Change Detection and Spatial Variability in Dal Lake and Nigeen Lake using Remote Sensing and Geographical Information System

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Abstract: ***The city of Srinagar-the summer capital of Union Territory of Jammu & Kashmir, is bestowed with a large number of picturesque lakes and serene wetlands. Among these, the Dal and Nigeen lakes have been important tourist destinations. Lakes are not only of economic value but are also ecological and environmental resources. However, these lakes are facing challenges due to climatic and anthropogenic activities. As these changes are slow and take long time, the damage goes unnoticed. Hence, long historic data provided such as of remote sensors are concrete evidence of change, which help us to understand the cause and prevent further change to some extent. In the present study, geospatial tools were employed for quantifying changes in the spatial extent of famous Dal and Nigeen lakes. In this study, Linear Imaging Self Scanning Sensor (LISS) images of 10 years gap (2007-2017), were used to detect the changes in the Dal and Nigeen lake. The results of the study show that the area of lakes has shrunken but at the same time volume retention capacities of these water bodies has increased due to dredging. The loss in the spatial extent of these lakes has in fact affected the micro-climate of the city besides exposing it to flood threat. It is estimated from the study that there is shrinkage of about 0.64 % and 1.38 % in Dal and Nigeen Lake respectively, volume retention capacity of Dal Lake has increased by 18.9 % and that of Nigeen lake by 7.12 % and mean depth of Dal Lake has increased by 82.9 % and that of Nigeen Lake by 12.8 % from 2007-2017.***

Keywords: change detection, dal lake, digitization, remote sensing

1. Introduction

Change detection is the measure of the distinct data framework and thematic change information that can guide to tangible insights into underlying process involving land cover and land use changes than the information obtained from continuous change. Remote sensing satellites attain satellite images at varying resolutions and hence use these for determining change detection (Asokan and Anitha, 2019) [1]. Digital change detection is the science of determining the changes linked to land use and land cover properties with reference to geo-registered multitemporal remote sensing information. It assists in identifying change between two or more dates that has uncharacterized normal variation. Change detection is beneficial in various applications viz, land use changes, habitat fragmentation, urban sprawl, rate of deforestation, coastal change and many other cumulative changes through spatial and temporal analyzing techniques such as Geographic Information System (GIS) and Remote Sensing (RS)in addition with digital image processing techniques and thus used widely for a number of missions [2].

Remote sensing is the science, that derives data about objects by measurements taken from a distance. The term Remote sensing has been coined by Evelyn L. Pruitt, a geographer. Change detection (CD) is done to identify the changes between bitemporal images. Estimating the relationships among different spatial-temporal pixel enhances the performances of Change Detection methods [3]. GIS is the systematic application of numerous variable disciplinary spatial and statistical data, used for inventorying the environment, observing changes and constituent processes. Remote Sensing assists in acquiring multi spectral spatial and temporal data with the use of space borne remote sensors. Image processing technique is used in analyzing the dynamic changes associated with the earth resources viz, land and water with the help remote sensing data. Therefore, spatial and temporal analysis technologies have been useful in generating scientific statistical spatial data for better understanding the land ecosystem dynamics. Remote sensing and geographical information systems have been termed as proven tools in assessing land use and land cover changes [4]. Lakes are one of the major freshwater resources and provide several economic and ecological services, but their natural scenario has been continuously changing with respect to time [5]. Lakes and wetlands being the world's major fresh water resources are termed as ecological and socio-economic valued ecosystems [6]-[8]. Urban wetlands provide a wide variety of key ecological services viz, flood control, wildlife habitat, fisheries, livelihoods, carbon storage, water purification and recreation [9]. Although land use/land cover change is a natural phenomenon and is due to result of intricate and complex interaction among various environmental factors, yet this change is often induced by increased human activities that challenges its wellbeing. The lakes have been facing pollution stress for a few decades due to rapid increase in population and anthropogenic activities [10], [11]. In the mountainous region of Kashmir Himalayas, there are 3, 813 wetlands and water bodies. Wetland areas have been gradually squeezing and permanent wetland areas have converted into semi-permanent wetlands. Lakes are also known for their changing behaviour during different seasons, which may be either due to rainfall or temperature variability [12]. The change in land use brings a change in average annual temperature and humidity regimes, besides corroborating a simultaneous change in socioeconomic patterns of the inhabiting local populations. City Srinagar, a century ago, had a unique ecological setup with extensive regions under wetlands, water channels and lakes. Although, siltation brought into the lakes and wetlands especially during floods has been natural, but subsequent encroachment, planting, earth filling, and construction along with conversion of water channels into roads, displays a live example of how assets of natural landscape of Srinagar city have been destroyed. Brief literature review has been discussed. [13] analyzed the land use/land cover change detection techniques by using GRDSS (Geographic Resources Decision Support System), through temporal multispectral data (year1998 and 2002) of IRS 1C / 1D (Indian Remote Sensing Satellites). Change detection techniques using temporal remote sensing data provided detailed information for detecting and assessing land cover and land use dynamics. Different change detection techniques were applied to monitor the changes. The analysis of change examined on two dates, over a period of four years using supervised classification, depicted an increasing trend (2.5 %) of unproductive waste land and decline of spatial extent in vegetated areas (5.33 %). [14] employed geospatial tools for quantifying changes in the spatial extent of fragile ecosystems of some of the world's most famous lakes and wetlands located in the suburbs of Srinagar. The extent of lakes, wetlands and built-up land as depicted on the archive topographical map of the area dating back to 1911, was compared and analyzed with respect to the spatial extent of lakes, wetlands and built-up land of the area as interpreted from Indian Remote Sensing satellite (IRS 1D)Linear Imaging Self-Scanning Sensor-III (LISS III) satellite imagery of the year 2004 to reveal astonishing results where more than 50 % of the water bodies had been lost during the last century. It was stated that loss in the spatial extent of the lakes and wetlands has influenced the micro-climate of the city and subjected it to flood threat. [15] analyzed the impact of land use / land cover dynamics on spatial status of HokarSar wetland, a Ramsar Site situated in Kashmir Himalayas, by using the multi-temporal (1986, 1995, 2005) changes in the upstream land use / land cover characteristics of wetland watershed, with the use of remote sensing data of SPOT (Satellite pour I'Observation de la Terre) HRV-I (High Resolution Visible), Landsat-ETM (Enhanced Thematic Mapper) and IRS-LISS-III. The results revealed that significant changes have taken place from 1986 to 2005 in the watershed and HokarSar wetland exhibited changes in spatial extension, structure and hydrological characteristics. [16] investigated the land transformation of Srinagar city located in Kashmir valley and found that urban expansion of the city and land transformation had severely affected the aerial extent of agricultural land, water bodies and marsh area. The extent of urbanization on Srinagar city could be framed from the fact that the city had an area of 12.8 km² in 1901 that increased to 82.88 km² in 1971 and to 270 km² in 2001. For understanding the impacts of changing physical characteristics on land, geospatial tools like RS and GIS were depicted to be useful. In order to gain a better understanding of the land use/ land cover change around Srinagar city, topographic and a multi-spectral remote sensing data was used in the study to analyze the change around the city. [17] examined the spatiotemporal changes within a Himalayan wetland and its catchment area, and correlated those with the help of time series of satellite, historical data and field data. Significant change was depicted in the spatial extent, water depth, and the land system of the HokarSar wetland from the spatiotemporal analysis of the data from the year 1969 to 2008. It was noted that wetland area had decreased from 18.75 km^2 in 1969 to 13 km^2 in 2008. The area under marshy lands and that under habitat of the migratory birds had decreased from 16.3 km^2 in 1969 to 5.62 km^2 in 2008, and had been colonized by other different types of land cover. The land system and water extent changes in wetland were related to spatiotemporal changes in the land cover and hydro meteorological variables at the catchment scale. Significant changes in the areas under forest cover (88.33- 55.78 km^2), settlement area (4.63-15.35 km^2), and that under water bodies (1.75-0.51 km^2) were observed in the catchment. It was noted that the rapid urbanization, changed hydrologic and climatic conditions, increased deforestation, and different other changes in land system examined in the catchment might be the main causes for the depleting wetland, water depth, and biodiversity by affecting the hydrologic erosion and land surface processes in the catchment area. [18] presented an automated procedure that allowed mapping the actual number, size, and distribution of lakes at large scale. Landsat 7 ETM + (Enhanced Thematic Mapper Plus) mosaics from the GeoCover Circa 2000 dataset covering the land surfaces of 14.25 m spatial resolution were used as input data. An approach termed as GWEM (GeoCover^{TM} Water bodies Extraction Method) was developed that combined RS and GIS to study the abundance and morphometry of water bodies. The proposed method claimed to produce accurate results. [19] examined impact analysis of biophysical and socio-economic processes at the watershed level on the status of Dal Lake with the use of multi-sensor and multi-temporal satellite data, simulation modelling along with field data verification. Thirteen watersheds were examined for land use/land cover change detection. Data regarding the watersheds was integrated into the GIS environment based upon multi-criteria analysis and additionally knowledge-based weightage system was adopted for watershed prioritization based on its factors and after carefully observing the field situation. The results revealed significant changes with a uniform trend of decrease in vegetation and increase in impervious surface cover. [20] investigated the lakes of Pokhara city by using Landsat data of 25 years gap (1988-2013). Normalized Difference Vegetation Index (NDVI), Normalized Difference Water Index (NDWI) and Modified NDWI (MNDWI) were determined from Landsat data. A model was developed by using ArcGIS, differencing the water bodies derived from index methods and thus differences were calculated for positive and negative changes. It was noted that results were helpful in reclaiming and restoration of lake area, preserve and maintain the wetland ecosystem in the city. Also, the model presented could be used for change detection of surface water due to flood, or debris blockages in disaster prone countries. [21] examined satellite images taken from the earth's surface to identify the spatial and temporal changes (natural and manmade), and stated that real-time prediction of change provided a better understanding related to the land cover change, habitat fragmentation, environmental changes, urban sprawl and coastal alteration. The study involved various digital change detection approaches and their constituent methods. [22]-[23] concluded that impacts of anthropogenic activities on lakes, rivers and groundwater changes are higher rather than those of the natural factors. [24] examined a semi-urban wetland, Bodsar, situated in Kashmir Himalaya by using multicriteria analysis approach assimilating data on landscape fragmentation and land use land cover (LULC). Wetland and catchment-scale land system changes (1980 to 2022) were examined using high-resolution imagery. Satellite data depicted that land use with areas under exposed rock, orchards, built-up and sparse forest had increased by 1005%, 623%, 274%, and 37% respectively, and referred that the zones greater than 500 acres and less than 250 acres zones decreased by 16% and 64%, respectively and that 21% of the wetland experienced severe degradation, 62% moderate degradation, and 17% did not face any significant degradation. The study stated that novel GIS-based approach could act as a prototype for the wetlands in assessing the catchment-scale degradation worldwide.

2. Materials and methods

The present study was aimed to make an attempt to quantify the changes in the spatial extent of Dal and Nigeen Lakesusing RS & GIS technology. Landsat data of 10-year gap (2007-2017) was used to detect the change in the study areas. The objectives of the present study were to digitize the study areas using ArcMap and to determine change detection & spatial variability of study areas.

2.1 Description of the Study Area

The study area, Dal Lake, (Fig. 1)is located between 34°5′N and 34°9′N latitude and 74°50′E and 74°54′E longitude [25], situated in Jammu and Kashmir, the northern-most Union Territory of India. Itis a Himalayan Urban Lake, tectonic in origin and surrounded by mountains and located in the heart of Kashmir, (Srinagar)at an altitude of 1, 584 meters. It is the second largest fresh water body in the Kashmir valley [26], with an average water depth of 2.32 m [27] and watershed area of 337 km^2 [28]. The flat areas of the catchment are mostly used as cropland, horticulture and built-up where human activities have intensified during the last few decades. The mountainous areas are mostly covered by forest, grassland, scrub lands, and the hilly regions consist of natural vegetation and barren land. Major surface run off transporting the eroded soil and sediments originate from these mountainous and hilly areas of the catchment. Dal lake is a shallow, multi-basin lake with inflow and outflow water channels. The drainage pattern in the study area is a combination of trellis and dendritic patterns with the general flow direction being from east to southwest. The lake is fed by a numerous underground springs and streams, yet the primary feeding channel viz Dachigam Creek, originating from the Alpine Marsar lake, enters the lake from the northern side after draining from the Dachigam Wildlife Reserve enroute. The four basins that make up the lake are Hazratbal, Boddal, Nigeen, and Gagribal. Nigeen basin is the deepest having a maximum depth of 6 m approximately, while Gagribal basin is the shallowest having maximum depth of 2.5 m. Telbalnala, at Hazratbal basin, joins several smaller streams to merge into the lake. As of the year 2022, the Dal Lake water surface area is estimated to be about11.45 km^2, of which 4.1 km^2 is under floating gardens. The land area and marshy area, respectively are 1.51 km^2 and 2.25 km^2 (Samie and Khan 2022). The snow thaw in the upper catchment drains in maximum discharge through Dachigam & Dara Nallah which inflows into the Lake. Since a large population is dependent on the lake for varied services and products, therefore lake degradation, besides hindering sustainable development of the lake, exposes the human and aquatic life, within and in the vicinity of the lake to various risks [26], [29]-[31].

2.2 Climate

The Dal Lake catchment falls under a sub-Mediterranean type climate of four seasons depending on mean temperature and precipitation. Average annual rainfall of 650 mm at Srinagar station and 870 mm at Dachigam station is received by the catchment area the average annual precipitation in the Srinagar district is 730 mm [32]. March, April and May are the wettest months of the year. The entire Dal Lake catchment remains covered under snow during winter months (December to March) with minimum temperatures dropping below 0°C. The temperature ranges a monthly mean maximum of 33°C in July and a minimum of -4°C in January.

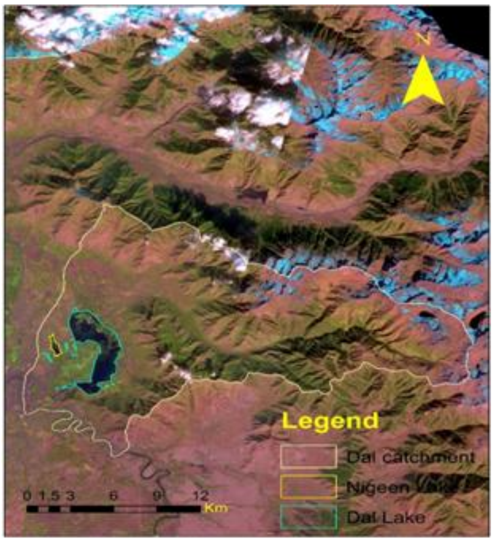

Figure 1: Dal Catchment

2.3 Remote Sensing data

Remote sensing involves the use of imagery. The common types of imagery used are satellite imagery and aerial photography. The satellite imagery has a lower resolution but has multispectral capabilities and is ideal for studying large areas than aerial photography. Remote sensing data in the form of satellite imageries in digital format was made available from National Remote Sensing Agency (NRSA). Remote sensing data used in this study involves Toposheet, LISS-III image, LISS IV image and Watershed map.

2.4 Softwares used

The softwares used during the study were ArcMap 10.2, Microsoft Excel and Google Earth Pro.

2.5 Data collection

LISS-IV image was provided by Centre for Climate Change and Mountain Agriculture (CCMA) Lab., Division of soil science, Sher-e-Kashmir University of Agricultural Sciences and Technology (SKUAST-K). Srinagar water bodies LISS-III was provided by Department of Ecology, Environment & Remote Sensing Bemina Srinagar. Depth variation of Dal Lake & Nigeen Lake was provided by J & K Lakes and Waterways Development Authority (LAWDA) now renamed as Jammu and Kashmir Lake Conservation and Management Authority (LCMA), Miskeen Bagh, Khanayar, Srinagar.

2.6 Methodology adopted

The following steps were performed to conduct the study (Table 1).

Table 1: Methodology adopted

Step 1	Digitization of images and preparation of maps using remote sensing data.
Step 2	Comparing maps of different time series for quantifying changes in spatial extent in the study area.
Step 3	Using parameters of area and mean depth for assessing volume change in water bodies.

Study area was first digitized by clipping it from LISS-IV and Google satellite image of 1: 10000 scale was geo-referenced in GIS environment. In this way coordinates (latitude and longitude) of the study area were defined. LISS-IV image was used for digitization of 2007 image and Google satellite image for digitization 2017 image. After digitization, (Fig.2) the maps were prepared and their properties were examined. Maps of different time series of study area were compared and area change was detected. For volume change detection, area was calculated after digitization in Arc Map 10.2 and the mean depth value of Dal and Nigeen Lake was calculated.

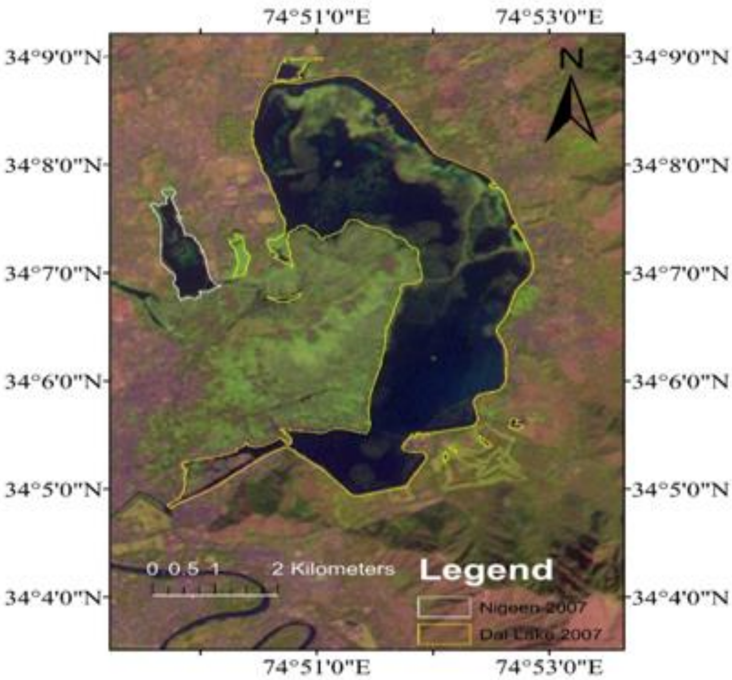

Figure 2: Dal-Nigeen 2007

2.7 Procedure for digitization using ArcMap 10.2

Launch ArcMap software. Click ona New Empty Map in the window. Click on the Add Data button to add basemap. Basemap can be added also from ArcGIS online. One must check the projection of these files before any data analysis. Failure to do this step can result in inaccurate results. Right click on "states" and click "properties". Under the Source tab it will be shown as Projected Coordinate System is WGS_1984_UTM_Zone_43N. Add Vector Shapefile using ArcCatalog. Go for zooming in and pan to the point location from where digitizing the boundary is to be started. Open the Editor toolbar and click the Editor dropdown arrow to select option of Start Editing. Select the Sketch tool. Move the cursor (now shaped like crosshairs) to the boundary lines marked on base map. Left-click for adding vertices at every place on the boundary line traces. To finish digitizing the polygon, just double-click with the left mouse button to close it (i.e., the second-to-last point or when you get close to where you placed the first vertex). Save Editing by clicking Save Edits from Editor drop down. The new layer has an Attribute Table and opens it by selecting Attribute

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icon in editor toolbar. To obtain the area of the watershed, right-click on the watershed layer (the one you converted to a polygon) and then select Open Attribute Table. Click on Options - Add Field (a Field is a column in the data table). Give the new Field a name ("Area") and select the data type. Repeating the procedure for precision is a good choice the genuine calculations.

2.8 Volume retention capacity calculation

Volume retention capacity = Average depth of water body × Area of water body

Results and Discussion

In order to detect the surface area changes of the lakes in the period 2007-2017, the water surface of each lake in each temporal image was extracted. The simplest way to detect changes is by subtracting the Digital Number value of area of one image from the other which shows the spatial change in the study area. The resulting maps (Fig. 3) depict that the area of Dal Lake has decreased from 1396 ha in 2007 to 1387 ha in 2017 and that of Nigeen lake has decreased from 72 ha in 2007 to 71 ha in 2017. Volume retention capacity of Dal Lake has increased from 0.037 km^3 in 2007 to 0.044 km^3 in 2017 and that of Nigeen lake has increased from 0.00407km^3 in 2007 to 0.00436 km^3 in 2017. The mean depth of Dal Lake has increased from 2.2275m in 1997 to 4.075 m in 2017 and that of Nigeen Lake has increased from 5.65m in 1997 to 6.375 m in 2017. It is thus evident that volume retention capacities of these water bodies have increased due to dredging, after analyzing the annual depths (Fig. 4, 5 and 6) of Dal and Nigeen Lake. The Change detection in Dal and Nigeen Lake from 2007 to 2017 is presented in Table 2.

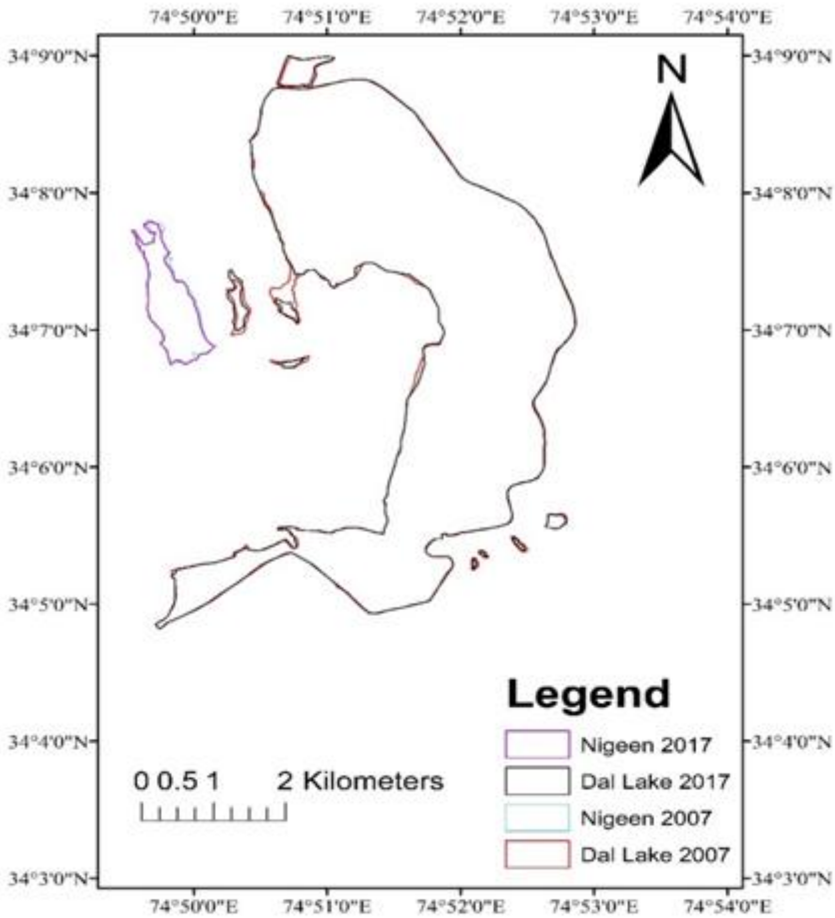

Figure 3: Overlapped image of dal and nigeen lake

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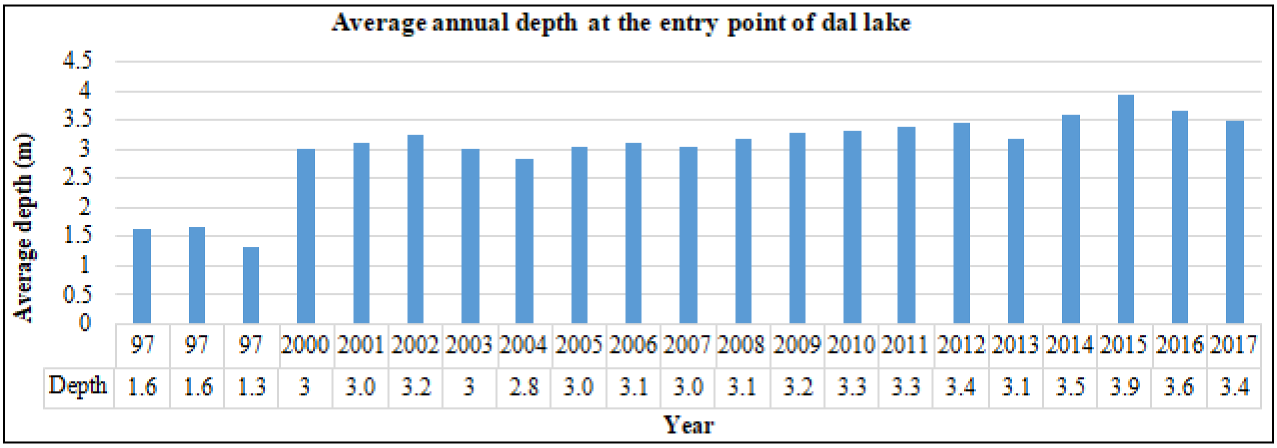

Figure 4: Average annual depth at the entry point of dal lake

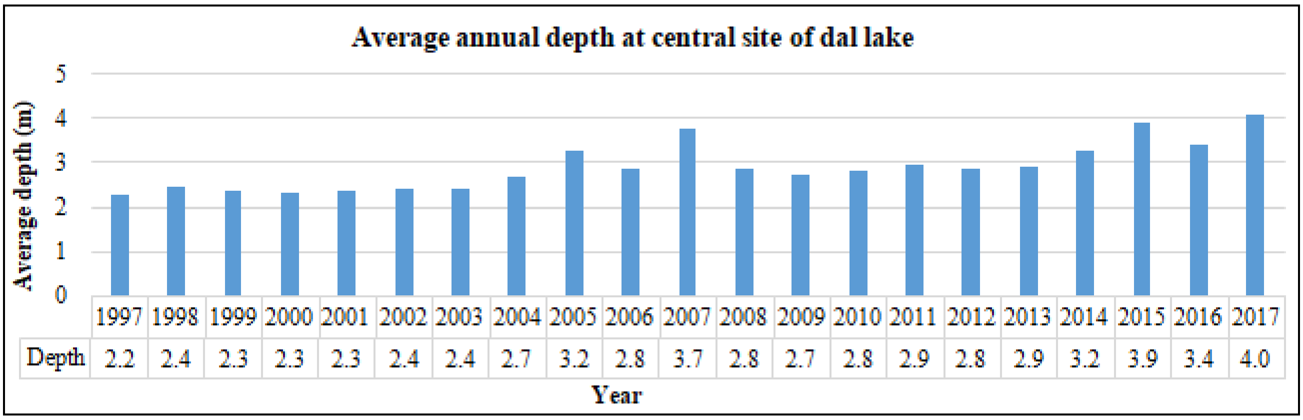

Figure 5: Average annual depth at central site of dal lake

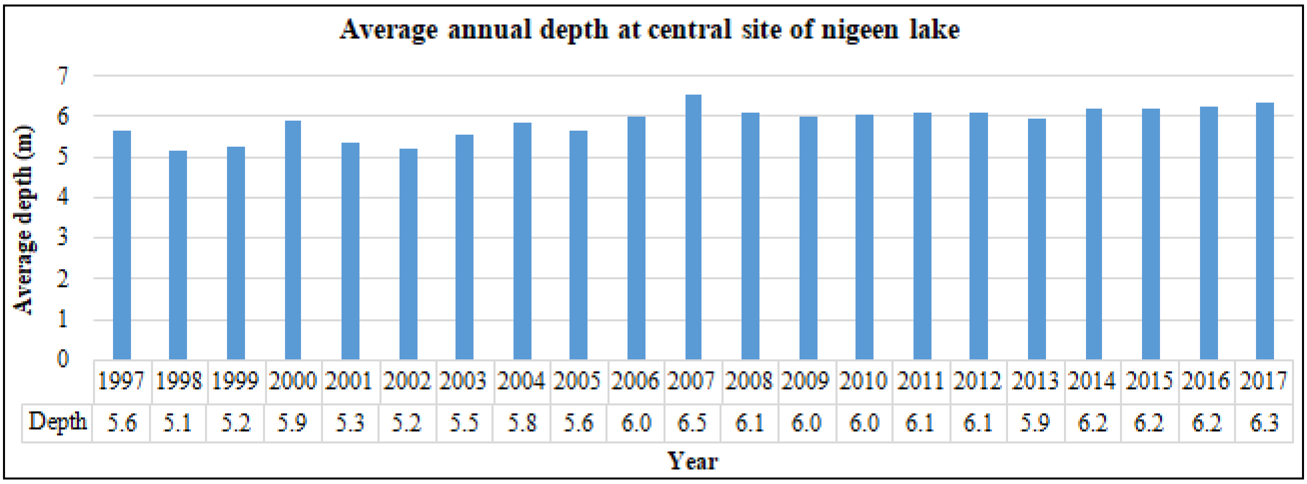

Figure 6: Average annual depth at central site of nigeen lake

Table 2: Change detection in dal and nigeen from 2007 to 2017

S. No.	Parameters	Dal Lake 2007	Dal Lake 2017	Nigeen Lake 2007	Nigeen Lake 2017
1	Surface Area (ha)	1396	1387	72	71
2	Annual Mean Depth (m)	3.775	4.075	6.575	6.375
3	Volume retention (km^3)	0.037	0.044	0.00407	0.00436

3. Conclusion

Various parameters like water surface area, annual average depth and volume retention capacity of lakes were used for postulating the change detection of lakes using LISS images of 10 years gap (2007-2017). Maps of different time series of study area were compared and area change was detected. It was concluded that the area of Dal Lake has decreased by 9 ha (0.64%) (from 2007-2017)and that of Nigeen lake has decreased by 1 ha (1.38 %) (from 2007-2017). Volume retention capacity of Dal Lake has increased by0.007 km^3 (18.9 %) (from 2007-2017) and that of Nigeen lake has increased by 0.0003km^3 (7.12%) (from 2007-2017). The average depth of Dal Lake has increased by 1.85 m (82.9%) (from 2007-2017) and that of Nigeen Lake has increased by 0.725 m (12.8 %) (from 2007-2017).

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References

[1] Acharya, T.D., Yang, I.T., Subedi, A., and Lee, D.H.,"Change Detection of Lakes in Pokhara, Nepal using Landsat Data", In Proceedings 2017,1(2): pp. 17, 2016. (doi.org/10.3390/ecsa-3-E005)

[2] Afaq, Y., and Manocha, A.,"Analysis on Change Detection Techniques for Remote Sensing Applications: A review", Ecological Informatics, 63, pp.101310, 2021.

[3] Alam, A., Rashid, S.M., Bhat, M.S., and Sheikh, A.H.,"Impact of Land Use/Land Cover Dynamics on Himalayan Wetland Ecosystem. Journal of experimental sciences", 2(3), 2011.

[4] Asokan, A. and Anitha, J.J.E.S.I.,"Change Detection Techniques for Remote Sensing Applications: A Survey", Earth Science Informatics, 12, pp.143-160, 2019.

[5] Badar, B., Romshoo, S.A., and Khan, M.A.,"Modelling Catchment Hydrological Responses in A Himalayan Lake as a Function of Changing Land Use and Land Cover", Journal of earth system science,122, pp. 433-449, 2013.

[6] Bazigha, B., Romshoo, S.A. and Khan, M.A.,"Integrating Biophysical and Socioeconomic Information for Prioritizing Watersheds in A Kashmir Himalayan Lake: A Remote Sensing and Gis Approach", Environmental Monitoring and Assessment,185(8), pp.6419-6445, 2013.

[7] Brown, T.C., and Froemke, P.,"Nationwide Assessment of Nonpoint Source Threats to Water Quality", BioScience, 62(2), pp.136-146, 2012.

[8] Chen, H., and Shi, Z."A Spatial-Temporal Attention-Based Method and a New Dataset for Remote Sensing Image Change Detection", Remote Sensing,12(10), pp. 1662, 2020.

[9] Dar, S.A., Bhat, S.U., Rashid, I., Dar, S.A.,"Current Status of Wetlands in Srinagar City: Threats, Management, Strategies, and Future Perspectives", Frontiers in Environmental Science,7, pp. 1–11, 2020. (doi.org/10.3389/fenvs.2019.00199).

[10] Diwate, P., Meena, N. K., Bhushan, R., Pandita, S., Chandana, K. R., and Kumar, P.,"Sedimentation Rate (^{210}Pb and ^{137}Cs), Grain Size, Organic Matter and Bathymetric Studies in Renuka Lake, Himachal Pradesh, India", Himal Geol, 41(1), pp. 51–62, 2020.

[11] Dudgeon, D., Arthington, A.H., Gessner, M.O., Kawabata, Z.I., Knowler, D.J., Leveque, C., Naiman R.J., Prieur-Richard, A., Soto, D., Stiassny, MLJ., Sullivan, CA.,"Freshwater Biodiversity: Importance, Threats, Status and Conservation Challenges", Biological Reviews, 81, pp.163–182, 2006.

[12] Guhathakurta, P., Krishnan, U., Saji, E., Menon, P., Prasad, A.K., Sangwan, N., and Advani, S.C,"Observed Rainfall Variability and Changes over Jammu &Kashmir", Met Monograph No. ESSO/IMD/HS/Rainfall/Variability/11(2020)/35,2020. https://imdpune.gov.in/hydrology/rainfall%20variability%20page/jk_final.pdf.

[13] Huang, F, Wang, X., Lou, L., Zhou, Z. and Wu, J.,"Spatial Variation and Source Apportionment of Water Pollution in Qiantang River (China) using Statistical Techniques", Water research, 44(5). pp. 1562-1572, 2010.

[14] Javaid, M., and Ahmad, A.,"Evaluating the Morphometric and Hydrological Characteristics of Dal Lake Using Remote Sensing and GIS", Journal of Himalayan Ecology and Sustainable Development,10, pp.49-56, 2015.

[15] Kumar, P., Mahajan, A.K.,"Hydrogeochemical Facie and Solute Acquisition at Dal Lake of Kashmir and Dal Lake of Mcleodganj, Northwest Himalaya, India", Journal of Earth System Science,132 (1), pp. 38, 2023.(doi.org/10.1007/s12040-023-02046-9).

[16] Kumar, P., Mahajan, A. K., and Kumar, P.,"Determining Limiting Factors Influencing Fish Kills at Rewalsar Lake: A Case Study with Reference to Dal Lake (Mcleodganj), Western Himalaya, India", Arabian Journal of Geoscience,13, pp. 1-21, 2020.

[17] Meena, N. K., Gaury, P. K., and Mahajan, A. K., "The Climatic and Anthropogenic Influences on Himalayan Glacial and Non-Glacial Lakes", Quaternary Climate Change over the Indian Subcontinent, 21, pp.47–48, 2021.

[18] Nelson, N.M., Loomis, J.B., P.M, Jakus, P.M., Kealy, M.J., Stackelburg, N., Ostermiller, J.,"Linking Ecological Data and Economics to Estimate the Total Economic Value of Improving Water Quality by Reducing Nutrients", Ecological Economics,118, pp.1–9, 2015.

[19] Papatheodorou, G., Demopoulou, G., and Lambrakis, N.,"A Long-Term Study of Temporal Hydrochemical Data in a Shallow Lake using Multivariate Statistical Techniques", Ecological Modelling, 193(3-4), pp.759-776, 2006.

[20] Pashaeifar, M., Dehghanzadeh. R., Ramazani, M. E, Rafieyan, O., and Nejaei, A.,"Spatial and Temporal Assessment of Groundwater Quality and Hydrogeochemical Processes in Urmia Lake Basin, Iran", Water Supply, 21(8), pp. 4328–4342, 2021.(doi.org/10.2166/ws.2021.180).

[21] Ramachandra, T.V., and Kumar, U., "Geographic Resources Decision Support System for Land Use, Land Cover Dynamics Analysis", In Proceedings of the FOSS/GRASS users conference,15, 2004.

[22] Rashid, I., Aneaus, S., Dar, S.A., Javed, O., Khanday, S.A. and Bhat, S.U.,"A Novel GIS-Based Multicriteria Analysis Approach for Ascertaining the Catchment-Scale Degradation of a Himalayan Wetland", Environmental Research,229,pp. 115967, 2023.

[23] Rashid, H., and Naseem, G.,"Quantification of Loss in Spatial Extent of Lakes and Wetlands in The Suburbs of Srinagar City During Last Century Using Geospatial Approach", In Sengupta, M and Dalwani, R. Proceedings of Taal 2007: The 12th World Lake Conference,pp. 653-658, 2008.
[24] Rashid, I., Romshoo, S.A., Amin, M., Khanday, S.A. and Chauhan, P.,"Linking Human-Biophysical Interactions with The Trophic Status of Dal Lake, Kashmir Himalaya, India", Limnologica, 62, pp. 84-96, 2017.
[25] Romshoo, S.A. and Rashid, I., "Assessing the impacts of changing land cover and climate on Hokersar wetland in Indian Himalayas", Arabian Journal of Geosciences, 7, pp.143-160, 2014.
[26] Sahin, G., Cabuk, S.N. and Cetin, M.,"The Change Detection in Coastal Settlements Using Image Processing Techniques: A Case Study of Korfez", Environmental Science and Pollution Research, 29(10), pp. 15172-15187, 2022.
[27] Samie, S. and Khan, A.A.,"Assessment of Water Quality of Dal Lake, Srinagar", International Journal of Advances in Engineering and Management (IJAEM), 4(1), pp. 912-917, 2022.
[28] Sharma, A., Singh, A.K., and Kumar, K.,"Environmental Geochemistry and Quality Assessment of Surface and Subsurface Water of Mahi River Basin, Western India", Environmental Earth Sciences, 65, pp. 1231-1250, 2012.
[29] Verpoorter, C., Kutser, T., and Tranvik, L.,"Automated Mapping of Water Bodies Using Landsat Multispectral Data", Limnology AndOceanography:Methods,10(12), pp.1037-1050, 2012.
[30] Walsh, P.J., Milon, J.W.,"Nutrient Standards, Water Quality Indicators, and Economic Benefits from Water Quality Regulations", Environmental and Resource Economics, 64, pp.643–661, 2016.
[31] Wang, S.W., Gebru, B.M., Lamchin, M., Kayastha, R.B., and Lee, W.K.,"Land Use and Land Cover Change Detection and Prediction in The Kathmandu District of Nepal Using Remote Sensing And GIS", Sustainability,12(9), pp. 3925, 2020.
[32] Wani, R.A., and Khairkar, V.P., "Quantifying Land Use and Land Cover Change Using Geographic Information System: A Case Study of Srinagar City, Jammu and Kashmir, India", International Journal of Geomatics and Geosciences,2(1), pp.110-120, 2011.