MODELLING FEEDBACK BETWEEN FUEL-REDUCTION BURNING AND FOREST CARBON AND WATER BALANCE IN EUCALYPT FORESTS

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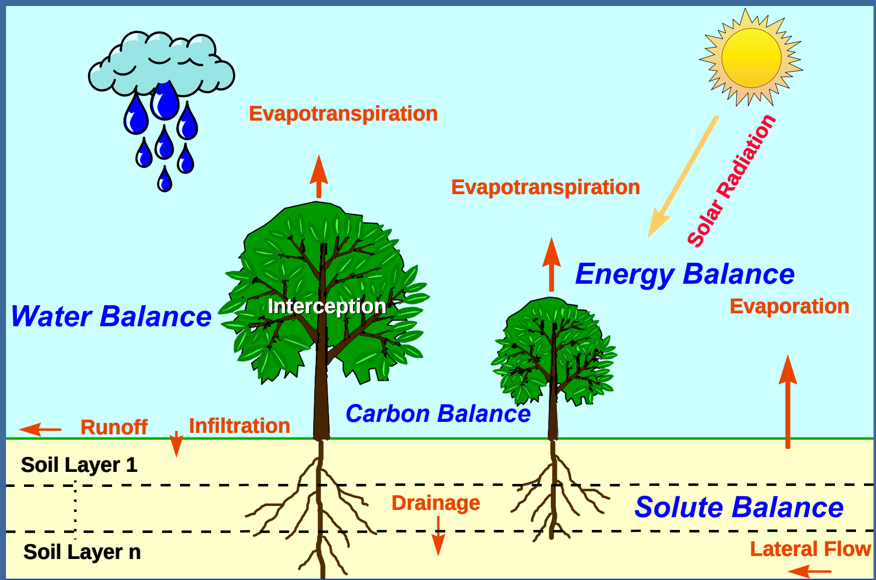
BACKGROUND

1) Fuel reduction burning (FRB) effective for reducing severity and extent of unplanned fires in Australia
2) Priority is for mitigation of risk to life and property
3) Integration of environmental values into fire management operations; high quality water, capacity for carbon sequestration

CARBON AND WATER PROCESSES ARE LINKED, WHY SIMULATE IN ISOLATION?

1) WAVES model (Zhang et al. 1996) - Simulating water, energy, carbon
2) Vegetation growth and death, one-dimensional, process based, daily
3) A new approach to quantifying management impact on carbon and water budgeting



Zhang L, Dawes W (1998) WAVES, an integrated energy and water balance model. TR 31-98, CSIRO, Canberra

MODELLED COMPONENTS

Energy balance

- Partitioning of available energy between soil and canopy – plant growth
- Beer's law

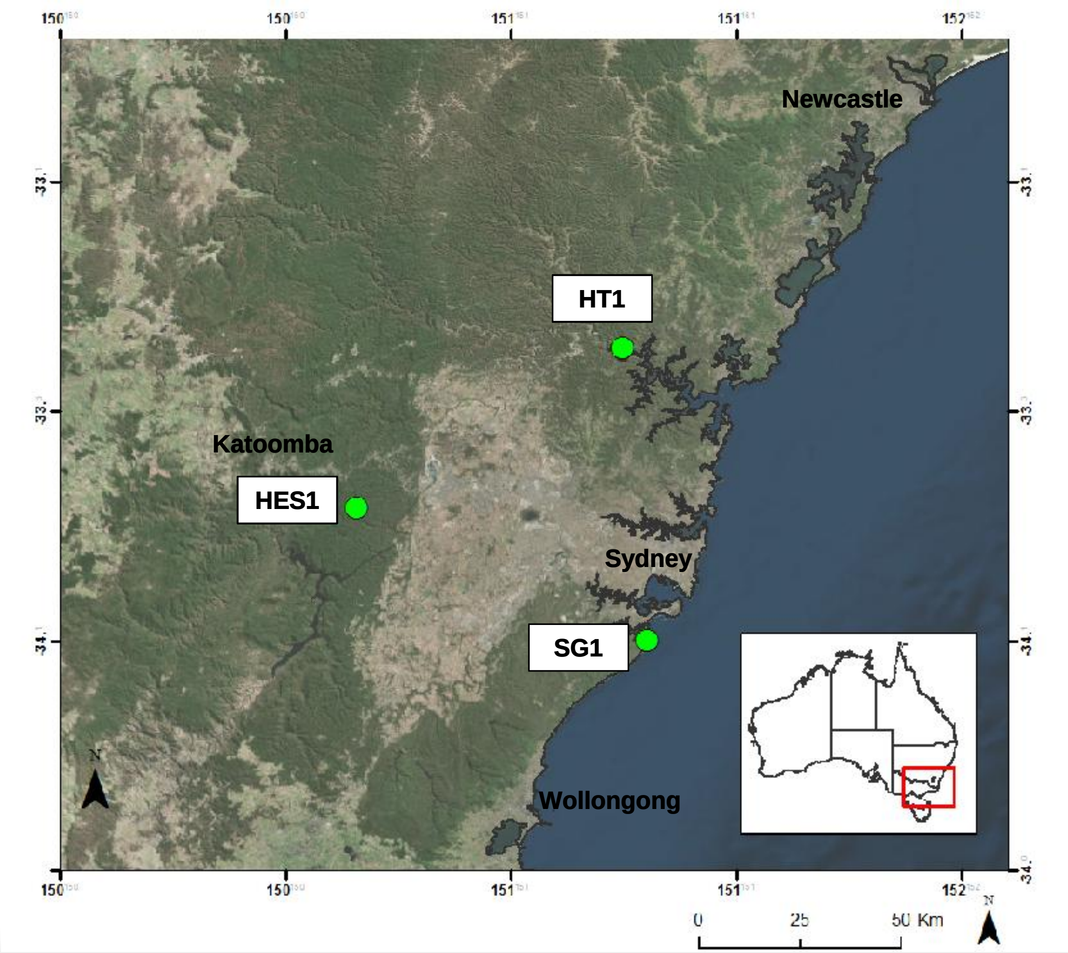
Water balance

- Infiltration
- Runoff
- Evapotranspiration
- Penman-Monteith and Darcy's law

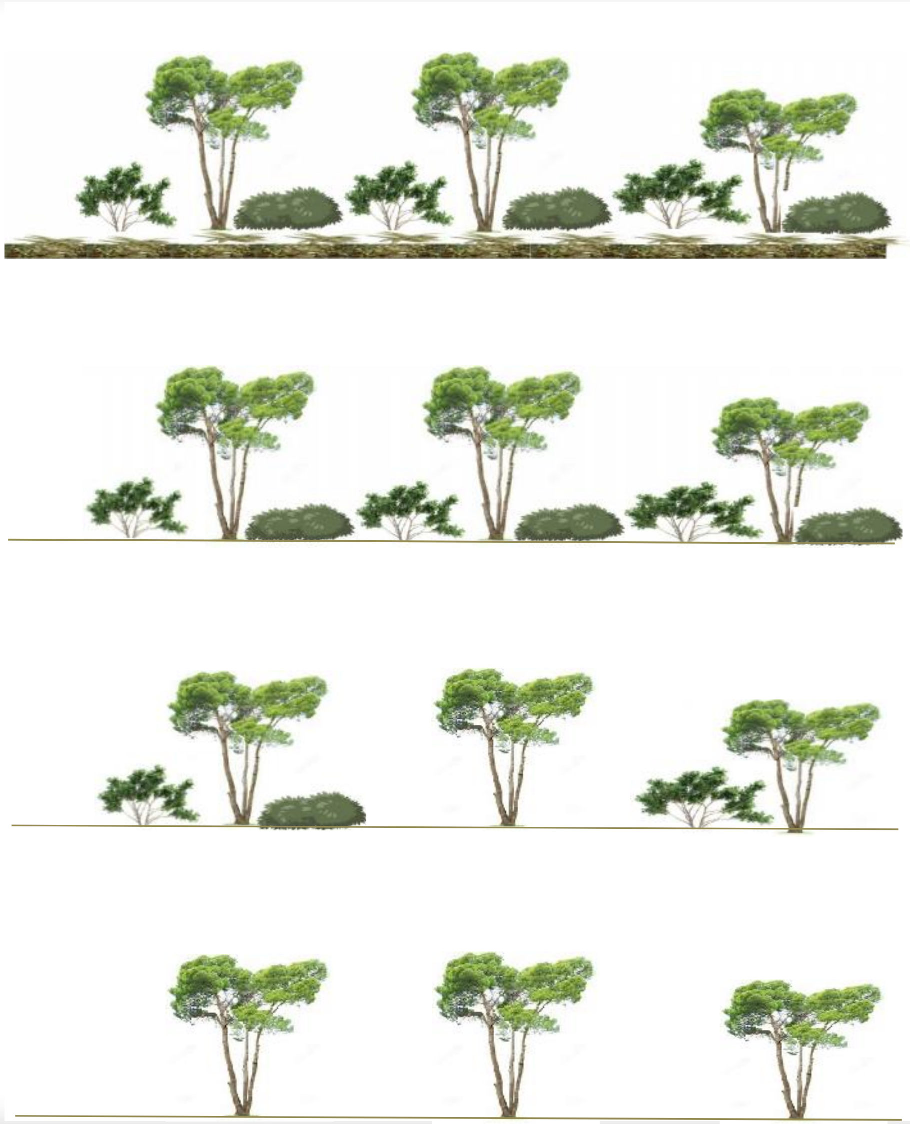
Carbon balance

- Carbon assimilation
- Carbon allocation
- Canopy conductance

STUDY AREA



150
150
151
151
152
Newcastle
HT1
Katoomba
HES1
Sydney
SG1
Wollongong
33
33
34
0
25
50 Km
N



Scenarios

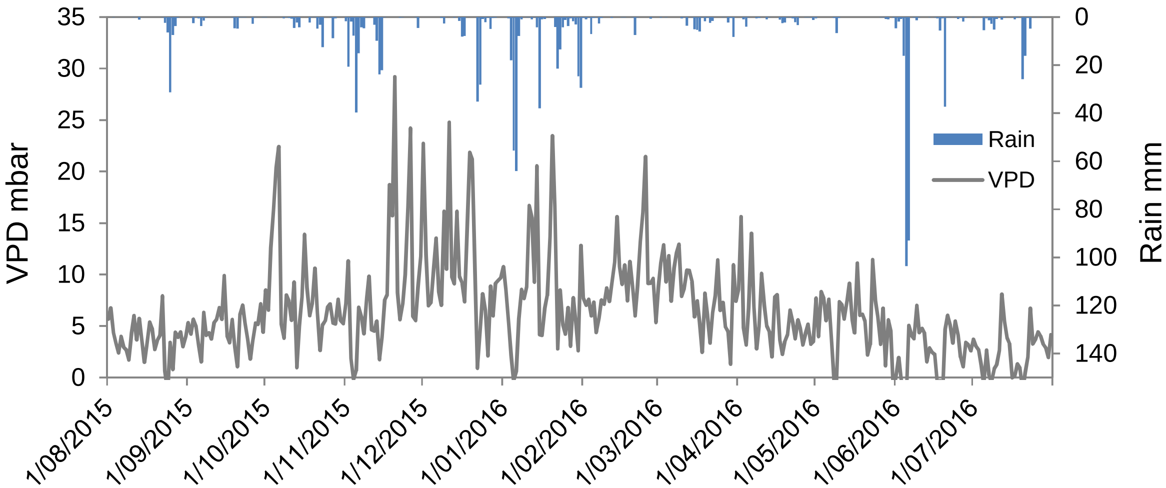
Unburnt

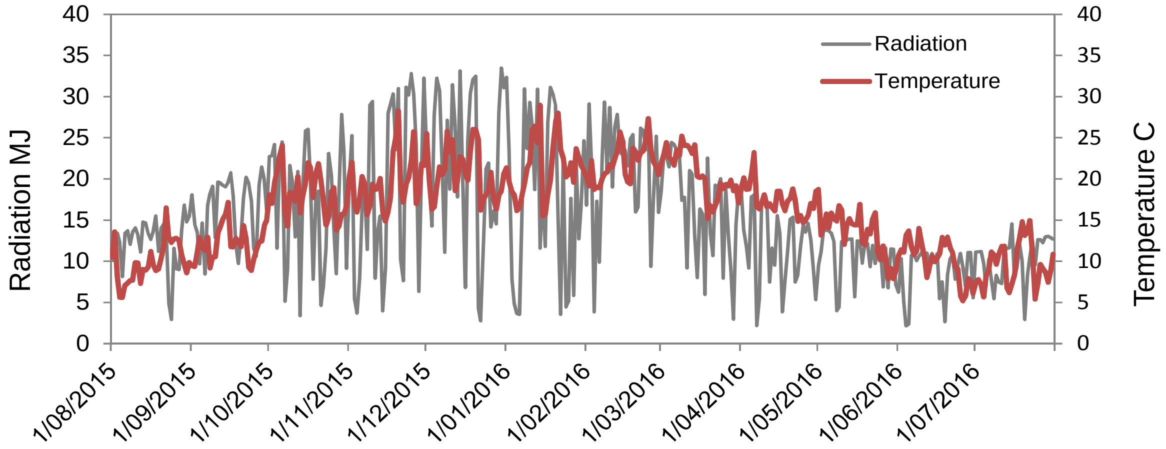
litter removed

litter + 50% understorey

litter + 100% understorey

CLIMATE INPUTS



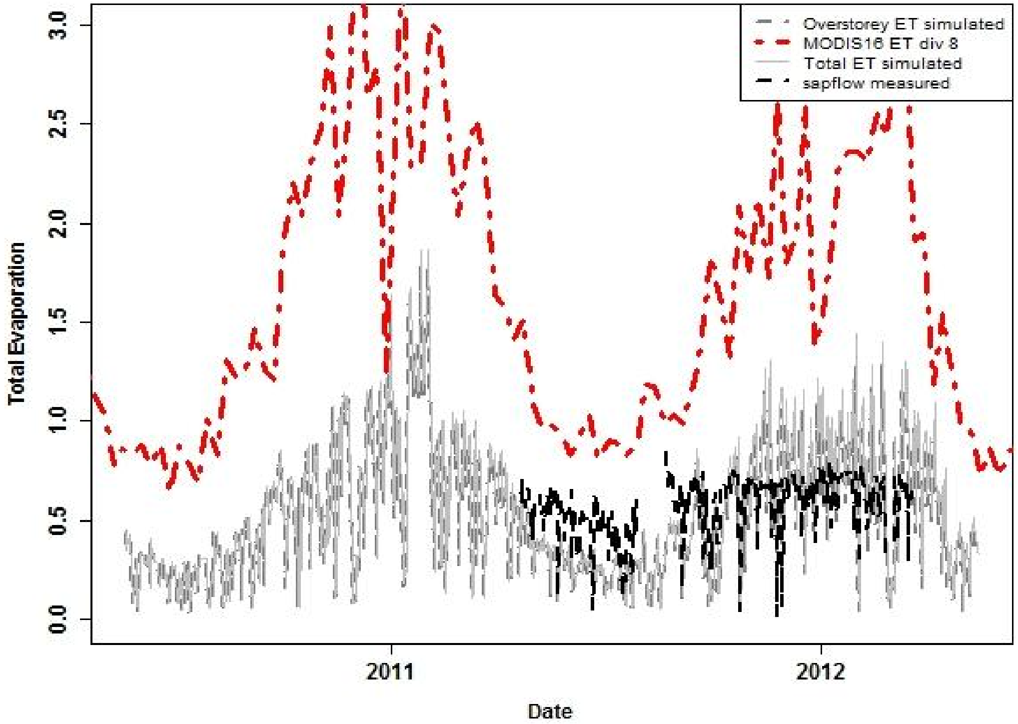


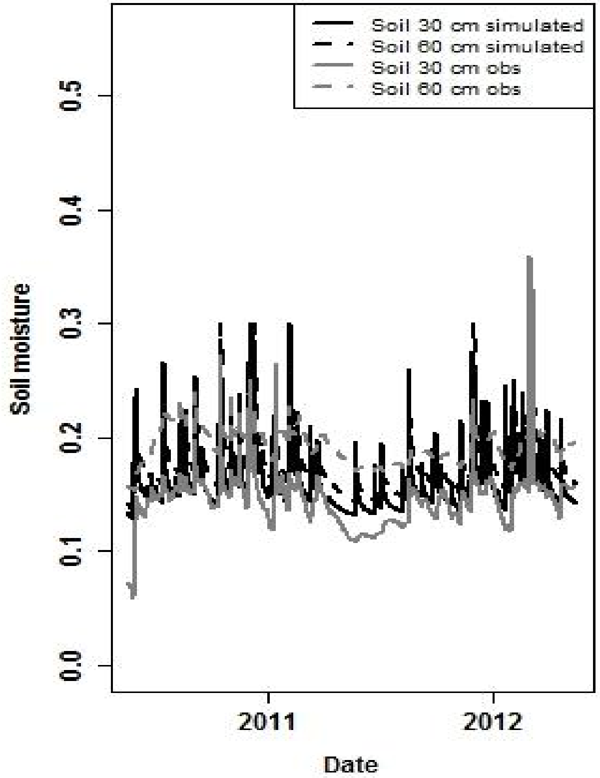
VEGETATION PARAMETERS

Vegetation parameters			
1	1 minus albedo of the canopy	14	Degree-daylight hours for growth
2	1 minus albedo of the soil	15	Saturation light intensity
3	Rainfall interception coefficient	16	Maximum rooting depth
4	Light extinction coefficient	17	Specific leaf area
5	Maximum carbon simulation rate	18	Leaf respiration coefficient
6	Slope parameter for the conductance model	19	Stem respiration coefficient
7	Maximum plant available soil water potential	20	Root respiration coefficient
8	IRM weighting of water	21	Leaf mortality rate
9	IRM weighting of nutrients	22	Above-ground partitioning factor
10	Ratio of stomatal to mesophyll conductance	23	Salt sensitivity factor
11	Temperature when the growth is 1/2 of optimum	24	Aerodynamic resistance
12	Temperature when the growth is optimum	25	Crop harvest index
13	Year day of germination	26	crop harvest factor

Parameterization with sap flow data, MODIS ET, soil moisture measurements (Vervoort et al. 2016)

PARAMETER IDENTIFICATION AND CALIBRATION





From Vervoort et al. (2016)

MODEL INITIALISATION

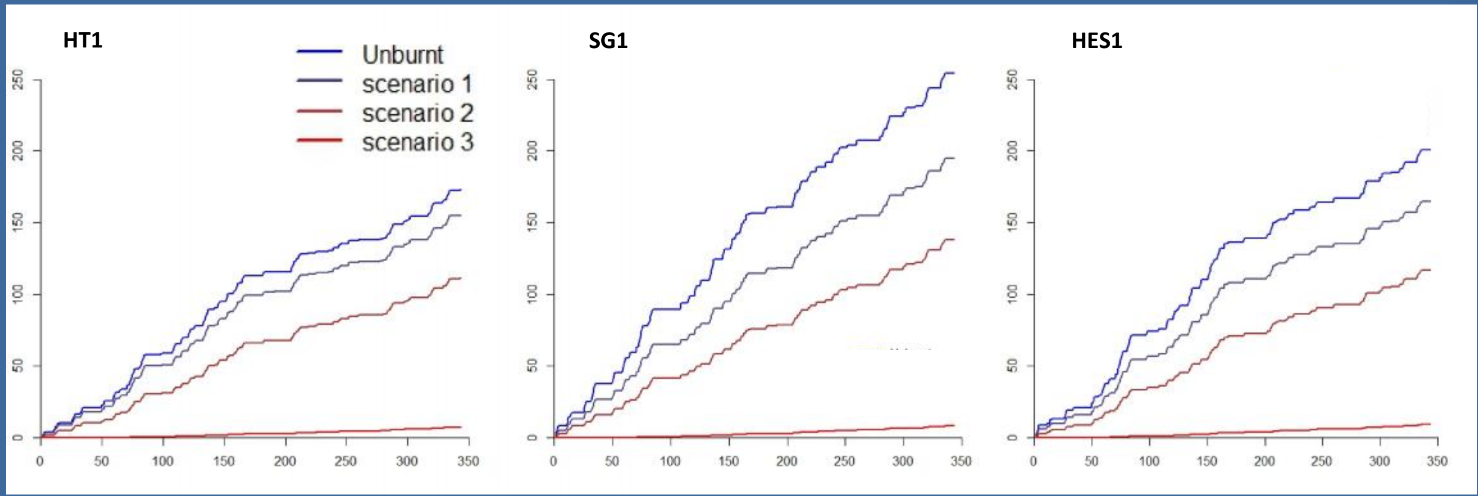
FRB name	FRB size (Ha)	Latitude	Slope (º)	Aspect	Overstorey biomass (t/ha)	Understorey biomass (t/ha)	Litter biomass (t/ha)
HT1	612	-33.0	4	NE	137.8	28.8	4.8
SG1	166	-34.1	5	NE	170.9	40.9	17.3
HES1	634	-33.8	5	NE	255.5	34.8	10.7

Measured litter carbon 47.1% ± 0.1 (± se of mean)

IMPACT ON VEGETATION INTERCEPTION

Response to different fuel reduction burns

Understorey interception (mm)



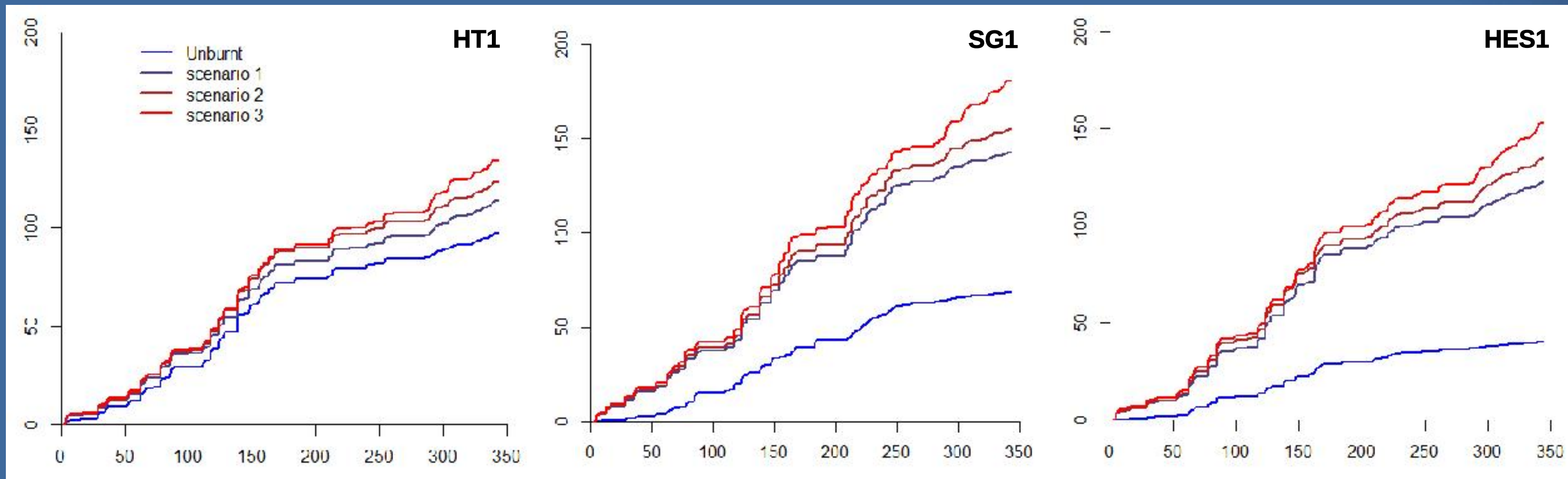
Days

- In the unburnt forests in 8-13% of the incoming rainfall is intercepted by the overstorey and 15-20% by the understorey.

IMPACT ON SOIL EVAPORATION

Response to different fuel reduction burns

Soil evaporation (mm)



Days

- In the unburnt forests only 5% of the net rainfall is lost to soil evaporation. This increases to 15% after fuel reduction burning.

SIGNIFICANT CHANGES IN PRODUCTIVITY AND WATER FLUX DUE TO BURNING?

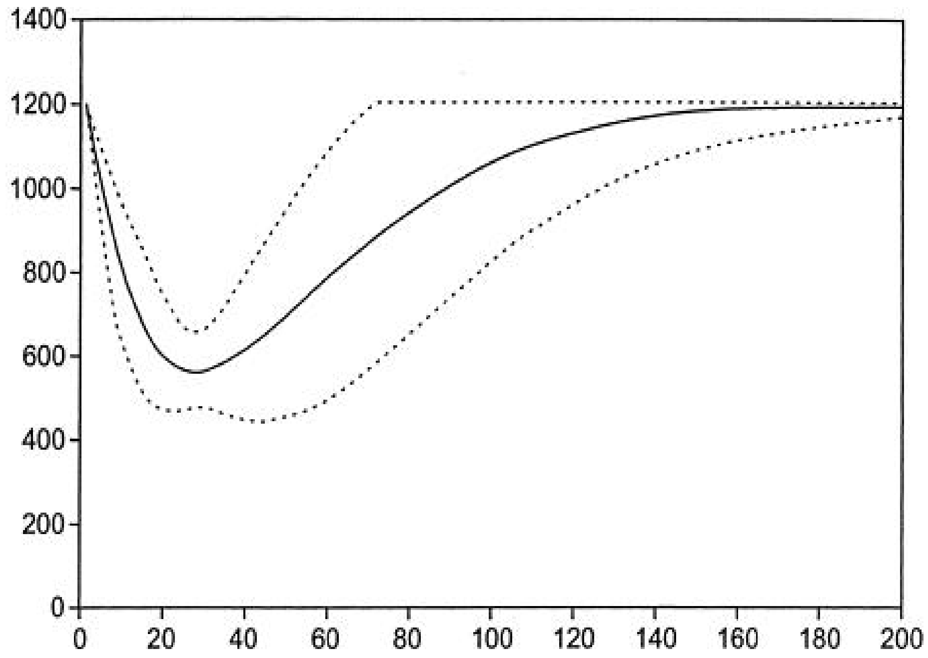
Site	HES1			HT1			SG1		
	S1	S2	S3	S1	S2	S3	S1	S2	S3
ET_{total}	ns	ns	ns	ns	ns	ns	ns	ns	ns
ET_{canopy}	ns	ns	ns	ns	ns	<0.05	ns	ns	<0.001
$ET_{understorey}$	ns	ns	<0.001	ns	ns	<0.001	ns	ns	<0.001
E_{soil}	<0.001	<0.001	<0.001	ns	ns	ns	ns	ns	ns
LAI_{canopy}	<0.001	<0.001	<0.001	ns	<0.05	<0.001	<0.001	<0.001	<0.001
$LAI_{understorey}$	<0.001	<0.001	<0.001	ns	<0.001	<0.001	<0.001	<0.001	<0.001
Litter	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Soil storage	<0.001	<0.001	<0.001	ns	ns	ns	ns	ns	ns

Significance levels tested at $\alpha = 0.05$ with the Mann-Whitney-Wilcoxon method.

IMPACT OF FUEL REDUCTION BURNING COMPARABLE WITH HIGH INTENSITY BUSHFIRES?

After Kuczera (1985):

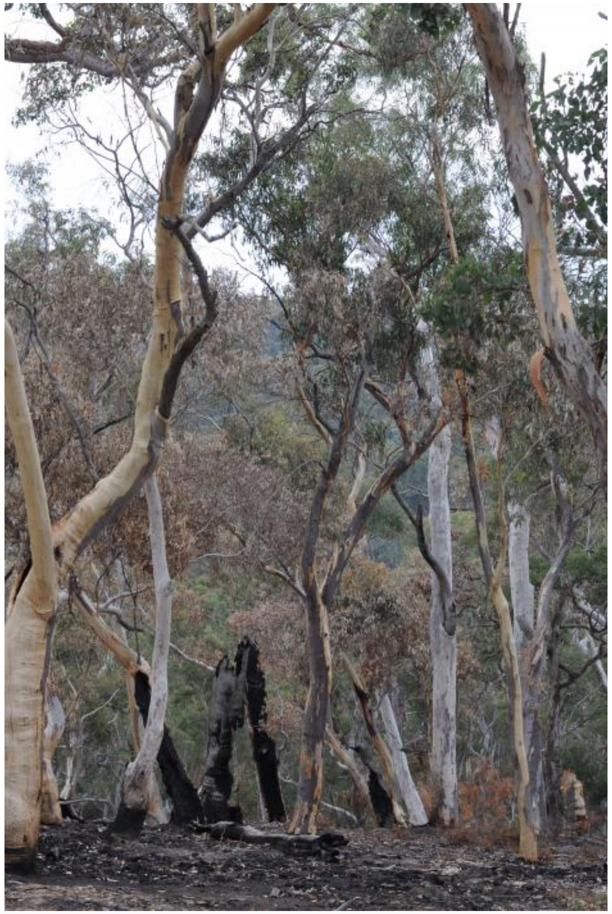
Annual water yield (mm/yr)



Stand age (years)

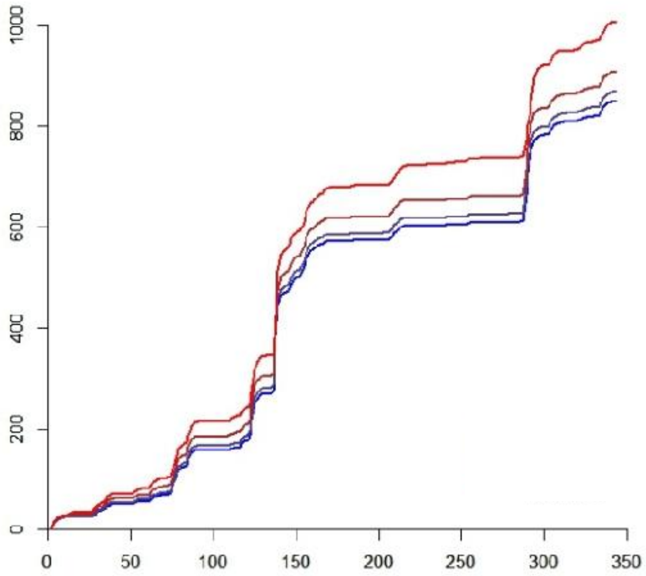
Mountain Ash forests, Falls Creek, Victoria

EFFECT ON CATCHMENT WATER YIELD?



Evapotranspiration (mm)

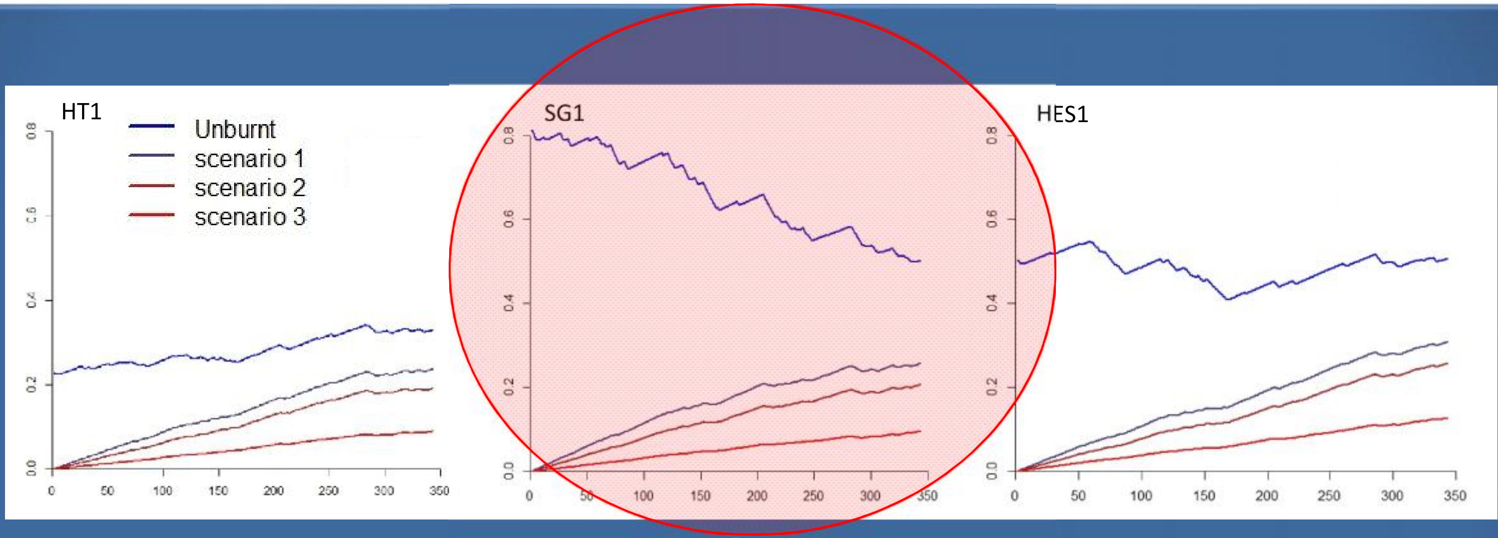
Q?



Days

IMPACT ON CARBON STORED IN FINE FUEL

Carbon in litter (Kg C/m²)



Days

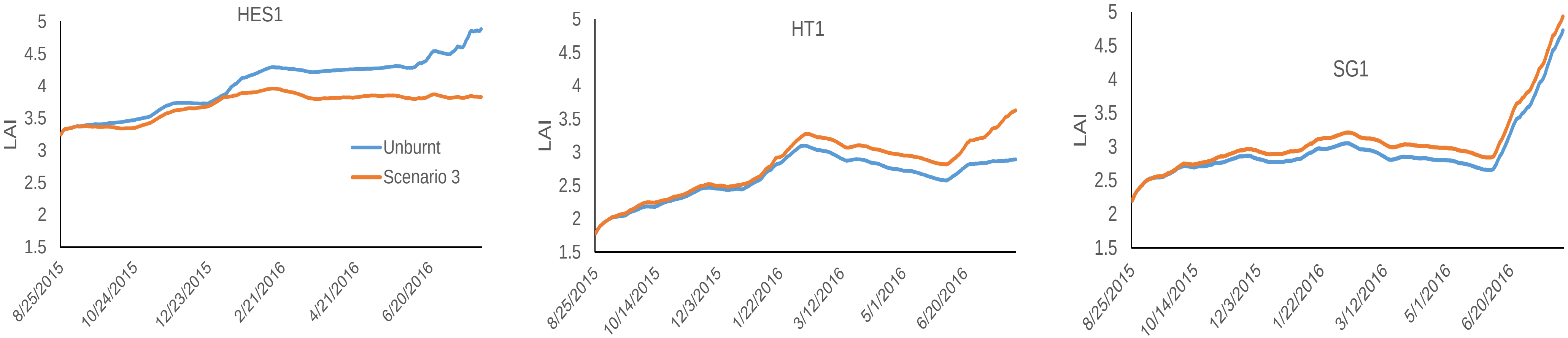
- Average rain mm yr^{-1} → HT1: 1127± 0.5 SG1: 1346 ± 0.6 HES1: 1102 ± 0.5
- Average temperature C → HT1: 18.5± 0.2 SG1: 18.7 ± 0.2 HES1: 16.2 ± 0.3

SIGNIFICANT CHANGES IN PRODUCTIVITY AND WATER FLUX AFTER FRB?

Site	HES1			HT1			SG1		
	S1	S2	S3	S1	S2	S3	S1	S2	S3
ET_{total}	ns	ns	ns	ns	ns	ns	ns	ns	ns
ET_{canopy}	ns	ns	ns	ns	ns	<0.05	ns	ns	<0.001
$ET_{understorey}$	ns	ns	<0.001	ns	ns	<0.001	ns	ns	<0.001
E_{soil}	<0.001	<0.001	<0.001	ns	ns	ns	ns	ns	ns
LAI_{canopy}	<0.001	<0.001	<0.001	ns	<0.05	<0.001	<0.001	<0.001	<0.001
$LAI_{understorey}$	<0.001	<0.001	<0.001	ns	<0.001	<0.001	<0.001	<0.001	<0.001
Litter	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Soil storage	<0.001	<0.001	<0.001	ns	ns	ns	ns	ns	ns

Significance levels tested at α = 0.05 with the Mann-Whitney-Wilcoxon method.

IMPACT ON CANOPY BIOMASS PRODUCTION



- Resource availability -> Increased overstorey growth (LAI)

CONCLUDING REMARKS

1) Global carbon modelling and accounting after fire

2) Application of physical models, over space and time

3) Fuel reduction burning impact on overstorey growth

4) Differences in carbon allocation related to stand density and site conditions (P, T)

5) Assumptions about nutrient limitation, rooting depth, soil properties with depth → More research needed…

THANK YOU

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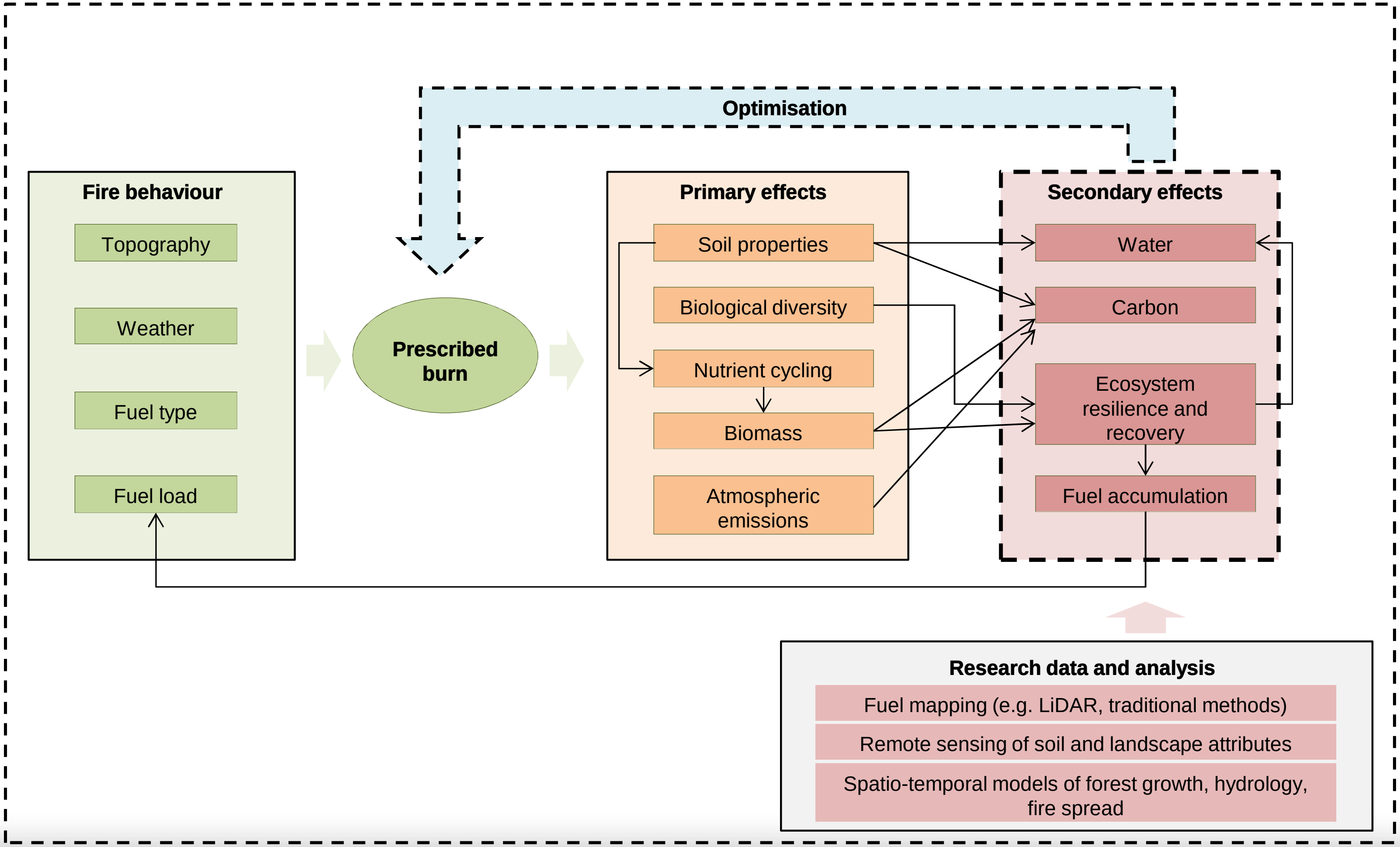
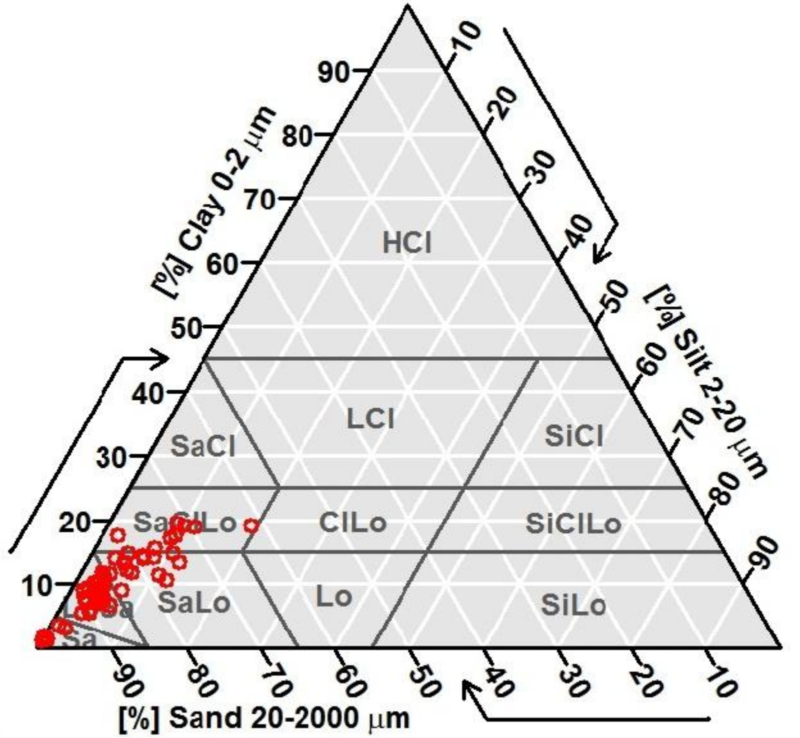
OPTIMISATION OF FUEL REDUCTION BURNING



SOIL PROPERTIES

- Soil hydraulic properties using the Broadbridge and White (1988) soil hydraulic model



VALIDATION WITH MODIS LEAF AREA INDEX