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REVIEW ARTICLE

Systematic review of wetland ecosystem services valuation in India: assessing economic approaches, knowledge gaps, and management implications

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Abstract
India boasts a wealth of wetland ecosystems that support diverse and unique habitats and provide numerous ecological goods and services but are under tremendous stress. To ensure the sustainability of these ecosystems and the provision of various ecosystem services (ES), a systematic understanding of wetland ecosystem services (WES) and their economic value is highly important for guiding WES research and management. This systematic review provides an in-depth assessment of existing knowledge on WES and summarize key interdisciplinary approaches for measuring and valuing them. The review deals with the economic valuation approaches adopted in India for the WES and addresses the pressing need for reliable economic valuation methods that quantify trade-offs across various spatial–temporal scales and can assess the efficiency of alternative wetland management scenarios. By meticulously examining the available scientific literature related to WES and analyzing a diverse range of research papers that explicitly quantify these services, this paper seeks to identify gaps, advancements, management approaches, and future requirements in the field of WES valuation in India. It emphasizes the need for a pluralistic approach that includes a wider range of social perspectives and valuation techniques to better understand the relationship between ecosystem functioning and human well-being. After describing the specificity of knowledge gaps, we conclude with lessons for future research on wetland valuation in India.

Keywords Wetland ecosystem services · Valuation techniques · Trade-offs · Management

Introduction

Wetlands hold significant importance in the natural environment as one of the most productive, diverse, and ecologically sensitive ecosystems on Earth (Xu et al. 2020), with significant value owing to their biological, ecological, social, cultural, and economic roles (Janse et al. 2019). They provide numerous socio-economic and ecosystem services (Ramsar Convention on Wetlands 2018) including water purification (Hammer and Bastian 2020), wildlife habitat, maintenance and conservation of biodiversity (Mitsch and Gosselink 2007; Whitehouse et al. 2008), fisheries and recreation (Keddy 2010; Junk et al., 2011), water supply (Lemly 1994), flood control (Penatti et al. 2015), carbon sequestration (Mitsch et al. 2013), nutrient removal (Fisher and Acreman 2004), and environmental restoration (Fink and Mitsch 2007). Wetlands serve as a means of livelihood for rural populations (Lamsal et al. 2015) particularly in developing countries and are highly valued by many cultures (Ghermandi et al. 2010). Owing to the high potential of wetlands for agricultural productivity, fisheries, and water supply, many of the wetlands of world have been historically relied upon by human civilizations. Wetlands also offer secondary human land use services such as recreation, tourism, and education, which are important for community well-being and livelihoods (Guo et al. 2017). In spite of the ecosystem functions and sustenance of human livelihoods, wetlands across the world are mismanaged and tend to be polluted, degraded at an unprecedented pace by diversion to alternate uses like agriculture, and residential housing development.

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Due to lack of understanding of the importance of wetlands in ecological and social health, 64 percent of the world's wetlands have been lost since 1900 (Davidson 2014). After analyzing 189 wetland changes studies, Davidson (2014) concluded that the global wetland long-term depletion rate is around 54–55%. Thus, support for wetland conservation and sustainable management is an top global priority in order to meet three high-priority 2030 Agenda targets of the Global Sustainable Development Goals: 6.3 "Improve water quality," 2.4 "Sustainable food production," and 12.2 "Sustainable resource management" (Jaramillo et al. 2019).

Wetland ecosystems currently cover the vast global area, roughly 7–10 million km^2 comprising 5–8 percent of the total land area (William and James 2015). The global monetary values of WES are worth Int$47.4 trillion a year, accounting for 43.5 percent of the total amount of all natural biomes (Davidson et al. 2019). Therefore, distilling current knowledge and synthesizing existing information in this field is extremely important. India, with its various topographies and climatological regimes, has all the wetland types delimited by the Ramsar convention definition (2006) in different geographical regions extending from Himalayas to Deccan plateau (Prasad et al. 2002) ranging from high altitude cold desert wetlands of Himalayas to hot wetlands of coastal zones. Wetlands in India are estimated to cover 4.7% of the country's total land area (SAC, 2011), and 75 wetlands have been designated as Ramsar sites (wetlands of international importance). However, given their use, wetlands have become, and continue to be, India's most vulnerable habitats due to large-scale land reclamation operations, agricultural practices, excess nitrogen runoff, water and soil loss, siltation, and over-exploitation of biological resources and unwise use of water resources (Central Pollution Control Board (CPCB) 2008). Recognizing the significance of wetlands, the government of India recently emphasized on developing strategies for conservation and wise use of wetlands (Wetlands, Conservation and Management Rules 2017) and has passed and implemented multiple acts and policies that emphasize the need to create a regulatory framework for all wetlands in order to preserve their ecological character and eventually support their integrated management. However, the legitimacy of wetland decisions depends on how science and values are combined and reflected in wetland management decisions. ES valuation, a method of estimating ecosystem benefits to people that helps us to carry out a cost–benefit activity in favor of environmental investment, is one approach to integrate them. The monetary valuation of ecosystem services offers a promising approach to highlight the relevance of ecosystem services to society and the economy, to serve as an element in the development of cost-effective policy instruments for nature restoration and management, and to use in impact assessments in cost–benefit analysis. In addition, valuation of ES has a wide range of potential applications at multiple spatial and temporal scales, including accounting for natural capital (Capriolo et al. 2020), evaluating specific policies (Peng et al. 2019), planning for land use (Bateman et al., 2013), raising public awareness (Costanza et al. 1997a, b), and developing ES payment schemes. One main goal of ecosystem service valuation is to offer a thorough evaluation of the return on investment in conservation, mitigation, and/or restoration initiatives. Valuation attempts have also been utilized to identify the external costs of activities that harm wetlands. Traditional benefit–cost analysis approaches do not account for external expenses. Recent collaborations between ecologists and economists have yielded a plethora of methods for analyzing wetland ecological and economic interactions and assessing their economic value. Scientists have created many ecosystem services frameworks (Nahlik et al. 2012) and valuation methodologies (de Groot et al. 2002; United States Environmental Protection Agency (US EPA) 2009; TEEB 2010) over the last two decades, resulting in a surge in ecosystem services research and resulting in a surge in ecosystem services studies. However, methods to quantify and valuate ecosystem services always pose a great challenge to devise effective tools for integrating ecosystem service and their trade-offs into management.

In this article, we focus on India to present an analysis of wetland wealth in terms of the benefits they provide, as well as the primary multidisciplinary approaches to quantify and evaluate them, which might serve as the foundation for important wetland management initiatives. This paper is structured in three parts. First, we thoroughly review WES, the basis for their valuation, and the methods that are used to place an economic value on wetlands. In order to uncover methodological gaps, the second step involves evaluating a variety of domestic case studies on the valuation of WES. Finally, we discuss methodological flaws and provide recommendations to advance future WES research in India.

Wetland ecosystem services

"Ecosystem services" (ES) are the ecological characteristics, functions, or processes that directly or indirectly contribute to human wellbeing (Costanza et al. 1997a, b; Millennium Ecosystem Assessment 2005). The study of ecosystem services is a multidisciplinary endeavor that necessitates understanding both the ecological provisions of services and the socioeconomic benefits derived from them. In the last few decades, economists and natural scientists have devised a plethora of classification schemes for ecosystem services (Costanza et al. 1997a, b; Daily et al., 1997; Millennium Ecosystem Assessment 2005), the most popular of which is the Millennium Ecosystem Assessment (MA). The Millennium Ecosystem Assessment classified ecosystem benefits into four broad categories: provisioning services, regulating services, supporting services, and cultural services (Fig. 1 and Table 1).

When assigning an economic value to ecosystem services, it is crucial to specify the goods or services being evaluated. Ecosystem economic value encompasses both use and non-use values (Pearce and Warford 1993). Use values involve human "interaction" with the resource and can be either direct (e.g., water supply, food, and recreation) or indirect (e.g., nutrient retention, groundwater recharge, storm protection, and flood control) (Ramachandra et al. 2005). Non-use values pose greater challenges for quantification as they rely on subjective assessments that are not directly linked to present or future utilization. In order to capture all the ecosystem services values, which includes both use and non-use values, economists have devised a comprehensive framework known as "total economic value" (TEV). This framework, introduced by Turner and Pearce in 1990, enables the distinction and categorization of these diverse values within the context of ecosystem assessments. Total economic value (TEV) is an all-inclusive framework that has become one of the most popular and widely recognized approaches for identifying and organizing various values associated with ecosystems and incorporating them into decision-making (Barbier et al. 1997). It was created to address the undervaluation of ecosystems' "priceless" assets in traditional analysis, as they escape typical evaluation techniques and are taken for granted (Krätli 2015). Non-use values, on the other hand, are more challenging to quantify because they entail people's subjective assessments that are unconnected to their own or others' current or future uses. In order to capture all the ecosystem services values (use and non-use values), economists have established a framework for "total economic value" for distinguishing and grouping these values (Turner and Pearce 1990).

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TEV actually equates values with the environmental benefits provided by an ecosystem. Due to this advantage over the classical economical analysis, Barbier et al. (1997) pointed out that it is a most widely used framework in decision making process. TEV can also provide decision-makers with vital information on the costs and benefits of alternative wetland use options that would otherwise not be taken into account in development decisions. It is also important to advise policy-making as it helps in determining the trade-offs between social goods and environmental quality (NRC, 2005).

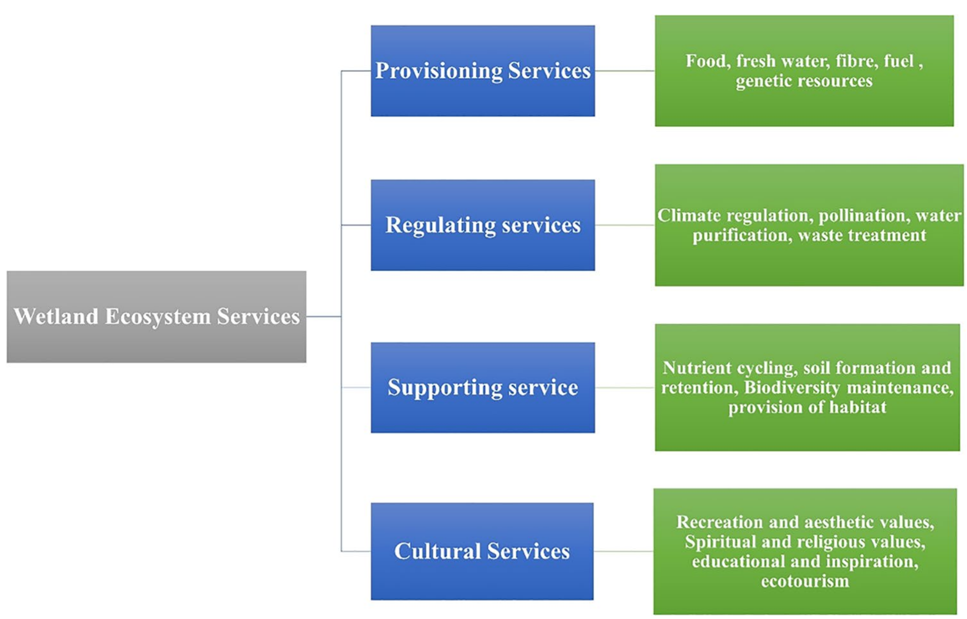

Fig. 1 Categorization of wetland ecosystem services

Table 1 Ecosystem services provided by or derived from wetlands

ES class	Services	Comments and examples
Cultural	Aesthetic value	Many people find beauty or aesthetic value in aspects of wetland ecosystems
	Recreation and ecotourism	Landscape features and wildlife that provide opportunities for tourism and recreational activities like bird watching and fishing
	Spiritual value	Source of inspiration; many religions attach spiritual and religious values to aspects of wetland ecosystems
	Value for research	Opportunities for formal and informal education and training
Provisioning	Genetic material from all present species	Genes for resistance to plant pathogens, ornamental species, and so on
	Fuel and fibre provisioning	Production of timber, fuel wood, peat, and fodder
	Provisioning of medicines/chemicals	Extraction of medicines and other materials from biota
	Water supply	Storage and retention of water for domestic, industrial, and agricultural use
	Food	Production of fruits, crops, and fish by gathering, harvesting, and fishing
Regulating	Soil quality	Retention of soils and sediments
	Quality of freshwater in the area	Retention, recovery, and removal of excess nutrients and other pollutants
	Air quality regulation	Capturing and mitigating dust and particulate matter like PM2.5
	Climate regulation	Source of and sink for greenhouse gases; influence local and regional temperature, precipitation, and other climatic processes
	Carbon sequestration	Biotic sequestration of CO2 through accumulated plant biomass and storing sedimentary C_{org} for long periods
	Pest control	Control of pest species and pollution
	Natural hazard regulation	Storm protection, flood control, and drought recovery
	Pollination	Habitat for pollinators
	Water regulation (hydrological flows)	Groundwater recharge/discharge
Supporting	Soil formation	Sediment retention and accumulation of organic matter
	Nutrient cycling	Storage, recycling, processing, and acquisition of nutrients
	Biodiversity maintenance	Diversity of biotic species
	Primary production	The assimilation or accumulation of energy and nutrients by vegetation or alga
	Water cycling	Water cycles through the biosphere via key processes, such as evapotranspiration, infiltration, runoff, and precipitation

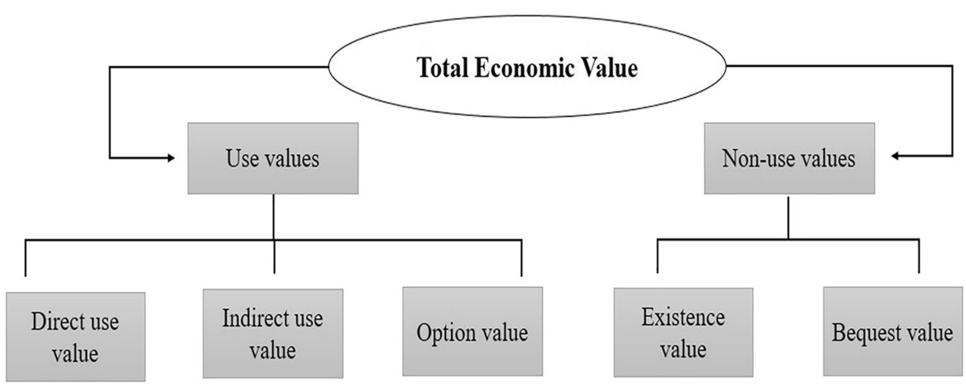

Fig. 2 Components of total economic value (TEV)

The economic values of wetlands

The values assigned to wetlands may be classified into three type: ecological, socio-cultural, and economic (de Groot et al. 2002; NRC (National Research Council) 2005; United States Environmental Protection Agency (US EPA) 2009; TEEB 2010). Ecological values of ecosystem services (ESs) refer to how these services contribute to the overall health and functioning of the ecosystem (de Groot et al. 2010). Economic values, on the other hand, encompass the use and non-use values of ecosystems quantified in monetary terms (Wilson and Carpenter, 1999). Socio-cultural values, on the contrary, pertain to the values assigned by people to the benefits they derive from ecosystems. Both economic and socio-cultural values reflect people's perceptions of the importance of ESs, but they differ in that socio-cultural values are not expressed in monetary terms (De Groot et al. 2010; Oteros-Rozas et al., 2014). Socio-cultural values take into account both tangible and intangible services and consider people's perceptions of these services (Jacobs et al., 2018; Scholte et al., 2015). Monetary valuation of WES becomes more accurate by incorporating trade-offs into cost–benefit calculations, with a focus on comparing the smallest difference in the supply of an ecosystem commodity with market value (e.g., amount of water produced) relative to a competitive land use that is also sold on the market (e.g., real estate).

However, it is essential to acknowledge that monetary valuation alone does not capture the entirety of ecological and socio-cultural values; it represents only a portion of the total value of a wetland (de Groot et al. 2010). A comprehensive assessment of ecosystem services necessitates considering ecological and social factors and their interactions since wetland function emerges from this complex interplay. Presently, two approaches integrate these factors into the evaluation of ecosystem services: the ecological production function and the social-ecological approach (SES). These methodologies provide a more holistic understanding of the diverse values of wetland ecosystems. These methodologies provide a more holistic understanding of the multifaceted value of wetland ecosystems.

Ecological production function and SES approach for ecosystem services measurement and management

The ecological production function is the most widely used tool for measuring the biophysical provision of ecosystem services today (TEEB 2010; Kareiva et al., 2011). It actually combines a set of biophysical variables to model the generation of an ecosystem service. Ecosystem structures and processes are the inputs to ecological production functions, and the outputs are final ecosystem services. Nutrient retention, for example, employs nitrogen and phosphorus processes as inputs to generate a valid metric of water clarity and safe drinking water. This method considers how a change in ecosystem service affects human wellbeing and most often the model has been used to combine functions with land use and land cover (LULC) to generate maps of ecosystem services (Kareiva et al., 2011) which allowed identification of variation in the service delivery between the habitats of the ecosystem, trade-offs, and service scale. Although this method highlights the ecological factors associated with the generation of ecosystem services, it frequently misses the social elements.

The socio-ecological approach widens the idea of ecological production functions by including both the ecological as well as social factors that are involved in ecosystem services production. In the human-dominated environment, it is broadly understood that various social factors are associated with ecosystem service production such as management regimes, skills, and technology (Easdale and Aguiar 2012), still ecosystem service frameworks are lacking it. Most cultural services, especially those with substantial social components (such as holy site customs and management, recreational preferences), have not been adequately represented using ecological production functions (Daniel et al. 2012). Moreover, there are currently a number of technologically improved provisioning services (e.g., development of horticulture has significantly increased the application of technologies such as irrigation and fertilizer). Therefore, if one has to model the production of horticultural crops, it is important to integrate biophysical soil and rainfall conditions, as well as the implementation of technologies such as irrigation and fertilizer, as well as farmers' skills. Socio-ecological approach not only aims to measure the provision of services provided by an area (e.g., agricultural production and water regulation) but also determine how those benefits flow to different beneficiary groups, i.e., the actual benefits gained by people (e.g., drinking water, flood protection, and food) (Syrbe and Walz 2012). This helps decision-makers to understand the importance of wetland changes in terms of their structure and functions, to examine the actual trade-offs, and to prioritize wetland restoration projects.

In spite of these things being proposed, the development of practical definitions and metrics as well as cohesive and all-inclusive policy objectives and targets has failed due to ecosystem service being a complex and broader concept. In addition, a few ecosystem services need the identification of social elements and their interactions with ecological factors in order for them to be subjected to a socio-economic model. The costs and benefits of wetland conservation or degradation to society are also challenging to assess using the biophysical and SES approach (Bockstael et al. 2000). On the other hand, economic valuation can help in assessing the financial trade-offs or synergies among several ecosystem services brought on by social investments like highways, hotels, or industries.

Utilizing various economic methodologies or indicators that may entail quantitative and/or qualitative study, the economic worth of wetlands may be estimated either monetarily or non-monetarily. There are various methods for valuing ecosystems, each of which may employ a different technique. Market-based (which includes market price and productivity methods), revealed preference (which includes avoided cost, travel cost, replacement/substitution cost, and hedonic pricing methods), and stated preference (which includes contingent choice and conjoint analysis methods) are the primary valuation methods. The benefit transfer approach, in addition to primary valuation methodologies, is the most often utilized valuation method. Using more than one approach to demonstrate different scenarios and/or evaluate different ecosystem benefits is typically advantageous.

Benefit transfer

It is a well-known economic valuation model that takes use of pre-existing ecological and social data from an established research site and then transfers it to a policy site in one of three ways: unit value adjusted, function, or meta-analytic value transfer. When there is a lack of system specific information, this type of valuation model is used to generate timely and economically cheaper valuation estimates. Gren (1995), for example, describes a case study of the benefits of nitrogen abatement at wetlands along the Danube River using information from wetlands on the Swedish island of Gotland. However, this model is prone to substantial transfer mistakes if applied poorly. One of its limitations is that it is only workable when sufficient primary valuation studies are available. It should not be used as a substitute for primary assessment but rather as a backup plan if primary valuation is not feasible. Obtaining suitable unit values to transfer from the study site to the policy site is a challenging process.

Primary valuation methods

The primary goal of economic valuation is to help and enhance rational use and management of wetland ecosystems by providing a means for determining people's preferences, including how much they are ready to pay for wetland services and how much better or worse off they will be as a result of changes in supply. By articulating these preferences, valuation tries to create "unpriced" wetland services to be compared with alternative sectors of the economy once investments are evaluated, activities are planned, land and resource use choices are made, or policies are framed (Emerton, 2005). The simplest and most easy approach of valuing a good or service is market-based techniques that measure the "willingness-to-pay" (WTP) by consumers for ecosystem benefits and are commonly used when the ecosystem good or service provided is a product bought and/or sold in commercial markets, such as commercial timber. It is not practical to perform a comparable calculation for non-market-traded wetland ecosystem values that include indirect use values (e.g., flood moderation, climate regulation, and nutrient cycling) and non-use values (Tallis et al. 2011). However, currently, there are nonmarket valuation methods of measuring wetland goods and services that go beyond the use of direct market prices and are classified into two types: revealed preference and stated preference methods (Boxall et al. 1996; Bräuer 2003; Rasul 2009). The revealed preference approach determines the value that people attach to an ecosystem good or service by using information about a marketed commodity to infer the value of a comparable, non-marketed commodity via a surrogate or proxy market. The purchase of water-purification equipment, for example, reveals the minimum that people are ready to spend for good water quality. The most commonly used techniques for evaluating revealed preferences are replacement costs, hedonic prices, and travel cost methods (Table 2). Stated preference methods are survey-based techniques used to establish valuations based on hypothetical questions, wherein respondents are asked to express their preferences and willingness to pay to a specific environmental attribute or changes in ecosystem services (Birol et al. 2006). By collecting this data, researchers and policymakers gain insights into public preferences and values, enabling them to estimate the economic value of the ecosystem services in question.

Current status, approaches, and gaps of wetland valuation in India

Despite its relatively short history, the concept of ecosystem services has garnered significant interest in policy circles and has led to numerous interdisciplinary research projects. Policymakers at the global, regional, and national levels are increasingly recognizing the importance of ecosystem services, integrating them into public policy initiatives. Ecosystem service valuation provides a common language for ecologists, economists, communities, and other stakeholders to communicate values effectively. Moreover, it aids decision-makers in assessing potential scenarios and policy impacts while prioritizing restoration projects. Recognizing the economic value of wetland ecosystems is crucial for developing sustainable conservation plans. However, there are methodological gaps in both ecology and economics that need to be addressed. Over the last two decades, researchers have conducted a wide range of wetland valuation studies across India, covering various wetland sizes, geographic locations, wetland types, spatial scales, and government designation levels (Zhang et al., 2010). Sarkar et al., (2016) found a total of 52 studies related to wetlands, covering various aspects such as ecology, economy, and management. These studies encompassed a wide range of scales, from local to national, and were sourced from different platforms from 2000 to 2014.

This paper presents a comprehensive compilation of nearly all the scientific research on the economic assessment of wetlands in India, adhering to the definition provided by the Ramsar Convention for wetlands (RCS, 2006). To ensure comprehensiveness and encompass a wide range of studies up to the year 2023, we conducted a thorough search using various academic platforms. The search was performed on Google Scholar, Research Gate, academia.edu, shodhganga.inflibnet, Science Direct, and Scholars Archive@OSU. We

Table 2 Methods and their applicability in valuation of WES

Methodology	Approach	Applicability to WES
Replacement cost	Use cost of replacement, restoration, or supplying alternatives for the lost goods and services	Can be applied for calculating the cost of operating man-made water treatment plants (filter and chemical treatment charges) in the absence of healthy functioning wetlands (substitution)
Preventive expenditure or defensive expenditure	Estimate the monetary value for an environmental good or service by examining the expenses individuals expend to avert its loss	Commonly used to estimate the monetary value of buying water filters to ensure safe drinking water owing to water pollution
Travel cost	Estimate the monetary value for travel costs	Estimate the value of recreational benefits to humans provided by an wetland ecosystem by assuming that the time and travel cost expenses that individuals pay to visit a site are the implicit price of a recreation trip
Hedonic pricing	Estimate the impact of environmental attributes on monetary value	Commonly used to estimate the economic benefits or costs credited to associated with wetlands like scenic beauty and clean water in housing or land prices
Contingent valuation method (CVM)	Ask respondents about their "willingness to pay" or "willingness to accept" for a particular ecosystem service	To estimate use and non- use value of different ecosystem services flood moderation services, biodiversity, cultural, aesthetic and religious services, and so on

used specific search terms to target relevant articles related to "ecosystem service," "valuation," "wetlands," and "India." The systematic search yielded a vast number of articles, which were then screened based on their abstracts and, if necessary, their methodologies and results. To further select relevant articles, two criteria were applied: (1) the assessment of at least one clearly defined ecosystem service and (2) the use of at least one monetary valuation technique to evaluate the benefits of the ecosystems, which resulted in 42 research articles. Table 3 provides a summary of several domestic case studies, offering examples of ecosystem service valuation applications and the various methodologies and techniques used in diverse scenarios. Our focus was primarily on three parameters: (1) WES valuation, (2) the use of ecological and social data (primary or secondary), and (3) the application of valuation methods. From this database, we illustrated the spatial distribution of study sites and ecosystem types, identified the methods used to quantify physical amounts of ecosystem service supply and monetary values, analyzed the spatial variations of ecosystem service values in different states of India. Among the valuation methods, market prices were most frequently used to estimate the monetary value of ecosystem services. The travel cost method from the revealed preference approach and the contingent valuation method from the stated preference approach were commonly utilized for evaluating cultural ecosystem services. However, it was observed that most methodologies for measuring and valuing ecosystem services primarily focused on regulating and provisioning ecosystem services. To gain a comprehensive understanding of the relationship between ecosystem functioning and human well-being, a pluralistic approach that incorporates a wider range of social perspectives and valuation techniques into the ecosystem service framework is essential (Kumar and Kumar 2008; Spangenberg and Settele 2010; Braat and De Groot 2012). This highlights the need for further interdisciplinary and integrative work in this domain, which will enhance scientific understanding and make research, management, and policy decisions more applicable (Abrahams et al. 2019). There is an emerging trend among researchers to employ socio-cultural valuation techniques to better capture the value of ecosystem services, thus incorporating a broader range of social perspectives and valuation techniques into the ecosystem service framework (Agbenyega et al. 2009; Casado-Arzuaga et al. 2013). Additionally, remote sensing techniques have been underutilized in the valuation of ecosystem services, even though they can provide valuable information for developing comprehensive land use and land cover (LULC) maps, estimating spatial and temporal variations in ecosystem service values, and identifying service beneficiaries (Maes et al., 2012; Mulligan 2013). Moreover, most wetland ecosystem service valuation studies do not account for trade-offs or synergies between ecosystem services, leading to findings that inadequately integrate numerous ecosystem services into

Table 3 Wetland valuation studies

Citation	Wetland	Valuation method	Function valued
Anoop and Suryaprakash (2008)	Ashtamudi Estuary, South India	CVM	Option value
Anoop et al., (2008)	Ashtamudi Estuary, South India	Market price, replacement cost	Direct and indirect use benefits
Hema and Devi (2015)	Mangrove areas of Ernakulam and Kannur districts of Kerala	CVM	Conservation
Ambastha et al. (2007)	Kabartal Lake, northern India	CVM	Conservation
Eruva (2009)	Kolleru Lake, Andhra Pradesh	Income estimation, CVM	Direct and indirect use benefits, and conservation
Verma et al. (2001)	Bhoj wetland (two lakes), Bhopal	CVM, market price, income estimation, supply cost, cost of illness approach, and hedonic pricing	Drinking water, stability of microclimate, recreation, and employment
Roy et al. (2012)	Lower gangetic basin	Income estimation	Conservation
Rao and Balasubramanian (2017)	Kuttanad coastal wetland ecosystem of Kerala	TCM	Recreation
Hirway and Goswami (2007)	Mangroves in Gujarat	Damage cost avoided	Coastal erosion control
Maharana et al. (2000)	Khecheopalri Lake	CVM	Recreation
Pathania and Kumar (2017)	Pong Dam wetland, Himachal Pradesh	CVM and hedonic pricing method	Direct use values
Thomson (2003)	Kali estuary (Karnataka) and Cochin estuary (Kerala)	Contingent valuation, TCM, market price	Direct use values, indirect use values, non-use values, and replacement
Hirway and Goswami (2004)	Mangrove Gujarat	Market price, CVM	Use values and non-use values
Imandoust and Gadam (2007)	Panava River	CVM	Direct use values
Mukherjee and Kumar (2012)	Gangetic flood plain	Market price	Direct use values
Ramachandra et al. (2013)	Estuarine ecosystem, Uttara Kannada District, Karnataka	Market price, CVM, benefit transfer	Direct use and indirect use values
Badola and Hussain (2003)	Bhitarkanika Mangrove	Replacement cost	Indirect ecosystem services (nutrient retention)
Hirway and Goswami (2004)	Gujarat mangrove	Damage cost avoided	Indirect ecosystem services (coast erosion control)
Rath (1997)	Chilika Lake	CVM	Preservation value
Sreeja et al. (2009)	Mangrove Kerala	Market price	Indirect use values
Jain et al. (2011)	Seven wetlands of Northeast	Market price	Direct use value
Ramachandra et al. (2011)	Varthur wetland, Bangalore	CVM	Direct and indirect use values
Bhatt & Abdullah (2011)	Hokera wetland J&K	CVM	Use and non-use values
DebRoy and Jayaraman (2012)	Pichavaram mangroves Tamil Nadu	CVM	Use and non-use values
Khaleel (2012)	Mangrove wetlands of North Malabar	Market price and benefit transfer	Use and non-use values
Roy et al. (2012)	Floodplain wetland in the lower Gangetic basin	Income estimation method	Direct use values
Chattopadhyay et al. (2002)	East Calcutta Wetland	CVM	Use and non-use values
Maharana et al (2000)	Sikkim Lake	TCM and CVM	Recreation and sacredness value, conservation value
Badola and Hussain (2005)	Bhitarkanika mangrove ecosystem	Damage-cost avoided approach	Storm protection
Boominathan et al. (2008)	Aghanashini estuary, Karnataka	Income estimation method	Direct use values

Table 3 (continued)

Citation	Wetland	Valuation method	Function valued
Abraham (dissertation)	Coastal wetlands Kerala	Market methods, TCM and CVM	Direct use values, indirect use values, non-use values, and recreational values
Taran and Deb (2017)	Rudrasagar Lake, Tripura	Market price	Provisioning and cultural services
Mamatha et al (2012)	Kolleru Wetland, Andhra Pradesh	Income estimation and WTP	TEV
Bala (2015)	Pong Dam wetland	Income estimation, market prices, and CVM	TEV
DebRoy and Jayaraman (2012)	Pichavaram mangroves, Tamil Nadu	Income estimation, market prices, and CVM	Provisionary and regulating services
Sinclair et al. (2021)	Ashtamudi lake Ramsar site in Kerala	Market price	Provisioning service
Kumar et al. (2020)	Son Beel wetland, Assam	Market price, production function approaches, travel cost/hedonic pricing, benefit transfer, and CVM	Direct and indirect use values
Joy and Paul (2021)	Ashtamudi Wetland, Kerala	Market prices, income estimation, and replacement cost	TEV
Ganguly et al. (2018)	Seagrass ecosystems of Palk Bay and Chilika	Social cost of carbon (SCC)	Carbon sequestration
Haque and Shah (2016)	East Kolkata wetland	CVM	Biodiversity conservation
Venkatachalam and Begam (2016)	Ousteri Wetland, Puducherry	Market price, production function approaches, travel cost/hedonic pricing, benefit transfer, and CVM	Recreational, irrigation, and biodiversity protection
Shah and Islam (2023)	Dal Lake	TCM	Recreational value
Roy et al. (2022)	Wetland of Middle Ganga plain	TEV and benefit transfer	Direct and indirect use values

CVM, contingent valuation method; *TCM*, travel cost method; *WTP*, willingness to pay policy decisions for optimal management methods. Integrating ecosystem service values and outcomes into restoration plans, such as setting targets, building structures, and defining success, has been relatively limited in existing studies. Additionally, clear guidance on linking ecological compensation programs to conservation goals is lacking. The integration of wetland ecosystem services, ecological information, socio-cultural practices of the ecosystem's inhabitants, and economic evaluations of goods and services is essential. Such studies can greatly benefit stakeholders and policymakers in the scientific and sustainable management of wetlands and their resources (Kovács et al. 2015; Guida et al. 2016). We propose the following suggestions to advance the integration of ecosystem services research into wetland conservation policies. The objective is to enhance the reliability and acceptance of measuring wetland ecosystem services and their economic value, thus providing valuable guidance for management decisions and policy-making across various levels.

- To advance the field of wetland valuation in India, researchers should focus on diversifying and implementing various economic valuation methods. This effort will lead to a better understanding of the relationship between ecosystem services and wetland management, enabling the comparison of the benefits of wetlands and the costs of conservation
- Addressing existing data and information gaps is essential to effectively utilize wetland ecosystem services in decision-making processes. Researchers should emphasize conducting biophysical measurements that establish connections between ecosystem characteristics and the services they provide. Additionally, establishing comprehensive monitoring systems will track trade-offs and risks associated with wetland management decisions
- Researchers should incorporate LULC data to enhance the spatial and temporal analysis of wetland ecosystem service valuation. This integration provides valuable insights for effective management and conservation planning, ultimately contributing to the sustainable use and protection of wetland ecosystems
- Researchers should prioritize the integration of socio-cultural perspectives into WES valuation studies. This can be achieved by actively engaging local communities, stakeholders, and indigenous knowledge holders to understand their perceptions, preferences, and cultural values associated with wetland ecosystems and their services. This understanding ensures that the valuation process reflects the diverse needs and preferences of the people directly dependent on the wetlands
- In policy formulation, there should be an emphasis on incorporating the value of ecosystem services into legislative and regulatory frameworks. This approach will enhance the understanding of how healthy ecosystems contribute to people's well-being. Developing wetland ecosystem service monitoring and assessment programs is crucial for gathering essential information on ecosystem characteristics and final service indicators. This data will facilitate the creation of social-ecological production functions to optimize resource allocation in wetland management

By following these recommendations and building upon the current knowledge, India can effectively utilize ecosystem service valuation to make informed decisions and ensure the sustainable management of its wetlands and their invaluable resources.

Conclusion

In the last two decades, India has seen a significant increase in wetland valuation studies conducted by researchers across the country. These studies have covered a wide range of wetland sizes, geographic locations, types, spatial scales, and government designation levels. Despite the comprehensive nature of these studies, some gaps and limitations still exist in the current literature. This paper highlights the importance of understanding the value of wetland ecosystem services in India. At the same time, we identified certain gaps and shortcomings in the current literature, particularly in the areas of data and information. The data gap pertains to the absence of biophysical measurements that link ecosystem characteristics to the final services they provide, while the lack of comprehensive monitoring to track trade-offs and risks represents an important information gap. Despite the awareness of the benefits provide by wetlands, knowledge gaps still exist in the mapping and evaluation of ecosystem services. A pluralistic approach that incorporates various social perspectives and valuation techniques, along with the integration of remote sensing data, can provide valuable insights for sustainable wetland management. By addressing methodological gaps and involving interdisciplinary collaboration, stakeholders and policymakers can make informed decisions to conserve and restore wetlands effectively.

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Data availability This study involved the compilation and analysis of existing literature and papers from various sources. As such, there are no original datasets associated with this study. All sources and references used in this compilation are duly cited in the references section of this paper.

Declarations

Conflict of interest The authors declare no competing interests.

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