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Assessment of Wetland Ecosystem Services (RAWES approach) in Urban Settlement Area: A case study of Bilaspur, Chhattisgarh, India

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Abstract: The wetland ecosystem provides several ecosystem services that support the life on earth and improve wellbeing of humans. In the era of rapid urbanization, the growing urban population can get benefit by implementing appropriate planning and management of wetland ecosystem services that are of prior importance. In order to comprehend the significance of the wetland ecosystem in an urban area, a study was conducted to evaluate the ecosystem services offered by 20 urban wetlands of Bilaspur, Chhattisgarh. This paper considers a case study from urban wetlands in order to understand the level of ecosystem services that they deliver. Based on the findings the highest significant positive contribution of any ecosystem service was local climate regulation (++ = 8), and primary production (+ = 15 each) was the most frequent ecosystem service making a positive contribution. In contrast, the most detrimental ecosystem services were livestock disease regulation and human disease regulation (- = 16 each), and waste disposal, water purification, and waste treatment (-- = 1). The highest Ecosystem Service Index among different categories was observed in Regulating services (0.66) and the lowest in Provisioning services (0.32). Trees growing in and around the ponds affects the ecosystem services provided by wetlands directly or indirectly. It has been observed that wetlands with the highest levels of recreation and tourism services have diversified tree species. The top 5 tree species most frequently observed around the wetlands are *Ficus religiosa, Acacia nilotica, Ficus benghalensis, Azadirachta indica* and *Peltophorum pterocarpum*. The Rapid Assessment of Wetland Ecosystem Services (RAWES) technique is significant in evaluating the deteriorating state of Bilaspur's urban wetlands as a result of disturbance caused by human settlements, which in turn diminished the urban wetlands' capacity to deliver ecosystem services.

Keywords: Wetland, Urban settlement, Ecosystem services, Rapid assessment, Degradation

Urban wetlands have been one of the most important tools in the life of Indian cities. Wetlands make essential positive contributions (McInnes et al 2016) to multiple dimensions of human wellbeing (Ghermandi et al 2010). According to the National Wetland Inventory and Assessment (Compiled by the Indian Space Research Organisation), in India, wetlands cover over 1,52,600 square kilometres that comprise 4.63 per cent of the total geographical area of the country (Bassi et al 2014). Their importance in human and urban lives grew as the population and the population-based pressures have increased recently (Mitsch and Gosselink 2000, Avishek and Nathawat 2004). The urban wetland provides a wide range of diverse benefits like basic biophysical needs (food, fresh water *etc*.), regulation of the environment, cultural enrichment and also support internal processes to ecosystems that maintain their functioning, resilience and capacities to produce more directly consumed services. Natural ecosystems provide benefits that are both generally acknowledged and poorly understood (Sharma et al 2022a) however, these benefits are not sufficiently recognised due to lack in decision-making (McInnes 2013), compromising the welfare (Faulkner 2004, Russi et al 2013) of ecosystems and many human beneficiaries such as yield benefits and economic value (Patil 2022) linked with it (Chu et al 2020, Rana and Bhardwaj 2022). The processes and activities that enable ecosystems to sustain and fulfil human life are referred to as ecosystem services (Baretha et al 2022). To evaluate these ecosystem services within the local context and at relevant scales, the Rapid Assessment of Wetland Ecosystem Services (RAWES) approach is presented as a systemic approach (McInnes and Everard 2017) for the assessment that is essential to avert prejudgements about which services are important and to assess the positive or negative contribution of these ecosystem services at local, regional, or global scales. The outputs from RAWES process can provide a qualitative assessment of the wide range of ecosystem services obtained from the wetlands and a comprehensive and rapid overview of the several benefits provided by the same across a large geographic area (Everard et al 2019).

The present study deals with the assessment of plurality of benefits or ecosystem services including provisioning services, regulating services, cultural services and supporting services provided by the selected 20 wetlands in reference to Bilaspur, Chhattisgarh, India, an area under urban settlement by implementation of RAWES approach.

MATERIAL AND METHODS

Study area: The study was conducted in the Bilaspur district of northern Chhattisgarh. One of the state's larger cities, Bilaspur, is situated 270 metres above mean sea level at 22.0797º N Latitude and 82.1409º E Longitude (Tiwari et al 2022).

The complete assessment was conducted during the period of October 2022 to December 2022. The site experienced largely dry and humid weather during the study period, with the lowest and highest temperatures of 13.40°C and 38.50°C, respectively, and an average rainfall of 5.8 mm. (Source: Climate department, TCB College of Agriculture & Research Station, Bilaspur, Chhattisgarh). Few rainy days were observed during the study period with light precipitations. The study site has several wetlands out of which the survey was conducted in 20 different wetland sites (Fig. 1) based on their characteristics of presence near urban settlements of Bilaspur, Chhattisgarh. All the selected wetlands (Fig. 2) are situated at approximately 25 kilometres from each other covering overall urban settlement areas.

Assessment of ecosystem services*:* A consensus was done to finalize the list of ecosystem services prior to conducting field assessments through consultation with resource persons who have an idea about the wetlands. As defined in the Millennium Ecosystem Assessment (2005), a total of 37 services grouped into four functional categories (Namely provisioning, regulating, cultural and supporting services) were selected for the analysis. The complete assessment was done by the assessors from October 2022 to December 2022 in 20 selected wetlands of the urban settlement area through regular visits to collect data about the site and other details of the wetland that needed to be assessed. The assessors used a combination of field observations and visual signs or indicators, combined with their ability to pose and answer a series of questions in order to evaluate the relative importance of each ecosystem service listed on the RAWES field assessment sheet. A five-point scale (Table 1) was used to record the importance of each ecosystem service. This scale is non-dimensional, insofar as there is no standard unit or measure between different points on the five-point scale.

Calculation of ESI: Obtained scores were numerically transformed for all ecosystem services, or alternatively for assessed ecosystem services within each service category

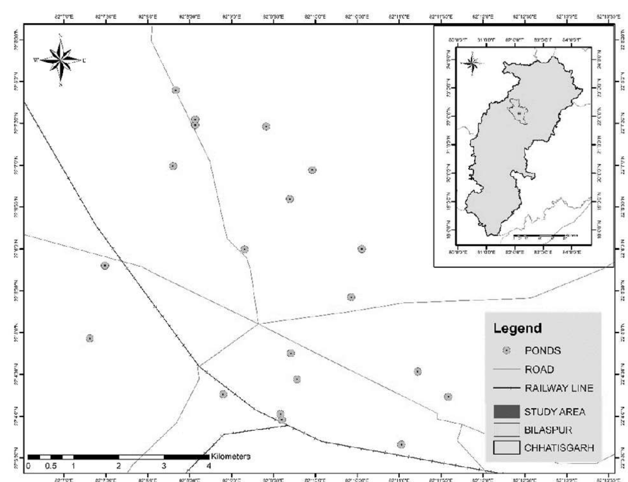

Fig. 1. Geographical location of study area locating 20 selected wetlands in Bilaspur, Chhattisgarh

Table 1. Five-point scale used to record the importance of each ecosystem service

Importance score	Numerical value	Assessment of ecosystem service	Rationale
+ +	2.0	Significant positive contribution (>1,000 people benefitting)	• Significant service provided by the wetland and a key element of its ecological character • Large number of beneficiaries (relative to wetland context)
+	1.0	Positive contribution (1-1,000 people benefitting)	• One of many services provided by the wetland and an element of its ecological character • Limited number of beneficiaries (relative to wetland context)
0	0	Negligible contribution	• No obvious beneficiaries or benefits • Not an important known part of the wetland's ecological character
-	-1.0	Negative contribution (1-1,000 people dis-benefitting)	Limited number of dis-beneficiaries
- -	-2.0	Significant negative contribution (>1,000 people dis-benefitting)	Large number of dis-beneficiaries
?	Remove from analysis	Gaps in evidence	Further evidence needs to be obtained

(provisioning, regulating, cultural and supporting), which was further analysed by deriving a comparable Ecosystem Services Index (ESI). An ESI is an index of observed ecosystem service production against potential maximum service production.

$$ESI = \frac{\sum(n_{+2.0} + n_{+1.0}) + \sum(n_{-2.0} + n_{-1.0})}{\sum(n_{Total})}$$

Assessment of scale of ESI: Through the application of RAWES approach, the benefits that wetlands provide accrue at a range of geographic scales, ranging from within the wetland itself (such as soil formation) through local, regional and up to international levels (McInnes and Everard 2017). Three scales of benefits delivery applied when conducting the RAWES assessment are:

Local benefits: Those experienced by individuals, households or communities living and working in the immediate vicinity of the wetland. (*viz.* storm buffering)

Regional benefits: Those delivered to individuals, households or communities living and working in the wider catchment of the wetland. (*viz.* flood or drought buffering across a catchment)

Global benefits: Those that extend beyond national boundaries. (*viz.* regulation of global carbon cycles)

Vegetation analysis: A vegetation survey was performed in and around the wetlands by enumerating the number of tree species present within the 15-meter radius of wetlands. The method provided a comprehensive data on vegetation composition and structure around the sites that can contribute to different functioning and services of wetlands.

Fig. 2. Water bodies selected for RAWES analysis in urban settlement areas of Bilaspur, Chhattisgarh (1. Ashok Nagar Pond, Birkona, 2. Bandhawapara Pond, 3. Bilasatal Pond, 4. Chhathghat Pond, 5. Chingrajpara Pond, 6. Deepupara Pond 1, 7. Deepupara Pond 2, 8. GGV Pond 1, 9. GGV Pond 2, 10. GGV Pond 3, 11. Ghuru Pond, Ameri, 12. Jorha Pond, Sarkanda, 13. Kalimandir Pond, Birkona, 14. Karbala Pond, 15. Mama Bhanja Pond, 16. Morum Pond, 17. Nag Nagin Pond, 18. Putha Pond, Mangla, 19. Smriti Van Pond, 20. Talapara Pond, Vyapaar Vihar)

RESULT AND DISCUSSION

Assessment of ecosystem services: Based on the field assessment and data analysis, ecosystem services making a significant positive contribution were recorded less frequently than those making a positive contribution (Table 2). The highest significant positive contribution of any ecosystem service was the local climate regulation (++ = 8) followed by aesthetic value and Nutrient cycling (++ = 6 each) and spiritual & religious value (++ = 4) also made a significant positive contribution in the study site. Water regulation and primary production (+ = 15

Table 2. Count data for the frequency of the ecosystem service scores

Ecosystem service	n	++	+	0	-	- -	L	R	G
Fresh Water	20	0	12	0	8	0	4	8	0
Food	20	0	11	9	0	0	10	1	0
Fuel	20	0	12	8	0	0	10	2	0
Fibre	20	0	1	19	0	0	1	0	0
Genetic resources	20	0	0	20	0	0	0	0	0
Natural medicines	20	0	2	18	0	0	2	0	0
Ornamental	20	0	2	18	0	0	0	2	0
Clay mineral, aggregate harvesting	20	0	6	14	0	0	2	4	0
Waste disposal	20	0	2	11	6	1	2	0	0
Energy harvesting from	20	0	1	19	0	0	1	0	0
Air quality regulation	20	0	12	3	5	0	3	7	2
local climate regulation	20	8	8	0	4	0	16	0	0
Global climate regulation	20	0	8	11	1	0	0	0	8
Water regulation	20	0	15	3	2	0	13	2	0
Flood hazard regulation	20	2	13	4	1	0	10	4	0
Storm hazard regulation	20	0	0	20	0	0	0	0	0
Pest regulation	20	0	3	5	12	0	3	0	0
Disease regulation human	20	0	1	3	16	0	1	0	0
Disease regulation livestock	20	0	0	4	16	0	0	0	0
Erosion regulation	20	0	12	6	2	0	12	0	0
Water purification	20	0	3	7	9	1	3	0	0
Pollination	20	2	8	8	2	0	1	9	0
Salinity regulation	20	0	3	17	0	0	3	0	0
Fire regulation	20	0	14	5	1	0	13	1	0
Noise visual buffering	20	0	12	6	2	0	4	8	0
Cultural heritage	20	0	3	17	0	0	0	3	0
Recreation and tourism	20	3	3	10	4	0	1	5	0
Aesthetic value	20	5	6	5	4	0	8	3	0
Spiritual and religious	20	4	9	7	0	0	3	10	0
Inspirational value	20	1	3	16	0	0	4	0	0
Social relation	20	2	12	4	2	0	14	0	0
Education and research	20	1	3	16	0	0	0	4	0
Soil formation	20	0	5	14	1	0	4	1	0
Primary production	20	2	15	2	1	0	15	2	0
Nutrients cycling	20	5	8	6	1	0	2	11	0
Water recycling	20	0	4	12	4	0	0	4	0
Provision of habitat	20	2	8	6	4	0	3	7	0

*L – Local benefits, R – Regional benefits, G – Global benefits each) were the most frequently occurring ecosystem service making a positive contribution. Fire regulation (+ = 14), flood hazard regulation (+ = 13 each) and freshwater, fuel, air quality, erosion regulation, noise and visual buffering and social relation (+ = 12 each) also made a positive contribution at more than half of all the study sites. Livestock disease regulation and human disease regulation (- = 16 each) made the most negative contributions followed by pest regulation (- = 12) in the study sites whereas waste disposal and water purification and waste treatment (-- = 1 each) made the most significant negative contributions. Out of all 37 ecosystem services, a total of 23 ecosystem services contributed negatively whereas 34 ecosystem services contributed positively in the functioning of studied urban wetlands.

Assessment of scale of ES: The benefits derived from the ecosystem services are delivered across a range of scales. For several services, there was sufficient information to make a judgement on the scale of the benefits (Fig. 3), as most of the ecosystem services were contributing to the local benefits whereas, services like nutrient cycling and facilitation of pollination were having broader ecological importance (Table 2). On the other hand, global climate regulation had a positive global benefit in the studied wetlands followed by air quality regulation. However, there were several services, where insufficient information was available to undertake an assessment of the spatial scale of benefit limiting the utility of the approach. The analysis of the information on the scale of benefit was less comprehensive than the significance of individual ecosystem services. The study reveals (Figure 4) that out of 20 total selected wetlands, GGV Pond 2 (26) provided best ecosystem service score followed by GGV Pond 1 (25), Bandhwapara Pond (22), Bilasatal Pond (20) whereas the most disturbed ecosystem service score was observed in Karbala Pond (-11) followed by Deepupara Pond 2 and Mama Bhanja Pond (-8 each). Similarly, Talapara Pond (Vyapaar Vihar) also showed negative ecosystem service scores and the rest of the studied wetlands showed positive ecosystem service scores. All these disturbed ponds are situated near the settlement area of Bilaspur city. One study was conducted in the major ponds of Bilaspur city and found that the pond near populated areas was contaminated exceeding the maximum permissible limit of WHO (Shrivastav et al 2008).

Calculation of ESI: The study of Ecosystem Services Index (Fig. 6) indicating the potentials of different ecosystem service categories that they possess in wetlands. The highest ESI was achieved by the Regulating services (0.66) which show its positive contribution to wetlands whereas the lowest ESI was observed in Provisioning services (0.32) which defines the least contribution in the services provided by the studied wetlands. However, both Cultural services (0.46) and Supporting services (0.6) achieved an ESI near about 0.5 showing their positive contribution to overall services provided by the studied urban wetlands of Bilaspur, Chhattisgarh.

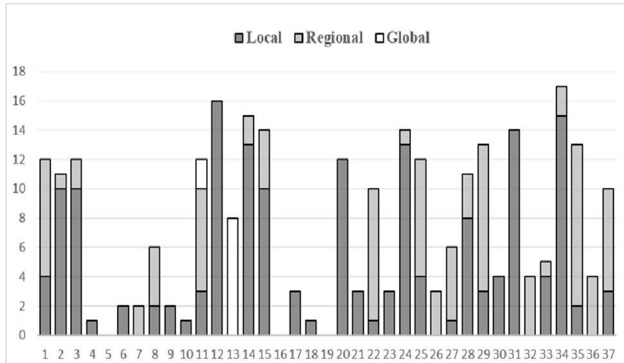

Fig. 3. Graphical representation of the scale of impact by 37 different ecosystem services on wetlands of Bilaspur, C.G.

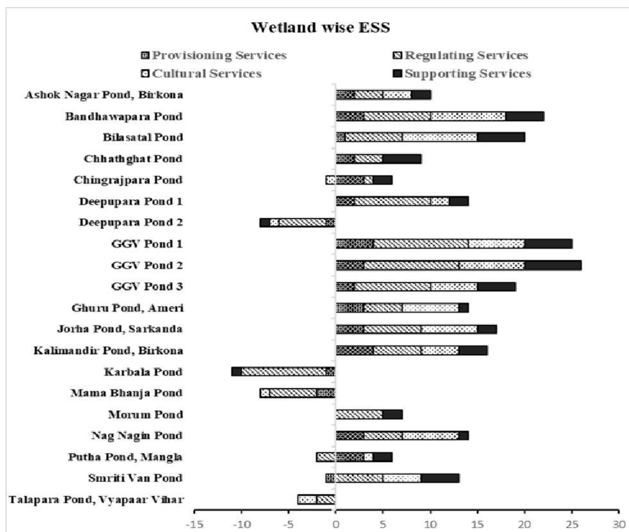

Fig. 4. Graphical representation of wetland wise ecosystem service scores of Bilaspur, C.G.

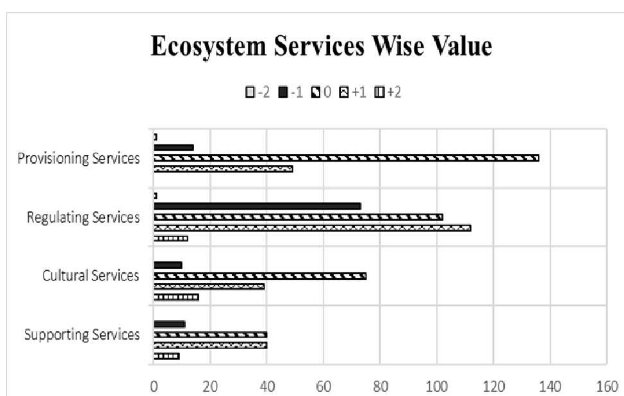

Fig. 5. Importance scores wise valuation of different ecosystem service categories

Assessment of importance scores: The evaluation of importance scores achieved by different ecosystem service categories in the 20 studied urban wetlands in which the provisioning services were dominated by negligible contributions with the least negative contributions whereas the regulating services were dominated by positive contributions but also with a maximum number of negative contributions (more than 50% of the total) when compared to other services as shown in Figure 5. Many most significant positive contributions were also observed in provisioning services whereas provisioning services and regulating services possessed an equal number of significant negative contributions (1 each).

Classifying sites based on ecosystem services: Agglomerative hierarchical clustering was done using SPSS software (version 25.0) for classifying the wetlands based on similar and dissimilar services provided by them (Fig. 7). The wetlands were divided into 4 clusters (A, B, C, D). Class B is the largest cluster (n=9) while cluster A is the smallest (n=3) and there is a high degree of similarity among them.

Cluster A represents the sites which provide a high level of regulating services score as compared to other clusters and site 10 is distinct among the two sites. Cluster B sites deliver the average ecosystem services score and represent the sites which are partially degrading. Wetlands fall in cluster C was the places with high cultural services for recreation and tourism and aesthetic value while cluster D shows the wetlands which are highly degraded and show negative services scores due to deposition of domestic waste from nearby settlement areas. The quantity and nature of domestic waste generation are influenced by the people living in a house as well as seasonal factors including summer, winter, and rainy weather (Sharma et al 2022).

Vegetation analysis: In total 65 tree species belonging to 29 families were observed near the 20 studied wetlands (Table 3). The most frequently occurring tree is *Ficus religiosa* due to its religious and spiritual values (Rutuja et al 2015) and its high invasion ability in various types of climatic and edaphic conditions (Sitaramam et al, 2009, Kumari et al 2022). The second most frequent species were *Acacia nilotica* which is arid-adapted species, and a study found the existence of most arid-adapted species in urban wetlands are drought-tolerant and need less water for growth (Avishek et al 2012) followed by *Ficus benghalensis* and *Azadirachta indica*. Vegetation analysis provided comprehensive data on vegetation composition and structure around the sites which showed that the highest number of tree species were observed in Bilasatal Pond (52) constituting 80% of the total observed species (Fig. 8) followed by Smriti Van Pond (39) and Bandhawapara Pond

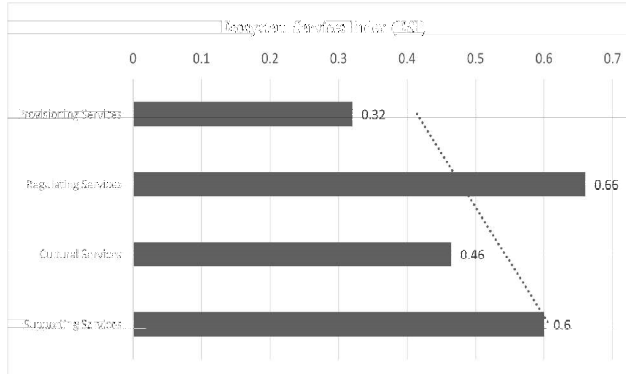

Fig. 6. Ecosystem Services Index (ESI) of different ecosystem service categories

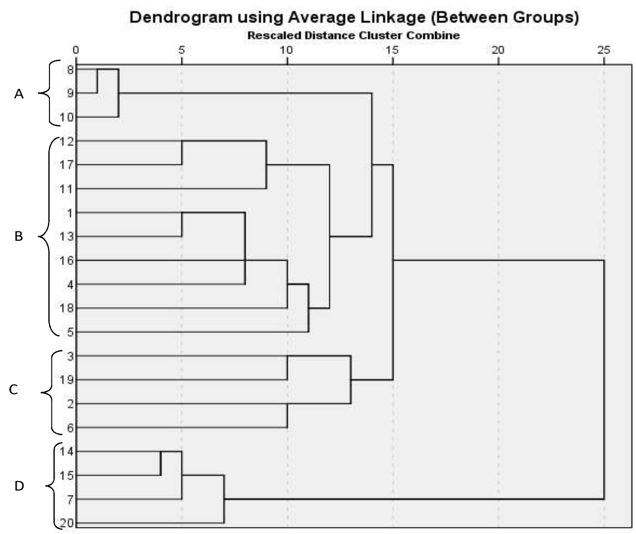

Fig. 7. Agglomerative hierarchical clustering of different wetlands sites

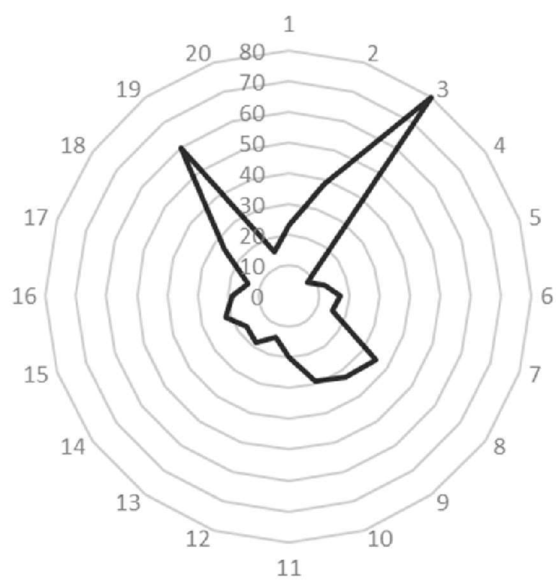

Fig. 8. Number of species observed per wetland

Table 3. Tree species distribution around studied wetlands of Bilaspur, Chhattisgarh

Common name of tree	Botanical name	Family	No. of wetlands	Frequency (%)
African Tulip	*Spathodea campanulate*	*Bignoniaceae*	5	25
Amaltash	*Cassia fistula*	*Fabaceae*	6	30
Amla	*Phyllanthus emblica*	*Phyllanthaceae*	6	30
Arjun	*Terminalia arjuna*	*Combretaceae*	2	10
Austalian Babool	*Acacia auriculiformis*	*Fabaceae*	3	15
Babool	*Acacia nilotica*	*Fabaceae*	18	90
Badam	*Prunus dulcis*	*Rosaceae*	11	55
Buddha Belly Bamboo	*Bambusa ventricose*	*Poaceae*	1	5
Male Bamboo	*Dendrocalamus strictus*	*Poaceae*	5	25
Banana	*Musa spp.*	*Musaceae*	1	5
Banyan	*Ficus benghalensis*	*Moraceae*	17	85
Beal	*Aegle marmelos*	*Rutaceae*	4	20
Ber	*Ziziphus mauritiana*	*Rhamnaceae*	9	45
Black Siris	*Albizia lebbeck*	*Fabaceae*	3	15
Bottle Brush	*Callistemon acuminatus*	*Myrtaceae*	2	10
Champa	*Magnolia champaca*	*Magnoliaceae*	2	10
Chikoo	*Manilkara zapota*	*Sapotaceae*	1	5
Euclayptus	*Eucalyptus spp.*	*Myrtaceae*	6	30
False Ashoka	*Monoon longifolium*	*Annonaceae*	7	35
Gangaimli	*Pithecellobium dulce*	*Fabaceae*	2	10
Goolar	*Ficus racemose*	*Moraceae*	6	30
Guava	*Psidium guajava*	*Myrtaceae*	5	25
Gulmohar	*Delonix regia*	*Fabaceae*	6	30
Imli	*Tamarindus indica*	*Fabaceae*	1	5
Jamun	*Syzygium cumini*	*Myrtaceae*	7	35
Jharul	*Lagerstroemia speciosa*	*Lythraceae*	1	5
Kachnar	*Bauhinia variegate*	*Fabaceae*	3	15
Kadam	*Neolamarckia cadamba*	*Rubiaceae*	8	40
Kalmi/Haldu	*Haldina cordifolia*	*Rubiaceae*	1	5
Kapok	*Ceiba pentandra*	*Malvaceae*	2	10
Karanj	*Millettia pinnata*	*Fabaceae*	11	55
Kashi	*Bridelia retusa*	*Phyllanthaceae*	2	10
Kasood	*Senna siamea*	*Fabaceae*	4	20
Katahal	*Artocarpus heterophyllus*	*Moraceae*	1	5
Khamhar	*Gmelina arborea*	*Lamiaceae*	3	15
Krishna Fig	*Ficus benghalensis var krishnae*	*Moraceae*	1	5
Lemon	*Citrus limon*	*Rutaceae*	1	5
Litchi	*Litchi chinensis*	*Sapindaceae*	1	5
Mahaneem	*Ailanthus excelsa*	*Simaroubaceae*	6	30
Mahua	*Madhuca longifolia*	*Sapotaceae*	2	10
Malshree	*Mimusops elengi*	*Sapotaceae*	3	15
Mango	*Mangifera indica*	*Anacardiaceae*	11	55
Mudhi	*Mitragyna parvifolia*	*Rubiaceae*	2	10

Cont...

Table 3. Tree species distribution around studied wetlands of Bilaspur, Chhattisgarh

Common name of tree	Botanical name	Family	No. of wetlands	Frequency (%)
Munga	*Moringa oleifera*	*Moringaceae*	12	60
Neem	*Azadirachta indica*	*Meliaceae*	17	85
Oleander	*Nerium oleander*	*Apocynaceae*	2	10
Palash	*Butea monosperma*	*Fabaceae*	7	35
Palm	*Arecales*	*Arecaceae*	5	25
Parijat	*Nyctanthes arbor-tristis*	*Oleaceae*	3	15
Peepal	*Ficus religiosa*	*Moraceae*	19	95
Peltophorum	*Peltophorum pterocarpum*	*Fabaceae*	13	65
Putranjeeva	*Putranjiva roxburghii*	*Putranjivaceae*	2	10
Rohina	*Swietenia febrifuga*	*Meliaceae*	1	5
Rudraksh	*Elaeocarpus angustifolius*	*Elaeocarpaceae*	1	5
Saja	*Terminalia elliptica*	*Combretaceae*	1	5
Samea	*Samanea saman*	*Fabaceae*	3	15
Saptparni/ Chatim	*Alstonia scholaris*	*Apocynaceae*	7	35
Semal	*Bombax ceiba*	*Malvaceae*	4	20
Sissoo	*Dalbergia sissoo*	*Fabaceae*	10	50
Sitaphal	*Annona reticulata*	*Annonaceae*	5	25
Subabool	*Leucaena leucocephala*	*Fabaceae*	11	55
Teak	*Tectona grandis*	*Lamiaceae*	3	15
Weeping Fig	*Ficus benjamina*	*Moraceae*	2	10
White Siris	*Albizia procera*	*Fabaceae*	6	30
Yellow Kaner	*Cascabela thevetia*	*Apocynaceae*	2	10

(25). All three-study site comes under the public park and hence plantations with aesthetic and fruiting species were seen there which contributed to increased species diversity in the area. Similarly, in all the three ponds of Guru Ghasidas Vishwavidyalaya *viz.*, GGV Pond 1, GGV Pond 2 and GGV Pond 3 being an institutional campus, a total of 23, 21, and 19 species were observed respectively. Whereas, Chhathghat Pond (5) and Chingrajpara Pond (8) had the least species diversity in comparison to other urban wetlands with 7.70% and 12.31% species constitution respectively. Thus, due to less biotic pressure, the GGV ponds are good in quality and support biodiversity which leads to the highest ecosystem services scorer among all wetlands of the study area. The Guru Ghasidas Vishwavidyalaya campus has a high species richness, as evidenced by the number of species there (Anand et al 2021). As a result, it can say that the small water structure can be preserved and kept alive with the least amount of human interference and effort. As we all know, nature is self-sufficient in improving itself, so it is crucial to preserve it in order to support biodiversity, human health, and to get benefitted from the area's ecosystem services.

CONCLUSION

The current investigation of the pond ecology reveals various functions that have never been examined in the region. Outcomes are helpful to gain an understanding of the various advantages of a small inland ecosystem that is subject to heavy residential pressure, both directly and indirectly, in terms of concrete and intangible benefits. Results have indicated about the impacts of disturbance in a pond on various services connected to that ecosystem and human life. For instance, dumping rubbish into a pond reduces its cultural value and causes pests and diseases to proliferate, which has an impact on regulatory services. The removal of wastes can also cause an algal bloom, have an impact on the cycling of nutrients, reduce biological oxygen demand (BOD) and affect supporting services. Consequently, interlinked services have a significant impact on our environment. Thus, the assessment helps to comprehend the condition of the ponds and their advantages on a local, regional, and worldwide scale.

AUTHORS CONTRIBUTION

A.M., D.S., P.S., G.B., and R. contributed to the design of the research and also carried out the implementation. A.M., D.S., and P.S. analyzed the data. D.S., G.B. and R. performed the calculations. A.M. and P.S. wrote the manuscript with input from all authors. G.P. conceived the study and was in charge of overall direction and planning. All authors provided critical feedback and helped shape the research, analysis and manuscript.

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