Chapter 13
Assessing the Economic Impacts of Climate Change on Mountain Forests: A Literature Review

Giorgia Bottaro, Paola Gatto, and Davide Pettenella

Abstract The effects of climate change are increasingly more visible on natural ecosystems. Being mountain forest ecosystems among the most vulnerable and the most affected, they appear to be, at the same time, the most suitable for the assessment of climate change effects on ecosystem services. Assuming this, we review the literature on the economic assessment of climate change impacts on European mountain forests. Initially, the trends in the provision of mountain forest ecosystem services are discussed. We, then, considered the effects on forest structure and tree physiology, these two being strictly associated with the capability of the ecosystem to provide ecosystem services. The results have been grouped into a table that displays the trend, the quality and the quantity of the information found. 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 implementation examples have been introduced to better understand its functioning. Concluding, the main gaps still existing in literature concerning the effects of climate change on ecosystem services provided by mountain forests have been highlighted. Finally, some more considerations about the existing methods for the economic valuation of ecosystem services have been done.

Abbreviations

CICES	Common International Classification of Ecosystem Services
CM	Choice Modelling
CSG	Cost of Substitute Goods
CV	Contingent Valuation
DE	Defensive Expenditures
DIC	Damage and Insurance Costs

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ES	Ecosystem Services
HP	Hedonic Pricing
OC	Opportunity Cost
PF	Production Function
RC	Replacement Cost
TC	Travel Cost Method
TEV	Total Economic Value

13.1 Introduction

Climate change is one of the main drivers of changes in mountain ecosystems and in their capability to provide related services. This is due to their higher vulnerability, compared to other terrestrial ecosystems, 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 quickly react to the changes and the limitation of their altitudinal range (Lindner et al. 2010). For these reasons, forests located in mountain areas are among the most appropriate ecosystems for climate change detection (Ding et al. 2016). Moreover, ecosystem services (ES) provided by mountain regions 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).

It is also for this reason that forest ecosystems, in Europe, cover an important role in relation to climate change mitigation and connected strategies. To understand the role of forests in climate change mitigation, see Chap. 15 of this book (Vizzarri et al. 2021).

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 ES are those material services related to the goods provided by ecosystems. Regulative ecosystem services are those intangible services that have a regulative function (e.g. erosion control, water purification, climate control). Finally, cultural ES are those intangible services that comprise aesthetic, spiritual, educational, recreational and touristic value. It is important to quantify and to value the provision of ES through numerical and economic indicators to be able to monitor and compare them. In this way, it is consequently possible to address them in political and economic discourses. ES values can then be presented to stakeholders for understanding and defining trade-off and synergies between material goods and intangible services (Grêt-Regamey et al. 2013). Whether provisioning services are easier to assess and evaluate, most of the regulative and cultural services cannot be measured in market terms, since the methods to quantify them and to assess their values 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 to detect the real value of ES for the society, taking into account both the positive impacts (benefits) and the negative ones, which cannot be described by market prices (externalities). This kind of analysis tries to include the so-called total economic value (TEV) of 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 economic analysis of the total value of forest ES in mountain regions has been rarely carried out. Moreover, notwithstanding the mentioned socioeconomic 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. The aim of this chapter is to contribute to the existing knowledge through a literature review on the existing economic assessment of climate change effects on mountain forest ES with a special focus on European mountain regions.

13.2 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 (Zisenis et al. 2010; Hartl et al. 2014). 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 (Lindner et al. 2007, 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 been made between the oceanic and the continental subareas. The bioclimatic map of the European countries is presented in Fig. 13.1. 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).

13.3 The Methodological Approach

To estimate the economic impact of climate change on the provision of European mountain forest ES, the chapter was organized in two parts. Firstly, the impact of climate change on forest ES was described. In order to meet this first objective, the analysis of the bibliography included also the effects of climate change on tree 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

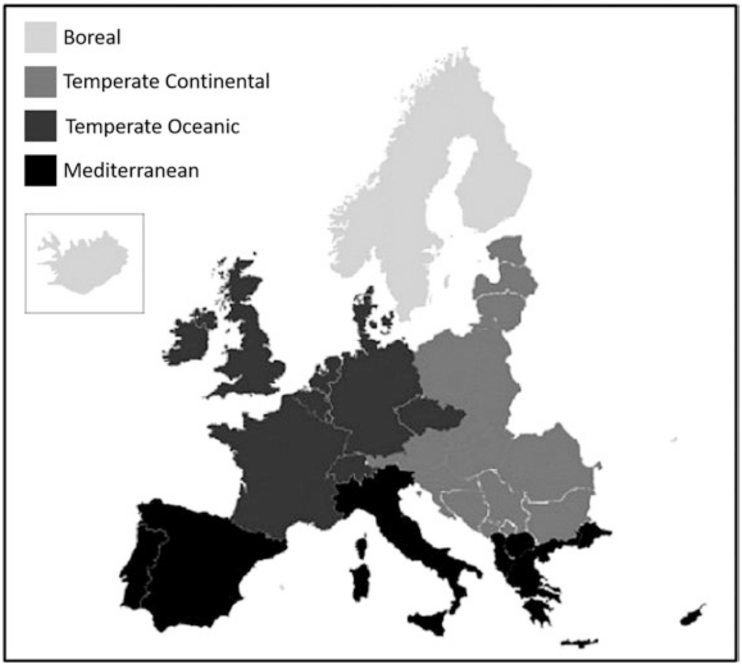

Fig. 13.1 European countries' classification divided by bioclimatic areas. (Modified from Lindner et al. 2010)

(Brockerhoff et al. 2017). This relation has been also analysed in Chap. 6 of this book (Pretzsch et al. 2021). In the analysis of the bibliography, papers predicting the effects of climate change through modelling have not been taken into consideration; this topic is explored in Chap. 7 of this book (Bosela et al. 2021). In the second part, the approaches employed for forest ES quantification and for their economic assessment were analysed. Also in this, case scientific literature was consulted.

The Scopus bibliographic database was used to analyse the literature and as a source of data for our research.

13.4 Climate Change Impacts on the Provision of Mountain Forest ES

In Table 13.1, the data found as a result of the review of the literature are summarized. The trends of the climate change 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 the evidence and correlations among them, the data obtained were classified as follows: "well established", "established but incomplete" and "unresolved" using a similar approach used by IPBES (2018).

Table 13.1 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	Mediterranean	Alpine
Provisioning services	Bioenergy production				▼	◆	▼
	Timber production		▲	◆	▽	◆	◆
	Non-wood forest products		▲		▼		▬
Regulating Services	Climate regulation	forests carbon stocks	▼	▼	▽	◆	◆
		Soil carbon stocks	▲			◆	▼
		Albedo	▼				
	Pest control		▼	▼	▼	▼	▼
	Natural hazard regulation	Forest fires/wildfires				▼	▼
		Erosion, avalanche, landslide					▼
		Flooding					▼
	Water quality regulation		▼	▼	▼	▼	▼
	Biodiversity		▲	▲	◆	▼	▽
Cultural Services	Recreation (fishing, nature enjoyment)	Hunting					
		NWFP picking					
	Tourism (skiing)						▼
	Aesthetic / heritage (landscape character, cultural landscapes)						▼

	TREND	CONFIDENCE LEVEL
△	increasing	well established
▲		established but incomplete
▬	stable	established but incomplete
▼	decreasing	established but incomplete
▽		well established
◆	mixed	unresolved
	NA	not enough data

Source: compiled by the authors based on: Kullman (1996), Beniston (2003), Meining et al. (2004),Jolly et al. (2005), De Wit et al. (2006), Friedrichs et al. (2009), Saccone et al. (2009), Tømmervik et al. (2009), Allen et al. (2010), Galiano et al. (2010), Lebourgeois et al. (2010), Scarascia-Mugnozza et al. (2010), Courbaud et al. (2010), Linares and Tiscar (2011), Forsius et al. (2013), Kozlov et al. (2013), Hartl-Meier et al. (2014), Horäk et al. (2014), Prietzel and Christophel (2014), Sarris et al. (2014), Fernàndez- Feurdean et al. (2016), Fernàndez-Martínez and Fleck (2016), Panayotov et al. (2016), Cudlín et al. (2017), Dupire et al. (2017), Fleischer et al. (2017), Vacek et al. (2017), Krupková et al. (2019), Rogora et al. (2018)

Provisioning Services Within this category of ES were considered the ones related to forest biomass (bioenergy and timber production) and non-wood forest products. Water provision is also generally considered dealing with provisioning services. Nevertheless, in this chapter, water issues were considered only in relation to water quality regulation dealing with regulating services.

Changes in net primary production (NPP), which influence timber provision, have different trends in diverse bioclimatic areas. In the Mediterranean region, tree growth increment is negatively affected principally by water scarcity (Linares et al. 2009; Scarascia-Mugnozza et al. 2010; Fyllas et al. 2017; Rogora et al. 2018). The opposite trend has been detected in the boreal region, where temperature tends to be the most limiting factor; in this region, climate change is, therefore, enhancing forest productivity, even if winter frost has a negative impact on it (Kullman 1996). In temperate regions, the trend is more heterogeneous with different impacts according to the local and environmental conditions, especially related to water and temperature trends (Kurbanov and Post 2002; Lindner et al. 2010; Loboda et al. 2017). In the north-western part of the temperate oceanic region, tree growth and increment is slightly higher because of temperature increase, a factor that significantly influences tree response in the area, while in more south-eastern and temperate continental regions, water scarcity negatively affects the radial growth dynamics (Friedrichs et al. 2009; Horak et al. 2014; Panayotov et al. 2016). Finally, considering alpine areas, they are characterized by a general increase in timber production (Rogora et al. 2018), with the presence of an inverse trend where soil moisture is not enough to support a high photosynthetic rate (Meining et al. 2004; Galiano et al. 2010).

Regulating Services 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 the boreal region, the expansion of forests is changing the capacity of forest ecosystems to mitigate climate changes, because forest expansion decreases the albedo of the area (Beniston 2003). Regarding carbon sequestration, the impact of climate change on this ES varies in different regions. In fact, being strictly related to tree growth, stand capacity of stocking carbon follows a pattern similar to stem radial increment. For instance, in temperate continental regions, the carbon uptake is negatively impacted by the higher temperature and lower precipitation, because of the reduction of tree photosynthetic rate (Horak et al. 2014). In alpine and Mediterranean areas, CO_2 absorption can follow different patterns: in some regions, the carbon uptake is enhanced by global warming, due to the longer growing season and the earlier melting of snow or due to the rise up of the timberline (Rogora et al. 2018). In some other regions, a negative impact of climate change on forest carbon stock is recorded due to the lower capacity of forest soils to store organic carbon mainly caused by the accelerated decomposition of soil organic matter (Prietzel and Christophel (2014)). In this second case, Mediterranean mountain forests are generally further 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 of insects' range, winter survival and frequency of pest outbreaks (e.g. Battisti and Larsson 2015; Pureswaran et al. 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 ecosystems is harder to manage in comparison with the other regions, due to vulnerability of trees caused by water scarcity (Scarascia-Mugnozza et al. 2010).

Biodiversity protection has been considered as a broad ES, more specifically described by lifecycle maintenance, habitat and gene pool protection. Considering these indicators, in the recent years, biodiversity protection has increased in most of Europe. The regions that experienced a decrease in species richness are the Mediterranean region and the alpine region (Pauli et al. 2012).

Climate change also affects the dynamics of disturbances, such as fire, landslide and wind, making forests more vulnerable and affecting their capability of natural hazards regulation. In their paper, Seidl et al. (2007) analysed the correlation between climate change and natural disturbances and argued there was a direct interrelation between them.

13.5 Economic Evaluation of Climate Change Damages in Mountain Forests

The effects of climate change on mountain forest capability to provide ES in the different European bioclimatic areas have been identified in the first part of this chapter. In order to understand which are the consequent economic impacts caused by these changes, it is necessary to estimate the value of the considered forest ES. Several methods have been developed to estimate ES value, and different frameworks have been designed to systematize and to classify them. Hereafter, the framework developed by Masiero et al. (2019) in their manual *Valuing Forest Ecosystem Services: A Training Manual for Planners and Project Developers* has been used as reference (Fig. 13.2).

In the next Sects. (13.5.1 and 13.5.2), the cases founded in literature that use the methods shown in Fig. 13.2 to assess ES value will be presented and described. In

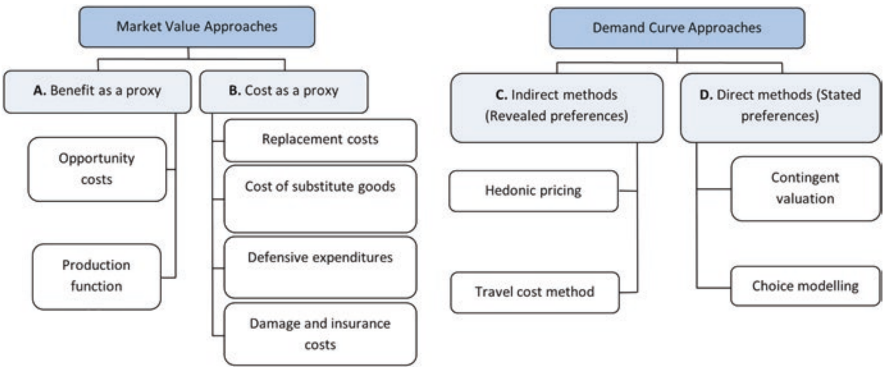

Fig. 13.2 Methods used to evaluate forest ecosystem services. (Masiero et al. 2019)

Sect. 13.5.1, the different ES provided by mountain forests are cross-checked with the methods used for their economic valuation with reference to the literature review.

The methods used for the assessment (financial and economic) of ES values can be divided into two main categories: “market value approaches” and “demand curve approaches”. In the first section (13.5.1), those cases where methods included in the first category have been implemented will be described. In the second section (13.5.2), 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 (Italy).

13.5.1 Market Value Approaches

This category comprises all the methods that are based on the use of values recorded by the market to carry out direct or indirect estimation of the value of mountain forest ES. Market prices can be a good signal of the value of 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 as “hard results”, i.e. connected with real evidence from the market. Nevertheless, in many cases, the results of the market value approaches represent an underestimate of the total economic value (TEV) of mountain forest ES.

(a) *Benefit as a proxy*

The “benefit as a proxy” methods comprise those methods that use the final revenues or economic benefits to estimate the value of goods and services. This category is represented by two main methods: *opportunity cost* and *production function*.

Opportunity Cost (OC) The OC describes the cost that the landowner has to incur when he/she decides not to change the specific land use or not to change his/her economic activities in order to maintain or enhance a particular mountain forest ES, therefore renouncing to an increase of his/her income. Let’s make some examples. The *opportunity cost* for a landowner that is involved in a project, aimed to enhance forest biodiversity, is represented by the income loss derived from the reduction on timber harvesting to comply with the project aim. The amount of income lost can be used to estimate the value of biodiversity protection in that forest, representing the additional revenue that the owner is willing to renounce to preserve biodiversity.

Because the OC strictly depends on the land cover or the activity performed in a specific area, its value is related to the local situation (Barton et al. 2013). Some examples of OC application are listed hereafter. Extensive application of this methodology was found in decision-making processes related to forest conservation, biodiversity protection, carbon sequestration or, at the contrary, forest exploitation (Kniivilä and Saastamoinen 2002; Seidl et al. 2007; Schröter et al. 2014; Hily et al. 2015). Similarly, OC approach has been used to consider the effects of land-use changes on the provision of different forest ES in Central and Eastern European countries (Ruijs et al. 2017) or to evaluate the different provision of forest ES, changing from a monoculture to a close-to-nature forest management system in order to estimate its costs and benefits (Schou et al. 2012). Another example in the use of OC is provided by Campos et al. (2020), where it has been used to estimate the environmental income deriving from different activities landowners can implement in a specific ecosystem, cork oak open woodlands, in southern Spain.

Production Function (PF) This method puts in relation a specific forest ES with the production of a specific good associated to the market. The forest ES is viewed as input for the provision of a specific good. The assessment of the economic value of the selected ecosystem service is calculated considering its contribution in the provision of the market good. The value of the forest ES is thus associated with the increase of income generated by the improved production system. In using this approach, it is necessary to know the existing relation between the forest ES and the provided good.

This method has been mainly used in literature for the valuation of regulating forest ES (see Table 13.2). To better understand the operational aspect of PF implementation, some authors that used it are here presented. Gren et al. (2018), for instance, used the *production function* method, in combination with another method called replacement cost that is described within the "cost as a proxy method", in order to assess the impact of pathogens spread in the capability of carbon dioxide sequestration in forest ecosystems. Another good example of the application of this method can be found in Nahuelhual et al. (2007), where PF was selected as a suitable methodology for assessing the economic value of water provision of the Valdivian forests in Chile. A similar application was used by Westling et al. (2020) to estimate the value of water quality regulation of Sweden forests used as input to produce drinkable water.

(b) *Cost as a proxy*

The "cost as a proxy" methods referred to those methods that use the cost incurred in producing a certain good or in substituting it with similar ones, as estimation of the economic value of the considered forest ecosystem service. This category comprises *replacement cost*, *cost of substitute goods*, *defensive expenditures* and *damage and insurance costs* methods.

Replacement Cost[1] (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

[1] 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).

Table 13.2 Forest ES and related economic evaluation approaches

ES			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	Replacement costs	Cost of substitute goods	Defensive expenditures	Damage and insurance costs	Hedonic pricing	Travel cost method	Contingent valuation	Choice modelling
Provisioning	Bioenergy production		x		x	x					x	x
	Timber production		x		x	x					x	x
	Non-wood forest products		x		x	x					x	x
Regulating	Climate regulation	Forest 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 regulation	Forest fires/ wildfires	x	x	x	x	x	x			x	x
		Erosion, avalanche, landslide	x	x	x	x	x	x	x		x	x
		Flooding	x	x	x	x	x	x			x	x
	Water quality regulation		x	x	x		x	x			x	x
	Biodiversity		x	x	x		x	x			x	x

Cultural	Recreation (hunting, nature enjoyment)	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

Source: Compiled by the authors based on the information from Forest Europe (2015) and Masiero et al. (2019)

value of the benefits associated with a certain forest ES is derived from the cost to replace the same benefit with different services or goods.

Several studies have used this methodology to assess forest ES values. Bianchi et al. (2018), for instance, carried out a literature review on the use of different methodologies to measure the value of protection services against rock falls, avalanches and landslides and for investment in flood protection in the Alps, in which RC proved its effectiveness (see also Notaro and Paletto 2012; Häyhä et al. 2015; Getzner et al. 2017; Accastello et al. 2019). Grilli et al. (2015) assessed the values of different forest ES in Italian alpine valleys. *Replacement cost* was also used to evaluate carbon sequestration in different forests, for instance, to assess the value of CO_2 sequestration in Swedish forests (Gren 2015), Italian forests (Notaro et al. 2009) and Iranian forests (Karimzadeh Jafari et al. 2020). The RC method was also used to assess water quality services provided by forests. In their paper, Hunter et al. (2019) estimated the value of water purification by coastal wetland in Louisiana, calculating the costs incurred by the treatment plants to provide drinkable water. A slightly different approach in the implementation of this method 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 plantation programme and assess its negative and positive aspects.

Cost of Substitute Goods (CSG) The rationale behind this methodology is to relate the value of the ecosystem service to the cost that would be necessary to produce a substitute good or service, also called surrogate, fulfilling the same or similar function. This method faces the difficulty of finding appropriate surrogates to forest ES that cover comparable functions. For this reason, the cases in which this method has been used are fewer compared to other methodologies.

An interesting application of this method was done to evaluate the different financial benefits, generated from provisioning ES in a specific region of Nepal, obtained by two different systems of community-based forest management (Acharya et al. 2020).

Defensive Expenditures (DE) This method analyses the value of a specific forest ES, associating it with the cost that would occur to avoid and/or reduce the negative environmental impact caused by the absence of the considered forest ecosystem service or with the hypothetic implementation costs for actions intended for the mitigation or compensation of the consequent damages caused by the absence of the considered ES.

This method was used in Morri et al. (2014) to quantify the monetary value of flood protection by forests of the Apennines in Italy. Moreover, in their paper, Snider et al. (2006) used the DE method to understand if the funds invested by the US federal government in forest fire prevention were effective. The value associated with the actions that had been implemented for forest fire protection by the government was used as a proxy of the value of the forest fire control services (regulating ES).

Damage and Insurance Costs (DIC) Always related to "cost as proxy", this method is used to assess the value of a forest ES, putting it in relation with the expenses incurred because of damages caused, for instance, by natural hazards or the insurance costs paid out as a result of the occurrence of the insured events.

In Pulkrab et al. (2011), this method was used to assess the value of pest control services of forests in the Czech Republic, calculating the damage caused by the outbreak. Similarly, in Gren et al. (2009), DIC was used to assess the damage caused by alien invasive species and their severe effects on biodiversity in Swedish forests. This method was also used to quantify the value of carbon sequestration of German forests (Wüstemann et al. 2014) and Irish forests (Clinch 2000). In Germany, DIC was also implemented to assess the monetary value of flood protection service of riparian forest (Barth and Döll 2016). Through this method, it was possible to estimate the avoided damage costs because of the presence of the riparian forest. The avoided costs were considered as a proxy of the value of the regulating ES itself. Finally, in Pavanelli and Voulvoulis (2019), DIC method was used to assess the value of those ES negatively affected by environmental damages.

13.5.2 Demand Curve Approaches

The second category of methods that allows the assessment of the economic value of forest ES is based on those methods that rely on the demand curve as a proxy. These methods are used whenever the assessment of market values is not applicable and when relevant non-market prices influence the calculation of the total economic value (TEV) of forest ES. This set of approaches works by estimating the value of forest ES through:

– The decisions made by real consumers revealed by their concrete expenditures (so-called indirect methods)
– The declared preferences of the real and potential consumers analysing their willingness to pay for a specific ES (so-called direct methods)

(c) *Indirect methods*

The "indirect methods" are those methods based on the revealed preferences of the end users and consumers. Through consumers' behaviour, in fact, it is possible to indirectly estimate the value they give to ES. In this category, two main methods are present: *hedonic pricing* and *travel cost methods*.

Hedonic Pricing (HP) This technique assumes that the final price of a specific good depends on its internal characteristics but also on some external factors. For instance, if house pricing is taken into consideration, houses with similar characteristics could have different prices. This is also due to the different location of the buildings that can be surrounded by different landscapes. The difference in the price of similar houses, which can be explained by the presence or absence of a specific landscape, is an indicator of the price that people indirectly give to that specific landscape. Dealing with ES, through this method, it is possible to estimate the value of different forest ES. For instance, the aesthetic value of a forest can be estimated as the additional amount people pay to buy a house surrounded by forest instead of a similar, but cheaper, house located in a small city.

A clear example of this is reported in a study implemented in Croatia, where *hedonic pricing* method was applied considering the price of hotel rooms to estimate the touristic value of Mediterranean forest (Marušić et al. 2005). In literature, it is also possible to find studies in which other ES were estimated through this method. For instance, the Austrian Federal Forests commissioned the valuation of the protective functions of forests against landslides, avalanches and rock falls (Getzner et al. 2017). In Switzerland, according to Schläpfer et al. (2015), the value of different landscape amenities (comprising forests) was estimated by analysing the variation in rental prices. According to Sundelin et al. (2015), through the analysis of the values of different forest features (such as fragmentation, density, shape and productivity), it was possible to detect which characteristics of forestland affect the Swedish land value. Finally, in Poland, this method was used to assess the value of the presence of urban forest, considering apartment prices (Łaszkiewicz et al. 2019). Outside Europe (in the USA and Canada), *hedonic pricing* was applied to evaluate, among the others, the impact on cultural ES (touristic and aesthetic services) in forest affected by insect infestation (Price et al. 2010), the value of hunting recreational services (Hussain et al. 2007) and the value of erosion control services provided by the Ohioan forests (Hitzhusen 1999).

Travel Cost Method (TC) In this method, the travel cost incurred by people who want to reach and visit a certain habitat/ecosystem is analysed to derive their willingness to pay for a specific forest ES or a combination of them. Generally, TC is used to estimate the value of cultural ES, specifically those related to tourism and recreation. In the implementation of TC, also the opportunity cost of time is considered in value assessment.

There are numerous applications of this method in assessing mountain forest ES. In Germany, for instance, it was used to estimate the value of cultural ES (recreation) provided by German protected areas (Mayer and Woltering 2018). It was also used to estimate the potential recreational value of forest in the UK (Ezebilo 2016), in the Czech Republic (Melichar 2014; Březina et al. 2019) and in Slovakia (Tutka and Kovalčík 2010). According to Moran et al. (2006), a more detailed TC method was carried out assessing the cultural services provided by Scottish forests, considering the cost of mountain biking as a recreational activity. In other cases implemented in the North America, specifically in the Rocky Mountains in Colorado (USA), this method was applied to assess the impact of forest fire on recreational ES (Loomis et al. 2001) and to assess the effects of tree density, influenced also by insect pests and other hazards, on the demand of recreational services (Walsh et al. 1989).

(d) *Direct methods*

The "direct methods" comprise those methods that collect the willingness to pay off end users in relation to specific ES. The main tools used by this methods' category are questionnaires and surveys that allow directly asking individuals' opinion when different scenarios are presented to them. The two direct methods that are hereafter described are the *contingent valuation* and the *choice modelling*.

Contingent Valuation (CV) This method aims to measure the willingness to accept the loss of a certain ES, if no actions for its provision or enhancement are implemented. Alternatively, it can be used to investigate the end users' willingness to pay for the implementation of actions aimed to support the provision of a specific ES. A representative sample of people who directly or indirectly take advantage of the presence of a defined ES is interviewed. The analysis of their responses allows gathering information about their readiness to accept the loss of the ES or their willingness to pay for its provision through the presentation of different scenarios.

The just described method was used to assess the value of forest recreational services in an Italian alpine valley (Grilli et al. 2014), in Slovakian mountains (Tutka and Kovalčík 2010) and in British woodlands (Christhe et al. 2007). Moreover, in the Appalachian Mountains, it was used to value the health protection function of forest ecosystems (Holmes and Kramer 1996). According to Bastian et al. (2017), CV was one of the methods used to assess the value of forest ES provided by Eastern Ore Mountains (Germany and Czech Republic). In Italy, it was used also to evaluate the aesthetic services of the national forest landscape (Tempesta and Marangon 2004).

Choice Modelling (CM) In *choice modelling* methods, consumers' willingness to pay is detected by asking them to choose the best option among 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 considered 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 into different attributes. One of the alternatives represents the current situation (baseline), and the other ones correspond to different variations of the selected attributes. Each scenario is associated with a different amount of money that has to be taken into consideration in selecting the most suitable alternative.

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

13.6 Conclusion

A large variety of studies can be found in the scientific literature about climate change and its impacts on forest ecosystems, but a deep interdisciplinary analysis investigating how global warming is affecting the provision of the different forest ES is still missing. Moreover, the literature highlights a lack of information regarding the impacts of climate change on the provision of certain forest ES, such as cultural ES and some regulating services, for instance, "natural hazard regulation" (see Sect. 13.4.1). Because of the high environmental and climatic variability of mountain regions, it would be necessary to rely on good quality and quantity of primary data to be able to have a comprehensive understanding of the whole phenomenon under discussion. For these reasons, there is the necessity to integrate the existing knowledge with studies aimed to investigate climate change impacts on tree physiology and stand structures and integrating these data with the consequent impact on the provision of forest ES. Changes in their provision significantly influence human livelihood, particularly in mountain areas where the interdependence between human and forest ecosystems is stronger and thus more exposed to changing climate.

Through the literature review, several methods to assess the economic value of goods and services were detected. The most frequently used methods are the *demand curve approaches*. This could be explained by the growing interest in the use of these methods, which makes it possible to assess the non-market value of ES, a value that often is not recorded in the financial analysis. Another explanation could be related to the fact that the *market value approaches*, such as *production function* or *cost of substitute good*, need a profound knowledge about the interrelation between forest functions and the resulting provision of ES, an interrelation that is still not always known or fully understood.

The aim of this chapter was to outline the existing methods used to assess the value of ES and give an overview of the climate change impacts on the mountain forests ES provision capacity. The methods described in this chapter allow the assessment of the TEV of mountain forest ES, which can be used to create a baseline to assess, in the future, how their value will be modified in relation to climatic changes. Implementing similar studies in the long period will allow monitoring the changing value of mountain forest ES, permitting proper estimate of the economic impact of climate change on them.

Moreover, the gathered data could be also used to fill in the knowledge gap existing in the evaluation of specific forest ES in specific areas of interest. In fact, through a different approach, known as *benefit transfer,* it would be possible to use the existing data on ES evaluation to estimate their value in different contexts.

Several databases are already present in the web, gathering valuations that can be used to transfer ES value from a specific geographic area to another. These databases are EUROFOREX (https://www.evri.ca/en), ENVALUE (https://www.environment.nsw.gov.au/envalue), RED Database (http://www.isis-it.net/red/start_search.asp), a database reported by Elsasser et al. (2016) and a database that is the result of a EC-financed research projects (http://ec.europa.eu/environment/enveco/studies.htm).

Concluding, the increasing importance of global warming and the need to estimate its impact on the different forest ES are increasing the attention of the academic world, citizens and policy-makers on it. Because mountain forests are ecosystems suitable for early detection of climate change impacts, they can be an interesting ecosystem to start the analysis about how climate change impacts on the provision of ES. A lot of studies already assess climate change impact on forest structures and tree growth, but it is necessary to improve the analysis of the impacts on ES provision to be able to estimate the economic loss (or gain) due to global warming. A deeper understanding could support the estimation of less evident impacts of climate change on forest ES in different contexts than mountain forest, implementing the *benefit transfer* methods. But it could also be necessary to provide some guidelines to forest managers and public authorities on the suitable forest management needs to minimize the negative impacts of climate change and maximize the positive ones.

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