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A Time Series Change Analysis of Lake Area and Their Response to Climate Change: Case Study of Nainital Region Lakes, Kumaun Himalayan

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Abstract – The lakes of Kumaun Lesser Himalayan region has undergone significant change in last five decades. Lake surface area is decreasing continuously under the influence of climate change viz., rainfall pattern affecting water resources of the area. In the present exercise we have examined 8 Kumaun Himalayan lakes from 1972 to 2019 with the help of Landsat 8 data and calculated lake area change for the last five decades. These 8 lakes include Nainital, Bhimtal, Naukuchiatal, Pannatal, Sattal, Khurpatal, Harishtal and Lohakhamtal. The Landsat image series from 1972 to 2017 were collected from United States Geological Survey (USGS) earth explorer for detecting the changes through time. The results show that the lakes of Kumaun Himalayan region showing overall shrinking trend from 1972 to 2018 with >81% overall accuracy, >0.84 overall kappa statistics. Overall lake surface area change has gone through three phases viz., a sharp increment of lake surface area during 1972-1981, a gradual decrement during 1982-2013 and slight increment during 2013-2017.

Key Words – Kumaun Himalaya, Landsat Series, Maximum Likelihood, Lake Area Change, Shuttle Radar Topography Mission (SRTM).

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INTRODUCTION

Lake surface area change in Kumaun Himalayan lakes is a very important factor as it is directly related to the rainfall pattern of the area and followed by water management in the Kumaun lesser Himalayan region. Study of physiographic changes lakes in the Himalayan region is extremely important as these are the main source of fresh water and are strongly related to geodynamics, anthropogenic activities and regional climate changes. Somehow the lacustrine water is always affected by the lithology, topography, and anthropogenic activities around the lake system. The geometry of the lake is also controlled by lithology, physiography, and anthropogenic activities. The main challenge is to assess the stability of lakes and understand the effect of ongoing deformation, climate change impact and issues related to their augmentation as lowering of lakes may be attributed to excessive withdrawal and lack of recharge. As the low altitude is the zones under human reaches, the lakes of low altitude are under human interference and widely affected by anthropogenic activities. Water is a basic requisite for living beings such as humans and wildlife, food production, alleviation of poverty, food security, sustainable development etc. Population increment, drinking water consumption, reduced rainfall, water pollution, poor sanitation, decrease rainfall, groundwater levels and water scarcity are factors that drag India into a major threat. In Kumaun lesser Himalayan region, 'water problem' is mainly due to poor management, ignorance, use of inappropriate technology in water management. Human interface with environ in Nainital area is started after 1841 as human habitation started after 1941 (Peeyush, 2013). After human habitation Nainital is continuously facing mass movement till now.

Climate change has become an important factor (Huang, 2011 and Lie et al., 2013) to control the lake surface area and its volume as lake surface area change with respect to rainfall, glaciations, evaporation etc. long term monitoring and mapping of Kumaun Himalayan lakes can provide a better understanding of climate change and ultimately the understanding of management of water resources. The dynamics of lake surface area change can be

monitored easily with the help of optical remote sensing. Lake water level is very sensitive to both climate change and human activities hence are great indicator of local ecosystem change (Haifeng et al., 2017 and Ma, 2010).

Landsat time series data is the medium resolution data which records earth's surface from 1972 to present (Roy, et al., 2014). The Landsat time series is open resource, having capacity to monitor temporal history. Many temporal studies have been done with the help of Landsat time series data to reveal spatial-temporal changes of high and mid altitude lakes of Himalayan region (Nie, 2013) (Liao, 2013). The main purpose of this study is to extract the surface area of lakes by maximum livelihood classification and manual method with the help of Landsat time series data from 1972 to present in order to make better understanding of climate change and its relation with lake surface area change. In this regard, it's an attempt to evaluate the past and present lake surface area change of Kumaun lesser Himalayan lakes.

STUDY AREA

Kumaun Himalayan lakes bounded between latitudes of 29º27'30"-29º10'30" N and longitudes of 79°50'0"-79°28'30"E. Kumaun Himalayan lakes are located in a densely populated valley of Kumaun Himalaya (Nainital district) of Uttarakhand. The study area experiences the climate of sub-tropical to sub-humid. The study area comes under the elevation range 474m to 2581m and slope range from 0° to 79.0672°. Lesser Himalayan region situated between main boundary thrust (MBT) in the southern regime and main central thrust (MCT) in the northern regime. Study area consist of eight natural lakes viz., Nainital, Bhimtal, Khurpatal, Naukuchiatal, Sattal, Pannatal, Harishtal, Lohakhamtal.

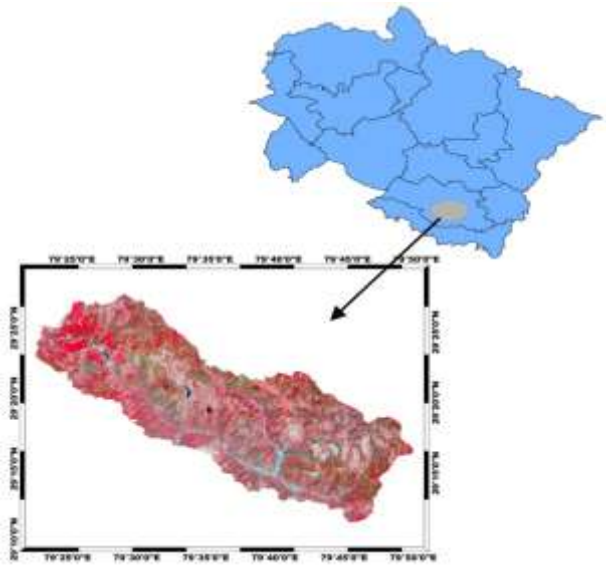

Figure 1: Study area map.

METHODOLOGY AND DATA USED

Landsat satellite time series data were acquired by United States Geological Survey (USGS) earth explorer. Radiometric and geometric correction is performed in all the satellite images later lake surface area has been extracted using supervised classification (maximum likelihood). (Need more detail description of the procedure) Further manual digitization of each lake has been performed to extract lake surface area of each lake of Kumaun lesser Himalaya. After extraction of lake surface area accuracy assessment has been performed. Flow chart of whole exercise is shown in Figure 2.

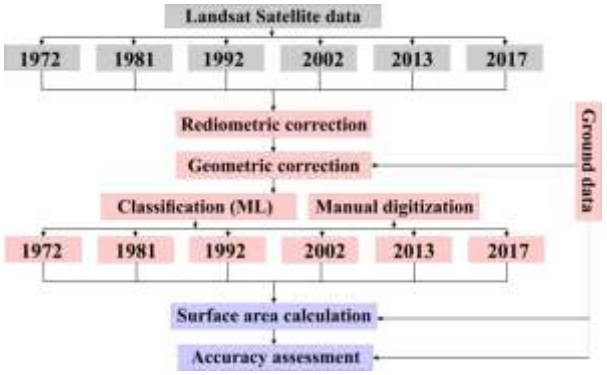

Figure 1: Flow chart of whole exercise.

SATELLITE DATA

In the present study Landsat time series data is used which is medium resolution data. For extraction of lake surface area, Landsat 1 MSS collected on 01 December 1972 (one scene), of Landsat 3 TM and Landsat 5 TM collected on 15 October 1981 and 22 October 1992 (two scene), Landsat 7 ETM+ collected on 23 October 2002 (one scene), Landsat 8 OLI collected on 13 October 2013 (one scene) were used. The satellite images can be downloaded free from the USGS earth explorer.

Table 1: Satellite data specification

Satellite	Sensor	Year of data used	Resolution (m)	Acquisition date
Landsat 1	MSS	1972	60	01 December 1972
Landsat 3	TM	1981	30	15 October 1981
Landsat 5	TM	1992	30	22 October 1992
Landsat 7	ETM+	2002	30 (Multi),15 (PAN)	23 October 2002
Landsat 8	OLI/TIRS	2013	30 (Multi),15 (PAN)	13 October 2013
Landsat 8	OLI/TIRS	2017	30 (Multi),15 (PAN)	24 October 2017

ArcGIS geospatial package was used for the extraction of lake surface area. Digital elevation model (DEM) (AlosPal SAR) and topographic maps (Survey of India toposheet at 1:50000) used for preparation of other layer.

RESULTS

We attempt to extract surface area of Kumaun Lesser Himalayan lakes with the help of Landsat time series data. The graphical representation of present study results is shown in Figure 2. The

present study shows that lake surface area change in Kumaun Himalayan lakes has gone through three phases viz., a sharp increment of lake surface area from 1972 to 1981, a gradual decrement from 1982 to 2013 and slight increment from 2013 to 2017. Surface area of Nainital Lake in 1972 was 46.6642 hectare with time it became 56.3831, 55.4111, 48.4699, 47.2064, 48.4699 hectare in 1981, 1992, 2002, 2013 and 2017 respectively. Surface area of Khurpatal Lake was 4.32 hectare in 1972 with time the surface area of lakes changes 4.68, 4.3158, 4.0978, 3.82868 and 3.9978 hectare in 1981, 1992, 2002, 2013 and 2017 respectively. Surface area of Pannatal was 4.8516 hectare in 1972 with time the surface area of lakes changes 5.6764, 4.62923, 4.03339, 4.0416 and 4.03339 hectare in 1981, 1992, 2002, 2013 and 2017 respectively. Surface area of Sattal was 26.08534 hectare in 1972 with time the surface area of lakes changes 28.5478, 23.98863, 22.542, 21.53924 and 22.542 hectare in 1981, 1992, 2002, 2013 and 2017 respectively. Surface area of Bhimtal was 50.8565 hectare in 1972 with time the surface area of lakes changes 51.9624, 47.5912, 46.0353, 44.0296 and 45.0353 hectare in 1981, 1992, 2002, 2013 and 2017 respectively.

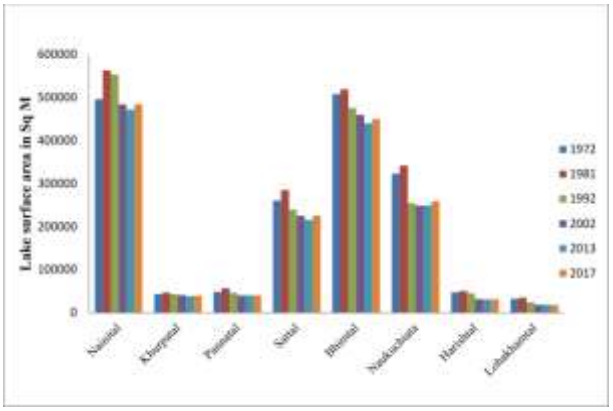

Figure 3: Lake surface area change in various Kumaun Himalayan lakes from 1972 to 2017.

Surface area of Nakuchiatal was 32.3141 hectare in 1972 with time the surface area of lakes changes 34.2395, 25.4811, 24.9121, 24.9233 and 25.9121 hectare in 1981, 1992, 2002, 2013 and 2017 respectively. Surface area of Harishtal was 4.74188 hectare in 1972 with time the surface area of lakes changes 5.06, 4.512673, 3.13966, 3.09093 and 3.13766 hectare in 1981, 1992, 2002, 2013 and 2017 respectively. Surface area of Lohakhamtal was 3.24 hectare in 1972 with time the surface area of lakes changes 3.52987, 2.38658, 1.826, 1.81418 and 1.824 hectare in 1981, 1992, 2002, 2013 and 2017 respectively. Pictorial representation of lake surface area changes from 1972 to 2017 in Kumaun lesser Himalayan lakes is shown in Figure 4.

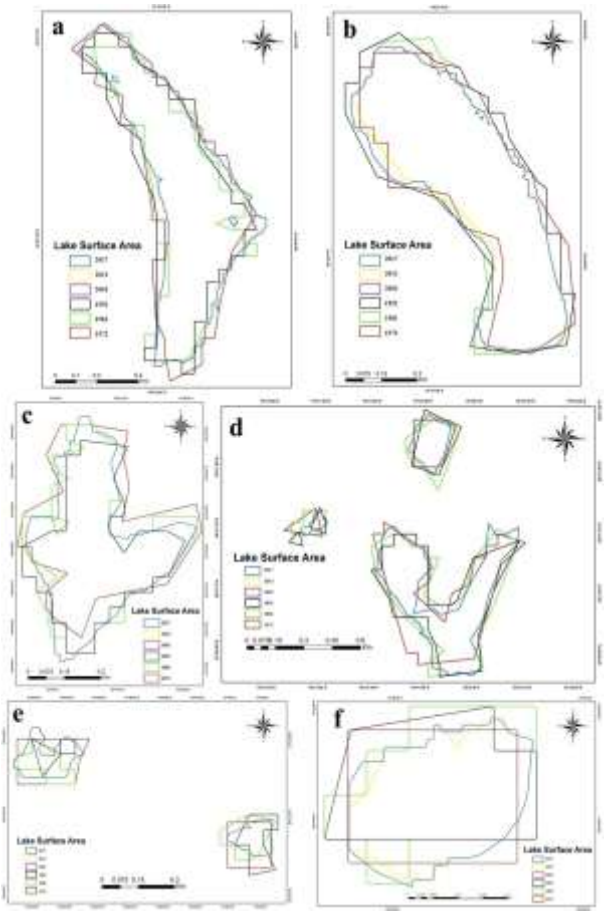

Figure 4: Pictorial representation of lake surface area changes from 1972 to 2017 in Kumaun lesser Himalayan lakes. a. Bhimtal, b. Nainital, c. Naukuchiatal, d. Sattal and panna lake, e. Harishtal and lohakham tal, f. Khurpatal.

DATA VALIDATION

Global surface water explorer dataset has been used for data validation purpose, this dataset is a virtual time machine which provides high resolution maps with location and distribution of global surface water over the last 3 decades. This study describes temporal changes along the Kumaun Himalayan lakes from 1984 to 2017. In this dataset 3 million multi temporal orthorectified Landsat 5, 7, 8 satellite images have been used to quantify global surface water with special and temporal variability for the last 31 years from 1984 to 2017 at 30m resolution. Surface water dynamics and high resolution seasonality map have been recorded from coarse-special resolution satellite observation and Landsat satellite imagery at 5 year to 10 year intervals and ultimately leads to map seasonality and changes at continental sub-continental region.

The Landsat data is classified as land, open water (fresh water and salty water) and non valid observations. The classification has been done by using 40,000 reference points, so very less probability of false water detection. The study found that lake of Kumaun Himalaya gradually shrinking.

DISCUSSION

The entire Nainital area is under the influence of the southwest monsoon, which generally arrives in month of the June and continues upto end of the September. 70–80 % of the total annual rainfall occurs during this period (Sneh, 2013). Precipitation in Nainital area is showing decreasing trend from 1992 to 2010 (Sneh, 2013). The rainfall pattern of the Nainital area is continuously showing a decrement confirmed by Local people of Nainital. It is observed that a significant reduction in recurrence percentage over the months June, July and August (Global surface water dataset), indicates great pressure in water demand in June, July and August respectively. The months from September to March showing more recurrence percentage indicates high water level over these months, so can be concluded that the main source of Kumaun Himalayan lake is snow water and surface runoff water. As in winter the Nainital and the surrounding area is covered by snow, all the Kumaun Himalayan lakes are fed by the snow water directly or indirectly**.**

CONCLUSION

The whole exercise concluded that of Kumaun Himalaya gradually shrinking. Shrinking lakes may results from many factors like high siltation, construction and encroachment in the catchment area, eutrophication of the lake water due to addition of solid waste, construction debris, comparative warming in Himalayan region and climate change, Over extraction and over dependent on lake water for drinking and irrigation purpose, sharp increase in human population, increase in anthropogenic pressure in the catchment area, Increase in tourist influx, Deforestation, lack of lake water management and long term planning.

REFERENCES

D. P. Roy, M. A. Wulder, T. R. Lovel and C. E. Woodcock, R. G. Allen, M. C. Anderson, D. Helder, J. R. Irons, D. M. Johnson, R. Kennedy, T. A. Scambos, C. B. Schaaf, J. R. Schott, Y. Sheng. E. F. Vermote, A. S. Belward, R. Bindschadler, W. B. Cohen, Z. Zhu. (2014), Remote Sensing of Environment, http://dx.doi.org/10.1016/j.rse.2014.02.001

Gupta Peeyush and Uniyal Swati, (2013), LHZ mapping of the area around Nainital using bivairiate statistical analysis, International Journal of Advanced Technology & Engineering Research (IJATER).

Haifeng Tian, Wang Li, Mingquan Wu, Ni Huang, Guodong Li, Xiang Li, and Zheng Niu, 2017, Dynamic Monitoring of the Largest Freshwater Lake in China Using a New Water Index Derived from High Spatiotemporal Resolution Sentinel-1A Data. Remote Sens. 2017, 9, pp. 521; doi:10.3390/rs9060521

Huang L, Liu JY, Shao QQ, Liu RG (2011) Changing inland lakes responding to climate warming in Northeastern Tibetan Plateau. Clim. Change 109: pp. 479– 502.

Lei YB, Yao TD, Bird BW, Yang K, Zhai J, et al. (2013) Coherent lake growth on the central Tibetan Plateau since the 1970s: Characterization and attribution. Journal of Hydrology 483: pp. 61–67.

Liao JJ, Shen GZ, Li YK (2013) Lake variations in response to climate change in the Tibetan Plateau in the past 40 years. International Journal of Digital Earth 6: pp. 534–549.

Ma, R.H.; Duan, H.T.; Hu, C.M.; Feng, X.Z.; Li, A.N.; Ju, W.M.; Jiang, J.H.; Yang, G.S. A half-century of changes in China's lakes: Global warming or human influence? *Geophys. Res. Lett.* 2010, *37*, pp. 6.

Nie Y, Liu Q, Liu S. Glacial lake expansion in the central Himalayas by landsat images, 1990–2010. PLoS ONE. 2013; 8(12): pp. e83973.

Sneh Joshi, Kireet Kumar, Varun Joshi, Bimal Pande (2013). Rainfall variability and indices of extreme rainfallanalysis and perception study for two stations over Central Himalaya, India. Natural Hazard, DOI: 10.1007/s11069-013-1012-4.

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