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Wood provisioning in Mediterranean forests: A bottom-up spatial valuation approach

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ABSTRACT

The science of ecosystem services has evolved significantly in the last decade following an increase in interest in the understanding and valuation of these services. Forests provide important ecosystem services that supply societal needs, such as timber, but this provision is not free of conflicts derived from the intensive management of forests. A GIS based approach using data from national forest inventories allows us to identify the provision of timber services and to conduct its valuation. The analysis includes a sample of 37,761 plots for 38 commercial tree species in the Spanish Mediterranean region, where we identify sustainable and non-sustainable forests in terms of harvesting intensities and value both the flow of benefits and their net present value. From the analysis we conclude that non-sustainable forests are providing higher economic returns than sustainable forests for most abundant tree species. However, when analysing long term trends, results show that sustainable forests yield higher economic benefits. This latter perspective is preferred when looking at the value of timber as a provisioning service of forests. According to our results, if we wish to encourage sustainability we need to (a) get lower discount rates adopted for the private sector and (b) ensure longer time horizons.

1. Introduction

Since the release of the Millennium Ecosystem Assessment (MA, 2005) a growing interest in the science of landscape functions and services has emerged (Fisher et al., 2009). The traditional focus of economics towards environmental valuation has been to look at natural resources as inputs to the production of commercial products, as well as non-market goods and services provided by the environment (Polasky and Segerson, 2009). The MA has shifted this focus towards the integration of ecology and economy, by considering the flow of ecosystem services that determine human welfare. Despite the growing body of literature on ecosystem services, many challenges still remain in the science of ecosystem production functions and ecosystem mapping (Daily and Matson, 2008; de Groot et al., 2010), as well as in structurally integrating ecosystem services in landscape planning, management and policy design (MA, 2005; Nelson et al., 2009). Knowledge on how ecosystem services are valued and how these economic values can be mapped to facilitate the use of ecosystem services in spatial planning and design is still under development (de Groot et al., 2010). Recently, growing attention has been focused on the spatial visualization and mapping of ecosystem services (e.g., Chan et al., 2006; Troy and Wilson, 2006; Chen et al., 2009 or Nelson et al., 2009). These studies carefully model the provision of services, but normally deal with one specific region. Approaches that combine local information with assessments at broader spatial and temporal scales are clearly needed.

Forests represent 31% of the world surface (FAO, 2010) sustaining biodiversity and providing ecosystem services critical to humans. Timber is one important ecosystem service from forests classified as a provisioning service by MA (MA, 2005). Worldwide, forests have produced over $100 billion per year gross value added in roundwood production in the period 2003–2007 (FAO, 2010). However, the ecosystem services approach requires timber extraction to be ecologically sustainable in order to be considered as a service. There is a conflict between the management of forests for commercial production of wood and management to protect biodiversity and ecosystem services other than timber (e.g., Noble and Dirzo, 1997). Thus a critical issue is to reconcile different components of ecological sustainability with forest management (e.g. , Zavala and Oria de Rueda, 1995; Von Gadow et al., 2000; Blanco et al., 2005). In this study we take an ecosystem services perspective and analyze ecological sustainability of timber flows over time.

Demand for timber is increasing in the world, driven partly by the global population increase, and is causing the decline of primary forests and the loss of forest land (Paquette and Messier, 2010; Fox, 2000). At the same time, more forest land has been put into conservation and recent studies have maintained that this increasing demand can only be met with intensive forest plantations (Powers, 1999; Fox, 2000; Fenning and Gershenzon, 2002). However, intensively managed forests and forest plantations are not free from controversy as

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forest managers still face the challenge of demonstrating that plantation productivity is sustainable (Powers, 1999). Given the need for wood supply and the adverse effects of intensive timber management, Paquette and Messier (2010) suggest multi-purpose land management be understood as a broader concept including land for conservation, intensive and extensive management.

Efficient multipurpose land use decisions, in this case for timber productivity and maintenance of related forest ecosystem services, can only be made through the understanding of the complexity of the real world (Bateman, 2009). In this sense, location of resources determines the physical changes in provision, leading to differences in the benefits obtained from forests that are driving management decision making. Ecosystem services are not homogeneous across the landscape and their supply changes over time (Fisher et al., 2009). For this reason, such services are best expressed and most easily studied at particular spatial and temporal scales (MA, 2003). Traditionally, economic valuations of ecosystem services have been addressed by estimating and describing direct use values with statistical data: such as the production value, or the GDP for the whole region, which might be appropriate at a macro level like national or regional valuations (Chen et al., 2009). Recent work is now shifting the economic analyses; approaches start from land use and habitat types to predict the provision of ecosystem services and their value (Polasky et al., 2005; Naidoo et al., 2006; Naidoo and Iwamura, 2007). GIS provides land managers with a tool for quantifying and mapping the values of multiple ecosystem services across landscape for improved resource planning and decision making. Moreover, GIS techniques can be employed to improve the modeling and transfer of market priced timber production values (Bateman et al., 2002). However, little attention has been paid to the spatial visualization and mapping (spatial/ecologic accuracy), which is essential to an accurate determination of the direct use of ecosystem services. Bateman et al. (2002) reviewed the existing economic valuation literature applying GIS tools. At that time, examples of GIS concerned mainly hedonic pricing (Bateman, 1994; Lake et al., 1998; Bateman et al., 2001) and travel cost (Bateman et al., 1999), where GIS tools were not completely explored although the potential is said to be huge. According to Bateman et al. (2002), environmental economists have not been quick to appreciate the importance of spatial factors in human and ecological processes, where the use of GIS in environmental economics is still a recent innovation.

In this paper we use GIS to estimate the value of timber provisioning services for Mediterranean forests in Spain. The Iberian Peninsula presents a high variety of factors that determine the high diversity and heterogeneity of forests (Blanco et al., 1997). It is located on the Northwest of the Mediterranean Basin where a millenary human occupation has played a vital role in shaping vegetation (Barbero et al., 1998). Climate varies from Mediterranean and Continental to Atlantic, conditioning, together with soils and the topography, the high diversity of species and habitats. In Spain forests occupy 14.7 million of ha (MARM, 2002). Valuation of these ecosystems in the Iberian Peninsula has focused on the income obtained from specific intensively exploited forests (Caparrós et al., 2001; Campos and Caparrós, 2006; Ovando et al., 2010). Applications do not employ geographical data, an exception being Lopez-Peredo et al. (2009), who recently estimated the timber and carbon flows for a Spanish province (Segovia).

The present analysis employs a broad database from forest inventories with 37,761 observations from plot data, including 38 different tree species. This allows us to conduct a bottom-up ecosystem approach, by estimating the current benefits forest timber provides to society and evaluating the sustainability of these flows over time. We are concerned that not taking into account long term sustainability will produce a flow of benefits from timber that are overestimated. For this reason, we conduct an analysis of mortality –including management-related felling – and growth at an aggregated level to see if managed given harvest is sustainable or not. We also examine the present value of ecosystem services by comparing observed benefits from sustainable and non-sustainable forests. Finally, we illustrate with an example the benefits from the point of view of the land owner.

The analysis conducted here contributes to the environmental economics literature in two main ways. Firstly, the results provide evidence on how the benefits from timber provisioning services may differ between long- and short term perspective policies; and when ecological sustainability is included in the analyses. Previous assessments of timber benefits do not always target long-term sustainability (Polasky et al., 2008; Chen et al., 2009) yet a sustainable approximation is key for long-term biodiversity and key ecosystem service preservation. Secondly, the paper shows promise of plot data from decadal forest inventories for the assessment of ecosystem services such as timber provision, setting the basis for future long-term bottom-up approaches for ecosystem services (de Groot et al., 2010). The paper is structured as follows: Section 2 describes the data and methodology for the analysis; Section 3 presents the main results; Section 4 discusses the findings in the context of ecosystem services valuation and Section 5 concludes.

2. Material and methods

2.1. Data acquisition

We used data from the second (1986–1996) and third (1997–2007) Spanish Forest Inventory (hereafter SFI) (Villaescusa and Díaz, 1998; MARM, 2008b) to estimate timber flows. SFI consists of a systematic sampling of permanent forest circular plots of 25 m radius, distributed on a grid of 1 km^2 over areas covered by forest. Each stand of the SFI is structured in four concentric circles where the inclusion of a tree is a function of its diameter at breast height (dbh) and distance to the plot center.[1] We combined the SFI grid (UTM coordinates) with WWF Terrestrial Ecoregions of the World information (Olson et al., 2001) so each SFI plot was assigned to a given region. Our approach was very conservative in terms of plot selection and error control. From the initial 96,664 3SFI plots in Spain, we only considered plots that had been securely relocated in both inventories (named as A-level plots in the SFI). We also disregarded all trees from plots in which there were more than 30% of individual-tree erroneous measurements, and we did not consider estimates from trees with at least one measurement error such as negative growth or recruitment. As a result of this error control procedure, we ended up with a total sample of 37,761 permanent plots, most of them located within the Mediterranean region as some plots from the Atlantic region had not been properly relocated. Diameter at breast height (dbh) and height were measured in trees with a dbh of at least 7.5 cm and height greater than 1.30 m. Up to 38 tree species with commercial timber use were considered (see Appendix A). The timber harvested was assessed at the stand level (see Section 2.2.) and its sustainability was evaluated at the polygon level. For this we used the Spanish Forest Inventory (SFI) and the vectorial Spanish Forest Map (hereafter SFM), a cartographic map that was created specifically to perform the 3SFI (Vallejo, 2005). The SFM is on a scale of 1:50,000 and consists of polygons that are homogeneous units in terms of present species, species composition and land use type. The SFM map is developed from the interpretation of aerial photographs, combined with pre-existing maps and field inventory data.

Timber is valued based on its current market price (Glenn, 2004). Since the returns of the asset are perceived over a long period of time, the asset may be valued based on net present value of the expected income stream over its lifetime. Stumpage prices are the value of timber as it stands uncut in the woods (before harvesting) (Glenn, 2004). National Forestry Annual Statistics (AEF, 2006) provides the stumpage

[1] The following were included: trees 7.5–12.4 cm in 5 m radius plot, 12.5–22.4 cm in 10 m radius plot, 22.5–42.5 cm in 15 m radius plot and larger or equal to 42.5 cm in 25 m radius plot.