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A forest ecosystem services evaluation at the river basin scale: Supply and demand between coastal areas and upstream lands (Italy)

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ABSTRACT

Many coastal communities benefit from a lively and profitable economy based on tourism but, simultaneously, cannot rely on the ecosystem services (ESs) provided locally, which have become insufficient because of increasing demand.

In the Apennines, a mountain range in central Italy, coastal areas are characterised by growing population and tourist demands and upstream lands mainly supply ecosystem goods and services. Mechanisms to re-distribute resources or payments for ESs would be helpful to foster the sustainability of regional systems. However, currently, there is neither an appreciation for such services nor institutions responsible for addressing this problem.

In this paper, we analyse and rank the ecosystem services provided by the forests of two river basins to assign economic values to four ecosystem services relevant for distinguishing provision and benefit areas: soil protection, water retention, drinking water supply and CO_2 sequestration. A simplified methodology was developed for contexts with poor environmental datasets. The aim was to provide ecological information to recognise ESs and encourage effective governance of ESs at a regional level. The results showed that the indirect value of the considered ecosystem services was three times higher than the direct value, and a spatial mismatch emphasised a "debt" in coastal areas from upstream areas for selected ecosystem services.

1. Introduction

Ecosystem functions are recognised as services when there are human beneficiaries (Fisher et al., 2008), and their supply affects stakeholders at all institutional levels (Hein et al., 2006). Although the ecological understanding of ecosystem services (ESs) remains limited (Kremen, 2005), policy makers are quickly becoming aware of their connection to well-being and local economies. Several international institutions and academics are involved in worldwide initiatives (e.g., IPBES) and research projects (e.g., TEEB, 2008; MEA, 2005). According to the EU Biodiversity Strategy to 2020 (COM 2011/244), local administrations (regional and municipal) must acknowledge the importance of ESs, and associated values should be integrated into environmental accounting and report systems. Particularly at the local level, many processes threaten ecosystem functioning, and decision makers may be effective in impact prevention and ecological value maintenance.

The main obstacle is often that the ES value is not recognised and the data do not specifically support local environmental decisions. ESs are not equally distributed in space (Costanza, 2008) and do not flow at identical rates, which causes a common spatial and temporal mismatch between ecosystems services and their beneficiaries (Ruhl et al., 2007; Fisher et al., 2008). The relative positions of local populations in the landscape determines the benefits from several services, e.g., communities residing at the bottom of a river basin depend on upland areas for a water supply (Hein et al., 2006; Brauman et al., 2007).

Several evaluations of ecosystem services on the river basin scale have been applied to ecosystem management and planning (Pires, 2004) according to the desired set of ecosystem services and involving the concept of Integrated Water Resource Management (IWRM) (e.g., Borsuk et al., 2001; Jewitt, 2002; Cavatassi, 2004; Van der Keur et al., 2008; Cosman et al., 2012). Indirect and direct drivers of ecosystem change may impair ES provision from upstream to downstream areas. The driving forces may be demographic, economic, socio-political, technological, physical or biological (Nelson et al., 2006). The main physical driver is land conversion, but in many cases, decision makers responsible for such changes may be unaware of its effects on ES provisioning. Land use conversion always affects the mix of services provided by ecosystems;

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ecosystem service trade-offs may occur without premeditation or even understanding that they are occurring (Rodríguez et al., 2006). Although the IWRM's definitions and concepts focus on and influence "thinking about sustainability", it does not appear to indicate how this proposed co-ordination, balance and integration is achievable in practice (Gooch and Stålnacke, 2006). The perspective of ecosystem services, wherein ES providers, beneficiaries and flows are identified and recognised in environmental policies (Syrbe and Walz, 2012; Palomo et al., 2013), may facilitate a spatial redistribution of resources, considering that the effects of the decision to alter the landscape become much more tangible because service values or degradation can be attributed to specific landowners or land managers (Villa et al., 2012). This process is particularly relevant for coastal areas, typically where richer areas on shorelines may benefit from a flourishing economy (e.g., tourism), and ecosystem services provided by the entire river basin.

Monetary evaluation, although controversial (Kelman, 1982) but always approximate (Costanza et al., 1997; Fisher et al., 2008), may help decision makers and the community of ES users focus on ecosystem functions (Gret-Regamey and Kytzia, 2007). The monetary values associated with ecosystem providing services may be pivotal in the formulation and evaluation of environmental policies (de Groot et al., 2010; Howarth and Farber, 2002). The valuation of ESs can support the involvement of all ES stakeholders (users and providers), which is crucial in maintaining ecosystem services for an equitable distribution of costs and benefits (Costanza et al., 1998; Farber et al., 2002) and to perform a supply/demand budget (Burkhard et al., 2012).

On a river basin scale, the forest ecosystems are often the main providers of a range of ESs (Quine et al., 2011), such as water regulation, soil retention and formation, climate regulation, supply of habitat, food production and recreational services. Previous studies (Bosch and Hewlett, 1982; Zhao et al., 2009) have shown that increased stream flow is correlated with deforestation or forest conversion in small-scale river basins (<1 km^2) and larger catchments (>700 km^2), and downstream water users should compensate upstream landowners for maintaining their forested areas for water regulation goals. Important quantitative relationships have been shown between drinking water treatment costs and the amount of forest cover: a portion of the variation in operating treatment costs could be explained by a percentage of the forest cover in the water source area, and the increase in cost for water treatment was based on a decrease in forest cover (Ernst, 2004; Abildtrup et al., 2011). River basins with a high proportion of land covered by forests and wetlands are particularly effective at decreasing and delaying runoff (Bosch and Hewlett, 1982; Schuler, 2006) and purifying water supplies (Postel and Thompson, 2005). Several studies about forest ecosystem services were conducted worldwide at different scales (Chiabai et al., 2009; Piña et al., 2008; Reyes and Mates, 2004), but only a few were developed in Italy (Gatto et al., 2009; Goio et al., 2008; Scolozzi et al., 2012) or other Mediterranean areas (Merlo and Croitoru, 2005).

In this paper, we focused on relatively small river basins on the eastern side of the Apennine Mountains in Italy. Precisely, we estimated the value of ecosystem services, such as water retention, drinking water supply, soil protection and carbon sequestration, and compared indirect to direct use values (e.g., timber, firewood, etc.). We then identified the associated local beneficiaries and quantified the related demand. The general objective was to understand whether and how much the coastal areas depended on the upstream ecosystem to understand the spatial mismatch between source areas and beneficiaries of ecosystem services. Water retention is particularly relevant in Mediterranean regions because of the significant temporal difference between the recharging ground water period (spring, autumn) and maximum water consumption level in the summer used for drinking water by tourists and in agriculture. Simultaneously, runoff and associated soil erosion, particularly along the Apennine range, frequently damages residential areas and agriculture in regard to solid transport accumulation at the bottom of the basin catchment (Nittrouer et al., 2004). We also considered CO_2 sequestration because, although this service benefits the global community and demand was not spatially variable (Luck et al., 2012), we sketched the current balance within the river basin between emissions by local communities and sequestration by local forest ecosystems.

2. Materials and methods

Four ecosystem services provided by the forests (Table 1) in the selected river basins were valued using economic techniques, such as indirect market pricing, avoided cost (Kremen et al., 2000; Merlo and Croitoru, 2005) and replacement cost (Brauer and Marggraf, 2004; Gunatilake and Vieth, 2000; Ming et al., 2007), as suggested by de Groot et al. (2002) and Farber et al. (2006) for regulating ecosystem service.

The economic values were calculated for three areas within each river basin according to the National Institute for Statistics (ISTAT, 1958): coastal hill or plain (0–300 m) as a Low region (L); inland hill (300–600 m) as a Medium region (M); Inland mountain (>600 m) as a High region (H) (Fig. 1). The objective of this breakdown was to study the supply and demand distribution of ecosystem services in different areas of the river basins.

Because economic data are available at a municipality level, the basin sections were drawn according to municipality territories included in each elevation zone. Further methodological details are specified below following the description of the study area.

2.1. The study area and current problems

The study area is located in the northern region of the Apennine Mountains in Italy and included the Foglia River Basin situated in the northern Marche Region and the Marecchia River Basin in the southern Emilia Romagna Region (Fig. 1). These river basins are representative of many others reaching the Adriatic Sea in terms of geo-morphology and socio-economic dynamics.

The two rivers have a torrential regime with drought periods in summer and two precipitation peaks in spring and autumn. The Foglia River is 90 km long, and its basin is 700 km^2, of which 28% is forested (20,542 ha) with 22 small municipalities and 204,800 inhabitants (ISTAT, 2001). The Marecchia River is 70 km long, and the basin is approximately 610 km^2, of which 33% is forested (18,697 ha) with approximately 200,000 inhabitants (ISTAT, 2001) and 12 municipalities.

Forests are common in the High regions and characterised by xerofile mesic deciduous forests. In the middle section of the river basins, the landscape is more heterogeneous and is characterised by a combination of agricultural areas, natural and semi-natural grasslands and patches of European hop hornbeam woodlands (*Ostrya carpinifolia*) or (*Salix* spp.) gallery forest along the rivers. The lower section of both basins is characterised by settlements and intensive cropland. The remnant forest areas in this section are mainly located along the rivers. The relatively high concentration of settlements, roads and industrial and zoo-technical activities with 48 sewage treatment systems (urban and industrial), two landfills and eight quarries cause qualitative degradation of underground and runoff water.

In the middle and lower regions, particularly close to the coast, there are irrigation, drinking and industry demands and water quality problems (namely, pollution by nitrates and eutrophication).