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Spatio-Temporal Detection of Land Use/Land Cover Changes in Kokrajhar District of Assam

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Abstract: ***The use of multi-temporal satellite images in digital change detection algorithms aids in the comprehension of landscape dynamics. This study presents the spatiotemporal dynamics of land use and land cover in Kokrajhar District, Assam, India. Landsat Satellite images of four different periods. i.e., Landsat Thematic Mapper (TM) images from 1991, 2001, 2011, and 2021 were acquired from the Google Earth Explorer site and used to quantify changes in the Kokrajhar district over the 30 years from 1991 to 2021. Supervised classification methodology has been employed using the maximum likelihood technique in the ArcMap 10.8 Software. The images of the study area were categorised into four different classes: vegetation, agriculture, built-up, and water body. The results indicate that during the last three decades, built-up regions have increased by 3.8% (658.75 km²), while agriculture, vegetation, and water bodies have decreased by 0.74% (708.9 km²), 0.56% (1494.46 km²), and 2.46% (273.5 km²), respectively.***

Key Words: Land Use/Land Cover, Change Detection, GIS, Remote Sensing, Kokrajhar

I. INTRODUCTION

Land cover encompasses the earth's surface attributes, including vegetation, water, and soil, as well as human-made features such as settlements and infrastructure. Land use delineates human activity on land, often emphasizing its economic function [1][19]. Regional LU/LC patterns reflect natural and socio-economic factors [2]. Understanding these informs optimal land utilization for meeting human needs and welfare, aiding in monitoring population-driven land use changes, Land use/cover changes, analysing gains and advantages from remote sensing's spatial and spectral resolution [3]. Integrating it with geographic data enhances accuracy, as it identifies vegetation and man-made structures through satellite imagery verified by ground truthing. Satellites enable efficient land use/cover change detection, offering rapid, cost-effective and accurate assessments [5]. Understanding landscape dynamics aids effective land management, especially for monitoring vegetation over time for gradual climate-related or dramatic human/natural changes like land conversion, crucial amidst rapid population growth, driving conversion of forest land into settlement and built-up area [6].

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Various Landsat Classification techniques aid in analysing land cover types. Unsupervised and supervised methods are standard [7]. Unsupervised relies on automatic classification without external input, but may lack accuracy [8]. Supervised involves creating signatures based on training sites for controlled classification [9]. Maximum likelihood is a widely used technique for classification [10]. The advancement of human civilization and enhanced living standards stem from the rapid exploitation of natural resources, altering global landscapes [11]. With over 80% degradation due to human activity, densely populated regions face intense repercussions [12]. Therefore, the proper concern should be made on highly populated and degraded landscapes to ensure long-lasting and suitable development as per the Sustainable Development Goals (SDGs) [13].

II. STUDY AREA

The study area (Fig. 1) in the Kokrajhar district is considered the gateway to northeastern India. The district encompasses a total area of 3,135.61 km², with a population of 887,142, as per the 2011 census. The population is comprised of 51.1% males and 48.9% females. Kokrajhar district is situated on the north bank of the River Brahmaputra, spanning longitudinally from approximately 89°27′36″ E to 90°22′48″ E and latitudinally from 26°11′24″ N to 26°32′24″ N. It shares its borders with the Himalayan kingdom of Bhutan to the north, Dhubri district to the south, Bongaigaon district to the east, and the Indian state of West Bengal to the west. The district's water needs are predominantly met by the river Gourang and its tributaries, Saralbhanga and Delpani. The district's expanse stretches from the Manas River in the east to the Sonkosh in the west. Presently, it comprises two revenue subdivisions: Kokrajhar and Gossaigaon. The river Gongia, known as Tipkai in the southern region, acts as a natural boundary between these two civil subdivisions. Gossaigaon town serves as the administrative centre of the Gossaigaon sub-division. Characterized by a humid subtropical climate typical of the lower Brahmaputra Valley of Assam, the district experiences abundant rainfall and high humidity levels. It boasts the largest concentration of forests in the state. The soil within the district is rich and conducive to paddy cultivation. Natural dongs and canals channel water for irrigation, sourced primarily from flowing water originating in the hills of Bhutan, trickling down along the foothills and reserve forests within the district. These Bhutanese hills also serve as the origin of several rivers coursing through the district, acting as tributaries to the formidable Brahmaputra, which flows from east to west far beyond the southern bounds of Kokrajhar district.

Among the significant rivers that traverse from north to south are the Champamati, the Gaurang, the Tipkai, and the Sonkosh, all of which derive their waters from the Bhutan hills. The district's soil composition varies, ranging from sandy textures in riverbeds to clayey consistency in different areas. Sedimentary rocks predominate throughout the district, with the southernmost region featuring two small hills comprising metamorphic rocks. Forest cover stands out as a defining feature of the Kokrajhar district, with reserved forests estimated to cover approximately 1,719 km². Despite historical records indicating that around 55% of the district's total geographical area is designated as reserved forest [4].

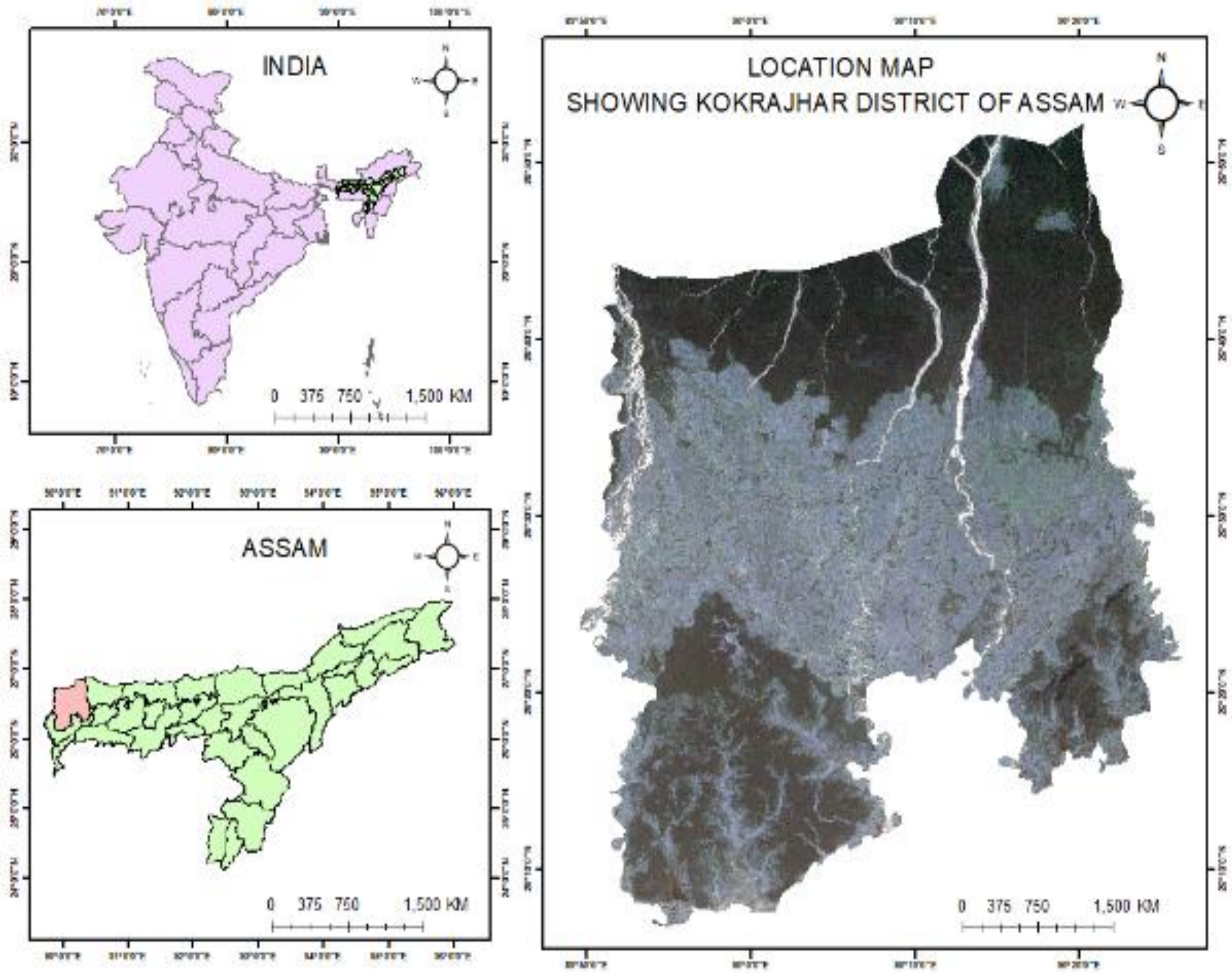

Fig 1: Location Map of the Study Area- Kokrajhar district, Assam

III. RESEARCH MATERIALS AND METHODS

The present study involves secondary data from various sources. Furthermore, to understand the changing pattern of land use and land cover, three satellite images from LANDSAT for the years 1990, 2005, and 2019 have been downloaded from the USGS Earth Explorer (Table 1).

Table 1: Types of Satellite Data Used in the Study

Satellite	Sensor	Path/Row	Acquisition Date	Spatial Resolution
Landsat 4-5	TM C2L1	138/41 138/42	19/12/1991 19/12/1991	30 30
Landsat 4-5	TM C2L1	138/41 138/42	02/04/2001 02/04/2001	30 30
Landsat 4-5	TM C2L1	138/41 138/42	08/11/2011 08/11/2011	30 30
Landsat 8-9	OLI/TIRS C2L1	138/41 138/42	21/12/2021 21/12/2021	30 30

Source: *USGS Earth Explorer, available at: https://earthexplorer.usgs.gov, date of access: 26/04/2024*

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A supervised classification method has been employed to classify the satellite images using the ArcGIS 10.8 Software and the Imagine software. In this regard, ground verification has also been conducted using an extensive GPS-based survey and Google Earth to confirm the results obtained for different land use characteristics. Hence, a detailed methodology is presented in the flow chart in Figure 2 below.

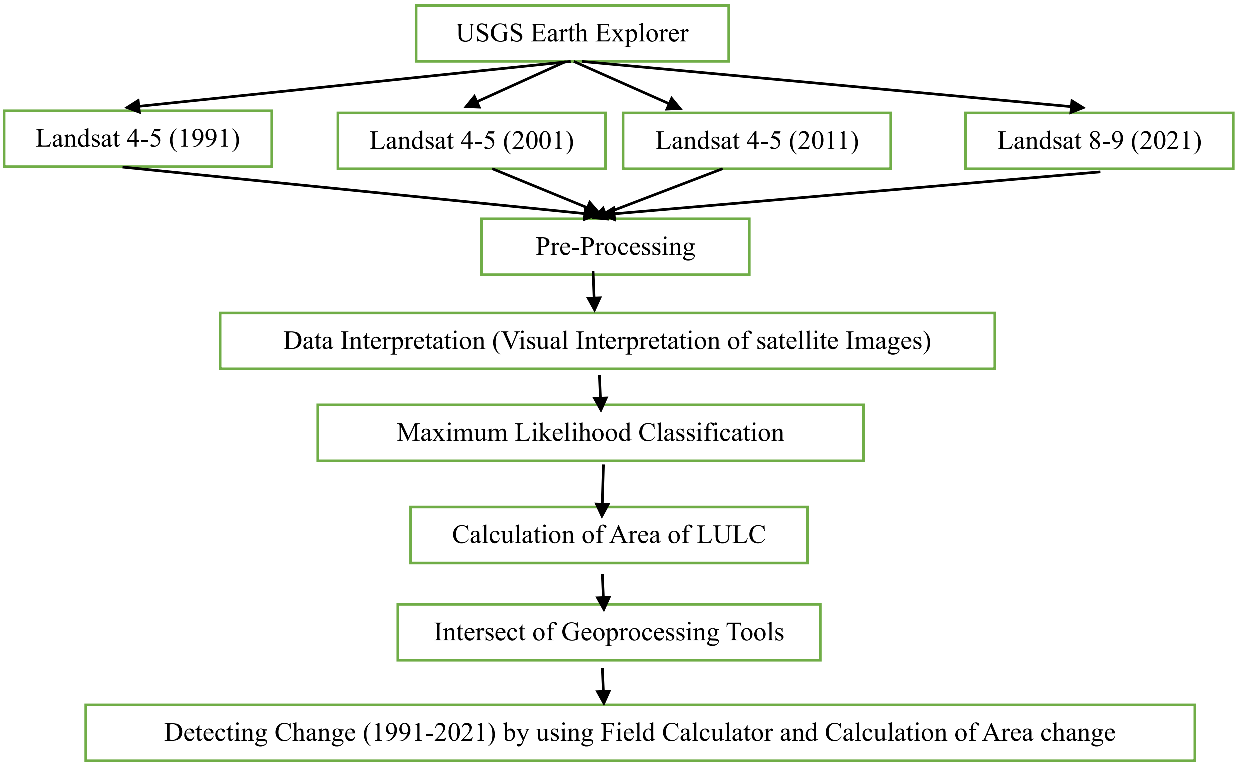

Fig 2: Methodology Prepared by Author

IV. RESULT AND DISCUSSION

A. LULC Pattern of Kokrajhar District

Fig. 3 shows the LULC map layout, created in 1991 from Landsat 4-5 TM data, which displays different land use categories. According to this survey, vegetation (1512.56 km^2, or 48.23% of the total studied area) is the largest land use group, and agriculture (732.38 km^2, 23.35% of the total area) is the second-largest land use group. The other land use classifications are waterbody (350.84 km2, 11.18% of the total area) and built-up area (539.83 km2, 17.21%). The figure also shows the LULC map layout, created in 2001 from Landsat 4-5 TM, which has been used to develop the categorised picture for 2001. Vegetation (1339.50 km^2, 42.72% of total area) and agriculture (791.23 km^2, 25.23% of total area) dominated the land area in 2001, according to the statistics. Built-up area (666.63 km^2, 21.26% of the total area) and waterbody are the other land use categories (338.26 km^2, 10.79% of the total area). Additionally, for the year 2011, the data reveal that 1297.46 km^2 (41.38%) is the area under vegetation, 872.07 km^2 (27.81%) is the area under agriculture, 780.76 km^2 (24.90%) is the area under built-up, and 185.32 km^2 (5.91%) is the area under water bodies. During the year 2021, the area under these categories was approximately 1494.46 km^2 (47.67%) under vegetation, 708.9 km^2 (22.61%) under agriculture, 658.75 km^2 (21.01%) under built-up areas, and 273.5 km^2 (8.72%) under water bodies. The present study focuses on how growth phenomena affect the natural environment of Kokrajhar district. Temporal analysis of data about land use and land cover classes for the years 1991-2021 has been used to aid this [14]. Additionally, as a result of the growing demand for land for residential, commercial, and infrastructure development, [15] there is an uneven rate of encroachment of natural resources and corresponding environmental deterioration due to rapid urban expansion.

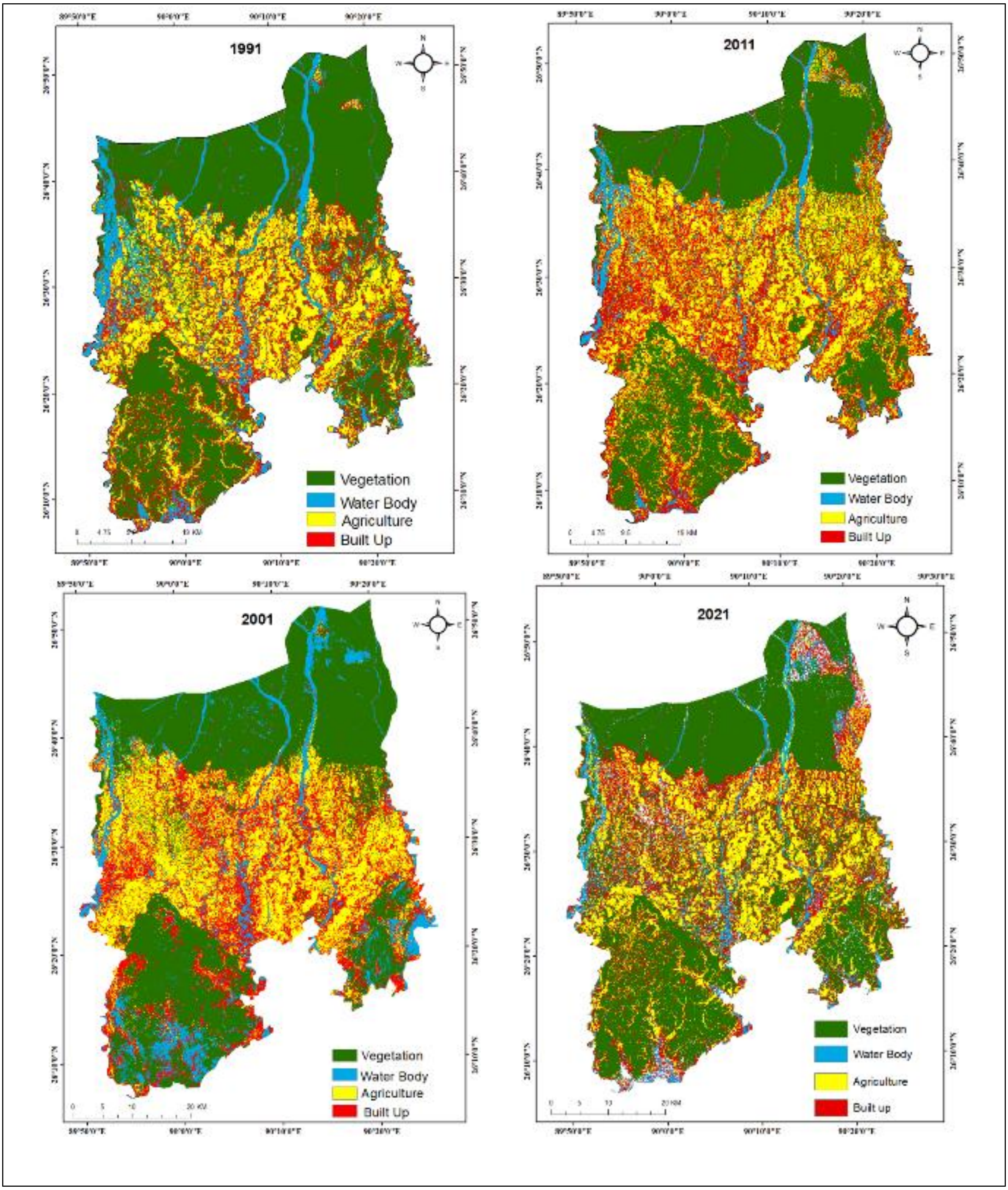

Fig 3: Changing Land Use/Land Cover in Kokrajhar District (1991–2021)

B. LULC Change Detection from 1991 to 2021

Fig. 4 contains the computed land use and land cover change detection. Vegetation and water bodies decreased by 18.1 km² and 77.34 km², respectively, and the agricultural field decreased by 23.48 km². On the other hand, the built-up area has increased by 118.92 km² between 1991 and 2021. The percent change (%) for the built-up area is the highest, 3.8%.

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Table 2: Area and Amount of Change in Different Land Use/Cover Categories in Kokrajhar District During 1991 to 2021

LU/LC	1991		2001		2011		2021		Change (1991-2021)	
	Area km^2	%	Area km^2	%	Area km^2	%	Area km^2	%	Area km^2	%
Vegetation	1512.56	48.23	1339.50	42.72	1297.46	41.38	1494.46	47.67	-18.1	-0.56
Water Body	350.84	11.18	338.26	10.79	185.32	5.91	273.5	8.72	-77.34	-2.46
Agriculture	732.38	23.35	791.23	25.23	872.07	27.81	708.9	22.61	-23.48	-0.74
Built Up	539.83	17.21	666.63	21.26	780.76	24.90	658.75	21.01	118.92	3.8
Total	3135.61	100	3135.61	100	3135.58	100	3135.61	100	0	0

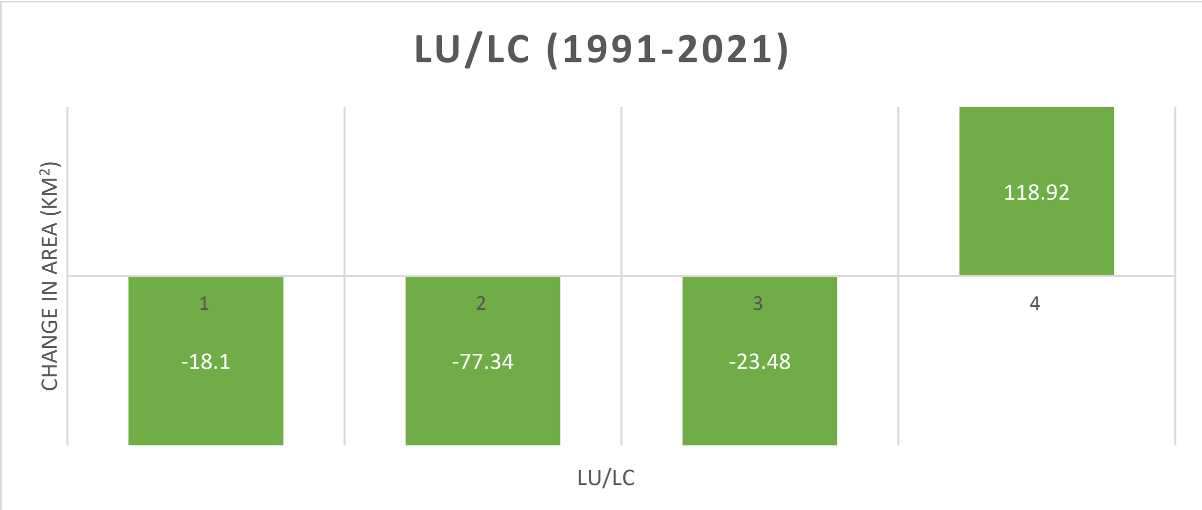
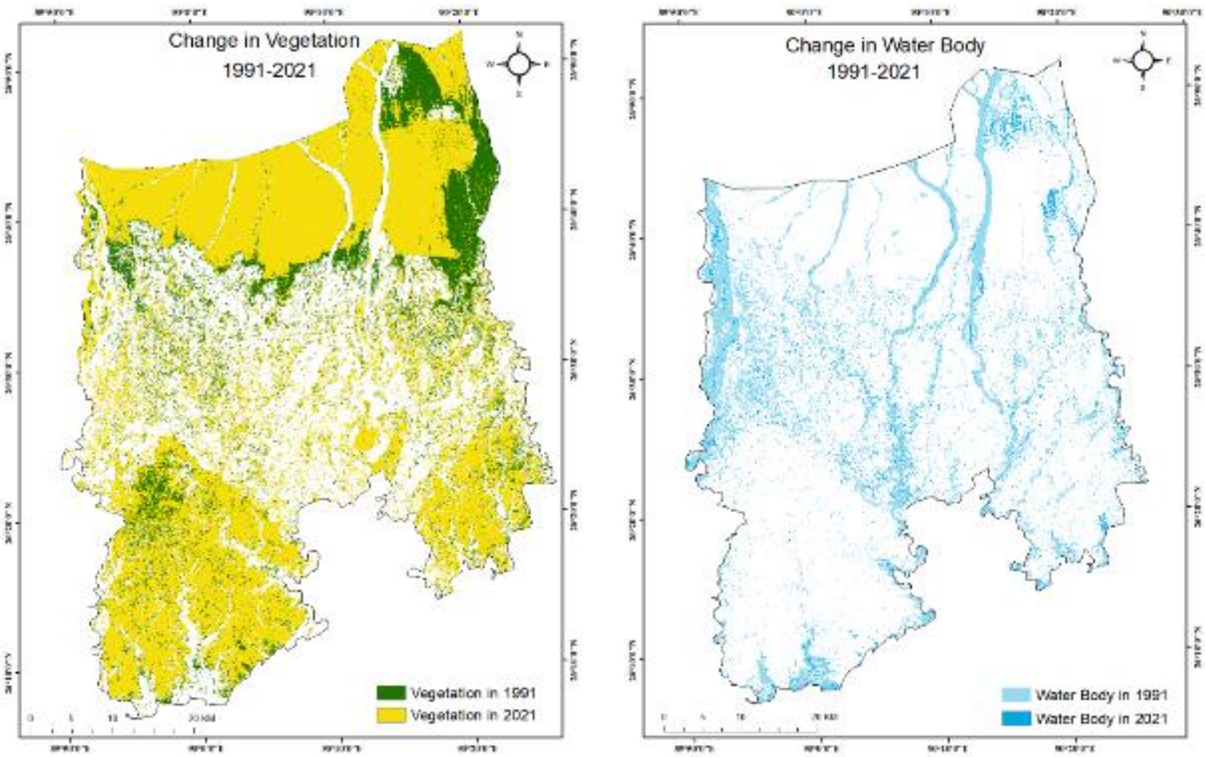


Fig 4: LULC Change Detection from 1991 to 2021

C. Discussion



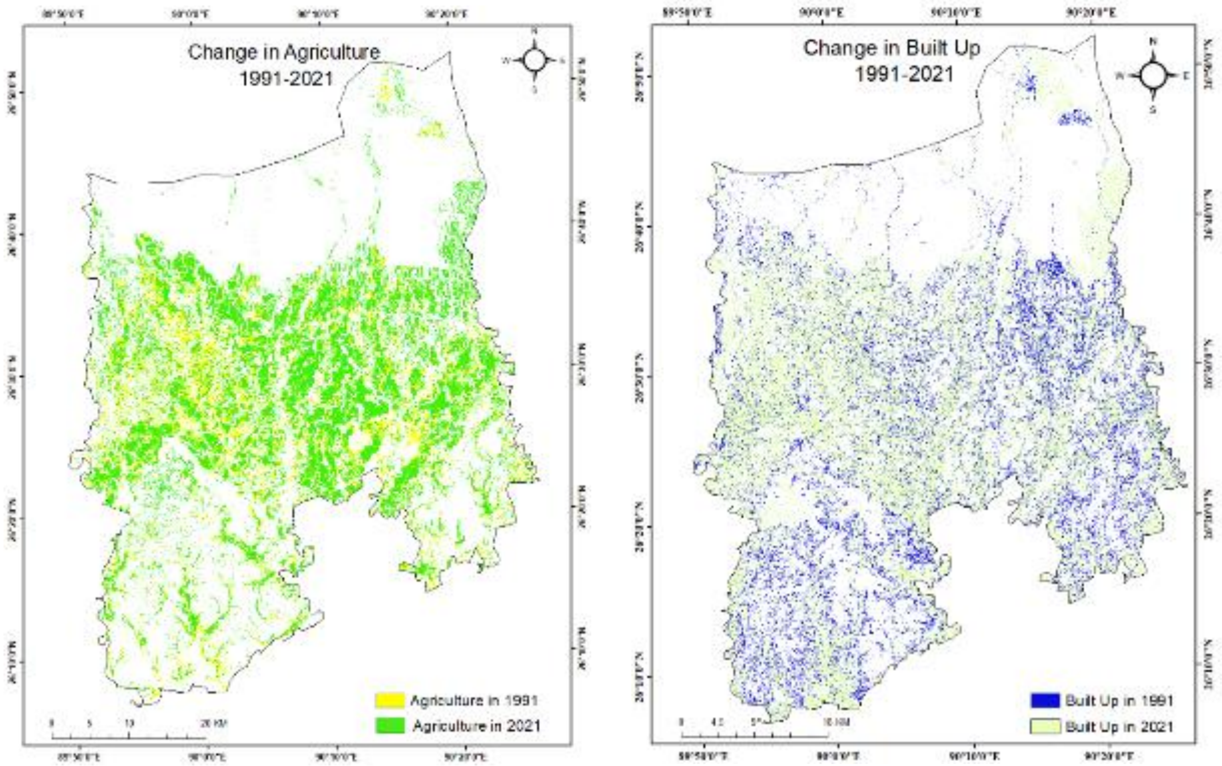


Fig 5: Area Change of LU/LC Classification (1991-2021)

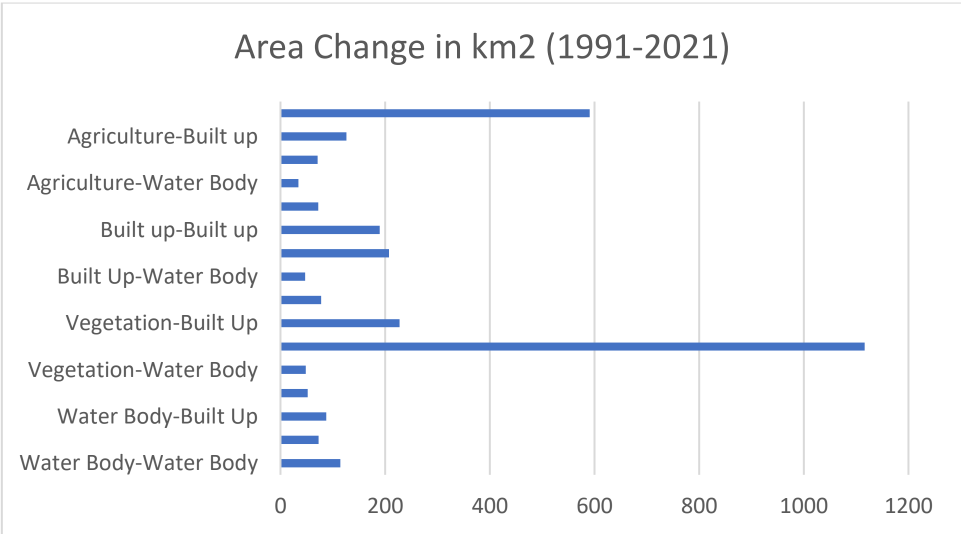


Fig 6: Area Change of LU/LC Classification (1991-2021)

a. Change in Vegetation

Figures 5 and 6 illustrate the dynamic changes in the Kokrajhar district area. In 1991, areas covered in dark green denote vegetation, while those in yellow represent the same areas in 2021. The diagram vividly portrays shifts in land use, with the most significant change occurring from vegetation to vegetation, with 1116.3 km². The transition from water bodies to vegetation accounts for 72.6 km², while the reverse shift from vegetation to water bodies encompasses 48.2 km². Additionally, there's a substantial conversion from vegetation to built-up areas, covering 227.4 km², and from vegetation to agriculture, covering 77.6 km². Conversely, there's notable reversion from built-up areas to vegetation, spanning 207.1 km², and from agriculture to vegetation, covering 70.8 km². The shift from agricultural land to vegetation is notable, attributed to the inclusion of various grasslands, planted gardens and shrublands in the vegetation class, resulting in increased vegetation cover. The phenomenon of deforestation, driven by factors such as agricultural expansion, logging and infrastructure development [16].

b. Change in Water Body

Figures 5 and 6 illustrate changes in land area within Kokrajhar district. In 1991, the light blue regions denote water bodies, while the dark blue areas represent water bodies in 2021. The diagram illustrates shifts in land use, showing that the area is composed of water bodies, vegetation, built-up areas, and agricultural areas, covering 114.4 km², 72.6 km², 87.5 km², and 52.3 km², respectively.

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Conversely, transitions from vegetation, built-up areas, and agriculture into water bodies encompass 48.2 km², 47.3 km², and 34.4 km², respectively. The discernible trend of human encroachment may be attributed to the decline in water bodies, potentially stemming from practices such as filling ponds and wetlands for residential and commercial development [17]. This phenomenon could also be influenced by climate change, including factors such as rising temperatures, droughts and decreased rainfall. Moreover, increased land values may have incentivized the conversion of marshlands into alternative properties. While overall wetland areas are decreasing, specific regions may experience an increase, possibly due to the growing popularity of activities like fish farming.

c. Change in Agriculture

Figures 5 and 6 illustrate the changes in land area within the Kokrajhar district. In 1991, the yellow areas represent agricultural land, while the green areas depict agrarian land in 2021. The diagram provides a clear depiction of transitions in land use, indicating that the area changes from agriculture to water bodies, vegetation, and the built-up regions, accounting for 591.2 km², 34.4 km², 708 km², and 126.1 km², respectively. Conversely, transitions from vegetation, built-up areas, and water bodies into agriculture encompass 77.6 km², 72 km², and 52.3 km², respectively. Rapid urbanization plays a significant role in the conversion of agricultural land into residential and commercial areas. As cities expand, they encroach upon surrounding farmland, resulting in a reduction of overall farmland areas. Economic factors such as changes in market demand, fluctuations in commodity prices, or shifts in agricultural subsidies can also influence land use decisions made by farmers [18]. It is essential to acknowledge that while agricultural land expansion can contribute to food security and economic growth, it also has environmental consequences, including deforestation and habitat loss. Therefore, balanced land use planning is essential to mitigate these impacts and ensure sustainable development.

d. Change in Built-up Area

Figures 5 and 6, depicting changes in land area in Kokrajhar district, offer valuable insights into the region's urbanisation and land use dynamics. The transition from dark blue areas, representing built-up areas in 1991, to light green areas denoting built-up areas in 2021, highlights a significant increase in urban development over the past three decades. One notable aspect revealed by Diagram 6 is the substantial conversion of water bodies into built-up areas, covering an area of 87.5 km². This conversion signifies the encroachment of urban development into previously natural areas, potentially leading to ecological disruptions and loss of water resources. Furthermore, the transition from vegetation to built-up areas, encompassing 227.4 km², highlights the impact of urban expansion on green spaces and natural habitats. This conversion not only reduces the area covered by vegetation but also contributes to habitat fragmentation and biodiversity loss. The reversion from built-up areas to water bodies and vegetation, accounting for 47.3 km² and 207.1 km², respectively, indicates some level of urban redevelopment, possibly through infrastructure projects or land reclamation efforts. However, it is essential to assess the environmental implications and sustainability of such transformations [19]. The significant conversion from agricultural land to built-up areas, covering 126.1 km², reflects the pressures of urbanisation and population growth on agricultural land. As the demand for residential, commercial, and industrial spaces increases, rural-to-urban migration and the conversion of agricultural land accelerate, leading to the expansion of built-up areas. Overall, the analysis highlights the complex interplay between population dynamics, economic growth and land use changes in Kokrajhar district. Sustainable urban planning and conservation efforts are crucial to mitigate the adverse environmental impacts of rapid urbanization and ensure the long-term well-being of the region's ecosystems and communities.

V. CONCLUSION

In this study, LULC detection of Kokrajhar district over the last four decades has been analysed. The study's results showed significant changes during the study period. The built-up area showed an increasing trend of 118.92 km², or 3.8%, while vegetation, water bodies, and agricultural fields showed a decreasing trend of 0.56%, 2.46%, and 0.74%, respectively. The provided analysis underscores the significant impact of land use land cover (LULC) dynamics on various aspects of the environment and local communities within the basin. The conversion of forest, bushland and grassland into agricultural and residential areas is highlighted as a key driver of environmental change, potentially leading to issues such as alterations in streamflow patterns, soil degradation and disruptions to the hydrological system [19]. These changes not only pose challenges for sustainable resource management but also have implications for the livelihoods of the local society, indicating the importance of addressing these issues proactively. The utilization of change detection analysis employing GIS and remote sensing is identified as a valuable tool for understanding the seasonal patterns of LULC dynamics.

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Ethical Approval and Consent to Participate	No, the article does not require ethical approval or consent to participate, as it presents evidence.
Availability of Data and Materials	Not relevant.
Authors Contributions	All authors have equal participation in this article.

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AUTHOR PROFILE

Jeshmi Machahary is a doctoral student of the Department of Geography, Gauhati University, Assam, India. I have completed my Master's degree in Geography with a specialisation in Human Geography. I have attended several workshops, including Awareness-cum Capacity Building Workshop organised by Assam Climate Change Management Society (ACCMS), Application of Statistical Techniques in Geo-Spatial Analysis: Theory and Practice, organised by DST-SERB Sponsored National Level Workshop, and Modern Surveying and Mapping Techniques, organised by NRSC (ISRO) sponsored Workshop Modern Surveying and Mapping Techniques. I have presented my research work at the 43rd and 44th IIG Annual Meetings and International Conferences (held at Osmania University and Cotton University), as well as the 30th Biennial Conference of the North East India Geographical Society (NEIGS), and an ICSSR-sponsored National Seminar.