Available online at www.ewijst.org

ISSN: 0975-7112 (Print)
ISSN: 0975-7120 (Online)

Environ. We Int. J. Sci. Tech. 13 (2018) 137-147

Environment & We An International Journal of Science & Technology

Assessment of Ecosystem Services and Threats in Fresh Water Inland Wetland: A case study of Okhla Bird Sanctuary

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Article history:
Received 15 April 2018
Received in revised form
24 August 2018
Accepted 12 September 2018
Available online
30 September 2018

Keywords:
Ecosystem service;
Climate changes,
Wetland risk assessment;
Species distribution;
Invasive macrophytes;
Macronutrient.

Abstract

Ecosystem service are the amenities of ecosystem where people get access to obtain benefits from each service. Different types of ecosystem service such as provisioning, regulating, supporting and cultural services are vital component of human life. In this connection, the study emphasised on understanding of the ecosystem services and key threats influencing ecological characters of Okhla Bird Sanctuary (OBS) was undertaken. It was observed that this sanctuary provides wide range of ecosystem service such as water for agriculture, fish, fodder, flood regulation, ground water recharge, pollution control, waste assimilation, micro climate regulation, tourism and recreational opportunities. We also identified some of the limiting factors of this inland wetland such as infrastructure development, water withdrawal, pollution, eutrophication and invasive species. Such process of degradation may lead to loss of the several benefits, thereby causing adverse impacts on native species of both faunal and floral resources which is crucial for ecosystem functioning of this wetland. The data presented here is an outcome of rapid assessment of this ecologically important inland wetland. We recommend that more research is required to understand the influence of each drivers of change on ecosystem service of Okhla Bird Sanctuary. This paper deals with wetland risk assessment with respect to ecological processes and its structural component in global change scenario.

Introduction

Ecosystem is functional unit of nature where interaction of living organism with non-living substance of environment takes place. Each ecosystem delivers a wide range

of services that contribute to welfare of societies. Ecosystem service originates from ecosystem function, which is a combination of biophysical structure and process called supporting service (MEA, 2005). Ecosystem services are contribution of ecosystem structure and function in combination with other input, which is transmitted as an output to human well being (Burkhard *et al*., 2012). Ecosystem structures are the biophysical architecture (Kumar, 2012) whereas ecosystem functions are intermediate between ecosystem processes and services (De Groot *et al*., 2010). It can be defined as the capacity of ecosystem to provide goods and services that satisfied human need directly and indirectly (De Groot *et al*., 2010). But over the past 50 years, ecosystems have been changing more rapidly and extensively than in any comparable period of time in human history due to various anthropogenic pressure to meet rapidly growing demands for food security resulting into a substantial and largely irreversible loss in the diversity of life on Earth (MEA, 2005). Ecosystem services are categorised into four main types; provisioning (e.g. food and water), regulating (e.g. floods and droughts mitigation), supporting (e.g. nutrient cycling) and cultural services (e.g. recreational and spiritual values). In addition of these, total economic value of the ecosystem involves assessing all these four categories of ecosystem service which can be further characterized as direct use values (correspond broadly provisioning and cultural service), Indirect use value (mainly regulating and support service), optional value (preserving the option to use in future service) and non-use values (MEA, 2005).

Integration of ecological and economic dimension visualised the flow of benefits from producer to consumer through quantification, modelling and mapping of ecosystem services (Crossman *et al*., 2013). Martinz – Harms and Balvanera, (2012) summarised the published literatures on mapping ecosystem services. They found that the carbon storage (19%) is the most studied component of service followed by carbon sequestration (16%), food production (16%), recreation (13%), provision of water (10%) and water quality (10%). Egoh *et al*., (2012) reviewed the most common indicators for mapping ecosystem services in the form of land use land cover (LULC), soils, vegetation and nutrients. He also found that the regulating services are mapped more frequent than other categories in almost all type of ecosystem. Dynamic relationship between landscape specific ecosystems with human hierarchy of need represent direct and indirect contribution of ecosystem service (Figure 1). Ecosystem services for societal welfare in changing landscapes arise from internal responses of ecological processes and external disturbances. A landscape or region, comprises of multiple ecosystem with criss cross connecting services represent a pivotal scale domain for the sustainability indicators (Wu, 2013). Significance of ecosystem service is recognised in international framework for development plans, policy document and sustainability guideline. The topmost cited ecosystem services information such as natural heritage and diversity, capture and culture fisheries, water management, crops, livestock, cultural heritage and diversity is mentioned in global sustainability policies such as Sustainable Development Goals (SDGs) and Aichi targets (Geijzendorffer *et al*., 2017).

Wetlands deliver bundle of ecosystem services that contribute to welfare of the societies. Wise use concept of wetland management signifying the maintenance of ecological character that support the provision of ecosystem services. Ramsar defines the ecological character of a wetland as "the combination of the ecosystem components (physical, chemical and biological parts of a wetland), processes (physical, chemical or biological changes or reactions occurring naturally in a wetland) and benefits/services (benefits that people receive from wetlands) that characterize the wetland at a given point in time" (Ramsar 2010). Its significance in socio economic and ecological dimension is recognized for human well being.

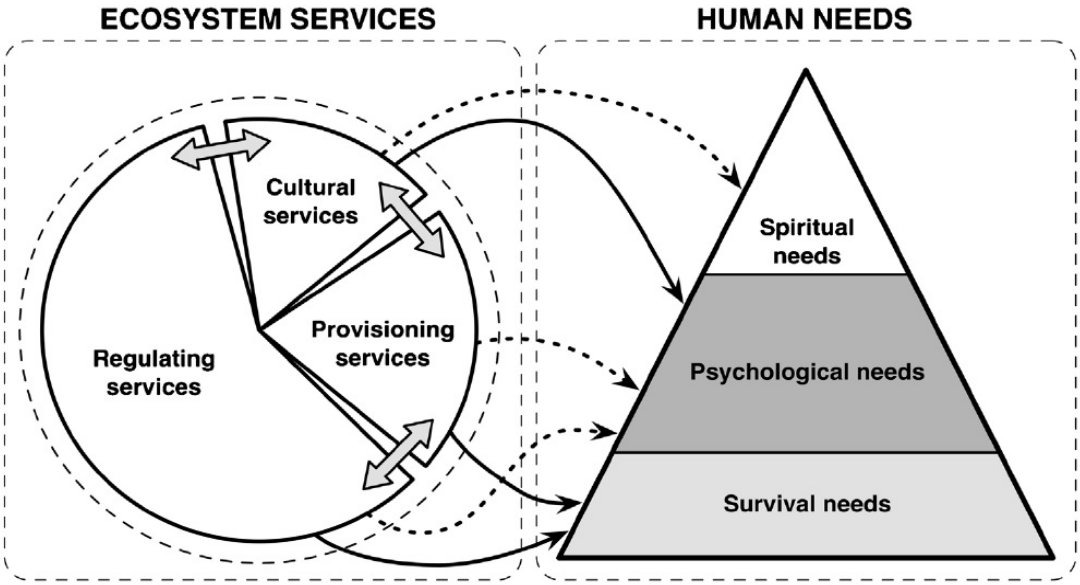

Figure 1. Contribution of ecosystem service to human well-being.

Source: Adapted from Geijzendorffer, 2017 and Wu, 2013

The Ramsar Convention recognises the great diversity of ecosystem service delivered by the wetlands. The set of Ramsar factsheets profiles on 'ecosystem services' demonstrated that the wetland ecosystems are part of natural wealth (Ramsar, 2009). Similarly, ecosystem functions with ecological balance initiated multiple services including an area for water storage supporting in lean season and maintaining water table high, recharging ground water and minimising the adverse impact of floods (Sharma *et al*., 2015). Despite being the source of a range of benefits, increased human pressure on wetlands results degradation such as drained, filled and converted for alternate uses in almost all over the world. The degradation and loss of wetlands is more rapid than that of other ecosystems. Similarly, the status of both freshwater and coastal wetland species is deteriorating faster than those of other ecosystems (MEA, 2005).

Study site

Okhla Bird Sanctuary is a constructed urban fresh water wetland, which covers 400-hectare area of Yamuna River floodplain. This wetland is located in National Capital Region at the border of Delhi and Uttar Pradesh (Figure 2). The geographical coordinates of sanctuary is marked between $28^0$32'43.5"N to $28^0$32'56.3"N latitudes and $77^0$18'41.7"E to $77^0$18'56.6"E longitudes in lower reach of Upper Yamuna River sub basin with an elevation of about 185 m above mean sea level. It consists of variety of habitats including water bodies, marshes, grasses and trees. These diverse habitats attract a large number of migratory birds throughout the year (Sharma *et al*., 2015). Sanctuary was formed due to the construction of Okhla Barrage across the Yamuna River. It has declared as protected area as bird sanctuary under the sanction 18 of Wildlife Protection Act 1972 by the Government of Uttar Pradesh notification 577/14-4-82/89 dated on 1990. Okhla Bird Sanctuary (OBS) is paradise for migratory bird and variety of plant species. It has recognised as one of the Important Bird Areas (IBAs) and Asian Water Bird Census (AWC) in India. Due to its fertile flood plain and green cover of the Yamuna River Ecosystem, this wetland is recommended as one of the potential "Ramsar Sites" (Urfi, 2003).

Methods

This study comprises of both primary and secondary source of information collected season wise during pre-monsoon, monsoon and post monsoon. Primary source of information include field observation and data collected from sampling station situated both side of the river in the sanctuary. Secondary source of information incorporated from review of literatures from published journals, books and periodicals and reports from government, NGOs and management authorities. Ecological transect along with River Yamuna including Okhla Bird Sanctuary were mapped in entire part of Delhi stretch. The study collected relevant information from field through ecological appraisal and participatory discussion on aquatic vegetation, drainage system and developmental activities around the sanctuary. Specific literature from all peer reviewed publication were identified using the electronic database of the Web of Science, Web of knowledge, Science Direct and Google Scholar. The study comprises of group of literatures highlighted ecosystem service assessment, wetland specific ecosystem service includes status of Okhla Bird Sanctuary and threats to ecosystem functioning.

Results

Ecosystem services of the sanctuary: The complexity of social context on perception of ecosystem services is classified according to their important economic, cultural and recreational values. It ranked wide range of ecosystem service such as water for agriculture, fish, fodder, flood regulation, ground water recharge, reducing pollution, waste assimilation, climate regulation, recreational opportunities and tourism (Table 1).

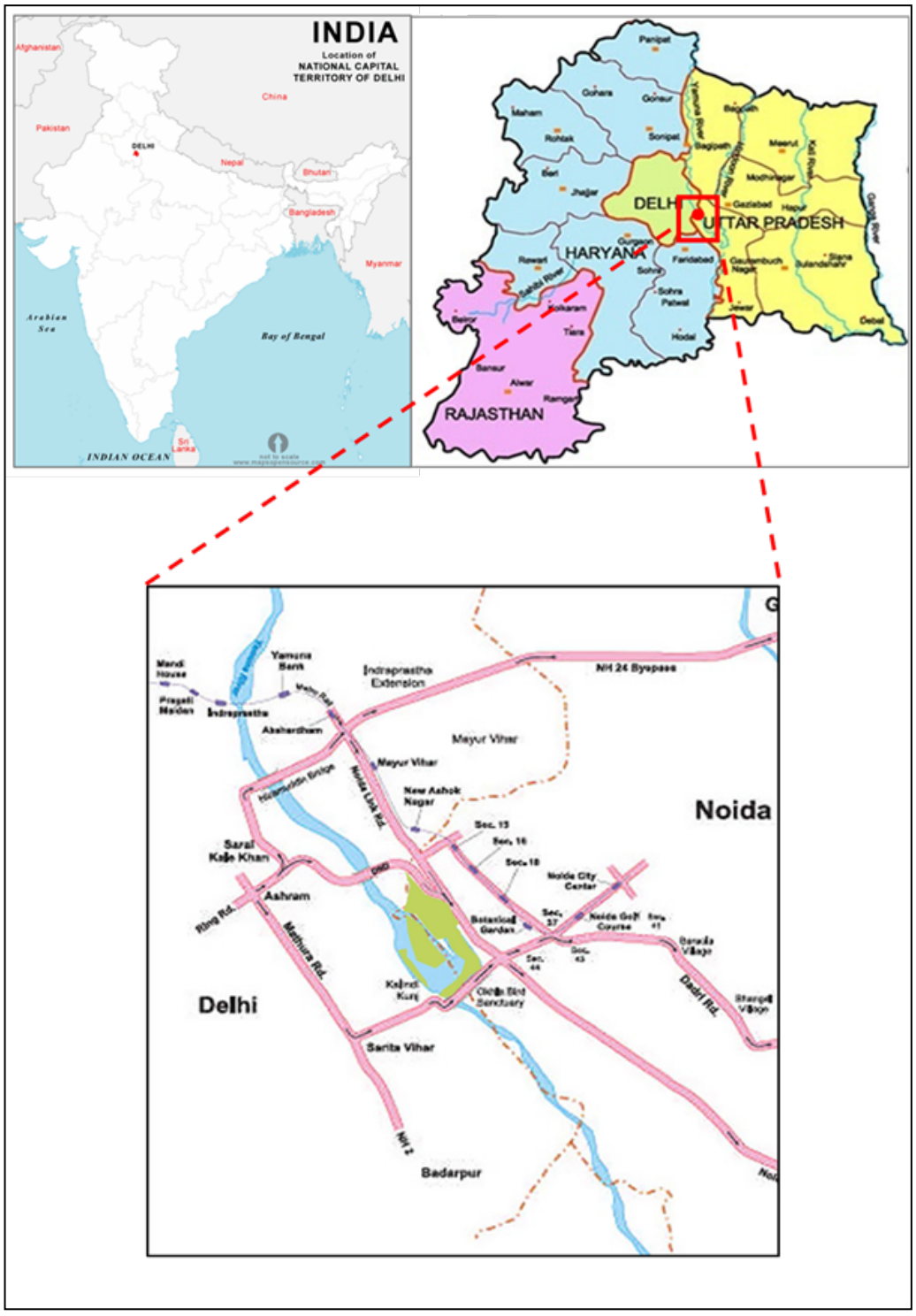

Figure 2. Location map of Okhala Bird Sanctury (OBS)

Source: http://surajpurwetland-up.com/location.php

Downstream communities of the sanctuary are benefiting water for agriculture due to its connecting Agra Canal. Agra Canal is about 412 km long irrigation canal initiated from left bund of the sanctuary. Average annual carrying capacity of canal is about 4000 cusec water that irrigates nearly 0.98 lakh hector Kharif and 1.31 lakh hector Rabi crop of command area at Uttar Pradesh and Haryana state (IWRD 2016) (Figure 3).

Table 1. Key ecosystem services of Okhla Bird

Services	*Uses*	*Ecosystem Service Values (High to low)*	*Significance of Ecosystem Service*
Provisioning	Water for agriculture		As a source of water for irrigation in command area of Agra Canal
	Fishes		As a source of fishes in surrounding buffer area leased by Fishery Department
	Fodder		As a source of fodder for livestock nearby village
Regulating	Flood regulation		As a buffer for floods adjacent low-lying areas
	Recharging ground water		As a means of recharging aquifer in floodplain areas
	Reducing pollution		As a lockup for pollutant via aquatic plants
	Waste assimilation		As a barriers for solid waste
	Climate regulation		As a source of carbon sink and regulate micro climate
Cultural	Tourism		As a tourist spot for recreational activities
	Education		As a source of learning centre for students
	Spiritual		As a religious and cultural centre

Fisher of surrounding buffer areas rejoice bumper catch during lease by Fishery Department. Sanctuary performs some vital ecological functions including fish breeding and nursery ground benefiting to downstream riverine fishery. Livestock of the adjacent village get their fodder from flood plain area in and around the Sanctuary. Floodplain of

sanctuary is also recharge aquifer. Depth of water level continuous maintained up to <2m to 10m bgl during pre and post monsoon in Yamuna River floodplain at Delhi stretch (CGWB, 2013, CGWB, 2014).

Sanctuary has played significant role in flood mitigation. Two marginal and seven spur of the sanctuary regulates river flow to protect water logging in low lying area. Green cover in sanctuary is act as "Bio-Wall" which reduces air and noise pollution from outside heavily urbanised landscape. It also helps in purifying water by locking up pollutant through aquatic plants. Dense vegetation traps solid waste so that sanctuary further reduces its dispersal in nearby area. Sanctuary is also serving as recreational service and education centres through its high biodiversity values. The site is home of 302 bird species hold more than 20,000 water bird population and rich fish diversity including 87 fish species belonging to 54 genera and 23 families (WII, 2010). OBS is one of the famous tourist spot in adjoining area of NCR invites thousands of tourist and generate revenue Rs. 2-3 lakh per annum (Figure 4) (WII, 2010).

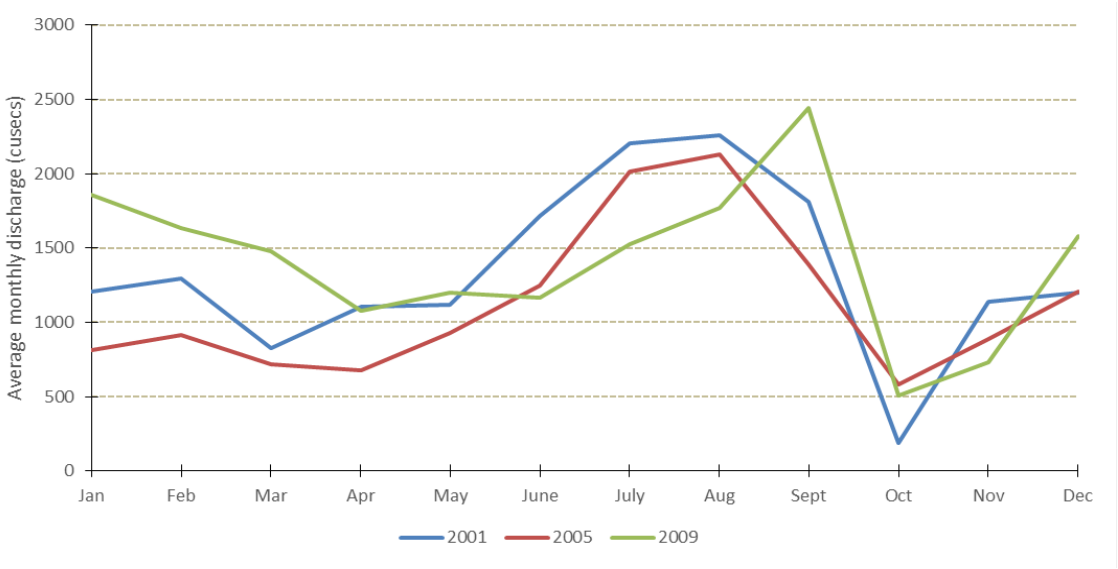

Figure 3. Water discharge from Agra Canal

Threats to ecosystem of the sanctuary

Key drivers of change threats structure and functions of wetlands ecosystem. Developmental activities, water quality, invasive species and draining of water for agriculture are some governing factors of inland wetlands. Developmental activities around highly urbanised landscape of the sanctuary such as power line, widening of roads with heavy traffic and crematorium is replacing the greeneries and generates pollution.

These green cover around the protected area is most crucial in terms of buffering external environment and resting ground for wildlife. It has been proven that increased anthropogenic pressure in protected areas are changing ecological character of wetland ecosystem.

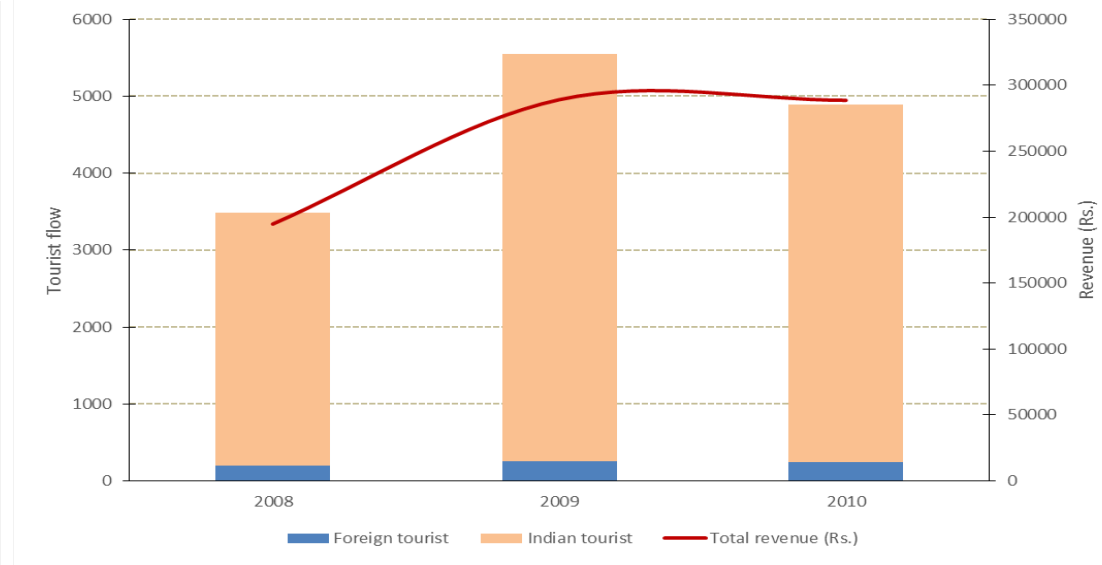

Figure 4. Tourist inflow and rever

Hydrological characteristics including quality and quantity of water are most critical factor that regulate the entire ecosystem services. Sewage discharge from 19 major drain between Wazirabad Barrage and Okhla Barrage causing adverse environment impact on health of the sanctuary. Twenty two kilometre of River Yamuna in Delhi stretch which is just two percent (1,376 km) carrying seventy percent of organic and inorganic substances (CPCB 1999). Water quality index of sanctuary exhibits Class "C", which is represented as "moderately polluted class" (CPCB 2011). Water quality assessment characterised low DO (2.26 ± 1.62 mg/l), high BOD (15.20 ± 3.75 mg/l) and COD (44.60 ± 12.07 mg/l), along with high levels of phosphate (0.64 ± 0.13 mg/l) increasing nutrient loads in entire part of OBS (Manral *et al*., 2012). High nutrient load in water is triggering eutrophic condition, which stimulates excessive growth of aquatic vegetation. These excessive growths further encourage accumulation of organic matter and reduction in rate of water flow. As a result aquatic plants with invasive macrophyte cover of the almost entire part of sanctuary up to 20% - 70% from December to May (WII, 2010). Some of the noted invasive species are *Eicchornia crassipes, Salvinia auriculata, Alternanther aphiloxeroides, Typha angustata, Ipomoea carnea, Lantana camara,*and *Parthenium hysterophorus* infested in the forms homogeneous and

heterogeneous colonies in various part of the sanctuary. Sanctuary is facing serious threats from *Eicchornia, Typha, Alternanthera and Luceanea* species that spread in larger part of the sanctuary. Water management without consideration of ecological significance is another major factor causing adverse impact on ecological functions. High water level for agriculture purpose during migratory season is affecting congregation sites for water bird (WII, 2010). Water abstraction from Agra Canal for irrigation is almost drain entire water and increase high proportion of nutrient loads in the sanctuary.

Discussion

Ecosystem functions of protected area are always influenced by dynamics of their buffer zones. Unfortunately, the buffer zone of this sanctuary had been long been occupied with human habitation and as such the sanctuary appears to be devoid of any buffer zone. Such dense habitation without buffer zone around the sanctuary poses one of the major threats to ecosystem. The Ministry of Environment, Forest and Climate Change of Government of India constituted an empowered committee called Central Empowered Committee (CEC) in the year 2012 to frame guidelines for determining the buffer zone ring around national parks and wildlife sanctuaries in India. Committee redefines the range of eco-sensitive zone as 0.1 to 2 km around protected areas (Sharma *et al*., 2015).

Degradation of wetlands leads to loss of the several benefits and impacts on native species, which are dependent on this ecosystem. The Benefits of ecosystem need to be evaluated that can be sensitise policy makers to restore wetland ecosystem. At present, two methods as being used for ecosystem service assessment. First method is monetary valuation approach putting ecosystem service values in terms of monetary units. In this method cost benefit analysis and polluter to pay technique is widely used with GDP indicators for environment conservation. Second method is biophysical accounting technique including quantitative experiment derived for service modelling (Costanza *et al*., 1997; Costanza *et al*., 2014). But other biophysical accounting methods with ecological footprint should be incorporate for ecosystem service evaluation.

In 2010, The Ministry of Environment, Forest and Climate Change (MoEFCC) launched the mapping of ecosystem services under the umbrella of The Economics of Ecosystem and Biodiversity-India initiative (TEEB). The initiative visualised mainstreaming of ecosystem services in sectoral plan using an evidence building approach for all three ecosystems, namely inland wetlands, forests and coastal & marine ecosystems (Kumar *et al*, 2017). Mapping of ecosystem service are important tools for decision making and enabling institutions to maintain ecosystem service as it can identify high priority of ecosystem services in each landscape through spatial and temporal approach (Balvanera *et al*. 2001).

Temporal trend of macrophyte invasion from 1970 to 2012 indicated that 28.9% of the investigations studied focus on population dynamics, 23.9% employed an approach

related to community level, 14.5% studied the economical aspect, 11.9% used an ecosystem perspective and 19.5% approach more than one level of organisation and finally 1.3% on genetics of these species (Evangelista *et al*., 2014). But global climate change and its impact in species invasion is received least attention in wetland risk assessment studies. Global climate and nutrient loading are projected key drivers of change in the next 50 years (MEA, 2005).

Conclusion

Although ecosystem service concept has received more attention than the mapping of ecosystem services in developmental programming. Moreover, applied approach of ecosystem services with general framework of wetland management is also a way to gain a better understanding of wetland function and processes. Engagement of multi stakeholders should be well defined in ecosystem assessment process so that the factual and perception profile of wetland can be effectively utilised in decision making. Maintenance of ecological character through efficient management of structural and functional component of ecosystem can reduce wetland degradation. Mainstreaming of ecosystem services must include creation of buffer zone, economic valuation of wetland resource and water balance assessment for ecological requirement. Integration of key wetland health indicators such as water and soil quality along with water bird census in regular monitoring process will help in proactive management of sanctuary.

Management of invasive macrophytes is being carried out through conventional flushing technique in many wetlands. But it leads to loss of wetland habitat especially feeding and foraging ground of migratory and resident birds. Community participation with traditional knowledge of "utilisation" has established as a control strategy for invasive macrophytes. The invasive macrophytes can be utilized in number of ways for example; leaves of *Typha* and *Phragmites* species are extensively used for thatching of roofs whereas shoots are also used for chairs, basket, toys and carpet making business. Some free floating plant such as *Eicchornia* and *Salvinia* species are also used for bio compost as organic manure in agriculture field. More research on wetland function and processes is required to understand influence of each driver on ecosystem service of Okhla Bird Sanctuary.

Acknowledgement: One of the authors (SK) acknowledges University Grant Commission (UGC), Government of India for providing financial assistance through National Fellowship Programme. The Authors thank Forest Department of Uttar Pradesh for granting permission to carry out field work. The authors are also grateful to Wetlands International South Asia (WISA), Delhi for their continuous encouragements to do research in wetland management in India.

***Authors Contributions**: Mr. Satish Kumar (Ph.D. Scholar) is responsible for field observation, data collection and analysis, literature review and writing of menuscript. Dr. Tuisem Shimarh (Assisatnt Professor) is supervisor of the entire study and made conceptual framework of this study. He is also the corresponding author.*

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