Broad-scale management of biodiversity in temperate grazing lands and implications for productivity and profitability

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Abstract: *The decline of paddock trees and loss of native perennial plant diversity are two significant issues that affect the sustainability of grazing systems and the conservation of biodiversity in grazed landscapes. Both are often poorly handled under traditional livestock exclusion and replanting measures most typically encouraged for biodiversity conservation on private lands. Scattered paddock trees and native pastures cover large areas throughout the temperate zone, and they play an important role in regional ecological processes (e.g. biodiversity conservation, climate adaptation, soil protection, nutrient cycling and retention). Tackling their management requires broad-scale approaches. In the long-term, neither paddock trees nor diverse, native perennial vegetation can be maintained under high-input grazing systems involving phosphate fertilizer applications. Hence, there is a clear trade-off between productivity, and the provision of ecosystem services and conservation of biodiversity. However, there is growing evidence that low-input grazing systems, that incorporate significant rest periods and lack fertilizer application, are compatible with their maintenance. While these grazing systems are low risk and can be profitable, they require significant capital expenditure and may be difficult to fund. Although there is growing adoption of low-input grazing management, many producers may not be in a position to adopt such systems. While it would seem that there is a case for government to provide incentives, more work should be undertaken to assess the public and private benefits of adopting these management systems.*

Introduction

In recent decades, there has been substantial investment in biodiversity conservation activities on private lands devoted to livestock production. While government investment in education, economic incentives and regulation have been fundamental to the adoption of these activities (Crowley 2001), private landholders have undertaken a large proportion of these management actions themselves, without outside financial assistance (Smith 2008). Frequent management activities involve fencing of remnant vegetation and drainage lines to exclude livestock, repairing eroded gullies, and replanting with indigenous trees and shrubs (Freudenberger *et al.* 2004, Smith 2008, Spooner & Briggs 2008). These areas are typically set-aside from day-to-day farm operations and contribute little to farm productivity.

Recent work in SW Australia, albeit in the wheat belt, suggests that most farms cease to set-aside land for conservation activities once these areas cover approximately 10% of the farm area (Smith 2008). This is slightly greater than the proportion we estimated was being managed for conservation on livestock grazing properties in central Victoria (Dorrough *et al*. 2007). Beyond 10% of a property, setting land aside for conservation outcomes can become prohibitively costly (Moll & Dorrough, unpublished data). In some cases, greater conservation set-asides (up to 15% of the farm area) can be funded through increasing and fine-tuning fertilizer regimes (Crosthwaite *et al*. 2008). However, these approaches can increase risk, and can have unforeseen negative impacts on native vegetation (Dorrough *et al.* 2007).

While the focus of private land conservation activities towards fencing and revegetation has been important, and the levels of private and public investment across temperate Australia are exceptional, two important aspects of native vegetation management are often not well addressed by either private investment or government incentives. These are: (1) the ongoing decline of woodland or paddock trees, and (2) the loss of native perennial plant diversity and plant "functional" diversity from pastures. These two issues have landscape-wide implications for biodiversity conservation and sustainability of grazing systems (Johnston 2001; Dorrough *et al.* 2004; McIntyre 2008; Fischer *et al.* 2009a). Because these components of native vegetation fall outside of what is regarded as "remnant" vegetation they have typically not received the same level of government investment. Also, because they often cover large areas of any one property, it is expensive for individual landholders to exclude such areas for primarily conservation reasons. To ensure that these two forms of native vegetation are retained within landscapes, broad-scale changes in management and management philosophy are likely to be required (Fischer *et al* 2009a).

In this paper, evidence is provided for both paddock tree decline and loss of perennial plant diversity and the implications of their loss for production, drought management and biodiversity conservation are discussed. The financial implications of adopting strategies to manage these two landscape-scale environmental issues are presented. The role of government in managing scattered trees and native pastures is also considered.

Declining paddock trees

Paddock trees are a widespread and well recognized feature of temperate grazing (and cropping) landscapes. Scattered paddocks trees are considered to be keystone structures within these landscapes, because their role in ecosystem processes is much greater than might be expected based solely on the small area they occupy (Manning *et al.* 2006). Scattered paddock trees play important roles in conservation and cycling of soil nutrients, infiltration of moisture, providing shade and shelter for livestock, acting as a potential source for natural regeneration of trees, and providing habitat and connectivity for native fauna, pollinators and insectivores (Manning *et al.* 2006). Paddock trees may also play an important role in assisting native biodiversity adapt to climate change (Manning *et al.* 2009).

While direct clearing of paddock trees has now largely ceased, they are continuing to decline at an alarming rate, due to mortality (most trees are old and many suffer varying stages of dieback) and a lack of sufficient natural regeneration (recruitment) to replace mature trees (Gibbons *et al.* 2008). Natural regeneration of paddock trees is almost non-existent when grazing is frequent and when soils are enriched by fertilizers or stock camping (Dorrough & Moxham 2005; Fischer *et al.* 2009b). Increased soil nutrients via fertilizers or livestock camping are also associated with increased rates of dieback of adult trees (Jurkis 2001; Close *et al.* 2008).

Paddock trees such as yellow box (*Eucalyptus melliodora*) are declining rapidly, and most will be lost within 50 to 120 years (Gibbons *et al.* 2008). As a result of this rapid rate of decline, natural regeneration potential could halve in as little as 30 years (Dorrough & Moxham 2005). In many cases, replanting trees is more costly than managing paddock trees in ways that improve their longevity and encourage natural regeneration. Delaying action to maintain paddock trees will increase the duration of bottlenecks in the provision of ecosystem services provided by paddock trees (e.g. shade and shelter, carbon storage, habitat for hollow dependent native species) (Vesk & MacNally 2006; Gibbons *et al.* 2008). This is because the density of mature paddock trees is predicted to drop to very low levels before naturally regenerating or replanted trees become mature enough to replace many of the services provided by older trees. Future declines in characteristic hollow breeding birds are expected to occur throughout the temperate grazing lands as a result of declines in these mature trees (Vesk *et al.* 2008).

Ground layer plant diversity

The ground cover of the natural woodlands of temperate Australia was originally dominated by a diversity of warm (C4) and cool (C3) season grasses, and supported a very large diversity of other plant species including broad-leafed daisies, lilies, orchids, twining legumes and low shrubs (Tremont & McIntyre 1994). Such grasslands are highly tolerant of drought, have relatively conservative growth patterns and slow cycling of nutrients. These grasslands and grassy woodlands evolved in a variable climate and on soils that are relatively nutrient poor. Hence, many native plant species have adaptations to assist survival through drought (e.g. underground storage organs or persistent, long-lived leaves), and rely on mycorrhizal associations to obtain phosphorus.

Most native plant species of the temperate woodlands are intolerant of both increased soil nutrients resulting from fertilizer application, and intensive, frequent grazing (Dorrough & Scroggie 2008). As a result, addition of fertilizers leads to a rapid loss of native perennial plant diversity. In almost all instances, the diverse perennial plant understory has been replaced by a small diversity of exotic plant species, mostly with an annual lifecycle (Dorrough & Scroggie 2008; McIntyre 2008). In contrast to the bulk of native plant species, most of the widespread exotic plants of the temperate zone have high growth rates and respond rapidly to increased soil fertility.

These major changes in plant diversity (diverse perennial grassland to a species-poor annual pasture) reflect significant changes in how the pastures function. The annual dominated pastures that replace the diverse perennial pastures are less drought tolerant, provide less permanent ground cover, and soils are more exposed to erosion (Johnston 2001; McIntyre 2008).

The shift from perennial- to annual-based pastures involves a shift in leaf types from thick tough leaves with high dry matter, to pastures with thin, soft leaves with low dry matter content (McIntyre 2008). Combined with higher soil fertility, these changes in the leaf attributes contribute to significant increases in pasture digestibility and productivity and, hence, livestock production. So there is a direct trade-off between diverse perennial pastures (with good soil protection, drought resilience and biodiversity) and highly productive pastures (McIntyre 2008). While this trade-off is a result of paddock level management decisions, it has implications for the productivity, profitability and sustainability of farms, as well as influencing regional soil loss, salinity, effects of drought and persistence of biodiversity.

We surveyed non-arable pastures on the south-west slopes of NSW and inland slopes of northern Victoria during the worsening drought conditions of October, November and December of 2006. At this time, pastures were under severe stress due to increasingly low soil moisture and high evaporative demands. The amount of live vegetation that persists through drought will influence how that pasture responds to any rainfall and how well it will provide soil protection. The live cover of native perennial plant species in pastures was most strongly influenced by available phosphorus and nitrates and recent stocking rate and only weakly affected by worsening drought conditions (Fig. 1B; Dorrough *et al.* 2008b). Pastures with a greater live groundcover dominated by native perennial species were those with low available nutrients and light stocking rates. In contrast, the live cover of exotic plants (both annual and perennial) declined rapidly as soils dried (Fig 1A). Pastures that had a history of intensive grazing and fertilizer additions had few native perennial species and were most vulnerable to drought (Dorrough *et al.* 2008b). Overall, the level of live cover provided by most pastures during the 2006 drought (average live groundcover of 13%) would not have been sufficient to protect soils from erosion in the event of heavy summer rainfall (Dorrough *et al.* 2008b). Farrell (2009) estimates that at 30% ground cover in similar grazed landscapes of central-west NSW, soil loss could range from 2.5 to 39 t/ha per year depending on soil type, rainfall and slope. Higher rates could be expected on the SW slopes where pastures have a lower perennial component.

Maintaining paddock trees and diverse perennial pastures

Management approaches for tackling declining paddock trees and persistence of diverse perennial pastures require a different approach to typical biodiversity conservation management activities, but share similarities with agronomic practices that aim to minimize soil and nutrient loss and achieve pasture persistence. To make any

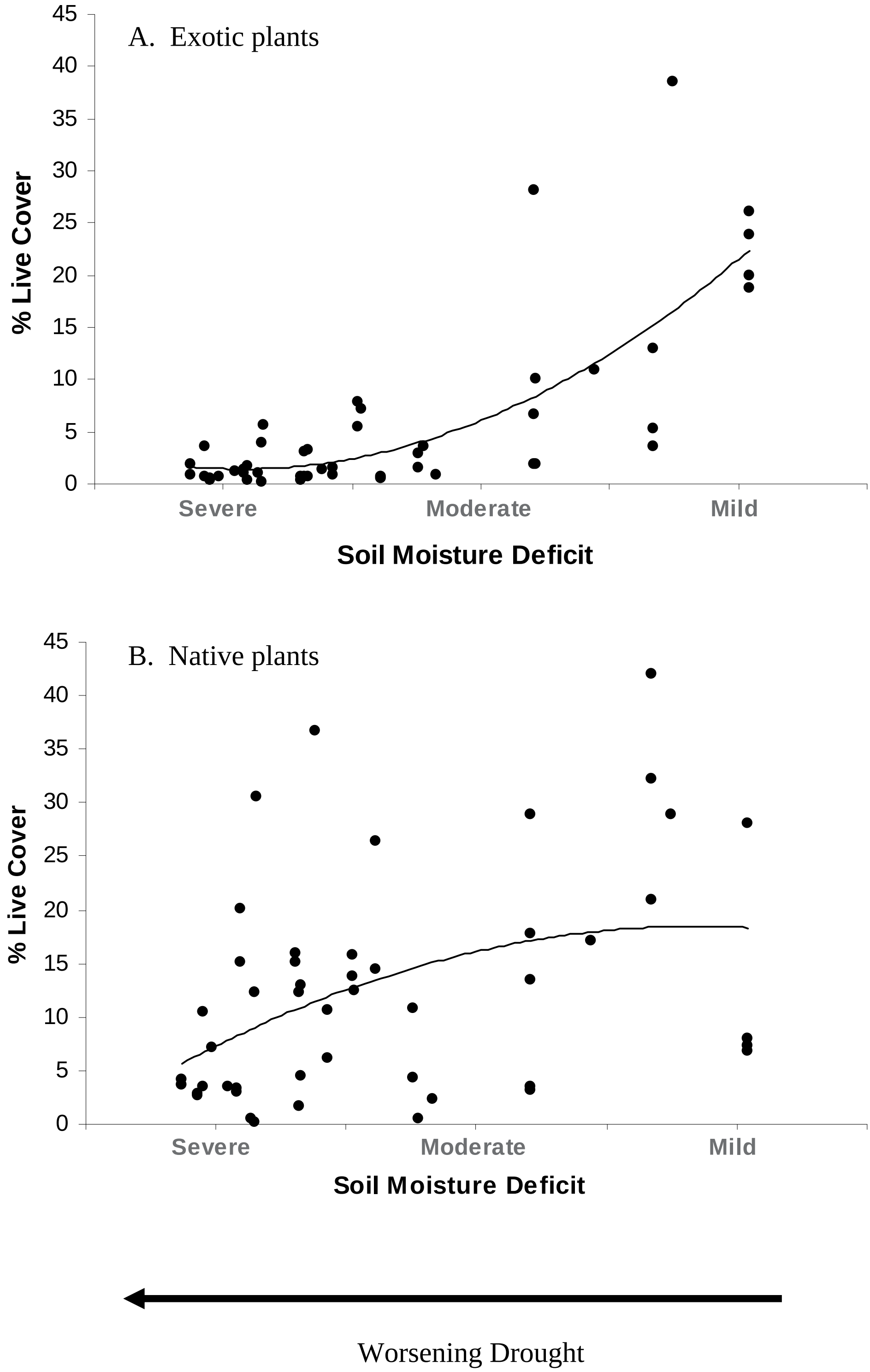

Figure 1. Relationships between plant live cover (A. exotics; B. natives) with an index of soil moisture deficit (ratio of rainfall to evapotranspiration).

reasonable contribution to regional processes requires actions at relatively large scales (Vesk & Mac Nally 2006; Dorrough *et al.* 2007; Fischer *et al.* 2009a). Scattered paddock trees and native pastures potentially occupy extensive areas of livestock grazing properties (Garden *et al.* 2000, Dorrough *et al.* 2007; Fischer *et al.* 2009a). The areas occupied by these types of native vegetation also often occur on productive parts of farms, or have significant potential for increased carrying capacity through fertilizer application and sowing of legumes (Dorrough *et al.* 2007; Crosthwaite *et al.* 2008). In contrast to small areas of remnant vegetation or drainage lines that have been the previous focus of conservation investment on farms, areas supporting scattered paddock trees and native pastures are likely to contribute significantly to farm income. The potential opportunity costs of adopting conservation management actions in these areas, when considered across whole landscapes, are massive (Crosthwaite *et al.* 2008).

To achieve natural regeneration it is assumed that livestock will need to be excluded for 5 to 10 years, in which time suitable conditions for recruitment are likely to have occurred, and trees will have established and grown to a height at which they could escape grazing by livestock (Vesk & Dorrough 2006). To be meaningful, areas excluded would need to be large and, so, whole-of-paddock management would seem appropriate. Excluding livestock for 5–10 years could be extremely costly, particularly for managers in fertile, productive areas that typify much of the temperate woodlands (Dorrough *et al.* 2008). Even when potential benefits of shade and shelter for livestock are considered, over a 15 year period, management for natural regeneration represents a significant cost to most land managers (Crosthwaite *et al.* 2008). Compared to planting of tubestock, managing for natural regeneration through destocking is only likely to be most cost effective in non-arable, low carrying capacity pastures (Dorrough *et al.* 2008a).

Within unfertilized native pastures, natural regeneration may occur without completely excluding grazing. The unique combination of drought, heavy grazing, followed by destocking can result in successful regeneration if rainfall occurs at the appropriate time (Vesk & Dorrough 2006). However, under this scenario, some medium-term commitment to reducing stock frequency and density are still required, or newly regenerated seedlings will be lost. Costs under this scenario are no doubt less that those estimated by Dorrough *et al* (2008) but, even so, some opportunity cost must be considered.

Other options for maintaining scattered trees include planting and guarding (using re-usable guards) of individual paddock trees (Fischer *et al.* 2009a). While there are up-front costs (guards, ground preparation and seedlings), the maintenance costs and opportunity costs are minimal. This is likely to be the most cost-effective strategy in previously fertilized or sown pastures where natural regeneration is highly unlikely, even in the absence of livestock (Dorrough & Moxham 2005). This strategy would allow livestock to continue grazing, but would not benefit existing mature trees, as livestock would continue to concentrate nutrients beneath them unless they too are fenced (Close *et al.* 2008).

There have been many reports of successful natural regeneration occurring in rotationally grazed pastures, and recent research supports this (Fischer *et al.* 2009b). If natural regeneration can be achieved in low-input rotationally grazed pastures, then this would provide an approach that significantly reduces the opportunity costs associated with maintaining paddock trees. As discussed below, such systems can sometimes be equally as profitable as high-input management of non-arable native pastures (Dorrough *et al.* 2008b, Crosthwaite *et al.* 2009).

Maintaining a diverse perennial native pasture does not require complete stock removal, as very high plant diversity can be maintained in lightly or infrequently grazed pastures but, crucially, only when soil fertility is kept low. Unfertilised native pastures in temperate Australia carry between 1–3 dse/ha, and much less during dry years. However, the potential carrying capacity can be doubled if these pastures are fertilized and sown to legumes (Crosthwaite *et al.* 2008). This represents a significant opportunity cost to many producers who plan to lift profitability through fertilizer applications. Crosthwaite *et al.* (2008) estimated it represents a potential difference in gross margin of $50/ha and, across the 2 million hectares of non-arable native pasture in Victoria alone, it has been estimated that the investment required to compensate farmers for not investing in fertilizer and legumes in non-arable areas could be equivalent to approximately $260 billion over 50 years (Crosthwaite *et al.* 2008). This estimate of course assumes that all farmers intend on fertilizing non-arable native pastures and that they do not value maintaining diverse native pastures.

The estimates cited above would suggest that it would be economically unsound for any producer to maintain a diverse perennial pasture system. However, low-input grazing systems, based on better pasture utilization and rest, can maintain and perhaps improve diversity of native pastures (e.g. Nie & Mitchell 2006) and, when adopted, can provide modest increases in profitability (Dorrough *et al.* 2007; Crosthwaite *et al.* 2008). While the financial return of these grazing systems may not always be equivalent to what would be expected through investment in fertilizers and legumes, for many it may be a low risk pathway with other benefits. High fertilizer prices and recurring drought are increasing the attractiveness of low risk management of native pastures. Many producers are also placing significant non-financial values on retaining diverse perennial pastures.

In Victoria, deferred grazing of native pastures (destocking over summer and early autumn when soil moisture deficits are high) combined with intensive grazing in spring has been shown to increase the cover and density of native perennial plant species (Nie & Mitchell 2006). Although the capital costs associated with deferred grazing (fencing to land classes, establishment of water points) are high, deferred grazing provides an approach to maintaining native pastures that is likely to be profitable on many properties (Crosthwaite *et al.* 2009). Planned grazing systems (rotational grazing) with few grazing days and long rest periods between grazing events could also have

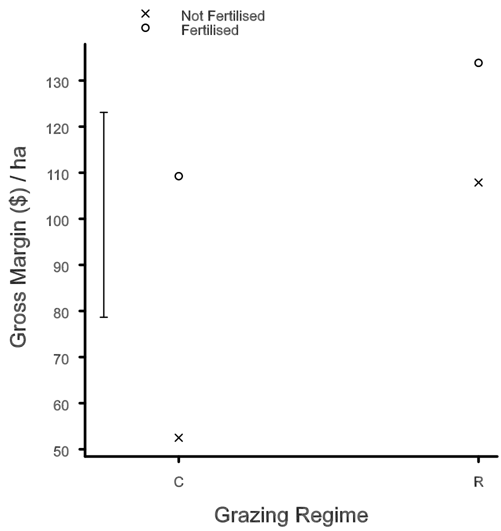

Figure 2. The average gross margin per hectare for continuous (C) and rotationally (R) grazed paddocks that are fertilized or not fertilized. Data based on 24 farms. Least significant difference is shown.

similar benefits for native perennial pastures, if implemented without fertilizer application. In many cases low-input planned grazing can be as profitable as high-input continuous grazing (Fig 2). However, profitable adoption of rotational management entails significant infrastructure to enable more efficient use of pastures and, thus, compensate for production lost through ceasing fertilizer applications (Crosthwaite *et al.* 2008).

Role of government

Widespread adoption of these low-input systems could be slow even if profitable (Crosthwaite *et al.* 2008). But, adoption of low input systems has potential to result in significant public environmental benefits and, so, incentives to encourage adoption, including payment of opportunity costs, seem to be warranted. The level of incentives required will vary, however. There are a growing number of producers already actively managing for lower production as an acceptable trade-off to achieve lower risk, improved resource condition and better life-style. Closer to major towns, shifts away from farming as the primary form of income have already resulted in significant increases in the cover of native vegetation in many parts of SE Australia, without any form of government investment. Many other producers may be willing to adopt low-input production systems but are unable to afford the capital costs of establishing the necessary infrastructure. A recent survey (May 2010) of farms involved in a native vegetation management research program between 2002–2005 indicates that while most producers would ideally adopt either deferred or rotational grazing of their native pastures, only a few actually made the investments required (Dorrough, Crosthwaite, Moxham, unpublished). Capital costs and lack of income owing to drought were cited as the primary reason. Recent government-funded, market-based (competitive tender) programs have demonstrated that broad-scale adoption of low-input management systems, that include limits to fertilization, can be achieved relatively efficiently, particularly when undertaken at a whole-farm scale (e.g. see http://www.gbcma.vic.gov.au/downloads/Biodiversity/Green_Graze_final_report.pdf).

While the importance of diverse perennial native pastures and paddock trees in delivery of regional ecosystem services is well established, the private and public benefits of adopting low-input grazing systems are less well understood. This does make government investment in adoption of low-input systems risky. For this reason, it is imperative that governments continue to invest in research and adequate monitoring of farms involved in current or recent incentive programs. Monitoring will need to consider farm profitability and productivity, in addition to changes in management practices and ecological attributes. While recent data is beginning to suggest that adopting low-input grazing systems can be profitable and improve the persistence of important ecological aspects of the temperate woodlands, more knowledge is required to ascertain whether the benefits apply generically or only under certain circumstances.

Conclusions

It is increasingly apparent that maintaining paddock trees and diverse perennial native pastures is the next significant challenge in biodiversity management in temperate SE Australia. There is growing evidence that low-input grazing systems can be compatible with both, but the absence of fertilizer application is crucial. Systems that involve infrequent grazing (deferred or rotational) with long rest periods and no phosphate fertilizer application are potentially beneficial. Although these systems can be profitable, and are less costly than traditional alternatives to conservation management (livestock exclusion), they often require large capital investment and significant changes in management philosophy.

Profitability and productivity are highest on pastures whose carrying capacity has been increased through fertilizer applications. However, this increase in profitability comes at a significant cost to the ecological condition of the pastures, as scattered paddock trees and diverse perennial native pastures cannot be maintained in high input pastures. Low-input grazing systems (rotational or deferred) appear to provide a potential pathway for maintaining profitable production systems and maintaining some aspects of the original temperate woodlands. More work should be undertaken to assess the public and private benefits of adopting these management systems and to assess whether government should be investing to accelerate their adoption.

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