

Assessment of Land Use/land Cover Dynamics and Deforestation Trends in Southwestern Nigeria Using Multi-temporal Landsat Imagery (1986–2026)

Samuel K. Udofia

ubongsam@gmail.com

University of Lagos

Ajibade Ariori

University of Lagos

Emmanuel Wunude

University of Lagos

Chinwe Ugwuzor

University of Lagos

Research Article

Keywords: Climate Change, Remote Sensing, Landuse, Landsat, deforestation

Posted Date: May 14th, 2026

DOI: <https://doi.org/10.21203/rs.3.rs-9449847/v1>

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Additional Declarations: No competing interests reported.

Abstract

Land use and land cover (LULC) changes have a significant role in regulating micro-climate systems through the carbon cycle and ecosystem services. However, increasing anthropogenic activities, particularly deforestation and forest degradation, have significantly altered the landscape structure of southwestern Nigeria. This study examines spatio-temporal changes in land use and land cover between 1986 and 2026.

Multi-temporal dataset from the United States Geological Survey (USGS) (Landsat) satellite images for the years 1986, 2016, and 2026 were used. Band stacking, mosaicking, and a supervised/unsupervised classification method guided by Intergovernmental Panel on Climate Change (IPCC) standards. Maximum Likelihood (MAXLIKE) was used within ArcGIS 10.8 to carry out classification. Land use/land cover classes were adapted from the USGS classification schema. Post-classification comparison was conducted to show Change detection analysis through multi-date imagery.

Results revealed substantial landscape transformation over the 40 years. Savannah woodland declined by 17,743.97 km², forest cover decreased by 2,316.99 km² at an annual loss rate of 35.66 km², while agricultural land expanded by 3,407.95 km². These findings indicate significant anthropogenic pressure on natural vegetation, particularly through deforestation and land conversion for agriculture. The study underscores the urgent need for sustainable land management policies and forest conservation strategies to enhance carbon sequestration capacity and mitigate the impacts of climate change in Southwestern Nigeria.

1. Background to Study

The diversity of plant species within an ecosystem is intricately linked to environmental factors such as climate, soil, and geology. These variables collectively shape the floristic composition of plants, influencing the biomass and carbon makeup of natural forests and savannah woodlands. Vegetation encompasses all plant species and ground cover, forming distinct clusters that characterize the spatiotemporal attributes of a location and the growth forms of dominant plants.

Forest loss can arise from both human activities and natural phenomena, although human-induced causes are more prevalent. Agricultural and urban expansion stand out as major contributors to the diminished carbon sequestration capacity of vegetation and the subsequent reduction in carbon stocks. Fasona, Adeonipekun, Agboola, Akintuyi, Bello, Ogundipe, Omojola (2020) have pinpointed key drivers of deforestation and forest degradation in Southwest Nigeria, including activities like lumbering, pole extraction, fuelwood and charcoal production, crop cultivation, urban growth, and animal grazing, all of which result in significant carbon emissions. While human activities predominantly drive forest loss, natural causes such as climate change, wildfires, and flooding played a role in tropical deforestation during the 1980s and 1990s. In the case of Nigeria, the primary forests have dwindled to 13,944 km², with a staggering 95% loss due to deforestation at an annual rate of 5% between 2010 and 2015. Presently, only 10% of the original forest in Nigeria remains (Oyebo, Bisong, & Morakinyo, 2010). focused on estimating aboveground biomass or carbon stocks across diverse land uses (Sun & Liu, 2020).

In recent decades, deforestation and forest degradation have emerged as pressing environmental concerns, profoundly affecting global carbon cycles. These processes involve the clearing of forests, either for

agricultural expansion, urban development, or unsustainable logging, leading to significant global warming. The released carbon compounds, primarily in the form of carbon dioxide (CO₂), contribute to the greenhouse effect, exacerbating climate change and its associated consequences in southwestern Nigeria. Therefore, the major issues faced are the ability to quantify the amount of forest loss over a very large area, like southwest Nigeria and quantifying the forest of past years.

Plate 1: Uncoordinated logging in the study area (source: Author 2017)

2. Study Area

2.1 Geographical Location

The study area encompasses the southwestern states of Nigeria, including Ogun, Osun, Oyo, Ondo, and parts of Ekiti. As shown in Fig. 1, the study area is delineated by longitude 3° 05' to 5° 25' East and Latitude 6° 05' North to 9° 10' North, covering an expansive area of approximately 6,364,030 hectares (63,641 km²).

Spanning from the northern savannah grasslands and woodlands to the lush southern forested regions, the study area boasts a diverse range of ecosystems. Bordered by the Republic of Benin to the west, Edo State to the east, Kwara State to the north, and Lagos State to the south, it occupies a strategic position within Nigeria's geographical landscape.

The choice of this study area is guided by several factors, chief among them being its substantial forest reserves, which represent some of the largest in Nigeria. This makes it an ideal location for investigating forest dynamics, carbon fluxes, and Land use changes. Moreover, the region is experiencing alarming rates of deforestation, making it a focal point for research aimed at understanding and mitigating this phenomenon. The urgency of addressing deforestation in the study area is underscored by reports from the Food and Agriculture Organization (FAO, 2017) highlighting the rapid pace of forest loss in the region.

Geologically, the landscape of the study area is characterized by a dissected plain developed on tertiary sediments. This geological setting influences soil composition, topography, and hydrology, shaping the distribution and characteristics of vegetation across the region. Understanding the geological context is essential for interpreting Land use patterns, ecosystem dynamics, and carbon sequestration potential within the study area. Overall, the study area's unique blend of ecological diversity, extensive forest reserves, and pressing environmental challenges makes it a compelling subject for scientific inquiry and conservation efforts. By conducting research in this region, scholars and policymakers aim to generate insights that can inform sustainable land management strategies, mitigate deforestation, and safeguard the region's invaluable natural heritage for future generations.

3. Methodology

3.1 Data types and sources

Data used for this study were obtained from various sources, as shown in Table 1. The data collected from the primary sources included field measurements, plant sampling, and enumeration. The other data collected

from secondary sources included satellite images. The satellite images were obtained for different years from the United States Geological Survey (USGS). In contrast, the Radiation data and the fraction of the absorbed photosynthetically active radiation (FAPAR) were obtained from the cds.climate.Copernicus. eu.

Table 1
Characteristics and Sources of Data

Sensor	Identification	Spatial Resolution	Date	Source	Application
Landsat 5 Tm	Path 191 Row 055, Path 191 Row 054, Path 190, Row 055	Spatial resolution – Pan – 15m B-IR 30mx30m TIR – 60m Spectral resolution – 8 bands	1986	US Geological Surveys, glovis.usgs.gov	Land use change Analysis, LST, VI, NDWI
Landsat 7 ETM+	Path 191 Row 055, Path 191 Row 054, Path 190, Row 055	Spatial resolution – Pan – 15m B-IR 30mx30m TIR – 60m Spectral resolution – 8 bands	2006	US Geological Surveys, glovis.usgs.gov	Land use change Analysis, LST, VI, NDWI
Landsat 8 OLI	Path 191 Row 055, Path 191 Row 054, Path 190, Row 055	Spatial resolution – Pan – 15m B-IR 30mx30m TIR – 60m Spectral resolution – 8 bands	2016	US Geological Surveys, glovis.usgs.gov	Land use change Analysis, LST, VI, NDWI
Administrative map	Southwest	1:250,000		GIS & Remote Sensing Lab, Department of Geography, Unilag	State Boundary Delineation

3.2 Land use/Land cover classification

The classification was done in line with the IPCC's good practice guidance. Stacking and mosaicking of the image bands to generate a composite image was carried out within the ArcMap GIS environment. For the Landsat TM imagery of 1986, ETM of 2001, the band combinations 2, 4, and 7 (blue, near-infrared, and far-infrared) gave the best band combination for the extraction of vegetation and Land use classes, while the OLI of 2016 was 3, 5, and 8 (blue, near-infrared and far-infrared). To carry out a detailed ecosystem classification that will reveal the various subclasses of the land cover, the third level of Anderson et al. (1976) schema was employed. A supervised/unsupervised classification method was carried out; training sites established according to spectral reflectance were developed into signature files. The signature classes were subjected to a soft classifier algorithm in the Image Classification plugin on ArcGIS 10.3 Software. The Hybrid classification was used for this study due to the large extent of the study area, as the entire locations could not be visited. Thus, Maximum likelihood (MAXLIKE) was employed. MAXLIKE is a powerful classification technique that acts on the differences between the classes of the spectral radiance and the variability and degree and type of correlation between bands (covariance matrices) (Eastman 2001). This method entailed using the Linear Pixel Unmixing. This method was employed when pixels integrate with discrete areas and conceptually fuzzy classes that arise from variability in the underlying classes (Borsoi et al., 2021).

Table 2
Classification schema

S/N	Level I	Level II
1	Urban or Built-up Land	Residential Commercial and Services Industrial Transportation, Communications, etc
2	Agricultural Land	Cropland Plantation Scattered Cultivation
4	Forest Land	Heavy Forest Light Forest Disturbed Forest
5	Water	Streams and River Lakes Reservoirs
6	Wetland	Mangrove Marsh
7	Open Surface	Sandy Areas Bare Exposed Rock Quarries Recreational Construction area

The land use/land cover of the study area was classified using the schema presented in Table 2. This was adopted and modified from the USGS classification schema of 1969. The classes presented in the table were used, and it is reflected in the land uses of this project.

3.3 Land Use and Landcover Change Analysis

A post-classification approach utilized in this research involves the interpretation and classification of vector land use/land cover data derived from satellite imagery, as outlined by Fichera et al. (2012). This methodology is essential for understanding changes in land use and land cover over time, providing valuable insights into landscape dynamics and environmental trends. Change detection analysis plays a pivotal role in this process, allowing researchers to identify and quantify alterations in land cover types between two or more time periods.

In the context of this study, change detection for land use and land cover entails comparing pixels from multi-date satellite images of the same location to detect changes, as elucidated by Vivekananda et al. (2021). This involves aligning and overlaying images acquired at different time points, enabling the detection of differences in pixel values indicative of land cover changes. The application of change detection algorithms within Geographic Information Systems (GIS) software, such as ArcGIS 10.8, facilitates the automated identification and analysis of land cover changes across the study area.

The process begins by preprocessing the satellite images to ensure consistency and accuracy in the data. This may involve geometric correction, radiometric calibration, and atmospheric correction to remove distortions and artefacts introduced during image acquisition. Once pre-processed, the images are classified into discrete land cover classes using supervised or unsupervised classification algorithms. Each pixel in the image is assigned to a specific land cover category based on its spectral characteristics, as captured by the satellite sensors.

After classification, change detection is performed by comparing the classified images from different time periods. This comparison involves identifying pixels that have undergone changes in land cover type between the two dates. Change detection algorithms analyze the spectral signatures of corresponding pixels in the two images, flagging areas where significant differences occur. These differences may include land cover conversions, such as the transition from forest to agricultural land, urban expansion, or deforestation.

ArcGIS 10.8 provides a robust platform for conducting change detection analysis, offering a range of tools and functionalities specifically designed for this purpose. The DN (digital number) values of corresponding pixels in the images acquired at time t_1 and t_2 are compared using these tools, allowing for the identification of areas where land cover changes have occurred. The output of the change detection process is typically a thematic map highlighting the locations and extent of land cover changes across the study area.

To further analyze and interpret the detected changes, researchers generate a land change matrix table. This table provides a systematic overview of the different types of land cover changes observed, categorizing areas that have remained stable and those that have undergone conversion to a different land cover class. By quantifying the extent and nature of land cover changes, researchers can assess the drivers and impacts of land use change, informing land management strategies and environmental policy decisions.

4. Findings

4.1 Static Land use and Land cover 1984 to 2017

The study area covers a land area of about 67,255.83 km². The distribution of the static Land use/Land cover for the area in 1986 is shown in Table 3 and Fig. 2. Savannah grassland and woodland cover 12,089.99 km² and 10,355.38 km² respectively. In the natural forest class, highly disturbed forest covered an area of 12,611.37 km², while the intensive arable cultivation in the Agriculture primary class covered 8,537.40 km², thereby accounting for 17.98% and 15.4%, 18.75% and 12.69% of the study area, Other ecosystem classes in increasing order included fallow (Scattered cultivation) (8.72%), Tree crop/secondary forest (8.03%) undisturbed forest (6.1%), Rock/Montane forest (3.57%), minimally disturbed forest (3.17%), swamp (1.49%),

urban (1.32%), sandbar (0.35%), Oil palm (0.68%) River/Lake (0.1%) and Coastal grassland (0.07%) respectively.

The Land use statistics for 2016 show that savannah woodland had an area of about 17,743.97 km² (26.38%). It is closely followed by a highly disturbed forest with a total area of about 12,390.57 km² (18.42%), and intensive arable cultivation follows the highly disturbed forest with about 11,330.40 km² (16.85%). The table reveals that the land use classes with the lowest land area are rubber 9.34 km² (0.01%), quarry 4.37 km² (0.01%), coastal grassland 39.32 km² (0.06%), and other ones, as shown in Table 3 above. The table reveals that some other land uses, such as oil palm, marshland, Banana was no longer available in 2026.

The Land use statistics for 2026, as shown in the table, reveal that savannah woodland had the highest land area of about 20,577 km² (30%), intensive arable cultivation had a land area of 14,064 km² (20.9%), and Teak/Gmelina plantation had a land area of 10,625.85 km² (15.8%).

On the other hand, the table shows that banana plantations had the lowest land area, of 0.47 km² (0%). The statistics show that Oil palm land use had no record area.

The analysis of Land use data spanning from 1986 to 2026 reveals dynamic changes in land cover within the study area. These changes have significant implications and reflect the complex interplay between environmental and anthropogenic factors. Initially, savannah grassland and woodland dominated the land cover in 1986, but subsequent years witnessed substantial shifts in their areas, indicating the sensitivity of these ecosystems to various influences. These findings align with research by Hirota et al. (2011), which emphasizes the susceptibility of savannah ecosystems to environmental and human-induced changes. Moreover, the emergence of new land cover classes such as Teak/Gmelina plantation and bare surfaces underscores the impact of human activities, including afforestation initiatives and land degradation processes. These changes reflect broader trends in land use and highlight the need for sustainable land management practices, as discussed by Chazdon et al. (2009) and Veldkamp et al. (2001).

Agricultural transitions and land use intensification are evident from the significant increase in intensive arable cultivation areas over the years. This suggests shifts in agricultural practices characterized by intensification or expansion, as noted by Verburg et al. (2019). However, the loss of certain land cover types like oil palm and banana plantations raises concerns about the underlying factors driving these changes, such as market dynamics and policy shifts impacting agricultural practices, as highlighted by Gibbs et al. (2010) and Carlson et al. (2012).

Forest dynamics and conservation challenges are also prominent themes in the Land use data analysis. The observed changes in forest cover, including declines in highly disturbed forests and increases in plantation forests, underscore the ongoing challenges of deforestation, forest degradation, and afforestation efforts. Addressing these challenges requires effective conservation strategies that promote sustainable land management practices, as advocated by Gaveau et al. (2014). Urbanization and infrastructure development have contributed to the expansion of urban areas, leading to habitat fragmentation and loss of natural ecosystems. These trends underscore the need for integrated Land use planning approaches that balance

economic development with environmental sustainability, as emphasized by Seto et al. (2012) and McDonald et al. (2008).

The dynamic changes in land use and land cover observed in the study area highlight the complexity of interactions between human activities, environmental processes, and policy interventions. Addressing these challenges requires interdisciplinary approaches informed by ecological, social, and economic considerations as portrayed in the conceptual framework of this study. Foley et al. (2005) and Lambin et al. (2003) emphasize the importance of integrated Land use planning and stakeholder engagement in promoting sustainable land management practices.

Table 3
LULC Characteristics of 1986, 2006 and 2016

S/N	Primary Class	Secondary Class	1986 (km ²)	%	2006 (km ²)	%	2016 (km ²)	%
1	Agriculture	Banana					0.47	0
2	Agriculture	Fallow (Scattered Cultivation)	5,864.70	8.72	6,022.36	8.95	1,626.17	2.42
3	Agriculture	Intensive Arable Cultivation	8,537.40	12.69	11,330.40	16.85	14,064.09	20.91
4	Agriculture	Tree Crop/Secondary Forest	5,583.14	8.3	4,993.49	7.42	8,367.32	12.44
5	Bare Surface	Quarry			4.37	0.01	2.58	0
6	Bare Surface	Rock/Montane Forest	2,400.93	3.57	3,692.08	5.49	191.92	0.29
7	Built-up Area	Urban	890.44	1.32	1,944.15	2.89	4,877.45	7.25
8	Natural Forest	Highly Disturbed Forest	12,611.37	18.75	12,390.57	18.42	3,817.42	5.68
9	Natural Forest	Minimally Disturbed Forest	2,130.66	3.17	2,433.65	3.62	1,770.13	2.63
10	Natural Forest	Undisturbed Forest	4,104.14	6.1	1,272.74	1.89	7.13	0.01
11	Plantation	Oil Palm	456.62	0.68				
12	Plantation	Rubber			9.34	0.01	30.37	0.05
13	Plantation	Teak/Gmelina	874.49	1.3	4,961.81	7.38	10,625.84	15.8
14	Savanna	Savannah Grassland	12,089.99	17.98	127.16	0.19	798.26	1.19
15	Savanna	Savannah Woodland	10,355.38	15.4	17,743.97	26.38	20,577.33	30.6
16	Water	River/Lake	68.09	0.1	129.56	0.19	93.99	0.14
17	Wetland	Coastal Grassland	47.98	0.07	39.32	0.06	6.15	0.01
18	Wetland	Marshland	1.25	0			171.61	0.26
19	Wetland	Sand bar	234.01	0.35	105.65	0.16	0.02	0

S/N	Primary Class	Secondary Class	1986 (km ²)	%	2006 (km ²)	%	2016 (km ²)	%
20	Wetland	Swamp	1,005.24	1.49	55.21	0.08	227.57	0.34
Total			67,255.83	100	67,255.83	100	67,255.83	100

Table 3 shows the natural forest ecosystem class facing competition from agriculture and savannah ecosystems. New landcover classes, such as bare surface, also emerged. Savannah woodland, highly disturbed forest, and intensive arable cultivation were the most important classes in 2006 with 17743.97 km², 12390.57, and 11330.40 km² (26.38%, 18.42%, and 16.85 km²) of the area, respectively. Fallow, tree crop and Teak/ Gmelina account for 6022.36 km² (8.95%), 4993.49 km² (7.42%) and 4961.81 km² (7.38%) respectively. Other ecosystem classes mapped for the area in 2006 in order of increase include Quarry 4.37 km² (0.01%), rubber plantation 9.34 km² (0.01%), coastal grassland 39.32 km² (0.06) swamp 55.21 km² (0.08%) sandbar 105.65 km² (0.16%), savanna grassland 127.16 km² (0.19%) undisturbed forest 1272.74 km² (1.89%), urban 1944.15 km² (2.89%), Minimally disturbed forest 2433.65 km² (3.62%) and rock/montane forest 3692.08 km² (5.49%). Rubber plantation land use and cover classes emerged in 2006, while oil palm was lost in an area.

The distribution of land use and cover classes in the study area in 2006 provides valuable insights into the patterns of human-environment interactions and land management practices.

The dominance of savannah woodland, highly disturbed forest, and intensive arable cultivation underscores the extensive conversion of natural ecosystems for agricultural purposes. These land cover classes are indicative of deforestation, land clearance, and agricultural expansion, driven by socio-economic factors such as population growth, urbanization, and agricultural intensification (Lambin & Geist, 2006). Fallow land, tree crops, and Teak/Gmelina plantations represent areas undergoing various stages of land use transition. Fallow land may result from shifting cultivation practices or temporary abandonment of agricultural fields, while tree crops and plantations reflect efforts to diversify agricultural production or promote agroforestry systems (Turner II *et al.*, 2007). The emergence of rubber plantations highlights shifts in land use priorities and economic activities. Rubber cultivation may be driven by market demand, government policies, or incentives for cash crop production, leading to changes in land cover and land use intensity (Mertens *et al.*, 2002). The decline in oil palm plantation area suggests changes in the dynamics of palm oil production, influenced by factors such as market trends, land availability, and environmental regulations. This trend underscores the need for monitoring and sustainable management of oil palm plantations to mitigate environmental impacts and ensure the long-term sustainability of palm oil production (Gibbs *et al.*, 2010). Overall, the distribution of land use and cover classes reflects the complex interactions between human activities and environmental processes shaping the landscape of the study area. Understanding these dynamics is essential for sustainable land use planning, conservation efforts, and natural resource management strategies.

Table 3 shows the emergence of a Banana Plantation of 0.47 km² in the ecosystem of the study area in 2016. the savannah woodland and intensive arable cultivation submerged other landcover ecosystems and claimed an area of 20577.33 km² (30.6%) and 14064.09 km² (20.91%) of the total area respectively, Another land use

and landcover ecosystem that also had a relatively high increase rate in 2016 were Teak/Gmelina and Tree crop/ secondary forest with an area of 10625.84(15.8%) km² and 8367.32 km² (12.44%) respectively.

The expansion of agricultural activities, particularly intensive arable cultivation and plantation crops such as bananas, reflects shifts in land use priorities, market demands, and agricultural practices. The substantial increase in savannah woodland and intensive arable cultivation areas, accounting for 30.6% and 20.91% of the total area, respectively, underscores the extensive conversion of natural ecosystems for agricultural purposes. This expansion may be driven by factors such as population growth, urbanization, agricultural intensification, and government policies promoting agricultural development (Lambin & Geist, 2006). Additionally, the notable increase in Teak/Gmelina plantations and Tree crop/secondary forest areas further illustrates the diversification of agricultural production and land use intensification strategies. Plantation forestry, including Teak and Gmelina cultivation, may be promoted for timber production, agroforestry systems, or reforestation efforts, contributing to landscape transformation and ecosystem services provisioning (Mertens *et al.*, 2002). These changes in land use and land cover patterns have significant implications for biodiversity conservation, ecosystem services provision, and socio-economic development. Understanding the drivers and impacts of these changes is essential for informing land use planning, environmental management strategies, and sustainable development initiatives aimed at balancing agricultural production, conservation objectives, and socio-economic priorities.

4.2 Trend of Landcover Change between 1986 and 2016

The analysis of land cover changes presented in Table 3 provides valuable insights into the dynamics of land use transformations in the study area over two distinct time periods: 1986 to 2006 and 2016 to 2026. These findings highlight both positive and negative changes in various land cover types, reflecting the complex interplay of natural and anthropogenic factors shaping the landscape (Lambin *et al.*, 2003).

During the period from 1986 to 2026, the study reveals substantial changes in land cover, with savannah grassland experiencing the most significant decrease in area, amounting to 11291.73 km² or a reduction of 17.79%. This decline may be attributed to factors such as agricultural expansion, urbanization, and deforestation, which often result in the conversion of natural habitats to croplands or settlements (Foley *et al.*, 2005). Conversely, savannah woodland exhibited a positive change, with an increase in area by 7388.59 km² or 10.00%. This could be indicative of afforestation efforts or natural regeneration processes occurring within the study area (Hirota *et al.*, 2011).

However, not all land cover types experienced significant changes during this period. Coastal grassland, for instance, showed a minimal loss of only 8.66 km² or 0.01%. Similarly, quarry and rubber plantation areas recorded negligible gains, indicating relatively stable land use patterns in these categories (Gaveau *et al.*, 2014). These findings underscore the importance of considering local context and specific land cover dynamics when assessing landscape changes and their drivers. The analysis further extends to the period between 2016 and 2026, revealing continued shifts in land cover composition. Highly disturbed forests emerged as the most affected category, experiencing a substantial loss of 8573.14 km² or 12.75%. This trend is concerning as it suggests ongoing deforestation and land degradation processes, likely driven by factors such as logging, agricultural expansion, and infrastructure development (Sodhi *et al.*, 2010). Similarly, fallow

and shifting cultivation land cover recorded significant losses, highlighting the vulnerability of these areas to Land use changes and degradation (Gibbs et al., 2010).

In contrast, certain land cover types demonstrated notable gains during the same period. Teak and Gmelina plantation, for example, exhibited the highest increase in area, with a gain of 5664.03 km² or 8.42%. This expansion could be attributed to reforestation initiatives, agroforestry practices, or commercial plantation establishment aimed at meeting timber demand (Chazdon et al., 2009). Additionally, urban areas and intensive agriculture witnessed considerable growth, reflecting urbanization trends and agricultural intensification efforts in response to population growth and economic development (Lambin & Meyfroidt, 2011).

Overall, the findings underscore the dynamic nature of land cover changes in the study area and highlight the complex interactions between human activities and environmental processes. Conservation efforts, sustainable land management practices, and effective monitoring mechanisms are essential for mitigating the adverse impacts of land cover changes, preserving critical habitats, and promoting ecosystem resilience in the face of ongoing global environmental changes.

4.3 Pattern Savannah and Forest Conversion

The analysis of land cover changes from 1986 to 2026 reveals significant transformations in various land cover categories, reflecting the complex interactions between human activities and environmental processes (Gaveau et al., 2014). Highly disturbed forest areas witnessed a substantial decline from 12,611.37 km² in 1986 to 3,817.42 km² in 2026, indicative of intensive Land use changes likely driven by urbanization, industrialization, or logging activities (Gaveau et al., 2014; Sodhi et al., 2010).

Conversely, undisturbed forest areas experienced a drastic reduction from 4,104.14 km² to 7.13 km² over the same period, highlighting severe environmental degradation and the encroachment of human activities into previously pristine forest landscapes (Gaveau et al., 2014). This decline in undisturbed forest areas underscores the urgent need for conservation efforts to protect remaining forest habitats and preserve biodiversity (Sodhi et al., 2010).

In contrast, minimally disturbed forest areas exhibited moderate stability, suggesting relatively lower levels of human disturbance compared to highly disturbed and undisturbed forest ecosystems (Gaveau et al., 2014). The stability in minimally disturbed forest areas may indicate the effectiveness of conservation measures or land management practices aimed at mitigating environmental impacts (Gaveau et al., 2014; Sodhi et al., 2010). Furthermore, savannah grassland areas remained relatively stable with a slight increase by 2016, indicating resilience to significant land cover changes observed in other ecosystems (Gaveau et al., 2014). This stability in savannah grassland areas may be attributed to natural ecological processes or sustainable land management practices that maintain ecosystem integrity (Gaveau et al., 2014).

Overall, the dynamic patterns in land cover changes highlight the complex dynamics of human-environment interactions and the need for integrated approaches to land management and conservation (Sodhi et al., 2010). Addressing the drivers of land cover changes, such as urbanization, deforestation, and agricultural expansion, requires coordinated efforts involving policymakers, stakeholders, and local communities to promote sustainable development and biodiversity conservation (Gaveau et al., 2014).

Table 4
Land cover statistics of Forest and Savannah

Landcover	1986 (km ²)	2016 (km ²)	2026 (km ²)
Highly Disturbed Forest	12611.37	12390.57	3817.42
Minimally Disturbed Forest	2130.66	2433.65	1770.13
Undisturbed Forest	4104.14	1272.74	7.13
Savannah Grassland	12089.99	127.16	798.26
Savannah Woodland	10355.38	17743.97	20577.33

The savannah woodland areas within the study region showed notable fluctuations over the three-decade period, with significant implications for land cover dynamics and environmental sustainability. The area covered by savannah woodland expanded considerably from 10,355.38 km² in 1986 to 20,577.33 km² in 2026. This substantial increase suggests potential afforestation efforts or changes in land management practices during the study period. These fluctuations underscore the dynamic nature of land cover changes within the study region and the complex interactions between human activities and natural ecosystems. The expansion of savannah woodland areas may be influenced by various factors, including reforestation initiatives, natural regeneration processes, or shifts in land use practices such as agricultural abandonment or land restoration efforts.

However, these trends also highlight the urgent need for conservation efforts, sustainable land management practices, and effective monitoring mechanisms to safeguard critical habitats, preserve biodiversity, and mitigate the adverse effects of human activities on the environment. While the expansion of savannah woodland areas may indicate positive changes in land cover, it is essential to ensure that these changes are sustainable and do not lead to unintended consequences such as habitat fragmentation, loss of biodiversity, or degradation of ecosystem services.

Furthermore, ongoing monitoring and assessment of land cover dynamics are essential to track changes over time, identify emerging threats, and inform adaptive management strategies. By implementing proactive conservation measures, promoting sustainable land use practices, and engaging stakeholders in participatory decision-making processes, it is possible to achieve a balance between human development and environmental conservation objectives.

Overall, the fluctuations observed in savannah woodland areas underscore the dynamic nature of land cover changes and the importance of proactive conservation efforts to maintain ecological integrity, promote biodiversity conservation, and enhance the resilience of ecosystems in the face of environmental change.

Table 5 presents the statistical overview of forest and savannah areas within the study region. In 1986, the highly disturbed forest covered an extensive area of 12,611.37 km². However, by 2026, this area had undergone significant reduction, shrinking to 3,817.42 km². This substantial decrease indicates a profound conversion of highly disturbed forest within the study area over the three-decade period.

Figure 6 provides a visual representation of land cover conversions within the study area. It reveals that the savannah grassland experienced the most substantial conversion, with an area reduction of approximately 13,000 km². Following closely behind, the highly disturbed forest underwent a conversion of about 9,000 km². Interestingly, the figure illustrates that the lowest conversion rate for forest occurred between 1986 and 2026, suggesting a period of relatively slower forest loss during this timeframe compared to other periods.

These findings underscore the significant changes in land cover dynamics within the study region over the past three decades. The considerable reduction in highly disturbed forest area highlights the extensive conversion of forested land for various purposes such as agriculture, urbanization, and infrastructure development. Similarly, the substantial conversion of savannah grassland underscores the pressures faced by natural ecosystems due to human activities and land use changes.

Understanding these land cover conversions is crucial for assessing the impacts on biodiversity, ecosystem services, and carbon stocks within the study area. Furthermore, these findings can inform land management strategies, conservation efforts, and policy interventions aimed at mitigating further land degradation and promoting sustainable land use practices. By monitoring land cover changes and their associated impacts, stakeholders can work towards preserving valuable ecosystems, protecting biodiversity, and mitigating the adverse effects of land cover change on the environment and society.

4.4 LULC Projection model from 2026 to 2066

The land use and land cover projection of the study area for the primary classes is shown in Table 5, and the result reveals that the projection statistics for the urban area have a progressive expansion from 3209.75 km² in 2026 to 4042.35 in 2066. On the other hand, the forest area had a sharp reduction in 2020 and might become 0 from 2022 to 2066. This result is evident since the population of the study area will continue to increase, while this increasing population depends on the forest resources for livelihood, the forest will continue to be reduced due to overexploitation, which is enhanced by weak policies.

The analysis of land cover changes over the period from 1986 to 2026 reveals significant trends with profound implications for environmental health and biodiversity conservation. Firstly, there has been a notable decline in highly disturbed forest areas, amounting to 8573.14 km² during this period. This decline underscores the severity of environmental degradation and Land use changes within the study area, likely influenced by factors such as urbanization, logging activities, and agricultural expansion. These findings align with research by Gaveau et al. (2014) and Sodhi et al. (2010), highlighting the urgent need for conservation efforts and sustainable land management practices to mitigate further degradation.

Table 6
Simulated land use land cover from 2026 to 2066 for STsim

Primary Land cover classes (sqkm)	Time step				
	2026	2036	2046	2056	2066
Agricultural	5117.27	1444.43	410.71	115.90	29.14
Bare Surface	293.24	96.85	26.90	6.95	3.81
Builtup Area	33930.34	41711.84	43909.54	44523.58	44699.79
Grassland	7403.07	2025.97	562.26	158.05	43.04
Natural Forest	0.45	0.45	0.45	0.45	0.45
Plantation	1652.70	510.70	137.43	36.99	8.74
Woodland	18858.76	21465.59	22208.55	22413.90	22470.85
Source: Author, 2020					

Similarly concerning is the drastic decline in undisturbed forest areas, shrinking from 4104.14 km² to 7.13 km² over the same period. This loss of pristine forest habitats poses significant threats to biodiversity and ecosystem services, emphasizing the importance of conservation strategies aimed at protecting remaining forested areas and restoring degraded landscapes. This aligns with the findings of Gibbs et al. (2010) and Chazdon et al. (2009), highlighting the critical need for biodiversity conservation and habitat restoration efforts.

On a contrasting note, the analysis reveals substantial fluctuations in savannah woodland areas, with an increase from 10355.38 km² in 1986 to 20577.33 km² in 2026. These dynamic changes suggest the influence of afforestation efforts or alterations in land management practices, highlighting the potential for ecosystem restoration and reforestation initiatives to mitigate deforestation and land degradation. This resonates with the research of Hirota et al. (2011) and Gibbs et al. (2010), emphasizing the role of afforestation in promoting landscape resilience and biodiversity conservation.

The observed land cover changes underscore the importance of conservation efforts, sustainable land management practices, and effective monitoring mechanisms to protect critical habitats and preserve biodiversity. Integrated approaches that consider ecological, social, and economic dimensions are essential for addressing the drivers of land cover change and promoting sustainable development. These findings align with the research of Foley et al. (2005) and Lambin et al. (2011), emphasizing the need for comprehensive strategies to mitigate the adverse impacts of human activities on the environment and promote the long-term health and resilience of ecosystems.

Conclusion

This study examined the land use and land cover dynamics in Southwestern Nigeria from 1986 to 2026, employing multi-temporal Landsat imagery downloaded from the United States Geological Survey. Remote sensing and GIS techniques in ArcGIS 10.8 were used to carry out hybrid (supervised/unsupervised)

classification using Maximum Likelihood and post-classification change detection. The research revealed significant landscape transformations across the region. Results show a substantial reduction in savannah woodland and forest, and an expansion of agricultural land. The consistency of forest loss highlights increasing pressure from anthropogenic activities, particularly from deforestation and land use conversion. The study reveals the efficacy of geospatial technologies for spatio-temporal environmental monitoring and provides empirical evidence to support sustainable land management planning. To mitigate further environmental degradation and climate-related impacts, there is an urgent need for strengthened forest conservation policies, improved land use planning frameworks, afforestation and reforestation programs, and enforcement of environmental protection regulations. Sustained monitoring using remote sensing and GIS tools should remain central to policy implementation and environmental governance in Southwestern Nigeria.

Declarations

Funding: No Funding

Clinical Trial Number: Not Applicable

Consent from Authors to Publish: Samuel Kevin Udofia

Ajibade Ariori

Emmanuel Wunude

Chinwe Ugwuzor

Reviewed_Samuel_Udofia_Landuse

Ethics approval and consent to participate

This study is based on remote sensing analysis using satellite imagery and does not involve human participants, plant specimen collection, or field sampling. Therefore, ethical approval, consent to participate, plant collection guidelines, and herbarium documentation are not applicable.

Consent for publication

Not applicable. This study does not involve human participants, personal data, or identifiable images.

Data availability

The datasets analysed during the current study are publicly available from the United States Geological Survey EarthExplorer repository and grid3 repository (<https://earthexplorer.usgs.gov/>) and (<https://grid3.org>). Processed data and analysis outputs are available from the corresponding author on reasonable request.

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Table

Table 5 is available in the Supplementary Files section.

Plate

Plate 1 is available in the Supplementary Files section.

Figures

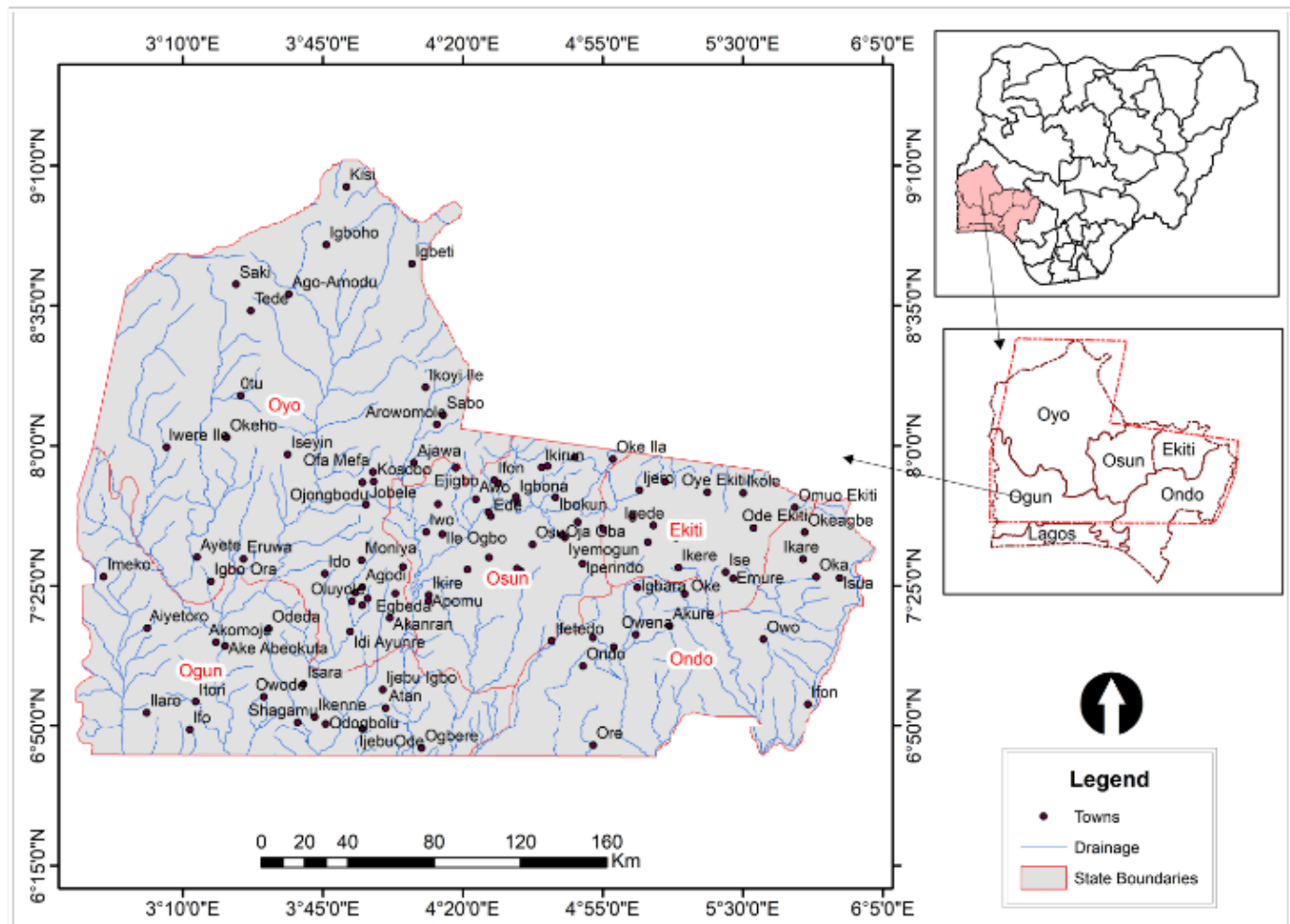


Figure 1

Study Area map (Source: Author 2017)

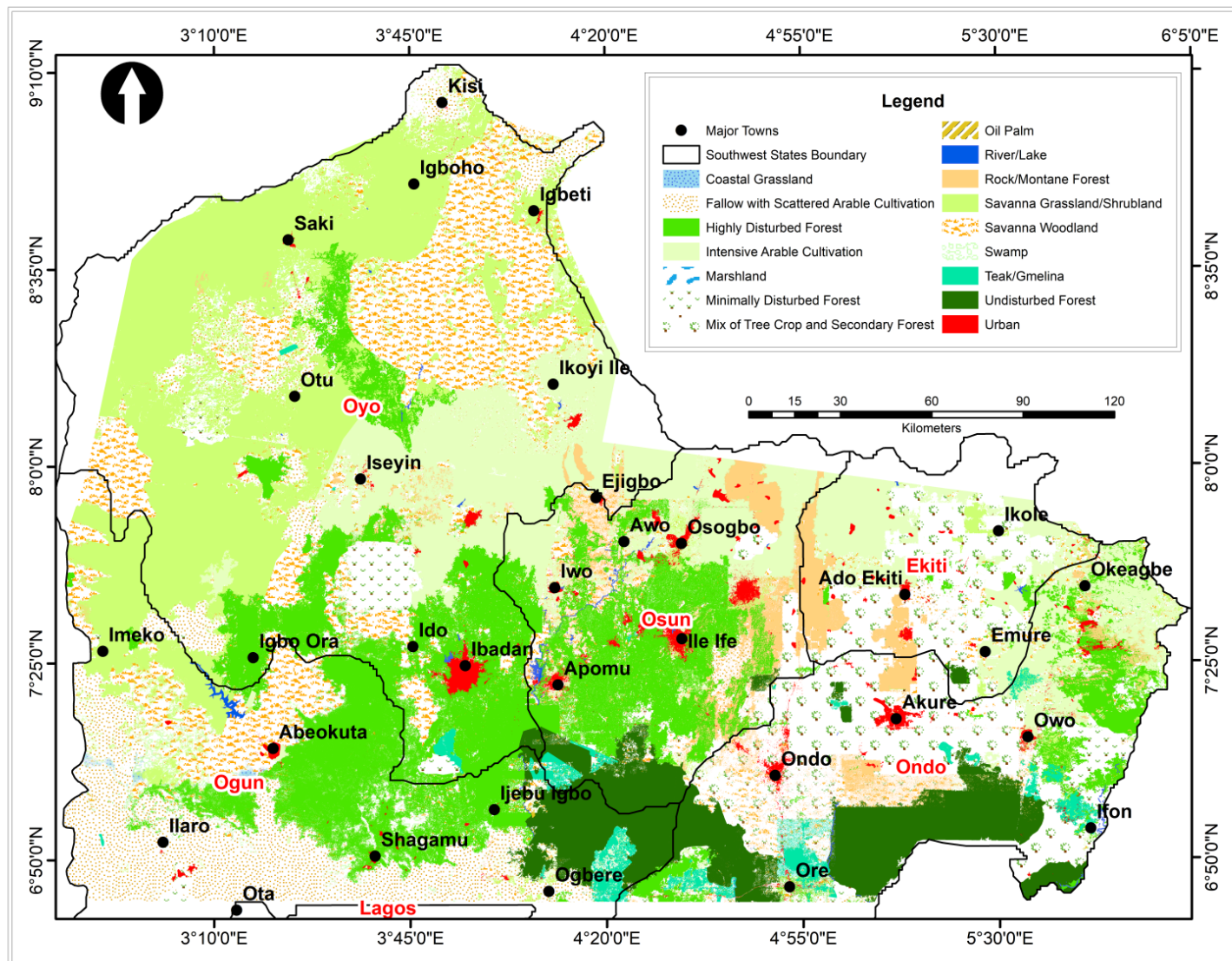


Figure 2

1986 land use characteristics

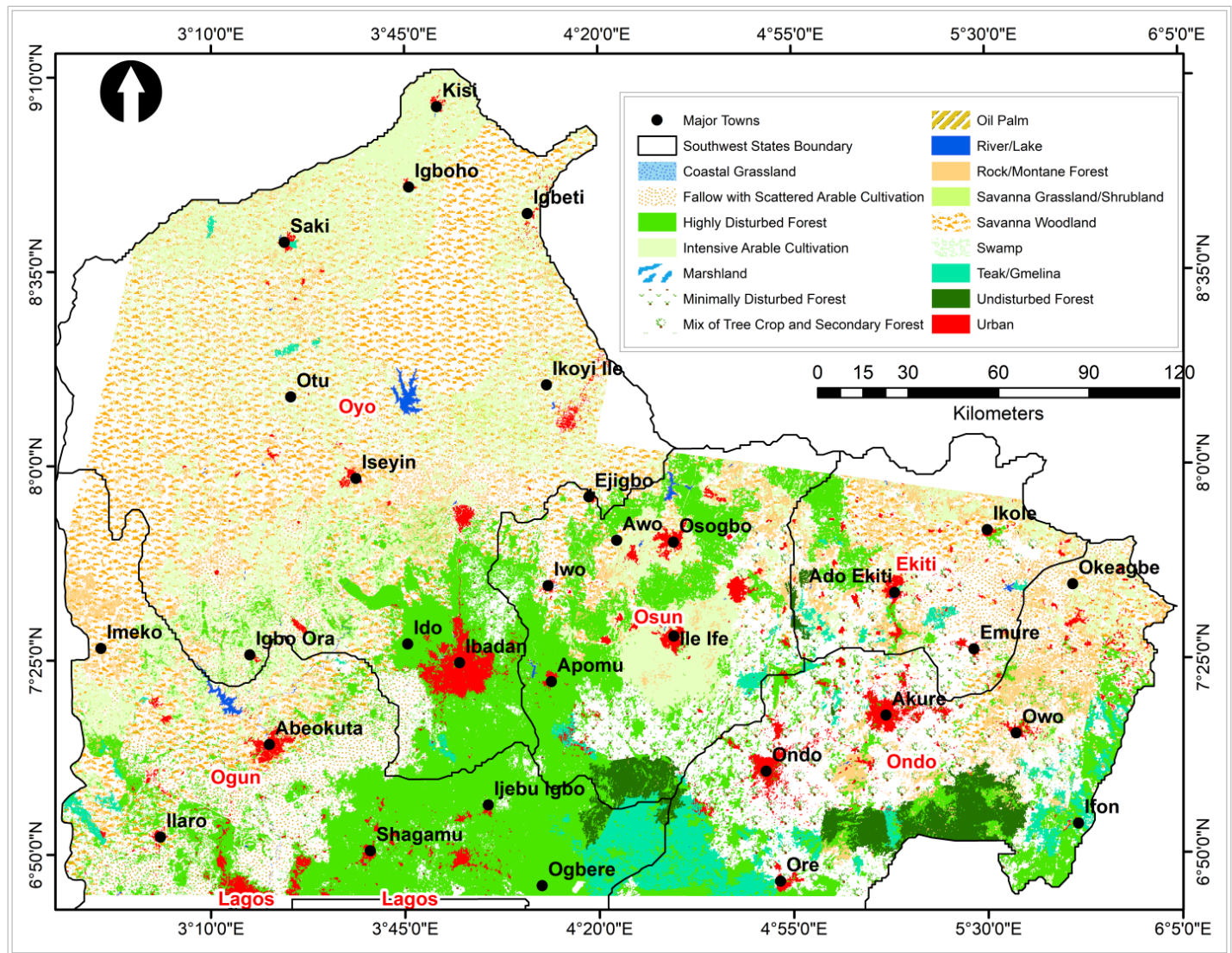


Figure 3

2006 land use characteristics

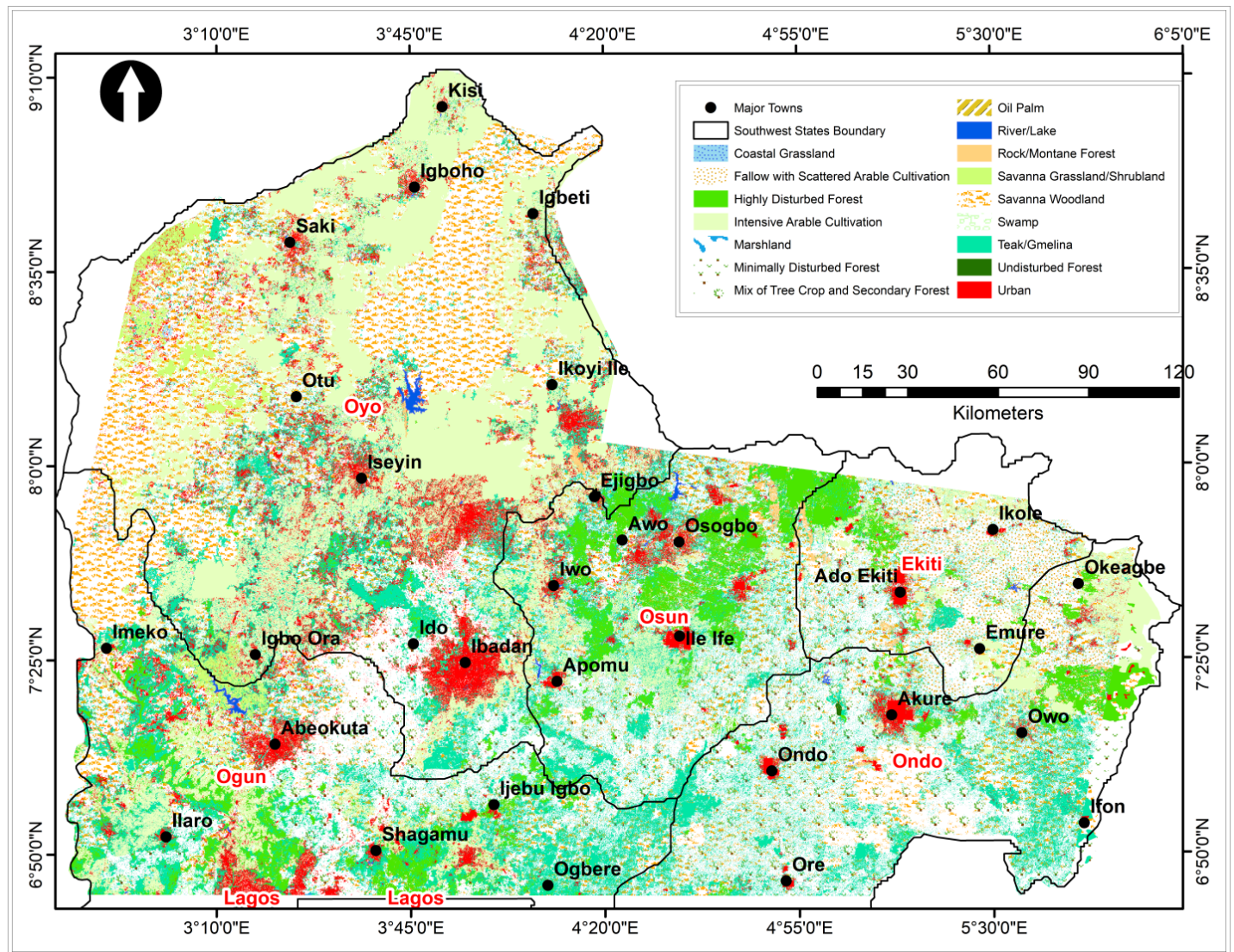


Figure 4

2016 Land use characteristics

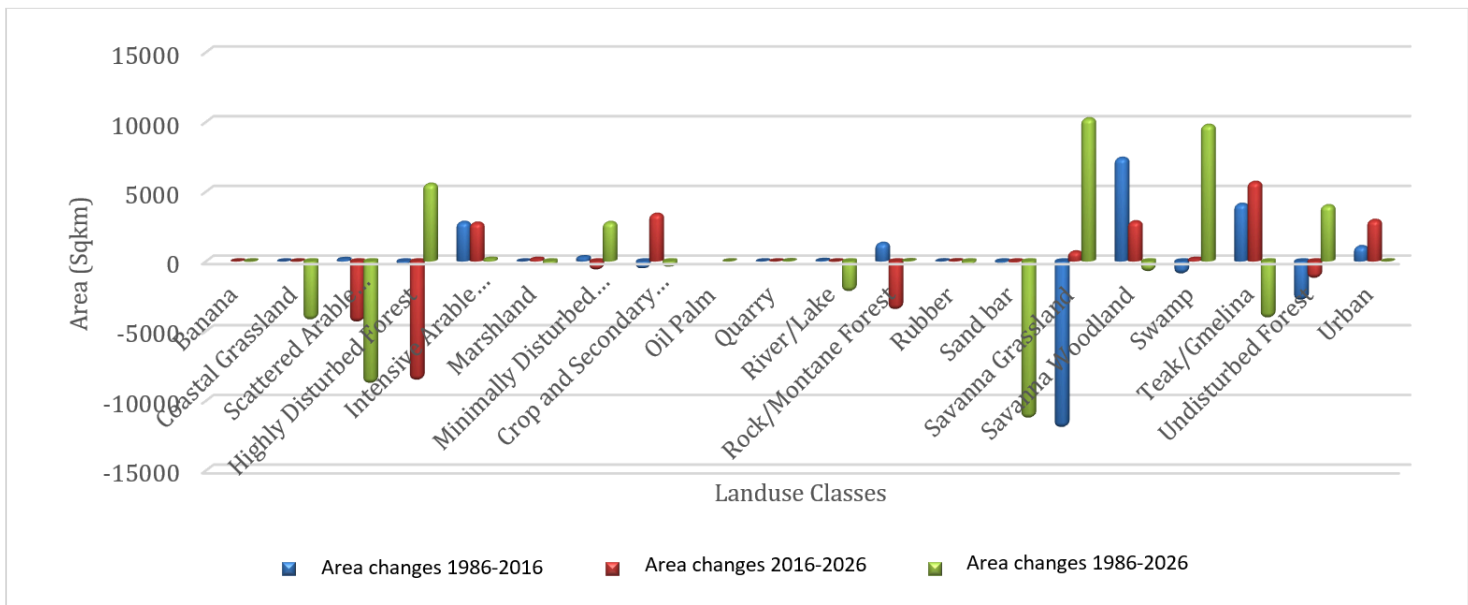


Figure 5

Land use/land cover change between 1986 and 2026

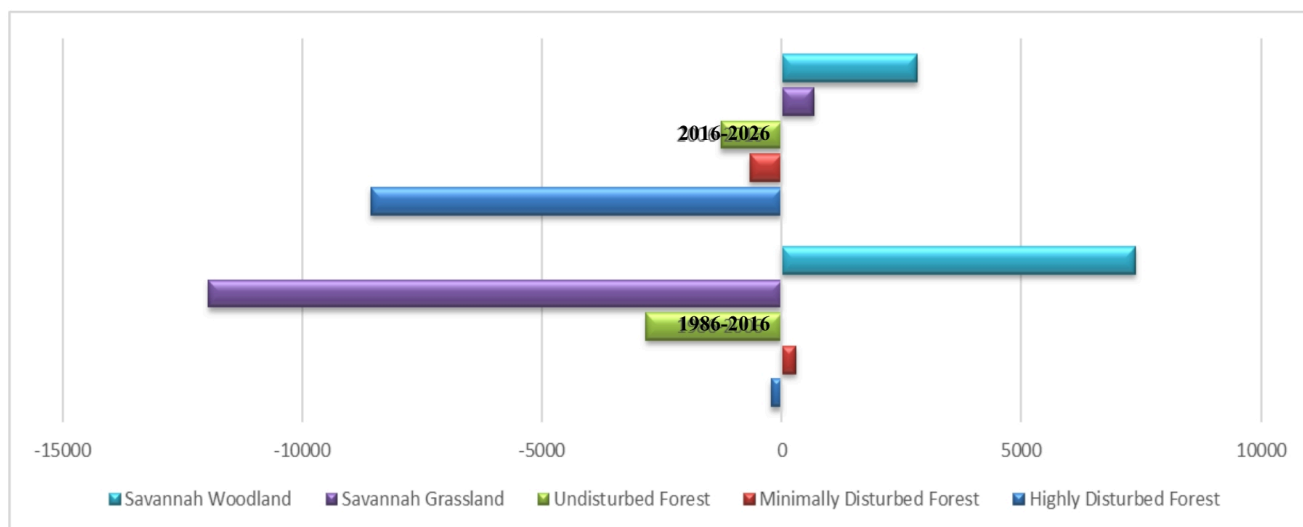


Figure 6

Forest and savannah conversion pattern

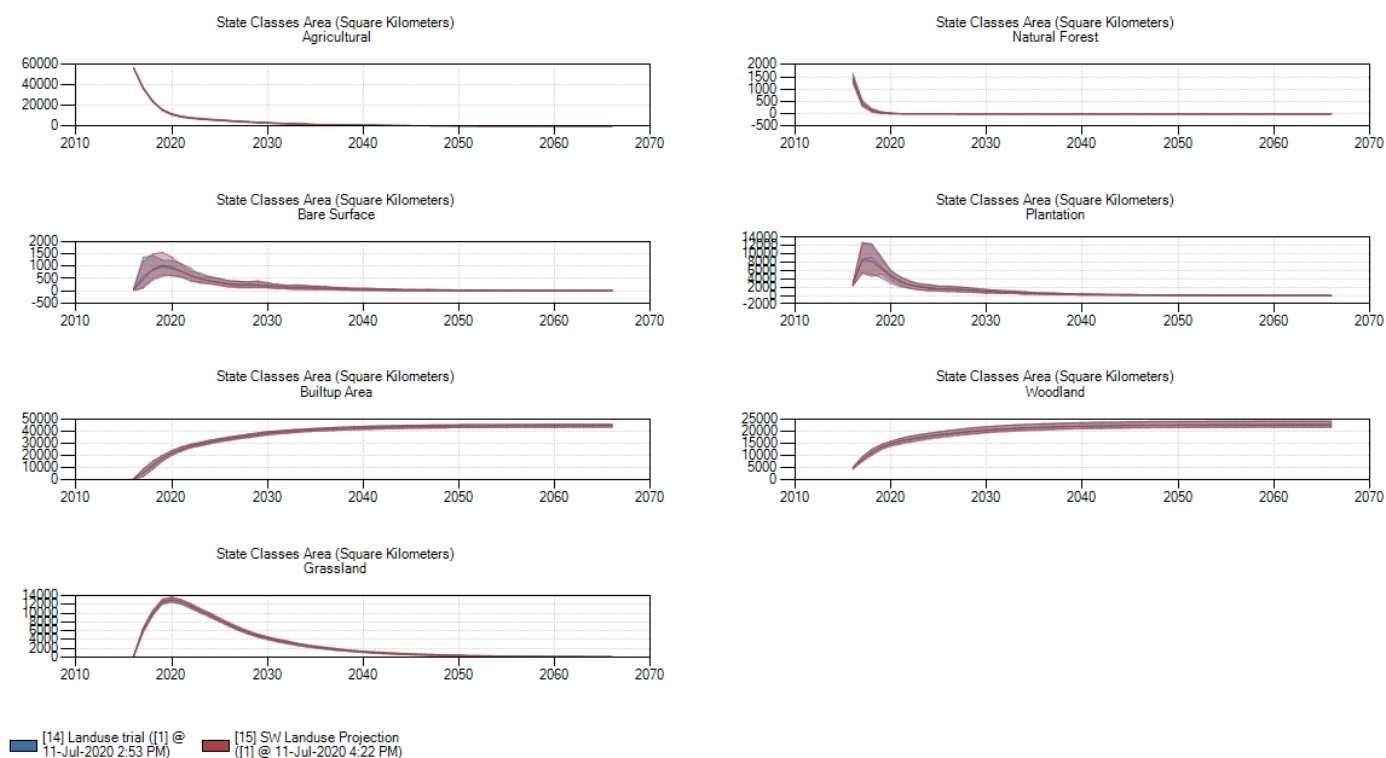


Figure 7

Future land use projection for the study area from 2026 to 2066

Supplementary Files

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- [Plate1.docx](#)
- [Table5.docx](#)