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Assessing Developmental Rate: A Remote Sensing and GIS Approach

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Abstract: This study uses Landsat imaging techniques to give an extensive analysis of developmental rates (DR) in the South West region of Osun State between 1986 and 2022. The purpose of the study is to assess historical land practices, and change patterns in the study area. The geographical information system method and remotely sensed data were used in the study to examine changes over time. The findings show a notable growth rate of 5.670% per year, with vegetation and built-up land increasing and barren ground decreasing. Based on the findings, the paper suggests institutionalizing remote sensing (RS) and GIS-based developmental rate monitoring to promote environmental cooperation in the area.

KEYWORDS: Developmental Rate (DR), Geographic Information System (GIS), Remote Sensing (RS), Land use (LU), Land cover (LC)

1.0 Introduction

The land is the region where every act of humanity is taking place. Depending on the demands it satisfies, people's use of land resources leads to a range of land uses, including food production, shelter provision, recreation, the extraction and processing of commodities, and the biophysical characteristics of the land itself. (Ghasemi et al., 2023). As a result, the way that land is used has been affected by two main sets of forces: human demands and natural characteristics and processes. The literature emphasizes the distinction between land use and land cover and the fact that they can alter. For proper usage in studies of the land and immediate subsurface, land cover is the biophysical state of the earth's surface differences (Rajesh & Nisia T., 2020). The physical features of the terrestrial surface, such as agriculture, mountains, or woods, are described. The amount and nature of surface plants, water, and soil materials, such as man-made structures (buildings, etc.), are all discussed in relation to land cover (Li et al., 2023). It illustrates the physical features of the land's surface such as agriculture, mountains, or woods. The extent of development refers to the quantity and nature of the surface plant, water, and earth materials, such as buildings and other man-made structures, as well as the materials used to construct homes (Borysiak & Stępniewska, 2022).

Variations in the use of land and its cover occur in places that are vulnerable to landslides due to the ongoing loss of forests and the vegetative cover that holds the topsoil together, as well as the change of forest land to agricultural and horticultural holdings. In terms of the distribution of plants, water, soil, and

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other physical aspects, land cover refers to the surface characteristics of the Earth (Kammerer et al., 2022).

The distinction between land utilization and land cover is not difficult to make. However, when developing information systems, we must take into account fundamental concerns such as the physical foundation for the observation (land), the necessary delineation of the segments to be taken into account during the observation (objects and observation units), and the type of categorization system to be developed. (Gribb & Czerniak, 2015). Osun State has had tremendous growth over the last two to three decades, which has caused the town's central urban sections to encroach on nearby rural regions. Since the beginning of human civilization, land use change has been an observable aspect of every expanding culture. Cities and towns in this state have grown rapidly in recent years. This rise has been accompanied by a complicated urban development pattern, as well as ever-increasing physical, social, and technological developments (Muschitiello, 2021). The most prominent issues in many African nations are those involving economic, political, and social difficulties. According to them, the political issues are related to corruption and weak governance, while the social issues are more related to the rapid population growth, particularly in the large cities where more than half of the population resides (Faria de Deus et al., 2023).By 2025, 80% of the world's population, according to the United Nations Population Fund's prediction, would reside in cities.

Most major metropolitan areas have challenges related to urbanization. Urban sprawl is becoming more of a problem. At a never-before-seen rate, undeveloped land is being replaced by residential and commercial development. Losses of natural vegetation, open spaces, and, at most, viable agricultural fields are caused by this urban sprawl. Although the typical citizen has benefited much from the move to the suburbs, it has also resulted in several urban problems. Cities that were once small and compact have grown larger, consuming more open space and using more resources. Sprawl is the name given to this type of urban growth (Vargas-Hernández, 2022). According to projections made by the United Nations (UN) Population Division, by 2028, urban dwellers will outnumber rural ones in each of the major emerging regions, and by 2050, two-thirds of those people are predicted to reside in cities (Montgomery, 2008). The population of these nations expanded by 40% between 1900 and 1975, and according to a number of demographic indices, by 2028, 60% of the people would reside in cities or other metropolitan areas (Ezeh et al., 2020). As a result, urbanization is occurring rapidly in many developing nations, particularly in sub-Saharan Africa (United Nations, 2013), which significantly contributes to urban sprawl in both big and minor cities. Urban sprawl refers to the process by which a city spreads out into its suburbs. In the vicinity of a city, structures for residential and commercial purposes are built in rural areas nearby or on otherwise undeveloped ground. Urban sprawl is generally agreed to be defined by an uncontrolled and uneven expansion pattern, (Jana & Sinha, 2021). Over the years scholars paid attention to changes in atmospheric condition which are caused by other factors but ignored the changes caused by human activity. This article aims to analyze the changes caused by human activities in Osun state from 1986 to 2022

2.0 Methodology

2.1 Data source

Thematic Mapper (TM), Enhanced Thematic Mapper (ETM+), and Operational Land Imager (OLI) are among the Landsat imagery (path 190; row 055). Every imagery was level 1T (L1T) captured and geometrically adjusted. Due to its scan line error-free nature, the Landsat 8–9 is mostly used to download data across a number of years (see Table 1 below). Due to cloud cover or technically problematic scenarios, there was a temporal difference of more than 20 days between all of the satellite photographs. To choose the satellite photos for this investigation, two criteria were used:

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(1) The satellite images had to have less than 10% cloud coverage, ideally cloud-free;
(2) If cloud coverage is more than 10%, the study area must not be affected by the cloud. The GPS observations of interesting spots in the study area, such as newly developed areas, vegetation, water bodies, and bare earth.

Satellite	Sensor	Path/Row	Date of acquisition (yy/mm/dd)	Spatial Resolution (m)	Cloud Cover (%)
Landsat 4-5	TM	190/55	1986/01/15	30	10
Landsat 8-9	OLI/TIRS	190/55	2016/01/03	30	10
Landsat 8-9	OLI/TIRS	190/55	2019/01/07	30	5
Landsat 8-9	OLI/TIRS	190/55	2022/01/04	30	10

Table 1. Details of the satellite data used in this study

2.2 Study area

The eastern part of Oyo State was split off to form Osun State in 1991.The northeastern state of Kwara, the eastern states of Ekiti and Ondo, the southern state of Ogun, and the western and northwesterly states of Oyo border it. It occupies a region of around 9,251 square kilometers (3,572 square miles) between latitude and longitude (7°35'15" N, 4°33'44" E), and (7°35'26" N, 4°34'00" E). Osogbo, the state capital of Osun, is situated in the southwest of Nigeria. It is classified as having a tropical wet and dry climate. Osun State was established in 1993 as an extension of Oyo State, and it shares borders with those states as well as Kwara, Ekiti, and Ondo. 3,416,959 people called Osun home as of the 2006 Census (NPC 2006).

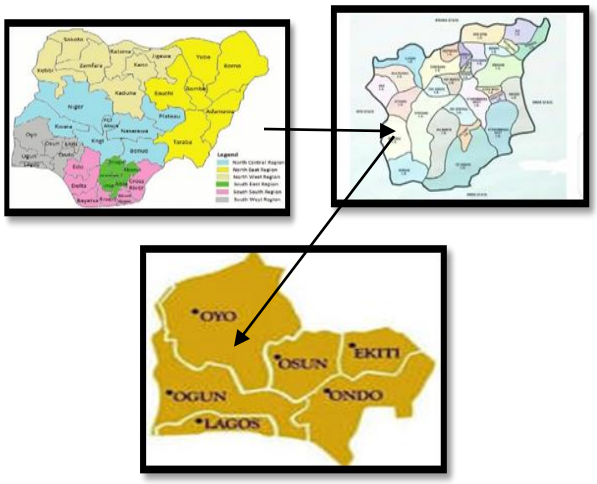

Figure 1. Showing Map of the Study Area

2.3 Map production and numerical value of changes

The maps were produced on ArcGIS software, where the different land use types were differentiated using different color codes, and the interpretation was displayed using a legend. The area in hectares of each land use coverage class was calculated, which assisted in the change detection determination.

2.4 Accuracy assessment

An accuracy evaluation was done to make sure the developmental rate that was analyzed was correct. The producer's accuracy, user's accuracy, and kappa statistics accuracy assessment factors were all employed to compare the ground coordinates to the categorized image. The following are the formulas for the various accuracy assessment processes:

i. Overall Accuracy (%) = Total No of Correctly Classified Pixel / Total No of Reference Pixels * 100%

ii. User Accuracy (%) = Number of correctly classified pixels in each category (Row) / Total number of classified pixels in that category * 100%

iii. Producer Accuracy (%) = Number of correctly classified pixels in each category (Column) / Total number of reference pixels in that category * 100%

iv. Kappa Coefficient (T)= $[(TS * TCS) - \sum(\text{Column Total} * \text{Row Total})/(TS^2 - \sum(\text{Column Total} * \text{Row Total})]$

Land cover class	1986		2016		2019		2022	
	Area Hec	Area %	Area Hec	Area %	Area Hec	Area %	Area Hec	Area %
Barren Land	31509	18	60406	20	26244	15	24282	7
Water Bodies	9	1	52	0	6179	4	75	0
Built-up	36349	22	60464	49	90872	53	579128	69
Vegetation	99267	59	200494	30	47226	28	36609	24
Grand Total	167215	100	32214	100	170521	100	640094	100

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(Note: The Kappa values range between 0 and 1. So, if Kappa is 0, it means there is no agreement between the classified image and the ground truth; then if Kappa is 1, it means the classified image and the ground truth totally agree

2.4 Land cover adopted

1. Barren Land is made up of soil that is unsuitable for plant growth.
2. Vegetation: which broadly refers to all plant life in a location, is the most pervasive biotic component of the biosphere. It speaks of the ground cover provided by vegetation..
3. Water Bodies: In its gaseous, liquid, and solid states, water is a material made up of the elements hydrogen and oxygen. It is one of the most prevalent and significant materials, present in areas such as streams, rivers, marshes, etc.
4. Built-Up Area: A built-up area is a region with a lot of structures, such as a town or city.

3.0 Results and Analysis

This section presents the rate at which development took place in 1986, 2016, 2019, and 2022 using Landsat images. A map showing the rate of development for the years was produced. Each class accuracy is also presented alongside the developmental rates, urban transformation, and urban prediction for the future.

3.1 Accuracy Assessment

Four different Landsat imageries acquired in 1986, 2016, 2019, and 2022 were classified with an average kappa coefficient and overall accuracy of 0.589 and 58.895% respectively as shown in Table 2

Table 2. Image classification Kappa coefficient and overall accuracy of Landsat imageries used

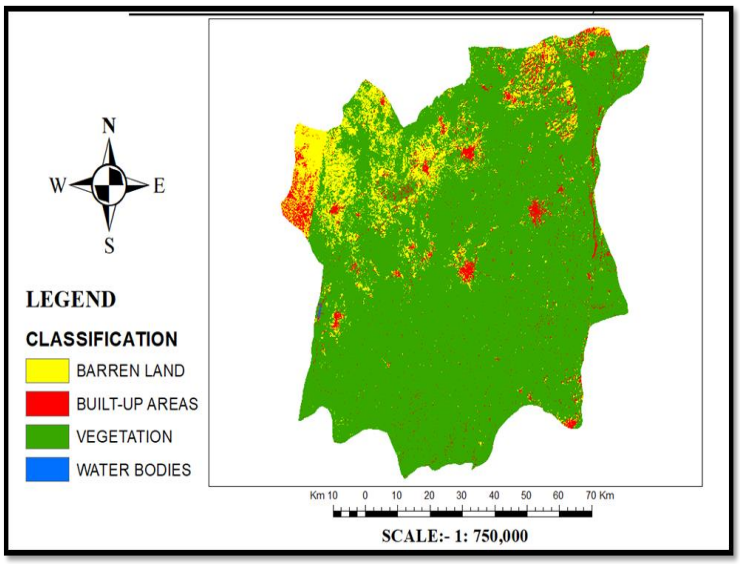
Year	Kappa Coefficient	Overall Accuracy (%)
1986	0.599	59.877
2016	0.498	49.845
2019	0.569	56.915
2022	0.689	68.944
Average	0.589	58.895

3.2 Analysis of the developmental rate between 1986 and 2022

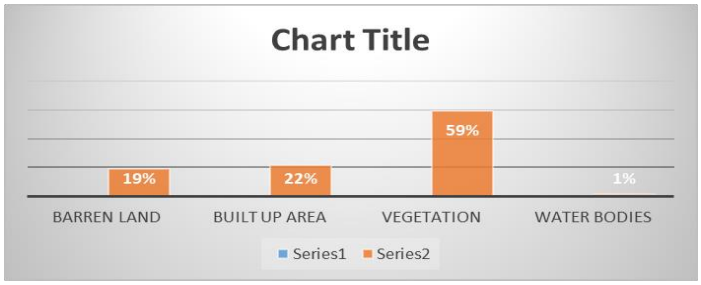
Table 3. Class statistics in Hectares (Hec.) and Percentage (%) for Landsat imageries

Figure2. Land use land cover map for 1986

Figure 3. Land Cover Classification of Osun State for the year 1986



It can be seen in Table 3 and Figure 2 above that, in 1986 Barren Land occupied about 19% (31509



hectares) of the total 167134 hectares of the study area. The built-up area occupied about 22% (36349 hectares), Vegetation occupied 59% (99267 hectares), and Water occupied 1% (9 hectares), respectively.

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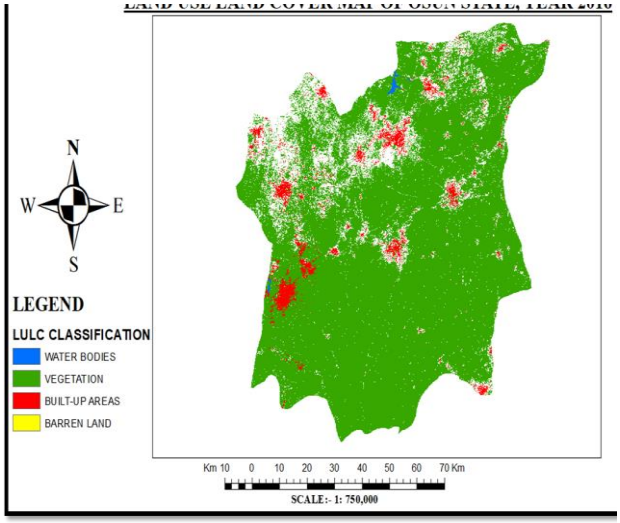
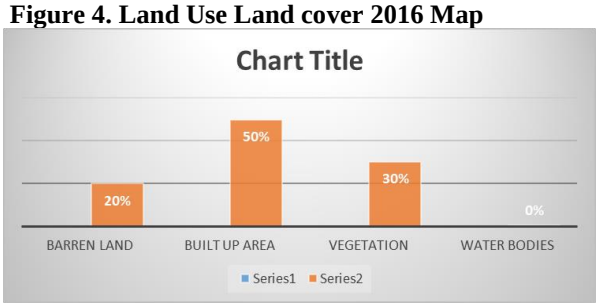
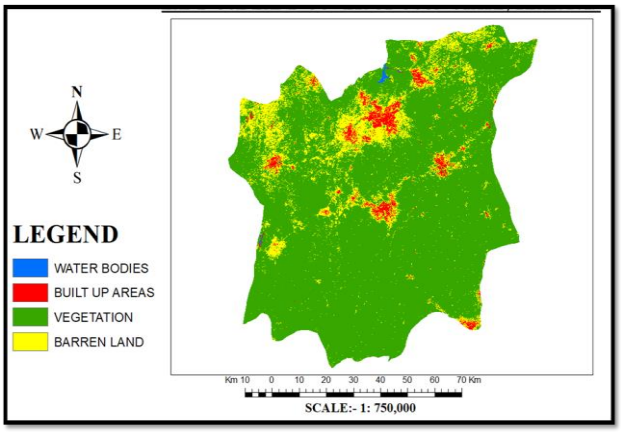


Figure 4. Land Use Land cover 2016 Map



`Figure 5. Land cover classification of Osun State



in the year 2016

The results for 2016 in Table 3 and Figure 4 show that Barren Land occupied about 20% (260406 hectares) of the total 321416 hectares of the study area. The built-up area occupied about 50% (60464 hectares), Vegetation occupied 30% (200494 hectares), and Water occupied 0% (52 hectares), respectively

Figure 6: Land use Land cover 2019

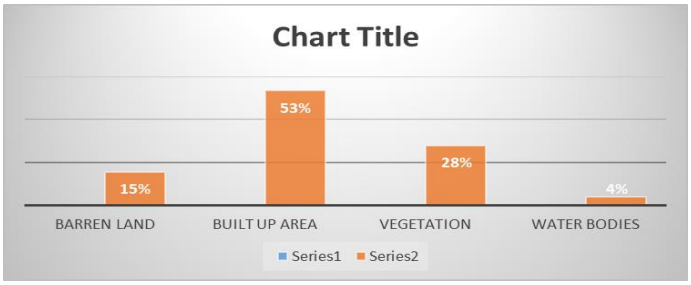
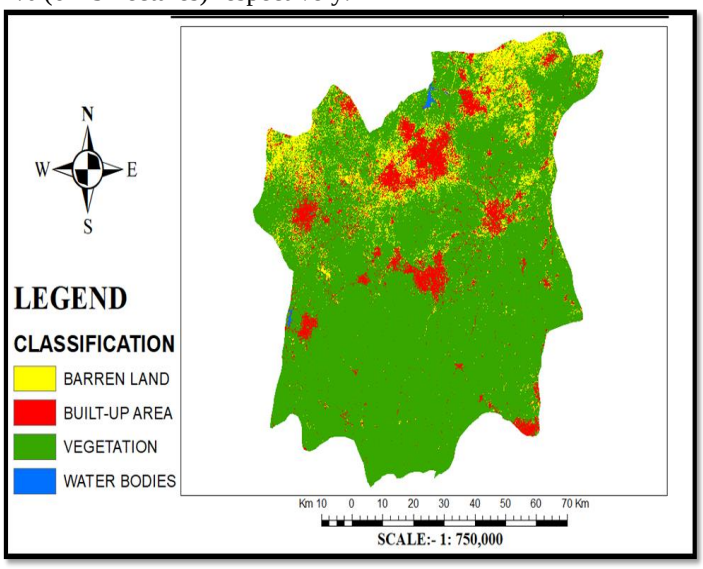


Figure 7. Land Cover Classification of Osun State in year 2019

In the year 2019, the results (Table 3 and Figure 6) show that the Barren Land reduced from 20% in 2016 to 15% (26244 hectares), the built-up area increased to 53% (90872 hectares) and Vegetation decreased to 28% (47226 hectares), while Water Bodies occupied 4% (6179 hectares) respectively.



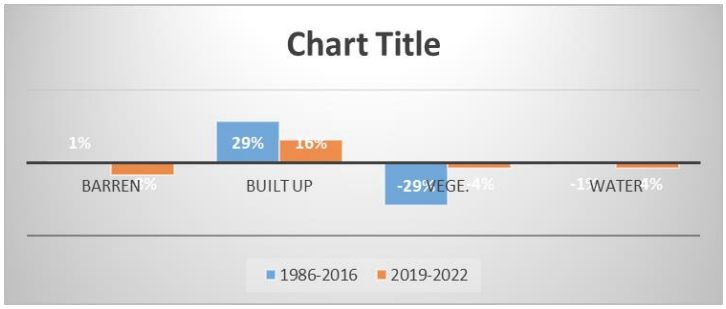


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Figure 8. Land cover map for 2022

Figure: 9 Classification of Land Cover in the Year 2022

It can be seen in Table 3 and Figure 8 above that, in 2022 Barren Land occupied about 7% (24282 hectares) of the total 640094 hectares of the study area. The built-up area occupied about 69% (579128 hectares), Vegetation occupied 24% (36609 hectares), and Water Bodies occupied 0% (75 hectares), respectively.

3.3 Land cover change analysis for the years 1986, 2016, 2019 and 2022

Magnitude = Magnitude of the new year - Magnitude of the previous year

Percentage change for each land use and land cover type was then calculated by subtracting the percentage of the second year's initial year from the second year.

Percentage change = percentage of the New Year –the percentage of the previous year. And it shows in Table 4 below:

Land Use Land Cover Class	1986 – 2016		2019 – 2022	
	Hectares	%	Hectares	%
Barren land	28897	1.1569	-I962	-8.2
Built-Up Area	24115	28.0644	488256	15.6443
Vegetation	101227	-29.2111	-10617	-3.8301
Water Bodies	48	-1.1533	-6104	-3.615
Grand Total	154287	-1.1431	469573	-0.0008

Table 4. Change in area coverage and percentage change of Osun State between 1986 and 2022 for Landsat imageries

From Table 4 and Figure 10 below, barren land, and built-up area percentage keep increasing at the detriment of vegetation, this implies that there are some construction activities in Osun State and also a decrease in agricultural lands.

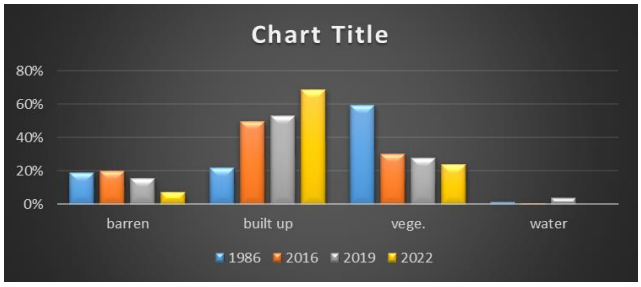

Figure 10: Land cover classification and change analysis for Landsat imageries

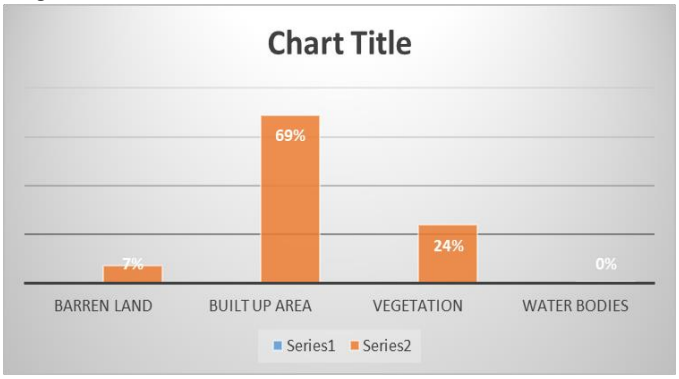

Fig 11. ***land cover change analysis for the years 1986, 2016, 2019, and 2022***

Built-up change analysis and predictive model for future expansion

Year	Growth Area (hectare)	Percentage (%)
1986	36349	21.7379
2016	60464	49.8023
2019	90872	53.2907
2022	227004	154.6395
2025	476814	311.8953
2028	1055727	699.8022

Table 5. Built-up Change Detection Analysis for Osun state for Land cover for Landsat imageries

The limits of Osun state, extracted from the Landsat satellite imageries shall experience a shift based on the future prediction by the year 2025 to 2028. In 1986, the area it occupied was about 36349 hectares, which increased to 60464 hectares in 2016, increased to 90872 hectares in 2019, 227004 hectares in 2022, increased to 476814 hectares in 2025, and increased to 1055727 hectares, in 2028.

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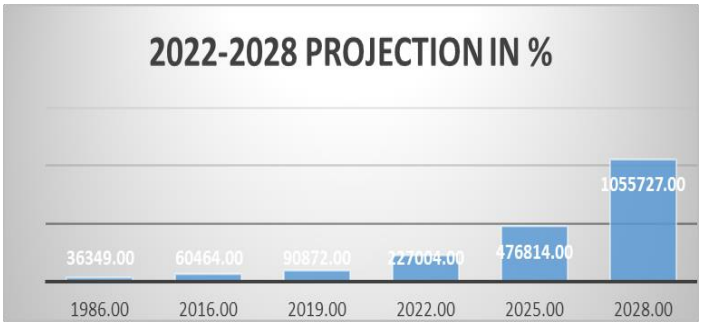

Figure 12. Expansion of the Built-Up Area of Osun State with Landsat Imageries

3.4 Discussion

The water body in the area, which occupied 9 hectares (1%) in 1986, was seen to have shrunk by 52 hectares (0%) in 2016, increased by 6179 hectares (4%) in 2019, and then shrunk by 75 hectares (0%), all of which occurred during the following two years. The observed decline can be attributable to natural dry-up which creates acceptable development areas.

The vegetation cover showed the greatest change among all other categories in 1986, growing by 99267 hectares (59%) overall. A reduction of 36609 hectares (24%) in 2022 follows a decline of 200494 hectares (30%) in vegetation in 2016 to 47226 hectares (28%) in 2019. The observed decline can be explained by site clearing for construction objectives to slow socio-economic development.

The built-up area, which was 36349 hectares (22%) in 1986, climbed to 60464 hectares (50%) in 2016, registering a total rise of 90872 hectares (52%) in 2019, and increased to 579128 hectares (69%) in 2022, according to observations. According to the observed change, socioeconomic developments have had an impact on physical development.

Within the 36-year period, the barren land saw a loss of 24282 hectares (7%) total. It took up 31509 hectares (19%) in 1986, climbed to 60406 hectares (20%), declined to 26244 hectares (15%) in 2019, and then increased to 31509 hectares (19%) in 1986. The socioeconomic development and expansion that have been observed in the research region can be linked to the observed decline. These findings enabled us to thoroughly investigate how land-use planning regulations have affected past, present, and future LULC change.

3.5 Conclusion

Using satellite data and GIS, the post-classification analysis of the dynamics of urban growth and land cover shows that the entire local government is growing at a rate of 5.670% per year. Between 1986 and 2022, there was an unplanned, rapid urbanization and population concentration that led to this. The investigation shows that the areas have greatly grown, which has resulted in a decrease in vegetation area. This work has demonstrated how the use of remote sensing data, which can offer chances for periodic surveys of land use and land cover changes and their geographical distribution, can help address the lack of pertinent spatial information necessary for planning. The area in hectares is used to generate the prediction, and a chart is displayed with the anticipated values for 2022, 2025, and 2028 (227004 hectares, 476814 hectares, and 1055727 hectares) respectively.

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