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Analysis of Vegetational Changes in River-floodplain using Sentinel – 2 Time Series: A Case Study in Okhla Bird Sanctuary in River Yamuna, India

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Abstract

This article assesses the distribution and dynamics of floodplain vegetation during two seasons in Okhla Bird Sanctuary (OBS). Okhla Bird Sanctuary is a wetland commission by barrage across the River Yamuna in Delhi NCR region. Vegetation analysis described that more than half of the area of the sanctuary covered with six broad groups of plant communities including both macrophytes and non-macrophytes of *Eicchornia crassipes, Alternanthera philoxeroides, Typha angustata, Phragmities karka, Saccharum spontaneum, Lantata camara, Prosopis juliflora etc.* The study also analysed the expansion of invasive macrophytes on the structural component of the wetland ecosystem. Monospecific and polyspecific population of *Eichhornia* and *Typha* species contributed in large section (46%) of invasive macrophytes in open water areas. Land cover change analysis of the sanctuary described a significant change in the area of water (74%) followed by vegetation (46%) and sand bed (13%) after the post-monsoon season. Discriminant analysis using Sentinel data series demonstrated that aggressive growth of macrophytes are causing a serious problem in the functioning of the sanctuary. There is a need for management prescription to be developed at several levels.

Keywords: NCR, Vegetation, Pixel, Wetland, Macrophytes

1. Introduction

The typical river floodplain landscapes are the interface between aquatic and terrestrial ecosystems. Both ecosystems represent a wide range of lotic, lentic and terrestrial habitat along with dynamic vegetation response. Vegetation not only plays an active role in ecological functioning but also sensitive to any change that reflects alternation in the riparian ecosystem. Vegetation in riparian zone is also classified into aquatic and terrestrial plant communities. These communities follow the basic principles of flow regime for their successional evolution (Nilsson and Svedmark, 2002). Distribution of vegetation is also influenced by the proliferation of invasive plants. Most of the vegetated aquatic ecosystem in the globe is infested with invasive species (Millennium Ecosystem Assessment, 2005). The impact of invasive species doubles over fifty years. This is one of the major threats for native species and ecosystem service (IPBES, 2019). Ecosystem services and threats in relation to vegetation has been assessed for ecological characters of Okhla Bird Sanctuary (OBS) (Kumar and Shimrah, 2018).

Monitoring of floodplain vegetation is very crucial for biodiversity assessment. In previous studies, vegetation mapping was difficult because of time-consuming field investigations and similar physiognomy of satellite data. There are several remote sensing techniques is used for vegetation monitoring in forest and urban ecosystems. Normalized Difference Vegetation Index (NDVI) gives information about the presence of vegetation. This index based information is used for monitoring the vegetation density and vegetation changes over times (Kaplan and Avdan, 2017).

Grassland, floodplain and wetland ecosystem need special kind of techniques for vegetation mapping because of similar appearance. In addition to this, the exhibition of short term (*i.e.* annual) spatial and temporal dynamics of aquatic plants due to hydrological processes also contributed error in such assessments (Dumont *et al.*, 2012). Accuracy of the vegetation mapping determined by the method is used to classify remote sensing data (Maxwell et al., 2018).

Hyperspectral remote sensing data can be used for accurate assessment for each species, but expensive acquisition cost limits its application (Burai *et al.*, 2015). To address this issue, the recently launched multispectral remote sensing satellite sentinel-2 time series with short repeat cycle was applied to discriminate plant communities of floodplain and wetland ecosystem (Rapinel *et al.*, 2019).

The aim of this study is to highlight the use of Sentinel-2 time series in combination with verified field information of quadrate for assessment of community structure, distribution and change of wetland vegetation in the Okhla Bird Sanctuary, Delhi - NCR region of India.

2. Materials and Methods

2.1 Study area

Okhla Bird Sanctuary (OBS) is located 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, bordering Delhi and Uttar Pradesh state of India (Fig. 1). The geographical location of the sanctuary is marked downwards in Upper Yamuna River sub-basin with an elevation about 185m above mean sea level.

The Sanctuary was formed due to commissioning of an Okhla Barrage across the River Yamuna. About 400-

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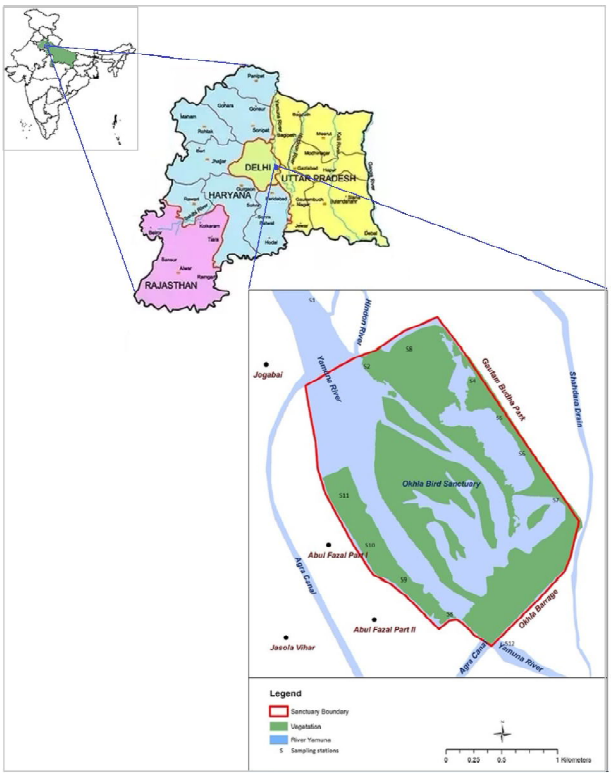

Fig. 1. Location map of Okhla Bird Sanctuary

hectare area of floodplain was declared as a protected area under the sanction 18 of Wildlife Protection Act 1972 by the Government of Uttar Pradesh notification 577/14-4-82/89 dated in 1990. Diverse landforms of water bodies, marshes, grasses and trees attract thousands of migratory birds of Central Asian Flyways. Ecological significance of the sanctuary indicated that the area included in Important Bird Areas (IBAs) and Asian Waterbird Census (AWC) in India.

2.2 Field Sampling

Field study was carried out during pre-monsoon (May), post-monsoon (October) and winter (February) in the year of 2018 -19. The study area was marked in twelve sites all along a different parts of the sanctuary. Sampling and field assessments were conducted in these marked places. An ecological assessment of plant species ware conducted through transit walk, data collection and field photographs under the described sampling framework (Fig.2). Terrestrial plants were identified through field guide of the tree of Delhi (Krishan, 2006). Identification of macrophytes was carried out using scientific nomenclature keys of Biswas and Mahapatra (2005). Invasive macrophytes of the sanctuary were identified with the help of invasive species catalogue developed by National Biodiversity Authority (NBA) and National Remote Sensing Centre (NRCS) earlier known as National Remotes Sensing Agency (Sandilyan, 2018 and Reddy, 2008).

Sampling techniques for quantitative studies for species description was prescribed through a line transect quadrat method. The distance of each point was maintained about hundred to one km in each random sampling on both the vertical and horizontal line of the sanctuary. The area was demarcated with the help of a rope to avoid the errors of counting. Species of herbs were counted in 1 x 1 meter plots whereas the area was increased in a continuous manner up to 10 x 10 meter for shrubs and trees. Quantitative data of community structure and species composition was analysed through frequency, density and abundance method.

2.3 Remote Sensing Data and Processing Geographical information system (GIS) based on classification of plant species is mapped on a satellite image (Sentinel 2a) with the help of ArcMap 10.5, and ERDAS imagine software (Fig.3). Cloud free Sentinel-2a image of pre-monsoon (25, April 2018) and post-monsoon (22, October 2018) data were acquired from the Copernicus Open Access Hub (https://scihub.copernicus.eu/).

Sentinel-2a included a set of 13 spectral bands at three spatial resolution: 1. A 10 m resolution four bands included blue (b2: 490 nm), green (b3: 560 nm), red (b4: 665 nm), and infrared (b8: 832 nm). 2. A 20 m resolution six bands carry four narrow bands for vegetation characterization (b5:705 nm, b6: 740 nm, b7: 783 nm, and b8a: 865 nm) and two larger SWIR bands (b11:1610 nm and b12:2190 nm) use for snow/ice/cloud detection or vegetation moisture assessment and3. A 60 m resolution three bands for aerosols (b1: 945 nm), water vapour (b9: 945 nm) and cirrus clouds detection.

The 20m bands of each Sentinel-2 image were subsampled to a 10m grid using the nearest neighbour approach. After, these subsampled bands were stacked with the other 10m bands (b2, b3, b4 and b8) into a temporary file. Finally, the images were stacked, subset and analysed through unsupervised classification. Unsupervised classification is the pixel-based classification where each pixel divided into different classes. This class is further validated in the field through quadrat based information of each species.

3. Results and Discussion

3.1 Community structure and species compositions

Vegetation characteristics of the Okhla Bird Sanctuary are described by the dense monospecific and polyspecific stand with unorganised stratification. Free-floating macrophytes such as *Eichhornia crassipes* along with *Alternathera philoxeroide* covered in the form of the thick mat and form one layered community structure in the open water area. In emergent macrophytes, *Typha angustata* and *Phragmites karka* often occur together forming two-layered vegetation within a habitat with height about one to five meters. A group of terrestrial plants included *Acacia nilotica, Prosopis juliflora and Lantana camara* organised in three layered stratifications which indicates a narrow difference up to two meters between tree species and large difference about ten meters between trees and shrubs.

Pistia stratiotes invades during the winter season after mechanical de-weeding of *Eichhornia crassipes* in post-monsoon. *Eichhornia crassipes* and *Pistia stratiotes* do not allow the invasion by other species, but it may readily invade the established strand of *Alternanthera philoxeroides*.

Community classification based on the quadrat method was analysed percentage for frequency, abundance and density of plant species (Fig 5). Variation in the frequency

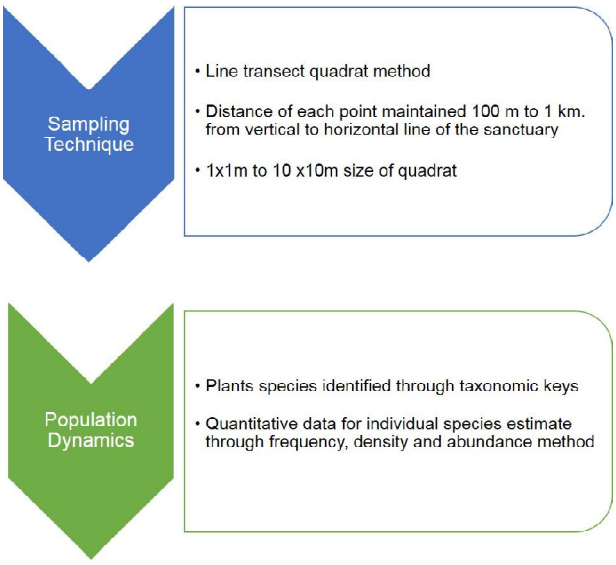

Fig. 2. Sampling framework for species structure and composition

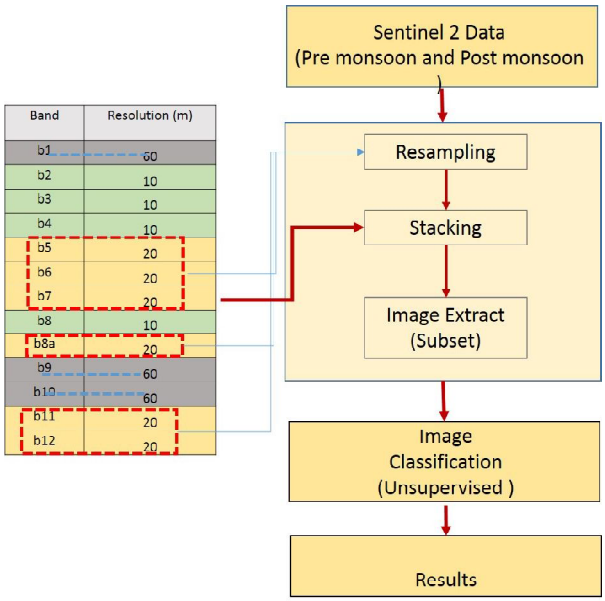

Fig. 3. Methodology for remote sensing image classification

Fig. 4. Field photographs A) Okhla Barrage over Rive Yamuna, B) Panoramic view of sanctuary C) Dense mat of *Eichhornia crassipes* on river bank and D) Quadrat sampling in OBS

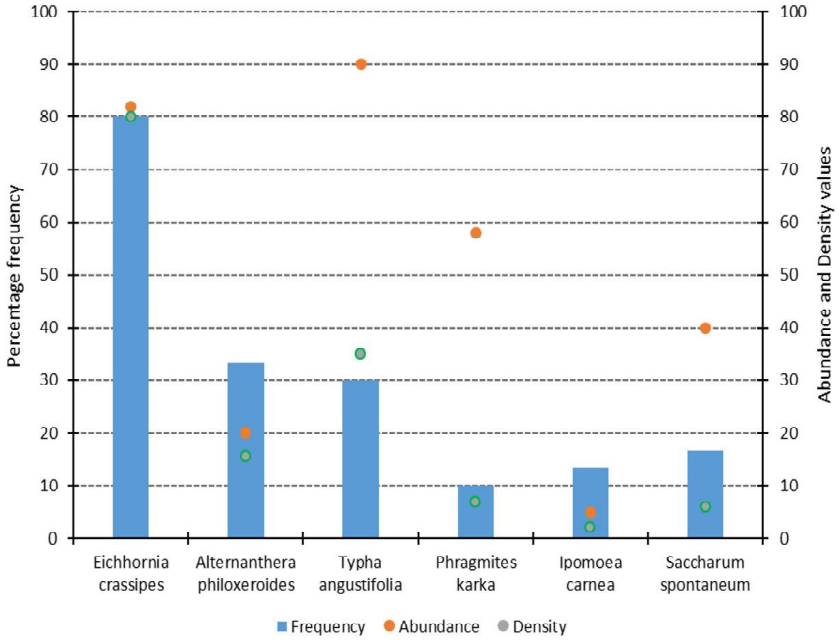

Fig. 5. Standard frequency, density and abundance diagram of the Okhla Bird Sanctuary

up to the level of ten percent is mentioned in the graph of sampled species. The most extent covering in study plots showed the highest percentage frequency distribution of *Eichhornia crassipes* (80%) followed by *Alternathera philoxeroides* (33%) and *Typha angustata* (30%).

Density, along with frequency gives an idea of the distribution pattern of the species while abundance represents the number of individual per unit area. Maximum density and abundance are shown by *Eichhornia crassipes* and *Typha angustata.* Density and abundance of the plant species depend upon the environmental conditions. Species which can tolerate harsh environmental condition have greater survival chance. Results reveal that *Eichhornia crassipes* and *Typha angustata* were more adaptive to the environment than *Ipomoea carnea.*

3.2 Vegetation distribution

The study developed a typology of plant communities through an unsupervised classification of the remote sensing images in combination with field base information.

Based on this information, six broad groups of communities of plant species have been identified in the sanctuary (Fig.6).

Group one species is free-floating macrophytes organised in sand bed, spur and upstream of barrage contributed maximum coverage of monospecific mat of *Eichhornia crassipes.*

Group two species are heterogeneous colonies of *Eichhornia crassipes* along with *Alternanthera philoxeroides* noticed in margin area whereas few colonies of *Ipomea cranea* also reported near right bund.

Group three and four species was observed in marsh area dominated with a monospecific strand of *Typha angustata* and polyspecific stand of *Typha angustata* associated with *Phragmities karka* agglomerated in the northern upward side of OBS.

Group five species are **small** pockets of a monospecific stand of *Saccharum spontaneum* reported in raised areas near the inflow of River Yamuna.

Group six species observed in dryland, embankment and shoreline areas dominated with trees and shrubs of *Acacia nilotica*, *Prospopis juliflora* and *Lantana camara* groups of species.

3.3 Land cover change

An analysis of land cover derived from remote sensing imagery within the sanctuary for the period of pre and post-monsoon, 2018 indicate a significant change in the area of vegetation, species composition and structural component of wetland (Fig. 6 and 7). These biophysical changes are the outcomes of periodical and systematic de-weeding in combination with natural flushing during monsoon season carried out by forest department.

Area of vegetation in each groups of the cluster shows the relevant change in the structure and composition of plant communities. In group one species, a monospecific mat of *Eichhornia* species declined about 67% from the sand bed, spur (both left and right) and upstream of barrage whereas heterogeneous colonies of *Eichhornia crassipes* along with *Alternanthera philoxeroides* of group two species entirely eroded in margin areas. Opening of the gates of barrage played crucial role in flushing of these free floating macrophytes of community group one and two species of OBS.

In emergent macrophytes, monospecific stand of group three species includes *Typha angustata* was reduced nearly 25% in marshes areas whereas polyspecific stand of *Typha angustata* along with *Phragmities karka* species increased up to three-fold under the group four species of plant communities in the sanctuary. Selection of native and exotic invasive species during mechanical de-weeding programme in post-monsoon are the prime reason for change in the area of group three and four species of OBS.

In group five species, dense colonies of *Saccharum*

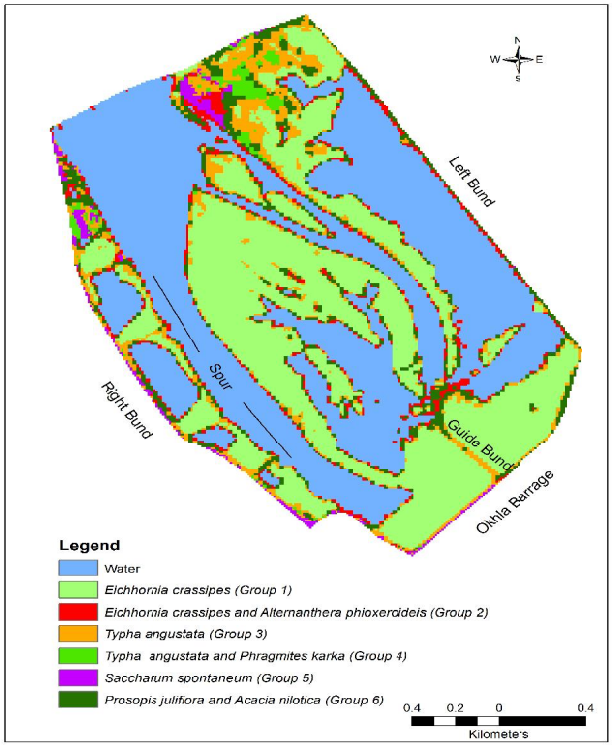

Fig. 6. Vegetation distribution in Okhla Bird Sanctuary during pre-monsoon

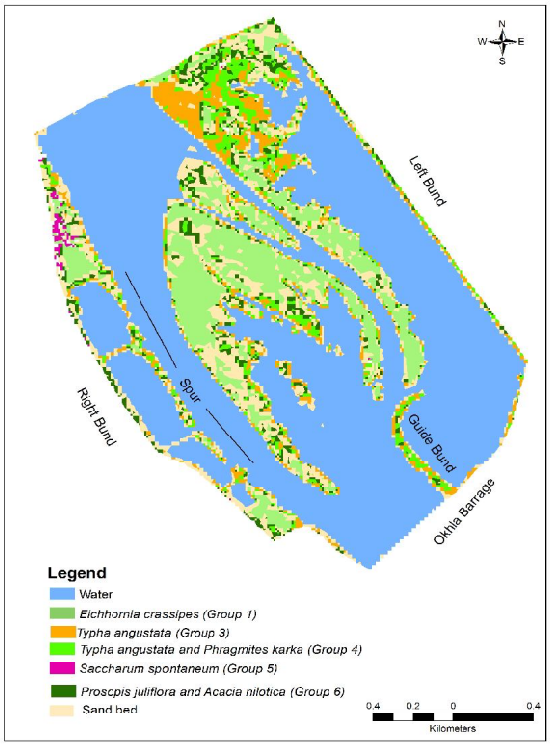

Fig. 7. Vegetation distribution in Okhla Bird Sanctuary during post -monsoon

spontaneum near the inflow on the bank of River Yamuna was eroded about 79% during monsoon season.

Group of terrestrial plants in number six communities includes *Acacia nilotica*, and *Prosopis juliflora* has declined half of the area in the OBS. Long rooted stable trees along the embankment were remain intact whereas small tree in the sand bed and marshes removed during monsoon season and de-weeding process.

Structural components of wetlands such as open water and sand dune without vegetation have also seen after the monsoon. Open water areas were increased by about 35% and 56 hectare sand bed without vegetation identified in the sanctuary. Finally, land cover change analysis of the sanctuary described a significant change in the area of water (74%) followed by vegetation (46%) and sand bed (13%) in OBS.

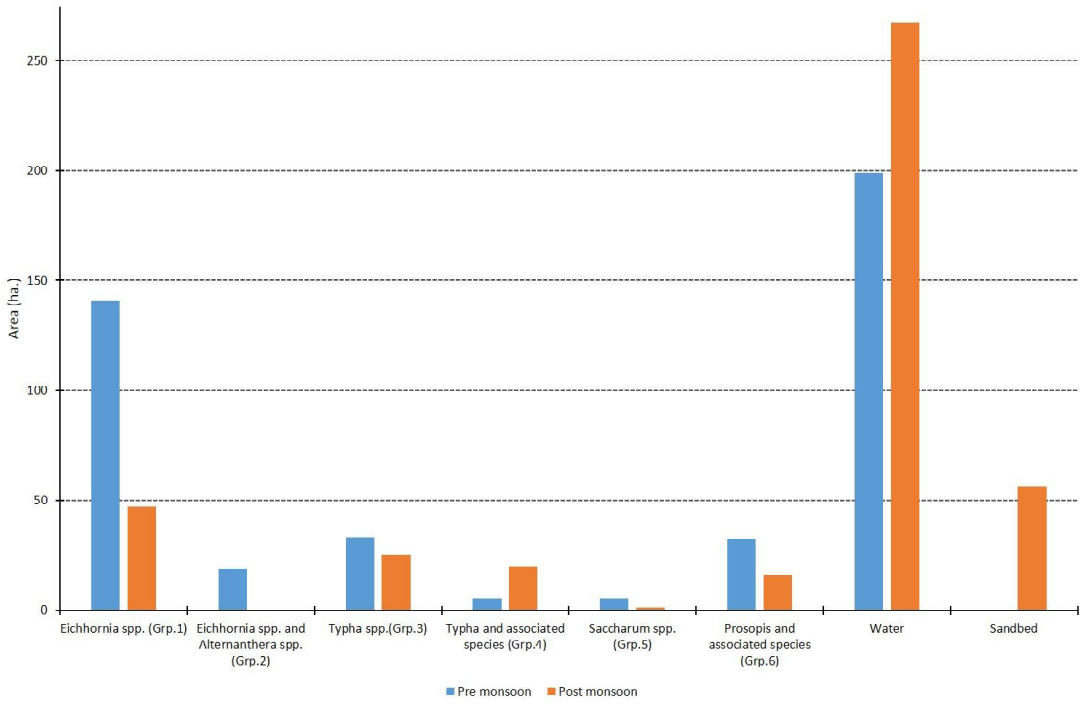

Fig. 8. Area under different land cover in Okhla Bird Sanctuary

4. Conclusion

This study highlighted the advantages of Sentinel -2 time series for assessments of wetland vegetation. Plant communities were discriminated through unsupervised classification and further validated through field-based information of quadrat method.

Dynamic nature of wetland vegetation reflected that the species structure and composition change because of influences of abiotic factors such as precipitation and de-weeding programme. A paradigm of invasion indicates *Eichhornia crassipes* and *Typha angustata* are major threats of ecosystem function in Okhla Bird Sanctuary.

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