KADUNA JOURNAL OF GEOGRAPHY
2025, VOL. 7, No. 1, 187-196
https://doi.org/10.47514/kjg.2025.07.01.021

SPECIAL ISSUE: CELEBRATING 20 YEARS OF GEOGRAPHY IN KADUNA STATE UNIVERSITY - ADVANCES AND FRONTIERS IN GEOGRAPHY

Land-Use Land-Cover Dynamics of Malam Aminu Kano and Murtala Mohammed International Airports in Nigeria

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ABSTRACT

The increasing demand for efficient transport systems has necessitated airports to evolve into modern facilities in line with global best practice, coupled with the competition over scarce resources have altered the land cover in many airports around the world. This study examines the Land-use and Land-cover (LULC) dynamics of Mallam Aminu Kano International Airport (MAKIA) and Murtala Muhammed International Airport (MMIA) in Nigeria from 1982 to 2022. Using a combination of multispectral Landsat imagery and high-resolution satellite data, the research evaluates the extent of land conversion driven by infrastructure expansion, cropland development, and population growth using supervised classification. The results reveal significant reductions in forest cover and grasslands, with infrastructure and cropland as primary drivers. At MMIA, forest cover decreased by 29%, while cropland expanded by over 1,000%. MAKIA recorded a 43% loss in cropland, largely replaced by infrastructure. The findings highlight the environmental trade-offs of airport development, particularly the decline in vegetation and biocapacity, which pose sustainability challenges. This study emphasizes the need for policy interventions, such as vertical infrastructure expansion and reforestation, to mitigate the ecological impacts of airport growth. The research contributes valuable understandings into the interplay between aviation development and land use changes in Nigeria.

ARTICLE HISTORY

Submitted 24 October 2025
Accepted 24 December 2025
Published 25 December 2025

GUEST EDITOR

A. M. Ahmed

KEYWORDS

Land Use Land Cover, MAKIA, MMIA, LULC Dynamics

1 Introduction

Changes in Land-Use Land-Cover (LULC) of an area are a major indicator of the pressure being put on ecosystem services at the global and regional scale, and Africa is experiencing substantial changes across the continent (Belčáková & Diviakva, 2017). In recent decades, African grassland, woodland, bushland, and other vegetation covers have been disappearing under agricultural lands or human infrastructure (Wackernagel & Bayers, 2019). It is estimated that about 50,000 km2 of natural vegetation is being lost per year in Africa due mainly to human-induced changes (Abebe et al., 2022). Monitoring these human impacts is vital in global discourse.

As human societies continue to grow, the demand for transportation will also continue to grow. Since the world is considered a global community, air transportation plays a major role in providing people and cargo with the global freedom of efficient movement (Bagamanova & Mota, 2020). Airports, being major components in the aviation industry along with the facilities and services they provide, are considered to be one of the most important parts of the infrastructure required for the regular operations of aircraft (Boussauw and Vanoutrive, 2019). Airports considerably contribute to the local economy, employment, and international communications. In the air transport industry, operations and ownership of airport infrastructures can be either public or private, depending on the country and mode of operations (Janic, 2011). Notwithstanding all the socioeconomic benefits they offer, environmental costs and impacts are inseparable results of Airport operations (Wackernagel & Kitzes, 2008; Bagamanova & Mota, 2020). Following the increasing demand for air travel by passengers and cargo, the aviation industry is anticipated to grow further, and this means more incentives and driving forces for building new airports or expanding the existing ones (Dursun, 2022), hence intensifying the significance and complexity of environmental and sustainable development concerns (Janic, 2011).

Obviously, there is a strong link between transportation and land use. Airports, which serve as the building blocks of the air transport sector, contribute their fair share to the impacts on the environment, especially by sometimes directly consuming large expanses of land. Moreover, airports indirectly take up land for road construction, leading to airports and for accommodation of various office complexes and halls of residences (Janic, 2011; Bahadir, 2022).

The Lagos and Kano airports are inarguably the two oldest airports in the country (Decker, 2008). While the Kano airport is in the savanna belt of Nigeria, the other is in the Forest belt, and thus the LULC changes are expected to reflect the situation across other airports in the country. Generally, airports, as important administrative, commercial, or tourist centers, attract huge traffic. More so, the traffic that flows through an airport may largely

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determine how much infrastructure and capacity are built into it.

This paper examines the land use and cover change in both airports, to ascertain the rate of conversion of natural vegetations to physical infrastructure in the needed in the aviation industry, to cater to the growing needs of travelers as a result of population increase and economic development.

2 Materials and Methods

2.1 Study Area

Historical background of MAKIA

Mallam Aminu Kano International Airport (MAKIA) is situated within Kano Metropolis in Fagge LGA. It occupies approximately 633 hectares of land. The airport is the oldest airport in Nigeria, which commenced operations in 1936. Preceding that year, Kano recorded the first-ever aviation operation in the country when a Royal Air Force aircraft operated by the British colonialists landed in the city at a polo ground in 1925. This reconnaissance flight during World War I later developed into regular military flights. The standardization of the airport development actually started in the 1930s, thus transforming the city of Kano into a veritable hub rivalled only by Khartoum, Sudan, on the continent.

The historical significance of MAKIA being the first airport in Nigeria makes the entire Nigerian airspace be called Kano FIR (Kano Flight Information Region) in the international aviation operational terminology to date. In fact, the airport plays host to KLM, the longest-serving foreign airline in Nigeria, which has been operating since 1947. Since 1957, the airport has been operating for 24 hours daily, with the Comet 15, DC-6, and Argon airliners becoming the first to use the main runway (Dukiya & Ahmad, 2014). Major international flights and Muslim pilgrimages to Makkah in northern Nigeria are from Kano airport. As an international airport, it has two runways (06/24 and 05/23) that are used for civil and military flights, respectively.

Historical background of MMIA

Murtala Muhammed International Airport (MMIA) is an international airport located in Ikeja, Lagos State, Nigeria. It has a size of approximately 1,436 hectares and is the major airport serving the entire state. The airport was initially built during World War II and is named after Murtala Muhammed, the 4th military ruler of Nigeria.

Originally known as Lagos International Airport, it was renamed in the mid-1970s, during construction of the new international terminal, after a former Nigerian military head of state, Murtala Muhammed. The international terminal was modelled after Amsterdam's Schiphol Airport. The new terminal opened officially on 15 March 1979. It is the main base for Nigeria's largest airline, Air Peace.

Murtala Muhammed International Airport consists of an international and a domestic terminal, located about one kilometer from each other. Both terminals share the same runways. This domestic terminal used to be the old Ikeja Airport. International operations moved to the new international airport when it was ready, while domestic operations moved to the Ikeja Airport, which became the domestic airport. The domestic operations were relocated to the old Lagos domestic terminal in 2000 after a fire incident. A new domestic privately funded terminal known as MMA2 has been constructed and was commissioned on 7 April 2007.

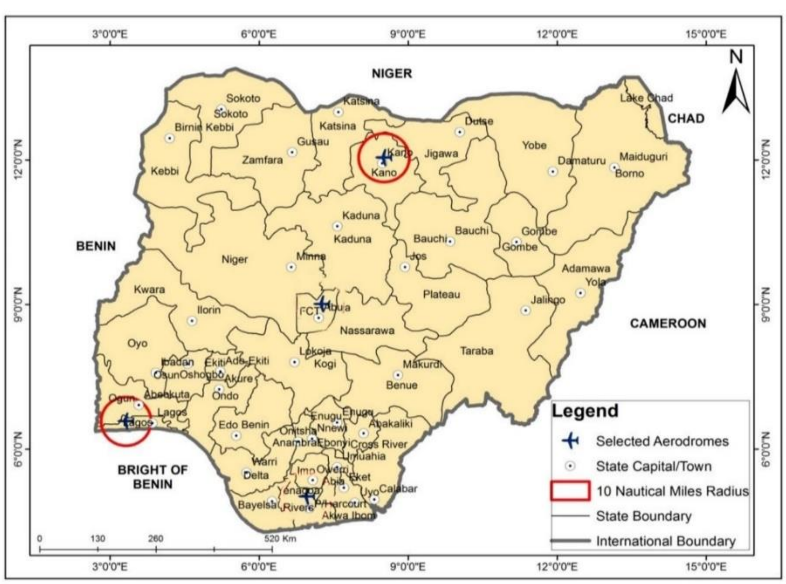


Figure 1: Nigeria showing the Study areas
Source: Modified from NAMA Enroute Chart (ICAO) 2023

2.2 Research Design

This research employed the use of a longitudinal observatory survey, by virtue of being an evaluation study in nature. This study involves continuous observation of variables and trends over a prolonged period of time, often years or decade and is generally observational in nature, with quantitative and/or qualitative data being collected on any combination of exposures without any external influence.

2.3 Data Sources

Satellite images

Multispectral Landsat imagery for the study areas was downloaded from the USGS' Earth Explorer portal (https://earthexplorer.usgs.gov/) for the three study periods (that is, 1982, 2002, and 2022). The details of the downloaded images are provided below.

Table 1: Landsat Images of both airports

Landsat	Sensor	Spatial Resolution (m)	Selected Bands	Path/row	Acquisition Date	Cloud (%)
5	TM	30	1-4	188/052	1984-12-29	0.00
7	ETM	30	1-7	188/052	2002-10-20	0.00
9	OLI	30	1-7	188/052	2021-12-11	0.00
5	TM	30	1-7	191/055	1984/12/18	2.00
7	ETM	30	1-7	191/055	2002-12-28	0.00
8	OLI	30	1-7	191/055	2022-01-25	0.69

Besides the Landsat multispectral imageries described above, high-resolution imageries were downloaded using Google Earth 7.3.2 software. The images obtained via Google Earth come from a variety of sources, such as Copernicus, American EOS, and DigitalGlobe, and have spatial resolutions between 0.3m and 4m (Copernicus, 2022; Maxar, 2023). The Smart GIS 20.5 software was used in combination with the Google Earth software to ensure that the high-resolution images were downloaded with their respective geographic coordinates. With this method, no georeferencing of the images was required, as the images downloaded were already Georeferenced.

The boundaries of both airports were very conspicuous when assessed from high resolution imageries. A combination of these images and survey maps obtained from the Admin Department of each airport was thus used to digitize the boundary of each airport. More so, the high-resolution historical imageries were used to aid further ground-truthing of the image classification and in effectively guiding the researcher where manual adjustments to the land-use classes were necessary. The high-resolution images obtained via Google Earth were obtained for the years 1985, 2002, and 2022.

2.4 Image Pre-processing

In order to mitigate unwanted sensor, atmospheric, or solar effects, the pre-processing of satellite imagery is important. In the current study, image pre-processing included radiometric and atmospheric correction. All data pre-processing procedures were performed using ENVI 5.3. The Radiometric correction tool in ENVI 5.2.1 was used to mitigate radiometric errors in all the Landsat multispectral imagery. This process aids in converting the digital number assigned to the image pixels into spectral radiance values and the radiances into reflectance values. Atmospheric correction was performed using the Quick Atmospheric Correction (QUAC) tool available in ENVI 5.2.1. The information needed by the software to perform this operation was contained in the header files (.mtl file) downloaded alongside the Landsat imageries.

2.5 Image Classification (Supervised)

The LULC classification scheme used for this study includes built-up area, bare land, forest land, agricultural land, and water bodies. After preprocessing the imagery, they were imported into the ArcGIS 10.4 environment, where the image classification was performed. Firstly, the Raster processing toolbar in ArcGIS was used to create image composites of selected bands as stated in Table 2. The Spatial Analyst toolbar was then used to create training sites based on careful examination of the image composites, as well as the sites preselected during the reconnaissance survey. More so, the high-resolution images earlier downloaded also guided the selection of the training samples for each year and for each location. Furthermore, the segmentation and classification toolbar in ArcGIS was used to conduct a supervised classification using the maximum likelihood algorithm. A number of iterations of the classification were performed, making certain adjustments to achieve good results.

2.6 Accuracy Assessment

A post classification accuracy assessment and Kappa coefficient were developed in order to assess the performance of the LULC classification system. It was challenging to carry out an accuracy assessment for the classified LULC maps of 1982 due to a lack of very clear past ground truth data. About 60 random sample points belonging to all the corresponding LULC classes were selected through the stratified sampling method and verified against the ground truth data and the high-resolution imageries earlier obtained. The results indicate over 90% of an overall accuracy for all the land classes and a kappa index of between 0.79 and 0.9 across the images.

Table 5: Summarized Accuracy Assessment Matrix

Location	Year	Overall accuracy	Kappa coefficient
MMIA	1982	88.92	0.84
MMIA	2002	92.35	0.89
MMIA	2022	95.47	0.92
MAKIA	1982	87.25	0.83
MAKIA	2002	98.23	0.96
MAKIA	2022	98.17	0.95

2.7 Change Statistics

Changes in landcover type between 1982 and 2022 were computed using the information from the LULC classification. This helped in establishing the extent of change within a given landcover class over the period being studied. A simple formula (Gravetter & Wallnau, 2014) for the computation of change statistics was utilized as presented in Equation (1).

$$\text{Change in X\%} = \left(\frac{X_2 - X_1}{X_1}\right)100 \quad (1)$$

Where X_1= Initial landcover size (ha or gha), X_2= Newer landcover size (ha or gha)

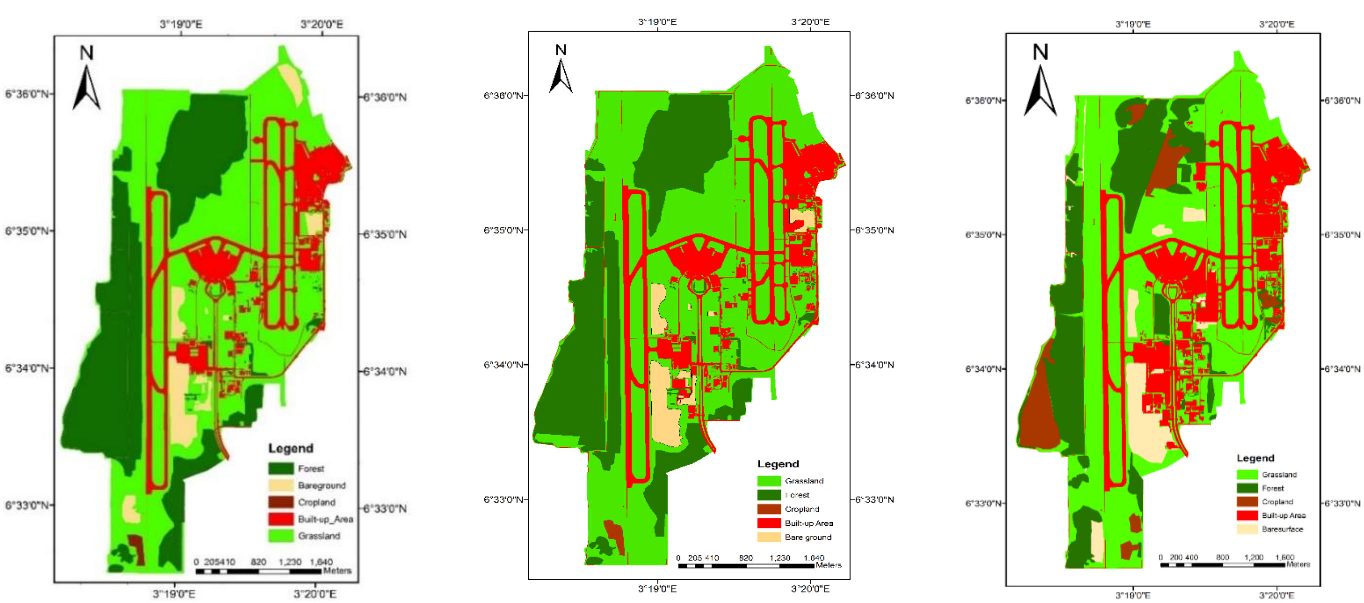
2.8 Data Analysis

It is worthy of note that bare ground is considered an unproductive area and thus not included in the computation. Hence, only five land-use types were utilized – forest, grassland, cropland, fishing ground (water body), and infrastructure (built-up area). More so, although the Kano airport is dominated by a grassland ecosystem, the few groupings of trees in the Kano airport were classified as shrubland and merged under the forest land type. This was done in order to achieve uniformity in the classification for both airports. Besides, this may not be out of place as forest land type is described as where provision for timber, pulp, and firewood could be made (Galli et. al., 2020). The results obtained here are presented in charts and tables and described accordingly.

3 Results and Discussion

3.1 Land-use Land-cover Change at MMIA

The results of the LULC dynamics for Lagos airport are presented in both Figure 2 and Table 2. They indicate that grassland is the dominant land cover at MMIA, taking up about 50% of the entire area for all three epochs under consideration, followed by forest cover with about 27 to 30% for the years 1982 and 2002, respectively.



1982 **2002** **2022**

Figure 2: LULC Changes at MMIA from 1982 to 2022

Figure 2 revealed that the major changes throughout the maps have mainly occurred at the central part of the MMIA airport, where infrastructure and bare ground have caused the disappearance of grass cover, and at the Western part and Northern parts, where forests have given way mainly to cropland and grassland. The declining of forest cover and other changes across the years can be better visualized further in Figure 3 and Table 2 accordingly.

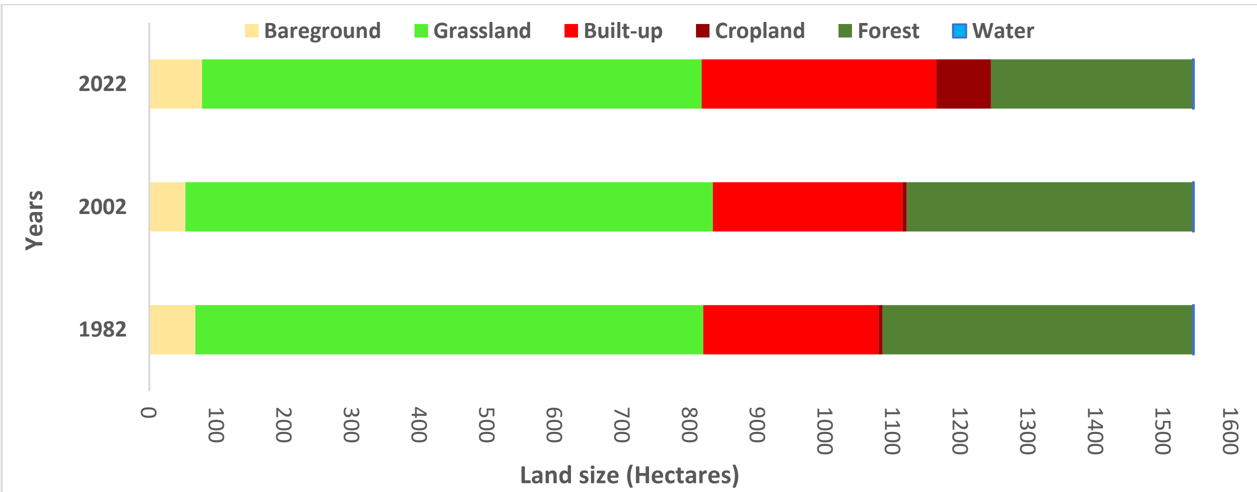


Figure 3: Intra-annual and Interannual LULC dynamics at MMIA from 1982 to 2022

The growth of infrastructure through the years places it as the second dominant land-cover by 2022 (Table 2), thereby displacing forest at that position. The LULC changes also indicate a marginal fluctuation in grassland and bare ground land-cover across the years. Major changes that can be observed include those of infrastructure, which has consistently increased throughout the period, while forest cover has been on the decrease.

Table 2: Dynamics of LULC at MMIA

	1982	Percentage	2002	Percentage	2022	Percentage
Bare ground	68.29	4.42	53.39	3.46	78.08	5.05
Grassland	750.93	48.60	779.99	50.49	738.99	47.84
Built-up	259.58	16.80	280.19	18.14	347.11	22.47
Cropland	5.40	0.35	6.99	0.45	80.47	5.21
Forest	459.42	29.74	423.15	27.39	299.04	19.36
Water	1.35	0.09	1.21	0.08	1.11	0.07
	1544.97	100.00	1544.93	100.00	1544.79	100.00

Generally, the changes observed across all the landcover appear to be more prominent in the 2002 – 2022 epoch than the 1982 – 2002 epoch, as shown in Table 3. Major gains in the 2002 – 2022 epoch include the increase in cropland (by about 1,000%), bare ground (46%), and infrastructure (about 24%). The major losses for the 2002-2022 epoch apply mainly to forest cover, with a loss of about 29%. Overall, infrastructure and cropland appear to be majorly responsible for the decline in forest cover, as can be observed from Figures 2 and 3, while bare ground could be fingered in the disappearance of grasslands.

Table 3: LULC Change Statistics at MMIA

Land Use Type	1982 – 2022 (Ha)	Percentage Change	2002-2022 (Ha)	Percentage Change	Overall (1982-2022)	Percentage Change
Bare ground	-14.9	-21.8	24.7	46.2	9.85	14.3
Grassland	29.1	3.9	-41.0	-5.3	-11.9	-1.6
Built-up	20.6	7.9	66.9	23.9	87.5	33.7
Cropland	1.6	29.5	73.5	1051.0	75.1	1390.1
Forest	-36.3	-7.9	-124.1	-29.3	-160.4	-34.9
Water	-0.1	-10.2	-0.1	-8.6	-0.2	-17.9

Summarily, Table 3 indicates that the major gainer is cropland, with an over 10-fold increase (about 1390%) from 1982 – 2022, while the major loss is recorded for the Forest land-cover with an overall decline of about 35%.

The changes that have been observed in the airports are similar to those observed by Xiong et al. (2018) in their study of the LULC changes occurring in and around the Hangzhou International Airport, China, where infrastructural expansion was majorly responsible for the decline in natural habitat. Similar observations were recorded by Koko et al. (2021) in their study of urban growth and LULC changes in Lagos, Nigeria, where built-up areas expanded by about 14% between 1990 and 2020.

The population of Lagos has also grown from 14,862,000 to 15,388,000 in 2022, and this has ultimately translated to the need to convert natural land to infrastructure and farmland. The growth in infrastructure at MMIA is likely because passenger traffic has also grown from about 4,110,395 in 2020 to about 5,689,234 in 2021(National Bureau of Statistics, 2023), thus necessitating an expansion to cater to the increasing traffic. Informal interactions with a few staff within the MMIA suggest that the increase in cropland over the period considered may be partly due to the decline of farmlands within the Lagos metropolitan area, as observed by Onilude and Vaz (2020) in their study of land-use change in Lagos between 2000 and 2010. This observed decline probably made some staff of the airport who might have lost farmlands in the township look within the airport for cultivatable space. Moreover, the astronomical rise in the prices of farm produce in the country over the past few years might have ignited the need to cultivate available spaces, hence the steady increase in the size of cropland over the years.

3.2 Land-use Land-cover Change at MAKIA

The dynamics of LULC for MAKIA are presented in Figures 4, 5, and Tables 4 and 5. From Figure 4, it can be deduced that grassland is the dominant land type in MAKIA, maintaining about 70% - 75% of the entire landcover between 1982 and 2022 (Table 4). This is not surprising considering that MAKIA lies in the Sudan savanna region of Nigeria, where grasses and shrubs are the dominant vegetation. This is followed by infrastructure, which makes up between 16 – 20 percent of the landcover between 1982 and 2022.

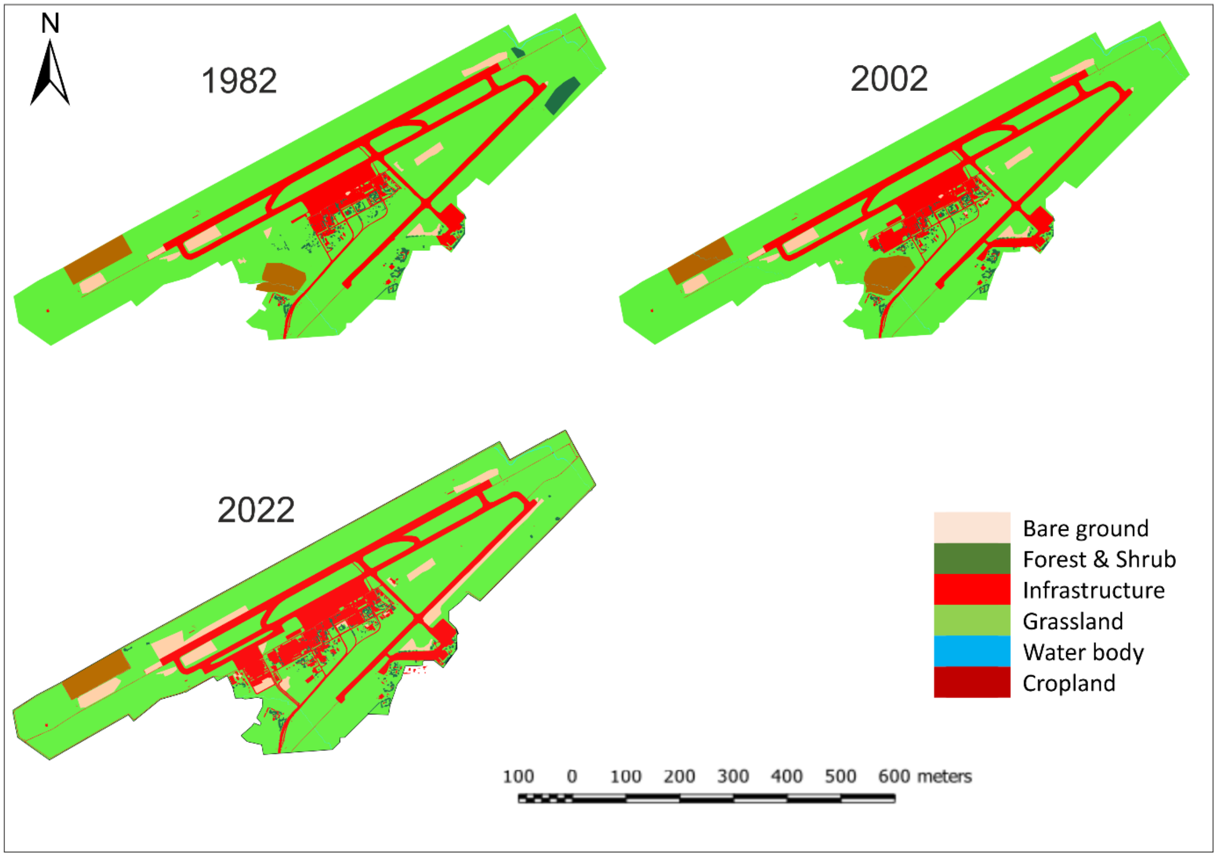


Figure 4: LULC dynamics at MAKIA from 1982 to 2022

Together, both grassland and infrastructure have maintained a dominance of over 90% of MAKIA's landcover leaving a meagre 10% to bare ground, cropland, shrubs, and water bodies in decreasing order of dominance (Figure 5).

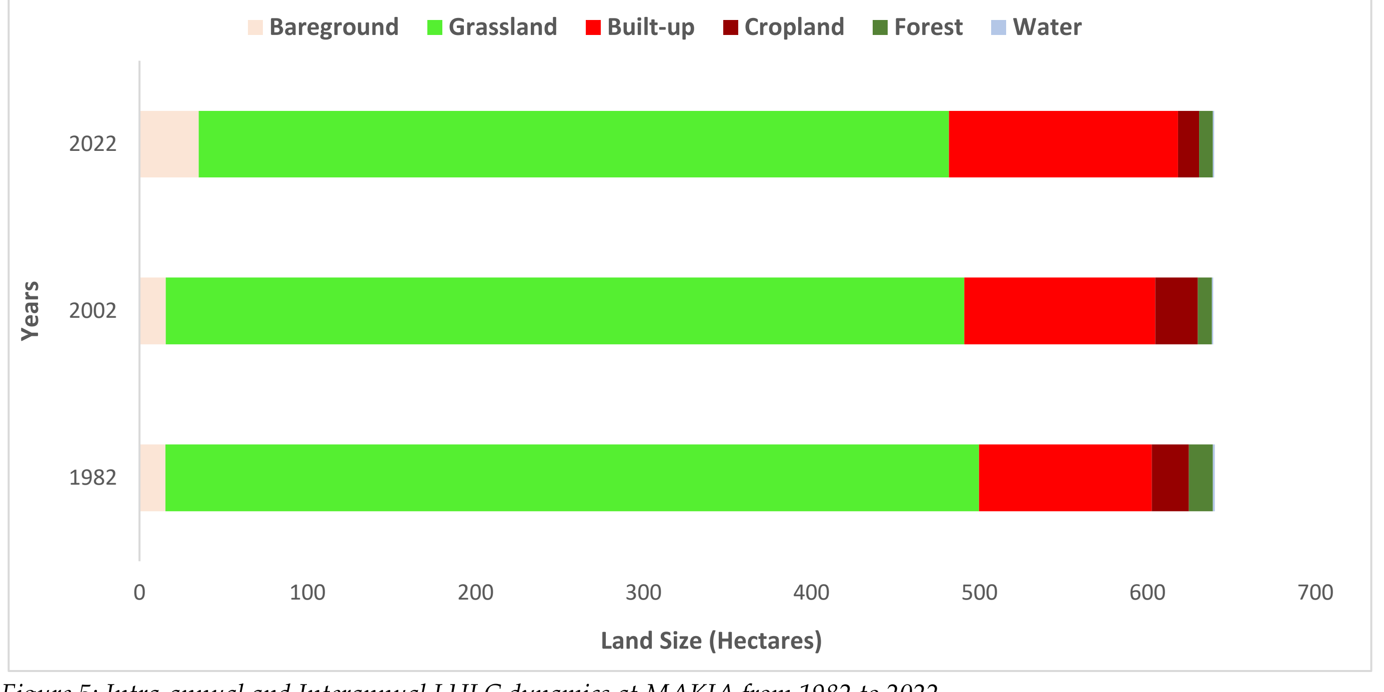


Figure 5: Intra-annual and Interannual LULC dynamics at MAKIA from 1982 to 2022

Table 4: The LULC Dynamics at MAKIA

Land Type	1982	Percent	2002	Percent	2022	Percent
Bare ground	15.47	2.42	15.65	2.45	35.33	5.52
Grassland	484.25	75.67	475.44	74.38	446.51	69.78
Built-up	102.96	16.09	113.70	17.79	136.49	21.33
Cropland	22.06	3.45	25.38	3.97	12.46	1.95
Forest	14.36	2.24	8.25	1.29	8.22	1.29
Water	0.83	0.13	0.83	0.13	0.83	0.13
	639.92	**100.00**	**639.24**	**100.00**	**639.85**	**100.00**

Generally, the overall changes observed across the land types, as shown in Table 4, seem more conspicuous in the 2002-2022 epoch than in the 1982-2002 period. Major change in the first epoch is the over 42% loss of shrubs and trees between 1982 and 2002. This is probably explained by the 15% and 10% increase in cropland and infrastructure Land-covers respectively, for the same period. The encroachment of cropland onto grassland surface can be observed in the Southeastern part of the LULC map of MAKIA (Figure 4).

Table 5: LULC Change Statistics at MAKIA

Land Type	1982 - 2002	Percentage Change	2002 - 2022	Percentage Change	Overall (1982-2022)	Percentage Change
Bare ground	0.2	1.2	19.7	125.7	19.9	128.4
Grassland	-8.8	-1.8	-28.9	-6.1	-37.7	-7.8
Built-up	10.7	10.4	22.8	20.0	33.5	32.6
Cropland	3.3	15.1	-12.9	-50.9	-9.6	-43.5
Forest	-6.1	-42.6	0.0	-0.2	-6.1	-42.7
Water	-0.1	-11.0	-0.1	-6.2	-0.2	-16.6

Consequently, cropland lost about 51% cover in the second epoch of 2002 to 2022, as shown in Table 5. Evidence from the LULC map (Figure 4) shows that the disappeared cropland was mainly taken over by infrastructure, mainly in the Southern part of the map. For the entire period (1982-2022), Table 5 shows that bare ground has increased by about 128%, while both cropland and forestland have each lost about 43% of their initial cover.

The LULC analysis conducted from 1982 to 2022 indicates a marginal increase in the size of the majority of the land types from 1982 to 2002, while major changes that involve either a decline or an increase in land-cover were more visible between 2002 and 2022 for both airports. Generally, we see the depreciation of grassland and forest land-covers in both airports, while infrastructure sustained its growth as seen in figures 2 and 3. Infrastructure has been majorly responsible for the disappearance of natural vegetation, and to a smaller extent, cropland. This is in agreement with the study of Obiefuna et. al. (2021) in the Western part of Lagos, where MMIA is situated. They established an over 50% decline in vegetation cover, 54% of which has been replaced by infrastructure. Ayila et al. (2014), Koko et. al. (2021), and Koko et. al. (2022) also reported similar changes in Kano, where encroachment by built-up areas has caused a significant disappearance of natural vegetation cover. These studies attributed these changes to the growing population, the consequence of which is the constant need for urbanization.

In addition, personal communication with the MAKIA Head of Operations Department indicated that the increase in passenger traffic and personnel of different agencies within the airport necessitated the expansion of the airport's infrastructure to meet the rising demand. For instance, the Lagos airport has recorded over 5million arrivals and departures per annum in recent years, unlike decades back when it only served a few hundred thousand people (Nigerian Bureau of Statistics, 2022). Thus, the larger the traffic, the more personnel of various agencies would be needed for various operations. This would therefore result in more demand for office spaces and possibly, residential quarters for certain personnel, hence the need for expansion. Part of the declining forestland, especially for the Western part of MMIA, was likely done to allow better visibility around the runway.

It is worthy of note that both MMIA and MAKIA are very important to the economy of the country. Besides being located in the two most populous states in Nigeria, MMIA sits in Nigeria's commercial capital, while MAKIA is situated in the commercial capital of Northern Nigeria. The combined effect of population growth and its consequent expansion of commerce in these commercial centers would naturally translate into more traffic for air travel and thus create demand for infrastructure expansion and remodeling.

The growth of cropland from 1982 through 2022 for both airports might also be related to the pressure that population expansion and urbanization place on existing croplands, thus necessitating the need for clearance of more natural vegetation for croplands. This may hold quite true, specifically for the Lagos airport, where an overall increase of over 1800% was observed from 1982 to 2022. The MAKIA also experiences similar growth in cropland but witnesses an interesting decline in the second epoch. Personal communication with the MAKIA Safety Manager revealed that the disappearance of the cropland visible in the Southeastern part of the MAKIA is due to the completion of the perimeter fencing and the subsequent prevention of locals from cultivating part of the cropland due to security concerns. That section of cropland has largely disappeared under infrastructure, while the remaining cropland still being cultivated is done by personnel working within the airport community who have acquired permission to do so.

In addition, there is a general rise in the size of bare ground, rising slightly by about 5% at the MMIA and by over 120% at MAKIA. While this may be attributed to increased human clearance activity, it may also be associated with the changing patterns of climate as also posited by Haruna et. al. 2020 in their study of LULC in Kano Metropolis, as well as Balogun and Ishola (2017) in their study in Akure, Southwest Nigeria, who both established climate change among some of the potent factors causing LULC changes.

4 Summary of Major Findings

For both airports, grassland remained the dominant land-cover, taking up about 50% of the entire area at MMIA and between 70% - 75% at MAKIA for all three epochs under consideration (1982-2022). At MMIA, forest cover was the second dominant land type, covering about 27 and 30% for the years 1982 and 2002, respectively, while infrastructure was the second dominant land type at MAKIA from 1982 to 2022, maintaining about 16-20% of the landcover. Major changes at MMIA occurred in the 2002 – 2022 epoch, which include the increases in cropland (1,000%), bare ground (46%), and infrastructure (about 24%). Within the same period, forest cover lost about 29%, with infrastructure and cropland being mainly responsible for the observed decline in forest cover. The major landcover loss at MAKIA was interestingly cropland, which declined by about 51% between 2002 and 2022, as shown in Table 4. Evidence from the LULC map (figure 4) shows that the disappeared cropland was mainly taken over by infrastructure, mainly developed in the Southern part of the area. At MAKIA, for the entire period (1982-2022), it was determined that bare ground increased by about 128%, while both cropland and forestland have each lost about 43% of their initial cover.

5 Conclusion

The findings of this research clearly show that human activities will continue to threaten the environment as we continue to satisfy human needs for resources. While the demand for infrastructure is necessary for effective airport operations, the environmental effects of such development are evident in both airports, where the scrubland and forest land are on the decline as a result of the expansions.

This study indicates that the taking up of vegetation by infrastructural expansion could be a major threat to sustainable development in the area. It is therefore recommended that policy makers and other stakeholders should consider constructing storey buildings rather than horizontal expansions. The construction of high-rise buildings to accommodate future infrastructure expansion needs could help control the disappearance of bio-productive lands under infrastructure. To protect the remaining bio-capable lands from being degraded, aggressive tree planting, especially for MAKIA in areas that may not impact the general safety of airport operations, may be an important consideration. Further research should focus on the biocapacity and Ecological Footprint of airports in order to make informed decisions by the authorities when expanding infrastructure in the airports.

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