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Chapter 5

Ecosystem Services across US Watersheds: A Meta-Analysis of Studies 2000–2014

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Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/intechopen.76650

Abstract

Despite increasing awareness on the importance of rivers in maintaining human well-being, there has not been a comprehensive inventory of watershed-scale ecosystem services across the USA. Here, we analyze and summarize the scientific literature within the context of the supply and demand for ecosystem services across 18 major watersheds of the continental US. We reviewed 305 articles and found that 68 provided information on both the biophysical delivery (supply) and the sociocultural and economic values (demand) of ecosystem services. Maintaining populations and habitats, water filtration, and nutrient sequestration/storage were the most extensively assessed services, while educational and aesthetic values were the least frequently studied. Biophysical assessments were the most frequent valuation followed by economic approaches. The majority of the studies were conducted in the eastern US, while the region least studied was the southwest. In addition to identifying the knowledge gaps in watershed-scale ecosystem services, we highlight the need for a common framework for assessing ecosystem services that includes both the assessment of the supply and demand of ecosystem services provided by US watersheds. There is an urgent need to incorporate the role that cultural services and values can play in water resources management and planning in the USA.

1. Introduction

Preserving freshwater resources is a critical global issue [1, 2]. Water resources are vital for maintaining the welfare of humans and wildlife; however, humans have often prioritized freshwater for economic development at the expense of ecosystem health [3, 4]. There is

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concern in the USA about how to maintain future water supplies because of rapid growing human populations and climate change [5, 6]. Tradeoffs between securing water for human needs and ecosystem health will only become more challenging in the future with increasing human demand for freshwater coupled with impending shifts in the duration and frequency of extreme climatic events. This challenge is already being realized with increasing interstate water disputes across the nation [7]. Thus, there is an urgent need to implement new frameworks that consider the interdependent social, economic, and biophysical dynamics of water resources [8, 9].

Ecosystem services are the benefits that humans derive from ecosystems [10]. Examples of ecosystem services provided by freshwater ecosystems include (1) provisioning services obtained directly from the ecosystem such as drinking water and irrigation; (2) regulating services such as water regulation and quality, habitat, and air quality; and (3) cultural services, which are nonmaterial benefits that people obtain from ecosystems through spiritual enrichment, cognitive development, education, recreation, and esthetic experiences [10, 11]. The ecosystem service framework is useful in natural resource management [12] because it enables focusing on human-environment interlinkages by translating ecosystem properties into human needs [4, 13]. However, watershed management in the USA has traditionally maximized the production of one ecosystem service (e.g., energy or agriculture production), resulting in declines in other services (e.g., water quantity and quality) and producing human conflicts [14]. Therefore, understanding the different tradeoffs among ecosystem services associated with different watershed management strategies is key to maintain ecosystem services and decrease conflict. Such analyses should include an assessment of both the supply and societal demand of ecosystem services [15–17].

Despite the increasing number of publications that present innovative ideas and complementary insights from various perspectives, there is growing uncertainty with respect to the appropriate methodologies for quantifying ecosystem services. A common challenge in implementing the ecosystem services framework for watershed management is to quantify the capacity of watershed to provide services (supply side) as well as characterizing the social demand for those services (demand side) [16, 18]. The supply-demand framework highlights that the status of an ecosystem service is influenced not only by the ecosystem's properties but also by societal needs [16]. Here, we define the supply side as the capacity of a particular watershed to provide a specific bundle of ecosystem services within a given time period [15, 18] and the demand side as the sum of all ecosystem services currently consumed, used, or valued in a particular area over a given time period [3, 4].

This chapter provides a meta-analysis of the scientific knowledge related to ecosystem services across the major continental US watersheds. First, we present the data structure followed in this analysis. Several classifications and analytical frameworks have been proposed to assess ecosystem services. Based on our exploration of the scientific literature, we structure the results of this review based on the biophysical supply and social demand of ecosystem services [8, 15, 18]. Second, we describe and analyze the published articles and case studies under multiple perspectives (e.g., type of approach, geographical distribution, main focus, services valued). Then, we present the current knowledge across US watersheds related to

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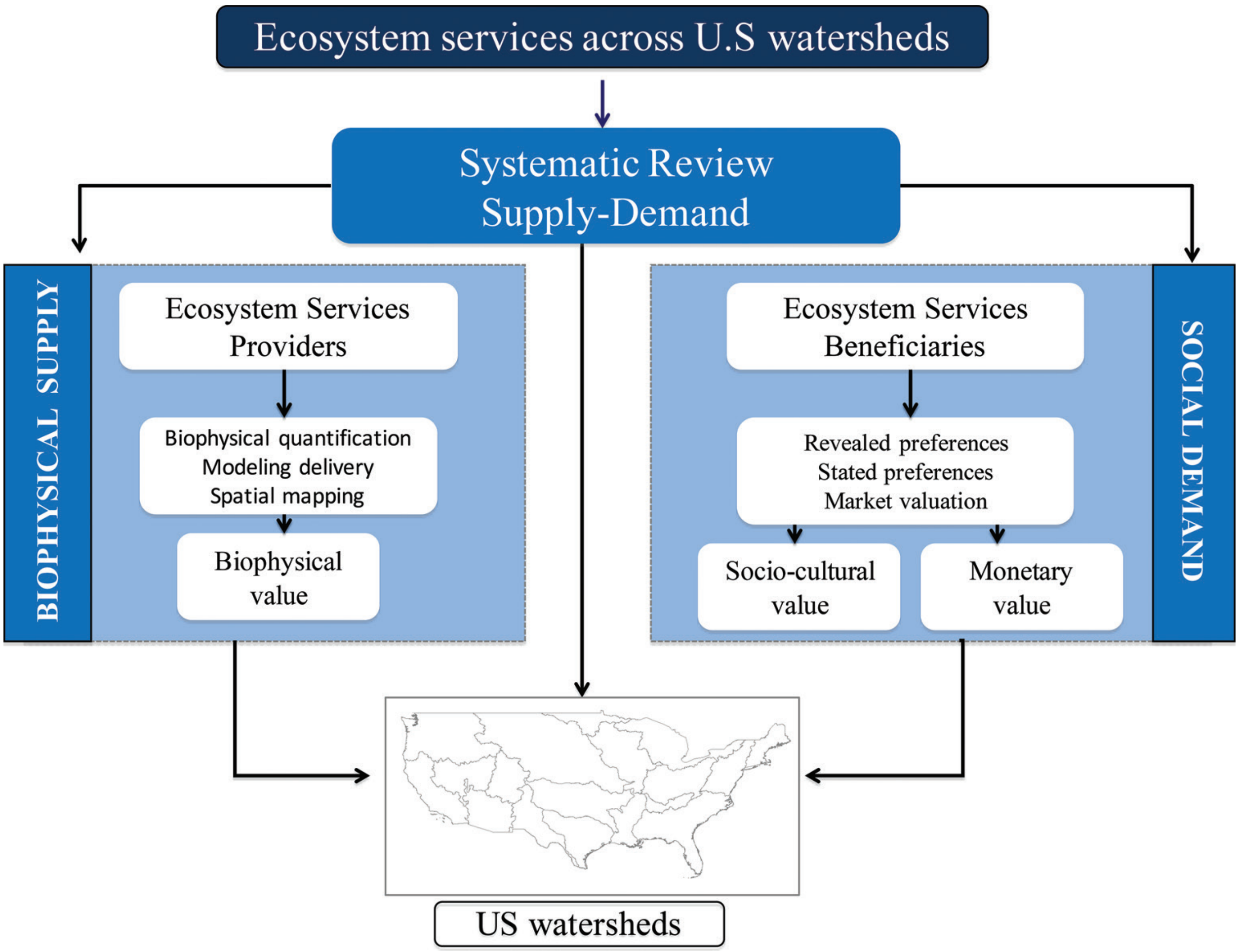

Figure 1. Ecosystem services framework used in reviewing the biophysical supply and the societal demand of services.

ecosystem services by differentiating between studies focused on the quantification of their biophysical supply and social demand. Finally, we identify the major knowledge gaps, both geographically and conceptually (**Figure 1**).

2. Methodology

2.1. Review criteria and selection

We reviewed scientific publications including journal articles and book chapters, from Web of Science (www.webofknowledge.com/) covering studies conducted at the watershed scale in the USA [19]. The systematic review follows the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) statement (**Figure 2**) [20]. The revision included terms related to the object of valuation (e.g., ecosystem services or environmental goods), the level of assessment (e.g., watershed or basin), and the location of the case study (e.g., U.S. or United States). See Appendix.1 for more detailed information. Eligibility criteria included manuscripts published between January 2000 and March 2014. Articles were screened to

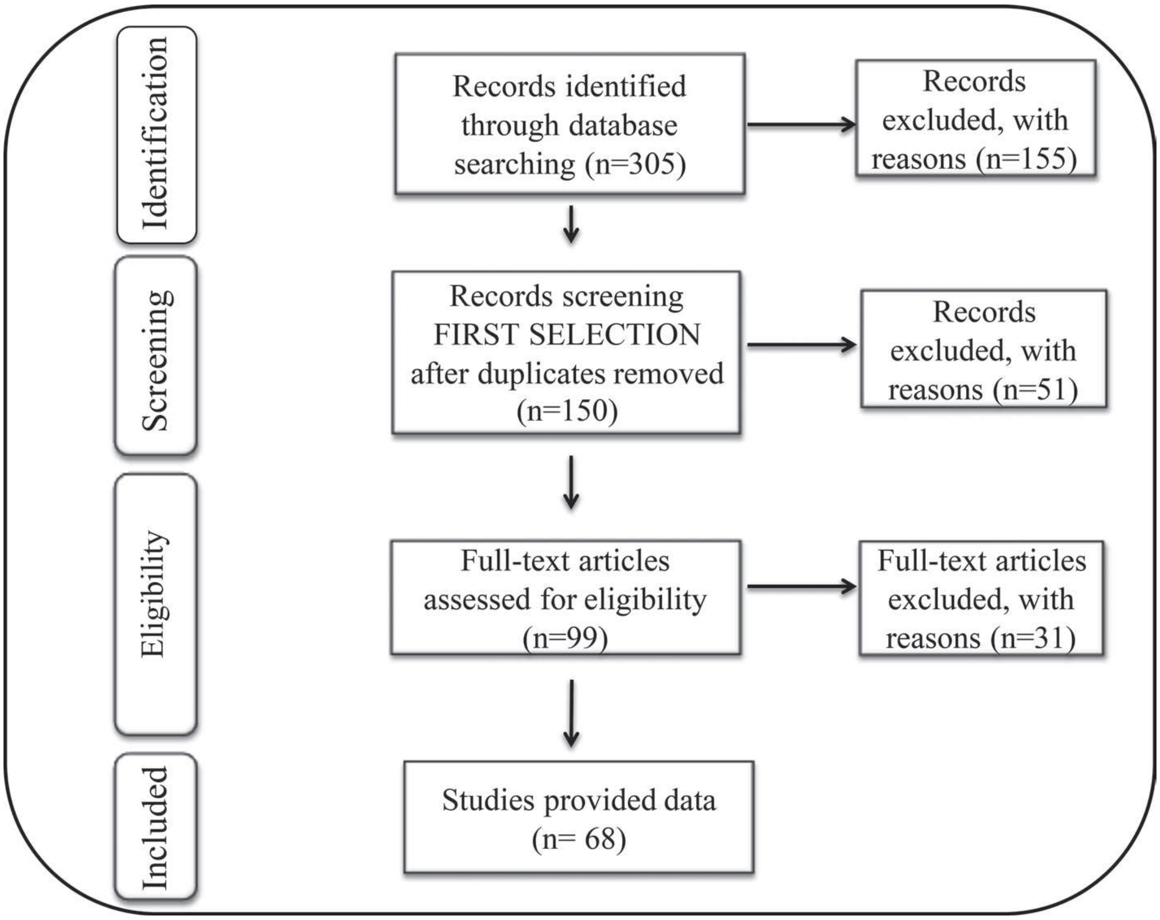

Figure 2. Flow diagram of the methodology and selection process of the systematic review following the Preferred Reporting Items for Systematic Reviews (PRISMA).

determine relevant articles for this study. Overall, 305 articles were selected. Gray literature was omitted from this review. Our search was focused on articles that had framed their work explicitly in the ecosystem service concept (i.e., measuring the supply and demand of ecosystem services) across US watersheds [21].

A total of 305 articles were screened to determine relevant articles for this study (**Figure 2**) [20]. In addition, articles were excluded if they used the concept of ecosystem service to justify or explain the study, but did not actually assess ecosystem services. Overall, 150 were selected after excluding duplicates. Then, only articles that carried out assessments of ecosystem services from supply and demand perspective were considered (n = 99 studies). In this second selection process, the exclusion criteria included factors related to the type of valuation methods based on the multidimensional assessment of ecosystem services [8]. After this final selection, 68 articles were kept for the quantitative review (**Figure 2**) [20].

2.2. Data collection and structure

We classified all studies using the supply–demand framework of ecosystem services [16, 18] and grouped them by major watersheds (hydrologic unit code, level 2; HUC-2). Data collection was organized based on the general characteristics of this chapter, and the variables and methods used to estimate both the biophysical supply and demand of ecosystem services (**Figure 2**). Appendix.2 shows a description of the variables collected in the review including the characteristics of the articles and study area, the type of ecosystem services valuation methods used, the classes of ecosystem services following the Common International Classification of Ecosystem Services (CICES), the type of biophysical quantification, the type of value, and the type of stakeholders involved. All the information was summarized and organized to facilitate its use by researchers and practitioners wanting maps of both the supply and demand of ecosystem services across the major US watersheds. Finally, we explored the current state of knowledge on the ecosystem service valuation through a general descriptive analysis of the studies. We analyzed the temporal evolution, methods, and type of analysis used, and spatial distributions of ecosystem services and publications across the major US watersheds.

3. Results

3.1. Analysis of published articles

The number of articles assessing ecosystem services from supply and demand perspectives in the USA increased exponentially after 2010 (**Figure 3A**), with only six articles published before 2004. From 2001 to 2010, the average rate of publication was around two articles per year. Thereafter, the publication rate rose to 11 articles per year. Most of the selected articles (60 articles) had a biophysical or an environmental perspective followed by economic (28 articles), interdisciplinary assessments (24 articles), and sociocultural assessments (14 articles) (**Figure 3B**). Only a few studies actually produced maps of ecosystem services. Almost half of the studies (45 articles) used empirical data for quantifying ecosystem services (**Figure 3C**). Over a third of studies performed modeling data analysis, and only 16 articles conducted theoretical approaches. From all the selected articles, 38 articles were carried out at a local scale, followed by 25 articles at a regional scale, and seven at a national scale (**Figure 3D**). Local scale was defined when the study covered just one US state, regional scale when for two US states, and national when it covered more than two US states.

3.2. Ecosystem services values and frameworks employed

Results show that over 78% of all studies did not use or mention any ecosystem services framework to structure goals, 21% used the [10] framework, and only 1% used the supply and demand frameworks (**Figure 4A**). Overall, considering the [10] classification of ecosystem services, we found that regulating services was the class most commonly quantified or valued (82%), followed by provisioning (41%) and cultural ecosystem services (21%) (**Figure 4B**). However, over half of the studies (52%) included more than one ecosystem service type in the analysis.

Using the Common International Classification of Ecosystem Services (CICES, www.cices.eu), we found that the regulating services were the most frequently studied category; however, the number of articles including cultural services in their assessments was higher than those studying provisioning services (**Figure 5**). Overall, the review identified a total of 308 ecosystem services studied. Among the regulating services, filtration, sequestration, storage and accumulation by ecosystems,

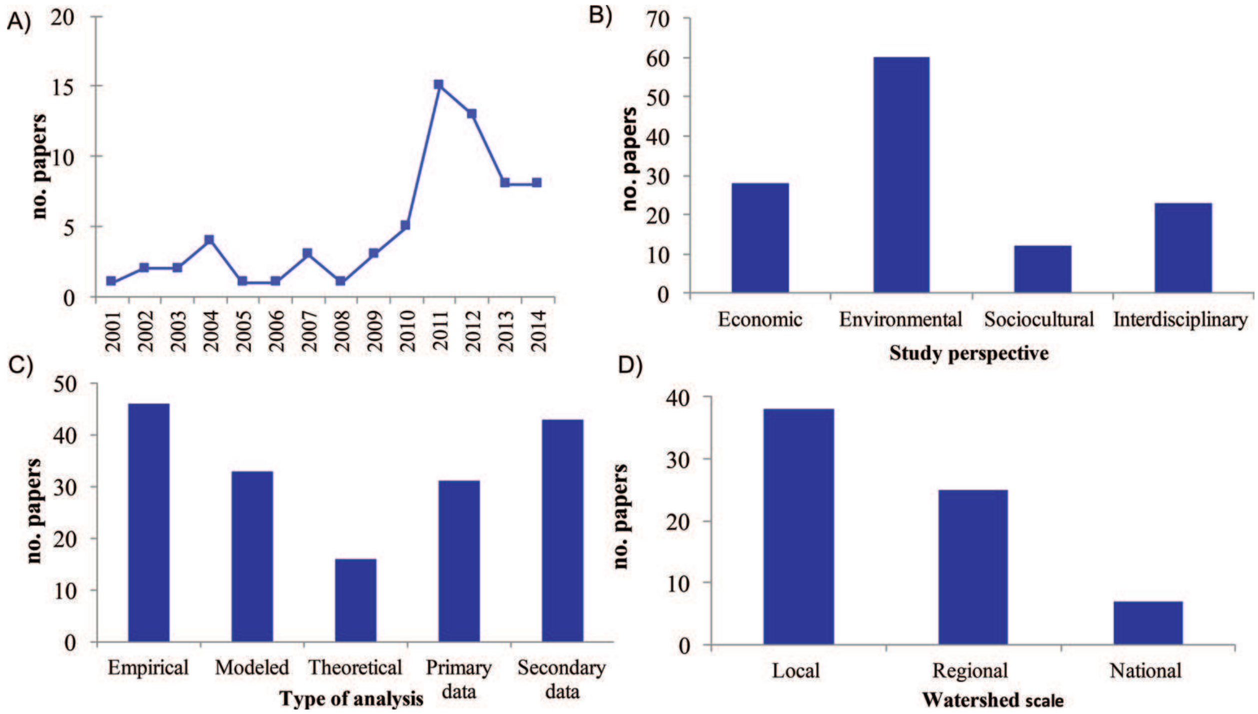

Figure 3. (A) Number of publications 2001–2014 that quantified ecosystem services across U.S. watersheds; (B) number of publications by authors' discipline(s); (C) number of articles by type of analysis, and (D) number of articles by spatial scale.

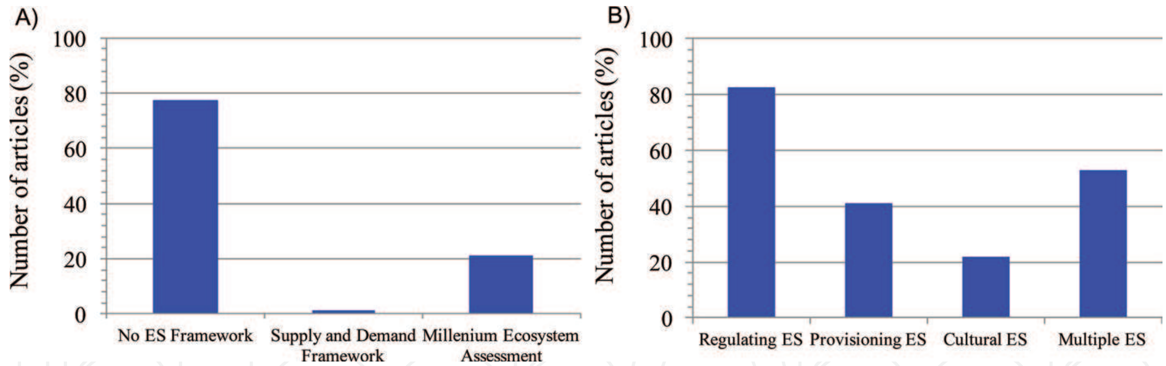

Figure 4. (A) Number of articles using different ecosystem services frameworks; (B) percentage of articles based on ecosystem service categories. Each article can be represented in multiple categories.

habitat maintenance, and chemical conditions of freshwaters were the services most studied, while disease control, pest control, and storm protection were the least studied (**Figure 5**). There were no studies that addressed pollination or seed dispersal. Regarding provisioning services, filtration and sequestration by biota, water for non-drinking purposes, and raw material were the most studied while groundwater for drinking purposes and physical and experimental use of plants and animals were the least studied. Genetic pools and raw medicines were not studied. Finally, in terms of cultural services, we found that recreation, existence value, and esthetic values were the most studied while educational and cultural heritage were the least studied (**Figure 5**).

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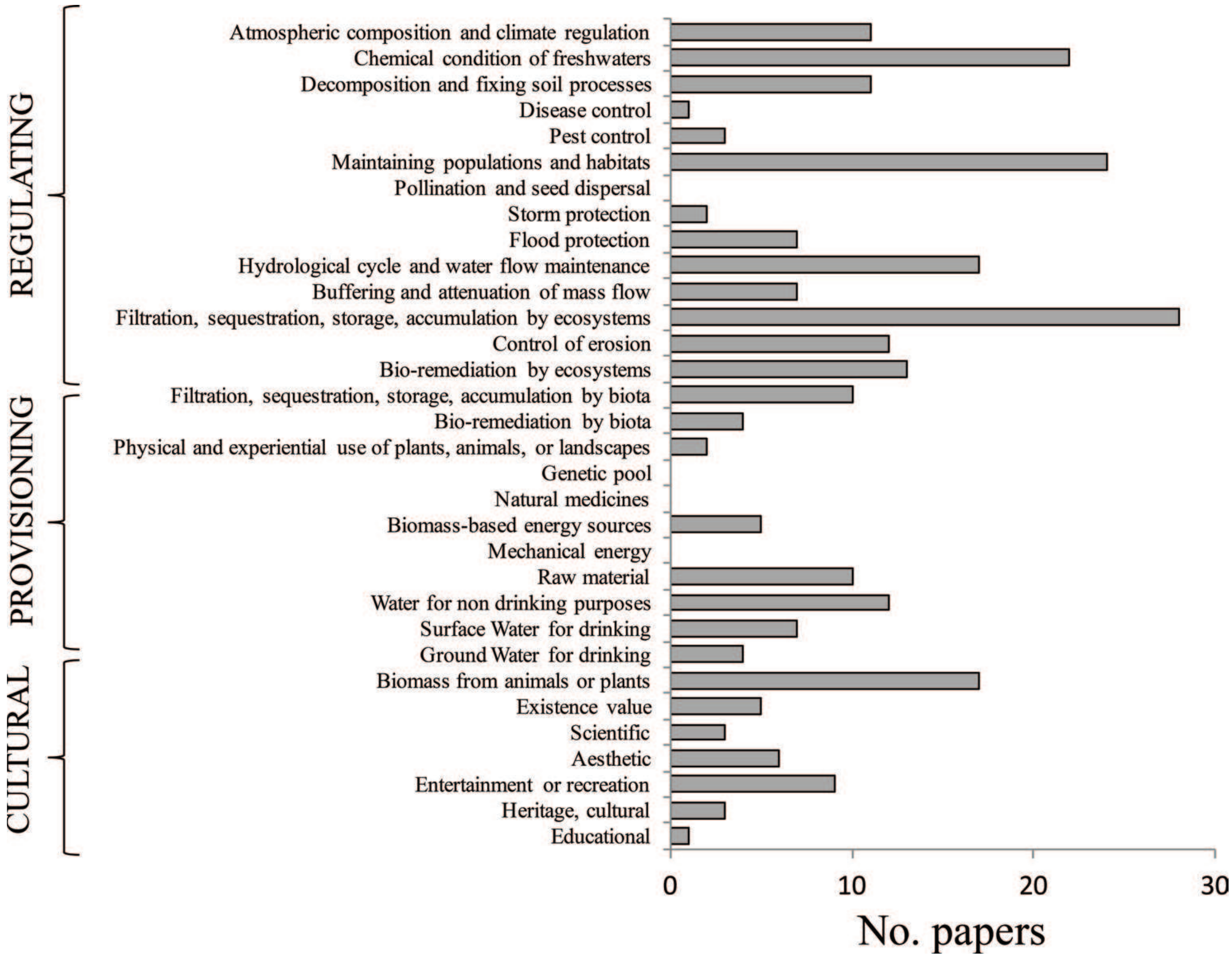

Figure 5. Number of articles assessing ecosystem services based on the Common International Classification of Ecosystem Services (CICES).

3.3. Ecosystem services across US watersheds

The 68 studies evaluated in our dataset covered 18 of the 21 HUC-2 US watersheds (**Figure 6**). The assessments predominantly focused on ecosystem services delivered by watersheds located in the eastern half of the USA, with the three most studied watersheds being the South Atlantic-Gulf (HUC 03, N = 15, the Mid-Atlantic (HUC 02, N = 8), and the Upper Mississippi (HUC 07, N = 17)). By contrast, the US watersheds with no studies were located in northern and western regions, respectively, the Souris-Red-Rainy (HUC 09, N = 0) and the Upper Colorado (HUC 14, N = 5) (**Figure 6**). Watershed regions including the Pacific Northwest (HUC 17), the Missouri (HUC 10), the Arkansas-White-Red (HUC 11), the Texas-Gulf HUC 12), and the Lower Mississippi (HUC 08) were well represented with 10–12 articles per watershed (**Figure 6**).

We found differences across US watersheds in relation to the number of studies implementing the assessment of the supply and demand side of ecosystem services (**Figure 7**). Results show that 47 articles performed studies of the supply of ecosystem services and 19 articles implemented assessment of the social demand of ecosystem services. From the supply perspective,

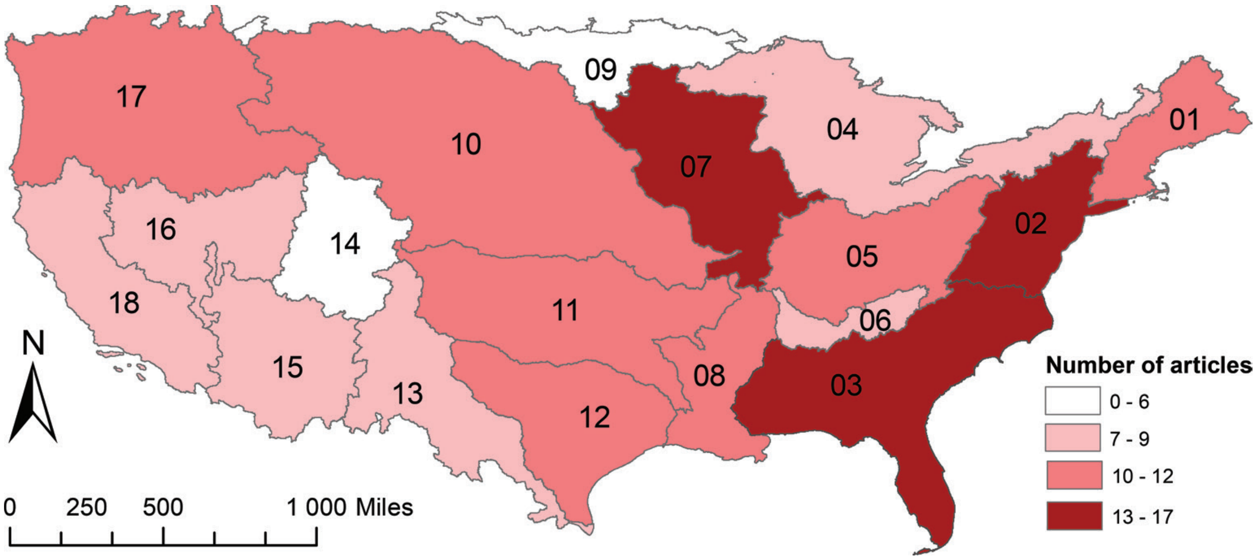

Figure 6. Number of articles evaluating ecosystem services across major U.S. watersheds. Only 18 of the 21 HUC-2 U.S. watersheds showed results. Legend: New England (HUC 01), Mid-Atlantic (HUC 2), South Atlantic-Gulf (HUC 3), Great Lakes (HUC 4), Ohio (HUC 5), Tennessee (HUC 6), Upper Mississippi (HUC 7), Lower Mississippi (HUC 8), Souris-Red-Rainy (HUC 9), Missouri (HUC 10), Arkansas-White-Red (HUC 11), Texas-Gulf (HUC 12), Rio Grande (HUC 13), Upper Colorado (HUC 14), Lower Colorado (HUC 15), Great Basin (HUC 16), Pacific Northwest (HUC 17), California (HUC 18).

using either modeling techniques or proxies, a total of 137 ecosystem services were assessed: 60 regulating, 42 provisioning, and 35 cultural services. From the social demand perspective, using either sociocultural or economic valuation techniques, a total of 60 ecosystem services were assessed: 26 regulating, 16 provisioning, and 22 cultural ecosystem services.

The major US watersheds with the greatest number of studies implementing biophysical assessment of the ecosystem services supply were located in southeastern and midwestern regions (**Figure 7A**). Overall, all watershed regions included supply assessment of the three classes of services, that is, regulating, provision, and cultural, with the exception of the Ohio and Tennessee regions that only included provisioning and regulating services. The watershed regions that were most studied from the supply perspective included the Upper Mississippi (HUC 07), the Missouri (HUC 10), and the South Atlantic-Gulf (HUC 03). The Souris-Red-Rainy (HUC 09) and the Upper Colorado (HUC 14) were the regions that were least studied using the supply dimension.

Studies that assessed the social demand of ecosystem services (i.e., implementing sociocultural or economic valuation) were concentrated in the eastern half of the country (**Figure 7B**). Overall, all watershed regions included assessment of the three classes of services, that is, regulating, provision, and cultural, with the exception of the Texas-Gulf region that only included cultural services. The most-studied major watersheds from the social demand perspective included the Upper Mississippi (HUC 07), the South-Atlantic (HUC 03), and the Mid-Atlantic (HUC 02). The remaining watersheds, with the exception of the Pacific Northwest (HUC 17), the Great Lakes (HUC 04), and the Lower Mississippi (HUC 08), had less than six studies on the social demand of ecosystem services.

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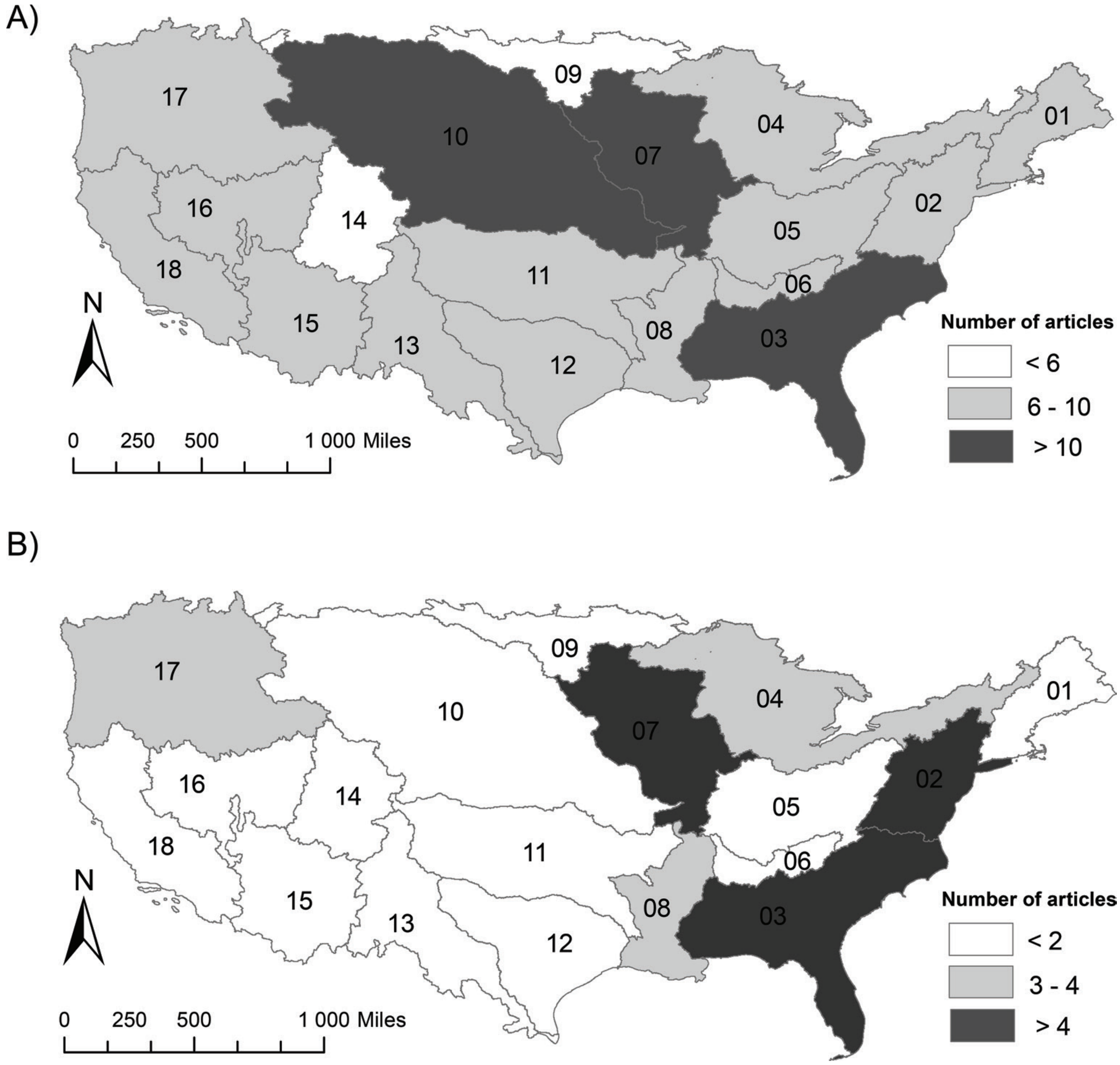

Figure 7. Number of studies evaluating the biophysical supply (A) and social demand (B) of ecosystem services across major U.S. watersheds. Only 18 of the 21 HUC-2 U.S. watersheds showed results. Legend: New England (HUC 01), Mid-Atlantic (HUC 2), South Atlantic-Gulf (HUC 3), Great Lakes (HUC 4), Ohio (HUC 5), Tennessee (HUC 6), Upper Mississippi (HUC 7), Lower Mississippi (HUC 8), Souris-Red-Rainy (HUC 9), Missouri (HUC 10), Arkansas-White-Red (HUC 11), Texas-Gulf (HUC 12), Rio Grande (HUC 13), Upper Colorado (HUC 14), Lower Colorado (HUC 15), Great Basin (HUC 16), Pacific Northwest (HUC 17), California (HUC 18).

4. Discussion

Water resources management and planning in the USA face the challenge of not only ensuring the needs for humans but also preserving ecosystem health, which has a direct connection to human well-being through ecosystem services [4, 6]. This meta-analysis provides a comprehensive inventory of watershed-scale ecosystem services knowledge across major US watersheds. More specifically, our analysis summarizes the scientific literature since 2000 within the context of the number of studies investigating the biophysical supply and social demand for ecosystem services. We found a temporal trend in the number of publications similar to that found from international studies following the global development trend in this research area [3, 22]. Our results emphasize the urgent need to implement interdisciplinary frameworks that take into account the interdependent social, economic, and biophysical dynamics of shared water resources and the need for using integrative approaches to capture different value domains [18, 23].

Overall, our results showed that the number of studies investigating regulating and provisioning services was higher relative to those investigating cultural services. This finding is consistent with similar studies across the globe, where research on the supply and demand of ecosystem services has focused mainly on provisioning and regulating services [24, 25]. In the Mediterranean region, for example, [21] showed that provisioning services attracted much more scientific attention, which is also consistent with most of the findings related to the assessment of ecosystem services in European landscapes [13, 23]. Furthermore, using the CICES classification, we found that from a total of 308 ecosystem services studied across all US watersheds, regulating services (e.g., filtration, sequestration, storage and accumulation by ecosystems, habitat maintenance, and chemical conditions of freshwaters) were most commonly studied, while cultural services (e.g., educational and cultural heritage) were the least studied. As recently highlighted by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), there is an urgent need for global efforts by governments, academia, and society to promote knowledge of earth's biodiversity and ecosystems, with the aim of informing sustainable policy and management of natural resources [26, 27]. One of the key components of the IPBES approach is the notion of nature's contributions to people, which recognizes the critical role that culture plays in defining all links between humans and ecosystems. We therefore argue that there is also a need to recognize the important role that cultural services and values can play in water resources management in the USA and the need to operationalize the role of indigenous and local knowledge in understanding watershed's contribution to people [26, 28].

Different disciplines have traditionally assessed ecosystem services separately [18, 24], which has led to the conclusion that ecosystem services values are multidimensional, and thus their evaluation must be conducted from the ecological, social, and economic perspective [23, 28, 29]. Although we found a small percentage of studies that used this multidisciplinary approach in their assessments, our results showed that most of the studies conducted across US watersheds implemented a biophysical approach, which points out the gap of integrating different approaches into ecosystem service research [30, 31]. We believe that this gap is due to the absence of a shared theoretical framework, as we found that over 78% of all studies in the USA did not use a standard ecosystem services framework. In a recent article, [32] concluded that integrated valuation of ecosystem service supply and demand still faces challenges in understanding the tradeoffs among ecosystem services. With regard to ecosystem service demand, it is necessary to use systematic methods for different stakeholders (beneficiaries, impairers, and managers) because of their different knowledge types, capabilities, demographics, rights, and value systems [32, 33]. We also identified methodological limitations in current ecosystem services research conducted across major US watersheds. Most of the studies were focused on a single ecosystem service without investigating the potential implications that trade-offs between multiple ecosystem services may have in watershed management [3, 4]. Many recent investigations have showed that investigations on single ecosystem services may result in producing a knowledge gap that can only be solved by integrative and holistic approaches for the assessment of multiple ecosystem services [22, 34, 35]. Understanding the different tradeoffs among ecosystem services should include assessments of both the supply and societal demand of ecosystem services [15–17]. Thus, we need to integrate multiple indicators, data sources, and methods in order to assess the suite of ecosystem services from supply to social demand across different spatial and temporal and stakeholder scales [32, 33].

5. Conclusions

Overall, we found that the use of the supply and demand framework of ecosystem services for watershed-scale studies in the USA has been extremely limited. The majority of the watershed case studies were found in the eastern half of US, with very few in the Southwest. Studies implementing biophysical assessment of the ecosystem services supply were located in the Southeast and Midwest, while studies investigating the social demand of ecosystem services were concentrated along the east coast of the USA. In addition to identifying the gaps in our knowledge of watershed-scale ecosystem services across the USA, we call attention to the scale issue in ecosystem services research, which describes the mismatch between the scale at which ecosystem services are provided and the scale at which those services are used, valued, or managed [16]. Future studies should not only address multiple spatial and temporal scales; they should also assess different stakeholder scales, from the individual to the community to the municipality to the state, and beyond.

Understanding and quantifying tradeoffs between ecosystem services, considering their ecological, cultural, and economic value, is a key challenge for water resources management and planning in the USA [36] and beyond [37]. Our study demonstrates the knowledge gap across US watersheds in terms of integrating biophysical, sociocultural, and economic dimensions to assess the biophysical supply and social demand for services, which is key for increasing public awareness of the importance of river systems in maintaining human well-being [3, 38]. Moving forward, we would like to see more comprehensive ecosystem service studies at watershed scales using integrative (yet standard) approaches to assess tradeoffs at multiple spatiotemporal and stakeholder scales.

Acknowledgements

This research was primarily funded by the Oklahoma Biological Survey and the South-Central Climate Science Center (SC-SCC) at the University of Oklahoma (US). AJC and CQS were supported by the NSF Idaho EPSCoR Program and by the National Science Foundation under award number IIA-1301792. JPJ was supported by Texas State University's Research Enhancement Program.

Appendix 1. Keywords used in the review based on the goal of the study, location and the level of assessment. Searcher = Web of Science

Category	Keywords
Localization	"US" or "USA" or "Unites States" or "United states of America"
Level of assessment	"Watershed" or "basin "or "catchment"
Goal: ecosystem services	"ecosystem serv*" or "environmental servic*" or "ecological services"

Appendix 2. Description of the variables collected in the analysis matrix for further analysis

Variables	Type	Description
Related with the type of article		
Number of authors	Ordinal	Number of authors in the paper
First author occupation (e.g., academia vs. government vs. private)	Qualitative	Academia versus government versus private
Field of expertise of the first author		
Economics	Binary	1 = If it belongs to economics; 0 = If it does not belong to econom*ics*
Natural sciences	Binary	1 = If it belongs to *Natural sciences*; 0 = If it does not belong to *Natural sciences*
Sociocultural sciences	Binary	1 = If it belongs to *Sociocultural*; 0 = If it does not belong to *Sociocultural field*
Interdisciplinary group	Binary	1 = If it belongs to an interdisciplinary group; 0 = If it does not belong to an interdisciplinary group
Social-ecological system (SES) framework	Binary	1 = If it uses the SES framework; 0 = If it does use the SES framework
Year of the publication	Continuous	Year of publication
Journal	Qualitative	Name of the Journal
Field of expertise	Qualitative	Area(s) where the paper is classified

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Variables	Type	Description
Approach of the study		
Type of study (case-study vs. comparative study vs. meta-analysis vs. review vs. conceptual vs. commentary)	Qualitative	Description of the study: case-study versus comparative study versus meta-analysis versus review versus conceptual versus commentary
Analytic or empirical	Binary	1 = If it is an *analytic or empirical* study; 0 = If it is not an *analytic or empirical* study
Modeled	Binary	1 = If it is a modeled study; 0 = If it is not a modeled study
Theoretical	Binary	1 = If it is an *Theoretical* study; 0 = If it is not a *Theoretical*
Source of data		
Primary	Binary	1 = If the study used primary data, 0 = any study using primary data
Secondary	Binary	1 = If the study used secondary data, 0 = any study used secondary data
Length of study period		
Punctual	Binary	1 = If the study period is considered *Punctual*; 0 = If the study period is not considered *Punctual*
Time series	Binary	1 = If the study period considers a *time series* 0 = If the study period does not consider a *time series*
Related with the study area		
Watershed	Qualitative	Name of the watershed
Geographical coordinate	Continuous	Description of geographical coordinates
Major US watershed	Qualitative	Name of the US watershed (see map)
Major LCC Landscape Conservation cooperative	Qualitative	Name of major LCC (see map)
River	Qualitative	Name of the river
WATERSHED OR BASIN SCALE		
Local	Binary	1 = If the study is defined as local scale, 0 = If the study is not considered local scale.
Regional	Binary	1 = If the study is defined as regional scale, 0 = If the study is not considered regional scale.
National	Binary	1 = If the study is defined as *national* scale, 0 = If the study is not considered as national scale.
State	Binary	Name of the state
Watershed surface occupied (entire or part of the watershed)	Qualitative	Description of the watershed (entire vs. part of)
Surface of the study area	Continuous	Description of surface occupied
MAJOR BIOMES (see map)		
Desert and dry shrubs	Binary	1 = If the study focuses on desert and dry shrubs, 0 = If the study does not focus on desert and dry shrubs

Variables	Type	Description
Flooded grassland	Binary	1 = If the study focuses on flooded grassland, 0 = If the study does not focus on flooded grassland
Mediterranean Shrubs	Binary	1 = If the study focuses on Mediterranean Shrubs, 0 = If the study does not focus on Mediterranean Shrubs
Temperate Broadleaf forest	Binary	1 = If the study focuses on *Temperate Broadleaf forest*, 0 = If the study does not focus on Temperate Broadleaf forest
Temperate coniferous forest	Binary	1 = If the study focuses on Temperate coniferous forest, 0 = If the study does not focus on Temperate coniferous forest
Temperate grassland	Binary	1 = If the study focuses on Temperate grassland, 0 = If the study does not focus on Temperate grassland
Tropical Coniferous forest	Binary	1 = If the study focuses on Tropical Coniferous forest, 0 = If the study does not focus on Tropical Coniferous forest
Level of protection		
Protected	Binary	1 = If the study area is protected, 0 = If the study is not protected
Federal level of protection	Binary	1 = If there is a federal protection, 0 = If there is not a federal protection
Sate level of protection	Binary	1 = If there is a state protection, 0 = If there is not a state protection
Local level of protection	Binary	1 = If there is a local protection, 0 = If there is not a local protection
Related with valuation methods		
Mapping values (both biophysical, social, or economic)	Binary	1 = If it maps values; 0 = If it does not map values
Valuation arguments	Qualitative	Arguments of the authors to perform the assessment.
Dimension of assessment		
Biophysical technique	Binary	1 = If the study uses a biophysical technique, 0 = If the study does not use a biophysical technique
Biophysical indicator	Binary	1 = If the study uses a biophysical indicator, 0 = If the study does not make a biophysical indicator
Sociocultural technique	Binary	1 = If the study uses a sociocultural technique, 0 = If the study does not uses a sociocultural technique
Sociocultural indicator	Binary	1 = If the study uses a sociocultural indicator, 0 = If the study does not uses a sociocultural indicator
Monetary or economic technique	Binary	1 = If the study uses a economic technique, 0 = If the study does not uses a economic technique
Monetary or economic indicator	Binary	1 = If the study uses a economic indicator, 0 = If the study does not uses a economic indicator
Methods used		

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Variables	Type	Description
Market valuation	Binary	1 = If the study uses market techniques; 0 = If the study does not use market techniques.
Revealed preferences	Binary	1 = If the study uses revealed preference techniques, 0 = any study uses revealed preference techniques.
Stated preferences	Binary	1 = If the study uses stated preference techniques, 0 = any study using stated preference techniques.
Biophysical quantification	Binary	1 = If the study uses a biophysical model to quantify the delivery, 0 = If the study does not use a biophysical model to quantify the delivery
Ecosystem services (CICES ES-classes)		
ES classification used (MEA, TEEB, IPBES, CICES)	Qualitative	Name of the classification used in the paper
Number of ES	Continuous	Number of ecosystem services valued by the study.
PROVISIONING		
Biomass from animals or plants	Binary	1 = If the study values food, 0 = If the study does not value food
Ground Water for drinking	Binary	1 = If the study values *Ground Water*, 0 = If the study does not value *Ground Water*
Surface Water for drinking	Binary	1 = If the study values *Surface Water*, 0 = If the study does not value *Surface Water*
Water for non drinking purposes	Binary	1 = If the study values *Water for non drinking purposes*, 0 = If the study does not value *Water for non drinking purposes*
Raw material	Binary	1 = If the study values *Raw material*, 0 = If the study does not value *Raw material*
Mechanical energy	Binary	1 = If the study values *Mechanical energy*, 0 = If the study does not value *Mechanical energy*
Biomass-based energy sources	Binary	1 = If the study values *Biomass based energy sources*, 0 = If the study does not value *Biomass based energy sources*
Natural medicines	Binary	1 = If the study values *Natural medicines*, 0 = If the study does not value *Natural medicines*
Genetic pool	Binary	1 = If the study values *Genetic pool*, 0 = If the study does not value *Genetic pool*
Regulating		
Bio-remediation by biota	Binary	1 = If the study values *Bio-remediation by biota*, 0 = If the study does not value *Bio-remediation by biota*
Filtration, sequestration, storage, accumulation by biota	Binary	1 = If the study values *Filtration, sequestration, storage, accumulation by biota*, 0 = If the study does not value *Filtration, sequestration, storage, accumulation by biota*
Bio-remediation by ecosystems	Binary	1 = If the study values *Bio-remediation by ecosystems*, 0 = If the study does not value *Bio-remediation by ecosystems*
Filtration, sequestration, storage, accumulation by ecosystems	Binary	1 = If the study values *Filtration, sequestration, storage, accumulation by ecosystems*, 0 = If the study does not value *Filtration, sequestration, storage, accumulation by ecosystems*

Variables	Type	Description
Control of erosion	Binary	1 = If the study values *Control of erosion*, 0 = If the study does not value *Control of erosion*
Buffering and attenuation of mass flow	Binary	1 = If the study values *Buffering and attenuation of mass flow*, 0 = If the study does not *Buffering and attenuation of mass flow*
Hydrological cycle and water flow maintenance	Binary	1 = If the study values *Hydrological cycle*, 0 = If the study does not value *Hydrological cycle*
Flood protection	Binary	1 = If the study values *Flood protection* , 0 = If the study does not value *Flood protection*
Storm protection	Binary	1 = If the study values *Storm protection*, 0 = If the study does not value *Storm protection*
Pollination and seed dispersal	Binary	1 = If the study values *Pollination*, 0 = If the study does not value *Pollination*
Maintaining populations and habitats	Binary	1 = If the study values *Habitat for species*, 0 = If the study does not value *Habitat for species*
Pest control	Binary	1 = If the study values *Pest control*, 0 = If the study does not value *Pest control*
Disease control	Binary	1 = If the study values *Disease control*, 0 = If the study does not value *Disease control*
Decomposition and fixing soil processes	Binary	1 = If the study values *soil processes*, 0 = If the study does not value *soil processes*
Chemical condition of freshwaters	Binary	1 = If the study values *Chemical condition of freshwaters*, 0 = If the study does not value *Chemical condition of freshwaters*
Atmospheric composition and climate regulation	Binary	1 = If the study values *climate regulation*, 0 = If the study does not value *climate regulation*
Cultural		
Physical and experiential use of plants, animals, or landscapes	Binary	1 = If the study values *experiential use*, 0 = If the study does not value *experiential use*
Educational		1 = If the study values *Educational*, 0 = If the study does not value *Educational*
Heritage, cultural		1 = If the study values *Heritage, cultural*, 0 = If the study does not value *Heritage, cultural*
Entertainment or recreation		1 = If the study values *Recreation*, 0 = If the study does not value *Recreation*
Esthetic		1 = If the study values *Esthetic*, 0 = If the study does not value *Esthetic*
Scientific	Binary	1 = If the study values *Scientific*, 0 = If the study does not value *Scientific*
Existence value	Binary	1 = If the study values *Existence value*, 0 = If the study does not value *Existence value*
Bequest value	Binary	1 = If the study values *Bequest value*, 0 = If the study does not value *Bequest value*

Variables	Type	Description
Several categories of services	Binary	1 = uses several categories of ecosystem services, 0 = use a single category of services ecosystem services
Type of biophysical quantification		
Mapping delivery	Binary	1 = If the study map the delivery, 0 = If the study does not map the delivery
Use of proxy to quantify ES	Binary	1 = If the study uses a proxy, 0 = If the study does not use a proxy
Biophysical units used	Qualitative	Description of the unit used
Biophysical model used	Qualitative	Name of the model
Trade-0ffs analysis	Binary	1 = If the study estimates Trade-offs analysis, 0 = If the study does not estimate Trade-offs analysis
Multiple ecosystem services	Binary	1 = If the study estimates multiples services, 0 = If the study does not estimate multiples services
Types of value		
Use value		
Direct	Binary	1 = If the study assesses direct use value 0 = If the study does not direct use value.
Indirect	Binary	1 = If the study assesses indirect use value 0 = If the study does not indirect use value.
Option value	Binary	1 = If the study assesses *Option value* 0 = If the study does not value *Option value*
Non-use value		
Existence value	Binary	1 = If the study assesses *Existence value* 0 = If the study does not *Existence value*
Bequest value	Binary	1 = If the study assesses *Bequest value* 0 = If the study does not *Bequest value*
Types of stakeholder group		
Beneficiaries involved	Binary	1 = If the study involves beneficiaries; 0 = If the study does not involve the beneficiaries.
Locals	Binary	1 = If the study involves locals; 0 = If the study does not involve locals
Professionals or experts	Binary	1 = If the study involves professionals; 0 = If the study does not involve professionals
Tourists	Binary	1 = If the study involves tourist; 0 = If the study does not involve tourists
Mixed	Binary	1 = If the study involves mixed stakeholders; 0 = If the study does not involve mixed stakeholders
Impact on beneficiaries	Binary	1 = If the study involves impact on beneficiaries; 0 = If the study involves no impact on beneficiaries.
Type of beneficiaries	Qualitative	Description the types of beneficiaries

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