ASSESSING THE IMPACTS OF CLIMATE CHANGE ON MOUNTAIN FORESTS: A BRIEF REVIEW

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The effects of climate change on natural ecosystems are increasingly more visible. Being mountain forest ecosystems the most vulnerable and therefore the most affected ecosystems, they appear to be the most suitable for the assessment of climate change effects on ecosystem services. Accordingly, the paper reviews the literature on the economic assessment of climate change impacts in European mountain forests. Initially, the trends in the provision of mountain forest ecosystem services are discussed. The literature review also takes into account the effects on forest structure and trees physiology, being these two effects strictly associated with the capability of the ecosystem to provide services. The results of this first part of the paper have been presented into a table that displays both the trends and the quality and the quantity of the information available. Subsequently, the main methods that can be employed to assess the economic value of the different ecosystem services have been described. For each method some examples of implementation have been described. In the conclusion, the main gaps still existing in scientific literature concerning the effects of climate change on ecosystem services provided by mountain forests have been highlighted. Because of the heterogeneity of the considered ecosystems it is of fundamental importance to have a comprehensive view of the phenomenon. Finally, some more remarks about the existing methods for the economic valuation of ecosystem services has been done.

Key words: *climate change, mountain forests, economic damages, ecosystem services, Europe.*

1. Introduction

Climate Change (CC) is one of the main drivers of changes in mountain ecosystems and in their related services provision, being more vulnerable than others to the changes in temperature and precipitation (Beniston, 2003). The upper shift of species and consequently their adaptation to changes is limited by the long-time span of trees that cannot react quickly to the changes and the limitation of their altitudinal range (Lindner et al., 2010). For these reasons forests located in mountain areas are the most appropriate ecosystems for CC detection (Ding et al., 2016). The purpose of this study was to address the growing societal demand on Ecosystem Services (ES) provided by mountain regions, which support a large number of components essential for human health and well-being (water, quality of food products, biomass, flood prevention, tourism and recreation, etc.) (Briner et al., 2013).

According to the new version of the Common International Classification of Ecosystem Services (CICES, V5.1, http://cices.eu/resources/, Haines-Young and Potschin, 2018) ES can be divided in three main categories: provisioning, regulating and cultural. Provisioning services are those services related to the goods provided by ecosystems. Regulative services are those services that have a regulative function (e.g. erosion control, water purification, climate control). Cultural ecosystem services comprise aesthetic, spiritual, recreational and touristic value. It is important to quantify and value the provision of ES through numerical and economic indicators in order to be able to monitor and compare them and consequently to address them in political and economic discourses. In such a way the value of ecosystems can be presented to stakeholders through the value comparison of material goods and intangible services (Grêt-Regamey et al., 2013). Whether provisioning services are easier to assess and valuate, most of regulative and cultural services cannot be measured in market terms, since the methods to quantify them and to assess their value have only recently been developed.

In the valuation of ES, using the terminology of the Cost-Benefit Analysis, a basic distinction should always be made between the financial analysis, which assesses the incurred expenditures and gained revenues, and the economic analysis, which is aimed at detecting the real value of ES for the society, taking into account the positive impacts (benefits) and the negative ones that cannot be described by the market prices. This kind of analysis tries to include the so called Total Economic Value (TEV) of the ES that incorporates not only their market values (wood, non-wood forest products, water, etc.), but also all their intangible benefits and costs (Thorsen et al., 2014). While the literature connected with the financial analysis of mountain forest ES has a long tradition in terms of the role and importance of provisioning services (with a focus on wood products), the economy analysis of the total value of forest ES in mountain regions has been randomly carried out. Moreover, notwithstanding the mentioned socio-economic characteristics of mountain forest ES (diversity and multiplicity of the ES, high perceived values, relevance and non-market benefits) there is no systemic analysis of the literature on their economic assessment. Our research's objective was to contribute to existing knowledge through a literature review on the economic assessment of CC effects on mountain forest ES with a special focus on European mountain regions.

This study has been conducted within the Belmont project "ClimTree". The project aims at the analysis of ecological and a socio-economic impact of CC on mountain forest in Europe.

2. European mountain forests

Mountains cover 29% of the EU territory and in this area the most diffuse land use is forest covering 41% of the total mountain areas (EEA, 2010; Hartl et al., 2015). Global warming does not evenly affect Europe, its impact varies depending on a bioclimatic region allocated at different elevations and latitudes (Rogora et al., 2018). Furthermore, the impact of climate change on forest ecosystems also depends on the bioclimatic zone and on the resulting forest types (EFI, 2008; Lindner et al., 2010).

The main European bioclimatic zones are polar, boreal temperate and Mediterranean. Because of the absence of forest in polar areas, the focus of our research has been on the other three regions. Within the temperate region an important distinction has to been made between the oceanic and the continental sub-areas. The bioclimatic map of the European countries is presented in Fig. 1. Besides, the alpine region was considered to better represent the characteristics of the main European mountain ranges: the Alps, the Pyrenees and the Carpathian (Lindner et al., 2010).

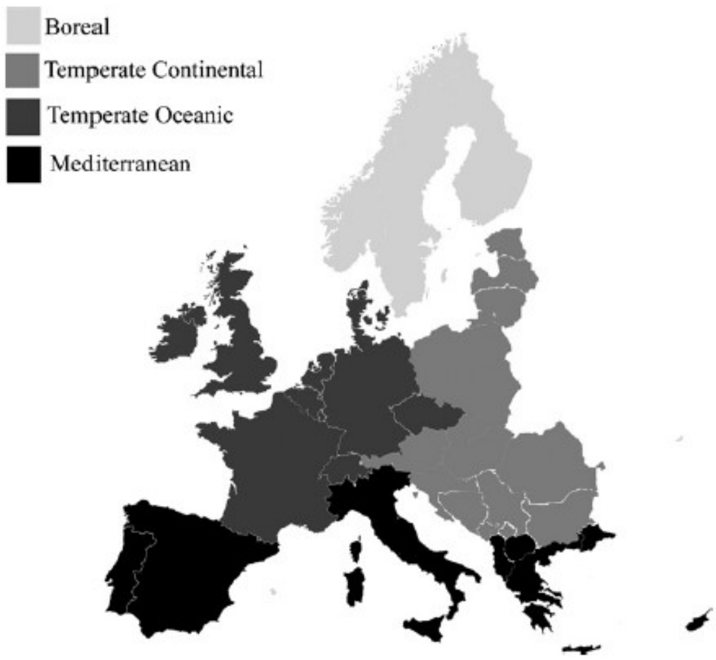

Fig. 1. European countries classification divided by bioclimatic areas (Lindner et al., 2010)

3. The methodological approach

In order to estimate the economic impact of CC on the provision of European mountain forest ES we have organized our research in two stages: firstly, we have tried to describe the impact of CC on the ES, and secondly we have analysed the approach employed for their quantification and economic assessment. In order to meet the first objective, the bibliography analysis has included also the effect of CC on trees physiology and forest structure (Kurbanov et al., 2007), due to the fact that changes in forest structure are strictly related to the ecosystem capability in delivering ES (Brockerhoff et al., 2017).

We used the Scopus bibliographic database as the source of data for our research.

4. Climate change impacts on the provision of mountain forests and Ecosystem Services

The data found as a result of literature review are summarised in Table 1. The trends of the CC impact on the provision of mountain forest ES are grouped in four categories: "increasing", "decreasing", "stable" and "mixed". Depending on the quantity and quality of evidence and correlation between them, the obtained data has been classified as follows: "established but incomplete", "well established" and "unresolved" with a similar approach used by IPBES (2018).

Provisioning services. Changes in Net Primary Production (NPP), that influence timber provision, have different trends in diverse bioclimatic areas. In the Mediterranean region the increment results are negatively affected principally by water scarcity (Fyllas et al., 2017; Rogora et al., 2017; Scarascia-Mugnozza et al., 2010; Linares et al., 2009). The opposite trend has been detected in the boreal region where temperature results tends to be the most limiting factor; in this region the climate change is thus enhancing forest productivity, even if winter frost has a negative impact on it (Kullman, 1996). In temperate region the trend is more heterogeneous with different impacts according to the local and environmental conditions, especially related to water and temperature (Lindner et al., 2010; Loboda et al., 2016; Kurbanov and Post, 2002). In north-western part of the temperate oceanic region the tree growth and increment is slightly higher as a result of temperature increase. This factor significantly influences the tree growth in the area. While in more south-eastern and temperate continental regions water scarcity is reducing radial growth dynamic (Panayotov, 2016; Horak et al., 2014; Friedrichs et al., 2009). Finally, alpine areas are characterized by a general increase in timber production (Rogora et al., 2017) with the presence of an inverse trend where soil moisture is not enough to support a higher photosynthetic rate (Galiano et al., 2010; Meining et al., 2004).

Regulating services. Due to carbon sequestration, forests play an important role in climate regulation, being able to store CO_2 above the soil level. Moreover, tree canopies can modify the albedo of the land surface. For instance, in boreal region the expansion of forests is changing the capacity of forest ecosystems to mitigate climate changes because forest expansion decreases the albedo (Beniston, 2003).

Regarding carbon sequestration, the impact of CC on this ES varies in different regions. In fact, being strictly related to tree growth, stand capacity of carbon stocks follows the pattern that is similar to tree radial increment. For instance, in temperate continental region the carbon uptake is negatively impacted by the higher temperature and lower precipitation because of the reduction of trees photosynthetic rate (Horak, 2014). In alpine and Mediterranean areas CO_2 absorption can follow different patterns: in some regions the carbon uptake is enhanced by the global warming due to the longer growing season and the earlier melting of snow or else, due to the rise up of the timberline (Rogora et al., 2017). In some other regions the negative impact is recorded due to the lower capacity of forest soils to store organic carbon mainly caused by accelerated decomposition of soil organics (Prietzel et al., 2014). In this second case Mediterranean mountain forests are generally limited in their carbon adsorption capability because of water stress (Scarascia-Mugnozza et al., 2010) or insect defoliation (Jacquet et al., 2012).

Another important regulating service provided by mountain forests is pest control. Several studies assessed the expansion on insects' range, winter survival, frequency of pest outbreaks (e.g. Battisti and Larsson, 2015; Pureswaran, 2018). Generally, pests spread depending on the altitudinal gradient, even if latitudinal expansion seems to be prevalent (Battisti and Larsson, 2015). In the Mediterranean region pest control in mountain forest ecosystem is harder to manage in comparison with the other regions due to vulnerability of trees caused by water scarcity (Scarascia-Mugnozza et al., 2010).

Concerning biodiversity, in the recent years it has increased in most of Europe. The regions that experienced a decrease in species richness are the Mediterranean and the alpine area (Pauli et al., 2012). Even if in some papers no indicators regarding abundance or species richness are used, the general information about the change in species composition is present (e.g. Galiano, 2010).

CC also affects the dynamics of disturbances such as fire, insects and wind making forests more vulnerable and affecting their capability of natural hazards regulation. In their paper Seidl et al. (2017) analysed the correlation between CC and natural disturbances and argues there was a direct interrelation between them.

5. Economic evaluation of climate change damages in mountain forests

We identified the effects of Climate Change that affect the capability of mountain forests on the provisioning of ecosystem services in the different European bioclimatic areas. In order to understand what economic impacts are caused by these changes it is necessary to estimate the value of the forest ES considered. Several methods have been developed and different frameworks have been designed in order to systematize and to classify them. Hereafter the framework developed by Masiero et al. (2018) in their manual "Valuing forest ecosystem services: A training manual" [under press] it has been used as reference (Fig. 2).

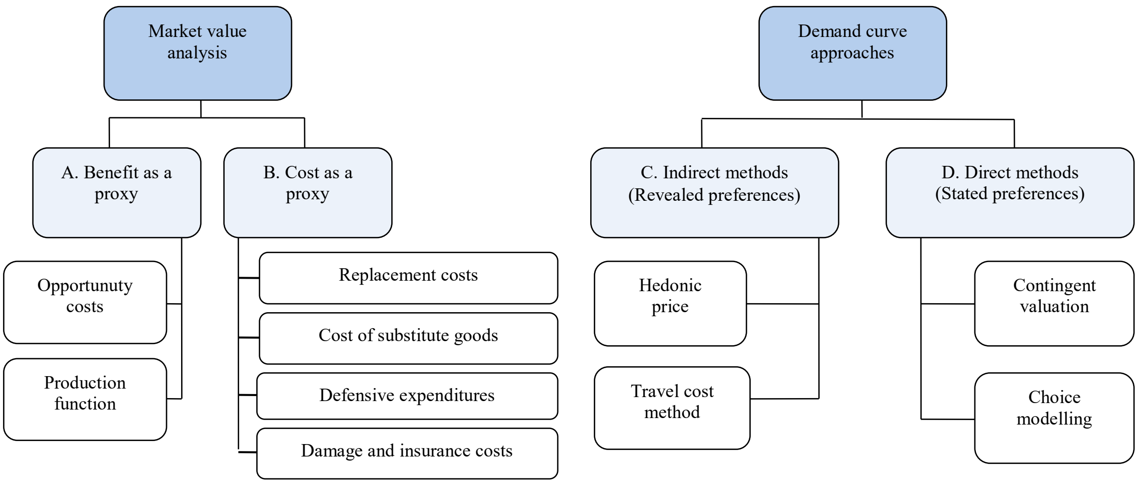

Fig. 2. Methods that can be used to evaluate Forest Ecosystem Services (Masiero et al., 2018). Valuing forest ecosystem services: A training manual. FAO, Rome [under press])

We will briefly outline the cases found as a result of literature review with the reference to the methodological approach framework described in Figure 2, while in Table 2 different mountain forest ES are cross-checked with the methods used for their economic valuation with reference to the literature review.

The methods used for value assessment (financial and economic) of mountain forest ES can be divided in two main categories: Market Value Analysis and Demand Curve Approaches. In the first sub-subparagraph (5.1) the cases where methods included in the first category will be taken into account and described, while in the second sub-subparagraph (5.2) the cases where methods based on the demand curve will be analysed. The examples founded through a literature review have been integrated with the cases described in a database developed within the Gestire project (2015) with the aim to assess the economic values of the Natura 2000 network in Lombardy region (North of Italy).

Table 1

Trends on the provision of forest ecosystem services affected by climate change

Forest Ecosystem Services	ES category	forest ES sub- category	Boreal	Temperate Oceanic	Temperate Continental	Medi-terranean	Alpine
Provisioning services	Bioenergy production				decreasing	mixed	decreasing
	Timber production		increasing	mixed	decreasing (well established)	mixed	mixed
	Non-wood forest products		increasing		decreasing		stable
Regulating Services	Climate regulation	forests carbon stocks	decreasing	decreasing	decreasing (well established)	mixed	mixed
		Soil carbon stocks	increasing			mixed	decreasing
		Albedo	decreasing				
	Pest control		decreasing	decreasing	decreasing	decreasing	decreasing
	Natural hazard regulation	Forest fires/ wildfires				decreasing	decreasing
		Erosion, ava-lanche, landslide					decreasing
		Flooding					decreasing
	Water quality regulation		decreasing	decreasing	decreasing	decreasing	decreasing
	Biodiversity		increasing	increasing	mixed	decreasing	decreasing (well established)
Cultural Services	Recreation (fishing, nature enjoyment)	Hunting					
		NWFP picking					
	Tourism (skiing)						decreasing
	Aesthetic / heritage (landscape char-acter, cultural landscapes)						decreasing

	TREND	CONFIDENCE LEVEL
increasing (dark green)	increasing	well established
increasing (light green)		established but incomplete
stable (yellow)	stable	established but incomplete
decreasing (light red)	decreasing	established but incomplete
decreasing (dark red)		well established
mixed (blue)	mixed	unresolved
(blank)	NA	not enough data

Source: compiled by the authors based on: Allen *et al.* (2010); Beniston (2003); Courbaud *et al.* (2011); Cudlín *et al.* (2017); De Wit *et al.* (2006); Dupire *et al.* (2017); Fernàndez-Martínez and Fleck (2016); Feurdean *et al.* (2016); Fleischer *et al.* (2017); Forsius *et al.* (2013); Friedrichs *et al.* (2009); Galiano *et al.* (2010); Hartl-Meier *et al.* (2014); Horäk (2014); Jolly *et al.* (2005); Kozlov *et al.* (2013); Krupková *et al.* (2018); Kullman (1996); Lebourgeois *et al.* (2010); Linares and Tiscar (2011); Meining *et al.*(2004); Panayotov *et al.* (2016); Prietzel and Christophel (2014); Rogora *et al.* (2018); Saccone *et al.* (2009); Sarris *et al.* (2014); Scarascia-Mugnozza (2010); Tømmervik *et al.* (2009);Vacek *et al.* (2017)

Table 2

Forest ecosystem services and related economic evaluation approaches

Ecosystem Services			**Market Value Analysis**						**Demand Curve Approaches**			
Section	ES category	ES sub-category	Benefit as a Proxy		Cost as a Proxy				Indirect Methods		Direct Methods	
			Opportunity Costs	Production Function	Replace-ment Costs	Cost of Substitute Goods	Defensive expendi-tures	Damage and Insur-ance costs	Hedonic Pricing	Travel Cost Method	Contingent Valuation	Choice Modelling
Provisioning	Bioenergy produc-tion		x		x	x					x	x
	Timber production		x		x	x					x	x
	Non-wood forest products		x		x	x					x	x
Regulating	Climate regulation	Forests carbon stocks	x	x	x		x	x			x	x
		Soil carbon stocks	x	x	x		x	x			x	x
		Albedo	x		x		x	x			x	x
	Pest control		x	x	x		x	x			x	x
	Natural hazard reg-ulation	Forest fires/ wildfires	x	x	x	x	x	x			x	x
		Erosion, ava-lanche, land-slide	x	x	x	x	x	x	x		x	x
		Flooding	x	x	x	x	x	x			x	x
	Water quality regu-lation		x	x	x		x	x			x	x
	Biodiversity		x	x	x		x	x			x	x
Cultural	Recreation (hunting, nature enjoy-ment)		x		x	x			x	x	x	x
	Tourism		x		x	x				x	x	x
	Aesthetic / heritage (landscape character, cultural landscapes)		x		x	x			x	x	x	x

5.1. Market Value Analysis

This category comprises all the methods that are based on the use of values recorded in the market to carry out direct or indirect estimate of mountain forest ES values. Market prices can be a good signal of the value of some ES being influenced by supply and demand functions, i.e. by the revenue generation capacity, current costs and the preferences of consumers. Compared to the other category of techniques (demand curve approaches) these methods are easier to apply due to the use of already existing values directly assumed from the real market. This is also the reason why the outcomes from the implementation of these methods are considered "hard results", i.e. connected with real evidence from the market, even if in many cases these results represent an underestimate of the TEV of mountain forests ES.

a) Benefit as a proxy. Within this subcategory two main methods are present: "Opportunity Cost" and "Production Function".

Opportunity Cost *(OC).* The OC describes the cost that the land owner has to incur when he/she decides not to change the specific land use or to change his/her economic activities in order to maintain or enhance a particular mountain forest ES. For instance, the OC for a landowner that is involved in the project aimed at enhancing forest biodiversity is represented by the income loss derived as a result of reducing timber harvesting in order to reach the project aim. The amount of income lost can be used to estimate the value of biodiversity protection in that forest. Because the OC strictly depends on the land cover or the activity performed, its value is related to the local situation (Barton et al., 2013). Some examples of OC application are listed below. Extensive application of this methodology is found in decision making processes related to forest conservation, biodiversity protection or carbon sequestration or, on the contrary, to forest exploitation (Hily et al., 2015; Schröter et al., 2014; Seidl et al., 2007; Kniivilä et al., 2002). Similarly, OC approaches have been used to consider land use changes or the provision of different mountain forest ES (e.g. Ruijs et al., 2017). OC has been employed to evaluate different provision of ES in forests changing from a monoculture to a close-to-nature forest management system in order to understand the benefits and costs of such process (Schou et al., 2012).

Production Function *(PF).* The method is based on the relationship between the selected forest ES and the production of a specific good associated to the market. The forest ES is viewed as input for the provision of goods. In order to be able to use this approach it is necessary to know the existing relation between the forest ES and the provided good. The value of the forest ES is thus associated with the increase of income generated by the improved production system.

The method has been used for the valuation of regulating forest-related ES (see Table 2). Gren et al. (2018) used PF in combination with another technique (Replacement Cost described below) in order to assess the impact of pathogen spread in the capability of carbon dioxide sequestration in forest ecosystems. A good example of the application of this method can be found in Nahuelhual et al. (2007), where PF was selected as suitable methodology for assessing the economic value of water provision in Valdivian forests (Chile).

b) Cost as a proxy

Replacement Cost *(RC).* In this approach the value of the forest ES is associated with the avoided cost to replace the service in case of its loss. In other words, the value of the benefits associated with a certain forest ES is derived from the cost to replace the same benefit with different service or good. This method has been described by Forest Europe as "*the most realistic method of re-creating non-market benefits*" (https://foresteurope.org/overview-valuation-approaches-methods).

Several studies have used this methodology to assess forest ES values. Bianchi et al. (2018) have carried out a literature review on the use of different valuation methodologies to measure the value of protection services against rock falls, avalanches, landslides and for investment in flood protection in the Alps, in which RC proved its effectiveness (Getzner et al., 2017; Häyhä et al., 2015; Notaro and Paletto, 2012). Grilli et al. (2015) have also assessed the values of different forest ES in Italian alpine valley using RC. Gren (2015) applied this methodology for the valuation of carbon sequestration in Sweden and Notaro et al. (2009) – in Italy. A slightly different approach in the implementation of RC can be found in the study of Clinch (2000). In this research RC was implemented in combination with other methodologies (Contingent Valuation and Damage Cost), to evaluate the Irish national forest plantations programmes and assess their negative and positive aspects. The application of the RC has been used in relation to the assessment of water quality and provision.

***Cost of Substitute Goods** (CSG).* The rationale behind this methodology is to relate the value of the ecosystem goods or services to the cost that would be necessary to produce a substitute, also called surrogate fulfilling the same or similar function. Little has been found using such keywords as "*substitute good*", "*surrogate*" or "*economic valuation*".

In the paper the method was used as a proxy to estimate the value of the natural capital providing forest ES (Petrosillo et al., 2009). Gret-Regamey et al. (2008) applied CSG method to assess the value of forest ES provided by European Alps. Merlo and Croitoru (2005) in their book used CSG in assessing forest function of Mediterranean forests against landslide and floods.

***Defensive Expenditures** (DE).* This approach associates the value of forest ES with the cost of avoiding and/or reducing the negative environmental impact on the services or with the hypothetic costs of implementation for actions intended for the mitigation/compensation of the consequent damages.

DE was used to quantify the monetary value of flood protection in German riparian forest (Barth and Döll, 2016) and Apennines mountain forest in Italy (Morri et al., 2014). In their paper Snider et al. (2006) used the method to understand if the funds invested by the USA federal government in forest fire prevention were effective. The value associated to the actions that had been implemented for forest fire protection can be used as a *proxi* of the value of the ES under consideration.

***Damage and Insurance Costs** (DIC).* Always related to cost as proxy this approach regards the value of forest ES as the expenses incurred as a result of damage caused by natural hazards or the insurance costs paid out as a result of the occurrence of the insured event.

The application of this method can be found to quantify the value of carbon sequestration in German forests (Wüsteman et al., 2014) and Irish forests (Clinch, 2000). In Pulkrab et al. (2011) this method was used to assess the value of pest control services of forests in Czech Republic. Finally Gren et al. (2009) assessed the damage caused by alien invasive species that can have severe effects on biodiversity in Swedish forests.

5.2. Demand curve approaches

These approaches are used whenever the assessment in market values is not applicable and when relevant non-market prices are influencing the TEV of forest ES. The main idea of this set of approaches is to estimate the value of forest ES through:

- the decisions made by real consumers as revealed from their concrete expenditures (so called "Indirect Methods"), or/and;
- the declared preferences of the real and potential consumers collecting information on their willingness to pay for the ES (so called "Direct Methods").

c) **Indirect Methods**

Among the indirect methods based on the revealed preferences of the end users, two main methodologies are used to estimate mountain forest ES.

Hedonic Pricing *(HP).* This technique assumes that the land prices depend on both the internal characteristics of the good providing an ES and to external factors affecting it. A clear example to explain the method could be made taking into consideration real estate prices. The price of this commodity can change depending on the location of the building because of the different landscape that surrounds it. The value of the ES close to the selected house can be approximated with the higher price of house when compared with a similar building located in another area without the investigated ES. Therefore, the value given to the presence of the forest ES can be calculated as the sum that people agree to pay to live close to it. The same method can be used also to evaluate some specific characteristic of the landscape.

For instance, Austrian Federal Forests commissioned the valuation with a HP technique of the protective functions of forests against landslides, avalanches and rock falls (Getzner et al., 2017). In Croatia the HP method applied to the prices of hotel rooms was used to estimate the touristic value of Mediterranean forest (Marušić et al., 2005). In Switzerland Schläpfer et al. (2015) have estimated the value of different landscape amenities (comprising forests) analysing the variation in rental prices. Sundelin et al. (2015) thought the analysis of the values of different forest features (such as fragmentation, density, shape, productivity) were able to detect which characteristics of forestland affect the cost of land in Sweden. Outside Europe (in the USA and Canada) HP was also applied to evaluate the impact on cultural ES (touristic and aesthetic services) in forest affected by insect infestation (Price et al., 2010), the cost administered to hunting recreational services (Hussain et al., 2007) and the cost of erosion control function of forests in Ohio (Hitzhusen, 1999).

Travel Cost Method *(TC).* In the method the cost of travel that people pay to reach and visit a certain habitat/ecosystem is elaborated in order to derive the willingness to pay for a specific forest ES or a combination of ES. Generally, TC is used to estimate the value of cultural ES, specifically the ones related to tourism and recreation. In applying TC also the opportunity cost of time is considered.

There are numerous applications of the TC in the assessment of mountain forest ES. In Germany TC has been used to estimate the value of cultural ecosystem services (recreation) provided by German protected areas (Mayer et al., 2018). TC was also used to estimate the potential recreational value of Tatras National park (Jaďuďová et al., 2017). With the same aim the method was applied by Ezebilo (2016) in the UK, by Melichar (2014) in Czech Republic and by Jozef (2010) in Slovakia. Moran et al. (2006) carried out a more detailed TC analysis assessing the cultural services of Scottish forests considering the cost of mountain biking as a recreational activity. In two cases in the Rocky Mountains in Colorado (United States) TC was used to assess the impact of forest fire on the recreational ES (Loomis et al., 2001) and the effects of tree density – influenced also by insect pests and other hazards – on recreational demand and services (Walsh et al., 1989).

d) Direct Methods

Unlike indirect methods direct methods collect the feedback from end users on their willingness to pay for a certain forest ES. These techniques in fact use tools as questionnaires and surveys asking the opinion of individuals directly.

Contingent Valuation *(CV).* This approach is aimed at measuring the willingness to accept the loss of a certain ES if no actions for its provision or enhancement are implemented or there is no willingness to pay by the end users for the implementation of the same action to support the provision of ES. A representative sample that directly or indirectly take advantage of the presence of some ES have been interviewed to collect information on their readiness to accept the loss or willingness to pay under different scenarios.

In order to understand the value of forest recreational services, CV has been used in an Italian alpine valley (Grilli et al., 2014), in Slovakia mountains (Jozef and Miroslav, 2010) and in British woodlands (Christhe et al., 2007). In the Appalachian Mountains it has been used to value the health protection function of forest ecosystems (Holmes and Kramer, 1996). In the study by Bastian et al. (2017) CV was one of the methodologies used to assess the value of forest ES provided by the Eastern Ore Mountains (Germany and Czech Republic). In Italy it has been used also to evaluate the aesthetic services of the national forest landscape (Tempesta and Marangon, 2004).

***Choice Modelling** (CM).* In CM consumers' willingness to pay is detected by asking them to choose from a variety of alternatives. The alternatives are characterized by different attributes of the ES under investigation. One of these attributes is the amount of money people would be willing to pay for the provision of the ES (and its attributes). The survey is designed to reveal the value given to the attributes and to their combinations. The assumption under this approach is that forest ES can be subdivided in different attributes. Because of its features this technique is universal and can be applied to all forest ES.

Some examples of its application can be found mainly regarding the valuation of different attributes of single ES. For instance CM has been applied in valuing recreation services and biological impacts (e.g. bark beetle attack) (e.g. Arnberger et al., 2018; De Valck et al., 2014; Christie et al., 2007; Horne et al., 2005) and in the assessment of biodiversity value carried out by different stakeholders (e.g. Czajkowski et al., 2017; Hoyos et al., 2012; Czajkowski et al., 2009; Meyerhoff et al., 2009; Horne, 2006). It has been also applied to the assessment of heritage values (particularly referring to the landscape characters, e.g. Garrod et al., 2009) and to evaluating different forest ES (e.g. Gatto et al., 2014; Giergiczny et al., 2015).

6. Conclusion

A large variety of studies can be found in scientific literature about CC and its impacts on forest ecosystems, but still some contribution has to be made to the analysis of how different forest ES are affected by the global warming. In fact our results founded a lack of information regarding the impacts of CC on the provision of some forest ES such as cultural ES and specific regulating services "natural hazard regulation" (see Table 1). Because of high environmental and climatic variability of mountain regions it would be necessary to rely on good quality and quantity of primary data in order to be able to have a comprehensive understanding of the whole phenomenon under discussion. For these reasons there is the necessity to sustain the studies on CC impacts on tree physiology and stand structures integrating ES approach.

Changes in the provision of forest ES significantly influencing human livelihood mainly in mountain areas where the interdependence between human and forest ecosystem is stronger and more exposed to the changing climate conditions. Through the literature review several methods to assess the economic value of these goods and services has been detected. The most frequently used methods were the "Demand Curve Approaches". This could be explained by the growing interest to the use of these methodologies which make is possible to assess non-market value of ES. Another explanation could be related to the fact that some methodologies, such as "Production Function" or "Cost of Substitute Good" needed profound knowledge about the interrelation between forest functions and the provision of the ES.

The importance and the necessity to systematise the present information about the economic value of forest ES is the focus of our research interest. The gathered data could be used to fill in the gap in knowledge base in the evaluation of specific ES in particular areas of interest. In fact, using "Benefit Transfer" approach it is possible to analyse the existing evaluation data to estimate the value of the same ES in different contexts. Several databases are already present in the web, such as: EUROFOREX (https://www.evri.ca/en), ENVALUE (https://www.environment.nsw.gov.au/envalueapp/), RED Database (http://www.isis-it.net/red/start_search.asp), that one reported by Elsasser et al. (2016) and the results of EC-financed research projects (http://ec.europa.eu/environment/enveco/studies.htm).

The outlined methodologies can be used to gather the Total Economic Value of mountain forest ES in order to create a baseline that could be used in future to assess how the value of ES will be modified depending on climatic changes.

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