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Original Research Article

National-Scale Land Use Transitions in Nigeria: Patterns, Rates, and Implications for Sustainable Landscape Management

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Abstract: Land Use/Land Cover (LULC) change remains one of the most influential processes reshaping ecosystems, livelihoods, and environmental sustainability in West Africa. Despite Nigeria's rapid population growth and economic expansion, comprehensive national-scale assessments of its long-term LULC dynamics remain scarce. This study analyses 27 years of LULC change (1992–2019) using ESA-CCI 300-m resolution datasets to quantify transitions among cropland, grassland, shrubland, forest/woodland, and other classes. My results showed substantial changes in land cover over the 27 years, with national-level increases in cropland by 14,470km^2, forest/woodland by 25,224km^2, and 'other' by 7,706km^2, but a decline in grassland and shrubland by 464km^2 and 51,585km^{2,} respectively, though with substantial interannual variability, reflecting both reforestation efforts and earlier deforestation pressures. Spatial patterns vary significantly across Nigeria's geopolitical zones, shaped by differences in climate, demographic pressures, agricultural policy, and urbanisation rates. My findings can stimulate discussion between researchers, planners, land management experts, and decision-makers at the private, state, and national government levels and support the development of policies that ensure the sustainability of land resources in Nigeria.
Keywords: Land Use/Land Cover, Change, Nigeria, Landscape Transformation, ESA-CCI.

INTRODUCTION

Land Use and Land Cover (LULC) change is one of the most significant drivers of global environmental transformation, with far-reaching implications for biodiversity, ecosystem services, carbon storage, and sustainable development. Across the world, landscapes are undergoing rapid shifts as cropland expands, forests contract or recover, and human activities increasingly modify natural vegetation. Recent global assessments indicate that cropland has expanded by approximately 80–100 million hectares since the early 2000s, equivalent to a growth rate of about 5–9%. This expansion has primarily occurred in Africa and South America, often at the expense of natural habitats (Potapov *et al.*, 2022). Concurrently, forest cover declined by about 100 Mha from 2000–2020 (≈2.4% of the 2000 forest area), signalling contraction in forested lands despite some regional recovery (Ju Ma, 2023). Globally, forest loss from 1960 to 2019 amounted to 437.3 million hectares (Estoque *et al.*, 2022). These changes are particularly pronounced in tropical regions, where demographic pressures and economic development interact strongly with environmental processes (Abel *et al.*, 2020).

Sub-Saharan Africa has become one of the regions experiencing the fastest rates of LULC change worldwide. Population growth, widespread agricultural expansion, urbanisation, and the intensification of resource use continue to transform land systems across multiple scales (Issa & Hambati, 2025; Olorunfemi *et al.*, 2022). Recent long-term LULC observations between 1992 and 2019 reveal significant structural changes within Nigeria's landscape (Akintuyi *et al.*, 2021). Cropland consistently expanded during the study period, while shrubland experienced a sharp decline of over 40%, indicating increased land conversion pressures (Onyekuru, 2014). Forest areas showed moderate but consistent growth, suggesting localised regeneration or afforestation processes, whereas grassland remained relatively stable with minor fluctuations. These long-term patterns offer empirical evidence of ongoing ecological transformation and emphasise the need for a systematic national assessment to understand their drivers, interactions, and implications.

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Nigeria's land systems are shaped by diverse ecological zones, from the humid rainforest belt in the south to the Guinea savannah and semi-arid Sahel in the north, each facing unique pressures from population surge, agricultural intensification, fuelwood extraction, and climate-induced stressors (Onyekuru, 2014). Rapid population growth and rural livelihood dependence on land resources continue to exert significant pressure on forests, shrublands, and grazing areas (Akello and Extension 2024). Coupled with weak land governance structures, tenure conflicts, and environmentally harmful practices, these dynamics complicate landscape management efforts. A national-scale analysis grounded in local realities is therefore essential to support climate-resilient planning and ecosystem sustainability. This gap constrains the ability of policymakers and stakeholders to anticipate land-system trajectories, evaluate environmental risks, and design sustainable land-use strategies.

Addressing this gap is essential for supporting evidence-based decision-making in areas such as agricultural planning, biodiversity conservation, climate mitigation and adaptation, and land-use governance. Although numerous studies (Abdulwakeel & Mamboleo, 2025; Benard Ifeanyi. *et al.*, 2024; Hassan & Syakir, 2023; Kile *et al.*, 2025; Koko *et al.*, 2021; Nnaji *et al.*, 2022; Onuegbu & Egbu, 2024) have evaluated LULC changes in specific states or ecological zones of Nigeria, few have examined countrywide transitions spanning nearly three decades using harmonised and comparable datasets. Even fewer studies (Iduseri *et al.*, 2024; Kolapo *et al.*, 2022; Nkeki, 2016; Otuoze *et al.*, 2021) combine temporal trends with an analysis of transition rates, category-specific dominance, and implications for sustainable land governance. The absence of a comprehensive national-scale synthesis restricts the development of integrated land-use policies and hampers efforts to align national planning with global sustainability frameworks such as the Sustainable Development Goal (SDG), the United Nations Framework Convention on Climate Change (UNFCCC), and the Convention on Biological Diversity.

Here, I decided to provide a comprehensive, multi-decadal assessment of national-scale land use and land cover transitions in Nigeria from 1992 to 2019, with a focus on quantifying patterns, rates, and the implications for sustainable landscape management. Specifically, the study examines category-specific land dynamics, calculates long-term changes and transition rates, and interprets their environmental and socio-economic significance. By analysing the national patterns, this work fills a critical scientific and policy gap and provides an essential empirical foundation for sustainable land-use planning and environmental management in one of Africa's most rapidly transforming landscapes.

MATERIALS AND METHODS

Study area

Nigeria - Africa's most populated country, with ~200 million people (Echendu, 2020) - provides a good case study to understand how different land covers are changed – extent and pattern. From 2004 through 2019, about 1850 km^2 of the total landmass of Nigeria was deforested, driven predominantly by a 5% expansion in the area of cultivated land (Arowolo & Deng, 2018). Many of these activities were concentrated in Biu, Mubi, Bauchi, and Niger states (North), and in Oyo, and Edo States (South; Figure 1). Cross River state (South) shows the lowest levels of fragmentation and human alteration. In line with this, I hypothesised that:

- The extent and patterns of land use and land cover changes within the country are expected to vary from 1992 to 2019.

Analysis

I used 300 m spatial resolution Land Cover CCI Climate maps spanning from 1992 to 2019 (McGarigal *et al.*, 2015). The Land Cover CCI Climate Research Data Package (CRDP) contains all data products that have been generated within the project.

This study selects the years from 1992 to 2019 to provide a comprehensive analysis of Nigeria's transformation over nearly three decades. This timeframe is sufficiently long to observe significant trends and patterns while remaining recent enough to ensure that the findings are relevant to current and future policy-making, as well as academic discourse. Several rationales underpin this selection, one of such is that the period from 1992 to 2019 witnessed rapid technological advancement and increased internet penetration in Nigeria. Incorporating these years permits an examination of how technological changes have influenced the study's focal areas.

To use the data at the national level, the data from each year were clipped to the international boundary (DIVA-GIS, 2022; Figure 1b). The original land cover map obtained from the European Space Agency Climate Change Initiative (ESA-CCI) has 38 classes (http://maps.elie.ucl.ac.be/CCI/viewer/index.php), which were grouped and reclassified into ten broader classes. Using the reclassification function of ArcGIS 10.8.1 software (ESRI 2020), the old value of the original class was assigned new values to form the new classes of nine classes of land use land cover. For this study, five LULCs (cropland, grassland, shrubland, forest/woodland-the open canopy and other) were used in quantification:

- **Cropland:** Cropland here refers to land that is used for the cultivation of crops. It is a critical component of agriculture and food production systems. This includes all cropland, be it rainfed, irrigated or flooded.

- **Grassland:** Grasslands refer to large open land areas dominated by grasses. This includes herbaceous cover and grassland.
- **Shrubland:** Ecosystems characterised by the dominance of woody shrubs and small trees, often with an understory of grasses and herbaceous plants. This includes tree or shrub cover, shrubland, evergreen shrubland, deciduous shrubland, shrub or herbaceous cover, included that present with flooded fresh/saline/brackish water.
- **Forest woodland (open canopy):** Forest woodlands with open canopies are ecosystems where trees are spaced widely enough to allow sunlight to reach the ground, supporting a diverse understory of grasses, shrubs, and other plants. This includes tree cover, broadleaved, evergreen, closed to open (>15%); tree cover, broadleaved, deciduous, closed to open (>15%); tree cover, broadleaved, deciduous, open (15 – 40%); tree cover, needle-leaved, evergreen, closed to open (>15%); tree cover, needle-leaved, open (15-40%); tree cover, needle-leaved, deciduous, closed to open (>15%); tree cover, needle-leaved, deciduous, open (15-40%). The extent of forest-woodland-closed canopy and forest woodland-flooded in Nigeria is minimal.
- The remaining LULC categories are grouped as ‘other’.
- This study focuses on the extent and pattern of change of the above LULCs from 1992 to 2019 in Nigeria.

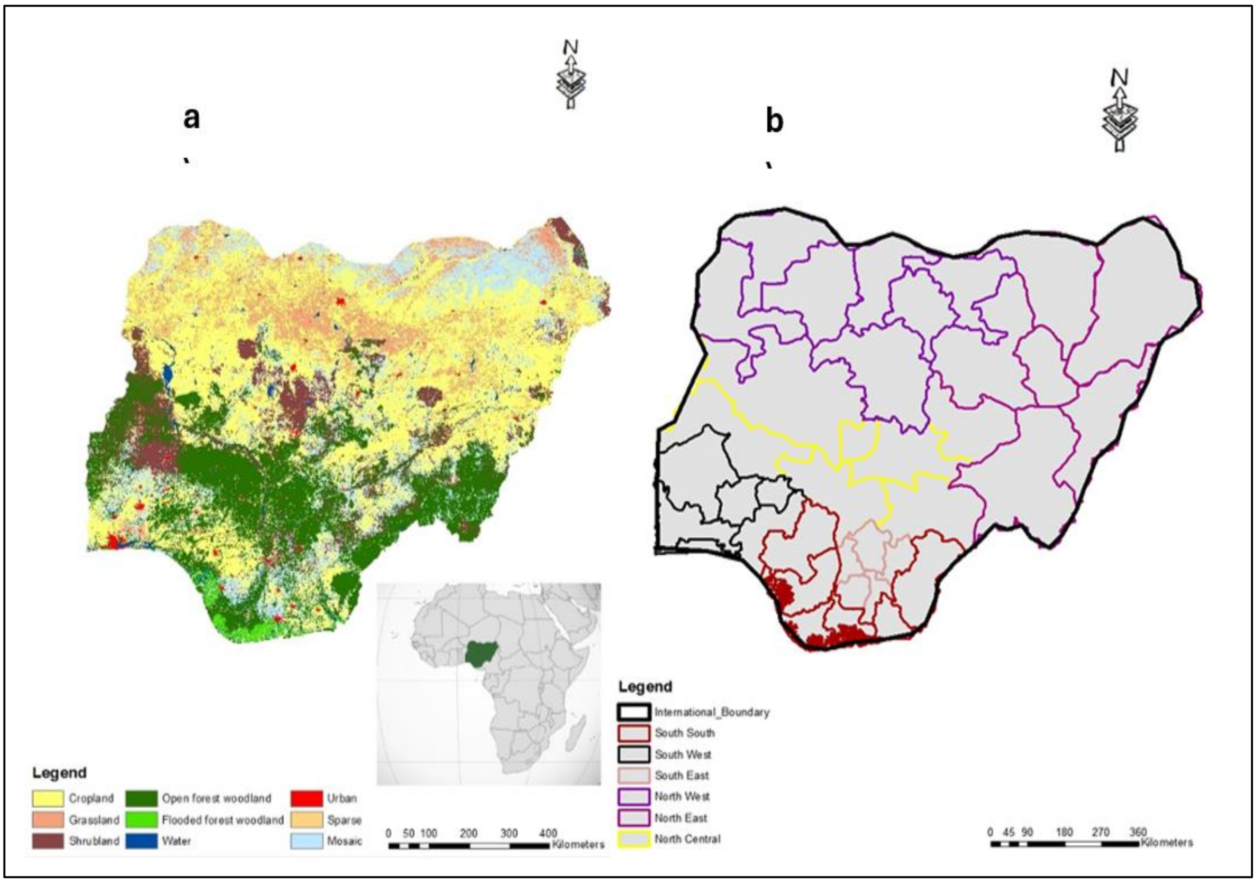

Figure 1: (a) Land cover in Nigeria in 2019 (the study area) using simplified land cover categories from the European Space Agency Climate Change Initiative (ESA-CCI; https://www.esa-landcover-cci.org).(b) An outline of Nigeria, the geopolitical zones (colours) and enclosed states

RESULTS

National Land Use land cover (LULC) change

The results of the size and spatial distribution of the change of LULC in Nigeria from 1992 to 2019 are presented in Table SI and Figure 2. The LULC categories (cropland, grassland, shrubland, forest, and ‘other’) have undergone substantial changes over the years. In 1992, cultivated land (cropland) occupied 341,818 km^2 (representing about 37.2% of the total land area), with slight declines evident in 1995-1996. From 1997 through to 2015, the cropland area experienced continuous growth from 348,935 km^2 (38.2%) to 361,529 km^2 (39.6%). A slight reduction was recorded in 2016, followed by an increase in 2017 to 359,265 km^2 (39.4%). The most recent decline saw cropland areas drop from 358,203 km^2 to 356,288 km^2 (39.2% and 39.0%, respectively) from 2018 to 2019. Overall, between 1992 and 2019, cropland experienced an area increase of 14,470 km^2, with an average annual increase of 0.16% (Table S1 and Figure 2).

Grassland, unlike cropland, exhibited more frequent decreases with occasional increases. In 1992, grassland stood at 100,172 km^2 (10.9%), with a reduction to 99,885 km^2 (10.9%) by 1995. The area further decreased to 98,661 km^2 (10.8%) by 1999. There was a marginal, steady, slight increase from 2001 to 2017 of 98,867 km^2 (10.8%) to 99,399 km^2 (10.9%). The latest increase saw grassland expand from 99,455 km^2 (10.9%) to 99,708 km^2 (10.9%) from 2018 to 2019 respectively. Overall, grassland saw a decrease of 463km^2, with an average annual decline of 0.02% from 1992 to 2019 (Table SI and Figure 2).

Shrubland showed substantial fluctuations, with more marked decreases than increases. Though the area covered by shrubland in 1992 was 126,970 km^2 (13.8%), the most dramatic decrease occurred as the area dropped from 122,043 km^2 (12.8%) to 56,521 km^2 (6.1%) from 1993 to 1994. Another notable decline decreased the area from 115,537 km^2 (12.7%) to 112,894 km^2 (12.4%) from 1996 to 1997. From 2017 to 2018, the area decreased from 78,404 km^2 (8.6%) to 76,809 km^2 (8.4%). Increases in shrubland area were observed in 1995 to 118,659 km^2 (13.0%) and to 115,537 km^2 in 1996 (12.7%), as well as in 2012, 2013, 2016 and 2017 (Table S2.1 and Figure 3). Overall, shrubland decreased by 51,586 km^2, with an average annual decline of 1.50% for all 27 years in the study (Table SI and Figure 2).

The forest/woodland category generally trended upward, with some years of decline. The area in 1992 was 162,536 km^2 (17.7%), with a slight decrease observed from that year to 162,513 km^2 (17.1%) in 1993. An increase to 249,551 km^2 (26.7%) was recorded in 1994, which eventually decreased to 163,410 km^2 (17.9%) in 1995. The forest/woodland area grew from 164,796 km^2 (18.0%) in 1996 to 187,761 km^2 (20.6%) in 2019. Overall, between 1992-2019, the forest/woodland area increased by 25,224 km^2, with an average annual increase of 0.57% (Table SI and Figure 2).

The 'other' LULC, encompassing land covers not classified in the previous categories, also experienced fluctuations. From 1992 to 1993, a substantial increase from 186,816 km^2 (20.3%) to 225,036 km^2 (23.6%) was noted. From 2000 to 2001, the area increased from 186,766 km^2 to 187,128 km^2 (20.5%). From 1993 to 1996, a decrease was recorded from 225,036 km^2 (23.6%) to 186,089 km^2 (20.4%). Overall, the 'other' category saw an increase of 7,706.01 km^2, with an average annual increase of 0.15% during the 27 years of study (Table SI and Figure 2).

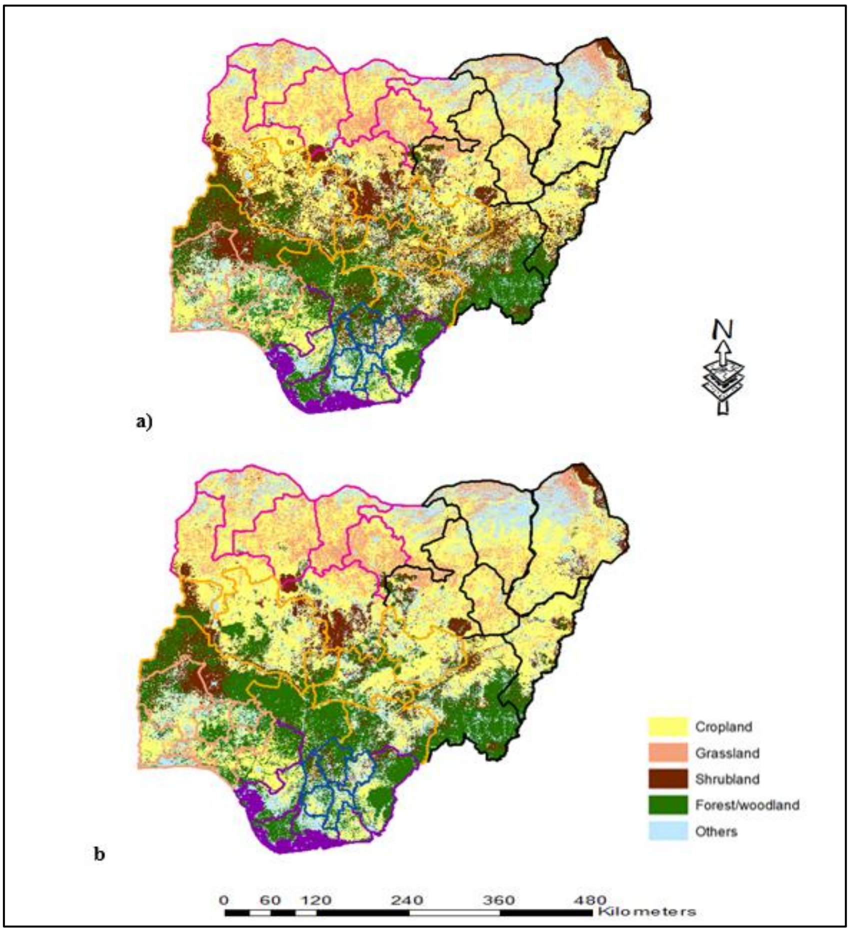

Figure 2: Spatial outline of Land Use and Land Cover (LULC)-cropland, grassland, shrubland, forest/woodland and others across Nigeria for a period of 27 years from 1992 to 2019; a) LULC 1992, b) LULC 2019

Major conversion or change from LULC.

The LULC conversion matrix result (Table 1) captures the extent and directionality of land use (cropland, grassland, shrubland, forest/woodland, and other) changes over a 27-year timeframe, revealing both stability and dynamism within the landscape of Nigeria. The total retained cropland area is 329,061 km^2, signifying a high degree of persistence. However, notable conversions occurred, with 6,344 km^2 transitioning to grassland, 26,804km^2 converting to shrubland, 2,535 km^2 shifting to forest/woodland, and 4,973 km^2 moving into other land cover types. The retained grassland area is 82,534 km^2. Key conversions include 2,725km^2 changing into cropland, 4,623km^2 turning into shrubland, 1,30 km^2 transitioning into forest/woodland, and 1,126 km^2 being reclassified into other categories. Shrubland exhibits moderate retention at 78,781km^2. It experienced cross-transitions, such as 2,246 km^2 turning into cropland and 63 km^2 into grassland. More notably, 2,807km^2 converted into forest/woodland, and 2,930 km^2 transitioned to other categories. Forest/woodland has a relatively stable retained area of 153,399 km^2. Conversions include 4,068 km^2 into cropland, 220 km^2 into Grassland, and 24,461 km2 into Shrubland, likely representing disturbances or changes in vegetation structure. Additionally, 9,519km^2 shifted into other types. The 'other' type of LULC, displays the most dynamic changes, with only 18,547 km^2 retained. Notably, 338,099km^2 converted into cropland. Similarly, 89,162km^2 turned into grassland, 134,668.41 km2 transitioned to shrubland, and 160,07 km^2 became forest/woodland.

Table 1: Land Use Land cover conversion matrix (in km^2) from one form to another in Nigeria from 1992 -2019

LULC	Cropland in 2019	Grassland in 2019	Shrubland in 2019	Forest/woodland in 2019	Other in 2019
Cropland in 1992	329060.84	6344.07	26804.37	2535.19	4972.67
Grassland in 1992	2724.65	82533.99	4622.90	1329.50	1125.83
Shrubland in 1992	2245.67	63.38	78780.64	2807.16	2929.60
Forest/woodland in 1992	4068.28	220.06	24460.50	153399.41	9519.14
Other in 1992	338099.44	89161.50	134668.41	160071.27	18547.24

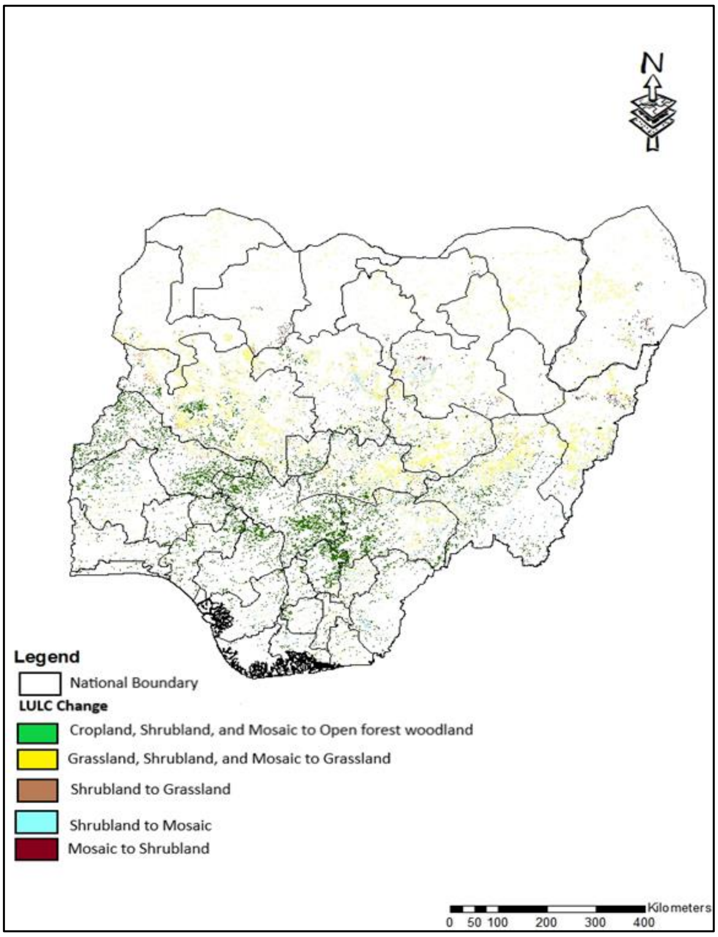

Figure 2.1: (a) Land use/land cover conversion map; conversion of one or more land use into a single type-grassland, shrubland, mosaic converted to cropland, also cropland, shrubland, mosaic into open forest woodland and other just one land cover into another as show in the map

DISCUSSION

The primary objective of this research was to investigate the spatiotemporal changes in LULC and quantify the fragmentation experienced in Nigeria over 27 years (1992–2019). The study aimed to address the key question of how various LULC types—cropland, grassland, shrubland, forest/woodland, and other—have varied in size, spatial distribution, and structural complexity, and to assess the degree of fragmentation to better understand the changes in these land types across different states of Nigeria. This is critical because LULC changes are widely recognised as key drivers of environmental change, particularly in biodiversity loss, ES disruption, and climate change mitigation efforts. My study's objectives align with a growing body of literature that has identified significant pressures on Nigeria's land resources due to factors such as agricultural expansion, deforestation, urbanisation, and unsustainable land management practices (Adegboyega, 2021; Adenle *et al.*, 2022; Adepoju & Salami, 2017; Muoghalu & Akanwa, 2021). Previous research has primarily focused on the drivers of LULC changes but has often lacked a comprehensive spatiotemporal analysis across such an extensive period and in-depth fragmentation process. Therefore, this study sought to fill this gap by employing a geospatial and temporal approach to monitor, measure, and map these LULC changes across Nigeria’s diverse states within each geopolitical zone.

The study period from 1992 to 2019 reveals substantial changes in LULC, reflecting the dynamic interactions between natural and anthropogenic factors. These changes indicate both expansion and decline across various land types, driven by agricultural expansion, population growth, urbanisation, environmental conditions, and environmental policies. My results show cropland expansion in Nigeria, with an increase of 14,470 km² (4.2%) over 27 years. Nigeria’s population has increased substantially over the past few decades, putting pressure on land resources as more land is converted to cropland to meet food security needs (Akinyemi & Ifejika Speranza, 2024; Sule & Deribe, 2023). This trend is not unique to Nigeria; it mirrors broader regional patterns documented in other parts of sub-Saharan Africa, where agricultural land has expanded at the expense of forests and other natural ecosystems, as agriculture remains the backbone of local economies (Adepoju & Salami, 2017; Edomah, 2020; Garzon Delvaux *et al.*, 2020). The slight decline in cropland area observed between 1995 and 1996 was likely attributable to a combination of factors, including unfavourable climatic conditions, declining agricultural investment, and a period of socio-political instability (Raimi *et al.*, 2021; Yeboua & Cilliers, 2022). From 1997 to 2015, the cropland area exhibited a consistent upward trend, increasing from 38.2% to 39.6%. This steady growth largely resulted from several key agricultural policies implemented during this period. Notably, the National Fadama Development Project (Fadama I and Fadama II), launched in 1993 and 2004 respectively, aimed to enhance productivity and expand the cultivable area through irrigation and rural development (Adeyemo & Kehinde, 2021; World Bank, 2003). Furthermore, the implementation of the Agricultural Transformation Agenda (ATA) from 2011 to 2015 played a crucial role in accelerating cropland expansion. This policy focused on increasing agricultural output, reducing dependency on food imports, and creating an enabling environment for private-sector agricultural investment (Amusan, 2022). A brief reduction in cropland area was noted in 2016, which can be attributed to the effects of the economic recession in Nigeria that resulted in diminished funding and support for agricultural expansion (Nzabarinda *et al.*, 2021). However, a subsequent increase was recorded in 2017, when the cropland area rose to 359,265 km². This rebound may be associated with the Green Alternative Agricultural Promotion Policy (APP), which succeeded the ATA. The APP sought to diversify the economy through agriculture, with an emphasis on the expansion of arable land and the adoption of improved farming practices (Nwozor & Olanrewaju, 2020). The most recent period, 2018 to 2019, displayed a decline in cropland area from 39.2% to 39.0%. This decrease, though marginal, may be linked to several interconnected factors, including the impact of climate variability, economic downturns, land degradation, changes in agricultural policy, and the intensification of conflicts between farmers and pastoralists (Mfon, 2023). The escalating frequency and intensity of these conflicts, driven by resource competition and changing land use patterns, have rendered large areas of agricultural land inaccessible.

Grassland in Nigeria has undergone notable changes in spatial coverage over the period from 1992 to 2019. While grassland exhibited fluctuating trends with periods of both decline and marginal increase, the overall trend points to a gradual decrease in its total area. Understanding these dynamics is critical to informing sustainable land management practices and policy decisions. At the start of the period in 1992, Nigeria’s grassland spanned 100,172 km, by 1995, was reduced to 99,885 km². The decline continued, reaching 10.8% in 1999, signifying a clear trend of grassland loss in the late 1990s. From 2001 to 2017, the grassland area showed a marginal increase, fluctuating from 10.8% to 99,399 km² (10.9%. This slight may be attributed to ecological and policy interventions aimed at preventing further degradation (Adenle & Ifejika Speranza, 2021). However, despite this period of relative stability, the grassland area did not return to its initial state. The latest observed change that occurred between 2018 and 2019 proves that. Several factors like agricultural expansion, urbanisation, climatic variability, and policy interventions (Muoghalu & Akanwa, 2021; Seun *et al.*, 2022), may have influenced the dynamics of grassland areas in Nigeria over the study period. The conversion of grassland to cropland and other agricultural uses has been a significant driver of grassland loss. As the country's population grows, the demand for food production has increased, leading to the clearing of natural grasslands for crop cultivation. This trend was particularly pronounced in the late 1990s and early 2000s (above), corresponding with the periods of grassland decline noted in 1995 and 1999. Major cities like Kano, Lagos, FCT, Kaduna and others experiencing rapid urbanisation, have resulted in the conversion of grassland into built-up areas. The expansion of road networks, industrial zones, and residential areas has encroached on traditional grassland regions. This land transformation has led to a direct reduction in grassland coverage, with noticeable impacts during the late 1990s. Climatic variability has contributed to the loss of grassland through desertification (Jimoh *et al.,* 2020). Periods of prolonged drought and erratic rainfall patterns have degraded grasslands, reduced their productivity and led to further land abandonment (Azare *et al.,* 2020; Iwuchukwu *et al.,* 2023). This pattern is particularly seen in the Northern regions where grasslands are under pressure from competing land uses, particularly in peri-urban areas. In addition, the regulatory and land-use policies put in place, targeting deforestation and the establishment of protected areas have also played a role. For example, the 2001 National Agricultural Policy aimed to balance agricultural expansion with environmental sustainability, which might have contributed to the observed stabilisation and slight increase in grassland area during this period. Furthermore, the National Action Programme to Combat Desertification (2001), and the National Forest Policy (2006). The slight increase in grassland area from 2001 to 2017 may reflect the influence of these policies, which emphasized sustainable land management and reforestation. These periodic increases in grassland suggest moments of regeneration, though these were insufficient to counterbalance the overall loss or decline of 464 km², with an average of 0.02% annually.

The sharp decline in shrubland, which decreased by 51,5896 km² (40.63%), with the most substantial reduction in shrubland area occurring between 1993 and 1994 - a marked a dramatic change in a single year, which may be a result of misclassification of the land cover map, with land switching to forest/woodland and back again. Another major reduction was observed between 1996 and 1997, where shrubland decreased from 12.7% to 12.4%, which likely reflected the ongoing conversion of shrubland into cropland and infrastructure, driven by a surge in rural population growth and governmental policies promoting food security through agricultural intensification (Fajobi *et al.,* 2023; (Abdourahamane & Oeba, 2020; Fajobi *et al.,* 2023). The recent (from 2017 to 2019) reduction in shrubland is associated with infrastructure development and land clearance for industrial and residential purposes, driven by the government's economic diversification agenda. The marginal decrease reflects a shift in the land use pattern, indicating a steady transition from natural vegetation cover to urban and industrial landscapes. All these suggest substantial land conversion, particularly to cropland and forested areas, in line with the contributing factors identified above. Agricultural expansion has been a primary driver of shrubland loss in Nigeria (Bununu *et al.,* 2023). The government's policies in the early 1990s, such as the Agricultural Promotion Policy (APP) and the Growth Enhancement Support Scheme (GESS), incentivized large-scale conversion of shrubland into arable land to boost crop production. These policies, though aimed at ensuring food security, led to unintended environmental consequences, including the degradation of shrubland. Nigeria's historical deforestation rates which have been among the highest globally, driven by the demand for agricultural land, fuelwood, and logging activities (Fajobi *et al.,* 2023). The National Forest Policy (NFP) of 1988 and subsequent amendments failed to enforce sustainable management practices, leading to widespread deforestation and degradation of shrubland. In addition, the rapid urban growth has contributed significantly to shrubland loss, especially in areas adjacent to major cities like Lagos, Abuja, and Kano. The National Urban Development Policy (NUDP) of 1997 aimed to streamline urban expansion but did not adequately address environmental conservation, resulting in the unplanned conversion of shrubland for residential, industrial, and infrastructural development. Lastly, climate variability and desertification (Sun *et al.,* 2023) have also played a role in shrubland dynamics. Northern Nigeria, in particular, has experienced severe aridification, exacerbated by climate change (Höhn *et al.,* 2021), leading to a natural reduction in shrubland cover. The decline in rainfall and increased frequency of droughts have further stressed the shrubland ecosystems, making them more vulnerable to conversion and degradation (Wei *et al.,* 2021). Despite the overall trend of decline, there were periods of increase in the shrubland area, notably in between 2012 and 2017. This growth can be linked to temporary reforestation efforts and a decrease in agricultural expansion during those years (Kurowska *et al.,* 2022). The government's National Afforestation Programme (NAP) launched in 1993 aimed at restoring degraded lands, contributing to these short-term increases. Also, programs such as the Great Green Wall Initiative (GGWI) and the National Environmental Action Plan (NEAP) played a role in stabilizing shrubland cover in certain regions or states. However, these efforts were not sufficient to reverse the long-term decline, at an annual rate of 1.5%, signals of potential environmental degradation or shifts in agricultural practices, where woody vegetation is cleared for cropping or grazing purposes (Akintuyi *et al.,* 2021b).

Nigeria has seen efforts to increase forest cover in response to deforestation and desertification. In 1992, Nigeria's forest/woodland area was 162,536 km², which slightly declined to 162,513 km² in 1993. This minor decrease suggests a period of relative deforestation likely due to agricultural expansion, logging, and urbanisation

(Obateru *et al.,* 2024)—common drivers of deforestation in Nigeria during the early 1990s. The limited policy framework in place to curb illegal logging and regulate land use conversion contributed to the forest loss. The most substantial increase during the study period saw the forest/woodland area with a sharp increase and volatile trends from 1994 to 1995, representing a dramatic rise of 9.6%. As discussed above, this unexpected surge could be attributed to mapping error. This is followed by gradual and sustained growth from 1996-2019. This gradual growth can be linked to several key policy interventions and reforestation efforts initiated by the Nigerian government and international organizations. Notably: National Forest Policy, Community-Based Forest Management programs, Great Green Wall Initiative. The National Forest Policy of 1998 emphasized sustainable forest management, conservation, and the expansion of forest plantations. Which have aided the restoration of degraded lands through afforestation and reforestation programs, contributing to the observed recovery from the late 1990s onwards. While the Community-Based Forest Management Programs (2000s), promoted the involvement of local communities in forest conservation, which helped in curbing illegal logging and reducing forest degradation. The community-based approach has been pivotal in enhancing forest cover at the sub-national level where government enforcement is weak (Nzegbule & Obiajunwa, 2023). On the other hand, Nigeria’s participation in the Great Green Wall (GGW) initiative from 2010 onward as a part of the African Union’s larger effort to combat desertification-to create a buffer against desert encroachment, thereby increasing forest/woodland cover, has helped restore forested land, especially in the northern parts of the country. All these efforts represent an overall increase of 25,224 km², corresponding to a 15.5% growth over the study period, or an average annual increment of approximately 0.6%. Overall, these national-scale patterns align with studies from other countries where the expansion of agriculture and urban settlements has led to similar reductions in natural vegetative cover.

The dynamics of LULC, such as cropland, grassland, shrubland, and forest in Nigeria, reflect broader global patterns. These global trends highlight a complex interplay between socio-economic, food security needs, environmental sustainability, and policy frameworks/changes. For example, the FAO, (2020) report “The State of the World’s Forests" emphasizes that the conversion of forests to croplands is a primary driver of biodiversity loss. It is important to note balancing agricultural expansion with sustainable practices will be essential to meet future food demands without further exacerbating environmental degradation. Across many African countries, there has been a notable increase in cropland area, largely driven by the need to increase food production for growing populations. A study by Wang *et al.,* (2020), thought that the expansion of cropland at the expense of grassland and shrubland in Ethiopia between 1982 and 2016 highlights the pressures of agricultural expansion driven by population growth and food security concerns. Similarly, Henok *et al.,* (2017) observed a decline in forest cover in northern Ethiopia, linked to the expansion of agriculture and settlements, akin to Nigeria's cropland increase. Cropland expansion has been a primary driver of deforestation, as demonstrated by Shapiro *et al.,* (2023) in their study of the Democratic Republic of Congo, which identified small-scale agriculture as a major contributor to forest loss and habitat fragmentation. Similarly, Qasha *et al.,* (2024) highlighted that land conversion in sub-Saharan Africa often leads to environmental degradation and biodiversity loss, emphasizing the need for sustainable practices. In Asia, intensive agricultural practices, coupled with infrastructure development, have driven rapid cropland expansion, particularly in China and India (Zhao *et al.,* 2024). The conversion of forests into oil palm plantations in Indonesia and Malaysia (Hughes, 2018) has led to severe biodiversity and carbon stock losses. Urbanisation, as noted by (Jiang *et al.,* 2013), further exacerbates cropland reduction around urban centres in Asia. Studies by (Roy *et al.,* 2016) also reported substantial increases in agricultural land, leading to declines in forest cover, grassland, and shrubland, driven by rapid urbanization and economic development. Likewise, (Zhao *et al.,* 2024) found that cropland expansion in Southeast Asia resulted in significant deforestation, especially in Peninsular Malaysia, Sumatra, and Borneo. In Europe, a stabilisation of cropland, influenced by policies such as the European Union’s Common Agricultural Policy, has resulted in some reforestation and land abandonment, as seen in (Ortyl & Kasprzyk, 2022) and (Perpiña Castillo *et al.,* 2021). The expansion of agriculture and urbanisation has led to similar patterns, particularly in Eastern European countries transitioning from centrally planned to market economies. (Kasianova *et al.,* 2023) documented the widespread conversion of natural vegetation to agricultural land across Eastern Europe (Kolecka, 2021), paralleling the cropland increases seen in Nigeria. In North America, agricultural efficiency and urban sprawl have driven cropland reductions, particularly around metropolitan areas, as shown by (Bren d’Amour *et al.,* 2017). Conversely, South America has experienced substantial cropland expansion for soy production, notably in Brazil and Argentina, contributing to deforestation and environmental degradation. These regional dynamics highlight the complex interplay between agricultural demand, policy interventions, and environmental sustainability, underlining the need for targeted land use strategies to balance development and conservation.

Grasslands are vital for carbon storage, livestock grazing and food security, and the increasing demand for livestock products (especially in Asia and Latin America) places additional pressure on these ecosystems. The global consumption of major food products, such as poultry and dairy, increased substantially, which heightened the demand for grassland-based feed and grazing land (O'Mara, 2012). The general decline of grassland in Nigeria from 1992 to 2019 is in agreement with previous studies; e.g. with Malunga *et al.,* (2022) showing a decrease in grassland area from 1984 to 2016, and (Milupi *et al.,* 2022) showing an increase from 1992 to 201, with similar drivers including; climate change (Tong *et al.,* 2019), and nutrient addiction (Ladouceur *et al.,* 2022) responsible. For example, climate change and land-use practices have been leading drivers of grassland degradation in Africa and Asia. In the Qinghai-Tibetan Plateau, overgrazing and changing precipitation patterns have been linked to long-term degradation, necessitating restoration efforts and better grazing management to preserve these ecosystems (Wang *et al.,* 2018). Similarly, in other parts of Asia, intensive land use and changing climate conditions have contributed to the decline in grassland quality and area (Xiao *et al.,* 2023). On the other hand, Europe and South America show mixed trends. In some areas, like Eastern Europe, grassland areas have remained relatively stable or even increased slightly due to changing agricultural practices and policies that encourage the preservation of natural habitats. In parts of South America, however, large-scale agricultural expansion has contributed to grassland conversion, leading to habitat loss and ecosystem changes (Šumrada *et al.,* 2021). Overall, while Nigeria's grassland changes show a moderate trend compared to the severe degradation seen in other regions, the global grassland scenario reflects complex and region-specific dynamics.

Shrubland has shown similar widespread declines across the entire African continent; e.g. between 1992 and 2015 (Nzabarinda *et al.,* 2021), from 1985 to 2017 (Belay & Mengistu, 2019). In neighbouring West African countries, the decline in shrubland has been attributed to agricultural expansion, overgrazing, and increased fire frequency. For example, in Burkina Faso, a study conducted by Ouedraogo *et al.,*(2015) indicated a similar trend, with shrubland areas decreasing by approximately 25% over two decades due to the expansion of cropland. In East Africa, contractions of shrubland in Kenya have occurred as a result of land conversion for agricultural purposes and settlements, as reported by (Zaehringer *et al.,* 2021). The decline of shrubland in Nigeria aligns with these regional trends, suggesting a broader pattern of land use change driven by increasing population pressure and agricultural demands. The trends observed in Nigeria can also be compared to findings from Central Asia, where shrublands have been subjected to both natural and anthropogenic pressures. For example, a study by Miao *et al.,* (2021) highlighted a loss of 20% of shrubland area in Mongolia over the past three decades, primarily attributed to overgrazing and climate change impacts, such as increased aridity. Similarly, shrubland cover in Northern China has been significantly reduced due to reforestation policies and agricultural development, with Li *et al.,* (2022) reporting a 15% reduction between 1990 and 2015. These cases illustrate that the drivers of shrubland dynamics in Asia often encompass a combination of policy-driven land use changes and environmental stressors, which may differ from the primary drivers of agricultural expansion in Nigeria. In Europe, shrubland dynamics have been largely shaped by land abandonment and reforestation initiatives. For example, in Spain, shrubland areas increased between 1990 and 2010 due to rural depopulation and the subsequent abandonment of land, as noted by (Quintas-Soriano *et al.,* 2022). In contrast, southern European countries such as Greece and Italy have experienced reductions in shrubland due to urban expansion and the intensification of agricultural practices. This dichotomy in European shrubland trends—expansion in some areas and contraction in others—illustrates a complex interplay of socioeconomic and environmental factors. Compared to Nigeria, where decreases in shrubland are predominantly linked to land conversion for agriculture, European dynamics are more significantly influenced by rural demographic changes and afforestation policies. In North America, changes in shrubland are often associated with wildfire regimes and land management practices. For example, in the western United States, shrubland has fluctuated due to the combined effects of wildfires, invasive species, and land use change, with Stavi, (2019) reporting a net decline in native shrublands due to encroachment by non-native grasses. Similarly, in South America, shrublands in Brazil's Cerrado region have sharply declined due to agricultural expansion, as reported by (Rausch *et al.,* 2019), who noted a 50% reduction over 30 years.

Given global deforestation patterns, it is noteworthy that my results indicate a sustainable increase in forest and woodland areas across certain states in Nigeria, as identified and elucidated above, between 1992 and 2019. This finding is consistent with previous studies (Amankwah *et al.,* 2021, covering the period from 1992 to 2018, and Suleiman *et al.,* 2017, examining data from 1985 to 2015). In contrast, other studies employing different definitions of forest—such as closed canopy—often report a decline in forest area over time (e.g. Ayanlade & Drake, 2016; Oyetunji *et al.,* 2020; Suleiman *et al.,* 2017). A comparative analysis with other regions globally reveals both similarities and differences in the factors driving changes in forest cover, as well as the observed outcomes. Throughout the African continent, forest dynamics have exhibited divergent trends contingent upon regional conditions and land use pressures. For example, a study by Acheampong *et al.,* (2019) indicated that Ghana's forest cover decreased by 60% from 1990 to 2010, primarily due to agricultural expansion and illegal logging. This finding stands in stark contrast to the increase observed in Nigeria, suggesting either a more effective forest management strategy or differing land use pressures. In East Africa, Uganda experienced an increase in forest cover between 2005 and 2015, largely attributable to afforestation initiatives and government policies promoting forest conservation (Twongyirwe *et al.*, 2015). These trends align with the observed forest growth in Nigeria, indicating that policy interventions and reforestation initiatives can yield positive outcomes. Forest and woodland dynamics in Asia have demonstrated varied trends, often influenced by national reforestation programmes. For example, China's extensive reforestation efforts, such as the Grain-for-Green programme, resulted in a significant increase in forest cover, with Wang *et al.*, (2019) documenting a 22% rise in forest area between 1990 and 2010. Similarly, Vietnam experienced a 40% increase in forest cover from 1990 to 2015 due to targeted reforestation policies (Ingalls *et al.*, 2018). These trends are comparable to the increases observed in Nigeria, although the magnitude of change in Asian countries is frequently higher due to more extensive reforestation projects and considerable government involvement. This suggests that the moderate growth in Nigeria's forest cover could be further augmented through more targeted policy measures and reforestation initiatives. In Europe, a contrasting picture emerges, with forest areas generally remaining stable or increasing, particularly in countries with well-established forest management systems. In Sweden and Finland, for example, sustainable forestry practices have resulted in a consistent increase in forest cover over the past three decades (Heder Brandt *et al.*, 2023). The expansion of forested areas in Southern Europe, such as Spain and Italy, has primarily resulted from land abandonment and rural depopulation, leading to natural forest regeneration (Bruno *et al.*, 2021; Lasanta *et al.*, 2016). Unlike Nigeria, where reforestation efforts are likely connected to deliberate conservation initiatives, Europe's forest dynamics are often influenced more by socio-economic changes than by direct policy interventions. In the Americas, forest dynamics are diverse, with South America experiencing significant forest losses, whereas North America has exhibited more stable trends. In Brazil, for example, the Amazon rainforest has faced an average annual deforestation rate of 0.52% from 2000 to 2018, primarily due to agricultural expansion and logging (Zanon, 2023). This sharply contrasts with the forest gains observed in Nigeria, underscoring the efficacy of reforestation or natural regeneration efforts in a context where forest loss remains a critical issue. Conversely, the United States and Canada have demonstrated more stable forest cover, with slight increases in some regions attributable to sustainable forest management and conservation policies (Rodriguez Franco & Conje, 2023).

CONCLUSION

This study reveals significant land use and land cover (LULC) transitions across Nigeria between 1992 and 2019, driven primarily by agricultural expansion, urbanisation, and environmental policies. Cropland and forest/woodland areas expanded, while shrubland experienced a sharp decline, and grassland showed marginal losses. These trends underscore the complex and regionally varied interactions between human activities and ecological systems. The findings highlight the urgent need for integrated, sustainable land management policies that balance agricultural development with environmental conservation to support Nigeria's long-term ecological and socio-economic resilience.

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Appendix:
Supplementary Information

Table SI: Annual Land Use and Land Cover Changes from 1992 to 2019 in Nigeria.

LULC		Cropland	Grassland	Shrubland	Forest	Others
1992	Area (KM^2)	341818.40	100171.91	126970.49	162536.23	186815.64
	%	37.22%	10.91%	13.83%	17.70%	20.34%
1993	Area (KM^2)	342143.65	100039.88	122043.52	162513.02	225036.29
	%	35.95%	10.51%	12.82%	17.07%	23.64%
1994	Area (KM^2)	341969.70	99926.09	56520.55	249550.88	186980.52
	%	36.58%	10.69%	6.05%	26.69%	20.00%
1995	Area (KM^2)	344870.43	99885.87	118659.56	163410.41	186401.02
	%	37.76%	10.94%	12.99%	17.89%	20.41%
1996	Area (KM^2)	347384.01	99666.11	115537.17	164795.96	186089.20
	%	38.03%	10.91%	12.65%	18.04%	20.37%
1997	Area (KM^2)	348935.33	99242.97	112893.79	165757.03	186512.06
	%	38.20%	10.87%	12.36%	18.15%	20.42%
1998	Area (KM^2)	349325.17	99035.85	111337.53	166405.20	186595.84
	%	38.27%	10.85%	12.20%	18.23%	20.44%
1999	Area (KM^2)	351096.52	98661.11	106313.71	169701.85	186838.46
	%	38.47%	10.81%	11.65%	18.60%	20.47%
2000	Area (KM^2)	352931.61	98683.62	102546.44	172450.35	186765.56
	%	38.64%	10.80%	11.23%	18.88%	20.45%
2001	Area (KM^2)	354278.36	98867.10	100871.05	172294.45	187127.86
	%	38.79%	10.82%	11.04%	18.86%	20.49%
2002	Area (KM^2)	355207.00	98908.03	99379.81	172706.32	187379.83
	%	38.88%	10.83%	10.88%	18.90%	20.51%
2003	Area (KM^2)	356361.20	98892.93	97676.78	172347.46	187912.52
	%	39.02%	10.83%	10.70%	18.87%	20.58%
2004	Area (KM^2)	357722.05	98576.85	92242.40	177158.99	188008.79
	%	39.15%	10.79%	10.10%	19.39%	20.58%
2005	Area (KM^2)	357893.94	98605.86	91341.26	176904.23	188694.88
	%	39.18%	10.79%	10.00%	19.37%	20.66%
2006	Area (KM^2)	359164.88	98560.54	89788.68	176430.77	189459.34
	%	39.32%	10.79%	9.83%	19.32%	20.74%
2007	Area (KM^2)	360128.22	98401.93	87618.33	176585.60	190416.54
	%	39.44%	10.78%	9.60%	19.34%	20.85%

2008	**Area (KM^2)**	361316.68	98367.96	85679.76	176668.01	191660.53
	%	39.54%	10.77%	9.38%	19.34%	20.98%
2009	**Area (KM^2)**	361923.29	98500.66	84091.81	176595.50	192430.80
	%	39.62%	10.78%	9.21%	19.33%	21.06%
2010	**Area (KM^2)**	362107.06	98576.08	83419.57	176423.50	192901.10
	%	39.64%	10.79%	9.13%	19.31%	21.12%
2011	**Area (KM^2)**	361426.15	99443.91	82797.48	176562.71	193372.45
	%	39.56%	10.88%	9.06%	19.33%	21.17%
2012	**Area (KM^2)**	362245.79	98960.36	81776.22	176424.46	194081.36
	%	39.66%	10.83%	8.95%	19.31%	21.25%
2013	**Area (KM^2)**	361943.34	99021.82	81416.95	176539.64	194547.28
	%	39.62%	10.84%	8.91%	19.33%	21.30%
2014	**Area (KM^2)**	361657.83	98947.18	80726.96	177218.58	194547.28
	%	39.61%	10.84%	8.84%	19.41%	21.31%
2015	**Area (KM^2)**	361529.14	98868.27	80360.35	177160.84	195474.09
	%	39.58%	10.82%	8.80%	19.40%	21.40%
2016	**Area (KM^2)**	357884.83	99363.73	79369.76	179254.08	195483.57
	%	39.27%	10.90%	8.71%	19.67%	21.45%
2017	**Area (KM^2)**	359265.89	99399.06	78404.21	180626.65	195577.58
	%	39.34%	10.88%	8.58%	19.78%	21.42%
2018	**Area (KM^2)**	358203.11	99455.01	76808.67	183690.30	194969.17
	%	39.23%	10.89%	8.41%	20.12%	21.35%
2019	**Area (KM^2)**	356288.73	99708.00	75384.61	187760.72	194521.65
	%	39.00%	10.91%	8.25%	20.55%	21.29%
Area Change		14470.33	-463.91	-51585.88	25224.49	7706.01
% Change		4.23	-0.46	-40.63	15.52	4.12
Change per year		0.16	-0.02	-1.50	0.57	0.15