

Spatio-Temporal Analysis of Land Cover Dynamics and Urban Expansion in Calabar Municipal, Nigeria (2000–2020)

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ABSTRACT: This study investigates the spatio-temporal patterns of land cover and land use change in Calabar Municipal, Nigeria, from 2000 to 2020. Using remote sensing-based classification techniques, six major land cover types were analyzed: forest, built-up area, low vegetation, cropland, open space, and waterbody. Results reveal a progressive increase in built-up area from 66.93 km² in 2000 to 79.71 km² in 2020, representing a cumulative growth of 12.78 km², while forest cover remained relatively stable, peaking at 180.92 km² in 2010 and slightly declining to 179.41 km² in 2020. Conversely, low vegetation and cropland significantly declined, with low vegetation decreasing by over 15.89 km². The land use intensity index (LUII) was highest between 2000 and 2010 (0.00987) and decreased to 0.00421 between 2010 and 2020, suggesting a deceleration in land transformation. The annual rate of change for built-up areas indicates rapid urbanization in the first decade, transitioning to slower growth in the second. The study emphasizes the need for sustainable land use policies that preserve ecological stability while accommodating urban development.

Keywords: Land cover change, urban expansion, Calabar Municipal, land use intensity index, spatial analysis, remote sensing

I. INTRODUCTION

Urbanization has emerged as a dominant force reshaping terrestrial landscapes across the globe, particularly in developing regions where demographic and economic transitions have accelerated land cover changes (Seto et al., 2012; Angel et al., 2011). In sub-Saharan Africa, urban expansion is often characterized by rapid, unregulated growth that results in significant alterations to land use configurations, with

implications for biodiversity, hydrology, food security, and ecosystem integrity (Cobbinah et al., 2015; Olarewaju et al., 2020). Understanding the patterns and drivers of such transformations is imperative for planning resilient cities that can adapt to both population pressures and environmental constraints (Abiodun et al., 2018).

In Nigeria, the urban footprint has grown considerably over the past few decades, driven by internal migration, economic activities, and administrative centralization (Ayeni et al., 2016). Calabar Municipal, the capital of Cross River State, exemplifies this trend. With its strategic administrative function and tourism potential, Calabar has attracted significant infrastructural development, prompting the conversion of natural and semi-natural land covers into urban forms (Ade & Afolabi, 2020; Eni et al., 2017).

Land use/land cover (LULC) change analysis offers a vital lens through which to evaluate the ecological and socioeconomic consequences of urban expansion. Geospatial technologies, particularly satellite remote sensing and geographic information systems (GIS), have become indispensable tools for monitoring these dynamics at multiple spatial and temporal scales (Lillesand et al., 2015; Jensen, 2016). These technologies facilitate not only the detection of land cover change but also the quantification of land use intensity and the prediction of future trends through modeling techniques (Guan et al., 2011).

Several studies have emphasized the utility of spatio-temporal land cover analysis in understanding environmental degradation, assessing urban sprawl, and supporting sustainable land management (Herold et al., 2003; Weng, 2012; Mundia & Aniya, 2006). The Land Use Intensity Index (LUII), in particular, provides a metric for

evaluating the magnitude and rate of land transformations over time, making it useful for comparative urban ecological assessments (Seto et al., 2012; Kintziger et al., 2020).

Despite increasing interest in LULC dynamics within Nigeria, most research has concentrated on megacities such as Lagos, Abuja, and Port Harcourt (Adepoju et al., 2018; Akinyemi, 2017), leaving smaller yet rapidly developing cities like Calabar underrepresented. There remains a dearth of empirical studies focusing on the nuanced ecological transitions occurring in mid-sized urban centers, which are often overshadowed in national urban policy discourses.

The present study aims to address this gap by undertaking a systematic assessment of land cover transitions in Calabar Municipal from 2000 to 2020. It applies geospatial techniques to quantify changes in major land cover types, computes LUI values to determine the intensity of change, and analyzes annual rates of transformation across three distinct time points. The findings are intended to inform spatial planning strategies that reconcile urban development with environmental sustainability.

II. MATERIALS AND METHODS

2.1 Study Area

Calabar Municipal is located in Cross River State, southeastern Nigeria. Geographically, it lies between latitudes 4°55'N and 5°10'N and longitudes 8°15'E and 8°25'E. The area is bounded to the west by Calabar South LGA, to the north by Odukpani LGA, and to the east and south by the Calabar River and the Atlantic estuary. Calabar Municipal serves as the administrative and cultural capital of Cross River State, characterized by significant residential, commercial, and institutional land uses. The municipality experiences a tropical monsoon climate with annual rainfall exceeding 3,000 mm and average temperatures ranging between 25°C and 28°C. Vegetation is dominated by tropical rainforest, interspersed with mangroves along the riverbanks. As a medium-sized urban center, Calabar Municipal has undergone notable transformation due to population pressure, urban infrastructure development, and land use reconfiguration.

2.2 Data Acquisition and Preprocessing

Landsat imagery for the years 2000, 2010, and 2020 was sourced from the United States Geological Survey (USGS) Earth Explorer platform. Specifically, Landsat 5 Thematic Mapper (TM) was used for the year 2000, Landsat 7

Enhanced Thematic Mapper Plus (ETM+) for 2010, and Landsat 8 Operational Land Imager (OLI) for 2020. Each image was selected during the dry season to minimize atmospheric interference and ensure temporal consistency. All images were geometrically corrected to the UTM Zone 32N projection (WGS 84 datum) and radiometrically calibrated to top-of-atmosphere reflectance.

2.3 Image Classification

The preprocessed images were classified using supervised classification techniques within a GIS environment. Training samples were generated based on visual interpretation, field knowledge, and high-resolution basemaps from Google Earth. The maximum likelihood classification algorithm was used to categorize the landscape into six land cover classes: built-up area, forest, low vegetation, cropland, open space, and waterbody. Post-classification filtering was applied to reduce classification noise.

2.4 Change Detection and Trend Analysis

Change detection and trend analysis were employed in this study to identify, quantify, and interpret the temporal dynamics of landcover and landuse transformation in Calabar Municipal between the years 2000 and 2020. These techniques served to provide both descriptive and inferential insights into how and to what extent landcover classes evolved over the 20-year period. The primary objective was to detect class conversions, determine spatial expansion or reduction trends, and highlight critical periods of change that correspond with observed or projected urban development patterns.

The change detection analysis was conducted using the post-classification comparison technique, which is widely recognized for its ability to generate accurate and temporally specific change information. This approach involves independently classifying each temporal image and then comparing the classified outputs to determine changes between corresponding landcover classes. Classified landcover maps for the years 2000, 2010 and 2020 previously produced through Random Forest classification were used as inputs for this analysis.

To execute the post-classification comparison, raster algebra was employed in QGIS environments. Pairwise comparisons were conducted across five intervals: 2000–2010 and 2010 - 2020. Each pair of classified rasters was overlaid and analyzed to detect the spatial extent and direction of change from one class to another.

The output was a raster change map showing all pixels where class transitions had occurred. These were further tabulated to calculate class-specific area changes, percentage change, and net gain/loss per class and interval.

For each landcover class, the rate of change was computed using the following formula:

$$\text{Rate of Change (\% per year)} = \left(\frac{A_t - A_0}{A_0} \times \frac{100}{\Delta t} \right) \quad (1)$$

A_t = Area of the landcover class at time t

A_0 = Area of the landcover class at the initial time

Δt = Number of years between observations

This rate enabled the analysis of not just the magnitude of change, but also the temporal intensity at which transitions occurred, highlighting periods of accelerated urban growth or environmental recovery.

Additionally, trend analysis was applied to understand the cumulative pattern of change across the entire study period. Using Microsoft Excel and Python's Pandas and Matplotlib libraries, tabular datasets were created to track the absolute and percentage change for each class across all time periods. Visualizations such as stacked bar charts, line graphs, and area plots were used to present changes in landcover composition and identify turning points or inflection years where the dynamics shifted significantly.

The integration of both quantitative tabulation and visual trends allowed for a nuanced interpretation of landcover transitions, providing the foundation for subsequent modeling and predictive analysis. Ultimately, the change detection and trend analysis offered a reliable mechanism to assess the direction, magnitude, and rate of landscape transformation, all of which are essential for informed land-use planning and environmental sustainability in Calabar Municipal.

2.5 Landcover and Landuse Intensity Index (LUI)

To assess the extent and evolution of anthropogenic pressure on the land surface within Calabar Municipal, this study employed the Land Use Intensity Index (LUI). The LUI is a composite metric used to quantify the intensity of land use over time, based on the proportion of each landcover class and the relative degree of human influence associated with them. It serves as a proxy for understanding how development patterns affect the landscape, providing a structured framework to interpret the environmental consequences of urban

expansion, ecological degradation, or land transformation.

The rationale for adopting the LUI lies in its capacity to integrate both qualitative and quantitative landcover characteristics into a single indicator. While traditional landcover change analysis focuses on area statistics, the LUI offers a value-added perspective by incorporating the weight of human activity assigned to each class. In this study, each of the four identified landcover classes was assigned an intensity weight, reflecting its level of human modification or environmental sensitivity as follows:

1. Built-Up Area = 4 (most intensive use)
2. Waterbody = 3
3. Cropland/Forest/Low Vegetation = 2
4. Open Space = 1 (least intensive use)

These weights were informed by existing literature on land transformation and urban ecological footprints, as well as expert judgment regarding the functional implications of each landcover category in the context of Calabar Municipal.

The LUI was calculated for each observation year 2000, 2010 and 2020 based on the classified landcover area values derived from remote sensing analysis. The formula used for calculating the index is:

$$LUI = \frac{\sum(A_i \times W_i)}{A_T} \quad (2)$$

Where:

A_i = Area (in km^2) of landcover class i

W_i = Assigned weight of landcover class i

A_T = Total land area of the study area (in km^2)

Each year's landcover area data was compiled in Microsoft Excel and validated against spatial outputs from QGIS to ensure consistency. The weighted sum of each landcover type was then divided by the total land area to generate a dimensionless index value.

Higher LUI values indicate greater land use pressure, typically characterized by urban sprawl, loss of ecological buffer zones, and reduction of natural land covers. Conversely, lower LUI values indicate a more balanced or ecologically dominant landscape. In this study, the LUI was computed for all six time periods and the results were plotted as a line graph to observe temporal trends.

III. RESULTS

3.1. Landcover/Landuse Class Distribution (2000–2020)

An assessment of the landcover/landuse statistics across the study period highlighted the profound transformations that occurred between 2000 and 2020. The landcover classes considered include open space, built up area, cropland, forest, low vegetation and waterbody.

In the year 2000, the landscape of Calabar Municipal was predominantly forested, with 174.397 km², accounting for 55.01% of the total land area. This extensive forest cover signifies a relatively undeveloped and ecologically intact environment. The second most prominent category was built-up areas, occupying 66.931 km² or 21.11%, indicating moderate urban development likely concentrated within core administrative and residential zones.

Low vegetation constituted 23.715 km² or 7.48%, reflecting patches of grassland, bush fallows, and secondary growth areas. Open space followed with an extent of 8.411 km² or 2.65%, which may represent unpaved areas, bare lands, and other vacant lands not under active vegetation or infrastructure use.

Cropland was the least represented landuse type, occupying only 0.452 km², a mere 0.14% of the total area. This minimal representation implies that agricultural activity within the municipal boundaries was limited, likely constrained by topographic, urban, or policy-related factors.

The landcover pattern in 2000 indicates a predominantly natural landscape, with signs of emerging urban influence, particularly in the growth of built-up areas, see table 1 and figure 1.

Table 1: Landcover/landuse Distribution for Calabar Municipal in 2000

S/N	Class (Year 2000)	Area (Km2)	Percentage
1	Open Space	8.411	2.653
2	Built Up Area	66.931	21.112
3	Cropland	0.452	0.143
4	Forest	174.397	55.01
5	Low Vegetation	23.715	7.481
6	WaterBody	43.12	13.601

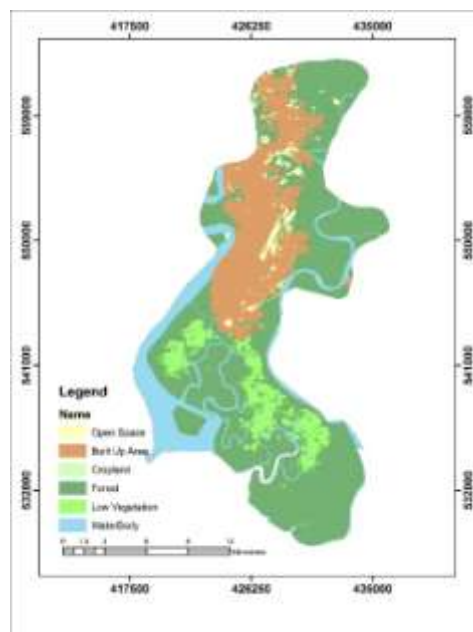


Figure 1: Landcover/landuse Map of Calabar Municipal 2000

By 2010, noticeable transitions had occurred across various landcover types, reflecting

significant urban and ecological dynamics. The forest class increased to 180.922 km², representing

57.07% of the total area. This increment indicates either forest regeneration or classification refinements that favored denser vegetative mapping.

The built-up area also expanded to 73.791 km², equating to 23.28%. This increase by nearly 6.86 km² within a decade indicates ongoing infrastructural development and spatial urban growth. The intensification of urban landuse during this period is consistent with broader trends in Nigerian urban centers where population growth and economic activity drive increased construction.

Low vegetation areas experienced a dramatic reduction, decreasing to 11.703 km² or 3.69%. This contraction of over 50% compared to 2000 underscores a loss of natural buffer areas, possibly due to conversion into residential estates or cleared land.

Open space also declined significantly to 4.776 km² or 1.51%, further reinforcing the trend of increased land utilization for human settlement and services.

Cropland expanded significantly to 1.883 km², which constitutes 0.59% of the land area. This more than fourfold increase may indicate the promotion of urban agriculture or conversion of some open/vegetated areas for farming purposes, possibly influenced by subsistence farming within peri-urban contexts.

In sum, the 2010 landcover structure reveals an intensifying human footprint, with urban development, agricultural adaptation, and vegetation clearance as defining dynamics. see table 2 and 2.

Table 2: Landcover/landuse Distribution for Calabar Municipal in 2010

S/N	Class (Year 2005)	Area (Km2)	Percentage
1	Open Space	4.776	1.507
2	Built Up Area	73.791	23.276
3	Cropland	1.883	0.594
4	Forest	180.922	57.068
5	Low Vegetation	11.703	3.692
6	Water Body	43.952	13.864

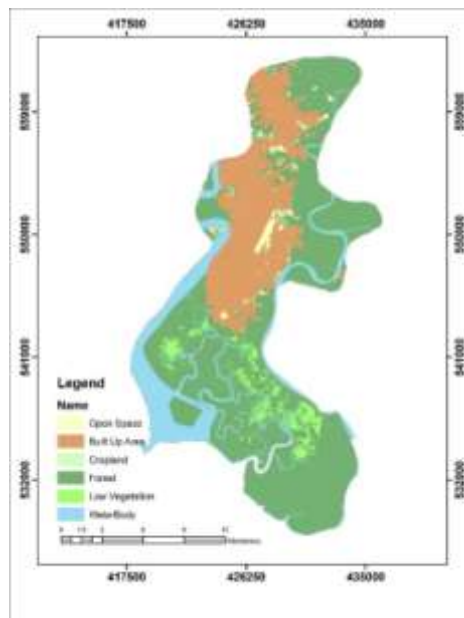


Figure 2: Landcover/landuse Map of Calabar Municipal 2010

By 2020, the trends observed in the preceding decade became more pronounced, with continued expansion of the built environment and

reduction of transitional landcovers. Forest cover slightly decreased to 179.409 km², yet still maintained the highest proportion at 57.14%,

indicating persistent dominance of natural forest ecosystems within the municipality.

Built-up area increased further to 79.711 km², comprising 24.51% of the total land area. This upward movement by approximately 5.92 km² from 2010 signifies sustained urban growth and possibly reflects intensification of land development around central zones and expansion toward peri-urban fringes.

Low vegetation reduced again, declining to 7.826 km² or 2.47%, thereby losing more than 15.89 km² since 2000. This consistent trend illustrates long-term suppression of transitional or secondary vegetative landcover, often a precursor to full urbanization.

Cropland area shrank dramatically to 0.887 km² or 0.28%, nearly halving its extent

compared to 2010. This reduction may result from spatial competition with residential, commercial, or infrastructural developments, marginalizing urban agriculture.

Open space slightly increased to 5.537 km² (1.75%), diverging from the previous decline. This resurgence may reflect deliberate planning to preserve or create public open spaces or the temporary clearing of land ahead of development.

The 2020 landcover distribution demonstrates an urban-ecological dichotomy: while urban infrastructure continued to expand, forested areas remained relatively stable, and transitional landuses such as low vegetation and cropland were diminished or absorbed, see table 3 and figure 3.

Table 3: Landcover/landuse Distribution for Calabar Municipal in 2020

S/N	Class (Year 2010)	Area (Km2)	Percentage
1	Open Space	5.537	1.747
2	Built Up Area	79.711	24.512
3	Cropland	0.887	0.28
4	Forest	179.409	57.14
5	Low Vegetation	7.826	2.469
6	WaterBody	43.657	13.852

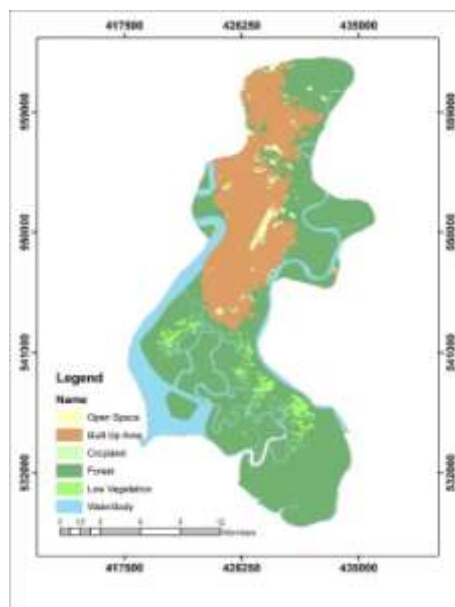


Figure 3: Landcover/landuse Map of Calabar Municipal 2020

The comparative analysis of landcover and landuse statistics in Calabar Municipal across the years 2000, 2010, and 2020 reveals distinct spatial-temporal patterns reflective of urban expansion, ecological transition, and shifting land use

priorities. The following synthesis examines the trajectory of each landcover type, highlights key transformations, and identifies possible drivers of change within the context of a rapidly urbanizing municipality.

Throughout the two-decade reference period, forest land remained the most extensive landcover category. From 174.397 km² in 2000, forest area increased slightly to 180.922 km² in 2010, followed by a marginal reduction to 179.409 km² in 2020. The percentage share hovered consistently around 55–57%, reflecting resilience against large-scale deforestation. The initial increase may indicate natural regrowth or improved classification techniques that identified denser canopy zones. The slight decline in 2020, though not drastic, might indicate growing encroachment from built-up developments or resource extraction pressures. Despite these shifts, the stability of forest extent indicates that Calabar Municipal still retains significant ecological assets that support biodiversity and provide environmental services.

Built-up land exhibits the most prominent trend of continuous growth. It expanded from 66.931 km² (21.11%) in 2000 to 73.791 km² (23.28%) in 2010 and further to 79.711 km² (24.51%) in 2020. This cumulative increase of 12.78 km² underscores persistent urbanization, likely driven by population growth, economic development, and increased demand for housing and infrastructure. The consistent rise also reflects infrastructural investments and the spatial reconfiguration of Calabar Municipal from a semi-urban environment into a more urbanized administrative capital. The built-up area's growth, though not exponential, follows a predictable urban trajectory, emphasizing the need for sustainable land management to prevent unchecked sprawl.

Low vegetation experienced the steepest decline among all landcover categories, shrinking from 23.715 km² in 2000 to 11.703 km² in 2010 and further to 7.826 km² in 2020. This consistent reduction by nearly 16 km² (a 66% decline)

indicates that low vegetation areas served as transitional zones rapidly absorbed into urban or forested environments. The decline may result from the intensification of development activities, suppression of natural successional processes, or conversion to infrastructure. These areas, which often serve as buffers and secondary ecological zones, are increasingly being replaced or degraded, thereby reducing the landscape's resilience to environmental change.

Cropland areas remained the least extensive landcover category throughout the period but exhibited notable fluctuations. From 0.452 km² in 2000, cropland increased more than fourfold to 1.883 km² in 2010, possibly due to increased urban farming or peri-urban agricultural practices. However, by 2020, cropland sharply declined to 0.887 km², almost returning to its 2000 level. This oscillation highlights the vulnerability of agricultural lands to urban encroachment and shifting landuse priorities in urbanizing landscapes. The decreasing trend toward 2020 also implies a reduction in food production potential within the municipal boundary, raising concerns about urban food security and land-use conflict.

Open space declined significantly from 8.411 km² in 2000 to 4.776 km² in 2010, reflecting early conversion to built-up or other productive uses. By 2020, a modest increase to 5.537 km² was observed, indicating a reversal or stabilization in land clearing patterns. The partial recovery may indicate either temporary land abandonment, construction pauses, or designated space for recreational and community uses. The open space trend underscores the dynamic competition between land preservation and utilization within the urban system, see table .4

Table 4: Summary of Spatial Trends (2000–2020)

Landcover Type	2000 (km ²)	2010 (km ²)	2020 (km ²)	Net Change (2000–2020)
Forest	174.397	180.922	179.409	+5.012
Built-Up Area	66.931	73.791	79.711	+12.780
Low Vegetation	23.715	11.703	7.826	-15.889
Cropland	0.452	1.883	0.887	+0.435
Open Space	8.411	4.776	5.537	-2.874

Table 4 summarizes the absolute landcover changes across the two-decade period. While the forest and built-up categories registered net gains, the others showed varying degrees of reduction, particularly in transitional or less protected zones. The expansion of built-up areas appears to be occurring primarily at the expense of low vegetation and open space.

The long-term implications of these transitions point to increasing anthropogenic influence, diminishing buffer zones, and a need to balance development with conservation. These findings provide a basis for evaluating urban planning policies, ecosystem health, and spatial equity in future land management initiatives.

3.2. Land Use Intensity Analysis of Calabar Municipal (2000–2020)

The Land Use Intensity Index (LUII) serves as a metric for quantifying the magnitude of landcover transitions within a defined spatial extent and temporal interval. This analysis evaluates the rate at which landcover types changed across Calabar Municipal over a twenty-year span and within two successive decadal intervals: 2000–2010 and 2010–2020. The calculation is based on the ratio of the sum of absolute landcover changes to the product of total land area and time duration.

During the first decade (2000 – 2010), the LUII was computed to be approximately 0.00987, signifying that about 0.987% of the total municipal land area underwent a change in landcover classification annually. This relatively higher intensity indicates a period of pronounced landscape transformation, likely driven by infrastructural development, land conversion for residential use, and the reduction of transitional ecological zones. The expansion of built-up areas

and concurrent reduction in low vegetation and open space were the predominant factors contributing to this high land conversion rate.

In the subsequent decade (2010 – 2020), the LUII declined to 0.00421, implying an annual landcover change rate of approximately 0.421%. This reduction in intensity indicates a deceleration in landscape transformation processes. The lower magnitude of change during this period may be attributed to regulatory planning measures, urban saturation in core areas, or stabilization of land development dynamics. Although urban growth continued, the relative rate of land conversion was less intense compared to the preceding decade.

Across the full 20-year period, the average LUII was calculated to be 0.00592, indicating that roughly 0.592% of Calabar Municipal’s land area experienced change per annum. This cumulative measure reflects a moderately dynamic landscape characterized by progressive but not abrupt transitions, predominantly in favor of urban expansion and marginal ecological reclassification.

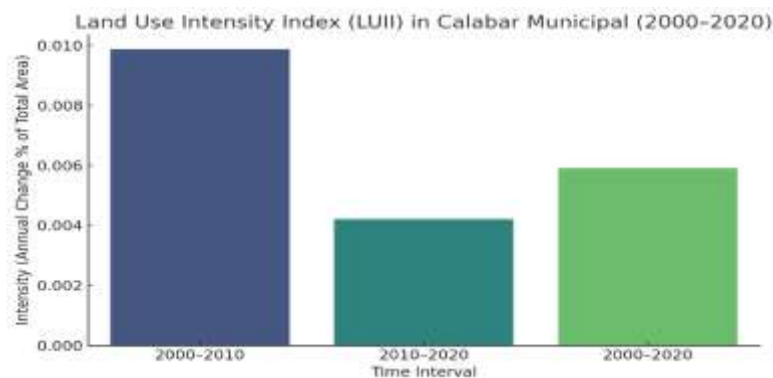


Figure 4: Landcover/Landuse Intensity Index (2000 -2020)

Figure 4 visualizes the Land Use Intensity Index (LUII) for Calabar Municipal across the intervals 2000–2010, 2010–2020, and the aggregated period of 2000–2020. The figure clearly illustrates the heightened intensity of landcover change during the first decade, followed by a noticeable reduction in the subsequent decade, resulting in a moderate overall intensity for the entire study period.

From a sustainable development standpoint, land use intensity offers insight into how efficiently and responsibly land resources are being utilized. According to global assessments (Seto et al., 2012; Angel et al., 2011), rapidly urbanizing cities in low- and middle-income countries often experience LUII values ranging from 0.01 to 0.03, reflecting aggressive land consumption patterns. Comparatively, the intensity

values observed in Calabar Municipal remain well below these thresholds, indicating a relatively controlled transformation of landcover types.

The high LUII of 0.00987 during 2000–2010 is consistent with early-stage urban growth, where land is rapidly converted to accommodate expanding infrastructure and population demands. However, the marked decline to 0.00421 between 2010 and 2020 reflects a phase of urban maturation, potentially indicative of either constrained development space, increased policy interventions, or demographic shifts.

Sustainable land use frameworks, such as those advocated by the United Nations Sustainable Development Goal (SDG) 11—"Sustainable Cities and Communities"—emphasize the need to contain urban sprawl, preserve green spaces, and minimize ecological disruption. The observed average LUII

of 0.00592 aligns with such principles, reflecting a spatial development path that, while transformative, does not appear to overexploit land resources.

Furthermore, regional studies in sub-Saharan African urban zones (e.g., Lagos, Accra, Kampala) have documented LUII values often exceeding 1.5% annually in peri-urban belts (Cobbinah et al., 2015; Olarewaju et al., 2020). In this context, Calabar Municipal demonstrates a more conservative trajectory of land development, potentially offering a replicable model for balanced urban-ecological co-evolution.

3.3. Temporal Trends and Annual Rates of Landcover Change in Calabar Municipal (2000–2020)

A detailed assessment of landcover dynamics requires the determination of absolute trends and annual rates of change. These metrics enable the evaluation of both the magnitude and pace at which different landcover types have transformed over time. For Calabar Municipal, the periods 2000–2010 and 2010–2020 were independently analyzed to capture decadal shifts in landscape configuration.

3.3.1. Trend Analysis between 2000–2010

The first decade (2000–2010) was marked by intensive land transformation, as evidenced by the high magnitudes of change across several landcover types. The built-up area increased by approximately 6.86 km², translating to an average annual expansion rate of 0.686 km²/year. This substantial growth reflects a period of accelerated urbanization, consistent with population influx, economic development, and administrative infrastructural expansion in Calabar Municipal. The built-up surge likely included construction of

residential estates, administrative buildings, commercial centers, and transportation networks.

Forest area also increased by 6.525 km² (0.6525 km²/year), which is notable given the simultaneous urban growth. This anomaly can be attributed to either reclassification of dense vegetation, recovery of secondary forests, or increased vegetative mapping resolution. It may also reflect the preservation of urban green belts or lowland rainforest reserves within or around the municipal perimeter.

Cropland, traditionally the least dominant landuse class in Calabar Municipal, recorded a fourfold increase from 0.452 km² to 1.883 km², marking a 1.431 km² gain at 0.1431 km²/year. This change may be linked to the emergence of peri-urban agriculture or reallocation of marginal land to short-cycle cropping, possibly driven by urban food demand.

Conversely, low vegetation suffered a significant reduction of 12.012 km², corresponding to an annual rate of –1.2012 km²/year. This class typically includes fallow lands, grasslands, and shrublands, which are often the first to be cleared for development. The sharp decline signifies a transitional shift where such lands were either developed or became ecologically dense and reclassified as forest.

Open space decreased by 3.635 km² at –0.3635 km²/year, indicating a loss of undeveloped plots, playgrounds, or vacant lots to building projects. This pattern is consistent with urban land pressures that typically lead to the occupation of all available non-vegetated space.

Overall, the 2000–2010 period reflects a landscape in flux, shaped by rapid urbanization, moderate ecological recovery, and the disappearance of transitional vegetative buffers.

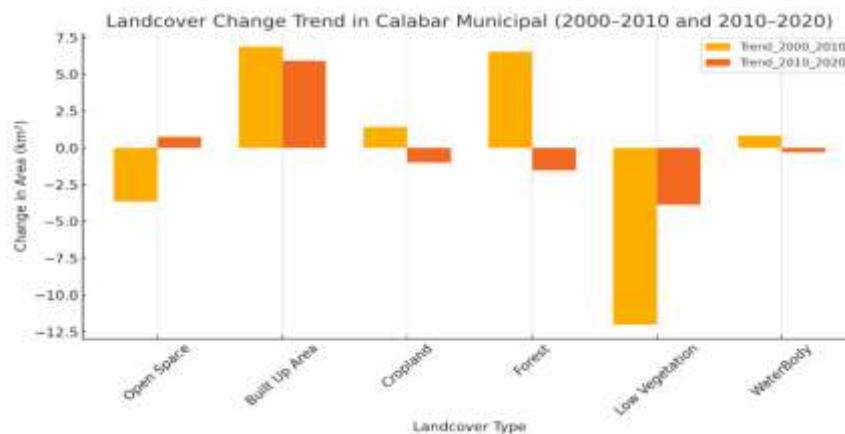


Figure 5: Trend of Change between 2000 -2020

3.3.2. Trend Analysis between 2010–2020

The subsequent decade (2010–2020) presents a different spatial trajectory, marked by slower rates of change and nuanced shifts in the landscape fabric. Built-up area continued to expand by 5.92 km², but at a reduced annual rate of 0.592 km²/year. While still significant, the deceleration indicates that the pace of new development may have stabilized, possibly due to urban saturation in core areas, improved zoning regulations, or the redirection of growth to satellite towns.

Open space saw a reversal from its previous decline, increasing by 0.761 km² (0.0761 km²/year). This modest gain indicates the formalization of open land, possibly through the development of parks, recreational areas, or temporarily cleared land awaiting construction. It may also reflect better urban planning practices and the intentional preservation of green infrastructure in response to sustainability guidelines.

In contrast, forest area, which had previously shown net positive growth, declined by 1.513 km² (–0.1513 km²/year). This shift signals the beginning of gradual ecological pressure where forested zones are being encroached upon—whether for roads, housing expansion, or commercial developments. If this trend persists, the long-standing forest dominance of Calabar Municipal could become compromised.

Cropland decreased by 0.996 km² (–0.0996 km²/year), reversing the prior decade's

increase. This indicates that agricultural spaces are being outcompeted by urban functions, or perhaps that agriculture is increasingly marginalized to more distant rural areas. The drop aligns with broader patterns of urban land consumption seen in sub-Saharan cities.

Low vegetation further contracted by 3.877 km², at a reduced rate of –0.3877 km²/year. Although the rate of decline slowed compared to the previous decade, this class remains the most consistently diminishing, underscoring its status as the most vulnerable landcover type in the urban transition zone.

Together, these patterns indicate that the 2010–2020 period was characterized by urban consolidation, rather than expansion, with marginal ecological losses and minor compensatory gains in open space. The rates of landcover change indicate a moderation of developmental aggressiveness, perhaps due to maturing city structures, land scarcity, or planning reforms. From a spatial development perspective, the contrasting trends between the two decades highlight the evolution of urban growth phases. The first decade (2000–2010) reflects a period of rapid landcover turnover, typical of early urbanization stages. In contrast, the second decade (2010–2020) exhibits temporal slowing, with selective transformation concentrated in ecologically sensitive areas.

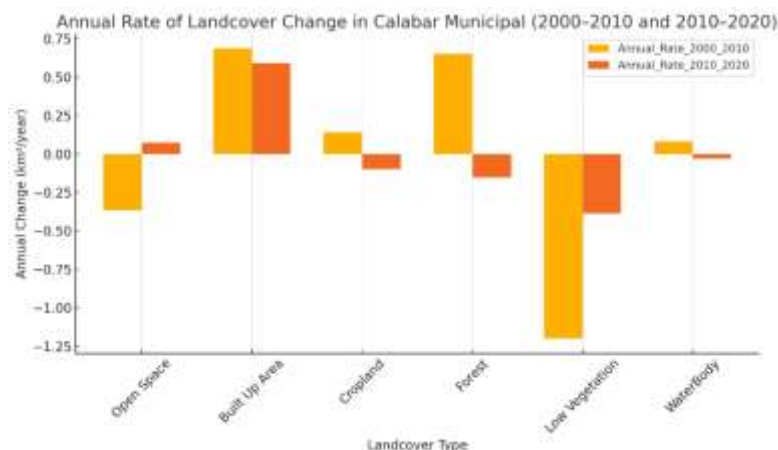


Figure 4.6: Annual Rate of Change between 2000 -2010

These findings have far-reaching implications. The reduction in low vegetation and cropland, if left unmanaged, may lead to ecological fragmentation, loss of urban food security zones, and increased surface runoff and urban heat island effects. Conversely, the modest gains in open space and retention of significant forest cover represent

opportunities for green space planning, climate resilience, and biodiversity conservation.

If continued urban growth is not paired with integrated land-use policies, Calabar Municipal may witness further loss of ecological assets. However, the trend moderation in recent years offers a window for adaptive planning,

including the designation of conservation zones, the use of spatial modeling tools for land allocation, and the reinforcement of sustainability guidelines through participatory governance.

IV. CONCLUSION

Calabar Municipal has undergone substantial but controlled land cover transitions between 2000 and 2020. The most prominent transformation is the expansion of built-up areas, which increased by 12.78 km² over the study period, indicative of consistent urbanization. This growth was particularly rapid between 2000 and 2010, with a corresponding high Land Use Intensity Index (LUII) of 0.00987, before slowing in the subsequent decade to a LUII of 0.00421. Despite this expansion, forest cover remained relatively stable, fluctuating only slightly over the years. This outcome suggests that urban development has, to a limited extent, respected existing forest boundaries or that protective policies may have contributed to preserving green cover.

Conversely, the decline in low vegetation (by over 15.89 km²) and cropland indicates ongoing pressure on transitional and agriculturally viable land. These land cover types are often the first to be encroached upon during urban development, serving as buffer zones between urban centers and core ecological zones. The depletion of cropland, in particular, raises concerns about urban food security and the sustainability of subsistence agriculture within municipal boundaries.

The significance of these land cover transitions extends beyond spatial planning to the realm of biodiversity conservation. The observed reduction in low vegetation and cropland translates into habitat fragmentation and the loss of ecological corridors that support terrestrial fauna and flora. Low vegetation areas often serve as intermediate habitats for pollinators, small mammals, and avifauna, while cropland can host a variety of beneficial species that contribute to agrobiodiversity. Their contraction may lead to reduced species richness, disruption of ecological processes, and increased vulnerability of remnant habitats to edge effects and invasive species.

The findings of this study provide an empirical basis for integrating biodiversity considerations into urban development plans. Urban planners, conservationists, and policymakers must prioritize green infrastructure, establish ecological buffer zones, and promote agro-ecological practices to mitigate the ecological costs of urban growth. The retention of forest cover presents a critical opportunity to reinforce

ecosystem services such as climate regulation, carbon sequestration, and water purification.

Ultimately, the results underscore the need for a multi-scalar land use policy framework that harmonizes urban expansion with ecological stewardship. By leveraging geospatial tools and longitudinal land cover data, authorities in Calabar Municipal and similar urban centers can proactively shape development trajectories that uphold both environmental and socio-economic resilience.

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