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Evaluation of aerial photography for predicting trends in structural attributes of Australian woodland including comparison with ground-based monitoring data

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Abstract

The accurate assessment of trends in the woody structure of savannas has important implications for greenhouse accounting and land-use industries such as pastoralism. Two recent assessments of live woody biomass change from north-east Australian eucalypt woodland between the 1980s and 1990s present divergent results. The first estimate is derived from a network of permanent monitoring plots and the second from woody cover assessments from aerial photography. The differences between the studies are reviewed and include sample density, spatial scale and design. Further analyses targeting potential biases in the indirect aerial photography technique are conducted including a comparison of basal area estimates derived from 28 permanent monitoring sites with basal area estimates derived by the aerial photography technique. It is concluded that the effect of photo-scale; or the failure to include appropriate back-transformation of biomass estimates in the aerial photography study are not likely to have contributed significantly to the discrepancy. However, temporal changes in the structure of woodlands, for example, woodlands maturing from many smaller trees to fewer larger trees or seasonal changes, which affect the relationship between cover and basal area could impact on the detection of trends using the aerial photography technique. It is also possible that issues concerning photo-quality may bias assessments through time, and that the limited sample of the permanent monitoring network may inadequately represent change at regional scales.

Keywords: Carbon accounting; Eucalypt savanna; Structural change; Vegetation thickening

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1. Introduction

It is generally accepted that there has been a recent trend for woody vegetation thickening in semi-arid rangelands occupied by non-forest ecosystems (van Auken, 2000). Estimating the current and historical rate of vegetation thickening is complex but has important implications for land-use industries and greenhouse gas accounting. Tree–grass relationships predict that increasing tree stocks in some Australian woodlands result in reduced pasture production (Scanlan, 2002). Thus, the nature of fluxes in the woody components of savannas is critical for livestock production industries. Recently established legislation in Queensland (*Vegetation Management Act 1999*) will allow thinning of vegetation shown to have thickened. A core argument underpinning this provision is that vegetation thickening is prevalent and of sufficient magnitude that restrictions on clearing will result in a major burden for primary producers.

Vegetation thickening could potentially amount to a major source of carbon sequestration (Scholes and Hall, 1996; Gifford and Howden, 2001). For example, Houghton et al. (2000) used estimates of woody encroachment ranging from 0.25 to 1.4 t $\mathrm{C\,ha^{-1}\,yr^{-1}}$ over 224 M ha of non-forested rangeland to model the contribution of this factor to the land use component of the national US carbon budget. The magnitude of this sink was estimated as 125 Tg $\mathrm{C\,yr^{-1}}$, about 32% of the estimated total sink represented by terrestrial vegetation in the US between

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1950 and 1990 or about 10% of the emissions from fossil fuels (Houghton et al., 1999). However, there are many assumptions implicit in these estimates and the uncertainties are profound. Not only are there problems accurately estimating the magnitude of the sink represented, but also under the Kyoto Protocol to the United Nations Framework Convention on Climate Change (Gifford and Howden, 2001; Keenan, 2002), it is necessary to distinguish between the components of the sink that are 'human induced' and those that have resulted from 'natural' processes. These substantial issues will have to be resolved if terrestrial carbon in vegetation not affected by deforestation is to be incorporated into national carbon budgets for greenhouse gas accounting (Gifford and Howden, 2001). Clearly, if ecological science is to provide an accurate context for government policy, there is a need to ensure that scientific assessments of the magnitude, direction and causes of structural change in woodlands are as rigorous and accurate as possible.

Two recent studies from Australian rangelands estimate very different rates of carbon sequestration in uncleared (not recently affected by mechanical or arboricidal treatment) rangeland vegetation. The first study estimates carbon sequestration in grazed eucalypt woodlands in Queensland and employs data from a network of ground-based permanent monitoring sites (Burrows et al., 2002). The second study covers a sub-set of the same geographical area and estimates basal area using aerial photography calibrated with on-ground measurements (Fensham et al., 2003). The change estimate for woody basal area from the aerial photography study, for an excised portion of the 43-year trend (1984–1995), is considerably less than that derived from the ground-based monitoring. However, there are a number of differences between the studies that confound direct comparison of change values (Table 1; see below).

This paper compares the two techniques at 28 common sites and incorporates other data to re-examine some of the methodological issues behind the aerial photography technique with particular emphasis on issues that may contribute to the discrepancy between the two estimates of carbon sequestration in uncleared Australian rangelands.

Table 1
Summary of the major features of the TRAPS study (Burrows et al., 2002) and the aerial photography study (Fensham et al., 2003) for assessing structural trends in Queensland woodlands

Feature	TRAPS study	Aerial photography study
Study area	Uncleared grazed eucalypt woodlands, Queensland (270 000 km^2)	Uncleared vegetation, central Queensland (64 000 km^2)
Sites	30 long-term (1982–2000, average 14.14 years) 27 short-term (1996–2000, average 2.1 years)	108 (average 1951–1995)
Sampling intensity	One site per 4740 km^2	One site per 592 km^2
Sampling procedure	Direct woody plant measurements within belt transects	Aerial photography assessment calibrated using linear plots (0.04–0.4 ha)
Sample size	Generally 0.2 ha (5 belt transects, 4 m × 100 m) within 1 ha plot	100 regular point-intercepts within 25 ha
Site selection	Non-random; located in representative vegetation in different regions	Random
Spatial auto-correlation	Long-term sites: 3 sites pairs and 2 site triplets are within 5 km; short-term: no sites within 5 km of another site	Sites were randomly allocated. Ten sites were within 5 km of another site
Representativeness		
Rainfall	Long term: relatively low over period Short term: relatively high over the period	Relatively low over period
Soil type	Represent range	Represented by large random sample
Basal area	Relatively low (as compared to remote-sensed estimates)	Represented by large random sample
Mechanical disturbance free period prior to initial measurement	At least 20 years (confirmed by interview)	At least 25 years (partly confirmed by interview)
Error analysis	Simple	Complex
Estimated live basal area change ($m^2 ha^{-1} yr^{-1}$ at 30 cm height[a])	Long-term sites: 0.066 ± 0.034	Total period: 0.051
	Short-term sites: 0.091 ± 0.075	1984–1995: 0.013
	Combined: 0.078 ± 0.039	
Estimated live carbon stock change (t $C ha^{-1} yr^{-1}$)[a]	Long-term: 0.209 ± 0.107	Total period: 0.132
	Short-term: 0.287 ± 0.236	1984–1995: 0.076
	Combined: 0.246 ± 0.124	

[a] Unpublished data from Burrows et al. (2002).