

Economic concepts for evaluation of risk mitigation strategies

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Index

Index.....	2
List of figures and tables.....	2
Acronyms.....	2
1. Introduction.....	3
2. Basic concepts of economic value.....	5
2.1 Definition of total economic value.....	6
3. Methods for the evaluation of ecosystem services	8
3.1 Applied methodologies	10
4. Results: fact sheets of main economic evaluation methods.....	12
4.1 The replacement cost method	12
4.2 The avoided damages method.....	15
4.3 The contingent valuation method.....	18
4.4 The choice modelling method.....	21
4.5 The benefit transfer method.....	25
5. Conclusions.....	28
Acknowledgements.....	30
References.....	30

List of figures and tables

Figure 1 – Supply and demand curves of a hypothetical good or service. Source: Hadley et al. (2011).	5
Figure 2 – Framework of the components of total economic value. Source: Turner et al. (2014).	6
Figure 3 – Framework of the main methods of economic evaluation of ecosystem services.	8
Table 1 – List of papers used for the application case included in the fact sheet	10

Acronyms

WTP: willingness to pay;

TEV: total economic value;

WTA: willingness to accept;

RCM: replacement cost method;

ADM: avoided damages method;

CV: contingent valuation;

CM: choice modelling;

BT: benefit transfer.

1. Introduction

One of the main functions offered by forests in mountain regions is to protect people, productive activities, settlements and infrastructure against natural hazards, such as rockfalls, landslides, floods and debris flow (Teich and Bebi 2009; Unit 2007; Brang et al. 2006; Dorren et al. 2004). This is also quoted in the first paragraph of the Mountain Forests Protocol of the Alpine Convention, which states: "The mountain forests offer the most effective, economical and suitable for landscape protection, against natural risks" (Dorren, Berger, and Putters 2006; Alpine Convention 2013). However, the effectiveness of this protective function is closely dependent on local conditions, especially at small scale level. For example, the forest has a protective action against rockfall thanks to the presence of trees with strong stems which can hinder the rolling boulders (Dorren et al. 2005) and a root system able to keep the masses, but also to disrupt them (thanks to the mechanical action conducted by the roots and enzymatic production of root exudates) (Stokes et al. 2005). In addition, climatic and edaphic conditions, presence, size and distribution of gaps, density and number of large trees, directly affect this function too (Schönenberger 2001; Notaro and Paletto 2008). All these factors characterize the extent, magnitude, and the likelihood for these events to occur (Dorren et al. 2005; Bebi, Kienast, and Schönenberger 2001; Teich and Bebi 2009).

Natural hazards, which nowadays seem to increase (Leiter 2011), and which are triggered by catastrophic events and by the current climate change, may decrease the ability of the forest to provide this specific function. In order to maintain this function, Miura et al. (2015) claim that a forest management based on a landscape or basin scale approach is essential (Kammerbauer and Ardon 1999; Postel and Thompson Jr 2005). In this regard, it is particularly useful the adoption of Social-Ecological Systems as a reference area. These systems consider the various interactions between society, environment and natural risks (Liu et al. 2007; Walker et al. 2004), through the creation of a multi-scale network (Zimmermann and Keiler 2015) whose boundaries are determined both by the characteristics of the ecosystem and by social and regulatory components (Hahn et al. 2008). Taking into account the management of all social and natural resources available including the forest, this approach contributes to the reduction of risks of natural hazards and creates greater resilience on a local scale, making the territory able to tackle climate change (FAO 2006, 2007). Vice versa, once the forest has been destroyed, the only solution is to adopt artificial protective measures, such as logs, wooden grids, dams and nets against rockfall with consequent changes in land use. All these elements have the task to reduce the risk and to prevent costly damages to infrastructure and local populations, but their high costs and impacts cannot be neglected (Olschewski 2013).

Despite many ecological studies were conducted in an attempt to quantify the importance and dynamics of the forests' protective function (Motta and Haudemand 2000; Brang 2001), only a few took into account economic aspects, obtaining different results, depending on the methodology used (Dupire 2011; Notaro

and Paletto 2012; Olschewski 2013; Bianchi et al. 2018). In spite of these differences, it was found that most of the authors of these studies assessed, among the different services offered by mountain forests, a greater economic value for the regulating service (especially protective service) rather than to other services, such as provisioning of raw materials, carbon sequestration, landscape and recreational services (Marangon and Gottardo 2001; Häyhä et al. 2015; Getzner et al. 2017; Blanc et al. 2018). On the basis of these reflections, it can be affirmed that for a correct planning and management of the forests offering this service (i.e., protective function), it is necessary to adopt an approach which takes into account not only ecological aspects, but also economic ones (Notaro and Paletto 2008). However, this approach is still little used today and without methodological uniformity.

The aim of this report, which is the deliverable T4.2.1 of WP4 of the Interreg Alpine Space project "RocktheAlps", is to define the main concepts for economic analyses of alternative risk mitigation strategies (e.g., avoidance, replacement and compensation), which are closely dependent on available economic data. To do this, it is necessary to collect and describe the main methods of economic evaluation of the forest protective role against falling rocks. The results will provide the necessary conceptual basis for the deliverable T4.3.1, consisting in the development of the economic evaluation model of the forests' protective function against rockfall, called ASFORESEE (Alpine Space FORest Ecosystem Service Economic Evaluation).

This report is divided into four sections after this introduction. The first outlines the basic concepts of economic value theory. The second describes the different methods of economic evaluation of ecosystem services, describing the applied methodologies. In the third section the available methods are extensively described and their adoption discussed in the light of the economic evaluation of the rockfall protection service. Finally, the Conclusions section resumes the general findings of the deliverable and depicts the future deployment of the project.

2. Basic concepts of economic value

The term **value** has different meanings depending on the field in which it is applied. From the economic point of view, it is: "The amount of money or goods to which a good or a service can be exchanged with" (Roncaglia and Corsi 2017). Although there are different ways to define and measure the value, such as friendship, faith and others, the economic value proves to be useful when we need to take a choice regarding trade-offs in resource allocation, even though in some cases it may be defined as illicit or unethical (e.g., the value of environmental damage cannot be defined exhaustively by money) (De Marchi and Scolozzi 2012).

Preferences, what individuals want to meet their particular needs, renouncing to the consumption of alternative goods or services, are the measure of the economic value (King, Mazzotta, and Markowitz 2000). To express preferences, people make choices and compromises daily, given certain constraints, such as income, availability, tastes and trends. In other words, preferences reveal the utility (since it cannot be measured directly) of a particular good or service and they reflect the willingness to pay (WTP) for it or the willingness to accept (WTA) to give it up (Novelli 2017).

The concept of WTP, which is equivalent to the economic concept of value, is illustrated and briefly described below (Figure 1) containing the demand and supply curves of a generic good or service (Hadley et al. 2011).

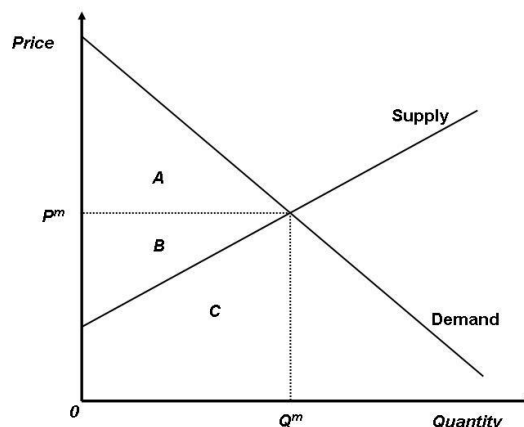


Figure 1 - Supply and demand curves of a hypothetical good or service. Source: Hadley et al. (2011).

It is often assumed, incorrectly, that the market price is a proper measure of the economic value. However, it only shows us the *minimum* amount that an individual is willing to pay to get a good or service (B + C). Many people are willing to pay a higher price than the market price; hence, their value is above their market price. In order to estimate the most appropriate economic value, it is really important to fix the *net*

benefit or the *surplus* of a good or a service (Triangle A). By summing the three areas: $A + B + C$, we obtain the *gross social benefit*, which is the economic value of the good or service (Johansson 1987).

2.1 Definition of total economic value

The ecosystem values measure the importance given by people to ecosystem goods and services (King, Mazzotta, and Markowitz 2000). They are measured by estimating the aggregate individuals' WTP in order to maintain or to improve a given good or service. However, this assessment is not always so simple, as different ecosystem services, such as biodiversity, the view of a panorama, etc., do not always have a market price or, alternatively, people are not familiar with the service provided by the ecosystem: in this case the definition of WTP becomes more complex (King, Mazzotta, and Markowitz 2000). Anyway, this does not mean that these services have no value, but simply the market does not recognise them: thus they can also be defined as *price-less goods*. As described in the next section, there are several ways allowing to elicit the WTP to obtain a certain good or service, or the willingness to accept (WTA) to transfer it (King, Mazzotta, and Markowitz 2000), determining its economic value.

In economics, in order to achieve the economic value of any ecosystem resource as a whole, the concept of total economic value (TEV) has been defined (Figure 2). The TEV is the amount of resources, expressed in common monetary terms, that society would lack if the ecosystem resource were lost (Adger et al. 1995).

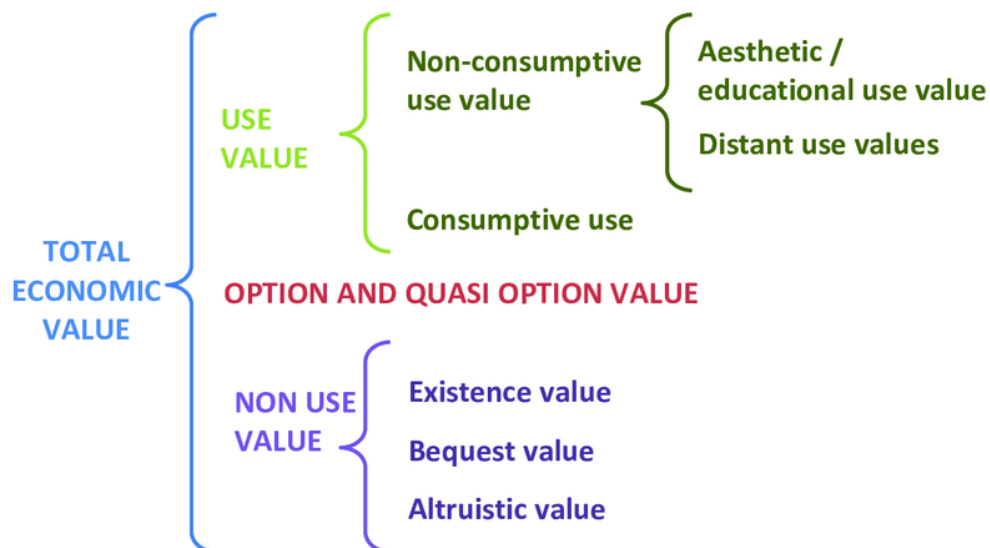


Figure 2 – Framework of the components of total economic value. Source: Turner et al. (2014).

The TEV includes several values, which are grouped under two main categories: *use value* and *non-use value* (or *passive use*) (King, Mazzotta, and Markowitz 2000). The former is based on use, therefore, there is a direct interaction with the resource, such as in the case of walking within a forest, fishing or mushrooms' picking, or indirect, like watching a documentary or photos which show a specific area and its nature, the carbon sequestration or the protection against natural hazards offered by a forest. On the contrary, the latter is more complex and difficult to assess, because it is strictly linked to ethical concepts, as the benefits which simply result from the knowledge of a particular ecosystem conservation (Hadley et al. 2011). The *non-use value* can be divided into different components depending on the authors. Hereinafter we show the division presented in a study conducted by Hadley et al. (2011):

- *existence value*: this value lies in the good itself (i.e., *intrinsic value*), for the simple fact that it exists, whether it can help others or not;
- *bequest value*: it relates to benefit awareness deriving from the conservation of the resource for future generations' use;
- *altruistic value*: it derives from satisfaction to ensure to current generation to get a resource.

Finally, there are two more categories, which are the *option value* which is the value that people attribute to the availability of an environmental resource for a hypothetical future use, such as bioprospecting, that is, e.g. the maintenance of biodiversity may be useful for as a future source of new medicines (Hadley et al. 2011). Lastly, the *quasi-option value*, which is very similar to the previous one, but it is associated with waiting for better information about the resource, in order not to give up on preserving it for a possible future use.

The *option value* also contains three fundamental concepts, which are:

- *uncertainty*: the imperfect knowledge of the proper functioning of ecosystems and benefits that could result from it;
- *irreversibility*: a destroyed or exhausted ecosystem or environmental resource, in many cases cannot be reconstituted; it follows that the information and benefits included in it are lost for good;
- *uniqueness*: an environmental good has some intrinsic characteristics that make it unique. Thus, the good is not replaceable.

Once the TEV is defined, it can be estimated by different economic evaluation methods, which are described in the following section.

3. Methods for the evaluation of ecosystem services

In this section, in order to pursue the aim of the report, we deal the monetary economic methods available to evaluate the rockfall protection service offered by protective forests. This value, within the framework presented in the previous section, is an example of *indirect use value* of a good. In this section, although aware of the presence of other non-monetary economic methods available, including the *Economic Quality of Woods* (Brun 2002), and non-economic one, such as discussion groups, citizens' juries and Q-method that allow to obtain qualitative or quasi-quantitative evaluations of certain ecosystem services (e.g., biodiversity) (Christie et al. 2008); we focused on economic methods only, in relation to the aims of this report.

The classification here adopted for the economic methods considered is the one proposed by Pascual et al. (2010), shown in Figure 3.

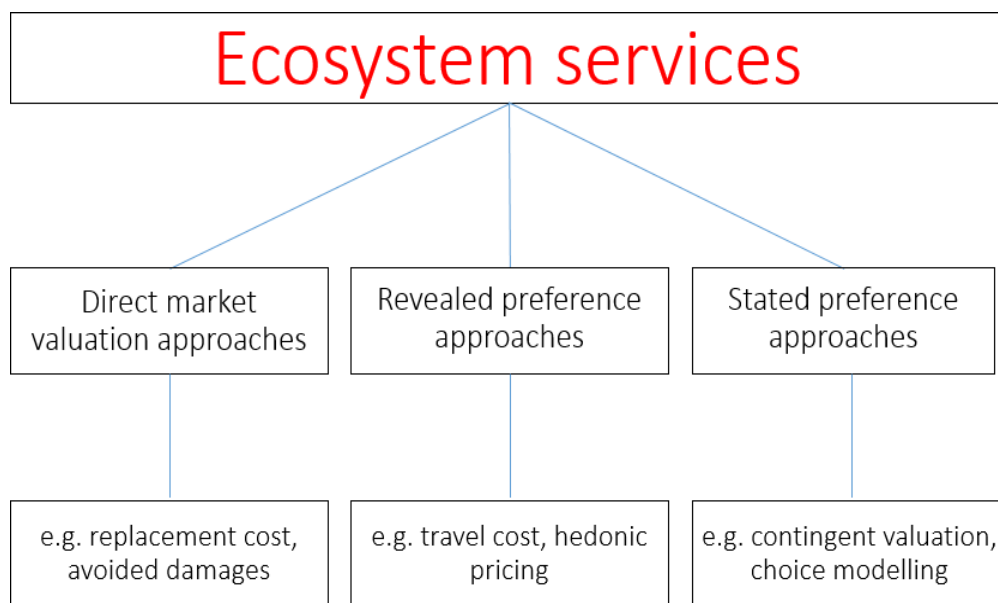


Figure 3 - Framework of the main methods of economic evaluation of ecosystem services.

Among the methods available, we have:

1. direct market evaluation approaches: they have the major advantage to use current market data, and thus, they are able to reflect the actual preferences of individuals (Pascual et al. 2010). Furthermore, they are also easy to understand, they can be used both by technicians and policy makers, and they can be used in situations in which resources and time are limited, since based on readily available data.

They only measure one component of the economic value, that is the *use value*. These approaches are divided into three different types (Pascual et al. 2010):

- 1.1. market prices-based approach: to estimate the value of provisioning services, because the resulting products are sold on the market. It is based on the notion that marginal costs and preferences are equal in a perfect market. It follows that the market price of a good may also be an efficient indicator of the value of that good;
 - 1.2. cost-based approach: it is very much used for the damages estimation and so it is appropriate to estimate the value of regulating services, such as the protective role of ecosystems against natural hazards. It is based on costs we should face in order to produce an artificial substitute able to supply as much benefits as we have with the ecosystem service, providing a proxy of its economic value (Garrod and Willis 1999). For example, the replacement cost method (RCM) and avoided damages method (ADM) are included in this group;
 - 1.3. production function approach: it is based on the relationship between a specific ecosystem service (e.g., regulating service) and the production of a market good (Pattanayak and Kramer 2001; Mäler, Gren, and Folke 2005). So, it estimates the value of the changed ecosystem service, according to the corresponding change in the production process of market goods offered by the market itself. Such approaches also make it possible to evaluate, for example the appropriateness of a land use change;
2. revealed preferences approaches: they are based on the observation of the individuals' actual behaviour in a surrogate market; in other words, to estimate the economic value of a given good, they refer to another good somehow connected to it. Travel cost method and hedonic price method are part of this approach. However, these methods cannot be used for the estimation of risk mitigation strategies as they are limited to certain sectors (e.g., parks, real estate market). In addition, one of the major disadvantage of these methods it is that we can only estimate the *use value*;
 3. stated preferences approaches: through the creation of a hypothetical market in which goods are not effectively exchanged, people are asked the WTP or WTA to keep or transfer a given good or service. They can be adopted to estimate the TEV, even if complex. This approach includes contingent valuation (CV) and choice modelling (CM).

There is one more method which does not fit into any of the categories above, which is the benefit transfer method (BT). It can use all the methods of economic evaluation, as it consists in applying the primary data of a pre-existing study (conducted by using different methods) to another study site. The major advantages of BT method are: reduced implementation costs and limited requested time (it requires less time than a

completely new study). However, the reliability of this method depends on the accuracy of the pre-existing study (Defra 2007).

3.1 Applied methodologies

On the basis of the above classification, and with the support of the results collected in the deliverable T4.1.1, the methodologies for the economic evaluation of the protective value of forest protection against falling rocks are listed and described below. Fact sheets are dedicated to each applicable methodology; they have been structured as follows: a brief description of the economic method used, the field of application, the main advantages and disadvantages deriving from its use, an application case and the conclusions.

In order to compile them, we collected and analysed several documents. We obtained them through bibliography research using different search engines, such as Web of Science, Scopus, and Google Scholar, but also thanks to the previous deliverable T4.1.1 of the project, namely "State of the art of economic valuation of the forest protection service" (Bianchi et al. 2018) and the contribution offered by the partners of the "RockTheAlps" project, with the sharing of their works. The documents chosen for application case in fact sheets met the following requirements:

- they should treat an economic evaluation method for the estimation of the forests' protective service;
- they should be focused on the service offered by forests against natural hazards;
- they should be located in a country of the Alpine Space.

The list of works used as an application case for the fact sheets of the different methods described is given in table 1.

Author(s)	Title	Year	Adopted method
Notaro e Paletto	The economic valuation of natural hazards in mountain forests: An approach based on the replacement cost method.	2012	RCM
Cahen	Ouvrages de parade contre les risques naturels en montagne et fonction de protection de la forêt : analyse économique comparative.	2010	ADM
Olschewski, Bebi, Teich, Wissen, Hayek and Grêt- Regamey	Avalanche protection by forests – A choice experiment in the Swiss Alps.	2012	CM

Table 1 – List of papers used for the application case included in the fact sheets.

The objective was to identify for each major economic evaluation method one or more articles which treated rockfall as natural hazards. It was not possible to do it for all application case. So we also took into account others gravitational natural hazards, such as avalanches, since the economic methods adopted for their evaluation can be similarly used for rockfall (Teich and Bebi 2009; Olschewski et al. 2012; Olschewski 2013).

4. Results: fact sheets of main economic evaluation methods

4.1 The replacement cost method

Description

The replacement cost method (RCM) uses, as measure to estimate the value of the ecosystem or its services, the incurred costs to replace it with artificial substitutes (Farber, Costanza, and Wilson 2002; Dixon et al. 2013). It is based on the assumptions that incurred costs are a proxy of the value and match the people WTP to replace environmental ecosystem services (King, Mazzotta, and Markowitz 2000). This method, as defined by Shabman and Batie (1978) and then discussed by other authors (Bockstael et al. 2000; Freeman III, Herriges, and Kling 2014) requires following conditions to be satisfied:

- the artificial substitute should provide people similar functions to those offered by the ecosystem;
- the artificial substitute should be the cheapest among all the available alternatives;
- society should be willing to support these costs rather than to sacrifice the ecosystem service.

The field of application

It is commonly employed in the estimation of support and regulating services offered by an ecosystem (de Groot, Wilson, and Boumans 2002), such as nutrient cycling and decomposition of pollutants (Xue and Tisdell 2001), quality of water (Gibbons 1986). In addition, the method is applicable to the economic evaluation of rockfall in forest as shown by Paletto (2015) and Getzner (2017), but it can also be employed to the assessment of other natural hazards such as avalanches, floods, erosion (Leschine, Wellman, and Green 1997; Niskanen 1998). We can also use this method together with other ecosystem services (ES) evaluation techniques, for example benefit transfer (Garrod and Willis 1999; Sundberg 2004) in order to increase its reliability.

Main advantages:

- it is easy to employ as well as to reproduce (EFIMED and CTFC 2015; King, Mazzotta, and Markowitz 2000);
- it may be an option when stated preferences approaches fail (i.e., misspecification biases and information biases) (Barkmann et al. 2008), as it is not connected to the demand function (Notaro and Paletto 2008);
- its use requires a relatively small number of data and limited time compared with preferences-based approaches (Gunatilake and Vieth 2000);

- it is useful when it is not possible to conduct detailed survey or when resources and data can be limited.

Main disadvantages:

- the RCM is not able to estimate the *non-use value* of an ecosystem good or service;
- perfect substitutes of natural capital do not exist: while this is multifunctional (e.g., timber production, climate and water regulation, protective services, cultural services), this method considers only one function;
- finding substitutes for some services can be difficult (Sundberg 2004; Edwards-Jones, Davies, and Hussain 2009);
- costs to replace ecosystem good or services are not always valid measures of benefits (i.e., possible underestimation) (EFIMED and CTFC 2015);
- the RCM does not consider social preferences for ecosystem goods and services (King, Mazzotta, and Markowitz 2000);
- it is just a partial measure of TEV (Hadley et al. 2011).

Application case

Source

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(4), 318-328. doi: <https://doi.org/10.1016/j.jfe.2012.06.002>.

Localization

Valdastico, Trento, Italy.

Purpose

Creation of a cursory method (e.g., for forest management plans by forest managers) for the estimation of the forests' protective service using the RCM.

Method

It is divided into two phases. The first consists in the use of ecological and physical data (available from forest management plans) in order to identify forest attributes directly or indirectly involved in protection (e.g., characteristics of the stand and the site), then assigning them protection scores based on the information contained in the management plan and in the literature. The second step is to use RCM to transform ecological and natural data into economic data, that is to translate data scores into economic values (i.e., per ha/year or per ha). This process is conducted using the average unit prices of the bioengineering works hypothesized as the most suitable alternatives for the protective function of the forest, obtained from the local market.

Results and Discussion

The income obtained, that is 284.20 €/ha/year, is consistent with incomes estimated from other research conducted in the Italian Alps. These vary approximately, depending on the spatial scale chosen and how the forest is considered (i.e., as a whole or only protective service), from 74 €/ha/year to 2,600 €/ha/year (Notaro and Paletto 2004; Goio, Gios, and Pollini 2008; Häyhä et al. 2015).

Comment

This method can be easily applied by forest technicians in the management and planning phases, as it uses data already included in forest plans. However, the disadvantages should also be remembered, such as the subjectivity in the choice of the best artificial substitute for the forest and in the assignment of scores, in addition to those typical of the RCM. The limitations mentioned above require further research to improve the application of this method, but it is believed that it can be used in evaluations relating to multifunctional forest management, representing a valuable tool to support the complex decision-making processes for forest management.

Conclusions

The RCM reveals itself advantageous because it is based on objective data and reproducible results, it is not directly related to a demand function and does not require laborious processes. It is a compromise between the quality of the information obtained and the cost of its implementation. For this it is one of the most used ES evaluation techniques, as emerged in deliverable T4.1.1 of this project (Bianchi et al. 2018). However, we should also remember disadvantages, including the difficulty to identify, in some contexts, the artificial substitute, or those relating to the correct size and the consequent cost, which is very important for the application to defensive value of the forest. Finally, while apt to territorially extended applications, there are limits when it is extrapolating the results obtained of a site specific assessment in non-homogeneous contexts.

4.2 The avoided damages method

Description

The avoided damages method (ADM) estimates the value of the protective service offered by an ecosystem on the basis of the reduction of expected damage to protected good (Bianchi et al. 2018). The elements necessary for the application of this method are the knowledge of the return period of the harmful event (which is influenced by the presence of the ecosystem), the vulnerability of the elements at risk, their value and the interest rate necessary to capitalize any expenses that should be incurred in the absence of the ecosystem (Moos 2018). In order to assess this benefit, different scenarios of expected losses with and without the ecosystem are usually compared for each possible event (Fuchs and McAlpin 2005; Bründl et al. 2009).

According to Beecher (1996) the cost items considered for avoided damages are:

- direct costs (actual loss);
- indirect costs (loss of profit);
- opportunity costs.

The field of application

It is commonly applied in the estimation of provisioning and regulating services offered by the ecosystem services (Pascual et al. 2010), such as water supply, carbon sequestration (Pimentel et al. 1997), protection against floods (Whiteman and Fraser 1997; Yaron 2001) and erosion control (Ruitenbeek 1992). In addition, the method is applicable for the economic evaluation of rockfall in forest as shown by Dupire (2011, 2014) and Blanchard et al. (2009), but it also applies to the assessment of other natural hazards such as avalanches, floods, erosion (Teich and Bebi 2009).

Main advantages:

- it is easy to apply, since it does not require high levels of skills and experience (Lucy 2014);
- it is based on objective data and available on the market (Pascual et al. 2010);
- its use requires a relatively small number of data and is less time-consuming compared with preferences-based approaches (King, Mazzotta, and Markowitz 2000);
- it provides estimates which are easily understood and supported by policy-makers (Lucy 2014);
- it can be used when data and resource constraints prevent the use of methods which estimate the WTP (Lee et al. 2010).

Main disadvantages:

- it is not replicable, as it is highly site-specific, that is it refers to conditions and place of study;
- the ADM just estimate the *use value*, so it is only a partial measure of TEV (Defra 2007);
- the value obtained is uncertain, as it is based on an estimate of a possible future risk of no certainty (e.g., difficult forecast of return periods of natural hazards). Nowadays this is even bigger because of abrupt and irreversible changes in ecosystem dynamics, for example because of climate change;
- it may cause ethical problems, as it involves estimating the value of human life (Fuchs and McAlpin 2005).

Application case

Source

Cahen, M. (2010). Ouvrages de parade contre les risques naturels en montagne et fonction de protection de la forêt : analyse économique comparative. AgroParisTech ENGREF, Paris.

Localization

Chavorie, Veyrer-du-Lac, France.

Purpose

Evaluation of the benefits of the forest's protective service against rockfall.

Method

It is based primarily on a spatialized approach, as the management of natural risks cannot be done without knowing local conditions. After that, the potential sites for rockfall release are identified and the hypothetical trajectories of the blocks are calculated using software (e.g., Rockyfor3D). In conclusion, an Excel calculation model was constructed in order to assess, in a standardized manner, the calculation of the risk of natural hazards, assuming different scenarios (i.e., with and without forest). This is done by means of different formulas, which take into account multiple variables (e.g., time of return, vulnerability, number of people involved). These formulas thus make it possible to calculate the extent of the potential damage to persons, buildings or property and to calculate the risk of the assumed scenario.

Results and Discussion

The income obtained, that is 1,400 €/ha/year, is in line with other income estimated using this method, as reported in a comparative table of the same work (Cahen 2010). They range from approximately 200 €/ha/year to 5,000 €/ha/year (Blanchard et al. 2009; Teich and Bebi 2009) and are also used for other natural hazards, such as avalanches.

Comment

In this study the adoption of the ADM shows how the role of the forest, if managed, can in some contexts (e.g., medium intensity hazard, risk with considerable linear extensions) be a valid alternative to civil engineering works, calculating the value of the damage avoided thanks to the protective action of the forest ecosystem.

Conclusions

The ADM is advantageous because the results it provides, based on an estimate of the damage of actual elements, are understandable even by a non-academic public, supporting with economic data the perception of the risk present. Moreover, being a cost-based approach, the data are objective and readily available as there is a market. For this reason, like RCM, it is one of the most used techniques (Pascual et al. 2010).

Among the main disadvantages, however, are the non-reproducibility, as it is closely linked to the conditions of the site and the ethical question about the value of human life translated into monetary terms.

4.3 The contingent valuation method

Description

The contingent valuation (CV) method estimates the value of ecosystem and environmental services by simulating a hypothetical market. In particular, through the implementation of survey questions to actual or potential users/consumers, it is possible to estimate the WTP in order to maintain or obtain a given good or service, or the WTA to transfer it (Gios and Notaro 2000; Christie et al. 2008; Carson 2011). The survey consists of three parts, as argued by Mitchell & Carson (2013):

- a detailed description of the good(s) to be valued and the possible circumstances under which it is made available to the respondent;
- the administration of the survey question in order to elicit the respondents' WTP/WTA;
- the gathering of information on the characteristics of the respondents (e.g., sex, age, income), their preferences and attitudes regarding the good to be valued.

Furthermore, during the drafting of the survey question, in order to obtain valid answers, it is necessary to clearly define the method to elicit the WTP/WTA (i.e., open ended, dichotomous choice, bidding games, payment cards); and the payment vehicle to support the resource to be evaluated, or the contribution to compensate its degradation (e.g., tax, donation, direct payment) (Massidda 2012).

The field of application

It is one of the few methods which gets to estimate, in addition to the *use value*, also the *non-use value* of the environment (King, Mazzotta, and Markowitz 2000) and for this reason it finds its main application, such as biodiversity (Christie et al. 2006; Garcia et al. 2007) the forest's conservation (Lehtonen et al. 2003), the recreational service of a territory (Loomis and Richardson 2000). However, as it is strictly dependent on the respondents' knowledge of the good or service in question, this method does not always fit the need of a for regulating ES evaluation (e.g., protection against natural hazards) or support services offered by ecosystems. Indeed, they are often complex topic (Nunes and van den Bergh 2001) and little known by public opinion (Häyhä et al. 2015) although attempts have been made, such as the study conducted by Brouwer & Bateman (2005) on the public evaluation of flood control measures or those conducted by Leiter & Pruckner (2005; 2009) on the society's WTP for avalanche risk reduction in Austria.

Main advantages:

- it is flexible (i.e., theoretically any ecosystem good and service could be estimated) and thus widely used;

- the CV is one of the few methods can estimate the TEV as a whole, that is both *use value* and *non-use value* (van Zyl 2014c);
- the results obtained are simple to analyse and describe, although the method is long and laborious (King, Mazzotta, and Markowitz 2000);
- it allows to make assessments of possible future scenarios (e.g., a hypothetical change in environmental quality), unlike market-based approaches or revealed preferences approaches (Christie et al. 2008);
- it allows to collect other types of information such as socio-economic and behavioural data, that can be useful in understanding of societal choices and preferences (Pascual et al. 2010; EFIMED and CTFC 2015).

Main disadvantages:

- its use requires a large amount of data and resources, as well as a long time (i.e., preparation and administration of the survey questions) (EFIMED and CTFC 2015);
- the result is not reliable if the goods or services to be evaluated are too complex and unfamiliar (Pascual et al. 2010);
- the CV can be subject to many biases (e.g., strategic biases, information biases, misspecification biases), which lead to an estimate of WTP inexact (King, Mazzotta, and Markowitz 2000);
- the respondents' WTP may change depending on the specific chosen payment method (e.g., use as payment the fee, leads to forms of protest by those who are not willing to get more taxes) (van Zyl 2014c);
- there is a deep divergence in terms of value between the two payment formats of the method (i.e., WTP and WTA), although the good or service to be estimated is the same, since, gains are estimated differently from losses due to phenomena such as cognitive dissonance (King, Mazzotta, and Markowitz 2000);
- it is controversial whether the *non-use value* is proportionate in monetary terms (Pascual et al. 2010), as well as the difficulty in externally supporting it (King, Mazzotta, and Markowitz 2000).

Application case

No application case for the CV method emerged from the deliverable T4.1.1 on the economic evaluation of rockfall protection service of forests.

Conclusions

Although this method has been much debated in the past (Kahneman and Knetsch 1992; Diamond and Hausman 1993), in recent years it has been accepted by both the academic community and by political decision-makers (Christie et al. 2008). Among the undoubted advantages of this method, as reported previously, we remember the possibility to theoretically evaluate any ecosystem good and service (van Zyl 2014c) and to make estimates of hypothetical future changes, thanks to the realization of a hypothetical market. Moreover, this method is one of the few which may estimate the *non-use value* of the good or service in question (King, Mazzotta, and Markowitz 2000).

However, the disadvantages are many, first of all the strong dependence of the results obtained with the knowledge of the good or service by the respondent, place a strong limit. For example, this method is well suited to estimate the cultural and recreational value of a good or service, but with regard to regulating services (e.g., the forest's protective function against natural hazards), the results obtained are still not very reliable, as reported by Gios & Notaro (2001). Therefore, the high costs of implementing such method, both in terms of the data needed and in terms of time, advise against its use in those estimates, standing the possibility to adopt other methods (e.g., cost-based approaches), that proved to be more convenient. Finally, the possibility that the method is flawed by errors is very likely and this invalidates the results (King, Mazzotta, and Markowitz 2000).

4.4 The choice modelling method

Description

The choice modelling (CM) method estimates the value of ecosystem goods and services as methods based on stated preferences, that is by creating a hypothetical market. The substantial difference between this method and CV is that instead of directly declaring the WTP, individuals are asked to make a choice from a list of (generally three) proposed alternatives. Among them, one usually consists of an alternative of doing nothing or maintaining the good or service as its current status (Christie et al. 2008; van Zyl 2014b). According to King et al. (2000) there are different varieties of formats to apply this method, below:

- contingent ranking: where respondents are asked to compare and classify, according to their preferences, different sets of choices made up of multiple alternatives for the supply of goods and services (Hadley et al. 2011);
- discrete choice (or choice experiments): where two or more alternatives are shown with their characteristics (e.g., associated costs or prices) and respondents are asked to identify the preferred alternative;
- paired rating: this format is a variation of the previous one, as respondents are asked to compare two alternatives and evaluate them in terms of strength or preference.

The field of application

As with CV, it is one of the few methods which can estimate not only the *use value*, but also the *non-use value* of the environment (King, Mazzotta, and Markowitz 2000). Adamowicz et al. (1998) were the first to conduct a study on the latter, assessing the protection of a threatened species in a given area, through the protection of an old growth forest. The method can also be used to estimate the economic costs or benefits of an environmental change (EFIMED and CTCF 2015). Indeed, it may have an impact on the *use value*, such as the recreational value which people give to a natural site (Boxall et al. 1996; Adamowicz, Louviere, and Williams 1994) or the value of a landscape (Bergland 1997; Rolfe, Bennett, and Louviere 2000); or the *non-use value*, such as the value of existence considered by people for biodiversity (Naidoo and Adamowicz 2005; Bienabe and Hearne 2006). However, as this method is highly dependent on respondents' knowledge of the good or service in question, it is still little used for regulating services (e.g., protection against natural hazards) or ecosystem support services. Such services are often complex (Nunes and van den Bergh 2001) and little known by public opinion (Häyhä et al. 2015). Nevertheless, in the last period, attempts have been made to evaluate them, such as studies conducted on avalanche protection offered by the forest (Löwenstein 1995; Olschewski et al. 2011, 2012).

Main advantages:

In addition to the standard advantages of contingent valuation given in Schedule 4.3, for this method we can add:

- the possibility to choose between different alternatives, not having to express monetary values directly, makes it possible to obtain more significant answers from the respondents (King, Mazzotta, and Markowitz 2000);
- it can reduce many of the errors resulting from CV studies conducted using the open-ended method, in which respondents may have to assess unfamiliar and complex goods or services (van Zyl 2014b);
- it is flexible (more than the CV), that is it can estimate all types of ecosystem services (van Zyl 2014b; EFIMED and CTFC 2015);
- it can be applied to all spatial scales and to different population sizes (van Zyl 2014b).

Main disadvantages:

In addition to the disadvantages that characterise the contingent valuation method (see fact sheet 4.3), for this methods are added:

- it may be difficult to assess some choices, given their complexity (van Zyl 2014b);
- respondents may lose interest or become frustrated if many questions of choice are asked (King, Mazzotta, and Markowitz 2000);
- the CM can elicit preferences in the form of attitudes and not intentional behaviour (King, Mazzotta, and Markowitz 2000);
- in order to estimate the WTP, the contingent ranking requires more complex statistical techniques (van Zyl 2014b).

Application case

Source

Olschewski, R., Bebi, P., Teich, M., Hayek, U. W., & Grêt-Regamey, A. (2012). Avalanche protection by forests—A choice experiment in the Swiss Alps. *Forest policy and Economics*, 17, 19-24.

Localization

Andermatt, Switzerland.

Purpose

Determine the WTP for the avalanche protection offered by forests using the choice experiment approach.

Method

The study conducted an interdisciplinary analysis, combining a choice experiment approach with risk analysis techniques, virtual reality visualizations (through GIS representations) and cost estimates of alternative protective measures. This has allowed both the costs and benefits of protective measures to be taken into account. Regarding the choice experiment approach, respondents were asked to choose their preference from different choice sets (three alternatives), which took into account different attributes of alternative measures against avalanche protection (i.e., type of measure chosen, start time, duration, avoided damages and costs). Assuming, as a starting scenario, a windthrow of about one hectare of the forest protection.

Results and Discussion

The estimated WTP varies from 110 \$ to 390 \$ depending on the scenario chosen, considering different levels of attributes. It also appeared from the study which the WTP for risk reduction estimated by the choice experiment approach is approximately at the same level as the collective risk estimate caused by the hypothetical windthrow scenario (i.e., 470 \$ per household). In addition, the WTP for risk reduction is clearly higher than the costs of wooden protective measures (e.g., logs and wooden grids), compared to the costs of steel bridges and nets. This shows that the local population is well aware of the reality in which they live, thus highlighting how the combination of timber construction and reforestation measures is the appropriate solution in wooden areas affected by avalanches.

Comment

The assessment of public goods against natural hazards is often cost-based. However, these do not necessarily reflect the benefits generated by the protection measures. The approaches of stated preferences (e.g., choice experiment approach) can thus be valuable and reliable tools in estimating these benefits. Moreover, as seen in this paper, the possibility to combine the choice experiment approach with other techniques and approaches, has made it possible to evaluate and compare different aspects of the services of protection against natural hazards (in this case avalanches). Therefore, it is a useful tool in the decision-making processes concerning landscape planning and silvicultural management.

Conclusions

The CM has the same advantages and disadvantages as the CV, such as the possibility to estimate the *non-use value*, flexibility, high costs and more time-consuming compared to other economic evaluation methods. However, it differs from CV as it facilitates choice by proposing preconfigured scenarios (King, Mazzotta, and Markowitz 2000). This makes it possible to reduce the possible difficulties of comprehension on the part of the respondent, but also the strategic behaviour, thus obtaining more significant answers. The choice modelling is particularly suitable for those political decisions in which a set of possible actions can lead to different impacts on environmental goods and services, as it focuses on choice sets with hypothetical scenarios having different characteristics (e.g., in the evaluation of ecosystem improvements) (King, Mazzotta, and Markowitz 2000).

Finally, among the disadvantages, there is the need for high skills concerning such as the implementation of the survey questions structure, the statistical modelling of data and economic skills on environmental resources. Moreover, the close dependence between the number or level of attributes constituting the selection set and the sample size and/or number of comparisons to be made by each respondent should be considered too. In fact, as the former increase, the latter must also increase (van Zyl 2014b).

4.5 The benefit transfer method

Description

The benefit transfer (BT) method is based on an inference process where economic data obtained from a previous valuation study at a given time and place (i.e., site study) are adopted to estimate the economic value of ecosystem goods and services of current political interest at a different time and place (i.e., political site) (Wilson and Hoehn 2006; Christie et al. 2008). According to Brander (2013) there are three different methods to transfer values:

- the *unit value transfer*, that estimates the value of the political site using unit values (generally per area unit or per beneficiary), for ecosystem services, transferred from the study site together with information on the number of units present in the estimation site;
- the *value function transfer*, which uses an equation estimated for the study site, which links the value of an ecosystem service to the characteristics of the ecosystem and its beneficiaries (i.e., value function). This equation then, combined with the parameters of the policy site, allows to calculate the unit value of an ecosystem service in the latter site;
- the *meta-analytic function transfer*, similar to the method previously exposed. The difference is that the value function is not estimated for a single study site, but for multiple sites, as it is the result of different original studies. This results in a more robust equation, thus better able to control and represent a variation of the characteristics of ecosystems, beneficiaries and other conceptual features.

The complexity of applying BT methods increases in the order in which such methods have been listed. Finally, it should be remembered that the increasing complexity does not necessarily correspond to a reduction in transfer errors (Pascual et al. 2010).

The field of application

Given the possibility of using BT by any evaluation method, it is thus applicable to all ecosystem goods and services, such as provisioning services (White, Ross, and Flores 2000; Economics 2010), drought costs (Logar and van den Bergh 2013), water quality management (Luken, Johnson, and Kibler 1992), or recreational forest services (Zandersen and Tol 2009; Grilli et al. 2015; Paletto et al. 2015). In addition, the method is applicable for the assessment of the environmental benefits of natural hazard mitigation (e.g., earthquakes, wind hazards, floods) (Whitehead and Rose 2009). However, BT has proved more reliable for the estimation of *use values* (e.g., recreational value) (EFIMED and CTFC 2015).

Main advantages:

- it is flexible, cost-effective and requires less time than to conduct a new evaluation study (EFIMED and CTFC 2015);
- BT can be derived from all economic evaluation methods (i.e., preferences-based approaches, cost-based approaches);
- it can be applied at all spatial scale levels, if it can find an appropriate comparable primary evaluation study (van Zyl 2014a);
- the method can be used as a verification tool during the applicability phase of a project, programme or policy, to see if a more in-depth evaluation or analysis is required, as it allows to obtain preliminary estimates of values in a relatively short time (van Zyl 2014a).

Main disadvantages:

- it is highly dependent on the quality of the original study, it follows that the estimates may be inaccurate and highly uncertain;
- its level of accuracy cannot exceed the one obtained from the primary evaluation study (King, Mazzotta, and Markowitz 2000);
- it is difficult to track appropriate studies, as they are often not published (EFIMED and CTFC 2015);
- it cannot be applied if there are no goods or transferable studies related to the topic in question (van Zyl 2014a);
- the unit value estimated can become outdated in a short time (EFIMED and CTFC 2015).

Application case

It has not been reported because the paper included in the deliverable T4.1.1 (De Marchi and Scolozzi 2012) deals with the topic but do not describe the process adopted for its application.

Conclusions

The BT is advantageous as it can be used in all situations where the budget or time available for data collection is prohibitive or difficult to obtain (Whitehead and Rose 2009; Logar and van den Bergh 2013). It is also quick, so it can estimate the economic benefits faster than an original evaluation study (van Zyl 2014a). Nevertheless, in relation to the above mentioned disadvantages, its application can generate, according to what reported by Pascual (2010), three main different sources of error, that is:

- errors related to original value measurements at the study site;

- generalisation errors, that is those resulting from the transfer of the value of the study site to the political site;
- errors in the selection of the publication.

It follows that an acceptable level of error transfer depends on the context in which the estimated value is used.

In conclusion the BT, if well applied, it can be a key point in the evaluation of a programme, project or policy, as it allows to verify during the evaluation of costs and benefits, if a more in-depth analysis/evaluation is required and thus the need to conduct a primary evaluation study (Defra 2007).

5. Conclusions

As already highlighted in the deliverable T4.1.1, of which this report is the natural continuation, it is clear that the most widely used approach for the monetary evaluation of the regulating services offered by forests (specifically the protective function against natural hazards) is the direct approach of market evaluation, namely the cost-based ones (i.e., RCM and ADM). This is due to the fact that these methods, which can be valid tools in situations where the resources and the available time could represent constraints, allow to obtain the *indirect use value* of environmental resources in a relatively simple way, based on data easily available on the market. This entails wide advantages, such as the repeatability of the method, the possibility to be used and understood by both forest technicians/managers and by political decision-makers and the reduced costs of implementation. The biggest disadvantage, however, is that only one component of TEV can be estimated, namely the *use value*.

The other available methods, those relating to stated preferences approaches, such as contingent valuation and choice modelling, while allowing the estimation of TEV as a whole, imply stricter limitations on their use in the context of the assessment of a protective service. Nowadays, although these methods are mainly used for the evaluation of the recreational service of an environmental resource, there is increasing experience of the evaluation of the latter type of service, often as part of an interdisciplinary analysis. The disadvantages, however, in comparison to the previous approaches, remain multiple, therefore these methods are still under discussion. These are: high execution costs, consumption of resources, time and skills in order to adopt them and the strong correlation between the value obtained and knowledge of the good or service (which in this case is often unfamiliar) evaluated by respondents. The benefit transfer method, on the other hand, has proved useful as a verification tool to see if a more in-depth evaluation or analysis of the study site is necessary or not. However, it has the drawback that the accuracy of the resulting estimate is highly dependent on the accuracy of the original study.

In general, this report confirms the great variability of methodologies available for this type of assessment. We believe the present work contributes to shed light on the subject through an in-depth analysis of the specific characteristics of each of them. The critical discussion of the pros and cons of each method, accompanied by an example of its use, represents a decisive advance over the evaluation of the previous deliverable which, while providing a comprehensive overview of the current situation on the topic, did not critically discuss its relevance for the project.

In the context of this project, the deliverable T4.2.1 is a fundamental part to provide an adequate conceptual and methodological basis on which to develop the main output of WP T4, consisting of the ASFORESEE model for the economic evaluation of protective forests. Analysing the economic concepts issued from the critical analysis of the output of A.T4.1.1, this report allowed to define the most suitable

approaches to adopt for the development of the economic model. Particularly, in consideration of the conceptual framework developed within these first two deliverables, ASFORESEE will be based upon two independent but adjacent pillars: the replacement cost and the avoided damages approaches. The adoption of these methods is consistent with the virtues that emerged from the previous works and fits the features of the study areas that will be selected within the project, allowing to build relevant scenarios of economic evaluation of forest governance for risk mitigation and support the adoption of the most effective nature based solutions. It is important to notice how the adoption of two different methods will allow the model to achieve a level of detail that any other study that emerged from the review has reached, being able to highlight different aspects of the forest role (its effectiveness for the RCM and the benefits of the society for the ADM) and support the application of these evaluation with actual study cases.

Apart from the development of the project, this analysis, thanks to the work of dissemination to partners and stakeholders that will characterize the second part of the project "RockTheAlps", will contribute to the dissemination of good practices of economic evaluation of ecosystem services to the target groups of the research. Although a single ecosystem service is evaluated in comparison to all forest services, the possibility of obtaining valid information about the protective service can support the decision-making processes, such as the evaluation of the convenience of a public work, a plan or a program or a classification criterion for different options of forest management and landscape planning. Therefore, the inclusion of these assessments entails undoubted decision-making benefits, increasing the information base on which the required decisions can be made. Furthermore, the diffusion of these practices, we believe, can increase the value recognized by society to forest resources, thanks to a greater awareness by society of the protective role that the forest has against falling rocks, but more in general of natural hazards.

In conclusion, this report has attempted to show the importance of economic evaluation of natural hazard risk mitigation strategies for decision-making processes. The economic evaluation of the services offered by forests, in particular the protective one, would allow forest technicians and managers, as well as political decision makers, to make more effective decisions, giving them the possibility to evaluate more objectively the relative importance of each single service and to compare it among several plausible solutions (Notaro and Paletto 2012). The critical discussion of the various methodologies that emerged from the report can provide effective guidelines on the choice of the most suitable monetary evaluation method to be applied in a given study according to the constraints and expected results.

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