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Spatial and Temporal Analysis of Land Use / Land Covers Changes Using Remote Sensing and GIS: A Case Study from Bijoy River Basin, Tripura, India

Masimalai Palaniyandi [a++*] and Dibakar Mahato [a]

[a] *Department of Geography & Disaster Management, Tripura University (A Central University), Suryamaninagar, Agartala, Tripura (West), PIN: 799 022, India.*

Authors' contributions

This work was carried out in collaboration between both authors. Author MP has conceived the concept, designed the study, planned the work, did data interpretation, and drafted the whole manuscript. Author DM performed the field and laboratory studies including data collection, image analysis, and preparation of tables, maps and diagrams. Both authors read and approved the final manuscript.

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[++] *Associate Professor (Remote Sensing and GIS, Applied Climatology, Spatial /Environmental Epidemiology, Health and Medical Geography, Land Use / Land Cover Studies, RS & GIS to Disaster Management, Geo-Statistics, Environment and Ecology)*
**Corresponding author: E-mail: palaniyandimasimalai@tripurauniv.ac.in;*

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ABSTRACT

Better understanding of land use / land covers changes in the transformation at the local, regional, and the national level provides guidelines for planning, management and monitoring developmental programs. The study area namely; Bijoy river basin is located from Northeastern part of the Tripura State in India, is mostly pretentious by LULC changes including deforestation, settlement encroachment swampy land filled, Jhum cultivation, rubber plantation etc., The increase or decrease of the geographical areal unit of each land use / land cover categories are analyzed. Mapping the spatial and temporal aspects of land use/land cover changes for the period of 20 years at five years interval from 2003 to 2023 is carried out using Landsat TM 4, 5, 6, 7, and 8 OLI/TIRS satellite data with the aid of QGIS software. The LULC are delineated that built-up area is steadily increased, signifying the growth and development of residential, commercial, and industrial regions from 1.573101 to 6.662455. The area under agricultural lands declined affectedly, indicating a conversion of agricultural lands to other land uses, such as urbanization or industrialization and rubber plantation from 34.37884 to 24.16139, and the forest cover declined from 35.83747 to 27.46631, indicating that factors such as agricultural development, urbanization, or illicit logging have contributed to deforestation. There has been a significant rise in the area covered by rubber plantations from 4.084427 to 25.86129, suggesting that commercial rubber cultivation has spread throughout the region. The area covered by water bodies is decreased from 7.012693 to 5.835399. The area under open ground dropped from 9.66931 to 7.395732, which could be a sign that different development activities are using open areas. The amount of barren land fell from 20.44768 to 2.479626, most likely as a result of various land uses such as urban expansion, agriculture, and plantations, and the area under brick chambers increased from 0.028178 to 0.137806, indicating a rise in infrastructure development and construction activity. Significant changes in land use / covers brought out by industrialization, urbanization, infrastructure growth, and the agricultural expansion. Increased rubber plantations, and building extension activities are caused a decrease in agricultural land, forest cover, water bodies, and open bare grounds.

Keywords: Digital mapping; land use / land covers; spatial and temporal analysis; Landsat TM; Remote Sensing and GIS; image classification; LU/LC change detection.

1. INTRODUCTION

Mapping of land use/land cover (LULC) categories and its changes are most important for rural development and urban planning. Land use /land cover classification has been interchangeably but has unique term of each meaning. In order to maintain a sustainable ecosystem, it is vital to monitor and identify changes in land use and covers [1], soil texture and soil erosion in different altitudes with land use / land cover [2], bio diversity, infectious diseases and vector ecology [3] as these factors play a significant role in our knowledge of how human activities interact with the environment. An essential component of the natural resources database study is the examination of land use and land cover changes [4]. Since it is regarded as a crucial component for modelling and comprehending the properties of the planet, knowledge of land use and land covers data is requisite for rural and urban planning and sustainable developments [5]. The present study is made to mapping of land use / land covers in the Bijoy River basin of Tripura State, India, and the geographical area covers 408.8 Sq. Km. One of the Tripura's small River Basins is called Bijoy river basin. Bijoy River originated from Baramura hill range which is located from Northeastern part of the state. Most of the basin area affected by land use Land covers conversion i.e., Deforestation, settlement Encroachment swampy land filled, Jhum cultivation, Rubber plantation etc., As a result, increases susceptibility of climate change, global warming, local ecological imbalance etc.

The land use / land cover classifications are analysed using Landsat TM satellite data for the period of 2 decades at the 5 years interval. The LULC characteristics are delineated with QGIS software. Land use / land cover is prepared for the study area which includes built-up land, open bare grounds, agricultural land, water bodies, forest cover, rubber plantations, and barren land. An effective approach to land use planning at both the macro and micro levels could be achieved by combining data on land use / land covers information on other natural resources, such as ground water, soil types and texture,

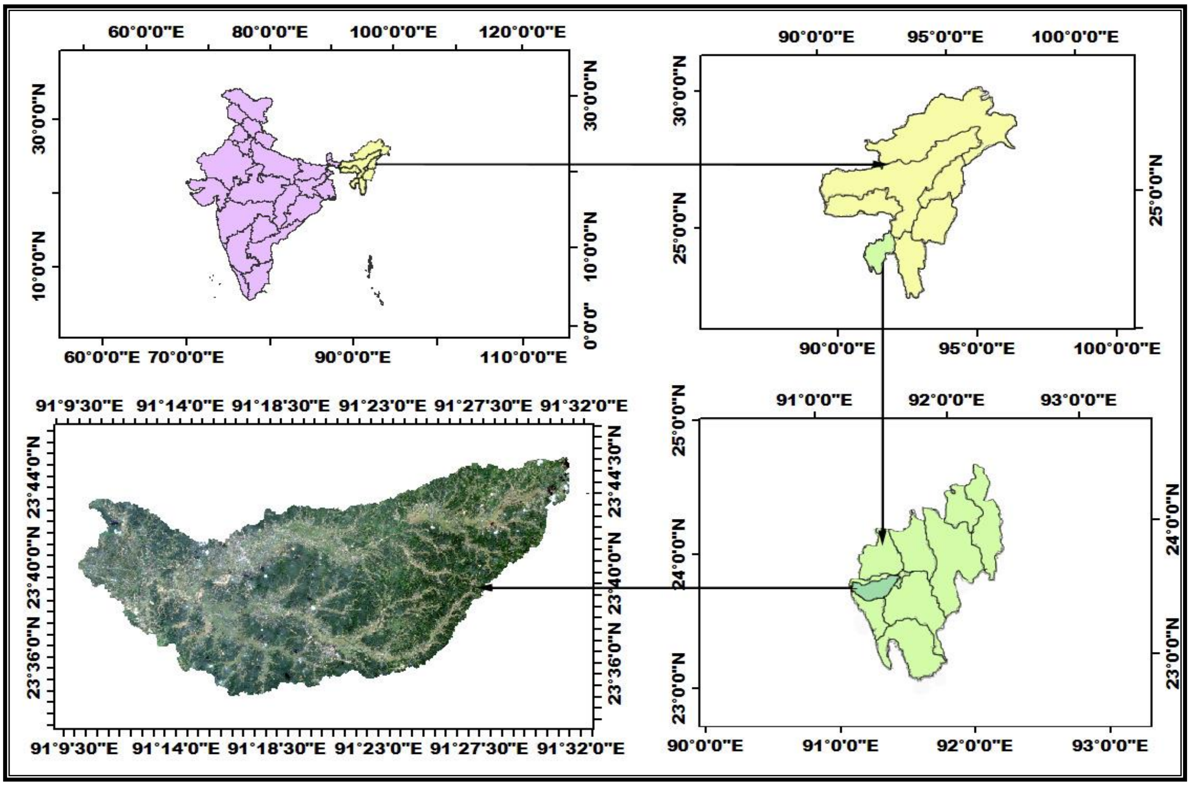

Fig. 1. Study area- Bijoy River Basin

hydro-geomorphology, landscape terrain, etc., [6-9], and thus, the present study is made to study the spatial and temporal changes in land use / land covers assist to assess the future trends also could be formed as the datum to prepare a guidelines for land management [10].

1.1 Study Area

Bijoy river basin is situated in the Sepahijala district of Tripura State, and it is geographically extended from 23° 46’ 21’’N to 23° 33’ 50’’ N latitudes, and 91° 34’ 26’’E to 91° 12’ 00’’ E longitude (Fig. 1). Bijoy river basin has two major tributaries Burigang and Rangapani. Among these two, Burigang is the longest right bank tributary of the Bijoy Nadi which is originated from Baramura range and come as a name of Gangraichara at Burmabari Village. Initially, it is running in the upper river basin in the name of Burigung till it reaches Chhaigharia village. Rangapani as a left bank tributary which has measured to 63 km. Rangapani is flowing from a dense bamboo jungle at the elevation of 73m from MSL, and flows for a distance of 35km. Both the tributaries are meeting in the Krishna Kishore Nagar village, afterwards, the river is called Bijoy Nadi and has flow of westward direction for a distance of 9 km, and finally, it is entering into the Bangladesh at Putia Village.

2. OBJECTIVES

To mapping the spatial and temporal aspects of land use/land covers changes over the period of 20 years from 2003 to 2023. The following objectives are included in the present study.

1. To mapping land use/ Land cover classification for 2003, 2008, 2013, 2018, and 2023
2. To analysis land use/land cover changes at the 5 years interval
3. To analyze the spatial and temporal dynamics of land use / land cover categories in the Bijoy River basin.

3. DATA SOURCE

The following data sources are used for mapping of land use / land cover categories in the Bijoy river basin.

- ❖ SOI Top sheet No-79M/2, 79M/6, 79M/9, 79M/10 of the surveyed year 1932-33 were used to demarcate the basin.

- Landsat TM 4, 5, 6, 7, and 8 OLI/TIRS satellite data are collected from United States Geological Survey (USGS) Earth explorer.
- Spatial and temporal aspects of land use / land covers changes are mapped using Quantum GIS (QGIS) software
- Ground Truth verifications are carried out with the help of GPS Google earth map.

3.1 Satellite Data Source and Methodology

Landsat TM 5, 7, and 8 OLI/TIRS data is used from the public open source for preparation of land use /land cover map for the years 2003, 2008, 2013, 2018, 2023. The National Remote Sensing Agency (NRSA) standard Land use / land cover classification procedure for Indian context was adopted to prepare 8 LU/LC Categories such as; built-up land, agricultural land, forest cover, plantation, water bodies, open fallow land, barren land, brick chambers are identified and are delineated using QGIS platform. Isolated village comes under built-up, river, lake, pond under water bodies. The changes in land use / land cover categories are mapped from 2003 to 2023 using supervised classification, and the maps commission and omission error estimation method is also used to calculate and assess the total changes.

Numerous primary and secondary sources of data are used in the study. These consist of satellite images and Survey of India (SOI) topographic sheets of 79M/2, 79M/6, 79M/9, 79M/10 at a scale of 1:50,000. Visual and digital interpretation of the Landsat TM data is carried out using image interpretation key elements (e.g., tone, texture, shape, pattern, association, etc.), and the open source QGIS is utilized to process, analyse, and integrate geographical data in order to meet the study's goals. Prior to the thematic maps being finalized, sufficient field checks are performed. Finding the types and variations in land cover and usage in the studied region is the primary objective of this research.

4. RESULTS AND DISCUSSION

One of the significant uses of remote sensing data is monitoring LULC changes (Kumar, D. 2017). It shows that how particular qualities evolve over a given period of time interval. The choice of an appropriate change detection method is crucial to the production of a high-quality change detection product for a certain research goal, once the study regions and remotely sensed data are identified.

4.1 Land Use / Land Cover Categories

The Landsat TM satellite data is digitally analysed, and the LULC map is prepared following comprehensive field verification. In the research area, different classifications of LULC are interpreted, such as; open space, water bodies, built-up land, fallow land, uncultivated land, barren land, forest cover, and rubber plantations, and are delineated (Table 1, and Table 2) (Fig. 2a, 2b, 2c, 2d, 3a, 3b, 3c, 3d, and 4a, 4b).

4.2 Built-Up land

Built-up land is made up of places where densely populated, with a large portion of the land being covered by structures. It has the geographical area of 6.4314 (1.57%), 16.5321 (4.04%), 21.535 (5.25%), 23.9994 (5.87%), and 27.2385 (6.66%) square kilometres, with respect to the years 2003, 2008, 2013, 2018, and 2023. It has covered cities, towns, villages, commercial and industrial complexes, and institutions.

In 2003, 6.43 Sq. Km (1.57%) the area was under the built up land, and gradually, the built-up land was increased rapidly 4.04 times (16.53 Sq.km) between 2003 and 2008. This area's quick growth points to a period of significant built-

Table 1. Land Use / Land Cover categories for the years 2003, 2008, 2013, 2018, and 2023

Land Use / Land Cover	2003	2008	2013	2018	2023
Built-up (in %)	1.57	4.04	5.25	5.87	6.66
Agricultural Lands (in %)	34.38	33.57	26.87	26.05	24.16
Brick Chamber (in %)	0.03	0.04	0.07	0.07	0.14
Water Bodies (in %)	7.01	7.13	7.05	6.88	5.84
Forest Cover (in %)	35.84	31.15	28.17	27.62	27.47
Rubber Plantation (in %)	4.08	8.71	20.28	21.62	25.86
Barren Land (in %)	20.45	7.07	3.98	3.26	2.48
Open Ground (in %)	9.67	8.32	8.31	8.63	7.40

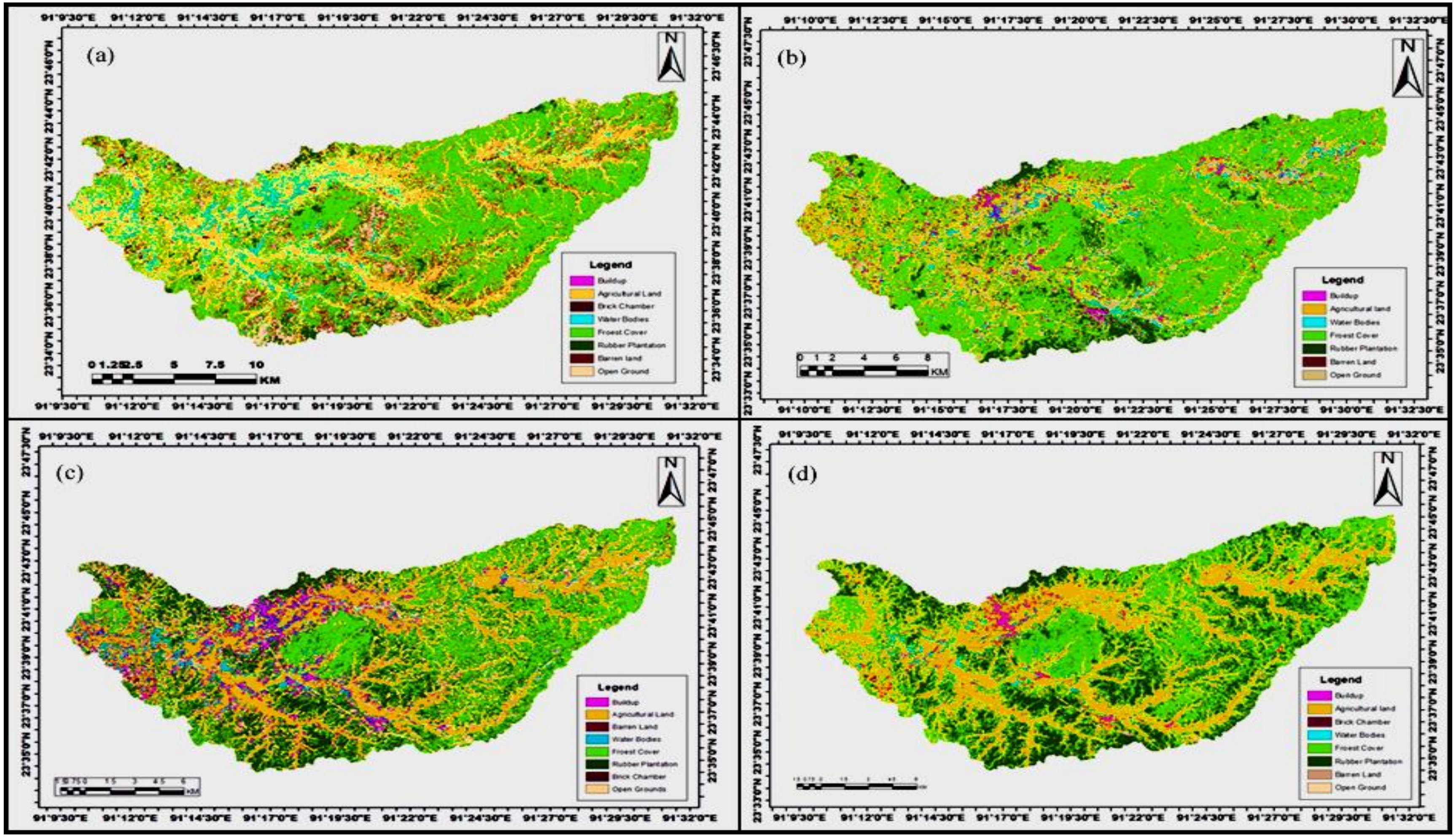

Fig. 2a, 2b, 2c, and 2d Land Use / Land Covers Categories for 2003, 2008, 2013, and 2018 respectively

Table 2. Land Use / Land Cover changes for the period of 2003-2008, 2008-2013, 2013-2018, and 2018-2023

Land Use / Land Cover	Base year 2003	2008	2013	2018	2023
Built-up (in %)	1.57	2.47	1.22	0.60	0.79
Agricultural Lands (in %)	34.38	0.81	6.71	0.81	1.89
Brick Chamber (in %)	0.03	0.02	0.03	0.00	0.07
Water Bodies (in %)	7.01	0.10	0.08	0.17	0.83
Forest Cover (in %)	35.84	4.69	2.98	0.55	0.15
Rubber Plantation (in %)	4.08	4.62	11.57	1.34	4.24
Barren Land (in %)	20.45	13.59	2.98	0.35	1.04
Open Ground (in %)	9.76	1.04	0.07	0.06	1.19

Note: Red colour indicates the negative changes

up area development, probably driven by grounds of population growth, urbanization, infrastructure initiatives, economic activity, and developmental activities. It's possible that migration from Bangladesh is a major factor at this time, increasing the need for infrastructure, housing, and commercial space.

Between 2008 and 2013, the built-up area growth rate decreased significantly, increasing by just 0.624361946 times in comparison to the five years prior, resulting in a total built-up area of 5.25% (21.54 Sq.km) (Table 2). This slowdown may have been caused by a number of circumstances, such as changes in migratory patterns, legislative restrictions, economic downturns, or saturation of accessible land. Furthermore, at this time, urban planning policies might have attempted to manage expansion in a more sustainable manner.

From 2013 to 2018, there was a similar increase of 0.624361946 times compared to the previous five-year period, and the total built-up area was 5.87% (24 Sq. Km). This continued the pattern of slower built-up area growth. The pace of urban expansion may have continued to be influenced during this time by variables like land use regulations, environmental concerns, infrastructure constraints, and economic situations.

The overall build-up area increase of 6.66 % (27.24 Sq. km) in 2023, and 0.79266171-times increase over 2018. This was a minor acceleration of the growing rate of build-up area. Factors like infrastructural projects, alterations in migratory patterns, policy or regulation changes from the government, or increased economic growth could have all had an impact on this surge. More effective urban development may also have been made possible by advancements in technology and construction techniques.

Overall, the findings point to a complicated interaction between a number of variables, including migration dynamics, economic situations, legal frameworks, environmental issues, and urban planning techniques, which affect the growth of built-up areas. In order to maintain sustainable and equitable urban development in the face of pressures from migration and population expansion, policymakers, urban planners, and stakeholders must have a thorough understanding of these reasons.

4.3 Agricultural Lands

Agricultural land area throughout the study period for two decades is consistently decreased. It is required to investigate the consequences of this tendency, specifically with the rise in build-up area and rubber plantations.

The area under cultivation is declined from 140.553 Sq. Km in 2003 to 137.2581 Sq. Km (34.38%) in 2008. This initial decline may be explained by the development of infrastructure and urbanization, which result in the conversion of agricultural land into built-up regions to support economic activity and population increase. In addition, there might have been encroachment on agricultural land for commercial or industrial endeavours or other developmental purposes.

The extent of arable land is decreased further, reaching 109.8342 Sq. Km (33.57%) in 2013. The increase of built-up area at this time suggests that there was probably more urban growth during this period. Shifting cultivation pattern [10-12], economic developments, and increasing population are contributed to the conversion of agricultural land into built-up one. During the period of 2013 - 2018, the area

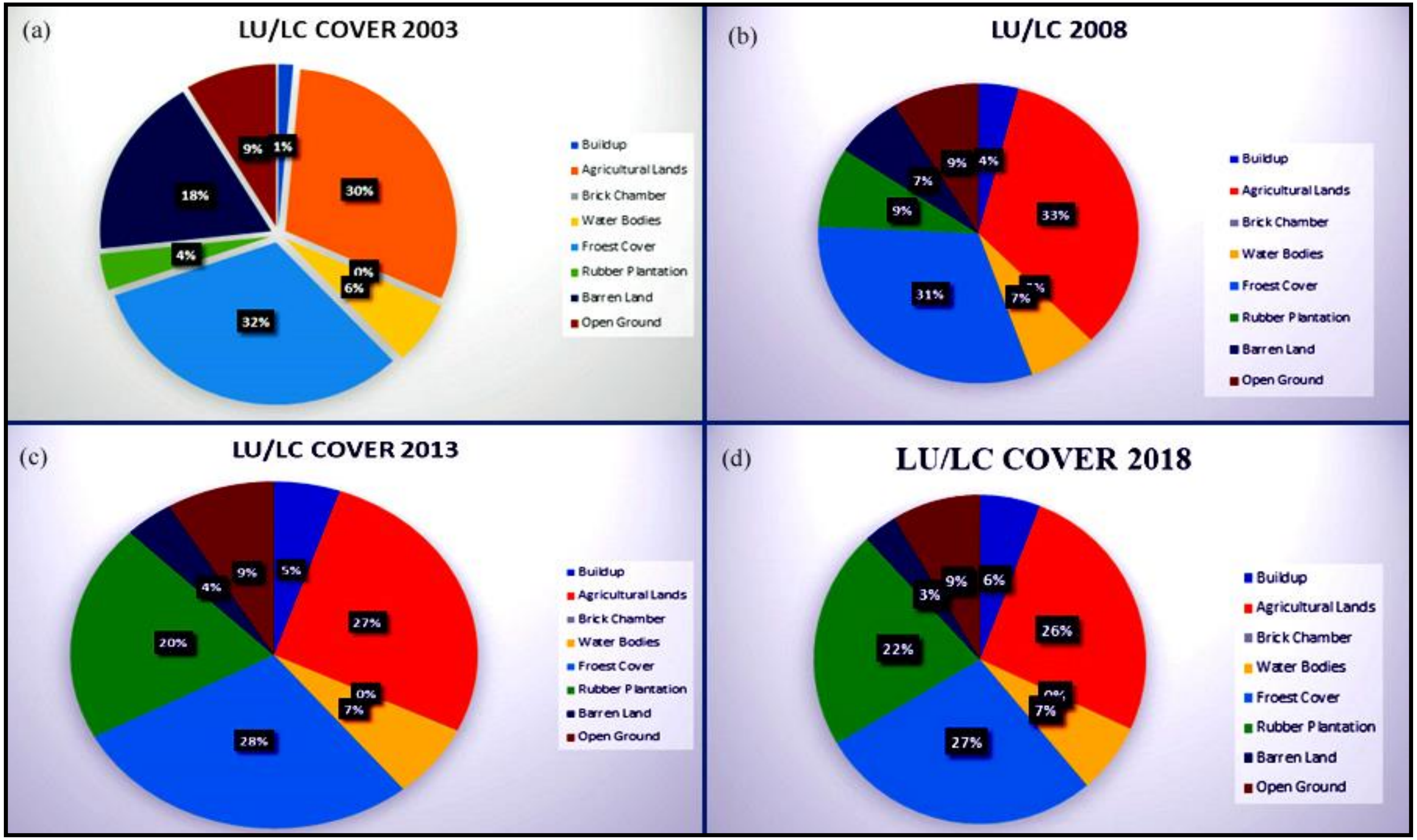

Fig. 3 (a, b, c, and d). Land Use / Land Covers Categories for 2003, 2008, 2013, and 2018 respectively

covered by agriculture was also decreased 106.5213 Sq. Km (26.05%). The continuous conversion of agricultural land would have been facilitated by the built-up areas' expansion during this time. There's also a chance that the creation of rubber plantations, which need a lot of space, would have further decreased the amount of agricultural land available.

The land under agriculture crop land is declined continues to a total of 98.7804 Sq. Km (24.16%) by 2023 (Table 2). Agricultural land was probably still under strain from the development of rubber plantations and the growth of suburban and urban agglomerations. A combination of population increase, industrialization, and urbanization processes would have pushed the transfer of agricultural land to non-agricultural uses.

The data reveals an alarming pattern of steadily declining agricultural land area over a period of study time (Table 2). The increase of built-up areas for urban development and the conversion of agricultural land for the rubber plantations are the root causes for declining trend. In order to negative effects on agricultural land resources, careful land use planning, conservation initiatives, and sustainable agricultural methods are required.

4.4 Rubber Plantation

Result shows that from 2003 to 2023, the area of rubber plantations increased significantly (Table 2). There are a number of reasons for this spatial and temporal changes, and magnitude trend, but economic causes are the main one

According to the data, the area under rubber plantations increased significantly from 16.6986 Sq. Km in 2003 to 88.407 Sq. Km in 2018. The rubber business probably grew significantly at this time because of the favourable market conditions, strong demand for rubber goods, and attractive profit margins. Therefore, in order to take advantage of the economic prospects that rubber production presents, agricultural land, open land, and other types of land may have been converted into rubber plantations.

The area of rubber plantations expanded dramatically between 2003 and 2008, rising from 16.6986 Sq. Km to 35.5959 Sq. Km. Economic factors, such as the high demand for rubber and the favourable market and environment during this time, probably persuaded landowners to turn their open and agricultural land into rubber plantations. It's also possible that this expansion was made easier by the government's incentives and the favourable landscape terrain, environment, and climate conditions.

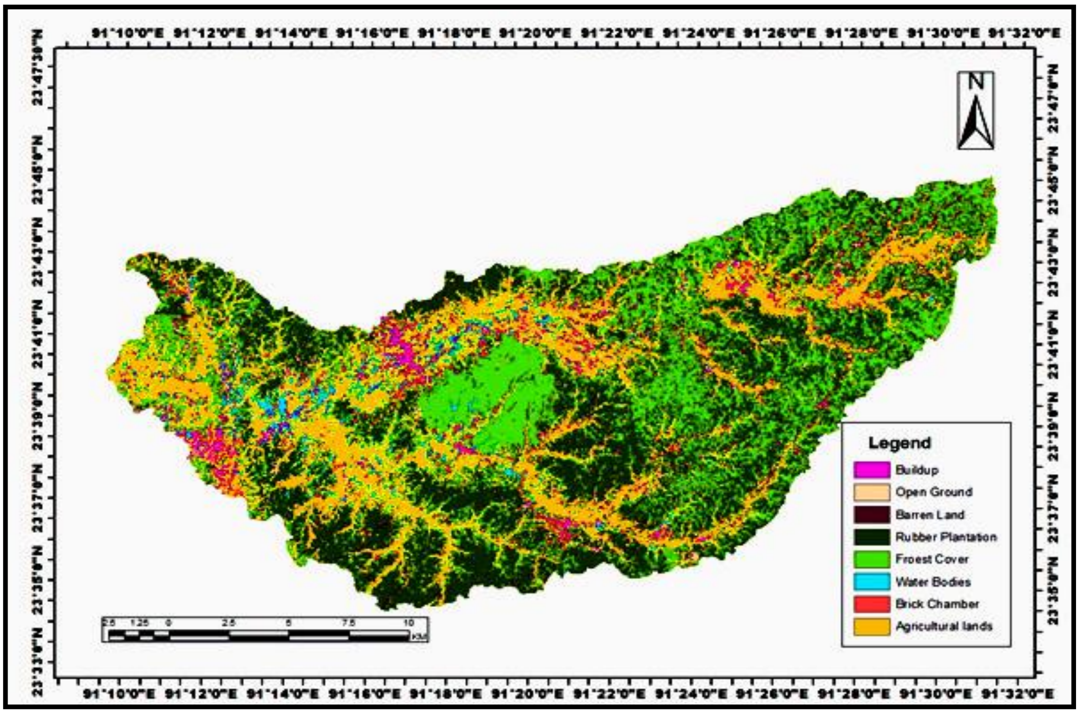

Fig. 4a. Land Use / Land Covers Categories -2023

Fig. 4b. Land Use / Land Covers Categories -2023

4.5 Forest Cover

There has been a steady decline in the amount of forest cover over time, with declines seen in 2008, 2018, and 2023 (Table 2). Multiple factors, such as the growth of agriculture, built-up areas, and rubber plantations, are responsible for this decline in forest cover. From 146.5164 Sq. Km in 2003 to 127.3599 Sq. Km in 2008, there was a decline in forest cover. The growth of agriculture at this time probably contributed significantly to the decrease in the amount of forest cover. It's possible that forest areas were removed to make room for cash crop cultivation, farming, or grazing [13]. Furthermore, it's possible that the expansion of built-up areas further encroached upon forests, converting them into zones designated for residential, commercial, or industrial purposes.

By 2013, the region had shrunk to 115.1658 Sq. Km as the trend of declining forest cover persisted. Driven by demands from urbanization, economic development, and population increase, agriculture and built-up areas most likely continued to expand during this time. The creation of rubber plantations may have contributed to the decrease in forest cover in addition to agriculture and urbanization, since significant areas of forest land may have been destroyed for rubber cultivation. By 2018, the amount of forest cover had further fallen to 112.9176 Sq.km. Forested areas would have been under threat throughout this time because to the on-going development of building areas, rubber plantations, and farmland. Increased deforestation rates due to land conversion for agriculture, urbanization, and rubber plantation growth would have resulted in habitat fragmentation, biodiversity loss, and disruption of ecosystem services.

The area decreased to 112.2921 Sq. Km by 2023 as the trend of declining forest cover continued. Driven by reasons including land conversion for economic development, population increase, and increasing demand for agricultural products and urban infrastructure, the expansion of agriculture, built-up areas, and rubber plantations most certainly proceeded uninterrupted. The decline of forested regions throughout time can be ascribed to several sources such as the growth of agricultural areas, constructed areas, and rubber plantations. Deforestation, soil erosion, habitat loss, and ecosystem degradation are the results of these activities [14], which have a big impact on preserving biodiversity, reducing the effects of climate change, and managing land use sustainably [15]. In order to address the root causes of deforestation, comprehensive strategies that support sustainable land use practices, strike a balance between economic growth and environmental preservation, and bolster laws pertaining to forest restoration and protection are needed [16]. The growth trend continued with a substantial increase in rubber plantation area to 82.908 Sq. Km in 2013. Economic profitability and market demand likely remained strong during this period, driving further land conversion into rubber plantations. Agricultural land, open land, and even forested areas may have been cleared or converted to accommodate the expanding rubber industry. The area covered by rubber plantations increased further, reaching 88.407 Sq. Km in 2018. Still, the rate of increase may have slowed due to the emergence of signals of saturation or declining returns. Landowner decisions about

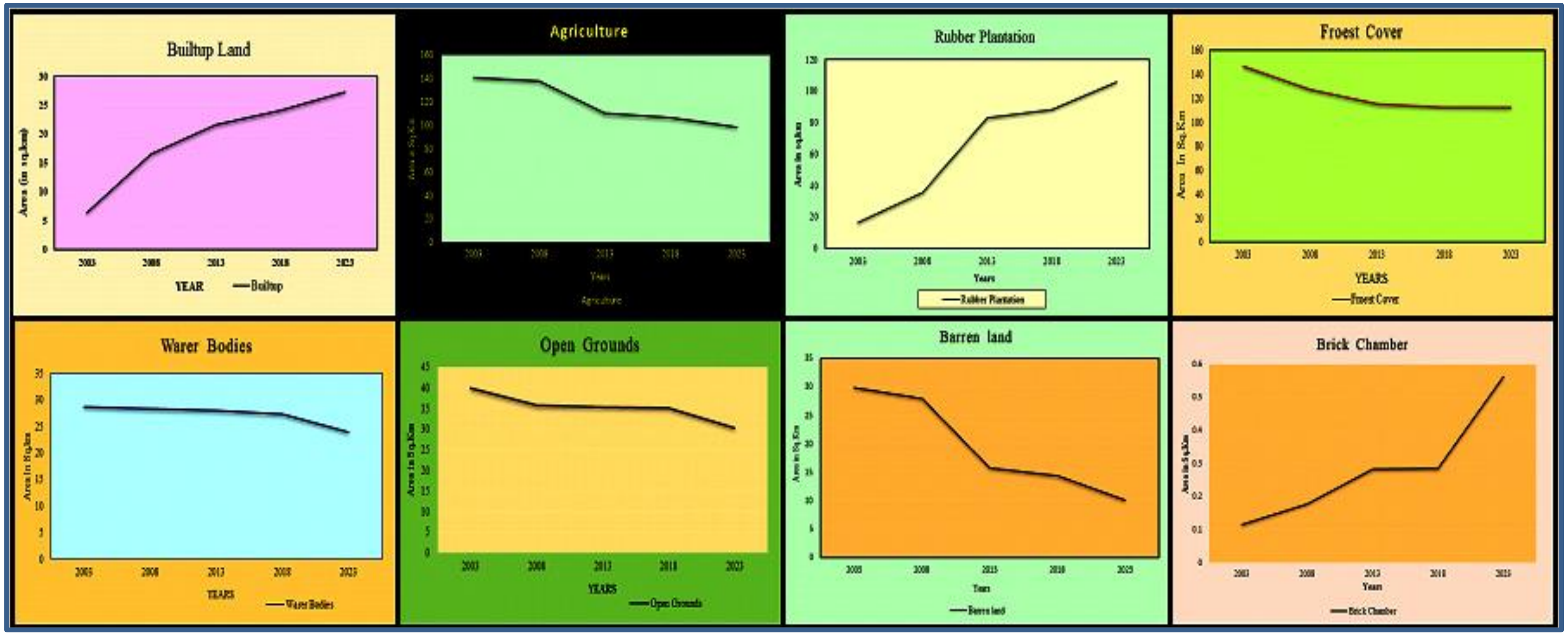

Fig. 5. The longitudinal trend of Land Use / Land Covers Changes over the year 2003, 2008, 2013, 2018, and 2023

additional investments in rubber cultivation might have been impacted by variables like growing competition, rising production costs, and environmental concerns.

The area under cultivation of rubber plantations becomes stable slightly to 105.7302 Sq. Km in 2023, indicating a change in trend. Undoubtedly, this drop was mostly caused by economic factors. The preceding expansion trend in rubber cultivation may have reversed due to diminished profit margins, market volatility, or shifts in customer tastes discouraging additional investments in the technology. The steady increase of spatial changes of land use trend of rubber plantation over the 20 years reflects the dynamic interplay of economic, market, and environmental factors influencing decision on land use purpose.

4.6 Water Bodies

Water body's coverage areas within a five-year period, is declined from 2008 to 2023. Numerous factors, such as marsh filling, climate change, and the growth of rubber, are to blame for this decrease in water bodies. Water bodies 28.67 Sq. Km in 2003 is reduced to 28.24 Sq. Km in 2008, and the area covered by water bodies shrunk slightly. Despite the seemingly little amount of this decline, it might be an indication of impending environmental pressures like climate changes. Temperature increases and shifting precipitation patterns might have also started to affect water availability and decrease of water bodies.

There was an additional decline in the amount of water bodies by 2013, and the area was shrunk to 27.94 square kilometres. The loss of water bodies might have worsened during this time due to reasons like wetland filling for urban growth or agricultural expansion. The decrease might also have been influenced by the on-going consequences of climate change, which include changes in evaporation rates and rainfall patterns. Water bodies continued to decline by 2018, and the area had shrunk to 27.24 Sq. Km. The growth of rubber plantations during this time probably put further strain on water supplies. Rubber trees demand a lot of water, and as rubber farming grew, it's possible that water extraction from nearby water bodies increased, which further reduced the size of the trees.

During this time, the area of water bodies decreased to the greatest extent, from 23.8572 Sq. Km in 2023 to none at all. It's possible that the growth of rubber plantations accelerated, increasing the demand for water and causing water bodies to dry up. Furthermore, it's possible that the combined effects of land use changes and climate change exacerbated each other, making the depletion of water resources worse. The downward trend in water bodies highlights the necessity of taking urgent action to combat climate change, save wetlands, and advance sustainable land management techniques. To protect water resources and lessen the negative effects of water body depletion on ecosystems and communities, it is imperative to put ecosystem restoration and water conservation techniques into practice

4.7 Open Grounds

The study reveals that a steady declining of open ground is analysed between 2003 and 2023 at every five-year intervals. There are a number of reasons for this reduction in open ground area, such as the growth of residential areas, agricultural practices, and the introduction of rubber plantations. Between 2003 and 2008, the open ground area fell from 39.8916 Sq. Km to 35.64 Sq. Km. The growth of accumulation areas as urbanization increased may be the cause of this reduction. The transformation of open space into residential, commercial, and industrial zones would have resulted from increased building and infrastructural development. By 2013, the open ground area has shrunk to 35.343 Sq. km, continuing the trend of decline. This reduction may have been exacerbated by the expansion of rubber plantations and agriculture. Open ground regions may have been further encroached upon by agricultural land expansion and land conversion for rubber cultivation. In 2018, the amount of open ground land decreased slightly to 35.1 Sq. Km. It is likely that open ground spaces continued to be consumed as built-up areas expanded due to urbanization and population growth. Further lowering the amount of available open terrain may have been the continuation of agricultural growth and the creation of rubber plantations.

This was the time when the area covered by open ground decreased the most, reaching 30.2364 Sq. Km by 2023. The loss in land utilization may be ascribed to increased pressures from agriculture, plantations, and urbanization. More acreage of open space was probably turned into built-up areas as urbanization and industry grew. Similarly, the availability of open ground would have been further reduced by the on-going expansion of agricultural and rubber plantation activities. Sustainable land use planning and management techniques are crucial, as seen by the declining trend in open ground area. To enhance environmental sustainability, resilience, and urban quality of life, urban expansion must be balanced with the preservation of green spaces, agricultural land, and natural ecosystems.

4.8 Barren Land

A continuous declining trend is observed in the extent of barren land during the period of 2003 and 2023. Numerous anthropogenic processes are responsible for this decrease in the extent of barren land. The amount of barren land fell from 29.9592 Sq. Km in 2003 to 28.0251 Sq. Km in 2008. Anthropogenic causes like residential, commercial, and road construction occurred during this time. The extent of bare land continued to decline, and by 2013, it had significantly decreased to 15.8274 Sq. Km. Barren land would have been further encroached upon by anthropogenic activities like land development projects, urban growth, and intensified agriculture. Barren land area continued to decrease 14.3937 Sq. Km in the year 2013 to 2018. The expansion of built-up areas, agricultural land, and industrial activities would have continued to consume barren land. The most significant decrease in barren land area was observed during this period, with the area reducing to 10.1376 Sq. Km by 2023. Continued urbanization, industrialization, and infrastructure development would have further reduced barren land availability.

4.9 Brick Chamber

The brick chambers are directly proportional to the increasing number of buildings in the urban settlements concrete buildings during the period of 2003 - 2023.

The brick chamber's initial size was 0.1152 Sq. Km in 2003.

The area grew by 0.1791 square kilometres in 2008. It grew by an additional 0.2835 Sq. Km in 2013. Another rise of 0.2853 Sq. Km occurred by 2018. Ultimately, there was an extra 0.5634 Sq. Km growth by 2023.

The result shows that the increase of a continuous upward trend in the brick chamber's area as a result of accumulated concrete development is upstretched, including human settlements, urban development, infrastructure development, population growth, and industrial expansion throughout the study period.

5. FINDINGS AND SUMMARY

A steady increase in the built-up area is signifying the growth and development of residential, commercial, and industrial regions from 1.573101 to 6.662455 in 2003 and 2023 respectively. The area under agricultural lands declined dramatically, indicating a conversion of agricultural lands to other land uses, such as urbanization or industrialization and rubber plantation from 34.37884 to 24.16139 in 2003 and 2023 respectively. The forest cover declined from 35.83747 in 2003 to 27.46631 in 2023, indicating that factors such as agricultural development, urbanization, or illicit logging have contributed to deforestation. There has been a significant rise in the area covered by rubber plantations from 4.084427 in 2003 to 25.86129 in 2023, suggesting that commercial rubber cultivation has spread throughout the region. From 7.012693 in 2003 to 5.835399 in 2023, the area covered by water bodies has shrunk. This drop may be related to encroachment, urbanization, or modifications in water management techniques. The area under open ground dropped from 9.66931 in 2003 to 7.395732 in 2023, which could be a sign that different development activities are using open areas. The amount of barren land fell from 20.44768 in 2003 to 2.479626 in 2023, most likely as a result of various land uses such as urban expansion, agriculture, and plantations. Between 2003 and 2023, the area under brick chambers increased from 0.028178 to 0.137806, indicating a rise in infrastructure development and construction activity. Significant changes in patterns of land use and cover brought about by industrialization, urbanization, infrastructure growth, and agricultural practices (Fig.6). Increase of developmental activities, rubber plantations, and building constructions are resulted from this shift, which has also caused a decrease in agricultural lands, forest cover, water bodies, and bare ground [17,18].

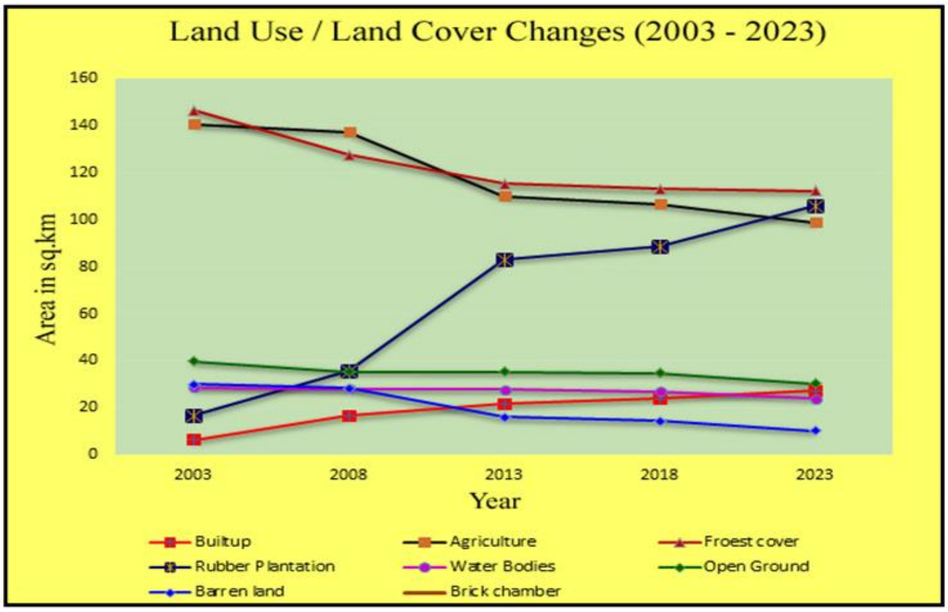

Fig. 6. Temporal Changes of Land Use / Land Covers over the years 2003, 2008, 2013, 2018, and 2023

6. CONCLUSION

Mapping of land use /land cover classification using remote sensing under the GIS umbrella is providing accurate level of changes among the LULC categories for 2 decades at the 5 years interval, which could be a guidelines for preparing environmental impact assessment, resource planning, environmental management for sustainable developments including soil, land and water resource, forest, and manmade infrastructure developments. Agriculture, forest, and water bodies are declined, on the other hands, human settlements, rubber plantation are increased upward, and thus, a scientific approach for prediction of land use and land cover changes by 2050 may be needed to make a plan for micro level as well as regional level environmental and ecological based niche spatial modelling for soil, forest, and land and water resource management.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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