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Viewpoint

Linking vegetation type and condition to ecosystem goods and services

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ABSTRACT

Our focus here is on how vegetation management can be used to manipulate the balance of ecosystem services at a landscape scale. Across a landscape, vegetation can be maintained or restored or modified or removed and replaced to meet the changing needs of society, giving mosaics of vegetation types and 'condition classes' that can range from intact native ecosystems to highly modified systems. These various classes will produce different levels and types of ecosystem services and the challenge for natural resource management programs and land management decisions is to be able to consider the complex nature of trade-offs between a wide range of ecosystem services. We use vegetation types and their condition classes as a first approximation or surrogate to define and map the underlying ecosystems in terms of their regulating, supporting, provisioning and cultural services. In using vegetation as a surrogate, we believe it is important to describe natural or modified (e.g. agronomic) vegetation classes in terms of structure – which in turn is related to ecosystem function (rooting depth, nutrient recycling, carbon capture, water use, etc.). This approach enables changes in vegetation as a result of land use to be coupled with changes to surface and groundwater resources and other physical and chemical properties of soils.

For Australian ecosystems an existing structural classification based on height and cover of all vegetation layers is suggested as the appropriate functional vegetation classification. This classification can be used with a framework for mapping and manipulating vegetation condition classes. These classes are based on the degree of modification to pre-existing vegetation and, in the case of biodiversity, this is the original vegetation. A landscape approach enables a user to visualise and evaluate the trade-offs between economic and environmental objectives at a spatial scale at which the delivery of ecosystem services can meaningfully be influenced and reported. Such trade-offs can be defined using a simple scoring system or, if the ecological and socio-economic data exist in sufficient detail, using process-based models.

Existing Australian databases contain information that can be aggregated at the landscape and water catchment scales. The available spatial information includes socio-economic data, terrain, vegetation type and cover, soils and their hydrological properties, groundwater quantity and surface water flows. Our approach supports use of this information to design vegetation management interventions for delivery of an appropriate mix of ecosystem services across landscapes with diverse land uses.

1. Introduction

Human well-being is inextricably linked to the provision of a wide range of goods and services from diverse ecosystems across bioclimatic regions. Human use of ecosystems results in ever changing spatial patterns and resource changes across both landscapes and social-ecological systems (Folke et al., 2004; Foley et al., 2005; Walker and Salt, 2006; Bennett et al., 2009). Several global assessments have shown that the pressures of human population growth and development are increasingly impacting on the resource condition of major ecosystems (e.g. coastal, forest, grasslands, dryland, cultivated and urban) and hence their capacity to meet human needs for goods and services (World Bank, 2004; United Nations (Millennium Ecosystem Assessment (MA)), 2005; World Resources Institute, 2007a). While considerable progress has been made in developing appropriate assessment frameworks, several authors note there is an ongoing challenge to develop practical applications and tools that demonstrate sustainable use and management of ecosystems for the delivery of ecosystem services at a range of scales (Millennium Ecosystem Assessment 2005; World Resources Institute, 2007a; Cowling et al., 2008; Walker et al., 2010). Such developments need to be widely applicable, effectively demonstrated and well publicised if they are to lead to real improvements in decision-making across scales and

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jurisdictional responsibilities. The methodology described here is a step in the direction of helping decision-makers better evaluate the consequences of land use changes on ecosystem goods and services.

When decision-makers set out to explore the possible redesign of landscapes, often at different scales, they need information about their ecological function and how a change in the mix of land uses will impact on trade-offs between production needs and other human well-being needs. Where possible, trade-offs should be quantified in terms of the sustainable delivery of ecosystem goods and services from resilient ecosystems and be matched to human well-being (Bennett et al., 2009; Cork et al., 2007). Land management practices can influence the resilience of different ecosystem types and their ecological function and in turn suggest which ecosystem service or set of services can be sustainably restored or maintained in the long term. Much of the recent literature in this field is covered in Maltby et al. (1999), Alcamo et al. (2003), Walker and Salt (2006), Rapport et al. (2003) and the Millennium Ecosystem Assessment (2005).

Three examples of practical approaches for developing information to support policy development and planning and natural resource management, and which have a focus on the delivery of ecosystem services, can be selected from the literature. First, Alcamo et al. (2003) describe an approach for assessing the condition of ecosystems, the provision of services, and their relation to human well-being. Alcamo et al. also outline a decision process used to determine which service or mixes of services is valued most highly and suggest how to maintain ecosystem services by sustainably managing the ecosystem and its ecological function. This approach was instrumental in underpinning the assessment framework for the Millennium Ecosystem Assessment. Second, Maynard et al. (2010) outline an approach developed in the south-east region of Queensland, Australia to establish relationships between four components to ecosystem-based decision-making; maps of the types of ecosystems, ecosystem functions, ecosystem services, and constituents of human well-being. The authors derived a series of interrelationships between the components using matrices with simple scores to map ecosystem services of the region. Third, The World Resources Institute et al. (2007b) present an atlas showing how people of Kenya currently use the landscape and it's ecosystems. Maps of population and household expenditures are compared to ecosystem types (e.g. mountains, rangelands and forests) and the services (e.g. water availability, food production, wood supply, wildlife populations) they provide. One of the benefits of the atlas is that it highlights the relationship between economy and ecosystems, e.g. revenues raised from tourism in various ecosystems and their wildlife resources and revenues from forests and timber production.

Our approach is to build on the observation that vegetation is a major driving force in the dynamics of terrestrial ecosystems such that, in Australia, it is often used as a proxy to classify ecosystem type and function. The nature of vegetation in a landscape – its type and condition – strongly reflects environmental variables related to soils and climate but it also reflects land use disturbances such as clearing and the replacement of deep-rooted perennial plants with annual crops. To a large extent, it is the mix of intact, disturbed and replaced vegetation cover types and their relative condition classes which characterise a region's natural ecological function and its capacity to deliver a set of ecosystem goods and services (Folke et al., 2004). The main environmental issues that need attention in the Australian context are water quality and quantity, habitat loss and biodiversity, soil structure decline, dryland and irrigation salinity, food and fibre security and fuel management for fire control. These are common issues in other countries with large-scale broad-acre agricultural land uses.

Characteristics of vegetation (e.g. extent of uniform types and condition classes) provide easy to identify practical focal points that become the focus for decision-makers and land managers to develop and apply appropriate land management practices (i.e. maintain or restore or modify or remove and replace) to meet the changing social and economic needs of society (Maltby et al., 1999; Bennett et al., 2009). Few enterprises manage only a single vegetation type. Most manage the mosaic of ecosystems that make up a landscape. The challenge is to provide a practical framework to strategically assist policy, planning and management within the inherent limits of social and economic realities and ecological function across the landscape and with sufficient flexibility to provide for change in the mix of ecosystem services required at local, regional, national and international levels (Fisher et al., 2008; Walker et al., 2010; Maynard et al., 2010).

We outline a way to describe vegetated ecosystems and their management to support policy development and planning and natural resource management, in this case at the regional level. This requires a stepwise approach to (i) classify vegetation, (ii) recognise vegetation condition classes (termed VAST classes) based on structure, regenerative capacity and composition, (iii) relate the VAST classes of vegetation condition to land use and ecosystem function, (iv) estimate the effect of changes in land management and/or land use on VAST classes (in accordance with scale, position in the landscape and likely cost) and (v) select and invest in vegetation management actions that will deliver required outcomes in ecosystem goods and services.

2. Vegetation classes, vegetation condition and ecosystem services

The ecosystems that comprise landscapes are complex entities featuring intricate interactions between above and below ground living and non-living elements, food-webs and biophysical processes of assimilation and renewal. Vegetation is the most evident component of terrestrial ecosystems and so is widely used, along with information on soils and landforms, to simplify ecosystems and landscapes into manageable units. The genesis of a systematic, landscape-oriented approach can be traced from the development and application of the Land Systems methodology, applied between 1949 and 1974 mainly by scientists in CSIRO, Australia and its continuing development in the discipline of "landscape ecology" (Christian, 1952; Stewart, 1968; Hills, 1976; McDonald et al., 1984; Forman, 1995; Jiangui and Taylor, 2002). Because vegetation is relatively easy to describe, vegetation classes are often defined and mapped as a first approximation of the underlying ecosystems (Zhiyuan et al., 2003). In Australia, native vegetation is commonly used to recognise and name ecosystem types, assess their condition and act as a surrogate for a range of values including biodiversity.

The yield of ecosystem services from Australian landscapes is strongly influenced by the kind of vegetation at a place and, in particular, how vegetation assets are managed in environments that have been subjected to large temporal variations in climatic conditions. Vegetation composition and dynamics are closely linked to a range of environmental variables that operate at a range of scales. Distributional patterns of vegetation are usually highly correlated and frequently causally related to a range of other ecosystem components such as soil fertility and water availability for plant growth, and to land use and land management practices – e.g. grazing, browsing, and tree removal with their unintended consequences such as erosion, soil acidification, water logging and salinisation on lower slopes and fire intensity. An additional complicating factor is that, over much of the Australia, soils are of ancient origin and consequently are nutrient and structurally poor and often fail to recover from large-scale disturbances (Walker and Reddell, 2007).

At a general level, we know how most vegetation types function in terms of biological and ecological processes across the soil-