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Monitoring Land Use and Land Cover Changes in Northeast India: A Case Study of Zunheboto District, Nagaland (1991–2021)

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Abstract

This study investigates the spatiotemporal dynamics of Land Use and Land Cover (LULC) in Zunheboto District, Nagaland, over a 30-year period (1991–2021) using remote sensing and GIS-based techniques. Landsat TM (1991) and Landsat 8 (2021) imagery were processed to generate False Color Composites (FCC) and classify six LULC categories: dense vegetation, low vegetation, agricultural land, built-up areas, barren land, and water bodies. Classification was performed using the LANDSAT-I classification system, and area statistics were computed using GIS-based geometry calculations. The results reveal a significant reduction in dense vegetation cover (-29.64%) and water bodies (-34.81%), while agricultural land, built-up areas, and barren land increased by 85.07%, 1046.17%, and 103.71% respectively. The findings highlight the intensifying anthropogenic pressures on natural landscapes, driven by settlement expansion and shifting cultivation practices. The study emphasizes the critical need for integrated land management strategies and sustainable development policies to ensure ecological stability in the region.

Keywords: land use, land cover, LANDSAT, change detection

Introduction

Land Use and land Cover (LULC) changes represent a significant environmental concern, particularly in ecologically sensitive and resource dependent region like Zunheboto district of Nagaland. Globally, LULC transformations have affected nearly one-third of the earth's land surface in just six decades between 1960 and 2019, primarily due to anthropogenic pressures and natural processes (Winkler et al., 2021). These changes are considered one of the most critical drivers of environmental degradation, biodiversity loss, soil erosion, and shifts in hydrological regimes (Lambin et al., 2003; Verburg et al., 2000). LULC change is not merely a biophysical process but also a socio-economic phenomenon influenced by demographic growth, and economic development (Setegn et al., 2009; Yalew et al., 2016). In many developing regions, including Northeast India, these changes occur in the absence of systematic land management and planning frameworks, leading to environmental stress in fragile ecosystems (Rahman et l., 2012; Chen et al., 2019).

In India, rapid urbanization, agricultural expansion, and infrastructure development have led to the widespread land transformation, especially in hilly and tribal-dominated states like Nagaland. Although Nagaland remains largely rural, population growth, infrastructural activities, and shifting cultivation practices (Jhum) have triggered significant alterations in LULC patterns, affecting both ecological balance

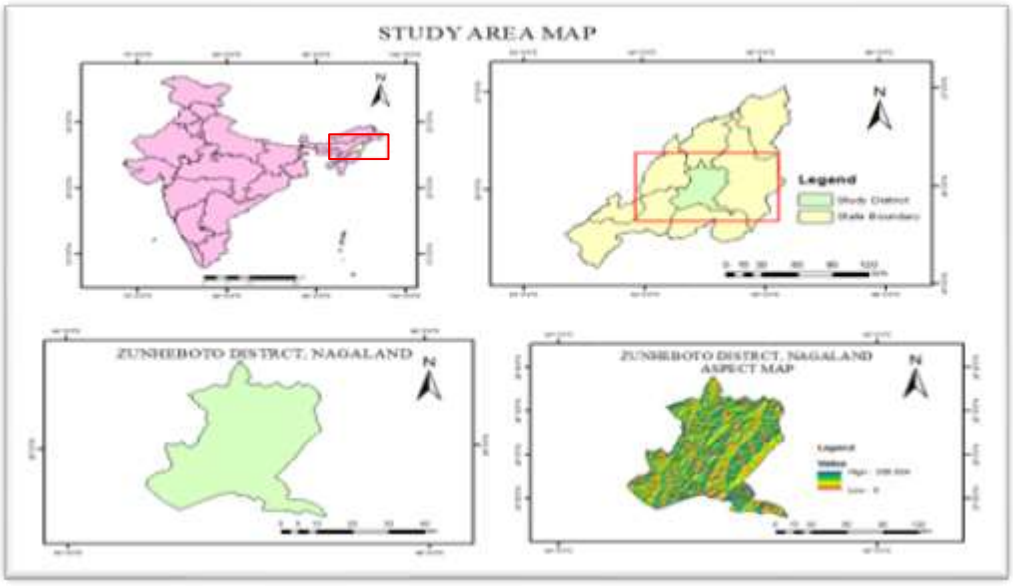
and sustainable development. Zunheboto, a district predominantly dominated by the Sumi Naga tribe, reflects these broader regional dynamics. The district's terrain, marked by rugged hills and forested landscapes, is increasingly subjected to land cover changes due to deforestation, cultivation pressure, and settlement expansion.

The dynamic relationship between land use and land cover is especially pronounced in regions undergoing socio-economic transition. In Zunheboto district, traditional land-use practices are now interfacing with modern development pressures, making it imperative to understand the pattern and drivers of LULC change for effective resource planning and policy formulations. Remote Sensing (RS) and Geographical Information System (GIS) have emerged as valuable tools in monitoring and analyzing LULC changes at spatial and temporal scales (Herold et al., 2003; Yuan et al., 2005). By employing the technologies, the present study aims to evaluate the present status and temporal changes in LULC of Zunheboto district, providing a basic understanding necessary for sustainable land and environment management.

Materials and Method

Study Area: Zunheboto is a district located in Nagaland, nestled in the rugged terrain of the Naga Hills, which form part of the Eastern Himalayan ranges. These ranges traverse the northeastern region of India and extend through states such as Nagaland, Manipur, and Mizoram, gradually descending towards the Bay of Bengal. The landscape of Zunheboto is predominantly hilly, with mountain ranges generally oriented from southwest to northeast, although some ranges also extend in other directions, contributing to the region's complex topography. Zunheboto district lies approximately between 94˚ 10' E to 94˚ 70' E Longitude and 25˚ 50' **N** to 26˚ 10' N Latitude, covering an area of around 1,255 sq km. It is bordered by Mokokchung and Tuensang districts to the north, Phek to the south, Kiphire to the southeast, and **Wokha** to the west. The district is drained by several rivers and streams, notably the Doyang, Tsutha, and Tizu rivers, which support both the ecology and the livelihoods of local communities. The altitude of Zunheboto ranges from approximately 500 to 1,800 meters above mean sea level. The terrain is marked by steep hills, deep gorges, narrow valleys, and a few small plateaus. The district experiences a moderate to subtropical climate, with high rainfall during the monsoon season and cooler temperatures in the winter.

Figure 1: Study area map



Methods:

The study employed geospatial techniques to analyze the Land Use/Land Cover (LULC) dynamics of Zunheboto District, Nagaland for the years 1991 and 2021. The methodology involved satellite image processing, classification of land use categories based on the LANDSAT-I classification system, and quantification of changes using GIS tools. Landsat Thematic Mapper (TM) satellite imagery for the year 1991 and Landsat 8 imagery for the year 2021 were downloaded from the USGS Earth Explorer platform. A False Color Composite (FCC) of each satellite image was created using bands 4 (Near Infrared), 3 (Red), and 2 (Green), which enhances the visual discrimination of vegetation, built-up areas, and water bodies. Change detection was performed by comparing the LULC layers of 1991 and 2021. Spatial overlay analysis and statistical comparison were conducted to determine the gain and loss in each LULC class over the 30-year period. Percentage changes and absolute differences in area were calculated to identify the magnitude and direction of land transformation. The classification and analysis revealed significant LULC changes, including a decline in dense forest cover and a sharp increase in agricultural and built-up areas. These results highlight the ongoing anthropogenic pressure and landscape transformation in the district.

Results and discussion

For the study purpose six different LULC types has been classified namely agricultural land, dense vegetation, low vegetation, built-up, barren land, and water bodies.

Table 1: Classification of LULC classes

LULC class	*Class classification*
Agricultural land	Includes plantation, jhum field area
Dense vegetation	Reserved forest, conserved forest, semi evergreen and deciduous forest
Low vegetation	Sparse area, ground cover %, scrub forest
Built-up	Rural-urban infrastructure, settlement etc
Water bodies	River, pond, wetland, fisheries etc.
Barren land	Fallow land, extremely low vegetation cover

LULC analysis – 1991

The land use and land cover status of Zunheboto district in the year 1991 was dominated by forest cover, with more than 80% of the total geographical area under forest cover. The area under forest cover is classified into dense vegetation cover and low vegetation cover areas. Dense vegetation cover accounts for 74.74% of the total geographical area, which is 1181.71 km². Low vegetation cover area covers 12% of the total area (189.59 km²). Agricultural land use covers 176.91 km², which accounts for 11.20 percent of the total geographical area. Water bodies, built-up areas, and barren land cover 28.21 km², 8.10 km², and 9.68 km², respectively, which collectively account for 2.26% of the total geographical area of the study area.

LULC analysis – 2021

The land use and land cover analysis of 2021 also indicate that the area under forest cover dominates the study area. Dense vegetation covers an area of 831.39 km², which is 52.61% of the total geographical area.

In contrast, low vegetation covers account for 20.34% of the total geographical area, which is equivalent to 321.49 km². Agricultural land use has drastically increased in terms of area. The total area under agricultural land was 327.42 km² in 2021 (20.72%). The area under built-up has significantly increased to 92.84 km² in 2021, which shares a total geographical area of 5.87%. The area under water bodies during the study period was 18.39 km2 and 19.72 km2 for barren land, respectively. The LULC classes have shown a significant change in all the classes in comparison to the 1991 analysis.

LULC dynamic 1991-2021

The LULC analysis of Zunheboto district for the years 1991 and 2021 shows a drastic change in the land use pattern. Forest cover has declined in its area from 1991 to 2021. The area under dense vegetation cover has declined from 1181.71 km² in 1991 to 831.39 km² in 2021, which shows a decline of -29.64% in the total area. On the contrary, low vegetation cover has increased in its total area by 69.57%. IIn 1991, low vegetation cover occupied an area of 189.57 km², which increased to 321.49 km² by 2021. Built-up areas witness the most significant change. The land use under built-up increased by a margin of 1046.17% between 1991 and 2021, which shows an absolute growth of 84.74 km². Land use under agricultural area also reports a growth in its area. It increases from 176.91 km² in 1991 to 327.92 km² in 2021, which shows a growth of 85.07% in the total area. Barren land has also seen an increase in the total area. The area under barren land was 9.68 km² in 1991 and 19.71 km² in 2021, which was a total growth of 10.04 km² (103.71%) during the two study periods. The land cover under water bodies shows a decline in area of -34.82% in the total area between 1991 and 2021. In the year 1991, the area under water bodies was 28.21 km², which declined to 18.39 km² by 2021.

Change detection analysis

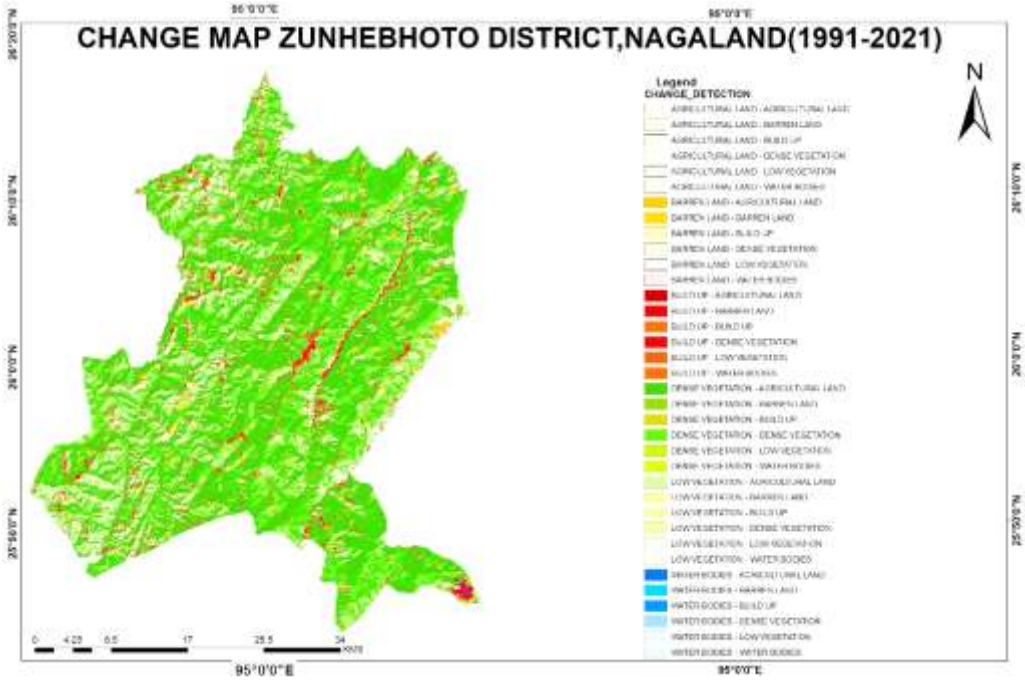
Table 2: Change detection 1991 - 2021

LULC class	1991	2021	Change in %
Dense vegetation	1181.71	831.39	-29.64
Low vegetation	189.59	321.49	69.57
Agricultural land	176.91	327.42	85.07
Built-up	8.10	92.84	1046.17
Barren land	9.68	19.72	103.71
Water bodies	28.21	18.39	-34.81

The change detection shows conversions in LULC classes during the study period. The land area under dense vegetation has converted to agricultural land by 202.56 km², barren land by 11.44 km², built-up land by 54.83 km², low vegetation by 197.70 km², and water bodies by 0.06 km². The land area classified as low vegetation has undergone changes in its size. Area under low vegetation has converted to agricultural land by 48.89 km², barren land by 22.07 km², dense vegetation by 29.48 km², and water bodies by 0.13 km². Agricultural land use is converted to barren land by 0.91 km², built-up land by 8.43 km², dense vegetation by 79.19 km², low vegetation by 17.35 km², and water bodies by 1.13 km². The conversion from built-up areas to other LULC classes is comparatively low as compared to other LULC classes. Built-up area alteration to dense vegetation, low vegetation, and water bodies was 0.13 km², 1.23 km², and 0.04 km², respectively. The transformation from barren land to dense vegetation was 3.42 km² and to low vegetation was 2.82 km², whereas it has transformed to a built-up area by 0.42 km², to water bodies by

0.01 km², and to agricultural land. Water bodies cover 1.16% of the total geographical area under the study area. From 1991 to 2021, it has transformed to agricultural land by 0.04 km², barren land by 0.06 km², built-up land by 0.84 km², dense vegetation by 0.15 km², and low vegetation by 0.066 km². The changes in land use over this period highlight significant urbanization and shifts in land cover types. These transformations reflect broader trends in development and environmental change within the region.

Figure 2: LULC detection map (1991 - 2021)



Source: Based on LANDSAT TM

Conclusion

Land use and land cover change detection are essential tools for understanding the complex relationship between humans and the environment. The use of remote sensing and GIS has helped researchers to monitor and analyze spatial and temporal change in LULC patterns, which anticipates valuable insights for proper environmental planning. The LULC change detection analysis indicates that the area under built-up has recorded the maximum growth in its total area, whereas the area under dense vegetation and water bodies has recorded a marginal negative growth. We attribute the growth in built-up areas to population growth and the expansion of social infrastructure. On the other hand, the decline in dense vegetation cover is attributed to the increasing practice of shifting cultivation, which eventually converts the land to low vegetation cover and later into barren land. All land use classes exhibit changes in Land Use and Land Cover (LULC). The transformation of LULC classes from one class to another shows the changing nature of humans towards their environment. The decline in forest cover, along with the increase in agricultural land and built-up areas, highlights that as environmental challenges intensify, detecting changes in Land Use and Land Cover (LULC) becomes increasingly important for ensuring the resilience and sustainability of both human society and the environment.

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