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Vegetation condition: A background review for social research into vegetation change in north-eastern Victoria

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Cover photo: Direct seeding site, private property, Indigo Valley, north-east Victoria.

LANDSCAPE LOGIC is a research hub under the Commonwealth Environmental Research Facilities scheme, managed by the Department of Environment, Water Heritage and the Arts. It is a partnership between:

- **six regional organisations** – the North Central, North East & Goulburn–Broken Catchment Management Authorities in Victoria and the North, South and Cradle Coast Natural Resource Management organisations in Tasmania;
- **five research institutions** – University of Tasmania, Australian National University, RMIT University, Charles Sturt University and CSIRO; and
- **state land management agencies in Tasmania and Victoria** – the Tasmanian Department of Primary Industries & Water, Forestry Tasmania and the Victorian Department of Sustainability & Environment.

The purpose of Landscape Logic is to work in partnership with regional natural resource managers to develop decision-making approaches that improve the effectiveness of environmental management.

Landscape Logic aims to:

1. Develop better ways to organise existing knowledge and assumptions about links between land management actions and environmental outcomes.
2. Improve our understanding of the links between land management actions and environmental outcomes through historical studies of the effects of private and public investment on water quality and native vegetation condition.

Vegetation condition: A background review for social research into vegetation change in north-eastern Victoria

By Wendy Minato, Charles Sturt University

Summary

Most of Australia's native biodiversity exists outside the public reserve system. This makes the management of native vegetation on private land critical for achieving the best outcomes for biodiversity. To understand what influences the management of native vegetation on private land, we need to first document the changes that have occurred in the recent past and understand what has driven those changes. This will lead to a greater appreciation of which management actions and policy interventions are likely to be effective in the face of other human and environmental factors that influence the extent and condition of native vegetation.

This review is part of a PhD project studying changes in native vegetation on private land in North-east Victoria. The focus of this research is teasing out which actions by landholders have lead to documented changes in vegetation extent. While native vegetation condition involves more than simply changes in extent, extent change is an important aspect of condition change and is easier to document and discuss with landholders than more abstract concepts of condition. Increases in extent are due to either revegetation or regeneration. While revegetation requires active management and often significant investment of time and money, regeneration is relatively passive and can result from either deliberate management or no management at all.

This review is an attempt to summarise the current state of knowledge of vegetation condition in Australia as context for this PhD project. The last section looks at vegetation condition in relation to one of the research questions, ''Is regeneration leading to an improvement in native vegetation condition?''

The key points that emerged from this review are:

- Vegetation condition is a subjective concept and has different meanings for different people with different management perspectives.
- Assessment of vegetation condition requires a clear statement of purpose and should acknowledge the limitations of the methods used.
- There are many attributes which can be used as surrogate indicators of condition and the purpose and context of a particular assessment will determine the most appropriate attributes.
- Vegetation condition can be affected by many factors, none of which act in isolation.
- Revegetation and regeneration are two different processes which influence the extent and condition of native vegetation. Social research exploring where and why these processes are occurring can potentially contribute to our understanding of past changes and possible future trajectories in native vegetation condition.

Introduction

This review of the literature relating to vegetation condition has been written as background to the author's PhD research into the management of native vegetation on private land. The PhD is funded by the CERF Hub Landscape Logic (see description on inside cover) and is a component of the social research contribution to Landscape Logic's aim of linking land management to environmental condition.

This PhD is examining increase in the extent of native vegetation (as a surrogate indicator of condition) on private land in north-eastern Victoria and the processes that have led to this change. Whilst policy interventions may be making a difference there is also the assumption that demographic change is contributing to increases in extent in some areas. This research will focus on the social factors that lead to better management and conservation outcomes. It is beyond the scope of the project to examine in detail the biophysical aspects of native vegetation condition; nonetheless a good understanding of the concept of vegetation condition is important background to the topic.

The following is a summary of current understanding in four areas related to native vegetation condition relevant to this research topic in an Australian context, namely how do we define vegetation condition, how do we measure it, what influences change in condition, and finally does regeneration lead to improvement in condition? This review has been published as a Landscape Logic Technical Report in response to partners within the collaboration who have suggested that this review may be of wider interest.

How to define it?

Vegetation condition is a relatively new concept which is increasingly being used by governments and natural resource management agencies for measuring and monitoring of habitat quality for biodiversity outcomes. Not new with respect to the idea of 'good' and 'bad' condition but new in the sense that condition is being defined and 'quantified' for predictive modelling and mapping at the local landscape and regional scales. There is an underlying assumption that 'condition' is an indirect measure of ecosystem health and habitat suitability for native flora and fauna, and therefore a surrogate measure for biodiversity. This assumption is problematic but provides a starting point for condition assessment. The increasing requirement to assess vegetation condition is recognition that vegetation management is not just about 'extent, type and configuration' and that 'health, function and viability' are equally important (Gibbons & Freudenberger, 2006).

'Condition' is a subjective term and will have different meanings for different people and from different management perspectives. One difficulty with defining 'condition' is that the term has been used widely but has multiple meanings. Good condition from a biodiversity or conservation perspective will be quite different from a farmer's perception of condition as it relates to grazing or cropping potential. In a farming context, production values might be used to assess native vegetation in terms of its ability to provide resources for income or consumption. From a biodiversity perspective 'condition' may relate to the suitability of the vegetation as habitat for indigenous plants and animals, although there are other values condition might also represent such as degree of connectivity or 'intactness'. From an aesthetic point of view 'condition' will be a value judgement based on an individual's preference for certain types of landscape. Any patch of remnant vegetation may have a mix of 'good' and 'bad' attributes for different species and from different perspectives. Keith & Gorrod (2006) and Williams (2004) recommend that more explicit explanations be given, to avoid confusion associated with the use of the term.

Defining vegetation condition therefore requires a framing of the question; 'good for whom' and 'good for what' (Gibbons & Freudenberger, 2006). The biophysical characteristics of the vegetation are then 'interpreted' according to that perspective (Gibbons & Freudenberger, 2006). In other words an assessment of vegetation condition is dependent upon context and can be defined and measured in different ways; the context will indicate the most appropriate choice of indicators (Gibbons *et al.* 2006; Oliver *et al.* 2002).

Judging or defining condition requires some reference point against which current condition can be compared, as condition is inherently a comparative concept (Parkes & Lyon, 2006). The use of benchmarks and reference areas provides a framework for assessing current condition and the direction and magnitude of anthropogenic change. Ideally the reference point for native vegetation should be the sort of condition that would support a range of indigenous plant and animal species under natural circumstances (Parkes & Lyon, 2006). This will usually mean areas of relatively undisturbed vegetation which have been as little interfered with by humans as possible.

Natural disturbance plays an important part in shaping ecosystem structure and function, and the range of natural variability will reflect this (McIntyre & Hobbs, 1999; Landres *et al.*1999). This type of disturbance is essential for maintaining diversity and ecosystems are generally considered to be more resilient within the natural range of variation (Holling

& Meffe, 1996). Disturbance due to human activity is different in that often the magnitude and rate of change limits the ability of species to adapt, and/or the range of natural variation is reduced so that a system loses resilience. Recent (post-settlement) anthropogenic change can be viewed as a continuum of change which ranges from slight modification of existing vegetation to complete destruction of habitat (McIntyre & Hobbs, 1999) along with alterations to natural disturbance regimes. Benchmarks represent areas that are still subject to the full range of natural variability; these will have maximum biodiversity and the most resilience to change. Reference areas will represent the best possible condition for a particular vegetation type in a particular location. In highly modified environments this might simply mean choosing an area least modified and under the least amount of threat from various pressures due to human activities.

Pre-European settlement vegetation condition is a concept commonly used in Australia on the premise that our endemic species are adapted to pre-European conditions and therefore require them for survival; one could argue that we should aim to 'restore' the landscape to this 'ideal' state to maintain maximum biodiversity. This choice of benchmark is problematic, especially where vegetation has been extensively cleared or fragmented (Greening Australia, 2005). Reference areas can be structurally different to fragments and fragments tend to be much more heterogeneous with a wide variation in the intensity of disturbance making it difficult to find truly comparable reference areas (MacNally, 1999). There is also an assumption that restored areas follow a trajectory towards the specified target state (Wilkins *et al.* 2003) which may not be the case. In highly modified landscapes attempts to restore existing vegetation to a pre-European benchmark are bound to fail, especially where change is irreversible (Oliver *et al.* 2002; Lunt & Spooner, 2005; Parkes & Lyon, 2006). For instance Aboriginal fire regimes played a significant role in the evolution of some Australian ecosystems. Even if those regimes could be re-established they might have unpredictable consequences given the nature and extent of change since European settlement (Keith *et al.* 2002). Pre–1750 benchmarks may also underestimate the value of native vegetation that differs from that predicted for a certain site (Oliver *et al.* 2002). Instead of rating poorly relative to some pre-conceived notion of naturalness, existing vegetation, although altered, can still have biodiversity value in terms of providing suitable habitat for native species. An alternative approach is to assess vegetation condition using existing ecosystems as well as historical benchmarks. The latter can be used to understand the nature and extent of change, in conjunction with other benchmarks more relevant to the setting of achievable restoration targets (Parkes & Lyon, 2006).

The 'habitat hectares' method of assessing native vegetation condition in a biodiversity context uses 'the average characteristics of a mature and apparently long-undisturbed stand of the same vegetation community' (Parkes *et al.* 2003). This benchmark is similar to the use of pre-1750 condition as the method assesses 'naturalness' in relation to vegetation which has not undergone 'major ecosystem changes' as a result of European settlement (Parkes *et al.* 2003). The authors are careful to point out that their choice of benchmark was a logical reference point and does not imply that pre-European vegetation was an ideal state which we should aim to recreate. On the other hand it is widely acknowledged that past conditions and processes have shaped present day ecosystems (Landres *et al.*1999; Foster *et al.* 2003; Lunt & Spooner, 2005) and that management strategies that aim to restore past conditions may be the best means of conserving the most diverse range of species (Landres *et al.* 1999). As Holling and Meffe (1995: 334) put it: ''…the default condition, unless clearly proven otherwise, should be retention of the natural state rather than manipulation of system components or dynamics.'' There is no certainty that this is the right approach; more a best attempt to maintain biodiversity in the light of current knowledge.

The main problem with the use of a term such as 'condition' in a biodiversity context is that a single condition assessment of 'good' or 'poor' (or somewhere in between) cannot possibly account for the multitude of plant and animal species with different habitat requirements ''that may be poorly correlated or inversely correlated with one another – what may be good habitat for one species may be poor for another'' (Keith & Gorrod, 2006: S9). Vegetation is often used as a surrogate measure of habitat which is a species specific concept that takes into account resources, predators, and a range of environmental conditions (Miller, 2000). In an unmodified environment vegetation might equate to habitat, but in human altered environments vegetation condition is too broad a concept and not really a surrogate for habitat or biodiversity as is sometimes assumed. A measure of condition needs to be combined with other considerations for a more meaningful assessment of biodiversity value. These will include attributes of the surrounding environment, current threats to existing vegetation, prior land-use history, the long-term viability of the vegetation under current and future management regimes and social context.

How to measure it?

Irrespective of how vegetation condition is defined, the assessment method must be as objective as possible and reliable. This requires a clear statement of purpose which will outline the perspective to which the condition assessment applies. Benchmarks and reference areas must be clearly defined for different vegetation types along with the list of attributes to be assessed. The method must be well documented, the results validated and the limitations of the method acknowledged. The method should enable condition to be assessed in a consistent and repeatable way, within defined limits. Because vegetation condition assessment is a relatively new component of natural resource management science, the methods should be reviewed and adapted as new information becomes available.

Vegetation condition can be 'measured' in a variety of ways and at various scales. No single method has universal application; the appropriate method of assessment will depend on the type of information needed and the context. Time constraints, the level of expertise required and the available resources will also influence the choice of method (Gibbons & Freudenberger, 2006).

Scale is a critical consideration when measuring condition. Scale can range from National (tens of millions of square kilometres), through State, Regional (bio-regions or catchments) and Landscape (subcatchment) scales right down to patch (1–100 ha) and site scales (Williams, 2004). At the site scale on-ground assessment methods will be the most appropriate whilst remote sensing techniques are more suitable for assessing condition over large areas although this may change as remote sensing methods become increasingly sophisticated (Lefsky *et al.* 2002). Ideally information on vegetation condition should be gathered across all scales, combining the accuracy of fine-scale assessment with techniques which allow monitoring and assessment within a much broader context. In reality there is the question of whether broad scale metrics connect to the local scale and vice versa so the 'ideal' is not always possible.

Methods used to assess vegetation at the site-scale are the most common. They typically use a set of measurable physical attributes which are combined to produce a single aggregate score as in 'Habitat Hectares' (Parkes *et al.* 2003) and the 'Biodiversity Benefits Index' (Oliver *et al.* 2005). This single score allows comparison between different areas or types of vegetation, or the same area at different times (Parkes & Lyon, 2006). The attributes selected will vary with context and vegetation type. Single attributes of vegetation such as structural complexity used to be equated with good condition because more structurally diverse vegetation tends to have greater bird and mammal abundance and diversity (Karr and Roth, 1971; Ecke *et al.* 2002; McElhinny *et al.* 2005). However, some vegetation types are structurally simple but not necessarily in poor condition (Oliver *et al.* 2002). It is now common practice to use a combination of structural, compositional and functional attributes as indicators of condition (Noss, 1990; Oliver, 2002; Williams, 2004). Table 1 lists some of the indicators associated with each of the three categories.

"Composition" refers to the identity and variety of species in a patch of vegetation. This list can also include measures of species diversity and genetic diversity and species specific indicators (Noss, 1990; Oliver, 2002).

"Structure" is the spatial configuration of a system, ranging from habitat complexity within communities to the arrangement of patches and vegetation classes at the landscape scale.

"Function" is an important component of vegetation condition assessment, as structure and composition provide only an indication of current condition and not much information about how the ecosystem is functioning as a whole. Functional indicators provide information about resilience, long-term viability, sensitivity to threat and possible trajectories (Smyth *et al.* 2003; Gibbons & Freudenberger, 2006) and ecosystem services such as soil and water retention, nutrient cycling and carbon sequestration.

The choice of attributes to be measured depends

Composition	Structure	Function
Native plant species richness	Tree density	Years since disturbance
Presence of rare or threatened species	Shrub density	Grazing Pressure
Evidence of introduced animals	Number of trees with hollows	Cultivation history
Cover of exotic species & type (eg invasive)	Number of vegetation strata	Regeneration
	Canopy cover	Soil properties
	Canopy height	Bio-turbation
	Abundance of litter	Patch size
		Ecosystem services

Table 1: Some examples of vegetation condition indicators.
(Sources: Oliver, 2002; Parkes et al. 2003; Gibbons & Freudenberger, 2006.).

not only on vegetation type or class but also on the stated objectives of the method i.e. the purpose for which the method was designed. 'Habitat Hectares' (Parkes *et al.* 2003) uses 7 'Site Condition' attributes which are judged to be important for a wide range of species and able to be rapidly assessed by non-experts. This method also uses 3 'Landscape Context' components which are generally assessed off-site using GIS. The NSW Environmental Services Scheme 'Biodiversity Benefits Index' (Oliver *et al.* 2005) uses 8 attributes of site condition which are combined with landscape context components (9) and a conservation significance assessment. This method was designed to produce a single measure that could be related to the environmental service being provided at a catchment or regional scale. The inclusion of landscape context components in both methods is recognition of the major influence that landscape features have on species composition and abundance and the long-term survival prospects of the vegetation being assessed.

There are various ways of combining attributes into a single index of condition (Gibbons & Freudenberger, 2006). A common method entails standardizing the data for single attributes relative to the relevant benchmark, and then summing individual scores to give a single measure of condition. Other methods multiply single attribute scores or use a combination of addition and multiplication. Single attributes can be weighted to overcome potential bias in the final score. Statistical methods such as ordination and classification can be used to differentiate between sites across a number of attributes.

The Vegetation Assets, State and Transitions (VAST) framework (Thackway & Lesslie, 2006) is a framework that aggregates condition assessments made at a range of scales to produce a continental picture. It classifies native vegetation as a series of states and transitions, which represent degrees of human-induced modification relative to a pre-European benchmark of condition. The framework requires input from existing vegetation condition data sets which may contain any number or type of attributes, provided they satisfy the diagnostic criteria (floristic composition, vegetation structure and regenerative capacity) upon which the classification is based. VAST was designed as a management tool for assessing and reporting vegetation condition and can accommodate data from a wide range of sources including site-based assessments, remote sensing and modelling data sets. Because the framework can accommodate data from multiple sites, which can be translated and compiled into one database, the VAST classification is a method that allows the reporting and mapping of condition Australia wide. This is useful from a policy perspective in that there is often a requirement to report vegetation condition at regional state or national scales.

Vegetation mapping at the landscape scale requires the use of maps from other sources, remotely sensed data and GIS. There are established methods for mapping vegetation extent, configuration and type, but mapping vegetation condition at the landscape scale across a broad range of vegetation types is a recent innovation in response to new policy and management objectives. There is now a requirement for natural resource management agencies to monitor condition over time, which necessitates mapped representations of vegetation condition at multiple scales (Zerger *et al.* 2006).

At this early stage of development there are only a few methods of for mapping vegetation condition at large scales. Zerger *et al.* (2006) describe spatial modelling of native vegetation condition using a combination of modelling, remote sensing and GIS. Site-based data and the use of explanatory variables were used to infer condition across entire regions and key predictors of vegetation condition were identified. Newell *et al.* (2006) have attempted to map condition over an area of more than 9 million hectares using a combination of site condition assessments and a neural network modelling procedure to identify relationships between site condition scores and 13 independent variables. Both methods generated statistical relationships that were used to predict scores for unknown sites. Predicted scores are compared with observed scores to estimate the accuracy of the models used. A different approach, which does not require modelling is that described by Molnar *et al.* (2007). They used a grid based field vegetation mapping method (MÊTA) supported by satellite imagery to map the vegetation of Hungary at a whole country scale (93,000 km^2). Multiple attributes were mapped including habitat types, area and spatial pattern, habitat quality, threats, neighbourhood, connectedness and regeneration potential, with the aim of not only mapping vegetation but to collect landscape ecological data for the prognosis of future changes in both vegetation and the landscape.

An alternative method of mapping condition and monitoring changes in condition over time involves sequences of satellite imagery which provide historical information with enough resolution to provide evidence of change at a range of scales from small remnant to region (Wallace *et al.* 2006). Regional and national vegetation monitoring programs using time series Landsat imagery are already operational in Australia (Wallace *et al.* 2006). The Australian Greenhouse Office has Landsat data collected over 13 time periods since 1972 which provide continent wide coverage. This sort of information is invaluable from a management perspective because vegetation condition is highly variable and will change from season to season and in response to disturbance and changing management regimes. The ability to visually monitor change over time is also a useful communication and research tool and data can be manipulated so that trends can be plotted for areas of interest. These sorts of change maps can highlight areas which might need a change in management or further on-ground assessment (Wallace *et al.* 2006). On the down-side satellite imagery is not always accurate, tells us very little without good ground data, and is really only suitable for monitoring of woody vegetation.

More recent advances in sensor technology are making the direct remote sensing of certain aspects of vegetation condition a useful research tool for ecological applications. Conventional 'passive' sensors such as those used in Landsat satellites for land-use and land-cover monitoring are limited in that they produce only 2-dimensional (x, y) images and become less sensitive and less accurate as above ground biomass and leaf area index increase (Lefsky *et al.* 2002; Turner *et al.* 2003). Newer 'active' sensors add a third (z) dimension and can be used to measure vegetation structure and biomass. Lidar (light detection and ranging) sensors are an example of new technology being applied to biodiversity research; they are able to provide high-resolution topographic maps and extremely accurate measurements of vegetation height, cover, canopy structure and ground surface elevation (Lefsky *et al.* 2002). Increasing spatial and spectral resolution afforded by new sensor technology means that remote sensing will have greater application at spatial scales ranging from site right through to continental scales and offer significant improvements in the potential to monitor vegetation responses to environmental and anthropogenic change.

Mapping condition over large areas has its limitations. The models used to predict vegetation condition rely heavily upon the reliability and availability of site condition data and the choice of variables readily available in GIS format. Site condition assessments are necessarily coarse estimations which are not always adequate for fine-scale spatial modelling (Newell *et al.* 2006). Newly developed methods for predicting vegetation condition have only 50% predictive accuracy and the condition maps produced are not able to detect differences in condition at the site scale and over short time frames. There can be data compatibility issues when trying to integrate ground-based assessments with remotely sensed data (Reinke & Jones, 2006). The detection of non-woody vegetation types is more problematic using satellite imagery so there are still issues related to the scoring of woody and non-woody vegetation (Pers.comm. Graham Newell). However, this type of spatial mapping is a very new field and the accuracy of the predictions will undoubtedly improve with time as new data is accumulated and models and methods are refined.

What factors affect condition?

This section briefly examines some of the more important factors which affect vegetation condition. This will logically lead to a consideration of how vegetation condition might improve over time.

Broad-scale land clearing of native vegetation for agriculture in Australia is by far the most significant cause of land degradation and biodiversity loss (Cork *et al.* 2006; Lindenmayer, 2007; McGrath, 2007). The immediate effect of native vegetation clearance is the destruction of plant species and a reduction in habitat for fauna, with subsequent species decline and loss of particular ecosystems and ecological communities. Preferential clearing of vegetation on fertile soils has meant that some classes of vegetation are particularly threatened. Grasslands, grassy woodlands, lowland riparian areas and wetlands are consequently under-represented in reserves and at risk outside of protected areas throughout Australia (Fitzsimons & Westcott, 2001).

Although vegetation clearance is now reduced as a threat due to legislative changes in all states, illegal clearing on private land has become an issue (Productivity Commission, 2004) and clearing of non-remnant or regrowth vegetation on previously cleared land is still allowed (Cork *et al.* 2006; McGrath, 2007). Changes associated with past clearing continue to threaten the existence of native plant and animal species. These include habitat fragmentation, grazing pressure, invasive species and diseases, altered fire regimes, changes in hydrological regimes and associated soil salinity problems. These pressures are all interrelated; inevitably detrimental change is magnified by flow on effects across the landscape.

Habitat loss and fragmentation of remaining vegetation is the most direct consequence of vegetation clearing. Fragmentation isolates remnants and creates 'edge effects' as they are exposed to external influences. These include changes in the physical and chemical environment outside and along the edge of a vegetation remnant, and changes in the abundance and distribution of wildlife and plant species in edge habitats. Flora and fauna remaining within the remnants are exposed to, and often threatened by, the conditions of a very different ecosystem (Murcia, 1995). Edges facilitate the transfer of pests and disease into the remnant area and expose remnant vegetation to invasion by agricultural and pioneer species which may out-compete native species (Saunders *et al.* 1991; Janzen, 1983).

Edges also create barriers to dispersal and migration and restrict the movement of some animal species (Yahner, 1988). Within the habitat fragments or 'islands' of remnant vegetation, there are changes in species composition, community structure and population dynamics (Donald, 2006). The gene pool is reduced and inbreeding is more likely to occur, reducing population viability. There is growing evidence that population size, plant fitness and genetic diversity are correlated (Broadhurst & Young, 2007) and these will be influenced by the degree of fragmentation in the landscape, the size of the remnant, species interaction and competition within and between patches, connectivity between patches, and surrounding land use. It is worth remembering that whilst habitat fragmentation has many deleterious effects it is overall loss of habitat that is the main threat to the evolutionary potential and persistence of many plant and animal species (MacNally 1999).

Vegetation condition can be seriously affected by invasive organisms. Human activities have both positive and negative impacts on biota with a majority of 'losers' adversely affected and a minority of 'winners' able to thrive in human altered environments (Low, 2002). This process has been termed 'biotic homogenisation' and the result is a decrease in biodiversity with less species at both regional and global scales. Homogenisation often means local biotas or unique endemic species, geographically restricted and with sensitive requirements, are replaced by already widespread species with greater tolerance to disturbance and human activity (McKinney & Lockwood, 1999). Invasive plant species have traits that promote successful transport and establishment in new environments including rapid growth and/or dispersal and a wide tolerance for environmental conditions.

Changing fire regimes have altered the composition and structure of native plant communities in Australia. Naturally-occurring fires increased in frequency as conditions became drier during the quaternary period (1.6 million years ago to the present) and promoted vegetation types which were 'increasingly fire-prone and fire-dependent' (White, 1994). Some of the unique adaptations to fire in the Australian biota include the re-sprouting of many species after fire (especially Eucalypts) and seed germination triggered by smoke (Read *et al.* 2000). The subsequent arrival of Aborigines in Australia at least 40,000 years ago also increased the frequency of fire, which was used as a means of managing vegetation to promote the food supply and increase access to it.

The ecological effects of burning were inhibition of the spread of non-fire-resistant plants and the maintenance of an open parkland appearance (Jones, 1969). In semi-arid woodlands, regular burning ensured a grassy under-storey with shrubs remaining a minor component of the vegetation. With the arrival of Europeans, semi-arid areas became rangelands for grazing sheep and cattle, Aboriginal burning ceased and woody shrubs began to invade native grassland (Jones, 1969). Prescribed burning is now the main method of controlling the growth and spread of unpalatable woody weeds in semi-arid woodlands (Perrings & Walker, 1997). Naturally occurring fires have decreased in frequency since European settlement and when burning does occur, it is often intense, extensive and uncontrolled fire rather than the managed low intensity fires used by the Aborigines (Williams *et al.* 2001). Future changes in climate will further influence fire regimes and their affect on Australian ecosystems.

Heavy grazing by stock and feral animals has had a huge impact on Australian agricultural landscapes. The gradual shift from grass to shrub dominance in the under-storey of semi-arid woodland communities is thought to be the direct result of the introduction of grazing animals by white settlers. In these areas overgrazing by introduced herbivores removed the herbaceous layer, especially in periods of drought (Noble, 1997). Soils deteriorated due to reduction in ground cover, erosion and nutrient loss, reduced water infiltration and compaction (Braunack & Walker, 1985). Grazing has similar detrimental effects in other ecosystems and the impact can be greater in more fertile alluvial areas, riparian zones and refuge areas (Cork *et al.* 2006). Huge populations of rabbits decimated native vegetation by grazing palatable herbage, ring-barking trees and shrubs, and eating plant roots. More recently livestock grazing has been found to be a useful management tool for achieving conservation objectives in instances where it can be used to control biomass of grazing sensitive plants which might become dominant or be invasive, or where grazing can increase heterogeneity of habitat in some landscapes (Lunt *et al.* 2007).

The links between clearance of native vegetation and changes in hydrology are relatively well understood, with vegetation removal directly affecting the water balance of an area leading to changes in local ground water systems and their chemical composition, altered flow regimes in waterways and changes in local soils and climate (Williams, *et al.* 2001; Cork *et al.* 2006). The native vegetation of Australia is perennial and deep rooted, well adapted to surviving floods and drought (Beresford *et al.* 2004). Replacing native species with shallow-rooted crops and pasture that use less water leads to increased run-off, increased infiltration and rising water tables. The movement of dissolved salts to surface layers of the soil profile can cause water-logging and/or death of any vegetation which is not salt tolerant. Where saline groundwater discharges at the soil surface the salt is concentrated by evaporation, damaging soils, reducing water quality and degrading wetland habitats (Beresford *et al.* 2004).

The nature of the matrix between native vegetation remnants influences vegetation condition within fragmented landscapes. The composition and structure of the matrix can be just as important for the survival of native flora and fauna as the condition of a remnant itself, reducing the negative effects of fragmentation (isolation) which are most pronounced when the matrix is formed by agricultural land. The latter is usually less heterogeneous than 'softer' matrices which have a high complexity of vegetation structure and ground cover (Fischer, 2005; Donald, 2006). The matrix is often discussed in terms of connectivity and habitat for wildlife but it can be equally important for vegetation condition. Scattered trees are a key component of the matrix and can represent a substantial proportion of tree cover for some woodland communities and a large proportion of the remnant vegetation (Gibbons & Boak, 2002). Scattered trees also perform a range of ecological functions: the microclimate is cooler and often more humid under trees; they can provide favourable conditions for the recruitment of other plants; they can preserve local tree genotypes and be a source for natural regeneration (Manning *et al.* 2006). Scattered trees and very small patches of remnant vegetation are often located in productive agricultural land and frequently considered (by some) to be of little value for conservation purposes. Legislation in Australia does not recognize the ecological importance of small patches and scattered trees; in NSW for instance clearing exemptions allow the removal of 7 trees per hectare per year for farm purposes and the clearing of up to 2ha of native vegetation each year. Paddock trees are in serious decline due to age, clearing, harmful agricultural practices and lack of regeneration (Carruthers *et al.* 2004; Manning *et al.* 2006).

A final, major influence on vegetation condition is land-use history. Past decisions regarding land use are known to be key determinants of existing and future patterns of remnant vegetation (Lunt & Spooner, 2005). For this reason the structure and composition of remnant vegetation at certain sites may not represent historical (pre-European settlement) condition (Spooner & Lunt, 2004) and sites which appear natural today may be more a consequence of historical anthropogenic activity rather than the product of site conditions and natural disturbance (Foster *et al.* 2003). Lunt & Spooner (2005) convincingly argue that present day remnant vegetation patterns are not accidental, but are spatially distributed according to historic land use decisions made during early agricultural development. By studying regional land-use history it may be possible to predict the structure and composition of many remnants.

The same authors also postulate (p1863) that ''anthropogenic disturbances and resultant ecosystem attributes have changed over time and continue to change. Some deleterious disturbance regimes have declined in intensity over time, leading to potential improvements in vegetation condition. Consequently, a priori assumptions of ongoing degradation are not always valid.'' This is an important point which is particularly relevant to this research. It underpins an assumption which led to the formulation of one of the research questions for this PhD: that despite concerns expressed by scientists and land managers there is evidence that improvements in native vegetation are occurring.

"Is regeneration improving vegetation condition?"

Previous sections have examined vegetation condition and how it might be assessed, usually in relation to some historical benchmark. The question of improvement in vegetation condition introduces the element of time and the need to quantify change over relatively short periods of time. It implies that some or all of the attributes of a particular patch or type of vegetation have changed in a way that has led, or will lead, to positive outcomes for biodiversity.

At site scale, monitoring this sort of change in the field requires that condition assessments be repeated over time. Improvement could mean that vegetation at a particular site is less weedy, more structurally complex or is perhaps providing habitat for a greater number of species. At landscape scale, time series aerial or satellite photography can provide evidence of change in extent or coverage. This sort of change could occur by means of regeneration or revegetation. One could argue that an increase in the extent of native vegetation coverage does not necessarily equate to an increase in quality but it is logical to assume than an increase in extent is a good indication that quality is improving or will improve in the future. MacNally (1999) argues that loss of habitat has been the primary cause of land degradation and biodiversity loss, rather than fragmentation of the landscape and so increases in extent should be the first consideration when aiming to redress the negative effects of native vegetation clearance. Regeneration and revegetation are phenomena which can be readily identified and discussed without the need for the specialist scientific knowledge required to identify change in condition in the absence of change in extent. This makes them particularly suitable as a focus for social research into the behaviours which lead to improvements in vegetation condition. The following section briefly describes regeneration and revegetation before expanding a little on the use of qualitative methods to support the hypothesis that improvement is occurring.

Regeneration is the term used to describe various reproductive strategies used by many plant species, although it usually refers specifically to the colonisation of woody plants from remnant trees and shrubs (Vesk & Dorrough, 2006). To give an example Australian eucalypts Angophora, Corymbia and Eucalyptus species (Myrtaceae family) have four regenerative strategies which include sexual and asexual modes of reproduction. The trees in this family can be lignotuber sprouters (mallees), stem sprouters, combination sprouters or obligate seeders, with the latter usually having a relatively short life span in natural environments because of their inability to regenerate vegetatively after complete crown destruction (Nicolle, 2006). Natural regeneration is a term often used in the literature and implies reproduction without human intervention, both cheaper and more ecologically preferable to active revegetation as a means of improving vegetation condition (Kirkpatrick & Gilfedder, 1999; Spooner *et al.* 2002). Regeneration from remnants of native vegetation may play a significant role in the conservation of genetic resources enabling population survival and resilience to environmental change (Moran & Hopper, 1987).

Revegetation is a human activity which involves direct seeding or planting seedlings in a way that is designed to re-establish native vegetation, usually for conservation reasons. It is considerably more labour intensive and costly than natural regeneration. The cost of revegetation using tube stock has been estimated to be at least 1200 times greater than direct costs of natural regeneration (Dorrough & Moxham, 2005). Aside from being expensive and time consuming revegetation for restoration purposes can require a lot of active management and intervention, and conservation outcomes can be variable. Hobbs (2006) questions the amount of intervention that is desirable if it leads to artificial and potentially unsustainable communities, especially if species are planted back into situations that threatened their survival in the first place. Wilkins *et al.* (2003) found that even after 10 years, restoration plantings (to restore grassy eucalypt woodland on abandoned agricultural land) had not 'facilitated any significant unassisted recruitment of native plant species', nor did the revegetated area resemble local remnant vegetation. Obviously revegetated areas may take many decades to develop structure and other elements of habitat quality required to sustain plant and animal populations.

The justification for focussing on regeneration rather than revegetation for this PhD project is that regeneration is preferable to revegetation in terms of creating habitat and preserving local genetic material and is much more cost effective. There is considerable potential for natural regeneration on agricultural land if, as Lunt & Spooner (2005) claim, the disturbance regimes such as clearing and grazing have declined (and may continue to decline). It may be that less investment would be required for much better biodiversity outcomes if the focus for policy and management was on natural regeneration rather than revegetation. There are many factors which might lead to improvements in vegetation condition by means of regeneration, including reductions in clearing of native vegetation and the removal of individual trees, destocking, altered grazing regimes, less fertiliser use, improved weed and feral pest control. An alternative means of documenting evidence to demonstrate improvements in native vegetation condition is the use of qualitative data obtained from land managers to explore in some detail the range of factors which have led to that change and may continue to do so into the future.

Remote sensing is one method of assessing the extent of regeneration. However it is unlikely that analyses based on remotely sensed data will allow researchers to understand the relative importance of and inter-relationships between factors leading to regeneration. Interviews with landholders, NRM practitioners and other key informants should be an effective way to achieve this. Qualitative data may be more powerful in that it can potentially provide evidence of change before it becomes visible on the ground and also indicate whether or not improvements will be sustained into the future.

Using an historical landscape perspective, this research will attempt to integrate quantitative and qualitative data to provide evidence for improved condition of native vegetation on private land. The systematic use of inference from interview data combined with quantitative information on vegetation extent change from aerial photography should make it possible to test the hypothesis that regeneration is improving vegetation condition. The real value of the research will lie in its exploration of the reasons for change, as there is a pressing need to understand which factors have had the most influence on present day condition. Greater understanding of the outcomes of past interventions can be used to guide future investment in natural resource management for biodiversity conservation.

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