**Assessment of Wetland Ecosystem Services using RAWES Approach: A Case Study of Raipur, Chhattisgarh, India**

**Abstract**: Urban wetlands are important for sustaining and maintaining ecological balance and human well-being. This study applied the Rapid Assessment of Wetland Ecosystem Services (RAWES) approach to assess the ecosystem services provided by 38 urban wetlands located within urban settlements of Raipur, Chhattisgarh, India. The assessment of urban wetlands was conducted during 2025, and classified ecosystem services into provisioning, cultural, regulating and supporting groups. Result showed that among provisioning services fresh water (++ = 11) and food (++ = 12) showed the significant positive contributions. Regulating services like air quality (+ = 24) and climate regulation (+ = 24) showed positive contributions whereas services such as pest regulation (- = 26), disease control (- = 21) and nutrient cycling showed negative contributions mainly because of degradation or pollution. Cultural services such as recreation and tourism (++ = 4) showed positive contributions whereas, spiritual and educational services showed limited benefits. Vegetation analysis showed the dominance of ecologically and culturally important tree species such as, *Ficus religiosa* and *Azadirachta indica*. The ecosystem service index was used for quantification of the services and to highlight the need for better conservation strategies. The RAWES framework is a participatory tool used for identifying, quantifying and supporting the conservation of urban wetlands.

**Keywords**: ecological balance, climate regulation, wetland conservation, sustainable urban planning.

**INTRODUCTION**

Wetland ecosystems play a critical role in supporting human well-being. (Millennium Ecosystem Assessment, 2005; Russi *et al*., 2013). A considerable amount of evidence indicates that wetlands can offer a multitude of benefits to human society (Ghermandi *et al*., 2010). These advantages encompass, though are not restricted to, the administration of flood risk (Mitsch and Day, 2006) and declining peak air temperatures studies (Sun *et al*., 2012) that enhance water quality (Shutes, 2001; Dhote and Dixit (2009) emphasize the importance of safeguarding coastal communities from storms (Gedan *et al.*, 2011), facilitating agricultural output (Lannas & Turpie, 2009; and Verhoeven and Setter, 2009, offer essential contributions. Natural resources (McGregor *et al.*, 2010) and the provision of sites for a numerous educational and recreational opportunities (Cachelin *et al*., 2009; Finlayson *et al.*, 2013).

Wetlands are considered one of the most biologically productive eco-system globally. They support human societies through the execution of biological, ecological, hydrographic and geological roles. Numerous species and ecosystems globally are maintained and sustained by wetlands (Mwakaje, 2009). Through. by definition, wetlands are environment characterized by the presence of both water and vegetation, which may be natural or artificial and encompass swamps, marshes, peatlands, fens, and various others. Ecosystem service is an overarching term for the various goods and services generated by ecosystems that provide benefits to humanity (Jenkins *et al.* 2010).

Barbier (2011) defines ecosystem services as natural assets generated by the environment and employed by humans, including clean air, water, and food. Ecosystem services enhance social and cultural well-being (Fischer *et al.* 2009) and possess significant economic value (Barbier *et al.* 1997, Emerton and Bos 2004, Turner *et al*. 2008). Over the last ten years, advancements have been achieved in comprehending how ecosystems deliver services and how the provision of these services is converted into economic value (Daily 1997, MA 2005, NRC 2005). In a highly referenced ecosystem service valuation study, Costanza *et al*. (1997) approximated the annual value of the services offered by Earth’s ecosystems to be a minimum of $33 trillion.

Evaluating wetland ecosystem services in urban environment is essential for multiple reasons Wetlands located in urban areas offer significant ecosystem services that enhance human well-being and quality of life. (Pedersen *et al*., 2018). Evaluating these services aids in quantifying their significance and worth to urban populations, which is crucial for securing public approval and backing for wetland preservation and development (Pedersen *et al.,* 2018). Urban wetlands encounter considerable challenges as a result of accelerated urbanization and alterations in land use. Evaluating ecosystem services facilitates the identification of the effects of urban growth on wetland ecosystems and their capacity to deliver services. (Huang *et al*., 2019). Ecosystem service assessments offer critical insights for urban planning and policy formulation. They assist in recognizing the trade-offs and synergies among various services, which is essential for sustainable urban development. (Pan *et al.,* 2023). Moreover, evaluating the ecosystem services provided by wetlands can facilitate the formulation of efficient management strategies and policies. (Xu *et al.,* 2018; Zhang *et al.,* 2023).

Urbanization affects urban wetland ecosystems by causing habitat loss and fragmentation, leading to reduced wetland areas and disrupted ecosystems. (Mitsch & Gosselink, 2015). Urban wetlands face pollution from heavy metals, fertilizers and pathogens that harm water quality and aquatic life. (Zedler & Kercher, 2005). Wetland pollution harms biodiversity and possess risks to human health, especially where wetlands provide drinking water or recreation. Key challenges include invasive species, pollution and habitat loss. To address these, effective pollution management strategies and the creation of buffer zones and green infrastructure are essential. (EPA, 2021). Conservation and habitat restoration are important for species health and wetland contamination filtering, involving native vegetation reintroduction and community engagement. (Mitsch & Gosselink, 2015). Furthermore, it is essential to manage invasive species.

**MATERIAL AND METHODS**

**Study area**: The study was conducted in Raipur district of Chhattisgarh. Raipur is situated 298.15 m above mean sea level at 21.2514° N, 81.6296° E.

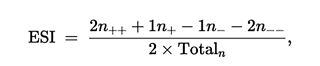
The complete study was conducted during 2025. The study sites were mostly dry and had humid weather during the study period with the lowest and highest temperatures of 25oCand 41oC respectively, and an average rainfall of 0.57mm to 16mm. During the study period very, few rainy days were observed with very less precipitations. The study site has several wetlands out of which the survey was conducted in 38 different wetland sites, based on their characteristics of presence near urban settlements of Raipur, Chhattisgarh.

**Assessment of ecosystem services**: A consensus was reached to finalize the list of ecosystem services before beginning field assessments by consulting with experts knowledgeable about wetlands. According to the Millennium Ecosystem Assessment (2005), a total of 37 services were identified and categorized into four functional groups: provisioning, regulating, cultural and supporting services. The thorough evaluation was carried out by the assessors during 2025 across 38 selected wetlands within the urban settlement area, involving regular site visits to gather data relevant to the assessment of the wetlands. The assessors employed a blend of field observations and visual cues or indicators, along with their capability to ask and respond to a range of questions to gauge the significance of each ecosystem service documented on the RAWES field assessment sheet. A five-point scale (Table 1) was implemented to log the significance of each ecosystem service. This scale is non-dimensional, meaning there are no defined units or measures between the varying points on the five-point scale.

**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 |

**Calculation of ESI:** The scores gathered were numerically converted for every ecosystem service or, alternatively, for the evaluated ecosystem services within each category (provisioning, regulating, cultural and supporting) which was subsequently analyzed by calculating a comparable Ecosystem Services Index (ESI). The ESI represents an index of actual ecosystem service production compared to the potential maximum service production.



**Assessment of scale of ESI**: By utilizing the RAWES method, the advantages offered by wetlands emerge at various geographic levels, spanning from the wetland environment itself (like soil development) to local, regional, and even global dimensions (McInnes and Everard 2017). The assessment of RAWES involves three tiers of benefit delivery, which are:

**Local benefits:** These are encountered by individuals, households, or communities residing and working in close proximity to the wetland. (storm buffering)

**Regional benefits**: These are offered to individuals, households, or communities living and working in the broader catchment area of the wetland. (flood or drought buffering across a catchment)

**Global benefits**: These extend beyond national borders. (regulation of global carbon cycles)

**Vegetation analysis**: A survey of vegetation was conducted in and around the wetlands by counting the variety of tree species present around the wetlands. This approach yielded detailed information on the composition and structure of vegetation surrounding the sites, which can play a role in the various functions and services of wetlands.

**RESULT AND DISCUSSION**

**Table 2: Count data for the frequency of the ecosystem service scores**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Ecosystem service** | **N** | **++** | **+** | **0** | **-** | **--** | **L** | **R** | **G** |
| Fresh water | 38 | 11 | 15 | 3 | 9 | 0 | 26 | 0 | 0 |
| Food | 38 | 12 | 19 | 3 | 4 | 0 | 29 | 1 | 0 |
| Fuel | 38 | 0 | 0 | 38 | 0 | 0 | 0 | 0 | 0 |
| Fibre | 38 | 0 | 0 | 38 | 0 | 0 | 0 | 0 | 0 |
| Genetic resources | 38 | 0 | 0 | 36 | 1 | 1 | 0 | 0 | 0 |
| Natural medicines and pharmaceuticals | 38 | 0 | 0 | 37 | 1 | 0 | 0 | 0 | 0 |
| Ornamental resources | 38 | 0 | 2 | 35 | 1 | 0 | 0 | 0 | 0 |
| Clay mineral, aggregate harvesting | 38 | 0 | 1 | 36 | 0 | 1 | 0 | 0 | 0 |
| Energy harvesting from natural air and water flows | 38 | 0 | 0 | 38 | 0 | 0 | 0 | 0 | 0 |
| Air quality regulation | 38 | 2 | 24 | 5 | 6 | 0 | 28 | 0 | 0 |
| Local climate regulation | 38 | 3 | 24 | 7 | 4 | 0 | 26 | 0 | 0 |
| Global climate regulation | 38 | 0 | 0 | 30 | 8 | 0 | 0 | 0 | 0 |
| Water regulation | 38 | 0 | 21 | 13 | 4 | 0 | 21 | 0 | 0 |
| Flood hazard regulation | 38 | 0 | 13 | 12 | 13 | 0 | 13 | 0 | 0 |
| Storm hazard regulation | 38 | 0 | 0 | 18 | 20 | 0 | 0 | 0 | 0 |
| Pest regulation | 38 | 0 | 0 | 12 | 26 | 0 | 0 | 0 | 0 |
| Disease regulation human | 38 | 0 | 0 | 15 | 21 | 1 | 0 | 0 | 0 |
| Disease regulation livestock | 38 | 0 | 0 | 14 | 23 | 1 | 0 | 0 | 0 |
| Erosion regulation | 38 | 0 | 14 | 13 | 11 | 0 | 14 | 0 | 0 |
| Water purification | 38 | 1 | 4 | 26 | 7 | 0 | 5 | 0 | 0 |
| Pollination | 38 | 0 | 16 | 14 | 8 | 0 | 16 | 0 | 0 |
| Salinity regulation | 38 | 0 | 0 | 32 | 6 | 0 | 0 | 0 | 0 |
| Fire regulation | 38 | 0 | 0 | 38 | 0 | 0 | 0 | 0 | 0 |
| Noise visual buffering | 38 | 0 | 0 | 34 | 4 | 0 | 0 | 0 | 0 |
| Cultural heritage | 38 | 2 | 10 | 25 | 1 | 0 | 12 | 0 | 0 |
| Recreation and tourism | 38 | 4 | 10 | 24 | 0 | 0 | 14 | 0 | 0 |
| Aesthetic value | 38 | 2 | 11 | 25 | 0 | 0 | 13 | 0 | 0 |
| Spiritual and religious | 38 | 1 | 8 | 29 | 0 | 0 | 9 | 0 | 0 |
| Inspirational value | 38 | 0 | 2 | 35 | 1 | 0 | 2 | 0 | 0 |
| Social relation | 38 | 0 | 16 | 22 | 0 | 0 | 16 | 0 | 0 |
| Education and research | 38 | 0 | 3 | 32 | 3 | 0 | 3 | 0 | 0 |
| Soil formation | 38 | 0 | 4 | 25 | 9 | 0 | 4 | 0 | 0 |
| Primary production | 38 | 0 | 14 | 17 | 7 | 0 | 14 | 0 | 0 |
| Nutrient cycling | 38 | 0 | 1 | 22 | 16 | 0 | 1 | 0 | 0 |
| Water recycling | 38 | 0 | 1 | 22 | 15 | 0 | 1 | 0 | 0 |
| Provision of habitat | 38 | 0 | 0 | 22 | 16 | 0 | 0 | 0 | 0 |

**Table 3: Tree species distribution around studied wetlands of Raipur, Chhattisgarh**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Common name of tree** | **Botanical name** | **Family** | **Number of wetlands** | **Frequency (%)** |
| Neem | *Azadirachta indica* | Meliaceae | 21 | 55.26 |
| Palash | *Butea monosperma* | Fabaceae | 2 | 5.26 |
| Palm | *Arecales* | Arecaceae | 6 | 15.78 |
| Peepal | *Ficus religiose* | Moraceae | 29 | 76-31 |
| Peltophorum | *Peltophorum pterocarpum* | Fabaceae | 9 | 23.68 |
| Weeping fig | *Ficus benjamina* | Moraceae | 4 | 10.52 |
| Yellow kaner | *Cascabela thevetia* | Apocynaceae | 6 | 15.78 |
| Mango | *Mangifera indica* | Anacardiaceae | 10 | 26.31 |
| Almond | *Prunus dulcis* | Rosaceae | 7 | 18.42 |
| Ashoka | *Saraca indica* | Fabaceae | 2 | 5.26 |
| Eucalyptus | *Eucalyptus globulus* | Myrtaceae | 8 | 21.05 |
| Coconut | *Cocus nucifera* | Arecaceae | 1 | 2.63 |
| Champa | *Magnolia champaca* | Magnoliaceae | 5 | 13.15 |
| Amaltas | *Cassia fistula* | Fabaceae | 3 | 7.89 |
| Sheesham | *Dalbergia sissoo* | Fabaceae | 5 | 13.15 |
| Saptaparni | *Alstonia scholaris* | Apocynaceae | 4 | 10.52 |
| Banana | *Musa acuminate* | Musaceae | 4 | 10.52 |
| Babool | *Vachellia nilotica* | Fabaceae | 12 | 31.57 |
| Indian cherry | *Cordia dichotoma* | Malpighiaceae | 2 | 5.26 |
| Banyan tree | *Ficus benghalensis* | Moraceae | 12 | 31.57 |
| Gulmohar | *Delonix regia* | Fabaceae | 2 | 5.26 |
| Oak | *Quercus species* | Fagaceae | 1 | 2.63 |
| Semal | *Bombax ceiba* | Bombacaceae | 4 | 10.52 |
| Karanch | *Pongamia pinnata* | Fabaceae | 1 | 2.63 |
| Munga | *Moringa oleifera* | Moringaceae | 1 | 2.63 |

**Assessment of Ecosystem Services:**

The RAWES Approach assessment was conducted across 38 urban wetlands of Raipur, which highlighted various contributions among provisioning, cultural, servicing and regulating services.

1. Provisioning Services

Provisioning services are important for human sustenance, especially in urban areas. The study showed that food (++ = 12) and freshwater (++ = 11) were the most significant provisioning services, showing their high suitability to local communities (Table-2). The wetlands that showed the most significant positive categories were those with sufficient water availability and local community dependency for fish, aquatic vegetables, or water supply. In the contrary, other provisioning services such as, fuel, fibre, energy harvesting and fire regulation showed negligible benefits showing non-existence of such resources in the urban wetlands.

1. Regulating Services

The assessment of regulating services showed inconsistent trend. Significantly, air quality and local climate regulation showed positive contributions across 24 of the 38 wetlands assessed, showing the role of urban wetlands in mitigating air pollution minimizing urban heat island effects (Table-2). Wetlands ample in trees, particularly those with high numbers of *Ficus religiosa* and *Azadirachta indica,* were interrelated with aerial scores in this area, establishing the crucial role of vegetation in giving ecosystem services.

In table 2 Observable negative contributions were recorded for pest regulation (- = 26), disease regulation affecting humans ( - = 21) and those effect livestock ( - = 23). These findings indicate a decline in wetland health, definitely a trait to stagnant water, the increase in organic waste and urban pollution, which create favorable environment for pests and diseases.

Services such as storm hazard and flood regulation were inconsistently distributed with 20 wetlands showing negative benefits for storm hazard buffering, mainly due to inadequate vegetative barriers. Such results highlight the need of integrate green infrastructure into urban flood management approaches.

1. Cultural Services

Urban wetlands turn as foremost focus for cultural ecosystem services, hence enhancing community well-being. In this assessment, recreation and tourism (++ = 4, + = 10) were identified as important cultural ecosystem services, especially in wetlands nearby urban parks or defined by aesthetic characteristics (Table-2). Similarly, aesthetic value and cultural heritage services showed intermediate benefits.

Services such as education and research, along through inspirational values and spiritual significance were followed to have limited contributions. This underutilization may cause from a lack of standardize environmental programs or degrade cultural involvement with natural atmosphere.

1. Supporting Services

Most wetlands showed little or no benefits supporting sustainable operation of wetland ecosystems. Especially soil creation, nutrient cycling, and habitat provision showed negative contributions, indicating poor ecological performance. For example, nutrient cycling (- = 16) and water recycling (- = 15) showed disturbed biogeochemical processes, due to urban runoff, pollution and vegetative loss (Table-2). This assessment shows the need of restoring vegetation and lowering contamination.

**Vegetation Analysis:**

Vegetation analysis showed that Peepal (*Ficus religiosa*) is the most common species in around 29 wetlands, followed by Neem (*Azadirachta indica*) and Banyan tree (*Ficus benghalensis*) in around 21 and 12 wetlands respectively (Table-3). The presence of appreciated or ecologically friendly trees points to a link between biodiversity and cultural heritage, therefore underlining the need of plants for offering vital services.

**Calculation of ESI:**

The Ecosystem Services Index (ESI) calculation helped in the quantification and comparison of ecosystem service contributions across different study sites and different service types. Provisioning services and regulating services showed positive contributions as compared to supporting services with limited benefits as observed which shows that the wetlands provide services locally. Further various services such as, storm hazard regulation, disease regulation and nutrient cycling showed significant negative benefits because of pollution, urbanization or degradation (Fig 1 and 2).

Highest ESI is showed by food (0.487), which indicates strong provisioning services. Climate regulation, air quality, water regulation (0.26-0.41), indicating regulating services. Whereas, pest and disease regulation, nutrient cycling showed negative contributions in ESI. Recreation and tourism (0.342) showed positive contribution in cultural services (Fig-3).

Fig 1: Assessment of key Ecosystem Services in Urban Wetlands of Raipur

Fig 2: Tree species distribution around urban wetlands in Raipur

Fig 3: Graph showing comparison of four different ecosystem services

**CONCLUSION**

The study of 38 urban wetlands in Raipur using the RAEWS Approach stated that these wetland ecosystem services offer significant provisioning and regulating services, with fresh water, food, air quality and climate regulation were the most beneficial services. However, there are negative scores in regulating services like pest and disease control, nutrient cycling and storm regulation either due to degradation or ecological stress. The presence of various tree species around the wetlands which are culturally important such as, Peepal and Neem shows the combined nature ecological and cultural values. For sustainable urban planning, implementing ecosystem service assessments in decision making is important by enhancing public participation, promoting vegetation and implementing pollution control measures. These measures are key to improve the health and functioning of urban wetlands. The RAWES framework is an effective participatory tool in quantifying and capturing ecosystem services and thus enabling long term conservation strategies.

**Disclaimer (Artificial intelligence)**

All the authors declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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