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Using active optical sensing of biomass to investigate the effect of scattered trees on native perennial pastures

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Abstract

Trees scattered throughout paddocks have long been considered keystone structures in agricultural landscapes, however little is known about how they actually influence pasture growth. Assessing pasture biomass with sufficient spatial detail requires a cost and time-effective sensor. In this study we test whether an active optical sensor, utilising red and near-infrared wavebands to derive the normalised difference vegetation index (NDVI), can be used as a surrogate measure of photosynthetically active biomass (PAB) associated with native perennial grasses around scattered trees in grazing paddocks. Pasture cuts were acquired to create and test NDVI-biomass calibrations in the vicinity of 12 scattered trees across a range of species and soil parent materials. Observed regressions beneath the tree between NDVI and PAB were statistically significant although R^2 were generally less than 0.33. We believe that this result is largely due to the variable composition of the native pastures (live and dead fraction, physical structure). Overall, no significant difference was found in PAB with distance from the tree, meaning that under the tree there was similar pasture biomass to the open paddock.

Introduction

Scattered paddock trees act as keystone structures across agricultural landscapes of New South Wales, providing important ecosystem services in their immediate environment, both above- and below-ground (Manning *et al.* 2006). However, these trees are being rapidly lost from the landscape and it has been estimated that, due to a range of processes, they will have disappeared in 40-185 years (Gibbons *et al.* 2008). For this reason, there is an urgent need to understand their functions in order to help remediate their loss from the landscape. Green pasture biomass is one of the most critical components for graziers, as it drives the attainable levels of production in grass fed grazing systems. It is commonly perceived that trees in grazing landscapes reduce pasture biomass around them and are only left in the landscape to provide a shade and shelter function. However, it is unclear if and how scattered trees modify the pasture in their immediate vicinity.

Pasture biomass is an inherently difficult attribute to measure, due to its high variability across a small scale, especially across native grasslands. Direct measures of pasture biomass are destructive and time consuming, and often require skilled operators. Therefore, techniques which provide objective and rapid assessment in heterogeneous landscapes are needed. One such potential is the use of an active optical sensor (AOS) with its own light emitting diode configured for Red (≈650nm) and NIR (≈880nm) outputs that records the spectral reflectance characteristics of plants, thereby capable of distinguishing the green fraction within pasture swards (Trotter *et al.* 2010). The reflectance of these bandwidths can be used to calculate spectral indices to estimate green herbage biomass. One popularly used index is the NDVI (normalised difference vegetation index), (NIR – Red)/(NIR + Red) (Rouse *et al.* 1974). Such sensors have been widely used in cropping systems (e.g. Imman and Khosla 2005; Lamb *et al.* 2009) and most recently in monoculture pastures (Trotter *et al*. 2010). However, there has been little work investigating the potential of such sensors in native perennial pasture systems.

This project set out to (a) assess the prediction accuracy of the CropCircle as an AOS for estimating PAB in native pastures around scattered trees, and (b) investigate the influence of trees on PAB over a range of tree species and soil parent materials.

Methods

The study was conducted near Armidale (elevation 980 m a.s.l.) on the Northern Tablelands of NSW, Australia (371119E 66239095S [WGS84 56S]). In autumn 2009, 6 sites were selected for detailed study, 2 sites on tertiary basalt, 2 sites on permian granite, and 2 sites on carboniferous meta-sediment parent material. A range of eucalyptus species were examined within in the study. Scattered yellow box (*Eucalyptus mellidora)* trees were common to both parent materials studied, while one of the sites on each parent material also contained another eucalypt species (*E. viminalis* [ribbon gum], *E. blakelyi* [red gum]), which varied across the parent materials. All sites in this study were in paddocks currently grazed.

Three scattered trees were selected at each site. Around each tree an area out to 3.5 x canopy radii of the tree was scanned using a handheld GPS CropCircle^{TM} optical sensor in 1 m transects. Using the NDVI output from the CropCircle^{TM} the PAB around each tree was spatially mapped using an exponential variogram krigging function with a lag and grid size of 1m in Vesper (Whelan *et al.* 2001). To calibrate the effectiveness of the NDVI output from the CropCircle^{TM} to PAB at each tree, two transects were used for pasture biomass calibration. Along each transect at increments of 0.25 canopy radius (cr), 0.75cr, 1.75cr and 3.5cr, three 25x25 cm quadrats of pasture were removed to ground level. Each sample was sorted into the live and dead components and this material was dried at 70˚C. Regressions were used to assess the strength of the association between NDVI and PAB

Results and Discussion

NDVI output from the CropCircle^{TM} did not have a strong goodness of fit with PAB in native pastures, limiting its prediction accuracy (Table 1). The poor correlations were the result of the majority of the calibration data points occurring between the 0-200 g/m^2 range for PAB but recording an NDVI of between 0.2-0.8 (full range is 0-1) over those same data points. This result may be due to the challenge of matching the pasture cuts with the sensing footprint of the AOS. The prediction accuracy of the NDVI improved under the tree's canopy compared with the open paddock. We believe that this may be the result of the higher proportion of standing dead fraction in the pasture in the open paddock than under the canopy masking the effectiveness of the sensor.

On the other hand, the spatial distributions of NDVI around trees commonly illustrated that to the south in the outer canopy and inter zones there was a trend for pasture to increase the NDVI value (Fig. 1). This pattern remained largely consistent among the soil parent materials and tree species. The consistency of this pattern suggests that the AOS detecting a change in the pasture around scattered trees, however more work is required to investigate what attribute it is observing.

Table 1. Regression fits for NDVI as a predictor of PAB across tree species and parent materials

		Canopy area	**Adj r2 (%)**	**A**	**B**	**C**	**R**
basalt	yellow box	under	32.9***	0.443	0.000	0.1186	1.126
		outside	$0.0^{\text{n.s.}}$	0.507	-0.030	0.0092	1.009
	ribbon gum	under	26.6**	0.636	-0.268	-0.0134	0.987
		outside	$0.5^{\text{n.s.}}$	-280.700	0.000	0.1723	1.188
granite	yellow box	under	$3.7^{\text{n.s.}}$	0.307	-0.095	-0.2395	0.787
		outside	$0.0^{\text{n.s.}}$	0.314	-0.038	-0.0380	0.963
	red gum	under	21.7**	0.626	-0.241	-0.0068	0.993
		outside	$0.0^{\text{n.s.}}$	0.486	0.036	-0.0063	0.994

A, B, C and R values are the coefficients for the exponential model NDVI = A + B*exp(C*PAB), where C is the natural logarithm of R (*** = $P < .001$, ** = $P < 0.01$, n.s. = not significant)

The calibration cuts showed no significant difference in PAB with distance from the tree ($p > 0.05$, data not shown). This demonstrates that scattered trees did not negatively impact green pasture biomass, questioning the strength of common perceptions regarding trees in grazing landscapes.

Due to the large amount of unexplained variability in all correlations we conclude that using the NDVI index to examine fine-scale changes of PAB in native pastures around trees should be used cautiously. However, based on the calibration cuts scattered trees did not deplete PAB beneath them, as is commonly believed.

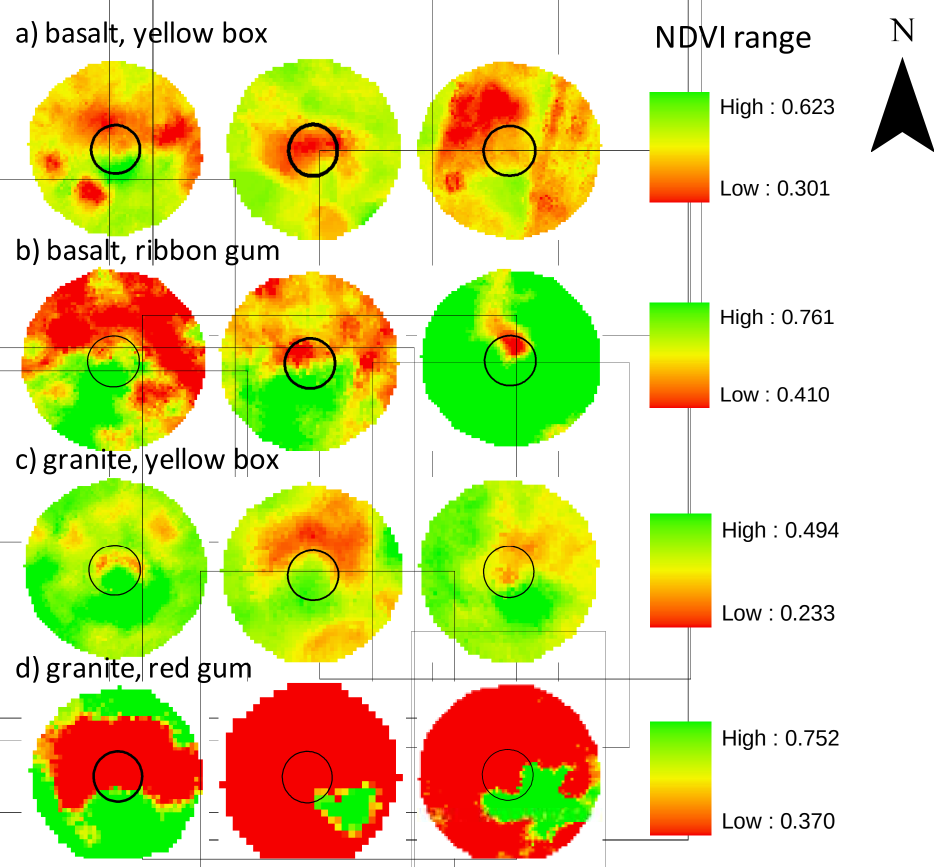

Fig.1.NDVI maps of changes in native and improved pasture around scattered trees at the 6 sites. The circle represents the edge of the canopy around the tree.

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