Background briefings on emerging issues for fire managers from AFAC and Bushfire CRC.

bushfire CRC afac

FIRE NOTE

ISSUE 66 SEPTEMBER 2010

FIRE DYNAMICS IN MALLEE-HEATH

SUMMARY

This research focused on characterising fuel dynamics and fire behaviour characteristics in South Australian semi-arid mallee-heath fuels. An experimental burning program was carried out in the Ngarkat Conservation Park, SA, to develop the base data from which a new model system describing fire behaviour in mallee-heath fuels was developed. The system describes fire characteristics commonly required by fire managers in semi-arid environments, namely: fire sustainability (go/no-go thresholds), rate of fire spread, flame front characteristics, the onset and propagation of active crown fires and associated spotting activity. The models have particular relevance in planning and conducting prescribed fire operations, leading to a more effective and safe use of available resources.

ABOUT THIS FIRE NOTE

This is a summary of the research conducted as part of Project A1.1: Fire Behaviour Modelling, and is part of Bushfire CRC Program A: Safe Prevention, Preparation and Suppression.

The authors: Miguel Cruz (right) and Jim Gould, CSIRO Ecosystem Sciences and Climate Adaptation Flagship, Canberra.

CONTEXT

Knowledge of the fire behaviour potential associated with a specific fire scenario (fuels, weather, topography) is key to a variety of fire management actions. The accurate and comprehensive prediction of fire behaviour potential is critical for (1) improving assessment for bushfire hazards and risks; (2) supporting bushfire suppression tactics and strategies; (3) designing and comparing fuel treatments and outcomes; and (4) prioritising fuel treatment and response options.

BACKGROUND

Mallee-heath vegetation in semi-arid and Mediterranean climates develops a vertically non-uniform and spatially discontinuous fuel complex. The heterogeneity of the fuel layers sustaining fire propagation leads to fire behaviour characterised by nonlinear dynamics where small changes in the drivers of fire spread lead to large changes in observed fire behaviour. These sudden changes in fire spread and intensity are associated with the fire transitioning between different fuel strata (litter and near surface → elevated → overstorey) and the onset of fire dependent mechanisms such as spotting phenomena. As such, fire behaviour in mallee-heath fuels is not just a function of fuels and weather, but to a large extent determined by the interactions between those variables and the structure of the flame front. Current fire behaviour models available to fire managers do not incorporate these features, hence failing to adequately describe fire potential in mallee-heath fuel complexes. Furthermore, current models do not describe the fire characteristics necessary to understand the effects of fire on ecosystem components, limiting the linkages between fire behaviour components of a fire prescription and the expected impacts in soil, water, flora, fauna and air quality.

BUSHFIRE CRC RESEARCH

To develop a model system that would allow accurate predictions of prescribed fire behaviour in mallee-heath fuel complexes the study focused on four main research subjects:

- To quantify how fuel structures change with time since fire in mallee-heath

END USER STATEMENT

"It has been known for some time that fires burning in mallee fuels behave very differently to forest and grassland fuels. A particular problem has been predicting when fires will actually burn and spread in these discontinuous fuels. South Australia alone has some 120,000 km^2 of mallee vegetation (almost half of the total area in Australia). It is hoped this work will provide fire managers of mallee vegetation with fire behaviour models for both rate of spread, and more importantly the window of sustained burning for this extensive fuel type. These tools will be essential to effectively conduct prescribed burning in mallee."

– Mike Wouters, Department of Environment and Natural Resources (DENR), SA

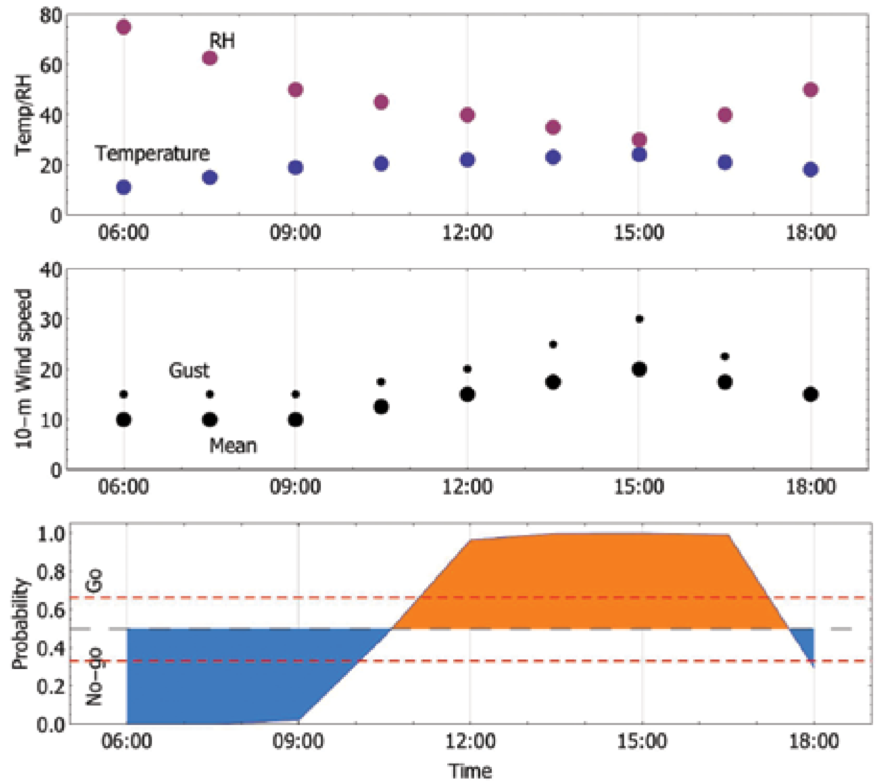
vegetation types and its effect on fire behaviour.

- To quantify how weather variables and vegetation type influence within-stand micro-climate and determine diurnal and seasonal dead fuel moisture cycles.
- To characterise the effect of vegetation structure in determining the vertical wind speed profile.
- To quantify and develop functional relationships that describe the effect of fuel, weather and fire dependent processes on fire behaviour.

Experimental design

In collaboration with the South Australian Department for Environment and Heritage, an experimental site characterised by a mosaic of fuel ages and types (mallee-heath vs. pure heath) was selected within the Ngarkat Conservation Park, South Australia. The variety of fuel complex structures available in the experimental area allowed for the characterization of fuel changes after fire and the effect of fuel complex structure on fire behaviour.

- Fuel structure was characterized at a plot basis relying on destructive and visual assessment methods.
- A total of 67 experimental fires were conducted in plots ranging from 1 to 6 ha in size under a wide range of burning conditions. A number of plots were burned within Very High Forest Fire Danger Rating (35< FFDI<50) conditions to capture data representative of typical wildfire burning environment. Dead fuel moisture contents and 10-m open wind speed varied respectively between 2 – 20% and 2 – 24 km/h.



▲ **Figure 1:** An example of integration of forecasted diurnal fire weather data (top two graphs) to pinpoint ideal burning period for prescribed burning operations (bottom graph). The fire sustainability model (or go/no-go model) integrates standard weather data and fuel complex characteristics to determine under which condition fire will successfully spread. In the bottom graph the orange area identifies the period when the probability of sustained propagation is >0.5 (i.e. 50%).

- Fire behaviour ranged from self-extinguishing fires to sustained active crown fire propagation. Rates of spread in sustained fires ranged from 0.2 to 3.5 km/h.

Modelling

To model the full range of fire behaviour characteristics relevant to fire managers a number of distinct modelling approaches were used. Particular attention was given to develop models that could be readily applied by users with basic fuel type and weather information. The needs of potential model users located in distinct work environments were taken into consideration. Specific models were developed bearing in mind the data available to users in a field versus office situation.

RESEARCH OUTCOMES

Fuels

- Mallee-heath fuel complexes are made of discrete fuel layers with distinct dynamics. Three main fuel layers, near-surface, elevated and overstorey, were identified as relevant for fire behaviour prediction. A succession of fuel layer dominance with time was identified. The initial prevalence of near-surface fuels in the first years after fire is followed by a dominance of the elevated fuel layer at an approximate age of 10-years. As the mallee stand matures the overstorey layer reaches an asymptotic coverage level and load stage and the lower layers decline in relevance. This dynamic is approximate and dependent on edaphoclimatic conditions and relative short-scale climatic cycles.
- Low fuel coverage and load were identified as the main fuel characteristics limiting fire propagation in mallee-heath. Average fuel loads were typically low, varying between five and seven tonnes/ha. Fuel structure was similar to what found in similar fuel complexes in previous studies in Victoria and New South Wales.
- Visual Hazard Scores (Gould et al. 2007) varied between Low to Moderate for the near-surface and elevated fuel layers and Nil to Low for litter and overstorey layers.

Fuel moisture

- Fuel moisture regimes at Ngarkat were similar to those that have been observed in similar vegetation in other parts of Australia (McCaw et al. 1995). The sparse canopy of both mallee and heath contributed to very low fuel moisture contents on sunny days.
- The difference between litter and

FIRE IN MALLEE-HEATH FUELS

Range in fire behaviour observed in mallee-heath experimental fires. **Top-left:** Break-up of flame front in discontinuous heath vegetation under marginal burning conditions; **Top-right:** Marginal propagation in mallee litter; **Bottom-left:** Moderate intensity, fast spreading fire in heath fuels; **Bottom-right:** High intensity experimental fire in mallee-heath fuels (mallee clump height 2.5 - 3 m).

suspended fuel moisture varied depending on time of day, with litter fuel 3-4% drier than suspended fuel at midday. After rainfall, litter fuels remained damp for longer periods than suspended fuels. During burning conditions heath fuels were approximately 1% drier than mallee fuels.

- During dry conditions fuel moisture can by determined by relative humidity, air temperature, solar radiation, and fuel type. In the absence of rain as a variable simple nomogram models or tables are just as accurate as a full process-based model.

Wind speed profile

- The effect of stand structure in reducing the wind speed impinging on the surface fire flames was seen as an important variable determining fire sustainability. Wind speed profiles in mallee and heath fuel types were quantified and wind reduction factors determined allowing converting 10-m open wind speed into eye-level or mid-flame wind speeds. In Mallee stands wind reduction factors varied between 0.6 in young fuels (< 2 m tall clumps) and 0.33 in mature stands (clump height >4 m).

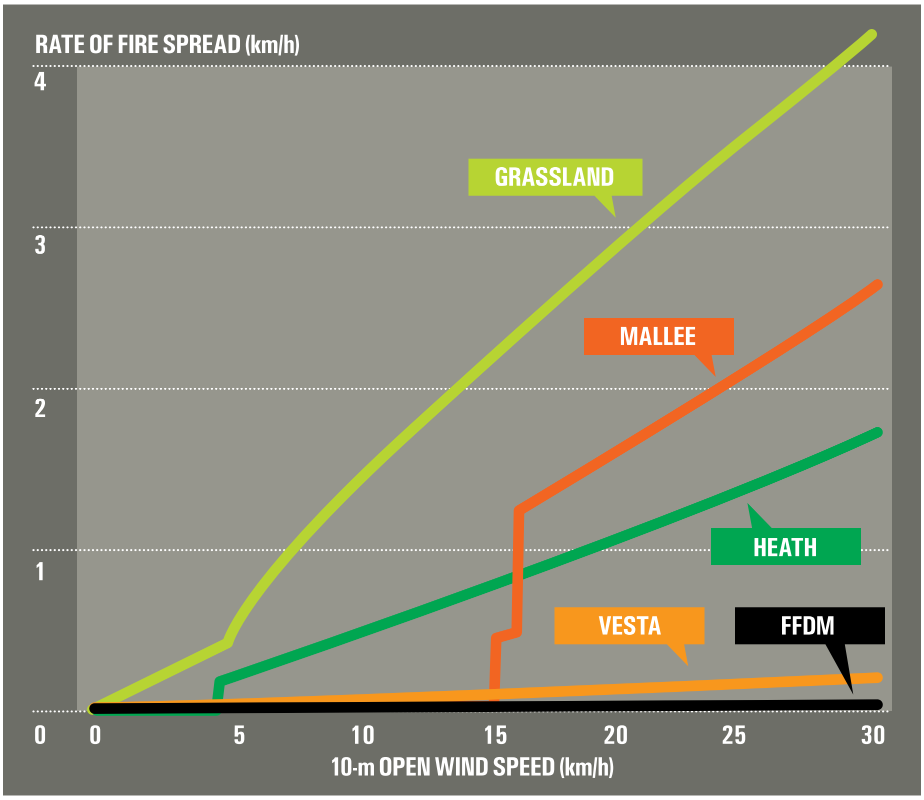
Fire behaviour

- Fire behaviour in mallee-heath was characterised as highly discontinuous with three stages of fire potential: failure to spread; sustained surface fire propagation and active crown fire propagation.
- Dead fuel moisture content was the most significant variable determining the likelihood of sustained propagation. Threshold moisture contents for sustained propagations were lower in mallee than in heath fuels. The effect of an increase in moisture content in reducing the likelihood of fire propagation can be offset by an increase in wind speed for suspended dead fuel moisture contents <16%. For suspended dead fuel moisture content above 16% fire is highly unlikely to spread.
- Wind speed was the variable that best explained the variation in surface fire rate of spread and the onset of active crown fire propagation.
- The near-surface fuel layer was the principal fuel layer influencing the onset of sustained propagation, but once a sustained flame front developed it had no significant effect on the rate of fire spread.
- The rate of surface fire spread was linked to elevated fuel layer descriptors, namely percent cover score (PCS) and fuel hazard score (FHS).
- Flames tended to be deep at the head of the fire but shallow at the flanks. Flame residence time varied between 20 seconds in young sparce fuels and 2 minutes in the accumulated litter under mature mallee clumps.
- Crowning and spotting were identified as fire-dependent phenomena associated with high intensity propagation. Active crown fire propagation will occur in mature mallee stands when 10-m open wind speeds are greater than 20 km/h and suspended dead fuel moisture content is less than 8%. This is accompanied by extensive short distance spotting that allows the fire to maintain high rates of spread and breach areas of fuel discontinuity. The onset of crowning is associated with a sudden and significant increase in the fire rate of spread.

Fire behaviour prediction in mallee-heath fuels

The researchers developed a model system to describe fire behaviour in South Australia semi-arid mallee-heath fuel types. The system is most applicable to prescribed fire burning conditions in mallee-heath fuels, and extending into Very High to Extreme Fire Danger Rating classes. The system integrates a series of models aimed at predicting various fire characteristics required by fire managers to plan and conduct prescribed burns. The system comprises the following sub models:

- Likelihood of sustained fire propagation (go/no-go model).



▲ **Figure 2:** Comparison of potential rate of spread as function of wind speed for mallee-heath fuel complexes with outputs from natural grassland (Cheney et al. 1998) and forest fire spread models (McArthur 1967, Gould et al. 2007). Graph shows the specificity of fire behaviour in mallee-heath when compared with other fuel types, namely dry sclerophyll eucalypt forest. Simulation for 20-year old mallee and heath fuels with suspended dead fuel moisture fixed at 11%). Forest fire behaviour models are not appropriate to support fire management decision-making in mallee-heath vegetation. The sudden changes in rate of spread observed in the graph for the heath and mallee fuels are related to the onset of sustained surface fire (first step in both mallee and heath simulations) and development of active crown fire propagation (second step in mallee vegetation).

- Rate of spread of a surface fire (modelled separately for pure heath and mallee-heath stands).
- Likelihood of crown fire propagation (applicable to mallee-heath stands).
- Rate of spread of an active crown fire in mallee fuels.
- Flame height and length models.

The model system has most application in developing burn prescriptions, support the development of burn plans, optimise the allocation of suppression resources prior to ignition and support decision-making during the execution of prescribed burns.

The integration of flame characteristics, such as expected residence time and flame dimensions, with information on mallee-heath species response to fire will allow integrating a fire effects component in the fire prescription.

HOW IS THE RESEARCH BEING USED or HOW COULD IT BE USED?

Meeting societal goals for sustainable semi-arid ecosystems where fire has played an historic role requires management and planning based on the best available biological, and physical science. The knowledge and models developed from this project provide an essential foundation for developing integrated approaches to consider the effects of fires on ecosystems functions, landscape patterns, and fire management practices. Also, the fire behaviour system for mallee-heath fuels provides a better understanding of fire weather and behaviour into tools to improve the efficiency and effectiveness of fire and fuel management decisions and will lead to enhancement in public safety and ecosystems sustainability.

REFERENCES/FURTHER READING

Cheney, N.P., Gould, J.S., Catchpole, W.R. 1998. Prediction of fire spread in grasslands. Int. J. Wildland Fire 8(1):1-15.

Cruz M.G., Matthews, S., Gould, J., Ellis, P. Henderson, M. Knight, I., Watters, J. 2010. Fire dynamics in mallee-heath: fuel, weather and fire behaviour prediction in south Australian semi-arid shrublands. Bushfire CRC report A.10.01.

Gould JS, McCaw WL, Cheney NP, Ellis PF, Knight IK, Sullivan AL (2007a) 'Project Vesta : fire in dry eucalypt forest fuel structure, fuel dynamics and fire behaviour.' (Ensis-CSIRO, Canberra ACT, and Department of Environment and Conservation, Perth WA)

McArthur, A.G. 1967. Fire Behaviour in Eucalyptus Forests. Commonwealth of Australia, Dep. Nat. Devel., Forest and Timber Bureau, Canberra, Leaflet107, 36 p.

McCaw, W.L.; Burrows, N.D.; Friend, G.R.; Gill, A.M. 1995. Predicting fire spread in Western Australian mallee-heath. In: Proceedings, Landscape Fires '93: Proceedings of an Australian Bushfire Conference, Perth, Western Australia. 27- 29 September 1993. CALM Science, No. 4 Supplement: 35-42.

Bushfire Cooperative Research Centre
Level 5/340 Albert Street
East Melbourne VIC 3002
Telephone: 03 9412 9600
www.bushfirecrc.com

Bushfire CRC is a national research centre in the Cooperative Research Centre (CRC) program, formed in partnership with fire and land management agencies in 2003 to undertake end-user focused research. Bushfire CRC Limited ABN: 71 103 943 755

Australasian Fire and Emergency Service Authorities Council
Level 5/340 Albert Street
East Melbourne VIC 3002
Telephone: 03 9418 2388
www.afac.com.au

AFAC is the peak representative body for fire, emergency services and land management agencies in the Australasia region. It was established in 1993 and has 26 full and 10 affiliate members.