

Ecosystem Service Assessment – Police Lines Wetland



Prepared Under HCL Foundation Supported Project entitled “Promoting Conservation and Sustainable Management of Urban Biodiversity in Noida”.

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List of Acronyms

BCR	Benefit-Cost Ratio
BOD	Biological Oxygen Demand
DBH	Diameter at Breast Height
DO	Dissolved Oxygen
EPA	Environmental Protection Agency
ES	Ecosystem Service
GEAG	Gorakhpur Environmental Action Group
MoEFCC	Ministry of Environment, Forest and Climate Change
MoJS	Ministry of Jal Shakti
NGO	Non Governmental Organization
NPV	Net Present Value
RP	Revealed Preference
SOC	Soil Organic Carbon
TEV	Total Economic Value
TOC	Total Organic Carbon
U. P.	Uttar Pradesh
WTP	Willingness To Pay





1. Wetland Ecosystem

Significant ecological services provided by urban wetlands include water supply, waste treatment, local climate regulation, and flood control

According to the National Wetland Atlas (2011), wetlands constitute 4.6% of India's land area (15.26 million ha) (Murthy et al, 2013). The Ramsar Convention defines wetlands as "areas of marsh, fen, peat land, or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish, or salt, including areas of marine water the depth of which at low tide does not exceed six meters" (Ramsar Convention, 2004). With more than 54 percent of the global population living in cities or urban habitats, the management of urban catchments must consider freshwater and wetlands ecosystem management more explicitly (Finlayson et al. 2005).

Within urban landscapes, wetlands provide invaluable services that contribute to local health and well-being. The most significant ecological services provided by urban wetlands are water supply, waste treatment, local climate regulation, and flood control (Millennium Ecosystem Assessment, 2005; Huang et al. 2019).

They serve as natural sponges, absorbing and storing excess rainfall, thereby mitigating floods and reducing the risk of urban flooding. This function is particularly vital in urban areas where impervious surfaces like concrete dominate, leading to increased runoff and drainage issues. By acting as buffers against flooding, wetlands protect infrastructure, properties, and human lives. Furthermore, wetlands act as natural filtration systems, purifying water by trapping sediments and pollutants. This role is indispensable in urban settings where pollution from various sources threatens water quality. Wetlands help to maintain clean water supplies, benefiting both humans and wildlife alike.

Urban wetlands support rich biodiversity, providing habitat for diverse plant and animal species. Despite the constraints of urbanization, wetlands offer refuge for numerous species, including migratory birds, amphibians, and aquatic organisms. Preserving urban wetlands is essential for safeguarding biodiversity and promoting ecological resilience within cities.



Wetlands offer recreational opportunities and aesthetic benefits to urban residents. They provide green spaces for leisure activities such as birdwatching, hiking, and nature photography. Accessible urban wetlands enhance the quality of life for city dwellers, providing serene environments for relaxation and enjoyment amidst the hustle and bustle of urban life.

In the face of climate change, wetlands play a critical role in enhancing urban resilience. They help to mitigate the impacts of extreme weather events such as storms and heatwaves by providing natural cooling effects and reducing urban heat island effects. Preserving and restoring wetlands can contribute to climate adaptation efforts, making cities more resilient to climate-related challenges.

Several studies have shown that wetlands provide vital ecosystem services to urban dwellers (Boyer and Polasky, 2004), offering a multitude of benefits ranging from flood mitigation and water purification to biodiversity conservation and recreational opportunities. Recognizing their significance in urban ecosystems is essential for sustainable urban development and the well-being of urban residents. Protecting and restoring urban wetlands should be prioritized in urban planning and management strategies to ensure resilient, liveable cities for future generations.

Scientists around the world have attempted to identify, quantify, evaluate, and understand the importance of ecosystem services of different wetlands at various scales and perspectives (Banerjee, 2018). Various valuation methods exist and have been applied to estimate the value of different ecosystem services. An important distinction exists between market-based and non-market-based valuation methods. Market-based valuation uses the existing market behaviour and market transactions as a basis for the valuation. Direct markets use price as a reflection of value and then use data from actual markets to estimate direct use values. Unfortunately, direct markets for many goods and services do not exist and direct market price is missing. In such cases, the changes in supply or quality of ecosystem services are often valued through the Revealed Preference (RP) method. When there are no market prices available, RP methods are not possible and when the changes are hypothetical, the stated preference method is used. This method uses surveys to create hypothetical markets using to calculate the value of ecosystem services related to both use and non-use values and that could be applied to all ecosystem service categories.

Total Economic Value (TEV) of services encompassing the 'Use values' (that is, materialistic value) and 'Non-use values' (that is, existence value, altruistic value, and bequest value) has been estimated by adopting diverse methods (Brander et al., 2010; Sharma et al., 2015; Emerton, 2015; Mangi, 2016; Baral et al., 2016). The economic value of provisioning goods may be logically assumed by market prices. The concept of TEV (Turner et al. 1994) serves as a good framework for scoping values and ensuring that, wherever possible, the broadest range of values is considered in decisions relating to the management of wetlands and other natural assets (Brander et al. 2006). In contrast, the estimation of the value of the other three categories is convoluted and doubtful due to the non-marketability of those services (Barbier et al., 2011).

There are several alternative approaches to valuation of ecosystem services from wetlands (Barbier et al. 1997, King & Mazotta, 2001, Wilson & Carpenter, 1999, Stuij et al., 2002, TEEB, 2010).

The relationship between ecosystems and biodiversity is complex and nonlinear. (Naidoo et al., 2008). There arise trade-offs between different types of ecosystem services. For e.g., increasing the provisioning services often comes at the cost of decreased regulating and supporting services.

Ecosystem Service (ES) values cannot and should not be fully translated into economic terms and must be complemented or approached using other tools such as sociocultural analysis (TEEB, 2010). Recent developments in the field include hybrid methodologies that combine non-monetary and monetary methods

Wetlands provide vital ecosystem services to urban dwellers offering a multitude of benefits ranging from flood mitigation and water purification to biodiversity conservation and recreational opportunities.

or multidimensional methods. Depending on the availability of data on relevant ES, the assessment method adopted could be:

a) Qualitative assessment: Describing the importance or judging the state of the relevant ecosystem services, as well as showing the connectivity and interrelations between ecosystems and social and economic systems on a spatial scale (this may serve as a communication and awareness-raising exercise, and highlight often-ignored, but important, ecosystem services).

b) Quantitative assessment: This assessment is used for indicating the increases/decreases in the flow of ecosystem services expected to result from a certain policy; or estimating the number of jobs affected by a problem that could be solved through preserving ecosystem services. Some of these quantitative services can be valued in monetary terms, enabling an economic evaluation.

TABLE 1. Possible Wetland Ecosystem services according to Millennium Ecosystem Assessment (Finlayson et al. 2005).

Sl. No.	Services	Parameters	Indicators
1.	Provisioning	Food	Production of fish
		Freshwater	Storage and retention of water Provisioning of water for irrigation
		Fibre and fuel	Production of fodder
		Genetic material	Medicine
2.	Regulating	Climate regulation	Regulation of greenhouse gases Regulation of temperature/microclimate
		Hydrological regime	Groundwater recharge and discharge
		Pollution control and detoxification	Nutrient retention Recovery and removal of excess nutrients
		Erosion protection	Retention of soils and prevention of structural changes
		Natural hazard	Flood control Storm protection
		Pollination	Support for pollinators
3.	Cultural	Spiritual and inspirational	Personal feelings and well being
		Recreational	Opportunities for tourism/ Opportunities for recreational activities
		Aesthetics	Appreciation of natural features
		Educational	Opportunities for formal and informal education and training
4.	Supporting	Biodiversity	Habitat for residents and transient species
		Soil formation	Sediment retention Accumulation of organic matter
		Nutrient cycling	Storage recycling, processing, and acquisition of nutrients

Biodiversity forms the basis for all ecosystems, but a biodiverse ecosystem services does not necessarily provide more ecosystem than a less diverse ecosystem.

2. The Study Area: Police Lines Wetland

The Police Lines wetland is a restored urban wetland in Police Lines, Gautam Budh Nagar district (Figure 1). The waterbody has a total perimeter of 0.45 km and a total surface area of 1.21 hectares. The wetland on its eastern boundary is an extension of the Surajpur Bird Sanctuary, an urban wetland in the Yamuna River basin in Greater Noida. The Police Lines wetland, after restoration has rendered many benefits to the residents around the wetland. The residents of the police line are government servants and thus do not hold the land ownership rights. The area is under the control of the UP Police Commissionerate.

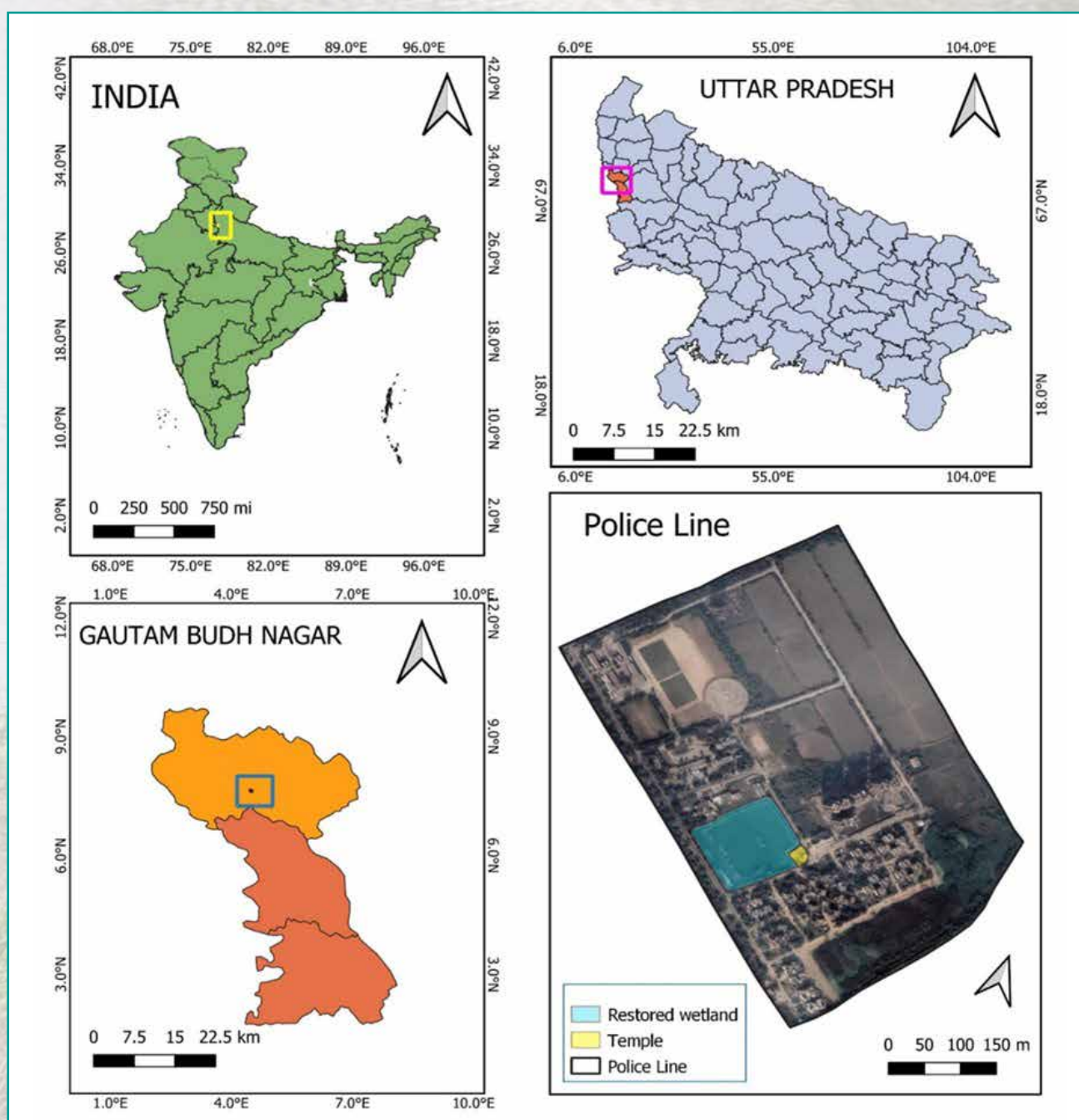


FIGURE 1. Location of the Wetland

Police Lines, Gautam Budh Nagar, where the water body is located, is part of Dadri Tehsil, a populous sub-district in the Gautam Budh Nagar district. The district is experiencing rapid development and urban sprawl, since it is part of the NCR. The Police Lines settlement, occupying around 67.57 sq. acres, was established in 2005. At least 1,820 police officers and their families, making up approximately 370 households, live in this area.

The water body is a natural patch of shallow water that lies on the eastern boundary of Police Lines, Gautam Budh Nagar district. It extends from 77°28'50.2" E to 77°28'58.8" E and 28°31'50.0"N to 28°31'35.0"N. The police line wetland was rejuvenated in August 2020 by the Gorakhpur Environmental Action Group (GEAG), with support from HCL Foundation on the recommendation of the UP Police Commissionerate. The pond was a dumping site and sewage cesspool. The primary goals for the rejuvenation of the pond were the enhancement of groundwater recharge and various ecosystem services. The restoration initiative focused on addressing wastewater management and solid waste management, along with pond rejuvenation as summarized in Figure 2.

The primary goals for the rejuvenation of the pond were the enhancement of groundwater recharge and various ecosystem services.

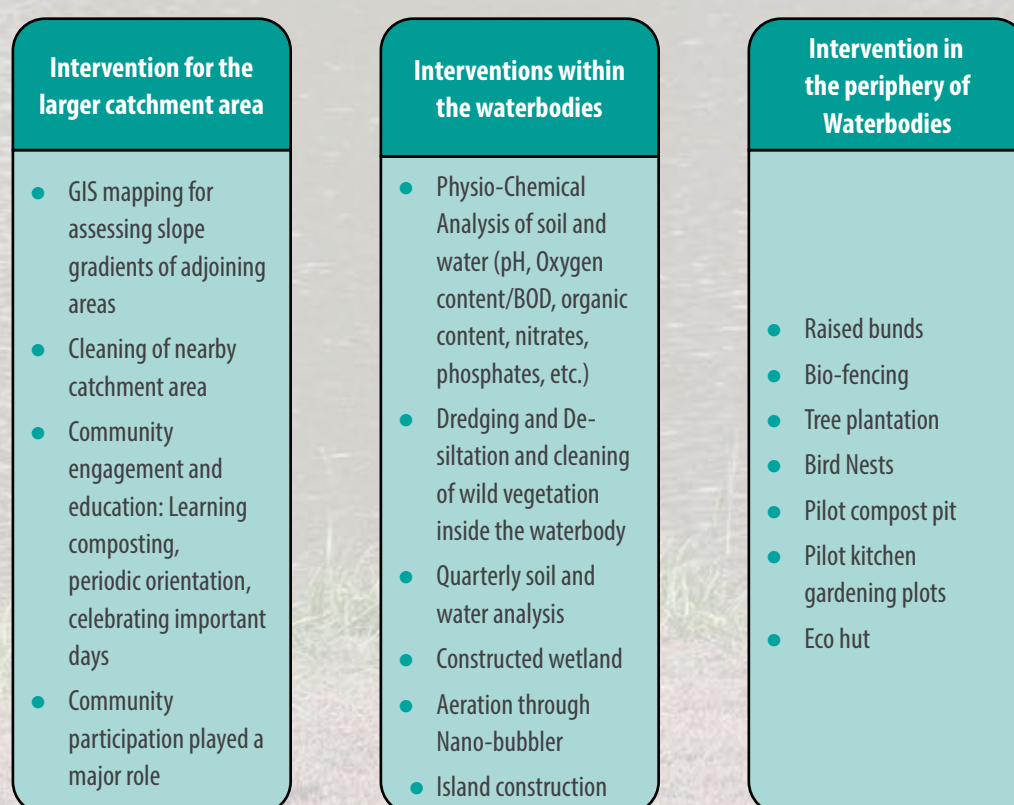


FIGURE 2. Summary of the interventions at Police line wetland

The aquatic flora of the water body consisted mainly of *Eichornia crassipes*, *Lemna major*, *Lemna minor*, *Ipomoea aquatica*, *Phragmites karaka*, *Enhydra fluctans*. Invasive plants including *Parthenium hysterophorus*, *Lantana camara*, were dominant and abundant in the open fields.

The Police Lines wetland has served as a dump yard for solid waste and sewage from Police Lines households. The effective interventions by GEAG in collaboration with HCL Foundation have not only improved the wetland but also improved overall quality of lives of the residents. The wetland offers provisioning, regulating, cultural, and supporting services that generate economic value from their direct, indirect, or potential use.

The present study was therefore undertaken with the aim of understanding the ecosystem services rendered by the restored wetland at Police Lines. Quantifying the benefits provided by wetlands provides evidence to support the narrative of incorporating them into the decision-making process related to wetland restoration and management.

3. Methodology

The methodology followed, comprised of primary data collection (through questionnaire survey and stakeholder consultations), literature review and data analysis. The same is depicted in Figure 3.

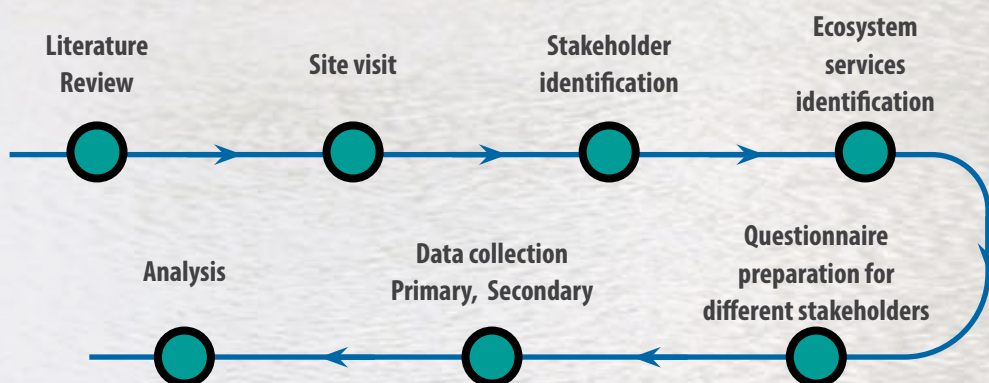


FIGURE 3. Methodology

3.1. Literature Review

An extensive literature review was carried out on ecosystem services and their possible quantification techniques. A preliminary list of ecosystem services provided by the wetland was compiled through a literature review and expert consultations.

3.2. Initiation Activities

Several initiation activities were undertaken. These activities as given below, were designed to provide a holistic understanding of the wetland's ecosystem, engage with stakeholders, and gather essential information for subsequent assessment steps.

3.2.1. Preliminary Site Visits

A preliminary site assessment was carried out to gather first-hand knowledge about the wetland's current condition, key features, and potential ecosystem services. This involved field visits, mapping, and observations of the wetland area.

3.2.2. Stakeholder Identification

A comprehensive list of stakeholders involved with or impacted by the wetland restoration initiative was developed. This included local communities, government agencies, NGOs, research institutions, among others, as detailed below:

- **Residents:** The people living around the wetland area directly interact with and depend on the restored wetland's ecosystem services. Their insights and involvement is critical for the success of any restoration initiative. The Police Lines comprises 370 households. The residents enter the wetland area for the recreational, educational, and aesthetic services, it provides.
- **Visitors:** Apart from residents, non-residents also visit the wetland for recreational benefits and fodder collection.

Initiation activities were designed to provide a holistic understanding of the wetland's ecosystem, engage with stakeholders, and gather essential information for subsequent assessment steps.

The Ministry of Jal Shakti (MoJS) identified 255 districts and a total of 765 urban local bodies across the country as water-stressed, of which Gautam Budh Nagar is one.

- **Government Agencies and Departments:** Various government bodies such as Ministry of Environment, Forests and Climate Change (MoEFCC), Ministry of Jal Shakti (MoJS), UP Police Commissionerate, and Greater Noida authority are key stakeholders. They provide regulatory frameworks, policy guidance, and necessary approvals for restoration projects. UP Police Commissionerate holds the land ownership. The Ministry of Jal Shakti identified 255 districts and a total of 765 Urban Local Bodies, across the country as water-stressed, of which Gautam Budh Nagar is one. The Police Line restoration initiative is aligned with the Jal Shakti Mission.
- **Non-Governmental Organizations (NGOs):** Gorakhpur Environmental Action Group (GEAG) played a major role in the execution of the wetland rejuvenation initiative. They are also responsible for regular monitoring and maintenance of the restored wetland. Currently, four people are involved with the activities at the restored wetland. Apart from GEAG other NGOs are also involved in activities related to awareness campaigns. Environmental and conservation-focused NGOs played an active role in wetland restoration by mobilizing resources, conducting awareness campaigns, and implementing on-ground restoration activities.
- **Researchers:** Researchers and research institutions contributed technical expertise, data collection and analysis, helped in evidence-based decision-making, and assisted in monitoring the progress of restoration efforts. The initiative encourages research in various domains of environmental sciences. Small-scale project work by researchers was carried out on the site as well.
- **Birdwatchers and Nature Enthusiasts:** Individuals and groups passionate about wildlife and nature conservation often visit the wetland. They can advocate for proper restoration practices, habitat protection, and the overall well-being of the wetland's flora and fauna.
- **Educational Institutions:** Local schools were engaged with to generate awareness among students about wetland ecosystems and their importance. Awareness campaigns and educational activities were often organized by GEAG in five schools, namely Yakubpur government school, Kuleshra composite school, Jalpura government school, Salarpur composite school and Naglacharan government school.
- **Religious Leaders:** Wetlands have cultural or spiritual significance and involve associated religious practices, which create a sense of reverence for the ecosystem. Restoration of the wetland has led to the increase in the number of devotees as well as religious events being performed.
- **Funder:** HCL Foundation provided all the financial support.
- **Key Stakeholders:** Key stakeholders that were directly involved or impacted by the restoration initiative were separated in this study based on their interconnections (such as dependence, influence, and religious and cultural perspectives) and responsibilities in the restoration and maintenance of the wetland.

3.2.3. Key Informant Interview

Key informant interviews were conducted with the experts, and the management authority familiar with the



FIGURE 4. Direct stakeholders of Police Line wetland

wetland and its history. A list of questions was prepared to understand the site history, ecosystem services, community participation, and changes after the intervention. These interviews provided valuable context, historical information, and insights into the wetland's significance.

3.2.4. Ecosystem Services List Refinement

The preliminary list of ecosystem services was revisited and refined based on the inputs received during the key informant interviews and site assessment.

3.3. Questionnaire Development

Possible wetland ecosystem services and key stakeholders (residents, visitors etc) were identified. Separate questionnaires were prepared for different stakeholder groups to collect data on the ecosystem services, stakeholder perceptions, and questions to gather the details on willingness to pay for maintenance and conservation of the wetland. The questionnaires (Annexure 2 to 5) were validated by Dr. Purnamita Dasgupta, an eminent environmental economist.

3.3.1. Household Questionnaire Survey

This questionnaire survey was conducted (from April to June 2023), among the residents of Police Line area, surrounding the restored wetland. A total of 66 households in Police Lines were covered. Both open-ended and closed-ended questionnaire was used to interview 66 households that were randomly selected. Data was collected on aspects such as demographic characteristics, socio-economic issues such as education and income levels, resources used from wetlands, composting practices, kitchen gardening, religious significance, and so on.

This survey helped to gather quantitative economic data on household use of wetland ecosystem services and also to assess the qualitative changes in the ecosystem services and the local perceptions. Structured survey questionnaire was developed for the same (Annexure 2: Household Survey Questionnaire).

Sampling: The main objective of the household survey was to understand the benefits derived by households and the perspectives of individual respondents. There are approximately 372 households in Police Lines. The sample size was calculated at a 90% confidence interval.

$$n = N \times X/X + N - 1$$

where N = population size (approx. 370 households) (for maximum sample size estimation)

$$X = Z^2 \times p \times (1 - p) / d^2$$

where Z = critical value of normal distribution from the statistical table

p = sample proportion (10%)

d = margin of error (6%)

The sample size for the survey was identified to be 58 households. A total of 66 households were selected as representative, for conducting the household-level survey.

3.3.2. Visitor's Questionnaire Survey

Police Lines residents, several non-residents from Sarin Farms and birdwatchers visit the wetland. A detailed questionnaire was developed to collect responses from these visitors regarding the changes in the wetland and perceptions of the services from the wetland (Annexure 5).

A list of questions was prepared to understand the site history, ecosystem services, community participation, and changes after the intervention.



FIGURE 5. Data collection from households and visitors through questionnaire survey

A contingent valuation approach was adopted to assess the monetary values for maintaining and conserving the wetland.

3.3.3. Discussions with Purohits

The wetland hosts a temple, which had perceived a significant change in visitor density after the wetland rejuvenation. To map these changes two purohits of the temple were interviewed (Annexure 4).

3.4. Data Collection

The survey involved on-site data collection. The primary data was collected through the questionnaire survey while the secondary data regarding the water quality status, monitoring data, documentation and expenditure was collected from project authorities.

3.5. Ecosystem Service Assessment

The ecosystem services were assessed through multiple approaches. Both qualitative and quantitative assessment methods were used. A mix of direct and indirect techniques were adopted for the assessment of monetary values. The methodology for valuation of the uses of the wetland in Police Lines followed includes the following

3.5.1. Provisioning Services

Wetland restoration produces provisioning benefits like fodder, flowers, compost etc. Compost is used in kitchen gardens. The monetary value of these benefits and the income generation from these activities has been calculated by considering the number of people consuming or producing these services. Data was collected through secondary sources, as well as through primary surveys.

$$\text{Total Value} = \text{Unit Market Price} * \text{Quantity}$$

3.5.2. Recreational and Other Services

A contingent valuation approach was adopted to assess the monetary values for maintaining and conserving the wetland. The contingent valuation survey was conducted for household respondents and visitors. Respondents were asked what they are willing to pay as a voluntary contribution towards the maintenance of the wetland in its improved (current) condition. The respondents were presented with the follow-up question to elicit their maximum Willingness To Pay (WTP).

Separate questions were posed to household respondents and visitors. Respondents who were willing to pay for maintaining the wetland, were asked for their maximum WTP. Reasons for not being willing to pay were also asked and documented for respondents who declined to pay for the maintenance of the wetland (refer questionnaire in Annexure 2 and 5).

3.5.3. Wetland Carbon Stock Estimation

Two parameters were considered for the estimation of the carbon stock of wetlands: Total/Dissolved organic carbon, and soil organic carbon. (Zhu, 2010; Lele et al, 2020).

Total Organic Carbon (TOC): Two water samples from the wetland were collected (Figure 6). TOC was estimated using a total carbon analyzer.

Soil Organic Carbon (SOC): Two soil samples (10cm x 10cm x 10cm) were taken from the wetland and the carbon stock density was calculated (Pearson et al., 2007):

$$SOC = rb \times d \times \%C$$

where,

SOC = Soil organic carbon stock per unit area (t/ha), rb = Soil bulk density (g/cm³)

d = Total depth at which sample is taken (cm),

%C = Carbon concentration- estimated by the Rapid titration method (Walkley-Black method).

The total carbon stock was converted to tones of carbon equivalent using the factor 3.67 (IPCC,2003) and the social cost of carbon was applied (Ricke et al., 2018) (1 US\$ = INR 82.6).



FIGURE 6. Collection of a water sample from the wetland at Police Lines



4. Biodiversity Surveys

Opportunistic sampling was carried out in all the seasons at Police Lines wetland, in order to document the biodiversity. The species documented are detailed in Annexure 6 to 9. A detailed pictographic depiction of the trees, along with their height and diameter at breast height (DBH) was also developed (refer Annexure 10). Table 2 summarises the ecosystem services and the data collection approach.

TABLE 2. List of ecosystem benefits that have been assessed and quantified for the restored wetland

Ecosystem services	Quantitative Indicators	Monetisation/ Financial Value	Data collection
Biomass (Fodder/ Flower)	Yes	Yes	Household/visitor
Water storage	Yes		Management questionnaire
Hydrological regime	Yes		Secondary data
Wastewater treatment	Yes		Secondary data
Carbon sequestration	Yes	Yes	Primary data
Recreation	Yes	Yes	Household/ visitor survey
Religious value	Yes		Site survey/ Household survey
Biodiversity	Yes		Surveys
Kitchen garden	Yes	Yes	Household survey
Compost	Yes	Yes	Household survey/ site survey
Employment generation	Yes		Locals employed for maintenance



5. Descriptive Findings on Respondents

5.1. Socio-economic Profile

5.1.1. Household Characteristics

A total of 66 households were visited for face-to-face interviews in Police Lines, around the restored wetland. Most of the families residing in the Police Lines have belong to Meerut, Bhagpat, Shamli, and Muzzafarnagar regions of Uttar Pradesh. The respondents were majorly female (73%) with only 27% being male (Figure 7). The average age for respondents stood at 34 years. Most respondents were between the 31-41 age group, followed by the 21-31 age group (Figure 8).

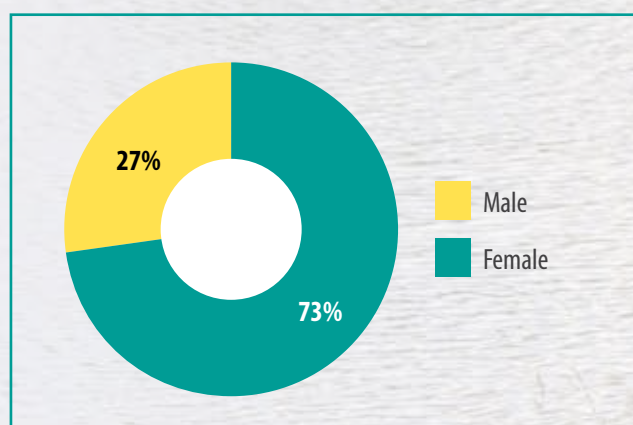


FIGURE 7. Respondents' gender profile

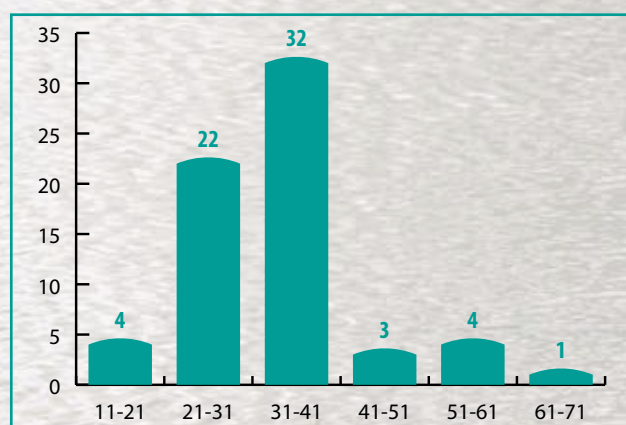


FIGURE 8. Respondent's age structure

48% of respondents interviewed were working in the Government sector, followed by homemakers and students constituting 41% and 11%, respectively (Figure 9). 51% of respondents said they have graduated from university, while 28% have completed secondary education and 16% have attained primary level education. 5% of respondents said they had attained no formal education (Figure 10).

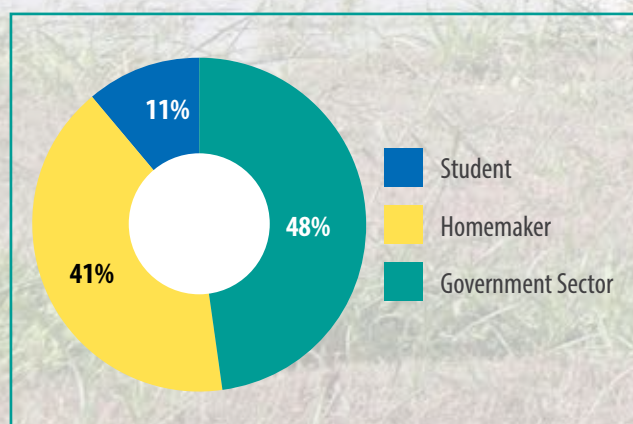


FIGURE 9. Occupation of respondents

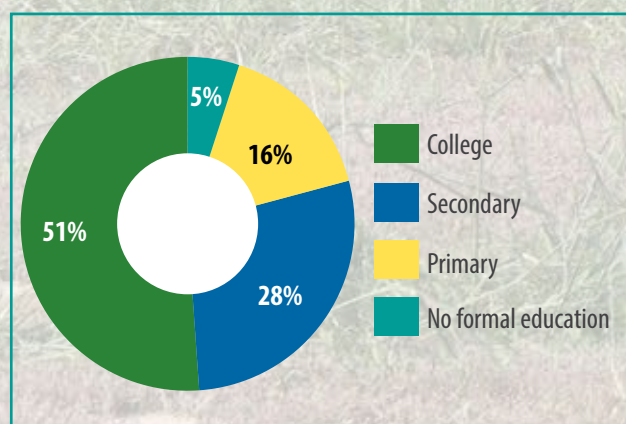


FIGURE 10. Respondents' education status

Table 3 details the household structure including the percentage of men or women in the households interviewed, average household size, and the different occupations that the community members are involved in.

TABLE 3. Household structure of surveyed residents

Gender	
Male (%)	53
Female (%)	47
Average household size	4
Occupation (%)	
Homemaker	22
Government sector	33
Private sector	4
Student	36
Self-employed	5

The result of the analysis revealed that the households surrounding the wetland were comprised of 53% males and 47% females. The average household size was four people. The major occupation was found to be in Government services (33%).

5.1.2. Household Income

The households were asked about their monthly income based on pre-fixed income categories. Majority (44%) of households interviewed earn between INR 21,000- 49,000 per month while 21% earn less than INR 20,000 and 35% earn more than 50,000, per month (Figure 11).

5.1.3. Period of Residence

38% of the households surveyed have been staying for 5-10 years, followed by 33% staying for 1-5 years and 23% have been residing at Police Lines for more than 10 years. This indicates that most respondents interviewed were aware of wetland's pre-and-post restoration condition. Only 6% have moved to Police Lines within the last year (Figure 12).

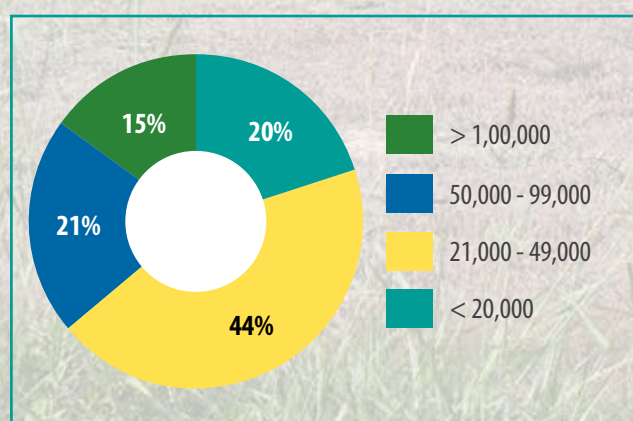


FIGURE 11. Household income structure

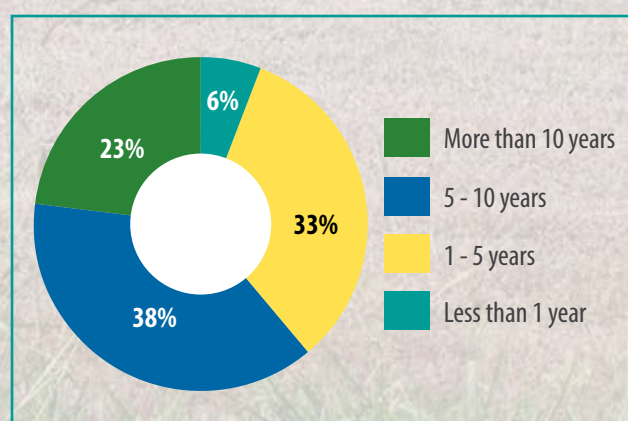


FIGURE 12. Period of residence at Police Lines

5.2. Visitors Profile

The wetland is a popular spot for Police Lines residents to spend leisure time. The restored wetland has also enhanced the beauty of the area. The wetland is also visited by several non-residents including those from Sarin Farms Society, bird watchers, and some fodder collectors. The data on visitors was collected through a questionnaire survey to capture their perceptions of the restored wetland and the initiative. A total of 78 visitors were interviewed in, of which 59% were female and 41% were male (Figure 13).

The occupation of respondents fell under 5 categories – Student, Government sector, private sector, homemaker, and self-employed. 51% of respondents were students, followed by homemakers (22%). Government and private employees constituted 15% and 7% respectively. 5% were self-employed or owned businesses (Figure 14).

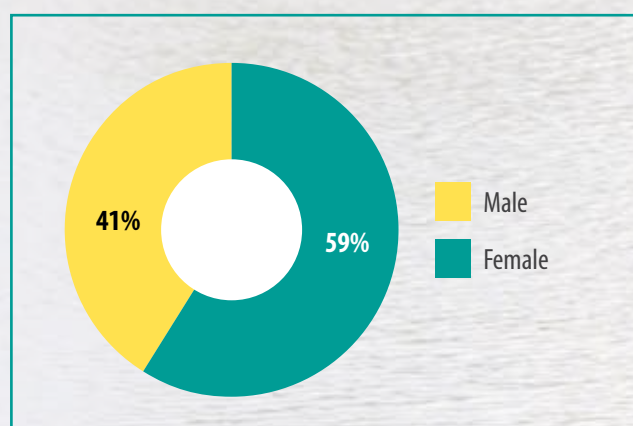


FIGURE 13. Gender profile of visitors

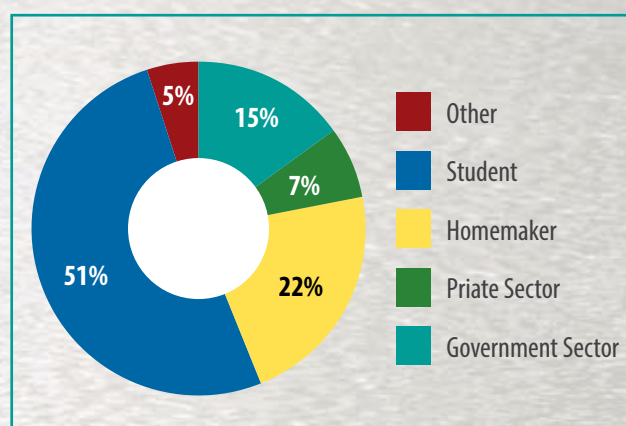


FIGURE 14. Occupation structure of visitors

Local residents comprised 83% of the visitors, while the remaining 17% was comprised of residents from Sarin Farms Society or nearby areas (Figure 15).

Among the residents who visit the wetland, 52.3% were students, 24.6% home makers and 18.5% have government jobs. Similarly, non-residents who visited were mainly students (46.15%). Private sector employees and people with other occupations (like business) comprise 23.08% of the visitors (Figure 16).

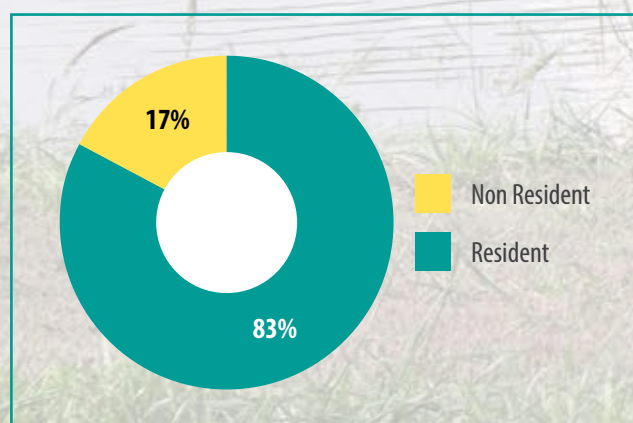


FIGURE 15. Residential status of visitors

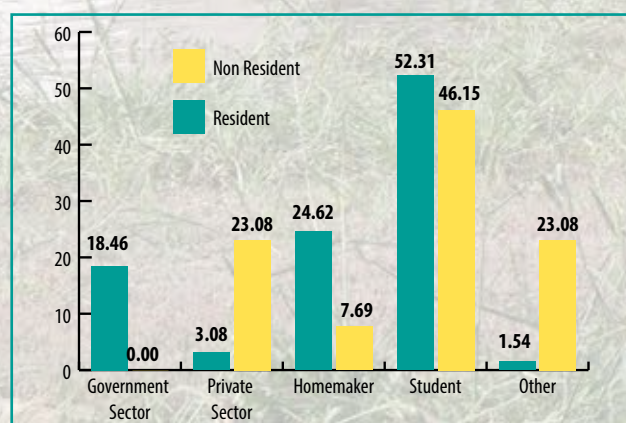


FIGURE 16. Occupation disaggregated by residential status

45% of respondents have been visiting the wetland since 2 years, while 25% have been visiting since 3 years, indicating that 70% of respondents are aware of the wetland restoration initiative (Figure 17). In fact, over the last two years the number of non-residents visiting the wetland has increased (Figure 18). 51% of the visitors come to the wetland on weekly basis and 45% are daily visitors. Visitors coming to the wetland on monthly basis constituted 1% while 3 of the visitors were first time visitors (Figure 19). The frequency of visits by residents was found to be higher, when compared with non-residents (Figure 20).

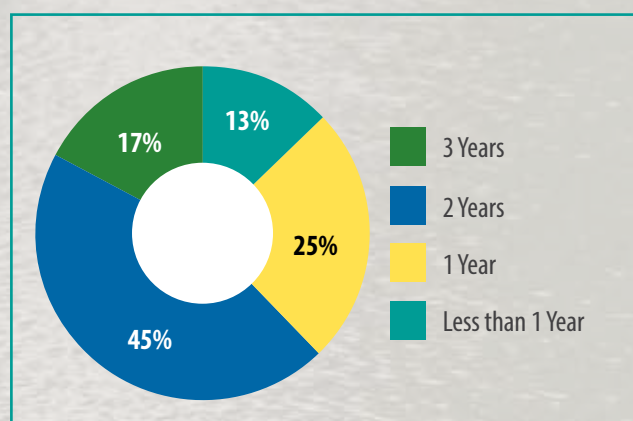


FIGURE 17. Visiting history of respondents

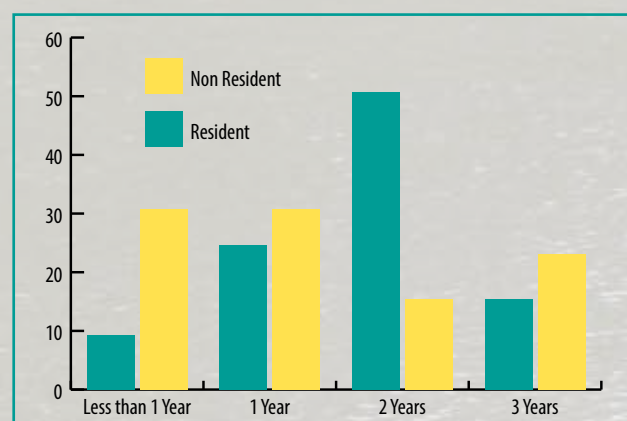


FIGURE 18. Visitor numbers over the years, disaggregated by residential status

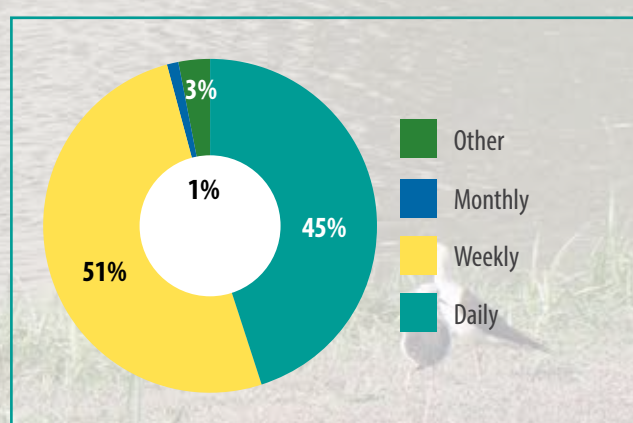


FIGURE 19. Frequency of visits

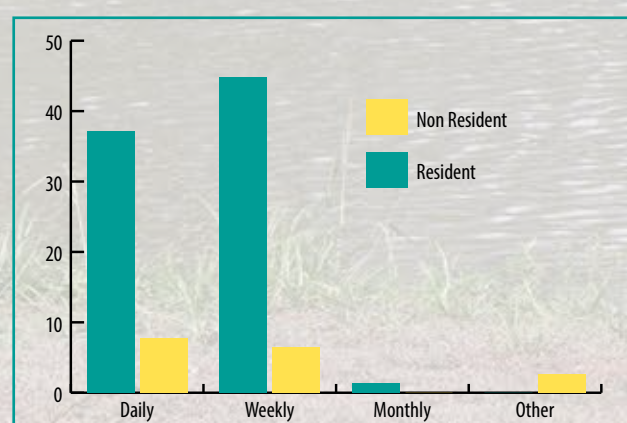


FIGURE 20. Visiting frequency disaggregated by residential status

The wetland is also visited by several non-residents including those from Sarin Farms Society, bird watchers, and some fodder collectors.

Enjoying the natural environment, walking, bird watching, photography, religious purpose, fodder collection, and attending educational events were among the reasons cited for visiting the wetland. Most of the respondents visit the wetland to enjoy nature (44%), followed by for physical exercise (35%). 13% of the respondents came to attend the events organized by the GEAG, of which the majority were students. 4% of respondents visit for the purpose of photography followed by bird watching (2%). Some visitors (1%) were witnessed performing the religious practice of *Mandap siya* at the wetland and the rest 1% collected fodder from the wetland. When disaggregated by residential status, it indicated that residents and non-residents mostly use the wetland for its cultural services, i.e. nature watching, physical exercise and events. In terms of provisioning services, 8% of non-resident visitors collect fodder (Figure 21 and Figure 22).

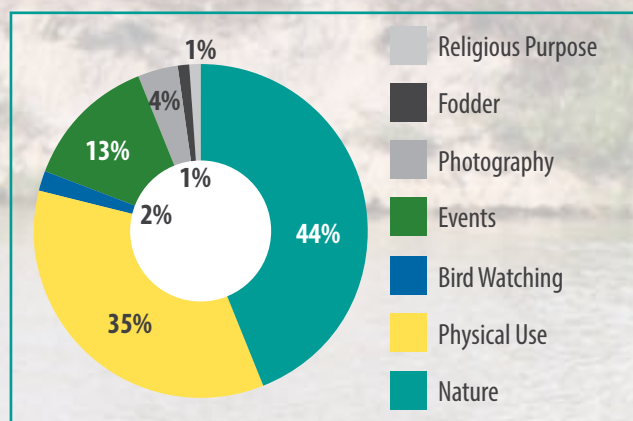


FIGURE 21. Reasons for visiting the wetland

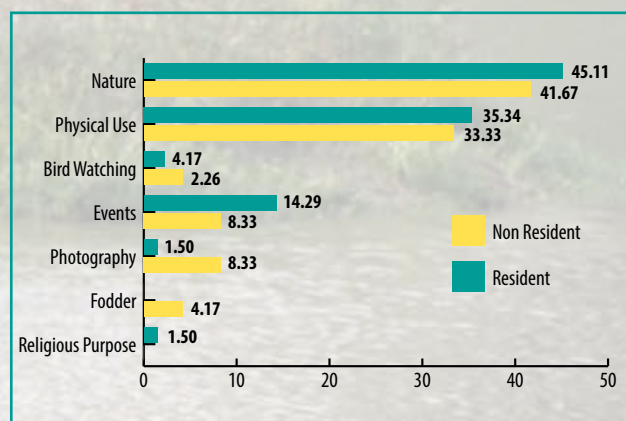


FIGURE 22. Reasons for visiting the wetland, disaggregated by residential status

Over the past years, visitors have witnessed several changes in the area, biodiversity, and water quality of the wetland. The visitors stated that the area of the wetland has increased. The aesthetic appeal of the wetland and the surrounding area has increased over the years. According to most visitors, birds coming to the wetland have also increased (Figure 23).

In order to understand the perception of change due to restoration, the visitors who have been coming to the wetland for less than a year were removed, from the analysis. It was seen that all the visitors who had seen the wetland in pre-and post-restoration phases, greatly appreciate the positive impacts (in terms of increase in area under the wetland, visitor density, improvement in water quality, vegetation, bird sighting and aesthetics), due to the initiative (Figure 24).

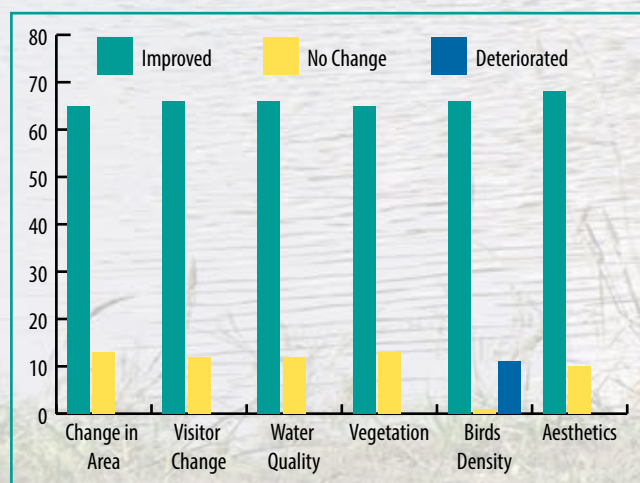


FIGURE 23. Visitor's perception of changes in the wetland

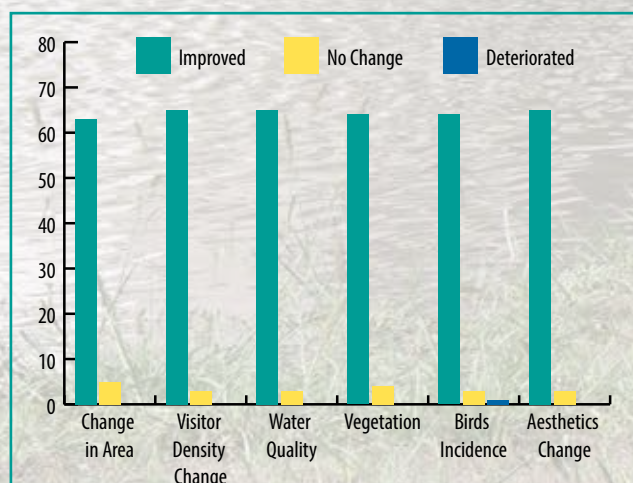


FIGURE 24. Visitor's perception of changes in the wetland (with inputs of the visitors who had come for one year or less, removed)

6. Ecosystem Services Assessment

All the respondents stated that they receive several benefits from the restored wetland. The findings from the assessment are documented in this section.

6.1. Provisioning Services

The wetland and the restoration initiative provide many direct benefits to the residents of Police Lines. These benefits include kitchen garden, compost, flowers, and fodder. More than one-third of households (35%) have used at least one of these benefits. 35% of households either contribute to compost production or produce their own compost using the small compost units provided by GEAG. 32% of households maintain kitchen gardens, using seeds and training provided by GEAG, as part of the community engagement activities, which are an integral part of the restoration initiative (Figure 25). These ecosystem services were previously (pre-restoration) absent. Therefore, all these ecosystem services listed below have increased by 100%, since the restoration initiative.

The aesthetic appeal of the wetland and the surrounding area has increased over the years. According to most visitors, birds coming to the wetland have also increased.

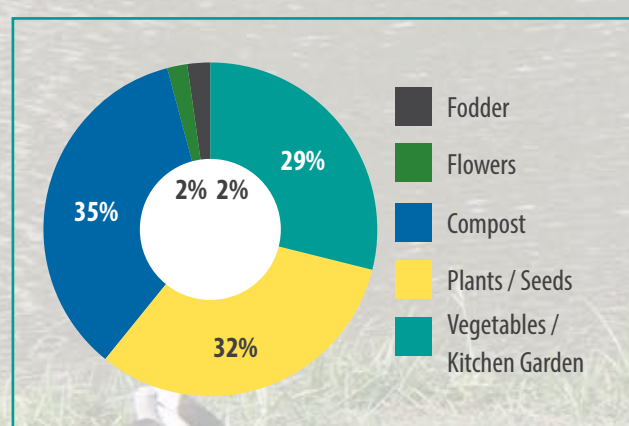


FIGURE 25. Provisioning services used by households

6.1.1. Fodder

One household in the neighbourhood of Police Lines collects fodder from the wetland. During the survey, it was also found that a few non-residents in the vicinity of the wetland also collect fodder. The fodder collected by the respondents is 2,880 kg per year, which is worth INR 14,400 (Table 4). Approximately one-third of their fodder requirements are met from the restored wetland, as reported by the households.

TABLE 4. Quantity of fodder collected from the wetland and its price

Fodder	Quantity	Quantity/ Month(kg)	Quantity / Year (kg)	Price @ INR5 / kg
Resident	30kg/week	120	1440	7200
Non-resident	10-12kg/3 days	100-120	1440	7200
Total			2880	14400

6.1.2. Flowers

One of the respondents collects flowers from the wetland on a regular basis for worship. The price of the equivalent quantity of flowers (for worship), in the local market, for was used to estimate the monetary value of these flowers collected (refer Table 5).

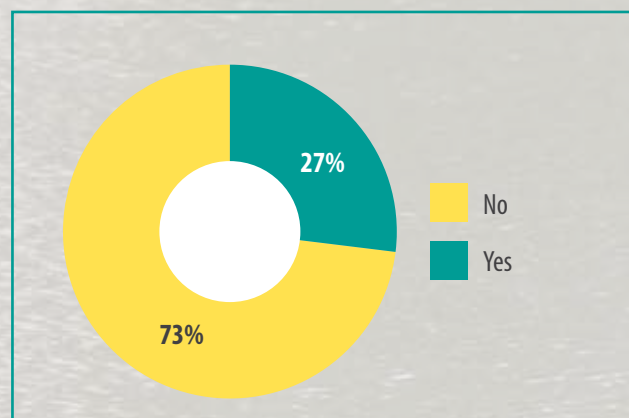


TABLE 5. Quantity of flowers collected from wetland and its pricing

Flower name	Quantity (no.)	Quantity in Year (no.)	Price per year (@5 flowers/INR 5)
Tecoma stans	20 / month	240	240

6.1.3. Kitchen Garden

A total of 27% of households are engaged in kitchen gardening (Figure 26). GEAG provides seeds and technical inputs for the development of these gardens.

**FIGURE 26.** Households with kitchen garden

The vegetables grown and their yield in a year was documented, along with their market price. Ridge gourd along with bottle gourd and tomato are the most frequently grown vegetables (Figure 27). On estimating the yield of these gardens and the market rates (as per July 2023) of the vegetables, it was found that they contribute monetary benefits worth INR 30,050 in a year (Table 6).

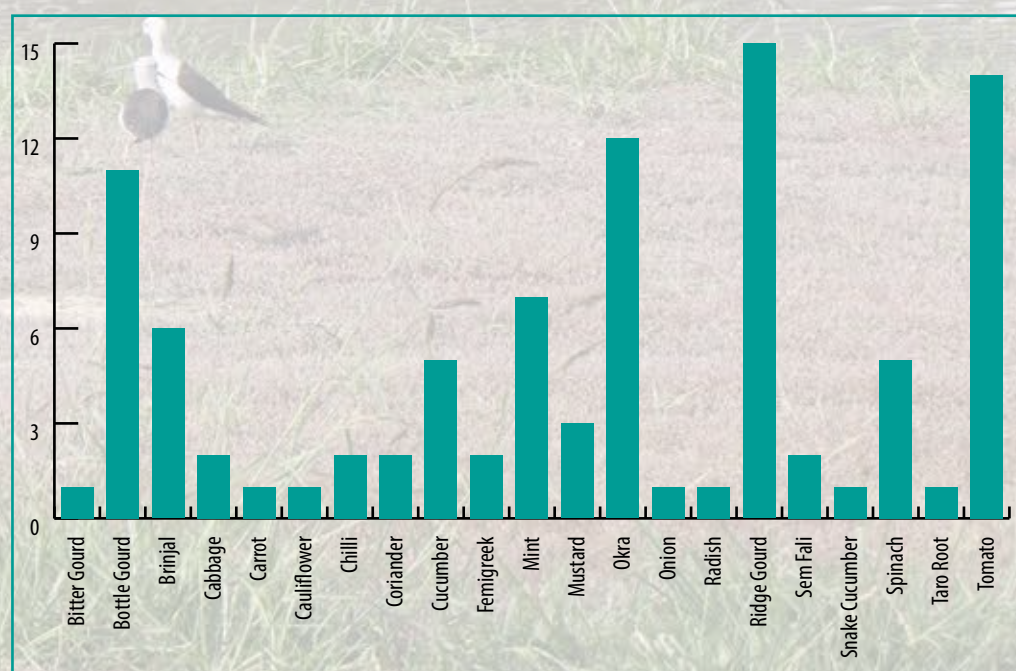
**FIGURE 27.** Vegetables grown by number of households per year in kitchen gardens

TABLE 6. Quantity and Price of vegetables grown in Kitchen Gardens

Vegetables	No. of households	Yield (kg)/year	Rate (INR per kg)	Price (INR)
Bitter gourd	1	2	40	80
Bottle gourd	11	81	40	3240
Brinjal	6	42	40	1680
Cabbage	2	15	40	600
Carrot	1	25	40	1000
Cauliflower	1	1	60	60
Chilli	2	6	100	600
Coriander	2	10	100	1000
Cucumber	5	19	40	760
Fenugreek	2	4	40	160
Mint	7	17	150	2550
Mustard	3	12	40	480
Okra	12	41	60	2460
Onion	1	6	30	180
Radish	1	6	80	480
Ridge gourd	15	113	40	4520
Lima Beans	2	13	80	1040
Snake Gourd	1	5	30	150
Spinach	5	36	40	1440
Taro root	1	2	60	120
Tomato	14	149	50	7450
				30,050

33% of surveyed households either contribute green waste to the compost pits set up by GEAG or produce their own compost using the small compost unit provided by GEAG

6.1.4. Compost

33% of surveyed households either contribute green waste to the compost pits set up by GEAG or produce their own compost using the small compost unit provided by GEAG (Figure 28).

It was found that 15% of the households contribute green waste to the compost pit, with an average of 900 gm of green waste added per day from each household (Figure 29, Table 7).

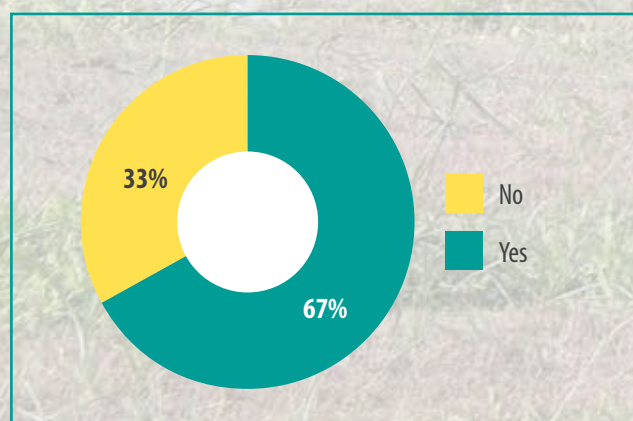
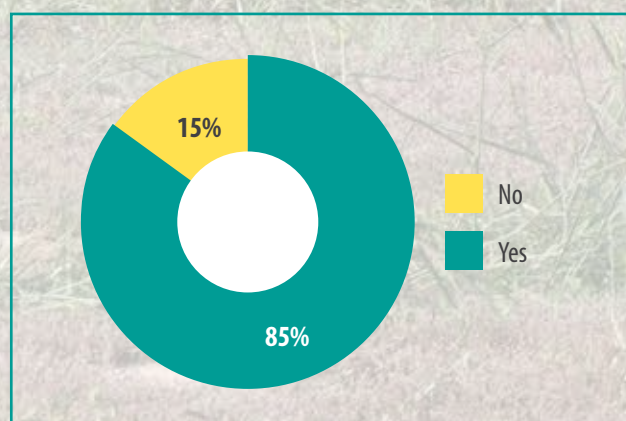
**FIGURE 28.** Households contributing to compost production**FIGURE 29.** Green waste contribution by households to the compost pit

TABLE 7. Green waste contribution by participating households

Quantity in gm	No. of household	Total quantity per day
1000	4	4000
200	4	800
500	3	1500
300	1	300
3000	2	6000
Total	14	12,600gm/ day

A total of 12.6 kg/day is contributed to the compost pit by the households surveyed, which works out to be 4,599 kg of green waste contributed per year. In addition, 3,229 kg of kitchen waste is processed yearly in the 22 small compost pits provided by GEAG.

Compost unit

A total of 15% of households own compost units and produce their own compost from their green waste. Some households keeping livestock also use cow dung to produce compost.

In addition, 4100 kg of vermicompost is generated annually (per. comm. GEAG).

6.2. Cultural Ecosystem Services

The restoration of the wetland has not only contributed to the ecological balance but has also revitalized the cultural significance of the area, fostering a deeper connection between the community and the environment. While cultural services are often challenging to monetarily quantify, their value is immense in terms of enhancing the overall quality of life and well-being of the residents. The restoration of the wetland goes beyond ecological benefits; it has enriched the cultural fabric of the community and strengthened the bond between humans and nature. These have been detailed below.

6.2.1. Recreational Value

There is absence of a visitor register at the wetland. Thus, there is no record of the actual number of visitors who come to the wetland. Nevertheless, Police Lines residents visit the wetland area regularly. There were no visitors to the wetland before the restoration took place. This number has increased since the intervention and continues to increase. Most of the visitors as previously detailed in Figure 21, come to immerse themselves in nature and for physical exercise. 98% of the resident respondents stated that there has been a rise in the number of visitors from the previous year (2022) with an average visitor change of 22% (Figure 30).

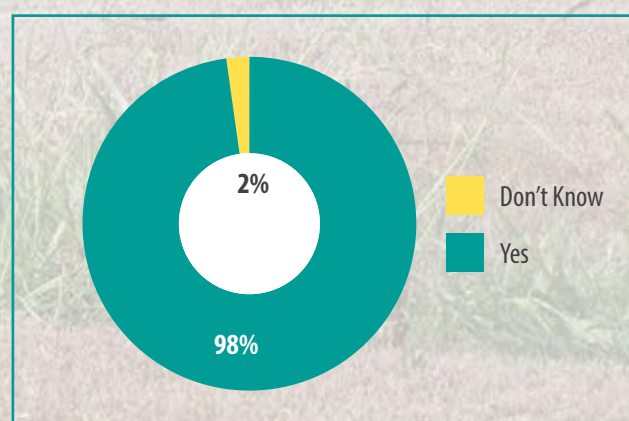


FIGURE 30. Perception of visitors with regard to change in number of visitors

The restoration of the wetland has not only contributed to the ecological balance but has also revitalized the cultural significance of the area, fostering a deeper connection between the community and the environment.

6.2.2. Aesthetic Value

In order to understand the aesthetic value of the area, respondents of the household surveys were asked about their preference for choosing quarters in proximity of the wetland. This proxy indicator reflected the aesthetic value provided by the restored wetland. 71% of households responded that if given a choice, they would prefer to have their quarters near the wetland (Figure 31).

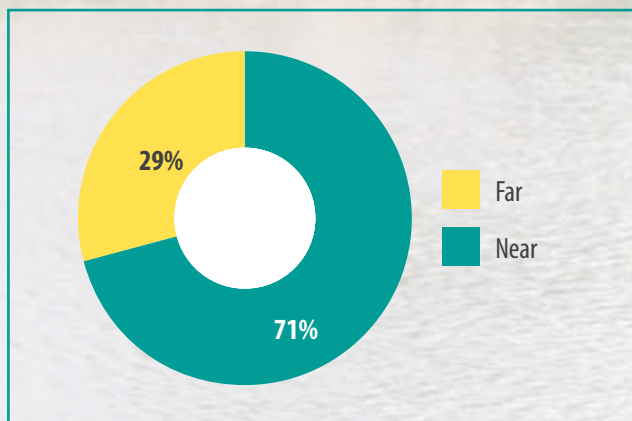


FIGURE 31. Preference of respondents with regard to distance of quarters from the wetland

6.2.3. Religious Value

Before the restoration initiative, the wetland area had little to no religious significance due to neglect and degradation. However, post restoration efforts, the wetland has gained religious significance and has seen an increase in associated religious practices. The presence of cleaner waters, thriving flora, and a serene ambiance has resulted in religious practices and rituals being performed by the residents. Households were asked about their awareness of religious significance and practices performed at the wetland. 26% of respondents agreed with the statement that the wetland has a certain religious significance associated with it (Figure 32).

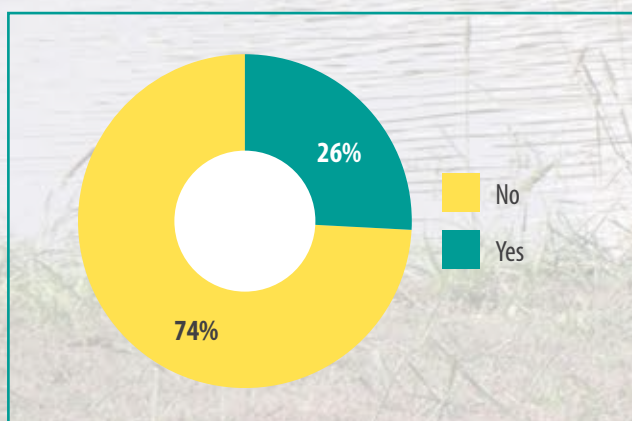


FIGURE 32. Religious significance associated with the wetland

According to the local purohit and from the household surveys, the number of people performing religious rituals has increased at the wetland since 2020. 24% of respondents (Figure 33) stated that there was an increase in the number of people performing religious rituals at the wetland. According to the purohit, the rejuvenation of the wetland has led to a 10% increase in the number of visitors to the temple. He also stated that there have been other benefits like cleanliness and an aesthetic environment that have come due to the restoration of the wetland.

The presence of cleaner waters, thriving flora, and a serene ambiance has resulted in religious practices and rituals being performed by the residents.

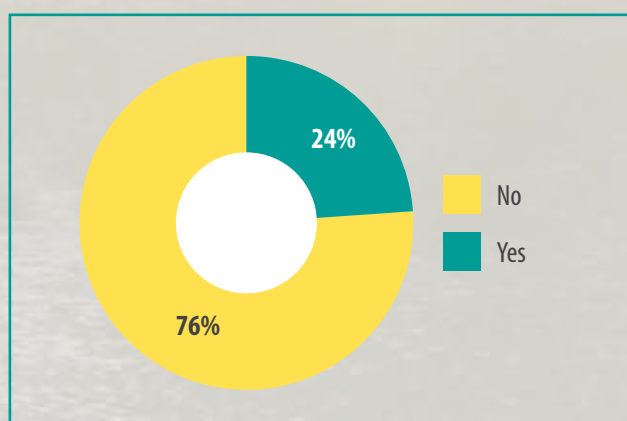


FIGURE 33. Proportion of people performing religious rituals

Religious practices performed by the households were also recorded (Table 8). The main activity performed at the wetland as per the responses was fish feeding and diya silai.

TABLE 8. Religious practices performed at the wetland

Kua Pujan
Bhagwat Path
Durga Puja
Janmashtami
Murti Visarjan
Diya Salai
Mandap Siya
Navratri Murti Visarjan
Fish Feeding

6.2.4. Educational Value

The restored wetland has emerged as an open-air classroom and recreational hub for educational institutions and the local community alike. GEAG often organizes campaigns, workshops, and activities, introducing students and residents to the importance of biodiversity, water conservation, and sustainable ecosystems. The wetland acts as an educational laboratory, fostering environmental awareness and nurturing a sense of responsibility towards nature.

6.3. Regulating Services

6.3.1. Carbon Stock Estimation

The value of carbon stock was calculated after considering the parameters: dissolved organic carbon and soil organic carbon. The percentage SOC in the wetland is 0.75% which was converted to tonne/ha carbon stock using bulk density 1.191 g/cm³ and 10 cm depth.

TABLE 9. Carbon stock estimation

Carbon pool	Carbon stock (tonne/ha)	Area (ha)	Carbon stock (in tonnes)
Soil organic carbon	9.014	1.21	10.90
Total			10.90

The restored wetland has emerged as an open-air classroom and recreational hub for educational institutions and the local community alike. GEAG often organizes campaigns, workshops, and activities, introducing students and residents to the importance of biodiversity, water conservation, and sustainable ecosystems.

The total soil carbon stock of the wetland was found to be 10.90 tonnes (Table 9). The total carbon stock was converted to tonnes of carbon equivalent using the factor 3.67 and the social cost of carbon (US\$86) was applied. The US\$ value was further converted to INR using a conversion rate of US\$1 = INR 82.6. The economic value of the carbon storage service provided by the Police Lines wetland is INR 2,84,346.

6.3.2. Wastewater Treatment

In order to restore the Police Lines wetland, a constructed wetland was established. The constructed wetland treats the waste water, before the water enters the wetland. The amount of sewage water that is treated by the constructed wetland per day is 90 cu m/day (pers.comms. GEAG). An analysis of the water quality parameters was carried out for the wetland. The results are summarised in Table 10.

TABLE 10. Water quality parameters of the wetland

Parameters	Description
pH	The pH value of pond water lies between the range of 7.5 and 8.8 which is within the permissible limit (6-9) according to the EPA. The slightly alkaline pH value is favourable for the growth of primary producers.
BOD	The BOD of the pond water has come down from 17 mg/l to 11 mg/l (post restoration), which is within the permissible limit. A decreasing value of BOD indicates that the amount of dissolved oxygen has increased, which is good for aquatic life.
DO	The dissolved oxygen content has been increased from 6.8 mg/l to 7.3 mg/l (post restoration), which is good for the survival of the pond aquatic life.
The overall water analysis report indicates that the wetland water quality has improved when compared to pre-restoration and is good for the survival of aquatic life.	

6.3.3. Hydrological Regimes

The main aim of the restoration initiative was to enhance groundwater recharge by improving water holding capacity. The water holding capacity of the water body prior to the intervention was 7,986 cu.m. which has increased by 144% to 19,524 cu.m. after the intervention (per. comm., GEAG).

6.4. Supporting Services

6.4.1. Habitat for Biodiversity

Biodiversity surveys conducted for five taxa showed distinct increases across three (plants, birds and arthropods) and no change for two (herpetofauna and mammals). This indicates that the wetland has witnessed increase in biodiversity, post restoration (Table 11 and Figure 34).

TABLE 11. Taxa surveyed before and after the restoration initiative

Taxa	Before Restoration (Source: GEAG)	After restoration (Source: ICLEI South Asia)	Percentage increase
Flora	62	86	27.9
Avifauna	37	71	47.8
Herpetofauna	7	7	0
Mammals	6	6	0
Arthropoda	4	22	81.8

The main aim of the restoration initiative was to enhance groundwater recharge by improving water holding capacity. The water holding capacity of the water body prior to the intervention was 7,986 cu.m. which has increased by 144% to 19,524 cu.m. after the intervention

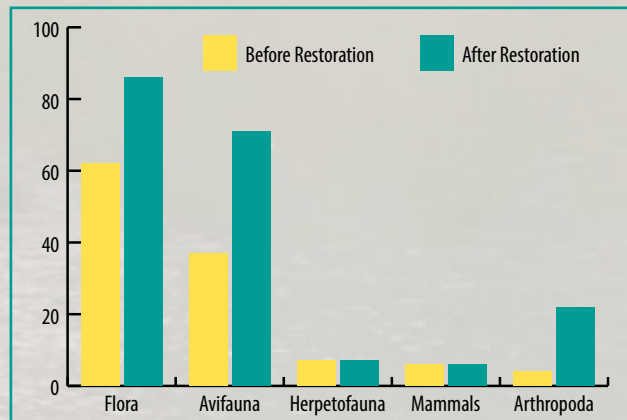


FIGURE 34. Comparison of increase in the number of species across five taxa surveyed at Police Lines Wetland

6.5. Willingness to Pay

6.5.1. WTP Survey in Households

92% of surveyed households in Police Lines were willing to pay for the conservation and maintenance of the wetland, while 8% were not willing to make monetary contributions (Figure 35).

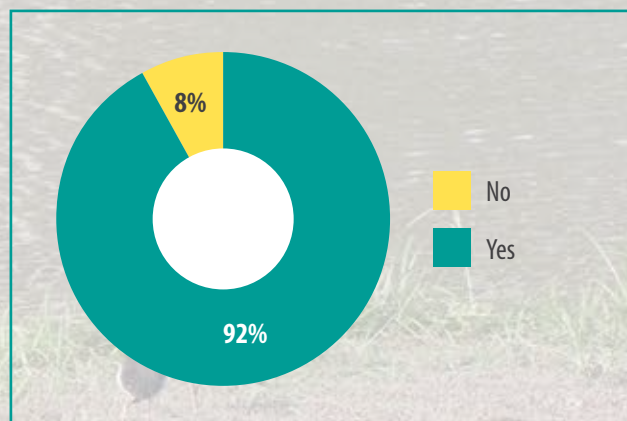


FIGURE 35. Households' willingness to pay

59% indicated a contribution to the maximum amount of INR 100 monthly to maintain the present wetland in Police Lines, 20% stated a monthly contribution of INR 50 and 15% indicated a monthly contribution of INR 200. 6% of respondents quoted INR 500 as their maximum monthly contribution (Figure 36).

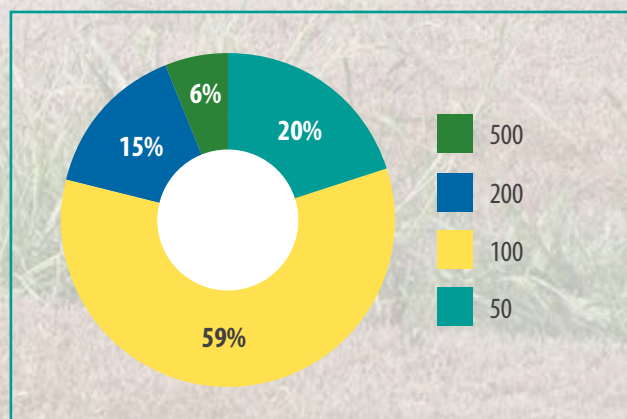


FIGURE 36. Willingness to pay in terms of monthly contribution from the residents

Average individual monthly WTP	INR 129
Average yearly WTP	$\text{INR}129 * 12 = \text{INR } 1,548$
Total Annual WTP (extrapolated to the total population)	$\text{INR } 129 * 12 * 372 = \text{INR } 5,75,856$

Respondents who were not willing to pay anything felt that the wetland should be managed through national or international funds. Some did not consider the wetland as important enough to pay for its conservation. One respondent was willing to volunteer for wetland conservation, but not contribute monetarily as he was not in a position to put any value on nature (Figure 37).

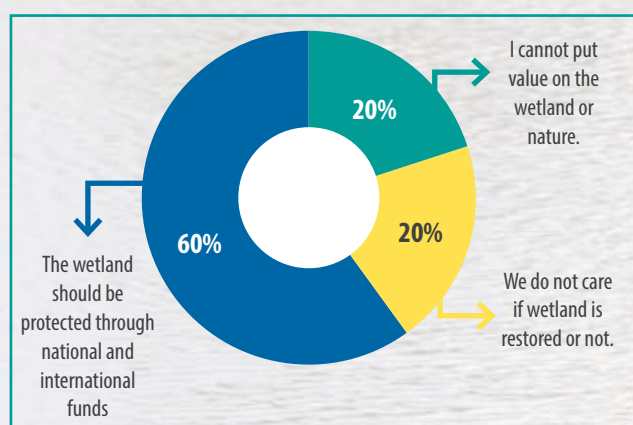


FIGURE 37. Reasons for not being willing to pay

WTP was seen to be higher among the respondents who have stayed at Police Lines for a longer duration (more than one year at least). These respondents have seen the benefits from wetland restoration (as they have been there from pre-restoration time) and thus appreciate its significance better (Figure 38).

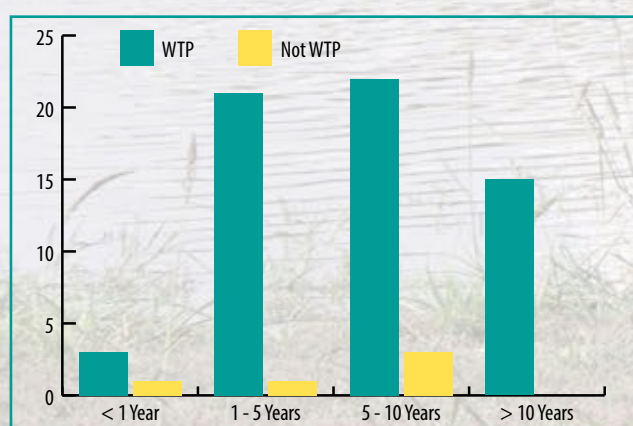


FIGURE 38. Comparison of WTP with duration of stay at Police Lines

6.5.2. WTP Survey Among Visitors

A detailed questionnaire was used to elicit the WTP from the visitors for increased recreational and aesthetic benefits from the wetland. The visitors were then asked to state how much they would be willing to pay as a monthly gate fee for the maintenance and provision of recreational benefits. 94% of visitors were willing to pay for the conservation of the wetland (Figure 39) with the average maximum WTP of INR 47.

45% of visitors selected INR 20 as their maximum WTP as the monthly gate fee followed by 33% and 21% who selected the monthly contribution of INR 10 and INR 50 respectively. Only 1% were willing to go as high as INR 100 per month (Figure 40).

Respondents who were not willing to pay anything felt that the wetland should be managed through national or international funds.

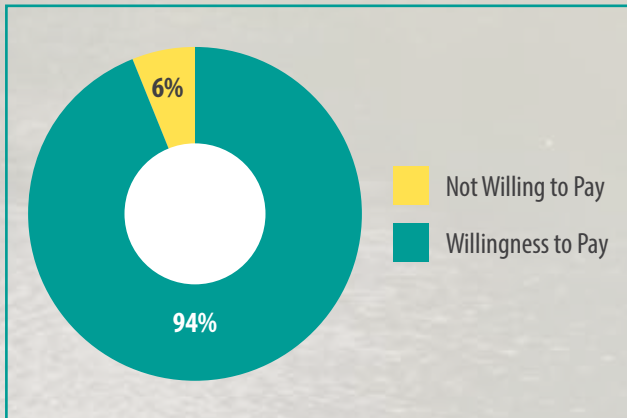


FIGURE 39. Visitor's willingness to pay

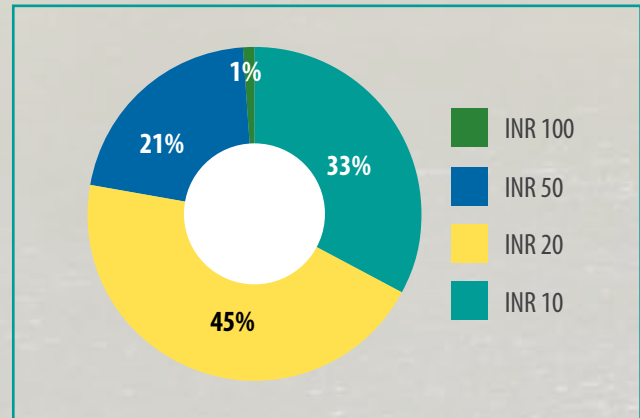


FIGURE 40. Willingness to pay amount as gate fee

A total of INR 1,750 was the present amount that respondents of the survey were willing to contribute as a monthly entry fee to access the wetland, which would go towards its conservation and maintenance. Extrapolating this figure to an annual one, INR 21,000 can be expected for a year from a total of 73 visitors. The representative WTP for a gate fee, based on the visitor responses is approximately INR 24, per person per month.

80% of the visitors who expressed the view that they are not willing to pay stated that the protection of the wetland should be carried out through national or international funds. 20% of the visitors who are not willing to pay expressed that it is not financially feasible for them to afford the same (Figure 41).

Both male and female visitors expressed their willingness to pay. However women seem to value the wetland a little more (95.6% women were willing to pay, as compared to 90.6% men).

Higher WTP by Police Lines households and visitors signifies a stronger bond between the community and the wetland, suggesting that restoration efforts align with community preferences and aspirations.

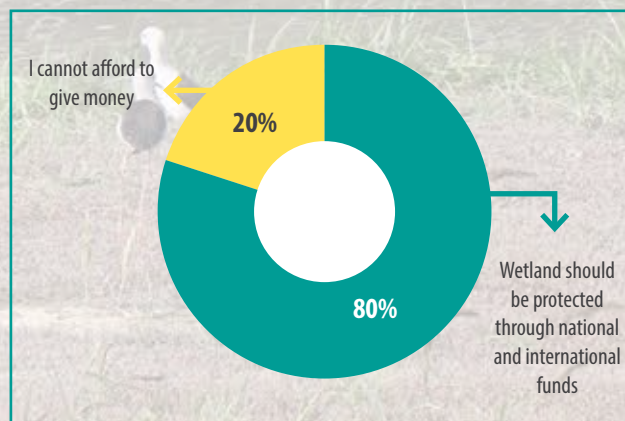


FIGURE 41. Reasons of visitors for not being willing to pay

A comparison of the WTP among residents and visitors shows that 97% of the residents are agreeable to the same. 80% of the visitors expressed WTP.

Higher WTP by Police Lines households and visitors signifies a stronger bond between the community and the wetland, suggesting that restoration efforts align with community preferences and aspirations. This alignment is crucial for the success of any restoration initiative, as community support plays a pivotal role in ensuring the sustainability and long-term maintenance of the restored ecosystem. The community's WTP provides adequate evidence for policy makers to look into policy level interventions for this wetland.

7. Summarising Wetland Benefits

Table 12 demonstrates the benefits accrued by the community via utilization of goods and services. This table also presents the estimated value of the goods/services from the wetland, in terms of monetary or other relevant units, based on the opinion of the beneficiaries. All the ecosystem benefits that are present due to the restoration initiative show a 100% increase in ecosystem services.

People's perception on wetland conservation was evaluated through their willingness to pay. Respondents were willing to pay for the conservation and maintenance of the wetland. The awareness on the need for the conservation of the Police Lines wetland was high among the residents. A considerable difference between residents and non-residents has been observed regarding awareness of ecosystem services.

TABLE 12. Monetary valuation of the assessed services from the wetland

Ecosystem Service	Number of households	Monetary Value (INR)	Total Value (INR)
Fodder	372	14400*6	86400
Flower	66	240*1	1333
Kitchen Garden	66	30050	166944
Household Compost	66	90000	500000
Vermicompost	372	328000	328000
Compost pit	372	193740	193740
Carbon	Entire Wetland	284346	284346
Total			1560763*

*Only tangible benefits can be monetized

Assumption: All 66 households are representative of the total pool of 372 households, in terms of dependence on ecosystem services.

TABLE 13. Impact due to other ecosystem services

Ecosystem Service	Impact
Recreational	22 percent increase in visitors
Religious	24 percent increase in people performing religious rituals 2 percent increase in devotee contribution to temple

TABLE 14. Willingness to Pay

Type	Contribution (INR)	Total Amount (INR)
Households	129/household/month	575856
Visitors	24/visitor/month	21000
Total		596856*

*The alternative valuation of the services of the wetlands can thus be stated as approximately INR 600000/-

The awareness on the need for the conservation of the Police Lines wetland was high among the residents. A considerable difference between residents and non-residents has been observed regarding awareness of ecosystem services.

Conservation efforts have traditionally paid little attention to ecosystem services, or the economic values associated with it. In fact, the problem is not that wetlands have no economic value, but rather that this value is poorly understood, rarely articulated

Cost Benefit Analysis of the Initiative

A simple cost-benefit analysis is conducted to assess the merits of the pond restoration initiative from a financial investment perspective. Available estimates on costs incurred in setting up the initiative and its maintenance, and the estimated benefits from the evaluation exercise were used to project, and build a series on the costs and benefits over a period of 20 years from the start of the project. The net present value is also computed using a social discount rate of 4% (MoEFCC 2021)*. The findings are presented below:

Start Year (Year 1) : **2020**

Total Costs: Year 1: **INR 2595218.8**

Maintenance Costs (Annual): Year 2 onwards: **INR 550000**

Total Benefits (Annual): Year 3 onwards: **INR 1560763**

Results for a 20 year period:

Total Monetized Values (INR)	Costs: 13045218.8	Benefits: 28093734
Benefit – Cost Ratio (undiscounted)	2.15	
NPV (annual); INR	4,41,314.79	

The benefit-cost ratio (BCR) confirms the financial feasibility of the investments made in restoring the pond as the ratio is not only greater than 1, it indicates that the benefits yielded over the lifetime of the restoration project will be more than double the costs incurred. The restoration breaks even in the 5th year of its operation. The net present value accruing over the project period averages to an annual value of approximately 4.41 lakhs.

Notes:

- Costs and benefits are expressed in 2022-2023 prices
- The opportunity cost of land is not included in this analysis
- Benefits are assumed to accrue from the year 2022-2023
- Office Memorandum, MoEFCC, 2021. https://forestsclearance.nic.in/writereaddata/meeting_notice/22_Jan_2021_1945255701DraftCoSNoteonNPVrevision.pdf

Urban wetland preservation and restoration is a crucial step in the direction of the sustainable management of cities. Maintaining wetlands in urban areas faces many challenges, such as the reduction of hydrological functions, changed water regimes due to barriers, contamination by wastewater, habitat loss due to land-use change, and loss of biodiversity due to the entry of alien species (Alikhani et. al, 2021).

Conservation efforts have traditionally paid little attention to ecosystem services, or the economic values associated with it. In fact, the problem is not that wetlands have no economic value, but rather that this value is poorly understood, rarely articulated, and as a result is frequently omitted from decision-making (Emerton, 2003). A major factor contributing to the loss of wetlands is that decision-makers often have insufficient understanding of the economic values of these wetlands (Schuyt, et al. 2004).

The value of wetlands and their associated ecosystem services has been estimated at US\$14 trillion annually (Constanza et al., 2007). Yet many of these services, such as the recharge of groundwater, water purification or aesthetic and cultural values are not immediately obvious when one looks at the wetland. Planners and decision-makers at many levels are frequently not fully aware of the connections between wetland conditions and the

provision of wetland services and the consequent benefits for the people, benefits which often have substantial economic value (De Groot et al. 2006). Sustainable management of wetlands is crucial for the welfare of local communities. However, the management of the wetland often does not remain a priority and is recognized as an unproductive wasteland, mainly due to poor realization of the economic value of the wetlands.

Urban wetlands provide various ecosystem services and vital suppliers to human communities (Boyer et. al, 2004). Wetlands contribute to the liveability of cities by improving the water quality, and carbon sequestration, providing habitats for wildlife species, reducing the effects of urban heat islands, and creating recreation opportunities (Ampatzidis et. al, 2020).

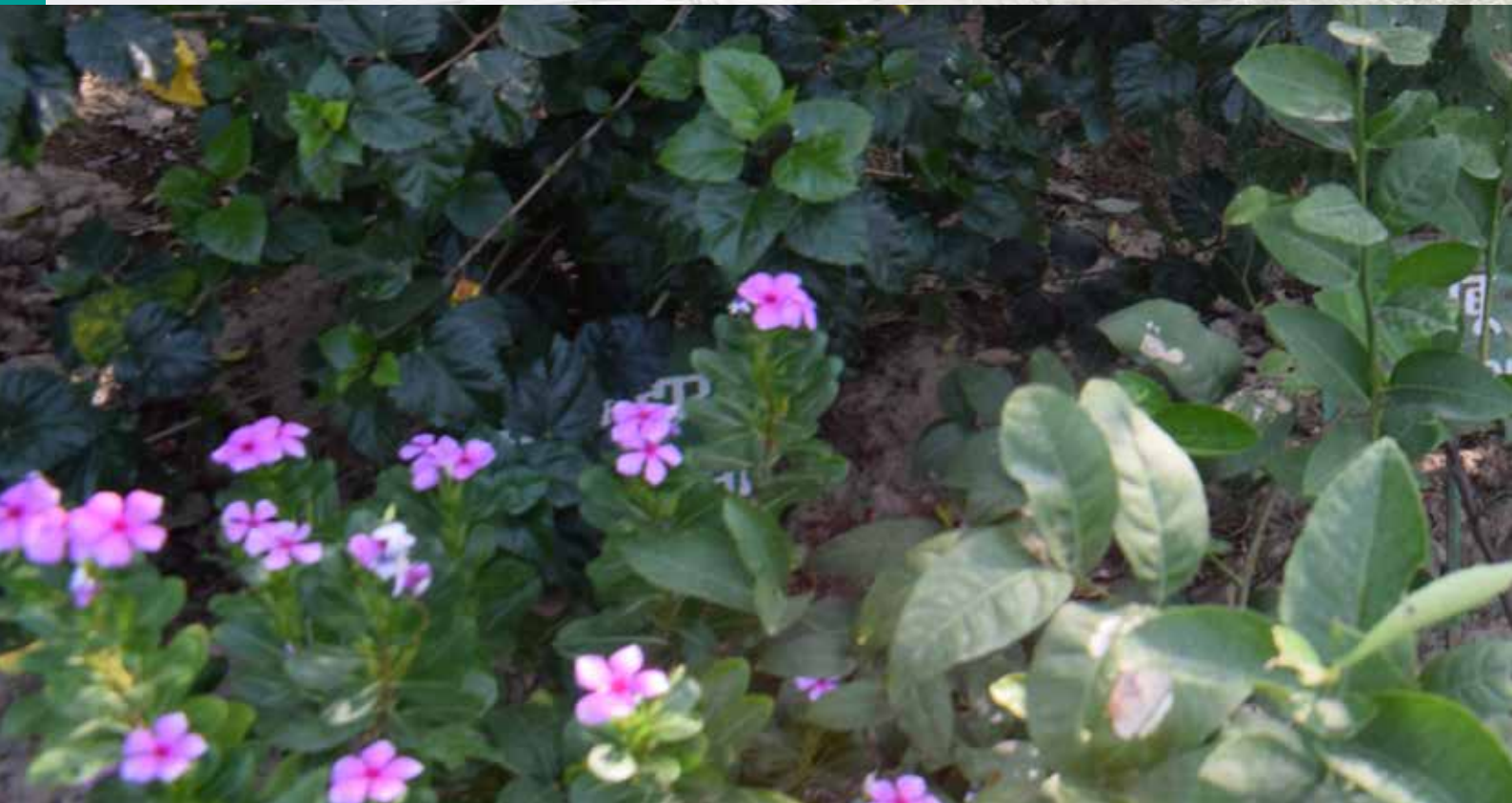
Police Lines wetland, has a positive benefit-cost ratio. The project benefits thus outweigh the costs. The benefits are infact higher, if the non-tangible ones are also taken into account. This restored wetland thus presents a perfect example of the successful partnership between the community and authorities involved, in the implementation of nature-based solutions to resolve societal challenges at a local level. This initiative can form an ideal case study and can be showcased for further replication and upscaling.



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Annexure 1: Ecosystem Service Assessment

The term “ecosystem services” refers to the benefits which humans can derive from the natural ecosystems for their physical, social, and economic well-being (Costanza et al. 1997; MEA 2005). The Millennium Ecosystem Assessment (2005) established a universal concept for identifying and classifying Ecosystem Services to assess the consequences of ecosystem change for human well-being and establish the scientific basis for actions needed to enhance the conservation and sustainable use of ecosystems and their contributions to human well-being.

- **Provisioning Service:** These are the material benefits people get directly from nature such as: Food and Fiber, Freshwater, livestock, Fuel wood, Biochemical, Genetic resources, Pharmaceuticals, and Plants.
- **Regulating services:** These are categorized as any benefits obtained from natural processes and the functioning of the ecosystem. These services help to reduce the impacts and effects from both natural and anthropogenic activities that cause risk to human health and ecosystem quality therefore protecting the natural environment using various mechanisms (MEA 2005; Sutherland et al. 2018; Villamagna et al. 2013). Regulating services include air quality maintenance, climate regulation, water regulation, erosion control, water purification, , storm protection, flood control, and carbon storage, among others.
- **Cultural service:** These are non-material benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experiences.
- **Supporting services:** These are those services that relate to habitat functioning themselves and therefore have an impact on survival. Without supporting services, the other three services would not exist. These include biomass production, production of atmospheric oxygen, soil formation and retention, nutrient cycling, water cycling, and provisioning of habitat.

The MEA (2005) framed a need to protect biodiversity and the world’s ecosystem in terms of ecosystem services. TEEB (2010) followed up by presenting an approach to help decision-makers recognize, demonstrate, and capture the values of ES and biodiversity.



Annexure 2: Household Survey

PART I - HOUSEHOLD DETAILS

Code for the household		
Name:		
Address:		
Locality:		
GPS:	Lat:	Lon:
Date of the interview:		
Time of the interview:	Start:	End:
Native place:		
Contact details:		

1. Household composition: How many people are in the household?

Status	Name	Description	Age	Gender	Education	Occupation
Head of Household						
Member 1						
Member 2						
Member 3						
Member 4						
Member 5						

Description – Wife=W / Husband=H / Daughter=D / Son=S / Mother=M / Father=F / Brother=B / Sister=Si / Daughter-in-law=DIL / Others=OTH

Gender - M (male), F (female), O (others)

Education level – 0) No formal education 1) Primary 3) Secondary 4) College/University

Occupation – 0) Homemaker 1) Government sector 2) Private sector 3) Student 4) Others – specify.

2. How much money does your household earn per month? (Once again, I would like to remind you that this is a confidential survey only to be used for scientific purposes; no authority will gain access to the data.

Monthly household income

a) less than 20,000 b) 21,000-49,000 c) 50,000- 99,000 d) more than 1,00,000

3. For how many years have you been staying at the police line?

1) Less than 1 year 2) 1 – 5 years 3) 5 – 10 years 4) 10 years or more

PART II - ECOSYSTEM SERVICES

Are you getting any benefits from the urban wetland: (0-No, 1-Yes, 2-I do not know)

Yes b) No c) I Do not know?

Which of these provisioning ecosystem services are used by your household?

Sr. No	Ecosystem services	Service used by the household.(Yes, No)
1.	Vegetables from kitchen garden	
2.	Medicinal plants	
3.	Compost	
4.	Other (Specify)	

3. Others – Fodder

Sr. No.	Plant species	Quantity collected	Frequency of collection	Price per Kg	Feed purchased	Price of Feed Purchased

4. Kitchen gardens

i) Quantity of water used per day for watering the plants _____

Sr no	Name of vegetable	Quantity per year in kg	Rate per kg in local market
1			
2			
3			
4			
5			

5. Compost

a. Do you contribute green domestic waste to the compost unit near the wetland? If yes, then how much waste do you contribute per day/per month?

b. Do you have your own compost unit?

How much compost do you produce per month?	How much green waste do you add to the compost unit per day or per month?

6. Cultural ecosystem services

i) Do you think no. of visitors to wetlands has increased over the years?

a) yes b) No

if yes, by how much it has increased _____

ii) Suppose if you are allowed to choose your quarter would you prefer to have a quarter near the wetland?

a) Yes b) No

If yes, how much nearer if given the opportunity?

a) 1km b) 2km c) 3km d) 4km

iii) If the wetland is filled up for the construction of the shopping mall, would you allow it to be filled?

a) Yes b) No

7. Religious services

i) Does the wetland have any religious significance?

a) Yes b) No

If yes, then what?

ii) Has the number of people performing religious rituals increased at the wetland since 2020?

a) Yes b) No

If yes, then by how much percent?

Willingness to Pay Questionnaire

Estimating value according to local people's willingness to pay for the conservation and maintenance of the wetland.

Suppose the administration requests a voluntary monthly contribution from residents to maintain the present wetlands in police line with the assurance that the fund will be properly utilized for the same, are you willing to contribute for the same? (0-No, 1-Yes) a) Yes b) No

If willing to pay, what maximum amount could you contribute? (INR)

a) 50 b) 100 c) 200 d) Maximum amount you could pay. _____

If you would not be willing to pay anything, why?

i) The wetland should be protected through national and international funds.

ii) I cannot afford to give money.

iii) I already pay too much tax.

iv) Others (Please specify)

Thank you very much for supporting this important research that will lead to better use and improved conservation of this wetland for the present and future generations.

Annexure 3: Questionnaire for Management Committee/ Administration

Respondent Details:

- Name:
- Date:
- Time:
- Role/ position:
- Team:
- Contact no.:

Management Committee/ Administration

1. Please provide a short description of the restored wetland. (Pre-restored condition, present scenario)

Sr.	Particulars	Response																		
1	Restoration started from																			
2	What factors led to the prioritization of this site over other restoration locations?																			
3	What were the goals for the restoration of the wetland?	a) Groundwater recharge b) Water quality management c) Stormwater management d) Debris removal e) Remove invasive species f) Native vegetation enhancement g) Recreation h) Education i) other																		
		<table border="1"> <tr> <td>Which of these was the primary goal for restoration?</td><td></td></tr> <tr> <td>Why was it important for wetland restoration?</td><td></td></tr> </table>	Which of these was the primary goal for restoration?		Why was it important for wetland restoration?															
Which of these was the primary goal for restoration?																				
Why was it important for wetland restoration?																				
4	Methods used for restoration																			
5	Management of site																			
6	Monitoring	<table border="1"> <tr> <td>Process: (often)</td><td></td></tr> <tr> <td>Parameters:</td><td>Physical</td></tr> <tr> <td></td><td>Chemical</td></tr> <tr> <td></td><td>Biological</td></tr> <tr> <td></td><td>Vegetation</td></tr> <tr> <td></td><td></td></tr> <tr> <td>Result Report:</td><td>a) Yes b) No c) I don't know</td></tr> <tr> <td></td><td>Media-</td></tr> <tr> <td></td><td>Frequency-</td></tr> </table>	Process: (often)		Parameters:	Physical		Chemical		Biological		Vegetation			Result Report:	a) Yes b) No c) I don't know		Media-		Frequency-
Process: (often)																				
Parameters:	Physical																			
	Chemical																			
	Biological																			
	Vegetation																			
Result Report:	a) Yes b) No c) I don't know																			
	Media-																			
	Frequency-																			

7	institutions engaged in the administrative–management fields for the site	Community (specify)-	
		Region(specify)	
		Forest department	
		Other (specify)-	
8		Pre restoration	Post restoration
a.	Area of Wetland		
b.	Use of Wetland		
c.	Odour from wetland		
d.	Treatment of water in the colony		
e.	Bird species		
f.	Plant species		
g.	Insect		
h.	Water quality		
i.	Community cooperation (before and after)		
9.	Did the wetland restoration project conduct any public engagement?		
10	Ecosystem services/benefits delivered by wetlands to the residents		
11	Sewage water received (per day)		
12	Total Treatment Capacity		
13	Water treated (per day)		
14	Total supply of water		
15	Total consumption	By household:	
		Others(specify):	
16	Cost:	Construction	
		Maintenance:	
		Other:	
17	Visitors	(number/%increase)	
		Kind: students (years data)	No. of School- Total no of students
		Researchers (years of data)	
		Residents ((years data/ % increase)	
		Other	
18	Employment generation from the wetland	Total no. employees:	
		Type of posts: Gardener	
		Salary:	
19	Has the land price in the area increased after the wetland was established?	Yes b) No	
		Percentage increase: a)10% b) 25% c) 75% d) _____	
		Price of land per unit:	
20	What are Future plans for the site?		

2) Is there anything else that I have not asked that you feel we should know about this site or restoration project?

Annexure 4: Questionnaire for Purohit of Temple

Respondent Details:

Name: _____

Date: _____

Time: _____

Gender: a) Male b) female c) other

Mobile: _____

1. Has the wetland rejuvenation led to increase in the number of visitors to the temple?
2. If yes, then by how much percent has this increase been?
3. Has there been any other benefit to the temple due to the restoration of the wetland?
4. Are there any religious rituals/practices associated with the wetland that have increased after restoration?
5. Has the number of people performing these religious rituals at the wetland (eg during weddings) increased? If yes, then by how much percent?

Annexure 5: Questionnaire for Visitors

Respondent Details:

1. Name: _____
2. Date: _____
3. Time: _____
4. Gender: a) Male b) female c) other
5. Occupation: a) Student b) Government sector c) Private sector d) Homemaker e) other
6. Residential status:
 - a) Resident b) non-resident
7. Since when have you been coming to the wetland?

8. How often do you visit the wetland?
 - a) Weekly b) Monthly c) Daily d) Other _____
9. Why do you visit the wetland?
 - a) To enjoy the natural environment b) Physical use (walking) c) Bird watching d) Photography e) Religious purpose f) Other _____
10. What changes have occurred in the wetland over the past years?

What has changed?	Improved	Deteriorated	No change
a) Change in the area			
b) Change in visitor density			
c) Change in water quality			
d) Change in terms of vegetation			
e) Change in terms of birds visiting the lake			
f) Change in terms of aesthetics			
g) Other (specify)			

11. If society wants to charge you a small amount for maintaining the wetland, would you be willing to pay? (0-No, 1-Yes)

- a) Yes b) No

- If yes, what maximum amount would you be willing to contribute (in INR) as a monthly fee for this purpose?

- a) 20 b) 50 c) 75 d) 100 e) none

If none of these, what would be the maximum fee you are willing to contribute _____

- If you would not be willing to pay anything, why?
 - i) The wetlands should be protected through national and international funds.
 - ii) I cannot afford to give money.
 - iii) I already pay too much tax.
 - iv) Others (Please specify)



Annexure 6: List of Trees

Sr. No	Common Name	Scientific name	Family
1	Bakain	<i>Melia azedarach</i>	Meliaceae
2	Yellow Bells	<i>Tecoma stans</i>	Bignoniaceae
3	Arjun	<i>Terminalia arjuna</i>	Combretaceae
4	Jamun	<i>Syzigium cumini</i>	Myrtaceae
5	Neem	<i>Azadirachta indica</i>	Meliaceae
6	Amaltas	<i>Cassia fistula</i>	Fabaceae
7	Gulmohar	<i>Delonix regia</i>	Fabaceae
8	Karanj	<i>Pongamia pinnata</i>	Fabaceae
9	Harshingar	<i>Nyctanthes arbor-tristis</i>	Oleaceae
10	Amla	<i>Phyllanthus emblica</i>	Phyllanthaceae
11	Goolar	<i>Ficus racemosa</i>	Moraceae
12	Peepal	<i>Ficus religiosa</i>	Moraceae
13	Dhak	<i>Butea monosperma</i>	Fabaceae
14	Shami	<i>Prosopis cineraria</i>	Fabaceae
15	Vilaiti Keekar	<i>Prosopis juliflora</i>	Fabaceae
16	Shisham	<i>Dalbergia sissoo</i>	Fabaceae
17	Ashok	<i>Polyalthia longifolia</i>	Annonaceae
18	Guava Tree	<i>Psidium guajava</i>	Myrtaceae
19	Banyan	<i>Ficus benghalensis</i>	Moraceae
20	Mango Tree	<i>Mangifera indica</i>	Anacardiaceae
21	Powder Puff	<i>Calliandra haematocephala</i>	Fabaceae
22	Kaner	<i>Nerium oleander</i>	Apocynaceae
23	Toot	<i>Morus alba</i>	Moraceae
24	Bael	<i>Aegle marmelos</i>	Rutaceae
25	Ber	<i>Ziziphus mauritiana</i>	Rhamnaceae
26	Nimbu	<i>Citrus aurantiifolia</i>	Rutaceae



Annexure 7: List of Shrubs and Herbs

Sr. No	Common name	Scientific name	Family
1	Congress Grass	<i>Parthenium hysterophorus</i>	Asteraceae
2	Gurhal	<i>Hibiscus rosa sinensis</i>	Malvaceae
3	Apple of Sodom	<i>Calotropes procera</i>	Apocynaceae
4	Indian Mallow	<i>Abutilon indicum</i>	Malvaceae
5	Karonda	<i>Carissa carandas</i>	Apocynaceae
6	Sarpagandha	<i>Rauwolfia serpentina</i>	Apocynaceae
7	Lantana	<i>Lantana camara</i>	Verbenaceae
8	Glory Bower	<i>Volkameria inermis</i>	Verbenaceae
9	Alligator Weed	<i>Alternanthera philoxeroides</i>	Amaranthaceae
10	Doob	<i>Cynodon dactylon</i>	Poaceae
11	Mokoi	<i>Solanum nigrum</i>	Solanaceae
12	Motha	<i>Cyperus rotundus</i>	Poaceae
13	Ban tulsi	<i>Croton bonplandianus</i>	Euphorbiaceae
14	Bhang	<i>Cannabis sativa</i>	Cannabaceae
15	Sarkanda	<i>Saccharum munja</i>	Poaceae
16	Green Amaranth	<i>Amaranthus viridis</i>	Amaranthaceae
17	Sandmat	<i>Euphorbia prostrata</i>	Euphorbiaceae
18	Sadabahar	<i>Catharanthus roseus</i>	Apocynaceae
19	Ragweed	<i>Conyza bonariensis</i>	Asteraceae
20	Aloe vera	<i>Aloe vera</i>	Asphodelaceae
21	Tulsi	<i>Ocimum basilicum</i>	Lamiaceae
22	Ashwagandha	<i>Withania somnifera</i>	Solanaceae
23	Kush	<i>Desmostachya bipinnata</i>	Poaceae
24	Brinjal	<i>Solanum melongena</i>	Solanaceae
25	Keli	<i>Canna indica</i>	Cannaceae
26	Lesser Duckweed	<i>Lemna minor</i>	Araceae
27	Copper cion	<i>Hydrocotyle vulgaris</i>	Araliaceae
28	Lal bhuinawal	<i>Phyllanthus urinaria</i>	Phyllanthaceae
29	Coffee Senna	<i>Senna occidentalis</i>	Fabaceae
30	Green Foxtail	<i>Setaria viridis</i>	Poaceae
31	Broadleaf Reedmace	<i>Typha latifolia</i>	Typhaceae
32	Duckweed	<i>Lemna major</i>	Araceae
33	Knotgrass	<i>Paspalum distichum</i>	Poaceae
34	Pepperwort	<i>Marsilea minuta</i>	Marsileaceae
35	Water fern	<i>Azolla Sp.</i>	Salviniaceae
36	Bougainvillea	<i>Bougainvillea glabra</i>	Nyctaginaceae
37	Ban kalmi	<i>Ipomoea sagittifolia</i>	Convolvulaceae

Annexure 8: List of Birds

S. No.	Common Name	Scientific Name
1	Indian Spot-billed Duck	<i>Anas poecilorhyncha</i>
2	Little Grebe	<i>Tachybaptus ruficollis</i>
3	Eurasian Collared-Dove	<i>Streptopelia decaocto</i>
4	Laughing Dove	<i>Streptopelia senegalensis</i>
5	Yellow-footed Green-Pigeon	<i>Treron phoenicopterus</i>
6	Greater Coucal	<i>Centropus sinensis</i>
7	Asian Koel	<i>Eudynamys scolopaceus</i>
8	Gray-headed Swampphen	<i>Porphyrio poliocephalus</i>
9	Red-wattled Lapwing	<i>Vanellus indicus</i>
10	Oriental Darter	<i>Anhinga melanogaster</i>
11	Little Cormorant	<i>Microcarbo niger</i>
12	Cattle Egret	<i>Bubulcus ibis</i>
13	Eurasian MarshHarrier	<i>Circus aeruginosus</i>
14	Black-headed Ibis	<i>Threskiornis melanocephalus</i>
15	Black Kite	<i>Milvus migrans</i>
16	White-throated Kingfisher	<i>Halcyon smyrnensis</i>
17	Asian green bee eater	<i>Merops orientalis</i>
18	Coppersmith Barbet	<i>Psilopogon haemacephalus</i>
19	Brown-headed Barbet	<i>Psilopogon zeylanicus</i>
20	Black Drongo	<i>Dicrurus macrocercus</i>
21	House Crow	<i>Corvus splendens</i>
22	Common Tailorbird	<i>Orthotomus sutorius</i>
23	Ashy Prinia	<i>Prinia socialis</i>
24	Plain Prinia	<i>Prinia inornata</i>
25	Wire-tailed Swallow	<i>Hirundo smithii</i>
26	Red-vented Bulbul	<i>Pycnonotus cafer</i>
27	Purple Sunbird	<i>Cinnyris asiaticus</i>
28	Baya Weaver	<i>Ploceus philippinus</i>
29	Rock pigeon	<i>Columba livia</i>
30	White breasted waterhen	<i>Amaurornis phoenicurus</i>
31	Eurasian Moorhen	<i>Gallinula chloropus</i>

Annexure 9: List of Dragonflies and Damselflies

S.No.	Common Name	Scientific Name
1	Wandering Glider	<i>Pantala flavescens</i>
2	Ruddy marsh skimmer	<i>Crocothemis servilia</i>
3	Ditch Jewel	<i>Brachythemis contaminata</i>
4	Green marsh hawk	<i>Orthetrum sabina</i>
5	Coromandel darter	<i>Ceriagrion coromandelianum</i>
6	Pygmy darter	<i>Agriconemis pygmaea</i>
7	Orange-tailed Marsh Dart	<i>Ceriagrion cerinorubellum</i>
8	Golden Dartlet	<i>Ischnura rubilio</i>
9	Senegal Golden dartlet	<i>Ischnura senegalensis</i>



Annexure 10: Schematic Representation of Trees at Police Lines

