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Ecosystem Services into Water Resource Planning and Management

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Summary

The broad economic notion of Ecosystem Services (ES) refers to the benefits that humans derive, directly or indirectly, from ecosystem functions. Provisioning ES refer to human-centred benefits that can be extracted from nature (e.g., food, drinking water, timber, wood fuel, natural gas, oils etc.), whereas regulating ES include ecosystem processes that moderate natural phenomena (pollination, decomposition, flood control, carbon storage, climate regulation etc.). Cultural ES entail non-material benefits accruing to the cultural advancement of people, such as the role of ecosystems in national, and supranational cultures, recreation and the spur of knowledge and creativity (music, art, architecture). Finally, supporting ES refer to the main natural cycles that nature needs to function, such as photosynthesis, nutrient cycling, the creation of soils, and the water cycle. Most ES either depend on or provide freshwater services, so they are linked to Water Resources Management (WRM). The concept of ES initially had a pedagogical purpose to raise awareness on the importance of reasonable WRM, however, later it started being measured with economic methods, and having policy implications.

The valuation of ES is an important methodology aimed at achieving environmental, economic and sustainability goals. The Total Economic Value (TEV) of ecosystems includes market values (priced) as well as non-market values (not explicit in any market) of different services for humanity's benefit. The valuation of ES inherently reflects human preferences and perceptions regarding the contribution of ecosystems and their functions to the economy and society. The ES concept and associated policies have been criticised on the technical weaknesses of the valuation methods, interdisciplinary conflicts (e.g., ecological vs economic perception of value), and ethical aspects on the limits of economics, nature's commodification, and its policy implications.

Since valuation affects the incentives and policies aimed at conserving key ES, e.g., through payment schemes, it is important to understand the way that humans decide and develop preferences under uncertainty. Behavioural Economics attempts to understand human behaviour

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and psychology and can help to identify appropriate institutions and policies under uncertainty that enhance ecosystem services that are key to water resources management.

Keywords: Ecosystem Services, Water Resources, Management, Valuation, Total Economic Value.

Ecosystem Services (ES) and their connection to Water Resources Management

Any work on the "Ecosystem Services into Water Resource Planning and Management" needs to start with the definition of the basic concepts: Ecosystem Services (ES), Water Resources Management (WRM), Planning, its goals and connection with ES, economic approaches of ES, and then the integration of the above under right purposes and rationale. Overall, the aim of this work is to provide a broad overview and description of how ES are being approached and related to Water Resources Management (WRM).

Ecosystem Services (ES): definitions and relations

Ecosystems provide functions and services that are essential for human well-being and planetary health. Despite the lack of unanimity in the definition, all known and used definitions of ES are to a large extent similar, linking ecosystems to human-centred well-being and outcomes. According to Daily (1997), ES are "The conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfil human life", whereas Costanza *et al*. (1997) add that they are "Benefits human populations derive, directly or indirectly, from ecosystem functions". In a similar fashion to Daily (1997), Fisher *et al*. (2009) postulate that ES consist of "The aspects of ecosystems utilized (actively or passively) to produce human well-being", while Arias-Arévalo *et al*. (2018) provide examples in their definition of ES as "[…] to the benefits people obtain from ecosystems, such as fresh water, food, climate regulation, recreation or aesthetic experiences". Finally, the approach of Burkhard *et al*. (2012) coincides with the one by Fisher *et al*. (2009) but with the additional reference to "other inputs" that contribute to human well-being.

De Groot *et al*. (2002) presented a detailed typology of 23 functions, goods and services of natural and semi-natural ecosystems, with many more sub-categories and the majority of economic activities. The main functions associated with Water Resources Management include climate regulation; disturbance prevention (storm protection and flood prevention); water regulation (e.g., land cover, regulation of runoff, river discharge); water supply; soil retention (vegetation, arable land, prevention of erosion); soil formation; nutrient regulation; waste treatment; aesthetic features; recreational uses; cultural, artistic, spiritual, historic, scientific and educational values.

The most commonly used classifications of ES (De Groot *et al*., 2010; Häyhä & Franzese, 2014; MA, 2005) are the following:

- *Provisioning*: food, timber, other raw materials, biomass, water.
- *Regulating* (and maintenance): ecosystems' capacity to regulate processes, life support systems, e.g., climate and flows regulation, etc., pest and disease control. Other similar processes such as photosynthesis, nutrient uptake, soil formation etc. can also be found in the literature as "supporting" or "production" functions of ES.

- *Cultural*: recreation, aesthetic experiences - physical, intellectual, and spiritual interaction with ecosystems.
- *Habitat*: nursery habitat, gene pool protection - wild plants and animals, evolutionary processes.

It can be understood that ES transform natural assets into things that we value, hence there exists a direct connection with economic principles and economic tenets such as the market. As such, the concept of ES and their valuation contributed to viewing environmental and socio-economical issues as an integrated system, with constantly interacting sub-systems (Häyhä & Franzese, 2014; Alamanos *et al*., 2022). Chan *et al*. (2012) stress that standard ES approaches based primarily in economics do not encompass all dimensions of value, and thus fail to address significant intangible attributes that are of value both in an anthropocentric and a biocentric manner. The prevalence of economic theory in the ES valuation process has, according to the authors, marginalized several social and ethical concerns. In their view, a more suitable typology distinguishes among services, benefits, and values, postulating that ES yield benefits which are of anthropocentric as well as intrinsic value. Ecosystem Services economic valuation has gained prominence in the field of environmental science, as it is perceived as the most comprehensive way to assign monetary values to the improvements or losses of environmental resources. Insofar as pecuniary values can be attributed to ecosystem services, policymakers can make fact-based decisions regarding the allocation of funds, the priority of climate projects and also elicit the public's views on environmental assets. Especially when faced with tight budgets and constraints from macroeconomic and social variables, policymakers can only benefit from the economic valuation of ES. According to the 2008 *The Economics of Ecosystems and Biodiversity* (TEEB) 'you cannot manage what you do not measure' (p8). Attaining reliable, science-based information and pinpointing economic values can be of great use in the decision-making process as policymakers can assess whether a specific project or policy intervention can spur net benefits that compensate for its cost and, therefore, validate or reject certain initiatives (World Bank, 2004).

Acquiring critical quantitative information was the main constraint for public and private stakeholders in the field of environmental policy in the 20th century, despite the growing concern of environmental protection (Bingham *et al*., 1995). Economic valuation of ES is a necessary step in undertaking Cost-Benefit Analysis (CBA). The method of CBA is popular in environmental policy because it "forces the decision-maker to look at who the beneficiaries and losers are in both the spatial and temporal dimensions" (OECD, 2006 p.34). In contrast to other methods, defining the multiple uses and benefits of ecosystem services through the proposed typologies allows for the evaluation of impact on diverse stakeholders rather than a specific group of people or an industry. Daily *et al*. (2009) underscore the interdependencies and feedback loops among policy decisions and ES. Coherent valuation informs on the benefits rooted in ecosystems, which in turn mould the institutions that guide policy and decisions in many levels. These actions affect ecosystem quality and the services it provides, thus regenerating the entire process on a new knowledge basis. Taking into consideration the multifaceted notion of ES total economic value and utilizing tools from diverse fields (economics, biophysics, sociology), decision makers can gain substantially from carefully designed valuation techniques in order to pursue interventions that preserve or restore environmental resources and can mitigate the adverse effects of climate change.

Water Resources Management (WRM) and Planning

WRM refers to all methods and activities required for the rational utilization of water resources; it includes: i) scientific methods and techniques (hydrological analysis, observation of the water resources, and understanding of water demands across space and time, ii) operational interventions and administrative measures aiming to maximize the benefit from the use of water systems, according to criteria, priorities and goals, already set (socio-economic analysis), iii) and all technical works and legislation required to achieve the above (Loucks & Beek, 2017).

According to the aforementioned definition, WRM can be paralleled with an economic activity that is subject to the laws of supply and demand, with the difference that the good that is offered is water: a natural good under conditions of scarcity, with strong social characteristics (Alamanos *et al*., 2020). This suggests an integrated and interdisciplinary planning character, as it involves a variety of water consumers, including human and natural consumers, a series of decision-makers (government, regions, municipalities, companies, etc.), and a variety of managers as well as uncertainties regarding the availability and use of water resources. The planning objectives refer to supply adequate water of acceptable quality, to protect water resources and the environment from pollution and extreme phenomena, to preserve ecosystems and the natural environment, and to use water resources efficiently for economic and social prosperity as well as environmental sustainability. Its aims of sustainability, as described in the above paragraph are also described and stated in the recent Sustainable Development Goals (SDGs) – which are explicitly related also to WRM, the European Green Deal, Paris Climate Agreement, etc. (European Commission, 2019; United Nations, 2015, 2016). WRM and planning is directly associated with SDG 6 in particular, *namely ensuring availability and sustainable management of water and sanitation for all.* According to the latest reporting from the UN (2022), a holistic and sustainable approach on water management is required in order to meet SDG 6 targets and provide for the most marginalized communities. Hence, cooperation from the different actors involved (multilateral organizations, private finance, civil society, national and regional governments), trust, and participatory planning are essential. As it can be understood from the above, WRM is inherently interacts with individual preferences and goals, since the water users are (a defining) part of the system – see for example Socio-Hydrology (Sivapalan *et al*., 2012).

ES in WRM and Planning

Water resources include surface water, groundwater, inland water, rivers, lakes, transitional waters, coastal waters, and aquifers (Chave, 2001). These resources are of perennial importance for livelihoods, well-being, and economic growth, nonetheless they have suffered immense degradation and, in some cases, depletion. Water resources are necessary inputs to production in agriculture (arable and non-arable land, aquaculture, commercial fishing, and forestry), industry (e.g., power generation) and tourism, as well as to household consumption (UNEP, 2005). Having said that, WRM is crucial in preserving and enhancing water ecosystems to maintain and increase their services. Ecosystem Services germane to water include direct use values such as drinking water, irrigation, and industrial input. Indirect use values of water resources include *inter alia* flood control, nutrient retention, and storm protection. Finally, option value for water resources therefore represents their potential to provide economic benefits to human society in the future. (Birol *et al.*, 2008).

The concepts of ES and WRM have numerous common elements, objectives, and threats since both interconnect environmental with social science. Indicatively, these include:

<u>Environmental Aspects</u>: Water needs of natural ecosystems are considered in environmental studies (e.g., estimated as *environmental* or *ecological flows* – the minimum water requirements needed for the functioning of ecosystems).

<u>Social Aspects</u>: The social aspect of both ES and WRM is a common field, as humans are part of ecosystems, obtain goods and services, value them, use water resources, so they are a dynamic part of the 'equation' (Alamanos *et al*., 2022).

<u>Socio-economic Implications</u>: As already mentioned, humans benefit from ecosystems and water resources, in a plethora of ways. Also, water is recognised as an economic good (so it has an economic value in all its competing uses). Economists monetise these values using econometric models and utility functions. Individual preferences play an essential role here (e.g., results from surveys, direct or indirect valuation methods, behavioural or experimental economics). Furthermore, decisions of WRM often include large-scale projects of high costs, have an irreversible character, and affect a big part of the population and its activities. Subsequently, a socially acceptable, cost-effective, and globally beneficial WRM planning, is not depending only on the technically optimum solution (Loucks and van Beek, 2017; Alamanos *et al*., 2020).

<u>Challenges</u>: Overexploitation of resources and ecosystems, qualitative degradation and irrational management are common challenges, that both ES and WRM concepts aim to address with another concept, that of sustainability. Any degradation in WRM is in fact a degradation of ES (Bellver-Domingo *et al*., 2017).

The concept of ES is broad, as it refers to an all-encompassing function such as the ecosystem, and can act complementarily with eco-hydrology, hydrogeology, socio-hydrology, etc. If ES and their value are well-perceived from the public, it can only be beneficial for WRM. Understanding the challenges, considering the environmental flows in design studies, and building on the right social principles facilitate WRM's processes, and contribute to its objectives. Since our goals relate to our increasing "Utility", or economic prosperity, or growth, and are directly or indirectly connected with water resources and ecosystems, the economic benefits are the outcomes of this management process.

Economic perception of ES

The evolution of the ES concept

The concept of ecosystem services emerged in the 1970s to describe the linkages between ecosystem degradation and human development outcomes. Its initial use was pedagogical (Westman, 1977): natural scientists described how biodiversity loss directly affected ecosystem functions underpinning critical services for human well-being with the aim to trigger action for nature conservation (Gómez-Baggethun *et al*., 2010). According to Gómez-Baggethun *et al*. (2010), the ES concept was mainstreamed in the sustainability sciences literature during the 1990s (Daily, 1997; Costanza *et al*., 1997). Since then, the concept has been integrated in the decision-making and the policy agenda (MA, 2005).

In their seminal paper, Costanza *et al*. (1997) estimated the value of the world's natural capital and ecosystem services (17 ES) at US $16-54 trillion/year. Considering that the value of global GDP stood at almost US $32 trillion in the same year, the monetization of ES highlights the importance of these systems. Another influential publication was the 2005 MA which raised awareness of the threats ES face and placed the ES concept on the top of the biodiversity policy agenda. Both studies gave impulse to ES assessments and valuation studies. The Economics of Ecosystems and Biodiversity (TEEB, 2007) is a major international initiative that evaluates the costs of biodiversity loss and the associated decline in ecosystem services worldwide, comparing them with the costs of effective conservation and sustainable use.

Despite the emergence of a rich theoretical and empirical literature on ES and valuation after 2000, the challenge to develop comprehensive assessment frameworks, which entail biophysical, social, and monetary variables remains. Hence, according to Martin-Lopez *et al*. (2012) recent literature has sought to construct frameworks that integrate the different sources of information and indicators of ES and utilize biophysical information (supply side) to the ES users (demand side). Remme *et al.* (2014) point to the fact that while regulating ES are completed by the ecosystem, provisional ones require human contribution. It is, therefore, difficult to identify the true benefits from the ecosystem and to underline the biophysical indicators to be measured and used in policymaking. According to Sannigrahi *et al.* (2020) biophysical dynamics (e.g., changes in climatic conditions, soil properties, plant functional structure, ecological compositions, and structures) destabilize ES and should, therefore, be considers in the valuation process.

Valuation of ES in Economics

Ecosystem Services and environmental quality are of immense interest, primarily because they create value for humans. Total Economic Value (TEV) encompasses all channels through which ES contribute to tangible and intangible benefits and enhance well-being. Figure 1 outlines the broader value categories. *Use value* derives from the immediate exploitation of ES for human wellbeing and includes: (i) *direct use value*, whereby humans make deliberate use if the ecosystem, for example, for nutrition, irrigation, timber etc. (ii) *indirect use value*, whereby human beings benefit from ES without directly using environmental resources, as is the case with carbon sequestration, pollution filtering, water regulation etc. and (iii) *option value*, which refers to the knowledge that an individual will be able to derive a use value in the future, where this use could be direct or indirect, hence it is the value attributed to preserving environmental resources such as a natural park. *Non-use value (passive value)* lies in the premise that acknowledging the existence of ES is of value to human beings and can be further categorized in: (i) *bequest*, i.e., valuing the fact that an ecosystem will be passed on to future generations, (ii) *existence*, i.e., the value of the existence of the ecosystem as it stands, and (iii) *altruistic*, i.e., valuing the fact that an ecosystem can be enjoyed by other people in the community. Of course, the typology of ES and values vary, however Figure 1 and Table 1 summarises the most common classifications.

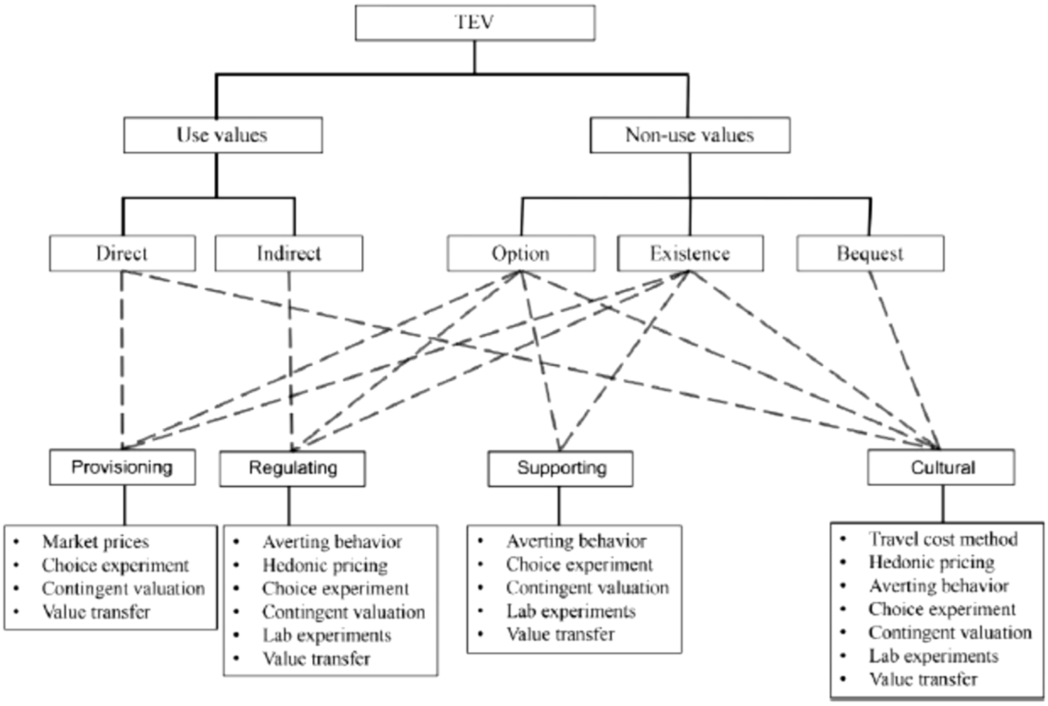

Figure 1. Deriving the Total Economic Value (TEV)

Table 1. Examples of Use and Non-Use values for water resources as parts of the Total Economic Value (Adopted from Birol *et al*., 2006).

Use values	
Direct use values	***Indirect use values***
Irrigation for agriculture	Water purification
Domestic and industrial water supply	Waste treatment
Energy resources (hydro-electric, fuel wood, peat)	Flood control, protection, and stabilization of water flows
Transport and navigation	Natural hazard mitigation
Recreation/amenity	External eco-system support
Fish and livestock production	Micro-climatic stabilization
Option values	Reduced global warming
Potential future uses of direct and indirect uses	Shoreline stabilization
Future value of information of biodiversity	Soil erosion control
	Stabilization of Water Flows
Non-use values	
Biodiversity	
Aesthetic value	
Cultural heritage	
Bequest, existence, and altruistic values	

Valuation is a quantitative process of determining the fair value of an asset or a service. Assigning monetary values to ES according to their aforementioned uses provides the ground for the design and implementation of environmental policies as it offers an estimation of the benefits that can be used for a cost-benefit analysis. In broad terms, valuation methods are divided into *Stated Preference Methods* and *Revealed Preference Methods.* The former includes collecting data through carefully structured questionnaires (e.g., Contingent Valuation Methods and Choice Experiments) and the latter attempt to elicit human preferences for ES through secondary data (e.g., Hedonic Price Method, Travel Cost Method). Examples of valuation methods are presented in Table 3.[4]

Two important stages at any valuation process are the Willingness to Pay (WTP) estimation (the proper problem formulation), and the selection of the appropriate technique. The most used tools for the application are questionnaires and/or interviews to derive the weightings of the desired variables, and then their statistical editing, and fitting of the appropriate econometric model, usually based on regression techniques exemplified in Figure 2.[5]

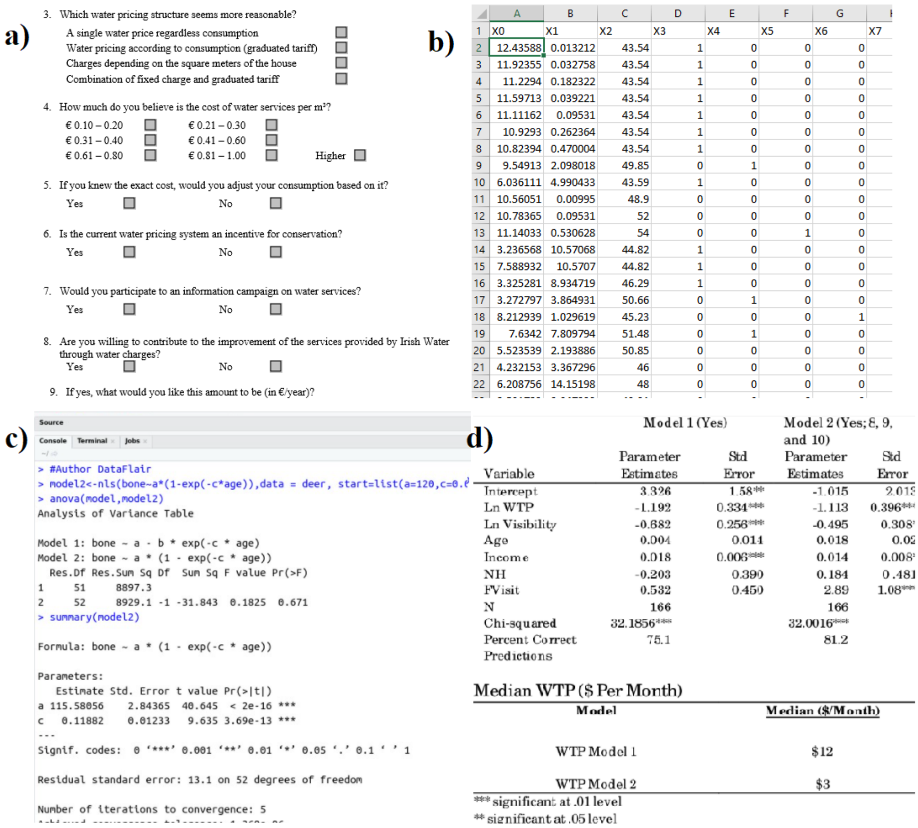

Figure 2. Indicative example of how economists implement a valuation process: a) desk-study to develop an appropriate questionnaire, b) organising the results according to the variables retrieved from the sample (0 and 1 refer to binary variables expressing qualitative questions, e.g. Yes-No), c) econometric model (here shown in R), d) results-table interpretation. Source: Authors' elaborations

There are two key points for the effective valuation of ES: the clarity about the type of valuation employed and the service(s) considered, and the adoption of a strong theoretical basis guided by ecological knowledge. Table 2 presents a brief review of studies germane to ES valuation. Elaborating on these studies reveals that most catchment-related ES are non-marketed and as a

[4] For a description on valuation methods see Halkos (2016).
[5] Statistical software is usually used, such as STATA, SPSS, or programming languages (e.g., R, Matlab, Python).

result their valuation is not explicit in any market (e.g. aesthetic values). Moreover, some of the benefits may be derived by the actual use of the ecosystem, whereas other types of benefits can be derived only by the knowledge of their existence, even if there is no actual use of the ecosystem. The implementation of the economic analysis of ES approaches requires the identification and quantification of all types of values that an ecosystem can provide. This leads to the framework of the Total Economic Value (TEV) estimation, presetned in Figure 1.

Table 2. A review of studies on ES valuation.

Study	**Topic**	**Description**
Costanza & Farber (2002)	Dynamics and value of ES: integrating economic and ecological perspectives	Provides an overview of ES values, concepts, literature review and research questions, and highlights the importance of understanding the theory of ES first
Villa *et al.* (2002)	Designs an integrated knowledge base to support ES valuation	A web-database for ES to facilitates their valuation methods selection
Chee (2004)	An ecological perspective on the valuation of ES	Describes the economic framework and valuation tools. Acknowledges that economic valuation techniques provide valuable information for conceptualising ES, but there are practical limitations (participation, uncertainties & transparent decision-making)
Winkler (2006)	An integrated dynamic approach for the valuation of ecosystem goods and services	The ecological valuation methods derive values by a cost-of production approach, while the economic valuation methods focus on the exchange value of ES, hence a model - framework is proposed to assess these two different approaches
Hein *et al.*, (2006)	Spatial scales, stakeholders and the valuation of ES	A framework for the valuation of ES, with specific attention for stakeholders. Analyses the spatial scales of ES: the ecological scales at which ES are generated, and the institutional scales at which stakeholders benefit from ES
Brauman *et al.* (2007)	The Nature and Value of ES: An Overview Highlighting Hydrologic Services	Valuation and policy tools review, including the aspect of the ES concept evolution
Kumar & Kumar (2008)	Valuation of the ES: A psycho-cultural perspective	Based on the difference of the common person's perception of ES than economists', argues about how people understand ecosystems based on psychology
Plummer (2009)	Assessing benefit transfer for the valuation of ES	Argues on the issue of correspondence of case study and example sites, and provides guidelines to apply benefit transfer
de Groot *et al.* (2010)	Challenges in integrating the concept of ES and values in landscape planning, management, and decision-making	Supports the structural integration of ES in landscape planning, management, and design. Several studies highlight that need (e.g., Deal et al.,2012)
Gómez-Baggethun & Ruiz-Pérez (2011)	Economic valuation and commodification of ES	Role of the institutional setup of environmental policy, and the broader economic and socio-political processes (mainly institutional-political context)
Sagoff (2011)	Quantification and valuation of ES (Differences between	Conceptual distance between market-based and science-based methods of assembling information and applying

	economic and ecological criteria)	knowledge defeats efforts to determine the “value” of ES in any integrated sense
Pascual *et al*. (2012)	The Economics of Valuing ES and Biodiversity (approaches for the estimation of values)	Relationship between valuation methods and value types, comments on methods, and discussing approaches may overcome disadvantages of valuation methods
Farley (2012)	Economics debate on ES, based on how the definitions and structure can define the appropriate methods and economic institutions	Conventional economists (Pareto efficiency through markets) versus Ecological economists (highest possible quality of life compatible with environment through economic institutions)
Keeler *et al*. (2012)	Linking water quality and well-being for improved assessment and valuation of ES	Describes the multiple biophysical and economic pathways that link actions to changes in water quality-related ecosystem goods and services and provide guidance to researchers interested in valuing these changes
Ojea *et al*. (2012)	ES for economic valuation: the case of forest water services	Defining and classifying ES, describing double counting risk
Costanza *et al*. (2014)	Changes in the global value of ES	An update to the 1997 paper, with emphasis on different valuation purposes, and different values per ES which entail different methods
Hansjürgens *et al*. (2016)	Justifying social values of nature: Economic reasoning beyond self-interested preferences	How economic valuation methods could be improved by integrating deliberative elements to capture social value components in valuation exercises
Pandeya *et al*. (2016)	Comparative analysis of ES valuation approaches for application at the local scale and in data scarce regions	Weaknesses of valuation at local scale, review of studies, and importance of the data used
Wam *et al*. (2016)	Conflicting interests of ES between monetary and non-monetary values	Multi-criteria modelling and indirect evaluation of trade-offs between monetary and non-monetary measures and how to assess different values
Hackbart *et al*. (2017)	Theory, practice of water ES valuation, and future trends	Valuation of ES still involves very different terminology, conceptual, and have very simplistic biophysical background, so arguing on valuation methods, connection with ecological background, and social control
Schmidt *et al*. (2017)	Testing socio-cultural valuation methods of ES to explain land use preferences	Questions five groups of people with different land use preferences (forest and nature enthusiasts, traditionalists, multi-functionalists and recreation seekers) to find predictors for land use preferences
Arias-Arévalo *et al*. (2018)	Widening the evaluative space for ES: a taxonomy of plural values and valuation methods	Multiple, and often conflicting, valuation languages – corresponds value definitions to valuation methods
Balasubramanian (2019)	Economic value of regulating ES	A review at the global level of value estimates
Naime *et al*. (2020)	Economic valuation of ES from secondary tropical forests	Value estimates, trade-offs, and implications for policy making

Conceptualisation of ES in Economics

The economics literature conceptualizes ES through a variety of use and non-use (protection) values, with all their direct and indirect values. Table 3 reviews studies that linked ES concepts with economic analysis. Understanding the interlinkages among complex ecosystems and their *contributions to the economy* will enhance the relevance and the efficiency of policymaking and will ensure that the environment and the economy are treated in a holistic fashion, and not competitively. All studies described in Table 3 refer to ES use values, however valuation and subsequently policymaking were always meant to be the next steps. The extensive literature on the correct perception of the fundamental concepts is indicative of how important this is so as the next steps to be built on solid bases. Farley (2012) notes that ES definitions and structure define the appropriate methods, economic institutions, and thus decisions.

Table 3. A review of studies on ES concepts and use in Economics.

Study	**Topic**	**Description**
Salzman *et al*. (2001)	Protecting ecosystem services: Science, economics, and law	This book combines the economic concept of ES with law to scrutinise their relations. Frameworks for managing ES within a district, including modelling and legislative aspects
De Groot *et al*. (2002)	Typology for classification, description and valuation of ecosystem functions, goods and services	23 ecosystem functions that provide a much larger number of goods and services. These are then linked to the main ecological, socio–cultural and economic valuation methods
Fisher *et al*. (2008)	ES and Economic Theory: integration for policy-relevant research	A perspective on how ES economics can be integrated in policymaking, reviews the relevant literature, and uses a questionnaire of researchers on the topic
Fisher *et al*. (2009)	Defining and classifying ecosystem services for decision making	An attempt to classify ES, based on both the characteristics of the ecosystems of interest and a decision context for which the concept of ES is being mobilized
Sandhu *et al*. (2010)	Organic agriculture and ecosystem services	Redesign of small-scale farms using new eco-technologies based on novel and sound ecological knowledge
Deal *et al*. (2012)	Coordinated, integrated approach in transferring ES valuing to public services	Bundling of ES to increase forestland value and enhance sustainable forest management
Häyhä & Franzese (2014)	A review of ES under an ecological-economic and systems perspective	Definitions, classification, and categories of values and methods for ES research
Lautenbach *et al*. (2015)	Gap identification in ES research and implementation	Issues on stakeholder involvement and good modelling practice. “Most practices have not improved significantly, although the geographical spread of ES research is broad”
Martin-Ortega et al. (2015)	The book gives a global perspective of ES research and how it is incorporated in water resources management	Definitions of ES-based approaches, risks, and applications where ES can be used as tools, including case-study examples
Maes *et al*. (2018)	Inclusive character of ES and ability to deliver multiple values	Argues on the concept of nature's contributions to people, how multi-factorial it is, and that it needs a multi-disciplinary approach
Schmidt *et al*. (2019)	Key landscape features in the provision of ES	Provides insights for management, through comparing results of participatory mapping of ES with maps of targets, and examining to what extent these landscape features are the focus of current management plans, to identify gaps

Thompson *et al*. (2020)	ES as new framework for old ideas, or advancing environmental decision-making?	The Millennium Ecosystem Assessment ES framing may assist planners connecting local land-use change to human wellbeing, assessing trade-offs, and accounting for future uncertainty
Vermaat *et al*. (2020)	Applying ES as a framework to analyse the effects of alternative bio-economy scenarios in Nordic catchments	ES in Nordic catchments, depending on the CORINE land use with framework potential land uses effects, as assessed through scenarios

The essence of the valuation process is to establish and gauge the ES *contributions to the economy* implying the provision of good, services, or wellbeing that economists can convert into monetary units. The book by Salzman *et al*. (2001) uses a simple example to describe the use of economics for ES, what questions it attempts to answer, and what evidence it can provide for relevant policy decisions. The example consists of a simplified hypothetical district (or catchment for our purpose) that consists of:

- an upland forest, which provides timber and sequesters and stores carbon.
- a farmland below, whose irrigation water comes from the forested watershed; and
- a city, whose drinking water is also supported by the upland forest.
- A river flows from the forest through the farmland to the city.

The catchment features a variety of ES: food, timber, climate stability (via carbon storage and sequestration), flood control, clean water, recreation, biodiversity, as well as options for future changes in policies (i.e., flexibility for future decisions on land use changes). Clearly, there are inherent interactions among these (e.g., if one component is degraded or destroyed, there will be chain-impacts for the whole system, including the economy).

However, although there is an increasing amount of information regarding the ecological and socio-economic value of goods and services provided by natural ecosystems, much of this information is scattered throughout academic literature. A notable attempt to gather and organize this kind of data was made by De Groot *et al*. (2002), who provide a comprehensive framework of a range of 23 ecosystem functions linking them also to the main ecological, socio-cultural and economic valuation methods. Ecosystem functions are then defined as “the capacity of natural processes and components to provide goods and services that satisfy human needs, directly or indirectly” (De Groot, 1992). To this end, De Groot *et al*. (2000) group ecosystem functions into four primary categories: regulation functions, habitat functions, production functions, and information functions. Water regulation and water supply are among the basic functions and they are linked to specific goods and services, i.e., drainage and natural irrigation, medium of transport and provision of water for consumptive use (e.g., drinking, irrigation and industrial use).

The concept of economic valuation is focused on the estimation of the impacts of changes in ecosystem services on the welfare or utility (satisfaction) of individuals. Gains or losses are proxied by economists using values measured as a monetary payment or a monetary compensation, which are linked to the two basic concepts of willingness to pay (WTP) and willingness to accept (WTA) respectively. Economists seek the best combination of goods and services that can be produced from a system’s resources, to maximise benefits for humans. The services provided by the natural environment affect directly human welfare in many ways, but they are often overlooked by some people and policymakers who only focus on jobs and revenues. Valuation is of utmost importance as it highlights the fact that although the environment is "free", this does not imply that it is not valuable. As some environmental goods are not traded in the markets, non-market valuation techniques need to be employed in order to assign a monetary value to these non-market goods and services. Non-market valuation methods require a link to be established between changes in the quantity or quality of the resources and changes in the stated or observed behaviour of people. The main non-market valuation techniques include the revealed preference and stated preference techniques. Stated preference techniques usually refer to contingent valuation and choice modelling. The main revealed-preference methods that have been used to value ecosystem services are travel-cost, random utility modelling hedonic pricing, and production function models.

The production function approach requires conducting experiments from which a production function is obtained. For instance, a change in output from a unit increase in water input keeping other input variables constant, gives the marginal contribution of water to output. On the other hand, random utility modelling introduces the concept of satisfaction that individuals receive from buying and using a product or service. Random utility models aim at modelling the choices of individuals among discrete sets of alternatives and these preferences can be described by a utility function. A simplified example is given by Farber *et al*. (2002), who use the *Utility* we derive from food, explaining that the total utility is a function of the characteristics of goods or services. So, the utility (U) from food consumption can be a linear function of the caloric (C), protein (P), and vitamin (V) content:

$$U = \alpha \cdot C + \beta \cdot P + \gamma \cdot V \qquad (1)$$

Where α, β, and γ denote parameters reflecting the weighting (importance) of each food component that overall determine the utility from consumption. So, if we 'transpose' this logic to our catchment example, the utility can be a function (linear, non-linear, exponential, logarithmic, etc.) of the individual preferences/choices of goods and services such as food or water. In other words, utility is used to model worth or value. The concept of utility (as used in the food example above) is closer to the outcome that people get from this process, which can be direct or indirect (e.g., a service and not necessarily a good). When utilities are measurable in monetary willingness to pay (WTP) or willingness to accept (WTA) compensation, then the parameters α, β, and γ represent the marginal monetary values of each characteristic. The ability to convert these ES, utilities, or services into monetary measurable (WTP or WTA) values, is synonymous to the valuation process.

Valuation methods and an example

The economic valuation is an important part of the ES concept, as it is necessary and instrumental for policymaking. Policy makers faced with tight budgets need to assess the benefits of ES in monetary terms where possible. Economic valuation of ES is pivotal for allocating scarce governmental resources and prioritizing climate-related projects, identifying public values associated with environmental assets and maximizing the efficiency of environmental policies.

For example, valuation is necessary to implement several tasks of the UN Agenda 2030, specifically:

- SDG15 - “Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss”,
- SDG13 – “Take urgent action to combat climate change and its impacts”,
- SDG14 – “Conserve and sustainably use the oceans, seas and marine resources for sustainable development”, etc.

Many techniques-approaches have been developed (Figure 3) to best perform the valuation process according to the TEV approach, attempting to be objective and user-friendly, and numerous studies have been elaborated on the topic from the ES perspective (Table). The key steps of valuation are to formulate the problem, clarify the expected outcome (key question) to design the study, accordingly, define the variables that affect the value people assign to a service, and estimate how important each one is (their weightings).

Market valuation	**Revealed preferences**	**Simulated valuation**	**Benefit transfer**
Market price-based approaches Uses prices of ES traded in markets (e.g., water, timber) as a proxy for its monetary value	Travel cost method Uses the costs of travel to a natural area as a measure of the value of recreation	Contingent Valuation Method (CVM) Constructs hypothetical markets and asks about WTP to obtain a specified ES, or WTA for giving it up	Estimates the monetary value of an ES by transferring a measure estimated in a similar context (literature of similar cases)
Cost-based (Estimates the costs that are averted due to the ES functioning): • Avoided cost of a damage/degradation • Replacement cost of another solution • Mitigation/Restoration cost, of e.g., a natural hazard	Hedonic pricing method Reveals the monetary value of ES (e.g., green areas) mainly through house prices	Choice modelling Infers WTP through trade-offs incurred when choosing between alternatives with different levels of ES and costs	
Production functions/ factors income Estimates contributions of goods to the production			

Figure 3. Valuation methods categories and description (in blue) (Adapted from Arias-Arévalo *et al*., 2018).

To better understand the variety of economic methods that can be used to value water- and related ecosystem services, a review of approaches to value the flood control purposes of wetlands is summarized in Table 4.

Table 4. An example of studies on the valuation of wetlands' ES to flood control (values in USD2020 prices).

Study	**Study Area**	**Description**	**Method**	**Wetland value for flood control/**
Gupta & Foster (1975)	(Costanza *et al*., 1989) Massachusetts, USA	Economic criteria for freshwater wetland policy	Avoided cost of flood damage	\$157–1190/ha/yr
Thibodeau & Ostro (1981)	Boston, USA	Economic analysis of wetland protection	Hedonic pricing, replacement cost	\$6975/ha/yr
Costanza *et al*. (1989)	Louisiana, USA	Valuation and management of wetland ecosystems	Econometric model	\$301/ha/yr
King & Lester (1995)	East Anglia, UK	Value of salt marsh as a sea defence	Replacement cost	\$17137/ha/yr
Stevens *et al*. (1995)	New England, USA	Public attitudes and economic values for wetland preservation	CVM	\$56/ha/yr
Farber (1996)	Louisiana, USA	Welfare loss of wetlands disintegration	Avoided cost	\$173–888/ha/yr
Leitch & Hovde (1996)	North Dakota, USA	Empirical Valuation of Prairie Potholes	Avoided cost of flood damage	\$27–140 /ha/yr
Leschine *et al*. (1997)	Western Washington, USA	Wetlands' Role in Flood Protection	Replacement cost	\$3203–15812/ha/yr
Gerrard (2004)	Laos, Asia	Integrating Wetland Ecosystem Values into Urban Planning	Avoided cost of flood damage	\$85/ha/yr
Bin & Polasky (2005)	North Carolina, USA	Amenity values of rural wetlands	Hedonic pricing	"House prices depending on the distance from wetlands, hence the floodplain"
Ming *et al*. (2007)	Momoge, China	Flood mitigation benefit of wetland soil	Replacement cost	\$10046/ha/yr
Morris & Camino (2011)	UK, Europe	Economic Assessment of Freshwater, Wetland and Floodplain (FWF) Ecosystem Services	Benefit transfer	\$1029/ha/yr for inland and \$10448/ha/yr for coastal wetlands
Kakuru *et al*. (2013)	Uganda, Africa	Wetland valuation	CVM	\$1,702,934,880/ha/yr
Barbier (2013)	Louisiana, USA	Valuation of coastal wetland protection and restoration	Engineering modelling and cost estimations	Wetland area relation with flood damages

Kadykalo & Findlay (2016)	Global	Flow regulation services from wetlands	Weighted meta-analysis (random effects model)	"Positive flow regulation services corresponding to reduced frequency and magnitude of flooding, increased flooding return period, augmented low flows, and reduced streamflow and runoff"
Watson *et al.* (2016)	Vermont, USA	Quantifying Flood	Avoided cost of flood damage	$19-67/ha/yr
Barth & Döll (2016)	Germany, Europe	Mitigation Services flood protection of a riparian forest	Replacement cost	$2372/ha/yr for an extreme flood and $4901/ha/yr for a 10-year flood
He *et al.* (2017)	Quebec, Canada	Wetland valuation	Comparison of CVM and choice experiment	$301–712/household/yr
Narayan *et al.* (2017)	Northeastern USA	The value of coastal wetlands for flood damage reduction	Avoided cost of flood damage	$711,691,298
Pattison-Williams *et al.* (2018)	Saskatchewan, Canada	Flood control ES from wetland	Social return on investment (SROI)	Flood control services provide a 3.17 return on investment

Table 4 is indicative of the different methods that can be applied for the same valuation problem, for different scales (some of them refer to a catchment, others to the national level). This results in a large range of values for each case, even on the same continent or country. As Kadykalo and Findlay (2016) note, the estimates of flow regulation services are associated with larger uncertainty, resulting in a larger range of calculated values.

However, commonly applied approaches can be found and serve as guidance for future estimates (e.g., using the method of avoided damage costs due to flood water retention, or the replacement cost of the flood-controlling service with constructed infrastructure). This highlights the importance of reviewing the relevant literature for evaluating the ES of interest.

Both the above points reflect the valuation of other ES and can be generalised: there are commonly applied techniques and findings that can be found in the literature; however, the uncertainties can be large, hence the variability of the estimated values. This last statement leads us to the uncertainty section, focusing on such issues.

Uncertainty

The use of valuation depends on the policy questions it aims to address (e.g., raising awareness and interest, full cost accounting, retention of a certain ecosystem, payment schemes, specific policy analyses, etc.). As explained above, the value of ES is their contribution to the services and goods that humans enjoy. As a result, most ways to assess this are based on individual's perceptions of such benefits. Subsequently, valuation methods are subject to the samples' preferences, including the accompanied uncertainty. The uncertainty occurs from gaps in knowledge about ecosystem dynamics, human preferences and technical issues in the valuation processes (Chee, 2004). There is a need to control for uncertainty in valuation studies and to acknowledge the limitations of valuation techniques in situations of radical uncertainty or ignorance about regime shifts. According to the IPCC (2014, p.37) "Uncertainty can result from a wide range of sources. Uncertainties in the past and present are the result of limitations of available measurements, especially for rare events, and the challenges of evaluating causation in complex or multi-component processes that can span physical, biological, and human systems. For the future, climate change involves changing likelihoods of diverse outcomes. Many processes and mechanisms are well understood, but others are not. Complex interactions among multiple climatic and non-climatic influences changing over time lead to persistent uncertainties, which in turn lead to the possibility of surprises. Compared to past IPCC reports, the AR5 assesses a substantially larger knowledge base of scientific, technical and socio-economic literature". Even though there are assumptions that describe the behaviour of an agent operating in a market ('rational actor'), many deviations can be observed in practice. For example, decisions related to the ES of water resources or catchment issues are complex and refer to large scale projects whose effects cannot always be well understood by the public. Moreover, climate change, including extreme events and changes in precipitation levels are challenging to predict, amplifying uncertainty for larger-scale water- and related ES. Thus, the individuals' preferences may change in the course of time, or may not be single and stable, or not even consistent anymore. External factors (e.g., education, advertising, extreme phenomena, such as Covid-19, or income changes) can make individuals act 'irrationally' compared to the known budget constraints when they try to maximize their utilities (preferences satisfaction). Simply put, preferences are not fixed but mutable, particularly over longer-term important environmental decisions. Sustainability has been suggested as a criterion to stabilise preferences, as it embodies notions of appropriate scale, fair distribution and efficient allocation (Chee, 2004).

Given the vastness and ubiquitous nature of the Earth's water resources, the uncertainty governing water ecosystems and the services they provide is pronounced (Kundzewicz *et al.*, 2018). Having said that, the authors pinpoint on certain aspects creating uncertainty, namely data issues (scarcity, measurement errors, lack of representativeness of the measurement site etc.), inherent uncertainty embodied in the underlying variables and their distributions, model uncertainty (model selection, empirical equation, and form of submodules), and caveats in measurements and observations. Uncertainty surrounding the trajectory of climate change due to the many intertwined natural, economic, and social variables involved casts the projections for future ES provided by water resources extremely uncertain. In the presence of different scenarios on shared socioeconomic pathways, Katz (2002) has suggesting assigning weights according to their estimated prevalence probabilities. Apart from climate change, Benssoussan and Fahri (2010) classify water system uncertainty inti four categories, namely: (i) *hydrologic uncertainties* such as stream flows and rainfall; (ii*) hydraulic uncertainties*, such as uncertainties within the hydraulic structure and the flow processes; (iii) *structural uncertainties* such as water saturation, erosion, or wave action and (iv*) economic uncertainties* such as construction and costs, uncertain projected revenue, and inflation. The spatial aspect of uncertainty of climate models concerning water ecosystems lies in the fact that key climate variables are required at smaller spatial scales than those simulated by standard climate models (Refsgaard *et al.*, (2013). Even with the same climate input, different global hydrological models (GHMs) can yield contrasting projections the model performance in the, and due to the much higher uncertainty associated with meso- to macroscale river basins compared with the basin-scale models (Hattermann *et al*., 2017; Rehana *et al*., 2020). Hence, the elevated uncertainty underpinning ESW hinders the efficiency of WRM insofar as water managers cannot rely on a specific scenario or projection for the future. As a consequence, adaptation procedures need to be complemented with projection ranges and uncertainty estimates, which can prove cumbersome (Kundzewicz *et al*., 2018).

The role of Behavioural Economics

In most cases people decide or develop preferences for a future situation or management option, based mostly on probabilities and not on something certain. Complex water management problems under changing climate and economic conditions make it almost impossible to develop solid ranges of probabilities for the examined preferences and decisions, thus implying deep uncertainty. Under deep uncertainty, the assumption of rational decision-makers leads to agents' behaviours and responding results, which often contradict the outcomes of the relevant economic-econometric models (valuation). Hence, designing the right policies warrants elaborating on the empirical evidence in addition to the predictions of standard economic models. Standard Economic Models (SEM) assume decision-makers who maximize a utility function with complete, transitive and self-regrading preferences, which are affected only by the levels of one's own payoffs (the payoffs of other individuals and other generations are not considered). The SEM has no ethical underpinnings and no distributional concerns. For developing interdisciplinary frameworks and systems which include socio-economic considerations, the SEM is therefore unsatisfactory. Economists started exploring alternative methods, focusing on the concept of Subjective Wellbeing (SWB) during 1970s, to clarify issues in welfare economics. SWB can serve as a proxy for the fundamental economic notion of utility previously deemed unobservable. Since then, the understanding of the structure of the utility function has changed.

Behavioural Economics (BE) focus on the understanding of human behaviour using, among others, concepts from psychology. Revisiting the SEM from that perspective enables making welfare-enhancing decisions under deep uncertainty and over short and long-run horizon. Behavioural Economic bring psychology into economic analysis with the basic premises that cognitive limitations lead people to apply heuristics and routines that yield outcomes which individuals consider satisfactory, not optimal. Everything else being equal, an agent that has better algorithms and heuristics could make more "rational" (more optimal) decisions than one that has poorer heuristics and algorithms. For example, advances in technology (artificial intelligence and big data analytics) expand the bounds that define the feasible rationality space, also social networks structures in socio-ecological systems drive towards improved rationality (Campbell & Smith, 2020; Smith & Wilson, 2019). The traditional SEM development from the use of questionnaires/interviews is enhanced by the BE, through Experimental Economics (EE). EE study human behaviour in a controlled laboratory setting or out in the field.

A practical example to understand the significant added value of BE relates to changes in water prices. Correia & Roseta-Palma (2014) highlight the need to complement non-experimental data with the use of experimental data, underscoring that the distinction between aggregate and household data is not of relevance in this case. The use of behavioural data can enable a more holistic study of optimal pricing policies, the frequency of price updates, etc. with safer results, leading to wiser decisions. Analysts and policymakers must have a good understanding of the situation regarding household water consumption, sense of trust, other direct and indirect drivers which determine human behaviour towards water conservation, past water use behaviour, pricing attitude, etc. In this vein, Ferraro and Price (2011) use data from a large-scale water conservation scheme utilizing insights from behavioural economic theory in Atlanta, Georgia that commenced in 2006. The project commingled the messages on how to conserve water with information on the social appeal of water conservation, i.e., why to conserve water. A treatment group was presented only with technical information, while control groups received messages appealing to social norms with varying levels of message strength. The results showed that stronger social messages were associated with statistically significant greater reduction in water use by 8-53 % compared to the control group.

On that basis, the empirical testing of behavioural assumptions will assist discovering new parameters and relations in water management. This of course, requires the development of environmental economics data along with social and psychological data. The lack of such databases is one of the fundamental issues holding back the development of behavioural economics in the water domain, according to Correia & Roseta-Palma (2014): "Information needs to be periodically collected, compiled, and organized, always respecting confidentiality constraints, especially in the case of household data. We believe that the development of more powerful databases and the growing importance of the sustainability issue will bring new researchers into water resource economics".

Payments for Ecosystem Services (PES) and Markets

The original emphasis on ES as a pedagogical concept intended to raise public interest for biodiversity conservation has given way to developing benefit streams for those who conserve ES (Peterson *et al*., 2010). Following the valuation results, especially perceptions and estimations on WTP or WTA, the most common policy follow-up is an upcoming technical project/work, or a policy scheme/ decision, i.e., Payments for Ecosystem Services (PES) and relevant markets, aiming to improve ecosystems, and create economic incentives for conservation and/or improvements. Positive externalities which are inherently associated with ES are, by default, not covered in monetary transactions. Hence, the market mechanism is not adequate for the efficient provision of such services and is complemented with payment schemes (PES) for the stakeholders which benefit from or impede ES (Azqueta and Sotelsek, 2007).

Examples of commodified ESs in Markets could be the cap-and-trade systems such as the emission trading of greenhouse gases (atmospheric sink functions of CO_2), or SO_2, wetland mitigation banking, etc.[6] Wetlands provide an array of ES including watershed protection, carbon sequestration, habitat conservation, wildlife services, bio prospecting, agro-environmental

[6] A wetland mitigation bank site where wetlands are restored, created, enhanced preserved to provide compensatory mitigation in advance of unavoidable impacts to wetlands or other aquatic resources. These banks allow the purchasing of credits to counterbalance the unavoidable impacts of a project.

measures, etc. The increasing degradation wetlands in the presence of the positive externalities indicates that PES can be of relevance for their sustainable management. Mombo *et al.* (2014) conclude that carefully designed PES have the potential to internalize environmental externalities and shape shareholders' incentives in the case of the Kilombero wetlands in Tanzania. In order for such payment mechanisms to function, policymakers and national governments need to commingle PES with the development of sound institutional structures allowing for transactions in market exchanges, as has occurred with the establishment of markets and PES schemes (Gómez-Baggethun *et al.*, 2010).

Table 5 presents a review of methods and tools developed in the last 20 years that provide incentives for the conservation of ES. The evidence shows that there have been two, almost parallel developments in this area:

- On the one hand some conservationists perceived well the ES valuation as a tool to communicate the value of nature and ecosystem functioning using a language that has higher influence to politicians. Indeed, this contributed to the ES mainstreaming and attracted political support for conservation
- On the other hand, framing ecological concerns in economic terms could be used for opportunistic policies. This perspective sees that commodification and pricing of natural and ecosystem functions can support ideologies or institutional forms that are in favour of revenue-raising planning and provide the incentives for rent-seeking behaviour.
- According to the relevant studies of Table , the successes of the first bullet were largely attributed to the use of On the contrary, the example presented by Silva *et al*. (2016) highlights the importance of the appropriate design of such tools, taking into account stakeholders' opinions and customising each scheme according to the case-study. This supports the finding of Schomers and Matzdorf (2013, p.16), that the "overall design of national PES programs in Latin America resembles the design of those in the US and EU considerably" .

The next chapter presents the critics of the ES concept and its use. As mentioned, the key driver that can lead us to a good or bad practice example, is the *purpose*, which defines the *use*. The final chapter provides an analysis of this aspect.

Table 5. A review of studies on ES policy implications, market, and payment schemes.

Study	Topic	Description
Murtough *et al.* (2002)	Creating Markets for ES	Why create markets and what happens if we do not have markets, describes different types of market creation
Whitten *et al.* (2003)	Markets for ES: Applying the concepts	Market-based instruments, as an answer to the fact that ES have largely been ignored in both domestic and international law and policy
Perrot-Maître (2006)	Good practice example of PES	Vittel, France PES example with emphasis on farmers and legislation
Duraiappah (2006)	Good practice report for markets for ES	The potential for using Markets for ES to enhance the implementation of multilateral environmental agreements (MEAs)

Swinton *et al.* (2007)	ES and agriculture: Cultivating agricultural ecosystems for diverse benefits	Many agricultural ES lack markets; thus, the policy design is described, and supports pricing (or higher charges) for markets and PES of agriculture
Kroeger & Casey (2007)	An assessment of market-based approaches to providing ES on agricultural lands	Markets failure in ES, features and applicability, and some promising forms that can allocate ES to rural cases
Corbera *et al.* (2007)	The Equity and Legitimacy of Markets for ES	Equity and legitimacy are limited in ES markets, Mexico state examples, promotes equity for sharing ES market outcomes and legitimacy in application
Bulte *et al.* (2008)	PES and poverty reduction: concepts, issues, and empirical perspectives	PES potential to reduce poverty, different PES schemes, social objectives. Flexible payment schedules and the importance of effective collective action amongst suppliers are also identified as key to success
Corbera & Brown (2008)	Building Institutions to Trade ES	Institutional tools for ES markets, example of forest carbon in Mexico
Jack *et al.* (2008)	Designing PES: Lessons from previous experience with incentive-based mechanisms	Short-review of experiences, explaining each concept around PES/ policy
Turpie *et al.* (2008)	The working for water programme: Evolution of a PES mechanism that addresses both poverty and ES delivery	Case-study example (South Africa). The success of the programme is largely attributed to it being mainly funded as a poverty-relief initiative & prospects for expansion of PES for including more ES
Redford & Adams (2009)	PES and the Challenge of Saving Nature	Future challenges of PES, outlines seven ES problems that need to be addressed in order to have clear and efficient PES
Ribaudo *et al.* (2010)	ES from agriculture: Steps for expanding markets	"One possible way to increase private investment in ES is to create a market for them" & lessons from six different markets
Gómez-Baggethun *et al.* (2010)	The history of ES in economic theory and practice: From early notions to markets and payment schemes	ES, markets, concepts in economics, their view in policy and decision making, PES and market applications
Farley & Costanza (2010)	PES: From local to global	Goods vs Services, the appropriate PES scheme, scale factors, "PES tries to force ES into the market model, with an emphasis on efficiency"
Goldman-Benner *et al.* (2012)	Water funds and PES: practice learns from theory and theory can learn from practice	Theoretical-practical examples. "Theory limits the use of creative finance mechanisms such as trust funds"
Schomers & Matzdorf (2013)	PES: A review and comparison of developing and industrialized countries	Different analytical perspectives on PES concepts/types/geographic focus, presents similarities-differences. "The overall design of national PES programs in Latin America resembles the design of those in the US and EU considerably"
Brann (2014)	PES in the Developing World: Non-Market Contributors to National PES Program Development	Theoretical description of Concepts, Literature gaps, Methods, and practical insights from Costa Rica, Mexico, Vietnam, China, and International Organizations' role

Kolinjivadi *et al.* (2015)	Juggling multiple dimensions in a complex socio-ecosystem: The issue of targeting in PES	Case study and GIS analysis of PES in Nepal. Assumptions for spatial targeting criteria of PES, insightful for practical applications and consideration of spatially PES
Leimona *et al.* (2015)	Fairly efficient, efficiently fair: Lessons from designing and testing PES services in Asia	Comments on how to achieve fairness and efficiency, describes scheme designing
Galati *et al.* (2016)	Actual provision as an alternative criterion to improve the efficiency of PES	Applications on agri-environmental payments in Italy for carbon sequestration in semi-arid vineyards
Bellver-Domingo *et al.* (2016)	A review of PES for the economic internalization of environmental externalities: A water perspective	Importance of multidisciplinary team- environment function & social aspects/ PES to improve water quality and supply the ever-greater demand while reducing environmental impact
Silva *et al.* (2016)	Operationalizing PES in Brazil's sugarcane belt: How do stakeholder opinions match with successful cases in Latin America?	Compares local scheme (Brazil) to other established ones (same principles, but when stakeholders' opinions are different, then it is a problem), highlights the importance of the proper customization
Salzman *et al.* (2018)	The global status and trends of PES	Reviews programs, global transactions, geographical spread, to understand better the range of PES mechanisms over time and to examine which factors have contributed to or hindered growth. "Four key features stand out for scaling up PES: motivated buyers, motivated sellers, metrics and low-transaction-cost institutions"
McElwee *et al.* (2020)	Hybrid Outcomes of PES Policies in Vietnam: Between Theory and Practice	Transfers money for forest protection from water and energy users to households who live in upland watersheds. "Strong state involvement in transactions; no use of markets to set payments; poor definition and monitoring of ES; and the adoption of non-conditional incentives that strongly resemble livelihood subsidies for poor rural areas"

Valuation for Water Ecosystems

As discussed in previous sections, Water Systems embody all the traits of ES, hence they are of material economic value (both in use and non-use terms) and their impact valuation should be underscored by scientists, policy makers and the civil society. Water-related ecosystem services (henceforth ESW) are among the most important according to scholars (de Groot *et al*., 2010; Keeler *et al*., 2012 Hackbart *et al*., 2017). Hackbart *et al.* (2017) underline the growing prevalence of the literature on ESW after 2005, and classify the approaches in five categories, namely: (i) economic valuation; (ii) ecological valuation; (iii) socio-economic valuation (iv) ethical valuation and (v) mixed valuation. The authors note that, in most cases, ESW are evaluated in conjunction to other ES, thus corroborating the holistic nature of ES and climate research. In their thorough review of the literature, they conclude that caveats are significant as very few studies focus predominantly on water systems rather than ES in general and databases mainly address secondary information at different scales.

Acknowledging the fact that water ecosystems encompass use and non-use value (as do most environmental resources), most of the well-known valuation methods apply.[7] Revealed preference methods for ESW include the hedonic price method, the cost of travel method, the Replacement Cost Method, and the Aversive Expenditures Method. The hedonic pricing method (HPM) is based on Lancaster's characteristics theory of value (Lancaster, 1966), which postulates that the price of any good depends on an array of attributes and their respective levels. It is deployed in order to gauge the impact of a change in an environmental resource on the price of the underlying good and is most frequently applied to variations in housing prices that reflect the value of local environmental resources. Koundouri *et al.* (2003) apply this method to estimate the impact of water salinity on land prices in Cyprus and Latinopolous *et al.* (2004) attempt to gauge the implicit value of irrigation water in Chalkidiki in Northern Greece. Moore *et al.* (2020) attempt to tackle the issue of endogeneity in their HPM approach for lake water clarity using data for 113 lakes in the United States. Their results indicate that a meter increase in water clarity is associated with a 10% increase in nearby housing prices, an effect that is used to extrapolate the effect on housing values of bringing lakes into compliance with the US Environmental Protection Agency's regional recommendations for phosphorous concentration. Choe *et al*. (1996) apply the Travel Cost Method (TCM) to estimate the local community's valuation of surface water quality improvements in the rivers and seawater in Davao, Philippines. In a similar fashion, Yapping (1998) finds that that lake users of the East Lake in Wuhan, China report noteworthy willingness-to-pay (WTP) for the use of the lake and its facilities. The results demonstrate that the costs of maintaining water quality in the site can be compensated to a substantial amount. Hwang *et al*. (2021) use the TCM on Black Crappie angler behaviors and attitudes including travel distance, fishing mode, catch effort, and other socioeconomic factors that affect their fishing trips in 2017. Their results on estimating the latent demand curve for the specific fishery point to a total annual consumer surplus (CS) of $470 million–$904 million, for Florida residents and $26 million–$40 million for non-residents, depending on model specification.

Apart from revealed preference methods, researchers and policymakers rely on stated preference methods, for example Contingent Valuation (CVM) and Choice Experiments (CE). A CVM survey must be carefully designed to reduce biases associated with imperfect information, selection, free-riding and feeling good about oneself. These limitations notwithstanding, a large body of research has been dedicated to CVM for water resources aiming to elicit the public's valuation of water quality, fishing and other activities associated with ESW. Birol *et al*. (2006) deploy CV techniques to estimate non-use values from the sustainable management of the Cheimaditida wetland and Goksen *et al*. (2002) attempt to measure the WTP for reduced water pollution in the Bosphorus, Istanbul. Tussupova *et al*. (2015) use the CVM to elicit that more than 90% of the consumers were willing to pay for better water quality and regular water supply in the Pavlodar Region in Kazakhstan. Finally, the Choice Experiment Method (CEM), grounded on random utility models, uses carefully designed "experiments" to reveal the factors that shape individuals' choice regarding specific attributes of an environmental resource. In the

[7] For an overview of valuation methods see Pearce *et al*. (2005).

case of ESW this technique can be deployed to use preferences on bathing water quality as a means to evaluate coastal waters. Travisi and Nijkamp (2004) focus on groundwater contamination from fertilizers and pesticides as an attribute to elicit WTP for agricultural environmental safety in Milan, Italy to conclude that reducing contamination would deliver notable economic value. Colombo *et al*. (2005; 2006) use surface and ground water quality as attributes of soil conservation measures for the Alto Genil and Guadajoz watersheds in Spain and find that water quality generated the highest economic value among all the soil conservation measures attributes included in the study.

A well-known direct use value arising from water ecosystems is irrigation for agricultural production. To this end, hydro-economic models (HEM), which integrate economic-productive objectives and environmental pressures into single model applications (HEM), are widely used. These models have gained traction in the field of WRM as well as climate mitigation and adaptation projects, agricultural issues, and policymaking (Blanco-Gutiérrez *et al.*, 2013; Nakic, 2017). Nonetheless, Nakic (2017) notes that applying HEM comes with significant challenges, among which are the appropriate description of the system, and the availability of precis and detailed data. Defining the model and the way they will interact is a tough task, as it requires data relative with hydrology, water infrastructure and the economy, combined with a through understanding of the underlying processes stemming from multiple scientific fields. Alamanos *et al.* (2020) highlight these caveats and build two HEM in their valuation of the Karla watershed in central Greece. The authors utilize data on irrigation methods, soil characteristics, climate and network conditions coupled with economic variables (crop prices, agricultural yield) to derive estimations on the system-based water balance, net profits from agriculture, irrigation water costs (monetary and environmental) and irrigation water value.

PES and the role of Water Resource Management

Wetlands are extremely fragile ecosystems which provide valuable ecosystem services (ESW), most of which encompass the characteristics of a public good and which are currently in peril caused by human pressure and climate change. In this context, Payments for Ecosystem Services (PES) have gained traction as a viable mechanism to avert greater degradation and depletion of wetlands in a global scale (Pagiola and Platais 2007; Wunder *et al*. 2020; Nimubona & Pereau, 2022). PES for ESW is a mechanism to concord demand for water ecosystem services spanning throughout human and economic activities and supply encompassing natural habitats as well as humans and land users. In this vein, PES schemes involve compensating land users for improvement of ecosystem services by internalizing the positive externalities stemming from ESW.

In terms of PES programs that are focused on ESW, the majority refer to the provision of water quantity and quality or for electric utilities and are incorporated in broader schemes to alleviate poverty in developing and emerging economies (Stanton *et al*., 2010; Bennett *et al*., 2014). UNECE (2007) underscores the pivotal role that PES can play for integrated water resource management (IWRM). The report addresses the importance of properly designed valuation schemes in the presence of data constraints and uncertainty as a prerequisite for the design of tailor-made, well-targeted PES for ESW. Political support is warranted in the designing and the implementation of the PES, which must be characterized by transparency and close monitoring throughout the process. An important aspect, according to the report, is promoting stakeholder involvement as PES referring to water ecosystems affect multiple parties and there is a pending need to balance diverting interests. Stakeholders from the private sector are expected to contribute both in monetary terms (through their financing) as well as through the dissemination of knowledge acquired from previous PES projects. Finally, in the case of transboundary water eco-systems, international cooperation and the role of multilateral and regional institutions is essential for the efficiency of the scheme. The report concludes that governments need to design policies for the development and implementation of PES schemes to improve ecosystem services under existing and future WRM plans pertaining to all water ecosystems. Apart from publicly designed PES, it is essential for public authorities to provide the private sectors with incentives, act as mediators between potential buyers and sellers in privately designed schemes and ensure that guidelines (on the financial arrangement, transaction costs and balance of income-expenditure accounts) are followed throughout the procedure. Nimubona & Pereau (2022) corroborate the latter view in their research as they consider different negotiation scenarios ranging from one-to-one to many-to-many negotiations. Their simulations indicate a third party such as a government entity can play a material role in validating the efficiency of the PES and also diminish transaction costs which are commonly associated with the process.

Hack (2015) argues that traditional top-down approaches of WRM at the river-basin level imperfectly address the issues of spatial fit, involvement of all stakeholders and public awareness. Departing from regulatory measures, PES account for the incentives of land users in order to achieve environmental targets and harness the full potential of water environmental services. The author argues that PES can be incorporated in WRM and improve its efficiency through the alignment of incentives for land users and water users. River-basin level payment systems for hydrological ecosystem services (PHES) have been incorporated in the national IWRM in Nicaragua since 2007. The review provided by Hack (2015) concludes that they have succeeded in ebbing the constraints imposed by spatial fit and lackluster participation by institutional partners through the increased knowledge on the ESW valuation process and thus should be considered an integral part for WRM in the future.

Implications for present and future water resources management from the inclusion of ES

The estimation of ecosystem service value of water resources is of great importance for resource allocation and ecological protection, and it entails considerable implications for current policy making and future guidance. There has been significant research progress on the value of water resource ecosystem services (Brown *et al*., 1992; Koundouri and Davila, 2015; Alamanos and Koundouri, 2022; Wilson and Carpenter, 1999; among others) that provided the ground for shedding light on the diverse benefits supplied by healthy ecosystems. Healthy ecosystems are crucial since they produce a variety of services critical for human and non-human life, like air and water purification, flood control, climate regulation, plant pollination, and food and fiber production. Therefore, integrating valuation of water services in decision and policy making is of utmost priority due to, one hand, the peculiarity of water as a public good and on the other hand, as a non-renewable resource especially in the case of groundwater in certain aquifers. In light of these special attributes of water resources, the better understanding offered by ecosystem services valuation can help in avoiding neglecting and undervaluing the ecological benefits of improved management of water quality and quantity, and thus, enables the design of more effective water management systems.

Water is vital for life and more precisely clean freshwater is necessary for drinking and sanitation, providing for our crops, livestock and industry, and creating and sustaining the ecosystems on which all life depends. Ecosystems constitute biological societies made up of biotic, living elements like plants, animals and organisms and a physical environment, such as soil, water, air, sunlight and climate. Water resources are really crucial, however, as they sustain every kind of life in the environment. The main ecological function refers to the natural processes, products or services that living and non-living environments provide or perform within or between species, ecosystems and landscapes, in which, biological, physical and socioeconomic interactions exist. This highlights the significance of ES valuation inclusion in water resources management as growing scarcity of water or other important goods delivered by nature can pose considerable threats to the survival of many species and biodiversity in general, resulting in huge economic, social and environmental losses.

Water is at the core of sustainable development as it constitutes an essential resource for humanity and for ecological balance. What is more is that resources are already being overexploited globally and there will be an urgent need for effective management since increasing water requirements due to population growth and industries development put huge pressures on efficient distribution. Sustainable management of limited resources is critical as water shortage in every region worldwide is growing. As a result, implementing water demand and supply management policies in order to reduce loss and inefficient use is highly required. The inclusion of ecosystem service valuation in water resources can contribute significantly in formulating and adapting water management policies, in order to be able to respond to the population's increasing demands and the need for development in the present and future.

Criticism

ES concept and relevant policies have been criticised on the technical weaknesses of the valuation methods, the inadequate description of human behaviour, interdisciplinary conflicts (e.g., ecological vs economic perception of value), and ethical aspects on the limits of the economic science, nature's commodification, and the purpose of the policy extents.

ES are an example-topic that has a multi-disciplinary character, thus interdisciplinary issues can arise from the approaches of different fields. For example, the way that ecologists and environmental scientists consider 'value' versus the economic point of view, according to Farber *et al*., (2002):

- 'Value' is a term that most ecologists and other natural scientists would prefer not to use at all (Farber *et al*., 2002). Environmental scientists approach nature as a system where natural processes are operating. Thus, the value for them is the degree to which an item contributes to an objective or condition in a system, when they study the causal relationships between different parts of a system (e.g., value of trees in controlling soil erosion in a high slope area, or retain stormwater to prevent floods, or the value of fires in recycling nutrients in a forest). Thus, most ecologists or environmental scientists are not familiar with the monetary interpretation of value.
- From an economic perspective, the ecosystem functioning, and processes are not a point of interest, while this energy theory of value has been criticised because it created a

biophysical theory of value, not completely determined by social preferences. The conceptualisation and approach of ES from economists has been analysed above, and one can understand that is based on monetary values. The ability to estimate costs of projects, damages (or cost savings) to the environment from a project-decision, provides guidance to valuing the resource as well as developing a decision rule. For example, preservation or conversion of an ES, when the costs allow it, and in order to use its functions and services more efficiently.

The differences between these two perspectives often lead to arguments and questioning of each other. Both could have a useful contribution to policymaking as long as their limits are respected and their purpose isproper, but we analyse this in the last chapter, where the solution is attributed to the ethical content of each approach. This balance between the two, or the 'middle state', has been the measure and criterion for evaluating an ES policy as good or bad practice.[8]

When the limits and the purpose are questionable or have issues, then we see examples similar to the ones mentioned in the last part of 'chapter 2', which end up expressing the preservations around nature's monetization and the use of ES policies. With respect to the interdisciplinary issues, Peterson *et al.* (2010) raised awareness regarding the decoupling of ecosystem function from services, as many people may be aware of the economic value of a given ES without recognising human dependence on local and global ecosystems and on their functioning. The spread of the ES concept has in practice set the stage for the perception of ecosystem functions as exchange values that could be subject to monetisation and sale, with profound ethical and practical implications (Gómez-Baggethun *et al*., 2010). Influential studies with a critical view on ES valuation are presented in Table 6.

Table 6. A review of studies with elements of ES criticism.

Study	Topic	Description
Gatto & Leo, (2000)	Pricing Biodiversity and ES: The Never-Ending Story	Different approaches for evaluation-pricing and arguing that it is impossible to give a monetary value to some ES
Howarth & Farber, (2002)	Accounting for the value of ES	"Values do not capture ecological sustainability and distributional fairness that are not reducible to individual welfare". "Valuation's operationalisation is constrained by the well-known limitations of nonmarket valuation methods"
Robertson (2006a)	Emerging ES markets: trends in a decade of entrepreneurial wetland banking	Challenges of standardized commodity measurement in environmental policy goals
Robertson (2006b)	The nature that capital can see: science, state, and market in the commodification of ES	Ecosystem science increasingly serves as a metrical technology for the commodification of ecosystem services.

[8] For example, Daily *et al.* (2009, p.23) state that "The biophysical sciences are central to elucidating the link between actions and ecosystems, and that between ecosystems and services (biophysical models of "ecological production functions"). The social sciences are central to measuring the value of services to people ("economic and cultural models"). Because this value is multidimensional, it makes sense to characterize it as fully and systematically as possible, in ways that will be meaningful to many different audiences".

		This may overwhelm the capacity of science to provide stable representations of commodity value, as the methods and the ways of interpreting the nature have limitations
Lant *et al*. (2008)	The Tragedy of ES	Property law and private rights vs ES
McAfee & Shapiro (2010)	PES in Mexico: Nature, Neoliberalism, Social Movements, and the State	Divergent conceptualizations reflect contrasting understandings of the roles of agriculture and of the state in sustainable development "Conservation policies in the global South, if imposed from the North and framed by neoliberal logic, are likely to clash with state agendas and local development goals"
Spangenberg & Settele (2010)	Monetising the value of ES	"The basic assumptions underlying economic valuation are far from realistic and represent rather a caricature of human behavior" while "the methods based on these assumptions are manifold and lead to wildly diverging results"
Van Hecken & Bastiaensen (2010)	A political view on the justification behind PES	Land users, who tend to be poorly, if at all, motivated to protect nature on their land, may be encouraged to do so through direct payments from ES buyers. "The hidden political ambiguities of the externality framework and the risk that PES, especially if user-funded, may perpetuate and deepen the regressive financing of global commons by poor local communities"
Muradian *et al*. (2013)	Payments for ES and the fatal attraction of win-win solutions	Over-reliance on PES as win-win solutions might lead to ineffective outcomes
McAfee (2012)	The Contradictory Logic of Global ES Markets	Experience of ten years of PES illustrates how, in practice, market-efficiency criteria clash directly with poverty-reduction priorities
Martín-López *et al.* (2014)	Trade-offs across value-domains in ES assessment	"ES concept reflect in a limited extent the concerns of their beneficiaries. ES assessment results are biased towards the information provided by markets at the expense of other value-articulating institutions"
Silvertown (2015)	the concept of ES is being oversold with potentially damaging consequences	"The origin of the problem lies deeper in anthropocentrism, and it has constrained thought, towards the monetization and financialisation of nature"
Kolinjivadi *et al.* (2019)	Neoliberal performatives and the 'making' of PES	Danger for creating a utilitarian relationality between humans and nature, and list of neoliberalisation aspects in different organisations promoting PES

The studies reviewed in Table 6 point to two main issues:

A) Ethical concerns regarding the use of the valuation of ES. A broad example lies in the conservation policies in the Global South imposed from the North and framed by neoliberal logic, not in line with the states' tailored needs, as described in McAfee & Shapiro (2010) and Van Hecken & Bastiaensen (2010). The aim of poverty reduction in line with SDG1 could be perceived as the incentive behind the designed policies, however, McAfee (2012) explains that the experience of ten years of PES illustrates how, in practice, market-efficiency criteria clash directly with poverty-reduction priorities.
B) Technical challenges, regarding the weaknesses of valuation methods to describe the human behaviour, and the partial approaches to value ecosystems, making it challenging to develop appropriate policies and institutions.

The second issue (B) can be addressed from the proper use and incorporation of BE into the valuation and policymaking process, including the public participation. The role of BE has been analysed in the previous chapter. The experience has shown that the successful implementation of public participation can be a challenge, too, however, it is not impossible. It can be achieved by two ways:

- In a long-term commitment, e.g., using an administrative body. The Water Forum in Ireland[i] is an example; it serves as a stakeholder platform including members and representatives from all sectors (Angling, Agriculture, Business, Community and Voluntary, Education, Water and Environment, Fisheries/Aquaculture, Forestry, General Consumers, National Federation of Group Water Schemes, Recreation, Rivers Trusts, Social Housing, Tourism, and Trade Unions) to ensure democratic and acceptable character in its consultations. The basic principles must be Transparency and Openness, Fairness, Equality and Respect, Efficiency, Collegiality and Tolerance, and Common Goal-vision. The continuous engagement allows knowing and understanding each group of stakeholders in depth (also behavioural aspects) and their interactions (Warner et al., 2006; Sigalla et al., 2021).
- In most cases, a continuous, long-term commitment is not possible, thus a stakeholder analysis must be performed in an integrated and scientific way, within the time limits of a programme or a research project. A novel way for stakeholder analysis based on system's analysis principles was recently applied by Koundouri (2021). The so called, Systems Innovation Approach, builds on the same principles mentioned in the previous bullet, integrates the different disciplines, balances the limits of each field ensuring the avoidance of interdisciplinary and contradiction issues, and aims to innovate the system as a whole (Alamanos *et al.*, 2021; 2022). The 'scientification' of Systems Innovation Approach is achieved through relevant software for stakeholder analysis.

The solution to the first issue (A) has been already outlined indirectly, by the description of stakeholder analysis, especially when combined with BE, and based on the right principles. Such an approach will:

- explore the deeper relations of our behaviour and functionality within systems, including the concept of fairness and equity,
- clarify the way that we make decisions over time and under uncertainty (as described, this is the nature of decisions on water resources management),

- allow to study humans' preferences that are not documented in any markets,
- formulate and build common vision/preferences in a healthy way, by co-designing and co-developing the technological, policy, financial pathways towards achieving those and by engaging all relevant stakeholders,
- use the right criteria throughout the procedure, in order to find efficient policies for the short-run and sustainable and resilient ones for the medium and long-run.

Conclusions: Using ES and related policies for WRM's benefit opens future research paths

This paper summarizes the basic tenets and critiques on the concept of ecosystem services (ES) with a focus on their potential role on water resource management (WRM). Climate change has had an immense effect on the quality of water ecosystems and the service they provide throughout the globe. This process has severe adverse implications on livelihoods, wellbeing of current and future generations and economic growth. Policies aiming at climate mitigation and climate adaptation are of material importance and require a holistic approach from all stakeholders, namely governments, research institutions, the private sector and the civil society. In order to design, monitor and implement these policies effectively, we have to grasp the benefits we derive from ecosystem services. To this end, a vast literature on ES valuation has emerged over the past thirty years, stemming primarily from the field of environmental economics. Assigning monetary values to the benefits from ES as valued by humans enables policymakers to apply techniques of Cost Benefit Analysis (CBA) in their environmental projects. This way projected benefits can be weighed against costs accruing to the taxpayer of the private sector leading to a more efficient way of deciding projects, allocating scarce resources, and gaining legitimacy against the public. Furthermore, decision makers can better prioritize among competing environmental projects or other issues demanding government outlays. Economic valuation of ES is also useful in the degree it internalizes part of the inherent externalities of environmental benefits. Apart from gauging pecuniary values to ES, market mechanisms can be designed to induce efficient behaviour in the form of payments for ecosystem services (PES), which involve voluntary transactions between the beneficiaries and providers of ecosystem services. These schemes, if designed carefully based on sound valuation methods, can stimulate the socially optimal economic behaviour by self-interest, profit-maximizing agents.

The concept of ES entails many benefits that are 'intangible' by design, so their valuation is a complex topic with varying interpretations. Economic valuation of ES has been subject to criticism from an ecological and an ethical perspective. It comes as no surprise that ES valuation has emerged from different scientific fields apart from the economic approach estimating the monetary losses and gains of ES. Ecological valuation is based on ecosystem or biophysical parameters to measure benefits and losses attributed to change in ES, sociocultural and economic valuation focuses on the distinct traits observed social and cultural groups observed under a cultural-social conservation, as well as valuations of ES through an ethical perspective. Although, cultural, ethical and non-use ES values in general are included in all known typologies, their part in empirical work and decision making is relatively small thus casting some doubt on the efficiency of CBA methods and market mechanisms used in practice. Having said that, scholars and policymakers alike are striving to make the valuation methods as inclusive and interdisciplinary as possible, and this has been reflected in the recent vintages of climate models. Although the science and the tools exist, it is being understood that the main concern must be the appropriate use, which is defined by the purpose, as already reflected by the literature. And this is a useful point for consideration, especially for studies that have an educational or consultation role. Obviously, ES based on economic principles (or related regulations and policies, e.g., PES and/or markets) have their purpose and their results: their purpose could be the improvement of our lives through providing healthier ecosystems and achieving sustainability or could be revenue-raising

Values of water resources, in particular, are very challenging to estimate for CBA purposes not only due to their public goods in nature, but also from their inherent characteristic of spurring both use and non-use values. Nonetheless, using the correct valuation techniques for estimation of water ecosystem services (ESW) is crucial to policy and management decisions as they can affect the allocation of scarce resources within competing socially valuable projects, as well as prioritizing conservation and preservation of different water resources. Market approaches in the form of PES depend on the valuation process and, in turn, help to identify potential gainers and losers from current depletion and degradation of water resources. This way, a coherent and efficient plan to compensate losing parties can promote climate policy and produce value, in broad terms, for society. In addition, many cases have demonstrated that PES mechanisms for wetland creation or conservation require the involvement of a third party to act as an intermediary and balance the needs of diverse stakeholder in order to maximize the social benefits associated with wetland ESs in the presence of the costs of such processes. Having said that, each concept, measure, or policy, and catchment is different and requires a specific approach, but having some stable principles when studying them, is required, too. Such principles will simplify the policy extensions and use of tools-concepts, and critically approaching their purpose. Water Resources Management (WRM) encompasses to all methods and activities required for the rational utilization of water resources. Earmarking ES valuation and PES for water ecosystems can be of great assistance to the design, implementation, and monitoring of WRM.

To conclude and generalise, every concept needs adjustments and critical customisation before application. The purpose and the principles presented in this section can provide helpful elements for this process. The combination of BE, using EE tools and a proper stakeholder analysis are the most promising research path to achieve these goals. Systems Innovation Approach can combine and coordinate these tools, and additionally make best use of innovative technologies, optimum solutions and establish collaborations/cooperation. Thus, this can be a future research trend to implement successfully the principles described in this section. Both computational or qualitative approaches mathematically and theoretically come from the optimum individual's or discipline's solutions, so this is the safest and more efficient basis to start from: Good, as defined by Aristotle, is an outcome of virtue, which is a function of 'per-head' effort, defined by right and healthy purposes.

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Notes

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[i] https://thewaterforum.ie/