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Analysis of Spatio-temporal Changes in Landuse and Land Cover in Kharagpur and Midnapore Municipalities of West Bengal, India

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Abstract

Since independence, the rate of urbanization in India has increased significantly. The huge population pressure in urban centers has altered or continues to alter the practical use of urban land, leading to changes in ecosystems, pollution, deforestation, decreasing fallow land, and rapid expansion of built-up areas. These changes have greatly impacted the pattern of land use and land cover in Indian cities. The use of satellite imagery and geo-informatics might be the best tool to detect and analyze these temporal changes. In the present study, the temporal changes in land use and land cover of the two municipalities, Midnapore and Kharagpur, were identified and analyzed using satellite images from LANDSAT_5 TM (1991 & 2011), LANDSAT_7 ETM (2001), and LANDSAT_9 OLI (2024). Before starting the pre-processing and classification of satellite imagery through ERDAS IMAGINE-9.2 and Q.GIS 3.28.3 software, a thorough field survey utilizing a global positioning system (GPS) was conducted throughout the research region. The Normalized Difference Vegetation Index (NDVI) and Built-up Index (BUI) were used to determine the changes in land use and land cover of the study areas. This study aims to assess the level of changes in different landuse and land cover (LULC) classes of the study areas between 1991 and 2024. The results show that significant changes have taken place in the area under settlement (increase), and vegetation cover (decrease) in both the municipalities during the period of study.

Introduction

Understanding the dynamics of urban areas and evaluating the temporal changes in land throughout time need an analysis of land use and land cover. Urban planners need this information to make well-informed decisions about resource allocation, infrastructure development, and zoning, which is provided by land use and land cover (LULC) studies. Planners may more accurately predict future needs and guarantee sustainable development by having a thorough grasp of how land is used and changed over time. Assessing the impact of urbanization on the environment is aided by keeping an eye on changes in LULC. This involves monitoring changes in ecosystem services, pollution, habitat loss, and deforestation. Policymakers can put conservation and restoration measures for the environment into action with the help of such a study. Certain forms of land cover are more vulnerable to landslides, floods, and wildfires than others. Authorities can identify places at risk and put policies in place to lessen these threats by examining land use patterns.Changes in land cover over time can affect vulnerability to these hazards, and understanding this can help determine the influence of urbanization on these vulnerabilities. Planning the construction of infrastructure, such as roads, utilities, and public services, is aided by land use analysis. Planners can successfully serve community requirements by prioritizing infrastructure expenditures by identifying regions of high economic activity or population density.

Despite their distinction, the words "landuse" and "land cover" are frequently used synonymously (Dimyati et al., 1996). While land cover comprises all of the physical features of the surface of Earth, such as plants, water, soil, and other elementsboth natural and man-madeland usage refers to how people use the land and its environment. Numerous factors, including socioeconomic and environmental conditions, have an impression on the patterns of Landuse/Land Cover (LULC) in each region (Rawat and Kumar, 2015). However, two major factors contributing to the quick shift in LULC are industrialization and urbanization, which have resulted in some problems such as heat islands, flooding, health issues for people, and environmental degradation (Zope et al., 2016; Choudhury et al., 2019).

The Study Area

The Kharagpur and Midnapore Municipality both are located in the Paschim Midnapore district, West Bengal, India. The Kharagpur Municipality is extended from 87º12' E to 87°22' E longitude and 22°17′ N to 22° 22' N latitude with slight undulating topography with an average elevation of 40 m above the Mean Sea Level(MSL). The geographical location of Midnapore Municipality is the intersection of 22°23'44.56" to 22°26'34.91" North Latitude and 87°17'18.57" to 87°20'30.12" East Longitude. Both of the municipalities are situated along the banks of the Kangsabati River (Fig.1). The Kharagpur municipality consisted of 35 wards with a population of 293719 as per the 2011 census report. Whereas, the Midnapore Municipality has extended over 25 wards with a population of 169127 and a population density of 9212 persons per square kilometer (approximately) according to the 2011 census report.

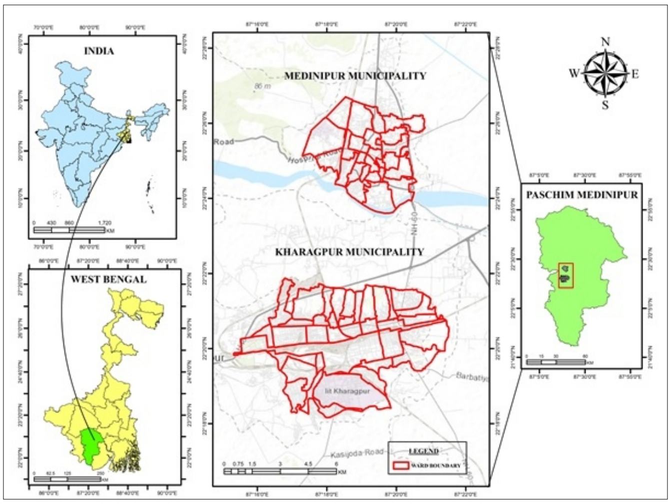

Fig. 1: Location Map of Midnapore and Kharagpur Municipalities, Paschim Medinipur, West Bengal, India

Research Gap

It may therefore have assumed that the research gap is probably going to be the absence of a current and thorough study on the particular temporal changes in land use and land cover (LULC) in the municipalities of Kharagpur and Midnapore over a substantial period, like the 33 years from 1991 to 2024. This study fills the void by offering a thorough investigation of LULC changes utilizing GIS techniques and satellite images of the study areas, which was possibly not done as recently or as comprehensively before. The study appears to be concentrating on the effects of these modifications on liquid waste management, environmental sustainability, and urban planninga topic that may not have received enough attention outside of these particular localities.

Objectives

1. To evaluate and record the changes in land use and land cover (LULC) patternsduring a period of 33 years (from 1991 to 2024) in the municipalities of Kharagpur and Midnapore.
2. To carry out spatial analysis to find trends and patterns in LULC changes in both municipalities.
3. To compare the changes in LULC pattern in a specific period between the two municipalities.

Hypothesis

According to the study, during the past 33 years, there have been noteworthy changes in land use and land cover (LULC) in Kharagpur and Midnapore Municipalities. These changes are mainly attributed to urbanization, intensification of agriculture, and infrastructure development. It argues that economic activity and population increase have caused natural vegetation, agricultural land, grassland, waterbodies, and other types of fallow land to give way to urban regions. Additionally, the theory contends that there is a positive correlation between the growth of built-up/settlement areas and deforestation and the loss of green and open spaces. It also takes into account how much these LULC changes have been influenced by economic activity, legislative decisions, and infrastructure projects. As a consequence, there have been noticeable changes in land use and land cover patterns observed in the municipalities. To give a thorough understanding of the causes and effects of LULC pattern changes in these municipalities, the study intends to evaluate these hypotheses using remote sensing data, GIS analysis, historical maps, and field surveys.

Literature Review

Several studies have explored changes in Land Use and Land Cover (LULC) across different regions of the world using satellite imagery and geo-informatics. Song and Ma (2011) analyzed LULC changes in Southeast Asian megacities using NDVI data, while Estoque and Murayama (2015) focused on spatial patterns from 1990 to 2010. Pal and Ziaul (2017) linked LULC changes to temperature variations, while Tran et al. (2017) examined LULC alterations and Land Surface Temperature (LST) in urban contexts. Appiah et al. (2017) studied LULC dynamics in Ghanaian peri-urban areas, and Siddique et al. (2020) assessed LULC and LST trends in Beijing from 1990 to 2018. Other studies covered diverse regions like Kathmandu (Wang et al., 2020), the Ashanti region in Ghana (Kullo et al., 2021), Khulna Town in Bangladesh (Moniruzzaman et al., 2018), Atlanta (Yang and Lo, 2002), and Shanghai (Yin et al., 2011), showing varied impacts of urbanization on LULC. Rawat and Kumar (2015), Choudhury et al. (2019), Anselm et al. (2018), Mathan and Krishnaveni (2020), and Gumma et al. (2017) also contributed insights into LULC changes across India and other regions. Basu and Saha (2017) studied Barasat Municipality, highlighting population-related LULC shifts, while Sarkar and Baral (2021) observed significant LULC changes in Siliguri over three decades, particularly in built-up and vegetation areas.A thorough study on the dynamicity of land use/land cover (LULC) in the rural and periurban areas of Durgapur Municipal Corporation in India was carried out by Halder, S. et al. (2023). The study demonstrates how Durgapur's well-planned communication network and economic opportunities drew in residents from other areas, influencing urban growth and ultimately leading to LULC modifications in the Durgapur Municipal Corporation in India.

Materials and Methods

To develop the Land use and Land cover map for Kharagpur and Midnapore Municipality, primary and secondary data were gathered from multiple sources. The primary data, which included 1: 50,000 scale topographical sheets and cloud-free multispectral Landsat satellite imagery data (Table - 1) for three dates throughout the last three decades for the relevant region, were gathered from Earth Explorer (USGS) (shown in Table - -1) and Survey of India (SOI), respectively. Here are additionally gathered data: 73 N/7 topographical sheets from the Survey of India; a true color Google satellite image of the study area, Midnapore Town; and a different time municipal boundary map of the study area from the Midnapore municipal office. The boundary map of Kharagpur Municipality is collected from the Kharagpur Municipality office. The data about the physical expansion of the municipal boundary of both municipalities are obtained from the respective municipal authorities.

Before starting the pre-processing and classification of satellite imagery, a thorough field survey utilizing a global positioning system was conducted throughout the research region. This survey was cross-checked using Google Earth and Toposheet to ensure accuracy. It aimed to create training samples, generate signatures, and obtain precise locational point data for each land use and land cover class included in the classification system.

For supervised classification using the Maximum Likelihood algorithm, spectral signatures were created using specific areas in the image, referred to as "training samples." Since these training samples are in raster format, Arc Toolbox was used to convert it vector layers comprising polygons covering various land use categories. This classification is the most popular quantitative approach for change detection, produces decent results.

Laboratory Work: Using satellite images, numerous laboratory approaches were carried out with the aid of ERDAS IMAGINE-9.2 and Q.GIS 3.28.3 software. Multiple banding techniques and stacking of all the gathered image content are used to create the composite images. To enhance the quality of each image, several image enhancement methods are also applied, such as data scaling and histogram equalization. Afterward, using ERDAS IMAGINE software, satellite images were corrected using a pre-referenced topographical sheet by the image-to-image rectification procedure with the geographic coordinate system (lat/long), Everest spheroid, and Datum-1830.

The ERDAS software's 'Area of Interest' (AOI) techniques are used to extract our research area. The research area was extracted by subset from the primary images following the development of the AOI. Sub-setting is carried out to extract the interested area after the AOI layer has been created. Categorization of Pictures: Both supervised and unsupervised classification techniques are used to categorize the previously processed images. The unsupervised classification method of the ISO DATA clustering algorithm is integrated into the ERDAS Imagine program based on the necessary number of classes and the digital number of available pixels. In contrast, the maximum likelihood algorithm in supervised classification would categorize the image according to the training sites (signatures) derived from the user's domain knowledge.

To determine which kind of pixel should be used for a certain land use category, user enters the training data into the programme. The distribution of pixels with varying digital numbers has been understood and used as a reference by using the unsupervised categorized image. Lastly, the land use and land cover image of the study area is provided by both classes, allowing researchers to explore the changing scenario. Fig.2 shows the methodology in detail.

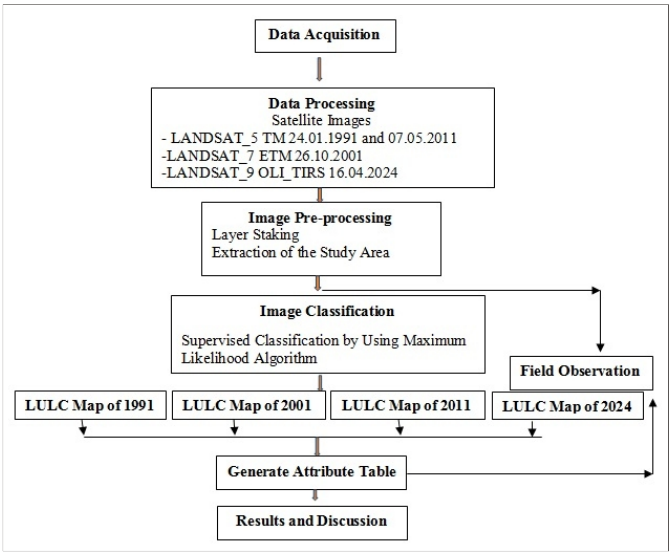

Fig. 2 :The Flowchart of Methodology taken into consideration for the preparation of LULC map

Normalized Difference Vegetation Index (NDVI): A useful tool for determining the changes in land use or cover is the Normalized Difference Vegetation Index (NDVI). The following formula is used to calculate the NDVI images for 1991, 2001,2011, and 2024 from visible (0.63-0.69 μm) and near-infrared (0.78-0.90 μm) wavelengths:

NDVI = (NIR - RED) / (NIR + RED),
where NIR = Near Infrared

In Landsat 5&7, NDVI= (Band 4- Band 3)/ (Band 4+ Band 3)
For Landsat 9, NDVI = (Band 5- Band 4)/ (Band 5+ Band 4)

Built-up Index (BUI): Another useful indicator for tracking changes in land cover and landuse is the built-up index. In 1991, 2001,2011, and 2024 the built-up index is calculated using the following formula from near-infrared (NIR) (0.78-0.90 μm) and middle-infrared (MIR) (1.55-1.75 μm) data.

BUI = (MIR - NIR) / (MIR + NIR)

Change Detection Analysis: Kharagpur Municipality

Change detection analysis is a technique used to pinpoint changes that have taken place in a certain area over time. The main objective is to compare various data sets from aerial photos, satellite images, or other sources captured at various times. Applications for such analysis include tracking changes in land cover, urbanization, deforestation, natural disasters, infrastructure development, and environmental evaluations. It offers vital data for developing policies, managing resources, making decisions, and promoting environmental protection.

In this study, the change detection analysis of Kharagpur municipality was done after preparing the land use and land cover map (Fig. 4 and 5) from the respective satellite images of 1991, 2001, 2011, and 2024. The main aim of such a study is to detect or explore how changes have taken place in Kharagpur municipality over the last 33 years. As mentioned earlier, Kharagpur town is the industrial and commercial town of Paschim Midnapore district. Rail wagon factory and Vidyasagar Industrial Park is located here. The land use and land cover map of the municipality has witnessed drastic changes in land use and land cover patterns. The changes in land use and land cover area of Kharagpur Municipality from the year 1991 to 2024 are mentioned in Table - 2. Besides that, the percentage of area in different LULC classes is also mentioned in Table - 3. The key changes in LULC are discussed here.

Results and Discussion

Changes in Vegetation Cover

It is evident from examining the quantity of vegetation cover area derived from satellite images taken between 1991 and 2024 that the vegetation cover area of this municipal area has declined dramatically over these 33 years in several different locations. A satellite image from 1991 (Fig. 5) revealed that the vegetation cover area measured was around 22.27 percent of the entire municipal area (Table - s 2 &3). However, based on data from the most recent satellite image from 2024 (Fig. 5), the area covered by vegetation is approximately 14.90%, of the entire municipality (Table - 2 &3). In other words, during these 33 years, the amount of vegetation in various areas of this municipality has declined by roughly 7.37% of the total municipal area. Fig. 4 shows the decreasing trend in the vegetation cover Area of the Kharagpur Municipal area. The LULC maps (Fig. 5)indicate the vegetation cover area.

The field survey revealed extensive felling of century-old deciduous trees like *shirir*a in vacant lots throughout the city. These large trees are notably absent near the railway colony and along main roads, and extensive cutting has also occurred near residential areas. Residents attribute the increase in tree cutting to government neglect, noting that natural causes have also led to the loss of centuries-old trees in government areas without adequate replanting efforts. The peripheral areas of the city have seen a decline in trees due to growing land demands from the increasing population. This was observed that most of the deforested areas were significantly replaced by built-up areas. Additionally, there has been significant tree reduction to meet industrial needs.

Changes in Agricultural Land

According to statistics obtained from 33 years of satellite images (Fig.5) from 1991 to 2024 (Table - 2 & 3), the amount of agricultural land mainly located on the northern and eastern borders of this municipality has decreased by more than 50%. In 1991, the amount of agricultural land was about 402.49 hectares, which has decreased to about 179.48 hectares according to the latest statistics of 2024 (Table - 2). It is evident from the statistics (Table - 2) that between 2001 and 2011, the agricultural land has decreased by about 156.10 hectares, which is the highest in the above assessment period. Fig. 5 shows the decreasing trend of agricultural areas in the municipal area. The LULC maps (Fig. 5) indicate the agricultural land cover area. It can be assumed that the increasing population of Kharagpur city has increased the demand for land at a proportional rate. As a result, the sale price of land has increased significantly. Apart from this, the industrial location called Vidyasagar Industrial Park has created an environment for many small and cottage industries in this municipal area. As a result, the demand for land has increased. These can be considered as one of the reasons for the conversion of agricultural land into built-up areas.It has been observed that a considerable amount of agricultural land has been sold off and is lying uncultivated or fallow land.

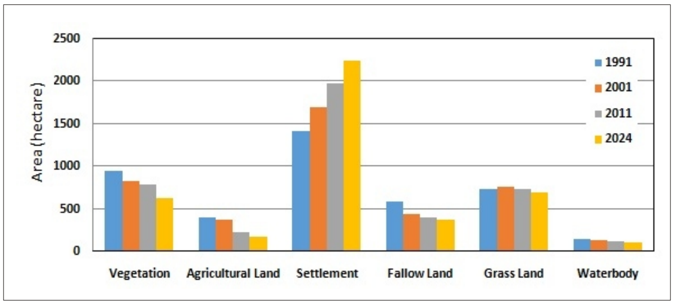

Fig.3: Changes in Areal Coverage in Different LU/LC Categories of Kharagpur Municipality

Changes in Built-up Area

Analyzing the Land Use and Land Cover map of Kharagpur municipality, it is seen that the maximum change in land use type in different parts of the municipality is observed in the case of Built-up areas or settlement areas. In the assessed total of 33 years (1991-2024), settlement or built-up area has increased by about 33.33% to 52.99% of the municipal area (Table - 2). Therefore, the built-up or residential areas were expanded by about 19.66%, indicating significant growth or develop built-up areas. In comparison with the other LULC classes, it is indeed a very quick change. Fig. 4 shows the upward trends with steep slopes indicating a significant extension of settlement area in the municipal area.

This transition may be the result of the Kharagpur municipality's current national highway, expansion of rail infrastructure, and conducive industrial development environment. Over the past twenty years, the Vidyasagar Industrial Park, which is close to Kharagpur town, has seen the establishment of numerous large, medium, and small-scale industries. Human encroachment and migration happened as a result of industrialization and a well-developed transportation system. Individuals from various regions arrived and established new communities here. Additionally, a variety of infrastructure has been created to meet the needs of the Kharagpur municipality's growing population. The study observed that mainly the fallow land, agricultural areas, and a significant portion of waterbodies are converted into built-up areas to meet the ever-increasing demand of the population.

Changes in Fallow Land

According to the statistics obtained from the satellite image of 1991, the amount of fallow land belonging to this municipality is about 589.85 hectares. And the amount obtained from the latest satellite image of 2024 is about 380.48 hectares. Therefore, the amount of fallow land reduced in these 33 years is about 209.37 hectares(Table - 2). The LULC maps of Kharagpur Municipality (Fig. 5) indicate the fallow land cover area.Fig. 4 shows the decreasing trend of fallow land area in the municipality over time.

Analysis of field surveys and satellite images shows that there has been very little change in fallow land area mainly in rail colony areas. In these lands under government control, a small amount of fallow land has decreased mainly for construction work, but there has been no major change in this area. But privately owned fallow land has decreased significantly in recent years. The growing population necessitates more space to accommodate their fundamental demands. There was a human intrusion to satisfy their demands. The majority of the fallow land has been transformed through this process into small-scale industrialized regions, populated areas, agricultural areas, and other uses. The soil of the Kharagpur municipal area is primarily lateritic. This soil is thick and often splits during the dry season, making it unsuiTable-for growing crops. Therefore, this type of land is turned into fallow areas rather than grassland.

Changes in Grasslands

No significant temporal changes in the grassland cover areas of Kharagpur municipality were observed. Within the assessing period of 33 years from 1991 to 2024, about (741.33 ha- 694.74 ha) 46.59 hectares of grassland areas have been decreased (Table - 2&3). The LULC maps (Fig.5) indicate the fallow land cover area of Kharagpur Municipality. Fig.4 indicates the reduction in grassland cover areas in the municipality. The government rail colony areas, playgrounds parks, etc., fall under the grassland cover areas. Most grasslands are owned by the railways or the government and are located in the rail colony areas. It may be assumed that for this reason no significant changes in grassland cover area have been observed.

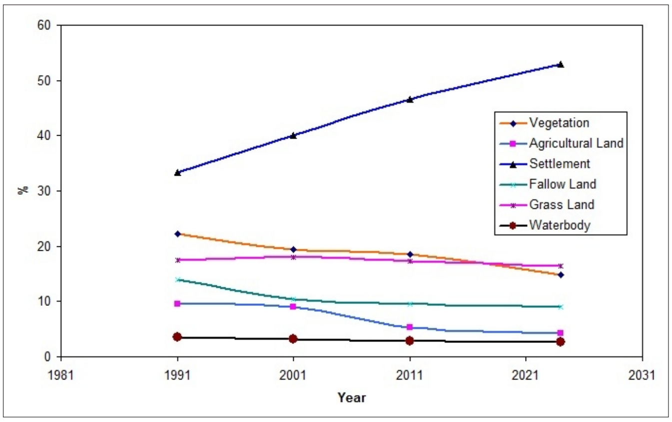

Fig.4: Changes in LU/LC Area in Kharagpur Municipality (1991 - 2024)

Change in Waterbodies areas

It has been calculated from the satellite image of 1991, that about 153.48 hectares of areas were under the waterbodies. Which occupied about 3.61% of total municipal areas. Which has decreased over time and according to the statistics of 2001, it reached 135.72 ha, 120.19 ha in 2011, and 110.48 ha in 2024. Therefore, within the assessing period of 33 years, there were (153.48 ha 110.48 ha) 43 hectares of waterbodies that were destroyed and mainly converted into built-up areas (Table - 2 & 3). The deep blue color in LULC maps (Fig.5).

Perhaps the pattern of human invasion is the cause of the diminishing water bodies. This has to do with filling in ponds and wetlands to develop residences and commercial areas. Furthermore, it may be asserted that the selling price of land has significantly increased, for that the waterbodies have also been turned to other land use but most dominantly in built-up areas.

Change Detection Analysis: Midnapur Municipality

The figure obtained from the land use and land cover analysis through the temporal changes of Midnapore Municipality shows a drastic change in land use and land cover pattern over time. The increasing trend of built-up area has been observed highest in percentage than to other components of land use and land cover area from 1991 to 2024 (Table - 4 &5). It is very alarming and shows how much population pressure increased day by day in the study area. Here, the LULC pattern in the study area has been carried out after taking the components into five classes i.e. waterbody, vegetation, fellow land, built-up area, and lateritic soil cover. Table - - 5 compares the land use area of various classes and displays the change diagram. Fig.6 portrays the temporal changes in landuse and land cover areas of the Midnapur Municipality.

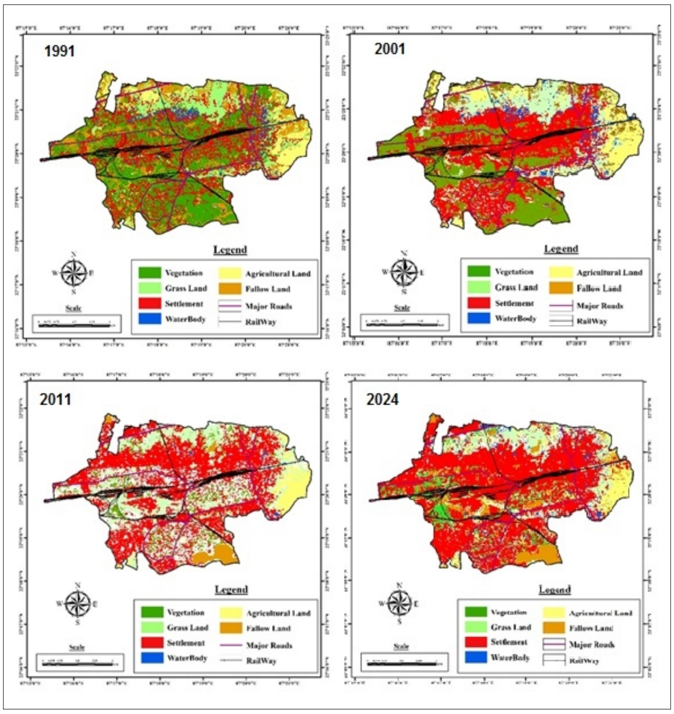

Fig.5: Spatio-temporal Changes in LU/LC Area in Kharagpur Municipality (1991 - 2024)

Changes in Vegetation Cover

For the change detection analysis concerning vegetation cover, a significant reduction in vegetation cover area has been observed in Midnapore Municipality between 1991 and 2024 (Table - 4 and 5). From the LULC map of 1991 (Fig.8), prepared using ERDAS Imagine image processing software, the calculated vegetation cover area was 610.68 hectares. This value decreased to 490.29 hectares in 2001, 320.28 hectares in 2011, and 290.16 hectares in 2024. The decreasing trend of vegetation cover area in the municipality is very alarming. Between 1991 and 2024, the vegetation cover area has drastically reduced by approximately 320.52 hectares (610.68 ha - 290.16 ha), which is a 52.49% decrease over 33 years. The LULC maps of Midnapore Municipality indicate the vegetation cover area. Fig. 7 iillustrates the decreasing trend of vegetation cover in the municipal area over the assessed period of 33 years, from 1991 to 2024. The LULC maps and field observation have shown that the majority portion of the vegetation cover area is converted into a built-up area.

In Midnapore Municipality, there has been significant deforestation observed over the assessment period. Analysis from satellite imagery using ERDAS Imagine software, combined with field observations and reports from residents, particularly the elderly, indicates widespread tree removal, primarily driven by urban expansion for settlements. This has led to a reduction in large trees near residential areas as cities have grown. Residents attribute the decline in tree population to various factors including greed, environmental apathy, population growth, unplanned urbanization, and infrastructure development. LULC maps depict maximum deforestation along the southern Kangsabati River and in the northwest parts of the city. Additionally, isolated trees within residential peripheries and vacant lands in central Midnapore Municipality have significantly decreased between 1991 and 2004. Dolui, Gour, et al. (2014) in their study showed that with a mean temperature of 19.32°C and a standard deviation of 1.821, the predicted LST (Land Surface Temperature) spans 15.32°C to 28.79°C. Higher temperatures (between 22.57°C and 28.79°C) are caused by lateritic soil and companion land in the western portion of the research area. The eastern section, with more water bodies and dense vegetation, experiences lower temperatures ranging from 15.32°C to 20.39°C. According to the 2001 LST geographical distribution, the estimated LST had a mean temperature of 21.69°C and a standard deviation of 1.943°C, with a range of 15.08°C to 29.75°C. Lateritic soil covers in the west and part of the east of the research region exhibited maximum temperatures between 24.80°C and 29.75°C. LST estimates for 2011 showed a range of 20°C to 35.31°C (mean value 27.78°C and standard deviation 1.512°C).

Vegetation plays a crucial role in maintaining ecological balance by performing photosynthesis, releasing oxygen, and absorbing carbon dioxide, which helps combat climate change and reduce air pollution. Trees and grasses also prevent soil erosion through their root systems and stabilize slopes. They contribute to cooling urban environments by evaporating water and providing shade, mitigating the urban heat island effect. Urban green spaces support biodiversity, and regulate the water cycle by absorbing rainwater and reducing runoff, thus preventing floods and replenishing groundwater.

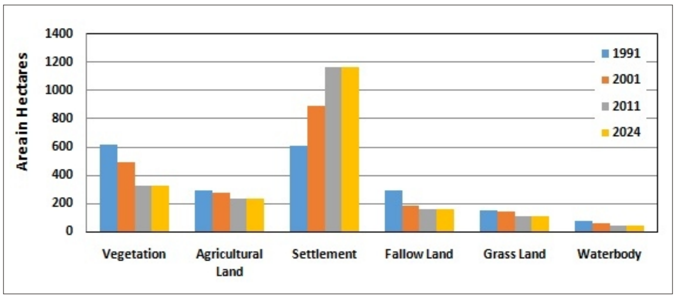

Fig.6: Changes in Areal Coverage in Different LU/LC Categories of Midnapur Municipality

Changes in Agricultural Land

The Land Use and Land Cover (LULC) map of Midnapore municipality (Fig.8) shows that there was a significant agricultural area lying under agricultural activities in Wards no. 1, 16, and 25 located at the eastern and western portion of the municipal area. Through the temporal analysis of the satellite images in the years 1991, 2001, 2011, and 2024, the changes in agricultural land area are seen. Throughout the period from 1991 to 2024, the agricultural area is reduced by around (290.43 ha - 207.43 ha) 83 hectares or 28.58% (Table - 4&5). The LULC map of 2011 and 2024 shows that the agricultural area in Wards no. 16 and 25 has drastically reduced and replaced by settlement areas in the majority portion. It may be said that the economically and most environmentally important areas are reduced due to population pressure which insists the Increase in land prices. Fig. 6 indicates the decreasing trend in agricultural land areas of the municipality.

Changes in Built-up Area

Water bodies, vegetation, and undeveloped terrain are connected with non-agricultural activity, while human settlement areas and the infrastructure that supports them are considered the built-up sections of towns. The built-up area based on the NDBI was retrieved for the three chosen years, 1991, 2001, 2011, and 2024. A town's built-up regions are steadily and dramatically expanding in all directions. The Midnapore Municipality underwent extensive concretization over 33 years, as seen by satellite images taken between 1991 and 2024 (Fig.8). Other particulars like vegetation, agricultural areas, grassland, lateritic soil, and waterbodies were drastically reduced throughout the aforementioned assessment period, where a large amount of settlement area increased in the Midnapore Municipal area.

Based on the satellite image dated 1991-01-24, the estimated value of the settlement cover areas in 1991 was approximately 608.36 hectares. In 2024, it is estimated to be about 1289.91 hectares. Between 1991 and 2024, the settlement area grew by about 681.55 hectares (Table - 4 & 5). Thus, there has been a rapid rise of built-up areas between 2001 and 2011. There were about 276.46 hectares of new built-up area, which is about 40.56% of the total increase over the last 33 years. The aforementioned computed statistics describe built-up or settlement areas that are sustained by the transformation of bare, agricultural, forest, and herbaceous land into built-up areas. One of the traits linked to the expansion of the built-up area as a consequence of urbanization is thought to be the decrease in forest land. The LULC map of Midnapore Municipality mentioned the settlement or built-up areas. Fig.7 with its upward trend indicates how much new built-up areas were developed in the last 33 years in the municipal area.

Unrestrained urban settlement growth significantly impacts liquid waste management systems in multiple ways. Rapid urbanization strains existing infrastructure such as sewage treatment facilities, pipelines, and pumping stations, often leading to system malfunctions, spills, and inadequate waste handling. This unchecked growth encroaches upon sensitive environmental areas like wetlands, rivers, and lakes, increasing the risk of contamination from improperly disposed liquid waste, particularly untreated sewage, which poses health risks and degrades ecosystems. The improper management of liquid waste can facilitate the spread of waterborne diseases and pollute water supplies, lowering water quality and harming aquatic life through nutrient loading and the release of pathogens. In informal settlements, where access to proper sanitation is limited and regulatory compliance is challenging to enforce, liquid waste management faces additional hurdles. Achieving sustainable management requires controlling settlement expansion and implementing effective urban planning practices to mitigate these environmental and public health risks.

Changes in Lateritic Cover / Fallow Land

Midnapore Municipality is the part of old Jungal Mahal district in undivided Bengal. Mainly the lateritic type of soil found in the municipal area. As per calculated values of lateritic soil cover area in this municipality through satellite images of 1991, 2001, 2011, and 2024 (Fig.8) respectively, there are significant changes observed. Within the 33-year assessment period around 148.32 hectares of lateritic cover areas have been reduced and mostly replaced by built-up areas.The lateritic soil-covered barren land accounted for approximately 14.37% of the Midnapore Municipality's total area in 1991.The latest calculated value of lateritic soil covers bare land from the analysis of the 2024 satellite image, which is only 7.03%. Almost 50% of the bare lateritic surface has been destroyed from the year of 1991 to 2024 (Table - 4&5). The conducted field observations during the research period found a huge amount of bare lateritic soil cover areas are converted into built-up areas,especially for settlement establishment.Fig.7 in its decreasing trend indicates the reduction of lateritic soil cover area.

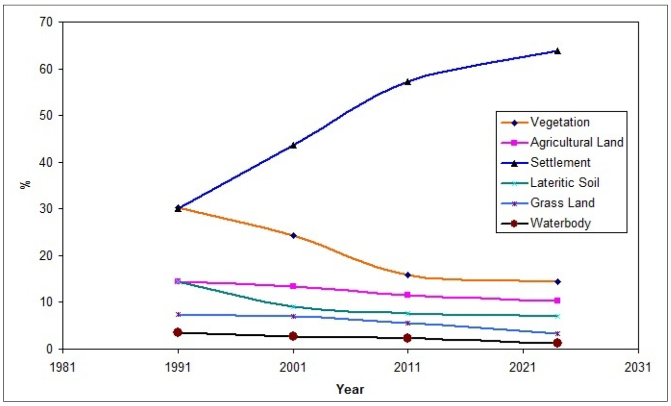

Fig.7: Changes in LU/LC Area in Midnapur Municipality (1991 - 2024)

The conversion of natural surfaces to built-up areas in urban regions significantly impacts liquid waste management. Impermeable materials like concrete and asphalt prevent rainwater from infiltrating the ground, increasing surface runoff during storms and overwhelming drainage systems. This leads to erosion, urban flooding, and pollution of water bodies from combined sewer overflows. The urban heat island effect exacerbates these issues by accelerating organic waste decomposition, increasing energy use for cooling, and contributing to air pollution. The lack of green infrastructure further complicates storm water management, as retrofitting urban areas with features like green spaces and permeable pavements is challenging due to property ownership issues, underground utilities, and limited space. Overcoming these challenges is essential for enhancing urban resilience, mitigating environmental impacts, and achieving sustainable liquid waste management in cities.

Changes in Grasslands

The grassland area comprises playgrounds, recreational parks, and educational institutions like schools, colleges, and university premises.Playgrounds, leisure parks, and academic buildings including schools, colleges, and universities are all located within the grassland area. The municipality's LULC map demonstrates that, between 1991 and 2024, there was a decline in the grassland cover area. The grassland cover area of the Midnapore municipality was approximately 7.50% of its total area in 1991 (Fig.8). Based on the 2024 satellite image, the estimated grassland cover area barely makes up 3.36 percent of the entire Midnapore municipality. Consequently, about 50% of the grassland cover area was eliminated in 33 years (Table - s 4 and 5). Fig.7 in its decreasing trend, indicates the reduction of grassland cover area. Field surveys showed that most of these degraded grasslands have been used for various construction activities.

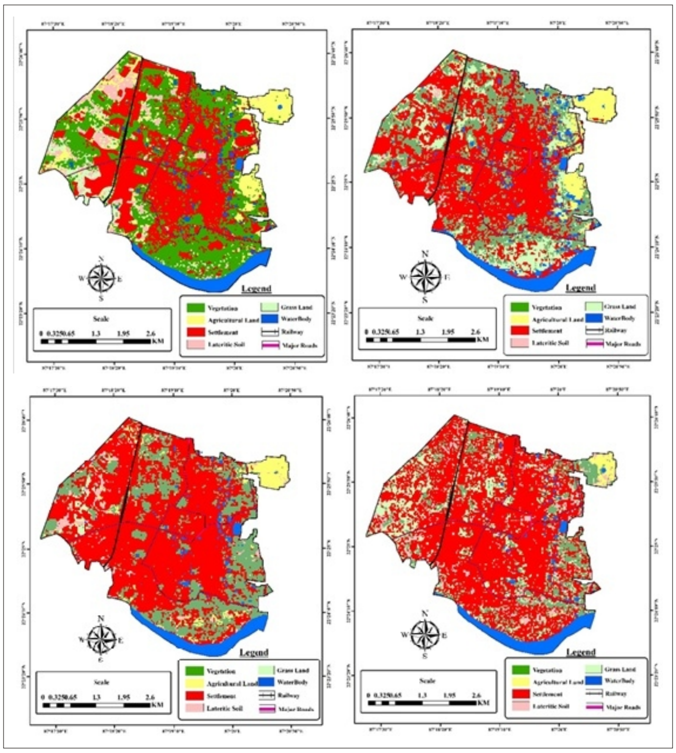

Fig.8: Spatio-temporal Changes in LU/LC Area in Midnapur Municipality (1991 - 2024)

Changes in Waterbodies

In urban areas, there is a significant role of water bodies as receiving bodies of surface runoff. The LULC map analysis of Midnapore Municipality during the period of 1991 to 2024(Fig. 8) shows that the volume of waterbody within the municipal area was significantly reduced. Within the assessing period of 33 years, the volume of waterbody decreased by about (71.27 hectares - 25.26 hectares) 46.010 hectares. Besides this, the decreasing trend of waterbody volume drastically reduced between 2011 and 2023. In this period about (45.39 hectares - 25.26 hectares) 20.13 hectares of waterbody area has been supplanted by built-up area and other types of constructional activities(Table-4&5).A noticeable decline in the coverage of these water bodies is depicted by the downward trend (Fig.7). This trend suggests a reduction in the extent of regions occupied by water bodies over the specified period.

The field survey in various wards of the municipality revealed ongoing construction activities involving the filling of ponds, despite minimal municipal intervention. Residents have expressed concerns over the municipality's indifference to this issue, particularly noting significant pond filling in the central business district. Data from 1991 to 2024 indicates a decline in water body volume, exacerbated by haphazard waste dumping and sediment accumulation leading to eutrophication. Many pond owners prefer not to purify water due to rising land demand and property prices, potentially leading to wetland conversion. Water bodies play crucial roles in urban environments, regulating water flow, mitigating floods, enhancing aesthetics, moderating climate, supporting agriculture, and fostering community well-being. Preserving these resources is essential for biodiversity, sustainable development, and urban ecosystem resilience.

A Comparative Analysis

Over 33 years of assessment (from 1991to2024), the changes of different LULC classes are briefly discussed here. The comparative analysis was done based on the calculated values of the classes mentioned in Table - s 2,3,4 &5.

Vegetation Cover

In the Kharagpur Municipality, the total area covered by vegetation has decreased by about 313.57 hectares between 1991 and 2024. In contrast, it dropped by about 320.52 hectares in Midnapore Municipality over the same evaluation period (Table - s 2,3,4 &5). Thus, it may be concluded that these two municipalities have been about equally affected by urbanization.

Agricultural Land

Statistics show that, in the case of the Kharagpur Municipality, the amount of agricultural land has declined dramatically during the previous 33 years. An estimated 223.01 hectares of agricultural land have been lost overall during this time. However, Midnapore Municipality has lost 83 hectares as a result(Table - s 2,3,4 &5).The comparative analysis has shown that during the period there were four times agricultural land lost in Kharagpur Municipality compared with Midnapore Municipality.

Settlement or Built-UpAreas

During the assessment period, these two municipalities have experienced the most increases in built-up areas or settlements. On the other hand, it can be observed from the statistics that Kharagpur Municipality has grown its highest built-up area in comparison to Midnapore Municipality throughout these 33 years. In the same time frame, the built-up area of Kharagpur municipality expanded by approximately 835.93 hectares, while the built-up area of Midnapore municipality increased by approximately 681.55 hectares. In other words, compared to Midnapore Municipality, the built-up area of Kharagpur Municipality has grown by roughly 154.38 hectares (Table - 2,3,4 &5).

Lateritic Soil Cover/Fallow Land

In Kharagpur Municipality the amount of fallow land reduced in these 33 years is about 209.37 hectares (Table - 2). Whereas, in the same period the fallow land/lateritic soil cover area of Midnapore Municipality has decreased by around 148.32 hectares and was mostly replaced by built-up areas(Table - s 2,3,4 &5).So it is seen that Kharagpur Municipality is much ahead of Midnapore Municipality in terms of fallow land reduction.

Grasslands

Within the assessing period of 33 years from 1991 to 2024, about (741.33 ha- 694.74 ha) 46.59 hectares of grassland areas in Kharagpur Municipalityhave been decreased (Table - 2 & 3). But in Midnapore Municipality a significant reduction of grassland area which is around 83.7 hectares took place in the assessing period.

Waterbodies

About 43 hectares of water bodies area have been destroyed within the assessing period of 33 years from 1991 to 2024 in Kharagpur Municipality. In the same time of period around 46.01 hectares of water body areas were reduced in Midnapore Municipality (Table - 2,3,4 &5).

Conclusion

This study illustrates how geographic information systems and remote sensing may be used to analyze urban growth mapping and detect changes in urban land use and cover patternsover several decades. The change detection analysis of the study areas of Kharagpur and Midnapore Municipalities in a specific period of 33 years (from 1991 to 2024) portrayed that a huge level of urbanization was taking place in both municipalities over time. There was a significant expansion in built-up/settlement areas in both municipalities.

The built-up area in Kharagpur Municipality grew from 33.33% in 1991 to 52.99% in 2024, a total increase of 29.66%. In Midnapore Municipality, the built-up area increased from 30.07% in 1991 to 63.76% in 2024, a growth of 33.69% over the same period.The results of LULC classes also show a drastic decline trend in vegetation cover areas of both municipalities. The vegetation cover area in Kharagpur Municipality decreased from 23.27% in 1991 to 14.90% in 2024, a reduction of 8.37% in 33 years. In Midnapore Municipality over the same period, the vegetation cover area reduced from 30.19% in 1991 and 14.33% in 2024. Compared to Kharagpur Municipality, Midnapore Municipality experienced major deforestation with more than 50% loss of vegetation cover area. Such loss has a great environmental impact on the urban environment. Other LULC classes like agricultural land, fallow land, and waterbody also decreased remarkably in both municipalities.

Agricultural area, fallow land, grassland, and waterbody area in Kharagpur Municipality decreased from 9.47%,13.88%, 17.44%, and 3.61% in 1991 to 4.22%, 8.95%, 16.34% and 2.60% in 2024 respectively. In Midnapore Municipality agricultural area, fallow land, grassland, and waterbody area decreased from 14.36%, 14.37%, 7.50%, and 3.52 in 1991 to 10.25%, 7.03%, 3.36% and 1.25% in 2024 respectively. The maximum decreasing areas of the five LULC classes were dominantly replaced by settlement or built-up areas in both municipalities. This study also demonstrates that changes in urban land use or cover can have an indirect impact on other significant environmental factors when they directly affect one of them. A very small portion of the area in both municipalities is occupied by vegetation cover areas which is environmentally imbalanced condition. This study claims that afforestation measures should be taken immediately to make the municipal environment beautiful and clean for the benefit of the citizens. Thus, when selecting, executing, and planning land use plans, it is essential to ascertain the potential for the most advantageous use of diverse land uses or covers to fulfill the increasing demands for human requirements and welfare. Monitoring the demands of a growing population in connection to the dynamics of land use change is made easier with information about land use and cover. The study also claimed that more precious studies and research are needed in the future. The study remarked that the urban local bodies of both municipalities should give more attention to urban planning immediately to overcome environmental degradation in the near future.

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Table -1: **P**articulars of the Landsat data obtained from the USGS for the preparation of LULC Map of Kharagpur and Midnapore Municipality.

Year	Spacecraft ID	Image Date	Sensor ID	Path	Row	ELLIPSOID
1991	LANDSAT_5	1991-01-24	TM	139	044	WGS84
2001	LANDSAT_7	2001-10-26	ETM	139	044	WGS84
2011	LANDSAT_5	2011-05-07	TM	139	044	WGS84
2024	LANDSAT_9	2024-04-16	OLI_TIRS	139	044	WGS84

Source: Image downloaded from the U.S. Geological Survey (USGS), https://earthexplorer.usgs.gov/, accessed on 02/04/2024.

Table - 2: Areal Coverage of different types of Land use and Land cover of Kharagpur Municipality (1991 – 2024)

Year	Land use type	Area in hectares	Year	Land use type	Area in hectares
1991	Vegetation	946.89	2001	Vegetation	826.02
	Agricultural Land	402.49		Agricultural Land	380.38
	Settlement	1416.93		Settlement	1700.78
	Fallow Land	589.85		Fallow Land	445.23
	Grass Land	741.33		Grass Land	762.84
	Waterbody	153.48		Waterbody	135.72
Year	Land use type	Area in hectares	Year	Land use type	Area in hectares
2011	Vegetation	789.12	2024	Vegetation	633.32
	Agricultural Land	224.28		Agricultural Land	179.48
	Settlement	1980.36		Settlement	2252.47
	Fallow Land	402.06		Fallow Land	380.48
	Grass Land	734.96		Grass Land	694.74
	Waterbody	120.19		Waterbody	110.48

Source: Manipulated by the author from LANDSAT_5(1991), LANDSAT_7(2001), LANDSAT_5(2011), LANDSAT_9 (2024) using ERDAS Imagine

Table -3: Percentage (%) of Area under different LULC Classes of Kharagpur Municipality from 1991 to 2024

LULC classes	1991		2001		2011		2024	
	Area in Hectares	%	Area in Hectares	%	Area in Hectares	%	Area in Hectares	%
Vegetation	946.89	22.27	826.02	19.43	789.12	18.56	633.32	14.90
Agricultural Land	402.49	9.47	380.38	8.95	224.28	5.28	179.48	4.22
Settlement	1416.93	33.33	1700.78	40.01	1980.36	46.59	2252.47	52.99
Fallow Land	589.85	13.88	445.23	10.47	402.06	9.46	380.48	8.95
Grass Land	741.33	17.44	762.84	17.95	734.96	17.29	694.74	16.34
Waterbody	153.48	3.61	135.72	3.19	120.19	2.83	110.48	2.60

Source: Manipulated by the author from LANDSAT_5(1991), LANDSAT_7(2001), LANDSAT_5(2011), LANDSAT_9 (2024) using ERDAS Imagine

Table - 4: Areal coverage of different types of Land use and Land cover of Midnapore Municipality (1991 to 2024)

Year	Land use type	Area in hectares	Year	Land use type	Area in hectares
1991	Vegetation	610.68	2001	Vegetation	490.29
	Agricultural Land	290.43		Agricultural Land	272.32
	Settlement	608.36		Settlement	882.89
	Lateritic Soil	290.64		Lateritic Soil	182.36
	Grass Land	151.65		Grass Land	139.72
	Waterbody	71.27		Waterbody	55.45
Year	Land use type	Area in hectares	Year	Land use type	Area in hectares
2011	Vegetation	320.28	2024	Vegetation	290.16
	Agricultural Land	232.94		Agricultural Land	207.43
	Settlement	1159.35		Settlement	1289.91
	Lateritic Soil	154.35		Lateritic Soil	142.32
	Grass Land	110.72		Grass Land	67.95
	Waterbody	45.39		Waterbody	25.26

Source: Manipulated by the author from LANDSAT_5(1991), LANDSAT_7(2001), LANDSAT_5(2011), LANDSAT_9 (2024) using ERDAS Imagine

Table - 5: Percentage (%) of area under different LULC Classes of Midnapore Municipality from 1991 to 2024

LULC classes	1991		2001		2011		2024	
	Area in Hectares	%	Area in Hectares	%	Area in Hectares	%	Area in Hectares	%
Vegetation	610.68	30.19	490.29	24.24	320.28	15.83	290.16	14.34
Agricultural Land	290.43	14.36	272.32	13.46	232.94	11.51	207.43	10.25
Settlement	608.36	30.07	882.89	43.64	1159.35	57.31	1289.91	63.76
Lateritic Soil	290.64	14.37	182.36	9.01	154.35	7.63	142.32	7.03
Grass Land	151.65	7.50	139.72	6.91	110.72	5.47	67.95	3.36
Waterbody	71.27	3.52	55.45	2.74	45.39	2.24	25.26	1.25

Source: Manipulated by the author from LANDSAT_5(1991), LANDSAT_7(2001), LANDSAT_5(2011), LANDSAT_9 (2024) using ERDAS Imagine

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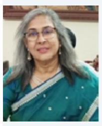

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