State of the art of forest protection service economic assessment

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Summary

Introduction

The aim of the first deliverable of WP4 is to provide an overview of the methodologies used to assess the economic value of a specific ecosystem service: the protective effect of forests, with a special focus on rockfall events mitigation. This service is gaining great relevance for the well-being of people, especially in difficult environments as the Alps are (Edens and Hein 2013; Grilli et al. 2015; Miura et al. 2015; Price et al. 2011) where their functions can be viewed as positive externalities, since the market is still not able to include their value into market prices (Brun 2002) (M**A** 2005; Riera et al. 2012; Gret-Regamey and Kytzia 2007). Thus, “ecosystem services” is the broad term adopted to include their effects, moving from the financial to the economic evaluations (Nuti 2001; Gomez-Baggethun et al. 2010). According to the aim of the evaluations, it is possible either to resume in a unique value all the material and immaterial benefits generated by forests, computing the so-called Total Economic Value (Markantonis and Meyer 2011; Deal, Cochran, and LaRocco 2012), either to account for each value separately, focusing on the single services provided. Following these distinctions, this report concerns studies focused on the evaluation of a single, non-marketable value, which is the forest protection service. This effect is increasingly acknowledged as the most important for the Alpine forests, in parallel with the growing anthropization of these areas (Miura et al. 2015; Hayha et al. 2015; Zoderer et al. 2016).

In the last two decades, several research experiences in the Alpine Space improved the knowledge about the interactions between forests and gravitational hazards, developing also many software tools to estimate the kinetic energy of boulders and even to include the protective capacities of the forest (Stokes 2006; Cordonnier et al. 2008; Jancke, Berger, and Dorren 2013; Radtke et al. 2014; Fidej et al. 2015; Dupire et al. 2016). These models allow to obtain quantitative data about the processes, useful for many purposes, including the estimation of the socio-economic value of protection service performed by forests (Busch et al. 2012).

The aim of this report is to describe a state of the art on the economic assessment of forest protection services, which is based upon the interaction between two elements: the regulating ecosystem service provided by forest and the gravitational natural hazards, rockfall especially. As shown in figure 1, in order to deal with the issue from an economical point of view we collect those papers that performed an economic evaluation of the service.

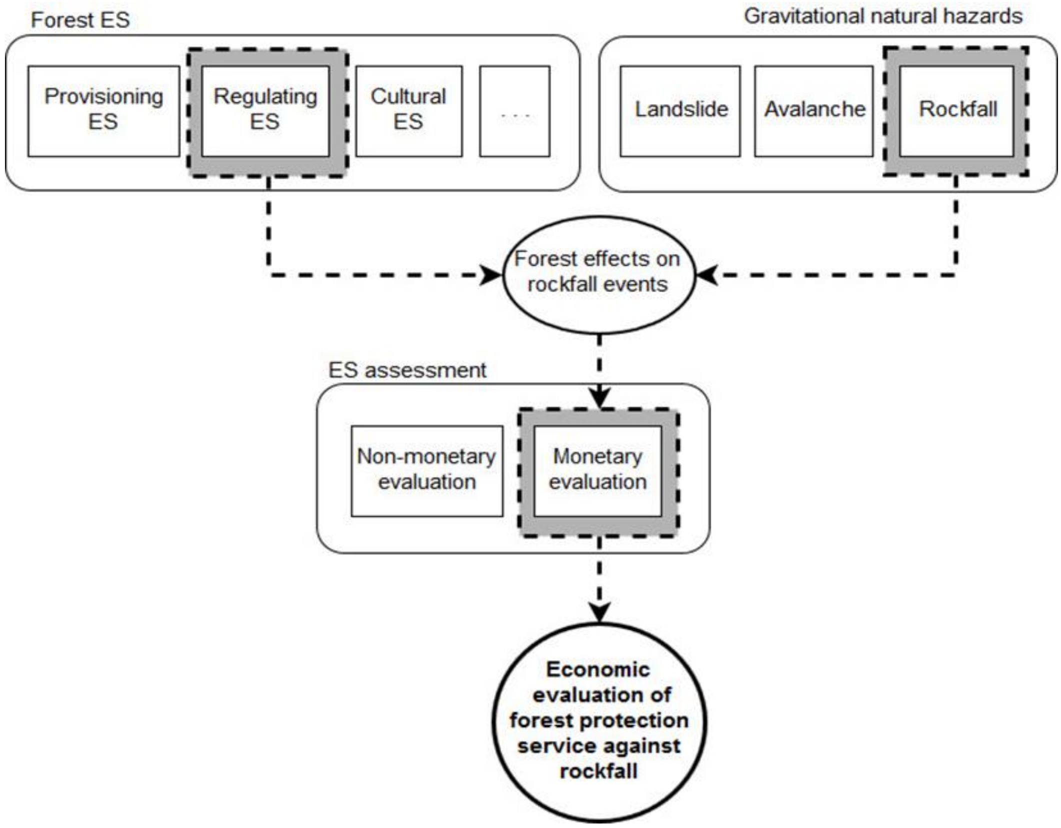

Figure 1 – Conceptual framework of the elements considered in the review, the focus of the report originates from the interactions between forest and rockfall from an economic perspective

This report is structured as follow. Initially, the most relevant concepts of the topic are introduced, that are the ES provided by forests in the Alpine space, mainly the mitigation of natural gravitational hazards, and rockfall especially; and the methodologies for the economic evaluation of the protection service. In the author's intention, these sections were included to ease the comprehension of the subject from its theoretical roots to the practical estimation of the value. Then, a specific focus has been dedicated to the territorial resilience, a topic linked to the forest protection service at a broader level, being mostly related to land management processes. Finally, we present the methodology adopted to achieve a "State of the art" of protection services evaluation, with the description of the results and a critical analysis of the data. After the Conclusion paragraph, in the Annex 1 we provide the full list of papers included in the research.

Ecosystem Services in the Alpine Space

The Alps are one of the most densely populated mountainous areas in the world: historically inhabited, they host important urban areas and a complex infrastructural network (Rudolf-Miklau et al. 2014). In this context, forests, covering 52% of their surface, hold an important role for local economies (Price et al.

2011). The benefits provided by forests range from raw materials extractions, food provision and climate regulation, to cultural and spiritual pleasure, all related with biodiversity (Haines-Young and Potschin 2010). Researches concerning Ecosystem Services are a relatively recent field of study but already relying on a vast literature, mainly produced in the last 20 years, not without disagreeing opinion and criticism (Boyd and Banzhaf 2007; Baveye, Baveye, and Gowdy 2013; Seppelt et al. 2011). A common feature to most of the studies is the need to define precisely which services are actually studied which depends upon the classification system that is used, and describe the natural process or elements involved in its proper territorial scale (Wallace 2007; Busch et al. 2012; Lindborg et al. 2017). To deal with such issues is a complicated task: in fact, the overlap of the services may easily lead to a miscalculation of their values (e.g. double counting) (Bateman et al. 2011; Deal, Cochran, and LaRocco 2012). Anyway, considering the socio-economic changes of the last 50 years and the anthropization of this territory (Holub and Hübl 2008; Zimmermann and Keiler 2015), the protection against the natural hazards ensured by forests (La Notte and Paletto 2008; Getzner et al. 2017) is gaining an increasing consideration and importance (Grêt-Regamey, Walz, and Bebi 2008; Miura et al. 2015; Grilli et al. 2017).

Dealing with “regulation and protection Ecosystem Service” we mean the physical or physico-chemical interactions between biomass and mineral fraction (de Groot, Wilson, and Boumans 2002), which in a forest are numerous and intense (Motta and Haudemand 2000; Ninan and Inoue 2013; FAO 2016). The protection service occurs only when the risk components can be observed (Fuchs et al. 2007; Olschewski et al. 2012), that is, when an event generates an abrupt release of energy in presence of an object prone to be damaged (Adger 2006). In fact, the risk is not considered for events occurring in absence of interactions with humans or human-related stakes (Brun 2002; Gret-Regamey, Brunner, and Kienast 2012).

Concerning these events, the role of forest for their mitigation has been widely recognised (Berger et al. 2013; Dorren 2003): the impacts of boulders with trees dissipate kinetic energy, reducing the probability of damages to buildings and people (Berger and Rey 2004; Saroglou et al. 2015; Hantz et al. 2016; Brauner et al. 2005). For a long time, given the lack of available evaluation methods, this service has been assessed only through empirical or qualitative methods (Volkwein et al. 2011). Moreover, accounting for the effectiveness of forest is recognized to be useful for a better design of defensive structures, which, apart from being expensive, generally have limited duration and strong environmental drawbacks (Holub and Hübl 2008; Howald, Abbruzzese, and Grisanti 2017).

The monetary evaluation of Protection Forest Services

As mentioned above, ideally, the value of forests can be broken down in several components, including both the “material” ones, related to wood and non-wood products, and the “immaterial” ones, concerning the other ecosystem services provided (Brun 2002)(See fig. 2).

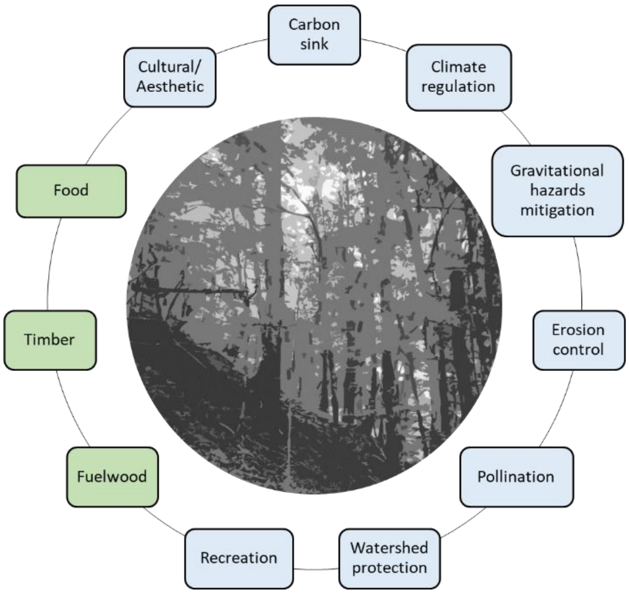

Figure 2 – List of the main forest ecosystem services, in light green the material ones

Depending on the evaluated service, some approaches are more suited than others (Farber, Costanza, and Wilson 2002; Hadley et al. 2011). How to properly evaluate the benefits provided by forests is still a debated issue, because of the changes in economy and society that have rendered obsolete the previous forms of accounting founded on market goods only (Goio, Gios, and Pollini 2008). Moreover, due to the relevance that ecosystems have for the wellbeing of people, the results of such evaluations assume often a political meaning, beyond the scientific one (Spangenberg and Settele 2010; Wallace 2007).

Methods dealing with preferences of people, stated or revealed, have enjoyed remarkable popularity in the past. Stated preference methods are survey-based economic valuation methods consisting in assessing the Willingness to Pay (WTP) or to Accept (WTA) of the participants of the survey to preserve (or reduce) an environmental asset. Revealed preference methods instead are designed to overcome the barriers related to perceptions by deducing, from the analysis of consumers’ habits, their preferences. They are commonly used in the literature to assess cultural and recreational services (Boyd and Banzhaf 2007). Many authors, instead, have expressed the opinion that such approaches were poorly suitable to evaluate the protection services, because their presence is often scarcely perceived or taken for granted by the beneficiaries (Mattea et al. 2016; Getzner et al. 2017; Farley and Voinov 2016). Regulation ecosystem services are usually assessed combining technical and monetary elements, often also involving experts opinion (Wolff, Schulp, and Verburg 2015; Grilli et al. 2015; Grilli et al. 2017).

Natural hazards and territorial resilience

The accounting of the protection service against rockfall, only one of the several aspects of the multi-faceted relation between ecosystems and society, is suitable for being included in a broader strategy of territorial management, whose key point is the concept of Social-Ecological Systems. A socio-ecological system (SES) is the representation of a bundle of interacting elements (a system) belonging either to natural elements either to technical and social spheres (Walker et al. 2004). Consequently, the boundaries of such SES are determined by ecosystem, social and normative characteristics, in order to consider any process from both the ecological and the human point of view (Hahn et al. 2008; Liu et al. 2007). In consideration of this connection, should be highlighted how disturbances altering some components of the society may then have impacts on the environment too and, vice-versa, in the ecosystem may be present elements that support the potential recovery of a community (Briner et al. 2013) (Fig.3).

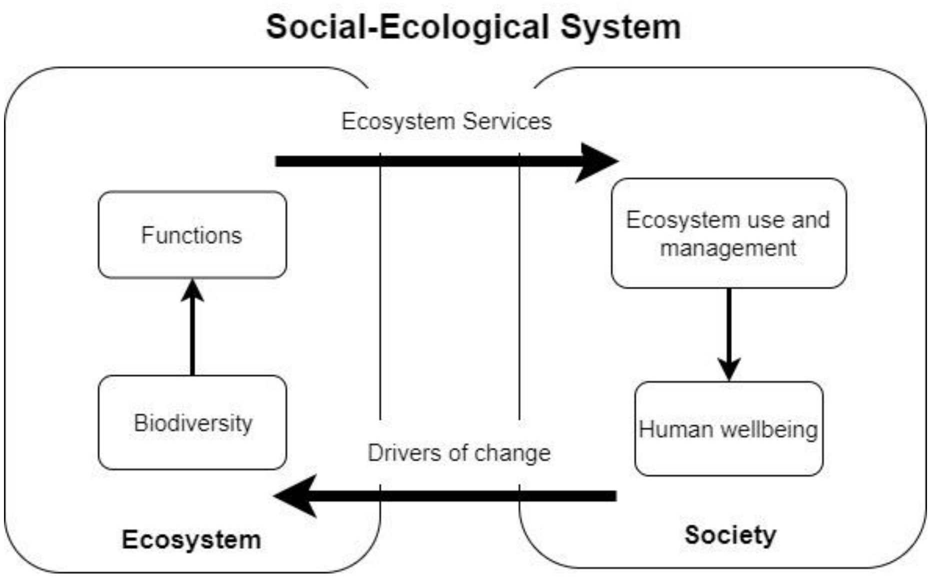

Figure 3 – Scheme synthetizing the interaction between ecosystems and society in a Social-Ecological system (Authors elaboration from (Maes et al. 2014))

In order to classify the response of a SES in presence of natural hazards, it is necessary to introduce the concept of resilience, whose applicability ranges to vast scales and fields of knowledge (Holling 1996; Fuller and Quine 2015). The definition of resilience itself is still controversial (Hosseini, Barker, and

Ramirez-Marquez 2016). It can be summarized as the capability of a given system to handle external forces of pressure and changes responding or reorganizing in ways that maintain its essential function, identity and structure, while also maintaining its ability to self-organize, learn and adapt (Hahn et al. 2008; Adger 2006; Hosseini, Barker, and Ramirez-Marquez 2016; IPCC 2014). Transposing the concept to SES, resilience can be viewed as the ability of a territorial system to maintain the present environmental and socio-economical equilibrium in spite of external influences (Carpenter et al. 2001; Brunner and Gret-Regamey 2016). The attention towards SES resilience is rising because of a growing environmental awareness of policy makers and stakeholders, coupled, on the other side, to the expected rise in intensity and frequency of natural hazards due to climate change (Newman et al. 2017). On a SES level, to consider the territorial resilience therefore means to account for the self-recovery capability of territories and the role of natural services in providing such function, crucial but still undervalued (Fratesi and Perucca 2017; Edens and Hein 2013). Often society tends to replace the natural processes with artificial means, that allow more short-term efficiency, but the multiple co-benefits provided by ecosystems should not be neglected. In fact, the inclusion of nature-based solutions in the risk management strategies would allow maintaining high performances in a durable and sustainable way through a positive redundancy of functions (Holling 1996; Maes and Jacobs 2017).

Resilience, anyway, is ultimately an aspect determined by human needs and it is problematic to ascertain a general unit of measurement (Fuller and Quine 2015) without specifying the “resilience of what to what” (Carpenter et al. 2001); nevertheless it can be assessed by taking some features as indicators to foresee the response to a stressor (Janssen et al. 2006). Some ecological indexes, like biodiversity, were proved to be related to resilience (Holling 1996; Blattert et al. 2017) and could provide a reliable proxy of its value. At the same time, the richness of an area in terms of trade networks, infrastructures and human capital, have a considerable weight in resilience processes as well (Fratesi and Perucca 2017; Cumming, Morrison, and Hughes 2017). Finally, another relevant feature is the number and quality of relationships existing between environment and society and, first of all, between social groups. The so called “social capital” determine how a community is capable to produce ecological consciousness (Hahn et al. 2008; Kenward et al. 2011; Farley and Voinov 2016) and to inform political decisions that may affect the fate of communities themselves and the supporting ecosystems (Adger 2006; Carpenter et al. 2001; Cumming, Morrison, and Hughes 2017). Finally, from the policy-makers point of view, the concept of territorial resilience supports a more flexible and bottom-up form of governance, favouring the involvement of stakeholders of different levels of interest and influence in the decisional process (Kangas et al. 2015). To consider all the resources (environmental and human) of a territory may help decision makers to face the challenge of providing essential services to people in spite of the current and future uncertainties, and to do this in the most timely and least burdensome way for the ecosystems (Rudolf-Miklau et al. 2014;

Brunner and Gret-Regamey 2016). Reliable accounting tools are therefore required to properly inform decision and policy-makers, leading, among the other, to a larger adoption of environmental evaluation techniques (Gamper, Thöni, and Weck-Hannemann 2006; Wallace 2007). Even if the transposition of natural goods in economic terms has been heavily criticized and often proved inadequate to meet sustainable goals (Krutilla 1967; Gomez-Baggethun et al. 2010; Spangenberg and Settele 2010; Baveye, Baveye, and Gowdy 2013), their employment results crucial to factor the natural assets together with human ones in decision-making processes (Daily et al. 2009). With this in mind, we can employ ecosystem service evaluation methodologies, as those listed and reviewed in this report, to account for environmental assets and their gains or losses in monetary terms, as any other economical good. Some examples of application could be the Cost-Benefit Analysis of risk reduction measures including nature-based solutions, adjustments in forest management and planning towards the optimization of the ES supply and, broadly speaking, a better allocation of resources supporting a sustainable territorial management (Teich and Bebi 2009). While being aware of the inherent limitations and problems of such an approach, its adoption is now necessary in order to influence, and hopefully improve, political decisions regarding the territorial management (Gret-Regamey and Kytzia 2007; Laurans et al. 2013; Moos et al. 2017).

Material and methods

A review of the international literature dealing with the protection services provided by forest was undertaken in 2017. The collected and analysed documents are those compliant with the following three requirements:

- Have a main focus, even if not exclusive, on natural gravitational hazards protection service supplied by forests;
- Perform an economic evaluation of the supplied service;
- Being located in the Alpine Space.

Any potential omission in the results have to be considered accidental or due to the lack of one of these requirements.

We created an excel worksheet with the studies that met the requirements (performed in the Alpine area, focusing on economical evaluation of protection services against gravitational hazards) collected by using search engines like Web Of Science, Scopus and Google scholar, and share it with the partners of the project RockTheAlps (see Annex B). The aim was to collect all the economic evaluations of the forest protection service against rockfall performed in the countries of the AS, i.e. France, Italy, Switzerland, Germany, Austria and Slovenia, even if published in grey literature, like reports, non-scientific journal articles and similar sources, and in languages other than English. Aside from rockfall protection service, the evaluation of other similar gravitational natural hazards like avalanches and landslides were considered, as well as generic evaluations of the overall protective function that specifically mention rockfall risks. This broadening can be considered scientifically coherent since the methodological approach to evaluate protection from such phenomena are the same (Hayha et al. 2015; Getzner et al. 2017). In the end, 24 studies were collected, of which 11 published on peer-reviewed journals (Tab 1 and Annex A). An ID number was assigned to each study in order to allow showing its features in the following analysis.

Project Partner	Number of provided studies
DISAFA	12
LWF	5
BRGM	3
SFI+SFS+BFFor	2
ERSAF	2

Tab 1 – Number of studies collected from the project partners

The following information was gathered from each study (Tab 2).

General info	**Study area**: municipality, region and country
	Spatial scale: local, sub-regional, regional or national
	Main **focus of the work**: overall protective function, rockfall, other gravitational hazards, …
Core info	Adopted **evaluation approach**: replacement cost method, avoided damages, revealed preferences, …
	Monetary value of the protection service: explicit value or range
	Expression of the monetary evaluation of the service: value /income, lump sum /annual,
	Time span considered in the evaluation
	Adopted **interest rate**
Additional info	**Measure of the effectiveness** of forest protection service: index, scale, energy measure, …
	Forest management Costs for the maintenance/improvement of the function
	Scenario analysis
	Stakeholder involvement in the evaluation process

Tab 2 – Resume of the information collected for each paper

Results and discussion

In general, the issues concerning this kind of evaluations are not a preeminent topic in scientific literature. A rising of articles conducted by searching some relevant keywords under the database of Web Of Science, displays a very uneven attention towards the issues that we are dealing with, as shown in tab 3.

	Rockfall*	Hazard*	Ecosystem service*	Econom* evaluat*	Protect*	Forest*	Alpine*
Rockfall*	**1696**						
Hazard*	605	**275594**					
Ecosystem service*	9	317	**25072**				
Econom* evaluat*	8	2334	1228	**131384**			
Protect*	342	18162	4081	6861	**1051262**		
Forest*	167	3112	6699	3437	21470	**342454**	
Alpine*	159	694	243	141	1288	4988	**33838**

Tab 3 – Numbers of records obtained through query with the keywords, separately (in bold in the table) and combined with the Boolean operator “AND” (Web of Science: accessed 30/10/2017) – Source: Authors own elaboration

Examining the results of single keywords search, shown in bold at the end of each row, it is evident that “Alpine*”, “Ecosystem service*” and, most of all “Rockfall*”, are significantly less frequent than others, probably due to their high specificity. Then, considering the keywords interactions, the aim of the report achieve very low records

The evaluation approaches used by the selected studies to assess the value of the protection service ensured by forests against gravitational hazards are briefly described afterwards.

- The replacement cost method adopts a substitution value equal to the expenses needed to reproduce the service with artificial means (Farber, Costanza, and Wilson 2002). This method explicitly relies on project documents to evaluate the costs of a defensive facility as effective as the forest (Notaro and Paletto, 2012). According to Bockstael, to be reliable, this approach has to satisfy three conditions: i) the hypothesized structure has to be as effective as the forest; ii) the structure with the least cost has to be chosen; iii) there must be a societal interest in maintaining the service, and in replacing it if missing (Bockstael et al., 2000).

- The avoided damages approach focuses instead on the stakes that are likely to be damaged from the event, and the probability for it to happen. In this case, the protective benefit of the forest is the reduction of expected damages for the exposed stakes in the area. To evaluate it, usually shall be carried out a comparison between scenarios of expected losses with and without forest for each kind of possible event (Bründl et al. 2009; Spangenberg and Settele 2010; Dupire 2011);
- Risk analysis, adopting an approach quite close to the avoided damages one, includes in the computation, in addition to the damages to buildings and human losses, the costs related to safety measures, emergency and first aid (Fuchs and McAlpin 2005; Fuchs et al. 2007);
- The contingent choice methods consist in eliciting, usually by means of interviews or surveys, from the people benefiting the protection how much would they value this ecosystem service: the results is the Willingness To Pay or Willingness To Accept (Hadley et al. 2011).
- The hedonic price approach is a revealed preferences method that consists in defining the effect of the service on the price of related market goods, usually residential buildings (Hadley et al. 2011; Spangenberg and Settele 2010);
- The benefit transfer method, finally, considers the results of similar evaluations with the same aim and adapt them to the object of the assessment (Ready et al. 2004).

According to those categorization, the papers were then classified in consideration of the main subject of the evaluation and of the evaluation approach adopted (tab.4).

n.	Replacement cost	Avoided damages	Contingent choice	Risk management	Benefit transfer	Hedonic price	Tot. *
Protective function	[2],[6],[7],[8], [13],[17],[19], [20],[21],[22],[24]				[16]		12
Gravitational hazards	[3],[23],[24]	[3]	[1]		[16]	[23]	7
Rockfall	[11],[12],[13],[22]	[11],[12],[18]					7
Avalanche	[11],[14],[22]	[9],[10], [11],[14]	[1],[14], [15]	[4],[5],[14]			13
Flood protection	[3]	[3]					2
Tot. *	22	9	4	3	2	1	-

Tab 4 – Analysis of the studies in consideration of object of the evaluation and the adopted approach; when a study adopts more than one evaluation method or investigates more than one aspect, it is repeatedly inserted in the correspondent cell

As expected, the studies not always put rockfall hazard or gravitational phenomena as principal focus (5 papers each), but instead a broader subject is considered, encompassing all the protection services of alpine forests (12 papers). In addition, a relevant number of studies are mainly dedicated to the economic evaluation of avalanches, adopting nonetheless the same approaches (Holub and Hübl 2008; Getzner et al. 2017). Those approaches are mainly classical of environmental economics, and among those emerges a clear primacy for the replacement costs, used in 18 studies, followed by the calculation of avoided damages, used in 7 studies. Only three studies rely on stated preferences of the service beneficiaries, although another one [20] undertakes a preliminary survey among stakeholders in order to establish a ranking list of ecosystem services, which are subsequently evaluated with different methods.

Regarding the avoided damages approach, the second most used, it relies on the assets in the study area: looking at their number, features and spatial layout it is possible to determine a value for the protective effectiveness of forests, in terms of variation of probabilities of harmful events. The presence of forest, for example, may determine longer return periods for disasters, and this effect can be isolated by constructing different scenarios (Dorren, Berger, and Putters 2006). Usually only direct damages are assessed, that means partial or total destruction of buildings and infrastructures like roads, railway, pipelines etc. and human losses, were a monetary value for human life should be somehow established. In some studies [4] the indirect damages, related to economic and social disruption were also estimated.

Comparative studies are interesting, as the one undertaken by Getzner et al. (2017) [23], where the protective value of public owned forests is assessed using both the replacement cost approach and the hedonic prices, showing that values obtained using the latter method are substantially lower. For one study only [16] we found appropriate the definition of "benefit transfer" for the adopted approach (Brouwer 2000), because it applies the measurements produced in another study [17] to a different territory. The scarceness of studies focusing on the evaluation of protective function is surely a circumstance that makes difficult to use benefit transfer in those estimations, because its fruitful use is linked to the availability of so-called prime studies carried out in other areas.

Concerning the geographical distribution of the collected studies showed in figure 4, it appears that all the countries of the Alpine Space are represented, albeit unevenly.

Figure 4 – Studies collected in the review by nation; the symbol "*" indicates the presence of transnational studies, that were counted for each represented country

The vast majority of the studies concern small areas (19 out of 24), being the effects of rockfall highly localised (Volkwein et al. 2011). Two studies [12 and 11] involve several case studies localised in different countries.

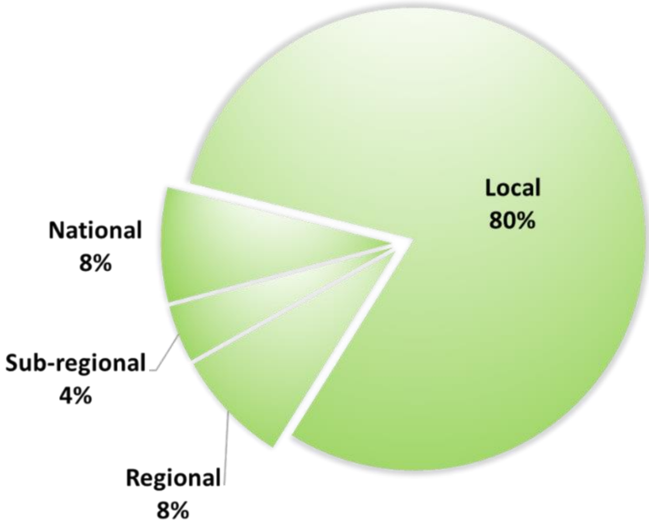

Figure 5 – Share of reviewed studies in respect of scale of analysis

Some areas, instead, mainly the ones where the avoided damages approach is used, appear in more than one study, which is reasonable due to the amount of data required to implement such evaluations. The few studies undertaking national scale evaluations show anyway some limitations: in one case, only the public owned forests are accounted [23], in the other, the estimation was carried out over the whole Alpine space, in a declared rough form, and the obtained value is sharply lower than others indeed [8].

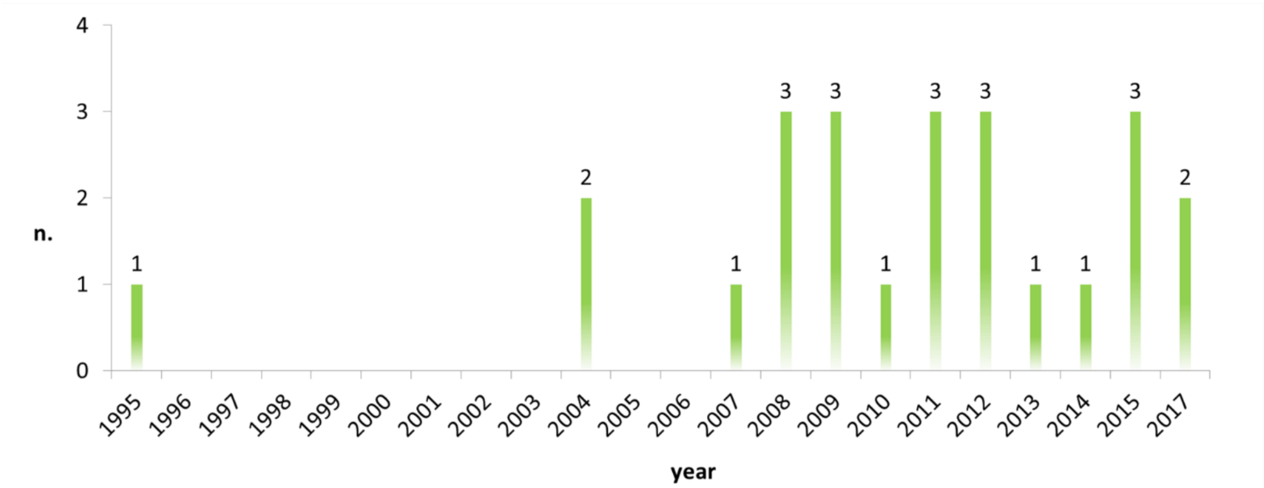

Figure 6 – The number of papers collected in relation to their publication year

The time pattern of the studies is interesting as well, allowing noticing how the issue, a highly specialized topic in the broad field of ecosystem services evaluation, has been the subject of studies only since the second half of the nineties (Figure 6). After the first study in German language in 1995 [1], new studies appeared only nine years later, in Italian [2] and in German languages [3], completely independently of each other. Since 2007 onwards, conversely, the issue has attracted a rising interest, being addressed almost yearly by one study or more.

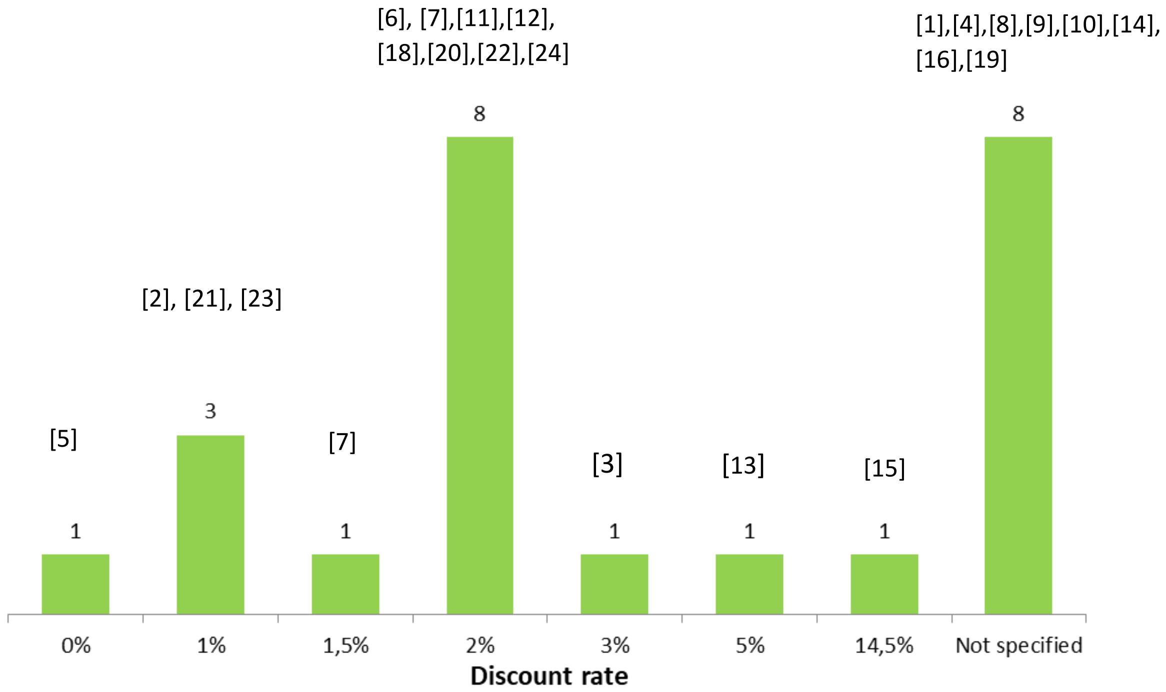

Figure 7 – Discount rates and related number of studies that adopt it; above any bar is reported the ID number of the corresponding study

Discounting is the financial mechanism that allows assessing the present value of future costs and benefits. It relies on a numerical factor called discount rate, whose value has strong implications for economic assessments. The higher the discount rate, the lower the present value of the future expected costs and/or benefits. Thus, discounting is indispensable to account for the time factor into economical evaluations (Gamper, Thöni, and Weck-Hannemann 2006) and make decisions in the present time. In the appraisal of environmental projects the chosen discount rate strongly affects the results and, therefore, the consequent operative decisions (Dupire 2011). All the studies we collected, but one [15], adopt low and fixed discount rates (from 0 to 5%, see Fig. 7), and justify the selection with respect to the societal function of forests and their self-renewal capacity (Dupire 2011). In France, only country among the alpine space, a decreasing discount rate, from 2,5% to 1,5% was established by law for the socio-economic impact of public investment projects. One study [15] adopt a very high discount rate, equal to 14,5%, obtaining it from interviews to the people about the willingness to pay to reduce hazard.

Not all the reported studies, however, use the financial calculation. Four of these ([3], [20], [22], [23]), use a discount rate but does not specify a time period in which to apply it. The reported time frames span from eight years to 100 and 300 years (in [12] and [10] respectively). Studies adopting the replacement cost use mostly the lifetime of protective facilities used to represent the environmental services: eco-engineering structures [17], net fences [12], steel grids [23] etc., whose lifespan ranges from 10 to 70 years. Discount rates have a paramount role in determining the monetary value that the studies achieve, especially when long time periods are involved (Hepburn and Koundouri 2007). This fact may partly explain the high variability of final values of the protection service, spread across several orders of magnitude, from hundreds of thousands (and even millions) of euros to negative values. Firstly, however, we have to mind the different measurement units adopted to express the protection service in monetary terms. In Fig. 4, we distinguish “values” from “incomes” (which is value/time).

Incomes	money/household/yr	From 18 to 56 $/household/yr	[15]
	money/area/yr	From 0 to 5’000 €/ha/y	[2],[3],[6],[8], [9],[10],[11], [17],[19],[20], [21],[22],[23], [24]
	money/yr	From 5’500 to 16’289’717 €/yr	[12],[13],[16]
Values	money/household	From 20 to 600 CHF/household	[14]
	money/ha	From 767,9 to 29’056 €/ha	[7]
	money	From -14’112’408 to 6’765’917 €	[4],[18],[5]

Figure 8 – Expressions of monetary value of protective function, grouped by values and incomes, beside any bar is reported the ID number of the corresponding studies

As we may observe, the majority of studies (19) express the monetary value in form of yearly income, referred to forest area or, in one case, protected households. The yearly income of a portion of agricultural land, or annuity, is a common parameter to value crops and forest, and many landowners are familiar with it. Either the remaining cases give lump sums instead, bounded to the individual household

[14] or to the sheltered area [7], in one case [5] the value is negative, emerging from a comparison between the current situation and a future scenario.

Finally, in the studies were noted the presence of four elements, identified as significant to characterize further the evaluation (Fidej et al. 2015; Blattert et al. 2017): the stakeholder involvement; an evaluation of forest effectiveness; the inclusion of costs of forest management and the use of scenarios analysis. Among the collected studies only four ([12],[14],[18],[23]) account for the forest management as an expenditure item, and five ([11], [14], [15], [18], [20,]) include the stakeholder involvement. More confidence, instead, emerges with the scenario building and the measurement of forest efficacy (10 and 7 cases respectively). It is also worth noting that 10 studies do not consider any of these topics ([1],[2],[6],[8],[9],[19],[20],[21],[22],[24]), and 7 consider just one of them ([3],[4],[5],[7],[13],[16],[17]). Finally, in two studies, [14] and [18], all those aspects were presented. Nevertheless, it should be stressed that the inclusion of those aspects may serve the purpose of the evaluation or not, depending on the chosen approach and data availability: for this reason their presence or absence should not be taken as a quality or accuracy indicator.

Conclusions

This report proved how, in the last decades in each country of the Alpine Space were carried out attempts to assess the forest protection service in monetary terms.

In line with the trends reported in literature, the most used approach is the replacement cost (54%), followed by the avoided damages method. These findings are consistent with some available guidelines on evaluation of ecosystem services (Hadley et al. 2011; Wolff, Schulp, and Verburg 2015), in which the replacement costs approach appears as the most straightforward way to evaluate protection services. Although this approach does not systematically account for the complexity of all socio-ecological processes (Farber, Costanza, and Wilson 2002), if properly adapted, it may lead to reliable results. Moreover, it is easy to understand (Bockstael et al. 2000). As for the application of methods based upon avoided damages, they are often hindered by the lack of reliable data (Galve et al. 2016).

Not all the evaluations involves financial calculations, but in such cases, low discount rates are preferred: the most adopted was a 2% discount rate. The reported values of the service greatly differ across studies due to the many aspects that may affect the final computation. With regard to the manner in which monetary results are expressed, a clear preference for regular incomes (e.g. annuity) appears. Methods based on stakeholder participation or the simulation of virtual scenarios are quite used but not essential. Other aspects like the evaluation of forest effectiveness as shelter and the costs related to forest management oriented to enhance this effectiveness can be interesting but are not often included.

Those findings are a valuable starting point for the following tasks of our WP and may offer useful insights for the developing of a harmonized evaluation procedure of forest protection service.

Acknowledgment

The authors wish to acknowledge the crucial contribution received by the partners of the Interreg Alpine Space project “RockTheAlps” that search for, and eventually provide, studies included in the review; we are deeply grateful for the support of them all.

Annex

Annex A – Full reference and corresponding ID number of the studies compliant with the review criteria.

ID	Full reference
[1]	Löwenstein W. (1995) Die monetäre Bewertung der Schutzfunktion des Waldes vor Lawinen und Rutschungen in Hinterstein (Allgäu). In: Bergen V, Löwenstein W, Pfister G (1995) Studien zur monetären Bewertung von externen Effekten der Forst- und Holzwirtschaft. Schriften zur Forstökonomie Bd. 2. Frankfurt a.M.: Sauerländer's Verlag. 185 S.
[2]	Notaro S. Paletto A. (2004) Economic evaluation of the protective function of mountain forests: a case study from the Italian Alps. In Buttoud et al. (eds.) 2004 The Evaluation of Forest Policies and Programmes, EFI proceedings, pag 75.
[3]	Kennel M. (2004) Vorbeugender Hochwasserschutz durch Wald und Forstwirtschaft in Bayern. LWF Wissen Nr. 44. 76 S.
[4]	Grêt-Regamey A., Kytzia S. (2007) Integrating the valuation of ecosystem services into the Input-Output economics of an Alpine region. Ecological Economics, 63, 786-798.
[5]	Grêt-Regamey A., Walz A., Bebi P. (2008) Valuing ecosystem services for sustainable landscape planning in Alpine regions. Mountain Research and Development, 28, 156-165
[6]	Notaro S., Paletto A. (2008) Natural disturbances and natural hazards in mountain forests: a framework for the economic valuation. -Discussion paper
[7]	La Notte A. and Paletto A. 2008. 'La funzione protettiva dei boschi del Cansiglio: una preliminare valutazione economica'. DENDRONATURA 2: 37-53.
[8]	Chevassus-au-Louis B. et al. (2009), Approche économique de la biodiversité et des services liés aux écosystèmes. Contribution à la décision politique. Centre d'analyse stratégique, rapport n°18, paris, 399 p.
[9]	Borsky S., Weck-Hannemann H. (2009) Sozio-ökonomische Bewertung der Schutzleistung des Waldes vor Lawinen. alpS Projekt C.2.5 Endbericht. 79 S.
[10]	Teich, M., Bebi, P. (2009). Evaluating the benefit of avalanche protection forest with GIS-based risk analyses-A case study in Switzerland. Forest Ecology and Management, Volume: 257 Issue: 9 Pages: 1910-1919
[11]	Cahen M. (2010), Ouvrages de parade contre les risques naturels en montagne et fonction de protection de la forêt : analyse économique comparative -
[12]	Dupire S. (2011) Action 2.4.1 Étude économique. Démarche et principaux résultats. In: Projet Interreg « Forêts de protection ». pp Page, AgroParisTech – ENGREF, Nancy.

[13] Žujo J., Marinšek M. (ACTUM) (2011) - Ekonomsko vrednotenje ekosistemskih storitev Lovrenških jezer

[14] Olschewski R., Bebi P., Teich M., Wissen Hayek U., and Grêt-Regamey A. (2011) Lawinenschutz durch Wälder – Methodik und Resultate einer Zahlungsbereitschaftsanalyse. Schweizerische Zeitschrift fur Forstwesen: November 2011, Vol. 162, No. 11, pp. 389-395.

[15] Olschewski R., Bebi P., Teich M., Wissen Hayek U., Grêt-Regamey A. (2012) Avalanche protection by forests — A choice experiment in the Swiss Alps. Forest Policy and Economics, 17, 19-24.

[16] De Marchi M., Scolozzi R. (2012) La valutazione economica dei servizi ecosistemici e del paesaggio nel Parco Naturale Adamello Brenta. Valutazione Ambient 22, 54–62.

[17] Notaro S., Paletto A. (2012) The economic valuation of natural hazards in mountain forests: An approach based on the replacement cost method. Journal of Forest Economics, 18, 318-328.

[18] Gouin V. (2013) Analyse coût-bénéfice appliquée aux risques naturels de montagne : Intégration des fonctions de la forêt dans l'évaluation économique des stratégies de protection contre les chutes de blocs, Mémoire de fin d'études, AgroParis Tech.

[19] Schirpke, U., Scolozzi, R., De Marco, C. (2014) Modello dimostrativo di valutazione qualitativa e quantitativa dei servizi ecosistemici nei siti pilota. Parte1: Metodi di valutazione. Report del progetto Making Good Natura (LIFE+11 ENV/IT/000168), EURAC research, Bolzano, p. 75.

[20] Grilli G., Nikodinoska N., Paletto A., De Meo I. (2015) Stakeholders' Preferences and Economic Value of Forest Ecosystem Services: an Example in the Italian Alps. Baltic Forestry, 21, 298-307.

[21] Hayha T., Franzese P., Paletto A., Fath B. (2015) Assessing, valuing, and mapping ecosystem services in Alpine forests. Ecosystem Services, 14, 12-23.

[22] Paletto A., Geitner C., Grilli G., Hastik R., Pastorella F., Garcia L. (2015) Mapping the value of ecosystem services: A case study from the Austrian Alps. Annals of Forest Research, 58, 157-175.

[23] Getzner M., Gutheil-Knopp-Kirchwald G., Kreimer E., Kirchmeir H., Huber M. (2017) Gravitational natural hazards: Valuing the protective function of Alpine forests. Forest Policy and Economics, 80, 150-159.

[24] Grilli G., Ciolli M., Garegnani G., Geri F., Sacchelli S., Poljanec A., Vettorato D., Paletto A. (2017) A method to assess the economic impacts of forest biomass use on ecosystem services in a National Park. Biomass and Bioenergy 98, 252-263.

Annex B – Database of the collected information

ID Number	Project partner	Full reference	Study area	Study scale	Topic (or object) of the evaluation	Adopted approach	Stakeholders involvement	Forest efficiency accounting	Are different scenarios presented?	Are silvicultural practices considered?	Range of the Results	Unit of measure of the Results	Interest rate	Time span	Link to reference
1	DISAFA - UniTo	Notaro S, Paletto A (2012) The economic valuation of natural hazards in mountain forests: An approach based on the replacement cost method. Journal of Forest Economics, 18, 318-328.	Valdastico; Trentino-Alto adige; Italy	Local scale	Overall protective function	Replacement costs	No	Yes, score assignation based on expert judgment	No	No	284,2	€/ha/yr (Annuity)	2%	8-35 years	http://dx.doi.org/10.1016/j.jfe.2012.06.002
2	DISAFA - UniTo	Grilli G, Nikodinoska N, Paletto A, De Meo I (2015) Stakeholders' Preferences and Economic Value of Forest Ecosystem Services: an Example in the Italian Alps. Baltic Forestry, 21, 298-307.	Valle di Non; Trentino-Alto Adige; Italy	Local scale	Overall protective function	Replacement costs	Yes, semi-structured interview to rank ecosystem services by preference	No	No	No	103,6	€/ha/yr (Annuity)	2%	Not defined	not available
3	DISAFA - UniTo	Hayha T, Franzese Pp, Paletto A, Fath Bd (2015) Assessing, valuing, and mapping ecosystem services in Alpine forests. Ecosystem Services, 14, 12-23.	Fassa valley and Fiemme valley; Trentino-Alto Adige; Italy	Local scale	Overall protective function	Replacement costs	No	No	No	No	0-5000; weighted average 1888	€/ha/yr (Annuity)	1%	10-20 years	http://dx.doi.org/10.1016/j.ecoser.2015.03.001
4	DISAFA - UniTo	Paletto A, Geitner C, Grilli G, Hastik R, Pastorella F, Garcia Lr (2015) Mapping the value of ecosystem services: A case study from the Austrian Alps. Annals of Forest Research, 58, 157-175.	Leiblachtal; Vorarlberg; Austria	Local scale	Water regulation and erosion control (indirect); rockfall and avalanches protection (direct)	Replacement costs	No	No	No	No	581 (indirect); 707 (direct)	€/ha/yr (Annuity)	2%	Not defined	https://www.researchgate.net/publication/272978094
5	DISAFA - UniTo	Getzner M, Gutheil-Knopp-Kirchwald G, Kreimer E, Kirchmeir H, Huber M (2017) Gravitational natural hazards: Valuing the protective function of Alpine forests. Forest Policy and Economics, 80, 150-159.	Austria	National scale	Gravitational hazards protection	acement costs and hedonic p	No	No	Yes	Yes	268 (replacement costs); 53 (hedonic prices)	€/ha/yr (Annuity)	1%	Not defined	http://dx.doi.org/10.1016/j.forpol.2017.03.015
6	DISAFA - UniTo	Notaro S, Paletto A (2008) Natural disturbances and natural hazards in mountain forests: a framework for the economic valuation. - Discussion paper	Valdastico; Trentino-Alto Adige; Italy	Local scale	Overall protective function	Replacement costs	No	No	No	No	284,74	€/ha/yr (Annuity)	2%	8-35 years	not available
7	DISAFA - UniTo	Gret-Regamey A, Kytzia S (2007) Integrating the valuation of ecosystem services into the Input-Output economics of an Alpine region. Ecological Economics, 63, 786-798.	Davos, Grisons, Switzerland	Local scale	Avalanche protection	Risk management approach	No	No	Yes	No	33001 - 38039	thousands of CHF	not specified	Not defined	http://dx.doi.org/10.1016/j.ecolecon.2007.02.026
8	DISAFA - UniTo	Grêt-Regamey A, Walz A, Bebi P (2008) Valuing ecosystem services for sustainable landscape planning in Alpine regions. Mountain Research and Development, 28, 156-165	Davos, Grisons, Switzerland	Local scale	Avalanche protection	Risk management approach	No	No	Yes	No	-14112408	variation across 48 years	0%	1997-2045	http://dx.doi.org/10.1659/mrd.0951
9	DISAFA - UniTo	Notaro S, Paletto A (2004) Economic evaluation of the protective function of mountain forests: a case study from the Italian Alps. In Buttoud et al. (eds.) 2004 The Evaluation of Forest Policies and Programmes, EFI proceedings, pag 75.	Province of Trento;Trentino-Alto Adige; Italy	Regional scale	Hydrogeological protection	Replacement costs	No	No	No	No	186,85	€/ha/yr (Annuity)	1%	10-26 years	not available
10	DISAFA - UniTo	Olschewski R, Bebi P, Teich M, Wissen Hayek U, Grêt-Regamey A (2012) Avalanche protection by forests — A choice experiment in the Swiss Alps. Forest Policy and Economics, 17, 19-24.	Andermatt; Uri; Switzerland	Local scale	Avalanche protection	Contingent choice	Yes	No	Yes	No	18-56	US$/yr/household (Annuity)	14,50%	50-70 years	http://dx.doi.org/10.1016/j.forpol.2012.02.016
11	DISAFA - UniTo	Dupire S (2011) Action 2.4.1 Étude économique. Démarche et principaux résultats. In: Projet Interreg « Forêts de protection ». pp Page, AgroParisTech – ENGREF, Nancy.	Bellevaux and Lioutre; Haute-Savoie; France - Fontaine; Isère; France - Grignon; Savoie; France - Morgex; Aosta Valley; Italy - Sarreyer; Valais; Switzerland	Local scale	Rockfall protection	cement cost and Avoided da	No	Yes	Yes	Yes	17855 - 57200 (Rep. Costs); 5500 - 99200 (Avo. Damages)	€/yr	2%	100 years	not available

12	SFI+SFS+ BFFor	Jasmina Žujo, Miha Marinšek (ACTUM) (2011) - Ekonomsko vrednotenje ekosistemskih storitev Lovrenških jezer - report committed by the Institute of the Republic of Slovenia for Nature Conservation	Lovrenška lakes (high-altitude wetla	Local scale	Protection agains soil erosion and rocfall	Replacement costs	No	No	Yes	No	0	€/yr	5%	50 years	http://www.zrsvn.si/dokumenti/64/2/2011/Vrednotenje_Lovrenskih_jezer_final_julij_2011_2476.pdf
13	SFI+SFS+ BFFor	Grilli G., Ciolli M., Garegnani G., Geri F., Sacchelli S., Poljanec A, Vettorato D., Paletto A.(2017) A method to assess the economic impacts of forest biomass use on ecosystem services in a National Park. Biomass and Bioenergy 98, 252-263.	Triglav national park- Slovenija	Regional scale	Indirect protection (soil erosion and water flow regulation), direct protection (protection of people and human activitities against	Replacement costs	No	No	No	No	707 (dir.pro.) and 581 (ind.pro.)	€/ha/yr (Annuity)	2%	15-35 years	http://www.sciencedirect.com/science/article/pii/S0961953417300582
14	BRGM	Gouin V. (2013) Analyse coût-bénéfice appliquée aux risques naturels de montagne : Intégration des fonctions de la forêt dans l'évaluation économique des stratégies de protection contre les chutes de blocs, Mémoire de fin d'études, AgroParis Tech.	Fontaine; Isère; France	Local scale	Rockfall protection	Avoided damages	Yes, from models	Yes	Yes	Yes	- 181 475 (sc. with forest and palisade) to 6 765 917 (sc. forest only)	€	2%	100 years	not available
15	BRGM	Cahen M. (2010), Ouvrages de parade contre les risques naturels en montagne et fonction de protection de la forêt : analyse économique comparative - Memoire de fin des etudes	Veyrier-du-lac; Haute-Savoie; France	Local scale	Rockfall protection, Avalanche protection	Avoided damages, replacement costs	Yes, from models	Yes	No	No	1400	€/ha/yr (Annuity)	2%	100 years	https://www.yumpu.com/fr/document/view/16530422/ouvrages-de-parade-contre-les-risques-naturels-en-montagne-et-
16	BRGM	Chevassus-au-Louis B, Salles J-M, Pujol J-L (2009), Approche économique de la biodiversité et des services liés aux écosystèmes. Contribution à la décision politique. Centre d'analyse stratégique, rapport n°18, paris, 399 p.	France	National scale	Overall protective function	Replacement cost	No	No	No	No	8	€/ha/yr (Annuity)	not specified	Not defined	http://www.ladocumentationfrancaise.fr/var/storage/rapports-publics/094000203.pdf
17	LWF	Borsky S, Weck-Hannemann H (2009) Sozio-ökonomische Bewertung der Schutzleistung des Waldes vor Lawinen. alpS Projekt C.2.5 Endbericht. 79 S.	St. Anton am Arlberg, surface of considered release area 7,5 ha, Austria	Local scale	Avalanche protection	Avoided damage in terms of risk (considered elements: human lifes, recreation, buildings, infrastructures)	not specified	no	no (risk calculation is based on a 150 yr return period avalance. Authors mention	no	10	€/yr/m2	not applicable	Not defined	not available
18	LWF	Löwenstein W (1995) Die monetäre Bewertung der Schutzfunktion des Waldes vor Lawinen und Rutschungen in Hinterstein (Allgäu). In: Bergen V, Löwenstein W, Pfister G (1995) Studien zur monetären Bewertung von externen Effekten der Forst- und	Hinterstein (Allgäu Alps), surface of protection forest 275 ha, Germany	Local scale	Avalanche and landslide protection	Contingent choice ?? (german: "Bedingte Bewertungsmethode"). Method is based on interviews with inhabitants and asks for	not specified	no	no (only one scenario to be valuated: maintaining current quality level of	no (see comment)	unit option a) 49,47 - 111,18 DEM/Person/yr (95% Confidence interval); mean 80,66	option a) DEM/Person/yr option b) DEM/yr	not applicable	Not defined	not available
19	ERSAF	De Marchi M, Scolozzi R (2012) La valutazione economica dei servizi ecosistemici e del paesaggio nel Parco Naturale Adamello Brenta. Valutazione Ambient 22, 54–62.	Parco Naturale Adamello Brenta, Tre	Sub-regional scale	1) Mitigation and prevention of damaging events 2) Overall protective function	1) Potential economic value - This evaluation is based on experts assessments and on the indirect estimation method referred as	not specified	No	Yes (referring to the value estimation adopted approaches)	No	1) 3.994.785,67 2) 16.289.717,67	€/yr	not specified	Not defined	https://www.researchgate.net/profile/Massimo_De_Marchi/publication/258511032_La_valutazione_economica_dei_servizi_ecosistemici_e_del_paesaggio_nel_Parco_Naturale_Adamello_Brenta/links/00b495286b459d0251000000/La-valutazione-
20	ERSAF	Schirpke, U., Scolozzi, R., De Marco, C. (2014) Modello dimostrativo di valutazione qualitativa e quantitativa dei servizi ecosistemici nei siti pilota. Parte1: Metodi di valutazione. Report del progetto Making Good Natura (LIFE+11 ENV/IT/000168), EURAC research, Bolzano, p. 75.	•Valvestino (SIC IT2070021), Lombardia, Italy •Bagni di Masino - Pizzo Badile - Val di Mello - Val Torrone - Piano di Preda RossaBagni (ZPS IT2040601, SIC IT2040019, SIC	Local scale	Protection against erosion and geological instability (landslide and slope instability)	Replacement costs	not specified	No	No	No	159,86 - 608,89	€/ha/yr (Annuity)	not specified	Not defined	http://www.lifemgn-serviziecosistemici.eu/IT/Documents/doc_mgn/LIFE+MGN_Report_B1.1.pdf
21	DISAFA - UniTo	La Notte, A. and A. Paletto. 2008. 'La funzione protettiva dei boschi del Cansiglio: una preliminare valutazione economica'. DENDRONATURA 2: 37-53.	Cansiglio, Veneto, Italy	Local scale	Overall protective function	Replacement costs	no	Yes	No	No	29056 (upper class); 6253 (middle class); 767,9 (lower class)	€/ha	1,50%	10-40 anni	not available
22	LWF	Roland Olschewski, Peter Bebi, Michaela Teich, Ulrike Wissen Hayek, and Adrienne Grêt-Regamey (2011) Lawinenschutz durch Wälder – Methodik und Resultate einer Zahlungsbereitschaftsanalyse. Schweizerische Zeitschrift fur Forstwesen: November 2011, Vol.	Andermatt; Uri; Switzerland	Local scale	Avalanche protection	four approaches: i) risk management, ii) cost for alternative technical measures, iii) willingness to pay based on choice experiment (interview),	yes, in the risk management approach based on methods in Teich&Bebi (2009) but not described	yes, authors state that within the risk approach, scenarios in form of different forest structures and a windthrow scenario were analyzed. The	yes	yes, used as a measure to compare to the economic evaluation	for different approaches: i) 470, ii) 60-600, iii) 440, iv) 20	CHF/household as a one-time payment	not specified	80 yr	https://doi.org/10.3188/szf.2011.0389
23	LWF	Kennel M (2004) Vorbeugender Hochwasserschutz durch Wald und Forstwirtschaft in Bayern. LWF Wissen Nr. 44. 76 S.	area a) example for a mountain forest: catchment of Halblech....area b) example for an alluvial forest: section of Mittlere Isar	Local scale	Flood protection	two approaches: i) replacement cost, ii) avoided damage	no	No	Yes. The resulting range of values is based on positive and negative	(no) but authors mention that opportunity costs (profit from other possible land use) would need to be	for different approaches and areas: ai) 0-60 bi) 0-600 aii) 0-40 bii) 0-10	€/ha/yr	for approach i) 3%	Not defined	http://www.lwf.bayern.de/service/publikationen/lwf_wissen/035020/index.php
24	LWF	Teich, M. ;Bebi, P. (2009). Evaluating the benefit of avalanche protection forest with GIS-based risk analyses-A case study in Switzerland. Forest Ecology and Management, Volume: 257 Issue: 9 Pages: 1910-1919	Andermatt; Uri; Switzerland	Local scale	Avalanche protection	Avoided damages	No	yes, authors state that within the risk approach, scenarios in form of different forest structures and a windthrow scenario were analyzed. The	Yes	No	184000	CFH/ha/yr	not specified	300 years	http://dx.doi.org/10.1016/j.foreco.2009.01.046

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