OPTIMISATION OF FUEL REDUCTION BURNING REGIMES FOR FUEL REDUCTION, CARBON, WATER AND VEGETATION OUTCOMES

Presented by: Malcolm Possell, Mana Gharun

Australian Government
Department of Industry and Science
Business Cooperative Research Centres Programme

THE UNIVERSITY OF SYDNEY

CURRENT TEAM MEMBERS

University of Sydney Researchers:

- Mana Gharun – Postdoctoral Research Associate in Spatial Modelling – Biogeochemistry and Fire (since November 2014, BNH CRC funded)
- Ariana Iaconis – Forester/Research Assistant (since October 2014, BNH CRC funded)
- A number of in-kind researchers and support staff
- Part-time research and field assistants (paid, students and volunteers)

End Users include:

- Felipe Aires and Naomi Stephens, Office of Environment and Heritage, New South Wales
- Max Beuker, National Parks and Wildlife Service, NSW.
- Mike Wouters, Department of Environment, Water and Natural Resources, South Australia
- Liam Fogarty, Department of Environment and Primary Industries, Victoria
- Neil Cooper and Adam Leavesley, ACT Parks and Conservation Services
- Lachlan McCaw, Department of Parks and Wildlife, Western Australia

WHAT DO LAND MANAGERS WANT TO KNOW?

At the start of our project:

1) What does it cost to implement fuel reduction burns (FRB) and how effective are they?
    - Fuel reduction outcomes
2) What is the cost to environmental values for each FRB?
    - Carbon outcomes
    - Water outcomes
    - Vegetation outcomes
3) How does the size of each FRB affect these environmental values?

More recently:

4) What are the risks associated with/without FRB?
5) What are the environmental costs of repeated FRB?

RESEARCH OBJECTIVES

1) Review of current modelling frameworks
2) Development of a sampling protocol to quantify key variables related to FRB
3) Design and test a statistical robust sampling scheme for use at range of spatial scales
4) **Application of sampling schemes and field techniques**
5) Data analysis and synthesis to assess the effects of size of FRB
6) **Developing spatially accurate measures of forest stand and catchment-scale water balances**
7) Developing routine and reliable measures of fire intensity/severity on soil carbon

ARE WE ACHIEVING OUR RESEARCH OBJECTIVES?

1) Captured variability at a range of scales
2) Field sampling protocols and schemes that are (1) statistically robust and repeatable and (2) can be used by a range of stakeholders
3) Our analytical and modelling efforts using field data are providing new insights into the impact of fire on environmental values

The integration of environmental values (e.g. maintenance of high water yield and quality, reduction of CO_2 emissions and conservation of biodiversity) into fire management operations is possible

TEACHING AND TRAINING

Houzhi Wang – Initiation of biomass smouldering combustion PhD commenced March 2014, University of Adelaide.

Mengran (Clare) Yu – Modelling the effect of fire on the hydrological cycle. PhD commenced March 2015, University of Sydney.

Gabriella Raducan – The impact of bushfires on water quality. PhD commenced in March 2014, RMIT.

Angela Gormley – Effects of surface litter on fuels and fire behaviour in the Sydney Basin. MPhil commenced in January 2016, University of Sydney.

Number of undergraduate student projects:

Bonnie Cannings (BEnvSys Honours), **Erika Sedlacek de Almeida** (University of Sydney Internship Program), **Amanda Josefsson** (self-funded internship), **Katharina Leser** (DAAD internship) and **Sebastian Pietz** (DAAD internship).

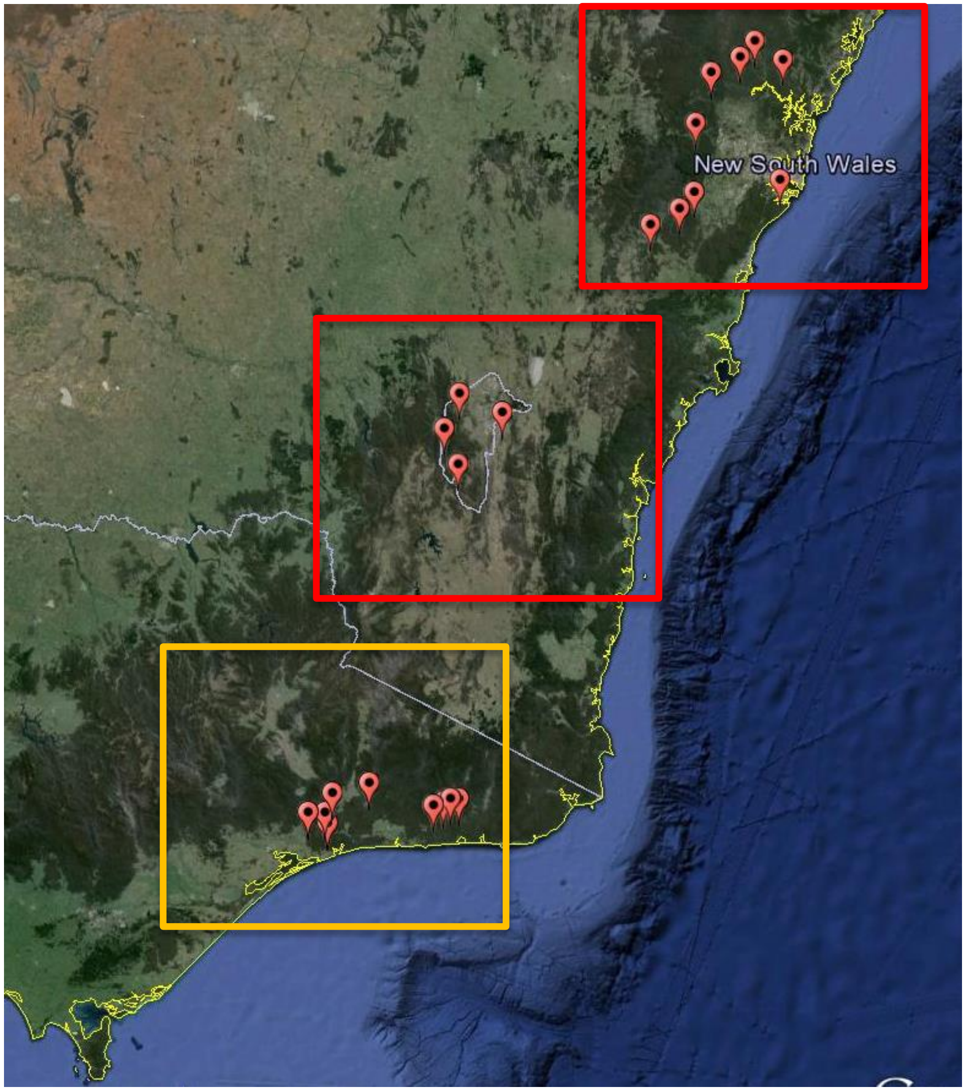
AREAS OF STUDY

9 sites → 27 burn units → 54 plots

4 sites → 12 burn units → 24 plots

9 sites → 27 burn units → 108 plots

Total = 186 sampling plots

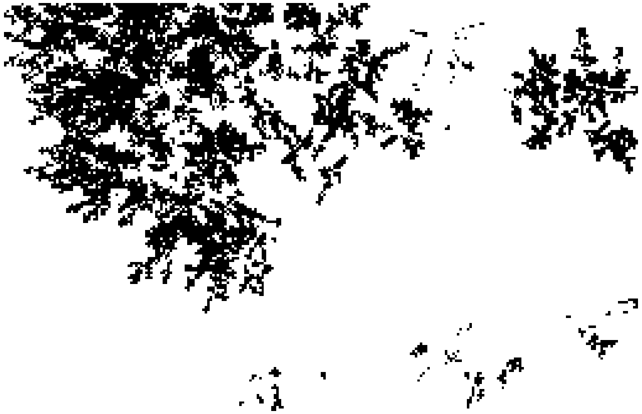


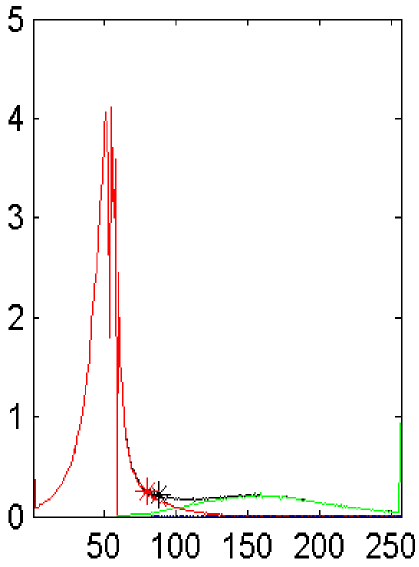
MEASUREMENT OF CARBON POOLS

- Overstorey biomass, canopy fuel
- Understorey biomass (trees and shrubs), elevated fuel
- Ground cover biomass, Near-surface fuel
- Litter biomass, surface fuel
- Coarse woody debris, surface fuel
- Soil carbon

Current field sampling protocol ("Sampling Schema") can be used as a training tool for staff

APPLICATION OF DIGITAL PHOTOGRAPHY
(UNDERSTOREY LEAF AREA + OVERSTOREY LEAF AREA)

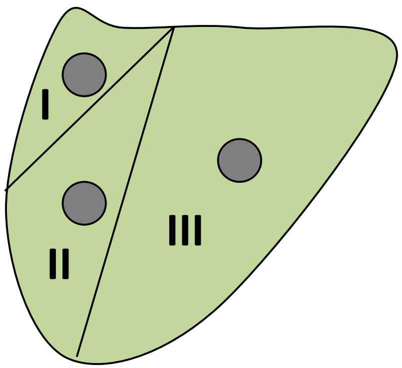




(Macfarlane *et al.* 2007; Fuentes *et al.* 2008; Macfarlane and Ogden 2012)

CALCULATING NUMBER OF SAMPLING PLOTS REQUIRED FOR ESTIMATION OF CARBON STOCK

What information is needed:



What is the size of the area of interest?
What is the size of individual sampling plots?
What is the desired level of precision? (10% in Land Use, Land-Use Change and Forestry)

What assumptions are made:

The project area is stratified into one or more strata.
Approximate area of each stratum is known.
Approximate value of the variance of biomass stocks in each stratum is known (e.g. from a preliminary sample, existing data related to the project area, or existing data related to a similar area).

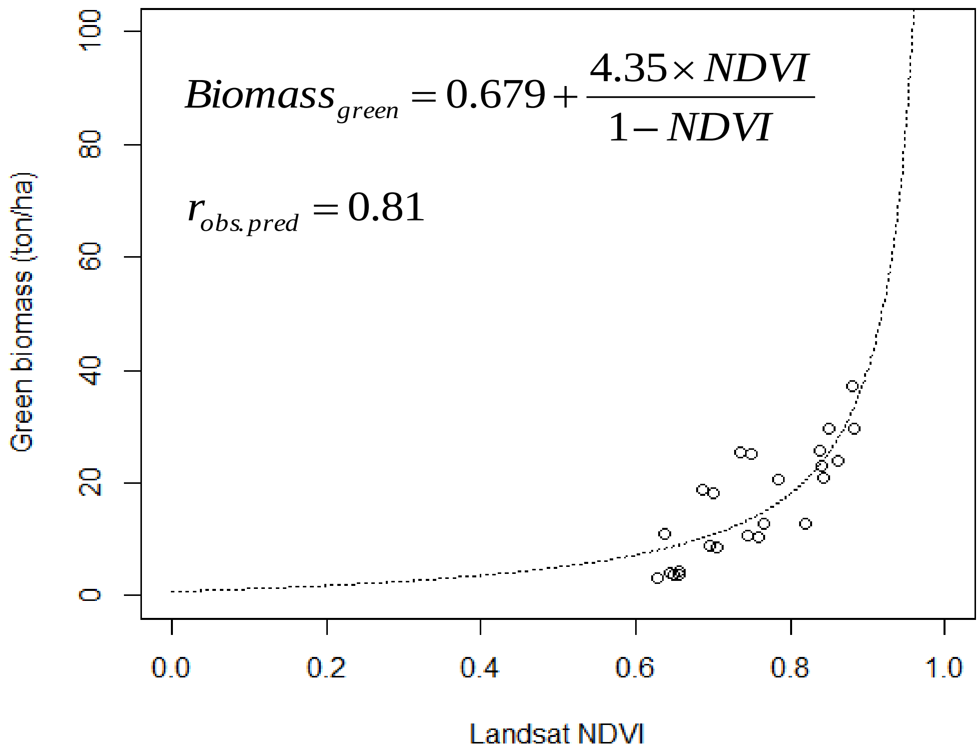
MODELLING GREEN BIOMASS USING SATELLITE DATA

Measurement of trees size, allometric relationships → Canopy Foliage biomass

Measurement of understorey stem diameter + allometric relationships → Understorey biomass

Measurement of ground cover biomass (weighing in the lab)

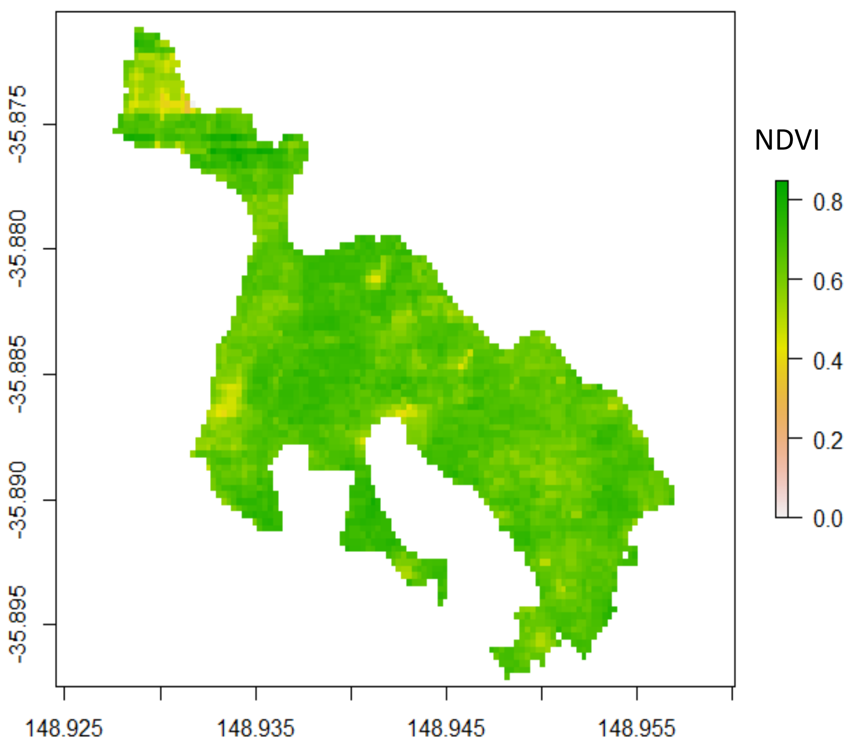
Plot-level green biomass (ton/ha)



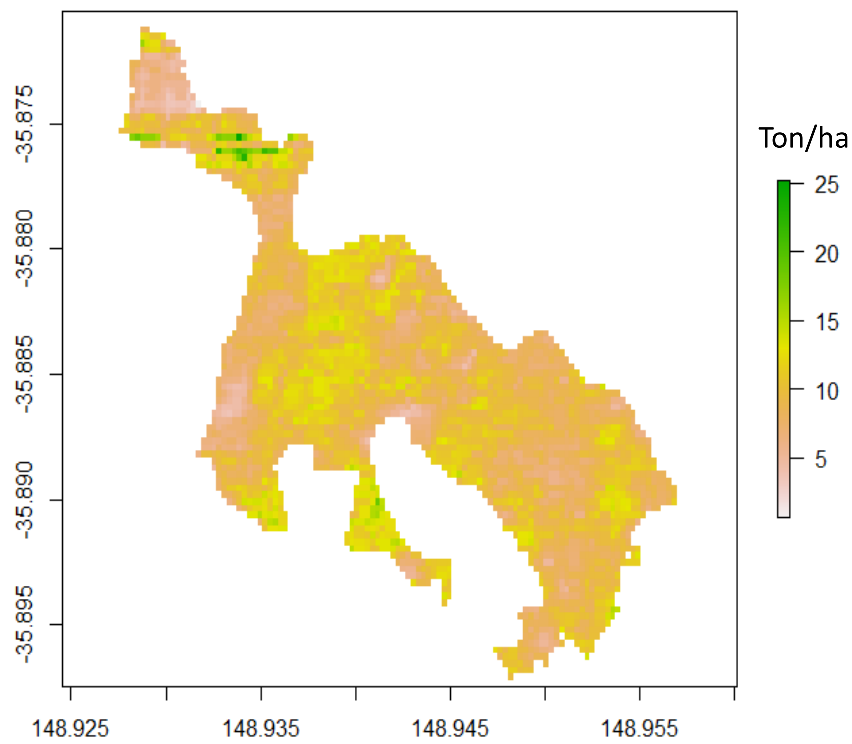
Normalized Difference Vegetation Index (NDVI) was extracted for each plot, Landsat 8, cloudfree Accessed from: http://espa.cr.usgs.gov./

MAPPING GREEN BIOMASS (TON/HA)

Landsat NDVI



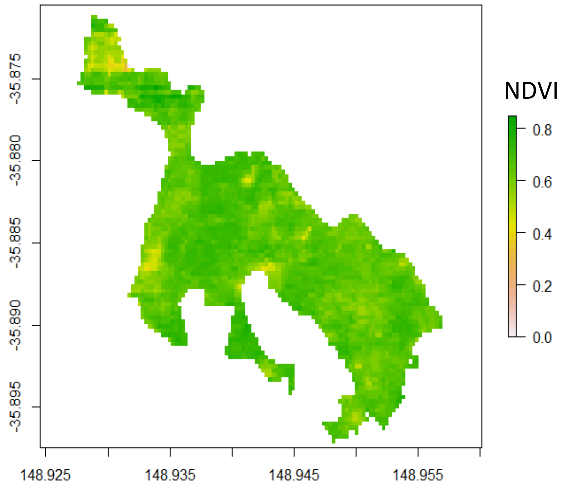
Modelled Green biomass

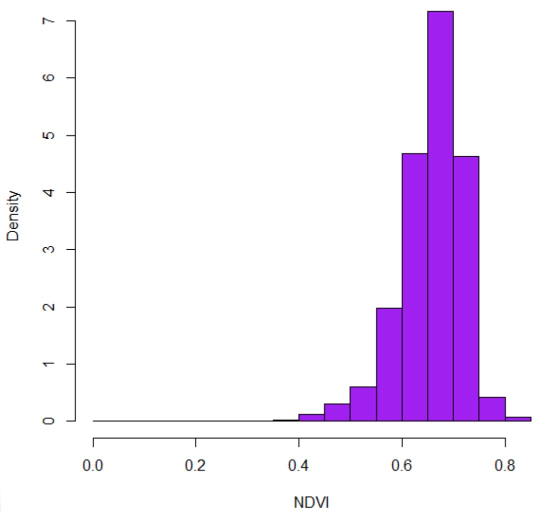


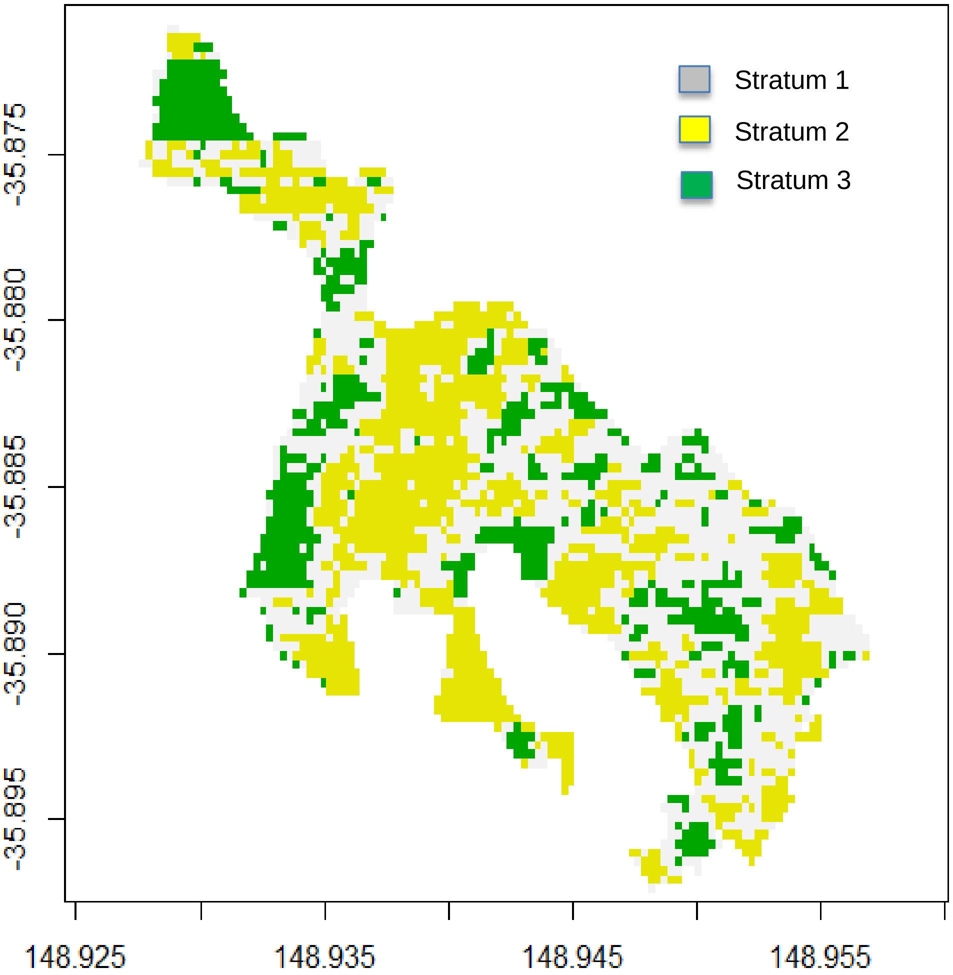
Mapping green biomass from NDVI:

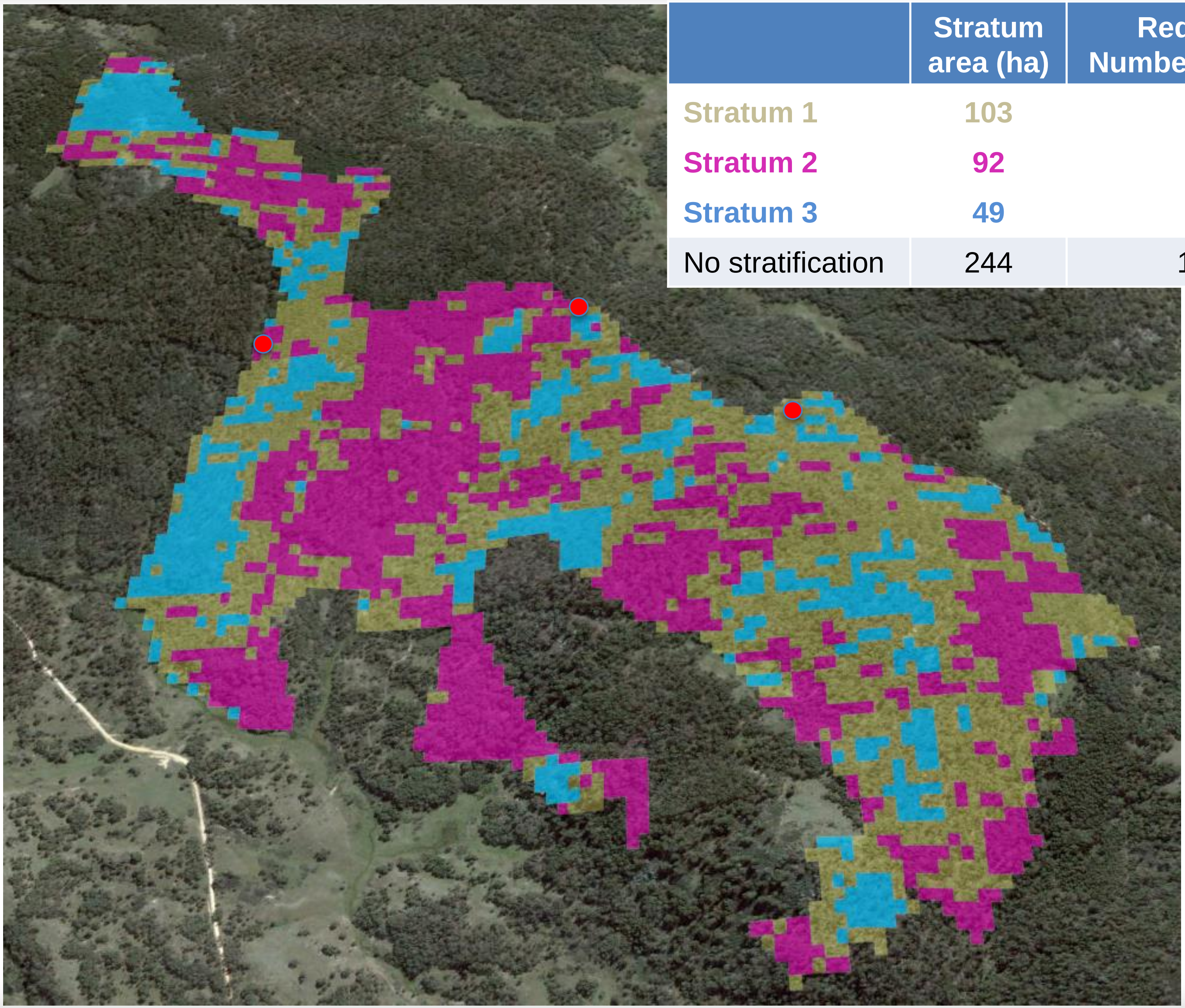
$$Biomass_{green} = 0.679 + \frac{4.35 \times NDVI}{1 - NDVI}$$

STRATIFICATION BASED ON LANDSAT NDVI



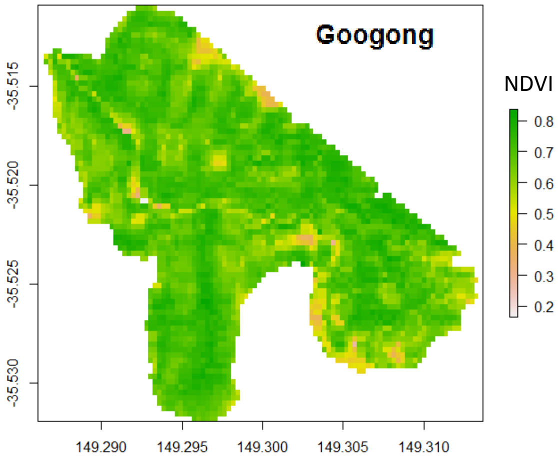




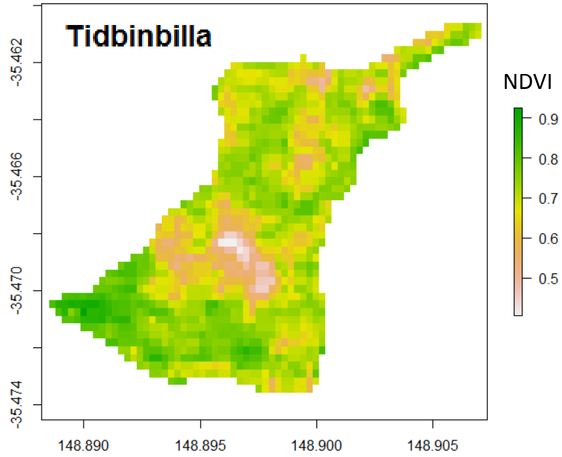


	Stratum area (ha)	Required Number of plots
Stratum 1	103	1
Stratum 2	92	3
Stratum 3	49	1
No stratification	244	110

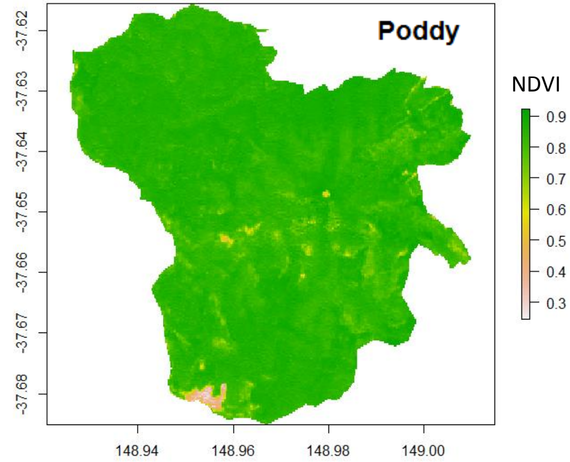
$N_{stratified}$ 6
$N_{not\ stratified}$ 4
Burn Area 281 ha



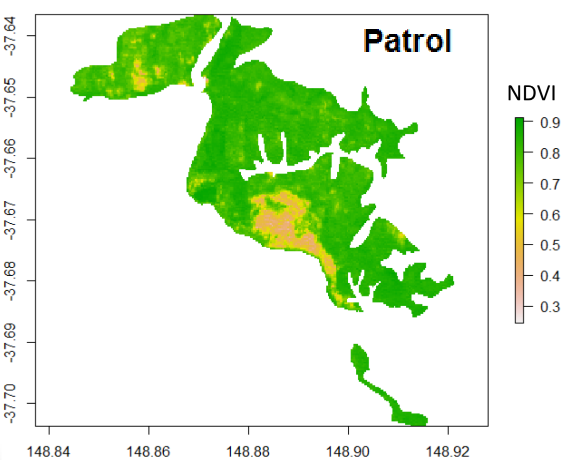
$N_{stratified}$ 16
$N_{not\ stratified}$ 156
Burn Area 94 ha



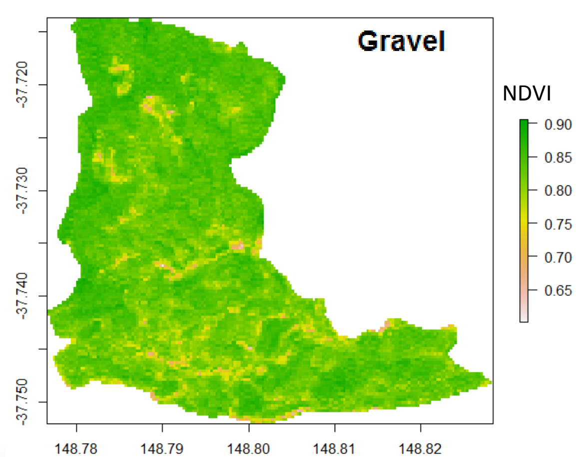
$N_{stratified}$ 3
$N_{not\ stratified}$ 3
Burn Area 3,474 ha



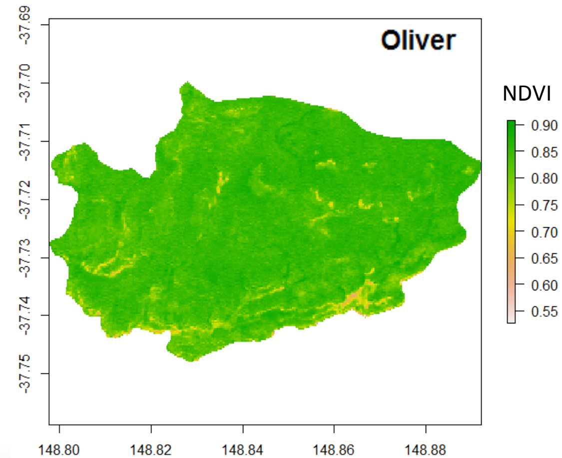
$N_{stratified}$ 9
$N_{not\ stratified}$ 87
Burn Area 1,359 ha



$N_{stratified}$ 2
$N_{not\ stratified}$ 19
Burn Area 968 ha



$N_{stratified}$ 2
$N_{not\ stratified}$ 4
Burn Area 2,829 ha



IMPACT OF FRB ON WATER AVAILABILITY

TREE WATER USE – MEASUREMENTS AND MODELS

Individual Tree water use (Q_{tree}, litre day^{-1})

+

Plot area (ha)

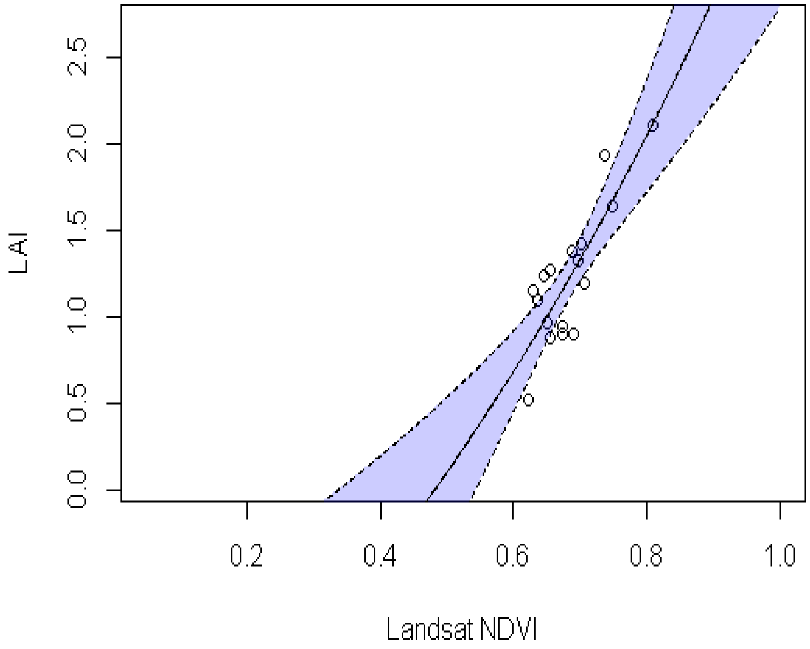
→

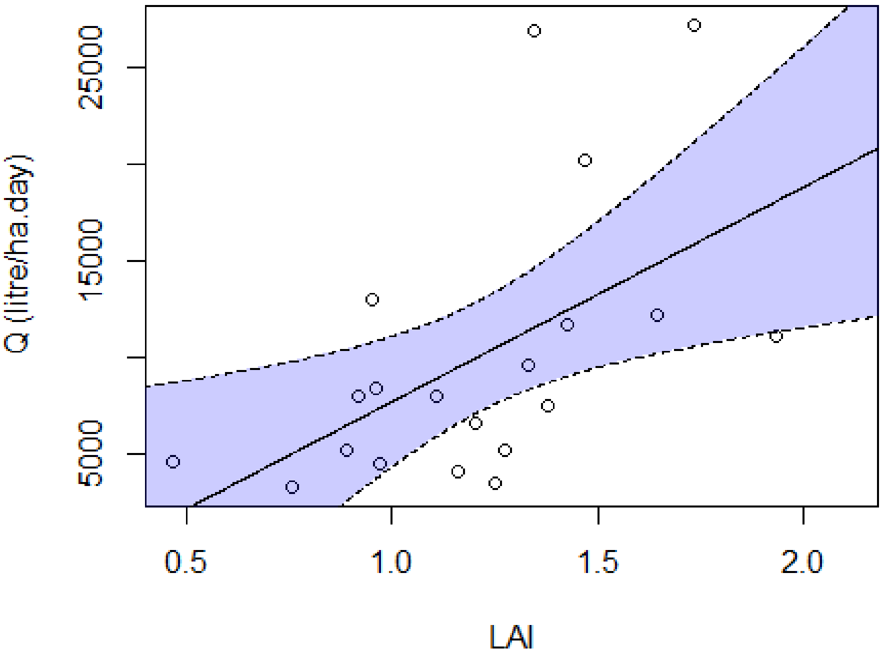
Plot-scale tree water use (Q_{plot}, litre ha^{-1} day^{-1})

MODELLING PLOT-LEVEL TREE WATER USE

Plot-level Leaf area index (LAI) is directly related to plot-level tree water use,

(more productivity → more water use)





$LAI = 0.04\ e^{4.88\ NDVI}$

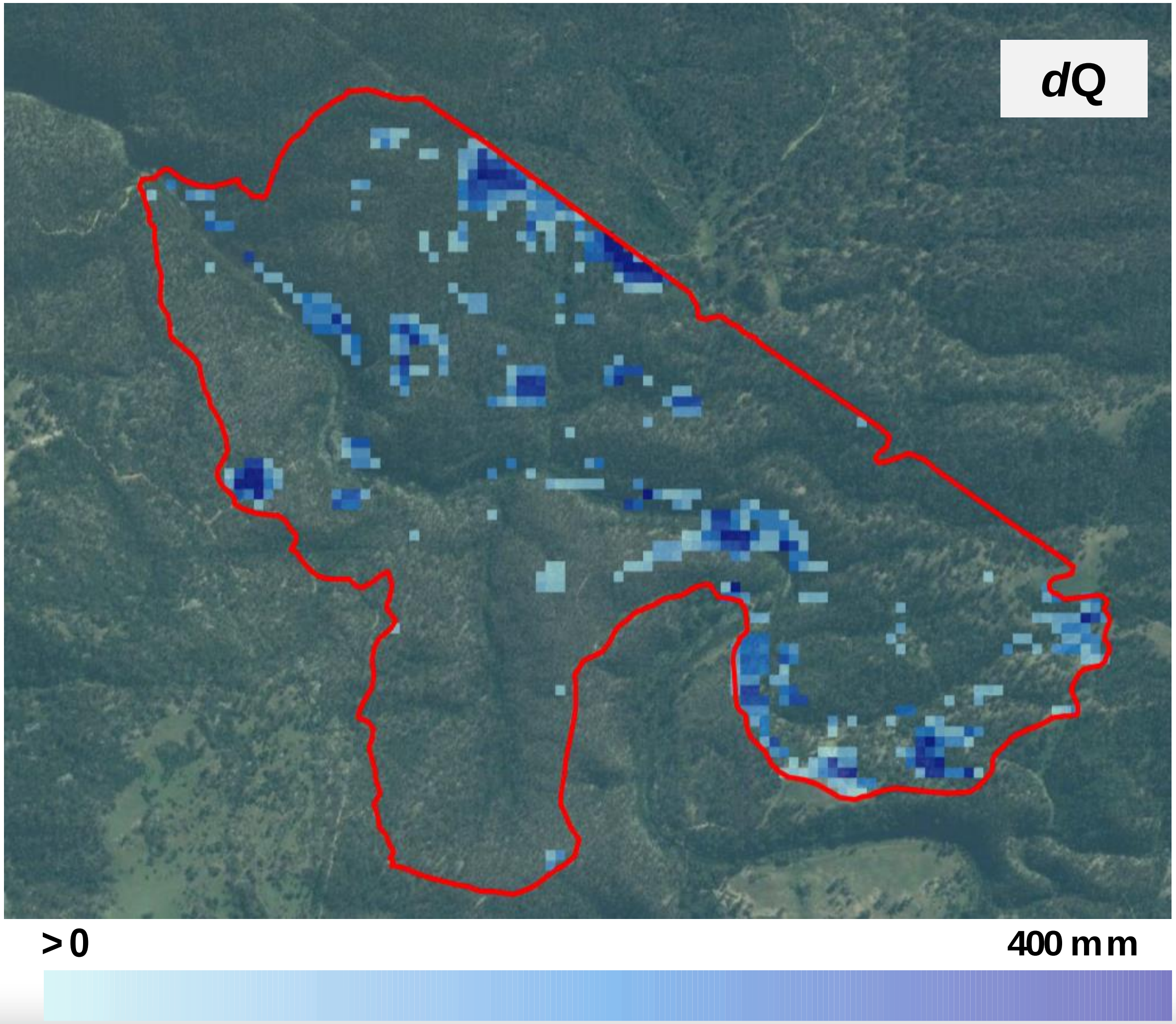
($p < 0.05$, $r^2 = 0.69$)

$Q_{plot} = 11107\ LAI - 3410$

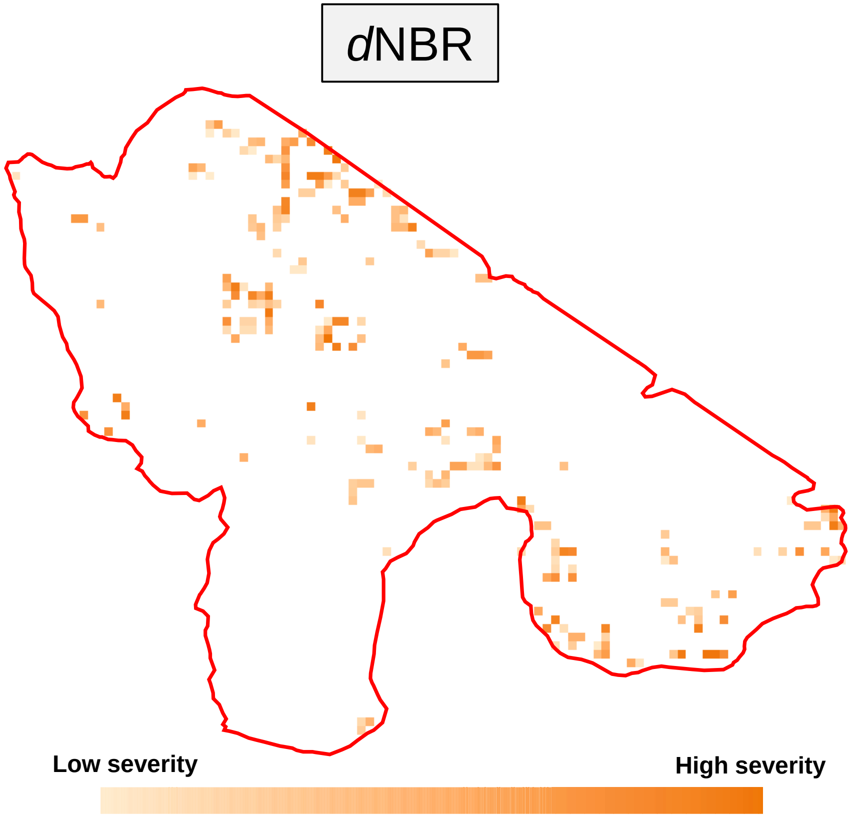
($p < 0.05$, $r^2 = 0.30$)

MAPPING CHANGES IN PLOT-LEVEL TREE WATER USE

$$dQ = Q_{\text{pre burn}} - Q_{\text{post burn}}$$



BURN SEVERITY AND IMPACT ON WATER AVAILABILITY



NBR = Normalized Burn Ratio

$$dNBR = NBR_{\text{pre burn}} - NBR_{\text{post burn}}$$

Burn severity level	Maximum decrease in *Q* (mm year^{-1})
Low to moderate severity	150
Moderate-high severity	230
High severity	400

SUMMARY

- Increasing sample plot area reduces variation among plots → small sample size at the same precision level.

- More variance in carbon stocks, more sample plots needed for a low uncertainty. Stratification reduced variability between plots → fewer samples required.

- A 1 unit reduction in forest LAI will result in 11,100 L ha^{-1} day^{-1} reduction in forest water use (~ 400 mm $year^{-1}$).

- Understorey LAI is commonly neglected in models of forest LAI while it is more affected by a FRB than the overstorey LAI.

- Identification of hydrologically sensitive areas in accordance with certain management objectives.

THE NEXT 12 MONTHS

1) Meeting sampling targets for 2016-17
2) Fieldwork in northern NSW and other states to validate model development
3) Calibration and testing of fuel, vegetation, water and carbon models

Future directions

1) The impact of risk-based FRB strategies on environmental values(e.g. high frequency FRB in areas significant at regional scales)
2) Incorporation of other sources of data into models (e.g. historical, from other BNH CRC projects, agency data)
3) End User input???