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Synthesising the effects of land use on natural and managed landscapes

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HIGHLIGHTS

- Linking the effects of past land use to vegetation condition need not be complex
- VAST-2 tracks the responses of native plant communities to the effects of management
- VAST-2 evaluates management effects on vegetation structure, composition and function
- VAST-2 integrates experimental, observational, and experiential information
- Standardized indicators assist land managers and ecologists assess land use outcomes

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ABSTRACT

To properly manage our natural and managed landscapes, and to restore or repair degraded areas, it is important to know the changes that have taken place over time, particularly with respect to land use and its cumulative effect on ecological function. In common with many places in the world, where the industrial revolution resulted in profound changes to land use and management, Australia's landscapes have been transformed in the last 200 years. Initially the VAST (Vegetation Assets, States and Transitions) system was developed to describe and map changes in vegetation over time through a series of condition states or classes; here we describe an enhancement to the VAST method which will enable identification of the factors contributing to those changes in state as a result of changes in management practice. The 'VAST-2' system provides a structure in which to compile, interpret and sequence a range of data about past management practices, their effect on site and vegetation condition. Alongside a systematic chronology of land use and management, a hierarchy of indices is used to build a picture of the condition of the vegetation through time: 22 indicators within ten criteria representing three components of vegetation condition—regenerative capacity, vegetation structure and species composition—are scored using information from a variety of sources. These indicators are assessed relative to a pre-European reference state, either actual or synthetic. Each component is weighted proportionally to its contribution to the whole, determined through expert opinion. These weighted condition components are used to produce an aggregated transformation score for the vegetation. The application of this system to a range of sites selected across Australia's tropical, sub-tropical and temperate bioregions is presented, illustrating the utility of the system. Notably, the method accommodates a range of different types of information to be aggregated.

1. Introduction

The landscape we see today is the product of millennia of evolution and change, usually incorporating some level of human intervention. Human modification of the landscape has arguably accelerated since the industrial revolution, certainly in the developed west, but increasingly in developing and emerging nations (Millennium Ecosystem Assessment, 2005). Many of the changes we see are undesirable, and we often discover them many years after their precipitating cause, or causes, as there is often more than one contributing factor (Adamson and Fox, 1982; Hobbs and Hopkins, 1990; Saunders et al., 1990; Lefroy et al., 2000; Tongway and Ludwig, 2011; Stone and Simpson, 2006; MacLeod et al., 2014). Failure to properly appreciate the human element, however, can lead to 'erroneous ecological interpretations, misdirected research emphases and misguided approaches to management' (Foster, 2000).

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A wealth of scientific effort has been invested to better understand the dynamics of ecological systems and the temporal and spatial interactions within and between them, but our knowledge is by no means comprehensive. The land manager seeks to plan for the future, and to do so, compile accumulated knowledge into hypotheses or models about the system being managed. The development of these models is nearly always based on data about past responses of the system to various management actions (Pollock et al., 2002; Walker et al., 2007).

The outcomes of past events can greatly influence the course of future changes (Lunt, 2002). In recently industrialised countries, such as Australia, the history of settlement, exploitation, land use and management is central to understanding the transformation of vegetated landscapes and the associated biophysical and chemical processes underpinning them. There is a plethora of evidence that Australian landscapes have been changed by both intensive and extensive use and management practices (Harrington et al., 1976; Adamson and Fox, 1982; Hobbs and Hopkins, 1990; Benson, 1991; Kirkpatrick, 1994; Stubbs, 1998, 2001; Atwell et al., 1999; Cocks, 2000; Lunt, 2002; Lunt and Spooner, 2005; Kirkpatrick and Bridle, 2007). The effects of management interventions can be dramatic and long term, or short term and more subtle (Groves, 1994; Foster et al., 1998). Exploitative industries, in particular agriculture, forestry and mining, have contributed substantially to Australia's economic development (Williams and Saunders, 2003; Lesslie et al., 2011) but a side-effect of this exploitation has been the fragmentation, modification and replacement of the aboriginal with European-like landscapes (Kirkpatrick, 1994; Gammage, 2011).

An understanding of the interactions between the natural environment and past and present use and management of the land, disturbance events and climate can provide important insights for future management (Cocks, 2000; McGlone, 2000; Lefroy et al., 2000; Lunt, 2002; Williams et al., 2002). A system is required that enables decision-makers to evaluate the level to which plant communities have been modified from their natural (pre-European) status. Such a system would assist with assessing, reporting and monitoring the response of ecosystems to land management interventions, and would be useful to assess the likelihood that candidate areas for restoration will follow a trajectory towards some specified target state (Hobbs and Norton, 1996; Wilkins et al., 2003).

There are some challenges to attaining an integrated product such as this. Vegetation science is a well-established discipline that includes the development and application of standardised methods for survey, classification and mapping of vegetation types and their extent (i.e. plant communities and associations) (Thackway et al., 2008). The same cannot be said for describing their condition, and in a manner suitable for land managers. Decision-makers need basic answers to fundamental questions such as how much of a particular plant community type remains where (i.e. extent and distribution), what is its condition, and how can these communities be best managed to maintain, enhance or restore them. We present a pragmatic approach to address the challenge of how to assess and report changes and trends in vegetation condition.

Several frameworks for site-based vegetation condition assessment have been developed and widely applied (e.g. Parkes et al., 2003). These mostly biodiversity-based frameworks start from a position of rigorous scientific independence and only consider post hoc the effects of changes in land management, in order to explain observed patterns of environmental information. Arguably a more integrated assessment framework is needed to properly account for the transformation of vegetated landscapes.

Current site-based condition frameworks also overlook qualitative and quantitative historical records of land use and biotic and abiotic elements which land managers (and others) have observed changing as a result of their management practices, such as: soil structure and nutrients, vegetation structure and species composition and fire regime. The current approaches (e.g. Parkes et al., 2003) for assessing changes in condition of biodiversity focus on attributes and indicators of ecosystems (where plant communities are a surrogate), excluding the systematic collection and analysis land use data and information. We present an alternative approach which uses the effects of land management practices over time as a key driver of observed changes and trends in condition. Fundamental to the approach is that qualitative and quantitative ecological datasets are available and fit-for-the-purpose (i.e. comprehensive, relevant, and adequate) for the assessment of spatial and temporal changes and trends in condition. Where ecological attributes are not fit-for-the-purpose, remote sensing and environmental modelling may be used to develop the requisite attribute data.

A national assessment framework that enables parallel recording of vegetation condition and management practices would be useful for several Australian natural resource management and reporting frameworks; for example the National Environmental Accounts of Australia (Wentworth Group of Concerned Scientists, 2008), the State of Environment Report (State of the Environment Committee, 2011), and the State of the Forest Report (MPIG AND NFISC, 2013). Models for such a framework have been developed for the national environmental accounting system by the Wentworth Group of Concerned Scientists (2008) and for ecosystem services by the Millennium Ecosystem Assessment (2005). Both models acknowledge that land management practices are used to deliberately modify the function of an ecosystem by manipulating an ecosystem's structure, composition and function affecting the delivery of ecosystem services (e.g. water availability, food production, wood supply, wildlife populations) (Yapp et al., 2010). These assessment frameworks help identify the key elements of a system for accounting and monitoring vegetation condition (Fig. 1):

(i) changes in climatic and hydrological conditions, land ownership and regulation and the occurrence of extreme events (background and contextual),
(ii) land use and management histories (human effects), and
(iii) changes in attributes and indicators of biodiversity (vegetation responses).

Integrating this information enables an interpretation of the effect of modes of land use on ecological integrity and function (Fig. 1). Such a system for accounting and monitoring vegetation condition over time at national level would enable users to:

- systematically synthesise information from disparate observations and measurements about vegetation status and land management practices through time,
- report change and trends in the condition of (native) plant communities at specific locations or across landscapes, and through this process, and
- project likely transitions and condition states in the future.

Assessing and reporting the effects of land use and management on plant communities requires a broader approach than simply monitoring changes and trends in spatial and temporal attributes of plant communities or land use. A broad assessment framework should have the flexibility to utilise relevant rigorously collected quantitative attributes of vegetation condition, and would enable researchers to build working partnerships with land managers to incorporate their knowledge and understanding.

These effects could be assessed and reported in space and over time as changes in vegetation condition in comparison to a fully natural reference state using indicators of regenerative capacity