International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-13 Issue-6, May 2024

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

Jeshmi Machahry

***Abstract:** The use of multi-temporal satellite images in digital change detection algorithms aids in the comprehension of landscape dynamics. The present study illustrates the spatio-temporal dynamics of land use/land cover of Kokrajhar district of Assam, India. Landsat Satellite imageries of four different time periods. i.e., Landsat Thematic Mapper (TM) of 1991, 2001, 2011 and 2021 were acquired from Google Earth Explorer site and quantify the changes of Kokrajhar district from 1991 to 2021 over a period of 30 years. Supervised classification methodology has been employed using maximum likelihood technique in ArcMap 10.8 Software. The images of the study area were categorised into four different classes namely vegetation, agriculture, built up and water body. The results indicate that during the last three decades, built up have been increased by 3.8% (658.75 km^2) while agriculture, vegetation and water body have been decreased by 0.74 (708.9 km^2) %, 0.56(1494.46 km^2) % and 2.46 (273.5 km^2) % respectively.*

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

I. INTRODUCTION

Land cover encompasses earth's surface attributes like vegetation, water, and soil, including human-made features like settlement. Land use delineates human activity on land, often emphasizing its economic function [1][21]. 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 advantages from remote sensing's spatial and spectral resolution [3][26]. Integrating it with geographic data enhances accuracy, identifying 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 forest land into settlement and built up area [6].

Various Landsat Classification techniques aid in analysing land cover types. Unsupervised and supervised methods are common [7]. Unsupervised relies on automatic classification without external input, but may lack accuracy [8]. Supervised involves creating signatures baed 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 reg regions face intense repercussions [12]. Therefore, the proper concern should be made on highly populated and degraded landscape to ensure long-lasting and suitable development as per the Sustainable Development Goals (SDGs) [13][25].

II. STUDY AREA

The study area (Fig. 1) in the district of Kokrajhar is considered as the gateway to northeastern India. The district encompasses a total area of 3135.61 km^2 with population of 887,142 as per the census, 2011 with males comprising 51.1% and females 48.9%. Kokrajhar district is situated on the north bank of the river Brahmaputra, spans 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 sub-divisions: Kokrajhar and Gossaigaon. The river Gongia, known as Tipkai in the southern region, acts as a natural boundary between these two civil sub-divisions. Gossaigaon town serves as the administrative center 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.

Manuscript received on 18 April 2024 | Revised Manuscript received on 24 April 2024 | Manuscript Accepted on 15 May 2024 | Manuscript published on 30 May 2024.
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Among the significant rivers traversing from north to south are the Champamati, the Gaurang, the Tipkai, and the Sonkosh, all deriving 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 Kokrajhar district, with reserved forests estimated to cover approximately 1719 km^2. Despite historical records indicating that around 55% of the district's total geographical area is designated as reserved forest [4].

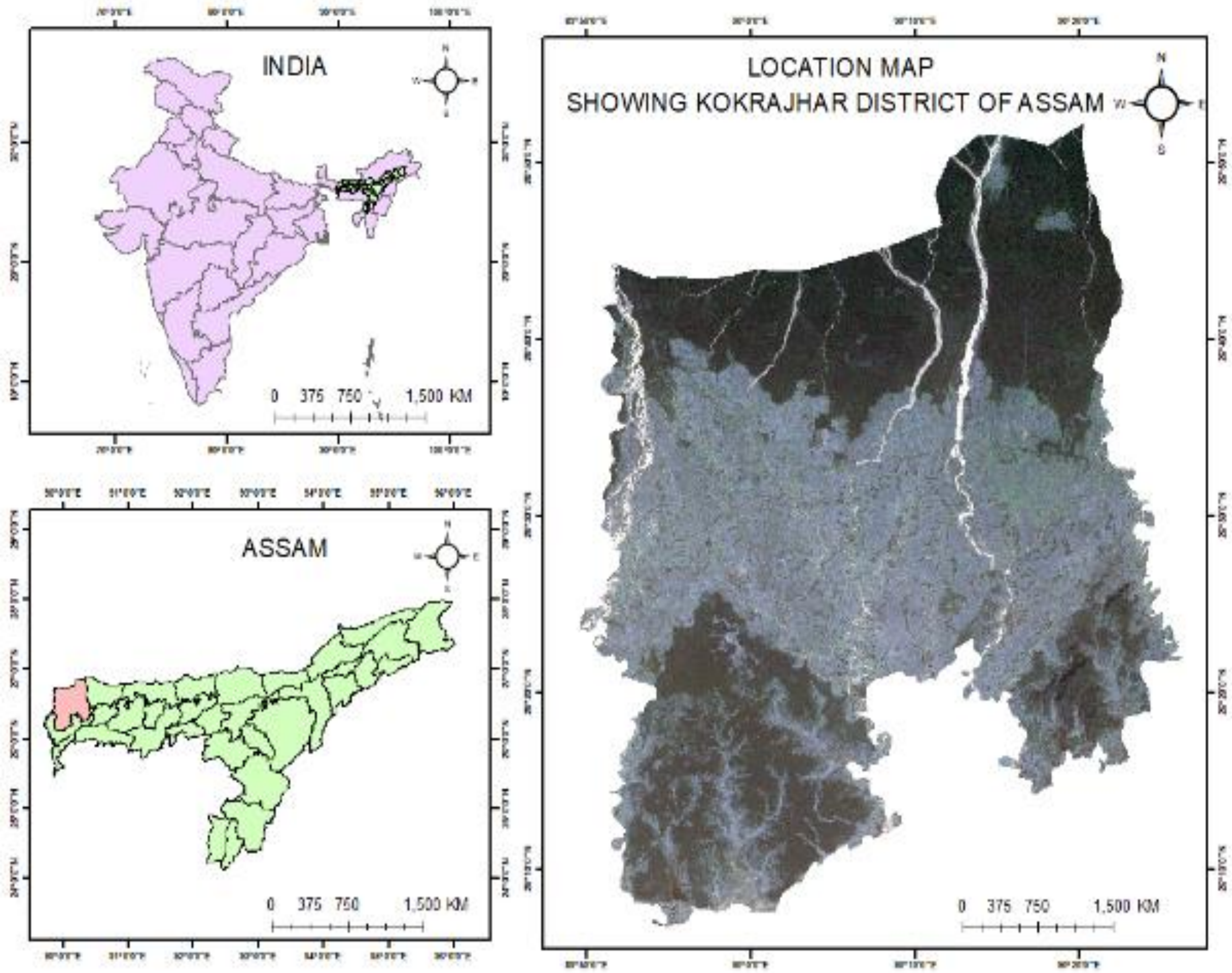

Fig 1: Location Map of the Study Area- Kokrajhar district, Assam

III. RESEARCH MATERIALS AND METHODS

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

Table 1: Types of Satellite Data Used in the Study

Satellite	Sensor	Path/Row	Acquisition Date	Saptial 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*

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

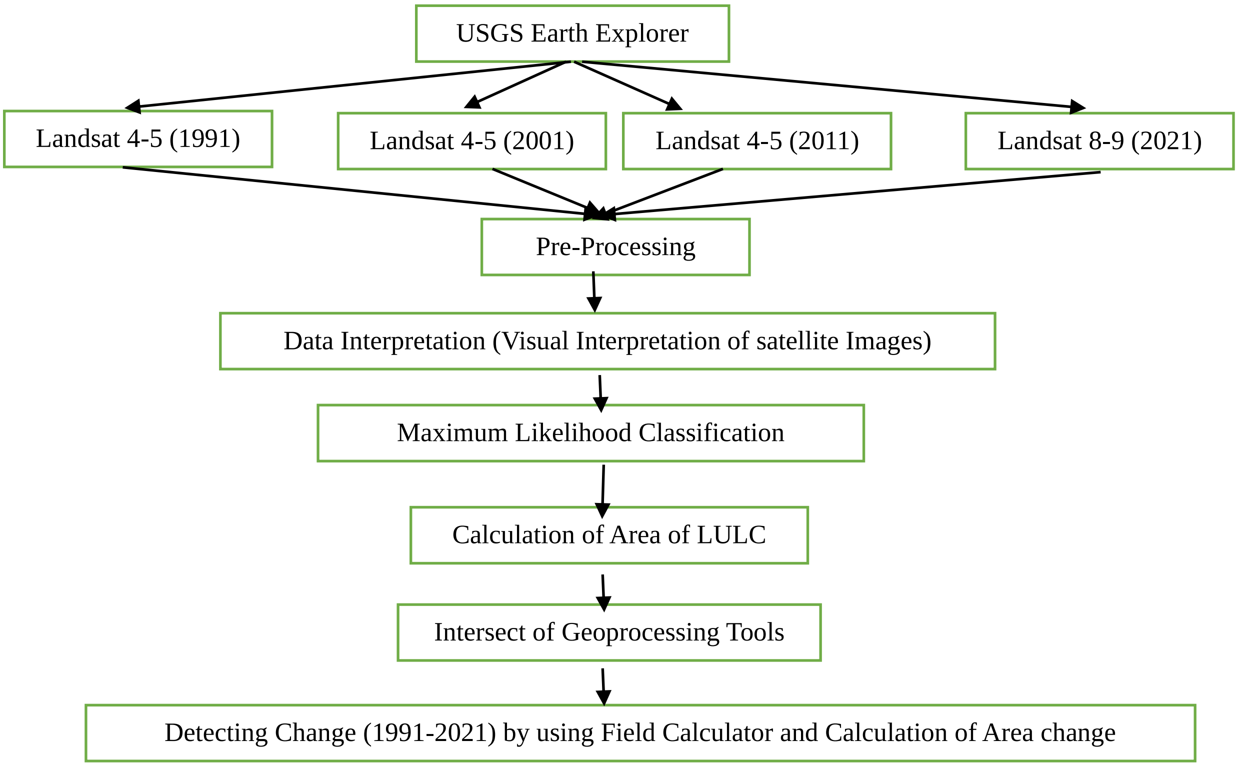

Fig 2: Methodology Prepared by Author

IV. RESULT AND DISCUSSION

A. LULC Pattern of Kokrajhar District

Fig. 3 shows the LULC map layout, 1991 created from Landsat 4-5 TM showing 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 classification waterbody (350.84 km^2, 11.18% of the total area), and built-up area (539.83 km^2 or 17.21%). The figure also shows the LULC map layout, 2001 created from Landsat 4-5 TM has been used to create the categorized 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 total area), and waterbody are the other land use categories (338.26 km^2, 10.79% of the total area). Additionally, it shows for the year 2011, the data reveal that 1297.46 km2 (41.38%), area under vegetation, 872.07 (27.81%), area under agriculture, 780.76 km2 (24.90%) area under built-up and 185.32 km2 (5.91%), area under water body. During the year 2021 the area under these categories was found about 1494.46 km2 (47.67%) under vegetation, 708.9 km2 (22.61%) under agriculture, 658.75 km2 (21.01%) under built-up area, 273.5 km2 (8.72%) under water body. The present study focuses on how growth phenomena affect the natural environment of Kokrajhar district. Temporal analysis of data pertaining to 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.

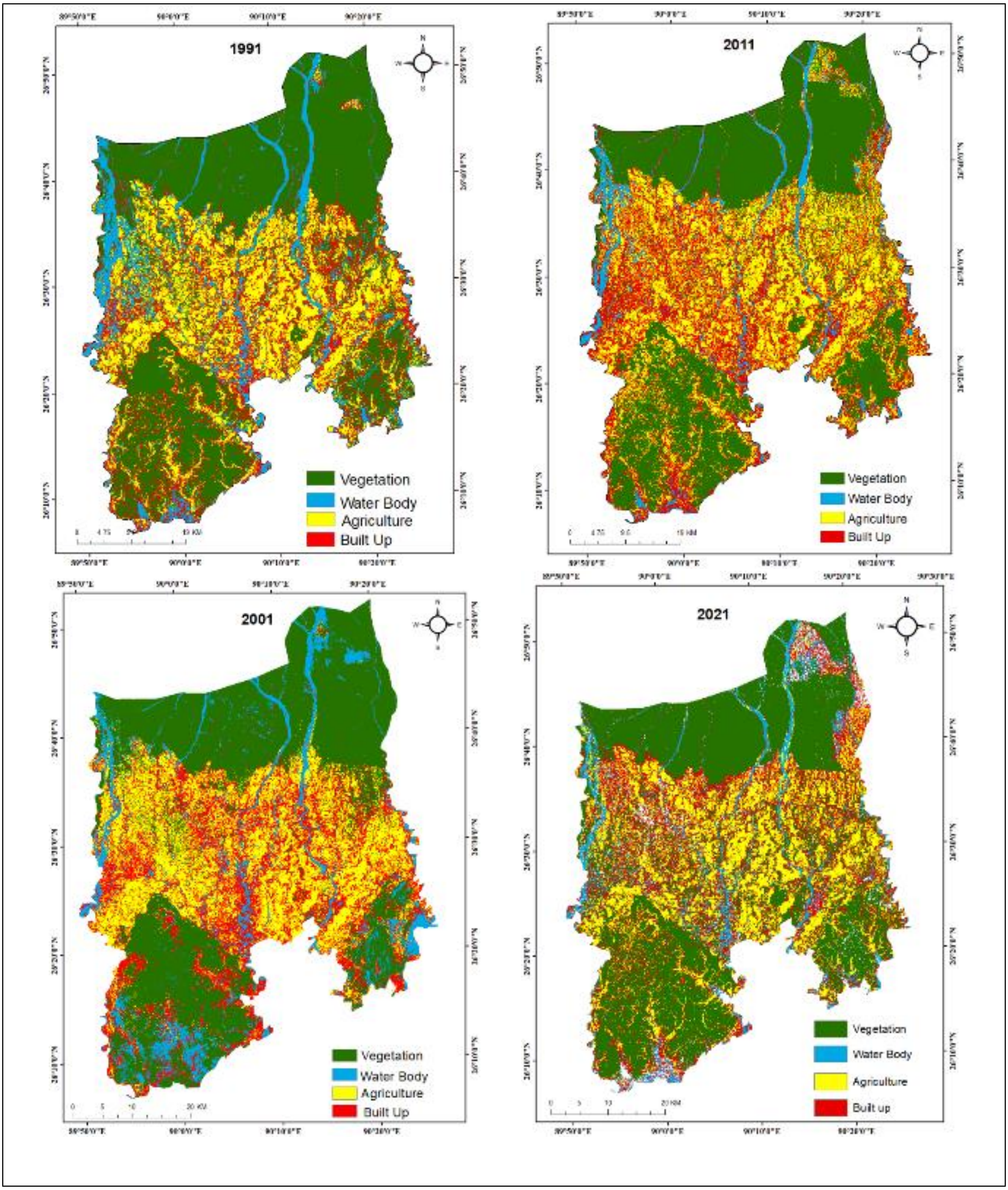

Fig 3: Changing Land Use/Land Cover in Kokrajhar District (1991–2021)

B. LULC Change Detection from 1991 to 2021

Fig. 4 contains the computed land use and land cover change detection. Vegetation, water body mostly decreased by 18.1 km^2 and 77.34 km^2 respectively as well as the agricultural field has also decreased by 23.48 km^2. On the other hand, built-up area has increased by 118.92 km^2 between 1991 to 2021. The percent change (%) for the built-up area is the highest, 3.8%.

Retrieval Number: 100.1/ijitee.F987213060524
DOI: 10.35940/ijitee.F9872.13060524
Journal Website: www.ijitee.org

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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

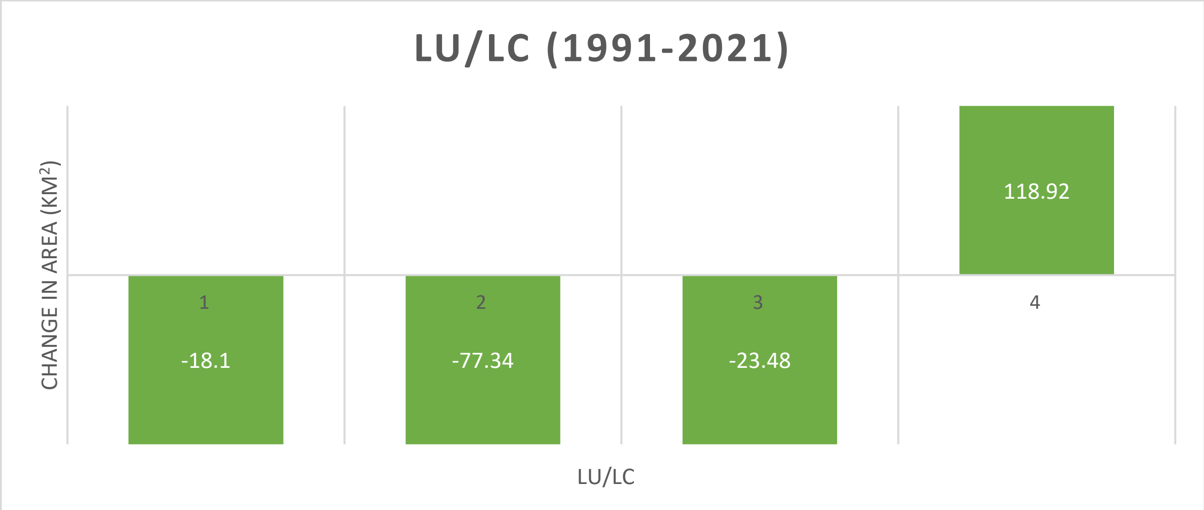
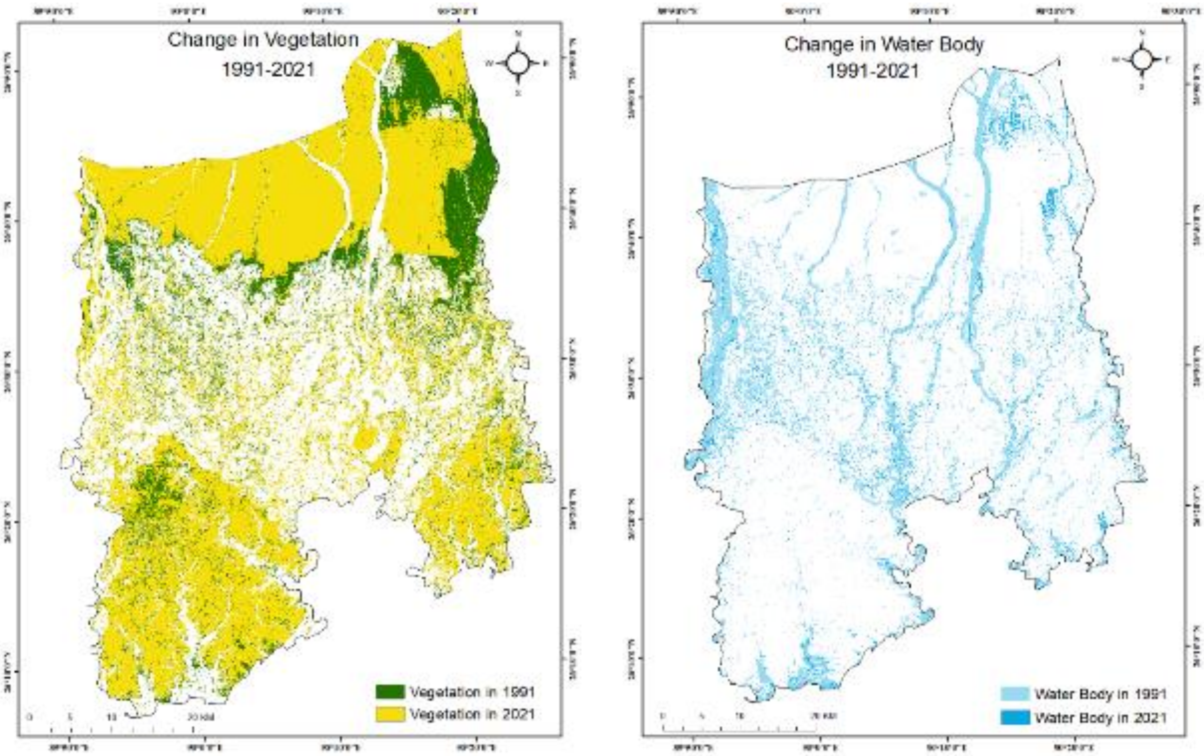


Fig 4: LULC Change Detection from 1991 to 2021

C. Discussion



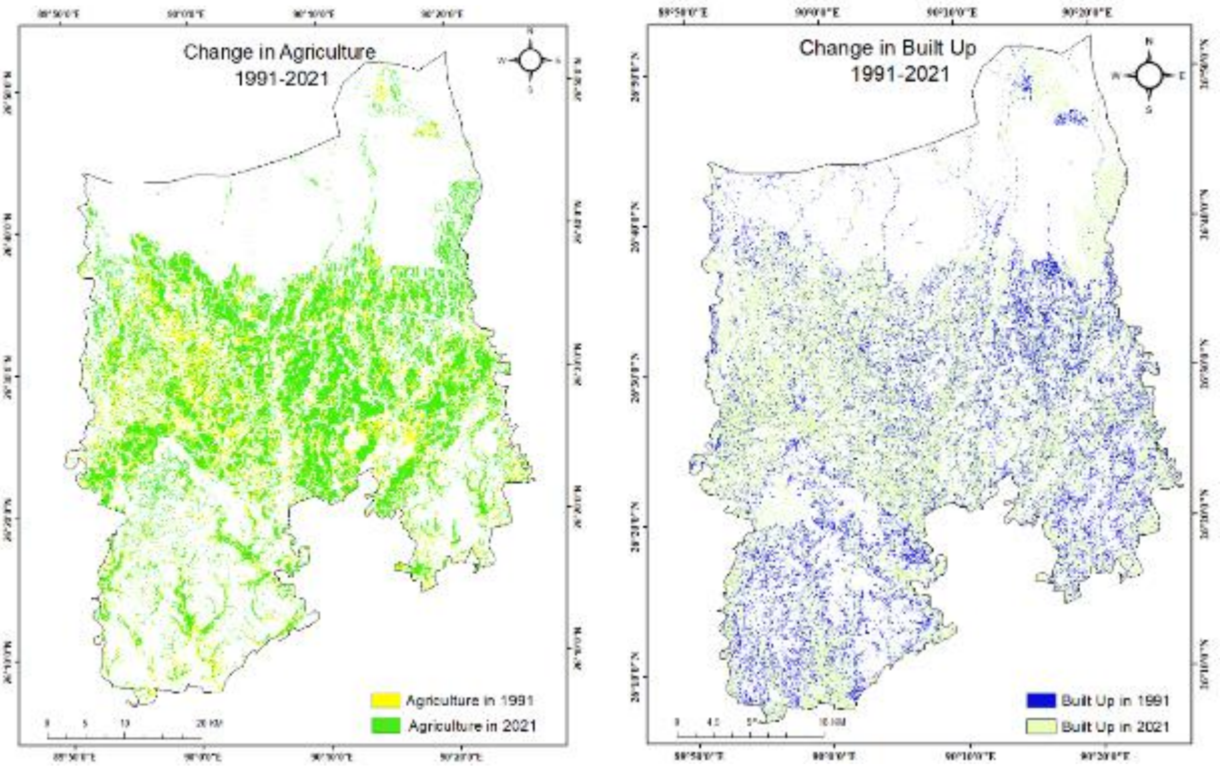


Fig 5: Area Change of LU/LC Classification (1991-2021)

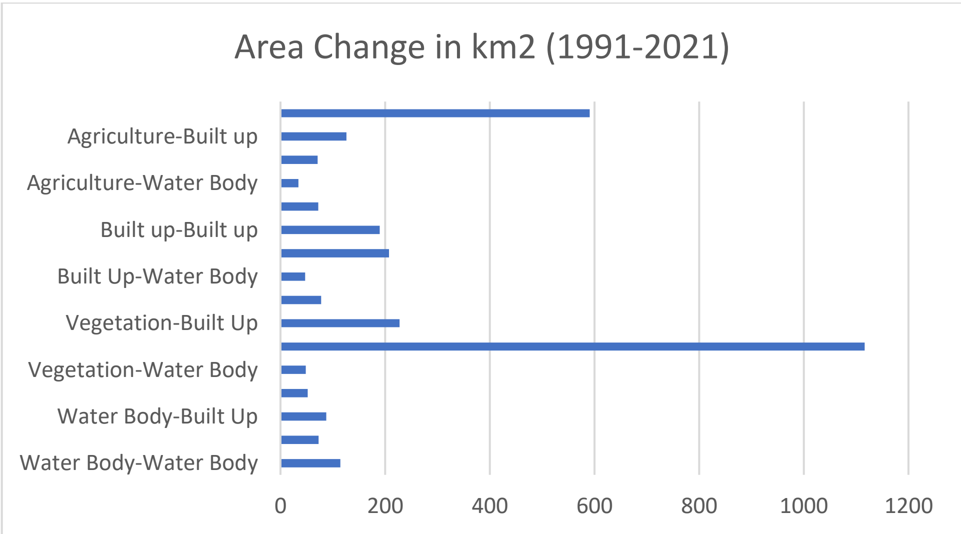


Fig 6: Area Change of LU/LC Classification (1991-2021)

a. Change in Vegetation

The Figure 5 & 6 illustrates the dynamic changes in the area of Kokrajhar district. In 1991, areas covered in dark green denote vegetation, while those in yellow represent vegetation in 2021. The diagram vividly portrays shifts in land use, with the most significant change occurring from vegetation to vegetation, with 1116.3 km^2. Transitioning from water bodies to vegetation accounts for 72.6 km^2, while the reverse shift from vegetation to water bodies encompasses 48.2 km^2. Additionally, there's a substantial conversion from vegetation to built-up areas, with 227.4 km^2 and from vegetation to agriculture, covering 77.6 km^2. Conversely, there's notable reversion from built-up to vegetation, spanning 207.1 km^2 and from agriculture to vegetation, covering 70.8 km^2. 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

The figure 5 & 6 illustrates changes in land area within Kokrajhar district. In 1991, the light blue areas denote water body, while dark blue areas represent water body in 2021. The diagram indicates shifts in land use, revealing that the area changes from water body, vegetation, built-up and agriculture accounts to 114.4 km^2, 72.6 km^2, 87.5 km^2 and 52.3 km^2 respectively.

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Journal Website: www.ijitee.org

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Conversely, transitions from vegetation, built-up and agriculture into water body encompass 48.2 km^2, 47.3 km^2 and 34.4 km^2 respectively. The discernible trend of human encroachment may be attributed to the decline in water body, 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, possible due to growing popularity in activities like fish farming.

c. Change in Agriculture

The Figure 5 & 6 illustrates the changes in land area within Kokrajhar district. In 1991, yellow areas represent agricultural land while green areas depict agricultural land in 2021. The diagram provides a clear depiction of transitions in land use, indicating that the area changes from agriculture to agriculture, water body, vegetation and built-up areas accounts to 591.2 km^2, 34.4 km^2, 708 km^2 and 126.1 km^2 respectively. Conversely, transitions from vegetation, built-up areas and water body into agriculture encompass 77.6 km^2, 72km^2 and 52.3 km^2 respectively. Rapid urbanization plays a significant role in the conversion of agricultural land into residential and commercial areas. As cities, they encroach upon surrounding farmland, resulting in a reduction of overall agricultural land 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][23][24]. It is important to recognize that while agricultural land expansion can contribute to food security and economic growth, it can also have 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

The Figure 5 & 6 depicting changes in land area in Kokrajhar district offers valuable insights into the region's urbanization 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 the diagram 6 is the substantial conversion of water bodies into built-up areas, covering 87.5 km^2. 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, accounting 227.4 km^2, underscores 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 reversions from built-up areas to water body, vegetation and built-up areas, accounting 47.3 km^2, 207.1 km^2 and 189.8 km^2 respectively, indicate 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 [21]. The significant conversion from agriculture to built-up areas, covering 126.1 km^2, reflects the pressures of urbanization 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 [19].

V. CONCLUSION

In this study, LULC detection of Kokrajhar district over the last four decades had been analysed. The result of the study showed that significant change detection had observed during the study. Built-up area showed an increasing trend of 118.92 km2 or 3.8%, while vegetation, water body and agricultural field 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 issue such as alternations in streamflow patterns, soil degradation and disruptions to the hydrological system [20]. 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.

DECLARATION STATEMENT

Funding	No, I did not receive.
Conflicts of Interest	No conflicts of interest to the best of our knowledge.
Ethical Approval and Consent to Participate	No, the article does not require ethical approval and consent to participate with evidence.
Availability of Data and Material	Not relevant.
Authors Contributions	All authors have equal participation in this article.

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