




Monitoring land use land cover changes in the Eastern Himalayan landscape of Nagaland, Northeast India

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Abstract The escalating demand for anthropic needs and urban development has highlighted the importance of monitoring and change detection of land use land cover (LULC). With an increase in agricultural expansion and infrastructural development, every land surface on earth calls for a long-term investigation of land modification patterns and their underlying contributory factors. The present investigation monitors the LULC changes and assesses the process controls in Kohima and Dimapur districts of Nagaland, India. Currently, these two districts encompassing the main urban cities of the hilly state are experiencing rapid urbanization and unplanned

developmental activities. Alike any other LULC changes observed in unplanned and developing cities, these districts are likely to face environmental degradation, and particularly, the occurrence of frequent landslides and flash floods. The study has three objectives—(i) LULC mapping of Kohima and Dimapur districts for three periods (1998, 2008, and 2018), (ii) comparative analysis of LULC change patterns in the two districts during the three epochs (1998–2008, 2008–2018, and 1998–2018), and (iii) assessment of the contributory factors. For the study, remotely sensed LANDSAT images (TM and OLI) in Geographical Information System (GIS) platform were utilized along with field surveys. Supervised classification technique was employed and four major LULC classes were identified using Landsat level-1 classification system. The overall accuracy of the classification varied between 91 and 98%. Results showed that Built Up areas have increased significantly in both the districts at the rate of 322.6 ha/year in Kohima and 301.9 ha/year in Dimapur during 1998–2018. On the other hand, Agricultural Land and Forest Land declined in both districts. Changes in LULC were mainly due to marginalization of shifting cultivation, deforestation, infrastructural development, urban migration, and flourishing of aquaculture farming. This study furnishes baseline information on LULC in the data-scarce region of Northeast India and is an insinuation to the policy-makers to ensure sustainable land use planning in the face of rapid urbanization.

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Introduction

Land is a primary natural resource comprising the soil, water, forest, and the associated flora and fauna, involving the entire terrestrial ecosystem, and is significant for the development and growth of a region or country (Rahman et al. 2012; Chen et al. 2019). Human civilization has a close relationship with the environment and is greatly dependent on the land resources for their livelihood and progress leading to LULC changes over a period of time (Walker and Homma 1996; Jaiswal et al. 1999). Land cover represents the physical attribute of the Earth's surface such as vegetation, water, soil, and other substantial features on the land while land use includes land modifications made by anthropogenic activities relating to economic development such as agriculture and infrastructure development. LULC is interdependent as any changes in land use affect the land cover and vice-versa (Dimiyati et al. 1996; Mukherjee et al. 2009; Rawat and Kumar 2015). LULC change is considered as one of the most significant human interventions altering the Earth's environment (Ayele et al. 2016). It is one of the primary issues in environmental and geographical studies. The LULC change studies include various factors such as the mapping and monitoring of land use change, analyzing the driving forces, modelling, and prediction of LULC change considering different scenarios and assessment of its effects on the ecosystem. Among these factors, detecting land use change is the most significant as it provides the basis for the subsequent investigations (Peng et al. 2008). The land use change is a function of biophysical and socio-economic driving force and determines the complex relationships in land use change systems providing comprehensive particulars about the extent and location of land use change (Aspinall 2004).

Land use, in general, is triggered by population growth. Population explosion is a serious problem for an emerging economy like India. According to a census by the World Bank (2018), the percentage of urbanization in India stood at 27.92% in 2001, which had increased rapidly to 31.28% in 2011 and 33.6% in 2017. With rapid population growth over the years, more forests are cleared to expand the human civilization for their livelihood, agriculture, and other activities. Many forests and mountain ecosystems are encountering broad changes in land use due to both natural and anthropogenic processes (Liu et al. 2003). The rise of socio-economic necessities because of growing

population creates pressure on the LULC leading to unplanned and mismanagement of agricultural land, urban, range, and forest land which in turn alters the LULC (Reis 2008). Uncontrolled changes in land use have significant impacts on the quality of air (Wu et al. 2012; Roy et al. 2007), drainage (Samant and Subramanyan 1998), water quality (Ahearn et al. 2005), groundwater recharge hydrology (Scanlon et al. 2005), floods (Alexakis et al. 2014; Hazarika et al. 2015), rainfall (Zhao and Wu 2017; Pielke Sr. et al. 2007; Boyaj et al. 2020; Kishtawal et al. 2009; Niyogi et al. 2007), surface runoff (Yin et al. 2017), watershed (Bisht and Kothiyari 2001; Hossain et al. 2015), loss of ecosystem (Yirsaw et al. 2016), and climate (Pielke et al. 2011; Pielke Sr. et al. 2016; He et al. 2020). The failure of effectively managing the Earth's ecosystem brings about many challenges and the people must have an all-encompassing awareness about the way they utilize these resources. It is imperative to understand the consequences of anthropogenic initiatives and devise proper management strategies to negate the detrimental effects in order to maintain a balance in the environment and decision-makers must be enlightened with scientific knowledge in order to make decisions fairly (Li et al. 2004; McAlpine et al. 2010).

Information on the existing LULC pattern, its spatial distribution, and their changes is a pre-requisite for the formulation of policies and strategies for constructing any developmental plan and provides a considerate aspect of land utilization (Dhinwa et al. 1992; Kalkhajah and Jamali 2019). This information is even more vital for mountainous terrain where the physical features limit the accessibility to information and makes it difficult to update the information frequently in comparison to plain areas (Ghosh et al. 1996). Remote sensing (RS) technique in this realm is vital for observing the Earth and its environment (Ruiz-Luna and Berlanga-Robles 2003; Jayakumar and Arockiasamy 2003, Jha et al. 2000; Chen et al. 2019). Timely and accurate up-to-date information of diversely used LULC could be obtained from a wide range of satellite-based high-resolution RS data (Reis 2008; Yuan et al. 2005). Satellite RS facilitates visual interpretation and evaluate environmental changes of an area for different time periods providing valuable information in a cost-effective way and GIS provides the automated land cover classification and quantitative analysis of the landform (Mas et al. 2004; Hansen and Loveland 2012; Hazarika et al. 2015; Hazarika et al. 2016; Chen et al. 2019). LANDSAT

images give valuable and continuous records of the earth's surface for the last three decades and the entire LANDSAT archive is now accessible free of charge to the scientific community contributing a wealth of information for identifying and monitoring changes in the environment (Bastawesy et al. 2008; Rawat and Kumar 2015). The better-quality LULC changes can be distinguished by comparing two different timelines. These changes can be compared according to the land usage in various categories. The techniques of RS and GIS in LULC changes have been widely used by many researchers for different land use studies and their impact on the environment assuring it as a central tool for management and decision making to ensure the optimum utilization of the resources (Pathan et al. 1989; Pathan et al. 1991; Jaiswal et al. 1999; Jha et al. 2000; Sarma et al. 2001; Bhatta 2009; Dewan and Yamaguchi 2009; Xiuwan 2002; Abd El-Kawy et al. 2011; Kolios and Stylios 2013; Alexakis et al. 2014; Esmail et al. 2016; Basha et al. 2018; Chen et al. 2019). This work employs the recent and advanced technologies of RS and GIS for assessing and mapping LULC changes in Nagaland, Northeast India. Landsat archives have been utilized to prepare the LULC in different time periods spanning a period of 30 years. The LULC maps have been incorporated into GIS platform to detect and analyze the magnitude of the changes.

LULC change, a primary and central component of global environmental change have direct implications on climate, ecology, and human society that possess immense concern to policy-makers (Ganasri and Dwarakish 2015; Halmy et al. 2015). Therefore, considering the various challenges of LULC changes the present work focuses on assessing and mapping the LULC changes in the state of Nagaland, Northeast India, which is situated in the Indo-Myanmar biodiversity hotspot and is an extension of the Himalayan ranges. The region is mostly forested and preserves some of the pristine landscapes of the Himalayan ranges and Arakan–Yoma ranges. The state has very little access to motorable roads and infrastructures with a low population density but with time, the area is undergoing rapid changes with infrastructural development and rise in population. Off late, the region especially in its two cities viz., Kohima and Dimapur is experiencing rapid development and urbanization. Increases in the population aided by migration from rural areas the city boundaries are constantly experiencing expansion bringing more and more forest cover area into its limit. Kohima, the state capital, is

situated in a hilly region with marginal land for cultivation and infrastructural development. The land area is under pressure with constant upgradation and developmental activities along with the resettlement of the population in the capital. Dimapur, on the other hand, covers the smallest area in the state with a high population density. It is the only plain tract in the hilly state consisting of railways, airport, and an active commercial economy thereby increasing its susceptibility to uncontrolled land use in a minimal land area. The two districts are undergoing rapid LULC changes as a result of an increase in demand for land by the growing population and unplanned developmental activities. The major LULC change driving factors in the study area include poor management of land due to deforestation, *jhum* cultivation, soil erosion, improper drainage system, low-quality soil-and-water conservation measures, and unplanned infrastructural development. These factors leading to LULC changes could significantly affect the environmental characteristics of the region. It could also lead to an increase in frequency as well as magnitude of environmental hazards such as landslide, soil erosion, flooding, and land degradation. In the present scenario, assessment of LULC change becomes critically important for Nagaland, owing to its mountainous terrain and marginal utilizable land, for proper land management and to discern the course of changes for future developments. Therefore, the present work aims to detect the LULC changes of Kohima and Dimapur districts of Nagaland, Northeast India, during the periods between 1998 and 2018 using RS and GIS techniques. A near absence of such studies from the data-scarce region also inspires the present work. The research not only aims to contribute as a baseline data for future studies but also attempts to enlighten the policy-makers for the formulation of better management strategies leading to the sustainable management of land resources in the rapidly changing geographic terrain.

Material and methods

Study area

Nagaland is one of the North-Eastern states of India situated between 93° 20' E–95° 5' E Longitudes and 25° 12' N–26° 3' N Latitudes (Fig. 1). It has a total geographical area of 16,579 km² with a forest cover of 8,63,000 ha. Nagaland is a biodiversity-rich state,

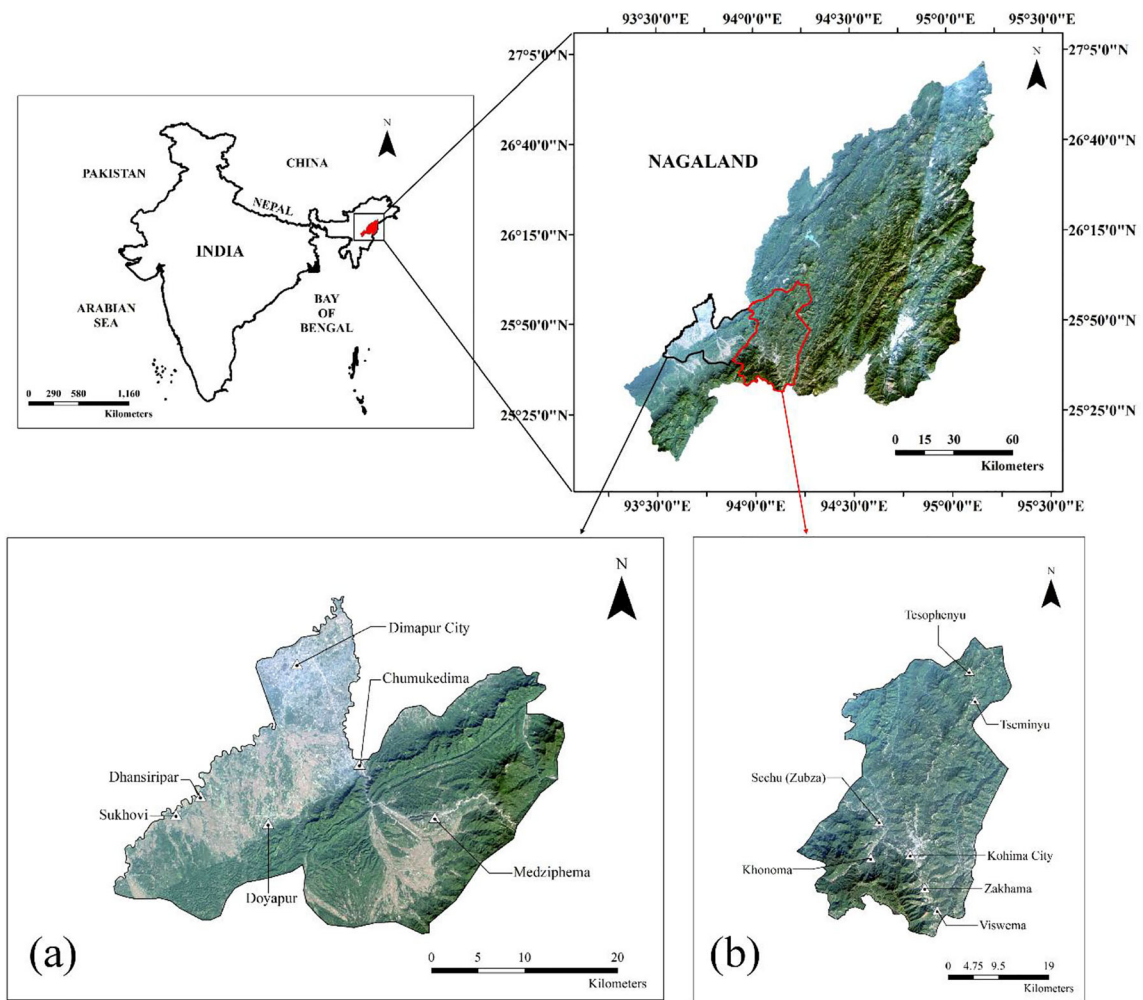


Fig. 1 Location map of the study area showing the districts of (a) Dimapur and (b) Kohima along with their major cities viz., Dimapur and Kohima respectively in Nagaland

dominated by tropical evergreen forest and sub-tropical vegetation type (Achumi et al. 2014). According to the Census (2011a), the state has a population of about 1.97 million and is projected to be 2.07 million by 2020. It has an annual rainfall ranging from 1800 to 2500 mm. Nagaland is bordered on the north by Arunachal Pradesh, on the west and north-west by Assam, on the south by Manipur and on the east by Myanmar. It has an extreme topography of ranges breaking into ridges and spurs (Rao and Jamir 1982). There are 16 major tribes in Nagaland, namely, Angami, Ao, Chakhesang, Chang, Kachari, Khiamnungan, Konyak, Kuki, Lotha, Pochury, Phom, Sangtam, Rengma, Sumi, Yimchunger, and Zeme-Liangmai (Zeliang), each having unique characteristics with distinct language, custom, and attire. Nagaland is divided into 12 administrative districts

including Mon, Longleng, Mokokchung, Tuensang, Noklak, Wokha, Zunheboto, Kiphire, Dimapur, Phek, Peren, and Kohima.

Kohima district lies between $25^{\circ} 31' N$ - $26^{\circ} 2' N$ Latitudes and $93^{\circ} 52' E$ - $94^{\circ} 17' E$ Longitudes encompassing a total geographical area of 1317 km^2 with an elevation of 1444.92 m AMSL (above mean sea level). Kohima city, in the district of Kohima, is the state capital of Nagaland. The district is centrally located and surrounded by Wokha on the north, Dimapur on the west, Phek and Zunheboto on the east, and the state of Manipur on the south. The eastern and northern regions are covered by sub-tropical deciduous forest whereas the western and southern regions by temperate evergreen forest. The central regions are hilly areas which are covered by temperate evergreen forests

(Kiyasetuo and Khare 1986). It is covered by sub-tropical deciduous forest in the eastern and northern regions, and temperate evergreen forest in the southern and western regions making the area rich in biodiversity (Kiyasetuo and Khare 1986). Kohima is home to the Angami and Rengma tribes. Being situated on the hilly terrains, the Angamis and Rengmas mainly practice terrace cultivation, producing rice and other minor crops. Kohima being the capital is a cosmopolitan city with a blend of all the tribes of Nagaland. It also harbors biodiversity-rich areas like Dzukou valley and mount Japfu. Puliebadze wildlife sanctuary with an area of 9.2 km² is also located in Kohima. According to the Census (2011b), Kohima has a total population of 2, 67, 988.

The Dimapur district lies between 25° 38' N-25° 58' N Latitudes and 93° 32' E-94° 1' E Longitudes having a total geographical area of 868 km² and elevation of 165.8 m AMSL. Dimapur city, the district headquarter, is the only plain tract in the hilly area and the largest city in Nagaland. The district is surrounded by the state of Assam to the west and north, Peren district to the south and Kohima district to the east. It has a heterogeneous mix of communities from the rest of India living with the dominant Naga community. According to the Census (2011b), Dimapur has a total population of 3, 78, 811. It is the only city in the state which offers both air and rail connectivity.

Data collection

Three LANDSAT images were utilized to monitor the LULC changes of Dimapur and Kohima districts. The images were downloaded using the United States Geological Survey (USGS) Earth Explorer website and the details are presented in Table 1. The 1998 and 2008 images are available from the TM sensor of LANDSAT 4-5 and the 2018 images are available in Real-Time (RT) maps of LANDSAT 8 OLI-TIRS. All of these images were downloaded for the months of November

and December as the cloud cover is minimal during these months.

Database preparation

The satellite images were imported to ERDAS IMAGINE software (Leica Geosystems, Atlanta, U.S.A.) and False Colour Composite (FCC) of the images were created with bands 4 (Near Infrared), 3 (Red) and 2 (Green) for LANDSAT TM and bands 5 (Near Infrared), 4 (Red), 3 (Green) for LANDSAT OLI TIRS by using the Nearest Neighbour Algorithm. The images were then masked out using boundary vector layers of the study area for individual years. Radiometric corrections were carried out in order to minimize the inconsistencies of the satellite images and enhance the quality of the images (Chander et al. 2009). Histogram equalization was performed in order to augment the contrast of the images (Weng 2001).

Image classification and change detection

Supervised classification method was adopted for LULC classification of images using ArcGIS Software. Supervised classification is a method by which the user performing the classification creates sample sites for a data set by making use of the pixels called training areas. Maximum likelihood algorithm, a popular and widely used algorithm, was used for the final transformation (Rawat and Kumar 2015). This algorithm assigns the pixels to the highest probability and the spectral signatures thus created are then used to classify the whole image by the computer algorithm. In this study, four LULC classes were established as Agricultural Land, Built Up, Forest Land and Water Body by using the LANDSAT Level-1 classification system. The descriptions for these classes are presented in Table 2. To assess the classification accuracy, a set of 130 and 200 random points for each classified image of Kohima and Dimapur respectively were utilized. The random points, also called the reference points, were overlaid on each image and were assigned a specific LULC class. High-resolution Google Earth images, topographical maps, limited site visits, and local knowledge about the area and changes over time were utilized for assigning the classes to each reference point. A confusion matrix was then created for each classified image by exporting the pivot tables generated by ArcGIS and importing it to Microsoft Excel 2016. Each row represents the

Table 1 Satellite data used in the study

Sl. No.	Satellite	Sensors	Paths/ rows	Resolution/ scale	Acquisition date
1	LANDSAT 4-5	TM	135/042	30 m	17/12/1998
2	LANDSAT 4-5	TM	135/042	30 m	10/11/2008
3	LANDSAT 8	OLI TIRS	135/042	30 m	08/12/2018

Table 2 Land use land cover classification scheme for the study

Sl. No.	Class	Description
1	Agricultural Land	Areas those are under cultivation, e.g., Farmland, Cropland, etc.
2	Built Up	Areas meant for settlement including homestead area, e.g., Transportation, Industrial, Rural and Urban Built-Up Land, etc.
3	Forest Land	Areas with dense/open forests, tall grass and scrublands.
4	Water Body	Open water bodies such as lakes, ponds, and rivers.

classified land use classes and each column represents the reference points of the land use classes. The overall

accuracy and the Kappa coefficients for each map are then calculated.

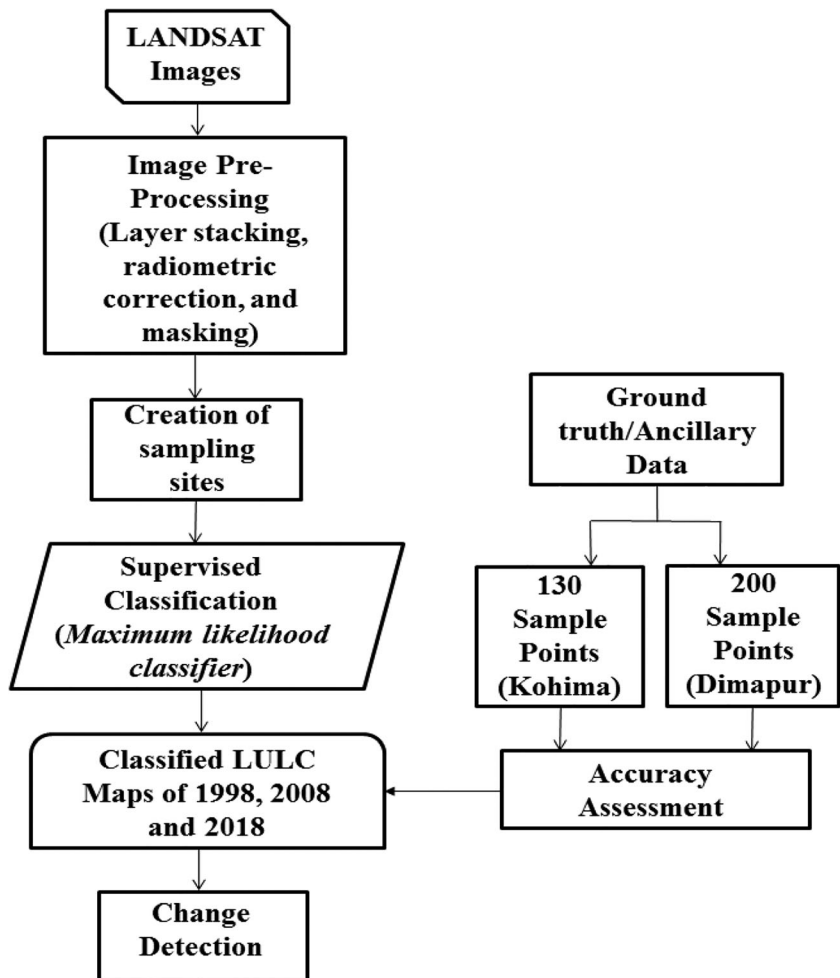
After the classification process, the classified layers were then imported to ERDAS Imagine for change detection during 1998–2008, 2008–2018, and 1998–2018. The schematic representation of the methodology is shown in Fig. 2.

Results

Classification accuracy

The overall accuracies for the classified images (Fig. 3) of Kohima District are 91.54%, 94.62%, and 97.69% for the years 1998, 2008, and 2018 with kappa coefficients of 0.84, 0.90, and 0.96 respectively. For Dimapur

Fig. 2 Schematic representation of the methodology followed in the study



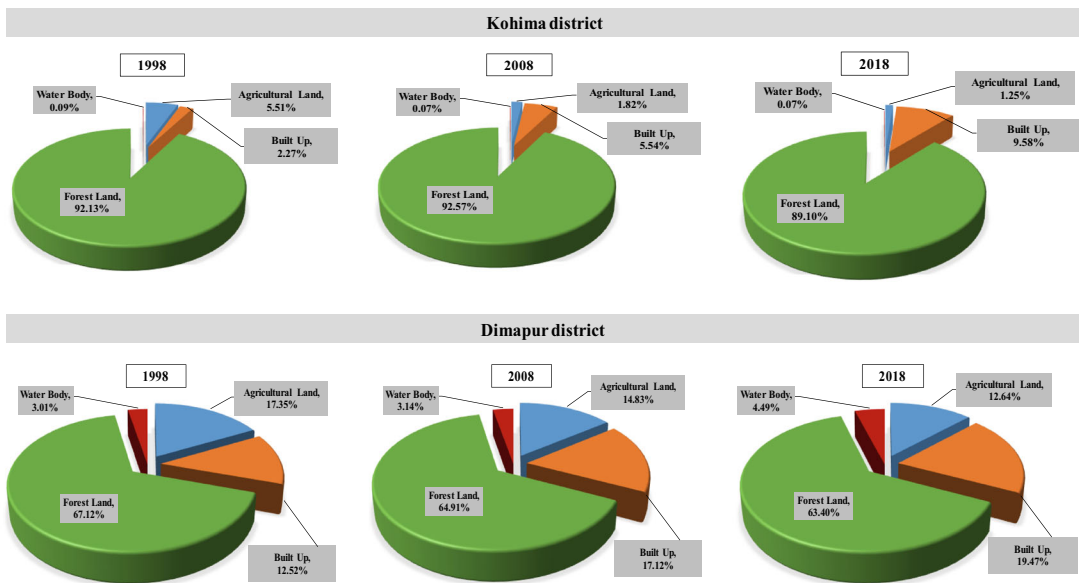


Fig. 3 Percentage area composition of the four LULC classes in Kohima and Dimapur district during 1998, 2008, and 2018

District, the overall accuracies of classifications are 91.5%, 96.5%, and 98.5% for 1998, 2008, and 2018 with kappa coefficients of 0.88, 0.95, and 0.98 respectively (the details of confusion matrices are shown in Table S1 (a, b, c) for Kohima District and Table S2 (a, b, c) for Dimapur District, provided as a supplementary material). Forest Land is classified as the best class among the four classes due to its distinct separation from other classes. The Built Up also shows reliable classification. Some tall grasses and grassland are often confused with agricultural areas. As a result of mixed pixels in some transition areas, parts of sand bars in nearby rivers are sometimes misclassified as Agricultural Land. However, the overall accuracies highlighted the reliability of the classification in the present study and showed that the images are acceptable for further analysis.

Land use land cover mapping and area information

Kohima district

In 1998, out of the four LULC classes, Forest Land constituted the largest area of the Kohima district with 121,367.4 ha (92.13%) (Table 3 and Fig. 3). It is evidently due to its geographical influence, which is the extension of the forested Eastern Himalayan ranges (*Purvanchal Range*). It is followed by Agricultural Land (5.51%), Built Up (2.27%), and Water Body respectively (0.09%) (Fig. 3). After a decade, the percentage composition of Built Up (5.54%) surpassed Agricultural Land (1.82%) in 2008, while the other classes retained the order albeit little change in area composition. While an increase in percentage composition of Forest Land

Table 3 Area information (in ha) on land use land cover of Kohima and Dimapur districts during 1998, 2008, and 2018

LULC classes	Kohima			Dimapur		
	1998	2008	2018	1998	2008	2018
Agricultural Land	7254.09	2399.67	1649.61	15,063.84	12,877.47	10,972.08
Built Up	2984.85	7296.3	12,612.51	10,864.08	14,860.71	16,901.91
Forest Land	121,367.4	121,935.5	117,368.9	58,268.43	56,347.29	55,039.5
Water Body	116.73	91.62	92.07	2614.86	2725.74	3897.72
Total	131,723.1	131,723.1	131,723.1	86,811.21	86,811.21	86,811.21

and Built Up is observed in 2008, in the contrary, class area declined in Agricultural Land and Water Body. In 2018, decrease in areas occurred in Forest Land, Agricultural Land, and Water Body, with exception in Built Up areas. The order of area occupied by the classes followed Forest Land, Built Up, Agricultural Land, and Water Body (Table 3 and Fig. 3). In all the three study periods, the area of Forest Land is the highest, and Water Body is the lowest. The LULC maps of Kohima district for the study periods 1998, 2008, and 2018 are depicted in Fig. 4.

Dimapur district

Similar to Kohima, Forest Land constituted the highest area of Dimapur district in all the study periods, while Water Body area is the lowest (Table 3). However, the percentage area composition of each class differed as compared to Kohima. During the entire study period, the percentage composition of Forest Land in Dimapur is lower than Kohima, but the other classes are higher. In 1998, Forest Land covered an area of 58,268.43 ha, i.e., 67.1% of the total area of Dimapur district. It is followed by Agricultural Land, Built Up, and Water Body comprising of 15,063.84 ha (17.35%), 10,864.08 ha (12.52%), and 2614.86 ha (3.01%) respectively (Table 3 and Fig. 3). During the latter periods, 2008 and 2018, areas of Forest Land and Agricultural land decreased, while area increase is observed in Built Up and Water Body. Alike Kohima

district, the Built Up areas exceeded the percentage area composition of Agricultural Land between 1998 and 2008. The LULC maps of Dimapur district in 1998, 2008, and 2018 are shown in Fig. 5.

LULC changes in Kohima and Dimapur districts during 1998–2008, 2008–2018, and 1998–2018

LULC changes in Kohima district

All the four LULC classes of Kohima underwent changes throughout the study period (Table 4). Area of Agricultural Land has been declining during 1998–2008 and 2008–2018 resulting in a total area reduction of 5604.48 ha between 1998 and 2018. An opposite trend is observed in the case of Built Up class, which experienced an increase in area during 1998–2008 and 2008–2018 leading to a net area gain of 9627.66 ha in the two decades. Area of Forest Land increased during 1998–2008, but decreased significantly in 2008–2018, which led to net area decrease of 3998.52 ha. In contrast to Forest Land, the area of Water Body decreased in 1998–2008 and increased in 2008–2018, but resulted in a net area decline of 24.66 ha during 1998–2018. Overall, during 1998–2018, only Built Up areas increased which stood at a massive 322.6% change (Table 4). Among the classes which shows decline in areas during 1998–2018, Agricultural Land is the highest (77.3%) followed by Water Body (21.1%) and Forest Land (3.3%). The rate

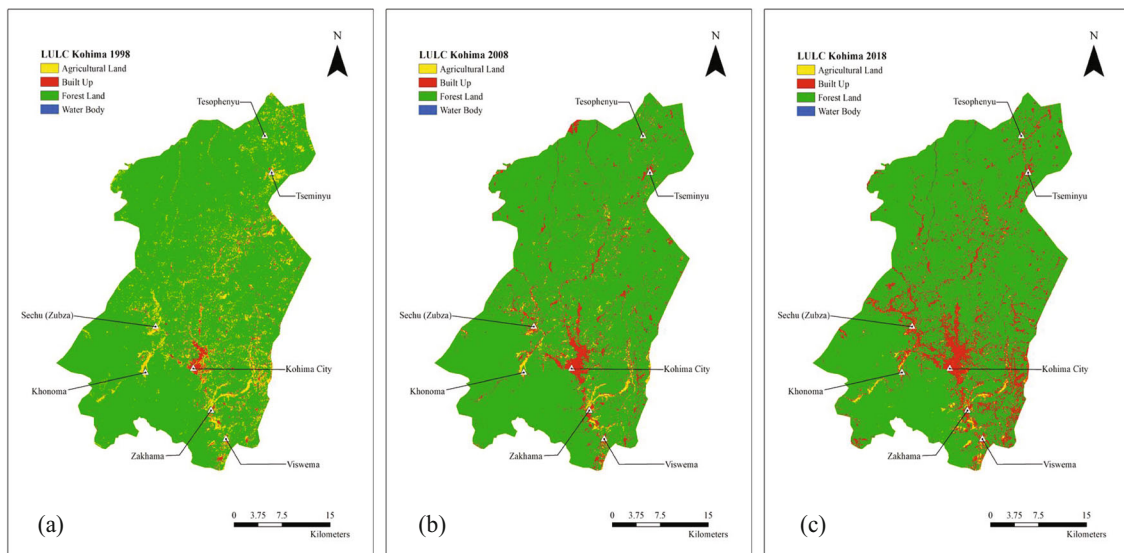


Fig. 4 Land use land cover maps of Kohima district in 1998 (a), 2008 (b), and 2018 (c)

Fig. 5 Land use land cover maps of Dimapur district in 1998 (a), 2008 (b), and 2018 (c)

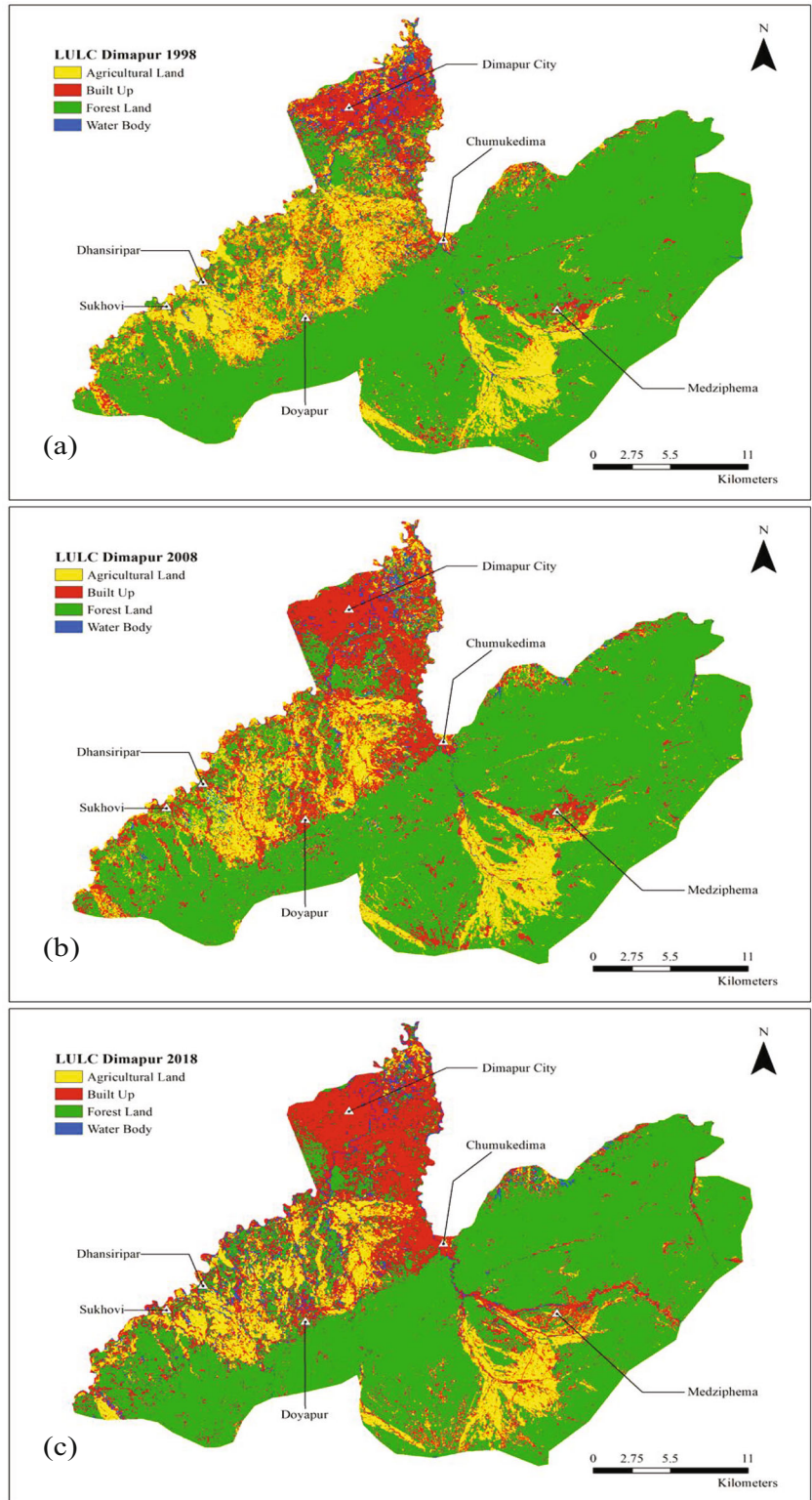


Table 4 LULC changes of Kohima district during 1998–2008, 2008–2018, and 1998–2018

LULC classes	Area change (ha)			Percentage change (%)			Rate of change (ha/year)
	1998–2008	2008–2018	1998–2018	1998–2008	2008–2018	1998–2018	1998–2018
Agricultural Land	- 4854.42	- 750.06	- 5604.48	- 66.9	- 31.3	- 77.3	- 77.3
Built Up	+ 4311.45	+ 5316.21	+ 9627.66	+ 144.4	+ 72.9	+ 322.6	+ 322.6
Forest Land	+ 568.08	- 4566.6	- 3998.52	+ 0.5	- 3.7	- 3.3	- 3.3
Water Body	- 25.11	0.45	- 24.66	- 21.5	+ 0.5	- 21.1	- 21.1

Positive (+) and negative (-) signs indicate inter-periodic increase and decrease in values respectively

of area change of Built Up area is the highest during the two decades (1998–2018) which has been increasing at the rate of 481.4 ha/year (Table 4). On the other hand, the rate of “area decline” is the highest in Agricultural Land at 280.2 ha/year, followed by Forest Land (199.9 ha/year) and Water Body (1.2 ha/year). Spatial distribution of LULC changes of Kohima district during 1998–2008, 2008–2018, and 1998–2018 is shown in Fig. 6. There is no pattern in the spatial distribution of area changes in any of the classes, but the south-western region (hills with dense forest) of the district has remained largely unchanged throughout the study periods. Built Up areas have emerged throughout the district with distinguishable area additions in towns/cities like Kohima, Zakhama, and Khonoma (Fig. 6).

LULC changes in Dimapur district

During all the periods (1998–2008, 2008–2018, and 1998–2018), Agricultural Land and Forest Land

suffered a continuous decline in area, while area increased in Built Up and Water Body classes (Table 5). The area changes of Agricultural Land, Built Up, and Forest Land in 1998–2008 are higher compared to 2008–2018, indicating lower changes in the later decade. In the contrary, area change of Water Body class is higher in 2008–2018 than 1998–2008. Overall, net areas of Built Up and Water Body increased by 55.6% and 49.1%, while Agricultural Land and Forest Land decreased by 27.25 and 5.5% respectively during 1998–2018. Similar to Kohima, the highest area increase is observed in the Built Up class at 6037.83 ha, and the highest area decrease is in Agricultural Land at 4091.76 ha. Consequently, the rates of area increase in Built Up and Water Body stood at 301.9 and 64.1 ha/year, and the rates of area decline of Agricultural Land and Forest Land are 204.6 and 161.4 ha/year respectively. The spatial distribution of changed areas is confined to western and south-eastern regions of the districts (Fig. 7), which are the habitable plain areas. Similar to

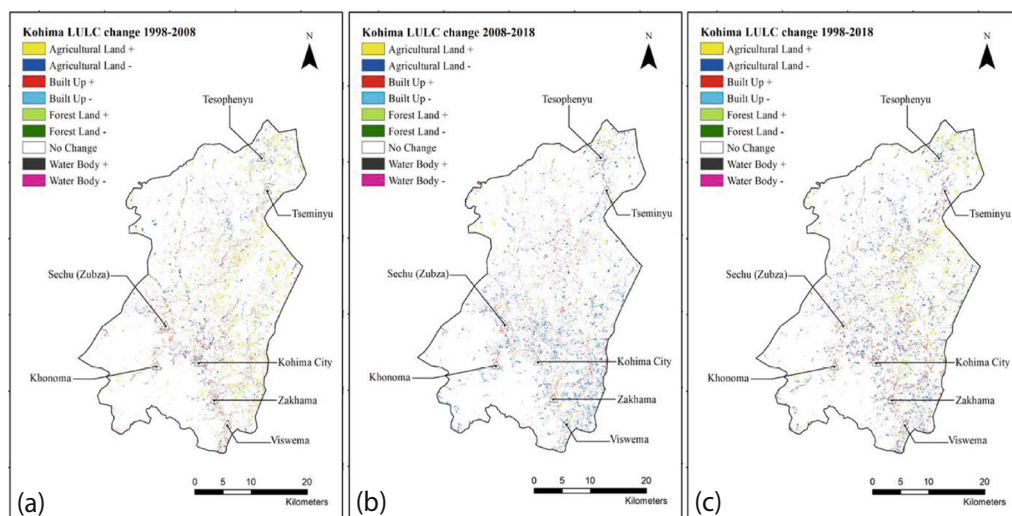


Fig. 6 Land use land cover change maps of Kohima district during 1998–2008 (a), 2008–2018 (b), and 1998–2018 (c)

Table 5 LULC changes of Dimapur district during 1998–2008, 2008–2018, and 1998–2018

LULC classes	Area change (ha)			Percentage change (%)			Rate of change (ha/year)
	1998–2008	2008–2018	1998–2018	1998–2008	2008–2018	1998–2018	1998–2018
Agricultural Land	– 2186.37	– 1905.39	– 4091.76	– 14.5	– 14.8	– 27.2	– 204.6
Built Up	+ 3996.63	+ 1983.24	+ 6037.83	+ 36.8	+ 13.3	+ 55.6	+ 301.9
Forest Land	– 1921.14	– 1307.79	– 3228.93	– 3.3	– 2.3	– 5.5	– 161.4
Water Body	+ 110.88	+ 1171.98	+ 1282.86	+ 4.2	+ 43	+ 49.1	+ 64.1

Positive (+) and negative (–) signs indicate inter-periodic increase and decrease in values respectively

Kohima, unchanged areas lay mostly in the northeastern region of the district where dense forest with steep landscape is predominant.

Comparison of LULC changes in Kohima and Dimapur

The attribute data of LULC of the two districts for the study period demonstrated significant changes in feature classes. Kohima, the capital of Nagaland and with mountainous terrain, is experiencing changes at a faster rate in comparison to Dimapur. Dimapur is a low lying and floodplain area with a diversified economy and heterogeneous mix of people but the rate of change is lesser in comparison with Kohima. According to the Census (2011b), the total population of Dimapur (3, 78, 811) is considerably more than that of Kohima (2, 67, 988) despite Kohima having larger geographical area. The relatively higher population in Dimapur may be due to its geographical setup, i.e., a floodplain area, unlike Kohima, which is mountainous. Dewan and Yamaguchi (2009) supplement this with similar results where the physical setting of the geographic area is a driving force of LULC changes. Similar results were also seen showing a direct relationship between the population growth and urban development despite the population not being homogenous in a particular area (Ruiz-Luna and Berlanga-Robles 2003).

There is a significant variation in the rate of change in the two districts (Tables 4 and 5). The rate of increase in Built Up of Kohima is slightly higher than Dimapur. The reasons might be the increasing demand for land resources for developmental activities such as urbanization, construction of roads, and resettlement of the population as more developmental activities take place in the capital city. Rahman et al. (2012) also reported that Built

Up activities in the capital cities are taking place at a rapid rate due to urban fringe development, thereby replacing other land use classes. The area of Water Body is lesser in Kohima in comparison to Dimapur as a result of steeper slopes and fewer water sources. The area under Water Body class in Dimapur depicts an increasing trend during the study period. Increase in aquaculture, fish ponds, artificial ponds for brick construction, and water logging due to unplanned drainage system are the primary reasons for this as evident during ground verification.

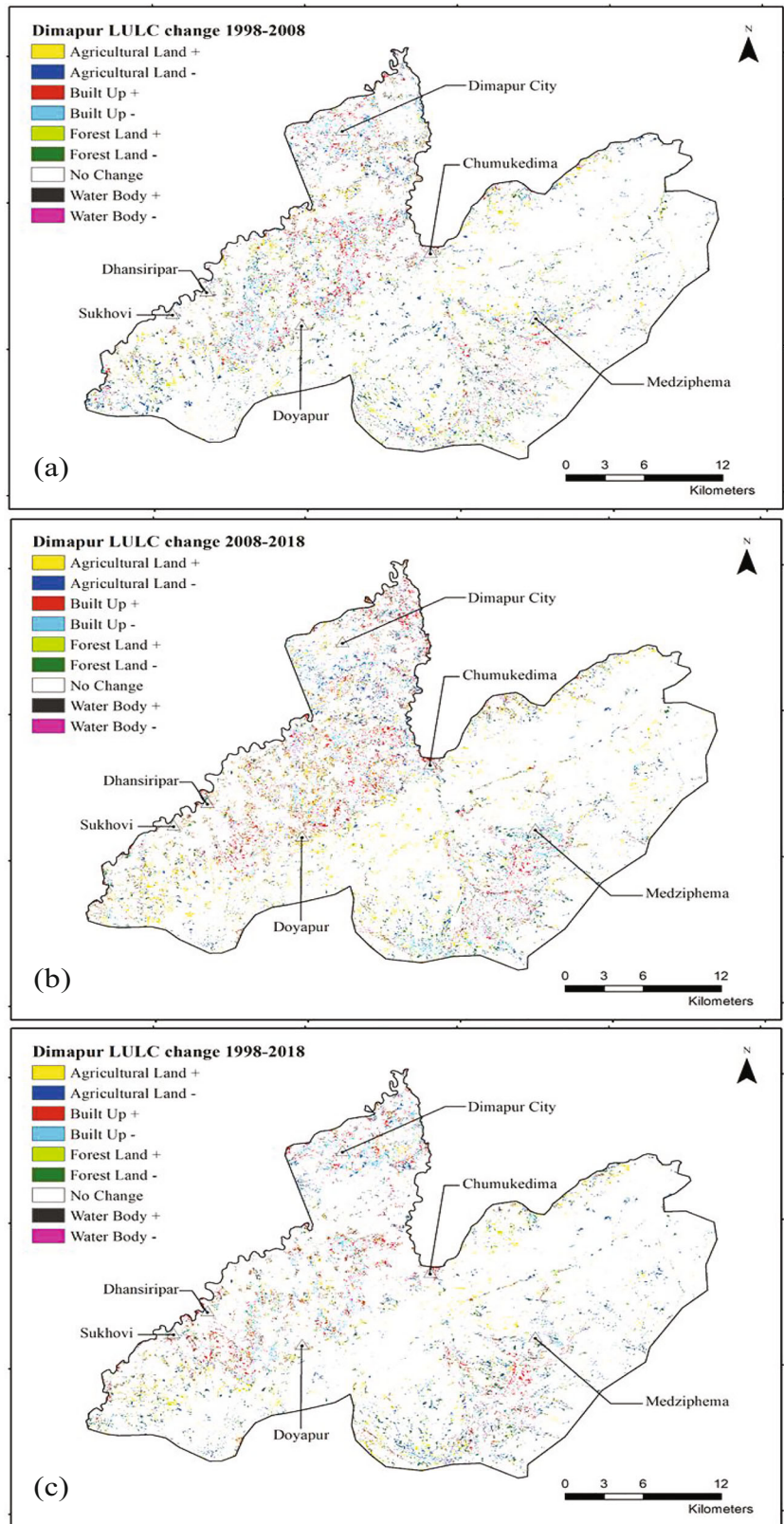
LULC changes rapidly taking place in response to urban development and population settlements without proper planning cause pressure in other land classes, i.e., Forest land, Agricultural land, and Water Body, which might eventually disturb the environment setup.

Discussion on causative factors of LULC changes in Kohima and Dimapur

The causative factors for LULC changes are plentiful and vary in regard to different study areas (Turner II and Meyer 1994). A number of factors are responsible for changes in LULC of Kohima and Dimapur districts like deforestation, population expansion, migration, infrastructure development, and dynamics in shifting cultivation.

In our study, Agricultural Land showed high rates of area decline in both the districts. In Nagaland, shifting cultivation (*jhum* or slash and burn) is the main agricultural practice and has been followed by the Naga people for centuries. But recently, shifting cultivation has been marginalized due to combine effect of (a) growing awareness among the farmers regarding the ecological adversities and soil infertility caused by shortened

Fig. 7 Land use land cover change maps of Dimapur districts during 1998–2008 (a), 2008–2018 (b), and 2008–2018 (c)



rotation cycles, and (b) schemes undertaken by the Central Government body like NITI Aayog (National Institution for Transforming India) to curb the cultivation technique (Pant et al. 2018; Anon 2000; Pandey et al. 2019). Farmers have resorted to regenerating shifting cultivation lands and alternative farming systems like permanent crop cultivation, agro-forestry, and tree farming (Nongkynrih et al. 2018; Pant et al. 2018; Choudhury and Sundriyal 2003; Cairns et al. 2010). Lack of able-bodied labour due to migration from rural to urban areas and the growing importance of education also contributed to reduction of the cultivation (Choudhury and Sundriyal 2003). Therefore, areas of Agricultural Land classes have declined over the years. Similar observations have also been witnessed in Wokha, Mokochung, and Teunsang districts of Nagaland (Nongkynrih et al. 2018). A report published by the Indian Council of Forestry Research and Education (ICFRE) in 2014 also suggested a significant reduction in areas under shifting cultivation during 2000–2010 (Pant et al. 2018).

Built Up areas expanded at a much higher rate in both the districts during both decades. Evidently, larger Built Up area is observed in Dimapur, as it is the only district with vast plain tract and acts as a commercial hub. The rapid increase in Built Up area is mainly in response to the demands for basic amenities (housing, electricity, garbage disposal, supply of drinking water) due to the growing population, development, and urbanization process. Among the districts of Nagaland, highest population growth is recorded in Kohima (131.81%) followed by Dimapur (127.29%) during the last census (Census 2011b). In the era of globalization and modernization, population growth drives infrastructural and transportation (road) developments. Urbanization involves a process by which the rural population becomes urban residents through a transition from agriculture-based occupation to modern industries (Bromley and Gerry 1979). Bigger urban areas like Kohima (the capital city) and Dimapur (commercial hub) have to deal with more Built Up areas to meet the demands for the increasing urban population. Growth in urban population is due to migration, which may be divided into two groups—rural to urban migration within the State, and migration from other states (Aier and Kithan 2011). Rural to urban migration within the State occurs due to search for better education, employment opportunity, quality of living standard, and to follow

family members who are already urban dwellers (Aier and Kithan 2011). In Nagaland, Kohima and Dimapur cities are reported to have the highest urban population and are steadily growing (Aier and Kithan 2011). On the other hand, migration from other states occurs mainly due to business, marriage, and employment.

During 1998–2018, both the districts experienced area reduction in the Forest Land class. Forest areas are deforested to make space for the construction of roads, infrastructure, and agriculture fields, which are all driven by demographic dynamics (as mentioned earlier). An increase in Built Up area affects the Forest Land inversely (Rahman et al. 2012). Among the Indian states, Nagaland is one of the ten states with significant forest cover loss caused by uncontrolled exploitation of forests, extensive bamboo cutting, and conversion to agricultural lands (Reddy et al. 2013, 2016). It is also observed that Forest Land in Kohima increased slightly (0.5%) during 1998–2008, which may be attributed to the inclusion of regenerated *jhum* (shifting cultivation) areas and the practice of alternative farming like agro-forestry into Forest Land. For instance, people in Nagaland have adopted the growing of alder trees (*Alnusnepalensis*) in *jhum* areas (Cairns et al. 2010; Arunachalam et al. 2002).

The area occupied by Water Body (lakes, ponds, and streams/rivers) in Kohima is much lower compared to Dimapur. Among the districts of Nagaland, fish farming (fishery) is reported to be most suitable in Dimapur due to its pH range (5.2 to 6.0) and has been practiced largely in many places (Sharma et al. 2018). This contributed to increasing areas of Water Body in Dimapur through the study periods. Sarma et al. (2001) also depicted similar results where the Water Body increased as a result of artificial ponds and aquaculture practices for commercial purposes supplementing the possibilities for an increase in Water Body in the area. Another cause may be the water-logging problem in urban areas as a result of unplanned drainage system due to the increase in population and built-up activities (Samant and Subramanyan 1998). Dimapur suffers severe water logging during the monsoon season leading to flash floods as experienced in the past couple of years. On the other hand, Water Body of Kohima district had declined during 1998–2018, which may be due to siltation (descending from runoffs of eroded steep slopes), pollution, and improper dumping of waste in waterbodies

(Hossain and Rahman 2011; Poletto and Beier 2012; Sundersingh 1990; Eduful and Shively 2015).

Conclusions

This work highlighted the significance of long-term geo-spatial assessment of LULC changes and their patterns in a data-scarce and rapidly developing region of India. In the context of an emerging economy like India, where development and population expansion are scaling high, our study throws light on the alteration of land features and its impact in the hilly districts of Nagaland. Apparently, Built Up areas are increasing at rapid rates in Kohima, the capital city, and Dimapur, the commercial hub. Urbanization and developmental projects are taking over large areas of Forest and Agricultural lands, resulting in depletion of forest cover and agricultural fields through the study periods. Auxiliary factors like urban migration, increase in fishery ponds, and marginalization of shifting cultivation played vital parts in the LULC dynamics of the study area. While the three classes—Built Up, Agricultural Land, and Forest Land—showed similar patterns of change over the two decades in the two districts; Water Body showed contradictory results highlighting the role of aquaculture occupation in growing waterbodies of Dimapur. Accumulation (in Dimapur) and shrinking (in Kohima) of waterbodies may also be attributed to improper planning and management of urban areas, which are adverse effects of rapid unplanned urbanization. This study provides first-hand information on monitoring of LULC changes of the two developing districts of Nagaland, which will be beneficial for authorities and stakeholders during land-use planning and implementation of developmental projects in the ensuing future.

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Code availability Not applicable.

Data availability The authors declare that data supporting the findings of this study are available within the article and its supplementary information files.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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