

Geospatial analysis of wetlands based on land use/land cover dynamics using remote sensing and GIS in Sindh, Pakistan

Science Progress

2021, Vol. 104(2) 1–22

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DOI: 10.1177/00368504211026143

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Abstract

In this study, the Land Use/Land Cover (LULC) change has been observed in wetlands comprises of Manchar Lake, Keenjhar Lake, and Chotiari Reservoir in Pakistan over the last four decades from 1972 to 2020. Each wetland has been categorized into four LULC classes; water, natural vegetation, agriculture land, and dry land. Multitemporal Landsat satellite data including; Multi-Spectral Scanner (MSS), Thematic Mapper (TM), and Operational Land Imager (OLI) images were used for LULC changes evaluation. The Supervised Maximum-likelihood classifier method is used to acquire satellite imagery for detecting the LULC changes during the whole study period. Soil adjusted vegetation index technique (SAVI) was also used to reduce the effects of soil brightness values for estimating the actual vegetation cover of each study site. Results have shown the significant impact of human activities on freshwater resources by changing the natural ecosystem of wetlands. Change detection analysis showed that the impacts on the land cover affect the landscape of the study area by about 40% from 1972 to 2020. The vegetation cover of Manchar Lake and Keenjhar Lake has been decreased by 6,337.17 and 558.18 ha, respectively. SAVI analysis showed that soil profile is continuously degrading which vigorously affects vegetation cover within the study area. The overall classification accuracy and Kappa statistics showed an accuracy of >90% for all LULC mapping studies. This work demonstrates the LULC changes as a critical monitoring basis for ongoing analyses of changes in land management to enable decision-makers to establish strategies for effectively using land resources.

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Keywords

Wetlands, Land Cover, Vegetation Index, GIS, SAVI, Sindh

Introduction

Wetlands are part of the Earth's structure which is considered one of the most important ecosystems on Earth after the interior lands.¹ In general, wetlands have substantial integrity to biotic and abiotic factors including limnological and hydrological scenarios, and also have culturally and aesthetically important for recreation and tourism activities.^{1,2} On the other side, the freshwater resources are mainly consisting of wetlands along with surface water which fulfills the domestic and agriculture needs that support the aquatic ecosystem as a potential source of protein and nutrients.³⁻⁵ The bulk of human operations are carried out on lands that in turn consume the natural resources, affect the environment and lead to land use land cover (LULC) change. LULC is one of the chief elements used in environmental change and sustainable development thanks to its generality on the local scale and its worldwide known environmental trend.^{6,7} Therefore, it is ethical right to monitor the changes in wetlands from preventing further losses by acquiring up-to-date LULCC information for better environmental management to understand the direct and indirect impacts on the ecosystem and for sustainable devolvement.^{2,8,9} de Almeida et al.¹⁰ investigated the LULCC and its impact on the landscape against the backdrop of oil palm agriculture using multi-temporal study spanning the years 1991 to 2013. The study revealed that 47.7% of primary forest was converted for other purposes, 17% of degraded forest increased, and 11% of oil palm plantation increased. During the 22-year study period, 30% of the primary forest was converted to oil palm plantation; nevertheless, between 2005 and 2013, primary forest conversion to oil palm rose by only 2%. The land surface temperature (LST) in Pakistan's lower Himalayan regions has been evaluated from 1990 to 2017 by Ullah et al.,¹¹ The LST results for LULC classes revealed that the built-up area had the largest mean LST as compared to other classes, while the results revealed a 5.75% and 4.22% rise in built-up area and bare soil respectively, while vegetation decreased by 9.88% during the study period. A hybrid prediction model based on cellular automata and artificial neural network (CA-ANN) was used, with transfer potential matrices obtained from the years 2002 and 2017 for simulation of LULCC between the years 2032 and 2047. According to the LULC and LST future projections, the built-up region is reported to be increased by 12.48% and 14.65% in 2032 and 2047, respectively, of the total LULC area, which was 11% in 2017. On the other side, the vegetation patterns have been analyzed for their long term dynamics by Yohannes et al.¹² The LULC images were mapped from 1972, 1987, 2002 and 2017 to 2047 and 2032. In addition, the factor analysis was used to choose the individual core landscape structure and landscape configuration metrics. A comparison of the postclassments found that the cover of natural trees, grassland, barren land and water sources dropped by 89,9%, 67,9%, 67,8% and 15,9%,

respectively between 1972 and 2017. In 2032 and 2047 a similar tendency is supposed to be continued, with the group of plantations marginally decreasing in 2047. Remote sensing (RS) is an indispensable technology for the observation of Earth resources and LULCC detection.^{11,13,14} The RS data can provide timely, credible, and comprehensive information on degraded lands at definite time intervals in a cost-effective way.¹⁵ Furthermore, it can monitor larger areas throughout satellite imageries assess ecological changes without distressing the landscape.^{13,16} Geographic Information System (GIS) and satellite imagery are increasing awareness of learning data, new patterns of detection, inter-relationships in the dynamic coastal environment.^{17,18} Moreover, GIS can facilitate smart decision-making in assessing coastal vulnerability, land use and coastal cover, urban planning, conservation of the threatened coastal environment, and dynamic shoreline transformation.^{13,15,19} It has been reported that LULC with the help of RS along with GIS tools can investigate several environmental changes, such as water cycle, temperature regime, and other ecological processes which obstruct the sustainability of ecosystems.^{20,21} Several LULC changes based on GIS tools have been studied during 40 years in the Lauderan region of Pakistan by Hussain et al.¹⁵ The study considered four key LULC types including water bodies, built-up area, bare soil, and vegetation. The obtained results indicated substantial transformation in bare soil, water bodies and cultivated areas caused by human impacts along with consequent need for arable areas.¹⁵ The LULC mapping has been done most effectively through satellite images of various spectral, spatial, and temporal resolutions.^{6,7,20} Multi-Spectral Scanner (MSS), Thematic Mapper (TM), and Operational Land Imager (OLI) provide numerous satellite data which are of crucial importance for the evaluation of LULCC.^{13,20} The MSS sensors were known as line scanning devices detecting the earth perpendicular to the orbital track.²² While TM sensors are more progressive sensors designed for achieving enhanced image resolution and better geometric fidelity with great accuracy rather than the MSS sensors.²³ The OLI sensors are a progression in Landsat sensor technology. It can measure in the visible and short wave infrared portions.¹⁷ Besides, it can provide abundant resolution to differentiate topographies and features, such as urban areas, farms, forests, and other land uses.²⁴ On the other hand, Soil Adjusted Vegetation Indices (SAVI) was found to have great accuracy in categorizing and classifying the wetlands and areas.² It has a high correlation as well as can be used to monitor shifting vegetation.^{25,26} The precision of various vegetation indices NDVI and SAVI have been evaluated by Chuvieco et al.²⁷ for burned land mapping. Six Landsat TM have been considered to conform pre-and post-fire conditions for several burned areas in Mediterranean countries (Italy, Greece, and Spain). Furthermore, Escuin et al.²⁸ considered the capacity of NDVI indices resulting from Landsat TM/ETM images for the determination of fire risk in three fires in southern Spain. Generally, the LULC change has significant environmental consequences since it directly linked to land degradation over a period of time which resulting in multiple environmental changes. The landscape structure, and change in configuration of the Corazón de Oro Forest, Southern Ecuador was evaluated by López et al.²⁹ for the assessment

of LULCC. The findings revealed a largely static landscape structure over time. Moreover, the establishment of the protected area altered considerably the vegetation composition and minimized the human impact on evergreen montane ecosystems.

In general, studies on LULCC and landscape structure quantification in Pakistan have not been well-targeted considering the high variability in the landscape of the Sindh country. Estimating wetlands of Sindh requires a complex and multidimensional understanding of LULC assessments that are not fully covered by the current mitigation-based tools portfolio. Therefore, an integrated system requires a new generation of dynamic approaches that can assess the economic, social, and environmental dimensions of freshwater resources in a sustainable, comprehensive way. Toward this end, the purpose of this research is to demonstrate an applied and novel approach to the LULC dynamics of the wetlands of Sindh. Additionally, assess past and current environmental conditions to better plan for sustainable wetland conversion and prevent further losses.

Study area

The sites selected in this study; Lake Manchar, Lake Keenjhar, and Chotiari Reservoir have great significance concerning Pakistani society and the environment. They have a major freshwater resource and are home to a wide variety of species and migratory birds. Any mishap with these sites will upset the entire Sindh province. For this reason, these three sites were chosen to monitor for decadal changes.

Manchar lake

Manchar is located in the western part of the Indus River at a distance of 18 km from Sehwan Sharif in district Dadu, Sindh (Figure 1). It is considered the largest shallow freshwater lake of Pakistan with an approximate depth of 2.5–3.75 m, constructed in 1930 comprises an area of 350–520 km² seasonally.³⁰ Flood embankments were built on the north-eastern and northern boundaries of the lake in 1932. The lake is fed by small streams fringed by the western part of Khirthar Hills and the southern part of Laki Hills. In the last 50 years, human activities and climate change have vigorously affected the original regime of the lake.^{31,32}

Keenjhar lake

Keenjhar has situated about 113 km from Karachi, in district Thatta, Sindh (Figure 1). It is one of the largest freshwater lakes covering 145 km² areas with 8 m depth. This lake was formed by the consolidation of Sonehri and Keenjhar lakes in 1930.^{33,34} The main feeding source of Keenjhar is the Kalri Baghar Canal and small seasonal streams. The southeastern boundary of the lake is the only outlet through Jam Branch Canal. People of Karachi, Thatta, and Ketibunder mainly

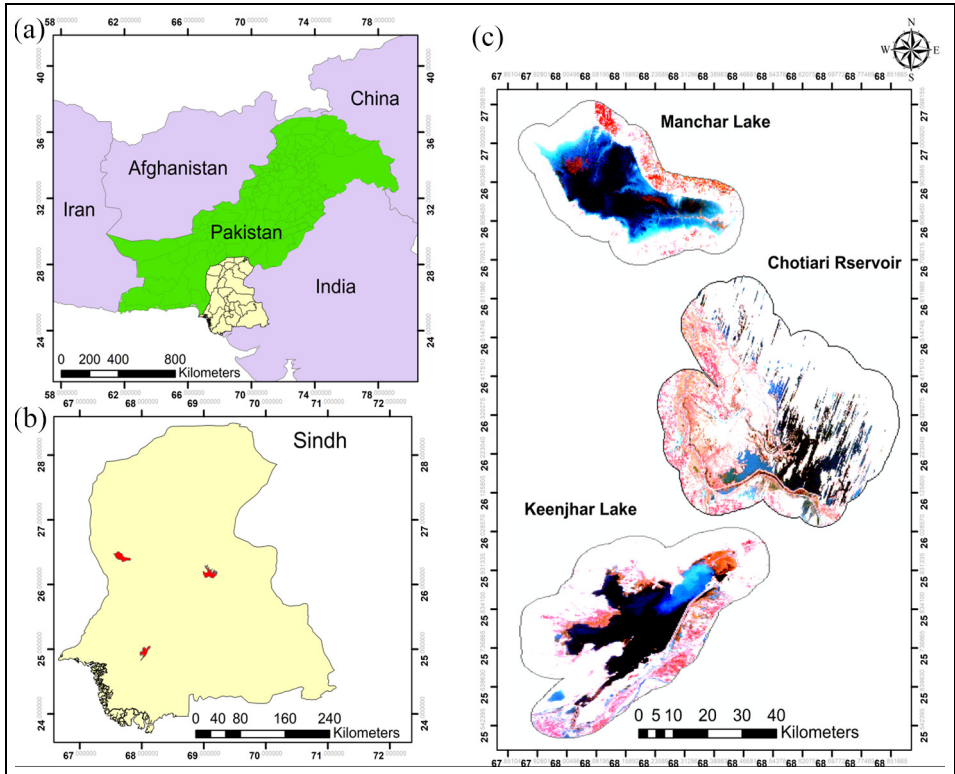


Figure 1. Inset map of study area showing: (a) Pakistan along with neighboring countries, (b) Sindh highlighted with study areas, and (c) wetland Sites.

depend on Keenjhar for water supply. Keenjhar lake deterioration has been reported due to the KB Feeder Canal, Haroolo Drain, and different anthropogenic activities including the direct disposal of toxic and hazardous waste in the lake.³⁵

Chotiari reservoir

District Sanghar comprises a great number of ponds, lakes, and reservoirs of fresh-water and brackish wetlands.³⁶ Chotiari Reservoir located on the western flanks of Achro Thar Desert, at a distance of about 30–35 km north-east of Sanghar town (Figure 1), covering an area of about 18,000 ha with a water storage capacity of 92,511 ha. The construction is started in 1994 along the left bank of Nara Canal at a natural depression and completed in 2003. It has a variety of Flora and Fauna diversity along the Nara river course and embankment especially rich in the mammal population.³⁷ The average maximum temperature in summer is about 40°C with

Table 1. The classification scheme used in the study.

Id	Land use/land cover	Description
1	Natural vegetation	The areas with natural vegetation cover in the form of herbs, shrubs, grassland, trees, and other plants.
2	Water	It comprises all forms of surface water present in drains, canals, ponds, lakes, wetlands, etc.
3	Agriculture	This class consists of cultivated and non-cultivated areas.
4	Dry land	It includes the land left which has no vegetation and has a rough terrain where the moisture is very low.

an average evaporation rate of 11mm. Chotiari is facing the depletion of its irrigation, forest, and fish resources over the last 5 years.

Materials and methods

The present study evolves the LULC analysis for the years 1972, 1986, 1992, 2000, 2010, and 2020 comprised of three wetland sites (1) Manchar Lake; (2) Keenjhar Lake; and (3) Chotiari Reservoir. The acquired data were classified into four LULC categories namely natural vegetation, water, agriculture land, and dry land for further analysis (Table 1).

Data acquisition

Remote sensing datasets of Landsat MSS, TM, and OLI were used to examine the LULCC and downloaded from the United States Geological Survey (USGS) official website shown in (Table 2). The detailed proposed methodology for this study is shown in Figure 2.

Image processing

In this study, all the images were projected to Universal Transverse Mercator (UTM) projection; Zone 42°N, World Geodetic System (WGS) 1984 datum.

Atmospheric correction. Atmospheric correction is used to confiscate the effects of the atmosphere on the reflectance values of remotely sensed images. Atmospherically corrected images are likely to give better results when there are multiple images under observation. There are two steps involved in atmospheric correction, in the first step digital numbers (DNs) are converted into radiance then top of atmosphere (TOA) reflectance is converted into surface reflectance. The method can increase the interpretability and accuracy of remote sensing data, which is especially useful when comparing different data sets over time.^{38,39} In this study, the Dark Object Subtraction method was applied to correct the atmospheric scattering in the geographic information system (GIS) environment. DOA method eliminates

Table 2. Details of acquired satellite data.

Satellite id	Sensor id	Month/year	Spatial resolution	Source
Landsat 1	MSS	September/1972	60 m	USGS website
Landsat 4	TM	September/1986	30 m	USGS website
Landsat 4	TM	September/1992	30 m	USGS website
Landsat 5	TM	September/2000	30 m	USGS website
Landsat 5	TM	September/2010	30 m	USGS website
Landsat 8	OLI	September/2020	30 m	USGS website

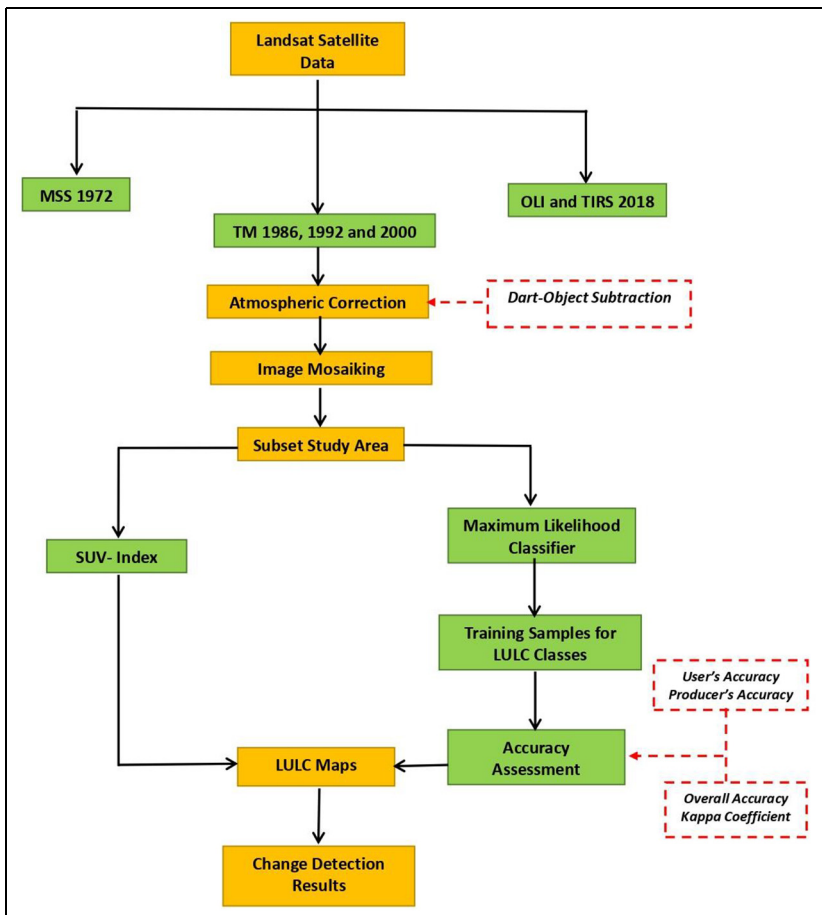


Figure 2. Flow chart methodology of LULC change detection.

the dark objects (which have very low reflectance) from the image to remove the atmospheric effects and normalize the image.³⁸ The images obtained after calibration have been used for LULC classification.

SAVI analysis

Huete's proposed transformation technique has been used in this study to normalize the soil background effect which influences the low vegetative areas by the reflectance of light in the Red and NIR spectra due to more soil exposure.⁴⁰ According to the Huete formula, SAVI can be described by (equation (1)). In this mathematical expression the factor $L = 0.5$, which is used as soil property constant, to reduce the effects of soil brightness values^{41,42} and provides a more precise and accurate vegetation index.⁴⁰

$$SAVI = \frac{(\text{Band NIR} - \text{Band Red})}{(\text{Band NIR} + \text{Band Red} + L)} \times (1 + L) \quad (1)$$

Results

SAVI analysis

Results of SAVI analysis showed that wetlands face great variations in vegetation indices which affect their natural ecosystem and habitat (Figures 3–5). SAVI indices of Manchar Lake in 1972 were 0.67 when the water availability was only 3666.9 hectares. As time passed, the water availability increases but the quality continues to degrade because of industrial effluents and sewage water discharge which drastically affects the vegetation cover. Several studies have been done on the physiochemical assessment of Manchar Lake. The constant source of pollutants including domestic, agricultural, and industrial is the Main Nara Valley Drain (MNVD) which continuously deteriorating this valuable wetland.⁴¹ It has been reported that the concentration of Se, Pb, Ni, K, Na, Mg, Fe, Cd, Ca, As, and Al exceeded the permissible limits.^{32,44,45} The water of Manchar Lake has an alkaline pH and having higher conductivity and hardness values, which resulted in the loss of vegetation cover and agricultural productivity. It also threatens the natural aesthetics of wetland as well as to the indigenous community.⁴⁶ The continuous increase of wastewater discharge and excessive use of pesticides and fertilizers lead to affect the natural vegetation and also affect the soil quality.⁴⁷

Maximum likelihood classification

Maximum Likelihood Classification (MLC) is considered one of the most common techniques used for image classification in remote sensing.⁴⁸ MLC can classify unknown pixels by evaluating variance and covariance of spectral response.^{13,17} It can place the pixels in the class where the highest probability exists.^{25,49} Based on the characteristics of the area, a classification scheme was developed for further

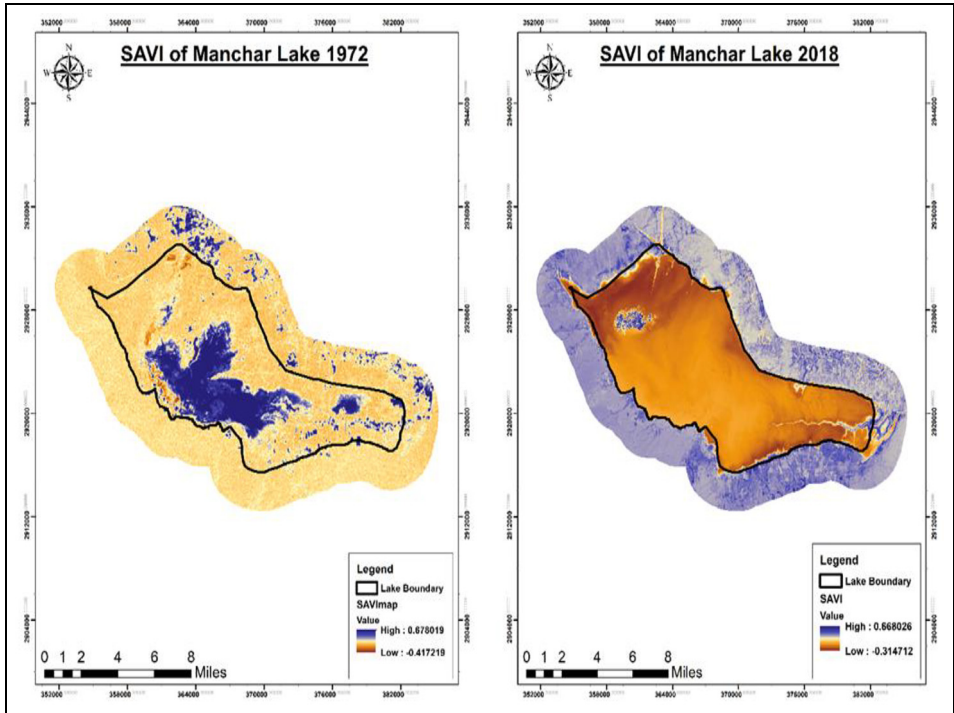


Figure 3. SAVI of Manchar 1972 and 2018.

image analysis by MLC. The study covers wetlands of different sizes of deep and shallow water so it has classified as a class of water. The buffer zone of all wetland sites is included in bare land and agricultural land as it is mostly covered with settlements and agriculture fields. While the vegetative structure of the wetlands was classified as natural vegetation. After making the signature files, MLS was applied on all remotely sensed images.

Classification accuracy assessment

Accuracy assessment plays an important role in image classification to validate the LULC. In MLS, many pixels remain misclassified because of the uneven distribution of the data. In this study, an accuracy assessment was conducted by summarizing and quantifying the data using an error matrix. Four different accuracy results were produced including producer accuracy, user accuracy, overall accuracy, and kappa coefficient index from overall accuracy assessment which provide a better understanding of the classification accuracy. The overall accuracy was computed for each satellite image of Lake Manshar in 1972, 1986, 1992, 2000, 2010 and 2020 are given as 99.71%, 99.59%, 100%, 98.50%, 98.62%, and 99.66%, respectively,

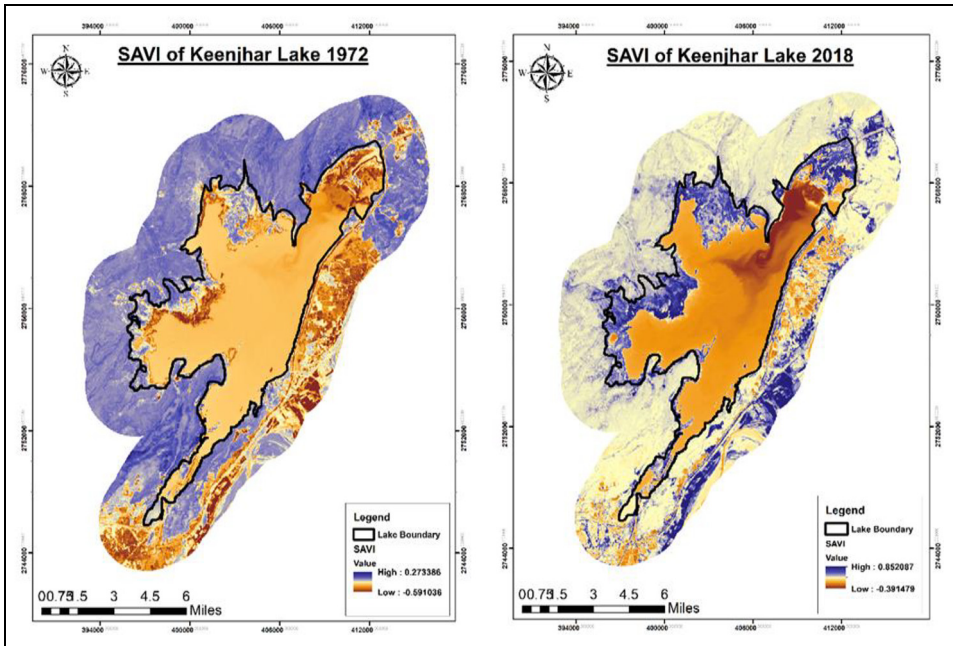


Figure 4. SAVI of Keenjhar 1972 and 2018.

with kappa statistics of 0.99, 0.99, 1.00, 0.97, 0.97, and 0.99, respectively. The overall accuracy results for Keenjhar Lake in 1972, 1986, 1992, 2000, 2010, and 2020 are 99.46%, 99.30, 99.27%, 95.07%, 93.95%, and 92.85% having kappa results 0.99, 0.98, 0.98, 0.93, 0.91, and 0.90, respectively. The accuracy assessment of Chotiari Reservoir provides overall accuracy of 96.17%, 98.01%, 96.17%, 98.94%, 96.40%, and 95.92% with calculated kappa statistics of 0.94, 0.96, 0.94, 0.98, 0.94, and 0.94 from 1972 to 2020, respectively. The overall assessment results of each classified image from 1972 to 2020 are shown in (Figures 6–8 & Table 3).

Discussion

In this study, the LULC analysis and Landsat imagery helped to identify the changes in wetlands from 1972 to 2020. Also, the drifts of impacts on wetlands due to unplanned agricultural activities and excessive discharge of industrial and sewage wastewater have been identified. The satellite images after image processing showed the LULC of the study area in Figures 6 to 8. These classified images present a better understanding of the LULC patterns of the study area. The present study reveals that the spatial patterns of land use are continuously increasing in an unplanned manner which leads to cause many environmental issues. The gained data from Figures 6 to 8 revealed that there was a rapid increase in the amount of

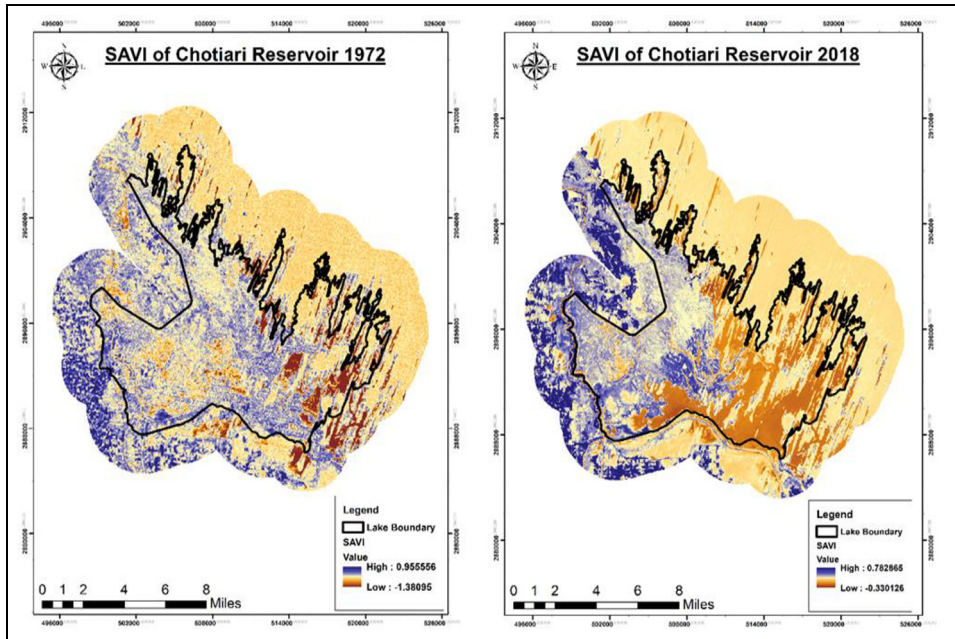


Figure 5. SAVI of Chotiari 1972 and 2018.

wastewater discharge into the wetlands and also the excessive use of synthesized chemicals in agricultural activities which can harm the environment and affect public health. Table 3 summarizes the area statistics of the analyzed LULC from 1972 to 2020. Water availability and natural land cover have a major role in newly emerging croplands. However, the decrease in water availability and unplanned agricultural practices can affect the aesthetics of the natural land cover and also drive desertification and soil erosion. The overall changes in the availability of each variable in wetland locations are illustrated in (Table 3) which shows both increasing and decreasing trends. The classified images of the whole studied sites; Manchar Lake, Keenjhar Lake, and Chotiari Reservoir show a significant variation that tends to be invisible reduction over the last 10 years in the whole studied classes; water, natural vegetation, agricultural land, and dry land (Table 3). This indicates the extent of the negative impacts that humans may have on the environment, which must be addressed. Similarly, the dynamics of plant and temperature were investigated using NDVI from 1972 to 2017 in Ekiti State, Nigeria.¹³ The resultant LULC maps indicated a decrease in forests and woodlands at a change rate of 51.25 and 0.72% over the studied period, however croplands, bare soils, and water sources have been increased by 267.58, 197.30, 714.11, and 4421.43%, respectively. The classified images of Manchar Lake in 1972 show that 6,510.6 ha were occupied by natural vegetation, which had shrunk to 173.43 ha in 2020. As for Keenjhar Lake which was occupied by 2751.48 ha of natural vegetation in 1972 has become

Table 3. A statistical table showing the LULC change and accuracy assessment from 1972 to 2020.

	Manchar Lake				Keenjhar Lake				Chotari Reservoir									
	Area (ha)				Area (ha)				Area (ha)									
	1972	1986	1992	2000	2010	2020	1972	1986	1992	2000	2010	2020						
Water	3666.9	23717.9	8488.6	11,647.1	21,036.8	25,041.7	14,937.5	12,675.7	10,682.5	10,510.1	14,428.1	11,070.2	16,426.8	13,198.3	6240.3	9458.9	11,072.7	5814.1
Natural vegetation	6510.6	5539.2	10,691.6	5375.2	369.6	173.4	2751.48	1959.5	3640.8	2607.39	3519.72	2193.3	7230.6	2397.2	12,802.7	7342.1	11,369.3	12,703.3
Agriculture land	0.0	4761.8	8515.9	12,555.1	9692.8	3214.8	0.0	6092.5	7565.7	6153.3	4257.4	7938.4	13112.3	12,528	12,379.1	15,837.4	7094.4	12,462.9
Dry land	36,274.7	2394.6	18719.8	11,839.7	12,316.4	19,984.1	25,067.2	21,996.8	20,843.6	23,456.3	20,527.2	21,524.4	21,459.6	29,191.6	26,782.7	25,566.1	28,661.3	27,224.5
Overall accuracy (%)	99.71	99.59	100	98.50	98.62	99.66	99.46	99.30	99.27	95.07	93.95	92.85	96.17	98.01	96.17	98.94	96.40	95.92
Kappa co-efficient (%)	0.99	0.99	1.0	0.97	0.97	0.99	0.99	0.98	0.98	0.93	0.91	0.90	0.94	0.96	0.94	0.98	0.94	0.94

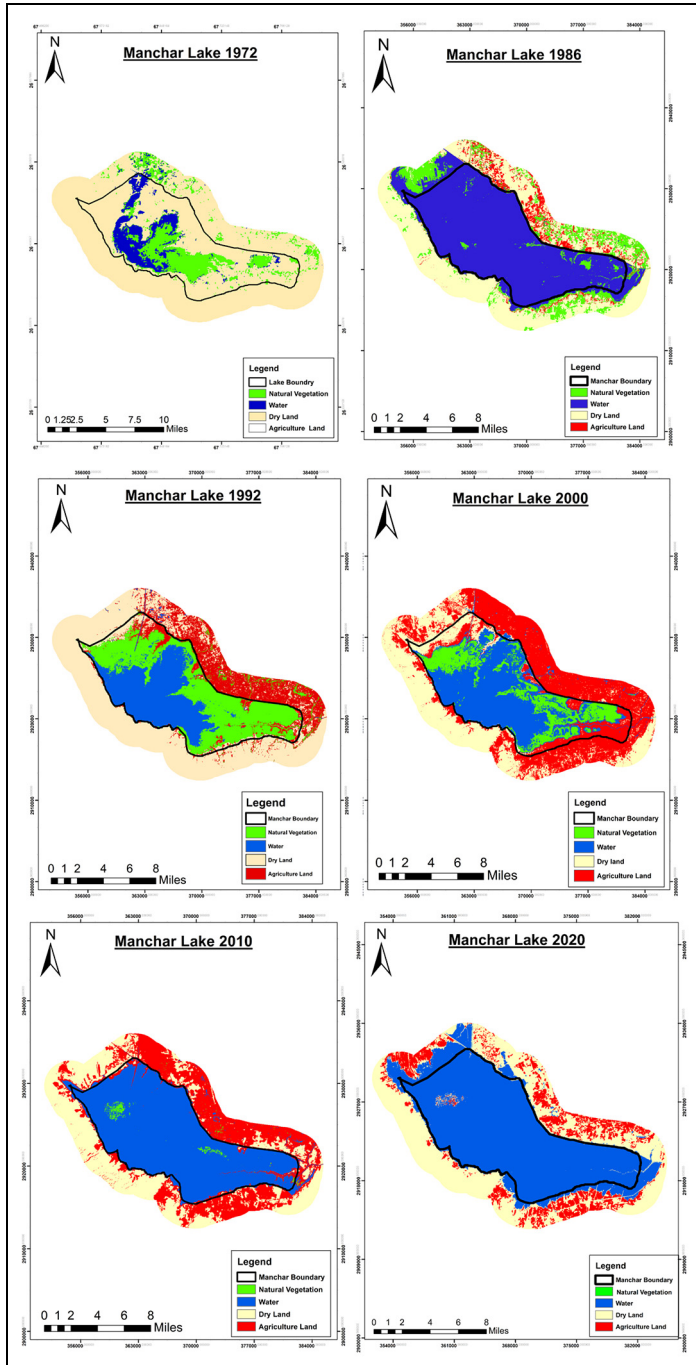


Figure 6. LULC maps of Manchar Lake from 1972 to 2020.

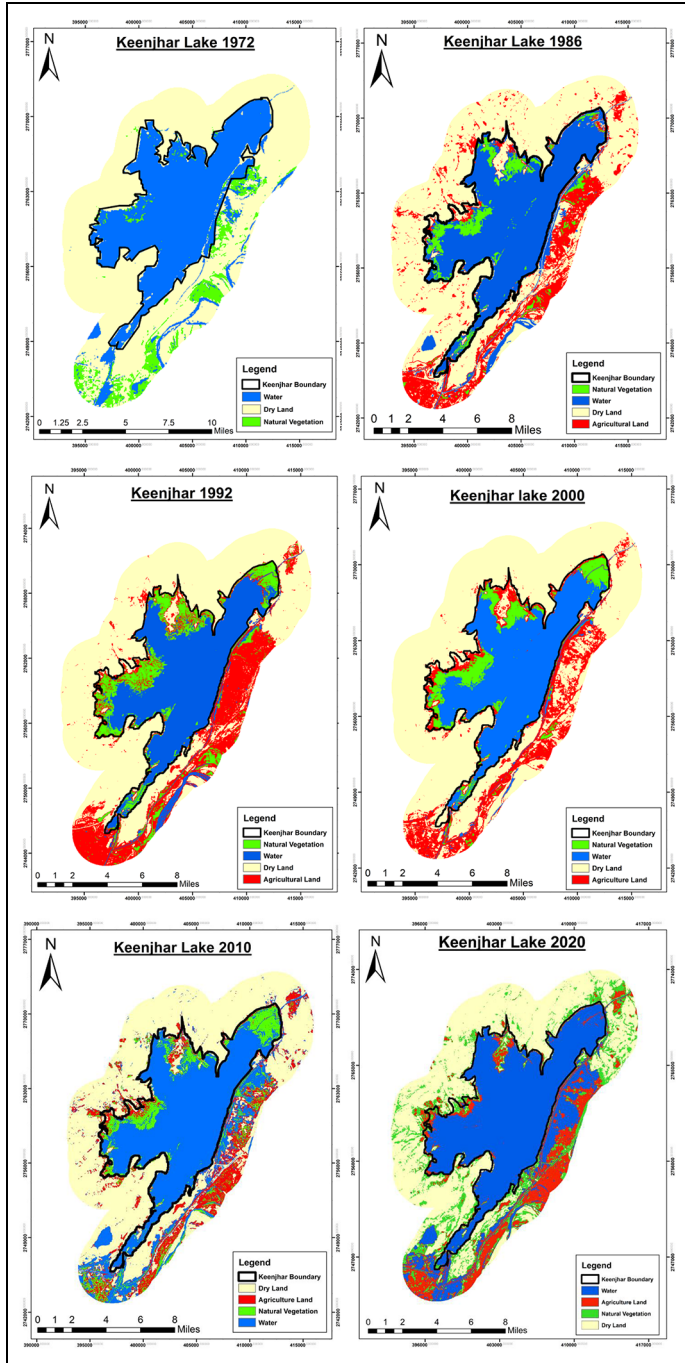


Figure 7. LULC maps of Keenjhar Lake from 1972 to 2020.

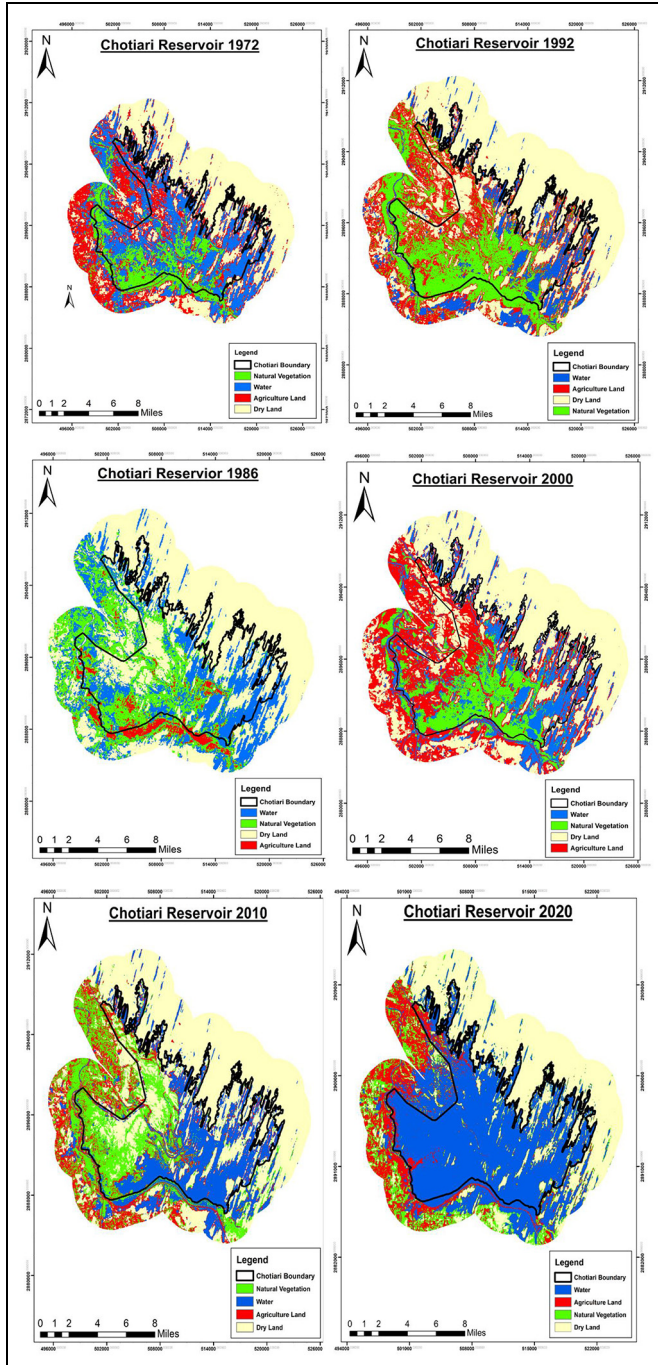


Figure 8. LULC maps of Chotiari Reservoir from 1972 to 2020.

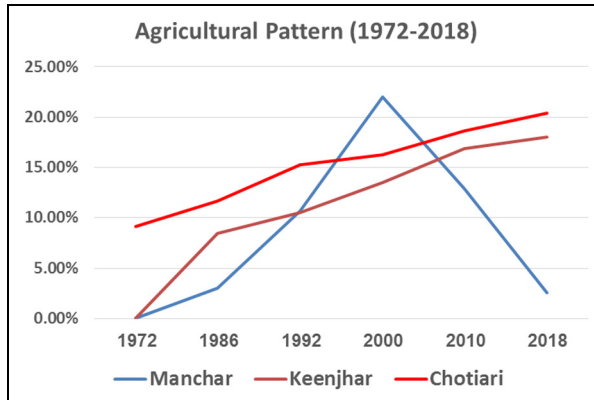


Figure 9. The agricultural trend over the wetland sites.

2193.3 ha in 2020. While the natural vegetation sites have become 12703.3 ha in 2020 after being 7230.6 ha in 1972 at the studied Chotiari Reservoir site. This significant decline in vegetation is attributed to the excessive discharge of industrial, municipal, and agricultural constituents through MNVD which also affects the availability of agricultural land (Figure 9) within the buffer zone of the wetland. The average availability of water during the pre and post-monsoon season has been increased due to the excessive discharge of wastewater and effluents in Manchar. Similarly, Keenjhar Lake is facing somehow the same environmental issues which conquered the natural aesthetic of wetland. Several studies have reported that the pollution rate in Kenjar is constantly increasing and threatening aquatic life as well as the local community. It was also observed that the natural vegetation cover had been depleted from 2751.48 to 2193.3 ha (Table 3) during the study period of this research. The continuous pollution load on Keenjhar via the KB Feeder Canal, Haroolo Drain, and municipal solid waste disposal contributes to the deterioration of this important wetland and gradually affects the soil quality, and tends to increase soil salinity. The variations in coastal belt characteristics including built-up land cover, mangroves & vegetation cover, and interrelationship of coastline morphology at the Karachi Coast (FKC) boundary, Pakistan have been studied by Khan et al.¹⁹ In similar, the land parcels recognized with a reduction in vegetation cover of mangroves by the built-up at respective sites of the FKC. Dense mangroves on the FKC are found to be declining dramatically from 119.7 to 96.3 hectares over the period 2010–2018. Moreover, our interpretation agrees with Kazi et al.⁵⁰ The water quality of Manchar Lake has been assessed based on multivariate statistical techniques. Complex water quality data sets have been evaluated and interpreted to gain improved knowledge on the water quality of Manchar Lake. The results showed that the main causes of the deterioration in water quality were attributed to the inflow of effluents from industrial, household, agricultural and saline seeps into the lake. Chotiari is an off-canal reservoir to store floodwater in

the Indus River from June to September. It is constructed according to sustainable agricultural practices during the offseason of water when the flow of the Indus River at its minimum level. The obtained results revealed that this vital resource has disappeared due to the improper management and anthropogenic activities which vigorously affect the natural regime of the reservoir as shown in Figures 6 to 8. In another study,⁵¹ the study aimed to determine the impact of the Chotiari reservoir construction on the vegetation cover and water saturation in the adjacent areas of the reservoir by using RS and geospatial tools. Satellite imagery analysis of the 5 km buffer zone around the perimeter of the reservoir showed that about 9% of the natural vegetation cover has reduced within the lake boundaries owing to the diversion of natural wetlands into the reservoir and led to lake depletion and to an environmental catastrophe.

Conclusion

This research study focused on the major wetlands of Sindh in which remote sensing along with GIS tools are coupled to examine the LULC dynamics and mapped the changes that occurred within the study area. Results illustrate the increasing anthropogenic activities including the industrial effluents, municipal discharge, waste disposal, and increase in population which lead to the direct and indirect impacts on LULC of the wetlands. The net decrease in the vegetation cover of Manchar lake is 6337.17 ha during the study period which attributes to the expansion of agriculture. The Main Nara Valley is the main source of industrial and domestic effluents which deteriorate the water quality of Manchar. While the Chotiari is suffering from the lack of water availability up to 64.60% due to the least flow of Indus and illegal construction of watercourses along the Chotiari. The continuous discharge of pollutants from KB Feeder Canal, Haroolo Drain, municipal and agricultural runoff has decreased the Vegetation of cover Keenjhar was by 558.18 ha. It is revealed that the ground roots of wetlands degradation are lack of proper freshwater recharge of wetlands through rivers and canals, extensive agricultural expansion, untreated industrial and wastewater discharge, urban expansion, and excessive drawing of groundwater. This study has limitations to encompass the aspect ratio between MSS, TM, and OLI. However, it concludes a more comprehensive scientific study to evaluate the current and future scenarios for ongoing analyses of changes in land management to enable decision-makers to establish strategies for effectively using land resources.

Authors' contributions

HI: Gathered, interpreted, and analyzed the satellite data of wetlands and their buffers. HA: Supervised this research, guides the authors, and provides resources. He also participated in the drafting of the manuscript. AK: Plays a major role in writing, editing, and reviewing the manuscript. MA: Contributed to the assessment of Soil Adjusted Vegetation Index and Normalized Vegetation Index to developed maps. AH: Performed the field survey and helps

to perform the geometric and atmospheric correction of the data. All authors read and approved the final manuscript.

Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.


Ethical approval


This research does not contain any studies with human participants or animals performed by any of the authors.

Consent to participate/informed consent

Informed consent was obtained from all individual participants included in the study.

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Availability of data and materials

The datasets used and/or analyzed during this study are available from the corresponding author on reasonable request.

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