Fuelling the fire behaviour models of the future

Sam Hillman
Tom Duff
Merinda Day-Smith

Overview

- What are fuels?
- Who measures the fuel?
- DRF Intro
- Assessing fuels
  - What are the current methods?
  - What are the gaps for the users?
- Opportunities to address gaps through DRF project

What are fuels?

What are Fuels?

- Vegetation that burns in a fire
- Fine AND heavy fuels
- Properties of fuels
  - Thickness of fuel elements
  - Degree of horizontal and vertical continuity
  - Condition of the fuels
  - Height of the fuel complex
  - Amount of fuel
- Mapped and assessed at different levels

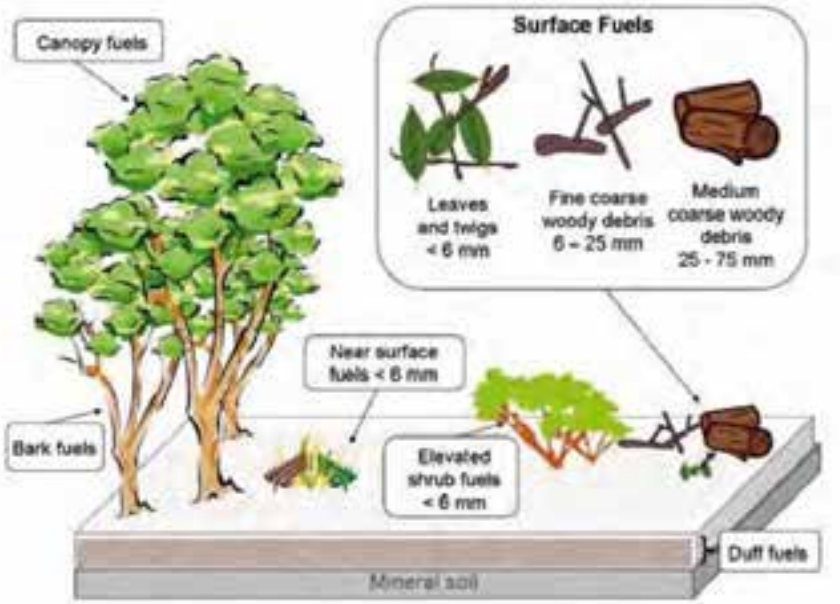

Figure 6: Fuel structure of ecologically mature eucalyptus forests in Victoria (Gellie *et al.* 2010).

Who assesses fuel?

Who and Why Do We Assess Fuels

Firefighters

Land and Fire Managers

Predictive Services and Forest and Fire Ecologists

Who and Why Do We Assess Fuels

Firefighters

Land and Fire Managers

Predictive Services and Forest and Fire Ecologists

Who and Why Do We Assess Fuels

Firefighters

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Predictive Services and Forest and Fire Ecologists

Fuelling the fire behaviour models of the future

- Disaster Ready Fund – projects to improve resilience to natural disasters
- Purpose:
  - *To develop a **fuel assessment manual and associated guides** to meet the demands of **current modelling needs** and **land and fire management decisions***
- Deliverables
  - Fuel assessment manual and associated guides
  - Field data
  - Vic Traditional Owner project

But wait....

Don’t we already have in-field fuel assessment methods to help with the **fire behaviour model** and **land management** needs.....

Operational Guides

Stand on the shoulders of giants

Elevated

Bark

Surface

Near-surface

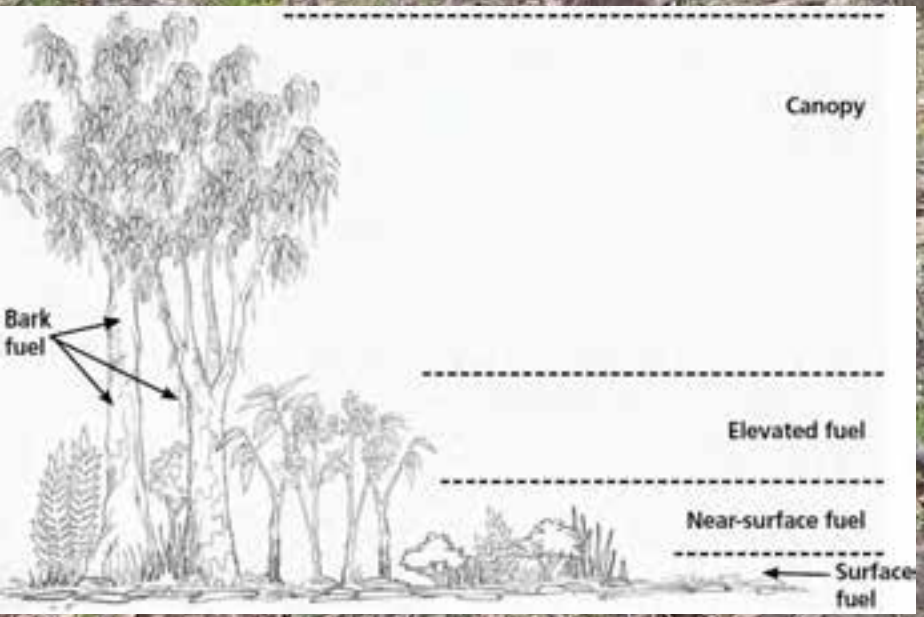


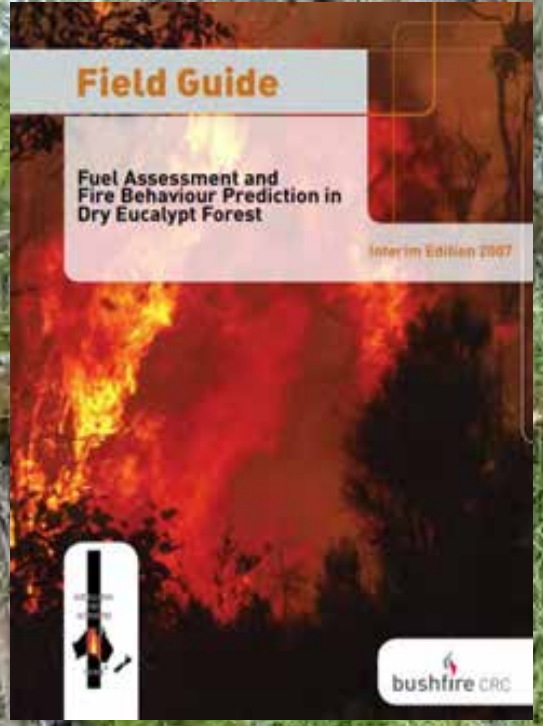
Table 4.1 Assessing elevated fine fuel hazard

To achieve a given hazard rating a best fit of all key attributes should be sought. Choices for the hazard rating of fuels that fit across several descriptions may be informed by the effect that different levels of key attributes have on fire behaviour.

Key attributes					Fuel hazard rating	Effect on fire behaviour (at FFDI 25)*
Plant Cover	% dead	Vertical continuity	Vegetation density	Thickness of fuel pieces		
<20% or low flammability species	<20%		Easy to walk in any direction without needing to choose a path between shrubs		Low	Little or no effect
20-30%	<20%	Most of the fine fuel is at the top of the layer	Easy to choose a path through but brush against vegetation occasionally		Moderate	Does not sustain flames readily
30-50%	<20%	Most of the fine fuel is at the top of the layer	Moderately easy to choose a path through, but brush against vegetation most of the time		High	Causes some patchy increases in the flame height and/or rate of spread of a fire
50-80%	20-30%	Continuous fine fuel from the bottom to the top of the layer	Need to carefully select path through	Mostly less than 1-2mm thick	Very High	Unburnt fuels mostly dictate flame height and rate of spread of a fire
>70%	>30%	Continuous fine fuel from the bottom to the top of the layer	Very difficult to select a path through. Need to push through vegetation	Large amounts of fuel <2mm thick	Extreme	Unburnt fuels almost entirely determine the flame height and rate of spread of a fire

Table 8.1 Determining the Overall Fuel Hazard rating

(1) Bark Hazard	(2) Elevated Fine Fuel Hazard	(3) Combined Surface and Near-surface Fine Fuel Hazard *				
		L	M	H	VH	E
Low or Moderate	L	L	M	M	H	H
	M	L	M	M	H	H
	H	L	M	H	VH	VH
	VH	VH	VH	VH	VH	VH
	E	E	E	E	E	E
High	L	L	M	H	H	H
	M	L	M	H	H	H
	H	L	H	H	VH	VH
	VH	VH	VH	VH	VH	E
	E	E	E	E	E	E
Very High or Extreme	L	L	VH	VH	VH	E
	M	M	VH	VH	E	E
	H	M	VH	E	E	E
	VH	E	E	E	E	E
	E	E	E	E	E	E



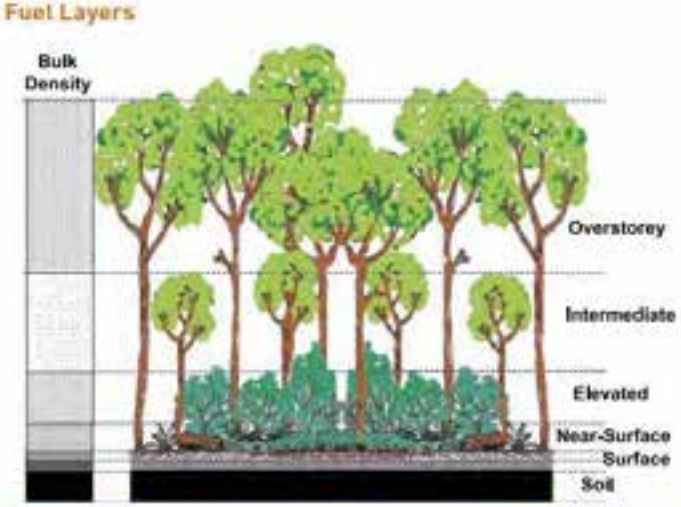
Overstorey

Intermediate Canopy

Elevated

Near-Surface

Surface



Fuel Assessment Field Sheet

Date:			Location:									
Assessor:			Map reference:									
		Plot number										
		1	2	3	4	5	6	7	8	9	10	Ave
Surface	Depth (mm)											
	FHS											
Near-surface	Height (cm)											
	FHS											
Elevated	Height (m)											
	FHS											
Bark	FHS											

McCorkhill forest, WA. Photo by Neil Burrows

Mixed Conifer: MC01

SAPLINGS AND TREES

	4 - 9	9 - 16
Most common species	*Pinus ponderosa*	*Pinus ponderosa*, *Pseudotsuga menziesii*
Tree density (stems/ac)	34	84
Live	34	34
Dead	0	50
Avg DBH (in)	6.2	12.0
Live	6.2	13.4
Dead	--	11.1
Avg height (ft)	29.0	52.0
Live	29.0	55.0
Dead	--	50.0
Avg ladder fuel height (ft)	4.0	6.6
Live	4.0	6.0
Dead	--	7.0
Avg ht to live crown (ft)	13.5	14.5
Live crown mass (tons/ac)	1.05	3.82

FOREST FLOOR

+ Add to custom site

	Depth (in)	Loading (tons/ac)
Woody material	1.2	9.70
Surface material	0.5	1.50
Duff	0.8	9.70

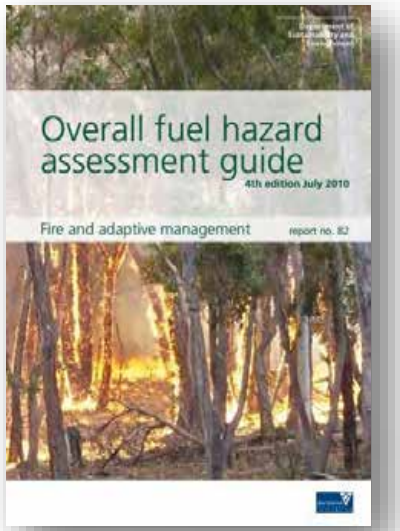
Purpose and users

About this guide …

"Spotting" in eucalypt forests commonly determines success or failure in controlling wildfires or managing prescribed burns. Spotting potential depends substantially on the surface texture and condition of eucalypt bark.


Eucalypt Bark Hazard Guide

RESEARCH REPORT No. 32
A A G WILSON
MAY 1992



1. About this guide

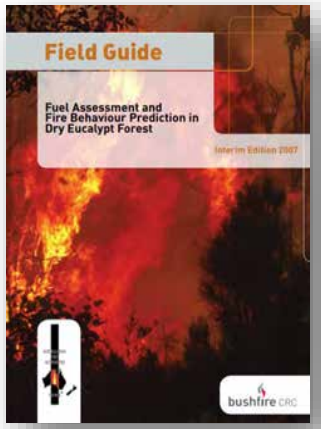
1.1 Purpose

The main purpose of this guide is to allow people to:

- make a rapid, visual assessment of fuel arrangement, and
- gain an understanding of how this will affect the chances of controlling a bushfire.

About this Guide

The purpose of this guide is to provide a systematic method for assessing fuel hazard and predicting potential fire behaviour (rate of spread, flame height, spotting distance) in dry eucalypt forest. Fuel assessment is based on the hazard



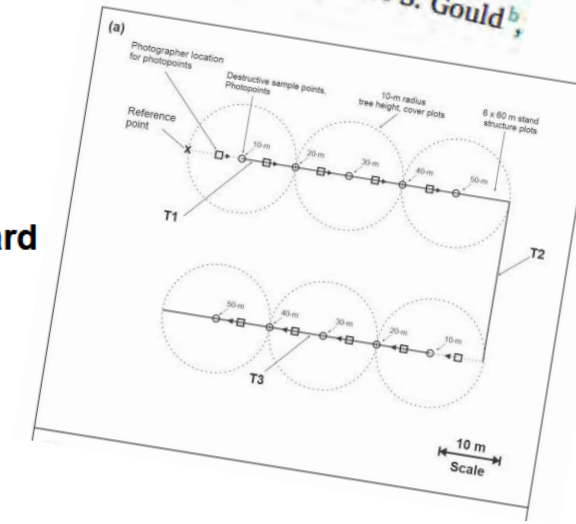
Extended assessment approaches

Extending methods for assessing fuel hazard in temperate Australia to enhance data quality and consistency

Bianca J. Pickering [A]*, Lauren T. Bennett [A] and Jane G. Cawson [A]

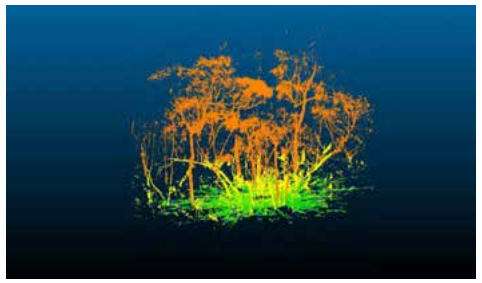
An efficient and comprehensive field protocol for assessing fu characteristics for fire behaviour modelling in Australian open forests ☆,☆☆

Jennifer J. Hollis [a,*], Miguel G. Cruz [b], W. Lachlan McCaw [c,d], James S. Gould [b], Stephanie A. Samson [a]



Terrestrial Laser Scanning: An Operational Tool for Fuel Hazard Mapping?

by Luke Wallace [1,*,†], Samuel Hillman [2,†], Bryan Hally [3], Ritu Taneja [3], Andrew White [3] and James McGlade [3]

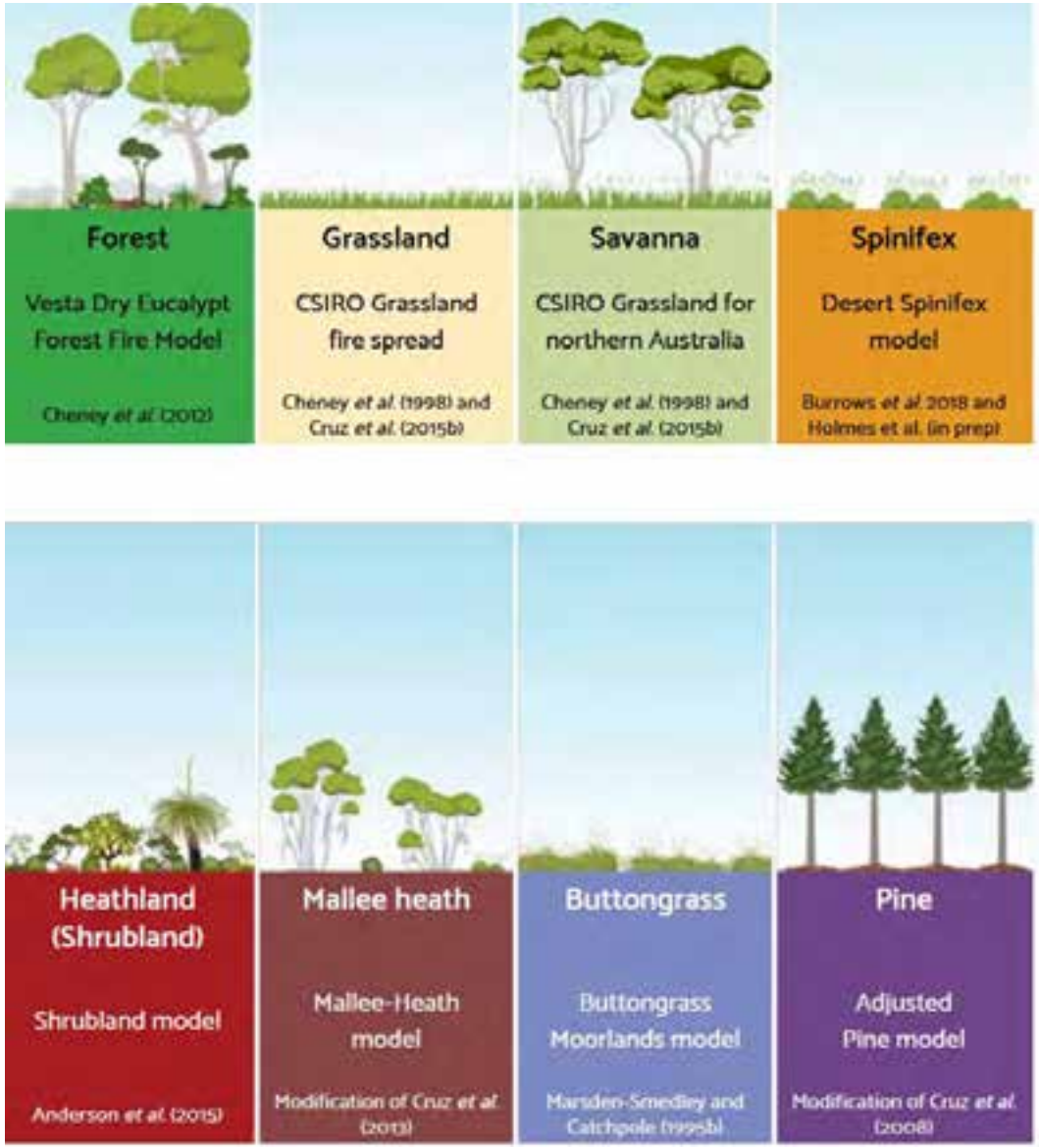


Gaps – Land Management

- Visual assessments work well for their original purpose
- Agencies invested in extended methods
- Several limitations known by users and highlighted by academics.
  - Separation between strata is challenging
  - Subjectivity and variability
  - Fine fuels only
  - Difficult to measure vertical and horizontal continuity
  - Link to fire behaviour is variable
  - Different frameworks between rapid and extended methods

Gaps – Fire behaviour model

- Assessment methods link to a specific fire behaviour model
- Gap between what the model needs and what is assessed in the field
- Knowledge exchange is difficult nationally and globally



Opportunities to address gaps

Fuelling Fire Behaviour Models of the Future

Product 1

Product 2

Product 3

Product 4

Develop a framework and Fue Assessment Manual (detailing what and how)

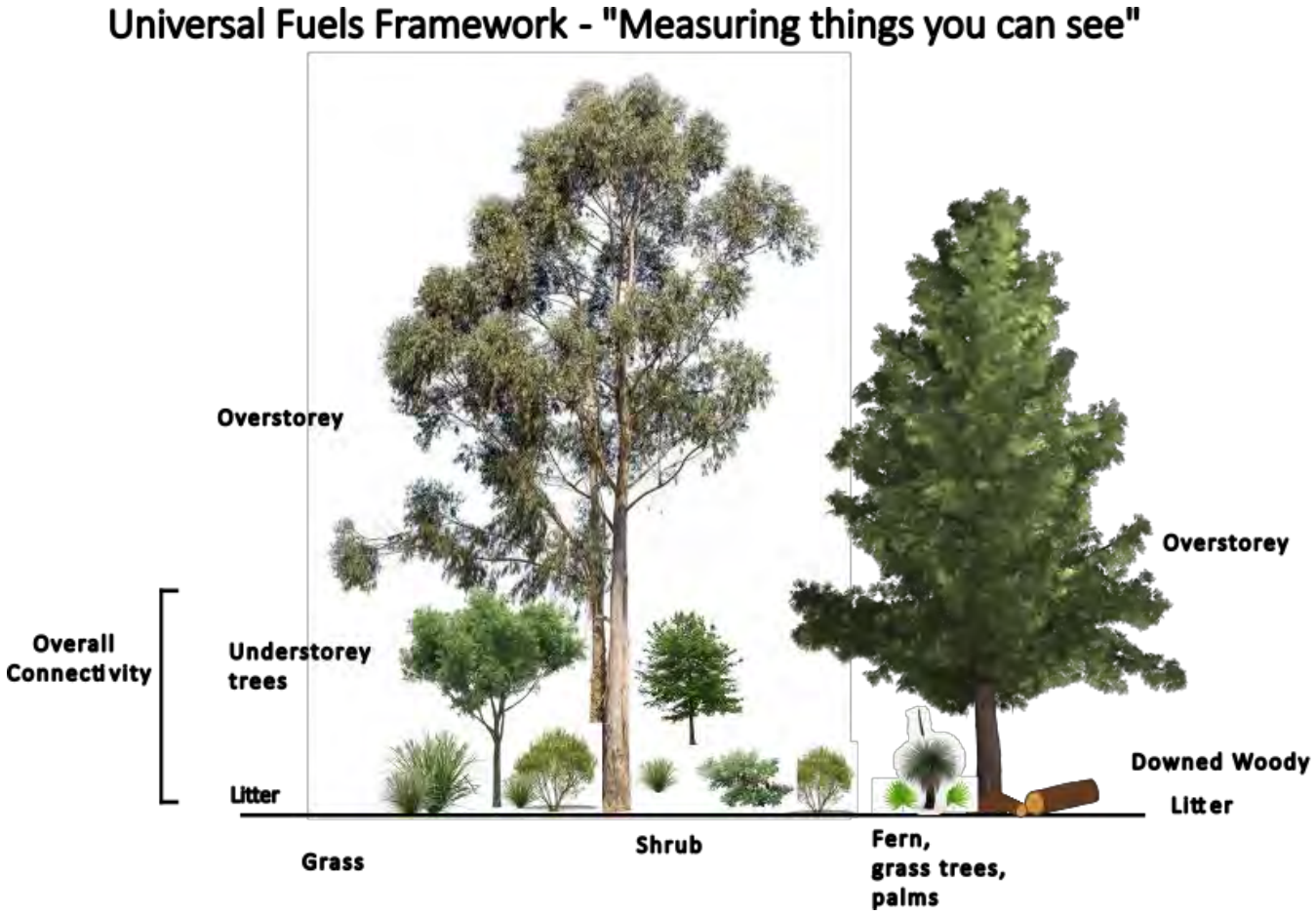
To meet the needs of...
Fire ecology
Planned burn effectiveness
Operational fire requirements
Monitoring change over time
Planned burn prescriptions
AFDRS/Spark/Phoenix/Future Simulators
Plus more....

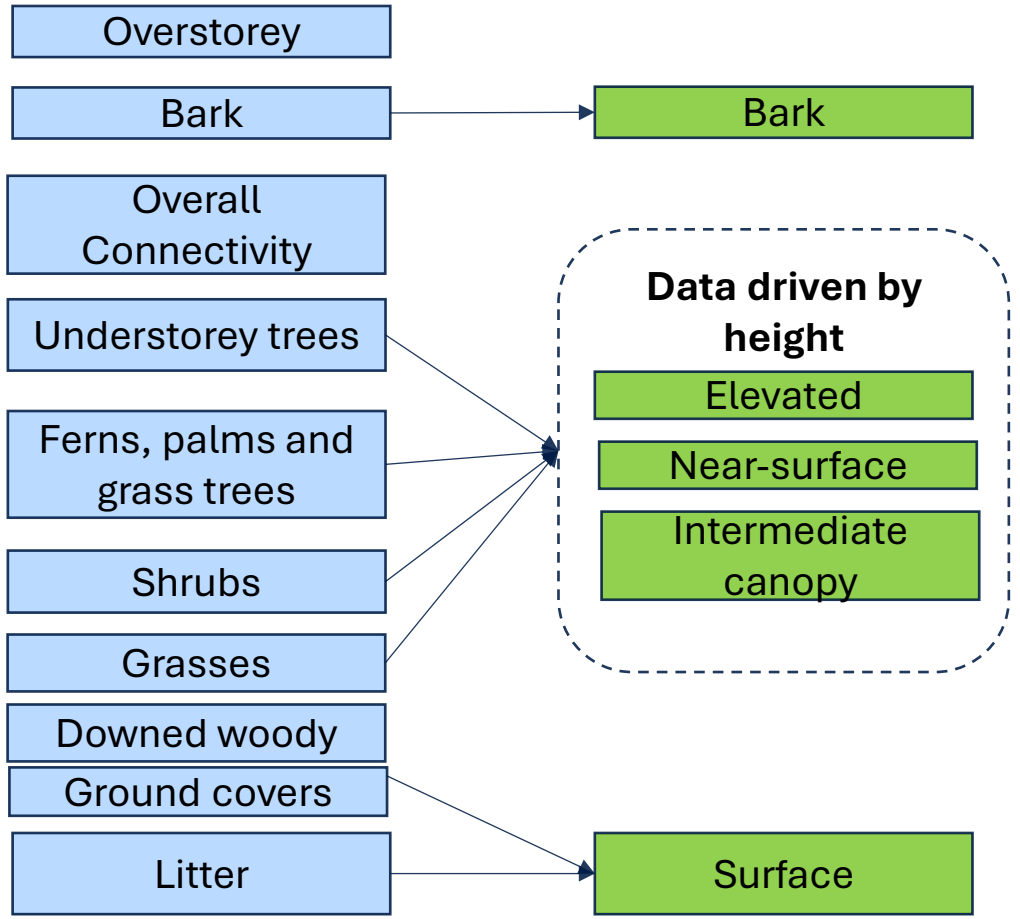
Traditional Owner led project(s) working with Cultural Fire Group

Gap to opportunity

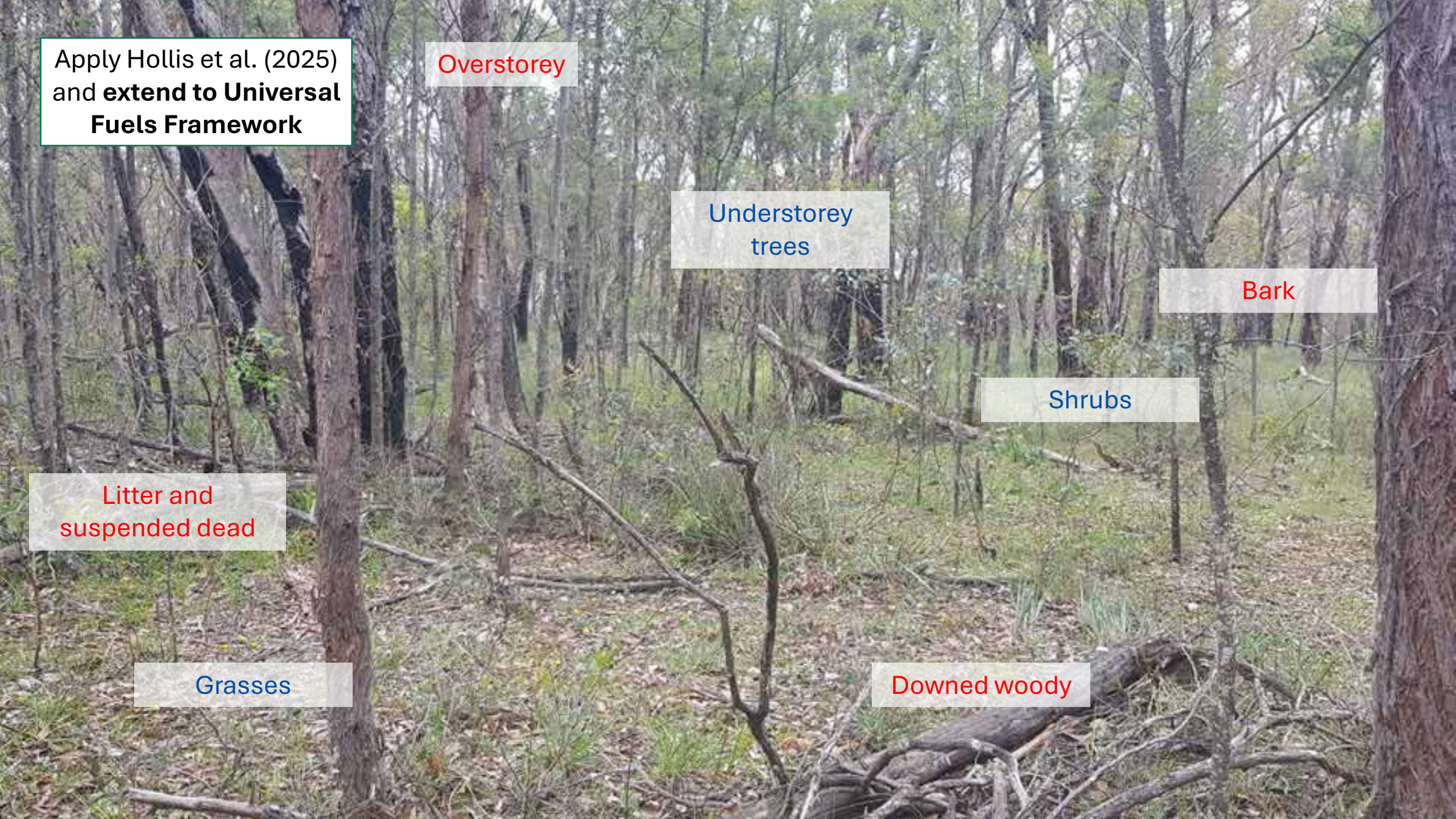
Gap 1. Separation between strata is challenging

Opportunity 1. Develop consistent fuels framework applied across all levels of assessment






Apply Hollis et al. (2025)
Overstorey
Understorey
Bark
Litter and suspended dead
Downed woody


Apply Hollis et al. (2025) and **extend to Universal Fuels Framework**
Overstorey
Understorey trees
Bark
Shrubs
Litter and suspended dead
Grasses
Downed woody

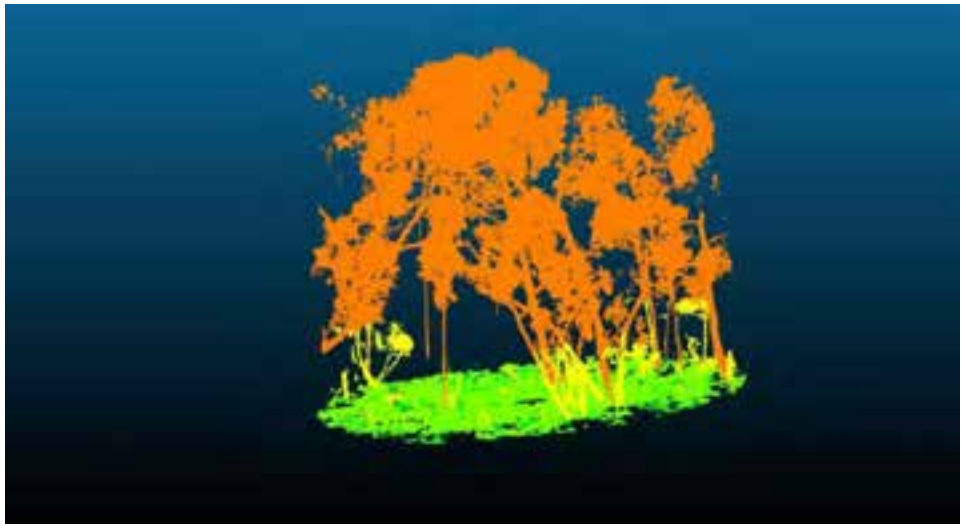

Overstorey
Understorey trees
Bark
Shrubs
Litter and suspended dead
Grasses
Downed woody
Ground cover


Overstorey
Understorey trees
Bark
Shrubs
Downed woody
Litter and suspended dead
Grasses

Gap to opportunity

Gap 2. Subjectivity and variability in structure and condition

Opportunity 2. Research new methods to reduce subjectivity of condition and structure



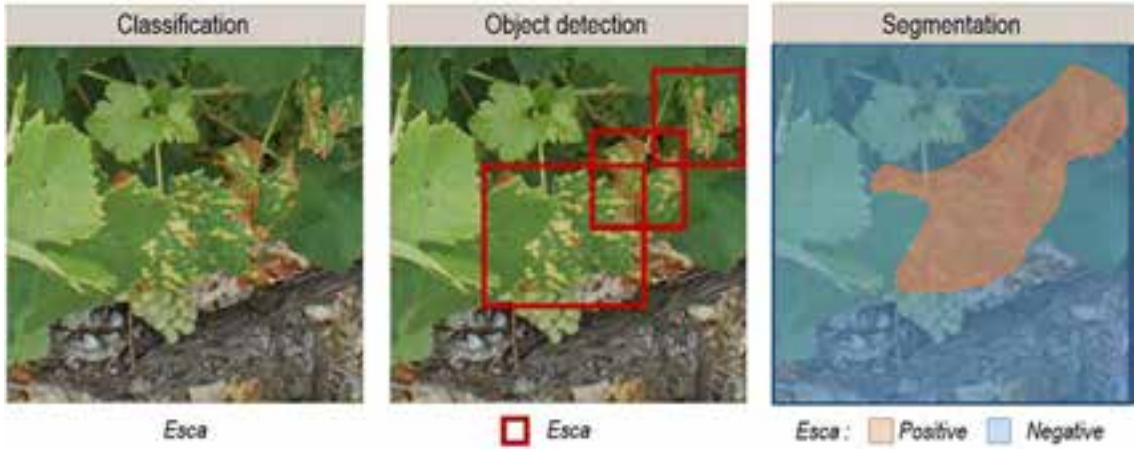
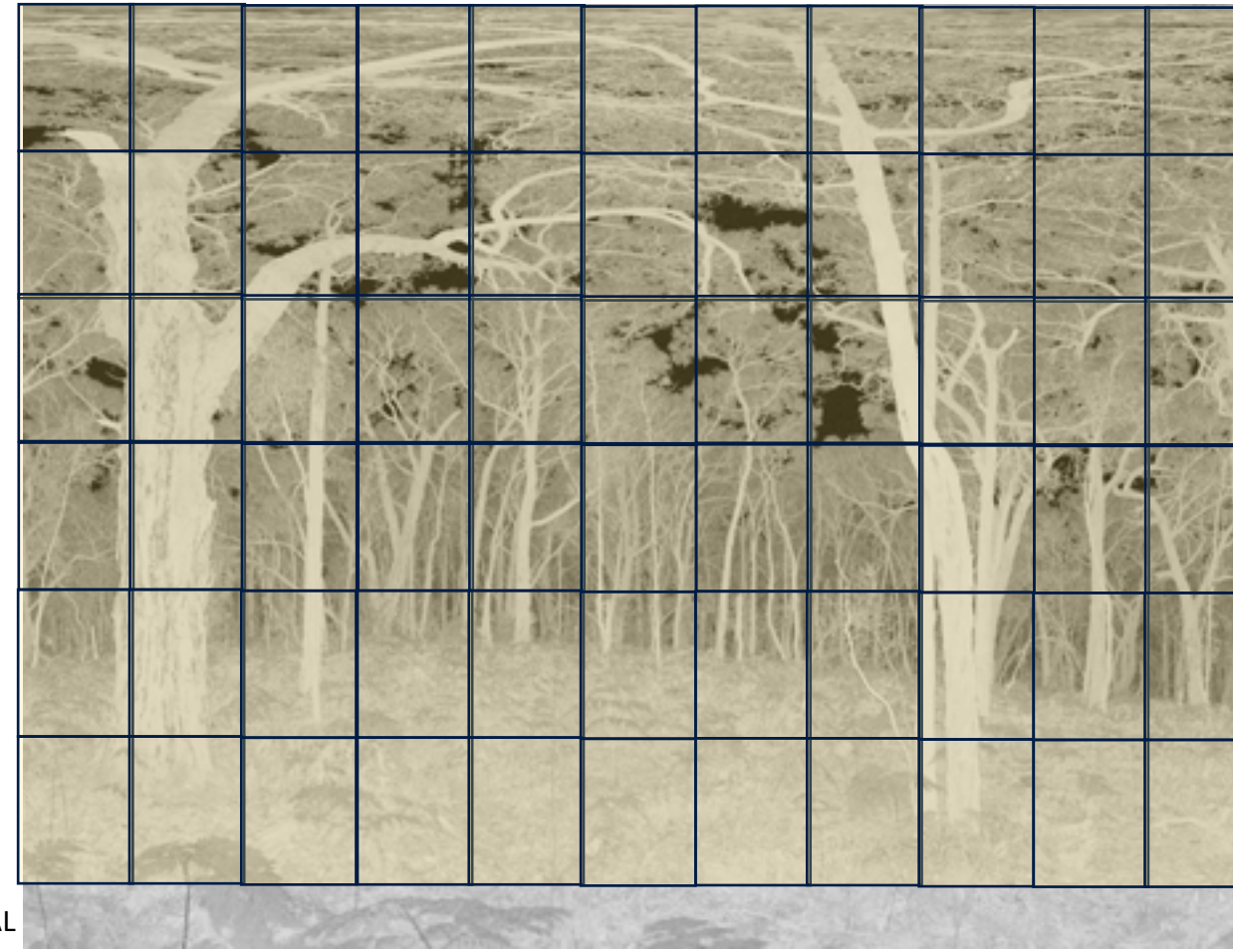


Fig. 2. Visual depiction of the six different fuel layers sampled by the students each hour through the sampling period. Red line depicts the boundary between the canopy above and the stems below (Photo credit: Kerryn Little).

Gap to opportunity

Gap 4. Difficult to measure vertical and horizontal continuity
Opportunity 4: Research and develop new metrics

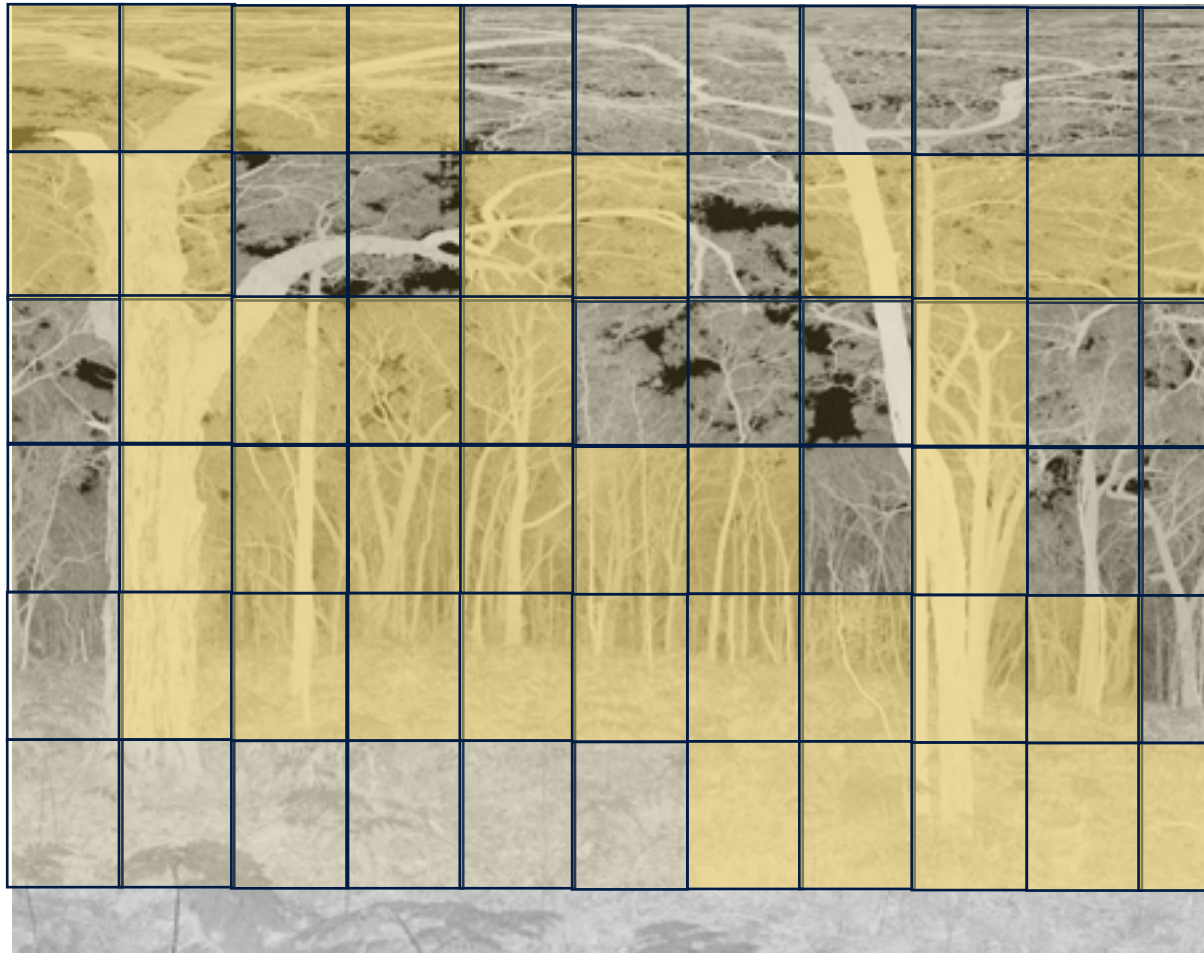


OFFICIAL

Gap to opportunity

Gap 4. Difficult to measure vertical and horizontal continuity

Opportunity 4: Research and develop new metrics



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Gap to opportunity

Gap 5. Link to fire behaviour is variable

Opportunity 5. Research factors relating fuel to fire behaviour under different conditions

Downed woody material

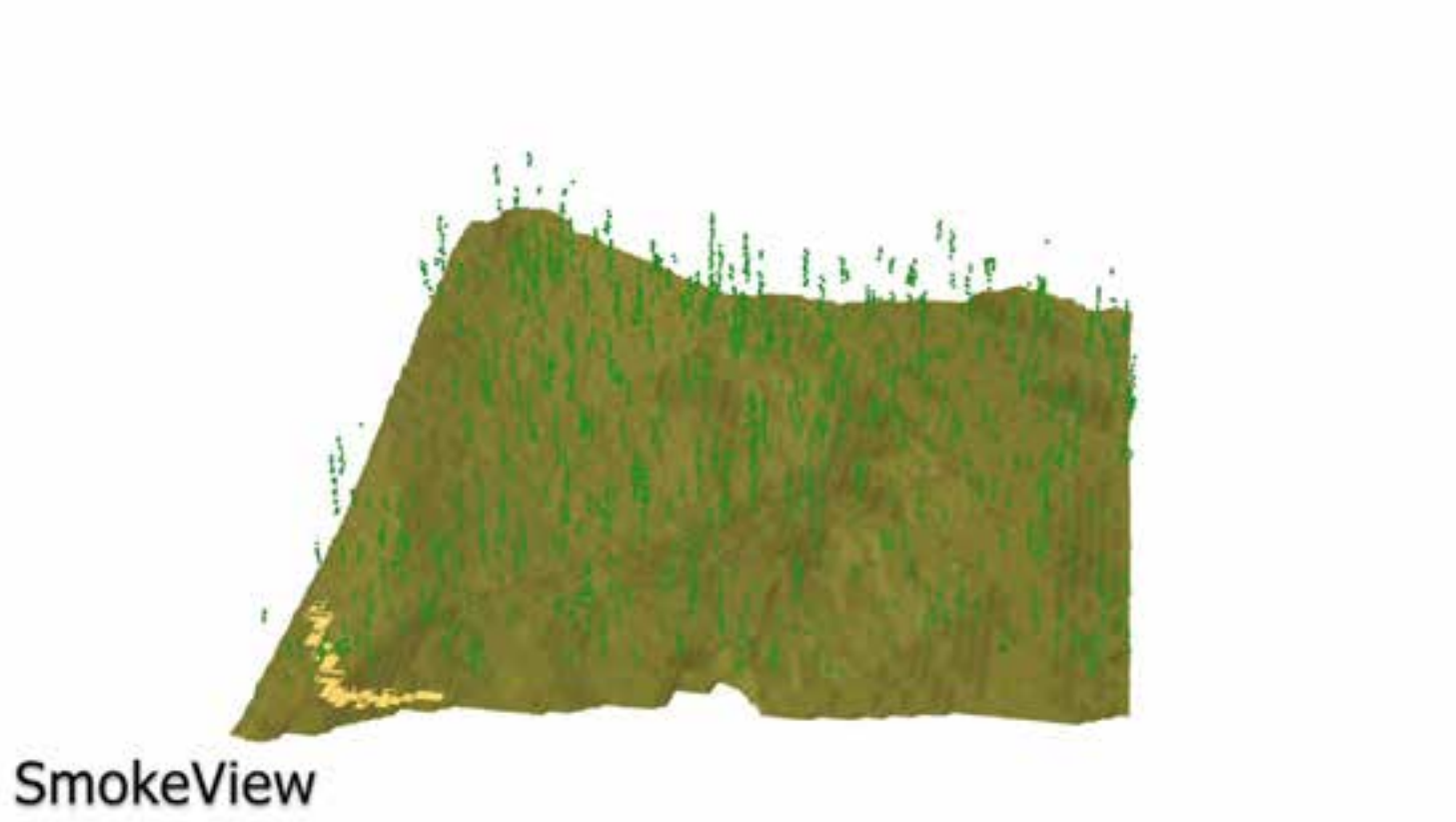
DBH, stems/ha, tree height

Overall connectivity

Gap to opportunity

Gap 6. Current assessment methods don’t capture requirements of fire behaviour models.
Opportunity 6. Develop methods that meet needs of current and future odels

- Work with researchers to identify future model requirements both inside and outside of Australia



Conclusion

What

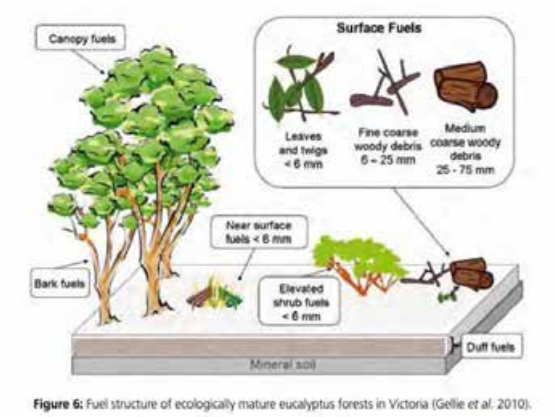


Figure 6: Fuel structure of ecologically mature eucalyptus forests in Victoria (Gellie *et al.* 2010).

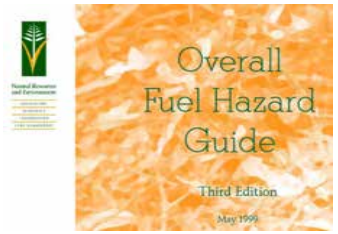
Who

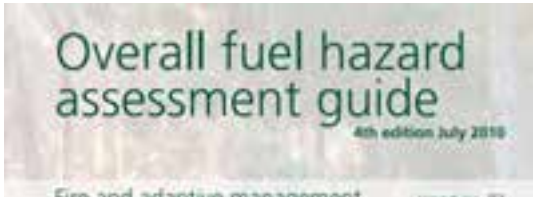
How

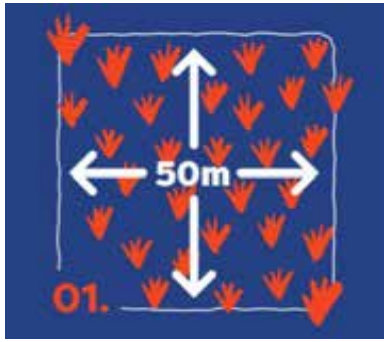
Eucalypt Bark Hazard Guide

Elevated Fuel Guide

RESEARCH REPORT No. 35
A A G WILSON
MAY 1993







Hollis et al. (2025)

Extra slides

Load vs Arrangement

- Early focus on quantifying surface fuel quantity as per model the requirements
- Arrangement was observed to be a more dominant influence than load by itself.
- More complex models were developed

Grassland Curing Guide

How to use this guide

Step 1.

Use the descriptions of the curing phases to narrow down the range of potential curing values (refer to Table 1 for descriptions).

Is the grassland in the:

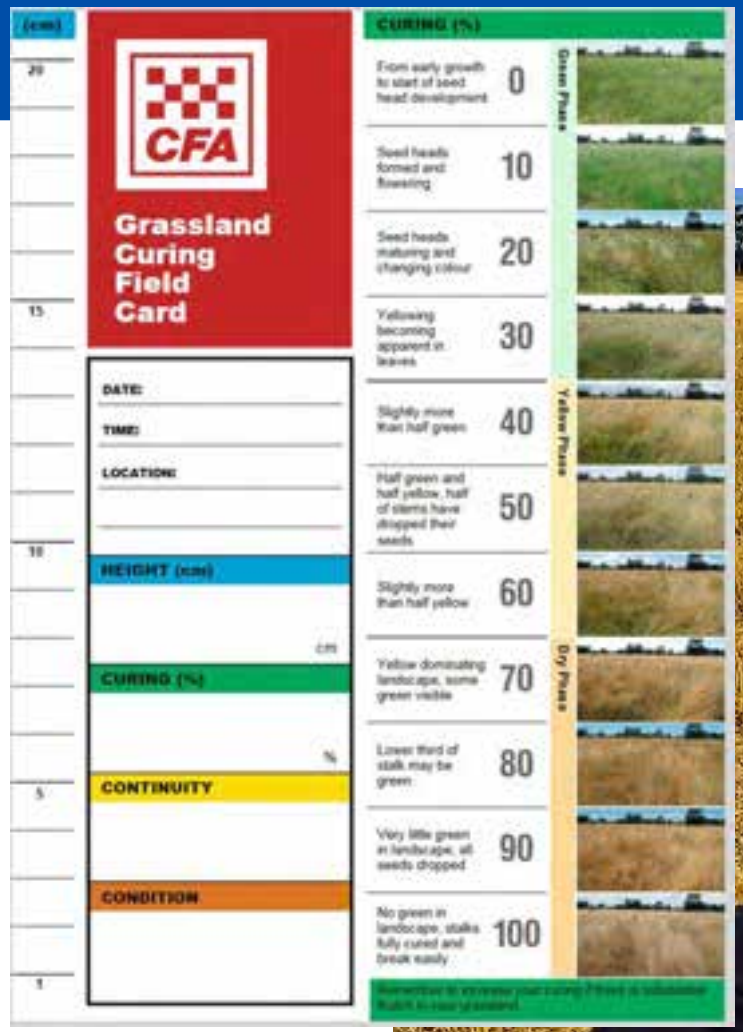
CURING PHASE	GO TO PAGE NO.
Green Phase	10
Yellow Phase	18
Dry Phase	24

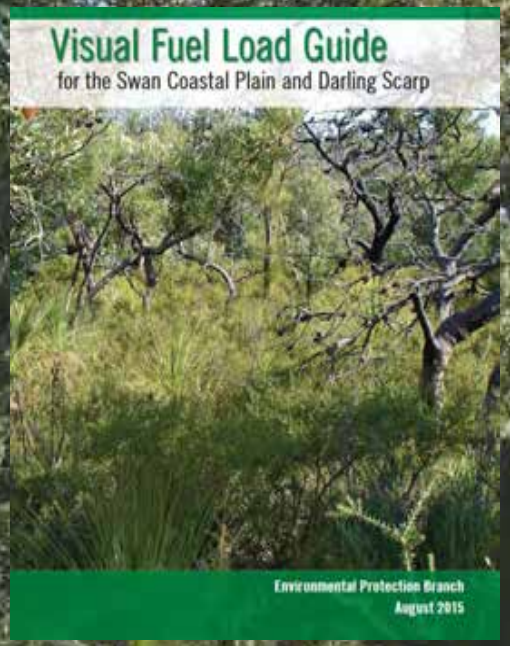
Step 2.

Determine the curing value by examining multiple points within the grassland up close and comparing them to the **key attribute** descriptions and photos.

Step 3.

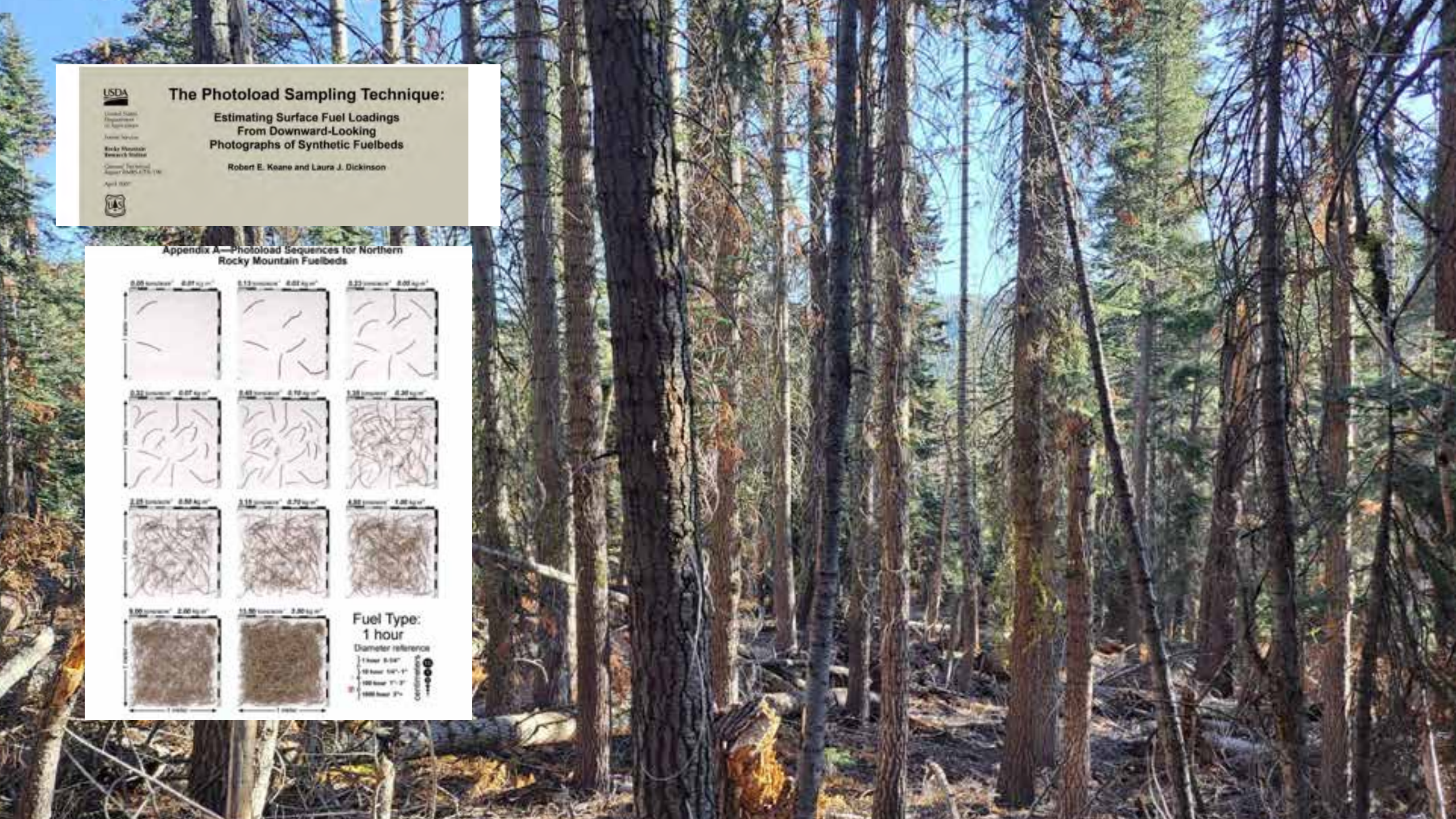
If your grassland has substantial thatch (see sidebar), increase your curing estimate by 10-20% depending on the amount present.





Near-Surface

Surface



USDA

United States Department of Agriculture

Forest Service

Rocky Mountain Research Station

General Technical Report RMRS-GTR-146

April 2004

The Photoload Sampling Technique:

Estimating Surface Fuel Loadings From Downward-Looking Photographs of Synthetic Fuelbeds

Robert E. Keane and Laura J. Dickinson

Appendix A—Photoload Sequences for Northern Rocky Mountain Fuelbeds

Fuel Type:
1 hour

Diameter reference

1 hour 0-1/4"

10 hour 1/4"- 1"

100 hour 1"- 3"

1000 hour 3"+

Centimeters

Fuel Characteristic Classification System (FCCS) Field Sampling and Fuelbed Development Guide

Susan J. Prichard, Anne G. Andreu, Roger D. Ottmar, and Ellen Eberhardt

Stratum		Category
Canopy		Trees, snags, ladder fuels
Shrubs		Primary and secondary layers
Nonwoody vegetation		Primary and secondary layers
Woody fuels		All wood, sound wood, rotten wood, stumps, and woody fuel accumulations
Litter-lichen-moss		Lichen, litter, and moss layers
Ground fuels		Duff, basal accumulations, and squirrel middens

Strata, category, and subcategory	Variable	Field data form
Herbs:		
Primary layer, secondary layer	Percentage cover (%)[a,b]	5, 6, 7
	Height (m)[a,b]	
	Percentage live[a]	
	Loading (Mg ha^{-1})[a,b,c]	9
	Species and relative cover (%)[a,b]	
Woody fuels:		
All woody	Total coverage by fine wood and 1-, 10-, and 100-hr downed wood (percentage)[a,b]	
	Depth (m)[a,b]	
Sound wood—	Species and relative cover (%)[a,b]	
1-hr	Loading (Mg ha^{-1})[a,b,c]	8
10-hr	Loading (Mg ha^{-1})[a,b,c]	8
100-hr	Loading (Mg ha^{-1})[a,b,c]	8
1,000-hr	Loading (Mg ha^{-1})[a,b,c]	8
10,000-hr	Loading (Mg ha^{-1})[a,b,c]	8
>10,000-hr	Loading (Mg ha^{-1})[a,b,c]	8
Rotten wood—	Species and relative cover (%)[a,b]	
1,000-hr	Loading (Mg ha^{-1})[a,b,c]	9
10,000-hr	Loading (Mg ha^{-1})[a,b,c]	9
>10,000-hr	Loading (Mg ha^{-1})[a,b,c]	9
Stumps—	Species and relative cover (%)[a]	2
Sound, rotten, lightered/pitchy	Height (m)[a]	2
	Diameter (cm)[a]	2

FIELD GUIDE TO THE CANADIAN FOREST FIRE BEHAVIOR PREDICTION (FBP) SYSTEM

FBP Fuel Type Descriptions

- C1 - Spruce–Lichen Woodland
- C2 - Boreal Spruce
- C3 - Mature Jack or Lodgepole Pine
- C4 - Immature Jack or Lodgepole Pine
- C5 - Red and White Pine
- C6 - Conifer Plantation
- C7 - Ponderosa Pine–Douglas-Fir
- D1 - Leafless Aspen
- S1 - Jack or Lodgepole Pine Slash
- S2 - White Spruce–Balsam Slash
- S3 - Coastal Cedar–Hemlock–Douglas-Fir Slash
- O1 - Grass
- M1 - Boreal Mixedwood–Leafless
- M2 - Boreal Mixedwood–Green
- M3 - Dead Balsam Fir Mixedwood–Leafless
- M4 - Dead Balsam Fir Mixedwood–Green

Field Guide: Sampling Fuels in the Context of the Next-Generation Canadian Forest Fire Danger Rating System (NG-CFFDRS)

Field Sampling Protocol and List of Attributes for Field Crews v1.1 (2024)

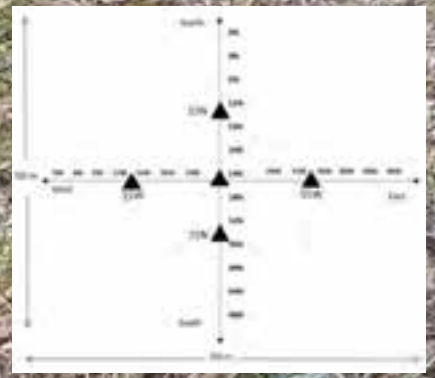
Table 3. Continued.

Forest floor and organic layer	Surface and ladder fuels	Stand structure and composition
Fuel Types M-1 and M-2 (Boreal Mixedwood)		
Continuous leaf litter in deciduous portions of stands; discontinuous feather moss and needle litter in conifer portions of stands; organic layers shallow, uncompacted to moderately compacted.	Moderate shrub and continuous herb layers; low to moderate dead, down woody fuels; conifer crowns extend nearly to ground; scattered to moderate conifer understory.	Moderately well-stocked mixed stand of boreal conifers (e.g., black/white spruce, balsam/subalpine fir) and deciduous species (e.g., trembling aspen, white birch). Fuel types are differentiated by season and percent conifer/ deciduous sp. composition.

Pilot project guides

Extending methods for assessing fuel hazard in temperate Australia to enhance data quality and consistency

Bianca J. Pickering [A]*, Lauren T. Bennett [A] and Jane G. Cawson [A]



Terrestrial Laser Scanning: An Operational Tool for Fuel Hazard Mapping?

by Luke Wallace [1,*,†], Samuel Hillman [2,†], Bryan Hally [3], Ritu Taneja [3], Andrew White [3] and James McGlade [3]

1 Testing the utility of terrestrial laser scanning for fuel

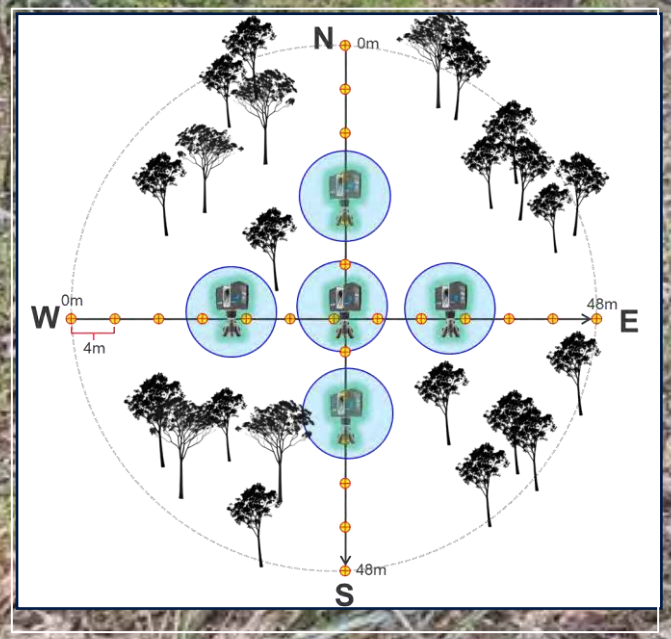
2 hazard assessments in temperate forests and woodlands of

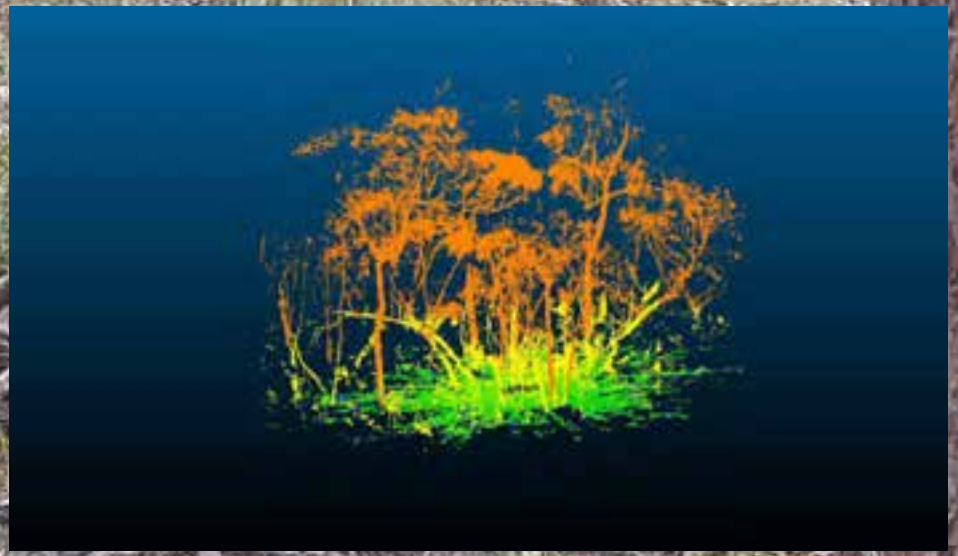
3 south-eastern Australia

4 Bianca J Pickering [1*], Samuel Hillman[2], Chris Medlin[2], Luke Wallace [3], Lauren T Bennett[1] and Jane G Cawson [1]

A comparison of terrestrial and UAS sensors for measuring fuel hazard in a dry sclerophyll forest

Samuel Hillman [a c], Luke Wallace [a], Arko Lucieer [b], Karin Reinke [a c], Darren Turner [b], Simon Jones [a c]





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by Luke Wallace [1,*,†], Samuel Hillman [2,†], Bryan Hally [3], Ritu Taneja [3], Andrew White [3] and James McGlade [3]

1 Testing the utility of terrestrial laser scanning for fuel

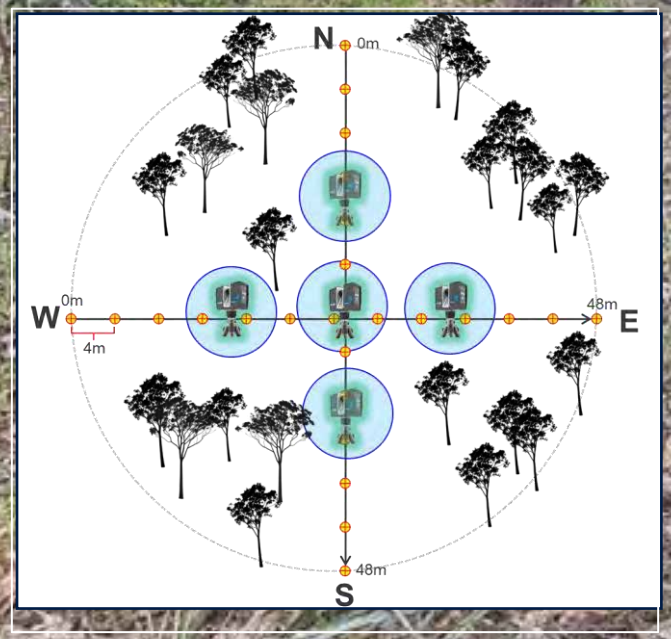
2 hazard assessments in temperate forests and woodlands of

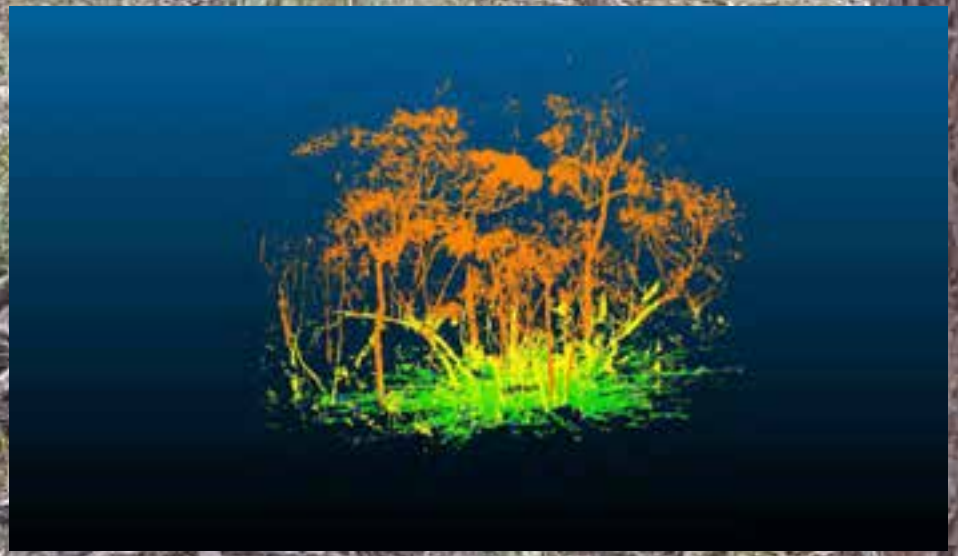
3 south-eastern Australia

4 Bianca J Pickering [1*], Samuel Hillman[2], Chris Medlin[2], Luke Wallace [3], Lauren T Bennett[1] and Jane G Cawson [1]

A comparison of terrestrial and UAS sensors for measuring fuel hazard in a dry sclerophyll forest

Samuel Hillman [a c], Luke Wallace [a], Arko Lucieer [b], Karin Reinke [a c], Darren Turner [b], Simon Jones [a c]





Overstorey

Understorey

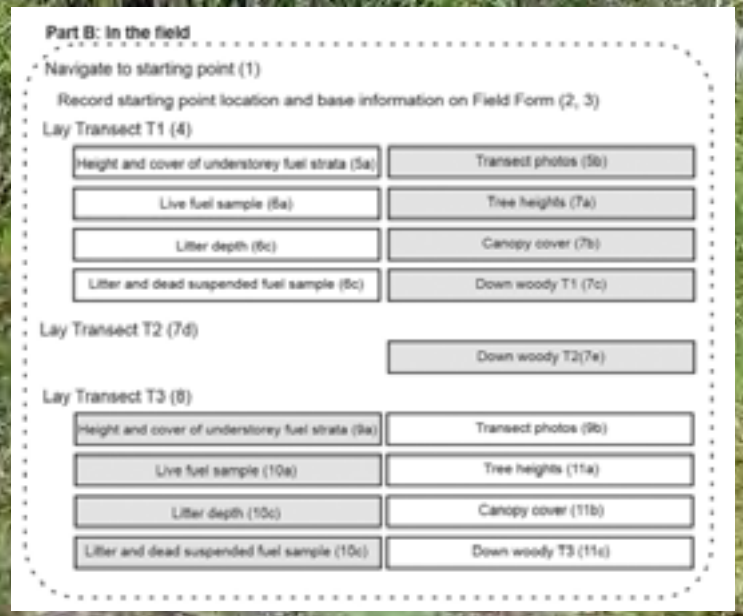
Bark

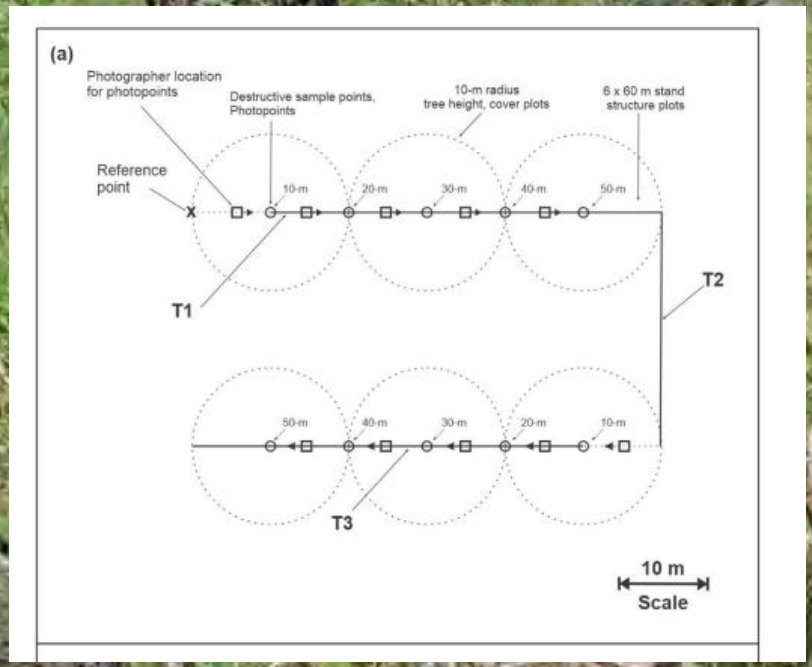
Downed woody

Litter and suspended dead

An efficient and comprehensive field protocol for assessing fuel characteristics for fire behaviour modelling in Australian open forests ☆,☆☆

Jennifer J. Hollis[a,*], Miguel G. Cruz[b], W. Lachlan McCaw[c,d], James S. Gould[b], Stephanie A. Samson[a]

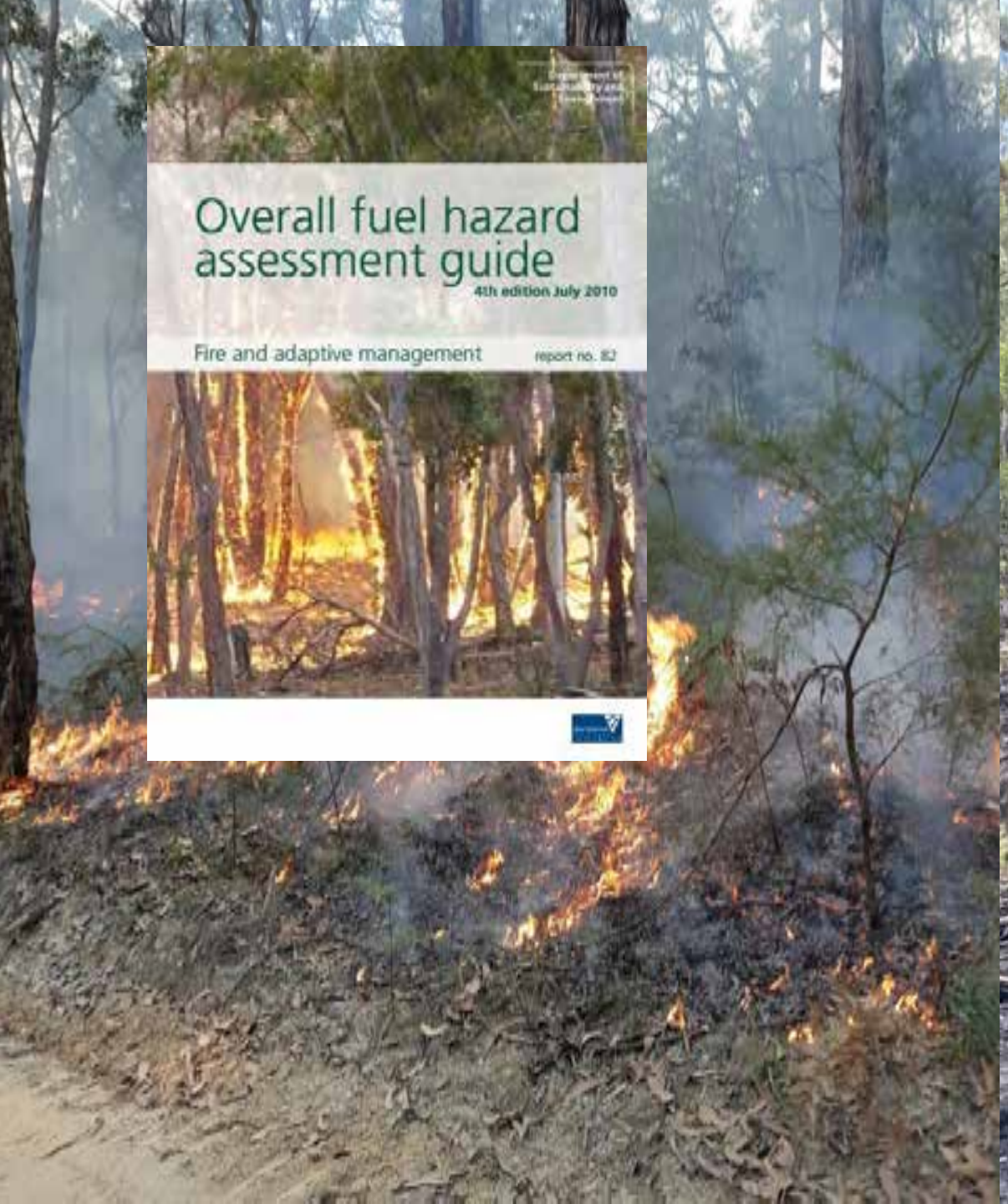




Australian states and Territories

State	Method
Victoria	Overall fine fuel hazard assessment guide 4th edition CFA Grass curing guide Pilot usage– Pickering and Cawson (Extended assessment guide), Wallace et al. (TLS)
New South Wales	Overall fine fuel hazard assessment guide 3rd edition RFS Grass Curing Guide
Queensland	Overall fine fuel hazard assessment guide 4th edition QLD Grass Curing Guide
South Australia	Overall fuel hazard guide for South Australia (essentially same as OFHAG 4th edition) CFA Grass Curing Guide
Australian Capital Territory	Overall fine fuel hazard assessment guide 4th edition CFA Grass Curing Guide
Western Australia	Vesta Fuel Hazard Guide? Visual fuel load guides? Hollis et al. 2025 WA Grass Curing Fuel Guide
Northern Territory	North Australian Grassland Fuel Guide


Overall fuel hazard assessment guide
4th edition July 2010
Fire and adaptive management
report no. 82


Overall fuel hazard assessment guide
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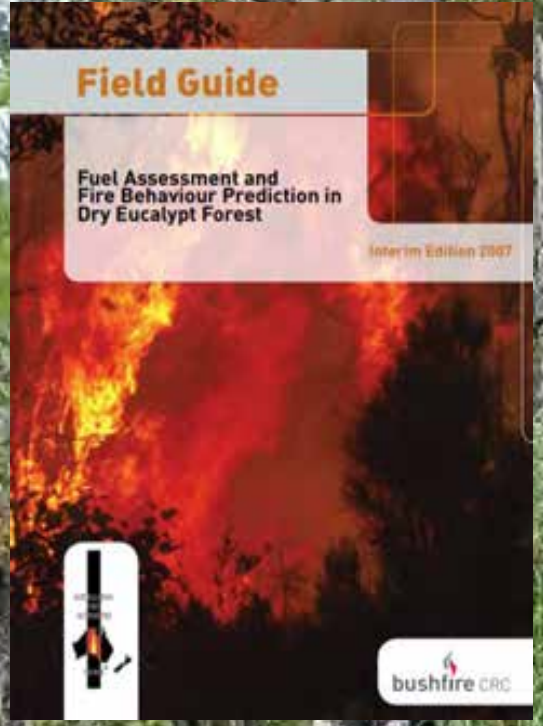
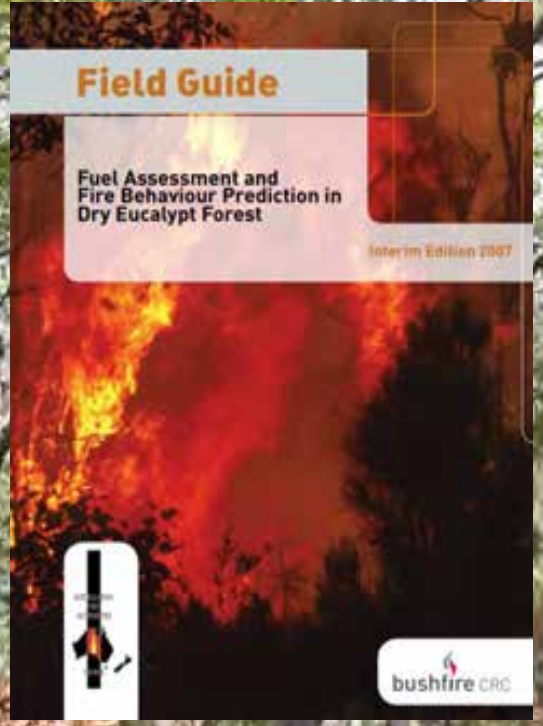

Field Guide
Fuel Assessment and
Fire Behaviour Prediction in
Dry Eucalypt Forest
Interim Edition 2007
bushfire CRC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