Predicting Fire Behaviour in Spinifex Grasslands

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Predicting Fire Behaviour in Spinifex Grasslands

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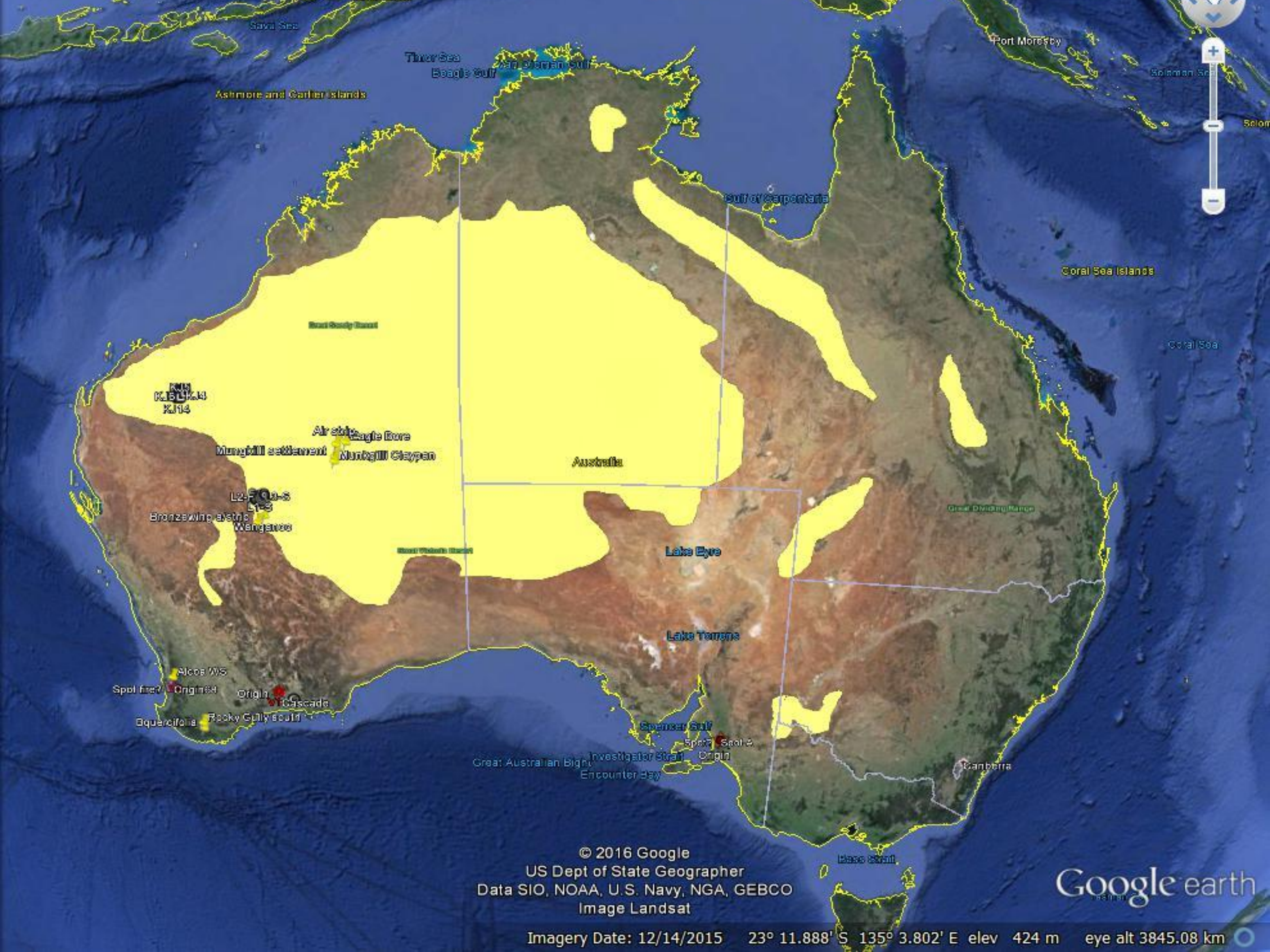
Purpose of this presentation

- Understand how the spinifex fire behaviour model was developed
- How the model works
- How to measure model inputs



Savu Sea
Timor Sea
Van Diemen Gulf
Ashmore and Cartier Islands
Port Moresby
Gulf of Carpentaria
Coral Sea Islands
Coral Sea
Great Dividing Range
Australia
KJ14
Air strip
Eagle Bore
Mungkili settlement
Munkgilli Claypan
Bronzewing airstrip
Wanganoo
Lake Eyre
Lake Torrens
Alcoa WS
Spot fire?
Origin
Cascade
Rocky Gully south
Spencer Gulf
Spot A
Great Australian Bight
Investigator Strait
Encounter Bay
Canberra
Bass Strait
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US Dept of State Geographer
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image Landsat
Google earth
Imagery Date: 12/14/2015 23° 11.888' S 135° 3.802' E elev 424 m eye alt 3845.08 km

Fire management

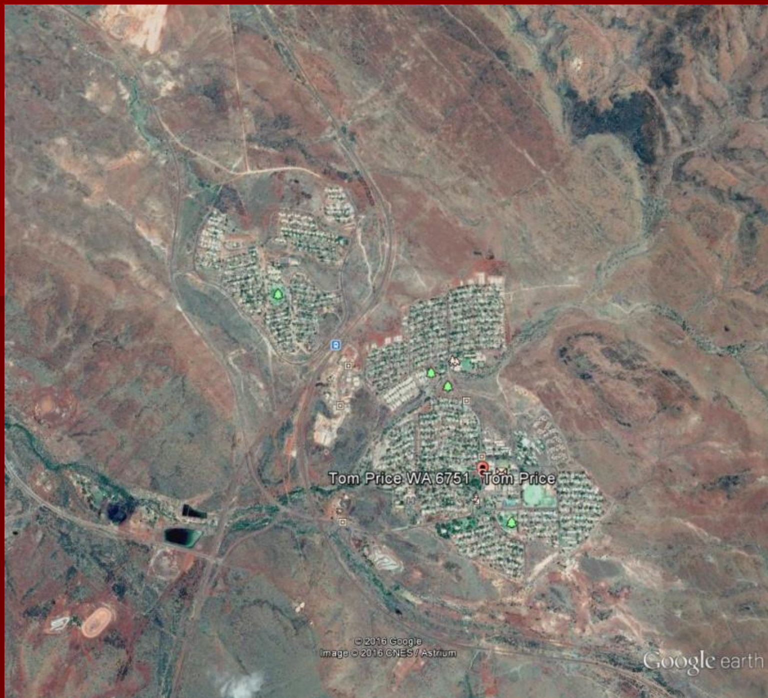
Key Objectives

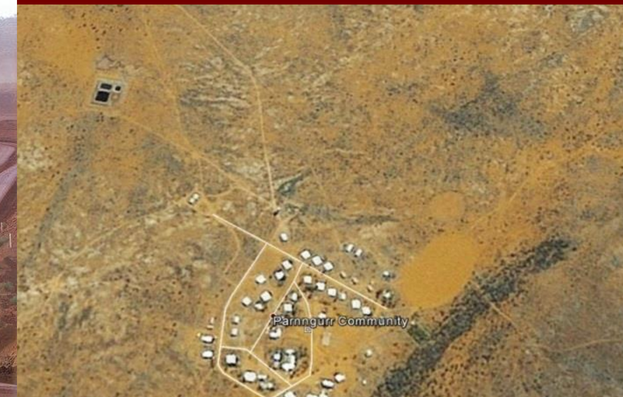
- Mitigate wildfire threat to assets
- Habitat management
- Pasture /forage management

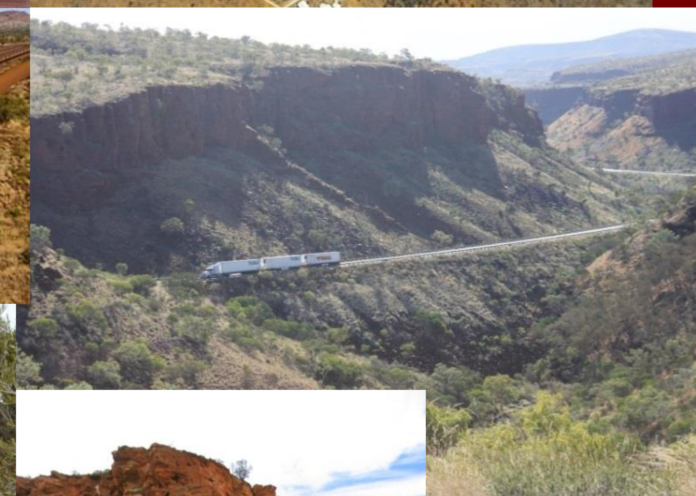
Key Strategies

- Prescribed burning
- Limited suppression capability

Some of arid Australia's assets







Spinifex fuel characteristics

- Live (perennial) fuel
- Discontinuous
- Varying proportions of dead fuel
- Highly flammable
- Simplex structure, often forms ‘pure’ meadows

Dehydrated

Rehydrated

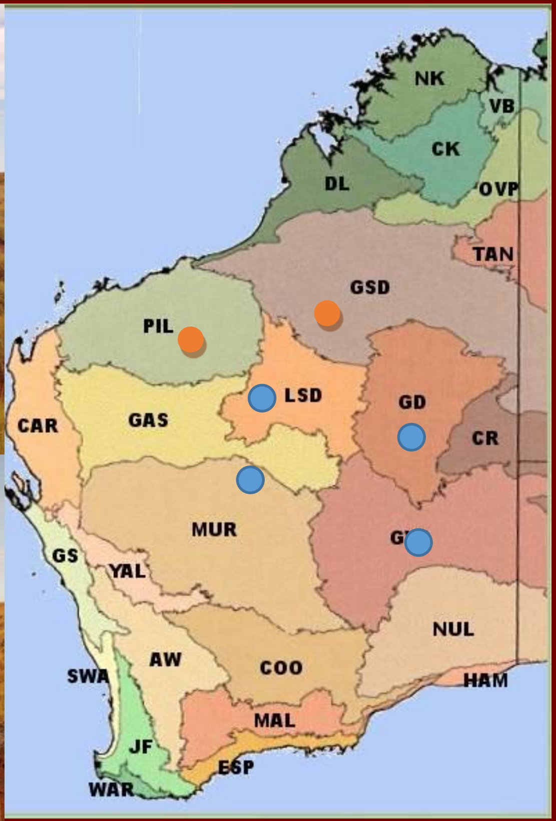
Changing structure and biomass is a function of time since fire, rainfall and edaphic factors






How the model was constructed

- 186 experimental line ignition fires across a range of spinifex-dominated bioregions, including data from Qld (courtesy Paul Williams)
- Lines 50 - 100 m
- Fires burnt for 50 - 200 m (one fire – 1.8km!)
- 150 fires used to develop the model; 36 fires used to validate the model



Burrows ND, Gill AM, Sharples J (2018)

Development and validation of a model for predicting fire behaviour in spinifex grasslands of arid Australia.

International Journal of Wildland Fire 27; 271-279

Modelling fire spread in discontinuous fuels

Because fuel is discontinuous, spinifex fires are GO / NO-GO

Multiple spread thresholds with feedbacks

If fuel is dry enough to ignite (average clump MC <~40%)

Step 1: Will fire spread?

Step 2: If it spreads, how fast and how big the flames?

Ignition but 'No-Go'

Ignition and 'Go'

Step 1: Will fire spread?

Spread thresholds

Provided it will ignite, whether or not fire spreads depends on combinations of:

- **Wind speed (U)**
- **Cover** of fuel **(c)**
- **Moisture Content (m)**

Step 1: Will fire spread?

The Spread Index (SI) gives the likelihood of fire spreading

$$SI = 0.412U_{1.7} + 0.311c - 0.676m - 4.073$$

Where:

- **U =** wind speed (km/h at 1.7 m) (for U_{10}, coefficient is 0.30)
- **c =** fuel cover (% ground cover of vegetation <1.5m)
- m = fuel moisture content (% odw clump profile)

Spread likely when SI > 0

Step 2: Predicting rate of spread

$$R = 40.98 \frac{U_{1.7}^{1.399} c^{1.201}}{m^{1.699}}$$

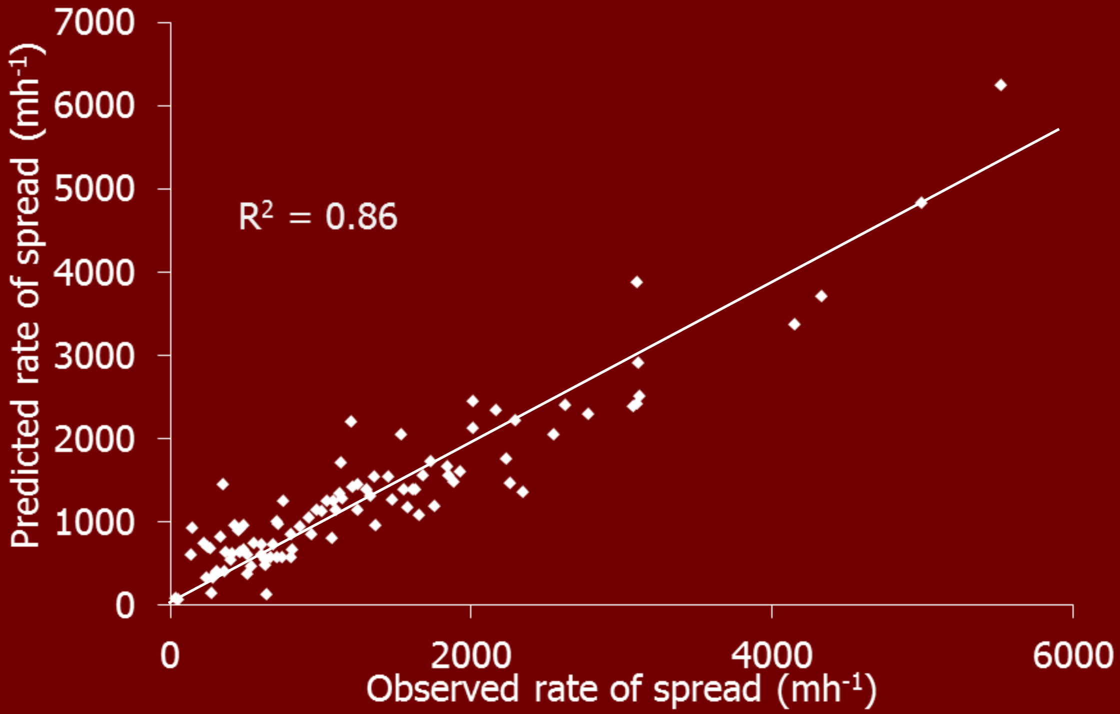
Where:

R = rate of spread (m h^{-1})

$U_{1.7}$ = wind speed at 1.7 m (coefficient = 1.275 for U_{10})

c = fuel cover (%)

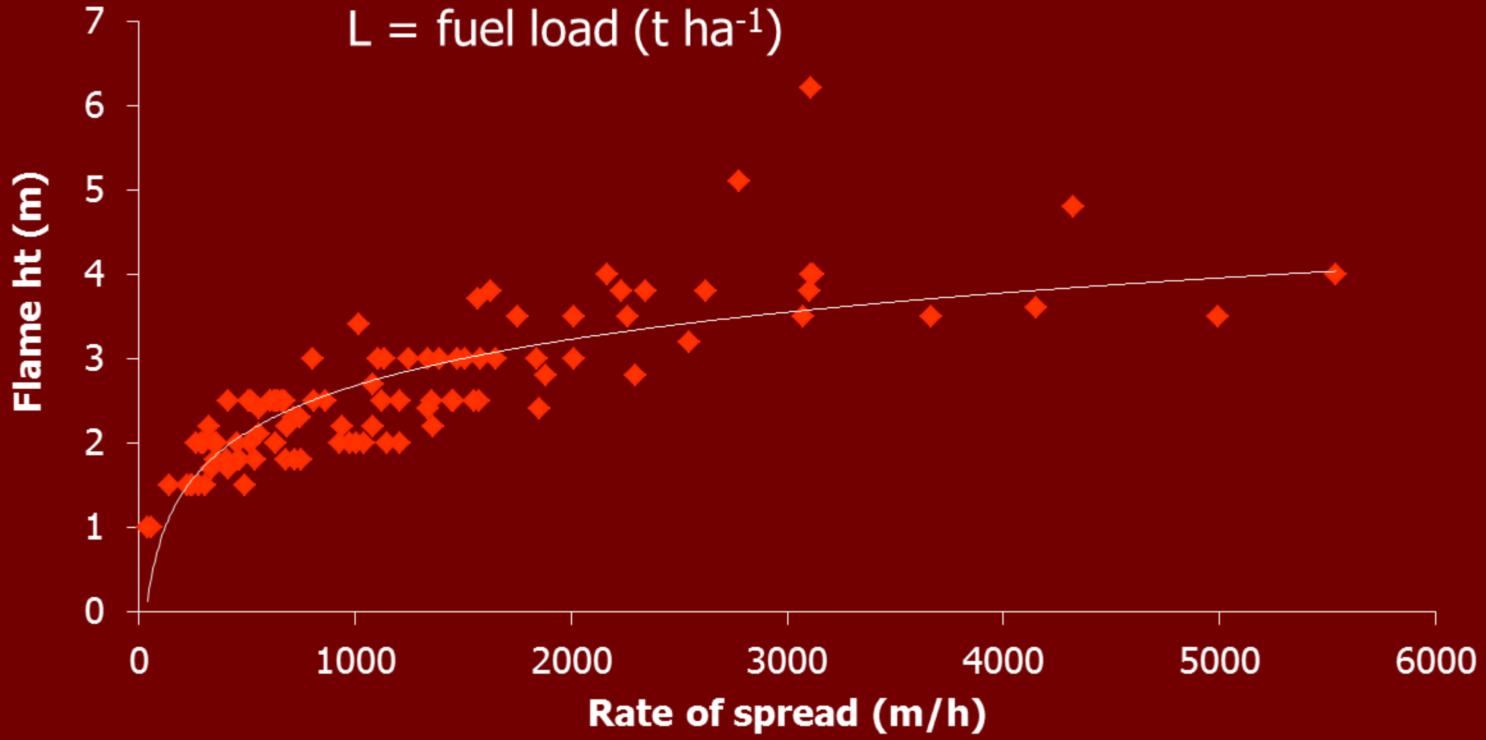
m = clump moisture content



Predicting flame height

$$f = 0.097R^{0.424} + 0.102l$$

Where:
F – flame height (m)
R = rate of spread ($m\ h^{-1}$)
L = fuel load ($t\ ha^{-1}$)



Measuring model inputs:
Wind speed (km/h)

Direct (in field):

- km h^{-1} at 'eye level' (~1.7 m) using a Kestrel
- Mean wind speed over 5 mins

Indirect:

- Meteye, spot forecasts (BoM)
- For open 10 m wind speed (U_{10}):
  - To calculate SI, change U coefficient to 0.305
  - To calculate ROS, change U coefficient to 1.275

(Caution: based on Cheney's wind reduction ratio for grassland; untested in spinifex grasslands)

Model inputs:
Fuel cover (%)

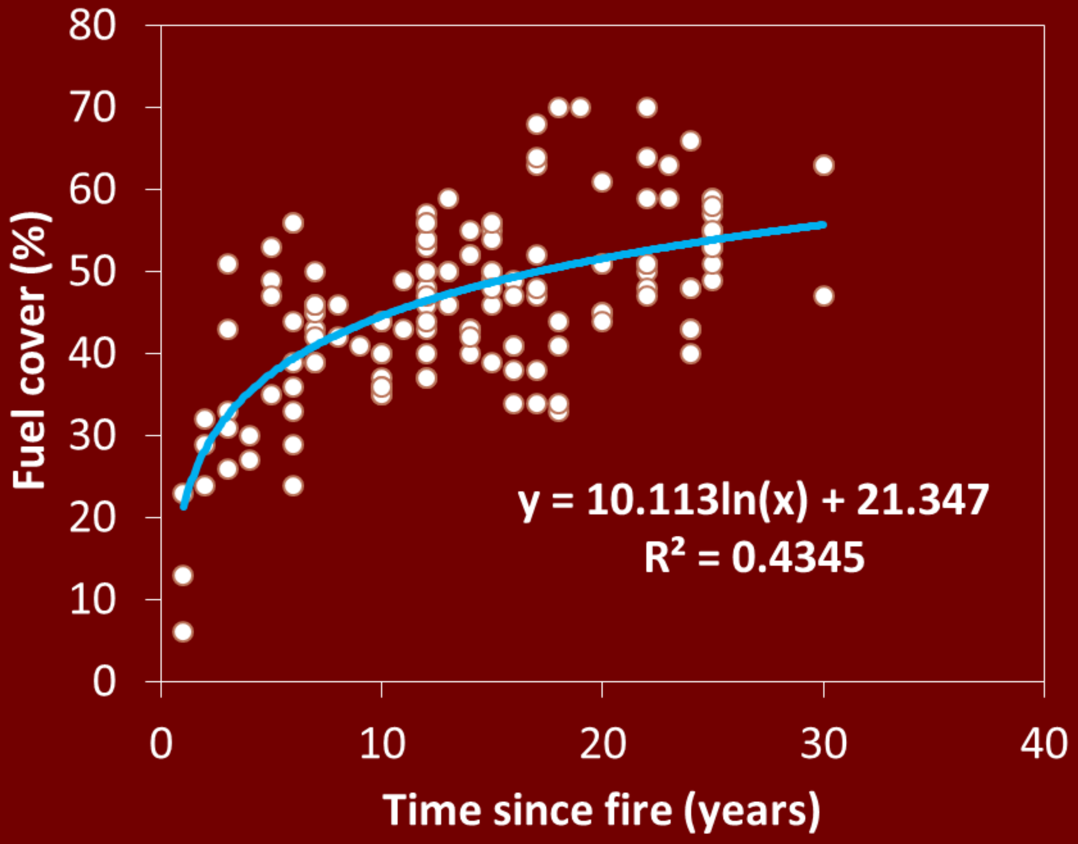
Direct (in field):

- See Burrows *et al*. (2018)

Indirect:

- From time since fire (fuel age)
- From remote sensing

Fuel cover (%)
from time since fire (fuel age)



- Highly variable – function of time since fire, rainfall, edaphic / site factors
- Cover can decline with age after about 30 years

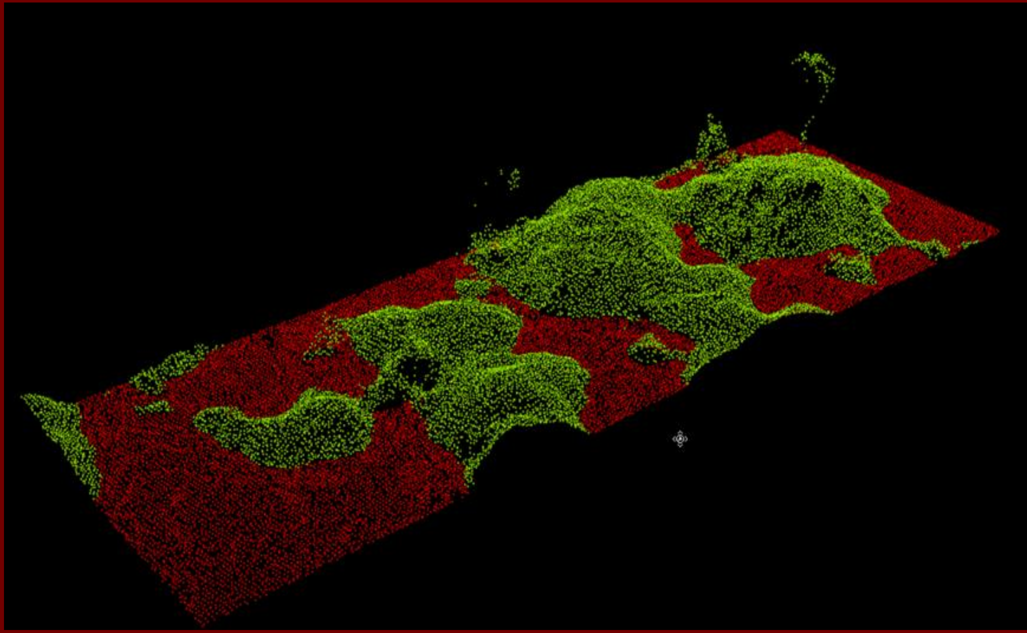
Model inputs:
Fuel load (t/ha)

Direct (in field):

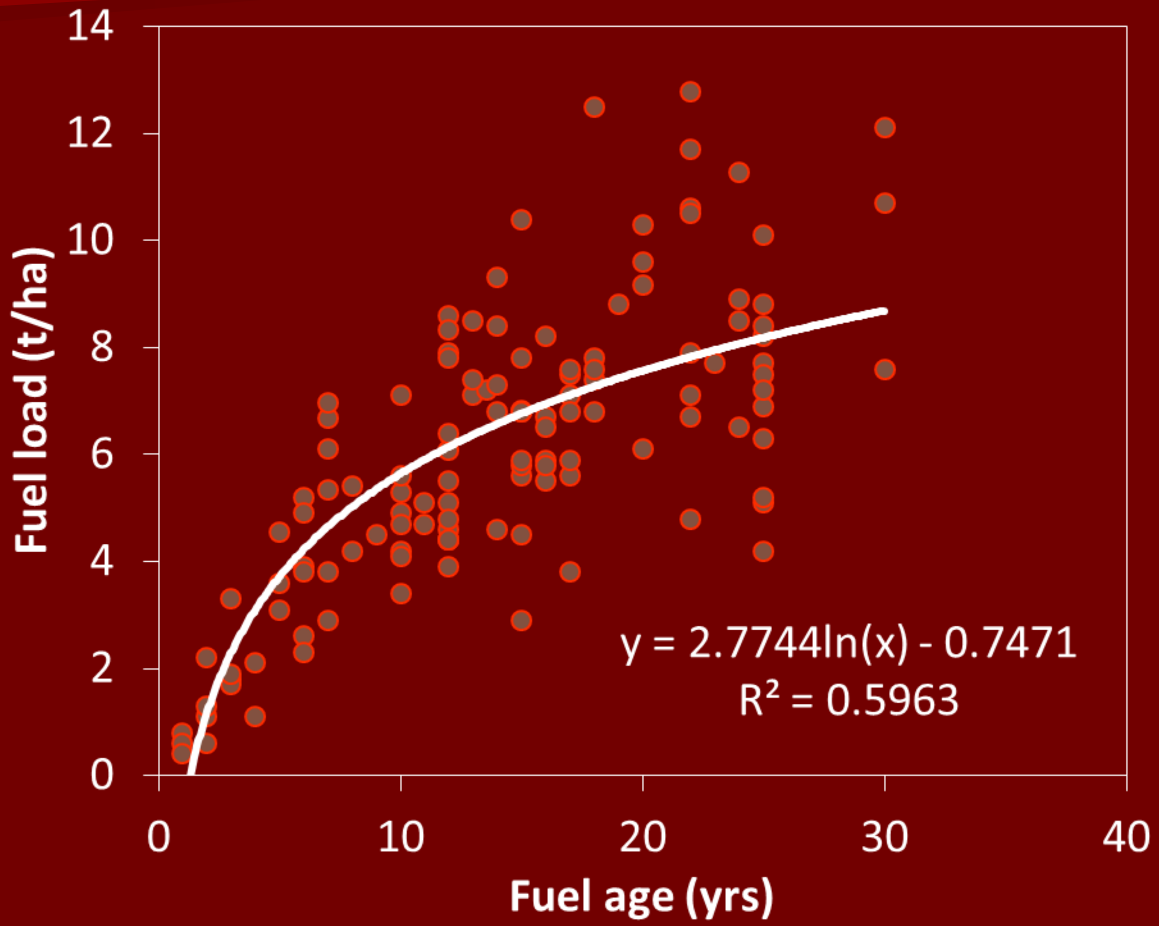
- See Burrows *et al*. (2018)

Indirect:

- From time since fire (fuel age)
- From height and cover

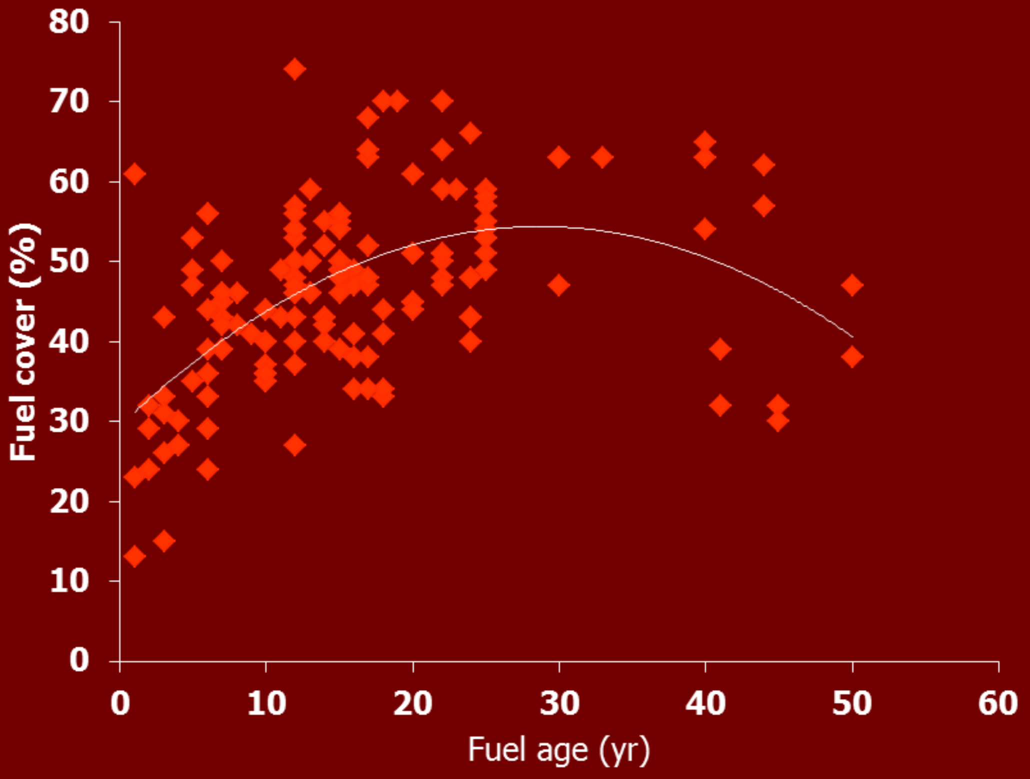


Model inputs:
Fuel load (t/ha) from time since fire



- Highly variable – function of time since fire, rainfall, edaphic / site factors
- Load can decline with age after about 30 years

Model inputs:
Fuel load (t/ha) from cover and height; cover only



Fuel load from fuel cover and fuel height

Fuel load (t/ha) = 0.08(cover-%) + 0.13(height-cm)

Model inputs

Fuel Moisture Content

- Spinifex is a live fuel with varying proportions of dead fuel
- Live fuel moisture varies depending on soil moisture
- Dead fuel moisture varies depending on RH
- Net fuel moisture is a function of live and dead fuel moisture and the proportions of each
- No fuel moisture content models available for spinifex

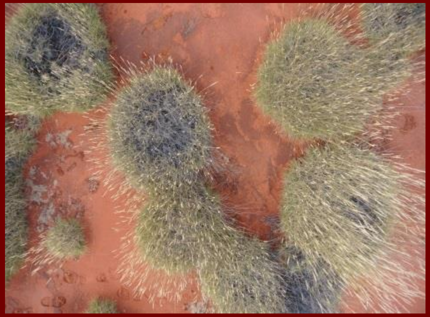
Model inputs

Spinifex fuel age / structural classes

Fuel Class 2 (6-10 years old)
Compact hummocks 20-30 cm tall and 20-30 cm wide. Mostly discrete, some joined. No or few dead leaves and stems evident in hummocks. Some soft grasses and herbs may be present.

Fuel Class 3 (11-15 years old)

Plants are roughly circular, dome-shaped clumps 20-35 cm high, 20-50 cm wide. Many discrete, but many are joined. Dead (black/grey) leaves and stems in the hummock, dead patch forming in the centre of the hummock.



Model inputs

Spinifex fuel age / structural classes

Fuel Class 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 band of dead stems behind the live front. Sometimes the growing front is fragmented. These meadows can be mixed age, with some younger plants.

Fuel Class 5 (20-25)

Oldest plants have formed 'crescents' up to 3 m diameter with a dense mat of dead (black) leaves and stems behind the growing front. There are similar proportions of live and dead material. Sometimes the growing front is fragmented. These meadows can be mixed age, with some younger plants.

Model inputs

Indirect measures of fuel moisture content (m)
Step 1: Determine m_{colour} from clump colour

1. Leaves bright green with few / no yellow leaves: m_{colour} ~31-38%

2. Leaves pale green with some yellow leaves: m_{colour} ~23-30%

3. Leaves yellow-green with many yellow leaves: m_{colour} ~17-22%

4. Leaves yellow / straw, little or no green leaves. m_{colour} ~12-17%

Model inputs

Step 2: Correct for fuel age /class (dead material)

- Class 2 fuel:

No correction required

- Class 3 fuel:

$m = m_{colour} - (1/(0.03 \times RH)) \times 1.5$

If m < 14%, then set m to 14%

- Class 4 Fuel:

$m = m_{colour} - (1/(0.03 \times RH)) \times 2.5$

If m < 13%, then set m to 13%.

- Class 5 Fuel:

$m = m_{colour} - (1/(0.03 \times RH)) \times 3.5$

If m < 12%, then set m to 12%.

Worked example:
m_{colour} = 17-22%; midpoint = 19.5%
For Class 3 fuel and RH = 20%:
$m = m_{colour} - (1/(0.03xRH)) \times 1.5$
m = 19.5 – 2.5 = 17%

Model Inputs

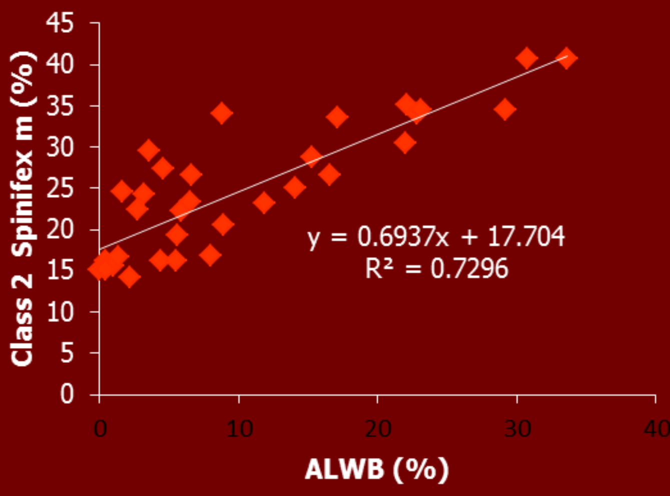
Fuel moisture content from soil moisture using the Australian Landscape Water Balance (ALWB) model

$m_{c2}(\%) = 0.69x(AWLB_{RZ}) + 17.7$

Where:

m_{c2} = moisture content of Class 2 fuel structure

$ALWB_{RZ}$ = Australian Landscape Water Balance root zone soil moisture (http://www.bom.gov.au/water/landscape)



Adjusting for different fuel structural classes / proportions of dead fuel, and RH, see above for m_{colour} corrections

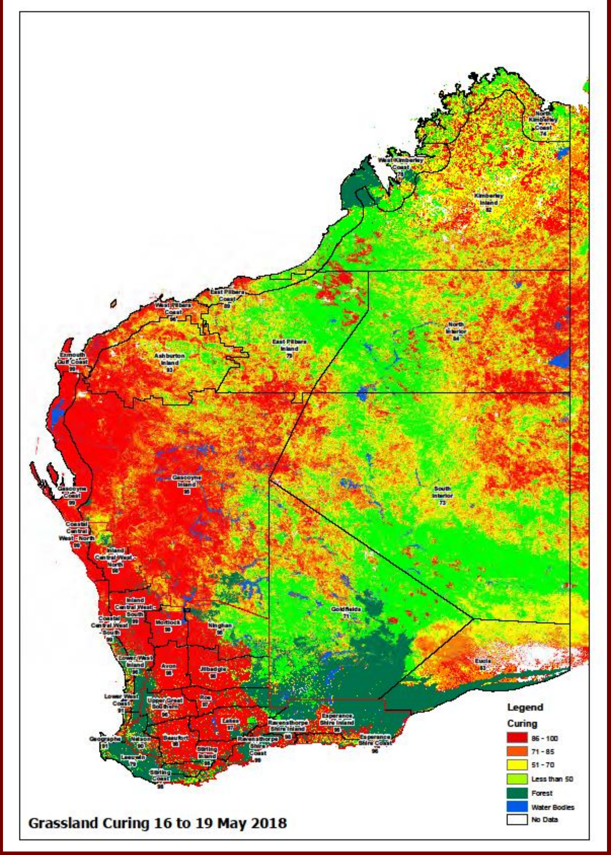
There will be a lag between soil and plant moisture, especially during rapid wetting and drying phases, but it's a good guide.

Model inputs

Indirect measures of fuel moisture content

- Remote sensing (NDVI)

A work in progress



Acknowledgements

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Questions

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