Assessing the Pattern of Land Use and Land Cover Changes and its Implication on Surface Water in Kaduna State, Nigeria

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Abstract
Over the years, Kaduna State has witnessed tremendous increase in population and urbanization that have changed the landscape of the area. The paper assesses the pattern of land use and land cover (LULC) changes in Kaduna State, and made hydrological inferences. The Landsat imageries were acquired from United States Geological Survey (USGS) satellite image database for the period of 1984, 1994, 2004, 2014 and 2019. Supervised image classification using the maximum like-hood Algorithm in ArcGIS *was adopted to classify the LULC of Kaduna State into six classes. There was about 60% increase in farmland, 7% in built-up area and 0.38% in water body between 1984 to 2019. The most significant decrease in LULC occurred in vegetation (21%) and Rock outcrop (10.62%) during this period. The predicted future LULC change suggests that only about 19.56% of the State will remain under vegetation cover by the year 2030. The results underscored the increasing anthropogenic activities in Kaduna State that influenced recharge rate, surface run-off, infiltration and incidences of soil erosion in the study area.The paper strongly suggests that the main solution to deforestation and unguided urbanization has to start from local action, a bottom-up approach between the responsible authorities and local people to work together in partnership to check deforestation and plan urban development. Planting of the loss native trees and protection of existing vegetation from fire and land clearing should also be encouraged, as well as the restoration of degraded lands and stabilization of ecosystem for combating climate variability or change.*

Keywords: Land Use, Land Cover Change, change detection, surface water, Geo-informatics techniques.

1. Introduction
Modification of the land and its related resources has gradually become one of the critical issues currently attracting global attention and is now at the heart of sustainability and environmental conservation (Bock *et al.*, 2018). This is perhaps due to increasing manifestation of land use and climate change repercussions (Jiang *et al.*, 2019; John and John, 2019). These repercussions have been further highlighted by increased Land Use and Land Cover Change (LULC) modifications as a consequence of rapid population growth and the accompanying socio-economic development activities (Orozco, Martinez and Ortega, 2020; Gogoi *et al.*, 2019; Yunfeng*et al.*, 2019).

The alarming impacts of climate change on water resources system in developing countries necessitated new solution to improve water governance on the basis of reliable, comprehensive and timely water information (Mandal, 2011). These are achievable through satellite imageries interpretation and mapping. It was reported by Adebimpe (2011), that different aspects of current global climatic changes affect the water cycle; and satellite remote sensing provides valuable global overview that can monitor changes in rainfall, extent of water bodies, agricultural land use, vegetation, and at a more local level, to identify the impacts of climate change on water and agriculture in any zone of the world.

Remotely sensed data and GIS techniques in recent years played significant role in the field of hydrology, surface water resources development and management studies. Remote sensing provides multi-temporal and multi-sensor data of the earth surface (Adebimpe, 2011). These tools are very effective in delineating surface water zones. It was reported by Ikusemoran, Mbaya and Wanah (2016) that surface water occurrence being a surface phenomenon, its identification and location is based on direct observation of terrain features like slope, soil, relief features and hydrologic characters and wise interpretation. Satellite remote sensing provides opportunity for better observation and more systematic analysis of various hydrological units' features following the integration of GIS.

LULC refers to two separate terminologies that are often used interchangeably (Hua, 2017; Rawat and Kumar, 2015). Land Cover can be defined as the physical characteristics of the earth's surface which include vegetation, water, soil, and other physical features created through human activities like settlements, while Land Use refers to land used by humans for habitats concerning economic activities (Rawat and Kumar, 2015). LULC patterns depend on human usage in terms of natural and socioeconomic development through space and time. In other words, Land Use changes have the ability to affect the Land Cover and vice versa (Umar *et al.*, 2021; Baig *et al.*, 2022). The negative impacts of land use are affecting the environment, especially in terms of biodiversity, water and earth radiation, trace gas emission, and other processes that come together to affect climate and the biosphere (Idowu and Zhou, 2021). These changes are attributed to only one main factor in terms of size and pattern, namely, "population growth." Increasing population growth directly and indirectly contributes to LULC changes, especially from the perspective of demand for built-up area, agricultural activities, and water resources. Ecological experts are concerned about LULC changes that impact biodiversity and aquatic ecosystems (Hua, 2017). LULC changes in a watershed or drainage basin will affect water quality, leading to increased surfa runoff, reduced groundwater discharge, and transfer of pollutants. Therefore, LULC informatic at the catchment area is important for selection, planning, monitoring, and management of wate resource so that the changes in land use meet the increasing demand for human needs and welfare, without compromising water quality.

The existing LULC in Kaduna State and the previous impacts of the earlier changes still operating in the system determines the response of the ecosystem to disruption in LULC (Martin *et al.*, 2011; Twisa and Buchrother, 2019). The LULC changes being experienced in Kaduna State, particularly increase in built-up areas and decrease in vegetation cover, advertently or inadvertently alter the hydrological processes which include changes in run-off pattern, modification of peak flow characteristics, alteration of water quality etc. (Inalpulat and Gene, 2020). In fact, changes in land use may have unintended negative impacts on hydrological regime of a drainage basin, thereby, increasing the chance of flood occurrence and also reducing the dry season flow (Idowu and Zhou, 2021). Studies have reported that change in LULC can influence surface run-off, infiltration, ground water recharge, water quality and supply in a drainage basin; depending on the degree of change, overlaid flow can increase or reduce (Turner *et al.*, 2001; Butt *et al.*, 2015; Ashaolu, 2018).

In the view of Baig *et al.*, (2022), Idowu and Zhou (2021), LULC change in a drainage basin include increase in population which resulted to rapid urbanization and deforestation which endlessly influence the water budget; the type and magnitude of surface and sub-surface water exchanges, thereby affecting drainage basin ecology and their various benefits to man. Nevertheless, enhanced water preservation schemes can be articulated through the appropriate identification of the spatio-temporal variation taking place in a drainage basin and the relationship between the various components of the basin (Butt *et al.*, 2015).

Over the years, Kaduna State has witnessed tremendous increase in population, farmers' settlements, urbanization and emerging cities, which have changed the landscape of the State. Therefore, assessing the pattern of LULC changes and its implication on surface water in Kaduna State is essential to the management and planning of water resources and land use allocation that will not jeopardize the State ecosystem.

2. Study Area

Kaduna State is located between latitudes 9° 02′′N and 11°32′′ North of the equator and between longitude 6°15′′E and 8°50′′E East of the Greenwich meridian in the North western region of Nigeria. Kaduna State is bounded to the North by Katsina, Zamfara and Kano States, to the West by Niger state, to the East by Bauchi and to the South by Plateau, Nasarawa and Federal Capital Territory, Abuja (Kaduna State, 2003). See (Figure 1).

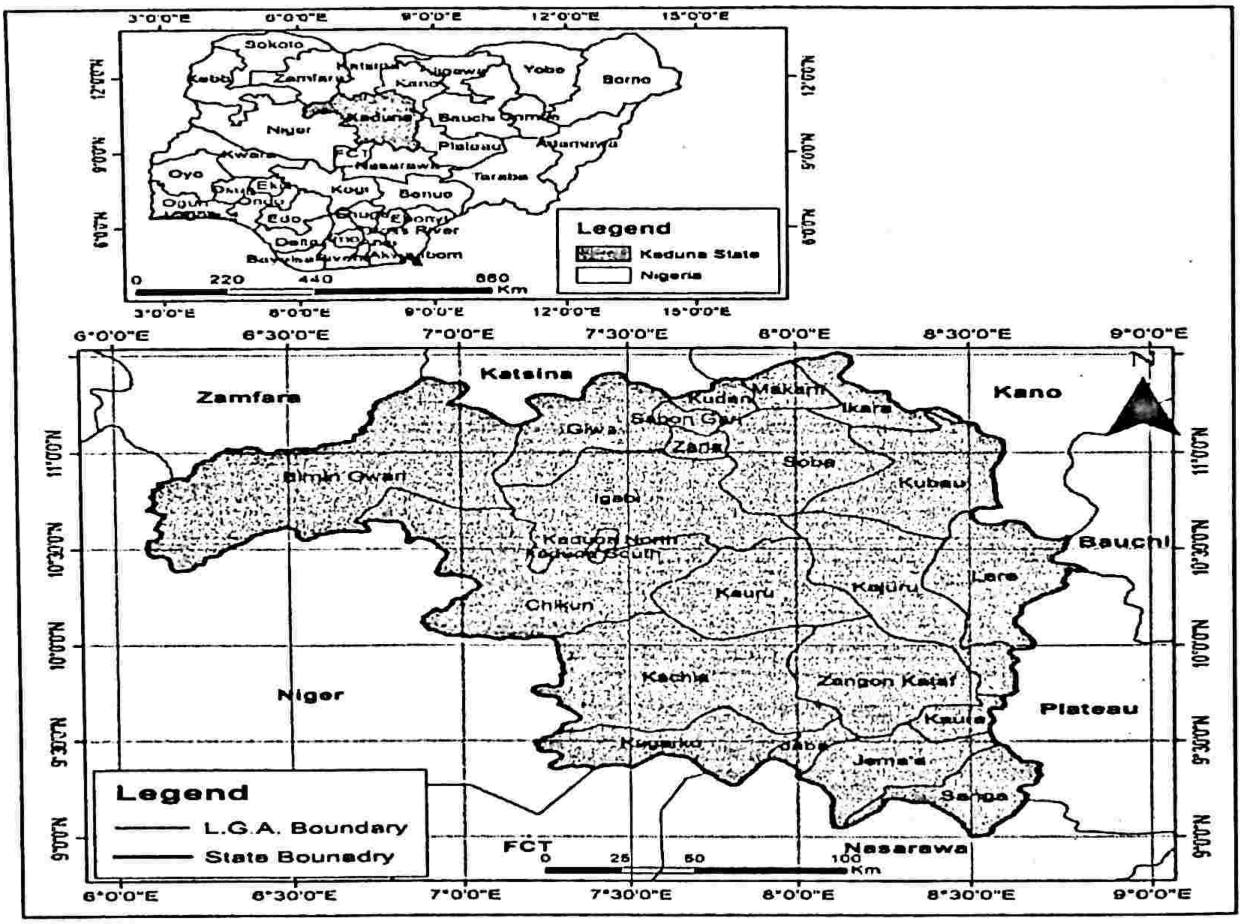

Figure 1: Location of the Study Area
Source: Adapted from Administrative map of Kaduna State

The Kaduna State latitudinal zone lies in the part of Western Africa, within the northern limit of the movement of the Inter-Tropical Convergence Zone (ITCZ). This phenomenon of the global circulation of the air masses is responsible for the general climatic characteristics of the study area, which is characterized by distinct two seasonal regimes, oscillating between cool to hot dry and humid to wet season. The climate of the study area can be described as the Sub-Humid type (Nigeria Vision 20:2020, 2009) characterized by tropical wet and dry or savannah climate (Aw).
Rainfall is the most important climatic variable and its seasonality and amount are of overriding interest to farmers, pastoralist and foresters. As both South Maritime and North Continental air masses are dominant for roughly half a year over Kaduna, there are two contrasting seasons. From

April or May, the moist south-westerly winds bring rain and both cultivation and tree growth respond immediately. However, from month of October to April/May, the study area is subjected to cool dry North-easterly wind which yield virtually no rain. This is the period that irrigation farming mostly take place (Yusuf, 2015). The variation on the onset of rainfall is attributed to the fluctuations of the boundary between these two air masses. Rainfall is heavy in the southern part of the state and reaches an average of 500mm per month between April and September. In the extreme north, the monthly average is 146mm, while Kaduna metropolis receives a monthly average of 361mm (Leah, 2003). The annual rainfall received in Kaduna State range from 1000mm-1270mm, with a raining period of 160-180 days. The peak of the raining season occurred during the month of August (NIMET, 2018). Also, considerable variation take place both in monthly and annual totals. This is mostly due to high intensity of many storms and narrow front with which they sweep across the country side. Generally, the storms are inter-spread with clear skies although during August and September, there can be consecutive days that are dull and over cast. This invariable seasonal regimen of dry and wet exerts a major and permanent influence on agriculture as well as on man's habitation and water availability in the State (Yusuf, 2015).

The combined Temperature and Rainfall of the State shows that, the mean maximum and minimum temperature experience in the State increases during the first part of every year to its peak during the hot season in late March and April. At the beginning of the rain, mean maximum temperature usually fall below 33.0°C and subsequently minimum temperatures are experienced during rainy season, which remains fairly constant (Yusuf, 2015). Toward the end of rainy season, daily maximum temperature rises throughout the little hot season which allow crops to ripe (KDSG, 2018).

3. Materials and Methods

This study utilised land use data from remotely sensed Satellite Imageries that covered 35 years (1984 – 2019). The choice of this span of time for study is to help project the LULC change to 2030.

Table 1: Sourced Data Sets

S/N	Data Type	Resolution (m)/Scale	Date	Sources
		Satellite Imageries		
1.	Landsat TM imagery	30m	25/10/1984	USGS
2.	Landsat TM imagery	30m	5/11/1994	USGS
3.	Landsat TM imagery	30m	21/12/2004	USGS
4.	Landsat ETM imagery	30m	12/11/2014	USGS
5.	Landsat8 imagery	30m	12/12/2019	USGS
6.	Kaduna State Boundary map	1:50,000		NCRS

(Source: United States Geological Survey, 2021).

3.1 Satellite Image Pre-processing

The satellite imageries were imported into ArcGIS 10.2.1 environment where they were rectified to a common projection (Universal Traverse Mercator). According to Wilford (1977), the UTM projection unlike the Geographic Coordinate System (Latitude/Longitude) is more reliable, since its measurements are expressed in linear, decimal units rather than in angular, non-decimal units. Geo-referencing which involves registering data to the real world was carried out and this helped to define the existence of those data sets in physical space as well as establish their location in the real world. The topographic map of 1: 50,000 for the study was scanned and geo-referenced in ArcGIS 10.2.1 environment.

3.2 Image classification

The supervised classification approach was used in the classification with Maximum likelihood classification (MLC) algorithm in ArcGIS 10.2.1 software. This technique enabled analysts to generate training classes based on the actual LULC themes within the study area and helped in curtailing ambiguity that is associated with the unsupervised technique of image classification (Liu *et. al.*, 2002). Each pixel is assigned to the class that has the highest probability (that is, the maximum likelihood). If the highest probability is smaller than the given threshold, the pixel remains unclassified (Helbich *et. al.*, 2012) However, this approach does not take contextual information about the neighbouring classes due to its pixel-by-pixel classification approach (Emil, 2010). The training site were generated through on-screen digitization of selected areas for each land cover classes identified. Essentially, it was a visual tool that gave an overview of where the classes were assigned in the image and whether additional classes were required.

3.3 Classification scheme

Based on the prior knowledge of the area acquired from the reconnaissance survey, a classification adopted from Anderson, Hardey, Rocach and Witmer (1976) was used for this study. The classification scheme utilizes six (6) classes as shown in Table 2:

Table 2: Land Use/Land Cover Classification Scheme

S/N	Code	Land Use/Land Cover Classification	Definition of Terms
1.	WB	Water bodies	Land covered by water bodies like rivers, streams, lakes, wetland/ marshland
2.	V	Vegetation	Land covered by vegetation
3.	BUA/S	Built-up Areas/Settlement	Land allocated to residential and office structures
4.	FL/A	Farmland/Agriculture	Land under cultivation
5.	BL	Bare land	Human induced barred lands
6.	ROC	Rock outcrop	Land covered with rocks outcrop

Source: Adapted from Anderson *et. al.*, (1976).

The software was programmed to determine the minimum level of change. The areas of observed changes were extracted into a GIS database using ArcGIS 10.2.1.

3.4 Change Detection Techniques

The data sets were having large gap of ten years and were designed to reflect the impacts of change in the past years of low population and the recent years when the population of the state has increased tremendously. All four images were acquired between October and December, which is the peak period of harvest. Climatic conditions during this period are the same all over the State (Olokor, 1995), hence the vegetation cover and land use types appeared the same on the images regardless of the year they were obtained. Some distinct land use types were selected for this purpose:

- Areas that were not with water bodies in 1984 but have changed with water bodies in 2019, to know whether there is expansion or not.
- Areas that were flood plains in 1989 but have changed to other land use types in 2019. This were done to determine the land areas of the flood plains that have been lost within the study period to other land use types.
- Areas that were not in intensive cultivation in 1984 but have changed to intensive cultivation in 2019, to evaluate the degree of land captured by intensive cultivation in the study period.

Three main change detection methods which have been previously applied by (Ikusemoran*et. al.*, 2016) were employed in this study. There are three steps in change detection calculation:

The first step first step is the calculation of the magnitude of change, which is derived by subtracting observed change of each period of years from the previous period of years.

The second step is the calculation of the trends, that is, the percentage change of each of the land use, by subtracting the percentage of the previous land use from the recent land use divided by the total land use and multiplied by 100, that is: is B-A/T×100.

The last step is the calculation of the annual rate of change by dividing the percentage change by 100 and multiplied by the number of the study years, that is 35 years.

The simulation of LULC changes into the future was centered on the following techniques:

- The classified LULC maps for the years 1984, 1994, 2004, 2014 and 2019 were used before the conversion methods (vector data to raster data) to obtain the transition matrices for the LULC classes from 1984 to 1994, 1994 to 2004, 2004 to 2014 and from 2014 to 2019 (Wang and Kalin 2018).
- The transition maps used to predict the LULC to 2030 and to reproduce the allocations in 2030 were established on the foundation of main transitions between the LULC classes from 2014 to 2019. Furthermore, the regular 5 ẋ 5 contiguity filter was used as the area classification.
- Lastly, following a related process, the LULC was forecasted on the basis of the transition possibilities matrix from 2019 to 2030 (with a Kappa Table of more than 0.85).

4. Result and Discussion

4.1 LULC Area Distribution and percentage change

Figures 2, 3, 4, 5 and 6 and Table 3, show the classified image of Kaduna State with six (6) distinct land use types. The vegetation in 1984 occupied 26516km² which represents 60% of the total land. Figure 2 represents the spatial distribution of the land use categories derived from classified image of 1984.

Table 3: Percentage change in Land use/ Land cover of the study area

Class Name	Area km² 1984	Area% (1984)	Area km² 1994	Area% (1994)	Area km² 2004	Area% (2004)	Area km² 2014	Area% (2014)	Area km² 2019	Area% (2019)
Water Body	57	0.13	96	0.22	72	0.16	158	0.36	167	0.38
Vegetation	26516	60	22055	50	20585	47	11874	27	9285	21
Built Up	1176	3	1210	3	2693	6	3113	7	3211	7
Farm Land	9978	23	12010	27	16220	37	20107	45	26416	60
Bare Land	225	1	1535	3	457	1	31	0	268	1
Rock Outcrop	6269	12.87	7314	16.78	4193	8.84	8938	20.64	4874	10.62
Total	**44221**	**100**	**44221**	**100**	**44221**	**100**	**44221**	**100**	**44221**	**100**

Source: Researcher's Analysis, 2021 classified satellite imageries

The vegetation area dominated as a result of low anthropogenic activities, low level of urban growth and other technological activities needed to convert vegetation land to built-up area for human settlement, commercial and agricultural land uses. In 1994 it decreased to 22055km² which account for 50% of the total area; in 2004 it further decreased to 20585km² which constituted to 47% of the total area, while in 2014 it occupied 11874 and it covered 27% of the total area. In 2019 it was reduced to 9285km² which represented 21% of the total area.
This finding is similar to that of Hammada*et al.*, (2018) in the Southern Syria coastal basin where vegetation area decreased from about 64% in 1987 to about 38% in 2017.

The vegetation area receded at an annual average rate of 10.25% during the period under investigation. This can be attributed to the years of human occupation and interference with the tropical vegetation. The longer history of agricultural practices and increasing population density in the area would have resulted in substantial modification to the natural vegetation. The socio-economic characteristics of the people in the study area has significantly influenced the changes in LULC observed. Most communities in Kaduna State earn their living through farming, logging and fuel-wood production. Furthermore, climate change is another major cause of the disappearing natural vegetation in addition to the prevailing human activities.

The Sudano-Sahelian zone was reported to have been advancing southward resulting in the loss of forest species and arable lands. All these are responsible for the rapid change in land use and land cover in Kaduna State (Mengistu and Salami, 2007). The implication of the change in LULC include increasing incidences of soil erosion, increasing reservoir sedimentation, soil degradation, climate change and unfavourable changes in the hydrological regime. Groundwater recharge is influenced by plant cover and land use practices. Hence, the type and nature of land cover can have a significant influence on infiltration, and groundwater recharge (Jyrkama and Sykes, 2006).

In 1984 the farm land occupied 9978km² which represents 23% of the total land but in 1994 it increased to 12010km² which constituted 27% of the total land area. The progressive significant increase continued to 2004 which occupied 16220km² and accounted for 37% of the total land. Meanwhile, in 2014 it occupied 20107km² which represented 45% of the total land and in 2019 it occupied 26416km² and was accounted for 60% of the total land area. It can be said that most of the increase in farmlands took place between 2014- 2019. This is because the demand for land for agricultural uses increased as the population increased which affected other land use types especially the decrease in vegetation in the study area. The increase in farm land is in agreement with Idowu and Muazu (2010) which posited that agricultural land increased by 2.18km² with percentage change of about 28.17%, they attributed the increase in farmland to the adoption of new agricultural practices which made some un-usable land before 2008 usable due to technological advancement. The increase recorded in the percentage area of farmland conformed to the work of Salami *et al.*, (1999), which reported that natural vegetation has largely been replaced by perennial and annual crops in many parts of the study area.

In 1984 water body occupied 57km² which constitutes 0.13% of total land area and in 1994 it increased to 96km² which accounted for 0.22% of total land area. In 2004 it decreased to 72km² which represents 0.16% of total land area. Meanwhile, there was an increase in 2014 as it occupied 158km² which accounted for 0.36%. In 2019 it occupied 167km² which accounted for 0.38% of total land area. The increasing farmlands and built-up areas can severely change the water balance of the study area, influence the rate of recharge, and impact the microclimate of the area. Also, the amount of direct groundwater recharge resulting from rainfall may reduce as a result of the increase in impervious surfaces from built-up areas, farmlands and bare surfaces, while surface run-off will increase significantly (Rose and Peter, 2001).

In 1984 the Rock outcrop occupied 6269km² which account for 12.87% of the total land area and in 1994 it increased to 7314km² which represented 16.78% of the total land area. In 2004 it occupied 4193km² which constituted 8.84% of the total land area, while in 2014, it increased to 8938km² representing 20.64% of the total land area. In 2019 it decreased to 4874km² which accounted for 10.62% of the total land area. In 1984 the built-up land occupied 1176km² which accounted for about 3% of total land area. In 1994 it occupied 1210km² which constituted 3% of total land area, but in 2004 it increased to 2693km² which accounted for 6% of total land area. Meanwhile, the increase in built-up area continued to 2014 in which it occupied 3113km² and by 2019 it was 3211km², which accounted for 7% and 7% of total land area respectively. This change is more pronounced between 2004-2019, partly attributable to the previous status of Kaduna as the capital of Northern Region that witnessed the establishment of both private and Government institutions, which led to the influx of people and the attendant spatial expansion in several directions. Prior to the establishment of major institutions in Kaduna State, that attracted the influx of population, Kaduna State had a population of 529,322 peoples in 1984, as farmers found new opportunities; some went into menial jobs, others took up security jobs while women served as cleaners. The population of the State increased substantially in 2019 with about 1,096,706 peoples with a population growth rate of about 1.28% and many went into different commercial businesses (Kaduna State Bureau of Statistics (KSBS), 2020). More employment opportunities attracted people and businesses, which consequently increased the built-up areas.

In 1984 bare land occupied 225km² which represented 1% of total land area but it increased in 1994 to 1535km² which accounted to 3% of the total land area. In 2004 it decreased to 457km² which constituted about 1% and further decreased in 2014 to 31km² which represented 0% of total land area and in 2019 it occupied 268km², accounting for 1% of total land. The bare surfaces are the transition areas and other land uses covered road networks, sports and recreational grounds and other infrastructure.

The result presented above imply that the LULC of the study area has undergone considerable changes over the period. While the farm land, water bodies and built-up areas have expanded significantly during the thirty-five (35) years period under study, the vegetation, bare surfaces and rock outcrop have declined with consequences of change in the climate in the area under study. The result also substantiates the finding of Oyinloye (2013) who found direct relationship between rapid urban growth, agrarian and factors such as creation of States, Local Governments and siting of institutions of learning, commercial centres, industrial centres, tourism resorts and population influx as bases of land use changes.

There were three main factors behind the high rate of vegetation or forest cover experienced in the first decade, given the limited built-up area, low population density and less agricultural activities. In addition, cultivators followed traditional practices and remained within their farming boundaries, with little additional land clearance. There were less of illegal logging and agricultural expansion, but only small-scale activities, including firewood and charcoal production for household use. Therefore, ecosystems and environmental disturbance were primarily limited to areas of low elevation, and close to roads and town environments. In the second decade, the proportion of forest cover declined more quickly to 50% and more than one-third of the area was exposed to human activities. The most likely cause of this relatively rapid deforestation can be traced to improved access to road infrastructure, built-up area, expansion in agriculture and population increase. These improvements may have facilitated illegal logging activities, firewood and charcoal production, and cultivation. Gaughan *et al*., (2009) underlined that land use changes from 1989–2005 in the Siem Reap watershed could be related to these factors, which were triggered by explosive growth in human activities such as tourism, agriculture, mining and infrastructural development.

In the third, fourth and fifth decades, the extent of forested area gradually dropped to 47%, 27% and 21% respectively, with some ups and downs due to fluctuations in the costs of agricultural production. Farmers often change their agriculture crops, and improved technological practice. The main reason behind the decrease in forest coverage in this last decade could be the further improvement of road infrastructure and large-scale agricultural expansion, including shifting cultivation, that has been a significant source of forest clearance in Kaduna State.

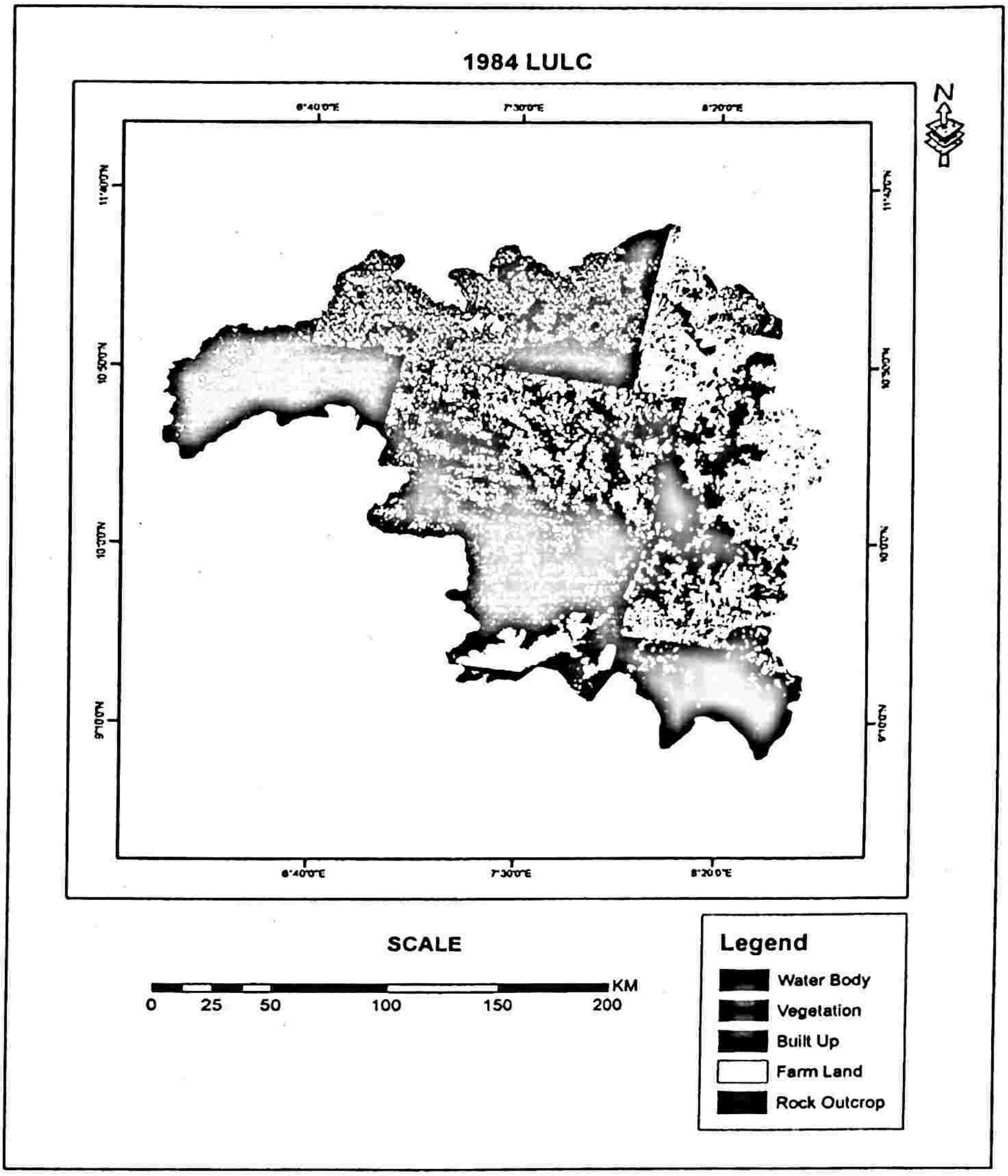

Figure 2: Land use/ land cover of Kaduna State in 1984
Source: Researcher's Analysis, 2021

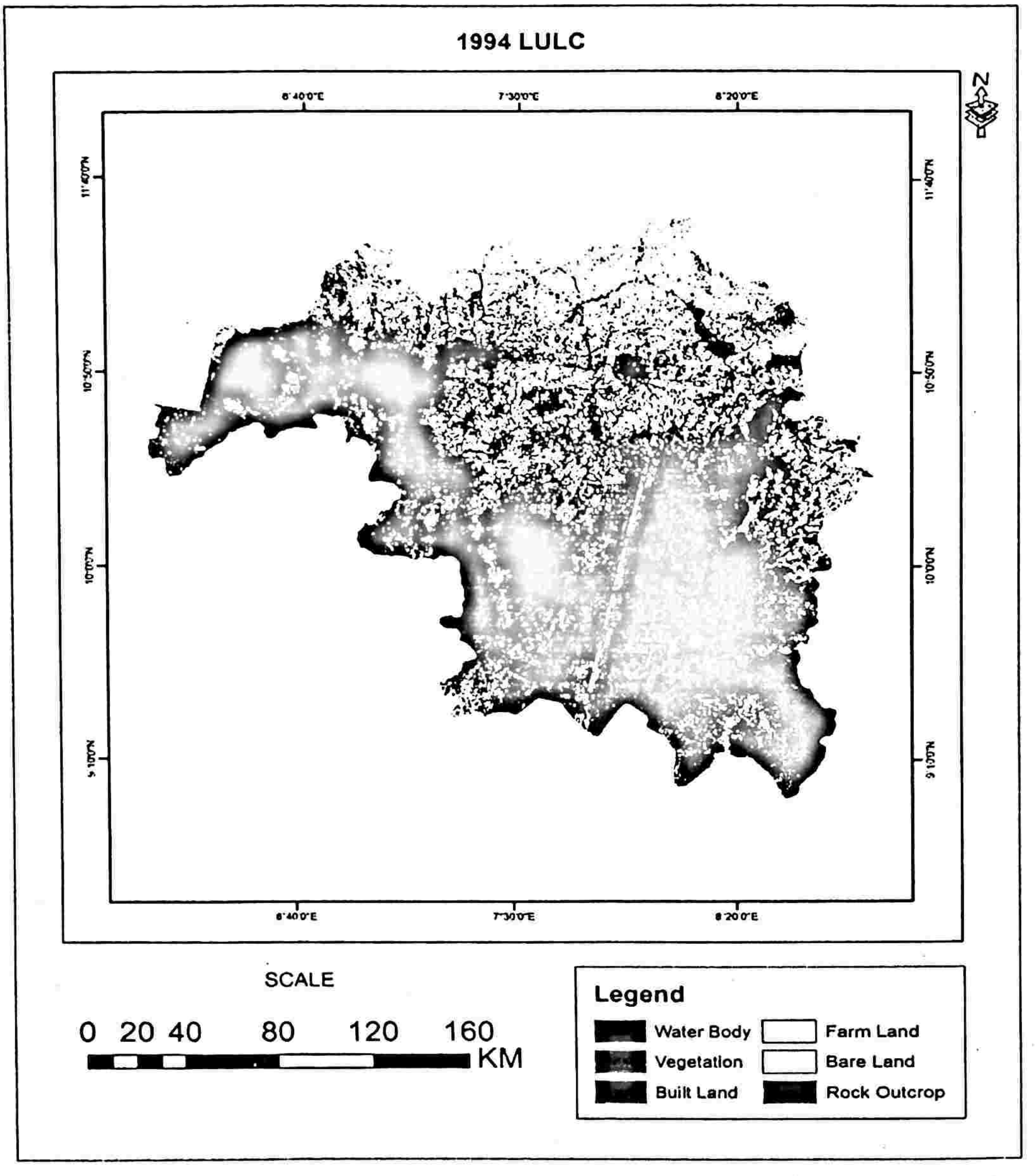

Figure 3: Land Use/Land Cover of Kaduna State in 1994
Source: Researcher's Analysis, 2021

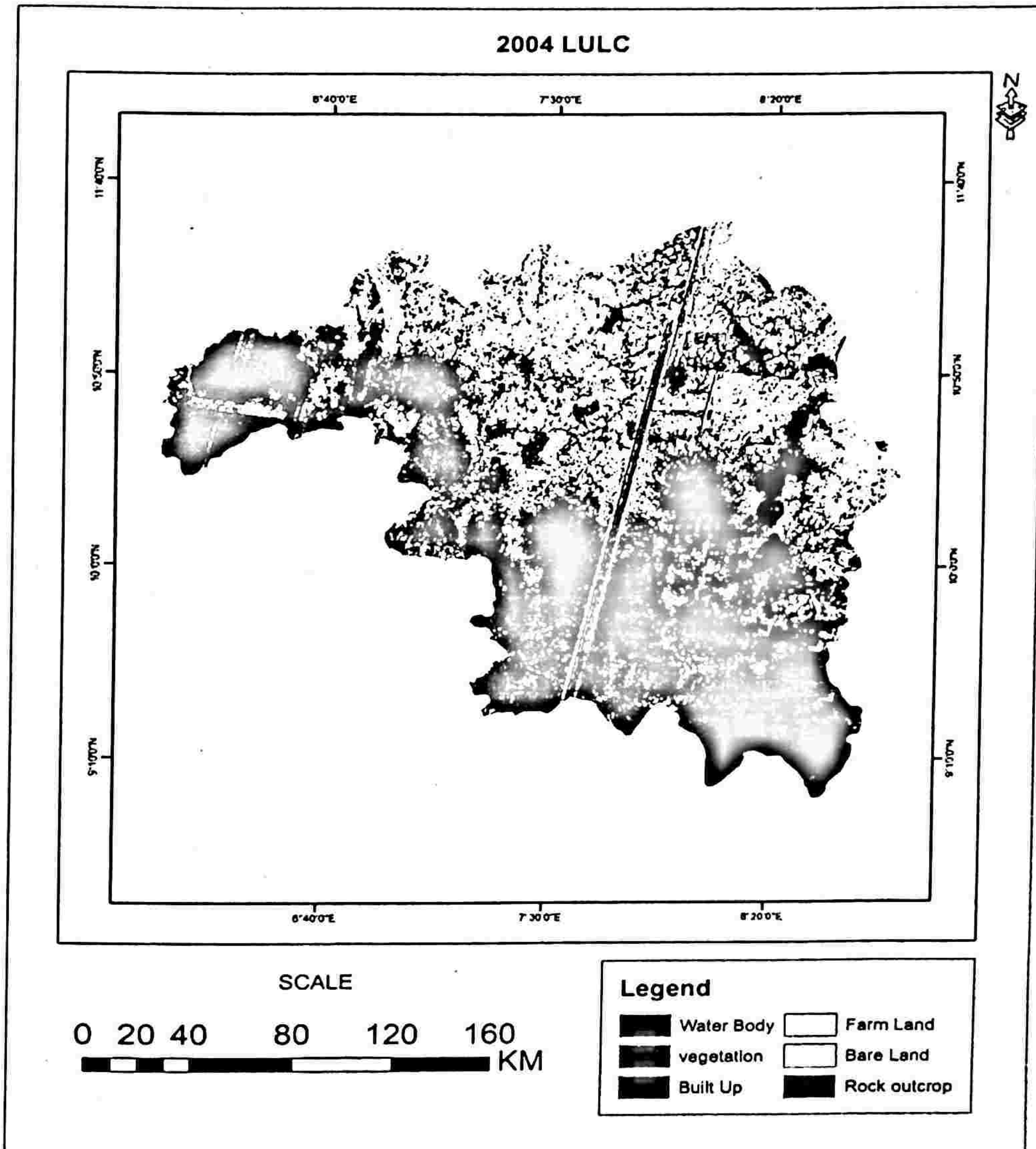

Figure 4: Land Use/Land Cover Change of Kaduna State in 2004
Source: Researcher's Analysis, 2021

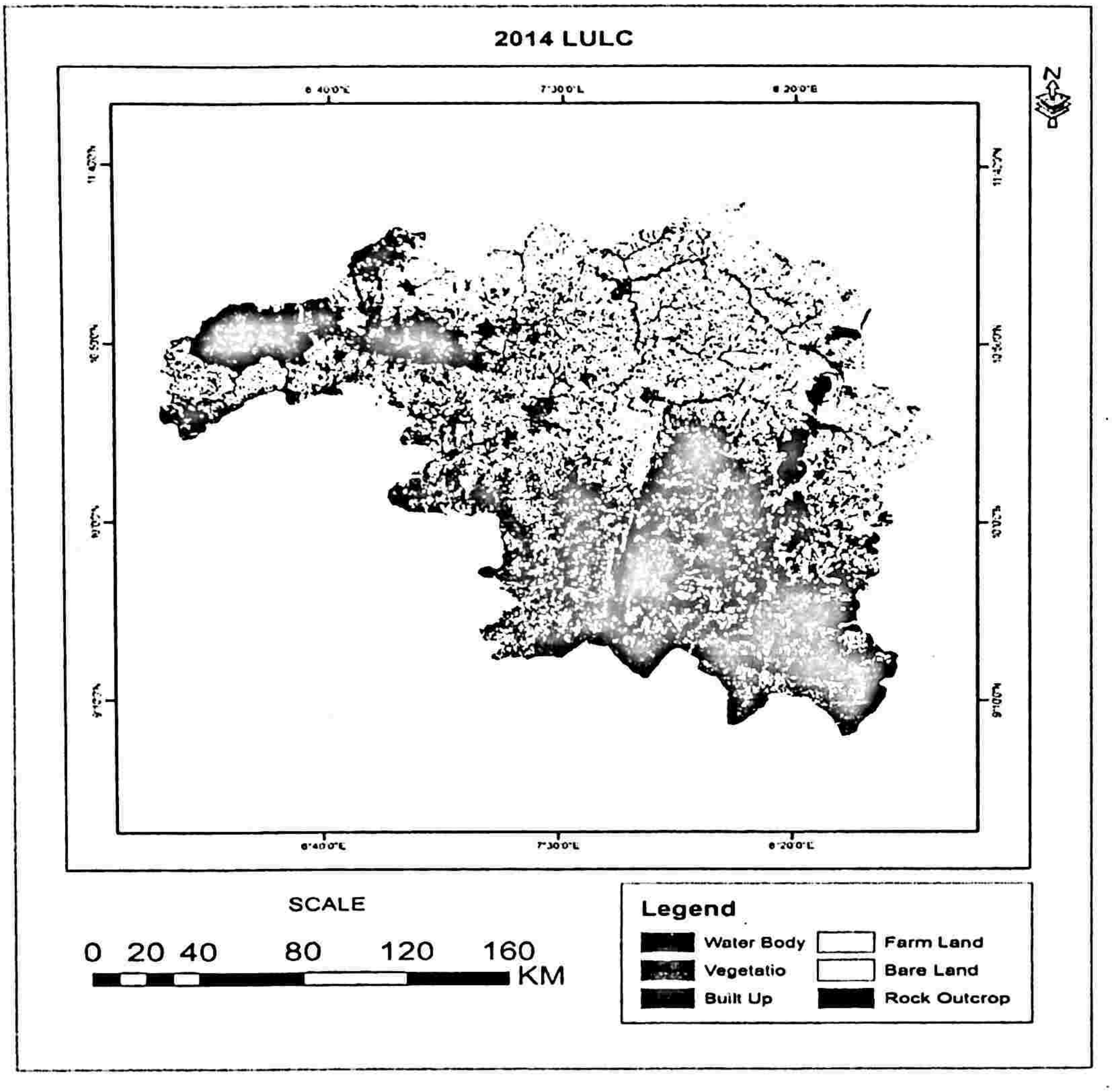

Figure 5: Land Use/Land Cover Change of Kaduna State in 2014
Source: Researcher's Analysis, 2021

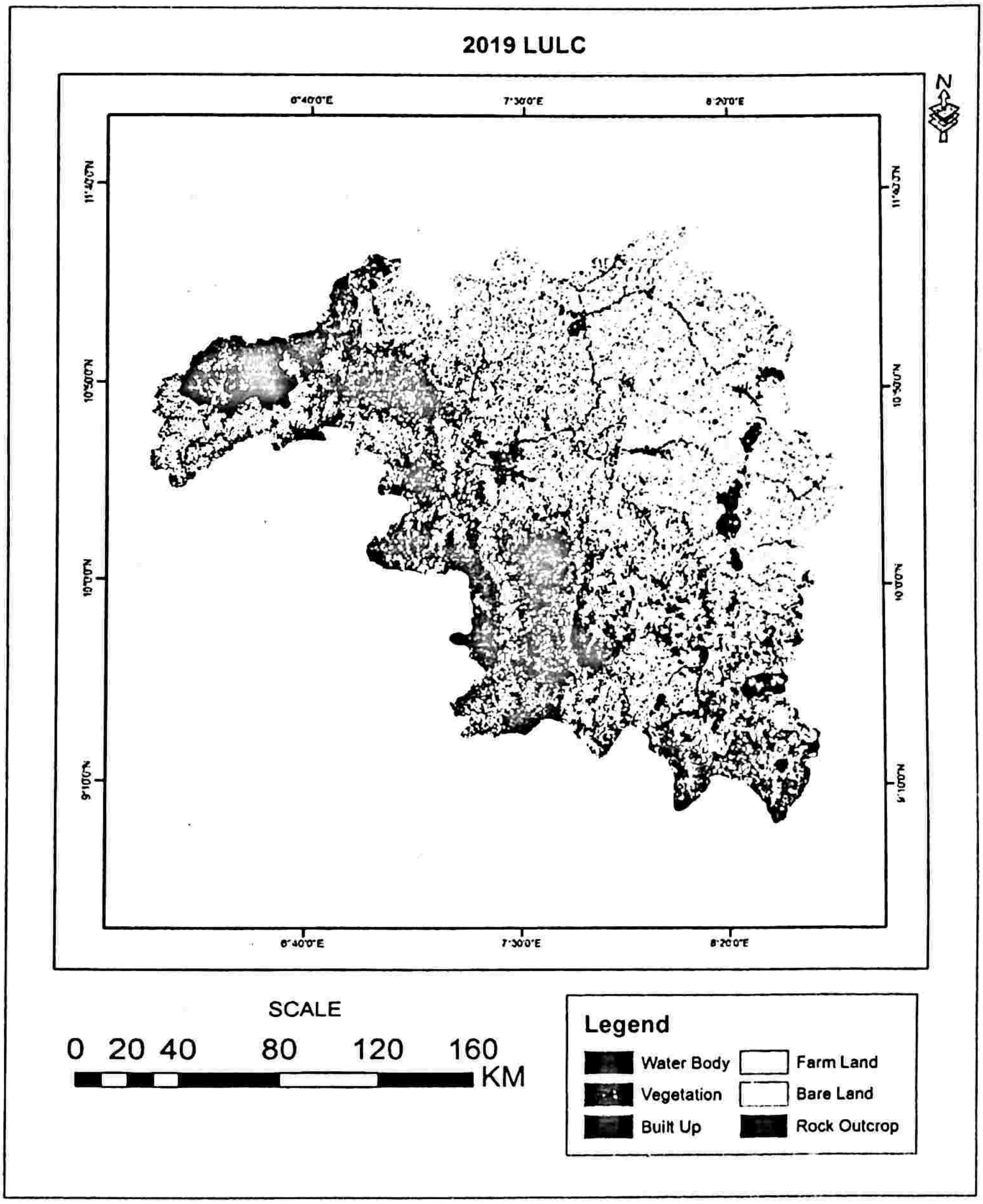

Figure 6: Land Use /Land Cover of Kaduna State in 2019
Source: Researcher's Analysis, 2021

4.2 Magnitude and rate of Change detection of Land use/land cover

Table 4 and Figure 7 show the magnitude and rate of change in different land use types in the study area.

Table 4: The Magnitude of Land use/Land Cover Changes Between 1984 to 2019 in Km²

Class Name	Net Change 1984-1994	Net Change 1994-2004	Net Change 2004-2014	Net Change 2014-2019	Overall Changes 1984-2019
Water Body	39	-24	85	9	110
Vegetation	-4460	-1470	-8712	-2589	-17231
Built Up	34	1483	420	98	2035
Farm Land	2032	4210	3887	6308	16437
Bare Land	1310	-1078	-425	237	43
Rock Outcrop	1045	-3121	4745	-4064	-1395

Source: Researcher's Analysis, 2021

Figure 7: Change detection 1984-2019
Source: Researcher's Analysis, 2021

4.3 Rate of change between 1984 and 1994

An important aspect of change detection is to determine what is actually changing. The major changes that occurred between the periods were mainly evident in the decrease in vegetation. Vegetation loss to other LULC categories was -4460km² while farm land increase more than all other land use categories, it gained 2032km² from other land use/cover classes. The land use types that also show appreciable increases are bare surface 1310km², rock outcrop 1045km², water body 39km² and built-up area 34km² as one of the least land use during the period. The rate of change in vegetation is basically as a result of the rapid increase in population which is evident in the rapid increase in land consumption rate.

4.4 Rate of change between 1994 and 2004

The net change was mainly apparent in the decline in water body -24km² which is attributable to decrease in vegetation. Vegetation indicated a negative decline of -1470km² which is associated with slight increase in built-up area and farm land with further decrease in bare-surfaces -1078km² and rock outcrop -3121km² land use types. But there is an increase in built-up land and farmland which has led to increase in other form of human activities in the area that brought about climate variability. Built-up land and farm land increases more than other land use/cover categories, gained 1483km² and 4210km² respectively. The rate of change in built-up land and farm land is basically as a result of increase in population.

4.5 Rate of change between 2004 and 2014

The main net change spanned the period of ten (10) years, where considerable change also took place. There was a negative decrease in vegetation and bare land use categories to -8712km² and -425km² respectively. There was positive gain on water body 85km², built-up land 420km², farmland 3887km² and rock outcrop 4745km² of total land in the study area.

4.6 Rate of Change between 2014 and 2019

The net rate of change shows that the different land use types such as vegetation and rock outcrop have a negative loss change. Vegetation rate of loss is -2589km^2 and rock outcrop is 4064km^2. It can be noticed during the period under consideration that, vegetation and rock outcrop LULC lost their size in favour of water body, built-up area, farmland and bare land. All these are negative changes that enabled water body to gain 9km^2, built-up area 98km^2, farm land 6308km^2 and bare land 237km^2. Vegetation land was the most affected and this has implication on the climatic condition and water resources in Kaduna State.

Vegetation provides many ecosystem services, they support biodiversity by providing habitat for wildlife, remove carbon dioxide from the atmosphere, intercept precipitation, slow down surface runoff, reduce soil erosion and flooding. The important ecosystem service will be altered or destroyed when forest areas are converted to farm land and built-up area. Deforestation along with urban sprawl and other human activities such as agricultural practices have substantially altered the climatic condition and fragmented the vegetal cover of the study area. It should be noted that continuous alteration of this LULC is a basis for climate variability witnessed in the State.

Table 4 and Figure 7 presents the overall changes in LULC. Farm land, built-up area, water bodies and bare land have significant increases in LULC classification, while vegetation and rock outcrop decreased negatively. This shows that there is spontaneous increase in human activities over the years as the population continued to increase in the area, thereby resulting in changes to the climatic conditions of the study area. The increase in built up area is due to increase in demand for housing which can be attributed to increase in population; where wetlands have been converted to urban developments and at the same time, agricultural lands have water needs through both irrigation and rain-fed agriculture. The increase in water bodies observed may be attributed to increase in rainfall, completion of Gurara multipurpose dam, expansion of both Kangimi and Galma dams by both Federal and State Government.

From Figure 8, water body which occupied 57km^2 in 1984 with a very low population, in 1994 it further increased to 96km^2 but in 2004 it decreased to 72km^2. In 2014 water body expanded to about 158km^2 and in 2019 it further increased to 167km^2 of the total land area. Despite appreciable increase in water body, high population increase, intensification of agricultural activities, infrastructural development and deforestation placed much demands on water, which had negative consequences on the water regime (reservoir) of the area.

Figure 8: Yearly Water Land Cover Area
Source: Researcher Analysis, 2021

4.7 LULC Change; Implication for Water resources

Before now, it could be said that available water in Kaduna State was sufficient to meet the demand of the populace while large quantity was still available for irrigation purposes. However, the present population of 1,133,430 with a growth rate of 1.82% (KSBS, 2020), the increased built-up area and the drastic increase in farming activities, had significant negative impacts on the available water in the State.

Climate variability and land use changes are the two main driving force affecting watershed hydrological processes and surface run-off, especially in flooding periods. The result confirmed the finding of Liu *et, al.*, (2020); Kang *et al.*, (2020), in Beichuan River Basin and Loess Plateau region in China, where they found that climate variability enhanced the minimum stream-flow in the whole river basin and advanced the occurrence of the daily minimum stream-flow. In the study area, temperature changes exerted greater influence on stream-flow regime, while LULC (farmland expansion and reservoir construction) were the primary reasons for stream-flow reduction. Farmland expansion contributed more to annual mean stream-flow changes, while reservoir operation greatly altered the monthly stream-flow pattern and extreme stream-flow. The overall increase in the seasonal flows could bring about reduced availability of water for crop production in Kaduna State, which is a chronic issue of subsistence agriculture in the area. The possible reduction in surface and ground water could also affect the availability of water resources and further aggravate water stress or crisis in the State.

The predicted LULC change (Table 5, and Figure 9) revealed that by 2030, water body will decrease slightly by 0.13%. Based on this, wetland which is one of the important water recharge mechanisms in a drainage basin would have decreased in size from 167km² in 2019 to mere 137.32km² in 2030. The future LULC change reveals that vegetation area will continue to decrease. As much as 8687.58km² which will account for 19.65% of vegetation land may be lost to other uses within the period.

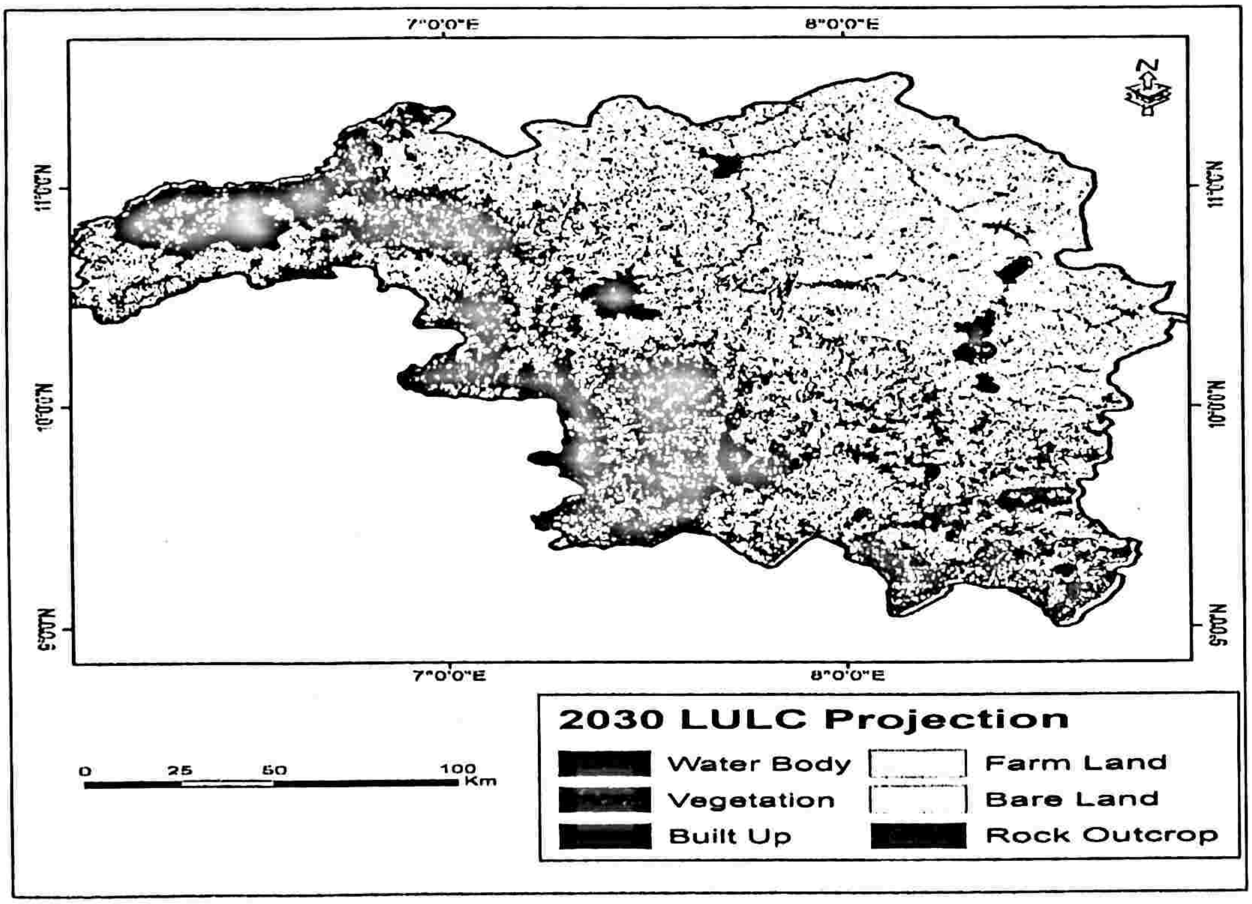

Figure 9: The predicted, Land use/land cover for 2030
Source: Researcher's Analysis, 2021

Table 5. Predicted Future Land Use/Land Cover Change in Kaduna State 2030

Class Name	(2030 LULC Projection)	% Percentage
Water body	137.32	0.31
Vegetation	8687.58	19.65
Built-up	3676.26	8.31
Farmland	25887.63	58.54
Bare-land	1198.94	2.71
Rock Outcrop	4633.26	10.48
Total	**44221**	**100**

Source: Researcher's Analysis, 2021

The reduction in vegetation area, is worrisome because it reflects the unrelenting activities of wood loggers in the study area. Continuous deforestation will certainly have significant impact on the water budget, especially groundwater recharge and surface run-off. Built-up areas would have increased steadily from 3211km² in 2019 to 3676.26km² by 2030 that is 8.31% increase. The simulated result shows that the increase in built-up area is closely associated with the existing built-up areas in Kaduna State. This will be more pronounced mostly in and around Kaduna metropolis, Zaria and Kafanchan.

The growth that will be experienced in this area is attributed to the population increase that will lead to the expansion of built-up areas. Also, farmland will increase slightly from 26416km² in 2019 to 25887.63km² by 2030, which is an increase of 1.46%. This suggests that farming activities in the study area will increase slightly. There may be further increases, if the effort of both Kaduna State and Federal Government of Nigeria to diversify the economy is vigorously pursued. Bare land will increase slightly by 1198.94km² and rock outcrop decrease slightly from 4874km², which accounted for 11% of the total land in 2019; thus reduced to 4633.26km² which will represent 10.48% of the total land by 2030.

4.8 Transition Probability Matrix of Changing by 2030

Table 6 indicated the summary of the probability matrix for major LULC conversions for all classes in the study area that took place between 2019 and 2030. The probability of changes for waterbody to waterbody from 2019 to 2030 is high at 0.7174, while the probability of future change of built-up area, vegetation, farmland, bare-land and rock outcrop to water body have low probability. The probability transition matrix indicates that the future change of vegetation to vegetation is high, with a probability of 0.6098 while waterbody, built-up area, farmland, bare-land and rock outcrop to vegetation has a low probability of change in future. The probability of future change of built-up area to built-up area (0.9401).

Table 6: Transition Probability Matrix

Changing from: 2019	Probability of Changing by 2030 to:					
	Water-body	Vegetation	Built Up	Farm Land	Bare Land	Rock Outcrop
Water-body	0.7174	0.0699	0.0095	0.2744	0.1288	0.0075
Vegetation	0.1515	0.6098	0.0451	0.2025	0.2211	0.0943
Built Up	0.0583	0.0701	0.9401	0.6659	0.4656	0.0034
Farm Land	0.0499	0.0487	0.0912	0.8889	0.0098	0.0765
Bare Land	0.0309	0.0488	0.0310	0.4301	0.7801	0.0235
Rock Outcrop	0.0011	0.1022	0.0012	0.0004	0.0347	0.9013

Source: Researcher Analysis, 2021

The probability transition matrix indicates that the future change of vegetation to vegetation is high, with a probability of 0.6098 while waterbody, built-up area, farmland, bare-land and rock outcrop to vegetation has a low probability of change in future. The probability of future change of built-up area to built-up area is 0.9401, built-up area to farmland and built-up area to bare-land have high probability of future change while built-up area to waterbody, vegetation and rock outcrop have low probability. The matrix indicates high probability of conversion of farmland to farmland at 0.8889 and farmland to built-up area at 0.6659, while farmland to water body, vegetation, bare-land and rock outcrop have low probability. Bare land has probability matrix for future change to bare-land at 0.7801, while bare-land to other land use classes indicated low probability. The rock outcrop also indicated high probability of future change only on rock outcrop to rock outcrop, while the remaining land use classes show low probability of future change.

5. Conclusion

LULC change for the period of 1984-2019 were examined based on the data generated from satellite imageries. LULC probability transition matrix changes were computed with a view to determining the percentage change of one land use class to another during the period under study. Also, the future LULC change was simulated to the year 2030, to understand the level and direction of change that may be experienced in the future in the State. The rate of change in LULC in the study area may not be unconnected to population increase and settlement expansion accompanying anthropogenic activities, which include fuelwood extraction, wood logging and dust from construction. All these anthropogenic activities resulted in net loss of the original vegetation in the study area. The LULC change scenario in the State will influence the water budget and hydrology of the study area, with the probability of changing the rate of interception, evapotranspiration, run-off and ground water recharge in the study area. In fact, the predicted future LULC change suggests that only about (19.65%) of the total land area will remain under vegetation cover by the year 2030.

The results have underscored the increasing human occupation and the high rate of conversion of the natural vegetation into other land use classes. The rate at which vegetation cover is declining in the State unabated is a pointer to the fact that even when the United Nations Sustainable Development Goals (SDG) is terminated in 2030, her goals (sixth) to ensure availability and sustainable management of water for all and combating climate change for environmental sustainability, by reversing the loss vegetation in all region of the world, may not be met. This is due to the rate of deforestation and unregulated land use in larger parts of the State. With the increase in agricultural land and the alarming rate of wood logging/grazing and the likes, it can be seen that between 1984 and 2019, land meant for vegetation and other purposes has gradually disappeared. If unchecked, there will not be sufficient vegetation available for transpiration and control of erosion in the area. Flooding will continue as a result of forest depletion by the inhabitants in the quest for cooking fuel (Mubi, 2001). Based on the findings, it is recommended that the main solution to deforestation and urbanization has to start from local action. In other words, a bottom-up approach with the responsible authorities and local people working together in partnership to check deforestation and plan urban development, will be most desirable. Planting of indigenous or native trees to protect existing vegetation from fire and land clearing, should also be encouraged, as well as the restoration of degraded lands and stabilization of ecosystems.

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References

Adebimpe, R.U. (2011). Climate Change Related Disasters and Vulnerability: An Appraisal of the Nigerian Policy on Environment. *Environmental Research Journal*, 5(3) 97-107.

Anderson, J.R., Hardey, E., Roach, J. and Witmer, R.E. (1976). A Land Use and Land Cover Classification System for Use with Remote Sensing Data. *US Geological Survey Professional Paper, 964*, Washington, DC. P. 28

Ashaolu E.D. (2018). *Effect of Climate and Land Use/Land Cover Change on Groundwater Recharge in Osun Drainage Basin Nigeria (Ph.D. Thesis)*, University of Ilorin Nigeria.

Baig M.F., Mustafa M.R.U., Baig I., Takaijudin H.B. and Zeshan M.T. (2022). Assessement of land use and Land Cover Changes and Future Prediction Using CA-ANN Simulation for Selangor Malaysia. *Journal of Water Resources Vol.14 p. 402.*

Bock, A. R., Farmer, W. H. and Hay, L. E. (2018) Quantifying uncertainty in simulated streamflow and runoff from a continental-scale monthly water balance model. *Advances in Water Resources 122, 166–175*

Butt A., Shabbir R., Ahmad S.S. and Aziz N. (2015). Land Use Change Mapping and Analysis Using Remote Sensing and GIS: A Case Study of Simly Watershed, Islamabad, Pakistan. *The Egyptain Journal of Remote Sensing and Space Sciences 18 251-259.*

Emil, N. K. (2010). *Land Degradation Assessment for an Abandoned Cool Mine with Geospatial Information Technologies* M.Sc. Thesis Middle East, Technical University, Turkey Retrieved from https://www.land assessment_Msc_Emil-234 on 14/2/2019.

Gogoi P.P., Vinoj V., Swain D., Roberts G., Dash J. and Tripathy S. (2019). Land use and Land Cover Change Effect on Surface Temperature Over Eastern India. *Scientific Reports 9 8859.*

Gaughan, A.E.; Binford, M.W. and Southworth, J. (2009). Tourism, Forest Conversion, and Land Transformations in the Angkor basin, Cambodia. *Journal of Applied Geography, 29*, 212–223.

Hammada, M., Mucsi, L. and Van-Leeuwen, B. (2018). Land Cover Change Investigation in the Southern Syrian Coastal Basin during the Past 30-years Using Landsat Remote Sensing Data. *Journal of Environmental Geography* 11 (1-2) 45-51

Helbich, M., Amelunxen, C. and Neis, P. (2012). *Comparative Spatial Analysis of Positional Accuracy of Open Street Map and Proprietary Geodata*. International GI Forum. Salzbur, Austria.

Hua A.K. (2017). Land Use and Land Cover Change Detection of Water Quality, A Study Based on Remote Sensing and Multivariate Statistics. *Journal of Environmental and Public Health 1, 2-13*

Idowu D. and Zhou W. (2021), Land use and Land Cover Change Assessment in the Context of Flood Hazard in Lagos State Nigeria. *Journal of Water Resources 13, 1105.*

Idowu, I.A. and Muazu, K.M. (2010). Mapping Land Use/Land Covers and Change Detection in Kafur Local Government Area, Katsina (1995-2008) Using Remote Sensing and GIS. *In (Ed.) A. Ogidiolu. Contemporary Issues in Infrastructural Development and Management in Nigeria* Published by Department of Geography and Planning, Kogi State University Anyigba.

Inalpulat M. and Gene L. (2020). Quantification of LULC Changes and Urbanization Effecta on Agriculture Using Historical Landsat Data in North-west Anatolia, Turkey. *Pol. Journal Environ. Study 30 (5) 3999-4007.*

Ikusemoran J. M., Mbaya L.A. and Wanah, B. (2016). Geospatial Techniques for Terrain Analysis of Gombe State Nigeria. *International Journal of Geography, Environment and Earth Science* 20 (1) 14-22.

Jiang, Z., Sharma, A. and Johnson, F. (2019) Assessing the sensitivity of hydro-climatological change detection methods to model uncertainty and bias. *Advances in Water Resources 134*, 103430.

John, R. and John, M. (2019) Adaptation of the visibility graph algorithm for detecting time lag between rainfall and water level fluctuations in Lake Okeechobee. *Advances in Water Resources 134, 103429*

Jyrkama, M.I. and Sykes, J.F. (2006). The Impacts of Climate Change on Groundwater. In: Delleur, J.W., (Ed.), *the Handbook of Groundwater Engineering*, 2nd Ed. CRC Press, USA, 1320

Kaduna State Bureau of Statistics (2020). *Population Dynamic Report*, Statistical Year Book Published by Government of Kaduna State Planning and Budget Commission.

Kaduna State (2003). Physical Setting Retrieved from http://www.onlinenigeria.com/links/kadunaadv.asp?blurb=294

Kaduna State Government [KDSG]. (2018). Profile of Kaduna State. Retrieved September 18, 2018 from http://www.kadunastateprofile.gov.ng/kaduna/

Kang, Y., Gao, J., Shao, H., and Zhang, Y. (2020). Quantitative Analysis of Hydrological Responses to Climate variability and Land use/land Cover Change in the Hilly-Gully Region of the Loess Plateau, China. *Journal of Water Resource Management* 12, 82.

Laah, J.G. (2003). *Demographic and Socio-economic Effects of HIV/AIDs in Kaduna State*, Unpublished Ph.D. Thesis, Submitted to the Department of Geography A.B.U. Zaria.

Liu C., Liu B., Zhao W.Z. and Zhu Z.C. (2020). Temporal and Spatial Variability of Water use Efficiency of Vegetation and its Response to Precipitation and Temperature in Heihe River Basin. *Acts. Ecol. Sin 40 (03) 888-899.*

Liu, X.H., Skidmore, A.K. and Oosten, V.H. (2002). Integration of Classification Methods for Improvement of Land Cover Map Accuracy, *ISPRS Journal of Photogrammetry and Remote Sensing* 56, 257-268

Mandal, D.K. (2011). Identification of Surface Water Zone, in and Around Dehra Doon Using Index Overlay Method, *Indian Cartographer Journal* 31(5) 190

Martin S.L., Hayes D.B., Rutledge D.T. and Hyndman D.W. (2011). The Land Use Legacy Effect: Adding Temporal Context to Lake Chemistry. *Limnology and Oceanography 56 (6) 2362-2370.*

Mengistu, D.A. and Salami, A.T. (2007). Application of Remote Sensing and GIS in Land Use/Land Cover Mapping and Change Detection in a Part of Southwestern Nigeria. *African Journal of Environmental Science and Technology* 1(5) 99-109.

Nigerian Vision 20:2020 (2009). *Report of the Vision 2020 National Technical Working Group on Agriculture and Food Security.* National Planning Commission, Abuja.

Nigerian Meteorological Agency (NIMET) (2018). 2018 *Seasonal Rainfall Prediction (SRP)* A Publication of Nigerian Meteorological Agency, Published by Avsatel Communications Ltd Abuja.

Olokor, J. O. (1995). *Climate of the Kainji Lake Basins from 1925- 1993*, Consultancy Report for the Nigerian German Kainji Lake Fisheres Promotion Project, New Bussa Niger State Nigeria.

Orozco I., Martinez A. and Ortega V. (2020). Assessment of the Water, Environmental, Economic and Social Vulnerability of a Watershed to the Potential Effects of Climate Change and Land Use Change. *Journal of Water Resources 12, 1682.*

Oyinloye, M.A. (2013). Geospatial Analysis of Urban Growth-the Case of Akure, Ondo State, Nigeria. *American Journal of Social Issues and Humanities* 3 (4), 200-212

Rawat, J.S. and Kumar M. (2015) "Monitoring land use/cover change using remote sensing and GIS techniques: a case study of Hawalbagh block, district Almora, Uttarakhand, India," *The Egyptian Journal of Remote Sensing and Space Science, 18, (1).* 77–84.

Rose, S. and Peters, N.E. (2001). Effects of Urbanization on Stream Flow in the Atlanta Area of Georgia USA: A Comparative Hydrological Approach. *Hydrological Processes* 15, 1441-1457.

Salami, A.T., Ekanade, O. and Oyinloye, R.O. (1999). Detection of Forest Reserve Incursion in South-western Nigeria from a Combination of Multi-Data Aerial Photographs and High-Resolution Satellite Imagery. *International Journal of Remote Sensing 20*(8), 1487-1497

Turner M.G., Gardner R.H. and O'Neil R.V. (2001). *Landscape Ecology in Theory and Pratice*: Pattern and Process. Springer-Verlag, New York.

Twisa S. and Buchroither M.F. (2019). Land Use and Land Cover (LULC) Change Detection in Wami River Basin, Tanzania. *Journal of Land 5, 136*

Umar, D.A., Ramli M.F., Tukur, A.I., Jamil N.R. and Zaudi M.A. (2021) Detection and Prediction of Land Use Change impacts on the Streamflow Regime in Sahelian River Basin North-western Nigeria. *H_2 Open Journal 4 (1) 92-113.*

Wang, R. and Kalin, L. (2018) Combined and synergistic effects of climate change and urbanization on water quality in the Wolf Bay watershed, southern Alabama. *Journal of Environmental Sciences 64, 107–121.*

Wilford, P.C. (1977). Using the UTM Grid System to Record Historic Sites http: www.nps.gov/nr/publications/bulletins/pdfs/NRB28.pdfNational Register Bulletin. US Department of the Interior, National Park Service. Retrieved January 10th 2019 from http://www.nps.gov/nr/publications/bulletins/pdfs/nrb28.pdf

Yunfeng H.U, Batunacun, Zhen L. and Zhuang D. (2019). Assessment of Land Use and Land Cover Change in Guangxi, *Change in Scientific Reports 9, 2189*

Yusuf, S. (2015). *Kaduna: Physical and Human Environment.* Department of Geography Kaduna State University, Kaduna. Published by Shanono Printers and Publishers Kaduna.