International Journal of Science and Research (IJSR)
ISSN: 2319-7064
Impact Factor 2024: 7.101

Spatiotemporal Changes in Forest and Settlement / Built-Up and Its Impact on the Environment: The Case of Kakching District

Dr. Naorem Sarita Devi[1], Chungkham Lalit Singh[2]

[1]Associate Professor, Department of Environmental Science, Dhanamanjuri University, Manipur, India
Email: *naoremsarita2013[at]gmail.com*

[2] Research Scholar, Department of Environmental Science, Dhanamanjuri University, Manipur, India
Email: *lalitchungkham555[at]gmail.com*

Abstract: ***The various human activities and process of rapid urbanisation has altered the landscape of an area or a region. It means that human beings have become the dominant agent for changing the landscape. Increased land cover/land use changes (LCLUC) can impact agricultural production efficiency including environmental impacts on urban, sub-urban, rural communities and natural areas. Human settlement / built-up increases the amount of impervious surfaces as a result of the building of roads and houses. This effect becomes an issue in the foothill, woodland. A detailed analysis of forest land covering and built-up area was conducted. This analysis provides insights into landscape-scale changes that have occurred as a result of human settlement. The significance of these changes for fire hazard, forest hydrology, and wildlife habitat are discussed. Forest is one of the key precious resources that support human well-being by providing ecosystem services. Unfortunately, the forest cover has decreased over time due to natural and anthropogenic factors. Forest cover has been declined in the study area for a variety of reasons, including fire wood collection, charcoal and timber extraction, semi-forest and settlements. Loss of forest cover can have significant implications for environmental sustainability, as forests have played an important role in ecosystem services, such as climate regulation, clean air, flood control, carbon sequestration, soil protection against soil erosion, and increased environmental resilience to the impacts of climate change. The present study aims to assess the spatiotemporal forest cover changes and built-up coverage and its implication on environmental sustainability. Low rates of economic growth indicate low adaptive capacities and therefore, high vulnerability to climate change and human induced pressures on ecosystems (Shukla et al., 2008; Lobell et al., 2008). LCLUC in the region is disrupting and perturbing biodiversity, regional climate, biogeochemical cycles, water resources and other ecosystem services (Turner and Annamalai, 2012; Madson, 2013). Understanding LCLUC requires addressing spatial scale issues, technological innovations, policy and institutional changes (IGBP, 2001).***

Keywords: Forest, Climate regulation, LCLUC, Built-up, Spatiotemporal

1. Introduction

Land cover refers to the physical and biological cover over the surface of land, including water, vegetation, bare soil, and/or artificial structures. Land use is a more complicated term. Natural scientists define *land use* in terms of syndromes of human activities such as agriculture, forestry and building construction that alter land surface processes including biogeochemistry, hydrology and biodiversity. Social scientists and land managers define *land use* more broadly to include the social and economic purposes and contexts for and within which lands are managed (or left unmanaged), such as subsistence versus commercial agriculture, rented vs. owned, or private vs. public land. While land cover may be observed directly in the field or by remote sensing, observations of land use and its changes generally require the integration of natural and social scientific methods (expert knowledge, interviews with land managers) to determine which human activities are occurring in different parts of the landscape, even when land cover appears to be the same

Changes in land cover continue to impact local- to global-scale weather and climate by altering the flow of energy, water, and greenhouse gases between the land and the atmosphere. Reforestation can foster localized cooling, while in urban areas, continued warming is expected to exacerbate urban heat island effects. Climate change affects land use and ecosystems. Climate change is expected to directly and indirectly impact land use and cover by altering disturbance patterns, species distributions, and the suitability of land for specific uses. The composition of the natural and human landscapes, and how society uses the land, affects the ability of the Nation's ecosystems to provide essential goods and services. The environmental issues and problems that humanity faces today can be attributed to the changes brought down to the landscapes around the world (Grimm et al. 2008). The anthropological and cultural forces in the form of land use/ cover change have tremendously altered the landscapes globally (Lambin and Geist 2008). The changes are so marked and profound that it is hard to find anywhere that is still untouched (Yang 2001; Nuwer 2016); therefore, it is being said that pristine landscapes are a myth (Denevan 1992). The ever-increasing population and subsequent demand for natural resources has resulted into transformation of landscapes at an immense scale (Tekle and Hedlund 2000; Musakwa and Wang (2018). The rate and intensity of such transformation are high especially in mountainous areas (Rao and Pant 2000); where land use/cover change and climatic variability have increased the landscape sensitivity thereby enhancing the ecosystem fragility (Pauchard et al. 2009). Landscapes are essentially the result of shared relationship between people and place (Hunziker et al. 2007). Understanding LCLUC requires addressing spatial scale issues, technological innovations, policy and institutional changes (IGBP, 2001).

Climate can affect and be affected by changes in land cover (the physical features that cover the land, such as trees or pavement) and land use (human management and activities on land, such as mining or recreation). A forest, for instance, would likely include tree cover but could also include areas of recent tree removals currently covered by open grass areas. Land cover and use are inherently coupled: changes in land-use practices can change land cover, and land cover enables specific land uses. Understanding how land cover, use, condition, and management vary in space and time is challenging, because while land cover and condition can be estimated using remote sensing techniques, land use and management typically require more local information, such as field inventories. Identifying, quantifying, and comparing estimates of land use and land cover are further complicated by factors such as consistency and the correct application of terminology and definitions, time, scale, data sources, and methods. While each approach may produce land-use or land-cover classifications, each method may provide different types of information at various scales, so choosing appropriate data sources and clearly defining what is being measured and reported are essential. Changes in land cover can occur in response to both human and climate drivers. For example, the demand for new settlements often results in the permanent loss of natural and working lands, which can result in localized changes in weather patterns, temperature and precipitation. Technological innovation has also influenced land-use change, with the expansion of cultivated lands from the development of irrigation technologies and, more recently, decreases in demand for agricultural land due to increases in crop productivity.

2. Study Site

Kakching District is situated in the state of Manipur which lies in the Eastern periphery of the Himalayan region, and in the North-Eastern part of the Indian sub-continent. The study area is situated between 24°13'19.092" to 24°33'36.125" North latitudes and 94°5'37.553" to 93°48'5.899" East longitudes with a total geographical area of 28,388 hectares. The elevation of the study area ranges from 753 to 951 meter above sea level. A major river called Sengmai river is flowing in the periphery of the district and is providing the irrigation facilities in the agricultural fields as well as in various household purposes.

The study area experienced a long rainy season, occurring from June to September, with moderate rains in autumn (October and November) and spring (March to May). The study area received annual precipitation of 205 mm. The temperature of the study area varied between 9°C and 33°C, with the average temperature of 19°C to 23◦C.

Objective

The present study aims to fulfill the following two objectives:
1) To examine the trend of spatio-temporal changes in relation with forest cover.
2) To study the changes in relation with the settlement/built-up in the district.

3. Materials and Methodology

Data type and sources:

Satellite Image Acquisition and Processing:

The digital images of IRS- LISS-IV were downloaded during the dry season (January to March) and have been used to prepare the land-use map of the study area, which is obtained from the Indian Institute of Remote Sensing (IIRS), Dehradun, under the Indian Space Research organization (ISRO). In this study, LISS-IV of 2019 and 2024 respectively with a spatial resolution of 5.8 meters which provides detailed in-depth information. The seasonal consideration has been taken into account while selecting the satellite images for better visibility and atmospheric clarity. In addition to the satellite images, some secondary data have also been used in the form of topographical sheets (1:50,000) and digital elevation model (DEM). Multiple field visits were also undertaken between 2019 and 2024where different villages of the district were visited which not only helped in knowing the present status of the land cover land use changes but the drivers of the land cover land use changes during the same period. The field visits included in-depth interviews such as focus group discussion (FGD), house hold surveys (HHS) and key informants interviews (KII) thus providing a glimpse about the nature of the past human-environment relations and forces responsible for changes in the spatiotemporal changes in this particular study area. Additionally, an accuracy assessment was conducted using ground truth GPS data to ensure the validation of the results before proceeding with image comparisons. Finally, images of 2019 and 2024 are classified into forestland and built-up/ settlement cover classes. Geographic Information System (GIS) and Image Processing techniques have been used for analyzing and mapping of the land cover land use changes (LCLUC) and other techniques are used in the study.

Table 1: Details of satellite data used in the study:

Satellite	Sensor	Year of acquisition	No. of spectral bands	Range of spectral wavelength (μm)	Spatial resolution (m)	Source
IRS	LISS-IV	20/03/2019	4	0.52-0.59 0.62-0.68 0.77-0.86 1.55-1.70	5.8	IIRS (ISRO)
IRS	LISS-IV	16/03/2024	4	0.52-0.59 0.62-0.68 0.77-0.86 1.55-1.70	5.8	

Source: Prepared by Authors using data from LISS-IV, IRS-Satellite.

Location of Study Area:

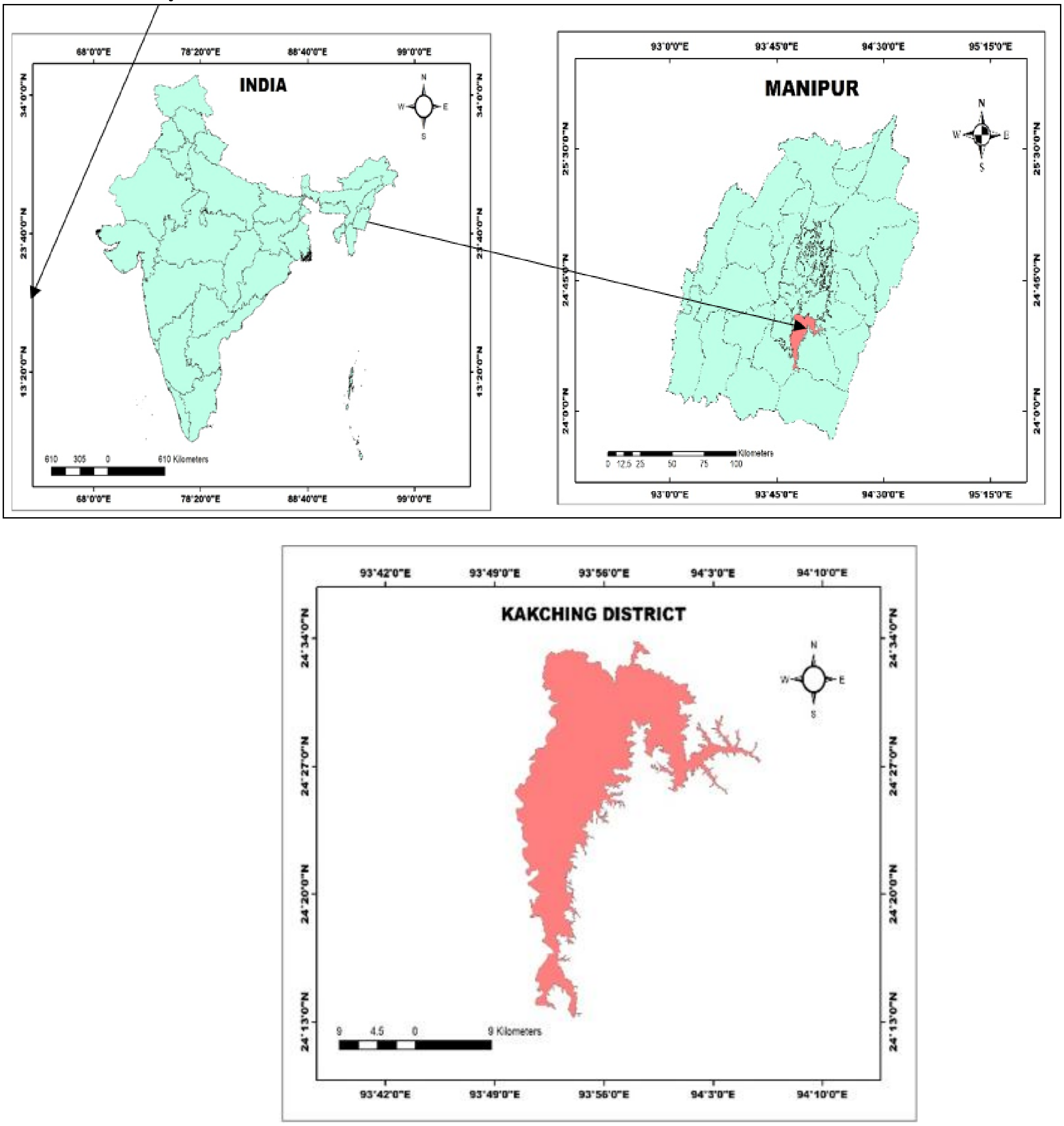

Figure 1: Map of the study area- Kakching district

Land Cover Land Use Changes (LCLUC):

Table 2: Land cover land use change pattern in 2019

LULC Types	2019 Area in hectares (ha)	2019 Area in %
Built-up/ Settlement	2655	9.4 %
Forest	1953	6.9 %
Total area coverage	**4608 ha**	**16.3 %**

Source: Prepared by Authors using data from LISS-IV, IRS-Satellite.

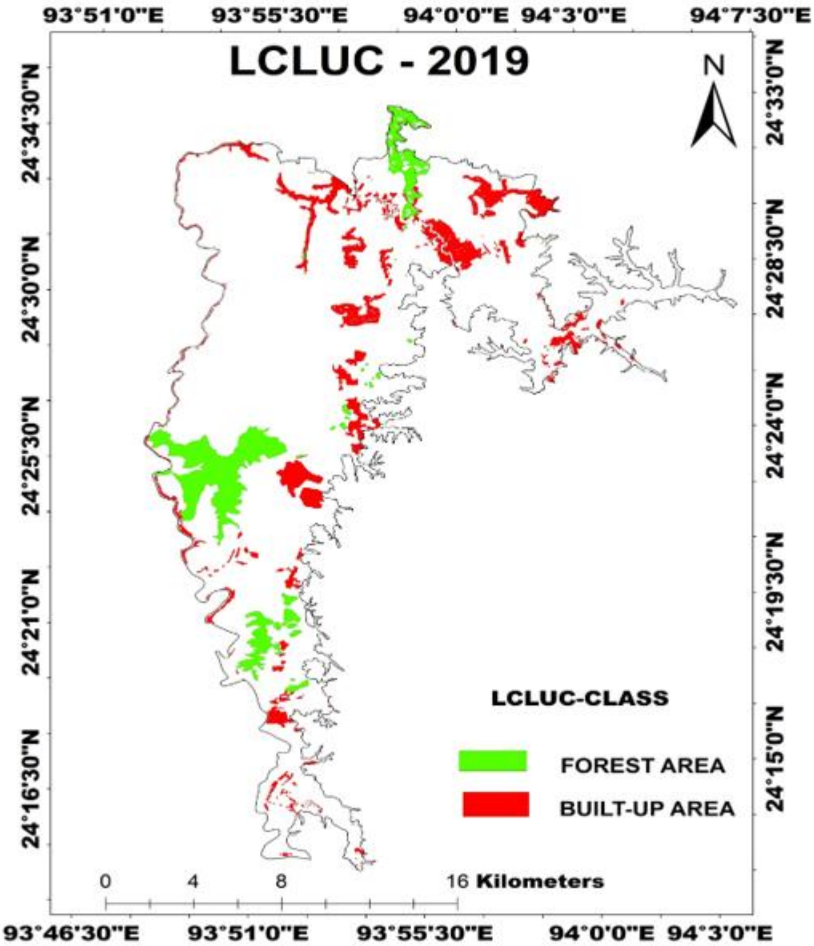

Figure 2: Land cover land use change map of the Kakching district in 2019

Table 3: Land cover land use change pattern in 2024

LULC Types	2024 Area in hectares (ha)	2024 Area in %
Built-up/ Settlement	2345.31	8.3 %
Forest	2481.9	8.8 %
Total coverage area	4827.21	17.1 %

Source: Prepared by Authors using data from LISS-IV, IRS-Satellite.

Paper ID: SR25528155229 DOI: https://dx.doi.org/10.21275/SR25528155229

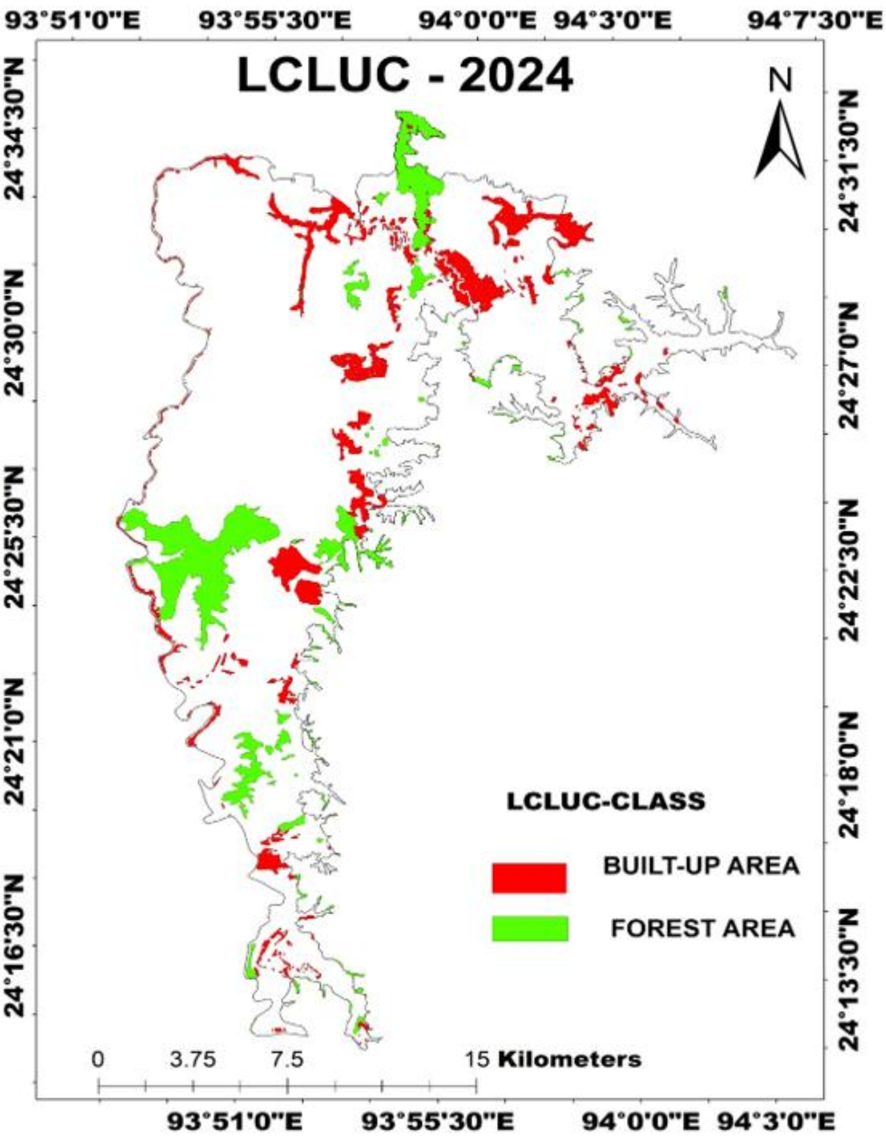

Figure 3: Land cover land use change map of the Kakching district in 2024

4. Results and Discussion

The present studies regarding to the spatiotemporal changes and land cover land use change have received a great impetus owing to advancement in spatial technology and more understanding of human environment interactions. The study area has witnessed increasing in the forest cover area including open forest and closed forest. The built-up / settlement area are seen decreasing in the district. These results are corresponding to the findings of the study.

Land cover land use change pattern in 2019:
The land cover land use change (LCLUC) map of 2019 is drawn from LISS-IV satellite image of spatial resolution 5.8 meter and was divided into two major classes (Table no.2 and Fig. no. 2). The total area of the study site is 28,388 hectares. In the present study, the spatiotemporal changes in the built-up/ settlement and forest land area are studied through remote sensing and GIS techniques. The built-up/ settlement covers an area of 2,655 hectares.

The built-up areas are of compact and sparse type of distribution. The compact type of settlements distribution are seen in the central part of the district, mainly in the Kakching sub-division including houses, markets, government offices, brick farms etc. In the northern part of the district, the built-up / settlements are compact along the sides of the Sengmai river. Out of the total land area, 9.4 % of the land are covered by the built-up/ settlement. The area is supported by the natural wetlands, rivers and lakes etc.

Out of the total land area, the forest covers an area of 1,953 hectares. The forest type includes the open forest, closed forest, scrub vegetation, evergreen and semi ever green forest etc. covering 6.9 % of the total area of the study site. The open forest type are found near the natural wetlands such as Pumlen Pat (Pat means Lake) and Khoidum Pat. The trees and vegetations are grown on the small hills and its surroundings.

Both the built-up / settlements and forest land cover an area of 4,608 hectares covering 16.3 % of the total land area of the district. The area covering by the built-up / settlements is higher than the forest land of about 702 hectares.

Land cover land use change pattern in 2024:
The spatiotemporal changes or land cover land use change (LCLUC) map of the year 2024 (Table no.3 and Fig.no.3)

with LISS-IV of spatial resolution 5.8 meter and two major categories are divided into built-up/ settlement and forest class. The map shows that built-up / settlement covers an area of 2,345.31 hectares, covering 8.3 % and the forest covers 2,481.9 hectares, covering 8.8 % of the total land area in the district respectively.

In the year 2024, the total covering area both by the built –up/ settlement and forest is 4827.21 hectares, with 17.1 % of the total land area. The area covering by built –up/ settlement is lower than that of the forest land of about 136.59 hectares.

Table 4: Land cover land use change pattern in 2019-2024

LULC Types	2019 Area in hectare (ha)	2024 Area in hectare (ha)	2019 to 2024 Change in hectare (ha)	2019 to 2024 Change in %	Remark
Built-up/ Settlement	2655	2345.31	-309.69	-1.1 %	Area decreased
Forest	1953	2481.9	+528.9	+1.9 %	Area increased
Total area coverage =	4608	4827.21	+219.21		Increase in area coverage

Source: Prepared by Authors using data from LISS-IV, IRS-Satellite.

The spatiotemporal changes for the period of 2019 to 2024 have been prepared, analyzed and discussed on order to provide depth-insights in to periodic/ temporal changes of the different LCLUC classes identified in the area mainly into two class such as built –up/ settlement and forest. The map showing LCLUC for the period between 2019 and 2024 have been used (Table no.4) and subsequent change detection analysis has been performed to get a comprehensive picture over all changes from the period 2019 to 2024 under tow major identified LCLUC classes. The period from 2019 to 2024 is marked by decrease in built –up/ settlement and increase in the forest coverage area. During the period 2019 to 2024, the area loss is experienced by built –up/ settlement which is reduced by 309.69 hectares of land (1.1 %) from 2019.

The change detection analysis from the map of LCLUC of the period 2019 to 2024 shows that a slight increasing is seen in the forest land which has shown an increasing area of 528.9 hectares with 1.9 % increase from that of 2019. Further analysis or the period 2019 to 2024 has shown the forest cover as the dominant class among the two major identified LCLUC classes. The total area coverage increased by 219.21 hectares from 2019 to 2024. The above data (Table no.4.) provides a clear comparison of land use changes over the specified period and highlights the trends in land cover changes.

The decrease in built-up or settlement areas might reflect efforts toward sustainable urban planning. In regions like Kakching, reducing excess urban sprawl can alleviate the urban heat island effect—a phenomenon where built-up areas become significantly warmer than their rural surroundings. This can improve local microclimates and reduce energy demands for cooling, indirectly mitigating climate change impacts.

The data reflects a significant shift in land use patterns, with a decrease in settlement area and an increase in forest area. These trends are consistent with global efforts to promote sustainable development, reforestation, and urban planning. Future research could explore the drivers behind these changes, such as policy interventions, economic factors, and environmental conservation efforts, to better understand their implications for land use management and climate change mitigation. The decrease in settlement area could be attributed to urban planning policies promoting densification, land restoration initiatives, climate adaptation strategies, demographic shifts and migration patterns etc. This pattern contrasts with historical urbanization trends and suggests a potential shift toward more sustainable land use management.

An increase in forest areas can enhance carbon sequestration, which is vital for mitigating climate change. In Kakching, where local climate patterns may be shifting due to global warming, enhancing forest cover could serve as a natural buffer against rising atmospheric carbon dioxide levels. This supports regional efforts to manage greenhouse gas emissions while preserving natural resources.

Forests also play a critical role in maintaining the water cycle. Increased forest cover can improve rainfall distribution and reduce runoff, which is particularly important in regions like Kakching that may experience irregular rainfall patterns or more intense monsoon events due to climate change.

An increase in natural forest cover generally benefits biodiversity. In Kakching district, where biodiversity is an important natural resource, a richer forest ecosystem enhances resilience against climate extremes—thus sustaining agricultural productivity and local livelihoods. Healthy ecosystems can also better adapt and recover from the stresses imposed by changing climatic conditions.

The shifts in LCLUC reflect broader trends that might be adopted as part of adaptive strategies to climate change. For instance, if the community in Kakching district is making concerted efforts to reforest or manage lands more sustainably, this can contribute to long-term climate resilience and improved environmental health.

5. Conclusion

Geographical Information System (GIS) and Remote Sensing have been used to derive accurate information on the spatial distribution of land use/land cover changes over large areas from Past to present studies conducted by organizations and institutions around the world. The present study of the spatiotemporal changes and the data provided for land cover land use change (LCLUC) changes particularly the reduction in built-up areas and the increase in forested areas—can be related to climate change impacts and adaptation strategies in regions like Kakching district, Manipur. In short, while the provided LCLUC data is from a broader perspective, its observed trends can be directly relevant to regions like Kakching in Manipur. The patterns of increased forest cover support crucial climate change mitigation strategies, while the reduction in built-up areas may indicate a move toward more sustainable urban practices, all contributing to a more resilient local ecosystem in the face of a changing climate.

6. Recommendation

The collected data from the present study of the spatiotemporal change of the Kakching district such as the decrease in built-up areas and the increase in forests provide valuable feedback to policymakers. Land management policies crafted for Kakching district can use these trends to increase climate adaptation measures. This might involve incentivizing afforestation, promoting green infrastructure in urban areas, and enforcing regulations that protect existing forests.

References:

[1] Abera, W., Tamene, L., Kassawmar, T., Mulatu, K., Kassa, H., Verchot, L., Quintero, M., 2021. Impacts of land use and land cover dynamics on ecosystem services in the Yayo coffee forest reserve, southwestern Ethiopia. Ecosyst. Serv. 50, 101338

[2] Appiah, J.O., Agyemang-Duah, W., Sobeng, A.K., Kpienbaareh, D., 2021. Analyzing patterns of forest cover change and related land uses in the Tano-Offin forest reserve in Ghana: implication for forest policy and land management. Trees For. People 5, 100105.

[3] Arvind C. Pandy and M. S. Nathawat. 2006. Land Use Land Cover Mapping Through Digital Image Processing of Satellite Data – A case study from Panchkula, Ambala and Yamunanagar Districts, Haryana State, India.

[4] Brown, H.C.A., Berninger, F.A., Larjavaara, M., Appiah, M., 2020. Above-ground carbon stocks and timber value of old timber plantations, secondary and primary forests in southern Ghana. For. Ecol. Manag. 472, 118236

[5] Bhagawatrimal. 2011. Application of remote sensing and GIS on land use/land cover change in Kathmandu metropolitan city, Nepal. Journal of Theoretical and applied information Technology. 23(2): 80.

[6] Bhaduri B, Harbor J, Engel B. and Grove M. 2000. Assessing watershed-scale, long-term hydrologic impacts of land-use change using a GIS-NPS model. Environmental Management. 26(6): 643-658.

[7] Dhyani, S., Singh, A., Gujre, N., Joshi, R.K., 2021. Quantifying tree carbon stock in historically conserved Seminary Hills urban forest of Nagpur, India. Acta Ecol. Sin. 14 (3), 193–203.

[8] Calama, R., de-Dios-Garcia, J., del Rio, M., Madrigal, G., Gordo, J., Pardos, M., 2021. Mixture mitigates the effect of climate change on the provision of relevant ecosystem services in managed Pinus pinea L. forests. For. Ecol. Manag. 481.

[9] Clark, B., Suomalainen, J. &Pellika, P. (2010). A comparison of methods for the retrieval of surface reflectance factor from multitemporal SPOT HRV, HRVIR, an HRG multispectral satellite imagery. Canadian Journal of Remote Sensing, 36: 397–411.

[10] Cotton, W.R. and R.A. Pielke Sr. 2007: Human Impacts on Weather and Climate, 2nd ed. Cambridge University Press, Cambridge; New York. 308.

[11] Irfan M, Negi V and Vatsal A. 2023. Land Change in Tirthan Valley: The Case of Great Himalayan National Park Conservation Area. Journal of Human Ecology. 83(1-3):1-16

[12] Negi V and Irfan M. 2022. Land use/cover mapping and change detection using remote sensing techniques: A case of Upper Kullu Valley, Himachal Pradesh. Current World Environment, 17(2): 417-426.

[13] Negi V, Chandel VBS and Brar K. 2022. Landscape change analysis of Upper Beas Valley, India using Corona and PlanetScope Imageries. Punjab Geographers. 18: 8- 30.

[14] Prakasam C. 2010. Land use and land cover change detection through Remote Sensing approach: A case study of Kodaikanal taluk, Tamilnadu. Department of Geography. The University of Burdwan. International Journal of Geomatics and Geosciences. 1(2): 150-158

[15] Pengfeng Xiao. 2006. A Land Use/ Cover Classification System Based on Medium Resolution Remote Sensing Data [J]. China Land Science. 20(2): 33-38.

[16] Sleeter, B.M., T. Loveland, G. Domke, N. Herold, J. Wickham, and N. Wood. 2018. Land Cover and Land-Use Change. In Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II.

[17] Vishwa CB, Kaur BK and Simrit K 2013. Land use/cover change and its implications for Kullu district of Himachal Pradesh, India. International Journal of Geomatics and Geoscience, 3(3): 538-551.

[18] Xiaomei Y and Ronqing L.Q.Y. (1999). Change Detection Based on Remote Sensing Information Model and its Application to Coastal Line of Yellow River Delta – Earth Observation Center, NASDA, China.