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Assessment of Wetland Dynamics in terms of Status and Temporal Changes Using RS & GIS in Aligarh District, UP, India

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ABSTRACT
Wetlands are some of the most diverse ecosystems in the world. The accurate mapping of wetland types and monitoring their dynamic changes provide the scientific foundation for wetland conservation and restoration. Aligarh district, located in Uttar Pradesh, had many wetlands but due to encroachment, they are shrinking. No wetland mapping has been done before to compare the past and present situation of wetlands. Therefore under this study, an attempt has been made to understand the status of wetlands in the Aligarh district in terms of their number and extent and also assess the temporal changes during 2002-2017 using the multi-temporal Landsat imageries. Supervised Classification with the Maximum Likelihood algorithm was used to classify the wetlands. We found that about 3988 ha area was covered by wetlands, which is one per cent of the total geographic area of the district. The maximum number of wetlands were point wetlands currently (having less than 1 ha area). In the last 15 years, the area of wetlands decreased by 49%. The overall accuracy of the supervised image produced was 87.50% with a kappa value of 0.75.

Key words: Remote sensing, wetland mapping, supervised classification, change detection, Landsat imageries

INTRODUCTION

Understanding the values and functions of wetlands and their responses to diverse anthropogenic pressures is important for conservation planning and management of wetlands. Wetland is an ecologically sensitive and adaptive system to climate and land-use changes due to its fragile and dynamic nature. It plays an integral role in climate regulation, the refurbishment of the hydrological cycle, the stability of ecosystem diversity and the provision of many important services to human society (Brink et al. 2012, Hu et al. 2017). Wetlands are immensely diverse in terms of their genesis, geographic location, different and dominant life forms, chemical condition of water, and quality of soil and sediment (Space Applications Centre 2011) They are among the richest and productive ecosystems after the tropical rainforest (Ghermandi et al. 2008, Ramsar Convention 2016), and delivers 45% of the world's natural productivity and ecosystem services (The Millennium Ecosystem Assessment 2005).

Wetlands have been acknowledged for their ecological and economic importance but still, they are being deteriorated at an accelerated pace, as per the report of the Ramsar Convention on Wetlands (2018). Wetlands are decreasing three times faster than forests and their depletion rate is growing. For example, 87 percent of wetlands have been destroyed since the 1700s (Ramsar Convention 2018). The key factors in forfeiting these unique resources are the developmental practices attributable to human demands such as land-use changes for the cultivation and industries, pollution and surplus nutrients, over-harvesting of the fish population, introduce invasive species, climate change, and formation of reservoirs, dams, and canals. Along with aquatic mammals, plants, and other species, wetlands are an important refuge for migratory birds. There is a significant reduction in wetland-dependent species in many regions. About 80% of inland wetland and 36% of coastal and marine ecosystems species have experienced losses since 1970 (Ramsar Convention 2018). Hence, wetlands need long-term planning for the preservation and conservation of these resources which are important to sustain a healthy environment.

Due to the tremendous potential of wetlands, many national and international efforts have been initiated to safeguard the wetlands. In 1971, the first international convention, the Ramsar Convention, was signed to endorse the conservation, restoration, sustainable and prudent use of wetlands. Since then the Ramsar Convention has expanded and now closely associated with Birdlife International, International Union for Conservation Nature (IUCN), International Water Management Institution (IWMI), Wetland International, WWF International, and Wildfowls & Wetland Trust and many more (Ramsar Convention Bureau 2001).

The distribution and extent of existing wetlands and studying their dynamic changes need to be monitored at local and global levels. Hence the first step in the conservation of wetlands is to establish and maintain the wetland inventories (Ramsar Convention Secretariat 2010) which can be defined as maps that provide information on the distribution of wetlands across geographical regions (Mahadavi et al. 2017). Thus wetland maps are a fundamental necessity to maintain, preserve and restore the wetlands. Awareness of wetland transitions or alterations is also an important management step that will be helpful to understand the impact of conservation measures and aids to develop the long-term planning (Baig et al. 2017, Jensen et al. 1993).

Remote Sensing in collaboration with the Geographic Information System and the Global Positioning System could play a significant role in mapping and monitoring of available data on water resources (Lyon et al. 2001, Ozesmi and Bauer 2002, Pattanaik and Reddy 2007, Rebelo et al. 2009, Adam et al. 2010, Lang et al. 2015). Remote sensing is the most economic approach to determine, plan, maintain and monitor land and water resources such as the wetlands across various space and time scales (Reddy et al. 2007, Reddy et al. 2008).

Till today in India, as per the Ramsar Convention, only 49 wetlands have been declared as Ramsar Sites (Ramsar 2022). Islam and Rahmani (1988) have identified 135 wetlands that fulfill Ramsar criteria. Many programmes have been implemented to monitor the status and trend of important wetlands in India but there is very little information on wetlands in the Aligarh district due to their small size and the small share of wetlands area of the total country's wetland area (National Wetland Atlas Uttar Pradesh 2010). Given this background, the objective of the study is to know the status and trend of wetlands in the Aligarh district, in terms of their distribution, number and areal extent and changes in the wetlands for 15 years. The present study will be helpful to managers and policymakers to maintain the ecosystem for the most preferred species, such as water birds especially migratory waterbirds, and wetland-dependent vertebrates and invertebrates.

STUDY AREA

This study was conducted in the Aligarh district of Uttar Pradesh, India (Figure1). Aligarh district is situated in the western part of Uttar Pradesh occupying a small part of Ganga – Yamuna doab. The extreme parallels of latitude are 27^0 33' and 28^0 11' north and 77^0 28' and $78^0$35' east longitude. The district lies in the upper Gangetic plains, areas of remarkable fertility. The general level of the district is extremely regular, the greatest height being 195 meters above mean sea level at Chandausi. Aligarh district with its uniform surface is largely constituted of the alluvial filling that is constituted by clay silt, sand, and *kankar*. It experiences a tropical monsoon type of climate characterized by hot summer (mid-March to mid-June), pleasant winter (mid-October to mid-March), and the monsoon season (mid-June to mid-September). The average rainfall is 647mm and mainly falls from July to August.

METHOLOGY

Data Collection

The present study was started from the first collection of 14 topographic maps (53H/08, 53H/12, 53H/16, 53L/04, 53L/08, 53L/12, 54E/09, 54E/13, 54E/14, 54I/01, 54I/02, 54I/05, 54I/06, 54I/09) of 1:50,000 scale from the Department of Wildlife Sciences (AMU), Department of Geography (AMU), Department of Geology (AMU) and Survey of India, Dehradun that was used for the identification of base features. After that, Satellite imageries of Landsat 7 Enhanced Thematic Mapper Plus (ETM+) (14 October 2002) and Landsat 8-Operational Land Imager (OLI) (15 October 2017) were downloaded from the USGS website for mapping and temporal comparisons. All image processing was performed in ERDAS IMAGINE 2018 and Arc Map 10.2

Data Processing

All the topographic maps were scanned and exported to ERDAS imagine for georeferencing and mosaicing, then re-projected into the universe transverse Mercator geodetic system-84 (UTM-WGS 84) projection for further analysis. An area of interest (AOI) was created along the border of the area from the mosaiced data to create a rectilinear map to collect information on different aspects of landscape cover, highways, etc. Satellite data were also imported into ERDAS software. Stacking and geometric corrections were done. After that a mosaiced map of toposheets was overlaid or swapped on a satellite image to check its accuracy by comparing the features like roads, railway lines, the crossing of canals, rivers, etc. on each other. Then a subset of AOI was made with the help of the mosaiced topographic AOI map. The image was displayed in the false-color composite (Imam and Kushwaha 2012).

Supervised classification with maximum likelihood technique was performed. It is the most common technique for wetland mapping (Ozesmi and Bauer 2002). The entire study area was categorized into two classes (i) Wetland and (ii) Non-wetland. The overall area of these two classes was calculated. After that, a clump operation was performed and then wetland class was classified into four categories based on their size, these categories were -

(i) Point wetland: less than 1 ha area
(ii) Small Wetland: 1 to 2.5 ha area
(iii) Medium Wetland: 2.51 to 5.0ha area
(iv) Large Wetland: more than 5.0 ha area

The accuracy of the maps was tested by Cohen's Kappa Statistics using100 randomly selected points. Temporal changes were assessed by comparing the images of 2002 and 2017. The image of 2002 was also classified into two classes, i.e. wetland and non-wetland with the help of supervised classification method given above and then compared with the total area of wetlands of 2017.

Field Survey

Field surveys of the study area were carried out from September 2017 to February 2018 for the ground-truthing. It was done by matching the features from the map and particular topographic features using GPS locations. The list of some wetlands and their location was prepared with the help of Google Earth and a literature survey that was also helpful in ground-truthing. The survey was conducted along the different roads with the help of vehicles that led to different towns and villages in the Aligarh district. Ground truthing was done for the 38 wetlands and total 76 hours were spent in the field.

RESULTS

Status of Wetlands in the Aligarh district

The current status of wetlands in the Aligarh district was recorded by delineating wetlands using supervised classification through Landsat satellite imagery of October 2017.The total area of wetlands including rivers, streams, canals, and all types of wetlands (whether natural or artificial) was 3,988 ha and covers only 1 % of the total geographical area of Aligarh district.

Furthermore, in the present study, wetlands were classified into different categories based on their size viz-a-viz point wetland (less than 1 ha), small wetland (1 to 2.5 ha), medium wetland (2.51 to 5.0 ha) and large wetland (more than 5.0 ha). A total of 869 wetlands were identified excluding rivers, streams, canals and sub-canals, in the Aligarh district covering 842 ha area. The result of this study revealed that the maximum number of wetlands falls under the category of Point wetlands (697), followed by small wetlands (130), medium wetlands (22) and the minimum number fell under large wetland (20) category. However, point wetlands covered maximum area (287 ha) that occupied 34% of the total wetland area, followed by large wetlands (280 ha), than small wetlands (196 ha) and medium wetlands covered minimum area (79 ha) that occupied only 9% of the area of total wetland area (Table 1, Fig 1).

Status and distribution of wetlands in different subdivisions of Aligarh district

The result of this study shows the distribution of wetlands in different subdivisions (locally called *tehsil*) of Aligarh have varied numbers and area of wetlands. Koil subdivision has a maximum number (236) of wetlands that covered 292 ha area followed by Iglas that have 191 number of wetlands that covered 190 ha area then Khair subdivision in which 166 ha covered by 178 number of wetlands whereas

Table 1. Status of wetland categories in Aligarh district (excluding rivers, streams and canals)

Wetland Categories	Size class (ha)	Area (ha)	Numbers
Point wetland	< 1	287	697
Small wetland	1 to 2.5	196	130
Medium wetland	2.51 to 5.0	79	22
Large wetland	> 5.0	280	20
Total		**842**	**869**

Gabhana subdivision has a minimum number (113) of wetlands that covered 72.71 ha area of the subdivision (Fig. 2, Table 2).

Temporal changes in wetland status between 2002 to 2017

The present study shows the temporal changes in the wetland status by comparing two satellite images of different years i.e. 2002 and 2017 (Fig. 3). In 2002, the total area recorded for all wetlands was 7,817 ha, and in 2017 which was declined to 3,988 ha. The area of wetland decreases by 49% from 2002 to 2017 (Table 3).

Accuracy Assessment

To evaluate the accuracy of the classified image, an accuracy assessment was performed for the 2017 image using 100 stratified randomly generated points (Table 4). The accuracy assessment was performed with an error matrix with a producer's and user's accuracy. The highest producer's accuracy was 92.86% for the wetland class whereas the user's accuracy was the highest 93.75% for the non-wetland class. The overall accuracy was found to be 87.50% and overall Cohen's Kappa value was found to be 0.75.

DISCUSSION

To conserve and manage wetland resources, it is

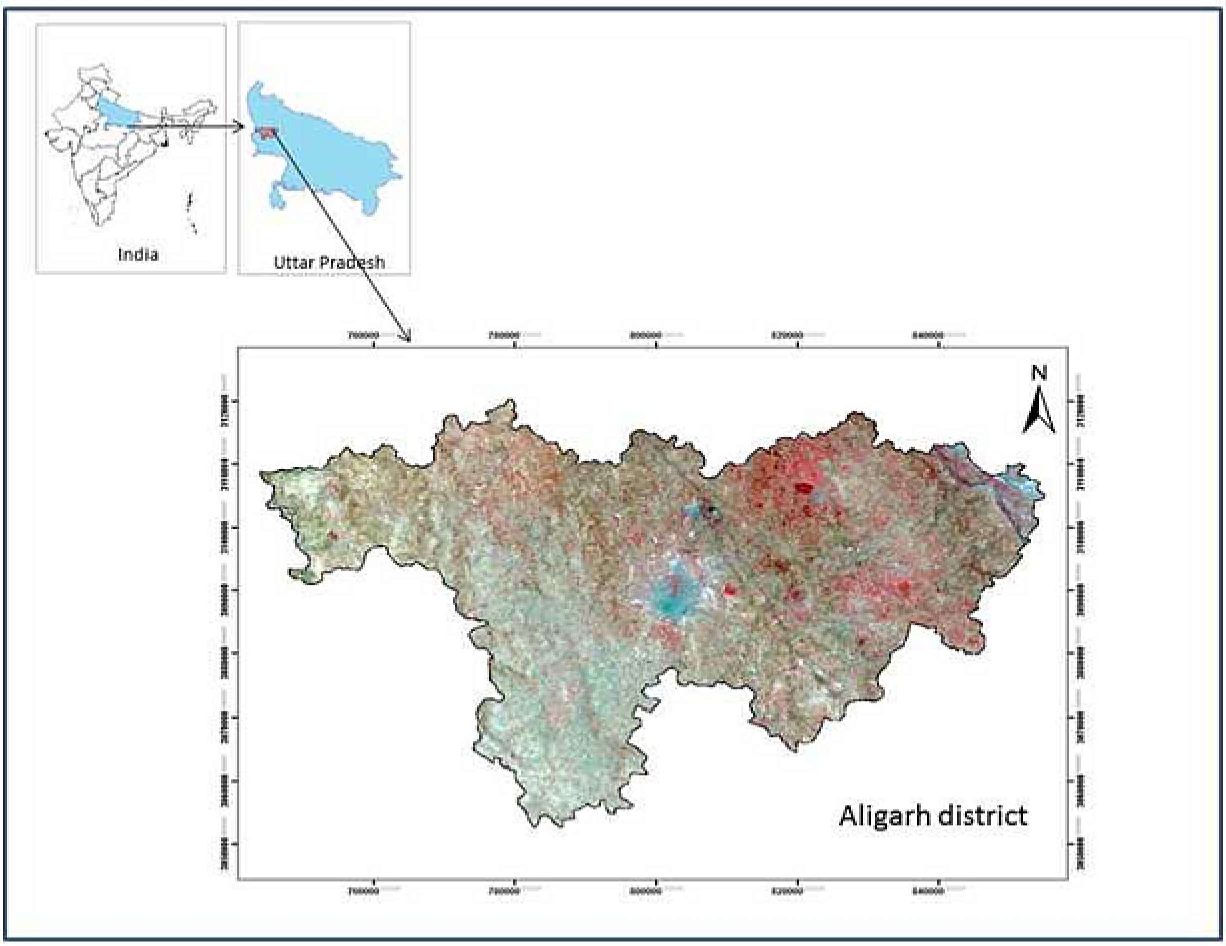

Figure.1 Map of Study Area

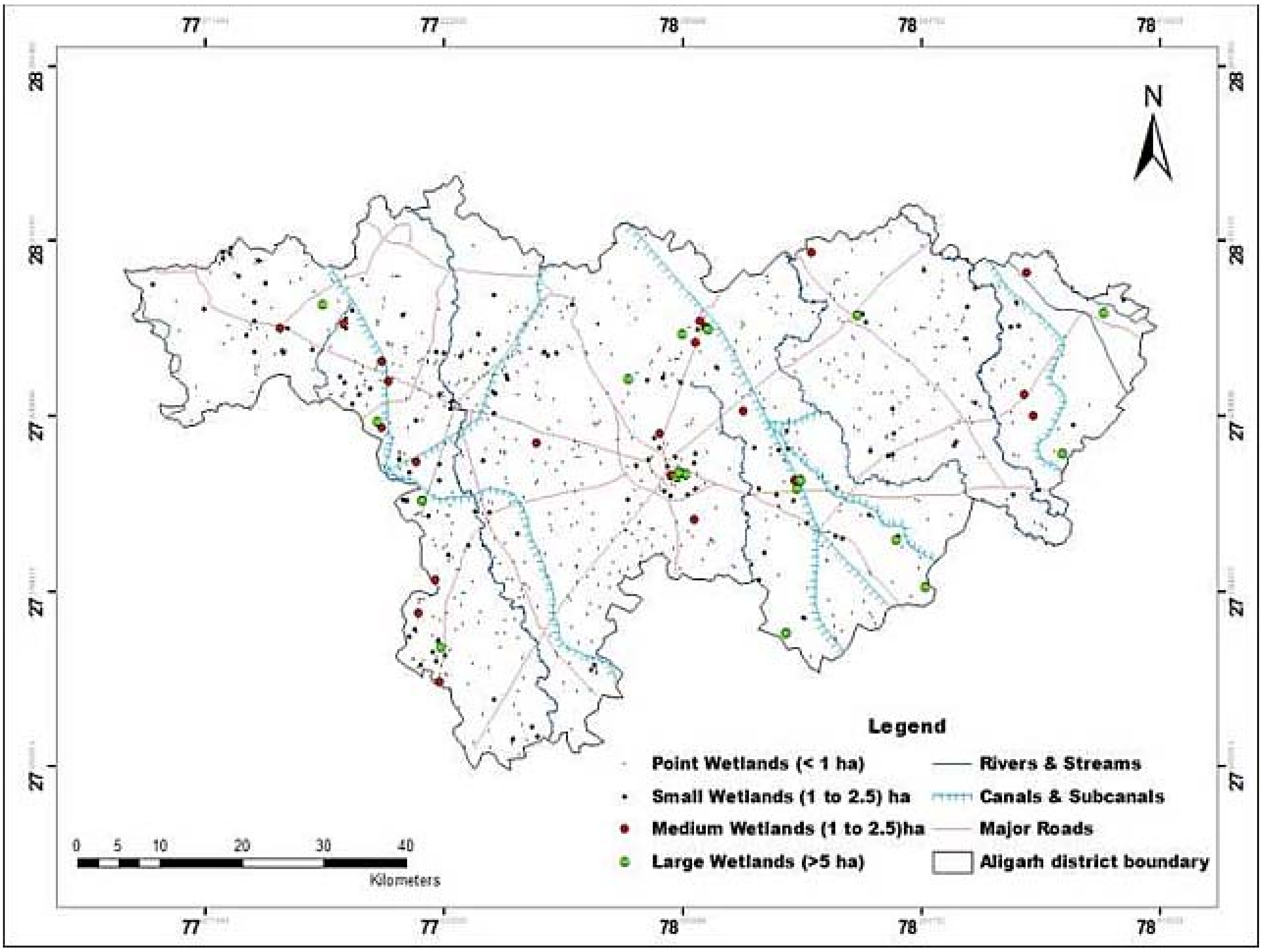

Figure 2 Distribution of wetlands of Aligarh District, UP, India (2017)

Table 2. Status and distribution of wetlands in different subdivisions of Aligarh district

Sub-divisions (Tehsils)		**Point wetland (< 1.00 ha)**	**Small wetland (1 to 2.5 ha)**	**Medium wetland (2.51 to 5.0 ha)**	**Large wetland (> 5.0 ha)**	**Total**
Atrauli	Numbers	122	21	4	4	151
	Area (ha)	52	30	14	25	121
Gabhana	Numbers	95	16	1	1	113
	Area (ha)	39	25	3	5	73
Iglas	Numbers	163	23	3	2	191
	Area (ha)	67	36	11	77	191
Khair	Numbers	132	37	7	2	178
	Area (ha)	60	54	25	27	166
Koil	Numbers	185	33	7	11	236
	Area (ha)	69	52	26	146	292

important to first prepare inventories and maps of wetlands. Hence remote sensing technology offers a rapid, precise, and efficient approach to extract information on wetlands. It overcome the difficulties of ancient traditional methods such as field surveys that not only take time but are difficult to implement so remote sensing has several advantages for monitoring wetland resources.

Landsat data is an appropriate source for this study due to its cost-effectiveness and appropriate quality.

Table 3. Comparison of wetland status between 2002 and 2017 (including rivers, streams and canals)

Year	Area of wetlands (ha)	% of area covered
2002	7817	2
2017	3988	1

Table 4. Accuracy assessment (%) of wetland and non-wetlands classes in Aligarh District

Classes	Producer's accuracy	User's accuracy	Kappa
Wetland	92.86	81.25	0.67
Non-wetland	83.33	93.75	0.85
Overall	87.50	0.75	

Classifications based on Landsat data have greater overall accuracies than other space sensors (Civco 1989, Hewitt 1990, Bolstad and Lilles 1992) but now apart from the Landsat data, many studies suggest that several other datasets or sensors that have been used for mappings and tracking of wetlands such as hyperspectral data (Rosso et al. 2005, Vaiphasa et al. 2005, Belluco et al. 2006, Pengra et al. 2007), Light Detection And Ranging (LiDAR) (Lang et al. 2012, Millard and Richardson 2013, Huang et al. 2014, Franklin and Ahmad 2017), Unmanned Aerial Vehicle (UAV) (Li et al. 2010, Zaman et al. 2011, Shahbazi et al. 2014, Boon et al. 2016), Synthetic Aperture Radar (SAR) (Mosen et al. 2016, Mlezco and Mroz 2018, Mahdianpari et al. 2019), Système Pour l'Observation de la Terre (SPOT) (Powers et al. 2012, Ji et al. 2015), World view satellite imagery (Ballanti et al. 2017, McCarthy et al. 2018) and so on. However, medium resolution images (Landsat data) were mostly used in wetland research through reviewed sensors from 1964 to 2015 (Guo et al. 2017).

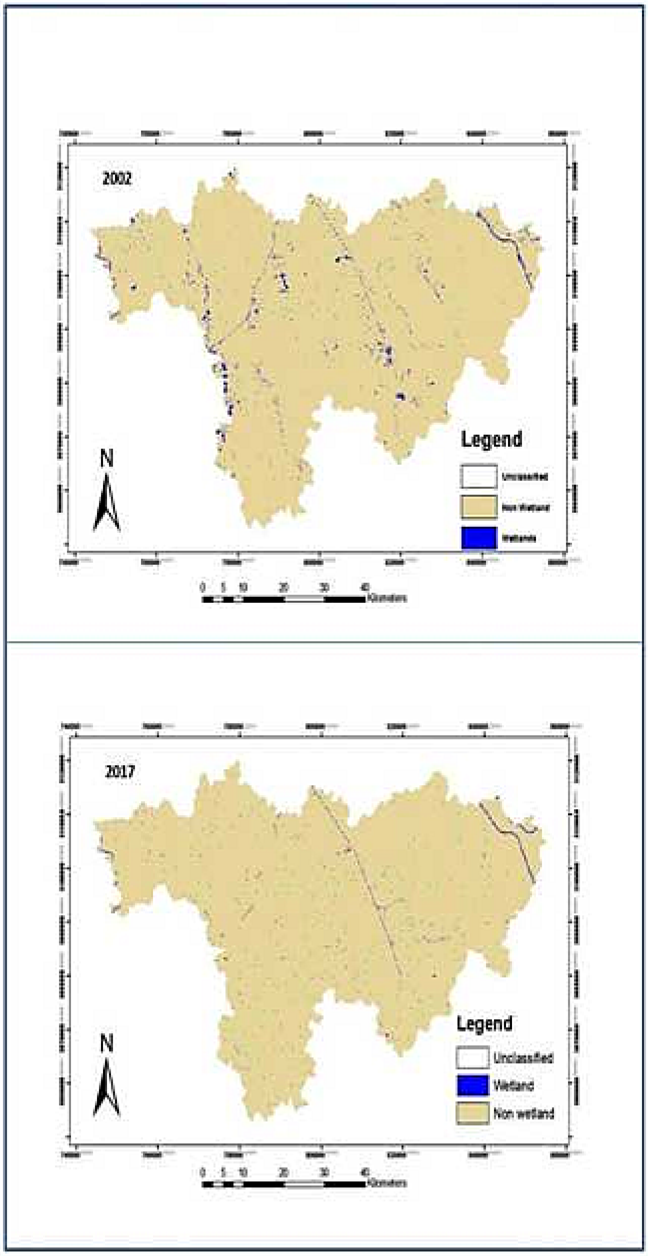

Figure 3. Change in wetland area in Aligarh District in 2002 and 2017

Many techniques have been used for the wetland extraction such as unsupervised classification, supervised classification, Normalized Difference Water Index (NDWI), Normalized Difference Vegetation Index (NDVI), and Modified Normalized Difference Water Index (MNDWI) (McFeeters 1996, Xu 2006, Du et al. 2012, Mabwoga and Thukral 2014, Rokni et al. 2014, Kavyashree and Ramesh 2016). Maximum Likelihood is the most widely commonly adopted parametric supervised classification technique so it was used in the present study (Jensen 1996, Liu et al. 2002, Ozesmi and Bauer 2002, Weng 2002). However wetland classification is difficult because of spectral confusion with other land cover classes and also due to the presence of cloud cover in some parts of the image. To overcome this problem, after processing the supervised classification, the classified images were compared with GPS, and Google Earth to check each wetland location.

In the present study, an area of 3,988 ha was covered by wetlands that included rivers, streams, canals, and all types of wetlands (natural and manmade). It covers only about 1% of the total geographical land of the study area. The current status of wetland area of nearby districts is not available but according to 2006-07 data of National Wetland Atlas Uttar Pradesh (NWAUP, 2010) report shows that Aligarh district and their nearby districts have a more or less similar trend of wetland area such as Aligarh (2.19%) and nearby districts Mathura (2.86%), Hathras (1.22%), Bulandshahr (3.09%), Etah (2.09%), Gautam Budh Nagar (2.88%). Despite the importance of wetlands, there is no substantial data available on the numbers and extent of wetlands in the Aligarh district. Wetlands of Aligarh district were documented in the reports of Wetlands of India (Garg et al.1998) and National Wetland Atlas Uttar Pradesh (2010). According to the report of wetland of India-1998, there were 21 wetlands found that covered 3588 ha. Rivers, streams, and small wetlands were excluded, and only large wetlands (that have $\leq$ 56 ha) were mapped. Whereas report of NWAUP-2010 shows that 1687 wetlands covered 4,917 ha. They included rivers, streams, and small wetlands. Out of this, 1,301 wetlands were small (having $\leq$ 2.25) and the rest were large wetlands (having $\geq$ 2.25). Hence the number and area of wetlands reported in these documents are contrary to the present work probably due to the different methods and techniques used in different time periods. The result of the present study also shows that 49 % surface area of wetlands has decreased from 2002 to 2017, due to the rapid growth of urbanization and industrialization. It is observed that declination in the wetlands due to the encroachment, weed infestation, domestic use, fish culture. There is no proper maintenance and management of the wetlands in the Aligarh district.

CONCLUSIONS

The study concludes that the wetlands of the Aligarh district have been reduced during the 15 years due to developmental activities and urbanization. Remote sensing and GIS technique is an effective tool in the detection of the dynamics of wetlands, especially small-sized wetlands. It provides baseline data for subsequent monitoring and ecological assessment. The number of wetlands detected by classification can be important for the study of the ecology and conservation of local and migratory waterbirds which occur in large numbers in the study area. However small wetlands are more in numbers than the large wetlands but small wetlands are also important for conservation purposes. The reduction in numbers and area of small wetlands affect negatively several native species and it also influences the population and community structure of wetland-dependent species such as amphibians, invertebrates, macrophytes and birds.

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