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Arresting the rate of land clearing: Change in woody native vegetation cover in a changing agricultural landscape

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ABSTRACT

Understanding the magnitude and drivers of background vegetation change at the landscape scale is an important step towards improving management strategies and policy. This study examined historical (1946–2008) and contemporary (2004–2008) change in extent of native trees in three case study areas in central Victoria, Australia using aerial photographs. To investigate the drivers and impacts of the documented change we used aerial photograph interpretation and workshops with landholders and natural resource management agency staff.

By 1946 much of the clearing in each case study had already occurred leaving native tree cover at 5–38% across the three regions. From 1946 to 2008 there was a slight net decrease in tree cover in all three case study areas. Spontaneous regeneration and revegetation, mapped using 2004–2008 aerial photographs, accounted for 1.9 and 1.0% gain of the case study areas respectively. In each region the gain in extent of immature trees was greater than the net loss of mature trees, excluding remnant paddock trees. Across all case study areas socio-economic factors, including commodity prices, government legislation and natural resource management incentives were the predominant and persistent determinants of vegetation change.

Attempts to increase the extent and quality of native vegetation in the landscape needs to consider: the impact of large-scale drivers of vegetation change; the biodiversity value of the regenerating vegetation compared to existing remnants and active revegetation.

1. Introduction

Land clearing for agriculture and resource extraction has, in many parts of the world, caused the loss of biodiversity (Vandermeer & Perfecto, 2007), habitat fragmentation (Ewers and Didham, 2006; Franklin, Noon, & George, 2002) and the disruption of ecological processes. Current threats to biodiversity and ecology within these landscapes suggest that we may face an extinction debt from past clearing (Tilman, May, Lehman, & Nowak, 2002), and these threats may be accentuated by climate change (Hughes, 2003). In addition to restricting further land clearing, urgent and large-scale revegetation and remnant restoration has been advocated to increase native vegetation cover, and consequently the likelihood that biodiversity and ecological processes can persist in fragmented landscapes (Saunders, Hobbs, & Margules, 1991; Vesk & MacNally, 2006).

Given that there is often little scope to increase native vegetation cover on public lands, which are typically vegetated, to achieve further gains governments may need to target private land using mechanisms such as landholder agreements and incentives (Merenlender, Huntsinger, Guthey, & Fairfax, 2004; Stoneham, Chaudhri, Ha, & Strappazzon, 2003). This may include revegetation (Smith, 2008) and facilitating regeneration through removing stock pressure (Dorrough, Vesk, & Moll, 2008; Robinson, 2006). Despite increasing public investment, in many cases even simple statistics such as land area replanted, or the net impact given different kinds of gains and losses are unknown (ANAO, 2004, 2008; DSE, 2008a). A quantitative analysis of the spatial impact of several decades of investment in landscape restoration is therefore timely, if not overdue.

The study of land cover and vegetation change has a long history in the environmental sciences (Meyer & Turner, 1992), and has become increasingly common with the advent of remote sensing (Coppin, Jonckheere, Nackaerts, Muys, & Lambin, 2004; Pontius, Shusas, & McEachern, 2004). Especially common are studies that examine the broad scale and sometimes-rapid displacement of native vegetation by primary production or urban development (Brink & Eva, 2009). The process of clearing is stark, and rates

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of clearing have been relatively easy to detect, particularly for woody dominated systems. Where the spontaneous recolonisation of abandoned and marginal production land by native shrubs and trees is considered undesirable, such as European uplands and Australian rangelands, the spatial extent of the phenomenon is also well studied (e.g., Flinn & Vellend, 2005; MacDonald et al., 2000; Vicente-Serrano, Lasanta, & Romo, 2004). Perversely however, where governments are actively investing in an increase in the spatial extent of native vegetation, such as the fragmented landscapes of southern Australia, only a few published studies are to be found quantifying change (e.g., Geddes, Lunt, Smallbone, & Morgan, 2011; Lunt, Winsemius, McDonald, Morgan, & Dehaan, 2010; Smith, 2008), or its potential impact on fauna (e.g., Robinson, 2006). Of these, only Lunt et al. (2010) have included the historical loss of vegetation cover, and only Smith (2008) has specifically examined the outcomes of government intervention.

The state government of Victoria, Australia, recently conducted an analysis of native vegetation change for the State for the period 1989–2005 using satellite imagery (DSE, 2008a). The analysis distinguished estimated gains and losses, and zero-sum flux from natural (e.g., wildfire) and anthropogenic sources (e.g., native hardwood harvest) and concluded that change in woody vegetation accounted for less than 1% by area. Although conceptually the contribution of government investment to the gain side of the equation was clearly identified, it was not detected in the quantitative analysis. Much of the investment in vegetation change such as restoration activities in native woodland and forest communities is small-scale, and in the case of revegetation is often narrow, for example plantings that follow features such as a fence or drainage line. Activities on this scale and shape are unlikely to be detectable with coarse-grained satellite data (Lechner, Stein, Jones, & Ferwerda, 2009), far less so when they are immature and present a less distinct 'signature'. DSE's (2008a) analysis also failed to detect processes such as recolonisation of marginal pastoral land by native shrub species, later targeted by Geddes et al. (2011), using aerial photography. Thus, although the overall picture of negligible net change in wooded cover that emerged was probably accurate; the resolution of the analysis did not help quantify the impact of diffuse government investments deployed at smaller, regional scales.

To provide a context for evaluating the contribution of public investment programs to landscape change we mapped and analysed change in wooded native vegetation cover in three case study areas using aerial photography. We combined interpretation of changes in cover of mature (1946–2008) and immature (as of 2008) native vegetation with workshops with local landholders and natural resource managers that referenced change as far back as the mid 1800s. Specifically we asked: (1) by how much did mature wooded canopy cover change between 1946 and 2008? (2) What has been the contribution of immature spontaneous regeneration and native revegetation of native trees to change over recent decades? (3) What socio-economic and physical factors might influence these sets of changes? By placing the spatial extent of government investments in the context of spontaneous regeneration and the previous decades of change, we aimed to take stock of landscape restoration progress to date.

2. Methods

2.1. Background

This study took place in three case study areas in northern Victoria, termed Muckleford, Longwood–Violet Town and Chiltern–Springhurst (Table 1 and Fig. 1). Our land management agency partners proposed notional areas according to agreed criteria, which included: (1) common land use and vegetation classes; (2) a range of land uses and land holders types; (3) regions known to have been the focus of investment in native vegetation restoration; and (4) a high likelihood of good data availability. We purposefully selected areas that were believed to have had a history of vegetation flux rather than those areas the had been extensively converted to irrigated agriculture or were largely comprised of intact forest, which would have seen little change or extensive clearance only. The specific areas were primarily circumscribed according to conservation planning region boundaries, with additional use of arbitrary features such as local government areas, major roads and water bodies.

On the one hand the case study areas represented pseudoreplicates of a fragmented landscape type common to the inland slopes and foothills of the Great Dividing Range in southeastern Australia. On the other hand, they were not true replicates by virtue of environmental characteristics and past land use. Prior to European settlement the case study areas were largely continuously wooded (DSE, 2008b). However, a large proportion of this tree cover was cleared following European settlement in the 1800s. Within Muckleford and Chiltern–Springhurst, the clearing activity was largely associated with gold mining whilst in Longwood–Violet Town vegetation was cleared initially for pastoralism. At present the main forms of agriculture by area are sheep and lamb production followed by beef, with a limited amount of grain production. Of the three regions, Longwood–Violet Town has the largest proportion of the landscape dedicated to primary production (ABS, 2008). As well as pastoralism and cropping, since the early 1980s nonfarming landholders have become increasing influential in these landscapes. So much so that Barr, Wilkinson, and Karunaratne (2005) has termed them "rural amenity" landscapes, where land value for lifestyle and amenity had outstripped the production value, and "transitional" landscapes, for those in the process of shifting from production dominated to amenity.

2.2. Mapping vegetation change

Our analysis of wooded vegetation change since 1946 was comprised of two distinct elements: (i) change in mature, wooded native vegetation, and (ii) change in immature, wooded vegetation resulting from native species revegetation and regeneration in 2004–2008 aerial photographs. For both mature and immature elements we mapped zones of trees, not individuals.

Change in the cover of native tree canopy was assessed using digitised and geo-rectified aerial photographs from 1946/47, 1970/71, 1989/90 and 2004–08 (hereafter referred to as 1946, 1970, 1990 and 2008, respectively for the sake of simplicity). Aerial photographs from 1946 to 1990 were sourced from archived poster-mosaics. These mosaics were poster-format hardcopies, each a composite of around 30 original images. The mosaics were scanned at 400 dpi using Adobe Photoshop 10.0 (Adobe, 2007) and then geo-rectified by matching at least nine control points, easily identifiable points such as road intersections and buildings from the aerial photographs with the same points on a survey map (e.g., Hughes, McDowell, & Marcus, 2006). Geo-rectification using the control points was undertaken using 'ImageWarp' software (McVay, 1999) available as an extension to ArcView 3.2 (ESRI). The resolution of the mosaics, defined as minimum pixel size of scanned mosaics, ranged from 12 to 500 cm with most mosaics under 100 cm. The mosaics covered from 74 to 100% of the case study areas. Wherever we lacked aerial photograph coverage for a given location-imagery set combination, we excluded the missing area from calculations of vegetation change.

We sub-sampled the case study areas using a lattice of 1.5 km diameter circles centred at 3 km intervals (Fig. 1). Each circle was 175.9 ha in area and, collectively, they accounted for 19.4% of the case study areas. When areas with no aerial photograph coverage