Impact of Land-use and Land-cover Change Dynamics on Flooding: A Case Study of Safilguda and RamakrishnaPuram Lake Watersheds of Hyderabad Metropolitan

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Abstract - *Rapid urbanization is a driving force in the transformation of the natural environment and the spatial layout of cities and towns. It has a negative impact on terrestrial ecosystem productivity and alters urban ecological security. Urbanization directly impacts the land-use land cover (LULC) change of an area, altering the ecological services and their functions. Natural water bodies like rivers, lakes, ponds, and wetlands are all part of the metropolitan landscape. And their importance grows as they carry out their most important environmental and socio-economic roles, including providing drinking water, functioning as sponges by recharging groundwater, maintaining biodiversity, and giving livelihoods. Because of urbanization pressure, various types of depressions and low-lying regions close to or around cities that were acting as cushions and flood absorbers are gradually filled up and built over. Water bodies are being encroached upon at several places and converted to built up to meet the growing populations' demands. LULC changes often determine the spatial dimensions of all of these ecological variables. Remote Sensing and geographical information systems are the best tools for understanding the changes over a period of time. Latest advancements in remote sensing technology and satellite data availability have made spatial analysis easier. The current study examines changes in the LULC of the Ramakrishnapuram and Safilguda Lake watersheds between 1997 and 2016. High-resolution satellite imagery Resourcesat LISS IV of 5.7m resolution was used to understand the change dynamics. The results demonstrate that the areas have seen significant conversions from vegetative areas to built-up areas. The change analysis shows how the rise in impervious surfaces has exacerbated flooding in certain places.*

Key Words: **LULC, Remote Sensing, GIS, Resourcesat, LISS IV**

1. INTRODUCTION

Land-cover refers to the dominating physical characteristics of the earth's surface for a given area at a specific point in time. It includes natural attributes such as type and distribution of vegetation, water bodies, soil cover etc, and man-made physical features such as settlements, agriculture fields, and modified vegetation covers. Land-use of a given area refers to how the land has been used by humans and their habitat, with an emphasis on the functional role of land for economic activities (Singh et al., 2015). In this way, a region's land-use and land-cover (LULC) pattern are the outcome of results from natural and prevailing socio-economic factors, as well as man's utilization of them over time and space (Rawat et al., 2013). Information on LULC is critical for selecting, planning, and implementing management methods to fulfill the growing demand for basic human requirements and the welfare of the world's population (Halmy et al., 2015). Proper information on LULC is required to implement multiple projects, planning, and land use plans to meet the ever-increasing demands for fundamental human necessities. Reliable and up-to-date information on LULC and their dynamics can assist in establishing a foundation for future decision-making in watershed management efforts (Rogan & Chen, 2004). Understanding land-use and land-cover changes (LULCC) are one of the focal areas in the fields of global climate change and global environmental change. LULCC is the most visible representation of human activity's influence on the natural ecosystem of the earth's land surface and a link between human social and economic activities and natural ecological processes (Mooney et al., 2013). Changes in LUCCs are linked to both human and environmental interactions (Liu et al., 2014). Anthropogenic actions drive LULC dynamics, which are extensive, rapid, and substantial processes that cause alterations that impact humans (Agarwal., 2002). For maintaining the sustainable development of natural resources and human habitats, it is strategically crucial to conduct long-term nationwide LULCC monitoring to detect spatial patterns of land-use changes (LUCs) and aid in formulating effective infrastructure management plans (Herrick et al., 2016).

Remote Sensing is useful in quickly evaluating and monitoring natural resources. Remote sensing and GIS integration allow the mapping of land-cover and changes in land-use, thus facilitating future planning, development, and decision-making, which is critical for fulfilling the increasing needs and welfare of an ever-growing population. (Aithal et al., 2017; Anand & Oinam, 2020; Erener & Düzgün, 2009). It is a dependable data source from which we can extract, evaluate and update LULC changes. Moreover, for successful land-use and water resource planning and management, extensive monitoring and modeling of the dynamics of urban sprawl and its implications on land-use patterns and hydrological processes within the watershed are necessary. As a result, the LULC change is recognized as an important measure for evaluating the efficacy of watershed management approaches (Rajesh, 2018).

Human activities have significantly altered the hydrological cycle through various water resource management modes and flow path changes. LULC changes are an important indication of such consequences and significantly influence hydrological processes, economics, and the ecology of watersheds. LULC changes and ecosystem vulnerability are key causes of global environmental change, with potentially severe consequences for human well-being and livelihoods (Umukiza et al., 2021). Rapid changes in LULC have resulted in extensive deterioration of terrestrial and aquatic ecosystems, influencing biological processes. The dynamics of LULC, comprising surface runoff, subsurface runoff, groundwater recharge, and other terrestrial fluxes, play an important role in the hydrological balance.

Flooding in cities is often caused by a complex set of factors primarily due to insufficient or poor land use planning. The natural forces affecting the urban environment are the same as those affecting the natural environment, and the presence of urban settlements exacerbates the situation. In cities and towns, very few open areas of land may be utilized for water storage. All precipitation and other flows must be removed as surface water or through drainage systems, which might be artificial and limited by competing demands on urban land. With expanding populations and strong demand for land, many metropolitan areas are experiencing the problem of increased urbanization. While there are laws in place and laws to regulate the development of new infrastructure, as well as the range of building types is frequently not enforced adequately due to economic or other considerations. This causes the obstruction in the natural flow path of water leading to flood (Jha et al., 2012). In many urban areas, flooding happens because the urban drainage systems are incapable of handling heavy rains.

The current study aims to comprehend the LULC changes in the study region and their impact on floods. The findings would allow for the development of appropriate mitigation strategies to mitigate the effects of floods.

2. Material and Methods

2.1 Study Area

The current study area lies between 17°27'28.805"N, 78°30'56.782"E and 17°29'45.006"N, 78°32'37.005"E. It includes sections of the Cantonment area and Malkajgiri circle of Greater Hyderabad Municipal Corporation (GHMC). It is the main residential neighborhood in GHMC's Malkajgiri circle. Neredmet, RamakrishnaPuram, and Safilguda are some of the residential areas. The study area includes watersheds of two large lakes, Ramakrishnapuram and Safilguda. This region covers an area of 772.34 hectares in total. All of the amenities of a suburban city are available, including medical, educational, retail, offices, and public transit. Military establishments occupy the major portion of the study area, and civilian trespassing is not allowed. It implies that the study area is more or less protected. The other portion of the study area has many residential colonies that have developed tremendously recently.

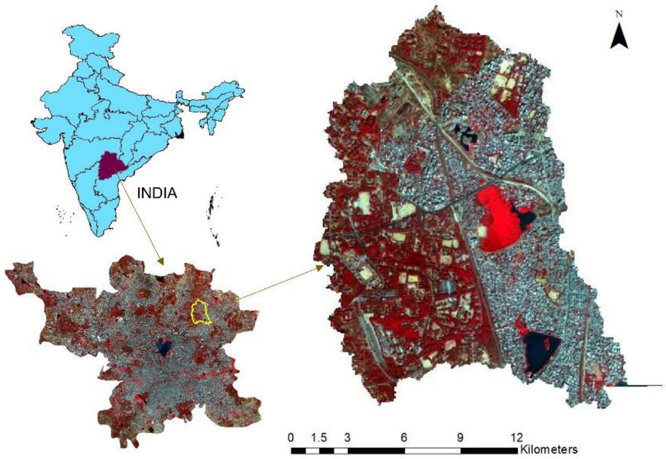

Fig.1. Location of Neredmet-Safilguda watersheds in Greater Hyderabad Metropolitan.

2.2 Data Sources and Methodology

For the current study, Satellite imagery procured from National Remote Sensing Centre (NRSC) IRS-1C PAN (panchromatic) image was used for 1997, and ResourceSAT LISS IV for 2008 and 2016. All the data procured were relatively cloud free and atmospheric-corrected.

2016, Resourcesat LISS IV satellite image was used for feature extraction using a semi-automatic feature extraction technique using the object and pixel-based hybrid feature extraction method on the ERDAS Imagine platform. The image was classified into six LULC classes and corrected by visual interpretation for misclassification errors. This vector layer generated was then overlaid on the previous images of 2008 and 1997 and classified. These LULC layers for 1997,2008, and 2016 were cross-verified using very high-resolution google earth imagery of the same dates.

LULC classification: For the LULC classification of the study area Indian Space Research 'Organization's Natural resource census LULC classification schema was referenced. The study area was classified into six categories; built-up-compact, built-up-mixed, built-up-sparse, vegetated open area, lakes, and shallow ponds.

Built-up area: Areas where the land cover is totally converted due to anthropogenic activities with concrete and are inhabited by people for residential and commercial purposes. Built-up area is categorized under three classes - Areas with less than 10% of vegetated areas are classified under the built-up compact. Areas with 11-40% of vegetated areas with mostly shrub-type vegetation are classified under built-up-sparse. Areas above 40% and below 60% of vegetated areas, mostly covered with large trees, are classified as built-up-mixed. These vegetated areas include all the parks, recreational areas, cemeteries, and the vegetation along the roads, usually trees with large canopies.

Vegetated open area: This class includes all areas covered with shrub-type and thorn-type vegetation cover.

Shallow ponds: These include non-perennial waterbodies filled during the monsoon period and usually dry in non-monsoon periods. These are usually small depressions for 10-20 feet in depth.

Lakes: These are perennial waterbodies filled with water throughout the year and are usually more than 30 feet deep.

3. RESULTS AND DISCUSSIONS

The present study's LULC change analysis reveals a significant decrease in vegetated areas. It has decreased in size from 134.59 ha in 1997 to 17.95 ha in 2016. Non-perennial waterbodies, which originally accounted for 15.20 ha in 1997, were also encroached upon for development. The results show that the number of residential communities created in 1997 was lower, with greater green space. Built-up has gradually expanded due to the migration of residents from nearby towns and rural regions. The present research area comprises cantonment areas that are occupied by military establishments and defense residences and are not eligible for civilian residential development. As a result, this region features a mixed built-up kind of land use, with buildings surrounded by large trees and lush vegetation covering around 60% of the area.

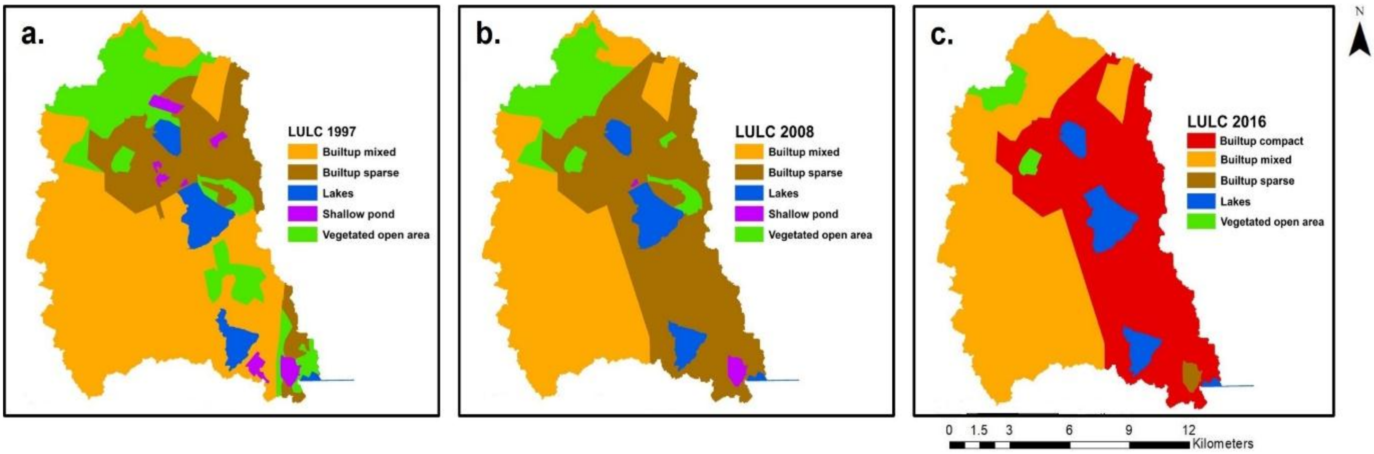

Fig. 2 LULC maps of the study area for the years 1997, 2008 and 2016

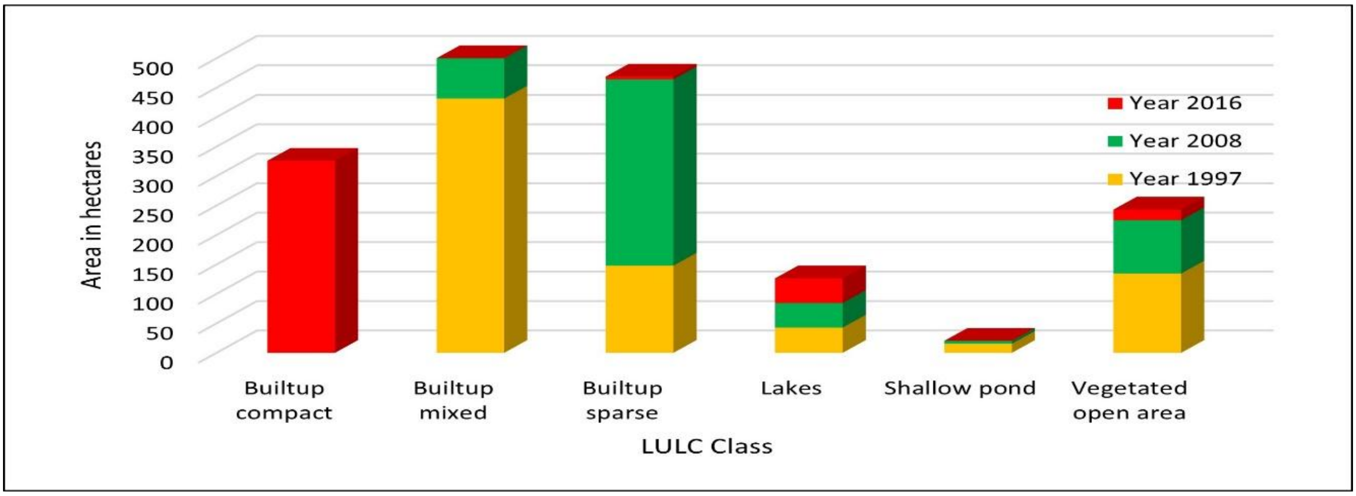

Fig. 3 Graph representing the area occupied by each LULC class during 1997, 2008, and 2016

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The Neredmet, RamakrishnaPuram, and Safilguda are the major residential localities included in the study regionThese places have all of the infrastructure advances of suburbs, as well as good educational institutions, are distant from city traffic, and are more peaceful and green. As a result many people have migrated to these localities and continue so even today. From 1997 to 2016, these places saw significant built-up class transformations. There was no built-up compact class in 1997, which grew dramatically only after 2008. In 2016, the built-up compact class accounted for 325.92 hectares in these locations and was continuously growing in a vertical direction to date. These residential neighborhoods are close to various government organizations like ECIL, NFC, South Central Railways, and others that are within a 6-8 km radius. The region is well connected to the railway station and has excellent bus service. This has encouraged more number of residents to add every year in these areas. All infrastructure projects in the study region have ignored the preservation of vegetation cover in favor of developing built-up areas to meet rising demand. This has finally resulted in the invasion of waterbodies (shown in fig. 4) and the narrowing of stormwater nalas. From the results, it is seen that by 2016 42% of the total area has converted to built up compact class. In 1997, there was no compact built up in the study region. Other major conversions are seen in the built up category itself where mixed and sparse buit up areas have converted to compact built up in 2016. Overall, there is a significant rise in impermeable surfaces in the study region.

Increases in impermeable surfaces increase surface runoff volumes, resulting in floods. The current research area contains two watersheds, each with a large lake into which water from all directions drains during the monsoons. The periphery of these two lakes has been encroached upon, and the shallow pond has been totally built over, limiting carrying capacity. Localized flooding in northern and eastern parts of Greater Hyderabad has become common lately. Several localities are flooded even for a small spell for short durations. Encroachments of non-perennial waterbodies and nalas have increased the surface runoff volumes during monsoons. The nalas, which should be more than 10 meters wide, have shrunk to two meters at several places in the study area, failing to carry away the storm waters. In Hyderabad, the built-up area has grown rapidly in the northeast direction, upstream of the Musi River. There are several high-rise buildings sprung up in these areas. The lack of a separate stormwater network in the city exacerbated the flood situation.

Table -1: Area statistics of each LULC class

LU Class	1997	2008	2016
Builtup compact	0.00	0.00	325.92
Builtup mixed	431.68	318.68	381.99
Builtup sparse	147.99	316.25	4.71
Lakes	42.87	41.76	41.76
Shallow pond	15.20	5.09	0.00
Vegetated open area	134.59	90.56	17.95
Grand Total	**772.34**	**772.34**	**772.34**

The increase in population has resulted in an increase in sewage volume. The sewage flow into the nalas, which is eventually discharged into the lakes, is not monitored. During the monsoons, the added load of sewage into stormwater nalas causes a localized flood-like impact in the area. Several routine constructional activities are reducing the vegetation cover. All the construction debris generated is illegally being dumped into the lakes, reducing their carrying capacity. Due to encroachment, shallow ponds have totally vanished in the area (shown in fig 5.). This water which can be captured in these lakes during monsoons, is overflowing on the roads and the streams, causing floods. All the excess runoff generated during the monsoons overflows onto the streets, causing floods in these localities. After 2016 almost all built-up class is completely impervious and prone to floods, even for low-intense spells. Several incidents are reported yearly that these localities of Safilguda and Neredmet face floods even with rainfall for small periods. From the current study, it is clear that the reduction in vegetation cover is the main cause of flooding in these areas. It requires a more scientific stormwater system design that is cost-effective and eco-friendly, like the green infrastructure to be constructed in these areas to reduce the effects of flooding.

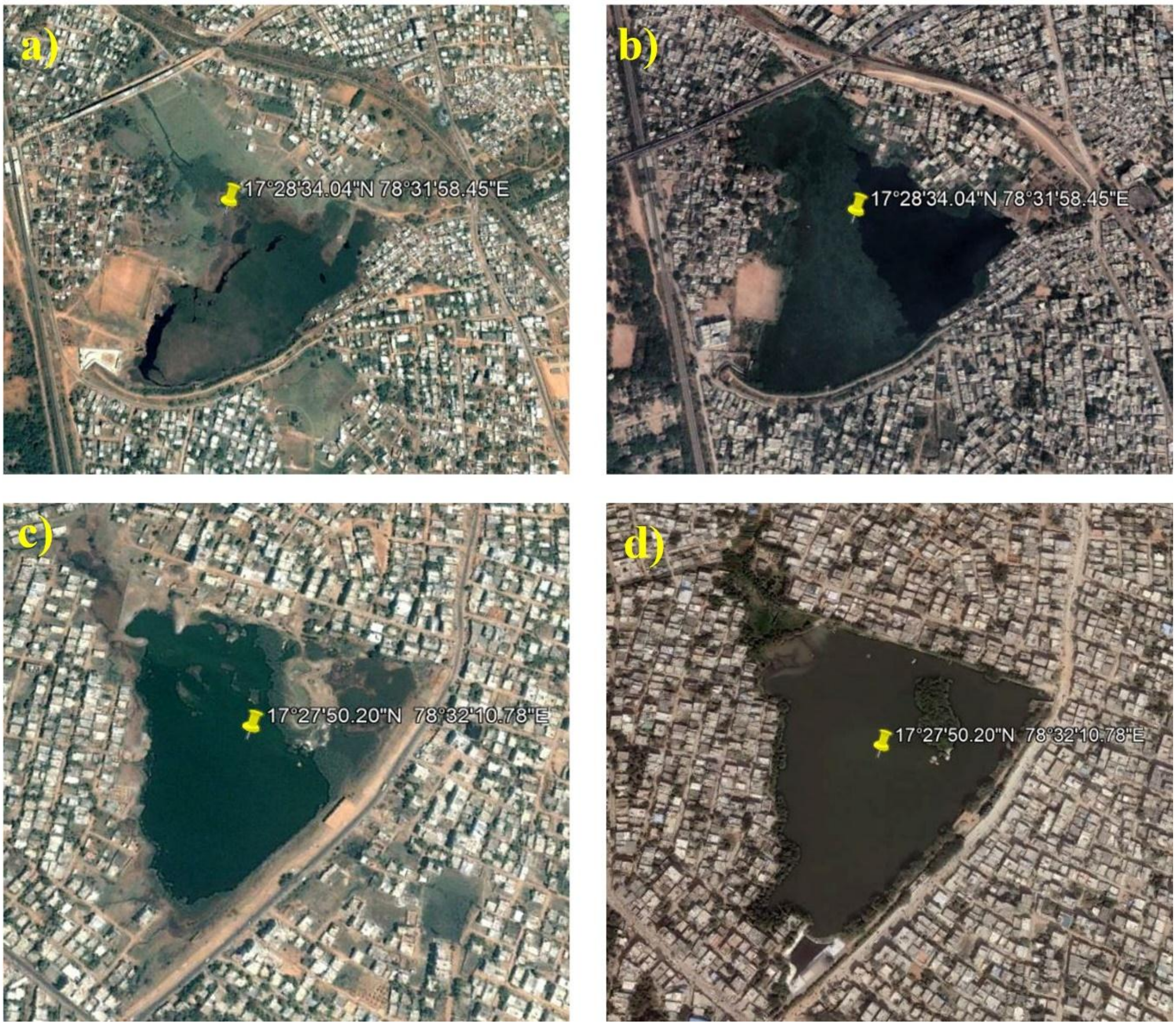

Fig.4. High-resolution Google Earth Imagery showing a & b Ramakrishnapuram and c & d Safilguda lake encroachments from a & c 2000 to b & d 2016.

Fig 5. High-resolution Google Earth Imagery showing shallow ponds totally converted to built-up areas from a) 2000 to b) 2016

4. CONCLUSIONS

According to the findings of the study, the conversion of vegetated open space to built-up space is extensive in the area. The area's infrastructure development has ignored the conservation of natural waterbodies and has not developed any structures for collecting stormwater or groundwater recharge systems. Population growth has resulted in the construction of multiple high-rise structures, where excess sewerage load is discharged into storm drains and lakes, diminishing carrying capacity. Construction waste is frequently dumped into waterbodies, eventually accumulating and reducing the storage capacity. Appropriate scientific methodologies are required for infrastructure design in order to preserve the natural landscape and control the intensity of floods.

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REFERENCES

[1] Agarwal Chetan, Green Glen M., Grove Morgan, Evans Tom P., S. C. (2002). Agriculture A Review and Assessment of Land-Use Change Models : Dynamics of Space, Time, and Human Choice Chetan Agarwal. July 2016.

[2] Aithal, B., Shivamurthy, V., & Ramachandra, T. (2017). Characterization and Visualization of Spatial Patterns of Urbanisation and Sprawl through Metrics and Modeling. Cities and the Environment, 10(1), 31.

[3] Anand, V., & Oinam, B. (2020). Future land use land cover prediction with special emphasis on urbanization and wetlands. Remote Sensing Letters, 11(3), 225–234. https://doi.org/10.1080/2150704X.2019.1704304

[4] Erener, A., & Düzgün, H. (2009). Prediction of Population in Urban Areas by Using High Resolution Satellite Images. Ocw.Metu.Edu.Tr. http://ocw.metu.edu.tr/pluginfile.php/3808/mod_resource/content/0/UA_CD/ek_kaynaklar/rast_population.pdf

[5] Halmy, M. W. A., Gessler, P. E., Hicke, J. A., & Salem, B. B. (2015). Land use/land cover change detection and prediction in the north-western coastal desert of Egypt using Markov-CA. Applied Geography, 63, 101–112. https://doi.org/10.1016/j.apgeog.2015.06.015

[6] Herrick, J. E., Beh, A., Barrios, E., Bouvier, I., Coetzee, M., Dent, D., & Elias, E. (2016). The Land- - Potential Knowledge System (LandPKS): mobile apps and collaboration for optimizing climate change investments. March. https://doi.org/10.1002/ehs2.1209

[7] Jha, A. K., Bloch, R., & Lamond, J. (2012). Cities and Flooding. In Cities and Flooding : A Guide to Integrated Urban Flood Risk Management for the 21st Century. World Bank. © World Bank (Vol. 8, Issue 1). The World Bank. https://doi.org/10.1596/978-0-8213-8866-2

[8] Liu, J., Kuang, W., Zhang, Z., Xu, X., Qin, Y., Ning, J., Zhou, W., Zhang, S., Li, R., Yan, C., Wu, S., Shi, X., Jiang, N., Yu, D., Pan, X., & Chi, W. (2014). Spatiotemporal characteristics, patterns, and causes of land-use changes in China since the late 1980s. Journal of Geographical Sciences, 24(2), 195–210. https://doi.org/10.1007/s11442-014-1082-6

[9] Mooney, H. A., Duraiappah, A., & Larigauderie, A. (2013). Evolution of natural and social science interactions in global change research programs. Proceedings of the National Academy of Sciences of the United States of America, 110(SUPPL. 1), 3665–3672. https://doi.org/10.1073/pnas.1107484110

[10] Rajesh, V. (2018). R j c e s. 6(October), 1–4.

[11] Rawat, J. S., Biswas, V., & Kumar, M. (2013). Changes in land use/cover using geospatial techniques : A case study of Ramnagar town area, district Nainital, Uttarakhand, India. The Egyptian Journal of Remote Sensing and Space Sciences, 16(1), 111–117. https://doi.org/10.1016/j.ejrs.2013.04.002

[12] Rogan, J., & Chen, D. (2004). Remote sensing technology for mapping and monitoring land-cover and land-use change. 61(July 2003), 301–325. https://doi.org/10.1016/S0305-9006(03)00066-7

[13] Singh, S. K., Mustak, S., Srivastava, P. K., Szabó, S., & Islam, T. (2015). Predicting Spatial and Decadal LULC Changes Through Cellular Automata Markov Chain Models Using Earth Observation Datasets and Geo-information. Environmental Processes, 2(1), 61–78. https://doi.org/10.1007/s40710-015-0062-x

[14] Umukiza, E., Raude, J. M., Wandera, S. M., & Petroselli, A. (2021). Impacts of Land Use and Land Cover Changes on PeakDischarge and Flow Volume in Kakia and Esamburmbur. i.