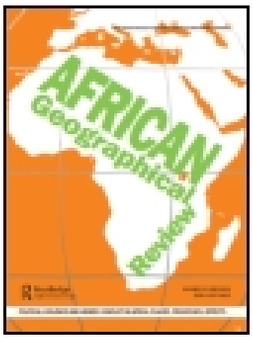

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Estimating the changes in the built-up area and land use development index of Minna, Nigeria

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ABSTRACT

This study estimates the spatial changes in Minna's built-up areas. For change detection and urban growth analysis, the topographical map of Minna in 1972, the township map for 1979, and the satellite imageries covering 1986, 1996, 2006, and 2015 were all employed. These maps were georeferenced using ArcGIS 10.3 . The study reveals as follows: 1972 (468.3 hectares); 1979 (893.7 hectares); 1986 (4,579.8 hectares); 1996 (5,205.4.5 hectares); 2006 (8,505.1 hectares); and 2015 (19,777.2 hectares). The land consumption rates were estimated as 0.0084, 0.0117, 0.0356, 0.0215, 0.0204, and 0.0273, respectively.We conclude that strategies birthed by systematic planning conclusions must guide cities.

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KEYWORDS
Built-up; cities; peri-urban; urban growth; urban development

Introduction

The late eighteenth-century industrial revolution was the genesis of current globalization and urbanization (Habitat, 2001). The maiden edition of the UN-Habitat publications on the state of the world cities admitted that the world is already urbanized, with slightly half of the people living in cities. With this assertion, the world had moved into the realm of the urban age. This era is characterized by cities' dynamism and intense vitality (2013; Habitat, 2001). In 2021, Kofi Annan, the former General Secretary of the United Nations, stressed that the world has entered into the urban millennium: a period with a remarkable difference in innovations for irresistible urban growth (Habitat, 2001). Knox and McCarthy (2005) further affirmed that cities are products of many forces as the engines of economic development, which centers on cultural innovation, social transformation, and political changes. By implication, new settlement within urban areas is not just the dominant form of habitation for humankind but as the engine-rooms for human development (Knox & McCarthy, 2005).

The United Nations (2001) presented the collective implications of the world population, which reported the growth of cities from less than 30 million to about 3 billion at the end of the 20th century. This statement indicates that there are 19 cities with 10 million or more people, 22 cities with 5–10 million people, 370 cities with 1–5 million people, and 433 cities with 0.5–1 million people residing there (2012, 2013; Habitat, 2001). Other studies corroborated the assertion that cities are at the receiving end as the world population increases American Planning Association (APA), 2007; Intergovernmental Panel on Climate Change (IPCC), 2015.

Mabogunje (1984), from a different viewpoint, as cited by 2007, posited that urbanization in Africa was not a result of economic development but rather the unfavorable effects of ineffective

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development policies, particularly in rural economies, which led to rural-urban migration. The reports by Habitat (2008) and UNDESA (2014) are among the most frequently cited sources concerning Africa's population statistics. Attention has been drawn to these sources, which put Africa as a region to experience high population growth and rapid urbanization by 2050. UNDESA (2014) and Brown (2015) emphatically stressed that out of 2.4 billion populations will be added to the world population between 2015 – 2050, while about 1.3 billion (54%) will come from Africa. However, the West African region will become predominant, with over 10 million people residing in different cities (Habitat, 2013, 2016a, 2016b; UNDESA, 2014).

The urban transition experienced in Nigeria after the 1970s oil boom in the country has been quite alarming (Olorunfemi, 1983). Cities and medium-sized towns in the country experienced unprecedented population growth and expansion of spatial coverage (Idowu et al., 2018). Consequently, Olorunfemi (1983) maintained that the population of Nigeria increased by 42.5% between 1952 and 1979, while in the study by Idowu et al. (2018), the country's population was estimated to 39.3% increase between 1979 and 2015. The country became preoccupied with the ideas of physical development, characterized by extensive land modification, rapid infrastructure development, and building development to create a conducive environment. Fundamentally, these adversely altered Nigeria's economic, political, cultural, and spatial components.

Urban growth and physical developments are terms used to explain the process of change in cities' landscapes and their impacts on the urban environment (Aljoufie et al., 2013; Bhatta, 2009; Muller et al., 2010). However, rapid urbanization across the world has translated into stressful urban dynamics, intensifying informal households and absorption of low-income families residing in peri-urban areas (Tamilenthi et al., 2011; Torres, 2011).

Consequently, as the population of people living in cities increased, the urban fringes, forestlands, and green spaces surrounding the urban environment were negatively affected. For instance, the US Census Bureau (2010) and Aguda and Adegboyega (2013) alluded that megacities and urban development have taken over an expanse of forestland and vegetation to house over 6.8 billion people. Perhaps these are justified Aguda and Adegboyega (2013) estimated that over 80% of the current houses were expected to be built in the peri-urban areas to meet the current housing demand in Nigeria. This statistic suggests that the drive for housing accommodation has created an unguided and unorganized urban expansion and the rapid development of medium-sized cities worldwide (Idowu et al., 2018).

Xie et al. (2006) highlighted the causes of urban expansion in China, which was traceable to increased population, institutional changes, and efficient transportation network to the suburban areas. Similarly, Xu et al. (2013) aligned with the view that the spatial expansion of China was not only affected by population growth but by the high demand placed on land and all its ecological services. Sanusi (2011) acknowledged that some spatiotemporal factors drove the rapid changes within urban settlements worldwide. These were primarily within the physically-stable land and viable, economically advanced regions.

The urbanization process has been typified by population increase, industrial growth, and improved economic prosperity, which have exacerbated the higher land consumption rate (Mundia & Aniya, 2005). Moreover, Olorunfemi (1985) asserted that Ilorin's land consumption rate and absorption coefficient increased steadily from 1973 to 1982, following Nigeria's independence in 1960. Expectedly, the expansion of Ilorin was traceable to the influence of the oil boom in Nigeria and the creation of Ilorin as the administrative capital of Kwara State. In another report on the urban land-use change analysis. Fabiyi (2006) highlighted the factors that cause the changes in the land cover of Ibadan. He contended that understanding the forces and processes at play and the elements that naturally distribute people of various socio-economic classes in space are necessary for urban planning.

Similarly, Sudhira et al. (2004) used both spatial and temporal data to analyze the growth of an urban area. The study acknowledged that using a temporal framework to analyze the factors influencing urbanization helps many regions address their future needs and overcome their spatial

problems. The implications of the unguided land consumption rate and urban expansion within the urban fringe, as observed by Durieux et al. (2008), were negatively presented. Sudhira et al. (2003) opined that the uncoordinated and unplanned urban fringe often impairs environmental resources and infrastructure planning and implementation.

Urban growth monitoring is crucial in estimating the urban land consumption rate and absorption coefficient for future spatial planning and infrastructure development (Opeyemi, 2008). This fact led to the conception of this study, which aimed to estimate the spatial transformation in Minna's built-up area between 1972 and 2015 to determine the rate of land compactness and the amount of land absorbed by a specific population. The study determines the town's land consumption rates and absorption coefficient for over forty-three years.

Study area

Geographical location and description

Minna is located between latitudes 9° 331 and 9° 401 and longitudes 6° 291 and 6° 351 (Figure 1). The settlement spanned the city's main trunk road, separating it into two sections: west and east. From Chanchaga in the south to Maikunkele in the north, this 20-kilometer road connects them. The West-East pattern span 15 kilometers from Gidan-Kwano in the west to Maitumbi in the east, through the Bida axis.

Geology and topography

Minna's location straddles a geological base reinforced by gneiss and magnetite rocks. To the Northeast of the town lies a continuous steep outcrop of granite, which forms the barrier to urban expansion and physical development along that axis. The city of Minna is spread on relatively high land between 240 m – 270 m above sea level. It is encompassed by a range of mountains that stretch north-east westward from Maitumbi toward Paida to Bosso and Tundun Fulani (Max Lock, 1980).

The town's steeply sloping hills to its north and east have ultimately impeded its growth along that axis by forming a large valley that pierces the town's center and extends to its southwest. It connects other minor streams and waterways, moving storm water run-off from the hills to the east. These streams form large areas of flood land in places where the land is relatively plain.

The Chanchaga River impedes reasonable development opportunities south of the town's center and has also affected development in that direction. The town's southwestward expansion is also significantly hampered by River-Suka, which is located nearby. Despite these geological formations and physical limitations, Minna is undergoing rapid development, expanding past these obstacles into the rural hinterlands.

Climate

The mean annual rainfall of Minna is 1334 mm, while we recorded the highest mean monthly rainfall in September of almost 300 mm. The rainy season in Minna starts in April and lasts till October, covering between 190 and 210 days. The temperature of Minna rarely falls below 22°C. However, in contrast, it peaks between February and March at about 40°C (Adefolalu, 2001).

Neighborhoods in Minna

In the past, at the introduction of the traditional head (Emir) of Minna in 1957, the town was subdivided into six (6) administrative wards, comprising the old settlement camps and the newly developed neighborhoods. By 1990, the number of wards increased to nine (9) to accommodate the growing neighborhoods at the fringe area. Due to the area and population increase, the number of

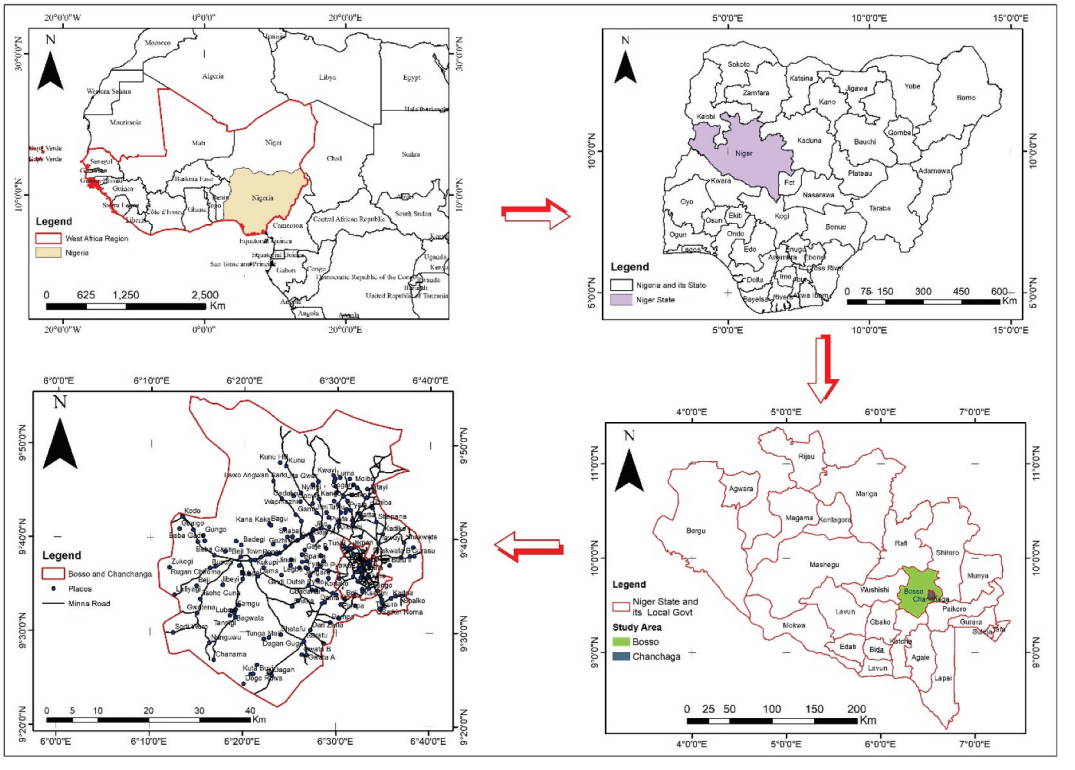

Figure 1. The study area in the context of West Africa and Nigeria .

communities increased to twenty-six. These communities/neighborhoods cover the Chanchaga in the South, Tudunfulani/Rafinyashi in the North, and Gidan-Kwano from the West to Maitumbi in the east.

Population of Minna

The 1952 census puts the population of Minna at 12,810 (Gana, 1997), while it was estimated at 59,989 people in 1963. It implies that the population has more than tripled within about ten years. The census of 1991 gave 190,750 people as the population figure of Minna. The census report of 2006 puts the population figure of Minna at 210,429, while it was estimated to be 435,588 in 2015, using an annual growth rate of 3.2%.

Socio-economic characteristics of Minna

Minna is a Gwari (Gbagyi) town. The word *'Minna'* in Gwari means to spread the fire. The colonial administration's construction of a rail line in 1905 enabled the conglomeration of the settlement. Therefore, Minna is a product of colonial administration in the middle belt of Nigeria. Trading activity influenced the migration of different groups and tribes into the town. The town was linked by rail lines in 1905 and had two major railway crossings: the Kano – Baro rail line (1911) and the Lagos – Jebba rail line (1915). It gave the town a comparative advantage over other towns within the region (Morenikeji et al., 2015; Sanusi, 2011). Max Locks' (1980) documentation of Minna revealed four stages of development the town had experienced before 1979. The fourth was Minna's change in status in February 1976 when it became the State Capital of the newly created Niger State.

As a state capital, Minna is mainly characterized by a working-class population. The employees are often classified as skilled, semi-skilled, and unskilled. Many are engaged in the private sector,

especially the economy's informal sector. The Kure Ultra-Modern Market remained the only central market for major commercial activities in Minna. In contrast, the building material market is located on the industrial site in the Sauke-Kahuta area of Minna. Regarding educational facilities, Minna has many primary and secondary schools in all the neighborhoods. Other educational institutions in the town include the Federal University of Technology Minna, National Headquarters of National Examinations Council (NECO), New Gate University, Minna, Niger State College of Education, School of Midwifery and Nursing, School of Health Technology, and Fati Lami Abubakar Advanced College for Legal and Social Studies.

Methodology

Materials

The topographical map of Minna in 1972, the township map of 1979 (Figure 2), and the satellite imageries covering 1986, 1996, 2006, and 2015 (Figure 3) were used for the change detection and urban growth analysis. The study employed topographical and township maps to explain the extent of the built-up area in the absence of the satellite imageries used for subsequent years. The techniques are classified under four major headings: georeferencing, satellite image processing, image classification, and change detection analysis.

Georeferencing

The georeferencing of the 1972 topo map and 1979 township maps (Figure 2) was conducted. The maps were scanned and converted as raster maps in Tag Image Format (TIF) using ERDAS IMAGINE 9.2 software. The location points (Table 1) were determined using a Global Positioning System (GPS) device for georeferencing purposes. The georeferencing and digitization of the maps were done using ArcGIS 10.3 software, and the features for the built-up area were composed and analyzed.

Figure 2. The 1972 topographical map and 1979 township map of Minna.

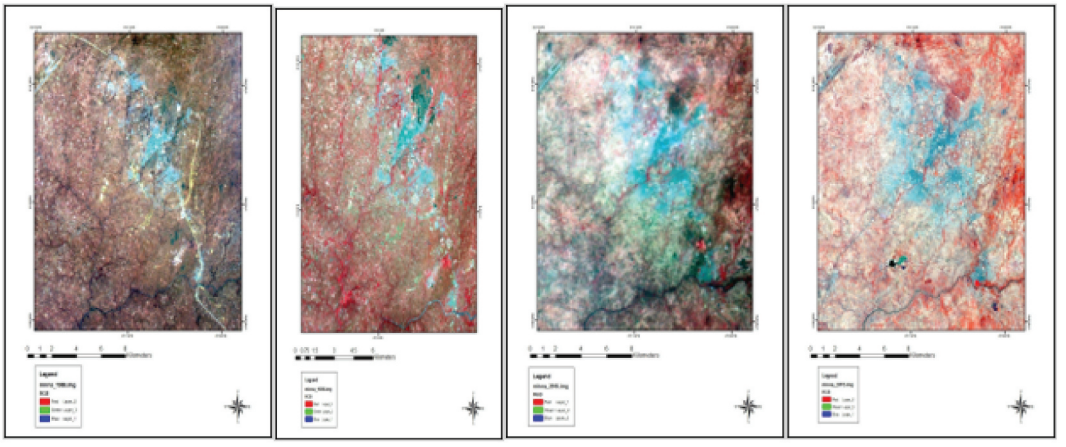

Figure 3. The false colour composite imageries of Minna in 1986, 1996, 2006 and 2015.

Satellite image processing

The collected images were stacked in processing the imageries used in this study. The area required for the exercise was a subset for use because imageries were of different separate layers, each representing a band. Three bands were stacked using ERDAS IMAGINE 9.2 software for band combination, and the composite imageries required were generated (Figure 3). The process of image sub-setting using ERDAS IMAGINE 9.2 software (Table 2 reveals the UTM coordinates points) was employed to bring out the area required for the study. Therefore, Table 3 presents the composition of the satellite imageries used in the study.

Image classification and change detection analysis

The imagery subset was exported into the ERDAS IMAGINE 9.2 program in various bands appropriate for image classification to perform change detection analysis and image classification. The required bands were combined using the 'New Map List' tool on the operation list, and the false-color composite was determined. For classification purposes, the training set adopted comprises the built-up area, the water body, the disturbed, and the undisturbed. For clarity, the built-up area that has undergone extensive land use development is distinguished by various land uses (residential, commercial, industrial structures, village settlements, and transportation routes). The vegetation distorted by human activity, such as cropland and pasture, is classified as disturbed

Table 1. Coordinate points for map geo-referencing.

	Raster Map 1972		Raster Map 1979	
Points	Easting	Northing	Easting	Northing
P1	6.512	9.669	6.533	9.621
P2	6.532	9.600	6.546	9.615
P3	6.568	9.583	6.564	9.634
P4	6.579	9.638		

Table 2. Coordinates for subset of Minna from the imageries acquired.

215319.04	LRX	2390444.62
1079221.86	LRY	1048525.69

Table 3. Details of the satellite imageries used.

Image year	Platform	Date Captured	WRS Path and Row	Band Combination	Spatial Resolution (m)	Sources
1986	Landsat ™	21/2/1986	P189 R53	5,3,1	30 meters	National Centre for Remote Sensing Jos.
1996	SPOT 3	16/11/1996	P189 R53	3,2,1	30 meters	National Centre for Remote Sensing Jos.
2006	Nigeria Sat 1	5/3/2006	P189 R53	1,2,3	32 meters	National Space Research and Development Agency
2015	Landsat (ETM+)	5/4/2015	P189 R53	5,3,1	32 meters	Land Cover Global Facility (LCGF)

vegetation. A forest canopy preserves land areas with unaltered vegetation that are not impacted by human activity.

The training sets areas were subjected to a supervised maximum likelihood classification using a classifier tool from ERDAS IMAGINE 9.2 software. All the classified imageries were transposed into ArcGIS 10.3 software. The built-up areas from various eras were digitalized to show the town's growth and development over time. The scale bar, true north, legend, and graticules were after that created for each image session. To estimate the changes in the built-up area and the town's development rate for twenty-nine (29) years, a change detection analysis of the spectral classes of the imageries was carried out.

Estimating built-up area density and development index

In estimating the density of the built-up area (land consumption rate) of Minna between 1972 and 2015, the extent of the built-up area is divided by the total population residing in the town for each period understudy. The formula is as follows:

$$\text{Land Consumption Rate} = \frac{\text{ExBuAr}}{\text{TP}} \tag{1}$$

For the rate of change in the consumption of new urban land (land absorption coefficient), the difference in the extent of the built-up area at different periods is divided by the difference in the population of people within the periods.

$$\text{Land Absorption Coefficient} = \frac{\text{ExBuAr2} - \text{ExBuAr1}}{\text{Popu2} - \text{Popu1}} \tag{2}$$

For the development index of land use, the urban expansion rates were estimated annually from 1979 to 2015 by determining the percentage rate of the difference in urban expansion divided by the recent areal extent within a determined period.

$$\text{Land use Development Index} = \left\{ \frac{\{\text{Urban extent B} - -\text{Urban extent A}\}}{\text{Urban extent B} \times \text{T}} \right\} \times 100 \tag{3}$$

The interpretation of the formulae is given as follows:

ExBuAr represents the extent of the built-up area for each period.
ExBuAr2: is the extent of the built-up area for the subsequent year.
ExBuAr1: is the extent of the built-up area for the previous year.
TP: Total Population
Popu2: is the population figure for the subsequent year.
Popu1: is the population figure for the previous year.
Urban extent 'A' and 'B' are urban expansion differences within two periods.
T" is the number of the year between A and B.

This assessment is central to the study. It calculates the town's compactness – a measure of its gradual spatial expansion and the changes in the consumption of new urban land with each unit increase in the urban population (Opeyemi, 2008).

Results and discussion

Areal extent of built-up between 1972 and 1979

From the analysis in Table 4, Minna's total area in 1972 was 468.31 hectares or 0.64% of the town's total land area. The estimated value of the extent of the town in 1972 conformed with the 1979 Master Plan report of Minna, which gives the areal extent value of 468 hectares (Max Lock, 1980). In 1979, the town's area was estimated as 893.74 hectares, representing 1.22% of the town's total land area.

1972 (Figure 4), the built-up areas were limited to neighborhoods like Kwangila, Makera, Limawa, Nasarawa, Tudunwada, and the old GRA on the hilltop. Minna in 1972 exhibited a concentric development pattern (Burgess, 1925), as the existing neighborhoods and land uses were linked to the railway station and the central market. The central market (Old Core Market) at Mobil, beside the railway station, formed the Central Business District of Minna.

The built-up area of Minna experienced growth to the tune of 893.74 hectares in 1979 (Figure 5). It implies that a total land area of 425.43 hectares was added to the town's size, representing a 90.84% increase. The rapid increase in the areal extent of Minna was attributed to the town's change in status as the administrative headquarters of a newly created Niger State in 1976.

With the recent nomenclature of Minna, the town retains a mix of historical artifacts and modern buildings, with development stretching from the CBD to the transition neighborhoods (Idowu et al., 2018). At the same time, the newly developed residential quarters were linked with primary transportation services. As a result, Minna demonstrated 'axial growth' in 1979, with growth and development radiating out from the city center along the main transportation arteries, in keeping with Hoyt's (1939) sectoral model of land use development.

Land use/land cover and areal extent of Minna between 1986–2015

Table 5 provides the detailed situation of Minna's land use/land cover between 1986 and 2015. The information documents the built-up area, disturbed vegetation, undisturbed vegetation, and water body.

For the land use and cover of Minna in 1986 (Table 5), the built-up area of Minna in 1986 was estimated at 4,368.7 hectares, which constitutes about 6% of the town's total area. The undisturbed vegetation accounts for a total land area of 65,616.8 hectares, representing 89.5% of the total land area. In comparison, the disturbed vegetation occupies a total area of 3,144.7 hectares (4.3%). The water body occupied 221.3 hectares, representing 0.30% of the total land area.

The analysis of the digitized areal extent of Minna in 1986 (Figures 6 and 7) shows that the town has increased compared with the 1979 areal coverage. Between 1979 and 1986, the central area of Minna was densely occupied by houses, while the satellite settlements grew in a linear stripe pattern toward the densely clustered areas. The major routes and untarred roads linked up these settlements. The town, in 1986, had an expanse of open spaces and undeveloped plots in-between the

Table 4. Areal extent of Minna in 1972 and 1979.

Year	Area (Ha)	%
1972	368.31	0.5
1979	893.74	1.22
Total	73,351.50	-

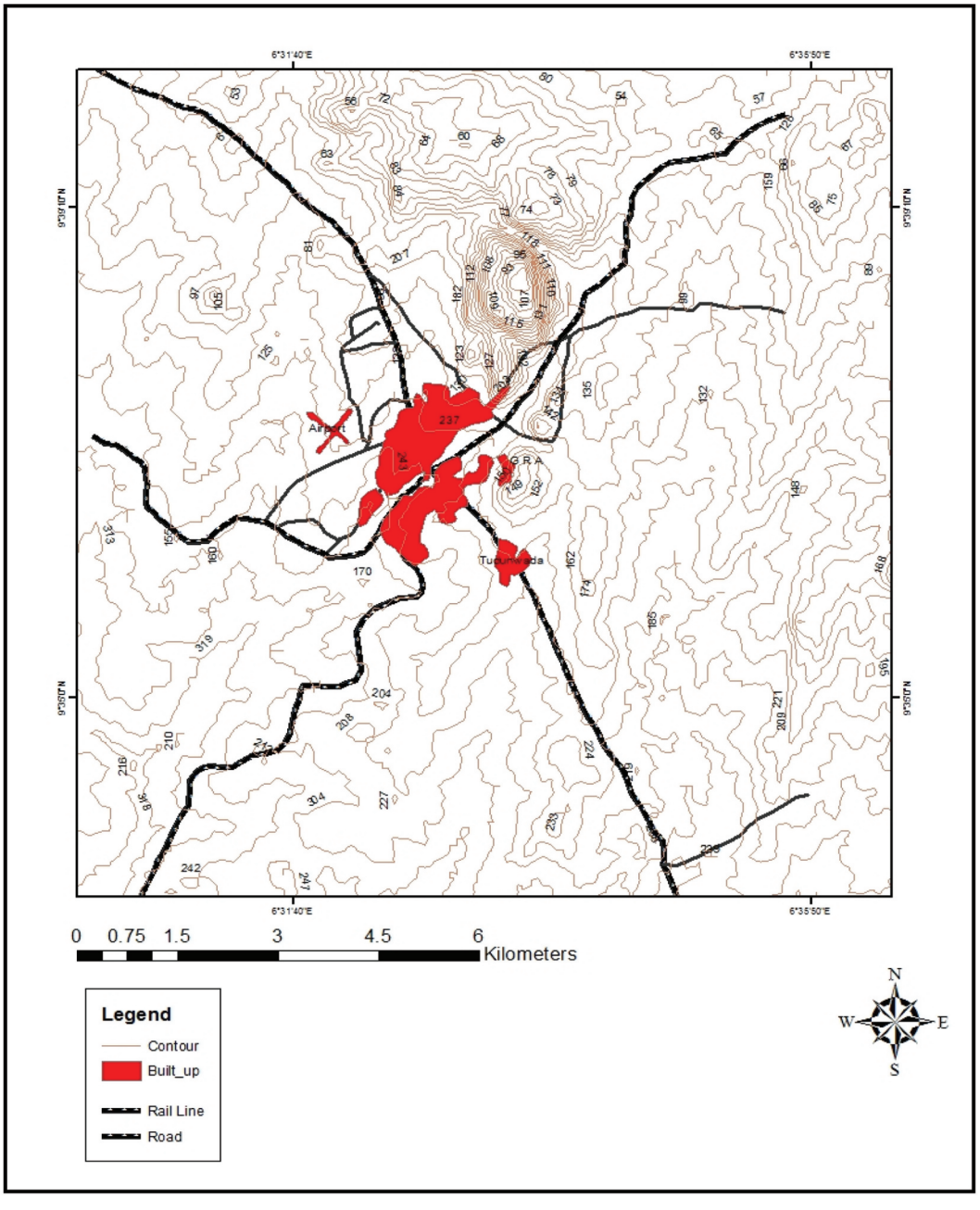

Figure 4. Areal extent of Minna in 1972.

built-up area. During the period, there was an expanse of farmlands and other forms of disturbed land that surrounded the town. Also, there was an expanse of undisturbed forest reserves captured in 1986. Due to the dry season (late February), which was in effect when the image was taken, the area covered by the water body was the least.

In 1996, the extent of the land use/land cover of Minna, as shown in Table 5, reflects that the built-up area has a total area of 4,706.5 hectares, which signifies 6.42% of the total land area of Minna. The undisturbed vegetation enrolled 55,816.8 hectares (76.1%) of the town's entire land.

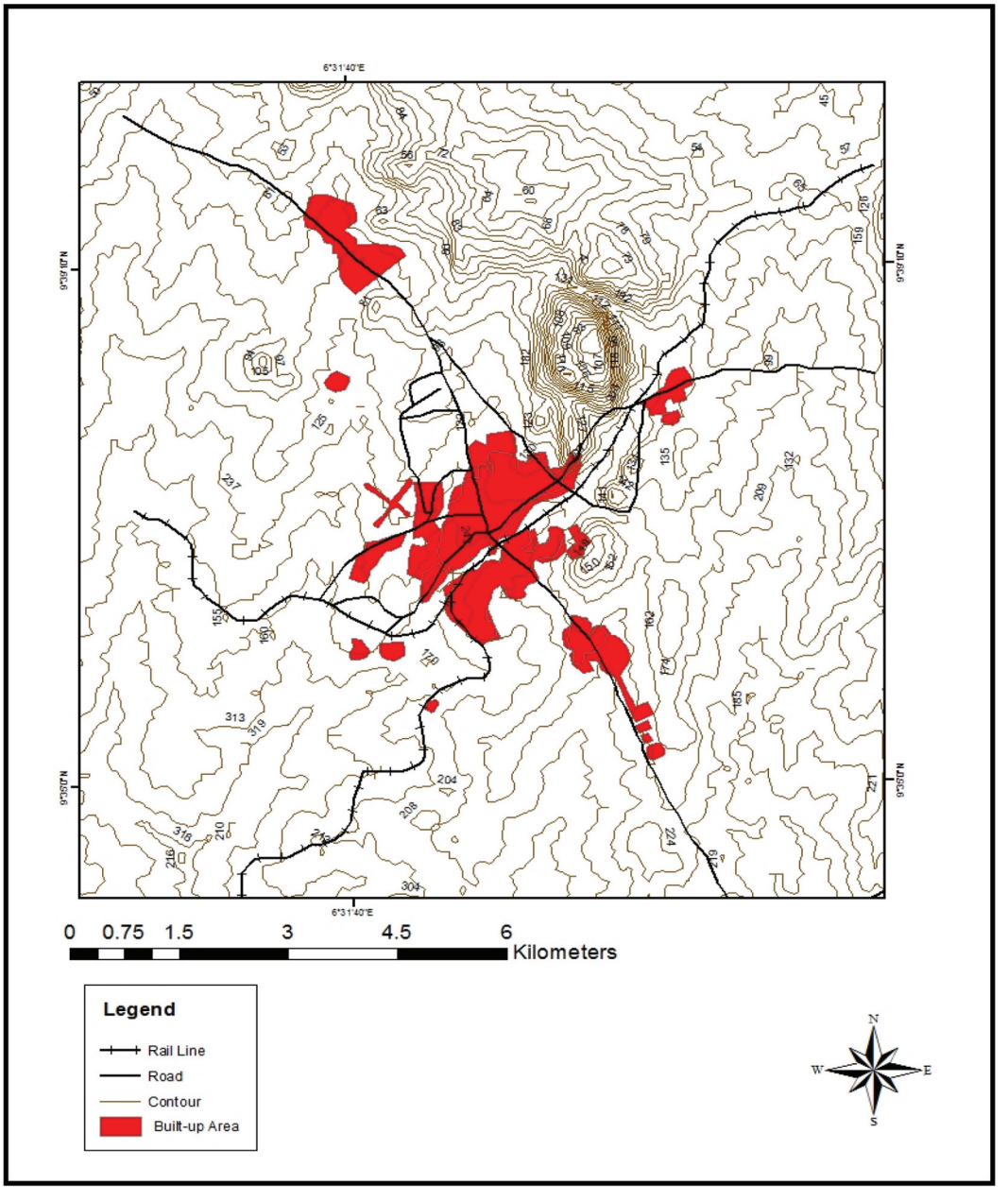

Figure 5. Areal extent of Minna in 1979.

Table 5. Rate of change for the land use/land cover of Minna between 1986 – 2015.

	The extent of Land in Hectares ('000) and the Percentage (%) Coverage							
Land use	1986	%	1996	%	2006	%	2015	%
Built-up Area	4,579.76	5.96	5,205.43	6.42	8,505.06	8.05	19,777.24	16.24
Disturbed Vegetation	65,616.80	89.46	55,816.80	76.1	61,454.80	83.78	53,535.30	72.98
Undisturbed Vegetation	3,144.70	4.29	12,512.00	17.06	5,287.90	7.21	7,568.60	10.32
Water Body	221.3	0.3	316.2	0.43	704.4	0.96	334.4	0.46
Total	**73,351.50**	**100**	**73,351.50**	**100**	**73,351.50**	**100**	**73,351.50**	**100**

Similarly, the disturbed vegetation has a total area of 12,512 hectares (17.1%). In comparison, the water body occupies a total area of 316.2 hectares representing 0.43% of the whole land of Minna.

The town showed a linear strip development pattern along the existing transportation routes in the classified image and extent of the built-up area map of 1996 (Figures 8 and 9). This result was due to a slight increase in the built-up area from the 1986 estimation. The area of the undisturbed vegetation decreased during the period while the area of the water body slightly increased in 1986. There was evidence of a sizable expanse of disturbed vegetation beyond the previous period. That shows that the built-up area increased with other human activities and construction exercises at the expense of the vegetation covers and the water body.

The land use/land cover of Minna in 2006, according to Table 5, reveals that the built-up area constitutes a total area of 5,904.5 hectares, representing 8% of the entire land area. The undisturbed vegetation occupied a total land area of 61,454.8 hectares (83.8%) of the total land area. The disturbed vegetation has an area of 5,287.9 hectares, representing 7.2%. In comparison, the water body has an aerial extent of 704.4 hectares (0.96%) of the total land of Minna.

Figure 10 depicts the classified image of Minna in 2006 with an increase in the total extent of the built-up land. The built-up area was increased (Figure 11) as the size of the open spaces and undeveloped plots within the settlements decreased. The clustered pattern of the town was evident in 2006. Apart from the population increase, Minna's growth in 2006 may be attributed to the location and distribution of infrastructure facilities across the town.

The land use/land cover of Minna in 2015 (Table 5) shows that the built-up area of Minna has a total land area of 11,913.2 hectares, which represents 16.2% of the total land area. The undisturbed vegetation constitutes 53,535.3 hectares, accounting for 72.98% of the total land area. The disturbed vegetation also has 7,568.6 hectares, representing 10.5% of the total land area. In hindsight, the water body occupies 334.4 hectares, representing 0.46% of the total land area.

The classified image (Figure 12) reveals an increased built-up area in 2015. The city, during this period, shows a fully clustered pattern of development, where the dispersed (satellite) settlements are now fused, spreading into the urban villages (Figure 13). The work of Morenikeji et al. (2015) and Idowu et al. (2020) corroborated Minna's growth pattern within the periods covered by the study. Other categories of land use in 2015 also experienced severe decreases in the area of land occupied. This pattern of land use/land cover in Minna in 2015 was attributed to the expansion of agricultural land use and the building of homes in the town's peri-urban area. These reduced the coverage of vegetation and water bodies.

The compact nature of Minna built-up area and the land-use development index

This section reveals the compact nature of Minna, as affected by the population growth and the spatial expansion between 1972 and 2015. The land absorption measured the consumption of new urban land by each unit increase in the population of the people who live in Minna. In contrast, the land consumption rate, which measured compactness, indicated the progressive spatial expansion of Minna over time. The need for the population figures of Minna is imperative. Therefore, the population figures were estimated from the population census and the Minna Master Plan final report. For instance, the 1972 population figure was estimated using the 1963 population figure, while Max Lock's (1980) report on the 1979 Minna Master Plan was adopted as the population figure of the year. The 1979 population was used as a base for the 1986 population figure. Subsequent population figures for 1996, 2006, and 2015 were estimated using the 1991 population census report of the town.

As indicated in Table 6, the growth of Minna started when the town became the capital of Niger State in 1976 (Max Lock, 1980). Primarily, in 1972, the extent of the built-up area was 468 hectares, which increased by 425.4 hectares in 1979. The gain in the built-up area was due to the series of projects that the government embarked on being the state capital. Changes in the town precipitated by administrative status triggered an influx of people to the town, and this set the pace that initiated

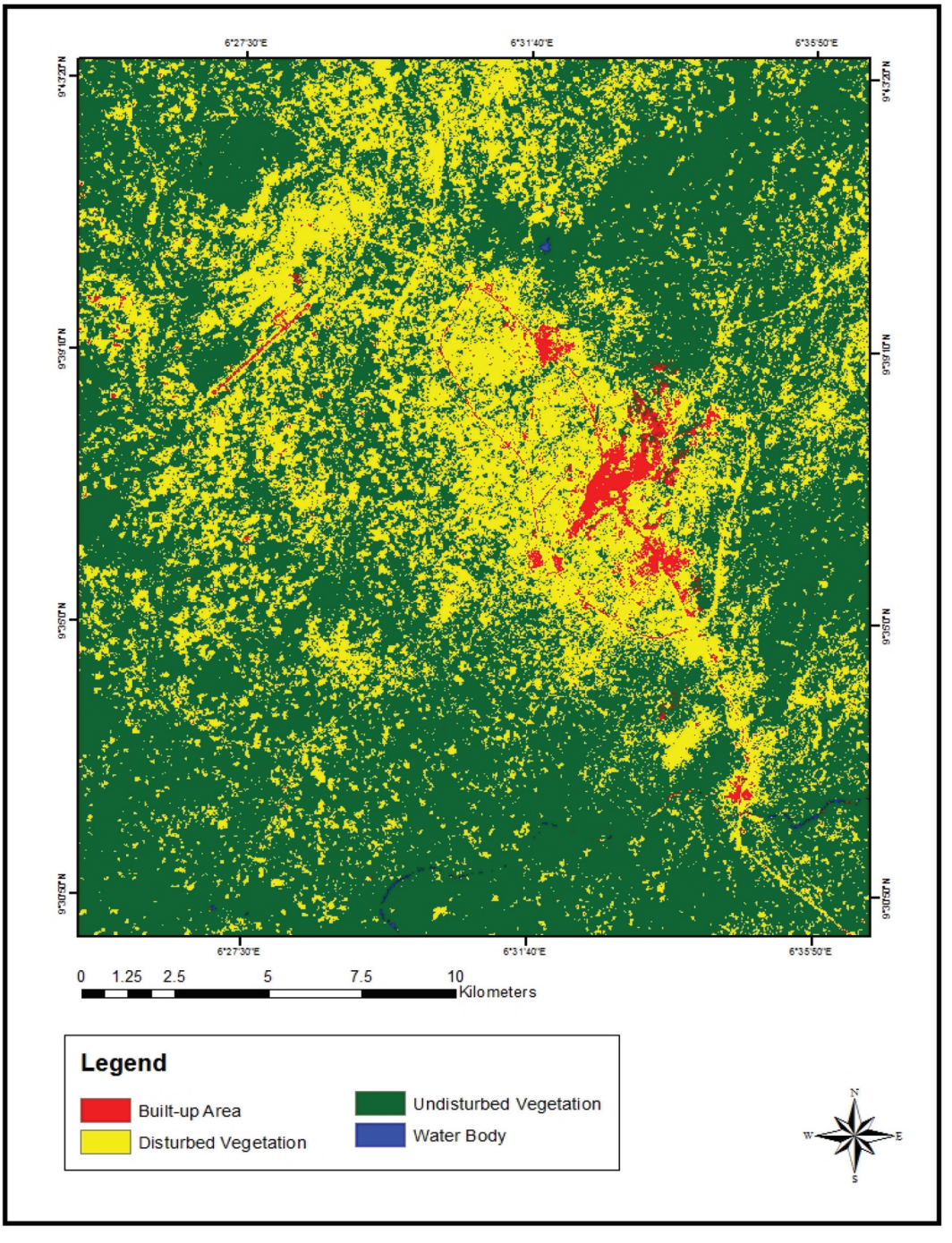

Figure 6. The classified image of Minna in 1986.

the rapid physical expansion of the town, as evident in the change of land consumption rate from 0.0084 to 0.0117. Invariably, the absorption coefficient of the town in 1979 stood at 0.0413. By implication, the land use development index (LUDI), which measures the city's expansion rate, is

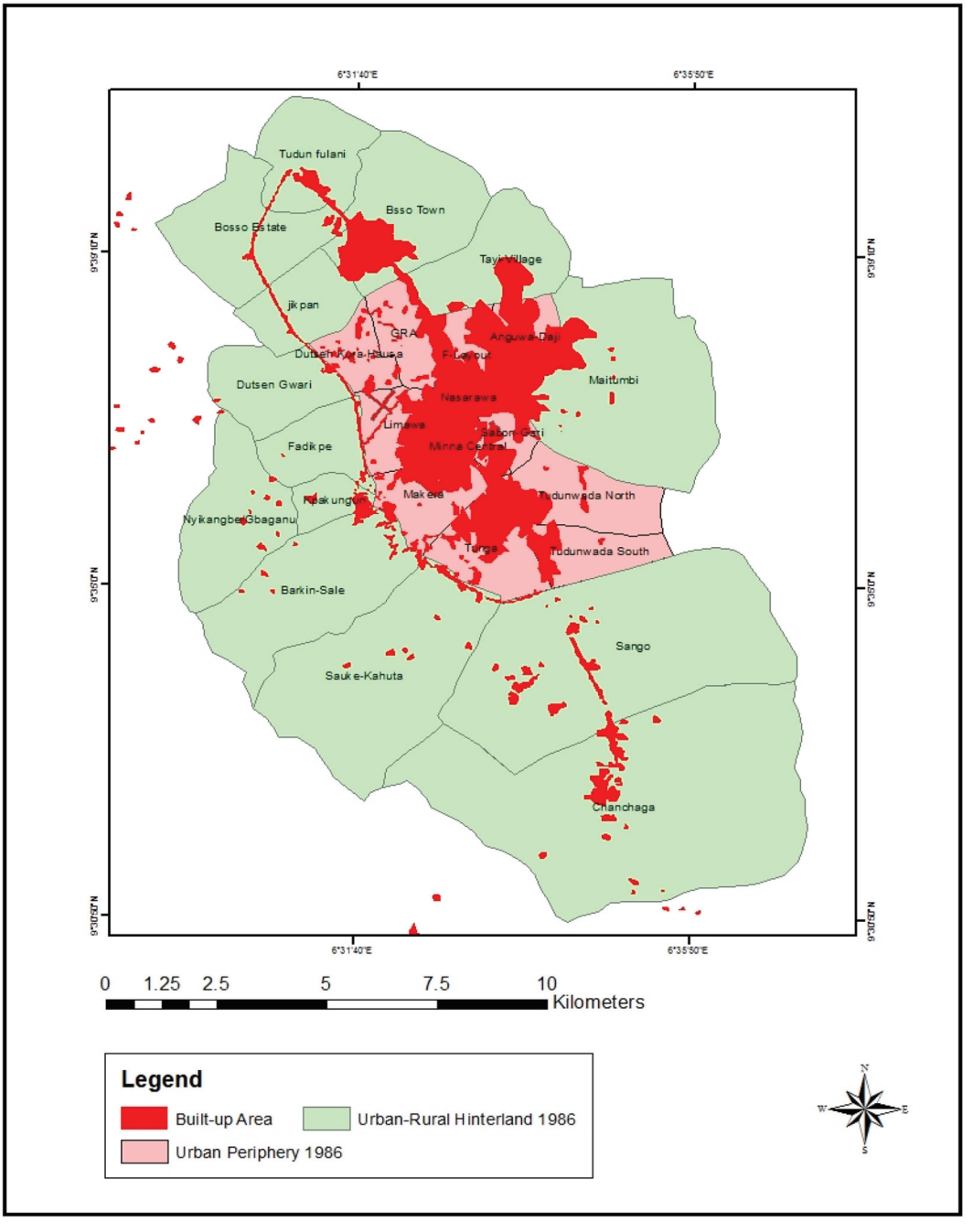

Figure 7. Extent of the built-up area of Minna in 1986.

estimated to be above 8% annually. Self-evidently, peri-urban sprawl development resulted in the loss of about 90.8% of open spaces and bare land (Idowu et al., 2018).

Between 1979 and 1986, there was a sharp increase in the resident population of Minna. That demonstrated the high rate of compactness of the town. The extent of land expansion was 4,579.76 hectares, suggesting that 3,686.02 hectares of vegetal covers and open spaces were absorbed for development. During this period, the land consumption rate sharply increased to 0.0356.

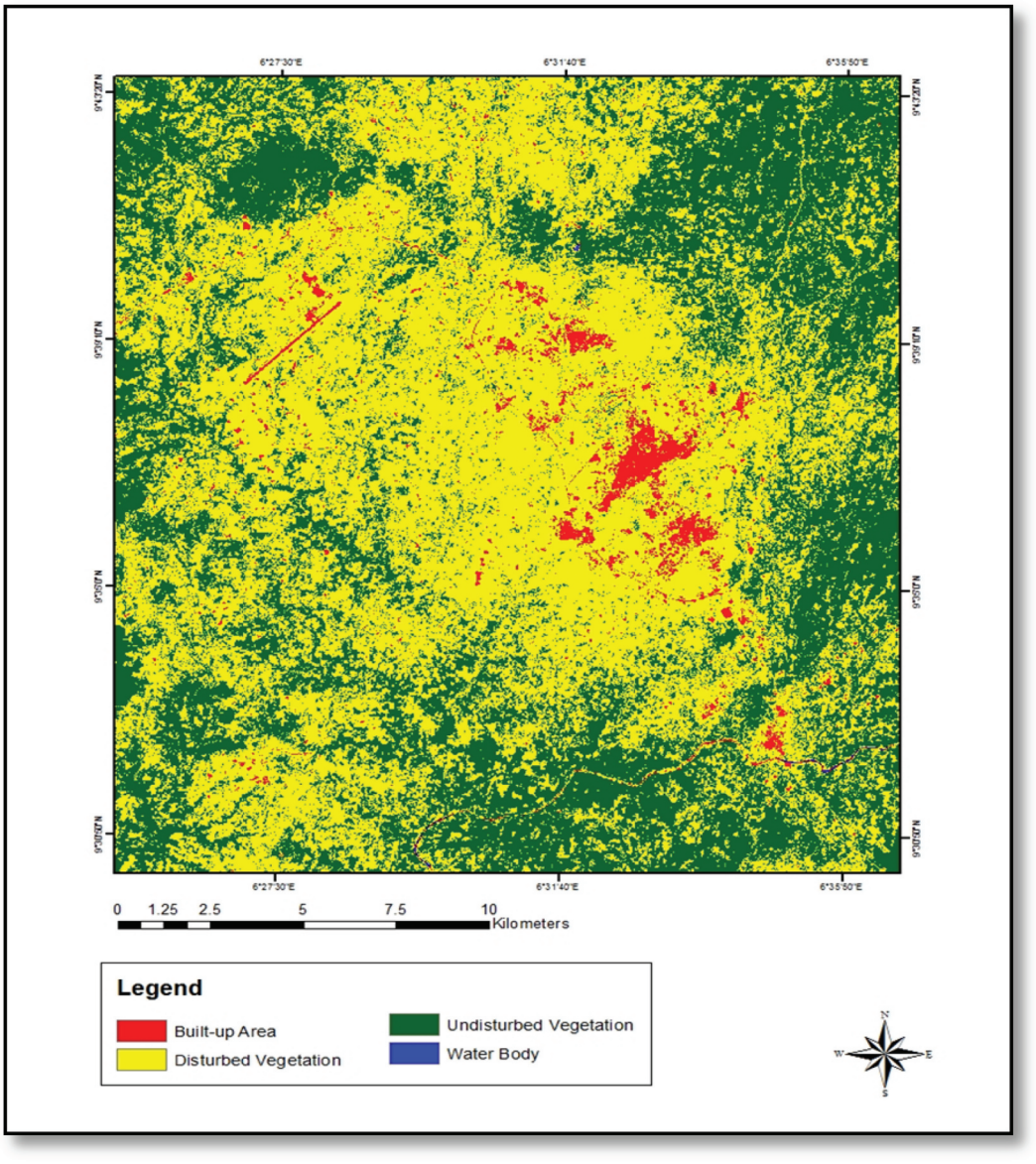

Figure 8. The classified image of Minna in 1996.

Additionally, there was a 0.075% increase in the absorption of new urban land during the same period. By estimation, the land-use expansion index (LUDI) was 11.4%. The rapid expansion and development in Minna were attributed to include the development of low-cost housing estates, provision of educational institutions such as the Federal University of Technology Minna, Niger State College of Education, construction of township roads and other infrastructural facilities

Furthermore, between 1986 and 1996, the urban land of Minna had a total area of 5,205.43 hectares. The estimated annual growth rate was 1.37%, while development engulfed a total land area of 626.67 hectares. The town at this time witnessed a slight drop in the rate of physical expansion. Meanwhile, the population figure seen to be very high could not translate to appreciable physical expansion. There was a drastic reduction in the consumption of new urban land by the unit of

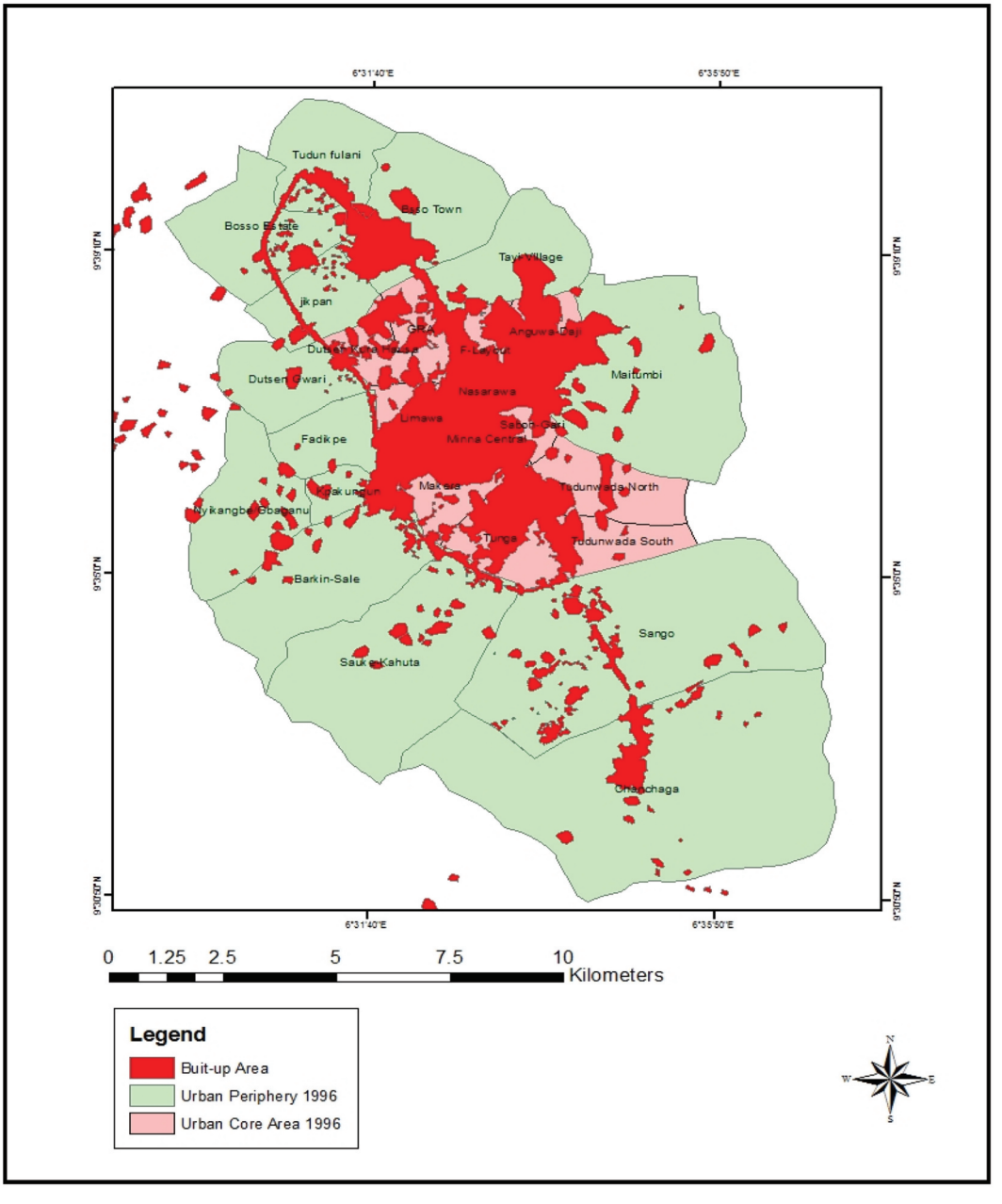

Figure 9. Extent of the built-up area of Minna in 1996.

population increase, as both the land consumption rate and land absorption coefficient decreased to 0.0215 and 0.0035, respectively. Consequently, the town's annual development rate (LUDI) was less than 1%. The economic recession strategy of the government of Nigeria (Structural Adjustment Programme), coupled with the political instability due to the annulment of the Nation's General Election in 1993 by the Military, were among the factors responsible for the decrease in urban expansion.

Between 1996 and 2006, there was no remarkable impact, with the high population increase and the land consumption rate. Expectedly, the increase in the population does not reflect an increase in

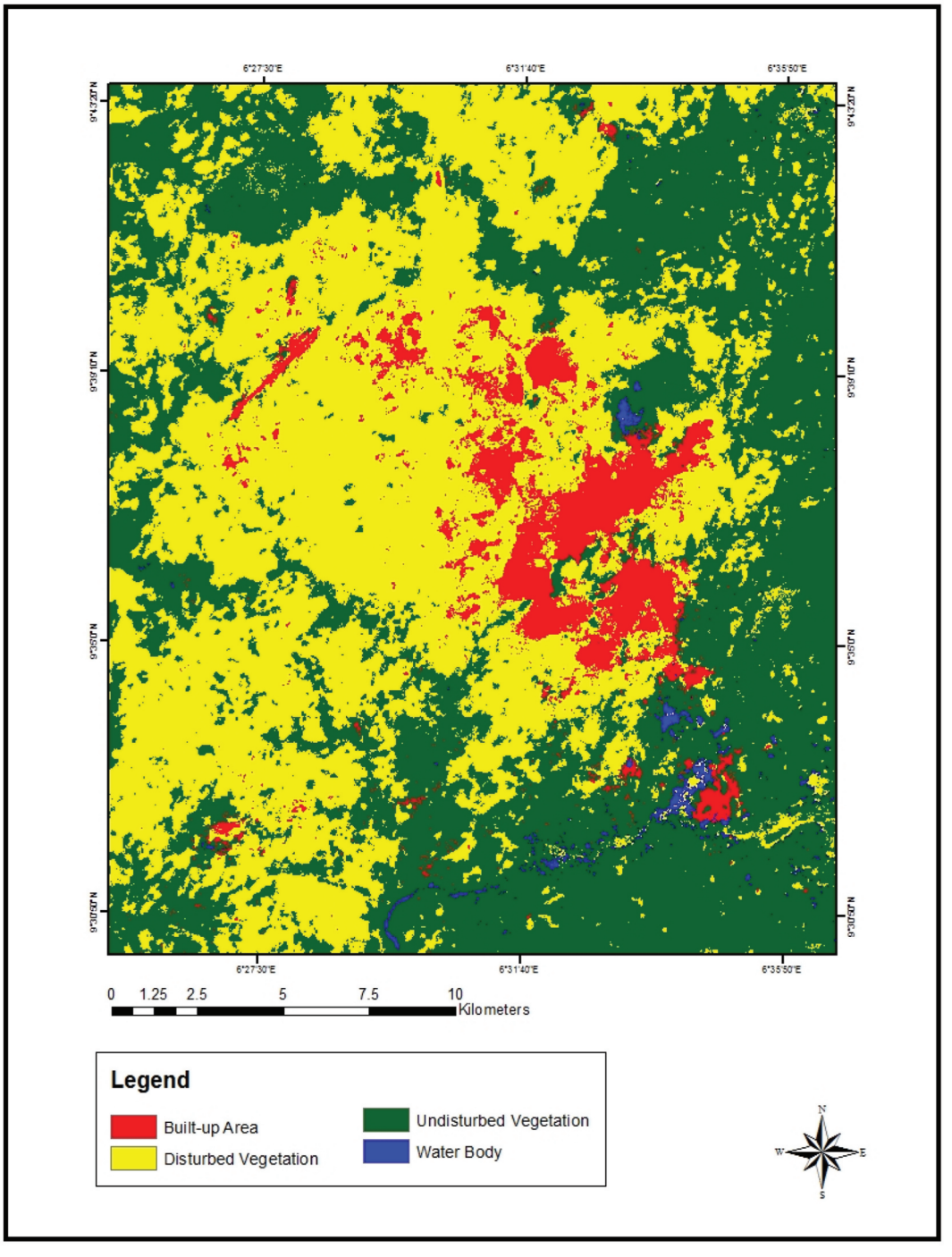

Figure 10. The classified image of Minna in 2006.

the rate of the city's compactness. However, the built-up area appreciated in the areal expanse with over 3000 hectares, and the land consumption rate slightly jumped to 0.0204. Contrariwise, the absorption coefficient of urban space sharply increased to 0.0175. In addition, the land use development index also recorded an increase to 2.03%. The changes that influenced the slight

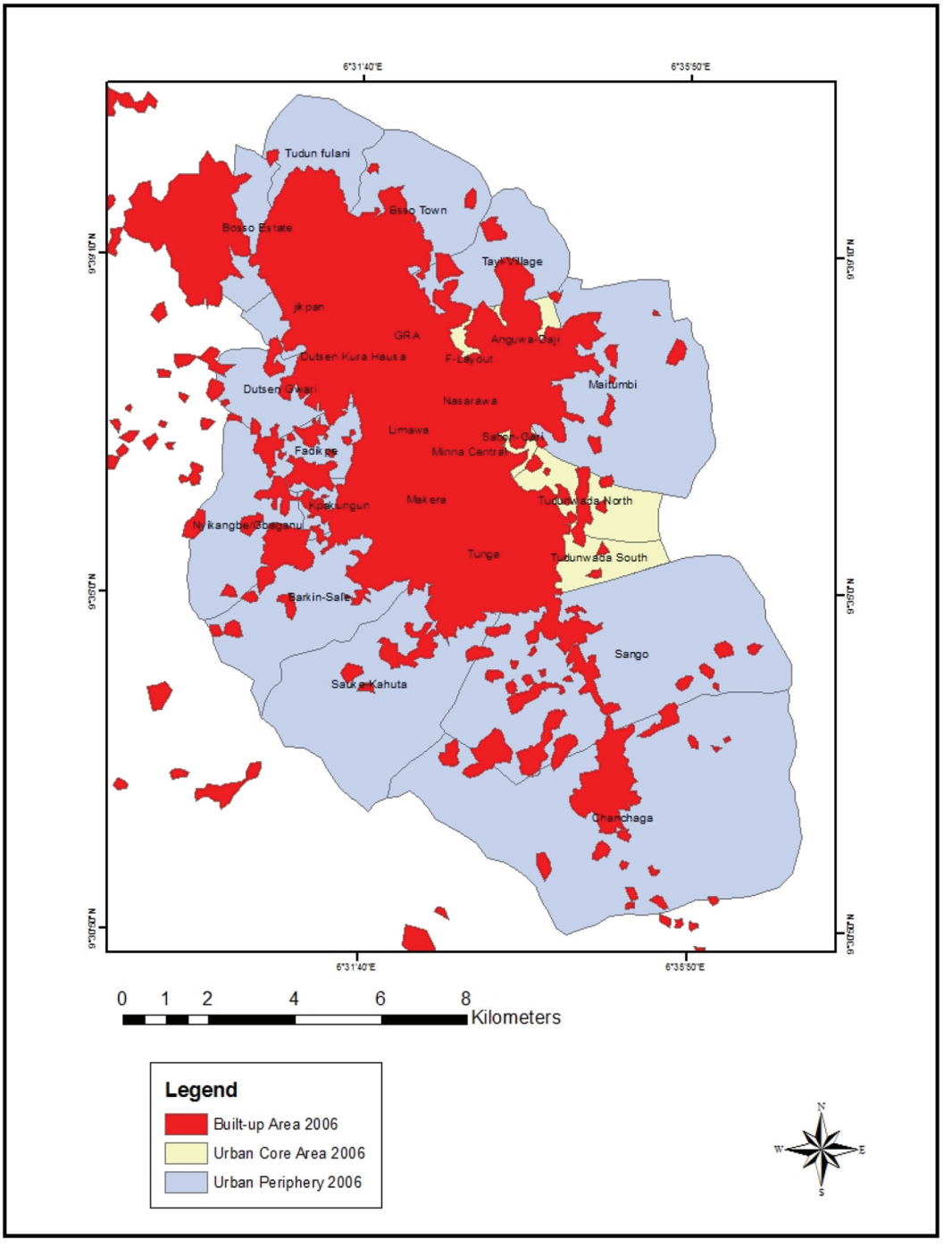

Figure 11. Extent of the built-up area of Minna in 2006.

expansion of Minna between 1996 and 2006 were traceable to the boost in the country's economy after the successful return of the government to the civil rule system in 1999. Also, the incident of demolition exercise in the Federal Capital of Territory (FCT) of Nigeria by the former Minister of

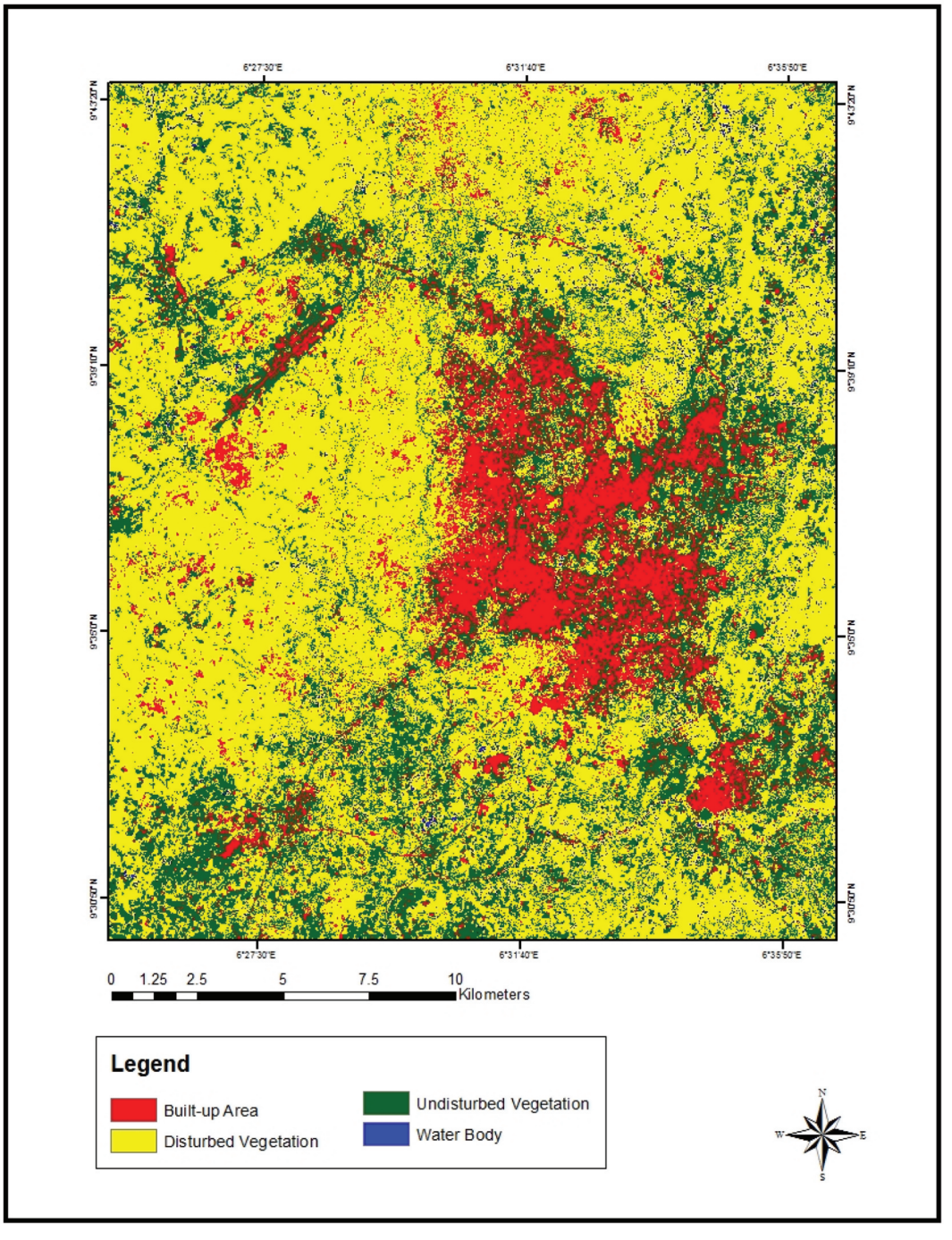

Figure 12. The classified image of Minna in 2015.

the FCT, Mal. Nasir El-Rufai was observed by Idowu et al. (2018) as part of the major factors that contributed to the influx of people into Minna from the Federal Capital Territory.

The built-up area of Minna grew to 19,777.24 hectares by 2015, implying an increase of 11,000 hectares in acreage over the previous four years. The annual growth rate within the period was

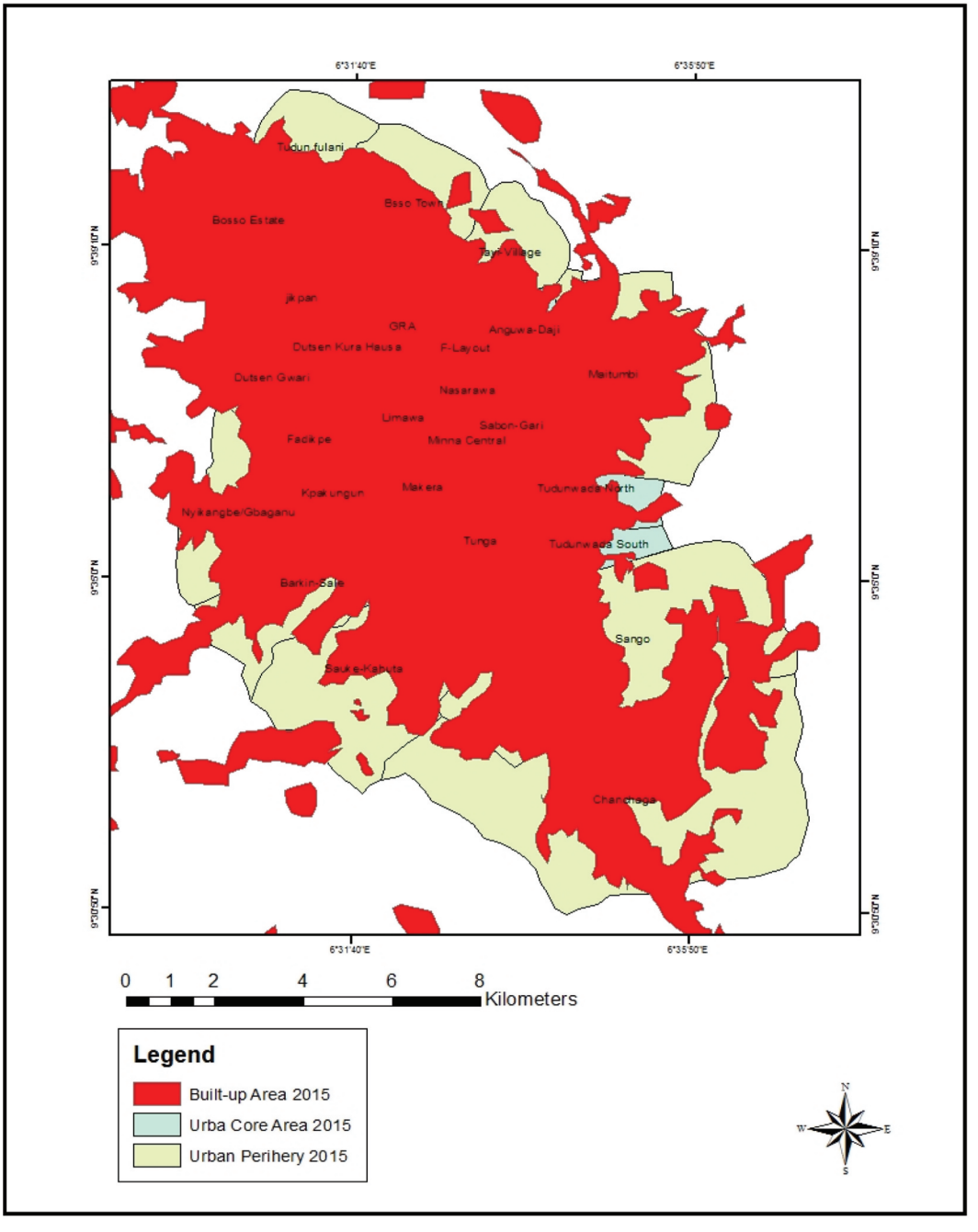

Figure 13. Extent of the built-up area of Minna in 2015.

almost 15%, while the percentage of land development was above 130%. Invariably, there was a considerable impact of the population increase on land compactness and development, as the land consumption rate recorded a sharp increase of 0.273, and the absorption coefficient rapidly increased by 0.0412. Correspondingly, the land use development index (LUDI) was 5.60%. The expansion of Minna between 2006 and 2015 was traceable to the large scale of township road construction and infrastructure distribution in all the city axes. Strands of reasoning by Sulaiman

Table 6. Compact nature of the built-up area and the land-use development index of Minna.

Year	Population	Population Growth Rate (%)	Urban Extent (Ha)	Built-up Area Expansion (Ha)	% Annual Growth Rate	% Of Land Developed (%)	Land Consumption Rate	Land Absorption Coefficient	Land use Development Index
1972	66,788	1.20	468.31	-	-	-	0.0084	-	-
1979	76,480	7.90	893.74	425.43	12.98	90.84	0.0117	0.0413	8.40
1986	122,810	7.00	4,579.76	3686.02	58.92	412.43	0.0356	0.075	11.36
1996	219,313	2.83	5,205.43	625.67	1.37	13.66	0.0215	0.0035	0.72
2006	289,909	2.83	8,505.06	3,299.63	6.34	63.39	0.0204	0.0175	2.03
2015	435,588	3.20	19,777.24	11,272.18	14.73	132.53	0.0273	0.0412	5.60

and Idowu (2020) attributed further changes in Minna's growth pattern to the affordability of rent/land value in the peri-urban area of the town. However, it fosters broader discussions by promoting a deeper understanding of some factors domiciled at the center or core that dictate the logic of marginal or peri-urban developments (Swyngedouw & Heynen, 2003; Tzaninis et al., 2021). Such factors spanning deprivation and poverty, residential self-selection, automobile dependency, and brownfields jointly culminate into urbanization processes precipitating city expansion.

Conclusion and recommendations

Sprawl processes and urbanization trends are inescapable truths of today. They pose immediate existential threats to forestlands, water bodies, and peri-urban green spaces. In light of this, this study documents, between 1972 and 2015, the developments in Minna's built-up regions using geospatial data. Expectedly, the built-up area grew from 4,368.7 hectares in 1972 to 19,777.2 hectares in 2015. Between 1986 and 2015, a total of 12,081.5 hectares occupied by vegetal cover was lost to urban development, while the disturbed vegetal cover increased by 140.7%. Despite the increase in the area occupied by water bodies (51.1%), it occupies less than 1% of the total land mass of the entire area. The rate of land consumption in 1972, which stood at 0.0084, increased to 0.0273 in 2015, implying the high compactness of vacant and open spaces within the core area and the peri-urban area of the town. The implication of the absorption coefficient of Minna between 1972 and 2015 indicates land units absorbed due to the population increase. The government's and city managers' inability to meet the demands of a growing population resulted in the unprecedented growth of informal and unplanned peri-urban neighborhoods. Minna's peri-urban development has altered the town's political, economic, cultural, spatial, and environmental landscape, creating new challenges for the administration, city managers, and researchers. With all of these considerations, state actors must build formidable partnerships with other non-state actors to implement eco-sensitive site selection programs, coordinate green belt policies, and other sustainable strategies at all levels of urban management. Consequently, the planning and development of Minna regions should not be left to chance or the interaction of economic forces but rather should be led by methods birthed by systematic planning outcomes that assure orderly growth and development.

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Disclosure statement

No potential conflict of interest was reported by the authors.

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