

Anatomizing spatiotemporal LULC changes and anthropogenic drivers of forest loss in Eastern Assam of India

Lonkham Boruah

lonkham.nhk@gmail.com

Bhattadev University

Pranjit Kr. Sarma

Mangaldai College (Autonomous)

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Abstract

Rapid change in land use land cover (LULC) and forest loss have become major environmental challenges. Dibrugarh -nestled in the eastern corner of Assam globally renowned as the “Tea city of India” and has recently been declared state’s second capital experiencing constant LULC change (LULCC) and forest loss in recent decades. This study analyses spatiotemporal LULCC dynamics, quantification of forest cover loss and anthropogenic drivers of forest decline in Dibrugarh district, from 2000 to 2023 using geospatial tools. Landsat TM and Sentinel 2 satellite imageries were used for 2000 and 2023 respectively considering eleven LULC classes and accuracy assessed via overall accuracy and Kappa statistics. Post-classification comparison was done to analyse the LULC changes. Anthropogenic drivers were identified from field observations, key informant interviews, focus groups discussions, published statistics and spatial overlay analysis. Classified maps showed high accuracy (96% -overall and 0.9554 -Kappa) confirming reliability. Urban built-up areas, agriculture, agri-plantation/ settlement rose from 0.96 to 1.26%, 46.87 to 47.35%, 17.39 to 17.67% respectively and forest cover decline from 11.86% to 11.05% between 2000 and 2023 indicating rapid urban and agricultural expansion. Dibrugarh City and industrial towns like Duliajan and Namrup witnessed steady urban growth. Tea plantation areas rose from 15.84 to 16.48% -one of the major drivers of forest loss in the district. Agricultural expansion especially increasing areas under tea cultivation, urban and industrial growth, cityward human migration, infrastructural and developmental activities were identified as prime anthropogenic drivers of forest loss with underlying drivers like population explosion, limited livelihood sources, poverty, weak governance, and lack of environmental awareness. Urban landscape of the Dibrugarh City has changed rapidly in recent decades and forest loss in the whole district has intensified. It therefore requires a consolidated town planning, implementation of proper land use and forest policies, strong governance, forest restoration and grassroots level environmental awareness.

1. Introduction

Land is an indispensable natural resources of biophysical and socio-economic significance. Pattern of land use land cover is changing rapidly owing to natural and anthropogenic causes [14]. LULC analysis is vital for understanding the societal developments and human-induced changes on the land surface [22]. LULC is a fundamental process influencing the environment, ecosystem, climate, hydrology, biodiversity, ecology, geology, economy, societal processes [24, 8, 21, 3]. It plays a significant role in climate regulation, effective land management, policy making and various institutional activities [14, 22, 18]. Understanding the dynamics of LULC change will help to find the root cause of such transitions and diminishing vital land cover such as forest cover, watersheds etc. LULC analysis is crucial to understand environmental shifts, urban and agricultural expansion, and forest cover loss [2, 27]. Recent studies showed global transitions in LULC, especially decline in forest cover converting into human habitat, urban built-up, agricultural plot or infrastructural development that negatively alter the environment, increased carbon emission, biodiversity loss, extreme climates and reduced ecological resilience [13, 15, 18].

LULC in India is undergoing rapid change due to human driven factors. The most prominent trend is the expeditious urban expansion and infrastructural developments with decline in forest cover, water bodies and agricultural lands. Built-up areas in the urban peripheries of India have surged by over 100% to 150% in last two decades [20]. In addition, croplands in the peri-urban areas are converted into commercial, industrial and residential land [25, 1, 26]. Likewise in Assam, LUCCC is also characterized by alteration in urban areas, agriculture and forest cover. Urban expansion is driven by growth of metropolitan cities like Guwahati, which has witnessed two-fold increase in urban population in 30 years (1990–2020). Urban growth in Guwahati took place at the expense of vegetation, fallow land, open areas and to some extent wetlands (19). Dibrugarh, as the second capital of Assam has also been experiencing rapid urban and infrastructural growth. Such expansion has led to clearance of huge forest cover of the district. The built-up area in Dibrugarh rose by 177.16 sq.km. during 2015-23 replacing green cover and water bodies [6]. Several agricultural and fallow fringe areas were converted into non-agricultural land. Dibrugarh lost 790 ha of humid primary forest during 2002-25, which accounted to 6% decrease in total area of forest category. From 2002-25, the district has lost 8100 ha of tree cover; 63% of forest loss has occurred due to deforestation [12]. Despite rapid change in LULC and excessive forest loss, few studies have been done on its quantification and cause of such loss. Geospatial and temporal data and examine the major drivers of forest decline, and are necessary for effective management and conservation.

Several studies have analysed the LULCC of Dibrugarh district and of the Dibrugarh City in particular, but some research gaps remain. Neog et al. (2020) [21] studied the urban heat island patterns in 16 selected urban hot spots of Dibrugarh and stated urbanization act as driver to convert green space to built-up areas. Das et al (2025) [12] analysed the LULC of Dibrugarh and found vegetation cover has declined with increase in built-up area, but the study lacks drivers of such transformations. Saikia (2021) [30] examined the effect of urbanization on land use. Saharia and Singh (2015) [29] conducted a multi-temporal LULC analysis and revealed that growth of cities negatively affects the ecosystem. Revised literature revealed limited study has been conducted on LULCC of Dibrugarh which examines its drivers. No empirical study on drivers of forest loss in Dibrugarh is found. As such addressing these research gaps, a quantitative assessment on LULCC particularly on forest cover is essential for effective land use and management, urban planning, biodiversity conservation, and sustainable economic growth.

2. Materials and methods

2.1 Study area

The study is confined to and concentrates on Dibrugarh district, situated on the southern bank of the river Brahmaputra. It extends from 27°5′38″ N to 27°42′30″N latitude and 94°33′46″E to 95°29′8″ E longitude. Dibrugarh plays significant role in providing infrastructural and health facilities, education, trade and commerce since Colonial Era, and has provided port facility to export tea, timber and coal. Dibrugarh town was established in 1870 on the bank of the river Dibu [10].

Dibrugarh has a geographical area of 3381 sq. km. and is situated 110 m above mean sea level. Physiographically, Dibrugarh district is a broad plain, drained by the river Brahmaputra and its tributaries. Climatologically, the district of Dibrugarh falls under the sub-tropical monsoon type of climate. The Brahmaputra is the main river in the district of Dibrugarh, which runs for 95 km in the district. A major portion of the district falls in the valley area, which has alluvium content in its soil and has great potential for agricultural prosperity. The district is home to patches of evergreen and mixed deciduous forests and diverse forms of flora and fauna. Joypore Rainforest- a part of of Dehing Patkai National Park and a section of Dibru Saikhowa National Park are flanked on districts south-eastern and eastern boundary respectively [7]. The district recorded 13,26,335 of human population in 2011. The city of Dibrugarh has 1,54,296 population and has ranked as third most populous towns of Assam after Guwahati (Census of India, 2011).

2.2 Data sources

This study has employed field based observation and information, multi-temporal satellite imageries, ancillary geospatial data, published and unpublished data sources. The primary datasets consist of Landsat TM (2000) and Sentinel 2 (2023) with 30 m and 10 m spatial resolution respectively, which were downloaded from USGS EarthExplorer archive (Table 1). These images provide high spatial resolution and comparable spectral characteristics for a effective landscape change analysis. Ancillary data were employed for ground truth verification, analyzing the drivers of LULCC and forest loss, further enhancing the accuracy in classification. Ground sample points (GSP) were collected from high-resolution Google Earth Pro imagery for identifying the training sample and assess the accuracy of the results. Additional data sources to support the drivers of forest loss were collected from government offices, published reports etc. Together these datasets helps to conduct a in-depth study and a better triangulation of the LULCC dynamics and drivers of forest loss in Dibrugarh district.

Table 1
Satellite imagery data used for land use land cover change assessment

Year	Sensor	Date of acquisition	Resolution
2000	Landsat TM	28.11.2000	30 m
2023	Sentinel 2	24.12. 2023 29.12.2023	10 m

2.3 Methodology

2.3.1 LULC Classification

Image pre-processing prior to classification removes atmospheric, radiometric and geometric distortions. Radiometric calibration and geometric registration were done to acquire a geographically aligned and accurate imagery [16, 4]. Image enhancement techniques like cloud and shadow masking

were applied to reduce misclassification, remove unreliable pixels and for accurate image classification. Study years (2000 and 2023) were chosen based on data availability and to show the recent transitions. Subset and clipping were employed to extract the required map boundary of the study area and to prepare composite images for subsequent classes. Training samples for supervised classification were used from high resolution satellite imageries and with data drawn from field observation and interviews with key informants.

Based on reviewed literature, field observations and local knowledge, eleven LULC classes were defined: Agricultural land-crop land-*kharif* crop, Agricultural land-crop land-*rabi* crop, Agricultural land-crop land-two crop area, Agricultural land-plantation- tea garden, Built up (urban), Forest-evergreen/semi evergreen-dense, Forest-evergreen/semi evergreen-open, Forest-scrub forest, Agri-plantation / settlement, Water bodies, River sand Urban built-up area comprise of roads, railways, infrastructure, public parks, sport complexes etc. Forest cover consists of three classes together- Forest-evergreen/semi evergreen-dense, Forest-evergreen/semi evergreen-open, Forest-scrub forest. Agri-plantation and settlement includes houses and tree cover in the premises like in kitchen garden. Water bodies includes small rivulets to rivers, ponds and wetlands.

Supervised classification is employed to address the heterogenous characteristics of LULC in Dibrugarh district (10). 60 GSP were acquired from high resolution imagery (Google Earth Pro) for training sample and assessment of accuracy of the classified output. Producers Accuracy, User Accuracy, Overall Accuracy and Kappa Statistics has been employed to assess the accuracy of the classified outputs [11, 5]. Post-classification comparison approach was used to detect LULC changes from 2000-23. Overlay analysis of classified maps performed to get class-to-class transitions and to quantify temporal and spatial variations [Nagasa] and values were converted to percentage for better interpretation. Net change (NC) between the two time periods were calculated from previous year value to current year value. The annual rate of change was calculated using standardised formula proposed by Puyravaud [23]. Following formulae were used to calculate NC_i = Net change of class and ARI = Annual rate of change and i = class.

Net change (NC_i)

Difference between area of previous year and area of current year

$$NC_i = A_{Fi} - A_{Pi}$$

where A_{Pi} is the area of the previous year and A_{Fi} is the area of the final year.

A positive value indicates a net gain; a negative value indicates a net loss.

Annual rate of change (ARI)

Rate of change per year for class i [23]

$$ARI = NCi / T$$

where T is the total number of years between the two time periods.

2.3.2 Drivers of forest loss

To examine the drivers of forest loss, a combined spatial and socio-economic analysis was conducted. Classified LULC maps and quantified data were used to analyse the transformation of LULC and forest cover loss. Diminishing forest is mainly driven by urban expansion and agricultural encroachment. Thus, correlation between forest cover and urban built-up areas has find out. Similarly, between forest cover and agricultural area was also examined. Population statistics were used to validate population growth, migration and urban growth. Population statistics were incorporated with classes that are responsible for loss of forest cover or economic activities that were took place on earlier forested zones. Urban expansion and its related growth of services were analyzed as the growth of settlements in the forested zone, agricultural land fallow land etc. Agricultural encroachment especially tea plantation by clearing forests and on existed cropland areas. Integrated assessment of spatial analysis, information gained from key informant interviews, focus group discussions, and field observations revealed that forest loss in Dibrugarh District is mainly driven by anthropogenic factors.

3. Results and discussions

3.1 Land use and land cover classification

With growing population and agricultural expansion Dibrugarh district experiencing rapid LULC change in recent decades. A spatial and temporal pattern of LULCC dynamics is illustrated in Figs. 2 & 3 and its substantiate statistics were shown in Table 2. Diagrammatic and tabular representation, together provides a comprehensive picture of how the landscape of Dibrugarh District has changed during 2000-23 over 23 years.

Table 2
Land use land cover change dynamics in Dibrugarh district, 2000–2023

LULC classes	LULC, 2000 (Area in sq.km)	LULC, 2000 (%)	LULC, 2023 (Area in sq.km)	LULC, 2023 (%)	Net change (NCi) NCi = AFi-API	Annual rate of change (ARi) ARi = NCi / T
Agricultural Land- Crop Land-Kharif Crop	965.53	28.56	969.18	28.67	+ 3.65	+ 0.16
Agricultural Land- Crop Land-Rabi Crop	48.15	1.42	42.25	1.24	-5.9	-0.26
Agricultural Land- Crop Land-Two crop area	35.19	1.04	32.19	0.95	-3	-0.13
Agricultural Land- Plantation- Tea Garden	535.81	15.84	557.24	16.48	+ 21.43	+ 0.93
Built Up (Urban)	32.42	0.96	42.47	1.26	+ 10.05	+ 0.44
Forest-Evergreen / Semi Evergreen- Dense	192.41	5.69	162.29	4.80	-30.12	-1.31
Forest-Evergreen / Semi Evergreen- Open	159.57	4.72	142.32	4.21	-17.25	-0.75
Forest-Scrub Forest	49.11	1.45	69.29	2.05	+ 20.18	+ 0.88
Agri-plantation / Settlement	587.9	17.39	597.54	17.67	+ 9.64	+ 0.42
Water Bodies	612.09	18.12	619.11	18.31	+ 7.02	+ 0.31
River Sand	162.82	4.82	147.12	4.35	-15.7	-0.68
	3381	100.01	3381	99.99		
Source: Calculated by the author						

3.2 LULC change dynamics

Figure 2 & 3 and statistics on Table 2 shows the land use and land cover change in Dibrugarh district for 2000 and 2023. Huge changes in land statistics has occurred during these 23 years. Change in agricultural area under *kharif* crop is an increase of 3.65 sq.km. In comparison, cultivation of *rabi* crops shows a decline by 59 sq.km. Percentage of agricultural land under *kharif* crop (28.67% in 2023) is higher

than *rabi* crop (1.24% in 2023). Rice cultivation dominates the major cultivable land of the district. Therefore, concentration of *kharif* crop is high. *Rabi* crops are seen mainly cultivated along the riverbanks of the Burhi Dihing. Occurrence of floods may impel the floodplain dwellers to practice *rabi* crop along the flood prone riverbanks. Areas under two-crop cultivation are observed along the banks of Burhi Dihing (at Dibrugarh West and Tengakhat revenue circle) and the Brahmaputra (at Dibrugarh East revenue circle). Tea plantation dominates one of the major land use of the district (15.84% in 2000 and 16.48% in 2023). In contrast, forest cover of the district declining with increase in agricultural land, tea cultivation and urban built-up.

Growth of urban settlements is found in the Dibrugarh City, industrial towns of Duliajan and Namrup, and urban areas of Chabua, Naharkatia and Moran. Urban built-up area shows an increase of 10.05 sq.km during 2000-23. The district records an increase of 0.44 sq.km. annually. Apart from urban built-up, other settlement along with agriculture and tree cover at house premises rose from 587.9 sq.km (2000) to 597.54 sq.km (2023). River Brahmaputra demarcates the extreme northern boundary of the district and covers a huge land cover. In addition, one of the important tributary of the Brahmaputra- Burhi Dihing and its sub-tributaries flows through the district covers a land area of 619.11 sq.km. Area under water bodies increased by 4.02 sq.km; it indicates river capture, bank erosion in the area as the district is one of the acute riverbank erosion affected of Assam. Area under river sand is decreased by 15.7 sq.km. Figure 2 depicts a large river sand area in the extreme north-eastern boundary of the district has changed to scrub forest in the LULC map of 2023. It shows transformation of river sand area to scrub forest.

3.3 Accuracy assessment

Classified LULC classes reliability was evaluated using accuracy indicators presented in Table 3 of the accuracy assessment results. The table shows a vivid account of classification reliability by comparing reference data with classified outputs for 2000 and 2023. Collective demonstration of producer's accuracy, user's accuracy, overall accuracy and kappa statistics provides a reliable performance of the classified outputs. 60 GSPs were taken for the accuracy of the results depict in Fig. 4.

Table 3
Accuracy assessment report of land use land cover analysis of Dibrugarh district

Class name	Reference total	Classified total	Number correct	Producers accuracy	User accuracy
Water Bodies	11	12	11	100.00%	91.67%
Agri-plantation /Settlement	6	6	6	100.00%	100.00%
Dense Forest	15	14	14	93.33%	100.00%
Open Forest	8	8	8	100.00%	100.00%
Tea Gardens	16	13	13	81.25%	100.00%
Agriculture <i>kharif</i>	12	12	12	100.00%	100.00%
Agriculture <i>rabi</i>	7	9	7	100.00%	77.78%
Agriculture double crop	4	4	4	100.00%	100.00%
Scrub forest	6	6	6	100.00%	100.00%
River sand	9	9	9	100.00%	100.00%
Total	100	100	96		
Overall Classification Accuracy = 96%					
KAPPA (K [^]) STATISTICS					
Overall Kappa Statistics = 0.9554					

Table 4
Conditional Kappa for each category of LULC

Class name	Kappa value
Water Bodies	0.9064
Agri-plantation /Settlement	1
Dense Forest	1
Open Forest	1
Tea Gardens	1
Agriculture <i>kharif</i>	1
Agriculture <i>rabi</i>	0.848
Agriculture double crop	0.7611
Scrub forest	1
River sand	1

Results shows high accuracy of the classified outputs, overall accuracy of 96% and a kappa coefficient of 0.9554 indicates strong reliability between the classified map and ground sample points. Cropland under *rabi* crop had relatively low user's accuracy (77.78%) in comparison to other classes. Apart, remaining categories shows high accuracy. Therefore, classified maps and output can be use for comparable and various analysis.

3.4 Loss of forest cover

With rapid population growth, the world is experiencing decline in forest cover. For every developmental, infrastructural and economic purpose, a plot of forestland is being cleared. The district of Dibrugarh with rapid urbanization, industrial growth, increasing population, increasing demand of food massive forest land were cleared to meet these demands. This study reveals, district's only 11.05% of total geographical area is covered with natural vegetation. During 2000-23, the district forest cover is decreased by 0.81%. The district is home to two important national parks of the country – Dehing Patkai (Joypore Rainforest section) and Dibru-Saikhowa, which were mostly dominated by evergreen forests. Dense and open evergreen/ semi-evergreen forest cover is declined by 30.12 sq.km. and 17.25 sq.km. from 2000 to 2023 respectively. Scrub forests which covers a lesser greenery is increased by 0.6%. Figure 5 demonstrates the forest cover change of Dibrugarh district during 2000-23.

Figure 5 Forest Cover Change of Dibrugarh district, 2000-23

Source: Calculated by the author

3.5 Anthropogenic drivers of forest loss

For the last few centuries, human beings have been altering the face of the earth surface. Most of the LULC changes are influenced directly or indirectly by the human activities [28, 33]. Human intervention and the management of land have transformed natural landscapes into urban spaces, agricultural zones, and other forms of anthropogenic land use. Such transformations have had significant implications for forest cover, biodiversity, ecological systems, and ecosystem functioning at both local and global scales [34]. Further, expanding infrastructure, developmental projects, and extractive activities such as mining have intensified pressures on natural forest ecosystems, contributing to environmental degradation and ecological imbalance [31, 25]. India has witnessed a six-fold human population increase from 200 million to 1200 million with major transformations in LULC including forest cover, built-up area and agricultural encroachment. An assessment conducted from the period of 1880–2010, revealed significant forest loss in India of more than 26 million ha (89 million ha to 63 million ha), whereas, cropland area rose from 92 million ha to 140.1 million ha [33].

As of 2020, 14% (48000 ha) of land cover in Dibrugarh was natural forests and 9.0% was non-natural tree cover (29000 ha). From 2000-20, 2200 ha forest cover accounts 2% of districts total forest area had lost [12]. This study revealed Dibrugarh district lost 2.06 sq.km of forest area annually during 2000-23. Based on geospatial analysis, in-field data collection and published and reviewed literature revealed following were the prime drivers of forest loss in Dibrugarh district.

3.5.1 Population explosion

Population of Dibrugarh district uprising rapidly from 1901 (1,55,172) to 2011 (13,26,335). Of the total population of 2011, 10,82,605 live in rural areas and 2,43,730 in urban areas. The district has a population density of 392 people per square kilometer. The district recorded has 11.92% decadal population growth rate from 2001 to 2011. Figure 6 depicts the decadal population growth of Dibrugarh district from 1901–2011.

Figure 6 Decadal Population Growth of Dibrugarh district, 1901–2011

Source: Census of India, 2011

**Note: Census of 2021 was not conducted, due to breakdown of COVID during that time*

Increasing population is one of the major drivers of LULC transformations and forest cover loss. Increasing population demands for more shelter (settlement), food (agricultural expansion), job opportunities (industrial growth), educational and medical facilities; to meet these demands, forest lands were cleared. An inverse relation exists between growing population and loss of forest cover.

3.5.2 Agricultural expansion

Increasing population demands for more food supply. To meet this demand agricultural expansion is obvious. India - home to more than 17% of the world population in only 2% of the world's total geographical area. Several regions of the country experiencing excessive land pressure (Mosp). This

study reveals that agricultural land during 2000-23 has increased from 1584.68 sq.km (46.87%) to 1600.86 sq.km (47.35%) [Table 2]. Such expansion reveals loss of forest over in the study area.

3.5.3 Tea plantation

District's 16.48% of total geographical area is dominated by tea cultivation. Dibrugarh globally renowned as the "Tea City of India". The very first tea garden of India was established in Dibrugarh district at Chabua. Since the Colonial period, the whole district is known for its tea production. Tea are cultivated in the house premises (in the place of kitchen garden). There are 29,771 registered small tea growers in Dibrugarh district collectively cultivate approximately in 22,303 hectares of land [Tea Board of India]. This study shows increase of 0.64% in area under tea cultivation from 535.81 sq.km in 2000 to 557.24 sq.km in 2023. Annually 0.93 sq.km. land area has come under tea plantation during 2000-23 [Table 2].

3.5.4 Urbanization

Urban areas are in unprecedented rise to meet the demands of growing population, rural to urban influx and economic growth (Nath). Urbanization incorporated with providing well infrastructural facilities. Huge forest lands were cleared for development of residential, commercial, educational, medical, transportation and communication facilities. Urban built-up area of Dibrugarh district has increased by 32.42 sq.km (2000) to 42.47 sq.km (2023) [Table 2].

3.5.5 Industrial growth

Industrial growth is prime essential for economic development. Oil producing areas like Duliajan, Naharkatia are situated in Dibrugarh district. Duliajan- one of the significant crude oil producing areas of India, experiencing rapid urban growth. Namrup- an industrial town deals in petrochemical, fertilizer production, electricity generation attracts job seekers. Such industrial units demands improvement in infrastructure, space for its establishment that negatively affects the green cover of the area.

3.5.6 Infrastructure

A developed infrastructure is the backbone of a growing economy. A sound infrastructure change the scenario of an area. Dibrugarh district has a well developed infrastructural system in the field of education, medical and transportation facilities. Dibrugarh is well connected by all modes of transportation- airport (Dibrugarh Domestic Airport), railway (Dibrugarh Railway Station), roadways (AT Road, NH 37), Waterways (Muhonaghat at River Brahmaputra) and pipeways (transportation oil and gas). Assam's first medical college and hospital was established in Dibrugarh. Higher educational institutions – Dibrugarh University, top colleges of India are situated in Dibrugarh district. To provide such robust infrastructural facilities huge land is required and which were done at the cost of cutting down of trees.

3.5.7 Resettlement of flood and erosion affected displaced people

Brahmaputra runs for 95km in Dibrugarh district causing massive floods and riverbank erosion. In many circumstances, flood and erosion induced displaced people were resettled in the forest periphery region.

It further promotes encroachment into forest areas. People engaged in illegal collection of fuel wood, trade of timber etc.

3.5.8 Limited livelihood sources

Although numerous industries were grown up in the district, because of increasing population, livelihood sources became limited among the people. Many people were dependent on forest resources for their livelihood. They engaged in illegal timbering, illegal trade of medicinal plants, firewood collection etc.

3.5.9 Limited environmental awareness

Most people or community are unaware about long-term implications of deforestation while they fulfilling their short-term livelihood needs. Only a few respondents were aware about policies of forest conservations, negative environmental effects of deforestation and sustainable forest management.

4. Conclusion

Land is ubiquitous but limited resource. LULC change affecting the economic growth, quality of life, biodiversity and management of environmental resources. Thus, land management is pivotal to ensure sustainable economic growth. Land assessment is necessary for effective and scientific land use planning and ecological restoration. Spatial planning and a holistic approach is required to regulate built-up area, infrastructure development and management of eco-sensitive areas like water bodies, natural vegetation, wildlife habitat areas, wetlands, peri-urban areas, coastal and mining areas etc.

Declarations

Data availability

Landsat TM (2000) and Sentinel 2 (2023) imagery used in the study are openly available from the USGS Earth Explorer platform. Administrative boundary data were obtained from District Administration, Dibrugarh, Assam. Sample points used for ground truth were interpreted using Google Earth. All data generated or analysed during the this study are included in this published article and its supplementary information files. Interview data from key informal interviews and focus group discussions are not publicly shared due to confidentiality constraints, but anonymised summaries can be provided upon request.

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Ethics approval and consent to participate

The research was conducted in accordance with standards and approval given by the Gauhati University Institutional Ethics Committee, Guwahati. Informed consent was obtained from all participants prior to their participation in the study.

Consent to Publish

Not applicable

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Figures

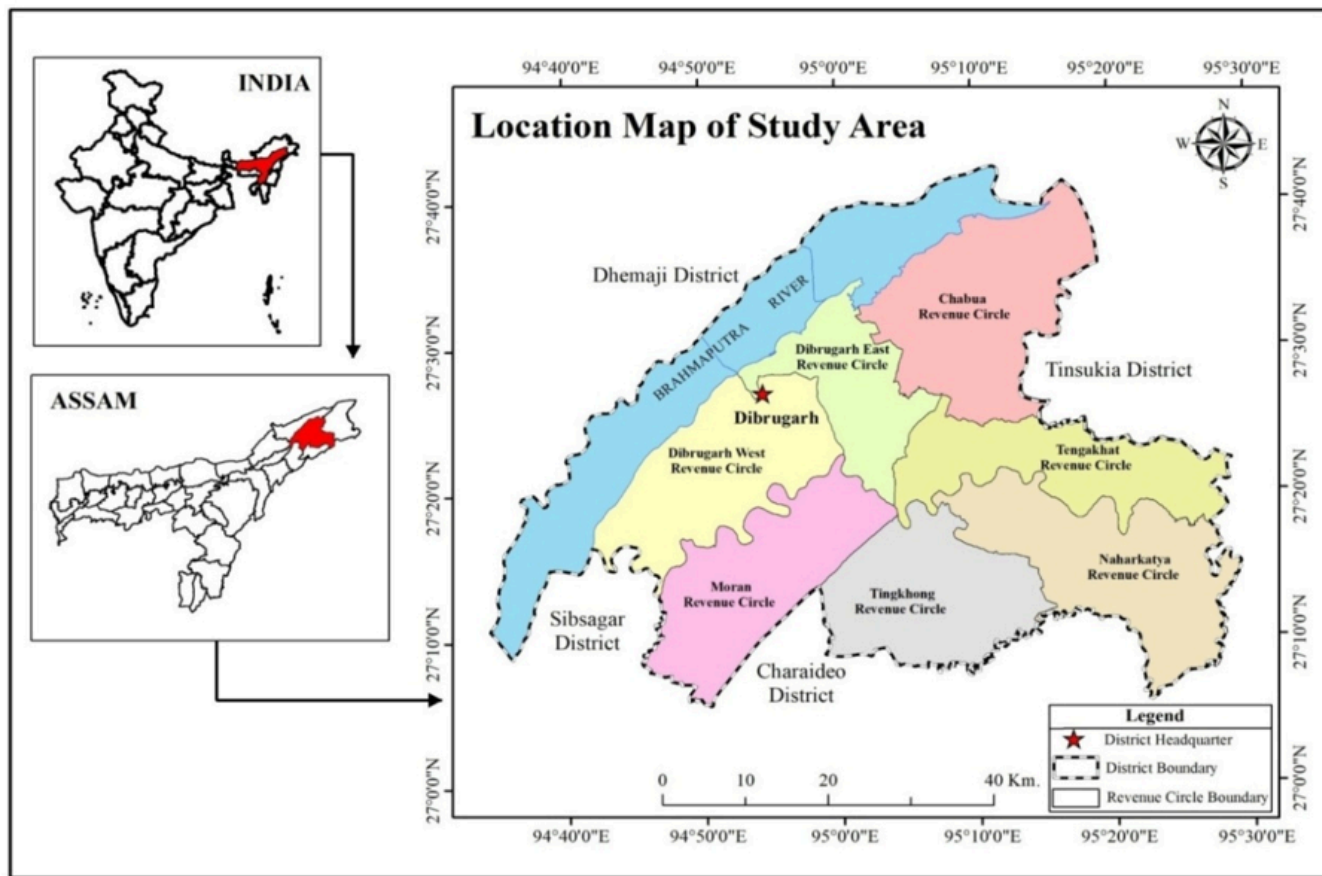


Figure 1

Location map of Dibrugarh District

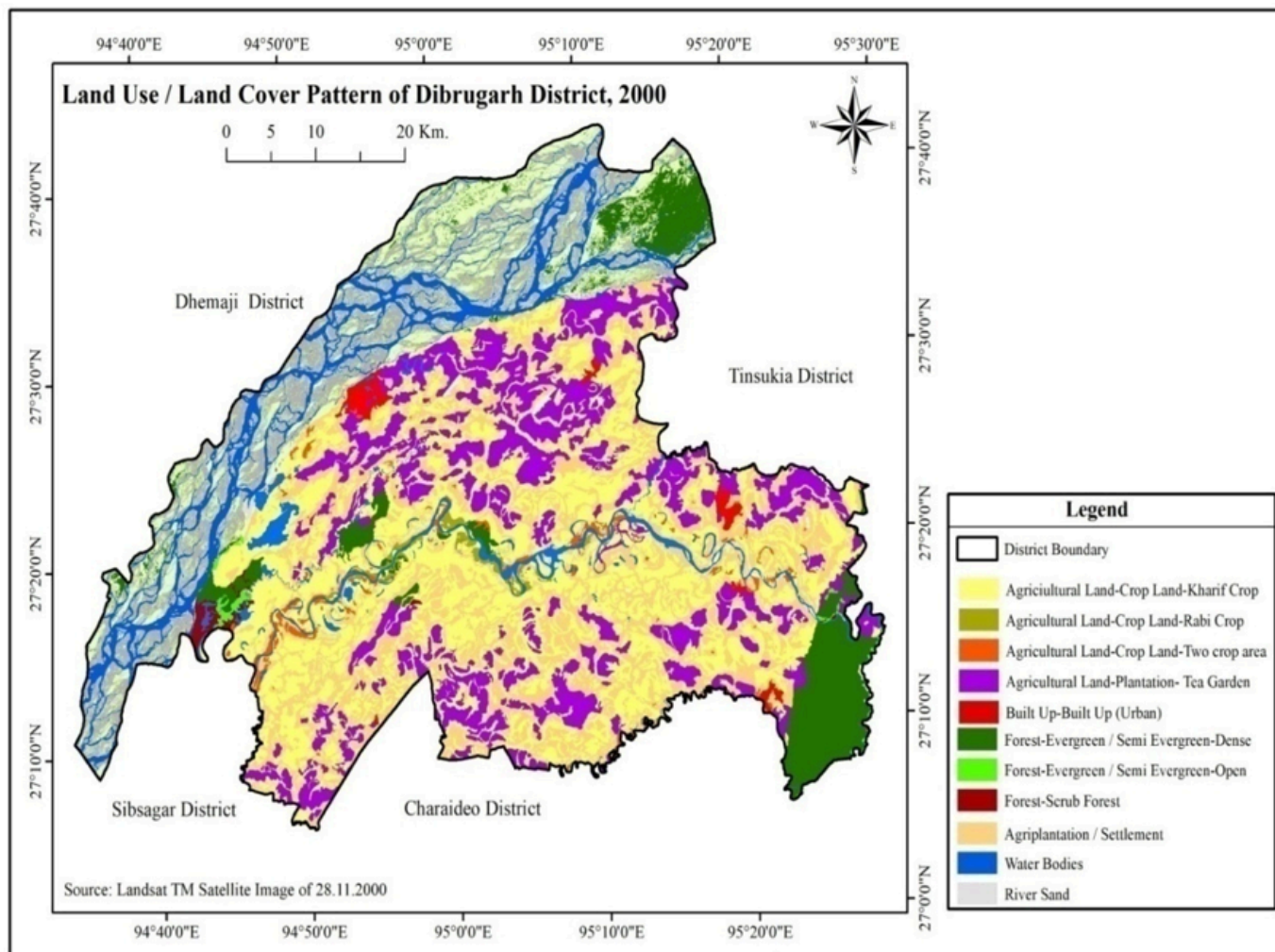


Figure 2

Land use land cover map of Dibrugarh district, 2000

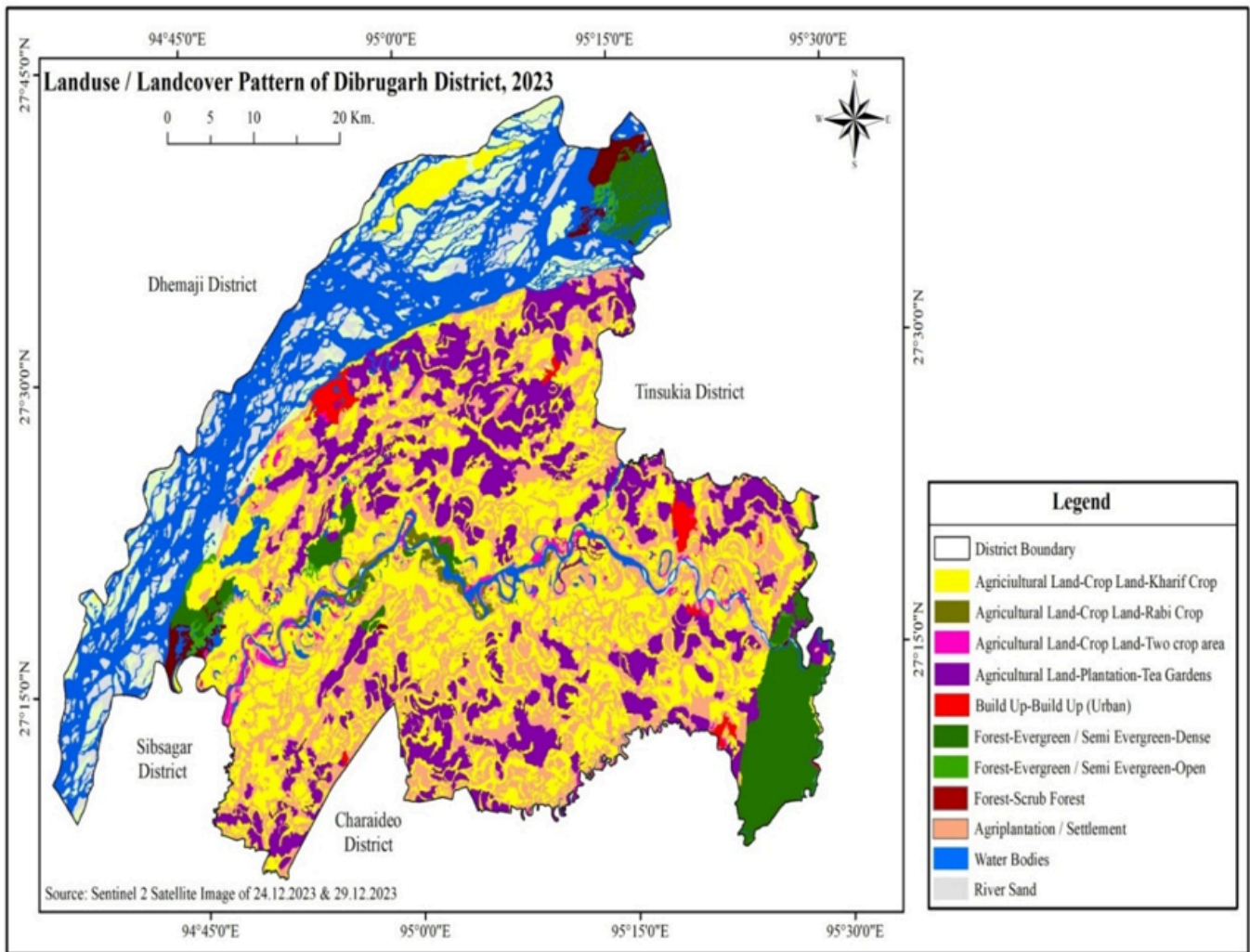


Figure 3

Land-use land-cover map of Dibrugarh district, 2023

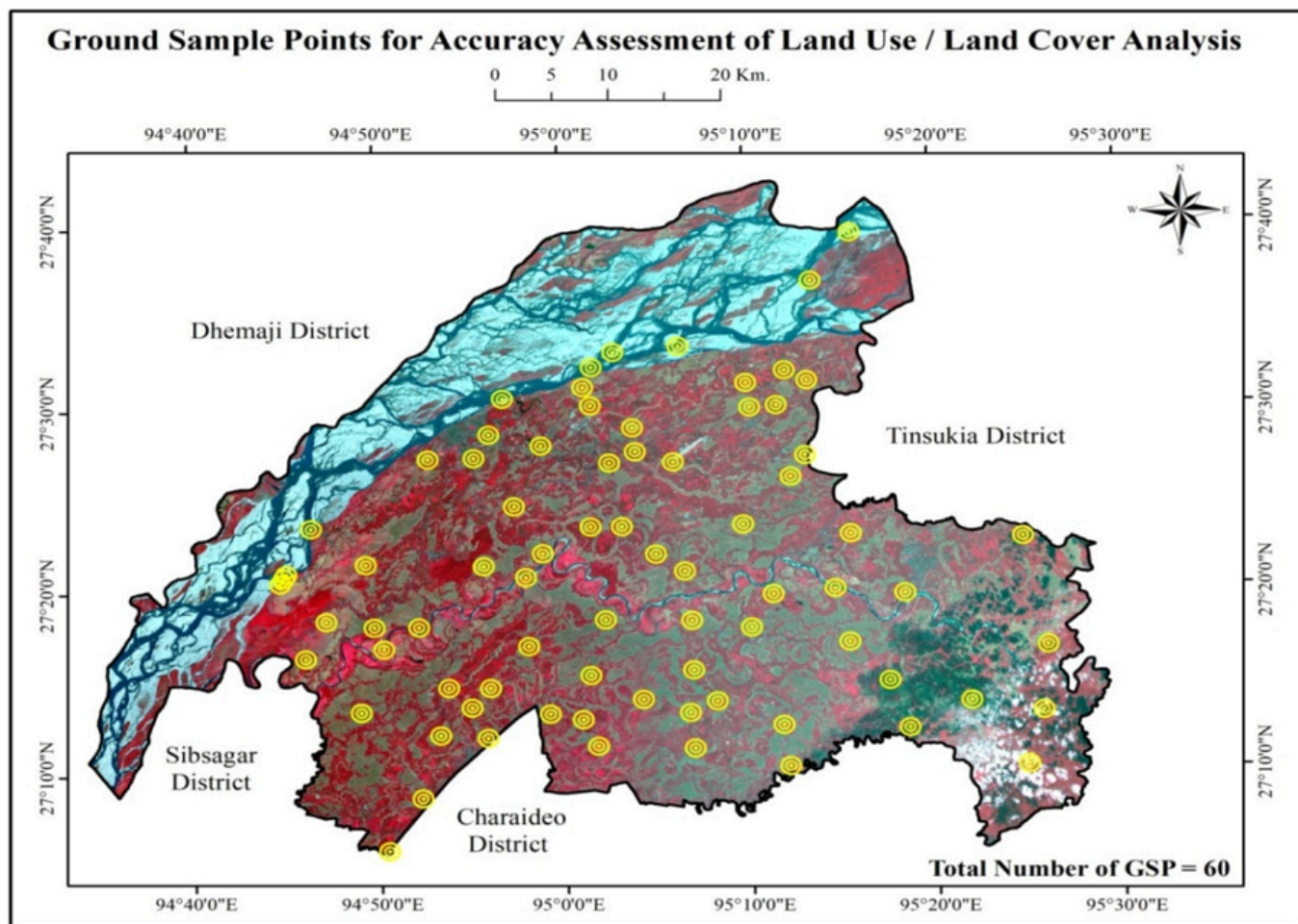


Figure 4

Ground sample points for LULC accuracy assessment

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Figure 5

Forest Cover Change of Dibrugarh district, 2000-23 Source: Calculated by the author

Image not available with this version

Figure 6

Decadal Population Growth of Dibrugarh district, 1901-2011 Source: Census of India, 2011

**Note: Census of 2021 was not conducted, due to breakdown of COVID during that time*

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- [LonkhamDatasetDibrugarhLULC.docx](#)