are probably the most important. Unlike dead fine fuels such as leaf litter, there are no meteorologically-based models to predict the moisture content of live spinifex meadows. Preliminary research by Burrows (2023) showed that reliable estimates of spinifex fuel moisture content could be obtained using root zone soil moisture content, as predicted by the Australian Water Outlook model ($AWRA_{RZ}$) (https://awo.bom.gov.au/products/historical/soilMoisture-rootZone/4.5,-24.238,123.966/nat,-25.609,134.362/r/d/2023-02-06soil moisture).

A longitudinal study was carried out in a spinifex meadow about 45 km north-west of the town of Wubin in the north-eastern wheatbelt of WA. The following relationships were developed from the study to predict spinifex meadow moisture content. This process makes adjustments to moisture content using RH to account for the increase in the dead fuel component in meadows as fuels age. Dead fuel is unaffected by root zone soil moisture, but is affected by relative humidity (RH):

Spinifex Fuel Class 2 MC% = 1.1 ($AWRA_{RZ}$) + 17

<u>MC% adjustments for older fuel classes:</u>

Fuel Class3 MC% = Class2 MC% - (1/(0.03 x RH%)) x 1.5; If MC = < 14%, then MC = 14%

Fuel Class4 MC% = Class2 MC% - (1/(0.03 x RH%)) x 2.5; If MC = < 13%, then MC = 13%.

Fuel Class5 MC% = Class2 MC% - (1/(0.03 x RH%)) x 3.5; If MC = < 12%, then MC = 12%.

Where:

Fuel Class refers to the dominant structural growth stage of the spinifex clumps in the meadow (see Burrows 2023), $AWRA_{RZ}$ = modelled root zone soil moisture content, MC = spinifex clump moisture content (% of oven dry weight) and RH = relative humidity. Older fuels generally have a higher proportion of dead material, hence the attempt to make adjustments to spinifex MC based on RH.

The purpose of the current survey was to independently test the efficacy of using soil moisture and $AWRA_{RZ}$ to predict the moisture content of spinifex meadows in central WA. It follows an earlier trip (July), which was not able to repeat the results of the Wubin longitudinal study due to sampling shortcomings.

Method

Twenty-five spinifex meadows of different but known times since fire (TSF) were surveyed. Most sites surveyed (18) were in the Great Victoria Desert with the remaining sites being in the Murchison and Yalgoo IBRAs (see Figure 1). At three sites, additional moisture content samples were taken of different fuel structural classes (ages) present on the site. TSF mapping was post 2003, so older fire scars were mapped as 20+ years. The following samples and measurements were taken at each site:

- Soil profile moisture content to a depth of 30 cm ($SoilMC_{30}$). This represents the root zone of spinifex. A 27.5 mm (internal) diameter steel corer was used to take samples, which were placed in an airtight container for moisture content determination in the laboratory.

- Three 'live', representative spinifex clumps were sampled by clipping a cross section of material from each clump and placing it in an airtight container for moisture content determination in the lab. Depending on the age/structure of the clump, this included varying proportions of live and dead material. The dominant species sampled were *Triodia basedowii* and *T. schinzii*.
- Time since fire (TSF) was estimated from satellite imagery provided by DBCA.
- The ground cover (%) of live and dead spinifex plants was estimated using the 50 m point transect method. It should be noted that this does not measure the proportion (by volume) of dead material in live clumps.
- The proportion (%) of dead material by volume in live clumps was estimated visually in the field and from photos. There is no other efficient field method of estimating the proportion of dead material in live clumps.
- Fuel structural class (see Appendix 1) was estimated visually following the methodology of Burrows (2023).
- Sample sites were geo-coded and photographed.
- Temperature and RH were recorded.
- Samples were oven-dried in the laboratory in a fan-forced oven at 90°C for 3 days.

Regression analyses were performed on four key variables – $SoilMC_{30}$, $AWRA_{RZ}$, live spinifex actual MC and live spinifex predicted MC (see above) to test the strength of relationships between the variables and whether actual spinifex moisture content could be predicted from either $SoilMC_{30cm}$ or $AWRA_{RZ}$.

The predictive models derived from the Wubin study (see above) were also evaluated on the independent data set collected during this survey.

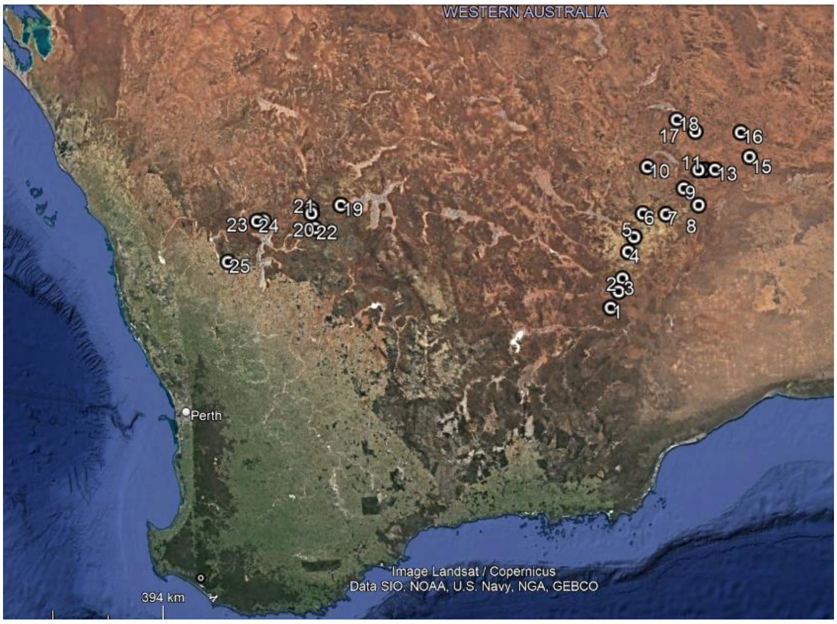


Figure 1. Map of sample sites

Results and discussion

Drought death

A summary of the spinifex meadow and soil moisture conditions observed during the survey is in Table 1. Photos and some details of the survey sites are in Appendix 1.

An important observation was that vegetation on 19 of the 25 sites sampled was affected by drought. Up to 90% of the foliar volume of live spinifex clumps comprised dead, black leaves with a few live yellow/green leaves remaining on each plant (see Figure 2 and App. 1) – so although the plants were classified as 'live', most (30-90%) of the foliage was dead. This was a consequence of an extended regional drought in the recent past. Being mostly dead foliage, the moisture content of spinifex clumps in these meadows was largely (but not entirely) independent of soil moisture. For example, knowing the relationship between the moisture content of dead leaves and RH, for meadows with >25% of dead material by volume, on average, about 50% of the moisture content of 'live' plants was from the atmosphere, and about 50% from the soil. However, the ratio changed, depending on the ratio of live-to-dead material.

Fuel class range	TSF range (yrs)	Sample time temp range (C)	Sample time RH range (%)	$SoilMC_{30}$ range (%)	$AWRA_{RZ}$ range (%)	Live spinifex clump MC range (%)
1-5	4-20+	20-34	10-51	0.9-4.6	0-5.0	4.7-33.8

Table 1: Summary statistics for spinifex fuel and soil moisture samples. TSF = time since fire.

Figure 2: Drought affected spinifex meadows with 'live' plants comprising a high proportion of dead, (black) leaves. Consequently the MC of these meadows was very low and unrelated to soil moisture.

For the relatively narrow range of environmental conditions observed during this survey (Table 1), there was an inverse relationship between the moisture content of live spinifex clumps, and the estimated proportion (by volume) of dead material in the clumps (Figure 3).

Finding 1:

It is not possible at this stage to reliably estimate the moisture content of meadows with >25% dead (black) foliage (by volume) in otherwise live clumps (such as the meadows in Figure 2) from soil or atmospheric moisture content.

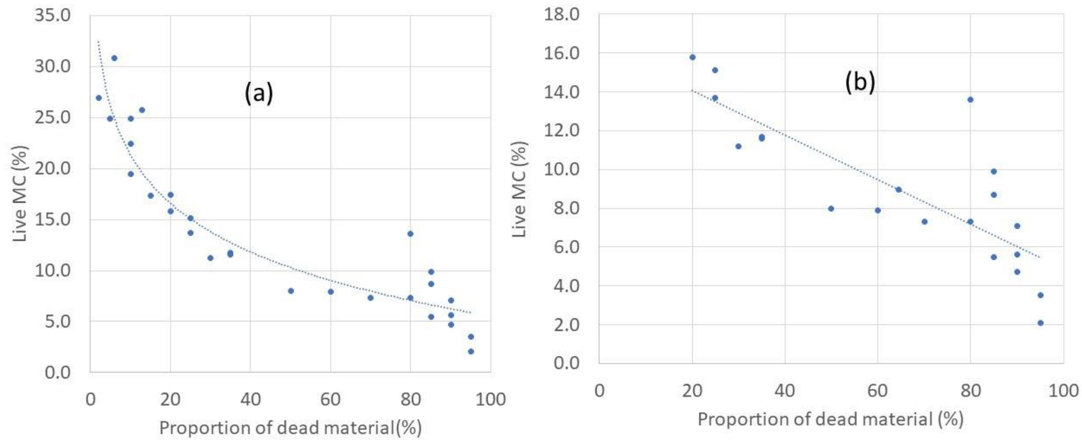


Figure 3: Relationship between the moisture content of 'live' spinifex clumps, and the proportion of dead material (volume) in the clump for (a) all meadows and (b) clumps with >25% dead material.

Soil moisture content

$AWRA_{RZ}$ and $SoilMC_{30}$

The relationship between $AWRA_{RZ}$ and soil profile moisture (0-30cm) was good, with an R^2 value of 0.74 (Figure 5a). The relationship is different to that developed from an earlier study by Burrows (the Wubin study). Differences are likely due to a number of reasons, including the current survey did not include the range of soil moisture / $AWAR_{RZ}$ / spinifex moisture conditions as the Wubin study. As can be seen from Figure 4a, most of the soils sampled in the current survey were 'dry'. Also, there may be differences due to soil and climate between the sites. The combined data (current survey and the earlier study by Burrows) and associated regression equation is shown in Figure 5b. It is encouraging that data from the current survey fit within the spread of data from previous surveys (Figure 4a).

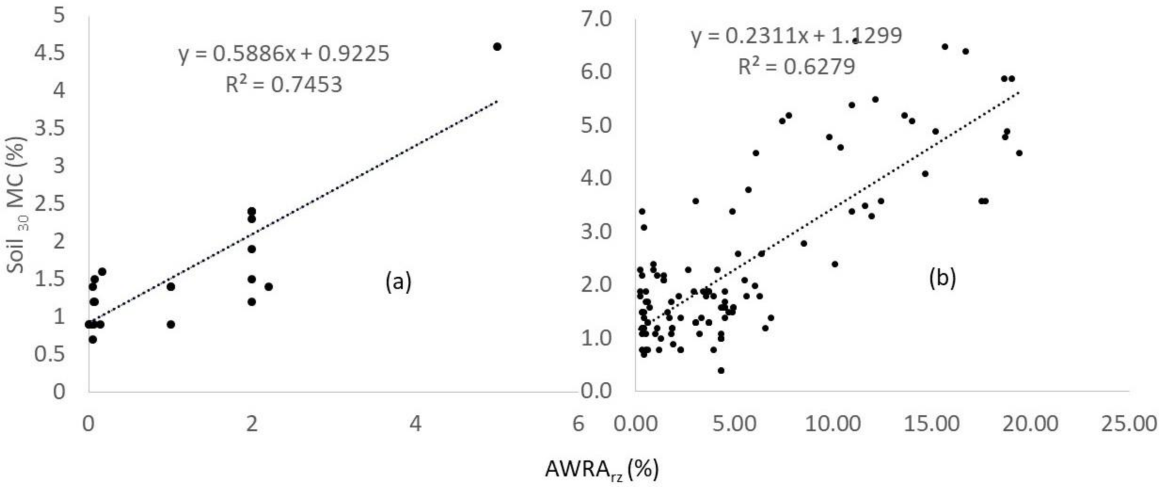


Figure 4: Relationship between profile soil moisture content (to 30 cm) and AWRA root zone moisture content for the current study (Fig. 4 a) and the combined data from previous surveys (Fig. 4b).

Finding 2

There is a fair to good relationship (based on R^2 values) between $AWRA_{RZ}$ and soil profile moisture content (0-30cm).

$SoilMC_{30}$ and live spinifex MC

After excluding meadows that were affected by drought from the analysis, there was a fair relationship between live spinifex clump moisture content and soil moisture content (Figure 5a). With the exception of one meadow that was 19 years since fire, all other meadows were 20+ years since fire, so had broadly similar proportions of dead material. The relationship in Figure 5a is similar in form to that for the earlier Wubin study. The combined data (this survey and Wubin study) are shown in Figure 5b. Note the slope and R^2 values are similar.

Finding 3

There is a fair relationship (R^2 = 0.65) between soil profile moisture content (0-30cm) and the moisture content of live spinifex clumps (controlling for the proportion of dead material in the clump).

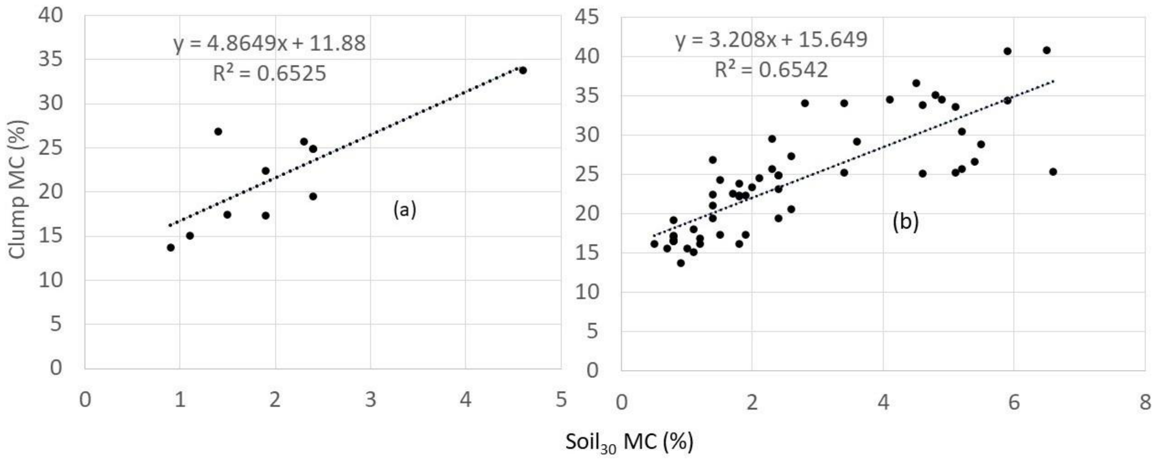


Figure 5: Relationship between soil profile moisture content (0-30 cm) and live spinifex clump moisture content (controlling for the proportion of dead material (fuel age/class)) for the current survey (5a) and the combined data from the current survey and the earlier Wubin longitudinal study (5b).

$AWRA_{RZ}$ and live spinifex MC

After excluding meadows that were affected by drought, there was a 'fair' relationship (R^2 = 0.55) between live spinifex clump moisture content and $AWRA_{RZ}$ (Figure 6a). As above, with the exception of one meadow that was 19 years since fire, all other meadows shown in Figure 6a were 20+ years since fire, so had broadly similar proportions of dead material by volume. The relationship in Figure 6a is broadly similar to that for the earlier Wubin study, although the slope of the regression is higher and the intercept lower. The combined data (Wubin data plus current survey data) are shown in Figure 6b. Combining the data has slightly changed the regression equation and slightly weakened the R^2 value from 0.64 (Wubin) to 0.60 (combined). Given the large regional difference in climate and soils, and the variation in the proportion of dead material in clumps between the sites, the limited moisture content / $AWRA_{RZ}$ range observed during this survey, the remoteness of the survey sites from weather stations, and the inherent shortcomings of the AWAR model, this difference is unsurprising. Nonetheless, the relationship is significant and 'fair'.

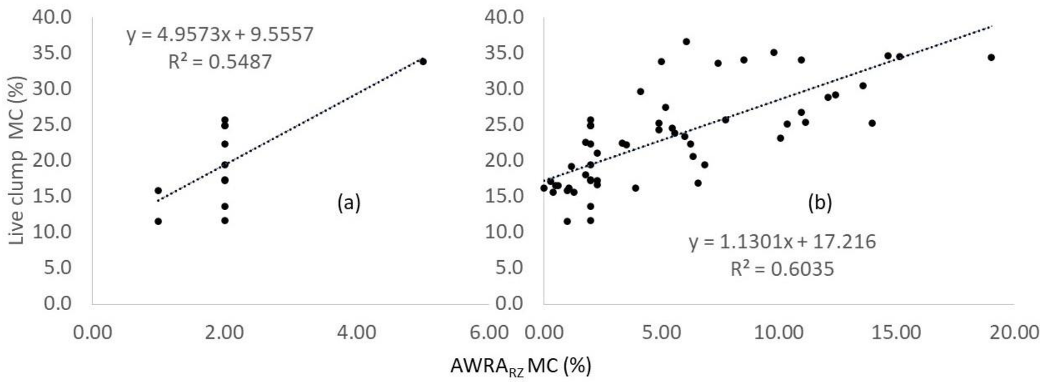


Figure 6: Relationship between AWRA$_{RZ}$ and live spinifex clump moisture content (controlling for the proportion of dead material (fuel age/class)) for the current survey (6a) and the combined data from the current survey and the earlier Wubin longitudinal study (6b).

Finding 4

There is a fair relationship ($R^2 = 0.55$) between AWRA$_{RZ}$ and the moisture content of live spinifex clumps (controlling for the proportion of dead material in the clump). Combining the survey data with the original Wubin data made a slight difference to the original (Wubin) regression equation and the R^2 value.

Predicted vs observed spinifex moisture content

The regression for predicting spinifex fuel moisture content from AWRA$_{RZ}$ developed from the Wubin study (see above) was used to predict the moisture content of live spinifex sampled in this survey. Drought affected meadows were excluded. Two analyses were undertaken. The first analysis (Figure 7a) compared predicted vs observed without adjusting for fuel class (dead material). The second analysis (Figure 7b) adjusted for fuel class using the equations shown above.

While there was a good correlation between observed and predicted moisture content for the unadjusted data ($R^2 = 0.72$, Figure 7a), the accuracy of predictions was poor – generally, the predictions under-estimated observed moisture content.

Adjusting the predictions to take account of dead material resulted in a weaker correlation between predicted and observed, but it increased the accuracy of predictions (Figure 7b) - predicted moisture content was consistently about 5-7% lower than observed (Figure 7b).

The caution here is that a) the current survey data were over a narrow range of soil / AWRA$_{RZ}$ / spinifex moisture content conditions and b) a single outlier (circled in Figure 7) had a significant influence on the correlation regression.

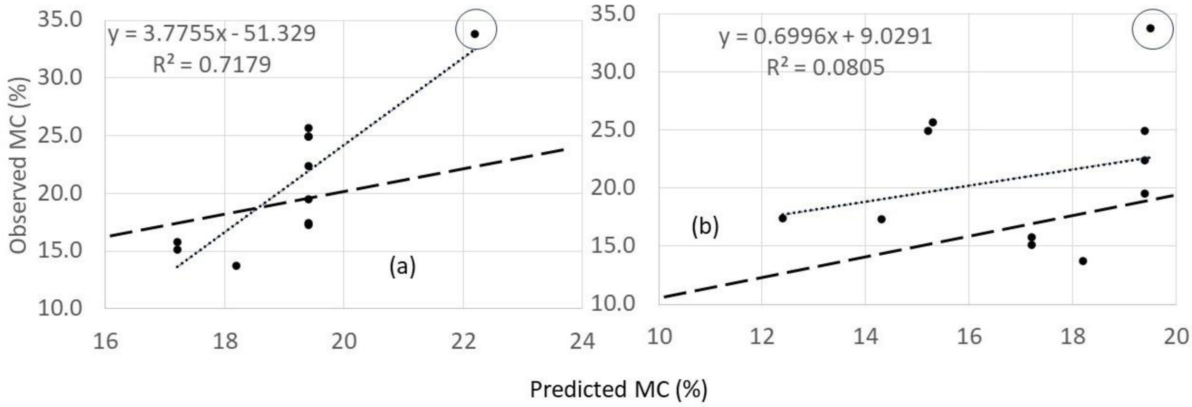


Figure 7: Predicted spinifex moisture content vs observed without adjusting for fuel class (dead material) (7a) and adjusting for fuel class (7b). Dotted line = regression, dashed line = perfect agreement. An outlier, which influenced the regressions, is circled.

Finding 5

While there was a good correlation between the unadjusted (for fuel class) predicted vs observed spinifex fuel moisture content, accuracy was poor. Because most meadows surveyed had been drought affected, the number of data points to make a comparison between observed vs predicted was low, which would have contributed to the poor accuracy. However, there is diversity of soils, climate and meadow structures across the range of spinifex grasslands, together with a paucity of weather observations and the inherent limitations of the $AWRA_{RZ}$ model, which would also contribute to the poor predictive capacity in this instance.

The encouraging outcome is that the current survey data fitted within the Wubin data scatterplot with little loss of regression 'goodness of fit' (Figure 6a).

Conclusions

This survey found:

1. The moisture content of spinifex meadows with a high proportion (by volume) of dead material, such as drought affected meadows, cannot be predicted from soil moisture content / $AWRA_{RZ}$.
2. There was a good relationship between soil profile moisture content (0-30 cm) and the $AWAR_{RZ}$ model.
3. There was a good relationship between soil moisture and the moisture content of 'live' spinifex when controlling for the proportion of dead material (volume <25%).
4. There was a good relationship between $AWRA_{RZ}$ and spinifex moisture content when controlling for the proportion of dead material (volume <25%).
5. However, the relationships between these variables developed from the longitudinal Wubin study, were different to the relationships developed from data collected during this survey. That is, the Wubin models were a poor predictor of the spinifex moisture content of meadows sampled during this survey. Possible reasons for this include the narrow range of conditions observed during this survey, and differences in regional climatic and edaphic factors. The spinifex species growing at the Wubin site (*Triodia desertorium*) is different to those sampled during this survey (*T. basedowii and T schinzii*), so may have a different physiology. Inherent limitations of the AWAR model, especially in remote areas such as the GVD, may also be a factor.

Recommendations

Notwithstanding the limitations described above, and in the absence of a better alternative, the $AWRA_{RZ}$ model for estimating the moisture content of spinifex meadows should continue to be used as an interim measure.

Because of the limitations of the $AWRA_{RZ}$ model demonstrated by this survey, it is recommended that the efficacy of remote sensing (high resolution satellite) to determine the Normalised Difference Vegetation Index (NDVI) as a tool for measuring the temporal and spatial variation in the moisture content (greenness) of spinifex meadows be explored.

It is recommended that a mini-workshop of remote sensing and spinifex fire behaviour specialists be convened to a) review the state-of-the-art of applying the NDVI to estimate the moisture content of spinifex meadows and to b) identify gaps in knowledge.

Acknowledgements

We thank Jackson Parker (DFES) for supporting this survey.

Appendix – survey sites

Sample#	Date	Time	Lat	Lon	YLB	Fuel class
1	12/09/23	1045	30.950	123.205	2007	4

Sample#	Date	Time	Lat	Lon	YLB	Fuel class
2	12/09/23	1420	30.662	123.496	2019	1

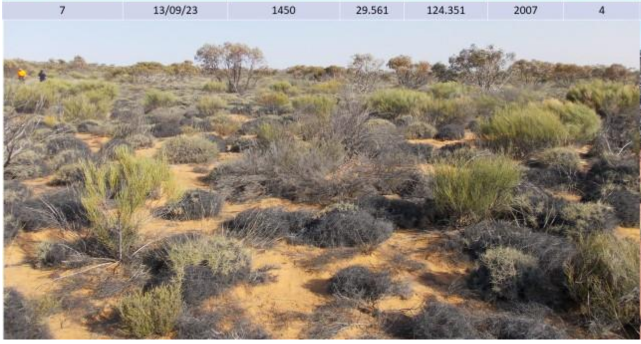
Sample#	Date	Time	Lat	Lon	YLB	Fuel class
3	12/09/23	1535	30.477	123.569	2007	4

Sample#	Date	Time	Lat	Lon	YLB	Fuel class
4	13/09/23	0930	30.090	123.685	2010	3

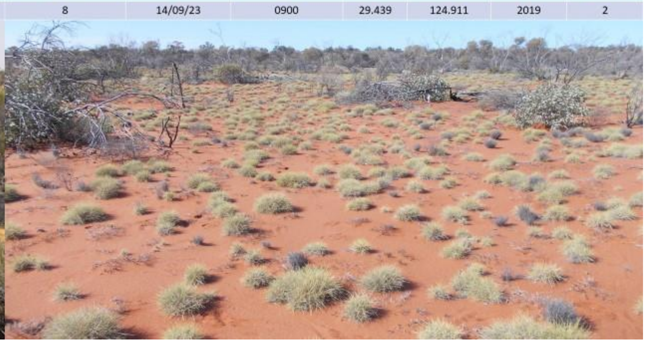
Sample#	Date	Time	Lat	Lon	YLB	Fuel class
5	12/09/23	1100	28.879	123.797	2017?	2

Sample#	Date	Time	Lat	Lon	YLB	Fuel class
6	13/09/23	1340	29.542	123.962	2012	3

Sample#	Date	Time	Lat	Lon	YLB	Fuel class
7	13/09/23	1450	29.561	124.351	2007	4

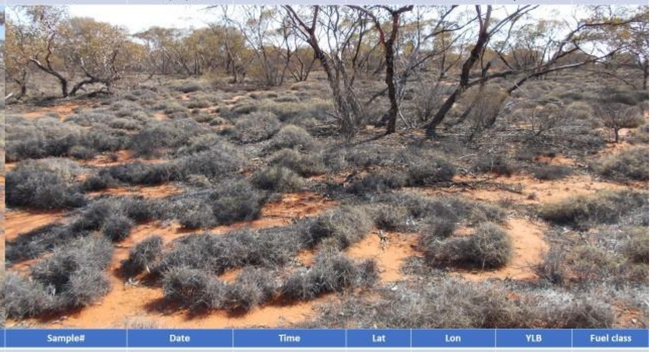


Sample#	Date	Time	Lat	Lon	YLB	Fuel class
8	14/09/23	0900	29.439	124.911	2019	2



Sample#	Date	Time	Lat	Lon	YLB	Fuel class
9	14/09/23	1035	29.190	124.670	pre2003	5

Sample#	Date	Time	Lat	Lon	YLB	Fuel class
10	14/09/23	1330	28.860	124.072	pre2003	5



Sample#	Date	Time	Lat	Lon	YLB	Fuel class
11	14/09/23	1430	28.923	124.933	Pre3002	5

Sample#	Date	Time	Lat	Lon	YLB	Fuel class
12	14/09/23	1520	28.922	125.013	Pre2003	4

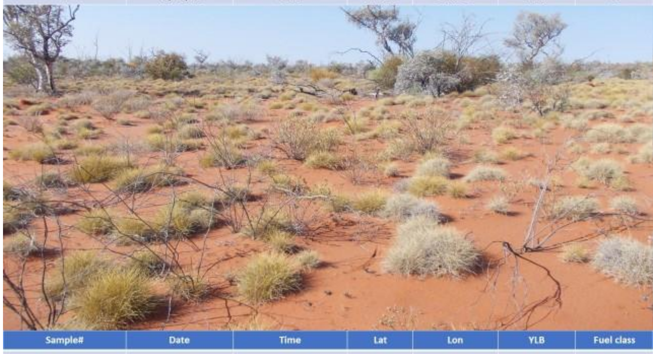
Sample#	Date	Time	Lat	Lon	YLB	Fuel class
13	15/09/23	0930	28.923	125.212	2009	2

Sample#	Date	Time	Lat	Lon	YLB	Fuel class
14	15/09/23	1040	28.922	125.042	2019	2

Sample#	Date	Time	Lat	Lon	YLB	Fuel class
15	15/09/23	1330	28.740	125.811	2007	5

Sample#	Date	Time	Lat	Lon	YLB	Fuel class
16	15/09/23	1430	28.376	125.675	pre2003	5

Sample#	Date	Time	Lat	Lon	YLB	Fuel class
17	16/09/23	0830	28.356	124.904	2017	2



Sample#	Date	Time	Lat	Lon	YLB	Fuel class
18	16/09/23	0938	28.177	124.602	2005	4

Sample#	Date	Time	Lat	Lon	YLB	Fuel class
19	17/09/23	1625	29.163	118.936	Pre2003	5

Sample#	Date	Time	Lat	Lon	YLB	Fuel class
20	17/09/23	1645	29.177	118.435	Pre2003	4

Sample#	Date	Time	Lat	Lon	YLB	Fuel class
21	19/09/23	0900	29.247	118.436	Pre2003	4

Sample#	Date	Time	Lat	Lon	YLB	Fuel class
22	18/09/23	0940	29.465	118.473	Pre2003	5

Sample#	Date	Time	Lat	Lon	YLB	Fuel class
23	18/09/23	1535	29.283	117.620	Pre2003	5

Sample#	Date	Time	Lat	Lon	YLB	Fuel class
24	18/09/23	1605	29.284	117.511	Pre2003	5

Sample#	Date	Time	Lat	Lon	YLB	Fuel class
25	19/09/23	1005	29.830	116.954	2004	3