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RESEARCH ARTICLE

ANALYSING THE SPATIO-TEMPORAL CHANGES OF LANGH AND DRIGH LAKES DUE TO ANTHROPOGENIC ACTIVITIES USING GIS AND REMOTE SENSING TECHNIQUES

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ABSTRACT

Ramsar sites are important habitats for the locals as well as for migratory birds that visit these sites across the borders every year. Langh and Drigh lakes were selected as the study area for this research. Drigh Lake is one of the important Ramsar sites, and Langh Lake is an important wildlife sanctuary of national importance. For the past few decades, these lakes are degrading due to anthropogenic activities. To quantify these variations, present study was carried out to detect the land use and land cover change in these lakes and their surrounding areas from 1988 to 2020. Level-2 imageries of Landsat 5, 7, and 8 were downloaded and analyzed using hybrid classification, and results were mapped in ArcMap. Accuracy assessment of the results of selected years was done to check the accuracy of results using the Kappa coefficient. Kappa coefficient resulted between 0.82 and 0.95 for this study. Classification results depicted a significant increase in the vegetation area which is 72% and 32% for langh and drigh lakes respectively since 1988. Results show an increase in the buildup area and a decrease in the barren land. The presence of dense vegetation in the lakes near their boundaries verifies encroachment of lakes by the local farmers.

KEYWORDS

Hybrid Classification, Drigh, Langh, Land Cover Change, Remote Sensing, Landsat, Ramsar Sites.

1. INTRODUCTION

Lakes and wetlands are considered important treasure troves for a country. Wetlands, present anywhere, offer ecological services, social, and economic benefits for the environment and people. Wetlands perform multiple functions such as storage for flood, rainwater, carbon, reduce soil erosion. Lakes also provide storm protection, improve water quality, stabilize local atmospheric conditions, i.e. temperature and rainfall, provide recreational and tourism opportunities, and produce food for humans and animals (Khan, 2006). Nevertheless, the value of wetlands remains largely underappreciated by policies and decision-makers. Wetlands are present in about 6 % of the earth's surface. Due to the negligence of policymakers, 35% of the world's wetlands have been diminished at a three times faster rate than the rate of decline in forests since 1970 (Lead et al., 2018). "Wetlands are the areas that remain covered by surface or subsurface water all over the year or for varying periods during the year" (US EPA, 2003). Lake and wetland are two words used interchangeably. A lake always remains fully saturated but, a wetland may or may not be. Every lake can always be called a wetland, but every wetland cannot be a lake (Siyal, 2020).

Globally, there are more than 2000 Ramsar Sites all over the world, and out of this 19 are present in the Sindh province, Pakistan (Chaudhry, 2010). Ramsar is an international convention that works for the conservation and sustainable use of the wetlands of international importance to provide a rich habitat to waterfowls that come on these sites across the borders each year. Drigh Lake is one of the Ramsar sites in Pakistan. Two lakes, Langh and Drigh were selected as a study area in this research. Both lakes were recognized as wildlife sanctuaries in 1972. Later on, in July 1976, Drigh Lake was also included in the list of Ramsar sites of international importance due to its significance for the migratory waterfowls. Drigh has an area of 164 ha and its water quality is slightly brackish, whereas, Langh is a freshwater lake. Both lakes are of greater importance and attract thousands of local and migratory birds (Sites and Service, 2002). Both lakes have open water surfaces, natural vegetation like Typha and Tamarix, and rice fields in their surrounding areas which offer a nutritious habitation to water birds, fishes, amphibians, mammals, and reptiles (Brohi and Rasheed, 2016; Gabol et al., 2005).

The interaction between humans and the environment causes a direct or indirect change in the environment. To detect these changes, LULC (Land

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Use and Land Cover) classification is used. Therefore land use and land cover facts are the essentials for the design of conservation and management strategies or plans. Remote sensing techniques have been used for the mapping of land use land cover change (LULCC) of the earth planet over the years. Landsat satellite is the longest series of satellites that are providing imageries since 1972. It is widely used for the spatial and temporal land cover and land-use change detection of earth surfaces over a long period. Land cover and land use are two separate terms but they are used interchangeably. The land cover represents the physical features of the earth's surface, i.e., open water surfaces, forests, hills, glaciers, and agriculture, whereas land use describes how humans use the land surface i.e. for conservation, development purposes, industries, or mixed-use. Few studies report the change in these lakes but there is no comprehensive study on the LULC changes of this study area. In this perspective, this research is conducted to map and quantify the LULC changes that have happened in the study area for the last three decades using remote sensing and GIS techniques.

2. MATERIAL AND METHODOLOGY

2.1 Study Area

Drigh Lake is located at 27°34' 35" latitude, 67°53'30" longitude and Langh Lake (Lungh Lake) is situated at 7°29'30" latitude, 68° 1'27" longitude in the district Qambar Shahdadt in Sindh province of Pakistan (Figure 1). Both lakes have great political and social status, and lie in the same climatic zones i.e. in summer temperature ranges between 47-49° C and receive average annual rainfall range between 127mm to 254mm.

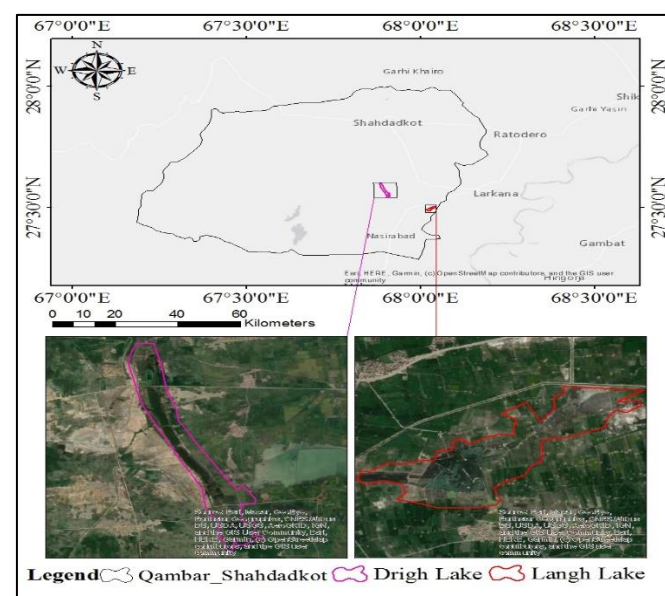


Figure 1: Location of Study Area

2.2 Data Collection

2.2.1 Precipitation Data

Gauge station precipitation data were collected from Pakistan meteorological department (PMD) from 1990-2018. Gridded precipitation data of Aphrodite -1 (Asian precipitation, highly resolved observational data integration towards evaluation of the extreme events) version V1101 (APHRO-MA_V1101) was downloaded from the Aphrodite website <http://aphrodite.st.hirosakiu.ac.jp/download/data/search/> in NetCDF format for the period 1972 to 1989. It gives gridded data of 0.25° 0.25 degrees over the Monsoon Asia region. Precipitation data were processed in MATLAB R2016b software to identify wet and dry years for the study area. Based on precipitation data, four driest years (1996, 2002, 2016, 2017), four wettest years (1988, 1989, 2010, 2020) were selected, and Landsat satellite imageries of these years were downloaded. Shapefiles of the area of interest (AOI) of both lakes were created using google earth pro.

2.2.2 Satellite Imageries

Landsat level-2 imageries of the study area, for the selected years, were obtained from the website (<https://earthexplorer.usgs.gov/>). The years and months were selected keeping in view the maturity period of the rice crop and the availability of the satellite data with less than 10% cloud cover. Table 1 shows the details of downloaded imageries. Level-2 of the Landsat dataset provides atmospherically corrected data on demand. Visible and infrared bands of Landsat-5 thematic mapper (TM), Landsat-7, the enhanced thematic mapper (ETM+), and Landsat-8 operational land imager (OLI) sensors were used.

Table 1: Selected satellite images

Sr. No.	Acquisition Date	Year (Status)	Satellite/Sensors
1	10 September 1988	Wet	Landsat 5 TM
2	29 September 1989	Wet	Landsat 5 TM
3	29 September 1996	Dry	Landsat 5 TM
4	10 October 2002	Dry	Landsat 7 ETM+
5	04 September 2010	Wet	Landsat 5 TM
6	20 September 2016	Dry	Landsat 8 OLI
7	9 October 2017	Dry	Landsat 8 OLI
8	01 October 2020	Wet	Landsat 8 OLI

2.3 Image Processing

The satellite imageries were processed in ArcMap 10.3.1 software. A buffer zone of 2 km was created around each lake to determine the land use and land cover changes in the lakes' surroundings. Composites of all the imageries were created with visible and infrared bands. AOI of lakes and buffers were extracted from the composite images using the "Extract by Mask" tool of the ArcTool box. All the composite images were classified into distinct and definite classes of land use/land cover by using the hybrid classification method (Hazarika et al., 2015). This method works in two parts, the first step is unsupervised and the second is supervised classification. Firstly, using the unsupervised classification tool "Unsupervised ISO Cluster" all the pixels were divided into several iso clusters, and the information was stored into signature files.

Signature files were developed by creating 13 clusters with 20 iterations for each lake area and 20 clusters with 28 iterations for each buffer area. Secondly, by utilizing a previously created signature file in maximum likelihood classification, all the pixels of the image were classified into 11 classes. These classified images were reclassified into distinct land use/land cover classes by overlaying and comparing with the NIR (near-infrared) composite image and spectral response of each pixel. Lakes images were classified into three classes named as water, vegetation, and barren land whereas buffer zones were classified into four classes named as water, vegetation, barren land, and built-up area. The area of each class for all the years was calculated in the attribute table. The above-mentioned process was applied to all images separately. The classification scheme used for the images is demonstrated in Table 2.

2.4 Accuracy Assessment

To check the precision of results, the accuracy assessment of the years (1988, 2002, 2010, and 2020) showing a change in results was done by calculating the kappa coefficient. For this purpose, google earth truthing was done in google earth pro software. A stratified random sampling technique was used to take random samples from each class. Stratified random sampling evenly distributes the sampling points between all the classes. The sample size for a single class was taken as 30 as it should be multiple of the number of classes. According to this, 90 sampling points were taken for a lake image, and 120 points were taken for the buffer image. Error matrix was prepared for every image and Kappa coefficient was calculated (Jensen, 2015).

Table 2: Classification Scheme

Land Cover/ Land Use	Description
Water	lakes' water, irrigation water standing in the fields
Vegetation	natural vegetation such as shrubs, permanent wetland, and agricultural fields with crops
Barren-land	uncovered soil, sand, or rocks
Built-up	manmade structures such as buildings, roads, water channels, homestead areas, etc.

3. RESULTS AND DISCUSSION

The change in land use and land cover was detected in the lakes and their surroundings from 1988 to 2020. This was carried out by processing Landsat imageries in GIS software and the accuracy of results was checked. Accuracy assessment results that the Kappa coefficient for selected imageries ranged from 0.82 to 0.95 which indicates strong agreement of the results, and suggests that the classification results of this study are appropriate for further research (Jensen, 2015). Landsat- 8 images show more accurate results than Landsat-5, and Landsat-7. This can be due to the narrower spectral bands of Landsat-8 as compare to bands of Landsat-5 and 7.

3.1 LULC Change in the Lakes

The change detected in the land use and land cover of the study area was quantified and mapped. Maps of the temporal change in the LULC of Langh and Drigh lakes are shown in Figures 3, 4 respectively. The quantified values of the detected change are given in Table 3. The period of 1st September to 1st October was selected to detect the rice crop cultivated in the fields nearby the lakes. In the maps, it is visible that the water extent of Langh Lake has been decreased since 1998.

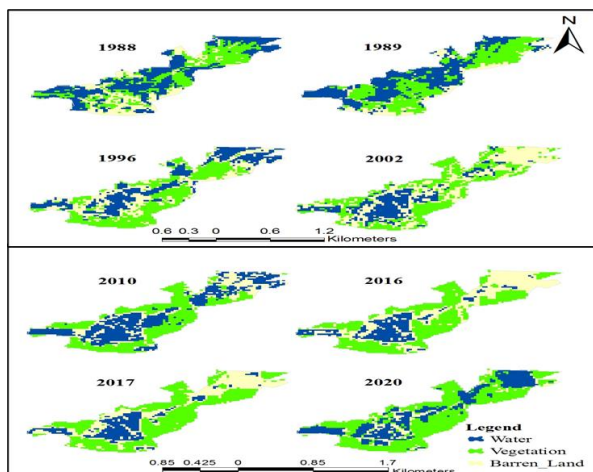


Figure 3: Temporal change in Langh Lake from 1988-2020

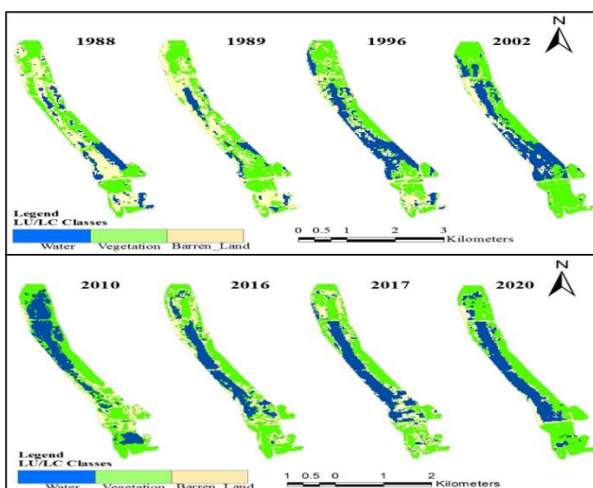


Figure 4: Temporal change in Drigh lake from 1988-2020

Initially, 0.81 ha (hectares) of Langh Lake area was covered with water in 1988 and it became 0.32 ha in 2017 and 0.58 ha in 2020. This indicates a significant decrease of 59.7 % in 2017 and 27.2 % in 2020 in the water area since 1988 as mentioned in Table 2. whereas, the vegetation has been increased 137.5 %, and barren land has been decreased up to 49.7 % since 1988. Similarly, the vegetation area of Drigh lake is increased from 1.77 ha to 2.34 ha from 1988 to 2020. Unlike the Langh lake, the water area of Drigh has been increased up to 119.7 % in 2017, 137.5% in 2020 since 1988 But the total area of Drigh lake is decreased. Barren land has been decreased 49.1 % since 1988. It can also be seen in the maps, both lakes had more water in the years 2010 and 2020. This increase in the water area in these two years could be due to the flood because both years are flood years. An increase in the vegetation area within the boundaries of the lake demonstrates the cultivation of crops by local farmers there. 1988 and 1989 both are the wet years, lakes should have more water in wet years but the water area in the lakes is less than the other years, this points towards the reduced supply of water to these lakes in these two years.

Table 3: Percentage changes in LULC of lakes

Years	% Change in water		% Change in vegetation		% Change in Barren land	
Lakes	Langh	Drigh	Langh	Drigh	Langh	Drigh
1988-1989	-3.23	-17.86	29.31	6.78	-35.33	-1.03
1989-1996	-29.46	169.57	-7.13	-3.17	104.97	-36.98
1996-2002	-28.71	8.06	-4.78	20.22	34.57	-39.67
2002-2010	77.57	2.99	6.74	-4.55	-46.82	8.22
2010-2016	-55.03	-23.91	14.60	-1.90	69.75	46.84
2016-2017	0.29	17.14	10.15	-2.43	-12.63	-11.21
2017-2020	84.13	8.13	11.86	16.42	-64.08	-41.75
1988-2017	-59.72	119.64	54.08	13.56	-49.46	-69.07
1988-2020	-28.24	137.50	72.36	32.20	-40.69	-46.91

3.2 LULC Changes in Lakes' Buffers

Changes that have happened in the Langh and Drigh's buffer areas in the last 33 years were also mapped as shown in Figures 5, 6 respectively, and quantified in Table 4. According to classification maps, a major increase in the vegetation area is recorded in the lakes as well as in their buffer zones since the last three decades, which is also noticeable in the maps.

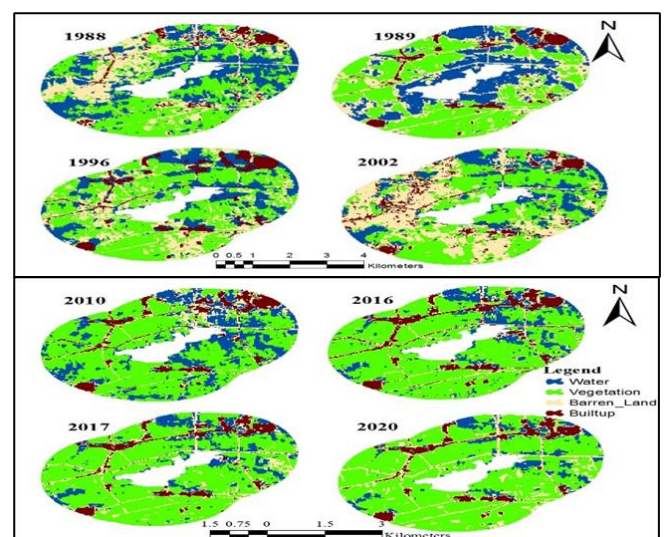


Figure 5: Temporal changes in Langh's buffer from 1988-2020

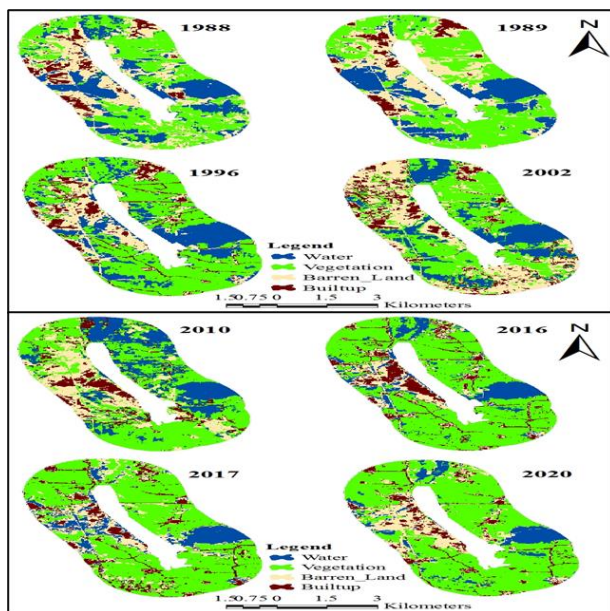


Figure 6: Temporal changes in Drigh's buffer

Table 4: Percentage changes in LULC of Lakes' Buffers

Years	% Change in Water		% Change in Vegetation		% Change in Barren land		% Change in Builtup	
	Langh	Drigh	Langh	Drigh	Langh	Drigh	Langh	Drigh
1988-1989	-9.95	-11.37	7.52	14.47	-3.46	-6.84	18.47	-10.99
1989-1996	-21.48	-1.83	13.55	14.24	-9.04	-38.15	38.66	85.19
1996-2002	-24.20	-4.39	38.71	-25.58	-53.51	68.42	-0.53	18.00
2002-2010	46.00	10.68	-11.34	23.15	-2.09	-32.21	1.94	-11.30
2010-2016	-39.97	-43.36	12.99	36.42	0.15	-44.92	19.97	17.41
2016-2017	-5.57	-10.99	4.45	-2.13	8.52	37.98	-26.55	-10.67
2017-2020	-30.99	-15.43	3.52	4.77	18.41	5.29	-5.41	-17.00
1988-2017	-55.64	-53.58	77.22	60.01	-56.56	-50.00	46.78	80.95
1988-2020	-69.39	-60.74	83.45	67.64	-48.56	-47.36	38.84	50.18

The vegetation area of Langh Lake's buffer was 10.44 km² in 1988 and it became 18.75 km² in 2020 with an increase of 83.45 %. Similarly, the vegetation area of the drigh lake's buffer has been increased from 16.38 km² to 27.46 km² with an increase of 67.64 % since 1988 as mentioned in Table 4. It can also be seen from the maps in Figures 5, 6 the vegetation in the lake's surroundings is continuously increasing. Whereas, Barren area is nonlinearly decreasing. Barren land has been decreased up to 38.8%, 50.18% from 1988 to 2020 for langh and drigh buffers respectively. This demonstrates that the farmers cultivating rice crops nearby lakes are continuously converting barren land into agricultural fields. This could be due to the reason farmers are converting barren land into agricultural fields and homesteads. There are several small villages, locally called

Goths, are present around the lakes. An increase in the built-up area is due to the development by the local communities.

4. CONCLUSION

Drigh and Langh lakes with their surrounding areas were examined for the change detection in LULC, using hybrid classification in GIS. It is concluded that there is a direct relationship between the rainfall and the water area of the lakes but the lakes in the wet years with the highest precipitation (1988, 1989) have no extended water area which reveals the reduced water supply to the lakes in these years. Nonlinear increase in the vegetation in the study area portrays that local farmers have encroached areas of the lake and converted their dried parts into agricultural fields by the time. Insufficient water supply is another factor that triggers the problem of lake shrinkage. Langh Lake has shrunk more in size as compared to that of the Drigh Lake. There is a need to develop a management plan for the sustainability of these lakes and this study could be used for this purpose.

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