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Mapping ecosystem services: an integrated biophysical and economic evaluation

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Contents

Abstract

Forests provide a wide range of ecosystem services, from timber and non-wood products (provisioning services) to carbon sequestration, hydrogeological protection (regulating services), and recreation and aesthetic experiences (cultural services). Non-marketed forest ecosystem services tend to be undervalued due to the lack of a market price and a clear understanding of their vital support to socio-economic systems. Ecosystem services are interlinked, and therefore the optimization of one typology of services can affect negatively other services. Consequently, forest management choices include trade-offs. This study focused on the supply and spatial distribution of ecosystem services in a forest area in the Italian Alps. The ecosystem services were evaluated both in biophysical and economic units. Spatial data on land cover and forest biomass growth and harvest rates together with data from field interviews were used. GIS was used to spatially analyze and visualize the distribution and provision of ecosystem services. The total supply and economic value of the forest ecosystem services was calculated and mapped. Provisioning services accounted for one third of the total economic value while regulating services resulted in almost 60% of the total. These were concentrated in areas of high risk of avalanches and landslides. The outcomes of this study highlight the need for integrating biophysical and economic evaluation, especially to assess and value regulating ecosystem services to better recognize both their importance and spatial distribution. Mapping ecosystem services serves as an important tool to identify priority areas and to better communicate and visualize information on ecosystem services.

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Tiina Häyhä

About the Author

Tiina Häyhä achieved the title of International PhD in Environment, Resources and Sustainable Development with a label of Doctor Europaeus from Parthenope University of Naples, Italy in 2014. In 2010 she received a Master's degree in Economics from University of Jyväskylä, Finland. Her main scientific interest includes ecosystem services assessment and valuation, environmental accounting, and Ecological Economics.

Mapping ecosystem services: an integrated biophysical and economic evaluation

Tiina Häyhä

Introduction

Connecting biophysical aspects of ecosystems and human well-being through the notions of natural capital and ecosystem services has been an essential step to recognize the societal dependence on natural ecosystems (Daily, 1997). The idea of the usefulness of nature's functions and services started to appear in the scientific literature from the late 1960s (Helliwell, 1969; Odum, 1971; Westman, 1977; Ehrlich and Ehrlich, 1981; de Groot, 1987). Costanza and Daly (1992) used a functional definition of capital to define the concept of "natural capital" focusing on the relationship between stocks and flows. The stocks of natural capital generate valuable flows of ecosystem good and services. Costanza et al. (1997) defined ecosystem services as "the benefits human population derives, directly or indirectly, from ecosystem functions". Boyd and Banzhaf (2007) provided an alternative definition stating that ecosystem services are the ecological component directly consumed or enjoyed to produce human well-being. Fisher et al. (2009) discussed several possible definitions of ecosystem services, proposing that ecosystem services derive from ecological functions and are directly or indirectly utilized to produce human well-being.

The Millennium Ecosystem Assessment showed that two thirds of our planet's ecosystem services are in decline or threatened, and the degradation of ecosystem services often causes substantial harm to human well-being (MA, 2005). The principle of strong sustainability suggest that natural capital can rarely be replaced by man-made capital, emphasizing the need for preserving ecosystem structure and function to ensure a continuous flow of life supporting ecosystem services (Ekins et al., 2003; van den Bergh, 2010; Farley, 2012).

To account for the benefits provided by ecosystems, several assessment and valuation methods have been developed to estimate the value of nature and its services (Costanza et al., 1997; Farber et al., 2002; Jørgensen, 2010; Ulgiati et al., 2011; Burkhard et al., 2012). Monetary valuation of ecosystem services has been proposed as an important tool to raise awareness and communicate the importance of ecosystems and biodiversity to policy makers (Balmford et al., 2002; Costanza et al., 1997; de Groot et al., 2012; TEEB, 2010). Decisions in resource management are mostly affected by ecosystem services for which it is possible to define a market price, while non-marketed ecosystem services are frequently disregarded with possible negative consequences on their integrity.

Ecosystems are complex, adaptive systems characterized by non-linearity. When reaching a certain threshold, ecosystems can switch into a new equilibrium state, possibly leading to a loss of life sustaining benefits (Holling, 1973; Folke, 2006; Burkhard et al., 2011). Crossing a threshold can lead to the irreversible loss of critical natural capital after which the ecosystem does not provide ecosystem goods and services. For instance, removing too much forest cover can lead to severe soil erosion driving the forest ecosystem to deforestation. In the vicinity of thresholds, a small decrease in the physical quantity of ecosystem services can cause a large increase in the marginal economic value, making monetary analysis of ecosystem services inappropriate (Farley, 2012; Limburg et al., 2002). According to Farley (2008), monetary valuation could be used to help allocation decisions between conservation and conversion when the stocks of critical natural capital or ecosystem services are healthy and resilient. Instead, when reaching ecological thresholds, the biophysical quantities and quality of ecosystem structure become more relevant information. Spangenberg and Settele (2010) provided a detailed discussion on pros and cons of applying economic valuation for ecosystem services assessment.

Forests provide a wide range of ecosystem services, from timber and non-wood products to carbon sequestration, watershed protection, and recreation (de Groot et al., 2002; MA, 2005). Forests in mountain areas are especially important for the protection of human activities against natural hazards such as avalanches, rock falls, and landslide erosion (Dorren et al., 2004). Concerns about greenhouse gas emissions, future shortage and rising prices of fossil fuels and natural resources are leading to a growing interest for wood biomass as renewable material and energy source (Buonocore et al., 2012, 2014). On the other hand, forests are intended to play an important role as carbon storage while also meeting the needs of biodiversity conservation and ecotourism. Since ecosystem services are interlinked, the optimization of one typology of services can affect negatively other services (Bennett et al., 2009), and therefore all forest management choices include trade-offs.

Former studies on forest ecosystem functions and services focused on a single or few services: timber production and carbon sequestration (Seidl et al., 2007; Böttcher et al., 2008; Canadell and Raupach, 2008; Cherubini et al., 2011), outdoor recreation (Zandersen and Tol, 2009), and protection against natural hazards (Teich and Bebi, 2009; Olschewski et al., 2012). Other authors studied forest ecosystems by considered multiple services (Grêt-Regamey et al., 2008, and in press; Grêt-Regamey and Kytzia, 2007; Hoffrén, 1997; Matero and Saastamoinen, 2007; Croitoru, 2007; Merlo and Croitoru, 2005; Pearce, 2001; Olschewski et al., 2010; Vihervaara et al., 2010). With specific reference to the Alpine context of North Italy, Gios et al. (2006) estimated the benefits of natural resources focusing on tourism while Goio et al. (2008) compared standard accounting, green accounting, and total economic value to evaluate the benefits produced by forests in the Province of Trento. In the same area, Notaro and Paletto (2012) performed an economic valuation of the protective function of forest against natural hazards.

Mainstreaming ecosystem services into policy and decision making depends on the availability of spatially explicit information describing ecosystems and the flow of their services (Maes et al., 2012). There are different approaches for mapping ecosystem services. Some approaches use biophysical measures (Vihervaara et al., 2010; Burkhard et al., 2012), while others generate maps of monetary values (Costanza et al., 1997; La Notte et al., 2012; Kubiszewski et al., 2013).

In this study, biophysical assessment and economic valuation were integrated to investigate multiple forest ecosystem services in Fiemme and Fassa Valleys (Province of Trento, North Italy). The research questions to address were: What is the supply and spatial distribution of ecosystem services in the study area, and what is the value of those ecosystem services? To address these questions, the ecosystem services were evaluated and mapped first in biophysical units and then in economic terms. Moreover, the Total Economic Value (TEV) of the investigated ecosystem services was calculated and mapped.

Material and Methods

The study area: Fiemme and Fassa Valleys

Fiemme and Fassa are two valleys forming the municipality of Cavalese located in the Autonomous Province of Trento, North Italy (Fig. 1). The total area of Fiemme and Fassa Valleys is 73,600 ha of which 39,970 ha are covered by forests (54% of the total surface), indicating the importance of forest ecosystem in the study area. The main forest types are: Norway spruce (*Picea abies* L.) with 80% of the total area, larch (*Larix europea* Mill.) with 10%, and Scots pine (*Pinus sylvestris* L.) and beech (*Fagus sylvatica* L.) accounting for 10% of the total area. The whole area is located in a mountainous region with an altitude ranging from 1,000 to 2,600 meters. The climate is characterized by cold, dry winters and cool, rainy summers. The snow period in the valleys lasts from November to March while the higher altitudes are affected by snow until May. The mean annual temperature is around 5°C with a mean annual precipitation of 1,108 mm (Marchetti and Panizza, 2001).

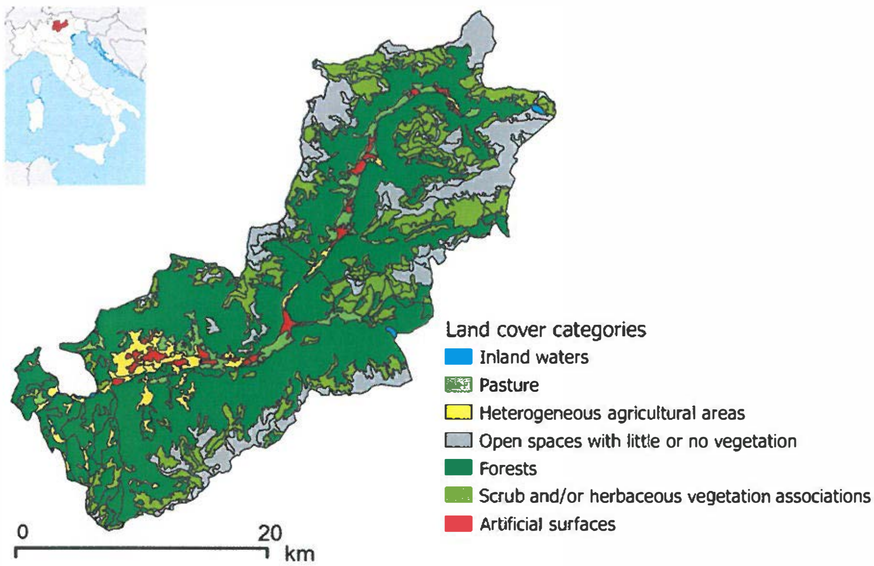

Fig. 1. Land cover map of Fiemme and Fassa Valleys, Province of Trento, North Italy. Data source: Corine Land Cover 2006.

Fiemme and Fassa Valleys are renowned for high quality timber productions, among which the valuable wood for the manufacture of the famous Stradivarius violins. All forestry activities in the study area take place according to 10-year forest management plans ensuring the sustainable exploitation of forests. The local forest management is based on the "close-to-nature" forestry approach that suggests selective cutting practices allowing the remaining forest to naturally regenerate over time (Carbone and Savelli, 2009). The forest area is divided into production and protection areas according to the characteristics of the landscape (i.e., steepness and risk of natural hazards) so that in the protection areas the rate of cutting ranges from 0% to 10% while in production areas it reaches about 65% of the annual increment. Of the total forest cover, 76% belongs to production and 24% to protection areas.

Timber production generates wood residues that are partially (around 50%) chipped and burned, together with wood residues from local sawmills, in local power plants to produce heat and electricity (Valente et al., 2011; Buonocore et al., 2014). The demand for wood biomass to supply local energy production is growing in the area (Zambelli et al., 2012). Wood biomass is also extensively used as firewood for heating private houses.

Another important economic sector in Fiemme and Fassa Valleys is tourism. The region attracts tourists especially for winter sports and summer trekking, with more than one million visitors per year to the region.

Data and calculation procedures

There are multiple definitions of the concept of ecosystem services (e.g., Costanza et al., 1997; Daily, 1997; MA, 2005; Boyd and Banzhaf, 2007; Fisher et al., 2009). They all agree on the general idea, but they also make some differences in the use of terms ecosystem process, ecosystem structure, ecosystem function, ecosystem service, and ecosystem benefit (Lamarque et al., 2011; Crossman et al., 2013). According to de Groot et al. (2010), the structure and processes of ecosystems are necessary to underpin ecosystem functions that have the capacity or potential to provide services. In this view, ecosystem services are the actual flows of services providing benefits to humans that can be valued in economic terms. The biophysical indicators used to assess the actual provision of different ecosystem services, as well as the economic indicators adopted for their monetary valuation, are shown in Table 1.

Table 1. Investigated ecosystem services and related biophysical and economic indicators.

Ecosystem service	Biophysical indicator	Economic indicator
Provisioning services		
Timber	Volume of harvest	Market value of timber
Wood fuel	Amount of wood fuel for bioenergy	Market value of wood chips
Firewood	Amount of firewood for heating private houses	Market value of firewood
Game	Number of hunted animals	Market value of meat
Mushrooms	Amount of mushroom harvest	Market value of mushrooms
Berries	Amount of berries harvest	Market value of berries
Regulating services		
Carbon sequestration	Amount of carbon sequestered above ground	Carbon emission permit price
Hydrogeological protection	Area (ha) protecting against natural hazards	Cost of bioengineering technologies
Water cycling	Water consumption	Market value of domestic water
Cultural services		
Recreation: Tourism	Number of tourists	Willingness to pay (WTP) of tourists
Recreation: Hunting	Number of hunters	Hunting cost (permit, license, insurance)
Recreation: Mushroom picking	Number of permits for mushroom picking	Cost of mushroom permits

Primary and secondary data on the biophysical indicators and their spatial distribution were collected from Autonomous Province of Trento, field interviews, and scientific publications, and then further processed. Geographical data on land cover together with forest biomass growth and harvest rates were used. Market price method was used to assign a monetary value to wood and non-wood forest products. For the economic value of timber, an average market price of 95 €/m^3 in Fiemme and 98 €/m^3 (PAT, 2011) in Fassa Valley was used. The current consumption of fresh water was estimated based on the average water consumption in Italy of 175 L person^{-1} day^{-1}(Istat, 2012). The market price of domestic water in the Province of Trento of 1.20 €/m^3 was used to calculate the monetary value of water. Carbon sequestration (kg of CO_2) was estimated using the following formula:

$$increase\ in\ wood\ biomass\ (m^3) * wood\ density\ \left({}^{kg}/_{m^3}\right) * \%\ dry\ mass * \%\ carbon * 3.67 * 120\%$$

where 3.67 is the conversion factor from C to CO_2 and 120% accounts for the roots. The emission permits regulated by the European Union Emissions Trading Scheme were used to estimate the economic value of carbon sequestration. An average price of 15 €/t CO_2 was used (World Bank, 2010).

Landscape stabilization is one of the main functions of forests in mountainous regions (Brang et al., 2006). In this study, the ecosystem service of hydrogeological protection included both direct and indirect protection against natural hazards. A forest provides direct protection for infrastructures and human activities, and indirect protection in terms of watershed protection and soil conservation. GIS data and thematic layers were used to estimate the hectares for each typology of hydrogeological risk: primary and secondary risk of avalanches and landslides. The replacement cost method was applied to estimate the monetary value of hydrogeological protection. Four different bioengineering technologies were identified and their production costs were calculated, assuming that these technologies would provide a substitute for hydrogeological protection required in the risk areas if the forest did not exist. The most cost efficient technologies were chosen: simple palisade and cutting terraces for primary and secondary risk of landslides and snow fences and snow stands for primary and secondary risk of avalanches.

The prices of hunting permits, license and insurance were used to estimate the minimum level of willingness-to-pay for hunting activities. The cost of permits for mushroom picking, required to people coming from outside Fiemme and Fassa Valleys, was used as an estimation of the recreational value for this activity. As mushroom picking is free of charge for the local population, local inhabitants were not considered in this valuation. The landscape and recreational value of the forests related to tourism was estimated by updating the outcomes of a former contingent valuation of the recreational and aesthetic value in the study area by Notaro et al. (2008).

Economic valuation methods

To allow the comparison of the benefits of various goods and services, the Total Economic Value (TEV) approach (Pearce, 1993) was used to encompass all components of utility derived from ecosystem services using money as a common unit of measurement. Demand curves for ecosystem services are difficult to estimate. When assuming that ecosystem services cannot be increased or decreased to a large extent by human actions, their supply curve is almost vertical (Costanza et al., 1997). In this case, a conservative estimate of the economic value of an ecosystem service can be defined as

$$EV = s_i p_i,$$

where s_i is the supply and p_i the price or shadow price of an ecosystem service i. Consequently, the total economic value (TEV) of ecosystem services can be calculated as

$$TEV = \sum_{i=1}^{n} s_i p_i$$

where n is the total number of services considered in the study. The methods used for economic valuation of ecosystem services were market price, replacement cost, and benefits transfer (using contingent valuation) method. When ecosystem services are tradable commodities they have a market price that can be used to indicate their value, assuming that the market is well-functioning. Typically, the provisioning services (e.g., food and timber) are proper market commodities and thus market price information can be used to calculate their values. However, for non-commodity ecosystem services, such as the regulating services, there are no individually observed market prices, so that non-market valuation methods are needed. These non-market valuation methods can produce a shadow price, which represents, in monetary units, the marginal contribution that an increase of a specific good or service can make to the satisfaction of human preferences (Howarth and Farber, 2002). In the case of ecosystem services, the shadow price is the net benefit that an additional unit of an ecosystem service will contribute to human well-being (Dasgupta, 2008; Dasgupta and Duraiappah, 2012).

Some common non-market valuation methods include replacement cost method that is based on the principle that the value of an ecosystem service can be estimated based on the cost of replacing that service with an artificial substitute (Dixon et al., 1997). This method is most appropriate in cases where the cost of replacement will be or has already been paid. When applying replacement cost method the following conditions should be met: 1) the human-made system provides the same functions as the original ecosystem (i.e., it is a close substitute for the replaced service); 2) the engineered system is the least costly alternative for the service; and 3) there is a public demand for this alternative, meaning that people would be willing to pay the costs instead of losing the service (Notaro and Paletto, 2012).

The benefit transfer method can be used to value ecosystem services by adapting an estimate of benefits from studies already completed in another location with similar characteristics (Richardson et al., in press). In this study, the benefit transfer method was applied to value the cultural service of tourism by transferring information from a previous study using a contingent valuation approach (Notaro et al., 2008).Contingent valuation is based on surveys where people are asked how much they would be willing to pay (WTP) for specific environmental services. It is a stated preference method because people are asked to directly state their values instead of deducing values from actual choices, as it is the case when using revealed preference methods (Bateman and Willis, 1995). The fact that contingent valuation is based on what people declare they would pay instead of what people are observed to pay induces both strength and weaknesses. One of the strengths is that this method is capable of estimating in monetary terms non-use values of ecosystem services that do not involve market purchases or direct participation. However, a weakness is that, especially in the case of regulating and supporting services, the general public is not familiar enough with ecosystem functions and services and, moreover, the complexity of the issue makes the survey description very difficult (Nunes and van den Bergh, 2001). In addition, if people have not had to pay for the services in the past, they could be also unwilling to understand the need to pay for them now or they might want to act as free-riders hoping that others would pay for the services.

Results

Table 2 summarizes the biophysical flows, the average economic values per hectare, and the total monetary values calculated for different forest ecosystem services in Fiemme and Fassa Valleys. The economic value of provisioning services accounted for about 10,063,000 € yr^{-1} of which 86% was due to timber. The economic value of regulating and cultural services accounted for around 19,136,000 € yr^{-1} and 3,569,000 € yr^{-1}. The TEV, calculated as the addition of all investigated ecosystem services, resulted in 32,768,000 € yr^{-1} (Table 2). The provisioning services represented 31% of the TEV, while the regulating and cultural services were 58% and 11% of the TEV. The service of hydrogeological protection showed a major relative importance both among the regulating services (68%) and in the TEV (40%).

Table 2. Total biophysical amounts, average economic values per hectare, and total economic values of ecosystem services in Fiemme and Fassa Valleys.

Ecosystem service	Biophysical value	Unit	Shadow price/unit	Economic value* (€/ha/yr)	Economic value (€/yr)
Provisioning services					
Timber	89,500	m^3	97	218	8,693,135
Wood chips	7,326	m^3	21	4	153,855
Firewood	15,176	m^3	24	9	364,234
Game	1,429	head	148	5	211,660
Mushrooms	39,645	kg	14	14	557,233
Berries	14,197	kg	6	2	83,156
Regulating services					
Fresh water	2,511,394	m^3	1	75	2,999,615
Carbon sequestration	201,350	t CO_2	15	76	3,020,246
Hydrogeological protection	6,946	ha	1,888	328	13,116,047
Cultural services					
Recreation: tourists	1,094,866	person	3	77	3,090,281
Recreation: hunting	498	person	774	10	385,425
Rereation: mushrooming	-	permit	-	6	227,423
Total Economic Value (TEV)					32,902,310

* Average value calculated considering the whole forest area in Fiemme and Fassa Valleys.

In Figures 2–5, the results of the spatial distribution of timber, carbon sequestration, hydrogeological protection, and recreation and aesthetic experiences are shown both in biophysical and economic units. Figure 6 shows the spatially explicit map of the total economic value of the bundle of ecosystem services.

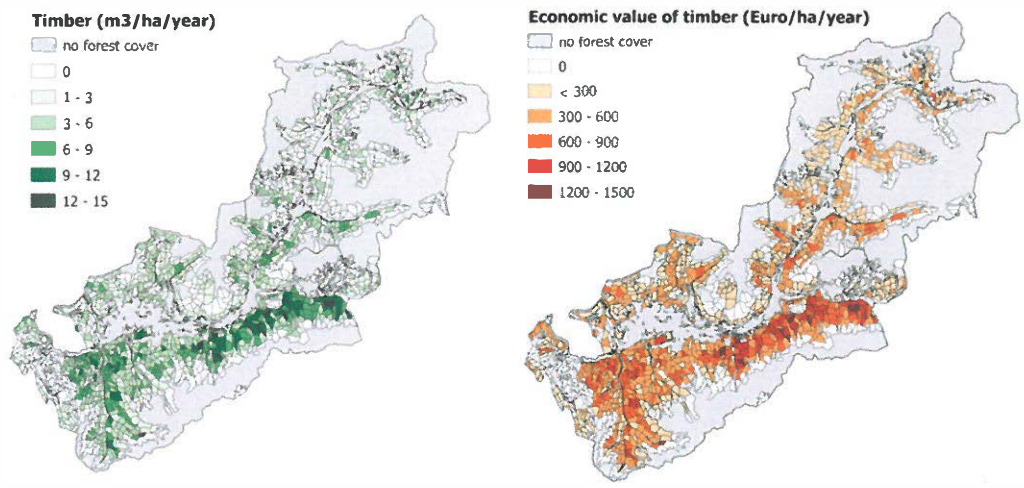

Fig. 2. Biophysical and economic value of timber.

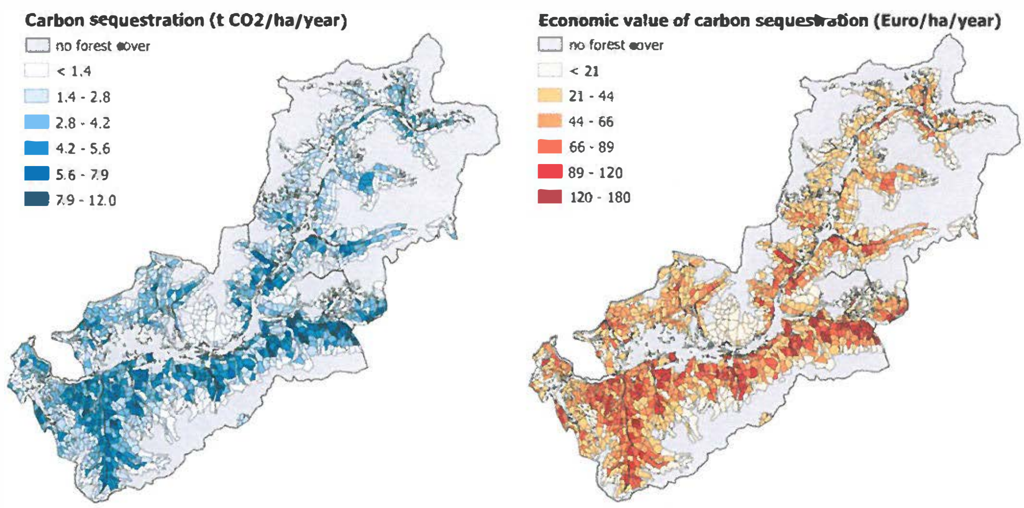

Fig 3. Biophysical and economic value of carbon sequestration.

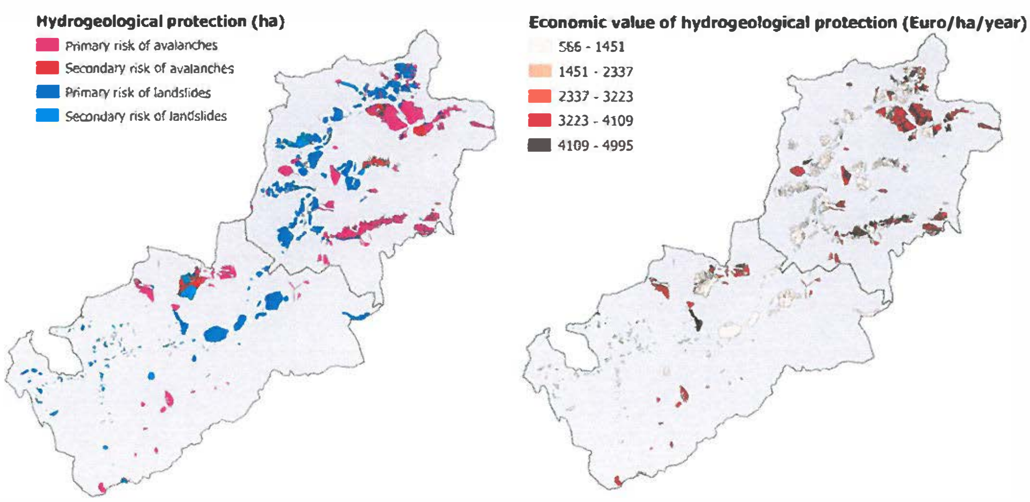

Fig. 4. Biophysical and economic value of hydrogeological protection.

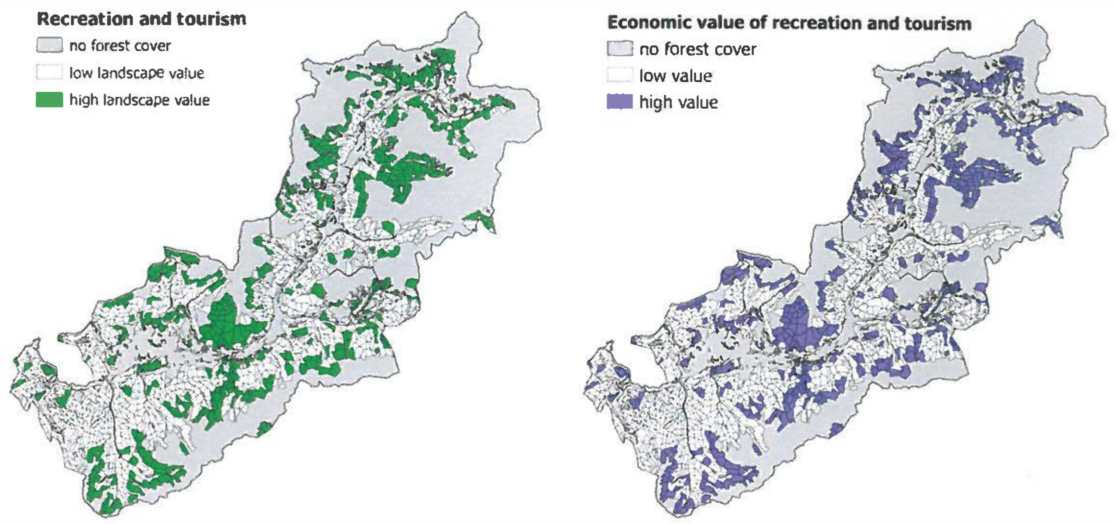

Fig. 5. Biophysical and economic value of recreation and aesthetic experiences related to tourism.

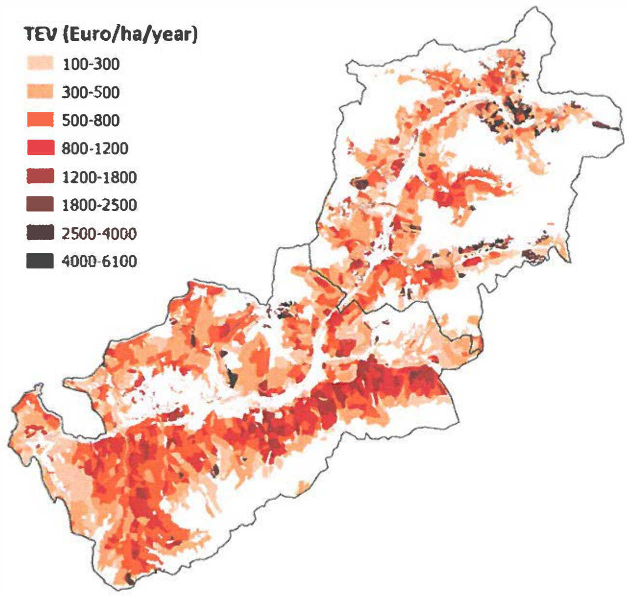

Fig. 6. Total Economic Value (TEV) of the investigated forest ecosystem services in Fiemme and Fassa Valleys

Discussion

In this work, the provision, spatial distribution, and value of forest ecosystem services were explored. The assessment performed to the forest ecosystem in the Alpine region of Fiemme and Fassa Valleys showed that the forests provide multiple valuable ecosystem services in the area (Table 2). As visualized in Figures 2–6, the investigated ecosystem services were not equally distributed as there were forest areas that provided different services with different levels of supply. For timber and carbon sequestration, the most important areas were located in Fiemme Valley, on the left side of the maps (Fig. 2 and 3). Instead, hydrogeological protection played a more crucial role in Fassa

Valley, on the right side of the map (Fig. 4). Aesthetic and recreational areas were found in both valleys (Fig 5). By producing spatially distributed estimates of ecosystem services based on a specific data collection of local biophysical and economic variables, instead of using only average values or benefit transfer, it is possible to better support local decision making involving forest planning and management.

Besides timber, the regulating ecosystem services, especially hydrogeological protection against natural hazards played a crucial role in the study area. Although timber production is often valued above other forest services, in the Alpine regions, the control of water courses and soil conservation has a primary role over wood production (Dorren et al., 2004; Brang et al., 2006; Notaro et al., 2008). Also, in this study, the hydrogeological protection was substantial. In fact, regulating services accounted almost 60% of the total economic value, and these were concentrated in areas of high risk of avalanches and landslides (Table 2, Fig. 4).

The value of hydrogeological protection was estimated using the replacement cost method. It can be argued that replacement cost is not a strict measure of economic value since it is not based on people's willingness to pay for the service. However, in the case of protection function, it is reasonable to assume that there would be a demand for the service, unless people would move, in case the forest cover was removed (Notaro and Paletto, 2012). Therefore, people would be willing to pay the most cost effective technological solution that could perform the same service, i.e., to directly protect infrastructures and human activities and indirectly protect soil and watersheds against natural hazards.

The contribution of the investigated ecosystem services to the money economy, i.e., the amount of money that actually passed through markets, was about 12,500,000 € yr^{-1} of which timber accounted for 70%, while the total economic value of the investigated forest ecosystem services was around 32,900,000 € yr^{-1} (Table 2) when considering also the services that are not currently marketed. These results mean that almost two thirds of the economic value was not visible to the markets. Markets determine economic decisions, and consequently, affect the use of natural resources. Market failures associated with ecosystem services that are often free public goods, can lead to greater conversion of ecosystems than is economically justified. In fact, at the global level, multi-functional forest landscapes are often being converted into mono-functional systems, like forest plantations or croplands maximizing only one service, thus providing short term economic benefits to some stakeholders at the expense of long-term well-being of many (de Groot et al., 2010).This confirms that it is important to explicitly account for and value all the ecosystem services, especially those without markets to facilitate well-balanced long term sustainable management of forest resources.

In the map of the total economic value (Fig. 6), the areas with higher values are characterized mainly by either high level of timber harvest and carbon sequestration (Fiemme Valley) or hydrogeological protection (Fassa Valley). Maximizing the total economic value of multiple ecosystem services has been proposed as one of the approaches to look for the optimal mix of ecosystem services in land use planning and management. TEV can be used as one of the indicators to identify areas with high ecosystem service value. Still, as an aggregated indicator, it does not consider what are the ecosystem services behind the value and who are the stakeholders receiving the benefits from ecosystems. Different stakeholders and stakeholders at different spatial scales can have diverse interests in ecosystem services (Hein et al., 2006). For example, increased timber production could increase the income of forest owners and companies and create some labor opportunities but could decrease the landscape and recreational benefits for local people and tourists. Similarly, at the scale of a watershed, upstream forest users influence downstream water supply and forest degradation might lead to increased risk of flood risk. Furthermore, for global stakeholders the service of carbon sequestration and storage might be valuable for climate regulation.

As noted before, 60% of the total surface in Fiemme and Fassa Valleys has a forest cover, and therefore forests area an important part of the natural capital in the area. Increasing demand for wood as renewable material and energy source can pose future challenges to the sustainable management of forests. In addition to the traditional wood production, forests should also provide increased amount of renewable energy, carbon storage and recreational possibilities.

Maximizing all ecosystem services simultaneously is often not possible but rather increasing one service leads in many cases to the decrease of another one. There can be also synergies among some services, for example among the regulating ones (Bennett et al., 2009). Based on the generated maps of ecosystem services (Figures 2–5) and a generalized functional relationship between different ecosystem services by Braat and ten Brink (2008) in Fig. 7, some possible trade-offs and synergies were reasoned. There are services that did not occur together at large extend, e.g., timber and hydrogeological protection, or timber and recreation and aesthetic experiences, and some that occur together, e.g., timber and wood chips provision. Understanding these trade-offs is important for policy when deciding among different forest management options.

The close-to-nature forest resource management, currently practiced in the study area, which uses mainly selective cutting, enables forests to keep their multi-functionality and provide a balanced combination of provisioning services (timber, bioenergy), regulating services (carbon sequestration, hydrogeological protection), and cultural services (recreation). The actual timber and bioenergy production could still be increased, in the sustainable harvest limits, because the annual felling is around 60% of the annual wood increment. Still, increased exploitation of forest in terms of timber and bioenergy could translate into lower level of several ecosystem services because of direct effects on land use and land-use change (Kraxner et al., 2013). Even if wood biomass was used in the limits of the annual increment, especially increased use of forest biomass for energy production, including the roots, can threat biodiversity and nutrient cycling of forest ecosystems (Pyörälä et al., 2012). On the other hand, increasing utilization of wood chips could reduce the use of fossil fuels in the local power plants and thus improve the environmental performance of energy production in the area (Buonocore et al., 2012, 2014; Häyhä et al., 2011). Further research should be carried out to quantitatively assess trade-offs among different ecosystem services, especially provisioning versus regulating and cultural services, within the forest ecosystem under alternate forest management regimes. To better analyze the trade-offs, dynamic ecosystem models or models of ecological production functions would be required (Daily et al., 2009).

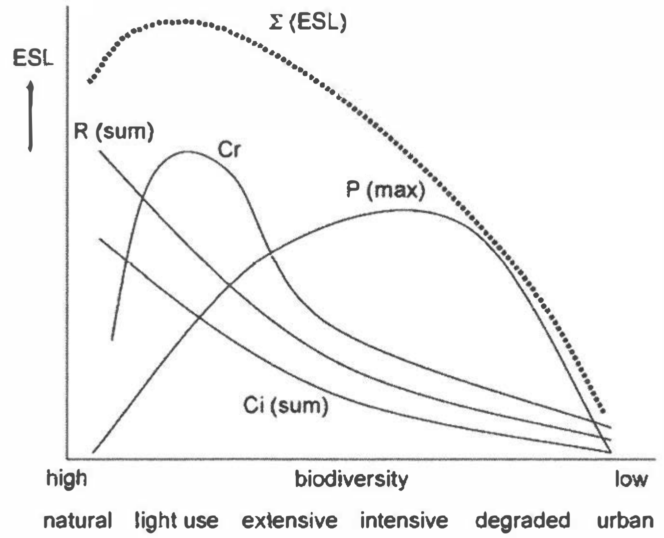

Fig. 7. Braat and ten Brink (2008) described the generalized functional relationships between the level of ecosystem services (ESL) related to different land use intensities. R – regulating, P – provisioning, Cr – cultural-recreational, and Ci – cultural-information services.

As highlighted by several authors, there is a urgent need for standardizing the ecosystem services assessment approach and framework in order to overcome some inconsistencies in definitions of services and method for assessing and mapping them (Maes et al., 2012; Seppelt et al., 2012; Edens and Hein, 2013; Crossman et al., 2013). Moreover, to gain a broad, interdisciplinary understanding of the system's features, it would be important to combine biophysical and economic evaluation approaches, starting from biophysical metrics to derive economic estimates of ecosystem service values.

Ecosystem functions and services have value because they are essential for our existence and to satisfy our material, cultural, and emotional needs (Daily, 1997). Although valuing nature is essential to mainstreaming conservation, it is not a goal in itself (Daily et al., 2009). Giving monetary value to nature does not mean that the values would be exchange values that could be considered substitutes to other type of capital (Kubiszewski et al., 2013). Rather, ecosystem service valuation is an essential instrument to underline the importance of healthy ecosystems for human well-being. Instead of contrasting conservation and economic activity of ecosystems, the ecosystem service approach aims at showing the added value that ecosystem functions and services provide to society (Primmer and Furman, 2012). Due to common metrics, a comparison of the market and non-market services becomes possible. However, from the methodological point of view, the received monetary value can vary greatly according to the chosen method. When mapping monetary values, the accuracy of the underlying biophysical maps also affects the results (Maes et al., 2012).

According to Ruckelshaus et al. (2013) the ability to derive economic values from biophysical ecosystem service estimates has proven to increase discussion of the importance of nature's services among decision makers. Nevertheless, they also found that decision makers do not always wish to have monetary estimated of natural capital and ecosystem services. In many cases, biophysical assessment of ecosystem services can be sufficient. Biophysical assessment in services' natural units can provide a solid accounting base. Still, data availability of the biophysical flows and relations between services and incompatible units can cause problems in the assessment.

Finally, ecosystem service assessments can support environmental resources management to protect and maintain overall ecological functioning. In particular, mapping ecosystem services serves as an important tool to identify priority areas and trade-off among different ecosystem services and to better communicate and visualize information on them. This can help include ecosystem services in policies of nature conservation, natural resources management, and urban planning. According to Maes et al. (2012), quantitative spatial data on the supply and demand for ecosystem services could also provide information for policy impact assessment to assess future gains or losses and support the development of financial instruments to finance investments in ecosystems.

Primmer and Furman (2012) stressed that the segregated administration of ecosystems (e.g., nature conservation, commercially exploited ecosystems, land use changes) poses challenges to the integration of different maps for spatial forest planning and management. They also argued that in many cases measuring and valuing ecosystem services have not directly led to increased use of this knowledge, and therefore applying ecosystem service values in concrete decision-making situations requires further attention. In this study, the benefits of forest ecosystem services were evaluated and their spatial distribution was assessed at local scale, based on local forest management units and related management plans, that is relevant for policy making. Further investigations should explore how ecosystem service assessment is perceived and applied by the local policymakers and forest managers in Fiemme and Fassa Valleys.

Conclusion

This study showed that forests in Alpine areas provide humans with a wide range of ecosystem services. Utilizing GIS allowed estimating the biophysical and economic values of forest ecosystem services both in the regional level but also in specific locations, thus enabling identification of the most important areas and possible trade-off and synergies among services. A major part of the benefits that the forests provide do not have direct markets but they are rather public goods. Therefore, their valuation is relevant to assist long-term decision on sustainable forest management. Finally, biophysical and economic assessments can complement each other to provide a more broad and comprehensive evaluation on both ecological and socio-economic dimensions of ecosystems and their services.

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