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Defining and classifying ecosystem services for economic valuation: the case of forest water services

Elena Ojea [a,*], *Julia Martin-Ortega* [b,1], *Aline Chiabai* [a,2]

[a] Basque Centre for Climate Change (BC3), Alameda Urquijo 4, 4-1, 48008 Bilbao, Spain

[b] The James Hutton Institute (JHI), Craigiebuckler, Aberdeen AB15 8QH, Scotland, UK

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ABSTRACT

The Millennium Ecosystem Assessment (MA) has become widely accepted as a framework for understanding and assessing the benefits that ecosystems provide to human well-being. Its classification of services into the categories of provisioning, regulating, supporting and cultural, has been increasingly widely adopted. However, several authors have recently argued that the MA's definition and classification of services may not be the most appropriate for monetary assessments. This paper seeks to understand in greater depth the sources of problems arising from the use of the MA's definition and classification of services for economic valuation. Firstly, we review and disentangle the critical literature to date. Secondly, we undertake a practical examination of existing primary valuation studies, which we analyse according to the MA classification and then compare with an output based-classification. We use water ecosystem services provided by tropical forests as an example for our analysis. Our results provide further evidence of the risk of double counting and the problems related to the secondary use of valuation estimates, as a consequence of service overlapping and service ambiguity.

1. Introduction

Since the release of the Millennium Ecosystem Assessment (MA, 2005), ecosystems have become widely recognised as natural capital assets supporting and supplying services which are highly valuable to humans. There is a growing appreciation of the important role that ecosystems play in providing goods and services that contribute to human welfare, and a recognition of the impact of human actions on ecosystems. The estimation of the economic value of ecosystem services (hereinafter called ES) is expected to play an important role in conservation planning and ecosystem-based management (Plummer, 2009; Stenger et al., 2009; Turner et al., 2007), and to become increasingly important for local, national, and global policy and decision making (Turner et al., 2010). It also has a role to play in ensuring that human actions do not damage the ecological processes necessary to support the continued flow of ecosystem services on which the welfare of present and future generations depends (MA, 2005), and therefore in ensuring sustainable development (Turner et al., 2010). This becomes more relevant under the threat of climate change, where a 3 °C warming is estimated to be sufficient to transform about one fifth of the world's ecosystems (Fischlin et al., 2007).

Not knowing the economic value of a resource can lead to the detriment and depletion of ecosystem services. As a consequence, the 'ecosystem service approach' as proposed by the MA is becoming more and more widely accepted at both

* *Corresponding author*. Tel.: +34 944014690.
E-mail addresses: elena.ojea@bc3research.org (E. Ojea), Julia.MartinOrtega@hutton.ac.uk (J. Martin-Ortega), aline.chiabai@bc3research.org (A. Chiabai).
[1] Tel.: +44 01224 39 5288.
[2] Tel.: +34 944014690.
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academic and policy levels. However, despite this widespread acceptance and an exponential growth in studies embracing the MA framework (De Groot et al., 2002; Fisher et al., 2009), quantifying the levels and values of these services has proven difficult (Bateman et al., 2011; Nelson et al., 2009; Turner et al., 2010). A recent review conducted by De Groot et al. (2010) identifies the understanding and quantification of how ecosystems provide services as one of the greatest unresolved questions. Also, there is still a great deal of confusion amongst decision-makers and academics from all disciplines about the validity and implications of ecosystem service valuation (Spangenberg and Settele, 2010; Turner et al., 2010).

This confusion is partly derived from the current definition of what represents an ecosystem service and what types of ecosystem services exist (i.e. how ecosystem services should be classified). The problems of the MA as a general ecosystem services framework have recently been highlighted by Norgaard (2010), who states that the literature explaining the scientific understanding of ecology and social sciences, including economics, does not fit neatly into the MA model. It has also been claimed that we have a limited ability to understand and manage the full socio-ecological system set by MA (Carpenter et al., 2009). In the case of economics, the literature on ES valuation is mixed as the terms ecosystem services, functions and benefits are often used with different meanings from one study to another (Fisher et al., 2009). Therefore, some recent studies have specifically claimed that when the objective of ecosystem service assessment is economic valuation the MA framework and its classification of services is not the most adequate (Wallace, 2007; Boyd and Banzhaf, 2007; Fisher et al., 2009, among others). Studies claim that MA is ambiguous as to the distinction between ecosystem functions (understood as the mechanisms by which services are generated) and the services themselves (Haines-Young and Potschin, 2010). There have been numerous attempts to classify ecosystem services (Daily, 1997; De Groot et al., 2002; MA, 2005), but the confusion prevails (Haines-Young and Potschin, 2010). Further efforts are needed in order to understand what limitations may potentially arise if the MA approach is employed directly for economic valuation, and how those limitations can be addressed.

The literature on this topic is moving very fast, but not always with clarity. Here we aim to shed light on the current debate about the definition and classification of ecosystem services by reviewing and clarifying the existing literature (mainly but not solely post-MA) to inform economic valuation. The added value of this paper over other critical papers is that we illustrate the discussion with a practical examination of actual primary valuation studies. So far the discussion has been mainly on a theoretical level but here we look at actual studies, adding new evidence on the practical implications of classifying ecosystem services for valuation. For this purpose, we compare the MA service classification with an alternative, output-based classification for a sample of original valuation studies. We focus on water ecosystem services provided by tropical forests to illustrate our analysis.

The paper is structured as follows: Section 2 reviews recent literature revisiting the MA framework and identifies the main sources of disagreement; Section 3 presents the case of water-related services in tropical forests to illustrate the controversies of ES classification and valuation; Section 4 analyses the main results; and Section 5 concludes with recommendations for future analysis.

2. Service classification and economic valuation

Different classifications of ES exist. Table 1 summarises the main classifications that have been used in recent literature. The MA classifies ecosystem goods and services as *provisioning services*, which consist of products obtained from ecosystems; *cultural services*, the nonmaterial benefits that people obtain from the ecosystem; *regulating services*, including benefits obtained from the regulation of ecosystem processes; and *supporting services*, those which are necessary for the production of all other ecosystem services (MA, 2005). The nature of these services is not reduced to purely ecological processes, and the MA regards cultural services as ecosystem services.

Boyd and Banzhaf (2007) define ecosystem services as the components of nature directly enjoyed, consumed, or used to yield human well-being. This definition advocates a pragmatic classification of nature's contributions to human welfare from the perspective of environmental accounting. These authors consider services as the end products of nature, and distinguish them from intermediate components and from benefits. They only value services, as defined above, and exclude benefits, in which anthropogenic inputs are involved (e.g. recreational angling would have non-natural inputs such as tackle, boats – Boyd and Banzhaf, 2007) and intermediate components, which they define as part of the processes resulting in ecosystem services. They suggest that these categories be excluded from the economic valuation to avoid double counting. Wallace (2007) relies heavily on the MA classification but argues that only end services should be considered in valuation. He presents three levels of classification: processes, ecosystem services or end services (what is valued) and benefits.[1] Fisher et al. (2009) define ecosystem services as the aspects of ecosystems utilised (actively or passively) to produce human well-being. Based on this definition, they provide a classification with four levels: (i) abiotic inputs such as sunlight, rainfall or nutrients; (ii) intermediate services such as soil formation, primary productivity, nutrient cycling, photosynthesis, pollination, etc.; (iii) final services such as water regulation, primary productivity; and (iv) benefits, such as water for irrigation, drinking water, electricity from hydro-power, food, timber, non timber products. Benefits are valued in economic terms and are always derived from intermediate or final services. The concept of final services has been followed in recent assessments such as in the latest TEEB report (TEEB, 2010), in the recent UK National Ecosystem Assessment (UK NEA) (Bateman et al., 2011), and in Haines-Young and Potschin (2010).

[1] One example would be water erosion and regulation. These are considered as regulating services under the MA approach, while according to Wallace both are processes for achieving potable water, which would be the final service.

Table 1 – Different classifications for ecosystem services.

Source	Daily (1997)	MA (2005)	Boyd and Banzhaf (2007)	Wallace (2007)	Fisher et al. (2009)	UK NEA (2011)
ES definition	The conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfil human life	Benefits people obtain from ecosystems	Components of nature directly enjoyed, consumed, or used to yield human well-being	Benefits people obtain from ecosystems	Aspects of ecosystems utilised (actively or passively) to produce human well-being	The benefits people obtain from ecosystems
Classifications and ES value[a]	**Production inputs** **Sustenance of plant and animal life** **Provision of existence and option values**	**Cultural** **Provisioning** **Regulating** **Supporting**	Intermediate components **Services** Benefits	Processes **Ecosystem services** Benefits	Abiotic inputs Intermediate services Final services **Benefits**	Ecosystem process/ intermediate services Final ES **Goods** Well-being value[b]
Types of economic value	Use and non-use values	Use and non-use values	Use values	Use and non-use values	Use values	Use and non-use values
Nature of the ES	Ecological and anthropogenic	Ecological and anthropogenic	Ecological functions	Ecological and anthropogenic	Ecological functions	Ecological and anthropogenic
Examples of ES valued						
Flood regulation	Yes	Yes	No	No	Yes	Yes
Recreation	Yes	Yes	No	Yes	No	Yes
Aesthetic	Yes	Yes	No	Yes	No	Yes

[a] The category in which economic valuation is performed under each classification is highlighted in bold.
[b] UK NEA also uses the MA classification but establishes the links between processes, services and goods, which are valued.

Recent literature critical of the mainstream ES classification for valuation purposes has also used different – and sometimes contradictory – arguments (Boyd and Banzhaf, 2007; Wallace, 2007; Fisher and Turner, 2008; among others). From a review of these studies, we have identified four key areas of conflict in the interpretation and classification of ES for valuation purposes. These are discussed in the following sections and are summarised in Table 1.

2.1. The definition of ecosystem services

There are as many definitions of ES in literature as there are approaches to ES classification. According to the MA, ecosystem services can be broadly defined as ''the benefits people obtain from ecosystems''. Previous definitions include ''the conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfil human life'' (Daily, 1997); and Costanza's (1997) definition of ecosystem services as ''the benefits human populations derive, directly or indirectly, from ecosystem functions''.

Fisher et al. (2009) review definitions of ES and find that concepts such as ''functions'', ''processes'', ''services'' or ''benefits'' are employed with no clear definitions, and often refer to different concepts. To overcome this problem, some authors recommend distinguishing between benefits and services, so that they are not considered the same (Boyd and Banzhaf, 2007; Fisher and Turner, 2008; Bateman et al., 2011). For these authors, *services* are processes of ecosystems that relate to well-being, while *benefits* are outcomes of ecosystem services and have a direct relation to human welfare (and therefore have an economic meaning). Based on this discussion, some authors defend the valuation of ecosystem services alone (Fisher et al., 2009; Boyd and Banzhaf, 2007), while others defend the valuation of both ecosystem services and benefits as separate elements (Wallace, 2007). Under this latter view, recreation would be understood as a benefit for which ecosystems provide important inputs, but not as a direct service from ecosystems.

2.2. The ecosystem services to be valued

One of the most frequently cited problems of the use of the MA framework for valuation is the risk of double counting (Boyd and Banzhaf, 2007; Fisher et al., 2009). Double counting may arise when a service is valued at two different stages of the same process providing human welfare, an example being a forest providing water flow (as a regulating service) and water supply for hydropower (as a provisioning service). On the one hand, many studies that have applied the MA framework for valuation have addressed this problem by excluding supporting services from the valuation (Chiabai et al., 2011; Ojea et al., 2010; TEEB, 2010; Ding et al., 2010). On the other hand, it has been argued that supporting services can have associated economic values that are not addressed through provisioning or regulating services, and could therefore be considered in the benefit assessment of ES (e.g. habitat support in freshwater systems). In relation to this, there is a debate on the best way to distinguish ecosystem services from functions and how to classify services to make them quantifiable in a consistent manner (Godoy et al., 2000). In this sense, this area is highly interrelated with the previous one. While some studies do not consider functions for purposes of valuation, some analysts have argued that the source of the value of biological diversity is linked to the functioning of ecosystems, and that this value may be more important than values arising from individual species, as in bio-prospecting (Polasky, 2009). Under this line of thinking, biological diversity is seen as important for sustaining the functioning of ecosystems, which in turn provide valuable life support services (Polasky, 2002). This value may differ from the benefits of individual species and from the intrinsic value of biological diversity (Uggla, 2010). Swallow et al. (2007) propose a distinction between ecosystem services and environmental services, the former being directly linked to and supported by the biological diversity and ecological processes while the latter have a more direct link to the market and related economic activities. According to this framework provisioning services, which are usually valued by market-based instruments, are environmental services and not ecosystem services. Other studies have avoided the complexity of ecosystem functioning by focussing on the final benefit that connects to human well-being (Fisher and Turner, 2008). Along these lines, Boyd and Banzhaf (2007) go further by defining the valuation of ecosystem services through ''components'' of nature, where components are understood as final goods coming from ecosystems that are consumed by people.

2.3. The nature of the services

Some authors claim that ES should strictly be defined as ecological phenomena, and thus cultural and scenic values should be excluded from the classification of ES (Boyd and Banzhaf, 2007). Other authors claim that services which are directly linked to or interact with human activity such as recreation (through the tourism industry) or timber production (through forestry) should not be considered as services from ecosystems. The main reason for this argument is that non-natural inputs are included in the provision of the service (e.g. labour, technology, etc.) (Boyd and Banzhaf, 2007). Boyd and Banzhaf (2007) justify this distinction as they are interested in the services of ecosystems that are purely contributing to national accounting, and thus increasing GDP. By contrast, if the intention is not purely to identify and value the ecosystem services contributing to GDP, we see no reason for excluding cultural services. It can be argued that cultural values, such as recreation and scenic beauty, may be determined by ecological phenomena. People's preferences for recreation may be conditional on the ecological status of the ecosystem, species composition, biodiversity richness and other aspects directly linked to the ecological features of the ecosystem. As an example, Santiago and Loomis (2009) find that the presence of waterfalls heavily increases the recreation value of visits to a national forest in Puerto Rico.

2.4. The types of value considered

A debate also exists regarding the inclusion of non-market values in the ecosystem services valuation, and specially, non-use values. Some studies criticise the bias related to stated preference techniques, although they do acknowledge that these methods still have a legitimate role (Fisher et al., 2009). One such criticism levelled at existence values has been their insensitivity to scope (Boyle et al., 1994; Desvousges et al., 1993; Diamond and Hausman, 1994). However, recent studies defend the idea that non-use values are strictly related to the existence of a resource, and scope insensitivity should not be a criterion for invalidating contingent valuation (Heberlein et al., 2005; Ojea and Loureiro, 2009). Existence values are in any case part of the cultural services of an ecosystem and contribute to the total economic value (TEV) of that ecosystem.

To a large extent, the above-mentioned problems are derived from the fact that the MA classification is not clearly focused on the final outcomes that ES's provide to humans, which are what generate an impact (positive or negative) on human well-being and therefore have an economic value. To explore the extent to which these problems can be identified and addressed by means of an adequate classification for valuation, in the next section we compare the MA classification with an output-based classification for the case of forest water services. For the purposes of this analysis, from now on we follow Fisher et al. (2009) and the UK NEA as regards general definitions of terminology. We use the term "ecosystem service" to refer to all the services provided by ecosystems that directly or indirectly provide well-being (irrespective of the whether they are intermediate or final products, processes or anthropogenic benefits). We employ the term "Benefits" or "outputs" to refer to those services which are directly used by humans. Note that we choose to place benefits and outputs in the same category (even with their differences as highlighted by previous authors), as they both represent direct uses for humans and can therefore be valued in economic terms.

3. Classifying forest water-related services for valuation

As the MA itself recognises, the water cycle plays many roles in the climate, chemistry, and biology of Earth, making it difficult to define it as a distinctly supporting, regulating, or provisioning service. This is because although ecosystems are strongly dependent on the water cycle for their very existence, at the same time they represent domains over which precipitation is processed and transferred back to the atmosphere or passed to another system – either aquatic systems or, for example, farmers who irrigate. This intimate inter-linkage makes the classification of water-related services particularly complex, so such services are a good illustration of the difficulties regarding the classification of ecosystem services for economic valuation discussed above.

The literature on water quality impacts is fairly well spread out (Alyward, 2002), and valuation studies have existed since at least 1970 (Wilson and Carpenter, 1999), but economic analyses of watershed services provided by tropical forests are still few (Lele, 2009) and fragmented. Those few studies that have been conducted quantify the value of environmental benefits such as water quality, but the valuation of ecosystem services provided by forests producing these benefits is less clear. With a view to improving this understanding, a practical examination of previous water valuation studies is undertaken here. We examine these studies under the MA classification framework and an alternative, output-based classification in which the services are defined in terms of their outputs to humans. The output-based classification follows the line of the recent UK NEA classification, based on Fisher et al. (2009). Different processes in the ecosystem result in services that can be enjoyed by humans, where the final output from the sequence of services is the actual benefit. We focus on water services from tropical forests and our geographical focus is Central and South America since, apart from Southeast Asia, this is the main region for water service valuation studies (Lele, 2009).

3.1. *Water-related services provided by forests*

Following the MA framework, it is common to list flood control, water regulation, soil erosion control and water purification under the heading of 'regulating services'; water supply as a 'provisioning service' and habitat function as a 'supporting service' (Lele, 2009). Prior to the MA, other ways of classifying water services were used. Alyward (2002) grouped together erosion, sedimentation and nutrient outflow under the category of 'water quality' impacts, but considered changes in water yield, seasonal flow, storm flow response, groundwater recharge and precipitation to be 'water quantity' issues. De Groot et al. (2002) included water regulation and water supply as part of 'ecosystem regulation functions'. According to this distinction, water supply refers to the filtering, retention and storage of water in streams, lakes and aquifers by the vegetation cover and focuses primarily on the storage capacity of forests rather than the flow of water through the system. The ecosystem services associated with water supply in this category relate to the consumptive use of water by households, agriculture and industry. Water regulation in this context deals with the influence of natural systems on the regulation of hydrological flows at the earth's surface. According to De Groot et al. (2002) ecosystem services derived from the water regulation function include maintenance of natural irrigation and drainage, buffering of extremes in discharge from rivers (thus flood protection), regulation of channel flow, provision of a medium for transportation, groundwater recharge, water purification and erosion control. It is worth noticing how De Groot et al.'s (2002) definition of water regulation functions is to some extent divergent from the subsequent MA classification. In the MA approach water supply is a provisioning service, and water filtering is classed under regulating services (where it is called 'purification'). Both the De Groot et al. (2002) definition and the MA approach coincide in splitting habitat functions off as a separate supporting category, as they provide living spaces for wild plant and animal species.

A common problem of these different classifications is that there is not always a clear distinction between the structure of the ecosystem, the ecosystem processes and the impacts that they produce (e.g. outcomes or benefits). Along these lines, Lele (2009) highlights that structural changes in ecosystems (e.g. timber plantations) can influence several watershed processes (e.g. erosion rates, increase/decrease in water flow, increase/decrease in groundwater recharge). These changes can result in different kinds of human impact, which can be negative (e.g. decreased reservoir capacity due to salinisation or increased sediment load resulting in a negative impact in terms, for example, of water use for hydropower) or positive (e.g. increased fertilisation of floodplains or increased groundwater recharge leading to increased water availability).[2] These impacts can affect different stakeholders (farmers, drinking water users, livestock owners, floodplain residents, hydropower companies) in different ways. We agree with Lele (2009) that the 'process' should not be the focus of valuation, and that it is rather the outcome of the process that has economic meaning and should be valued, as it represents an impact on human well-being (benefit or cost). Following this approach, a practical classification for economic valuation purposes should therefore be based on the outputs of ecosystem processes and not on the processes themselves. There is a growing consensus in the relevant literature that failing to do this may have important consequences for valuation. Those consequences are discussed below in the context of specific primary valuation studies already performed.

3.2. Materials and methods

In order to illustrate the problems arising from the classification of ES for economic valuation purposes, we have undertaken a review of previous primary valuation studies of the hydrological services provided by tropical forests. We analyse water services as valued under the MA classification and compare them with an output-based classification. For this purpose, we use the Brauman et al. (2007) classification of water-related services as a basis, though we introduce some modifications. Brauman et al. (2007) break down water services into improvement of extractive water supply, improvement of in-stream water supply, water damage mitigation, provision of water-related cultural services, and water-associated supporting services. Under this classification, extractive water supply is a service describing the modification of water in the ecosystem used for extraction purposes, which include municipal, agricultural, commercial and other use values. In-stream water supply includes hydropower generation, water recreation and transportation and freshwater fish production. Water damage mitigation includes ecosystem mitigation of flood damage and of sedimentation of water bodies, saltwater intrusion into groundwater and dry-land salinisation. Cultural services include spiritual uses, aesthetic appreciation and tourism. Brauman's is the closest to an output-focused classification that we have found in the literature. However, it should be noted that, as in the MA classification, it distinguishes supporting services, in which it include a wide-range of services such as provision of water for plant growth and the creation of habitat for aquatic organisms such as estuaries. However, as Fu et al. (2011) point out, water cycling (and other supporting services such as nutrient cycling) are not services pursued by humans but merely means of securing freshwater (or food, in the example of the nutrient cycling). Hein et al. (2006) also argue that supporting services are reflected in the other three (provisioning, regulating and cultural) and therefore should not be valued separately. Following this recent line of thinking, we adapt Brauman's classification and reduce it to four categories: (i) improvement of extractive water supply; (ii) improvement of in-stream water supply; (iii) water damage mitigation; and (iv) provision of water-related cultural services. Unlike Brauman, however, we also opt to classify recreation under water-related cultural services.

We have identified 25 forest water valuation studies set in Latin America that were published from 1985 to 2010, providing over 100 value observations. 60% of them were published in peer review journals but we have chosen to also include 'grey literature', which in this case means mostly technical reports from research organisations, e.g. a large number of studies prepared by the Tropical Agronomic Research Institute (CATIE) in Costa Rica as reports to Ministry of the Environment. This choice was made because it significantly increases the number of observations and because we seek to assess the problems of ES valuation in practice, so we are interested in how services are *actually* being defined in economic assessment for policy purposes not just in academic papers.

The studies include a range of valuation techniques from cost-based methods (including avoided costs, reforestation costs and opportunity costs) to non-market stated preference techniques (mostly contingent valuation) and market data (e.g. hydropower and agricultural production). The studies are aimed at a heterogeneous range of purposes, from simply eliciting public willingness to pay (WTP) for services to equity discussions regarding ES. We have also included in our dataset a number of studies on Payments for Ecosystem Services (PES).

Once the valuation studies were identified, a four-step methodological approach was followed. Fig. 1 illustrates this examination process, which consists of:

1. Identification of the water services valued. We identify the water services valued in the study as reported in the original paper, i.e. using the terminology and labelling originally included in the publication.
2. Identification of the corresponding MA categories. From the outset we associate the services under valuation with the main MA categories (MA, 2005). It should be noted that this does not mean that in the studies analysed the authors

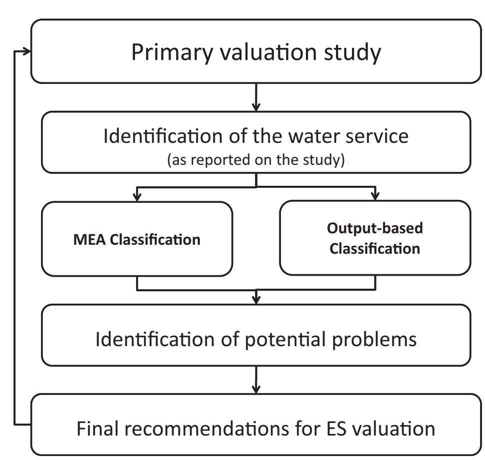

Fig. 1 – Steps for the classification of water-related ES from a sample of primary valuation studies.

[2] Aylward (2002) can be consulted for an exhaustive list of the nature of the impacts of tropical forest loss on water services.

made explicit the correlation between the service that they valued and a corresponding MA category (at least not in all cases). This correlation is made as part of our analysis and is aimed at illustrating the potential problems of the use of the MA classification.

3. Re-classification of the services valued via an output-based classification. From the outset we classify original services in an output-based classification adapted from Brauman et al. (2007).
4. Identification of potential problems derived from ES classifications: results from steps 2 and 3 are compared and discussed in terms of their implications for valuation.

4. Results and discussion

Table I in Appendix A presents the results of the examination analysis. This analysis shows that there are a number of situations where the MA classification enters into conflict with an output-based classification, leading to problems that we have categorised as: 'service overlapping' and 'service ambiguity'.[3] Both elements are pointed out by Fu et al. (2011) as being among the key sources of double counting in environmental valuation. Other problems such as value underestimation might also arise, and in any cases these problems make the secondary use of existing estimates problematic (for example for value transfer and meta-analysis). Table I in Appendix A presents the details of this comparison for all the studies analysed, and shows that these problems arise in almost half of all cases (48.64%). We then select two case studies which are used to describe these potential problems in detail.

4.1. *Service overlapping*

Applying the MA classification of services strictly to the cases reviewed, we find that there would be a significant risk of double-counting derived from the overlapping of ecosystem functions and ecosystem services. When the service valued corresponds to a process and not an output, there is a risk of the same service being valued twice, as part of the process and the outcome itself.

The study by Johnson and Baltodano (2004) is a good illustration of this problem. Johnson and Baltodano (2004) assess the economic value of improving local watershed services for residents in the hillsides of Nicaragua. A decline in water quality and water availability was identified by the community of San Dionisio as the most important consequence of resource degradation in the micro-watershed (as proven by participatory diagnoses undertaken in the context of a research project by the International Centre for Tropical Agriculture, CIAT). Residents blame deforestation and burning of fields for watershed resource degradation and the decline in the availability of water. The study is motivated by the need to compare the costs of interventions at local, regional and national levels for improving water resources with their benefits. For this purpose, the authors undertake a contingent valuation analysis of the value of water services at local level. Box 1 gives the details of this study.

Box 1. Details of the economics of community watershed management in Nicaragua (Johnson and Baltodano, 2004).

Location: San Dionisio, Nicaragua
Watershed: Rio Calico watershed
Surface: 144 km^2
Population: 24,000
Income: poorest in Nicaragua
Economic activity: agriculture (maize and beans)
Land use: crop-pasture (44%); permanent pasture (28%), coffee (14%) and gallery forest (8%)
Environmental problem: decline of water quality and quantity
Research objective: assess the benefits of improving water quality and quantity
Method: contingent valuation
Results: Average WTP: US$0.38. Total value: $10,000 per year
Ecosystem services as reported in study: potable water availability (water quality and quantity)
MA classification: provisioning and regulating
Output-based classification: improvement of extractive water supply

A total of 153 households (approximately 15% of the population) were interviewed in five of the sixteen communities within the micro-watershed. It is very clear from Johnson and Baltodano's paper that the focus of the valuation exercise is on assessing the welfare increase associated both with the improvement of the quality of water and the increase of water availability (water quantity) through the protection of water sources. Survey respondents were explicitly asked to pay for '*improving the source [which means] that there would be more water of better quality from the same source*'.

Looking at the deforestation problem and following the MA classification, both regulating services (water purification, water cycle) and provisioning (fresh water supply) would seem to be affected. However, the value given by the community's willingness to pay responses (WTP) relates to the availability of water for domestic consumption (as the service is discussed in the context of potable water projects in the community). Therefore, the benefits that are valued relate to the improvement of the extractive water supply, as provided by the forest. The regulating effect of forest over the water cycle would be the ecosystem function leading to the quality of the water being suitable for consumption, but it is the final output (enough water of high enough quality) that generates the welfare gain in the community. Any consideration of two services, as a strict interpretation of MA classification, with the corresponding assessment of two additional values, would have the potential for producing a double counting effect.

Another case similar to Johnson and Baltodano (2004) is Postle et al. (2005), who report the value for 'water flow' as provided by forests, which according to the MA classification is a regulating service. However, the output of that process (water flow) could be, for instance, hydropower generation. If

[3] Service overlapping and service ambiguity each account for 24.32% of the cases.

an additional value is given to hydropower, this would be double counting. This is also the case of Barrantes and Castro (1998a) who value 'permanence and continuity of stream-flow' (regulating service) for hydropower generation (provisioning service). Other cases in which the improvement of water quality and water quantity is assessed are presented by Valera (1998), who assesses WTP for water improvements in Costa Rica, and Wittington et al. (1990) who do likewise for Haiti.

It should be noticed, however, that none of the studies analysed here actually incur in the double counting problem because they always provide a single value (and do not value two services separately, i.e. by giving one value to increased water quality and another to increased water quantity). The problem arises when performing secondary analysis with primary valuations, where the ecosystem service can overlap with functions and processes. If the MA classification is applied strictly, we could actually be in a paradoxical situation where the tool (i.e. the classification) would be inducing the error (double counting). Our analysis confirms the potential risk of double counting derived from service overlapping, but also shows how, in the specific case of water supply provided by forest, current practice in primary studies is avoiding this risk.

4.2. *Service ambiguity*

Another source of double-counting is ambiguity in the definition of ecosystem services due to a lack of clarity in the service being valued or to outputs of different natures being valued together or indistinctively. Our analysis, as presented in Table I of Appendix A, shows that the strict use of the MA classification does not help in this respect.

The study by Barrantes and Castro (1998b) is here analysed in more detail (Box 2). The study is aimed at valuing water resources in the Arenal Watershed in Costa Rica, and it conducts an economic and ecological valuation of this water resource. Its ultimate goal was to internalise the environmental costs derived from the use of water resources through the re-structuring of water tariffs. The study was performed to help in the decision making process for more sustainable management of the resources of the region.

A cost-based approach (opportunity costs, restoration costs and changes in productivity) was used to estimate three different values: the value of the forests' water capture function, the value of the forests' potential for watershed protection, and the value of water as an input for production. This definition of services is ambiguous. The authors explain that the water capture function refers to the capacity of the forest to absorb and retain water, but no definition of watershed protection is given. The first two services (water capture function and watershed protection) clearly refer to forest functions and not final outputs. Applying the MA classification strictly, the two first services fall into the regulating category, while the third is a provisioning service. The crucial problem in this case is that the authors explicitly assert that 'the three values need to be added to provide a partial economic-ecological value of the resource'. But as values are given to functions and processes as well as to outputs, there is a clear risk of a double counting effect. Although Barrantes and Castro (1998b) are not using the MA classification, the distinction between regulating and provisioning services would lead to double counting. This problem is resolved by the output-based classification, under which only one category of service is actually involved: improvement of extractive water supply.

Box 2. Details of the economic and ecological valuation of water resources in the Arenal Watershed in Costa Rica (Barrantes and Castro, 1998b)

Location: Costa Rica
Watershed: Arenal watershed
Surface: 58,614 ha
Population: 52,663
Income: n.a.
Economic activity: livestock, coffee plantation and other farming activities
Research objective: estimation of the value of the water resources to internalise environmental costs through the re-structuring of water tariffs.
Methods: cost-based: opportunity costs, restoration costs, changes in productivity
Results: Water capture value: ¢0.62/m^3 (0.0023USD of 1998), watershed protection value: ¢0.44/m^3 (0.0016 USD of 1998) water value for production: ¢2.13/m^3 (0.0079 USD of 1998)
Ecosystem services as reported in the study: water capture function, watershed protection, water as input for production
MA classification: regulating, provisioning
Output-based classification: improvement of extractive water supply

Other similar examples are Reyes et al. (2004) and Munoz-Pina et al. (2008), who value 'hydrological services' in studies for the implementation of a PES scheme in Costa Rica and Mexico, respectively. The general terminology used ('hydrological services') does not allow the output valued to be identified. It is unclear whether it is the total value of all water services provided by the forests or a part of them, leading to potential double counting or even to value underestimation if the wide range of services provided by the forest is minimised into a single value.

There are other cases where there is less ambiguity about the type of service being valued, but where two services with different outputs are valued together. This is the case of Corbera et al. (2007), who report a PES scheme in Guatemala where a local hydroelectric utility paid a monthly fee to a State intermediary organisation to increase efforts in forest conservation. Corbera et al. (2007) specify that the payments were made to ensure continued water flow and a reduction in sediment loads. When classified, both these services fall within the regulating category of the MA, while under an output-based classification they represent outputs of different natures. The first – continued water flow – relates to the capacity of the forest to provide enough flow for use for hydropower generation (*in-stream water supply*). The second relates to the forest's capacity for reducing erosion (*damage mitigation*). One single value is considered as the compound value of two services bundled together. This is not strictly a problem derived from the MA classification, but as both the services fall within the regulating category of the MA it does not help to obtain a proper definition of the service, and the values involved can be either under- or over-estimated if only one of the services is considered (for example, if the value given to two compound services is split the resulting value for one of the services may be an underestimation).

Similar cases are those of the studies by Asquith et al. (2008) and Vargas (2004) who include in-kind payment for two environmental services in Bolivia: the protection of the habitat of migratory bird species and of upland vegetation for protecting dry-season water supplies, which are supporting and regulating services under the MA classification, respectively. In the study by Reyes et al. (2001) only one value is given for domestic water supply and hydropower.

4.3. *Implications for economic appraisal of ES*

It is important to notice that all the studies reviewed here had their own purposes, e.g. a cost–benefit analysis in the case of Mejías et al. (2000) and an analysis of PES schemes in the case of Pagiola (2008). It could be argued that these studies may have achieved their self-declared purposes, and therefore another definition of the service may not be necessary. However, we have shown that for a number of cases the MA classification might induce double-counting due to service overlapping and service ambiguity. This becomes relevant for ecosystem service assessments since primary studies can be a source for benefit transfer and meta-analyses, and can be used as policy inputs for wider analysis (e.g. the case of Barrantes and Castro (1998b) explained here, for which it is proposed to add together the three overlapping services to define new water tariffs). In these cases, double-counting can become an important problem. Therefore, clearly defining ecosystem services is a precaution that must be taken into account in future primary valuation designs.

It should be noted also that there are a number of studies for which we have found no conflicts between the definition of the service as reported in the original study and its corresponding MA category, with the output-based classification (51.35% of the observations). They are mainly studies of water supply provisioning services for extractive use or consumption (Barrantes and Castro, 1998a, 1999; Marozzi, 1998; Pagiola, 2008). This finding is consistent with Fu et al. (2011), who suggest that particular care is needed in relation especially to regulation and supporting services, which are more susceptible to double counting than provisioning services. There are very few valuation studies looking at supporting services (we have only found Asquith et al., 2008; Vargas, 2004) but these services are valued together with other services. While this could be a response to a lack of attention paid to these specific services, the question that arises is to what extent supporting services are actually producing an identifiable output for humans.

Primary studies can be sources for benefit transfer and ecosystem service assessment, and we show here the potential risks of double counting and underestimation entailed when primary studies are used for policy purposes. These problems arise when trying to classify values for ES, where services often need to be aggregated into different categories to simplify the analysis. For such complex secondary assessments, we recommend following an output-based classification.

5. Concluding remarks

Having accurate information on the welfare changes associated with ecosystem services is of crucial importance for the design of effective conservation strategies. The definition of the MA framework represents very significant progress in the recognition of ecosystem services and serves as an important basis for their valuation. However, recent literature is starting to question the suitability of employing the MA framework for the definition and classification of services for the purpose of accurate valuation. This literature is however not unanimous. In this paper we identify the main differences in interpretation between classifications of ES and their valuation according to the definition of services, the ES valued, the types of economic value considered in the services and the nature of those services. From this review, we conclude that there is a need for research into the definition, interpretation and classification of ecosystem services for the MA framework to be successfully applied for valuation purposes. While recent classifications improve the understanding of the economic valuation of ecosystem services (Fisher et al., 2009; UK NEA), our review shows that each classification is drawn up to fulfil its own valuation purposes, and that it is difficult to generalise them into a broader, transferable framework that can be easily used to value ecosystem services under different aims and ecosystems. Future studies need to focus on the relations between functions and services and on how valuation can produce double counting problems.

The exercise presented here should be understood as a first attempt to illustrate the conflicts between the MA framework classification of ES and an alternative classification that looks at the outputs that services provide for humans, with an impact on welfare. The case of water-related services has proven to be a good example for illustrating the potential problems of classifying ecosystem services given the current discussion in the relevant literature. The review of literature on existing research shows clearly how the valuation studies conducted to date have focused on different aspects of water services: sometimes they are valued at different stages of the same process providing human welfare (e.g. stream flow and hydropower supply) and sometimes one single value is assigned to two services of different natures (e.g. in-stream use of water and damage mitigation). A detailed analysis of water-related services in tropical forests shows that a straightforward application of the MA categories can potentially generate problems derived from service overlapping and service definition ambiguity. The identification of these potential problems should provide feedback for the design of primary valuation studies which can accurately assess the value of services and not the process of functions, focusing on the actual outputs of the service provided by forests. Particular care should be taken in defining the service to be valued so as to identify first the nature of the service in terms of its outputs (benefits) for humans. For example, in the case of regulation of water quality, it needs to be clearly defined whether it is for human supply (extractive supply), habitat conservation (supporting) or both. This is particularly true of non-provisioning services, which seem to be harder to define for valuation purposes and more susceptible to double counting and value underestimation. For water ES, we illustrate the potential risk of double counting but our analysis also shows how current practice in primary studies valuing water supply is avoiding this risk. Additionally, there is a lack of attention to non-use values and confusion in the valuation of supporting services, where processes and ecosystem functions are frequently valued.

From our analysis we can conclude that more efforts should be made when valuing ecosystem services to avoid the potential problems identified here. Our results support the idea that an output-based classification can provide a more accurate valuation than the direct application of the MA (Bateman et al., 2011; Fisher et al., 2009; TEEB, 2010). Some take-home messages from our analysis are: (1) the MA is a good framework for understanding the type of services that ecosystems provide to society, but when dealing with valuation, directly applying this framework can be counter-productive; in such cases (2) it is fundamental for the economic valuation of ES to understand the sequence of links between ecosystem processes, services and the outputs that benefit people; and (3) an output-based classification helps to avoid problems such as double-counting and value underestimation, which are particularly relevant in the case of regulating services.

Misleading classifications of ES need to be avoided if accurate benefit transfer exercises are to be implemented. Benefit transferability is considered to be one of the ways forward for widespread internalisation of ES values into policy making. How the service is defined in the original study is crucial for it to be appropriately used in the policy study. An unclear categorisation can lead to misleading application of transferred values and thus to erroneous policy decisions. Future research should explore which classifications of ecosystem services are most suitable for economic valuation at the case study level.

The analysis presented here is not exempt from limitations. For instance, a larger sample of studies could be analysed, e.g. by including the abundant literature on tropical forest ecosystem valuations in Southeast Asia or by expanding the analysis to another type of ecosystem such as wetlands. The output classification used here as an alternative to the MA has been selected from the existing classifications for water services as the most clearly output-focused, but it, too, is not without limitations. For example, the role of non-use related services is not clearly reflected in this classification and gets diluted under the category of water-related supporting services.

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Appendix A

See Table I.

Table I – Analysis of the classification services from water-related services.

Reference	Country	General purpose of the study	Ecosystem service as referred to on the site	Valuation method	Value 2005 USD/ha*	MA classification	Output-based classification[a]	Examination output
Adger et al. (1995)	Mexico	Estimation of total economic value of forests	Sedimentation avoided	Cost-based	0.40–1.76	Regulating	Water damage mitigation	No conflict detected
Asquith et al. (2008)	Bolivia	Analysis of ongoing Los Negros PES scheme	Water flow and supply and non-use value for bird habitat	PES	0.08–3.16	Regulating, provisioning and supporting	Improvement of extractive water supply; in-stream water supply	Service overlapping
Barrantes and Castro (1998a)	Costa Rica	Value of water service for cost internalisation	Permanence and continuity of stream flow	CV	3.03	Regulating	Extractive water supply	Service ambiguity
Barrantes and Castro (1998b)	Costa Rica	Value of water service for cost internalisation	Water capture function	Cost-based	n/a	Regulating	Improvement of extractive water supply	Service ambiguity
Barrantes and Castro (1998b)	Costa Rica	Value of water service for water tariff revision	Watershed protection	Cost-based	n/a	Regulating	Improvement of extractive water supply	Service ambiguity
Barrantes and Castro (1998b)	Costa Rica	Value of water service for water tariff revision	Water as an input for production	Market data	n/a	Provisioning	Improvement of extractive water supply	No conflict detected
Barrantes and Castro (1999)	Costa Rica	Value of water service for water tariff revision	Water supply	Cost-based and CV	1.96–144.74	Provisioning	Improvement of extractive water supply	No conflict detected
Barrantes et al. (2003)	Costa Rica	Economic appraisal of service	Water productivity of the forest	Cost-based	n/a	Regulating	Improvement of extractive water supply; in-stream water supply	Service ambiguity
Barrantes (2006)	Costa Rica	Economic appraisal of water services	Water capture function	Cost-based and PES	59.77–75.23	Regulating	Improvement of extractive water supply	Service ambiguity
Chomitz et al. (1999)	Costa Rica	Discussion and implications of PES	Water flow for hydropower generation	PES	18.85	Regulating and provisioning	In stream water supply	Service overlapping
Corbera et al. (2007)	Guatemala	Analysis of equity implications of PES	Continuous water flow and reduction in sediment loads	PES	22.14	Regulating	In stream water supply and water damage mitigation	Service ambiguity
De Sena (1997)	Costa Rica	Estimation of WTP for recreational activities	Recreation	CV and TC	n/a	Cultural and amenity	Water related cultural services	No conflict detected
Johnson and Baltodano (2004)	Nicaragua	Assessment of the economic value of improving local watershed services for residents	Potable water availability (quantity and quality)	CV	1.18	Provisioning and regulating	Improvement of extractive water supply	Service overlapping

Table 1 (*Continued*)

Reference	Country	General purpose of the study	Ecosystem service as referred to on the site	Valuation method	Value 2005 USD/ha*	MA classification	Output-based classification[a]	Examination output
Koellner et al. (2010)	Costa Rica	Potential demand for PES scheme	Watershed protection	WTP	n/a	Regulating and provisioning	Improvement of extractive water supply in stream water supply	No conflict detected
Kosoy et al. (2007)	Honduras Costa Rica Nicaragua	Comparison of water related PES	Water quality	PES	3.05–51.58 76.24–530.30 29.51–366.06	Provisioning and regulating	Improvement of extractive water supply	Service overlapping
Marozzi (1998)	Costa Rica	Feasibility of CV study	Potable water	CV	4.94	Provisioning	Improvement of extractive water supply	No conflict detected
Martinez et al. (2009)	Mexico	Effects of land use change on biodiversity and ecosystem services	Water regulation and recreation (mixed together)	Value transfer	147.75	Regulating and cultural services	In stream water supply and water cultural related services	Service ambiguity
Mejías et al. (2000)	Costa Rica	Cost–benefit analysis	Household water consumption	Market data	n/a	Provisioning	Improvement of extractive water supply	No conflict detected
Mejías et al. (2000)	Costa Rica	Cost–benefit analysis	Water quality and quantity	Cost-based	n/a	Provisioning and regulating	Improvement of extractive water supply	Service overlapping
Mejías et al. (2000)	Costa Rica	Cost–benefit analysis	Hydropower	Market data	n/a	Provisioning	In stream water supply	No conflict detected
Merayo (1999)	Costa Rica	Total economic value of potable water	Potable water for household supply	CV	2.81	Provisioning	Improvement of extractive water supply	No conflict detected
Munoz-Pina et al. (2008)	Mexico	Evaluation for PES scheme	Hydrological services	Survey	18.2	Regulating	Improvement of extractive water supply	Service ambiguity
Pagiola (2008)	Costa Rica	Analysis of current PES schemes in Costa Rica	Water supply for hydropower	PES	15–67.96	Provisioning	Improvement of in stream water supply	No conflict detected
Pagiola (2008)	Costa Rica	Analysis of current PES schemes in Costa Rica	Water supply for bottler	PES	41.24	Provisioning	Improvement of extractive water supply	No conflict detected
Pagiola (2008)	Costa Rica	Analysis of current PES schemes in Costa Rica	Water supply for irrigation	PES	30–51.21	Provisioning	Improvement of extractive water supply	No conflict detected
Pagiola (2008)	Costa Rica	Analysis of current PES schemes in Costa Rica	Water supply for tourist companies	PES	45	Provisioning	Improvement of extractive water supply	No conflict detected
Postle et al. (2005)	Ecuador	Analysis of water supply benefits for watershed protection	Water supply	Market data	0.32	Provisioning	Improvement of extractive water supply	No conflict detected
Postle et al. (2005)	Costa Rica	Analysis of water supply benefits for watershed protection	Water flow	PES	0.09	Regulating provisioning	In stream water supply	Service overlapping

Reyes et al. (2001)	Costa Rica	Service valuation	Hydropower and water consumption	Cost-based	152.71–268.77	Provisioning	Improvement of extractive water supply and in stream water supply	No conflict detected
Reyes et al. (2004)	Costa Rica	Water resource valuation for PES implementation	Hydrological services	Multicriteria (WTP)	n/a	Regulating	Unclear from the study (improvement of extractive supply only or also in-stream water supply)	Service ambiguity
Reyes and Cordoba (2000)	Costa Rica	Economic and ecologic valuation of the use of water for hydropower i	Hydropower	Market data	193.69	Provisioning	Improvement of in stream water supply	No conflict detected
Solórzano et al. (1995)	Costa Rica	Environmental costs internalisation in Natural Parks	Water consumption	Cost-based and CV	n/a	Provisioning	Improvement of extractive water supply	No conflict detected
Valera (1998)	Costa Rica	Assessment of WTP for water quality improvement	Water supply (quantity and quality)	CV	167.73	Provisioning and regulating	Improvement of extractive water supply	Service overlapping
Vargas (2004)	Bolivia	Evaluating economic basis of PES	Water flow and supply and non-use value for bird habitat	CV	0.63	Regulating, provisioning and supporting	Improvement of extractive water supply	Service overlapping
Veloz et al. (1985)	Dominican Republic	Analysis of soil conservation project	Avoided erosion	Market data	6016.55	Regulating	Water damage mitigation	No conflict detected
Wittington et al. (1990)	Haiti	Estimating households' WTP	Water supply (quantity and quality)	CV	238.40	Provisioning and regulating	Improvement of extractive water supply	Service overlapping

CV, contingent valuation; PES, payment for ecosystem services; TC, travel cost method; WTP, willingness to pay; n/a, not available.

[*] Missing values correspond to studies for which it was not possible to identify the related forest area and therefore value per hectare cannot be calculated.

[a] Adapted from Brauman et al. (2007).

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