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ECOLOGICAL AND ECONOMIC WORTH OF BANGALORE WETLANDS

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ABSTRACT

Wetland ecosystems provide diverse services to sustain livelihoods, which include the provision of food, fish, water, etc. (provisioning services), moderation of microclimate, carbon sequestration, groundwater recharge, remediation (regulating services), and aesthetic, spiritual, recreational, and information (cultural services). Despite being one of the most productive ecosystems, wetlands are being mismanaged due to a lack of knowledge of ecosystem services and economic worth. This necessitates the valuation of ecosystem services for valuable insights into their economic and ecological worth, which would help evolve appropriate policy initiatives for sustainable management and conservation of fragile lifeline ecosystems at decentralised levels. In this context, an attempt has been made to value the ecological and economic worth of four wetlands in Bangalore City through standard protocol by computing the total ecosystem supply value (aggregation of provisioning, regulating, and cultural services: TESV) and the net present value (NPV). The Hebbal wetland has the highest amounts of TESV (INR 51.20 million/year) and NPV (INR 1317.48 million) compared to Nagavara, Sankey, and Mathikere. The major contribution is from the regulating services, and the economic worth assessment highlights the vital role played by wetlands in sustaining the livelihood of the local people and the urgent need for prudent management of wetland ecosystems, involving all stakeholders to ensure cooperation and active participation in the conservation endeavour.

KEYWORDS: TESV, NPV, Ecosystem valuation, Wetland resources, Ecosystem benefits

INTRODUCTION

Wetland ecosystems provide an array of services that sustain social, economic, and cultural well-being, and the maintenance of ecosystem health contributes to economic prosperity. Wetland habitats serve as the cradle of biotic diversity through the provision of water and impetus to primary production, which is essential to the sustenance of biota (plant and animal species) ranging from algae, zooplankton, fish, invertebrates, amphibians, mammals, birds, and reptiles. The neighbourhood's biodiversity plays a crucial role in agriculture by promoting pollination, pest control, carbon storage, and sequestration. Ecosystem services can be broadly categorised into tangible (provisioning) and intangible (regulating and cultural) benefits (Ramachandra *et al.*, 2021). The provisioning services include crop production, water supply, firewood, fodder, craft materials, fish, sand, and medicinal plants (Moges *et al.*, 2018). Regulating services based on ecosystem processes encompass carbon sequestration, climate stabilisation, moderating microclimate, remediation (removal of

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contaminants), groundwater recharge, shoreline stabilisation, flood control, prevention of soil erosion, and mitigation of the impact of natural hazards (cyclones, tsunamis, etc.), while cultural ecosystem services encompass spiritual, recreational, aesthetic, and educational aspects (Ramachandra *et al.*, 2019; De Groot *et al.*, 2012; MEA, 2005). Biotic constituents of wetlands provide nutrition and medicine to cure a range of human ailments, including stomach problems, skin infections, coughs, snake bites, etc. (Kadoma *et al.*, 2023).

The provisioning services provided by Satajan Wetland and Bird Sanctuary in Assam are worth Rs 52,65,600 (Kakoti *et al.*, 2019). Disturbance regulation, cultural services, and waste treatment are crucial ecosystem services valued at NZ$3,242 million, NZ$787 million, and NZ$743 million in wetlands (Clarkson *et al.*, 2013). The importance of provisioning and regulating services in riverine and peri-urban wetlands is highlighted, and the key drivers of wetland degradation are settlement expansion, population growth, agricultural expansion, overharvesting, climate change, and pollution (Das *et al.*, 2022). The Moeyungyi Wetland Wildlife Sanctuary in Myanmar generated annual economic benefits of $22 million ($2130/ha/y) using the Toolkit for Ecosystem Service Site-based Assessment (TESSA) framework (Aung *et al.*, 2021). The annual net economic return of Ghodaghodi Wetland is estimated at $0.67 million, with 96% of its use value coming from wood products and edible food, according to local preferences (Aryal *et al.*, 2021).

Wetlands across the globe are facing severe challenges due to burgeoning populations coupled with unplanned anthropogenic activities leading to large-scale land cover changes due to urbanisation, agricultural development, economic expansion, etc. (Mondal *et al.*, 2017; Asselen *et al.*, 2013). Climate changes due to escalating greenhouse gas (GHG) footprint, are leading to the extinction of endemic biotic species and weakening the effectiveness of fragile areas due to the cascading impact on ecosystem functioning with impaired services. Land use changes leading to land degradation, habitat fragmentation, and the loss of habitat (Hoffmann, 2022; Fahrig, 2017) have aggravated global warming due to higher emissions and the loss of carbon sequestering abilities of an ecosystem. Maintaining the wetland ecosystems is crucial to sustaining ecosystem services, biodiversity, and the livelihood of the dependent local population. Still, the degradation and reclamation of wetlands will have significant negative impacts. Mismanagement leading to wetland transformations results in the erosion of crucial ecosystem processes that are irreversible and lead to the decline in ecosystem services, which impacts societal livelihood.

Assessing the ecological and economic worth through the valuation of ecosystem services would aid in bridging the gap between the science of ecosystems and economics while empowering decision-making for biodiversity conservation. The benefits of wetlands were assessed based on responses from various stakeholders through questionnaire-based surveys (Hempattarasuwan '*et al.*, 2021; Owethu Pantshwa and Buschke, 2019). The objectives of the wetland research are to (i) assess the ecological and economic worth of four wetlands in Bangalore through the appraisal of ecosystem services (ESs); (ii) compute the total ecosystem supply value (TESV) and determine the net present value (NPV). The insights of the current research will help to design sustainable management approaches to the conservation and protection of wetlands in rapidly urbanising Bangalore.

MATERIALS AND METHODS

Study area

The ecological and economic worth of wetlands were assessed based on the field investigation of wetlands (Nagavara, Hebbal, Sankey, and Mathikere) in Bangalore (Bengaluru) city, Karnataka, India. The location details of wetlands are provided in Table 1, and Figure 1 illustrates the spatial distribution of wetlands amongst urban jungles.

Table 1. Geographic location of select wetlands

Wetland	Latitude	Longitude
Nagavara	13° 2′42.24"N	77°36′28.64"E
Hebbal	13° 2′48.80"N	77°35′10.10"E
Sankey	13° 0′34.48"N	77°34′27.11"E
Mathikere	13° 2′8.14"N	77°33′3.55"E

Nagavara wetland, located along the outer ring road, sustains the livelihood of the fishing community apart from being a recreational and cultural hotspot with a garden, a children park, boat rides, a wave pool, etc.

Hebbal wetland was developed in the mid-15th

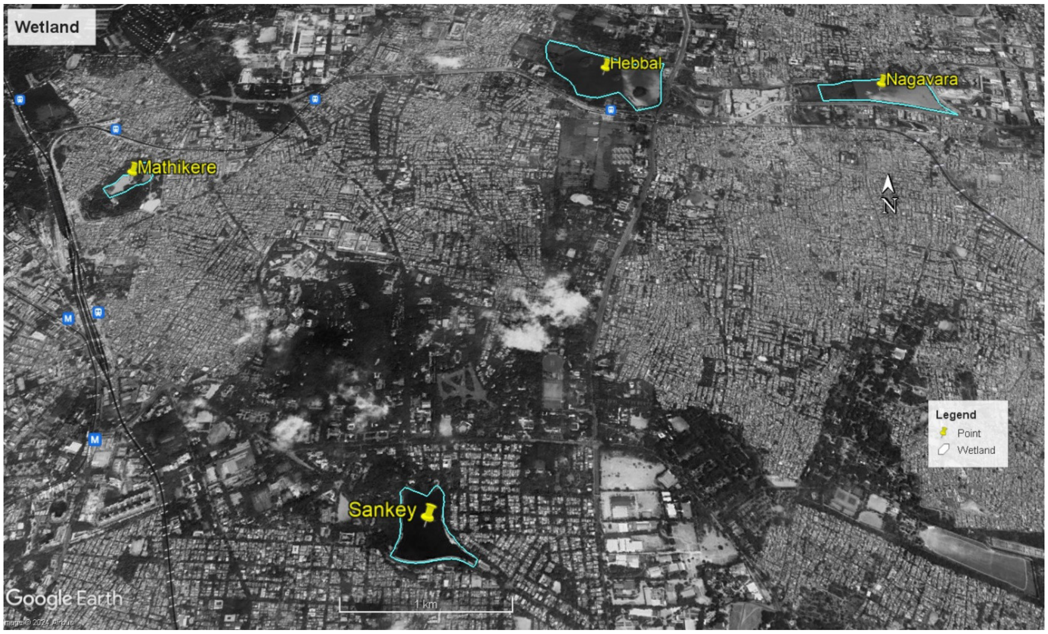

Fig. 1. Study area - Nagavara, Hebbal, Sankey, and Mathikere wetlands, Bangalore city

century (commissioned by Bangalore founder Kempe Gowda I) by constructing bunds along the natural valley systems. Islands provide habitat (food and breeding grounds) for fauna, including migratory bird species. The buffer zone with tall green trees provides shade for joggers, fitness enthusiasts, and nature walkers.

Sankey wetland was built in 1882 to satisfy the water supply needs of Bangalore city by Col. Richard Hieram Sankey of the Madras Sappers Regiment, and the lake is located in the midst of the suburbs of Sadashivanagar, Vyalikaval, and Malleshwaram in western Bangalore. The wetland provides diverse wildlife habitats, including fish, birds, aquatic plants, and other microbes.

Mathikere wetland attracts numerous birds, particularly migrating ones, and health-conscious individuals with a running track, a swimming pool, and a musical fountain. Part of the wetland was recently converted into a recreational park (JP Park or Jayaprakash Narayan Biodiversity Park) by ill-informed local politicians.

Method for appraisal of ecosystem services

The ecosystem services of wetlands are valued based on (i) residual value (provisioning services) and benefit transfer (regulating services and cultural services) methods. Data were compiled through field research (primary data) and the review of published literature, government agency reports, and websites (secondary data). The total ecosystem supply value (TESV) for each wetland is computed by aggregating provisioning services, regulating services, and cultural services. The present worth (net present value; NPV) of a wetland is assessed by discounting future revenue to the current accounting period based on the stream of income anticipated to be collected in the future, considering a 50-year ecosystem asset life and a 3% discount rate (Ramachandra *et al.*, 2021; SEEA, 2021).

RESULTS AND DISCUSSION

Wetlands have been acknowledged since time immemorable for their societal benefits, ranging from fish, fodder, food, water, and groundwater recharge, mitigation of the intensity of floods, silt, and recreational activities. Wetlands sustain the livelihood (employment and income) of society through the provision of critical resources such as raw materials, genetic resources, medicinal resources, ornamental resources, water for irrigation, and fuelwood while generating employment and income for society. Wetlands, through regulating processes, moderate microclimate, maintain air quality, sustain water flow, waste treatment (remediation), control floods, prevent erosion, maintain soil fertility, biological control, support migratory species life cycles, sustain genetic diversity, carbon sequestration, mitigate waterborne diseases, support pollination, conserve water, provide habitat or refugia, and facilitate groundwater recharge. Wetlands offer cultural services, which include spiritual, aesthetic, and educational values, as well as recreation and tourism opportunities. Cultural services manifest in complex interactions between stakeholders and nature, generating significant revenue for local communities and economies. Assessment of regulating services, provisioning services, and cultural services of wetlands shown in Figure 2 highlights that the regulating services are INR 20.15 million/year, INR 35.42 million/year, INR 8.39 million/year, and INR 4.06 million/year, respectively, for Nagavara, Hebbal, Sankey, and Mathikere wetlands (Table 2), which are higher than other services (provisioning and cultural).

Nagavara, Hebbal, Sankey, and Mathikere wetlands provide a total ecosystem supply value (TESV) of INR 291.68 lakhs per year, INR 512.05 lakhs per year, INR 118.45 lakhs per year, and INR 57.23 lakhs per year. The present worth (Net Present Value, NPV) of Nagavara, Hebbal, Sankey, and Mathikere wetlands amounts to INR 750.48 million, INR 1317.48 million, INR 304.77 million, and INR 147.26 million, respectively (Table 2).

Figure 3 illustrates that the contribution of regulating services is relatively higher compared to other ecosystem services: (i) provisioning (18%), regulating (69%), and cultural services (13%) in Nagavara and Hebbal wetlands, and (ii) provisioning (15%), regulating (71%), and cultural services (14%) in Sankey and Mathikere wetlands.

Threat to ecosystem functioning

Wetland ecosystem services are essential to both local and global water cycles and the relationship between water, food, and energy. However, the conservation of these fragile ecosystems is a challenge considering the burgeoning population, urbanisation, infrastructure development, untreated sewage (raw sewage released from dwellings,

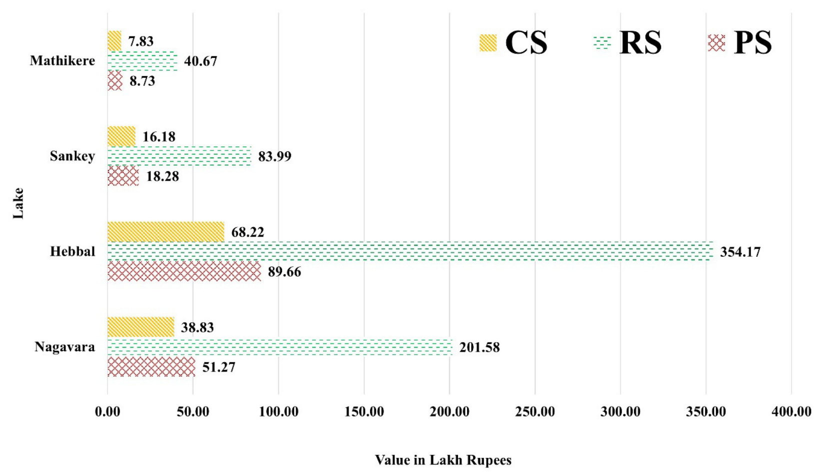

Fig. 2. Wetland ecosystem services (PS: Provisioning Services; RS: Regulating Services; CS: Cultural Services)

Table 2. Ecosystem service values in four wetlands

		Nagavara	Hebbal	Sankey	Mathikere
	Wetland: Total Area (Ha)	28.8	50.6	12	5.81
Provisioning Services	Total Rs/Year (in Lakhs Rupees)	51.27	89.66	18.28	8.73
	Production Rs/ha/Year	178011	177186	152329	150286
Regulating Services	Total Rs/Year (in Lakhs Rupees)	201.58	354.17	83.99	40.67
	Production Rs/ha/Year	699941	699941	699941	699941
Cultural Services	Total Rs/Year (in Lakhs Rupees)	38.83	68.22	16.18	7.83
	Production Rs/ha/Year	134822	134822	134822	134822
TESV	Total Rs/Year (in Lakhs Rupees)	291.68	512.05	118.45	57.23
	Production Rs/ha/Year	1012774	1011949	987092	985049
NPV	Rs (in Million Rupees)	750.48	1317.48	304.77	147.26

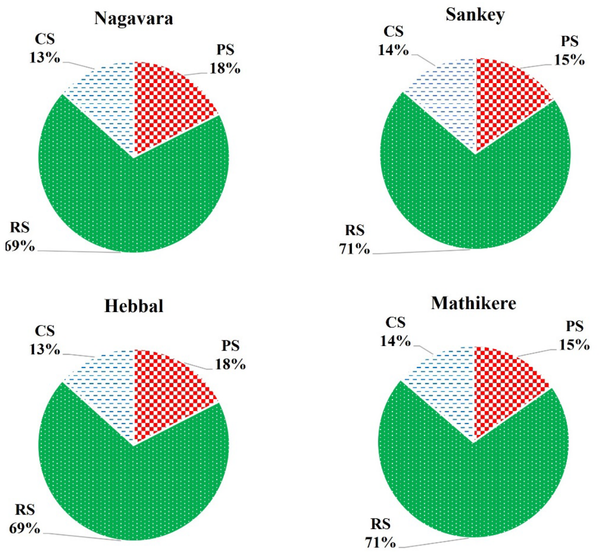

Fig. 3. Percentage distribution of ecosystem services (PS: Provisioning Services; RS: Regulating Services; CS: Cultural Services)

industries, and agricultural run-off), and solid waste dumping in and around wetlands. These anthropogenic activities have altered the physical and chemical integrity of wetlands, altering the biological integrity evident from the profuse prevalence of invasive exotic species and the disappearance of native flora and fauna (Ramachandra *et al.*, 2020; Akhtar *et al.*, 2021; Haidary *et al.,* 2013; Byomkesh *et al.,* 2009; Xu *et al.,* 2022). Deterioration of water quality is evident from recurring episodes of fish mortality due to oxygen deprivation and toxic algal blooms (Sincy *et al.,* 2022). The over-abstraction of water for industry, agriculture, and residential needs has further strained wetlands (Rands *et al.,* 2010). Wetlands are at risk due to high levels of pollutants, including persistent organic chemicals, which may render the water unsuitable for drinking, recreation, swimming, and fishing (Tibebe *et al.,* 2019). Sustained inflow of untreated wastewater leads to nutrient enrichment, resulting in eutrophication with disruption in food chains, biodiversity loss, exacerbated by harmful byproducts and algal blooms, and decline in ecological services, which impact fisheries and economic growth (Zeng *et al.,* 2022). This necessitates regular monitoring of wetlands involving local institutions (schools and colleges) to arrest the degradation of wetlands and improve water quality by restricting anthropogenic activities involving point and non-point sources of pollution (Asulabha *et al.,* 2022).

The primary drivers of biodiversity loss include resource overexploitation, the introduction of invasive alien species, pollution due to the sustained discharge of untreated wastewater, catchment degradation, and habitat fragmentation, apart from the emerging threat of changes in the climate (Ramachandra *et al.,* 2016). Despite the growing number of regional, national, and international policy instruments for the conservation of ecosystems and biodiversity, due to a lack of appropriate regulatory mechanisms, fragile ecosystems are facing a serious threat of existence, coupled with the serious challenges of extinction or extirpation of native biodiversity. This prompted the advocacy (the Ramsar Convention, 1971, the Convention on Biological Diversity, and the Sustainable Development Goals (SDGs) framework) of wise use or responsible use with the sustainable management of wetlands and their biodiversity. Wetlands, with their historical and contemporary biodiversity niches, demand special care and prudent management for the services that have been benefiting society.

CONCLUSION

Wetlands are highly productive and valuable ecosystems, offering numerous economic, social, environmental, and cultural benefits. The study evaluated the ecological services provided by four Bangalore city wetlands through quantifying provisioning, regulating, and cultural services. The wetlands provide a total ecosystem supply value of INR 1012774/ha/year, INR 1011949/ha/year, INR 987092/ha/year, and INR 985049/ha/year in Nagavara, Hebbal, Sankey, and Mathikere wetlands, respectively. The present worth (NPV) of Nagavara, Hebbal, Sankey, and Mathikere wetlands is INR 750.48 million, INR 1317.48 million, INR 304.77 million, and INR 147.26 million, respectively. Unplanned urbanisation, leading to haphazard industrial growth, a sustained inflow of untreated wastewater from households and industry, conversion of wetlands to other land uses, and changes in the climate have been posing serious challenges to the existence of wetlands ecosystems and associated biodiversity. Assessment of ecosystem services provided valuable insights into the contributions of fragile ecosystems and the need to develop strategies for prudent management with knowledge of species composition and wetland processes and an understanding of social, cultural, and political factors. The government policy integrating biodiversity conservation, poverty alleviation, and the resolve to implement sustainable development goals would help in the conservation of wetlands.

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Author Contributions: Conceptualization, development of methods, soft computing, field investigation, validation, writing, formatting, and reviewing were carried out by all authors. All authors have read and agreed to the published version of the manuscript.

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