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Economics of Incorporating Ecosystem Services into Water Resource Planning and Management

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Economics of Incorporating 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. ES are directly related with Water Resources Management (WRM), as any catchment's degradation is in fact a degradation of ES, and the opposite. The concept initially had a pedagogical purpose, later it started being measured with economic methods, and has policy extensions, such as markets and payment schemes.

ES's valuation is an essential process for achieving environmental, economic and sustainability goals, The Total Economic Value (TEV) of ecosystems includes market values (priced) and mainly non-market values (not explicit in any market), hence the different valuation methods for their explicit valuation. This process involves also human preferences regarding the perception of the nature's contribution to the economy, services, or production processes.

ES concept and relevant policies have been criticised on the technical weaknesses of valuation methods, the description of the human behaviour, the 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. Since valuation affects the policies (markets and payment schemes), it is important to understand the way that humans decide and develop preferences under uncertainty. Those preferences are changing, our behaviour is unpredictable under deep uncertainty (i.e. unknown policies, impacts, unknown probabilistic events, and under climate change) particularly over longer-term important WRM decisions. Behavioural Economics attempt to understand human behavior and psychology, and in a way model our valuation system, under uncertainty.

The purpose and use of concept must be based on solid principles, aiming to the development of policies that will improve our ecosystems and lives, achieved by scientific and stakeholder collaboration.

1. Ecosystem Services (ES) and their connection with Water Resources Management

This work on the "Economics of Incorporating Ecosystem Services into Water Resource Planning and Management" needs to define first the basic concepts: Ecosystem Services (ES), Water Resources Management, Planning, its goals and connection with ES, Economic approaches and their perspectives on ES, and then the integration of the above under right purposes and rationale.

Ecosystem Services (ES): definitions and relations

Nature has always provided environmental assets, essential for life, that we harvest, trade, use for production, and base our economies. Table 1 gives an overview of the alternative ES definitions.

Table 1. Alternative Definitions of ES.

Source	**Definition**
Daily (1997)	The conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfil human life
Costanza et al. (1997)	Benefits human populations derive, directly or indirectly, from ecosystem functions
Millennium Ecosystem Assessment Program - MA (2005)	Benefits people obtain from ecosystems
Fisher et al. (2009)	The aspects of ecosystems utilized (actively or passively) to produce human well-being
Burkhard et al. (2012)	Contributions of ecosystem structure and function – in combination with other inputs – to human well-being
Arias-Arévalo et al. (2018)	The concept of ES is used to refer to the benefits people obtain from ecosystems, such as fresh water, food, climate regulation, recreation or aesthetic experiences

The definitions converge, and research admits that ES also maintain biodiversity, production of ecosystem goods, include life-support functions, and they confer many intangible aesthetic and cultural benefits, too.

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 that actually include all environmental components and the majority of economic activities. The most commonly used classifications of ES are (de Groot et al., 2010; Häyhä & Franzese, 2014; MA, 2005):

- *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. There is a direct connection with the economy, and thus the concept of ES contributed to seeing environment and socio-economy as a system (Figure 1). This is a key step-stone for treating those concepts together, and not competitively, with everything this entails.

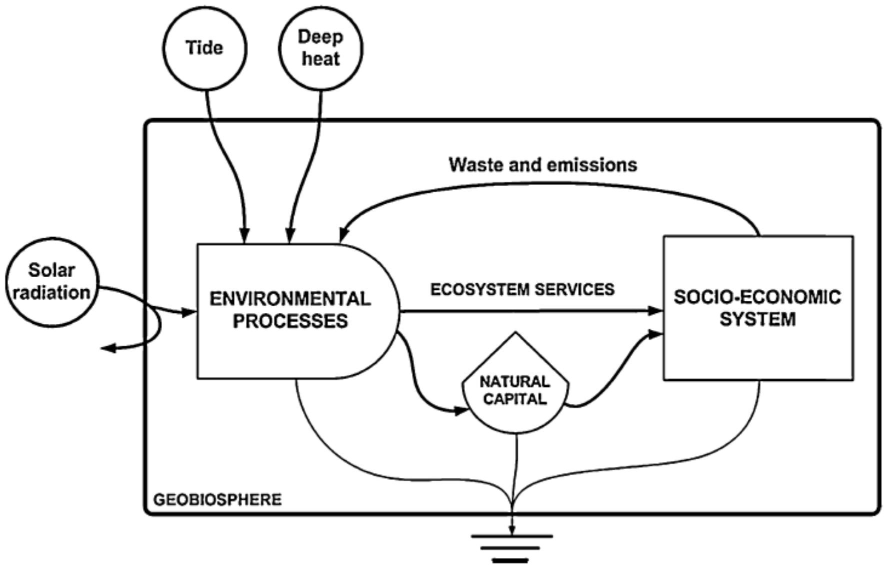

Figure 1. Aggregated example of the interactions between environmental processes and socio-economy as a system (Source: Häyhä & Franzese, 2014).

<u>ES concept evolution</u>

One could say that, given the importance of the last statement, integrated management and environmental consciousness is the reason that the ES concept emerged. Indeed, the initial rationale was mainly pedagogic (Westman, 1977). It started at the 70s and was used mostly by natural scientists to demonstrate how biodiversity loss directly affected ecosystem functions underpinning critical services for human well-being, thus aiming at triggering action for nature conservation (Gómez-Baggethun et al., 2010). In the late 80s the concept was used for market environmentalism purposes and privatisation (G. A. Smith, 1990). According to Gómez-Baggethun et al. (2010), the mainstreaming of ES in the sustainability sciences literature took place in the 90s (Daily, 1997; Costanza et al., 1997), and the last two decades ES has been integrated in the decision-making and the policy agenda (MA, 2005).

The 1997 paper by Costanza et al. estimated the value of world's natural capital and ecosystem services (17 ES) from $16-$54 trillion/year. This range of values was higher than the annual global GDP in the same year, and hence highlighted the ecosystems' importance. Another influential publication was the 2005 MA which raised awareness of the threats ES face and placed the ES concept in the top of biodiversity policy agenda. Both studies gave impulse to the ES assessment and valuation studies. The Economics of Ecosystems and Biodiversity (TEEB, 2007) is still a major international initiative to evaluate the costs of biodiversity loss and the associated decline in ecosystem services worldwide, comparing them with the costs of effective conservation and sustainable use.

The valuation, decision and policy making aspects, as well as the use of the ES concept are analysed after the definitions' section.

***<u>Water Resources Management (WRM) and Planning</u>*: WRM means all the methods and activities required for the rational utilization of water resources in order to fully meet the water needs; it includes (Loucks & Beek, 2017): i) Scientific methods and techniques (hydrological analysis, observation of the water resources, and the knowledge of the water demand timely and spatially), ii) Operational interventions and administrative measures aiming to the maximum benefit from the use of water systems, according to criteria, priorities and goals, already set (socio-economic analysis), iii) All technical works and legislation required, to achieve the above. According to the definition mentioned above, 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 strongly social characteristics (Alamanos et al., 2020). This indicates its integrated and interdisciplinary Planning character, as it involves water consumers, decision-makers (Government, Regions, Municipalities, companies, etc.), and a variety of related scientists. The Planning Goals 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, to achieve the maximum efficiency of water resources use, and economic and social prosperity. Its aims of sustainability, as described in the above paragraph are also described and stated in the recent Sustainable Development Goals (SDGs), the European Green Deal, Paris Climate Agreement, etc. (European Commission, 2019; United Nations, 2015, 2016). So, cooperation from the different actors involved, 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

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

Environmental: Water needs of natural ecosystems are considered in environmental studies (e.g. estimated as *environmental* or *ecological flows* – the minimum water requirements for the ecosystems' operations).

Social: 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'.

Socio-economic: 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 questionnaire 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.

Challenges: 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.

The concept of ES is perhaps theoretically more user-friendly than WRM, eco-hydrology, hydrogeology, socio-hydrology, etc. Also, it is broader, as it refers to the ecosystem as a whole. If it is well-perceived from the public, it can only be beneficial for WRM: Understanding the challenges, taking into account the environmental flows in design studies, and build on the right social principles facilitate WRM's processes, and contribute to its objectives. Since our goals are connected with 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.

2. Economic perception of ES

Conceptualisation of ES in Economics

The conceptualisation of ES for economists, in terms of definitions, follows the same norms as described above. The understanding of the variety of use and non-use (protection) uses, with all their direct and indirect values, is important, as it is an initial assumption for the valuation. The right perception of the interlinkages among complex ecosystems and their *contributions to the economy* will enable the best possible policymaking that will take both into account, and will treat them as a whole, and not competitively. This is a key message, also deriving from the studies of Table 2, that cover the last 20 years of the ES use, where 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 for the next steps to be built on solid bases. Farley (2012) notes that the ES's definitions and structure will define the appropriate methods, economic institutions, and thus decisions.

Table 2. 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 are discussed
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 an 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 analyze 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

In the previous paragraph we mentioned the ES's *contributions to the economy* which is the essence of the valuation process; these provisions of good, services, or wellbeing that economists can convert into monetary units.

In the book of Salzman et al. (2001) there is a simple example that representatively describes how the concept of ES is used in economics, what questions it attempts to answer, and what evidence it can provide for relevant policy decisions. Briefly, a simplified hypothetical district (or catchment for our purpose) is used. It consists of:

- an upland forest, which provides timber and acts as a watershed;
- a farmland below, whose irrigation water comes from the forest watershed; and
- a city, whose drinking water also flows from the forest.
- A river flows from the forest through the farmland to the city.

As one can understand, even in this three-component catchment there is a variety of ES: food, timber, climate stability (via carbon storage and sequestration), flood control, pure 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 to the whole system, including the economy).

Economists seek the best combination of goods and services that can be produced from a system's resources, in order to maximise benefits. **Production functions** answer the question of what can be obtained for each one of these goods and services. Farber et al. (2002) simplifies how this works, using the example of 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 the parameters α, β, and γ reflect the weighting (importance) of each food component that overall determine the utility from consumption. So, if we 'transpose' this logic to our catchment example, a production can be a function (linear, non-linear, exponential, logarithmic, etc.) of the necessary raw materials used to produce the desirable good, including labor, capital, etc. The concept of utility (as used in the food example) 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 value of each characteristic. The ability to convert these ES, utilities or services in monetary measurable (WTP or WTA) values, is synonymous with the valuation process, further analysed later.

Going back to our hypothetical catchment example, the interactions among the examined ES are expressed with mathematical interactions among their functions. This is described by a production frontier, and it practically shows for any level of e.g. timber output, the maximum amount of water purification and carbon sequestration that can be performed (Figure 2).

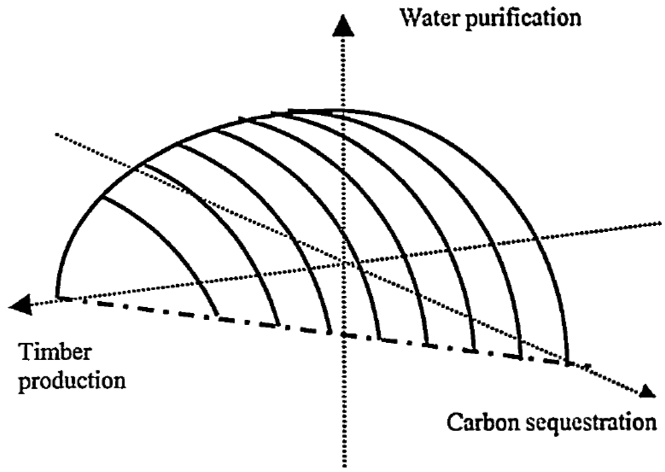

Figure 2. A production possibility frontier for three ES (Source: Salzman et al., 2001).

Similarly, if a production frontier is formulated for all the ES of this simplified catchment (food, timber, carbon sequestration, flood control, pure water, recreation, biodiversity, options for future changes in policies), we will have a 9-dimensional problem, difficult to visualise and solve (i.e. find the overall optimum solution with objective functions).

Salzman et al. (2001) find that the patterns of land use in the forest and on the farms influence the services provided, and thus the 9-D problem could be simplified in a 2-D problem, with these two variables. Different approaches exist today to facilitate such problems through mapping services according to multi-dimensional features (Alamanos & Papaioannou, 2020), as well as more advanced algorithms. However, the optimum output cannot be seen just as the most beneficial product mix that will define the land uses and their distribution; it must also consider the social aspect. The example used above, with a reference to the utilities people derive from ES, serves also as an introduction to the valuation process.

Valuation of ES in Economics

Two important stages at this process are the WTP estimation (the proper problem formulation), and the selection of the appropriate technique. The most commonly 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 (Figure 3). For the latter, statistical software is usually used, such as STATA, SPSS, or programming languages (e.g. R, Matlab, Python).

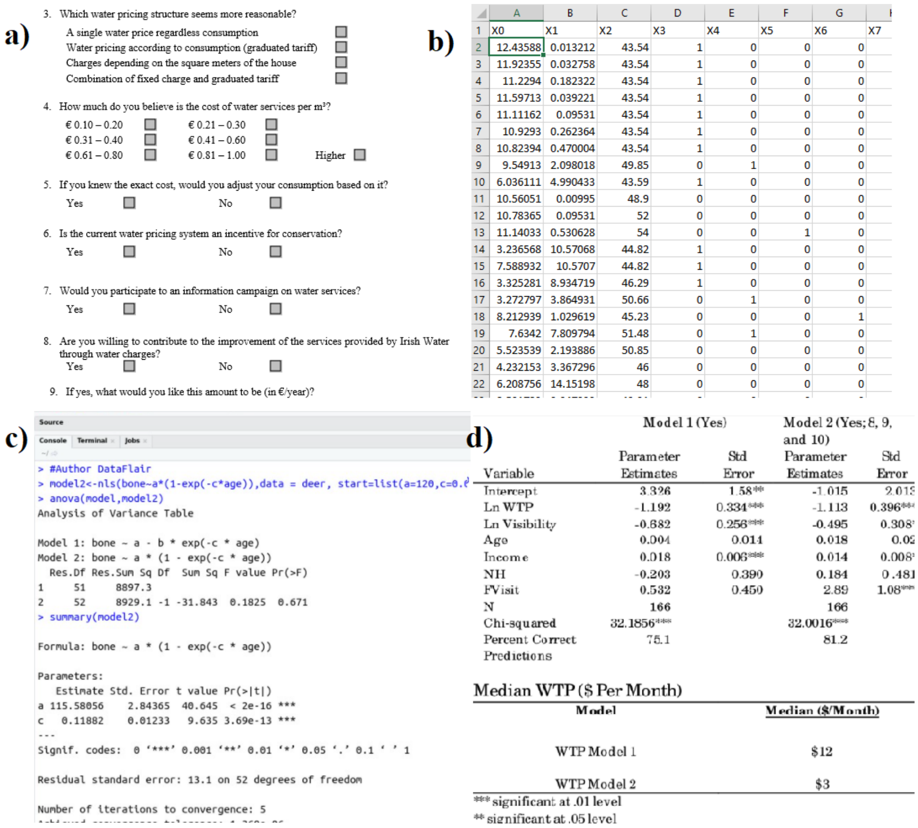

Figure 3. Indicative example of how economists work for a valuation process: a) desk-study to develop an appropriate questionnaire, b) organising the results according to the variables retrieved from the sample (0 and 1 refer to binary variables expressing qualitative questions, e.g. Yes-No), c) econometric model (here shown in R), d) results-table interpretation.

Table 3. 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 sociopolitical processes (mainly institutional-political context)
Sagoff (2011)	Quantification and valuation of ES (Differences between economic and ecological criteria)	Conceptual distance between market-based and science-based methods of assembling information and applying knowledge defeats efforts to determine the "value" of ES in any integrated sense
Fu et al. (2011)	Double counting in ES valuation: causes and countermeasures	Assesses the spatiotemporal scales, values of the final benefits from ES, consistent classification systems, appropriate valuation methods, and proposes ways to value them more precisely
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 particular 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
Vo et al. (2012)	Review of valuation methods for mangrove forests ES	Methods review, techniques employed for data analyses, and further discussing their potential and limitations
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
Torres-Miralles et al. (2017)	Employing contingent and inferred valuation methods to evaluate the conservation of olive groves and associated ES	WTP (econometric model) to develop a sustainable management plan to attenuate the trends of intensification or abandonment of olive groves and to ensure rural development
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 vale estimates
Acharya et al. (2019)	Global trend of forest ES valuation – An analysis of publications	Gaps in ES research in low and middle income countries, valuation methods trends
Naime et al. (2020)	Economic valuation of ES from secondary tropical forests	Value estimates, trade-offs, and implications for policy making

As the above Table and the concept analysis shows, most catchment-related ES are non-marketed and as a 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 its existence, even if there is no actual use of the ecosystem. The implementation of ES approach 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, where different methods have been used to calculate it (Figure 4).

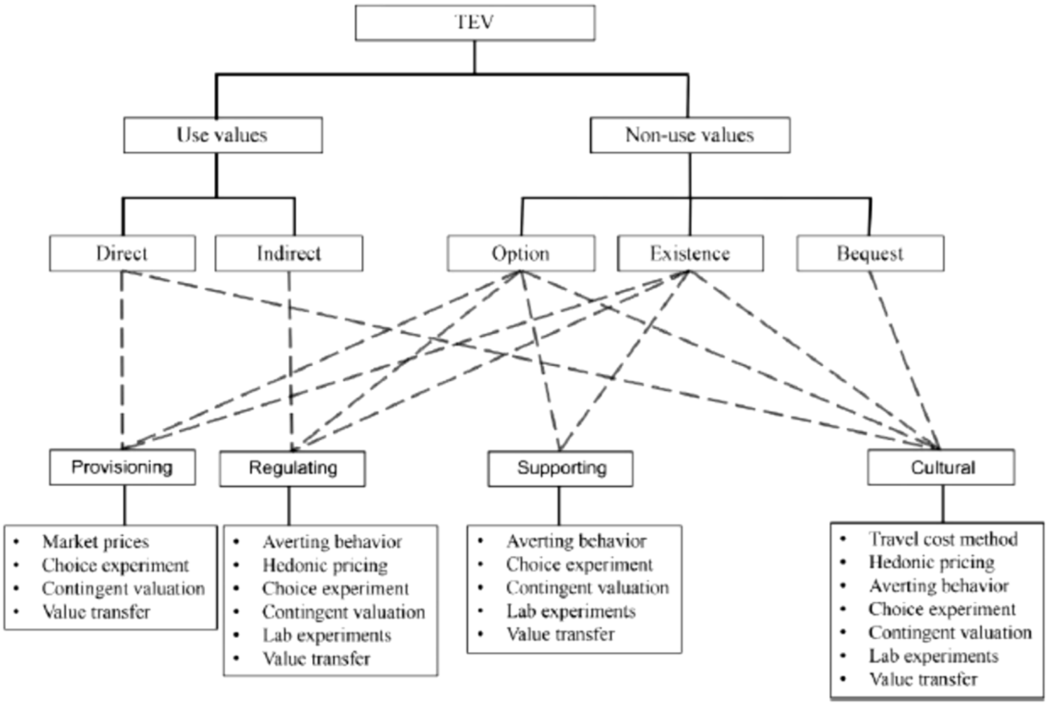

Figure 4. Deriving the Total Economic Value (TEV).

Table 4 below explains the broader value categories. *Use values* which can be: (i) direct use value, e.g. irrigation, (ii) indirect use value, e.g. carbon sequestration, and (iii) option value, e.g. paying for the conservation of a natural park, so it can be "used" in the future. *Non-use values* can be categorized in: (i) bequest, i.e. valuing the fact that an ecosystem will be passed on to future generation, (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. Table 4 contains examples of use and non-use values of water-related resources. Of course, the typology of ES and values are varying, however Figure 4 and Table 4 summarise the most common categories.

Table 4. 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 and protection
Transport and navigation	Natural hazard mitigation
Recreation/amenity	External eco-system support
	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
Non-use values	
Biodiversity	
Cultural heritage	
Bequest, existence and altruistic values	

Valuation methods and an example

The valuation process is an important part of the ES concept, as it is necessary and insightful for the policy-making. For example, valuation is necessary to implement several tasks of the UN Agenda 2030, especially[1]:

- 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 4) 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 3). The key issues of valuation are to develop properly the designed 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 5. Valuation methods categories and description (in blue) (Adapted from Arias-Arévalo et al., 2018).

[1] https://sdgs.un.org/goals

At this point an ES is used as an example: the flood control (or flow regulation) provided by wetlands. The following Table shows an overview of indicative studies that valuated that ES over the last five decades, using different approaches in different case studies.

Table 5. 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	$1,905,959,062/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

The above Table 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 a much bigger scale). This results in a large range of values for each case, even in the same continent or country. As Kadykalo and Findlay (2016) note, the estimates of flow regulation services have generally large uncertainty, which gives to their economic value a large uncertainty, too.

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 next section, focusing on the uncertainties.

Uncertainty

The use of valuation depends highly on its purposes (e.g. raising awareness and interest, full cost accounting, payment schemes, specific policy analyses, etc.). As explained above, the value of ES is their contribution to that services and goods that humans enjoy, thus 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 issues in valuation studies and to acknowledge the limitations of valuation techniques in situations of radical uncertainty or ignorance about regime shifts.

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 ES of water resources or catchment issues, are complex and refer to large scale projects that their effects cannot always be well understood by the public. 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, 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).

The role of Behavioural Economics

In most cases people decide or develop preferences for a future situation or management option, based not on something certain but on probabilities. Complex water management problems under changing climate and economic conditions make almost impossible to have solid ranges of probabilities for the examined preferences and decisions (deep uncertainty). Practically, this can lead to individual behaviours, often controversial with the initial economic-econometric models (valuation), thus the policies cannot bring the desirable outcomes. The initial models (Standard Economic Model - 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 unsatisfactory. Economists started exploring alternative paths, scrutinising in 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) are a future line of research that helps understanding the human behaviour and psychology. Revisiting the SEM from that perspective enables making welfare-enhancing decisions under deep uncertainty and over the short and long-run horizon. BE brings 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 studies human behaviour in a controlled laboratory setting or out in the field, in a similar way with stakeholder analysis, which is analysed below.

A practical example to understand the significant added value of BE is the policies on water price changes. After reviewing the last decades’ BE advances on such topics, Correia & Roseta-Palma (2014) highlight the need of experimental data, additionally to non-experimental data, besides the usual division between aggregate data and household data. The importance of having behavioural data will 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.

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 designed to raise public interest for biodiversity conservation has been increasingly moving towards emphasis on how to cash ecosystem services as commodities (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.

Examples of commodified ESs in Markets could be the emission trading of greenhouse gases (atmospheric sink functions of CO_2), or SO_2, or wetland mitigation banking, etc. Examples of commodified ESs in PES could be applied for watershed protection, carbon sequestration, habitat conservation, wildlife services, bio prospecting, agro-environmental measures, etc. This commodification process is finally completed with the implementation of institutional structures allowing for transactions in market exchanges, as occurred with the establishment of markets and PES schemes (Gómez-Baggethun et al., 2010).

Table 6. 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	Markets failure in ES, features and applicability, and some promising forms that can allocate ES to rural cases

	providing ES on agricultural lands	
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"

A review of the last 20 years on such actions (Table 6) shows that there have been two, almost parallel 'realities' of this topic:

- 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. However, the integration of ES in policies (such as PES and markets) led us with limited good practice examples compared to the number of applications (Table 6).
- 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, rather than the initial goal of ES.

According to the relevant studies of Table 6, the successes of the first bullet were largely attributed to the use of PES (e.g. "funded as a poverty-relief initiative and prospects for expansion of PES for including more ES"). 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), 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.

3. Criticism

ES concept and relevant policies have been criticised on the technical weaknesses of valuation methods, the description of the human behaviour, the 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 because of its multi-disciplinary character it can be interpreted with different definitions. This, as commented above, plays a crucial role to the valuation and policy aspects. The interdisciplinary issues arise from the different perception of the ES and their 'value' from the ecological and 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. 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 storm-water to prevent floods, or the value of fires in recycling nutrients in a forest). Another recognition of value from environmental scientists refer to thermodynamics, where energy is the only primary input to the global system (free and accessible by everyone) and its link to the economic output has been proved to be strong (Costanza, 1980; Costanza & Herendeen, 1984).
- From the 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 is right, 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.

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 service, 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).

Table 7. 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. 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 an utilitarian relationality between humans and nature, and list of neoliberalisation aspects in different organisations promoting PES

The studies reviewed in Table 7 have pointed out two main issues:

A) The ethical, as mentioned above, including the limits of the economic science and the purpose of the policy extents. A broad example are the conservation policies in the global South imposed from the North and framed by neoliberal logic, not in line with the states’ needs, as described from McAfee & Shapiro (2010) and Van Hecken & Bastiaensen (2010). The poverty reduction could be used as a motive, 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) The technical, regarding the weaknesses of valuation methods to describe the human behaviour, provide satisfactory answers to the nature’s value, and thus, lead to good policies.

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:

- Either in a long-term commitment, e.g. using an administrative body. The Water Forum in Ireland[2] 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 Vacant, 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.
- In most projects, a continuous, long-term commitment is not possible, thus a stakeholder analysis must be performed in an integrated and scientific way, in the time limits of a 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). 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.

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

The concept of ES (as well as other concepts developed with similar purposes) are not describing a specific natural process, they are 'intangible', and often have more than one interpretation. This results in the "good and bad examples" from their practical application experience, their interdisciplinary issues, criticisms, and questions referring mainly to their policy extensions and usage as tools. Of course, each concept, measure, or policy, and catchment is different and requires a specific approach, but having some stable principles when studying them, is required,

[2] https://thewaterforum.ie/

too. Such principles will simplify the aforementioned policy extensions and use of tools-concepts, and critically approaching their purpose.

Using the ES example, this work reviewed several studies, and the "good-practice application" examples were rare, in contrast to a number of criticisms. 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.

According to Aristotle, the end (ultimate purpose) is the *Good*. Not only life, but every act, action, technical work, product, etc. must have *good* as their end (Aristotle, *Ethics Nikomacheian, Book 1*)[3]. To get there, the necessary education and training are essential, to enable the appropriate use of the tools.

Obviously, ES (or related regulations and policies, e.g. PES and/or markets) have also 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.

But when these two purposes converge, then does the end justify the means? The result is that we will derive some ecosystem benefits, which is desirable; but can people manage the cost? The element that gives the answer here is the ethical content in the application and implementation of each action (Aristotle, *Ethics Nikomacheian, Book 1*). So, a series of such decisions and policies can be a measure of how much we care about the ethical content, and hence, what societies we attempt to develop.

Aristotle considers that humans are inherently *political beings* –not as parts of political parties, but as components of the society/community – a community that has Good as its end. WRM and ES rely on stakeholder engagement to develop policies and relations inside communities. The achievement of the Supreme Good of such measures is a continuous and difficult effort (and individually, it is a struggle). It requires (Aristotle, *Ethics Nikomacheian, Book 1*):

- The decision-makers to know what is the Supreme Good, so to have the knowledge. Because a man can judge reasonably the things that he best knows (knowledge instead of opinion).
- To have the necessary scientific support in methodological terms (the 'know-how' to achieve our end's application).
- To have the necessary experience to accompany the knowledge and to avoid strategies that may be based on empathy.

The approaches of continuous engagement, public participation, and Systems Innovation Approach contribute in building the three above points, through collaboration with stakeholders and scientists who seek to achieve the Good. The contribution of BE is more on the knowledge of the individual psychological drivers that develop our preferences. Again, according to Aristotle, policymakers must know the nature of the soul, and their role is pedagogical for the soul (not to manipulate its driving factors); a continuous exercise to achieve the Good. This process has clearly an ethical content, which is found:

A. In the co-existence of multi-disciplinary fields and mainly their appropriate limits-setting, in order to ensure their proper application for the overall good which is more important than the individual one (without undermining it, but in fact ensuring it will be also achieved).

[3] English translation: http://www.perseus.tufts.edu/hopper/text?doc=Perseus%3Atext%3A1999.01.0054%3Abook%3D1

B. In the motivation for the effort to achieve this Supreme Good; the motive must be healthy (e.g. faith, self- and community- growth), and not based on selfishness, comparison with others, or getting rewards.

This approach is important, because the end of the overall (or community) good, allows us to change our mind while searching for it, if we come across something better. In practice, this means that it prevents us from being stuck in ideas (or even blindly follow and defend them). This is a key point for approaching ES and WRM, even for scientists. Performing a solid stakeholder analysis allows the appropriate interaction for developing and even correcting the mind-sets of all the parts involved. The constant search for the overall good is a key purpose to approach concepts such as ES, or WS, as we saw.

Even Aristotle himself acknowledges that the good is not one, something that the studies reviewed, the concepts' evolution, and even the practical experience from a meeting can show, too. Nowadays, this is also scientifically confirmed and achievable:

- Quantitatively, through the fields of global or multi-objective optimisation, multiple-criteria or multi-agent based problems. Simply, these refer to solutions that maximise or minimise the objectives we set, together as a whole (i.e., inside their common space of feasible solutions).
- Qualitatively, where proper stakeholder analysis and consultation are paths to reach the end of the overall (multi-objective) good.

So, 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 in an attempt 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 is an outcome of virtue, which is a function of 'per-head' effort, defined by right and healthy purposes.

References

Acharya, R. P., Maraseni, T., & Cockfield, G. (2019). Global trend of forest ecosystem services valuation – An analysis of publications. *Ecosystem Services*, *39*, 100979. https://doi.org/10.1016/j.ecoser.2019.100979

Alamanos, A., Latinopoulos, D., Loukas, A., & Mylopoulos, N. (2020). Comparing Two Hydro-Economic Approaches for Multi-Objective Agricultural Water Resources Planning. *Water Resources Management*, *34*(14), 4511–4526. https://doi.org/10.1007/s11269-020-02690-6

Alamanos, A., & Papaioannou, G. (2020). A GIS Multi-Criteria Analysis Tool for a Low-Cost, Preliminary Evaluation of Wetland Effectiveness for Nutrient Buffering at Watershed Scale: The Case Study of Grand River, Ontario, Canada. *Water*, *12*(11), 3134. https://doi.org/10.3390/w12113134

Alamanos, A., Rolston, A., & Papaioannou, G. (2021). Development of a Decision Support System for Sustainable Environmental Management and Stakeholder Engagement. *Hydrology*, *8*(1), 40. https://doi.org/10.3390/hydrology8010040

Arias-Arévalo, P., Gómez-Baggethun, E., Martín-López, B., & Pérez-Rincón, M. (2018). Widening the Evaluative Space for Ecosystem Services: A Taxonomy of Plural Values and Valuation Methods. *Environmental Values*, *27*(1), 29–53. https://doi.org/10.3197/096327118X15144698637513

Aristotle. (n.d.). *Ethics Nikomacheian, Book 1* (May 2006). Zitiros. Retrieved February 28, 2021, from https://www.politeianet.gr/books/9789608437661-aristotelis-zitros-aristotelis-ithika-nikomacheia-protos-tomos-194312

Balasubramanian, M. (2019). Economic value of regulating ecosystem services: A comprehensive at the global level review. *Environmental Monitoring and Assessment*, *191*(10), 616. https://doi.org/10.1007/s10661-019-7758-8

Barbier, E. B. (2013). Valuing Ecosystem Services for Coastal Wetland Protection and Restoration: Progress and Challenges. *Resources*, *2*(3), 213–230. https://doi.org/10.3390/resources2030213

Barth, N.-C., & Döll, P. (2016). Assessing the ecosystem service flood protection of a riparian forest by applying a cascade approach. *Ecosystem Services*, *21*, 39–52. https://doi.org/10.1016/j.ecoser.2016.07.012

Bellver-Domingo, A., Hernández-Sancho, F., & Molinos-Senante, M. (2016). A review of Payment for Ecosystem Services for the economic internalization of environmental externalities: A water perspective. *Geoforum*, *70*, 115–118. https://doi.org/10.1016/j.geoforum.2016.02.018

Bin, O., & Polasky, S. (2005). Evidence on the Amenity Value of Wetlands in a Rural Setting. *Journal of Agricultural and Applied Economics*, *37*(3), 589–602. https://doi.org/10.22004/ag.econ.42789

Birol, E., Karousakis, K., & Koundouri, P. (2006). Using a choice experiment to account for preference heterogeneity in wetland attributes: The case of Cheimaditida wetland in Greece. *Ecological Economics*, *60*, 145–156. https://doi.org/10.1016/j.ecolecon.2006.06.002

Brann, H. L. (2014). *Payment for Ecosystem Services in the Developing World: Non-Market Contributors to National PES Program Development* [Undergraduate Honors Theses, Paper 51]. University of Colorado, Boulder.

Brauman, K. A., Daily, G. C., Duarte, T. K., & Mooney, H. A. (2007). The Nature and Value of Ecosystem Services: An Overview Highlighting Hydrologic Services. *Annual Review of Environment and Resources*, *32*(1), 67–98. https://doi.org/10.1146/annurev.energy.32.031306.102758

Bulte, E. H., Lipper, L., Stringer, R., & Zilberman, D. (2008). Payments for ecosystem services and poverty reduction: Concepts, issues, and empirical perspectives. *Environment and Development Economics*, *13*(3), 245–254. https://doi.org/10.1017/S1355770X08004348

Burkhard, B., Kroll, F., Nedkov, S., & Müller, F. (2012). Mapping ecosystem service supply, demand and budgets. *Ecological Indicators*, *21*, 17–29. https://doi.org/10.1016/j.ecolind.2011.06.019

Campbell, M. J., & Smith, V. L. (2020). An elementary humanomics approach to boundedly rational quadratic models. *ESI Working Paper 20-35*. https://doi.org/10.1016/j.physa.2020.125309

Chee, Y. E. (2004). An ecological perspective on the valuation of ecosystem services. *Biological Conservation*, *120*(4), 549–565. https://doi.org/10.1016/j.biocon.2004.03.028

Corbera, E., & Brown, K. (2008). Building Institutions to Trade Ecosystem Services: Marketing Forest Carbon in Mexico. *World Development*, *36*(10), 1956–1979. https://doi.org/10.1016/j.worlddev.2007.09.010

Corbera, E., Brown, K., & Adger, W. N. (2007). The Equity and Legitimacy of Markets for Ecosystem Services. *Development and Change*, *38*(4), 587–613. https://doi.org/10.1111/j.1467-7660.2007.00425.x

Correia, R., & Roseta-Palma, C. (2014). Behavioural Economics in Water Management: An Overview of Behavioural Economics Applications to Residential Water Demand. In *Sustainable Consumption*. Oxford University Press. https://oxford.universitypressscholarship.com/view/10.1093/acprof:oso/9780199679355.001.0001/acprof-9780199679355-chapter-9

Costanza, R. (1980). Embodied Energy and Economic Valuation. *Science*, *210*(4475), 1219–1224. https://doi.org/10.1126/science.210.4475.1219

Costanza, R., d'Arge, R., de Groot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O'Neill, R. V., Paruelo, J., Raskin, R. G., Sutton, P., & van den Belt, M. (1997). The value of the world's ecosystem services and natural capital. *Nature*, *387*(6630), 253–260. https://doi.org/10.1038/387253a0

Costanza, R., de Groot, R., Sutton, P., van der Ploeg, S., Anderson, S. J., Kubiszewski, I., Farber, S., & Turner, R. K. (2014). Changes in the global value of ecosystem services. *Global Environmental Change*, *26*, 152–158. https://doi.org/10.1016/j.gloenvcha.2014.04.002

Costanza, R., & Farber, S. (2002). Introduction to the special issue on the dynamics and value of ecosystem services: Integrating economic and ecological perspectives. *Ecological Economics*, *41*(3), 367–373. https://doi.org/10.1016/S0921-8009(02)00087-3

Costanza, R., Farber, S. C., & Maxwell, J. (1989). Valuation and management of wetland ecosystems. *Ecological Economics*, *1*(4), 335–361. https://doi.org/10.1016/0921-8009(89)90014-1

Costanza, R., & Herendeen, R. A. (1984). Embodied energy and economic value in the United States economy: 1963, 1967 and 1972. *Resources and Energy*, *6*(2), 129–163. https://doi.org/10.1016/0165-0572(84)90014-8

Daily, G. C. (1997). Introduction: What Are Ecosystem Services? In *Daily, G.C., Ed., Nature's Services: Societal Dependence on Natural Ecosystems* (pp. 1–10). Island Press.

de Groot, R. S., Alkemade, R., Braat, L., Hein, L., & Willemen, L. (2010). Challenges in integrating the concept of ecosystem services and values in landscape planning, management and decision making. *Ecological Complexity*, *7*(3), 260–272. https://doi.org/10.1016/j.ecocom.2009.10.006

de Groot, R. S., Wilson, M. A., & Boumans, R. M. J. (2002). A typology for the classification, description and valuation of ecosystem functions, goods and services. *Ecological Economics*, *41*(3), 393–408. https://doi.org/10.1016/S0921-8009(02)00089-7

Deal, R. L., Cochran, B., & LaRocco, G. (2012). Bundling of ecosystem services to increase forestland value and enhance sustainable forest management. *Forest Policy and Economics*, *17*, 69–76. https://doi.org/10.1016/j.forpol.2011.12.007

Duraiappah, A. K. (2006). *Markets for Ecosystem Services*. 25.

European Commission. (2019). *A European Green Deal* [Text]. European Commission - European Commission. https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en

Farber, S. (1996). Welfare Loss of Wetlands Disintegration: A Louisiana Study. *Contemporary Economic Policy*, *14*(1), 92–106. https://doi.org/10.1111/j.1465-7287.1996.tb00606.x

Farber, S. C., Costanza, R., & Wilson, M. A. (2002a). Economic and ecological concepts for valuing ecosystem services. *Ecological Economics*, *41*(3), 375–392. https://doi.org/10.1016/S0921-8009(02)00088-5

Farber, S. C., Costanza, R., & Wilson, M. A. (2002b). Economic and ecological concepts for valuing ecosystem services. *Ecological Economics*, *41*(3), 375–392. https://doi.org/10.1016/S0921-8009(02)00088-5

Farley, J. (2012). Ecosystem services: The economics debate. *Ecosystem Services*, *1*(1), 40–49. https://doi.org/10.1016/j.ecoser.2012.07.002

Farley, J., & Costanza, R. (2010). Payments for ecosystem services: From local to global. *Ecological Economics*, *69*(11), 2060–2068. https://doi.org/10.1016/j.ecolecon.2010.06.010

Fisher, B., Turner, K., Zylstra, M., Brouwer, R., Groot, R. de, Farber, S., Ferraro, P., Green, R., Hadley, D., Harlow, J., Jefferiss, P., Kirkby, C., Morling, P., Mowatt, S., Naidoo, R., Paavola, J., Strassburg, B., Yu, D., & Balmford, A. (2008). Ecosystem Services and Economic Theory: Integration for Policy-Relevant Research. *Ecological Applications*, *18*(8), 2050–2067. https://doi.org/10.1890/07-1537.1

Fisher, B., Turner, R. K., & Morling, P. (2009). Defining and classifying ecosystem services for decision making. *Ecological Economics*, *68*(3), 643–653. https://doi.org/10.1016/j.ecolecon.2008.09.014

Fu, B.-J., Su, C.-H., Wei, Y.-P., Willett, I. R., Lü, Y.-H., & Liu, G.-H. (2011). Double counting in ecosystem services valuation: Causes and countermeasures. *Ecological Research*, *26*(1), 1–14. https://doi.org/10.1007/s11284-010-0766-3

Galati, A., Crescimanno, M., Gristina, L., Keesstra, S., & Novara, A. (2016). Actual provision as an alternative criterion to improve the efficiency of payments for ecosystem services for C sequestration in semiarid vineyards. *Agricultural Systems*, *144*, 58–64. https://doi.org/10.1016/j.agsy.2016.02.004

Gatto, M., & Leo, G. a. D. (2000). Pricing Biodiversity and Ecosystem Services: The Never-Ending Story. *BioScience*, *50*(4), 347–355. https://doi.org/10.1641/0006-3568(2000)050[0347:PBAEST]2.3.CO;2

Gerrard, P. (2004). The Case of That Luang Marsh, Vientiane, Lao PDR. *The World Conservation UnionAsia Regional Environmental Economics Programmeand WWF Lao Country Office, Vientiane*, 35.

Goldman-Benner, R. L., Benitez, S., Boucher, T., Calvache, A., Daily, G., Kareiva, P., Kroeger, T., & Ramos, A. (2012). Water funds and payments for ecosystem services: Practice learns from theory and theory can learn from practice. *Oryx*, *46*(1), 55–63. https://doi.org/10.1017/S0030605311001050

Gómez-Baggethun, E., de Groot, R., Lomas, P. L., & Montes, C. (2010). The history of ecosystem services in economic theory and practice: From early notions to markets and payment schemes. *Ecological Economics*, *69*(6), 1209–1218. https://doi.org/10.1016/j.ecolecon.2009.11.007

Gómez-Baggethun, E., & Ruiz-Pérez, M. (2011). Economic valuation and the commodification of ecosystem services. *Progress in Physical Geography: Earth and Environment*, *35*(5), 613–628. https://doi.org/10.1177/0309133311421708

Gupta, T. R., & Foster, J. H. (1975). Economic Criteria for Freshwater Wetland Policy in Massachusetts. *American Journal of Agricultural Economics*, *57*(1), 40–45. https://doi.org/10.2307/1238838

Hackbart, V. C. S., de Lima, G. T. N. P., & dos Santos, R. F. (2017). Theory and practice of water ecosystem services valuation: Where are we going? *Ecosystem Services*, *23*, 218–227. https://doi.org/10.1016/j.ecoser.2016.12.010

Hansjürgens, B., Schröter-Schlaack, C., Berghöfer, A., & Lienhoop, N. (2016). Reprint:Justifying social values of nature: Economic reasoning beyond self-interested preferences. *Ecosystem Services*, *22*, 228–237. https://doi.org/10.1016/j.ecoser.2016.12.002

Häyhä, T., & Franzese, P. P. (2014). Ecosystem services assessment: A review under an ecological-economic and systems perspective. *Ecological Modelling*, *289*, 124–132. https://doi.org/10.1016/j.ecolmodel.2014.07.002

He, J., Dupras, J., & Poder, T. G. (2017). The value of wetlands in Quebec: A comparison between contingent valuation and choice experiment. *Journal of Environmental Economics and Policy*, *6*(1), 51–78. https://doi.org/10.1080/21606544.2016.1199976

Hein, L., van Koppen, K., de Groot, R. S., & van Ierland, E. C. (2006). Spatial scales, stakeholders and the valuation of ecosystem services. *Ecological Economics*, *57*(2), 209–228. https://doi.org/10.1016/j.ecolecon.2005.04.005

Howarth, R. B., & Farber, S. (2002). Accounting for the value of ecosystem services. *Ecological Economics*, *41*(3), 421–429. https://doi.org/10.1016/S0921-8009(02)00091-5

Jack, B. K., Kousky, C., & Sims, K. R. E. (2008). Designing payments for ecosystem services: Lessons from previous experience with incentive-based mechanisms. *Proceedings of the National Academy of Sciences*, *105*(28), 9465–9470. https://doi.org/10.1073/pnas.0705503104

Kadykalo, A. N., & Findlay, C. S. (2016). The flow regulation services of wetlands. *Ecosystem Services*, *20*, 91–103. https://doi.org/10.1016/j.ecoser.2016.06.005

Kakuru, W., Turyahabwe, N., & Mugisha, J. (2013). Total Economic Value of Wetlands Products and Services in Uganda. *The Scientific World Journal*, *2013*, e192656. https://doi.org/10.1155/2013/192656

Keeler, B. L., Polasky, S., Brauman, K. A., Johnson, K. A., Finlay, J. C., O'Neill, A., Kovacs, K., & Dalzell, B. (2012). Linking water quality and well-being for improved assessment and valuation of ecosystem services. *Proceedings of the National Academy of Sciences*, *109*(45), 18619–18624. https://doi.org/10.1073/pnas.1215991109

King, S. E., & Lester, J. N. (1995). The value of salt marsh as a sea defence. *Marine Pollution Bulletin*, *30*(3), 180–189. https://doi.org/10.1016/0025-326X(94)00173-7

Kolinjivadi, V., Grant, A., Adamowski, J., & Kosoy, N. (2015). Juggling multiple dimensions in a complex socio-ecosystem: The issue of targeting in payments for ecosystem services. *Geoforum*, *58*, 1–13. https://doi.org/10.1016/j.geoforum.2014.10.004

Kolinjivadi, V., Van Hecken, G., Almeida, D. V., Dupras, J., & Kosoy, N. (2019). Neoliberal performatives and the 'making' of Payments for Ecosystem Services (PES). *Progress in Human Geography*, *43*(1), 3–25. https://doi.org/10.1177/0309132517735707

Koundouri, P. (Ed.). (2021). *The Ocean of Tomorrow: The Transition to Sustainability – Volume 2*. Springer International Publishing. https://doi.org/10.1007/978-3-030-56847-4

Kroeger, T., & Casey, F. (2007). An assessment of market-based approaches to providing ecosystem services on agricultural lands. *Ecological Economics*, *64*(2), 321–332. https://doi.org/10.1016/j.ecolecon.2007.07.021

Kumar, M., & Kumar, P. (2008). Valuation of the ecosystem services: A psycho-cultural perspective. *Ecological Economics*, *64*(4), 808–819. https://doi.org/10.1016/j.ecolecon.2007.05.008

Lant, C. L., Ruhl, J. B., & Kraft, S. E. (2008). The Tragedy of Ecosystem Services. *BioScience*, *58*(10), 969–974. https://doi.org/10.1641/B581010

Lautenbach, S., Mupepele, A.-C., Dormann, C. F., Lee, H., Schmidt, S., Scholte, S. S. K., Seppelt, R., Teeffelen, A. J. A. van, Verhagen, W., & Volk, M. (2015). Blind spots in ecosystem services research and implementation. *BioRxiv*, 033498. https://doi.org/10.1101/033498

Leimona, B., van Noordwijk, M., de Groot, R., & Leemans, R. (2015). Fairly efficient, efficiently fair: Lessons from designing and testing payment schemes for ecosystem services in Asia. *Ecosystem Services*, *12*, 16–28. https://doi.org/10.1016/j.ecoser.2014.12.012

Leschine, T. M., Wellman, K. F., & Green, T. H. (1997). *The Economic Value of Wetlands—Wetlands' Role in Flood Protection in Western Washington* (Ecology Publication No. 97-100; p. 68).

Maes, J., Burkhard, B., & Geneletti, D. (2018). Ecosystem services are inclusive and deliver multiple values. A comment on the concept of nature's contributions to people. *One Ecosystem*, *3*, e24720. https://doi.org/10.3897/oneeco.3.e24720

Martín-López, B., Gómez-Baggethun, E., García-Llorente, M., & Montes, C. (2014). Trade-offs across value-domains in ecosystem services assessment. *Ecological Indicators*, *37*, 220–228. https://doi.org/10.1016/j.ecolind.2013.03.003

Martin-Ortega, J., Ferrier, R. C., Gordon, I. J., & Khan, S. (2015). *Water Ecosystem Services: A Global Perspective*. Cambridge University Press.

McAfee, K. (2012). The Contradictory Logic of Global Ecosystem Services Markets. *Development and Change*, *43*(1), 105–131. https://doi.org/10.1111/j.1467-7660.2011.01745.x

McAfee, K., & Shapiro, E. N. (2010). Payments for Ecosystem Services in Mexico: Nature, Neoliberalism, Social Movements, and the State. *Annals of the Association of American Geographers*, *100*(3), 579–599. https://doi.org/10.1080/00045601003794833

McElwee, P., Huber, B., & Nguyễn, T. H. V. (2020). Hybrid Outcomes of Payments for Ecosystem Services Policies in Vietnam: Between Theory and Practice. *Development and Change*, *51*(1), 253–280. https://doi.org/10.1111/dech.12548

Millennium Ecosystem Assessment (Program) (Ed.). (2005). *Ecosystems and human well-being: Synthesis*. Island Press.

Ming, J., Xian-guo, L., Lin-shu, X., Li-juan, C., & Shouzheng, T. (2007). Flood mitigation benefit of wetland soil—A case study in Momoge National Nature Reserve in China. *Ecological Economics*, *61*(2), 217–223. https://doi.org/10.1016/j.ecolecon.2006.10.019

Morris, J., & Camino, M. (2011). *Economic Assessment of Freshwater, Wetland and Floodplain (FWF) Ecosystem Services* (UK NEA Economics Analysis Report) [UK National Ecosystem Assessment]. UK National Ecosystem Assessment.

Muradian, R., Arsel, M., Pellegrini, L., Adaman, F., Aguilar, B., Agarwal, B., Corbera, E., Blas, D. E. de, Farley, J., Froger, G., Garcia-Frapolli, E., Gómez-Baggethun, E., Gowdy, J., Kosoy, N., Coq, J. F. L., Leroy, P., May, P., Méral, P., Mibielli, P., … Urama, K. (2013). Payments for ecosystem services and the fatal attraction of win-win solutions. *Conservation Letters*, *6*(4), 274–279. https://doi.org/10.1111/j.1755-263X.2012.00309.x

Murtough, G., Aretino, B., & Matysek, A. (2002). *Creating Markets for Ecosystem Services* (SSRN Scholarly Paper ID 322380). Social Science Research Network. https://doi.org/10.2139/ssrn.322380

Naime, J., Mora, F., Sánchez-Martínez, M., Arreola, F., & Balvanera, P. (2020). Economic valuation of ecosystem services from secondary tropical forests: Trade-offs and implications for policy making. *Forest Ecology and Management*, *473*, 118294. https://doi.org/10.1016/j.foreco.2020.118294

Narayan, S., Beck, M. W., Wilson, P., Thomas, C. J., Guerrero, A., Shepard, C. C., Reguero, B. G., Franco, G., Ingram, J. C., & Trespalacios, D. (2017). The Value of Coastal Wetlands for Flood Damage Reduction in the Northeastern USA. *Scientific Reports*, *7*(1), 9463. https://doi.org/10.1038/s41598-017-09269-z

Ojea, E., Martin-Ortega, J., & Chiabai, A. (2012). Defining and classifying ecosystem services for economic valuation: The case of forest water services. *Environmental Science & Policy*, *19–20*, 1–15. https://doi.org/10.1016/j.envsci.2012.02.002

Pandeya, B., Buytaert, W., Zulkafli, Z., Karpouzoglou, T., Mao, F., & Hannah, D. M. (2016). A comparative analysis of ecosystem services valuation approaches for application at the local scale and in data scarce regions. *Ecosystem Services*, *22*, 250–259. https://doi.org/10.1016/j.ecoser.2016.10.015

Pascual, U., Muradian, R., Brander, L., Gomez-Baggethun, E., Martín-López, B., Verma, M., Armsworth, P., Christie, M., Cornelissen, J., Eppink, F., Farley, J., Loomis, J., Pearson, L., Perrings, C., & Polasky, S. (2012). The Economics of Valuing Ecosystem Services and Biodiversity. *Ecological and Economic Foundations, Taylor and Francis*, 183–256.

Pattison-Williams, J. K., Pomeroy, J. W., Badiou, P., & Gabor, S. (2018). Wetlands, Flood Control and Ecosystem Services in the Smith Creek Drainage Basin: A Case Study in Saskatchewan, Canada. *Ecological Economics*, *147*, 36–47. https://doi.org/10.1016/j.ecolecon.2017.12.026

Perrot-Maître, D. (2006). The Vittel payments for ecosystem services: A “perfect” PES case? *International Institute for Environment and Development, London, UK*, *3*, 24.

Peterson, M. J., Hall, D. M., Feldpausch-Parker, A. M., & Peterson, T. R. (2010). Obscuring ecosystem function with application of the ecosystem services concept. *Conservation Biology: The Journal of the Society for Conservation Biology*, *24*(1), 113–119. https://doi.org/10.1111/j.1523-1739.2009.01305.x

Plummer, M. L. (2009). Assessing benefit transfer for the valuation of ecosystem services. *Frontiers in Ecology and the Environment*, *7*(1), 38–45. https://doi.org/10.1890/080091

Redford, K. H., & Adams, W. M. (2009). Payment for Ecosystem Services and the Challenge of Saving Nature. *Conservation Biology*, *23*(4), 785–787. https://doi.org/10.1111/j.1523-1739.2009.01271.x

Ribaudo, M., Greene, C., Hansen, L., & Hellerstein, D. (2010). Ecosystem services from agriculture: Steps for expanding markets. *Ecological Economics*, *69*(11), 2085–2092. https://doi.org/10.1016/j.ecolecon.2010.02.004

Robertson, M. M. (2006a). Emerging ecosystem service markets: Trends in a decade of entrepreneurial wetland banking. *Frontiers in Ecology and the Environment*, *4*(6), 297–302. https://doi.org/10.1890/1540-9295(2006)4[297:EESMTI]2.0.CO;2

Robertson, M. M. (2006b). The Nature That Capital Can See: Science, State, and Market in the Commodification of Ecosystem Services. *Environment and Planning D: Society and Space*, *24*(3), 367–387. https://doi.org/10.1068/d3304

Sagoff, M. (2011). The quantification and valuation of ecosystem services. *Ecological Economics*, *70*(3), 497–502. https://doi.org/10.1016/j.ecolecon.2010.10.006

Salzman, J., Bennett, G., Carroll, N., Goldstein, A., & Jenkins, M. (2018). The global status and trends of Payments for Ecosystem Services. *Nature Sustainability*, *1*(3), 136–144. https://doi.org/10.1038/s41893-018-0033-0

Salzman, J., Thompson, B. H. Jr., & Daily, G. C. (2001). Protecting Ecosystem Services: Science, Economics, and Law. *Stanford Environmental Law Journal*, *20*(2), 309–332.

Sandhu, H. S., Wratten, S. D., & Cullen, R. (2010). Organic agriculture and ecosystem services. *Environmental Science & Policy*, *13*(1), 1–7. https://doi.org/10.1016/j.envsci.2009.11.002

Schmidt, K., Martín-López, B., Phillips, P. M., Julius, E., Makan, N., & Walz, A. (2019). Key landscape features in the provision of ecosystem services: Insights for management. *Land Use Policy*, *82*, 353–366. https://doi.org/10.1016/j.landusepol.2018.12.022

Schmidt, K., Walz, A., Martín-López, B., & Sachse, R. (2017). Testing socio-cultural valuation methods of ecosystem services to explain land use preferences. *Ecosystem Services*, *26*, 270–288. https://doi.org/10.1016/j.ecoser.2017.07.001

Schomers, S., & Matzdorf, B. (2013). Payments for ecosystem services: A review and comparison of developing and industrialized countries. *Ecosystem Services*, *6*, 16–30. https://doi.org/10.1016/j.ecoser.2013.01.002

Silva, R. A., Lapola, D. M., Patricio, G. B., Teixeira, M. C., Pinho, P., & Priess, J. A. (2016). Operationalizing payments for ecosystem services in Brazil’s sugarcane belt: How do stakeholder opinions match with successful cases in Latin America? *Ecosystem Services*, *22*, 128–138. https://doi.org/10.1016/j.ecoser.2016.09.013

Silvertown, J. (2015). Have Ecosystem Services Been Oversold? *Trends in Ecology & Evolution*, *30*(11), 641–648. https://doi.org/10.1016/j.tree.2015.08.007

Sivapalan, M., Savenije, H. H. G., & Blöschl, G. (2012). Socio-hydrology: A new science of people and water. *Hydrological Processes*, *26*(8), 1270–1276. https://doi.org/10.1002/hyp.8426

Smith, G. A. (1990). Ecological Economics: Energy, Environment and Society. By Juan Martinez-Alier. Oxford: Basil Blackwell, 1987. 286 pp. *History of Political Economy*, *22*(4), 745–747. https://doi.org/10.1215/00182702-22-4-745

Smith, V. L., & Wilson, B. J. (2019). Humanomics: Moral Sentiments and the Wealth of Nations for the Twenty-First Century. *Journal of the History of Economic Thought*, 215. https://doi.org/10.1017/S1053837220000310

Spangenberg, J. H., & Settele, J. (2010). Precisely incorrect? Monetising the value of ecosystem services. *Ecological Complexity*, *7*(3), 327–337. https://doi.org/10.1016/j.ecocom.2010.04.007

Stevens, T. H., Benin, S., & Larson, J. S. (1995). Public attitudes and economic values for wetland preservation in New England. *Wetlands*, *15*(3), 226–231. https://doi.org/10.1007/BF03160702

Swinton, S. M., Lupi, F., Robertson, G. P., & Hamilton, S. K. (2007). Ecosystem services and agriculture: Cultivating agricultural ecosystems for diverse benefits. *Ecological Economics*, *64*(2), 245–252. https://doi.org/10.1016/j.ecolecon.2007.09.020

TEEB. (2007). The Economics of Ecosystems and Biodiversity. http://teebweb.org/

Thibodeau, F. R., & Ostro, B. D. (1981). An economic analysis of wetland protection. *Journal of Environmental Management*, *12*, 19–30.

Thompson, K. M., Duinker, P., & Sherren, K. (2020). *Ecosystem services: A new framework for old ideas, or advancing environmental decision-making? Learning from Canadian forerunners to the ES concept*. https://doi.org/10.1111/cag.12670

Torres-Miralles, M., Grammatikopoulou, I., & Rescia, A. J. (2017). Employing contingent and inferred valuation methods to evaluate the conservation of olive groves and associated ecosystem services in Andalusia (Spain). *Ecosystem Services*, *26*, 258–269. https://doi.org/10.1016/j.ecoser.2017.07.002

Turpie, J. K., Marais, C., & Blignaut, J. N. (2008). The working for water programme: Evolution of a payments for ecosystem services mechanism that addresses both poverty and ecosystem service delivery in South Africa. *Ecological Economics*, *65*(4), 788–798. https://doi.org/10.1016/j.ecolecon.2007.12.024

United Nations. (2015). *THE 17 GOALS | Sustainable Development*. https://sdgs.un.org/goals

United Nations. (2016). *The Paris Agreement | UNFCCC*. https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement

Van Hecken, G., & Bastiaensen, J. (2010). Payments for ecosystem services: Justified or not? A political view. *Environmental Science & Policy*, *13*(8), 785–792. https://doi.org/10.1016/j.envsci.2010.09.006

Vermaat, J. E., Immerzeel, B., Pouta, E., & Juutinen, A. (2020). Applying ecosystem services as a framework to analyze the effects of alternative bio-economy scenarios in Nordic catchments. *Ambio*, *49*(11), 1784–1796. https://doi.org/10.1007/s13280-020-01348-2

Villa, F., Wilson, M. A., de Groot, R., Farber, S., Costanza, R., & Boumans, R. M. J. (2002). Designing an integrated knowledge base to support ecosystem services valuation. *Ecological Economics*, *41*(3), 445–456. https://doi.org/10.1016/S0921-8009(02)00093-9

Vo, Q. T., Kuenzer, C., Vo, Q. M., Moder, F., & Oppelt, N. (2012). Review of valuation methods for mangrove ecosystem services. *Ecological Indicators*, *23*, 431–446. https://doi.org/10.1016/j.ecolind.2012.04.022

Wam, H. K., Bunnefeld, N., Clarke, N., & Hofstad, O. (2016). Conflicting interests of ecosystem services: Multi-criteria modelling and indirect evaluation of trade-offs between monetary and non-monetary measures. *Ecosystem Services*, *22*, 280–288. https://doi.org/10.1016/j.ecoser.2016.10.003

Watson, K. B., Ricketts, T., Galford, G., Polasky, S., & O'Niel-Dunne, J. (2016). Quantifying flood mitigation services: The economic value of Otter Creek wetlands and floodplains to Middlebury, VT. *Ecological Economics*, *130*, 16–24. https://doi.org/10.1016/j.ecolecon.2016.05.015

Westman, W. E. (1977). How Much Are Nature's Services Worth? *Science*, *197*(4307), 960–964. https://doi.org/10.1126/science.197.4307.960

Whitten, S. M., Salzman, J., Shelton, D., & Procter, W. (2003). *Markets for ecosystem services: Applying the concepts* (No. 414-2016–26122). AgEcon Search. https://doi.org/10.22004/ag.econ.58269

Winkler, R. (2006). Valuation of ecosystem goods and services: Part 1: An integrated dynamic approach. *Ecological Economics*, *59*(1), 82–93. https://doi.org/10.1016/j.ecolecon.2005.10.003