ESTIMATION OF THE IMPACT OF FUEL-REDUCTION BURNING ON CATCHMENT WATER BALANCE USING DIGITAL PHOTOGRAPHY

bushfire&natural HAZARDS CRC

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BACKGROUND

Fuel-reduction burning (FRB) impacts catchment water supply predominately by removing the vegetation and modifying the amount of vegetation water use (i.e. evapotranspiration). Vegetation water use is directly proportional to the amount of leaf area. Changes in the leaf area estimated from the Leaf Area Index (LAI) can be used to assess fire affected areas (Boer et al. 2008).

Aim: With a special focus on the understorey, we use LAI as a proxy to model spatial variability in the impact of FRB on catchment water balance.

Figure 1 Measurement plots in the ACT (4 sites, 24 plots) and NSW (Nattai and Hawkesbury areas, 9 sites, 54 plots).

LEAF AREA INDEX FROM DIGITAL PHOTOGRAPHY

LAI can be measured using digital cover photography (see Macfarlane et al. 2007). This method has widely been used and validated for the overstorey of eucalypt forests, but not for the understorey.

FRB mostly affects the understorey and rapid techniques for measurement of such effect in the field are called for.

We validated digital photography with destructive sampling (Figure 2) before measuring the leaf area index in 78 plots across south-east Australia:

$LAI_{total} = LAI_{overstorey} + LAI_{understorey}$

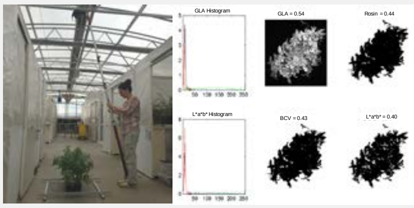


Figure 2 We used 70 pots of *E. globulus* seedlings to validate LAI derived from cover images (left). Biomass was harvested and the amount of leaf area was measured in the lab using a leaf area machine. Method of Macfarlane and Ogden (2012) was used to analyse the cover images (right). Understorey LAI measured with digital photography correlated strongly with the lab results (r^2 = 0.92).

LANDSAT AND GROUND-BASED MEASUREMENTS

Surface reflectance in the red (ρ_{RED}) and near-infrared (ρ_{NIR}) bands were extracted from cloud-free Landsat 8 scenes to estimate Normalized Difference Vegetation Index (NDVI) for each plot:

$$NDVI = \frac{(\rho_{NIR} - \rho_{RED})}{(\rho_{NIR} + \rho_{RED})}$$

Left: Diameter of the overstorey and understorey vegetation was measured in 78 plots (burnt and unburnt) and average water use (Q, litre ha^{-1} day^{-1}) was inferred from the sapwood area (see Pfautsch et al. 2010; Mitchell et al. 2012). Plot size is compatible with stand structure of dry sclerophyll forest and Landsat pixel size (30 m). LAI varied in average 31% in the overstorey and 52% in the understorey.

NDVI was particularly sensitive to the changes in the understorey LAI, and plot-level water use was directly linked to LAI (Table 1).

Table 1 Pearson's correlation coefficient between ground-based leaf area index (LAI), Landsat NDVI and vegetation water use (Q, litre ha^{-1} day^{-1}) for three main study areas separated based on the spatial proximity of the measurement sites.

Study area	LAI_{total} / NDVI	LAI_{over} / NDVI	LAI_{under} / NDVI	Q_{total}/ LAI_{total}	Q_{over}/ LAI_{over}	Q_{under}/ LAI_{under}
ACT	0.83	ns	0.81	0.54	ns	0.67
Nattai, NSW	ns	ns	0.62	0.71	ns	0.89
Hawkesbury, NSW	0.52	0.39	0.39	0.60	0.48	0.82

MODEL DEVELOPMENT

Linear regressions were used to relate (1) plot-level LAI_{total} to Landsat NDVI, and (2) plot-level Q (litre ha^{-1} day^{-1}) to combined overstorey and understorey LAI (Figure 3).

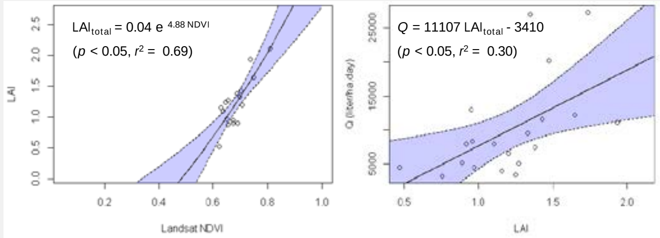
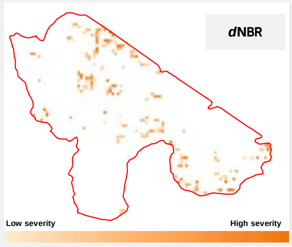


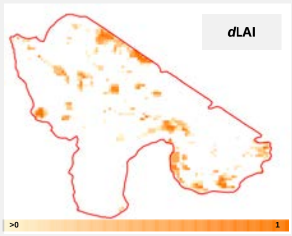
Figure 3 Regression coefficients of the models are specific to three main study area of the ACT, the Nattai National Park, and the Hawkesbury area. Model developed for the ACT sites were used as a case study to map FRB impact on water in a recent burn in the ACT (results below). Shaded area marks the 95% confidence interval (α = 0.05).

MAPPING IMPACT OF FRB ON WATER

We used a 280 ha FRB in the ACT as a case study to explore burn severity (USGS Differenced Normalized Burn Ratio, *d*NBR), changes in LAI ($dLAI = LAI_{pre\ burn} - LAI_{post\ burn}$) and the impact on vegetation water use ($dQ = Q_{pre\ burn} - Q_{post\ burn}$).

Modelled LAI provided useful detail about the distribution of the impact of low intensity fire. Areas of smaller decrease in LAI associated with parts of the landscape with greater topographic wetness. Water that is not used by the vegetation as a result of its removal by FRB, contributes to the overall water stock (Table 2).





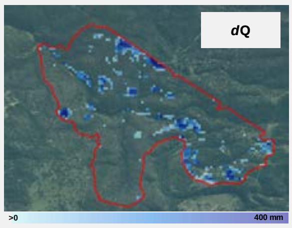


Table 2 Impact on water aggregated for different burn severity levels within the FRB.

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

In some parts up to 40% of the annual rainfall was ultimately affected by the FRB. However, this is an immediate impact. Vegetation regeneration processes combined with catchment's predominant hydrological flows need to be considered to assess longer term impacts of FRB.

SUMMARY

• Understorey LAI is commonly neglected in models of forest LAI. We modelled FRB impact on water using changes in the understorey LAI which is more affected in FRB than the overstorey LAI.

• Uncertainty in the evaluation of impact on water varies with the type of model developed and can be reduced using ancillary information about vegetation type and site conditions.

• Our results enable land managers to identify hydrologically sensitive areas in accordance with their management objectives.

Australian Government Department of Industry, Innovation and Science

Business Cooperative Research Centres Programme

ACKNOWLEDGEMENTS

We thank the ACT Parks and Conservation Service, and NSW National Parks and Wildlife Service for their support with the field work. We thank Ariana Iaconis, Erika Sedlacek De Almeida, Nicole Piaskowski, Marco Harbusch, Bonnie Cannings, Vicky Aerts and Felipe Aires for their help with the field work.

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