Visual assessment of fuel for fire behaviour prediction

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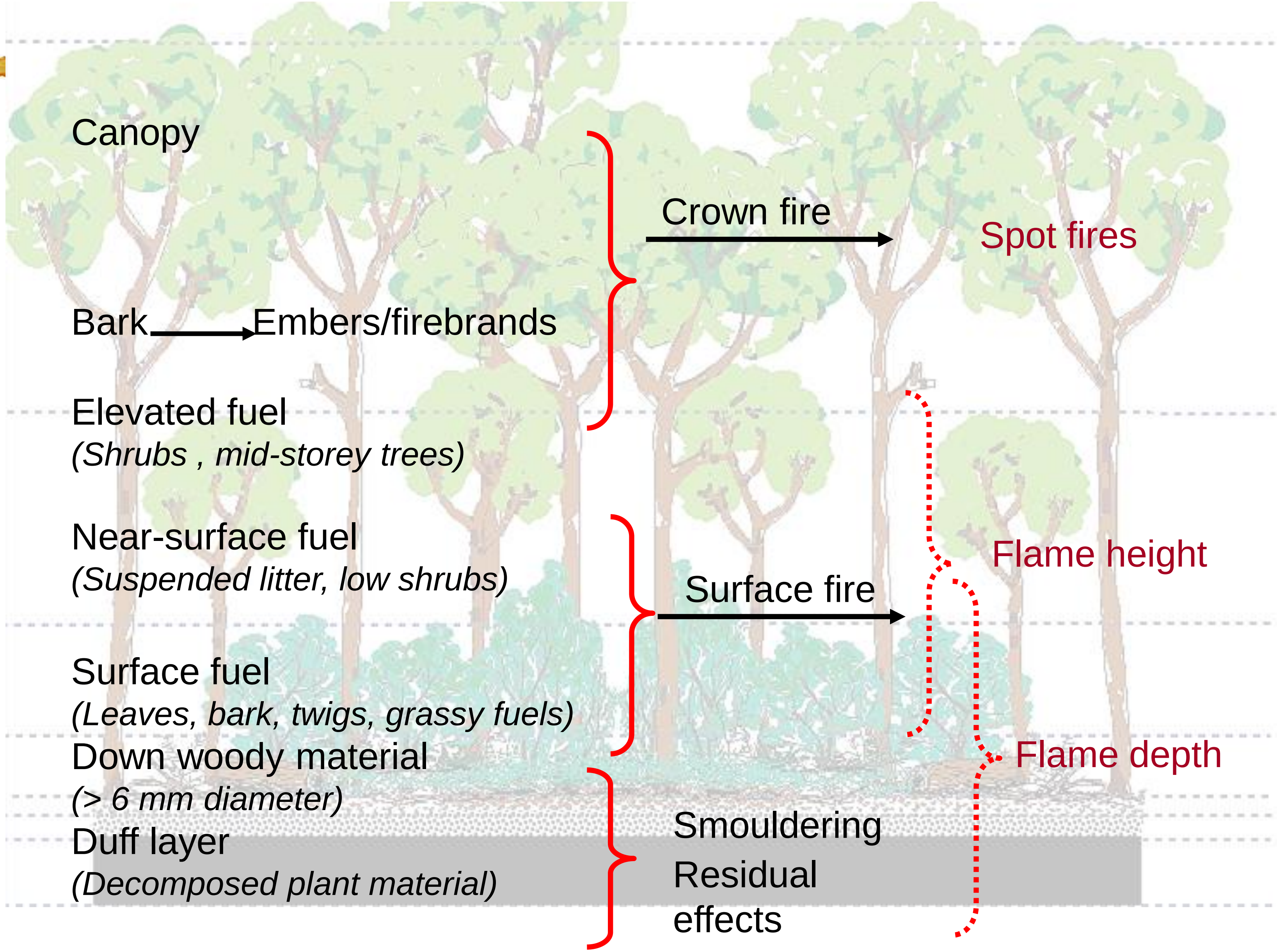
Outline

- Fuel – contribution to fire behaviour
- Fuel attributes & dynamics
- Fuel load as an input to predict fire behaviour
- Concept of fuel hazard
- Using fuel hazard to predict fire behaviour
- Practical applications
- Issues for further thought

Fuel – contribution to fire behaviour

- Rate of spread and intensity of bushfires
- Suppression difficulty at different stages of fuel development, and associated resource requirements
- Relative bushfire threat & hazard of different vegetation types
- Frequency and effectiveness and frequency of hazard reduction treatment

Fuel layers and fire behaviour




Near-surface Fuel

Physical attributes of fuel

- Thickness of fuel elements

- Degree of horizontal and vertical continuity

- Proportion of dead fine fuel in the fuel bed

- Height of the most continuous fuel stratum

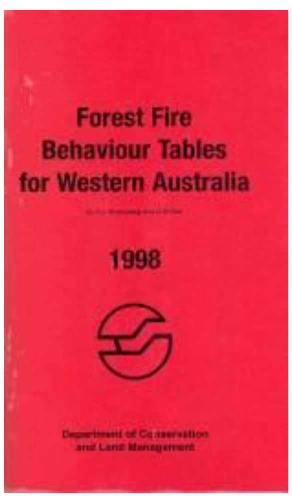
Fuel dynamics

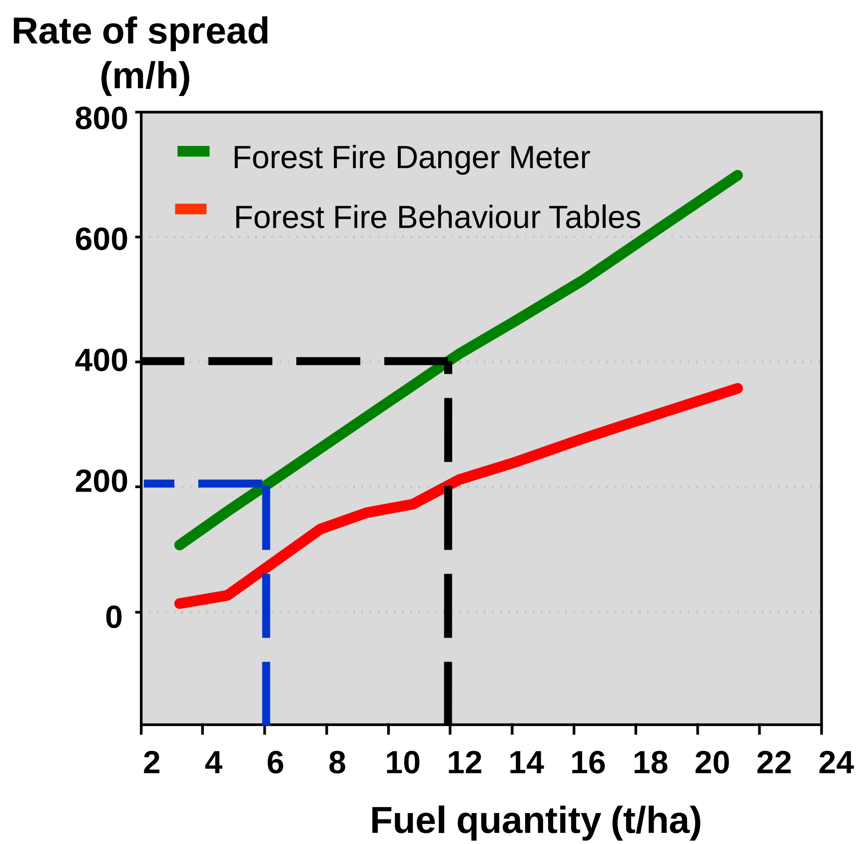
Fuel is dynamic and changes with time:

- Loading changes with time since fire, and may depend on severity of last fire
- Volume of space occupied both horizontally and vertically (structure)
- Proportion of fine and coarse fuel
- Proportion of live and dead fine fuel

Fuel load as an input to fire behaviour prediction

- Fuel load is sole fuel input to fire behaviour guides developed for eucalypt forest in the 1960s
- Double the fuel load = double the rate of spread

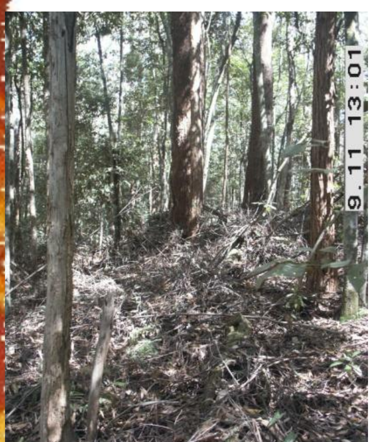




Concept of fuel hazard

- Fuel hazard reflects '*the current condition of the fuel and takes into consideration such factors as quantity, arrangement, current or potential flammability and the difficulty of suppression if fuel should be ignited*' Wilson (1992a) & subsequent
- Hazard is assigned a categorical rating (Low-Extreme), a numerical hazard score (Vesta) or both
- Correlated with fuel load but not an exact fit
- Linked to probability of initial attack success for a defined set of conditions and resource level

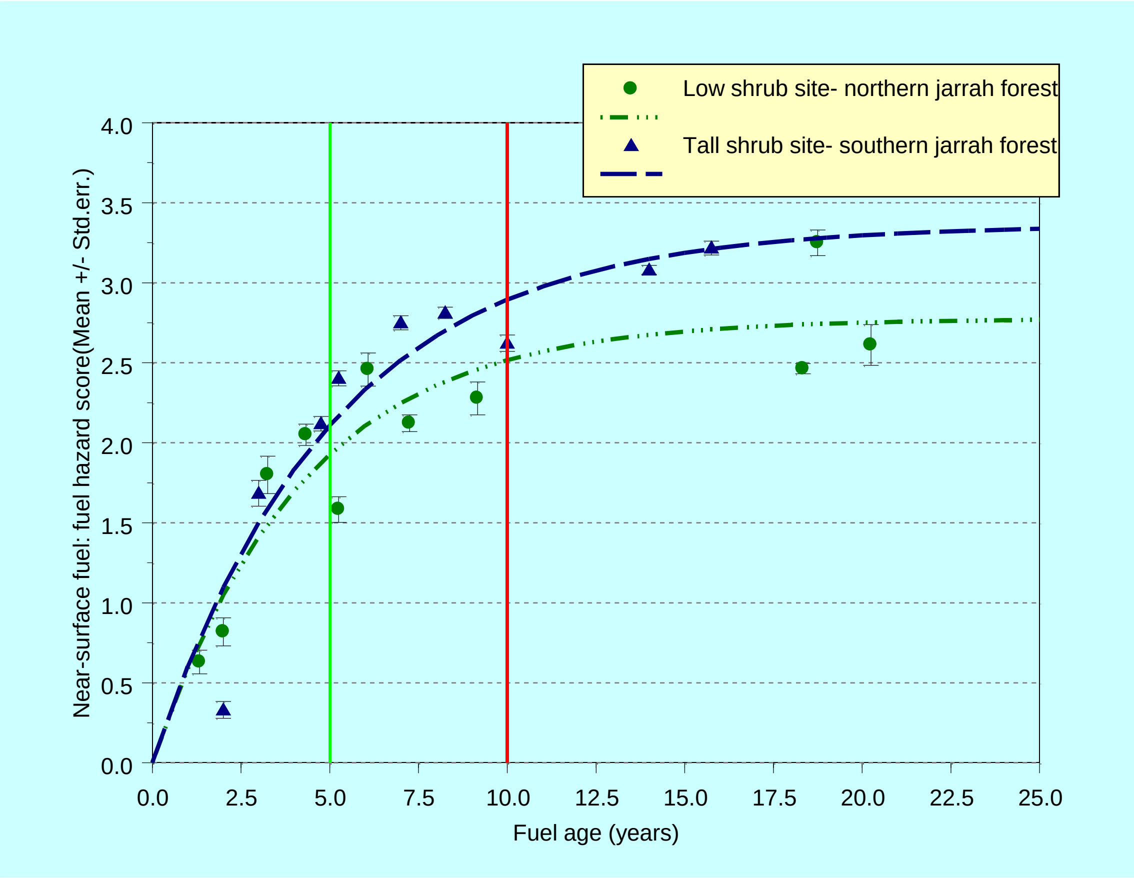
Near-surface fuel layer (NSF)



Hazard Rating	Description	Hazard Score	Available fuel (t/ha)
Nil	No near-surface fuel	**0**	0
Low	Sparse dispersed fuel, dead material virtually absent	**1**	1
Moderate	Scattered suspended leaves, twigs & bark, proportion of dead material is <20%	**2**	2
High	Scattered suspended leaves, twigs & bark, starting to obscure logs & rocks, proportion of dead material is 20-50%	**3**	3
Very High	Lots of leaves and bark suspended, 40-60% cover in the 5 m radius	**3.5**	3.5
Extreme	Large amounts of leaves, twigs & bark suspend I the layer, high proportion of dead material >50%, vegetation is senescent, obscuring logs & rocks	**4**	4

Trend in fuel hazard over time

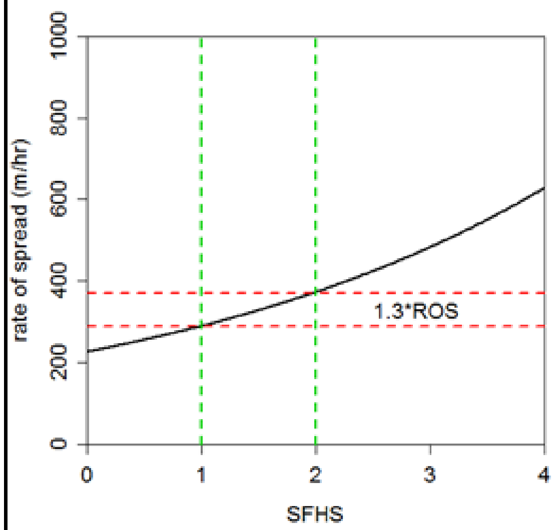
Near-surface fuel layer



Considerations for visual fuel hazard rating

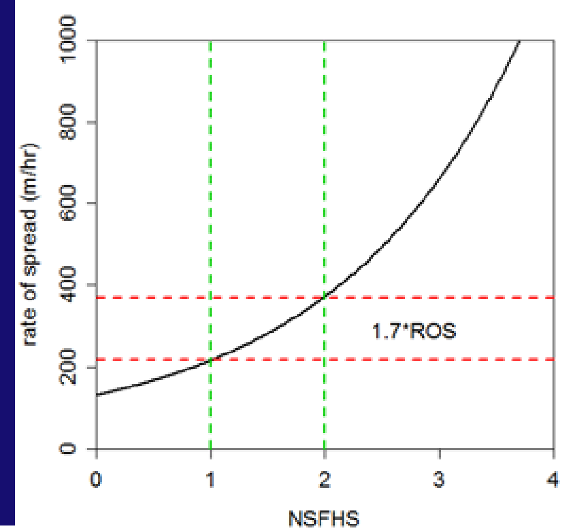
- Desirable attributes of the methodology:
  - outputs meaningful to the user
  - system is easy to apply in the field
- Rating needs to reflect the full potential range of hazard for the fuel type
- Numerous interconnections and interdependencies, hence a need for
  - consistency in application
  - training (study by Watson *et al*. 2012)

Relative influence of different fuel atttributes – dry eucalypt forest

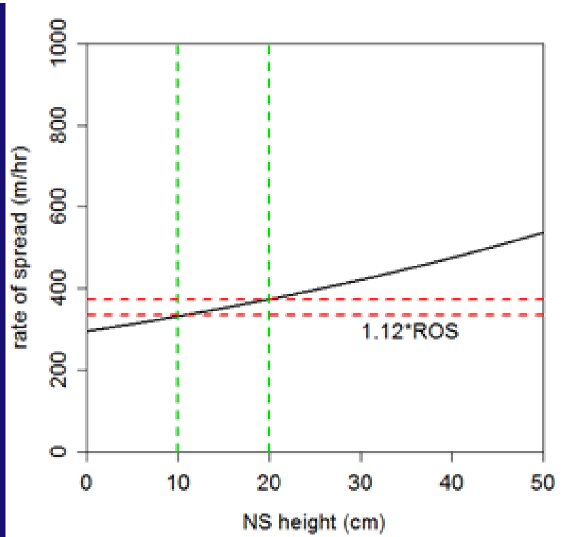


Near Surface Hazard Score

Surface Hazard Score



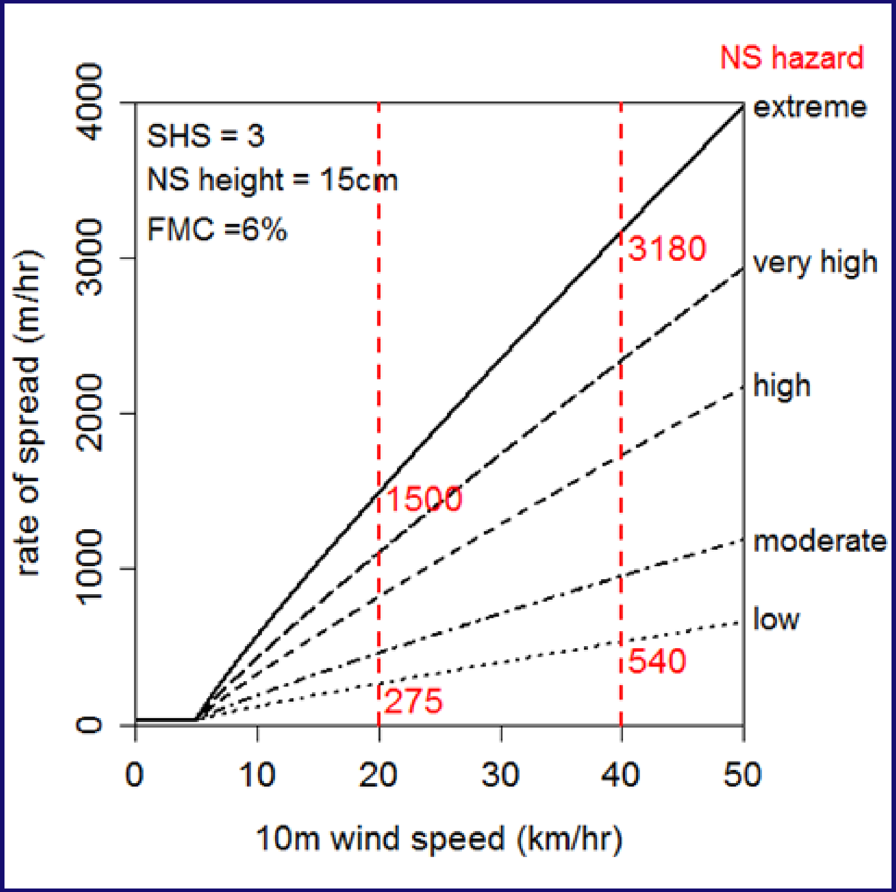
Fuel moisture 6%
Wind speed 20km/h



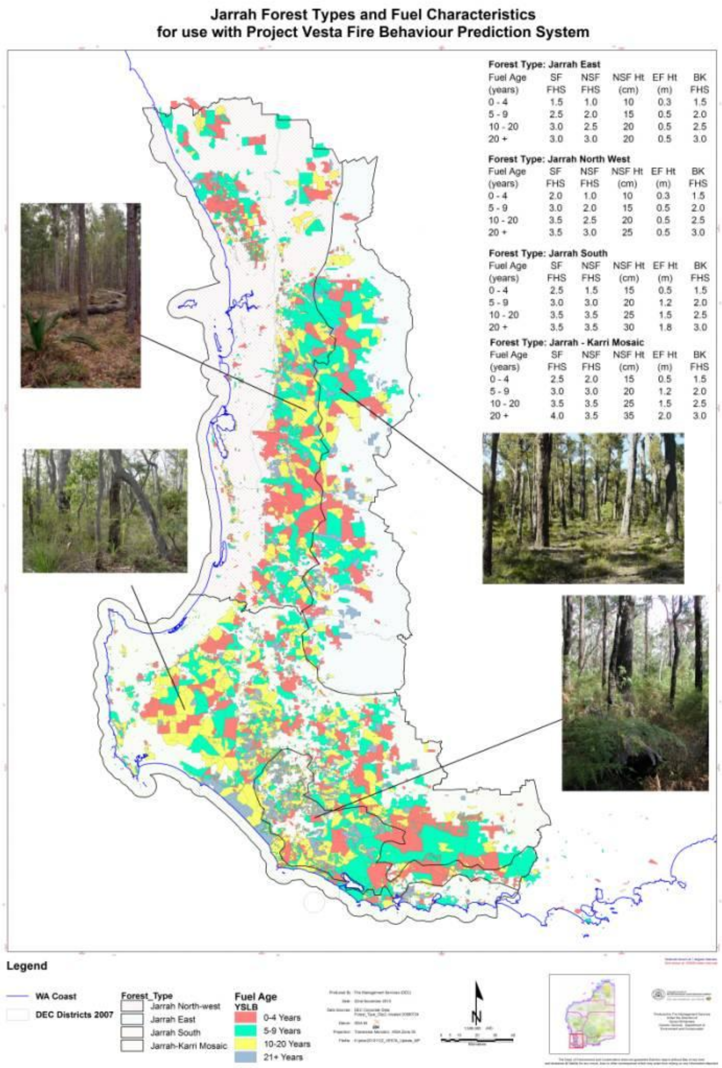
Near Surface Height

Sensitivity of fire behaviour to fuel inputs

Effect of NS Hazard Score



Practical applications



- Fuel hazard can be estimated from vegetation type and fire history, subject to field validation
- Default values provide a basis for fire behaviour prediction in the initial stages of an incident

EGLO 03 (1R): Late Rotation (7-10+ years)

Eight year old blue gum fuels

Extended rotation (10+) blue gum fuels

Fuel accumulations in an extended rotation blue gum plantation are increasingly dominated by twig, bark and leaf litter, with significant suspended bark

Typical stand characteristics

Stand density (trees/ha)	> 1000	Indicative Stand height (m)	7 year old: 16+ metres (green crown base 9 – 10 m) 8 year old: 18+ metres (green crown base 12+ m) 9+ year old: 20+ metres (green crown base 15+ m)
Row spacing (m)	3 - 4m		
Planting interval (m)	~ 2.5m		

EGLO 03 (1R): Late Rotation (7-10+ years)

Fuels

[SF = Surface Fuel; NSF = Near Surface Fuel; EF = Elevated Fuel]

Litter continues to accumulate with leaf fall supplemented by annual bark shedding, and fallen twigs/branches. Larger branches (>6mm) contribute coarse fuels to the surface layer.

SF Moderate – High . Litter deposition continues at the rate of around 1 to 2 t/ha annually, typically reaching around 10 - 12 t/ha by age 10. In high productivity sites, fuel loads can be substantially higher (reaching the Very High range)[2]. Fuels are typically heaviest along the rows (High to Very High) and lightest between the rows (Moderate to High).

NSF: Typically low in inter-rows, but can be Moderate to High around tree bases in planted rows, particularly in plantations at or near harvestable age. Bark ribbons may be suspended on lower trunk and building up around base.

EF: Stems retain significant quantities of 6 to 25 mm dead branches/stubs and ribbons of shed bark suspended on stems held by branch stubs.

Bark: Annual bark shed becomes a significant contributor to fuel loads, particularly around the base of trees. Some shed bark remains suspended from lower dead branches/stubs. Loosely held suspended bark becomes a source for short distance spotting.

Notes:

In drought affected seasons the full litter profile is typically available to burn.

2 Unpublished data CSIRO 2011

Fire Behaviour

In dry conditions, fire is likely to spread readily in 7 to 10+ year old plantations due to the presence of continuous litter fuels.

Surface fuels in the late stage of pulpwood blue gum plantations are sufficient in quantity and continuity to carry moderate to high intensity fires.

Under **Low to High** FDR conditions fire is likely to spread as a surface fire and may produce significant scorch and tree mortality.

Under **Very High** FDR conditions, a vigorous surface fire is likely with significant probability of torching and intermittent crowning (sustained crowning possible on upslope areas).

Under **Severe to Catastrophic** FDR conditions, surface fires will be vigorous with a high probability of intermittent or sustained crown fire development. Moderate to long distance spotting may occur.

There have been several examples where fires in blue gum plantations older than 8 yrs have burnt at moderate to high intensity and have been difficult to suppress, even though fire danger conditions have only been High. These fires have resulted in large areas of complete crown scorch of trees more than 20m tall, and in some instances torching of individual trees or crowning of patches up to 1 ha in area. Spotting distances are sufficient that breaching 10m wide firebreaks is likely under High FDR, and likely to breach firebreaks of 50m or more under Very High to Catastrophic FDR.

Experimental fires in 8 year old blue gum plantations in WA under mild weather conditions (mean wind speed <3 km/h, Temp 18 – 26^{o}C, and RH 32 – 50%) produced fires which sustained their forward spread (at 73 to 140 m/hr), causing significant scorch and tree mortality particularly among the smaller trees.

PRAD 02: Second Rotation – Unpruned (4-8 years)

Fuels
[SF = Surface Fuel; NSF = Near Surface Fuel; EF = Elevated Fuel]

SF: Low to moderate – mostly grazed or ungrazed shade-suppressed grass in inter-rows
- Duff layer absent in 1R sites
- Needle litter incipient under trees; grass in inter-rows

NSF: Standing grass and possibly shrubs/bracken in inter-row spaces. Lower branches of pines becoming prominent in NSF layer. Prior to crown closure, lower branches may be green, but progressively die with progress toward crown closure. PRAD 02 stands typically retain dead needles on dead lower branches

EF (ladder fuels): Continuous dead fine fuels from ground to bottom of live crown in planted rows.

Photo:

Unpruned section of a 7 year old radiata pine plantation on second rotation site of moderate-high site productivity.

Stand / fuel characteristic	Min	Max
Stand density (t/ha)	1400	1600
Stand height (m)	7	12
Canopy base height (m)	0.1	0.5
Litter fuel load (t/ha)	2	4
Duff fuel load (t/ha)	0	0
Woody fuel load (t/ha)	0	0
Canopy fuel load (t/ha)	10	12
Ladder fuel load (t/ha)	1	3
Silviculture	Unpruned	

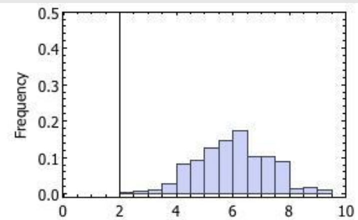
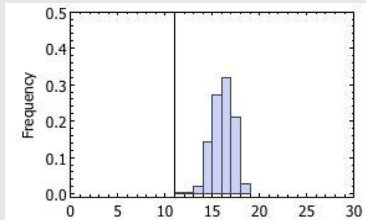
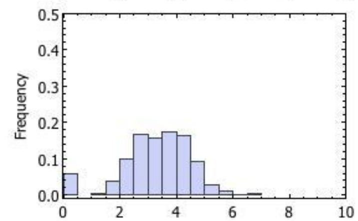
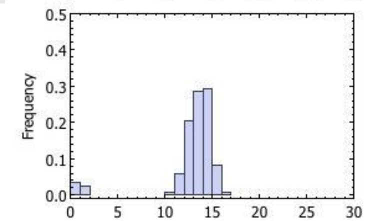
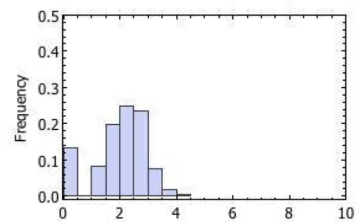
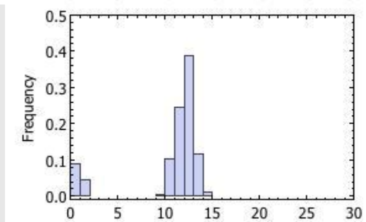
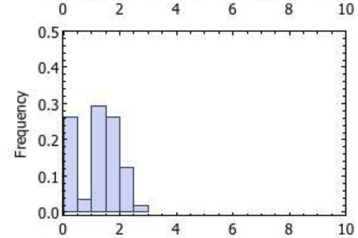
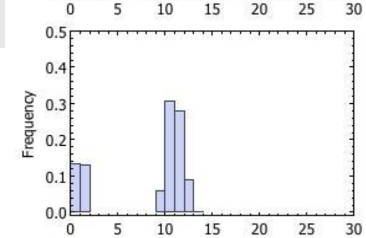
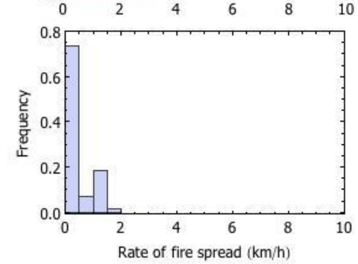
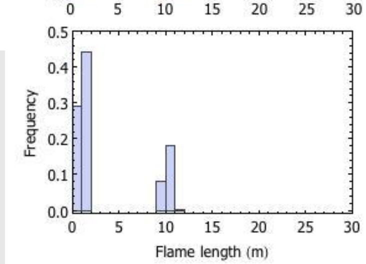
PRAD 02: Second Rotation – Unpruned (4-8 years)

Fire Behaviour

- Fire behaviour is highly dependent on inter-row fuel condition, and the extent of pine occupation of the site
- Even at Moderate FDR in relatively light winds (around 10 km/hr measured in the open) observed fire spread through PRAD02 fuels has involved some crown fire, when fine dead fuel moisture is low. This is due to the low crown height and exposure of fire to wind.
- Crowning fire can be expected at Moderate or higher FDR levels, if inter-row fuels are cured and sufficiently dry (Drought Factor = 10).

Fire behaviour modelling assumptions

The fire behaviour model run opposite was based on Cruz et al (2008) model relying on average fuel conditions from table in previous page.

FDR class	Crowning prop (%)	Rate of spread (km/h)	Rate of spread distribution	Flame length (m)	Flame length distribution
Ext.	100	6 2.0 – 9.3		16 11- 19	
Very High	94	3.3 0.1 – 6.6		13 1 – 17	
High	87	2.0 0.1 – 4.1		11 1 – 14	
Mod	80	1.2 0.04 – 2.9		8 1 – 13	
Low	63	0.5 0.03 – 1.6		4 0.6 – 11	

Issues for further thought……

- Can the concept of fuel hazard be applied consistently across the full spectrum of fuel types?
- Will there be ‘drift’ as time goes by, and what are the consequences of this?
- How does the concept of hazard fit within a more universal fuel classification based on physical fuel properties?

Thank you

Questions & Discussion