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Remote Sensing and GIS for Wetland Mapping and Change Analysis; A Case Study of Shivnath Basin, Chhattisgarh, India

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Abstract: Wetland ecosystem is one of the most naturally occurring and most multifunctional ecosystems, which provides various important habitats for wildlife, valuable biodiversity resources, aids in water quality improvement, supports for ground water recharge, helps in moderating climate change and in flood control. However, the rapid urbanization caused degradation of wetlands. Geoinformatics Technique is very useful for measuring and mapping the changes of wetlands. In this Study, Resourcesat -1 LISS-III satellite data has been used for the time frames 2006-07 and 2017-18. In order to analyse the changes in wetlands field surveys have been performed and Cross checking was done through high resolution Google Earth images. Results of the Study show that in the study area 14 wetlands have been disappeared with the area of 336.25 ha. whereas 152 new wetlands have been created with the area of 3308.03 ha. The outcomes of the Study will help in decision making for various purposes like fishery development, water conservation, land development etc. Results of the present study will be helpful for carrying out further research activities in the field of aquaculture, hydrology and biodiversity.

Keywords: Wetland, Geoinformatics Technique, Satellite images.

I. Introduction

Wetlands are amongst the most productive ecosystems on the Earth (Ghermandi *et. al*., 2008). Wetlands represent 'kidneys of the earth' because it could provide many ecological functions such as cleaning the atmosphere, storing and recharging the ground water, improving water quality, adjusting the floodwater, protecting shorelines, providing habitats for wildlife especially for endangered species. Wetlands are among the most productive ecosystems besides being a rich repository of biodiversity and are known to play a significant role in carbon sequestration. As per the Ramsar Convention definition most of the natural water bodies (such as rivers, lakes, coastal lagoons, mangroves, peat land, coral reefs) and man-made wetlands (such as ponds, farm ponds, irrigated fields, sacred groves, salt pans, reservoirs, gravel pits, sewage farms and canals) in India constitute the wetland ecosystem. Out of these numerous wetlands only 26 have been designated as Ramsar Sites (Ramsar, 2013).

The first scientific wetlands mapping of India was carried out during 1992-93 by Space Applications Centre (ISRO), Ahmedabad, at the behest of the Ministry of Environment and Forests (MoEF), Govt. of India using remote sensing data from Indian Remote Sensing satellites (Anon., 1993). There are about 4 % of wetland of the total land surface of world and 6% of wetland of the total land surface of India (Nitin Bassi *et. al*., 2014).

Wetland types and distribution in India created at 1: 250,000 scale using Resourcesat-1 (Indian Remote sensing Satellite - P6) Advanced Wide Field Sensor (AWiFS) data of 2004-05. A two-step hierarchical classification was used to map the wetlands and categorized them into 25 classes. The total area under various wetland categories was estimated as 11.69 Mha (Patel *et. al*., 2007).

Due to urbanization and different types of pollutions, wetlands have lost their naturality. Wetlands usually occur in depressions or along rivers, lakes, and coastal water where they are subjected to periodic flooding. Some wetlands also occur on slopes associated with the ground water seeps. Conceptually, wetlands lie between well-drained upland and permanently flooded to deep water of lakes, rivers and coastal embankments. Satellite technology has evolved over the years and currently being used to obtain various information regarding water level, river width, flood inundation, soil moisture, water quality, turbidity, aqua vegetation, evapotranspiration and ground water. Wetlands are considered to have unique ecological features that provide numerous products and services to humanity (Prasad *et. al*., 2002).

Ecosystem products provided by the wetlands mainly include water for irrigation; fisheries; non-timber forest products; water supply; and recreation. Major services include carbon sequestration, flood control, groundwater recharge, nutrient removal, toxics retention and biodiversity maintenance (Turner *et. al*., 2000).

The main objectives of the study were preparation of digital wetlands database of the study area at 1:50,000 scale using Resourcesat LISS-III data of the time frame 2006-07 and 2017-18 and Change Detection Analysis of Wetlands from 2006-07 to 2017-18.

II. Study Area

The study area is situated on the central part of Chhattisgarh state of India. Administratively Shivnath basin is a part of Bilaspur, Kabirdham, Mungeli, Rajnandgaon, Bemetara, Durg and Dhamtari districts in Chhattisgarh. The latitudinal and longitudinal extent of the basin are 20°16' N to 22° 41'N and 80° 25' E to 82° 35' E respectively. Location map of the study area is shown in Fig. 1. The basin is entirely located in Chhattisgarh State and covers an area of 30860 sq. km. Shivnath (a tributary of Mahanadi) river rises from Satpura-Maikal hill in the north west region of the Central Plateau. The river flows from north roughly through the central part of Chhattisgarh with a length of 375.79 km. and the average annual rainfall varies from 900 mm to 1200 mm. Temperature range of the basin varies from 11°C to 43 °C. It is an ideal basin which consists of hilly, plateau, piedmont and plain areas.

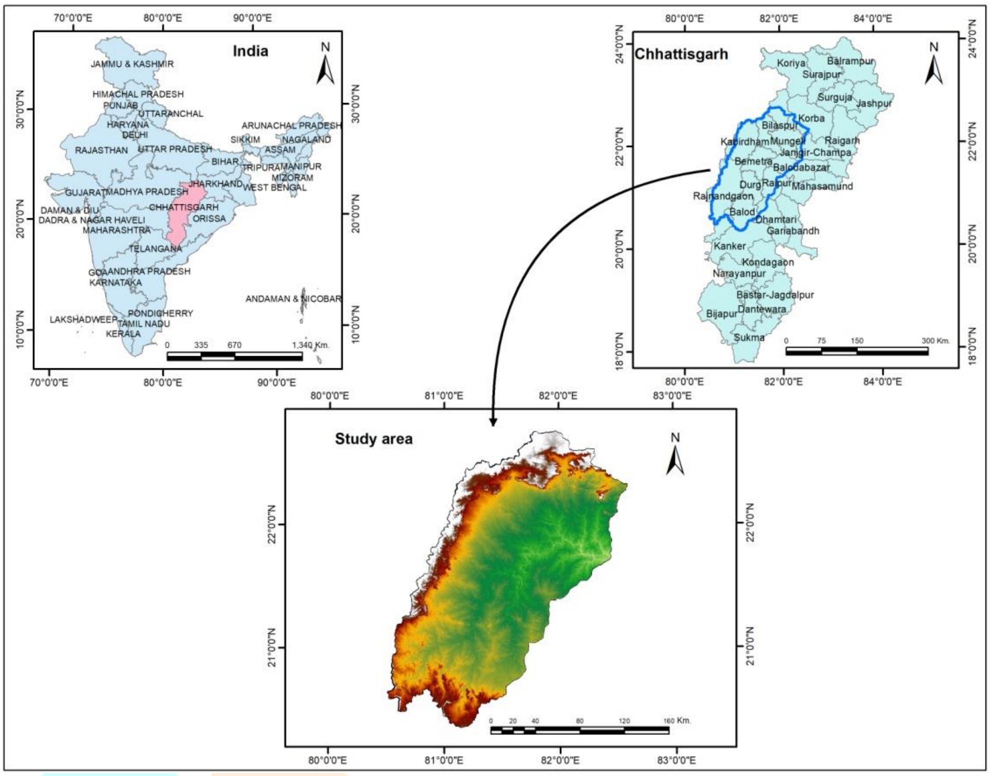


Fig.1: Location map of the study area

III. Data Used

Resourcesat-1 LISS III data was used to map the wetlands. LISS III provides data in 4 spectral bands; green, red, Near Infra-Red (NIR) and Short Wave Infra-Red (SWIR) with 23.5 m spatial resolution with repeat cycle of 24 days. The spatial resolution is suitable for 1:50,000 scale mapping.

Remotely sensed data require selective field observations called “ground truth” in order to convert it into authentic information. Such ground truth involves visiting test sites selected on the basis of the satellite data. The locations of the features are recorded using GPS. There are 92 wetlands points, shown in Fig 5, visited including disappeared and newly created wetlands.

Survey of India (SOI) topographical maps and National Wetland Maps at 1:50,000 scale were used for reference purpose.

IV. Method

- Georeferencing of satellite data
- Identification of wetland classes as per the classification system and mapping of the classes using a knowledge based digital classification and onscreen interpretation
- Verification of the data with NDWI (Normalised Difference Water Index), NDVI (Normalised Difference Vegetation Index) and Ground Truth Collection.
- Preparation of Digital database of wetlands for the years 2006-07 and 2017-18.
- Wetland Change Detection Analysis from 2006-07 to 2017-18

Flow Chart of methodology is shown in Fig. 2.

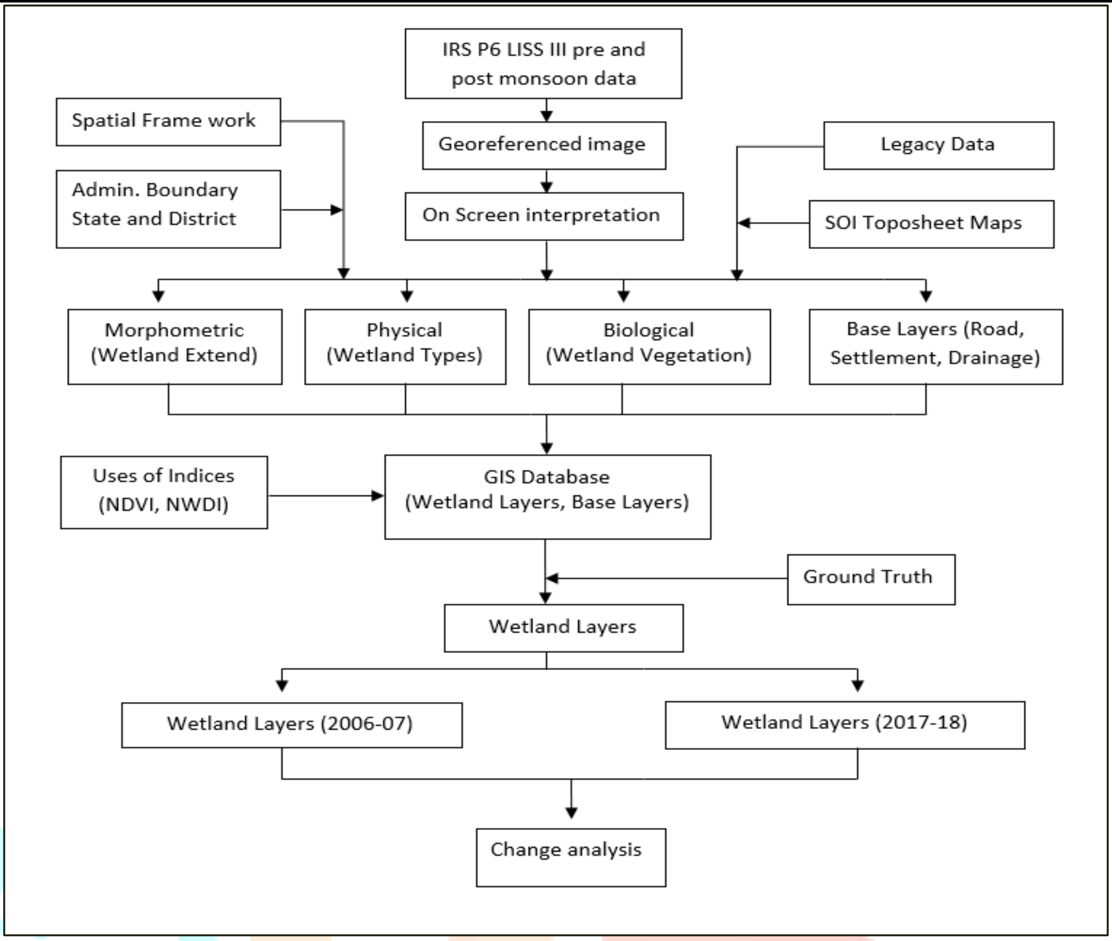


Fig. 2: Methodology Flow Chart

Delineation of wetlands through image analysis forms the foundation for deriving all wetland classes and results. Consequently, a great deal of emphasis has been given to the quality of the image interpretation. In the present study, the mapping of wetlands was done following digital classification and onscreen visual interpretation. There are various methods for extraction of water information from remote sensing imagery, which are normally divided into two categories i.e. single-band and multi-band methods. Single-band method usually involves choosing a band from multi-spectral image to distinguish water from land by subjective threshold values. It may lead to over or under-estimation of open water area. Multi-band method takes advantage of reflective differences of each band. In this study, two indices known as NDVI and NDWI were used to enhance various wetland characteristics.

India has a wide diversity of wetlands (MoEF, 1990, WWF, 1993). The Wetland Classification System, besides including all wetlands, incorporates deep-water habitats and impoundments. Main levels and classes followed in this system are given in Table 1.

Table 1: Wetland Classification System

Level I	**Level II**
Natural	
	Lakes
	Ox-Bow Lakes/ Cut-Off Meanders
	High altitude Wetlands
	Riverine Wetlands
	Waterlogged
	River/stream
Man-made	
	Reservoirs/ Barrages
	Tanks/Ponds
	Waterlogged
	Salt pans
	Aquaculture ponds
	Canal

Indices used for Wetland Extraction

The indices used in the present study are as follow:

i) Normalised Difference Water Index (NDWI) = (Green - NIR) / (Green + NIR)

ii) Modified Normalised Difference Water Index (MNDWI) = (Green - MIR) / (Green + MIR)

iii) Normalised Difference Pond Index (NDPI) = (MIR - Green) / MIR + Green)

iv) Normalised Difference Vegetation Index (NDVI) = (NIR - Red) / (NIR + Red)

v) Normalised Difference Turbidity Index (NDTI) = (Red - Green) / (Red + Green)

Where: NIR- Near Infra Red

MIR- Middle Infra Red

The indices were generated using standard image processing software using different bands. MNDWI has been generated with Green and MIR spectral bands whereas NDVI has been generated with Red and NIR spectral bands. NDWI has been generated with Green and NIR spectral bands These indices provided better information on wetlands. Indices used for extraction of wetlands for the time frames 2006-07 and 2017-18 are given in Fig. 3 and Fig. 4 respectively.

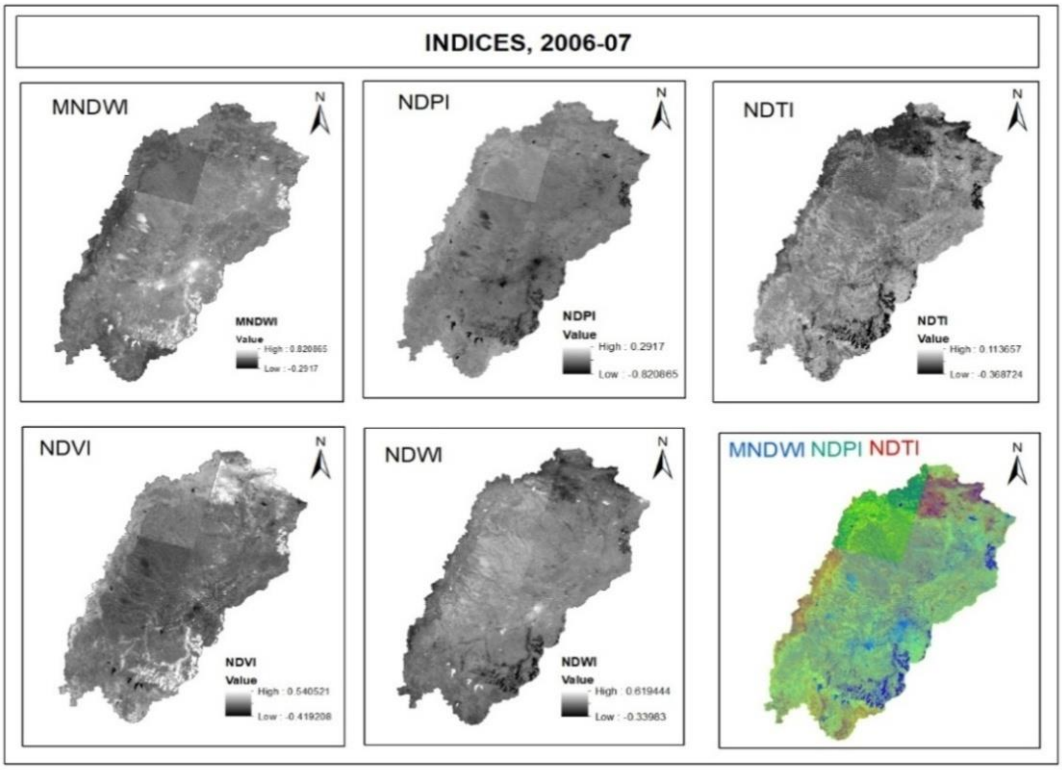


Fig.3: Indices of 2006-07

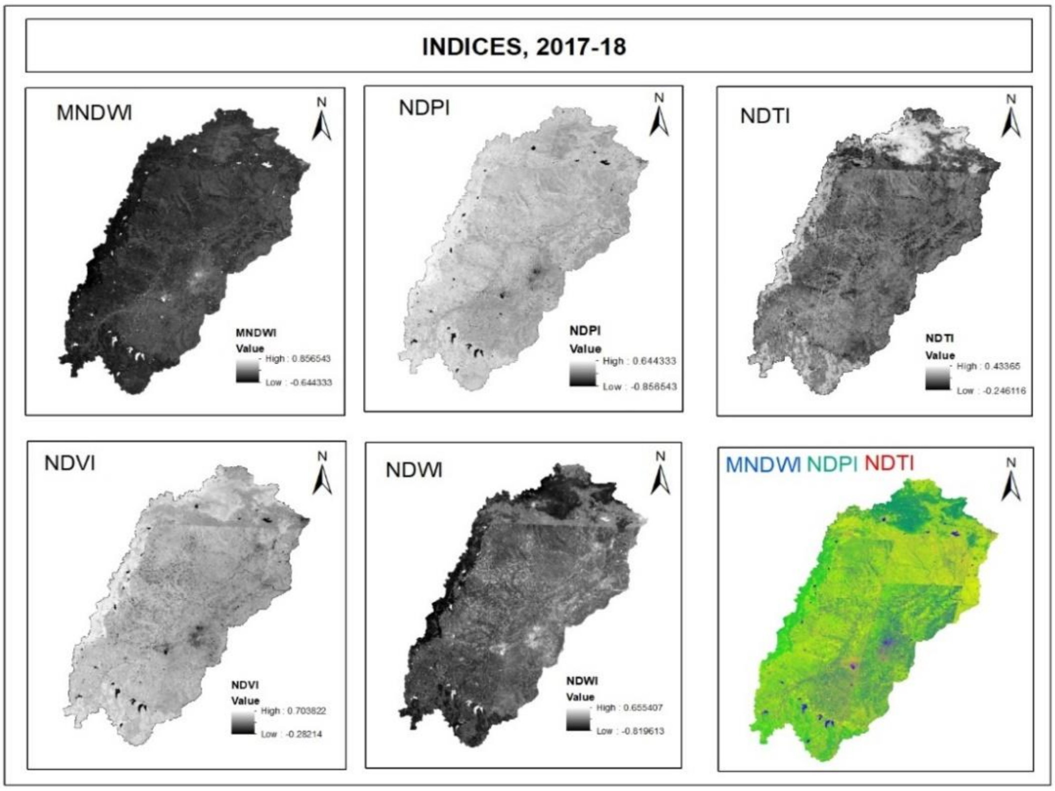


Fig.4: Indices of 2017-18

Ground truth survey is necessary for cross verification of disappeared wetlands, newly created wetlands and to measure the actual extent of wetlands. Field verification has been carried out for 92 Wetlands Point Checks through mobile GPS. During the field surveys many places with aqua vegetation have been found which are not clearly visible on satellite data. The outputs of field visits are helpful to mark and modify the boundaries of wetland with aqua vegetation. 02 disappeared wetland cases and more than 25 newly created wetland cases have been cross verified during the field surveys. Points map of field verification is shown in Fig.5.

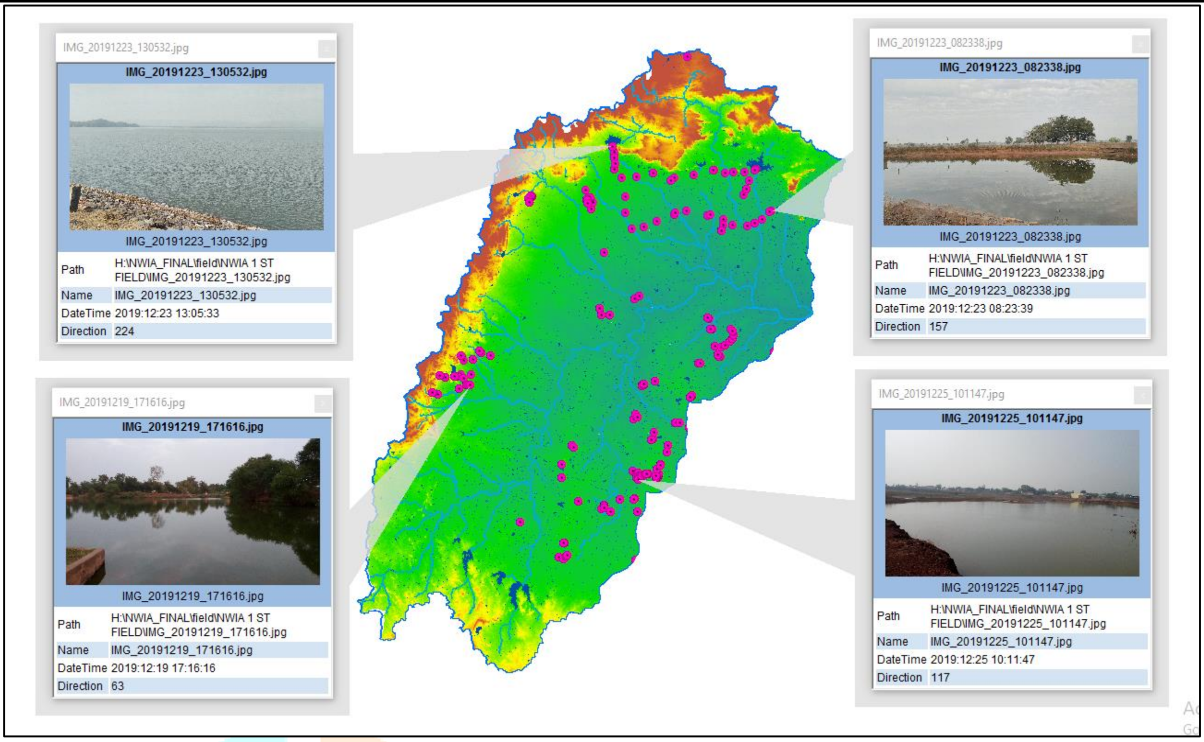


Fig.5: Point map of field verification

V. Results and discussion

NDWI, MNDWI, NDPI, NDVI and NDTI images were used to extract the wetland boundaries through suitable hierarchical thresholds (Fig. 3 and Fig. 4).

Wetland Extraction: 2006-07 and 2017-2018

Wetland database of 2006-07 has been prepared using IRS LISS-III data applying various Indices. After analyzing the changes it has been found that there were 5316 nos. of wetlands with the area of 84270.7 ha. in 2006-07 and 5460 nos. of wetlands with the area of 90616.27 ha. in 2017-18. Category wise Wetland area in 2006-07 and 2017-18 are given in Table 2. The major categories of the wetlands found in this area are Tank/Pond, Reservoir/Barrage and River/Stream. There are 5013 nos. of Tank/Pond and 253 nos. of Reservoir/Barrage found in 2006-07 and 5123 nos. of Tank/Pond and 279 nos. of Reservoir/Barrage found in 2017-18. Wetland maps of 2006-07 and 2017-18 are given in Fig. 6.

Table 2: Wetland area of 2006-07 and 2017-18

Category	2006-07		2017-18	
	Area (Ha.)	Nos. of wetlands	Area (Ha.)	Nos. of wetlands
Ox-Bow Lakes/ Cut-Off Meanders	17.67	2	17.67	2
Riverine Wetlands	8.95	2	8.95	2
Natural Waterlogged	47.62	2	41.69	1
River/Stream	27340.55	20	27003.31	25
Reservoirs/ Barrages	29108.34	253	33318.4	279
Tanks/Ponds	27557.71	5013	30003.21	5123
Man-made Waterlogged	189.86	24	223.04	28

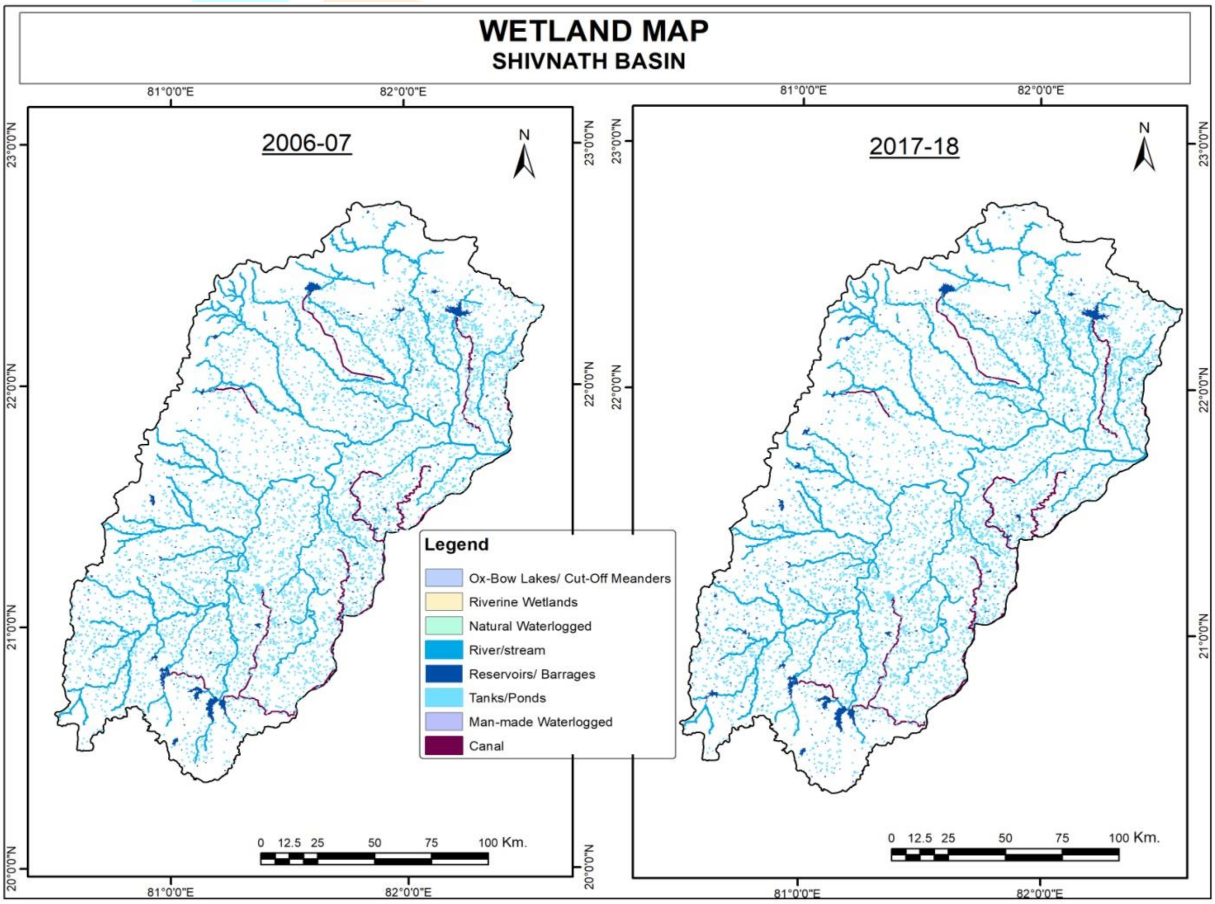


Fig.6: Wetland maps of 2006-07 and 2017-18

Wetland Change Analysis

Significant changes were found in wetland extent and newly created wetlands from 2006-07 to 2017-2018.There are 152 new wetlands with the area of 3308.03 ha. created for domestic, agricultural and industrial uses. 14 nos. of wetlands with the area of 155.08 ha. disappeared due to anthropogenic activities like industrialisation, mining reclamation, built up etc. Category wise newly created and disappeared wetlands are given in Table 3. Category wise Changes of Wetland area from 2006-07 to 2017-18 are given in Table 4. Bar diagram showing Category wise wetlands in 2006-07 & 2017-18 are given in Fig. 7.

Table 3: Category wise Disappeared wetlands and New wetlands

Disappeared Wetlands			New Wetlands		
Category	**Area (ha.)**	**Nos. of Wetlands**	**Category**	**Area (ha.)**	**Nos. of Wetlands**
Reservoirs/ Barrages	37.25	1	Reservoirs/ Barrages	2136.63	21
Tanks/Ponds	92.86	12	Tanks/Ponds	1135.19	127
Man-made Waterlogged	24.97	1	Man-made Waterlogged	36.21	4
Total	**155.08**	**14**	**Total**	**3308.03**	**152**

Table 4: Category wise Changes of Wetland area from 2006-07 to 2017-2018

Wetland Type	**2017-18**		**2006-07**		**Change**	
	Wetland area (ha.)	% of the total wetland area	Wetland area (ha.)	% of the total wetland area	Wetland area (ha.)	Wetland area (%)
Ox-bow lake/ Cut-off meander	17.67	0.02	17.67	0.02	0	0.00
Waterlogged (Natural)	8.95	0.01	8.95	0.01	0	0.00
Riverine wetland	41.69	0.05	47.62	0.06	-5.93	-12.45
River/Stream	27003.31	29.80	27340.55	32.44	-337.24	-1.23
Reservoirs/Barrages	33318.4	36.77	29108.34	34.54	4210.06	14.46
Tanks/Ponds	30003.21	33.11	27557.71	32.70	2445.5	8.87
Waterlogged (Man-made)	223.04	0.25	189.86	0.23	33.18	17.48

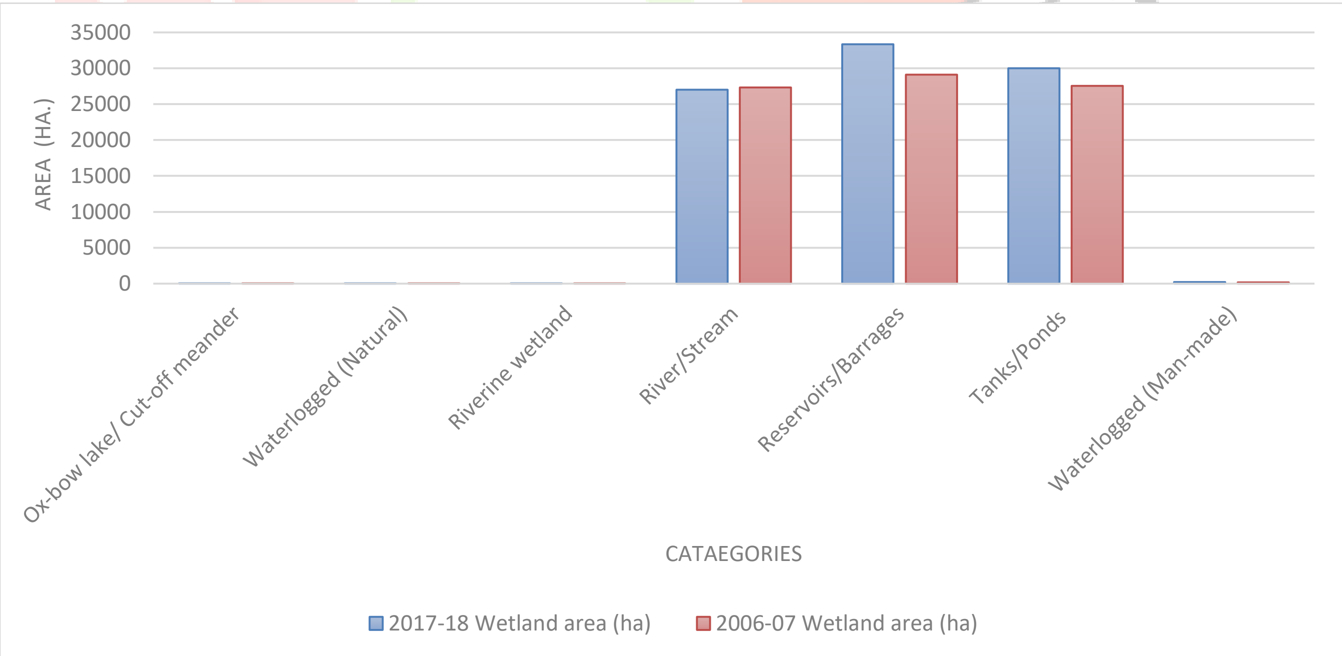


Fig.7: Bar diagram showing Category wise wetlands in 2006-07 & 2017-18

Some examples of the newly created wetlands and disappeared wetlands along with ground photographs are shown in Fig.8 and Fig. 9 respectively.

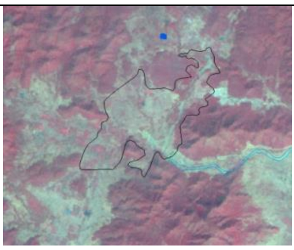
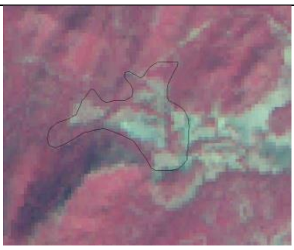
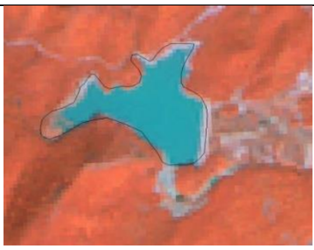
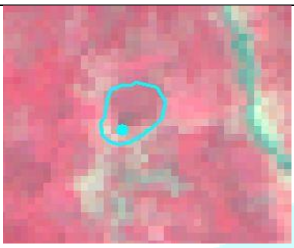
2006-07	2017-18	Field photo	Location
			Lat: 21° 49' 40" N Long: 81° 01' 24" E (Kawardha district)
			Lat: 21° 29' 58" N Long: 80° 51' 46" E (Rajnandgaon district)
			Lat:20° 49' 26" N Long: 81° 11' 06" E (Balod district)

Fig.8: Examples of new Wetlands

2006-07	2017-18	Field photo	Location
			Lat:21° 16' 30" N Long: 81° 32' 00" E (Durg district)
			Lat: 21° 11' 28" N Long: 81° 25' 40" E (Durg district)

Fig.9: Examples of Disappeared Wetlands

VI. Conclusions

Wetlands perform a range of environmental functions and provide numerous socio-economic benefits to the local communities. Due to increase of anthropogenic pressure, the fragile yet diverse ecosystem is under constant threat. It requires comprehensive monitoring in order to identify and analyze the changes occurring in the wetland area. Thus, the present research was carried out to study and visualize the spatial and temporal changes occurring in the wetland areas in Shivnath basin. It has been found that 14.46 % area of Reservoirs and 8.87 % area of Tanks/Ponds have been increased in 2017-18 in comparison to 2006-07. 92.8 ha. area of Tanks/Ponds have been disappeared because of industrial development and mining activities. Looking into the increasing threat to wetland ecosystems it is essential that ecologically important wetlands are identified and protected. Industrialization and urbanization are increasing to a huge extent. The conservation and management of the wetlands also needed to be expedited accordingly. Sustainable development is required with balance between environment and people in terms of development, production and consumption.

The integrated approach as applied in the present study using Geoinformatics techniques and various indices with selective field checks found very effective in identifying and verifying wetland extent. LISS III satellite data found to be useful for measuring the changes in wetland, identifying newly created wetlands and the wetlands which have been disappeared due to anthropogenic activities.

Conservation and management of wetland are the key factors for restoring an ecosystem successfully by minimizing the negative effects of human activities. Various development activities including urbanization, industrialization etc. are replacing the wetland ecosystems. Vegetation, hydrology, and soils are the basic elements that comprise wetlands. As such the present wetland mapping and change analysis will make a platform for carrying out various further research activities in aquaculture, hydrology including ground water and surface water and biodiversity management.

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