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REVIEW ARTICLE

Ecosystem services from mountain forest ecosystems: conceptual framework, approach and challenges

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Abstract
Mountain ecosystems play an essential role in sustainable mountain development, providing benefits and values to humanity not only for the rich biodiversity they contain, but also because of their important role in climate regulation, water cycle, provisioning of recreation, tourism, cultural or spiritual values. The high biodiversity of the mountain areas allow the provision of a wide range of ecosystem services. However, different impacts to the environment threaten the delivery of these services and, consequently, the quality of life of people, both living in the mountains and outside the mountains. Recognizing, demonstrating and capturing the value of ecosystem services can play an important role in setting policy directions for ecosystem management and conservation and, thus, in increasing the provision of ecosystem services and their contributions to human well-being. Quantifying and mapping of these benefits can also help managers and decision makers to realize the importance of these sites for conservation and to allow the proper understandings of the impacts of mountain forest ecosystems on territorial development and welfare of local populations.

The paper aims to outline the relevance and applicability of the ecosystem services approach for the assessment of the condition of mountain ecosystems and the services, they provide, for better understanding by the scientific community and to support decision makers in sustainable management of mountain regions.

Keywords: mountain ecosystems, ecosystem services, assessment, mapping, management

Introduction

The loss, fragmentation and degradation of natural habitats are among the major reasons for biodiversity loss at a global level. Having in mind the increasing anthropogenic pressure on ecosystems, the concept of ecosystem services (ES) has dominated the debate on sustainable land-use management since the Millennium Ecosystem Assessment (MEA, 2005). The identification and classification of a wide range of ecosystem services is still under discussion, but a consensus has been reached on the list of services published in the MEA and further developed in the TEEB study and the CICES project (MEA, 2005; TEEB, 2010b; De Groot et al., 2012; Haines-Young, Potschin, 2013). Nowadays, the ecosystem services related literature has increased exponentially focusing on the implementation of ES approach into decision making and policy (Fisher et al., 2009; Gómez-Baggethun et al., 2010; Schubert et al., 2018). Additionally, the concept of ecosystem services is successfully integrated into current biodiversity policies, both globally and at the European level (CBD, 2010). In general, policies describe how ecosystems and biological diversity can be successfully integrated into the public and business decision-making process and how they can contribute to a better understanding of the links between biodiversity, ecosystem functions, ecosystem services, the benefits they provide and the related social and economic values and human well-being.

According to the European policy, mountain regions are defined as territories with more than 50% of the surface covered by topographic mountain areas (European Commission, 2011a). In most cases, these regions are remote and are characterised with harsh natural environments, such as cold climate, infertile lands and risks of natural disasters. A typical feature of rural mountain regions is also the population decline, caused mainly by the unequal opportunities and low quality public services or the inappropriate infrastructure. In spite of the diverse natural capital that represents the basis of their economy this capital remains undervalued and mountain regions are among the low- to mid-income regions (European Commission, 2014; EEA, 2010). The intense socio-ecological dynamics determine mountain regions as social-ecological systems, which represent dynamic and interconnected units. These units are composed of a particular set of resources and humans, as well as their users, institutions and their mutual interactions and numerous studies have provided evidence of the capacity of these socio-ecological systems and their human-nature interaction to efficiently use resources (Berkes, 1989; Berkes, Folke, 1998; Poteete et al., 2010).

Mountain ecosystems have an important role in conservation of biodiversity, water resources, regulation of global climate, soil erosion prevention, etc. They are known as “hot spots of biological diversity” at genetic, species and ecosystem levels, encompassing a high diversity of ecosystem types, which provide a wide range of ES and benefits to the society (Körner, Ohsawa, 2005). Mountain areas are recognized as ecosystems supplying a vast variety of provisioning, regulating and cultural ES at the European level and globally (Maes et al., 2011; Grêt-Regamey et al., 2012). Moreover, such areas are considered as significant "science labs", since mountain ecosystems are highly sensitive and vulnerable to climate change (Beniston, 2003; Löffler et al., 2011). Key Biodiversity Areas, protected areas and natural World Heritage sites in mountain regions provide special value to humanity not only for biodiversity richness, but also because they sequester and store carbon, purify water, provide recreation and tourism opportunities, contain cultural or spiritual values and deliver a range of other benefits.

In Bulgaria, mountainous areas have been a significant element of natural capital and cultural heritage of the society and are largely presented within the protected areas (PAs), regarded as important for maintaining species and habitat diversity, as well as protecting specific landscapes (Brooks et al., 2004; Coad et al., 2008; Butchart et al., 2010). In the recent years, PAs have been recognised as a successful management tool to achieve the long-term conservation of nature with its associated ecosystem services and cultural values' and able to effectively contribute to improving the quality of life of residents. They can play an important role in counterbalancing the impacts of ecosystem degradation, mitigating the loss of ecosystem services and are essential for the development of policy strategies and management at local, regional and global scale (Körner, 2003; Panayotov et al., 2011; Schickhoff et al., 2015; Švajda, 2008; Wieser, Tausz, 2007).

However, despite providing such an unprecedented number of different ES, mountains remain among the poorest documented ecosystems. The greater understanding and use of ES framework and the implementation of ES approach could help to provide a large-scale view of the unique 'multifunctionality' of mountains, on the one hand, while, on the other hand, the quantifying and mapping of the benefits provided by mountain ecosystems can help managers and decision makers to justify the importance of these sites for conservation, to attract new sources of funding and to manage the sites more effectively.

This review paper discusses the conceptual framework, relevance and applicability of the ecosystem services approach in mountain ecosystems, including the different definitions, classification and measurement methods. Then we discuss several tools for assessing the socio-cultural, economic and ecological values of mountain forest ecosystem services, in order to achieve the sustainable use of biodiversity and relevant ES and to support decision makers to identify the sustainable management of these services.

Ecosystem services – concept, classifications, characteristics

The ecological systems play a fundamental role in determining people's economic performance and well-being by providing resources and services and by absorbing emissions and waste. They are considered the main form of capital (produc-

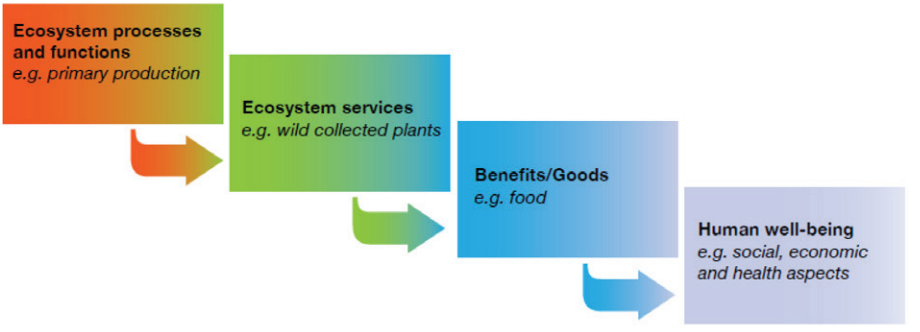

Figure 1. Conceptual framework of ecosystem services (Adapted from Haines-Young, Potschin, 2010)

tive, human, social and natural), ensuring the basic conditions for human existence. These conditions include fertile soils, multifunctional forests, productive land and seas, fresh water and clean air and include also services, such as pollination, climate regulation and protection from disasters (EU, 2013). ES are the result of ecosystem processes and functions, the main "flow" provided by natural capital, the benefits that nature provides to people, the contribution that ecosystems make to enhancing human well-being (Neugarten et al., 2018) (Figure 1).

Definition

The concept of ES was firstly described as "Environmental Services" in the report of the Study of Critical environmental Problems (SCEP, 1970), then introduced as "Nature's Services" (Westman, 1977). At the beginning of the 1980's, the term "Ecosystem Services" (ES) was firstly used by Ehrlich and Ehrlich (1981). The term ES became widely represented in scientific research in the 1990's and different methods were developed to assess the economic value of ES (Costanza et al., 1997). The original definition of ES indicated in the MEA, and namely "The benefits that people obtain from the nature" (MEA, 2005), has been continuously improved (Boyd, Banzhaf, 2007; Wallace, 2007; Fisher et al., 2009; TEEB, 2009) in order to increase the relevance of ES concept in the decision-making process.

As described in MEA (2005), the condition of an ecosystem is the result of its physical, chemical and biological state at a certain point in time, controlled by the natural state and anthropogenic pressure to which it is exposed and determines its effective capacity to provide services, which are closely related to its potential capacity. The interactions between biophysical structures, biodiversity and ecosystem processes strengthen ecosystems' capacity to provide ecosystem services representing the ecosystem functions (TEEB, 2010b).

Assessment of the ecosystem condition refers to the analysis of the physical, chemical and biological condition or quality of ecosystems at a particular point in time and under the impacts of major pressures (EEA, 2015). Different pressures can also be used as indicators of the assessment of the ecosystem condition in case that this condition cannot be quantified (Erhard et al., 2016; Burkhard et al., 2018). The basic pressures affecting the ecosystem condition include habitat change, pollution and nutrient enrichment, overexploitation, invasive alien species and climate change (Derneği, 2010; EEA, 2015). However, as a major pressure in all types of ecosystems is considered the habitat change, including loss, degradation and fragmentation (Maes et al., 2018).

The use of selected indicators, reflecting habitat quality, are usually used to interpret the ecological value and anthropogenic pressures of the examined sites (Drakou et al., 2011; Notte et al., 2012; Hossain et al., 2017). The most recent analytical framework for mapping and assessment of the ecosystem condition (Maes et al., 2018) proposes pressures indicators and conditions indicators (environmental quality – physical and chemical quality) and ecosystem attributes – biological quality). The assessment of biological quality usually includes biodiversity features: from genes, individuals and populations to species, habitats and ecosystems (Gaston et al., 2008). On the other hand, many initiatives also focus on biodiversity indicators, such as status of protected species, assessment of extinction risk of threatened species, habitat distribution and trends, abundance and distribution of populations of selected common species, etc. (McGarigal, McComb, 1995; Riitters et al., 1997; Rüdisser et al., 2012; Maes et al., 2014). Moreover, the data on species diversity and abundance, monitored under the EU Nature Directives, are also proposed by the MAES 5 Technical Report (Maes et al., 2018) as metrics to assess biological quality.

Ecosystem services represent the direct and indirect contributions of ecosystems to the society, including the provision of food and water, regulation of climate and water, support for habitats for wildlife and maintenance of cultural values (MEA, 2005; TEEB, 2010a). Moreover, they play a vital role in maintaining human well-being and, thus, the definition explicitly recognises the different values of mountain forest ecosystem services, including socio-cultural, economic and ecological values (Baral et al., 2017).

Classifications

Different classifications of ecosystem services has been widely debated in recent years (de Groot et al., 2002; MEA, 2005; Wallace, 2007; CICES, 2017; Liquete et al., 2013; Turner et al., 2014; Rhodes, 2015; Pascual et al., 2017), but none of them has been completely adopted. For instance, De Groot et al. (2002) attempted to classify the ES based on the ecosystem functions they delivered. A globally recognised scheme was introduced in MEA (2005) and was subsequently adopted in several studies and initiatives. According to this scheme, ES are classified on the basis of the

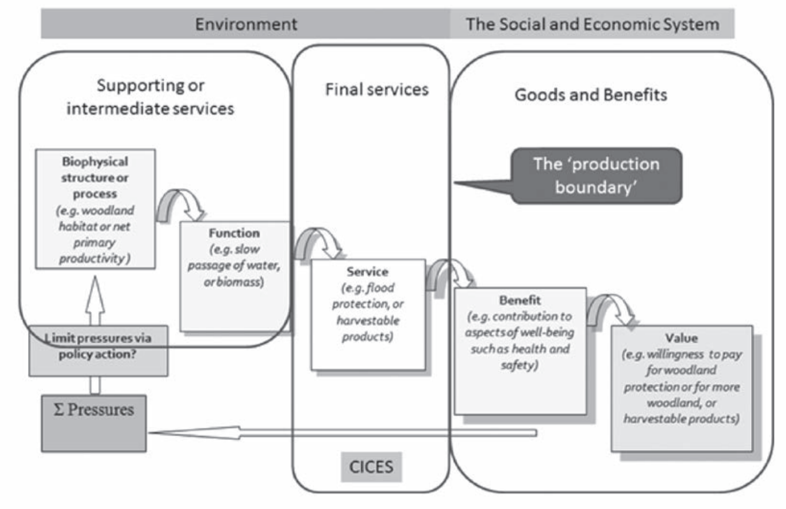

Figure 2. The cascade model (Potschin and Haines-Young, 2016)

type of benefits that humans can obtain from nature and the category "provisioning services" has been added, next to regulating, supporting and cultural.

TEEB proposes a typology of ecosystem services, based on the direct or indirect benefits that ecosystems provide to humans, in order to associate ES to the economic value. This classification divides ES in 4 main categories with provisioning, regulating, habitat and cultural & amenity services (Costanza et al., 1997; De Groot et al., 2002; MEA, 2005). Common International Classification of Ecosystem Services (CICES) classifies ES by ecosystem outputs that directly affect human well-being and, eventhough, it does not include the MEA "supporting services", it is completely accepted by scientists and policy makers (La Notte et al., 2017; Czúcz et al., 2018). In the IPBES classification system ES are defined as Nature's Contributions to People (NCP) (Pascual et al., 2017), but it largely resembles the CICES classification.

The Common International Classification of Ecosystem Services has been developed in order to support work on the so-called "environmental accounting" undertaken by the European Environment Agency (EEA). This classification is important, as there is a need to develop standardised methods for evaluating and comparing ecosystems and ecosystem services. CICES aims to classify the contributions that ecosystems make to human well-being, arising from living processes and the feedback from the user community is focused not only on biotic but also on abiotic outputs in order to broaden the classification scheme. The classification divides ecosystem services into four main categories which are generally accepted today: provisioning services such as food, water, timber and fibres; regulating services such as those mitigating climate related impacts, floods, diseases, wastes and water quality; cultural services that provide recreational, aesthetic, and spiritual benefits, and supporting services such as soil formation, photosynthesis and nutri-

Table 1. Ecosystem services provided by mountain forests

Adapted from the MEA, (2005) Chapter 21 and 24 – Forest and Woodland Systems; Mountain Systems (http://www.maweb.org/en/Condition.aspx#download)

Provisioning Services	Timber for use in buildings and infrastructural initiatives; fuelwood (critical for local populations); non-timber forest products (NTFPs), including wild game, foods (mushrooms, berries, edible plants etc.); the availability of grazing for subsistence farming.
Regulating and supporting services	Critical stability/protection function – forest cover enables soil retention and acts as a barrier to the impacts of avalanches and rock falls on valley communities; mountain forests (particularly cloud forests) have high water retention capacity, intercepting and storing water from rainfall, mist and snow and releasing it gradually, thereby maintaining hydrological cycles at large scales – limiting peak stream flow rates, reducing soil erosion and the severity of avalanches and downstream flooding; mountain forests represent a major carbon sink, with ongoing carbon sequestration being a critical component of climate change mitigation; due to their relative isolation and contrasting climates, mountain forests are high in endemism and commonly represent global hotspots for biodiversity, which is linked to tourism, recreation, hunting and fishing benefits.
Cultural services	Mountain forests have intrinsic spiritual and aesthetic values; their characteristics allow for considerable recreational opportunities globally; the customs and belief systems of many mountain communities are intricately linked with forest ecosystems.

ent cycling (Haines-Young, Potschin, 2018). These services are the outputs of ecosystems (whether natural, semi-natural or highly modified) that most directly affect the human well-being (Fig. 2).

Mountain forest ecosystems and ES – characteristics, challenges and recent trends

Mountain ecosystems provide a wide range of direct and indirect contributions to the people who live in the mountain territories and are characterised by a high degree of vulnerability and low environmental stability. They usually occupy steep terrains at high elevations and provide services, such as stabilising slopes, regulating hydrological cycles, maintaining rich biodiversity and supporting the livelihoods. In many cases, however, as a result of the impact of biotic, abiotic or anthropogenic pressure, different damages occur on forest vegetation, there are activation of erosion processes or biodiversity loss, etc., resulting in decreasing the potential of mountain ecosystems to provide important ecosystem services.

As a major limiting factor for the growth and development of forest vegetation on high mountain territories is the air temperature, determined by the 10°C July isotherm (Grace et al., 2002; Holtmeier, 2003; Panayotov, 2005; Gehrig-Fasel et al., 2007; Harsch, Bader, 2011). It is assumed that the temperature upper limit of the forests in Bulgaria is about 2200 m a.s.l. and in many places, it has been reduced due to both human activities and different natural phenomena. These areas are characterised with severely shortened growing season with low air temperature, strong winds and heavy snowfalls, avalanches and erosion processes at more steep slopes, causing difficult conditions for the survival and natural regeneration of the forests (Stoyanova, 2013).

Mountain areas are often remote regions, whose human populations are highly vulnerable to environmental, economic and social changes from local to global scale. The communities in mountain areas, both rural and urban, are highly dependent on forests, which provide them with a diverse range of services, including fundamentals such as fuel, food, clean water and protection from natural hazards (Table 1). Mountain forests are characterised by multifunctionality, providing a variety of ecological, social and economic services (Nijnik et al., 2012) and are also important as an instrument of climate regulation and a maintainer of the carbon cycle (Schlessinger, 1997). On the other hand, multifunctional character strengthens the dynamics and vulnerability of forests with regards to global change. As a result, dynamic land use changes, economic marginalisation and climate change are significantly affecting the quality of ecosystem services, provided by mountain forest ecosystems followed by increased risk of floods, droughts, storms, soil erosion and reduced food security (EEA, 2015, Ariza et al., 2013, von Haaren et al., 2011, Trumper et al., 2009). All of these specific characteristics of mountain areas establish "geographical barriers", often resulting in more primary forests, higher carbon stocks and higher biodiversity richness compared with lowland areas, but make local communities socially, economically and politically isolated from other urban areas.

Regardless of the good management practices of high-mountain ecosystems applied in recent decades, the negative trends are still observed and they could lead to decreasing of the adaptive ability of such ecosystems to successfully cope with changing environment. The variety of natural and anthropogenic factors influence ecological processes, through time and in space and could affect the functioning of ecosystems and ecosystem services supply. As IUCN Red List of Ecosystems framework states, an ecosystem can be at risk of losing one or more of three complexly interrelated features of ecosystems: biodiversity, ecosystem functions or ecosystem services (Keith et al., 2013).

Among the main threats for biodiversity in Bulgaria, identified in the National Biodiversity Conservation Strategy, are the direct loss and degradation of habitats, air pollution, soil and groundwater pollution, the overexploitation of economically important species, land-use changes and global climate change. The lack of knowledge and the ineffective policy can also be considered as threats for biodiversity and ecosystem services. Other threats are the insufficient information on biodiversity in specific geographic areas, inadequate understanding by the local community of the importance and the main risks for biodiversity and the poor implementation of nature protection legislation.

Approaches in ES assessment – models, valuation and applicability to

mountain forest ecosystems

Mountain forests are closely connected with people as they have a spiritual significance for local communities, produce inputs for economic activities of local population and provide ecological benefits to communities, both in and beyond mountain areas, and provide diverse socio-cultural, economic and ecological values to different stakeholders (MEA, 2005; Price et al., 2011). The assessment of these values is important for a comprehensive understanding of the ecosystem services provided by mountain forests, as they illustrate the direct and indirect benefits of mountain forest ecosystems to territorial development and human well-being.

The assessment of ***ecological values*** is important for the implementation of good management practices in mountain forests, since it contributes to the: quantification of ecosystem services, identification of main providers and users, decision making for sustainable land use and selection of conservation priority sites (Chen et al., 2009; Nelson et al., 2009; Burkhard et al., 2012). The assessment of ***economic values*** of mountain forest ecosystem services is crucial for analysing the recognition of market-based management schemes, such as payments for ecosystem services, voluntary carbon markets and biodiversity banks (Wunder, 2015; Hamrick, Gallant, 2017). Following the definition of the Millennium Ecosystem Assessment (MEA, 2005), ***socio-cultural values*** of mountain forest ecosystem can be defined as "non-material benefits" from these ecosystems, including recreational and tourism potential, aesthetic appreciation, inspiration, sense of place and educational value. Socio-cultural values play an important role in sustainable management of mountain forest ecosystems, since many communities live in these areas and any changes could affect their social development and welfare (Price et al., 2011; Paudyal et al., 2018; MEA, 2005).

For the assessment of socio-cultural, economic and ecological values of the mountain forest ecosystem services, several ***modelling tools*** have been elaborated. These tools can be grouped into stakeholder analysis, market analysis and modelling analysis (Burkhard et al., 2010; Häyhä et al., 2015). Some tools can be used for assessing several values (e.g. InVEST for ecological and cultural values), but they mostly focuses on recreation and tourism from socio-cultural values of ecosystem services. The selection of these tools must be consistent with targeted ecosystem services, assessment scope and scale, data availability, cost and time, as well as the technical support (Bagstad et al., 2013). Among the most frequently used modelling tools in assessing mountain forest ecosystem services are as follows:

Toolkit for Ecosystem Service Site-based Assessment (***TESSA***) has adopted a simple approach for assessment and monitoring of ecosystem services at the site scale (Peh et al., 2013). TESSA allows the assessment of watershed services, wild and cultivated goods and recreation in mountain landscapes. One of the advantages of this tool is that any advanced technical knowledge or financial resources are not required (Peh et al., 2013). Another important feature is that it requires assessing and identifying policy or strategy gaps in ES management, thus improving these policies at the site level or across a broader region http://tessa.tools/.

The Integrated Valuation of Ecosystem Services and Trade-offs Tool (***InVEST***) is an open-source software developed by the Natural Capital Project for spatial mapping, modelling and valuation of multiple ecosystem services (Sharp et al., 2016). The tool includes a diverse set of provisioning, regulating and cultural services from marine and terrestrial environments and has been widely used across various countries to support decision-making processes (Polasky et al., 2011; Baral et al., 2014; Kareiva et al., 2011). InVEST also provides several models for assessing ES related to mountain forests, including: habitat quality, forest carbon, nutrient delivery, sediment delivery, water yield, visitation of recreation and tourism and crop pollination (Sharp et al., 2016) www.naturalcapitalproject.org/.

Artificial Intelligence for Ecosystem Services (***ARIES***) is a new methodology and web-based application designed to assess ecosystem services, including from mountain forests (Villa et al., 2011, 2014). It supports artificial-intelligence-based data and model selection and quantifying ES flows from ecosystems to beneficiaries. Mountain forest ecosystem services assessable by this tool include carbon storage and sequestration, aesthetic views, flood and sediment regulation, water supply and recreation (Bagstad et al., 2011) http://aries.integratedmodelling.org/.

The Multiscale Integrated Models of Ecosystem Services (***MIMES***) is a set of models for land-use change (LUC) and decision making for spatial planning, including forest landscapes (Boumans et al., 2015). These models quantify the effects of LUC on ecosystem services and are applicable at global, regional and local levels (Boumans et al., 2007, 2015; Grigg et al., 2009). MIMES is designed to quantify causal linkages between ecosystems and the economy and allows individuals to map decisions/policies. The outputs of this tool illustrate how different choices could affect the economies and ecosystems www.afordablefutures.com/orientation-to-what-we-do/services/mimes.

ESTIMAP is a consistent and flexible set of spatially-explicit models, each of which can be run separately for the assessment of different ES at the European scale. They are all developed following the CICES classification and framed in the ES cascade model, which connects ecosystem structure and functioning to human well-being through the flow of ES. The models are dynamically linked to LUISA, the JRC land-use modelling platform (Lavalle et al., 2011) providing the opportunity to evaluate the impact of different scenarios of land use changes on ES provision. ESTIMAP is designed as a quantitative tool and produces outputs that mostly provide biophysical values for regulating services. However, the recreational indicator considers both supply and demand and reflects, to some extent, socio-cultural values associated with aesthetic beauty and recreation.

Many of the known approaches and techniques for valuing ES use various metrics – qualitative, quantitative or monetary (Cooper et al., 2013). The qualitative analysis generally focuses on non-numerical information as opposed to the quantitative analysis, which involves numerical data, while the monetary analysis translates quantitative data into currency values (TEEB, 2009).

Ecosystem services can be assessed in ***non-monetary terms*** and in ***monetary*** terms through using direct market, indirect market, contingent and group valuation (Turner, Schaafsma, 2015).

The *direct market* valuation method is useful to measure provisioning services and some cultural services that can be traded. For instance, the value of trees for firewood or construction wood, which could be priced on the open market or seagrass meadows and their value for fisheries or tourism (Vasallo et al., 2013; Jackson et al., 2015). *Indirect market* valuation is used when no markets for certain services exist and a variety of valuation techniques can be applied to establish the Willingness To Pay (WTP) or Willingness To Accept compensation (WTA) for the availability or loss of these services (de Groot et al., 2002; Freeman, 2003). *Contingent valuation* is the hypothetical demand for ES that involve describing alternatives in a survey or a questionnaire. For example, the respondents may be asked to express their preference of increasing the level of water quality in a stream, lake or river so that they might enjoy various activities, such as swimming, boating or fishing (Wilson, Carpenter, 1999). *Group valuation* brings stakeholders together to discuss the values of ES, which are regarded as public goods and their valuation should be based on public discussion (Sagoff, 1988; Jacobs, 1997; Wilson, Howarth, 2002; de Groot et al, 2002).

Non-monetary assessment is applicable in cases when ES values are difficult to assess directly and indicators are used as proxies (Layke, 2009; Layke et al., 2012; Muller, Burkhard, 2012; Kandziora et al., 2013). This assessment can aim at defining more aesthetic view of nature, ecosystems and biodiversity and their influence on social relationships, cultural evolution and spirituality (Chan et al., 2012; Raymond et al., 2013).

According to Boerema et al. (2017), the following proxies for measuring ES can be used:

- *Ecosystem properties* – often simple measures or indicators of biodiversity and population size are used for all ES that depend on biodiversity, such as genetic resources, biological control, pollination and life cycle maintenance.

- *Ecosystem functions* – the functions and processes underpinning each ES are diverse and often composed of different components (Smith et al., 2013). For example, proxies for pollination may be intraspecific diversity, pollination effectiveness, visit rate, plant growth rate and infestation rate.

In addition, many other social research methodologies have been elaborated (Christie et al., 2008; Cooper et al., 2013), ranging from spatially-oriented participatory GIS (Fagerholm et al., 2012; Brown, Fagerholm, 2015), to traditional social methods including interviews, surveys, observational studies or focal group discussions (Orenstein et al., 2015; Eizenberg et al., 2017).

Challenges for sustainable management of mountain forest ecosystems considering the ES conceptual framework

The main challenges, which must be considered in the process of assessment of mountain forest ecosystem services, are the complexity of defining and classifying ecosystem services; limited data on ecosystem services; uncertainties associated with climate change; diverse relationships among ecosystem services and limitations of assessments when developing successful payments for ecosystem services in mountain territories.

The variety of ***definitions and classifications*** for ecosystem services, including those for mountain forest ecosystem services, often confuse stakeholders and policy makers (Wallace, 2008). Different classifications are based on different disciplines, different purposes of ecosystem management (e.g. de Groot et al., 2002; MEA, 2005; Costanza, 2008; Fischer et al., 2009) but the most accepted and widely applied classification is from the Millennium Ecosystem Assessment (MEA, 2005). However, Fisher et al. (2008) note that using this classification poses a risk for double counting errors in cases of valuation of ecological processes, supporting multiple ecosystem services, such as weathering, soil formation, nutrient cycling, etc. Many authors consider that a common definition and classification framework for ecosystem services remains a major challenge, taking into account that studies on ecosystem services are often too singular (Haines-Young, Potschin, 2010, 2018; Burkhard et al., 2012). However, some of them support the thesis that the definition of a common classification framework is neither feasible nor necessary (Costanza, 2008).

The assessment of mountain forest ecosystem services can be complicated and/or constrained by ***limited data*** and/or high data collection costs (e.g. Sharma et al., 2015). For quantification and mapping of ES can be used proxies but sometimes they might not correspond to primary data for some key ecosystem services, such as biodiversity, carbon storage and recreation. Nevertheless, they could be used for general assessment of ecosystem services and for identification of hotspots or priority sites for multiple ecosystem services (Eigenbrod et al., 2010).

Due to variety of climate change scenarios, there are still considerable debates and uncertainties on the extent of climate change impact on the provision of mountain ecosystem services, which refers to ***uncertainties with climate change***, regardless they have been the main focus of many studies (Dossena et al., 2012; Garcia-Lopez, Allue, 2012; Jochum et al., 2012).

The process of assessment of mountain forest ES would be complex and further complicated also due to the diverse relationships among these services, including ***trade-offs and synergies***. In these cases, an increase in one service leads to a decrease in another service, representing important impact in current approaches to ecosystem services management (Rodriguez et al., 2006; Bennett et al., 2009).

Sustainable management of mountain forest ecosystems is an important part of sustainable territorial development of remote mountain areas. The main goal to ensure the policy actions that focus on preservation of natural forests, conservation of biodiversity and landscape values should be complemented with well-targeted measures to enlarge the provision of variety of ecosystem services and provide more opportunities for local communities living in remote rural areas. The general question of interest in mountain regions is the type of management approach and resource regime in the way of managing mountain forests and their potential to supply ES under the specifics of regional governance (Nijnik, Bizikova, 2008, Buttoud, 2002).

Following numerous studies (e.g. Berkes, Folke, 1998, Poteete et al., 2010, Prempl et al., 2015, Van Kooten et al., 2004), evidence has been provided on the positive role of self-management in which local users are capable of crafting their own rules that allow for the sustainable and equitable management of mountain systems. The quality of local knowledge, communication, trust, a willingness to follow own established rules can be considered as social innovation for sustainability of mountain socio-ecological systems and recognised as a long-term adaptation policy (Ostrom, Nagendra, 2006).

Conclusion

Mountain ecosystems are highly sensitive and vulnerable to environmental changes and different impacts. They provide ecosystem services that support rich biodiversity and are essential for climate regulation and water cycles, maintain many livelihoods and indigenous cultures, especially in rural areas. However, increasingly they are threatened by land abandonment, intensification of agriculture, infrastructure development, unsustainable exploitation and climate change. As a key component of mountain ecosystems biodiversity, including the number, composition of genotypes, populations, species, functional communities and landscape units, plays an important role and strongly influences the provision of ecosystem services.

Assessment is recognised as a main component of the sustainable management of mountain forests and the ecosystem services they provide and allows for proper understanding of the impacts of mountain forest ecosystems on human welfare. A focus on ecosystem services would help local and conservation authorities to build political support for conservation of these landscapes and make informed planning and management decisions.

From the conservationist point of view, the ecosystem services can be a powerful tool to preserve biodiversity and natural condition, and to engage multiple actors and sectors in this objective. Moreover, many stakeholders, including practitioners and end-users of ecosystem services, primarily measure provisioning goods or human experiences in nature and, thereby, dismiss the indirect contribution of habitats and species to human well-being.

The implementation of the ES approach is important for supporting stakeholders and policy makers in understanding the value of their natural capital in order to make proper land use decisions for the management of the ecosystem services provided by the mountain forest ecosystems and is a valuable tool for integrated management of mountain regions.

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