Urbanization and its Effects on the Environment in Maiduguri Metropolis, Borno State, North East, Nigeria

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Abstract

The study assesses the spatial growth and changes in land use in Maiduguri Metropolis and its effects on the environment. Landsat Multispectral Scanner, Landsat Thematic Mapper and Enhanced Thematic Mapper + images for 1975, 1987, 1999 and 2012 respectively of the area were used in this research. Taking 1975 as base year, the images of the different dates (1987, 1999 and 2012) were resampled and processed to same pixel size (30m), and projected coordinate UTM system (Minna Datum, Clarke 1880 Ellipsoid of Zone 33). This method allowed flexibility of all the images to be in common processing ground and overlay. The generated maps and images of the study area were classified and analyzed. Supervised image classification was used to categorize different land uses and detects all the built-up areas. Two classes (built-up and others) were identified in the supervised image classification method (SICM) and also used to detect change in the area. The findings confirmed a sharp increase in the urban area due to large scale development on the natural drainages. The areal extent of the city has increased from 43km^2 in 1975 to 145.4km^2 in 2012 thus, aggravating environmental problems such as flash floods and inundation, poor solid waste disposal and urban heat island in the metropolis. The occurrence and the effects of the floods were found to be more devastating in areas where natural drainage networks existed but were replaced by residential buildings due to urban sprawl. The aspect of poor solid waste disposal on the other hand has been a general problem, in most parts of the metropolis, while the urban heat island is mostly experienced in the city center where there are large commercial and vehicular activities. The paper recommends for improved land use planning; raising awareness of the residents, providing more drainage and continued vulnerability mapping, improving the functionality and capacity of the agencies responsible for flood and solid waste management among others.

Keywords: Borno, Environment, Maiduguri, Metropolis and North East

Introduction

The UN projects that the world's urban population will grow by 1.8 percent per year and by 2.3 percent per year in developing countries from 2007 to 2025. In fact, by 2020, the world's rural population will cease growing altogether and begin to decline. In part, the world's urban population will continue to grow simply because towns and villages not considered urban today will grow over time. Equally important, migration to urban areas can be expected to increase as economies grow and the likelihood of earning a higher income in cities increases (United Nations Population Division, 2009). Much rural-to-urban migration will take place as a result of hardship, as the rural and landless poor make their way to cities and towns in the hope of finding employment opportunities. In developing countries, many urban residents live in settlements with little access to road, limited availability of electricity, and little or no access to clean water or basic sanitation. In developed countries, the rural population, on the other hand, often has the same access to amenities and services as urban areas and is almost indistinguishable from the urban other than by location or size of place. The world is rapidly becoming more urban; the number of mega-cities in the developing world will grow over the next few decades as cities such as Kinshasa, Lagos and Jakarta are projected to grow to well over 10 million people by 2025.

Urban development has increased dramatically in recent decades, and this increase is projected to continue (Alig, Kline and Lichtensten, 2004). In another projection, the United Nations projected that half of the world's population would live in urban areas at the end of 2008 (Associated Press, 2008). It is predicted that by 2050 about 64% of the developing world and 86% of the developed world will be urbanized (The Economist, 2012). That is equivalent to approximately 3 billion urbanites by 2050, much of which will occur in Africa and Asia (UNFPA, 2013). Notably, the United Nations has also recently projected that nearly all global population growth from 2015 to 2030 will be absorbed by cities, about 1.1 new urbanites over the next 15 years. The phenomenon has been closely linked to modernization, industrialization and the sociological process of rationalization. Urbanization creates enormous social, economic and environmental changes, which provide an opportunity for sustainability with the "potential to use resources more efficiently, to create more sustainable land use and to protect the biodiversity of natural ecosystems." Urbanization rapidly spread across the Western world and, since the 1950s, it has begun to take hold in the developing world as well (Cohen, 2015). At the turn of the 20th century, just 15% of the world population lived in cities. Unfortunately in order to create an urbanized area, a natural environment must be destroyed. Urbanization and human activity within an urban system produces many destructive and irreversible effects on natural environments such as climate change, air pollution, sediment and soil erosion, increased flooding magnitude and loss of habitat.

Maiduguri the Borno State capital is a fast growing urban area. Over the years, rapid changes have been noted in its physical extent, population size and land use. A new pattern is appearing in the spatial characteristics of the city (Waziri, 2009). New areas are built up, while certain areas change in land use type, building structures and so on. Under the British system of indirect rule, the town remained almost wholly traditional and grew slowly, but with the creation of the states under the Federal Military Government in 1968 and with the selection of Maiduguri as the state capital, the town grew rapidly. According to Max report (1976) and Kawka (1997), some areas that were reserved for forest; agriculture and wild life park are now fully developed as residential area. Thus, in recent times, the city as an urban center is witnessing an unprecedented growth in physical structures. This has resulted in the turning of large hectares of open land to residential and business areas without equal emphasis on the construction of drainages. The spatial growth has equally contributed to other environmental problems. This paper, therefore, examines urbanization and its effects on the environment in Maiduguri Metropolis, Borno State, Northeast, and Nigeria.

Description of the Study Area

Maiduguri is located between latitude 11^o 40'N and 11^o 44'N and longitude 13^{o}05'E to 13^{o}14' E. It covers a total area of 543km^2, which makes it the largest urban centre in the Northeastern region of Nigeria (Daura, 2002), which now extends into MMC, Jere, Konduga and parts of Mafa Local Government Areas (Kawka, 2002). The area is developed on young sedimentary rocks with a relatively flat terrain sloping towards the Lake Chad with an average relief of 290 masl and 350 masl (Onlinenigeria, 2003). Maiduguri lies on and at the bottom of the Bama Ridge. The area is drained by River Ngadda and the Ngadda Bul (Mala, Maryah and Ali,2009). It is characterized by low precipitation (650 mm^3) and high evaporation (Waziri, 2009). The mean monthly temperature is always above 20°C, reaching up to 47°C in April. The climate of the area is affected by the North East Trade Winds and the South West Monsoons. The soils of Maiduguri are of aeolian origin which includes vertisol, fluvisol, brown and reddish brown, regosols, hydromorphic and alluvial soils (Daura, Gisilambe and Waziri,2001). The 2015 projected population was estimated to be over 1,112,449 as a result of influx of the Internally Displaced Persons (IDPs) (World Atlas, 2016).

Materials and Methods

The data used in this study included Landsat Multispectral Scanner – MSS (1975) downloaded from USGS Earth Explore/Glovis, Max Lock landuse map 1976, sourced from Borno State Urban Planning and Development Board, Landsat Thematic Mapper (1987), Enhanced Thematic Mapper plus – ETM+ (1999) downloaded from USGS Earth Explore/Glovis and Google image 2012 from Google Earth, of the study area. The MSS (1975) covering path 185-row 052 and Max Lock landuse map (1976) were used as baseline data to determine the initial spatial extent and for comparison as they are almost the same period. Landsat Thematic Mapper (1987) and ETM+ (1999) of the same path 185-row 052 were downloaded from USGS Earth Explore/Glovis and Google image 2012 from Google Earth of the study area.

The rate and extent of expansion of the study area were determined from Landsat TM, ETM+ and Quick Bird of different dates using the popular Supervised Image Classification Method (SICM). The study adopted maximum likelihood classifier method based on the distances towards class means and the variance-covariance matrix of each class. Additionally, since it was based on the assumption that spectral values of training pixels are statistically distributed according to a Multi-variate Normal (Gaussian) Probability density function, the method was opted. All the spatial data were re-sampled and projected to common coordinate system: Universal Transverse Mercator (UTM) projection system, with Clark 1880 ellipsoid, Minna datum and zone 33 to allow overlay and assessment of all corresponding pixels of the dates.

In terms of visual colour interpretation of features, standard, dynamic, 24 Bit RGB and 24 Bit HSI was used to create multispectral band colour composite that was carried into sample sets in ILWIS 3.3 Academic. The study considered the 24-Bit RGB for its simplicity and its representation as a true colour composite of the features in the image. Four images at different times (1975, 1987, 1999 and 2012) were used for the extraction of urban land use of the study area. Three bands (5, 4 and 3) of the four images were used for the colour composite. Band 3 (the red band) was passed through the red filter, while bands 4 (near infra-red) and 5 (mid infra-red) were passed through the green and blue filters – i.e. using RGB. This combination produced image in colour, used for easy understanding of the actual land use classes of interest (built-up area). The standard colour composite was used for the interpretation of (built-up). The choice of RGB was preferred because many studies such as Maathuis (2004) and Koolhoven, Hendrike and Nieuwenhuis (2007) have proved the method as one of the best. The values of the built-up area (mean digital pixel numbers: 73.8 for band 3; 70.7 for band 4; and 115.6 for band 5) were identified and strictly used for separation of the two classes. Therefore, on band 3 the mean digital number for built-up area was 73.8; band 4 (near infra-red wavelength, the mean digital number for built-up area was 70.7; and finally band 5 (mid-infrared wavelength, the mean digital number for built-up area was 115.6). Any other values referred to other class. The study, therefore, used the mean of digital values of each band to classify and extract the built-up areas. The areas were then converted into aerial extent from statistics module of ILWIS. The same method was used for all images (1975, 1987, 1999 and 2012). Image differences were produced between 1975 and 1987; 1999 and 1987; 2012 and 1999.To update the urban built-up area, quick bird satellite image (January, 2012) of Maiduguri and environs was used. The image was georeferenced, not only for overlay of other spatial features, but also to compute the extent of built-up area. After the image was georeferenced in ILWIS software, a polygon layer was created to delineate built-up area. The polygon area was computed as the aerial extent of the city. The computation of the area was made from ILWIS statistics operation. Supervised image classification was used to detect all the built-up areas. The built-up areas were used to calculate the spatio-temporal growth in Maiduguri urban, impact of the growth in terms of population, aerial growth and new artificial drainage channels to drain excess run-off were examined. The entire Maiduguri Metropolis urban expansions of different dates (1987, 1999 and 2012) were super-imposed in one image (Figure 8). The Red, Forest Green and Green signify surface built-up area in 2012, 1999 and 1987 respectively. GPS map 76CSx with ±3m accuracy was used in georeferencing the quickbird image (2012). Six control points were collected with the GPS in the field and the GPS UTM records were used to georeference the quickbird image.

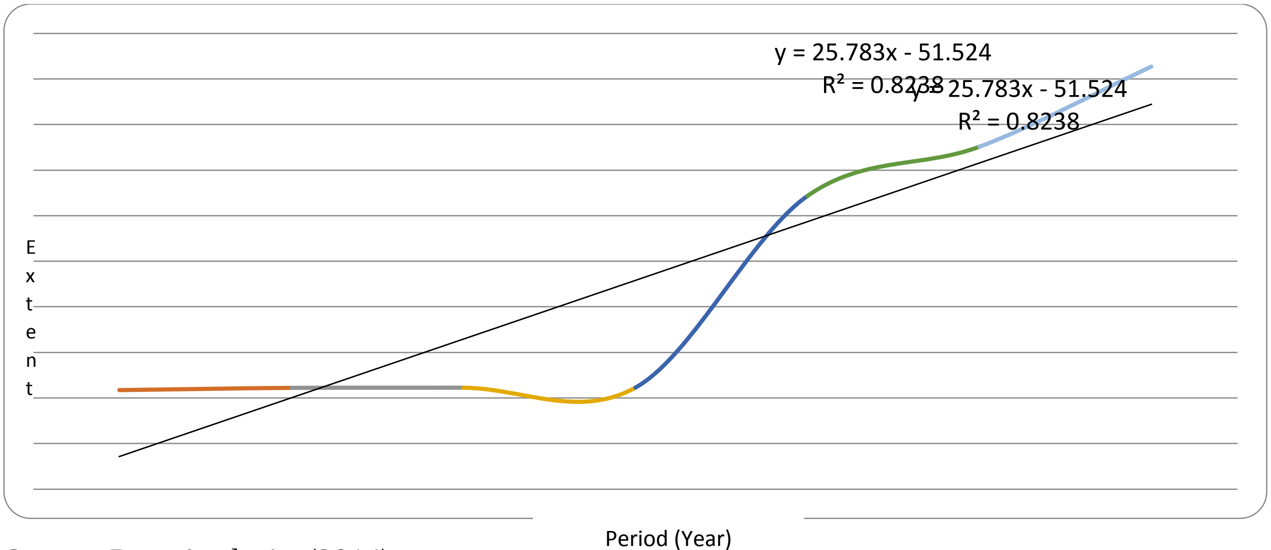
Results and Discussion of Findings

Population Growth

Maiduguri Metropolis within the last decades has witnessed a very large population explosion and pattern of population growth as a result of the migration from rural to urban centers because of the perceived improvement in living conditions in urban areas and availability of infrastructure. Maiduguri's population increase between 1910 and 1919 was moderate, as the population grew by 2.7 percent per annum. The annual growth rate for the next decade was higher. It reached 5.4 percent. This led to an expansion of the built up area into the rural hinterland. The size of Maiduguri in 1924 was 3.4 km^2, in 1957, it was 4.4 km^2 in 1970, it was 4.6 Km^2 and in 1963, it was 4.5 km^2 (Fig. 1). The approximate population densities for 1924 was about 4,500 persons per kilometer square, the figure rose to 12,400 per / km^2 in 1952 and then to 19,500 per/km^2 in 1963 and within forty years the population density quadrupled. The 1973 population was estimated at 165,000 to 170, 000. The past rate of growth based on the 1963 census has been about 7% per annum and in 1973 it was estimated about 10% per annum. Following the trend, perhaps the most significant changes in the population occurred between 1967 and 1991. With the drought episodes of the mid 1970s and 1980s, the rate of rural-urban migration has increased and the in-migration has more than doubled (Omoja, 1997). The drought phase of the period 1974-1984 and the social distress and the civil war in Chad republic made thousands of refugees to flee to Maiduguri from the immediate distressed areas within the State, and from Niger, Chad and Cameroon Republics (Thambyahpillay, 1993). During this period, the annual population growth rate of Maiduguri has been put at 5 percent per annum by the National Population Commission, while the growth rate of the rural areas of Borno is said to be 2.5 percent per annum (Engmann, 1991). However, the population results of the 1991 and 2006 census in the area revealed that the total population of Maiduguri was 653,401 people in 1991 and 140,402 households and by 2006, the population rose to 1.275million people in the city and its rural fringes (NPC, 2007) (Fig. 2). Although, detailed population of enumeration areas and other units are yet to be available, using population figures from Kawka (2002), the projected total population of the two LGAs which form Maiduguri city based on the 2006 census in 2011 is 956,095. Therefore, Yerwa/Maiduguri contains 24 % of the population of Borno State on a land size less than 1% of the total land area of the State.

Land use pattern

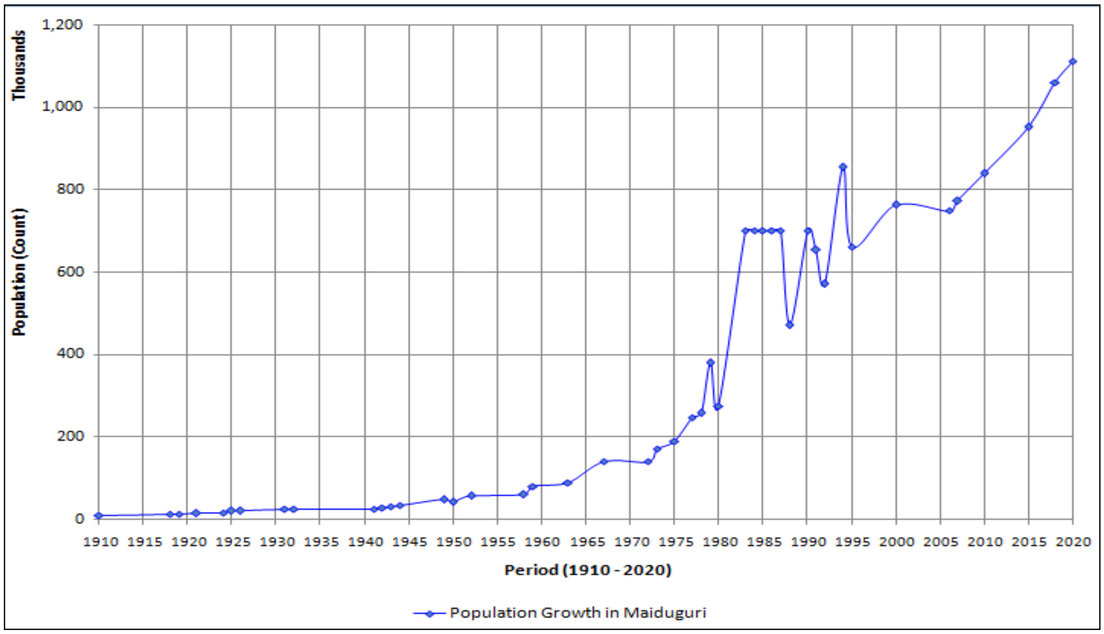
In Maiduguri Metropolis today, there are generally eight landuse types. These include residential, commercial, industrial, transportation, agricultural, recreational, institutional and public open spaces. The city is primarily a human settlement, therefore, residential land use mainly consists of all forms of human dwellings. The intensity of residential houses, however, reduces as one moves out of the city centre. The existing land use before the Max lock proposal was well adhered to as all structures were constructed according to their specifications (Fig. 9). The proposed land use plan of the city categorized the area into residential, institutional, services and open space uses. The areas earmarked for residential buildings consist of high, medium and low density areas (Fig. 10). The institutional land use comprised of educational, defense as well as public service and administration. The level of implementation of the land use plan can be described as fair as most designated areas were developed into the purpose they were reserved for. However, areas designated as open spaces (Public Open Space, Agricultural Production and land to remain undeveloped) in the proposed land use were transformed into residential areas in the current land use. For example, the public open spaces reserved along the two major rivers are now occupied by residential buildings, so also are the agricultural production areas mostly at the city periphery, where some outskirts villages transformed into nucleus of high residential density. Areas to remain undeveloped were also not spared, as most of them were since demarcated for both residential and industrial layouts. Although, the plan is expected to be reviewed after every ten years, up till date, the Maiduguri master plan has not been updated even once either by the ministry of land and survey or by the Borno State Urban Development Board. Although, the existing land use in 1976 shows a well patterned land use, this has been distorted by fragmentation in all the newly sprang wards.



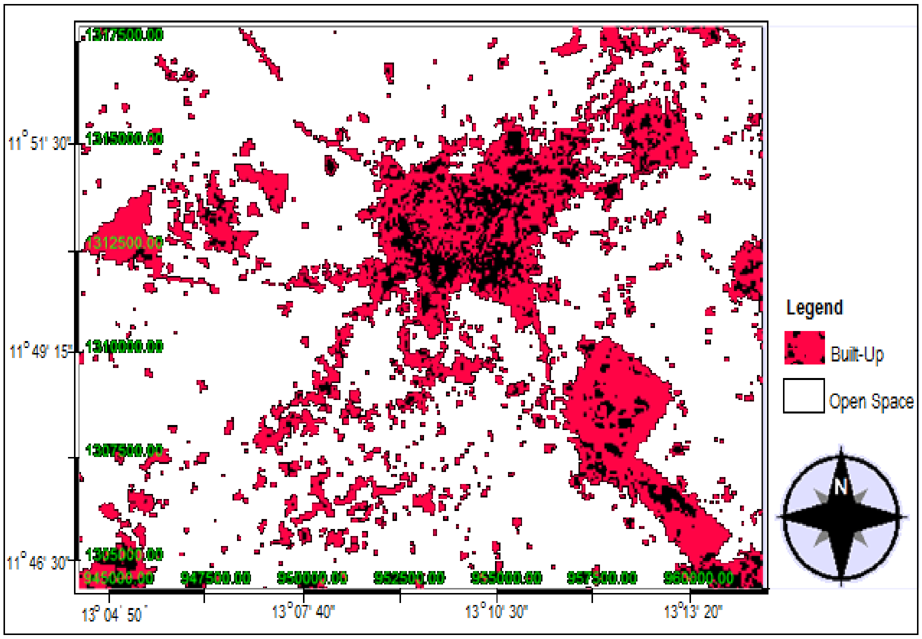
Source: Data Analysis, (2014)

Fig. 1: Spatial growth of Maiduguri metropolis (1924-2012)

The findings in figures 3 and 4 revealed that much of the expansion in Maiduguri urban were recorded especially at the hitherto periphery areas which include University of Maiduguri (Unimaid) and the surroundings, Bulumkutu/Ngomari area, areas along Gamboru Ngala and Baga roads, Brigadier Mai Malari and Giwa Barrack areas, some patches of land area between Biu and Damboa road and other suburbs. The noticeable developments around the University up north of Ngomari Costain were mainly to cater for the ever increasing demand of accommodation, mostly for the University students. Some residential areas were initially designed by the Ministry of Land and Survey or the Maiduguri Metropolitan Council and allocated to citizens to build which includes Gwange ward created in the 1950s and Bulumkutu which was built during the 1970s. On the fringes of the city, native farm owners sold out their farms to the growing city at different times. Some forest reserves have also given way to residential use as seen along Lagos Street, Jiddari and Dala. Some characteristics of such areas are narrow streets, poorly aligned houses and poor building structures. Umarari, Bulabulin Ngarannam, London ciki and Zannari are examples of such areas. However, some areas of predominant commercial structures can be identified in the city.



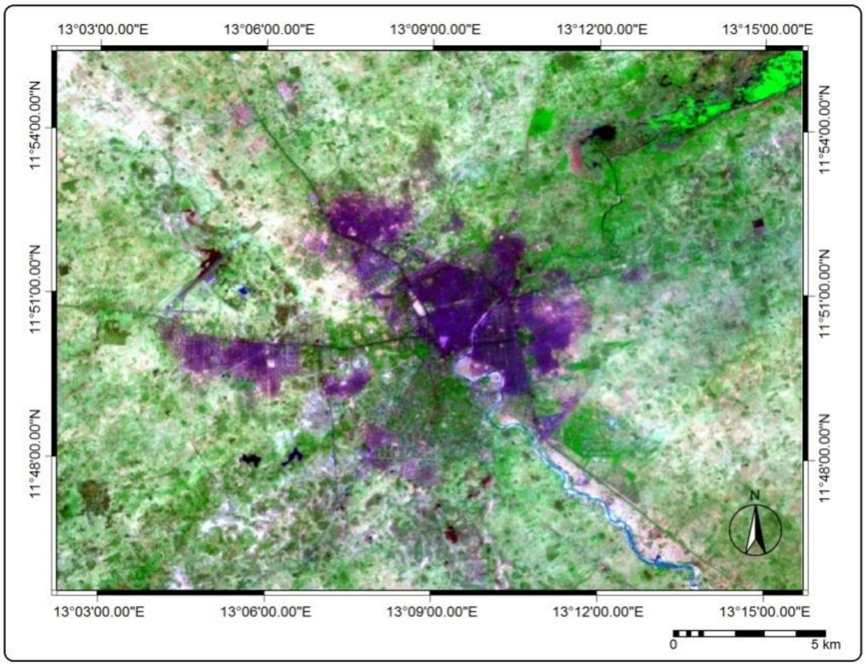
Source: Adopted and modified from Kawka (2002)
Fig. 2: Population growth trend of Maiduguri metropolis (1910-2011).



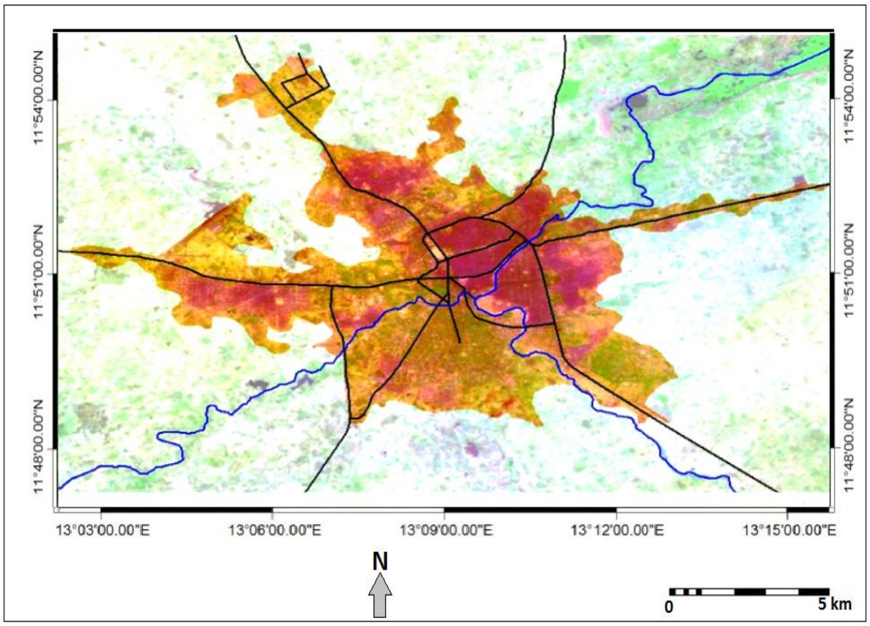
Source: Landsat multispectral scanner (MSS)
Fig. 3: Maiduguri satellite image of 1975

In Maiduguri Metropolis, a vast area is occupied by institutions and offices such as the State and Federal Secretariats, tertiary institutions, day and boarding secondary schools, Police

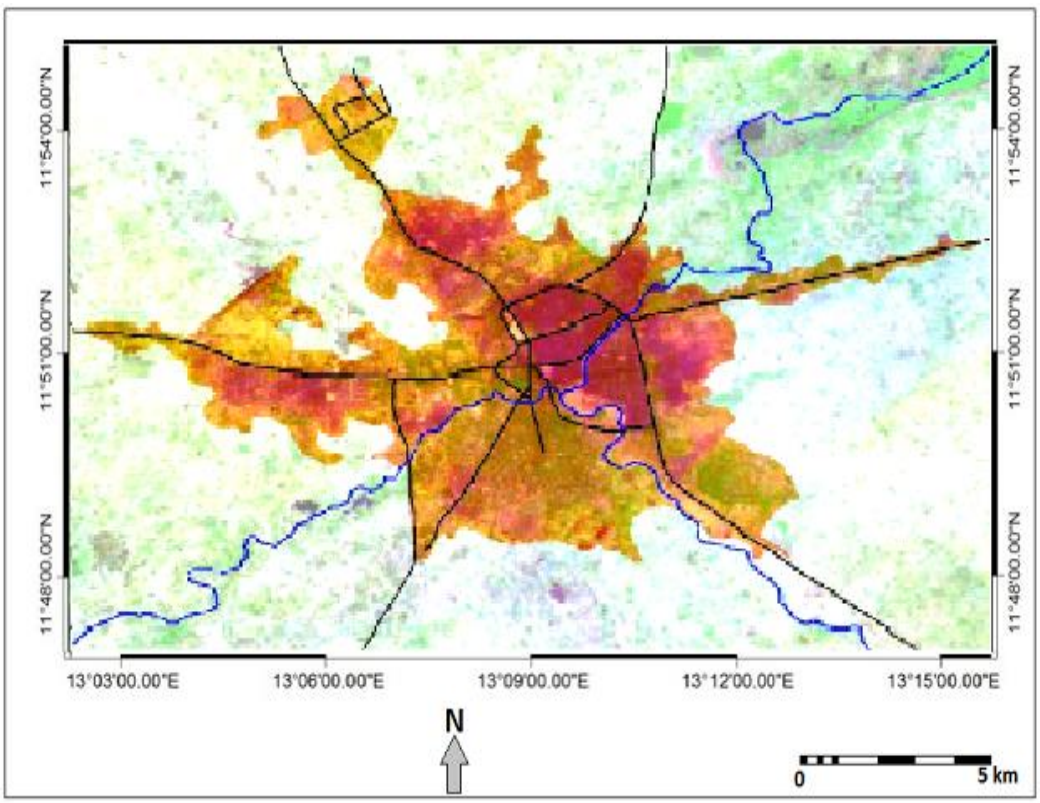
College, and some offices. Notable offices and institutions are the Federal Government College, the Teaching Hospital and the University of Maiduguri, Mohammed Goni College of Legal and Islamic Studies, College of Agriculture, the Chad Basin Development Authority, the Lake Chad Research Institute, Maimalari Army Barrack and the Maximum Security Prisons among others. The city is crisscrossed by several tarred roads, first built in 1945, of different width. Transport terminals in the city include the Maiduguri International Airport built in 1937, the railway terminus built in 1965 and motor parks which include Baga, Muna, Kano, Borno Express and Bama.



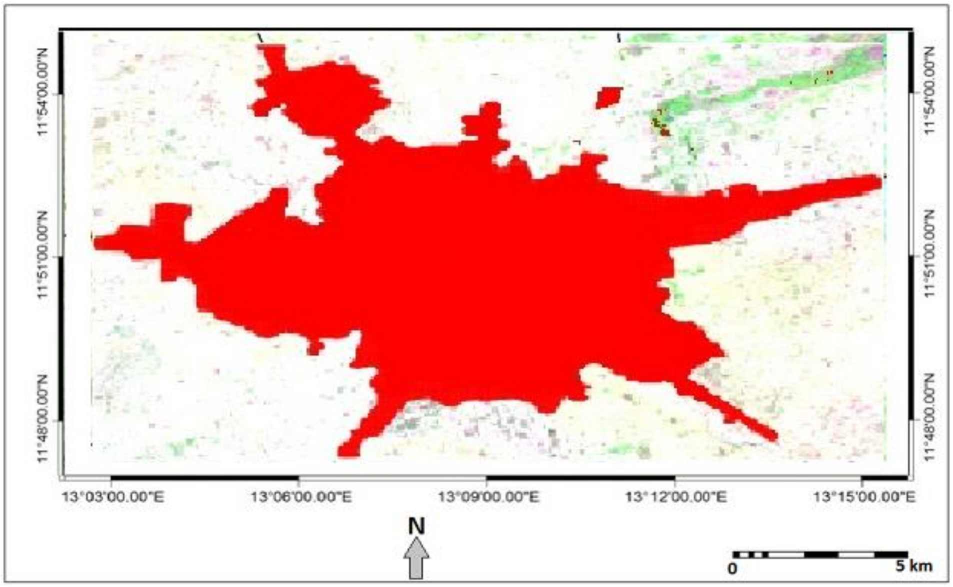
Source: Geospatial Database, Department of Geography, University of Maiduguri (2014)
Fig. 4: Colour composite RGB/743 to Conspicuously show built-up areas (in purple)



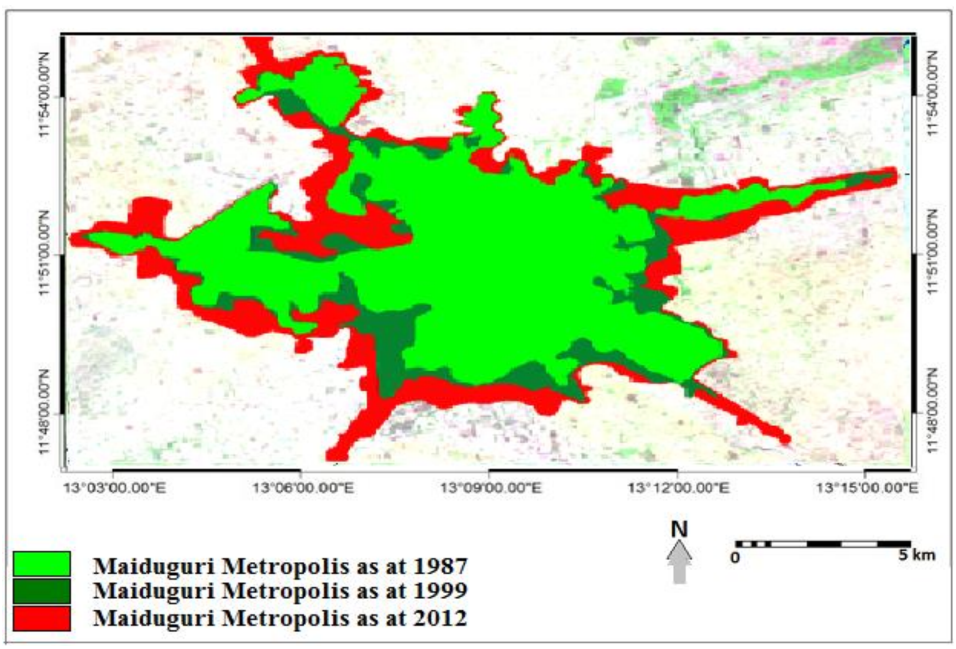
Source: Geospatial Database, Department of Geography, University of Maiduguri (2014)
Fig. 5: Maiduguri metropolis in 1987



Source: Geospatial Database, Department of Geography, University of Maiduguri, 2014)
Figure 6: Maiduguri metropolis 1999 (Pixel size of Landsat TM is 30m and Landsat ETM+ is 28.5m with 15m panchromatic (Band 8).



Source: Laboratory Work, (2014)
Fig. 7: Maiduguri metropolis as at (2012).



Source: Laboratory Work, (2014)
Fig. 8: Spatial growth of Maiduguri metropolis (2012, 1999 and 1987).

In designing residential layouts in Maiduguri, the Ministry of Land and Survey categorized areas into high, medium and low density of housing per unit area based on the size of the plots. However, houses in the traditionally built up areas in Maiduguri city are seldom regular in size and shape. There were no regulations for ideal size of a house when the city started. This development resulted in the unification of the different core settlements of Maiduguri in the 1980s to form a single urban body that reached the size of over 145.4 Km^2 in January, 2012. This expansion has led to an urban intrusion into the peri urban environs far beyond the original town borders. This agrees and conforms to earlier studies by Waziri, 2009 and Ikusemoran and Jimme (2014). This was followed by a significant change in land use that has increased the sealed surface by reducing the infiltration rate of rain water (Figures 5, 6 and 7). However, due to poor government attention on land matters, even the planned areas are now grossly distorted. So it is difficult today to give a clear demarcation between planned and unplanned areas.

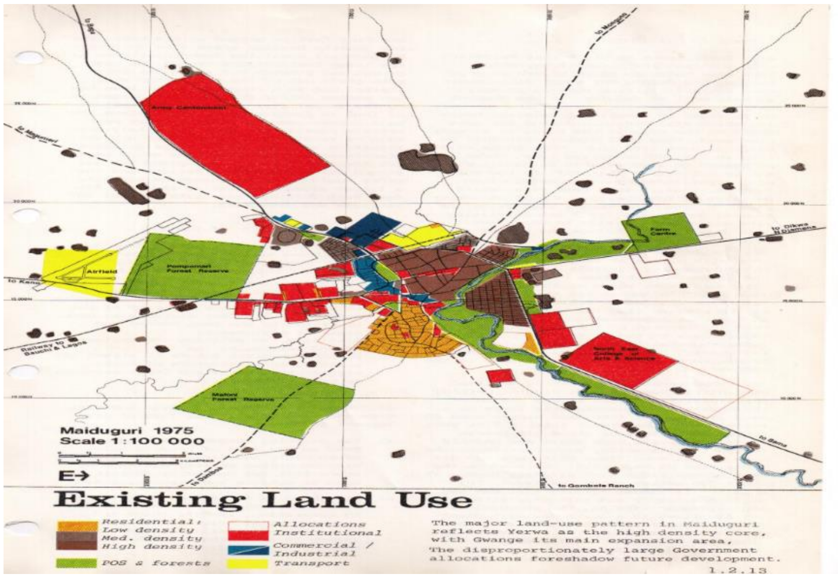


Fig. 9: Maiduguri existing land use, 1976.
Adopted from Max Lock, 1976.

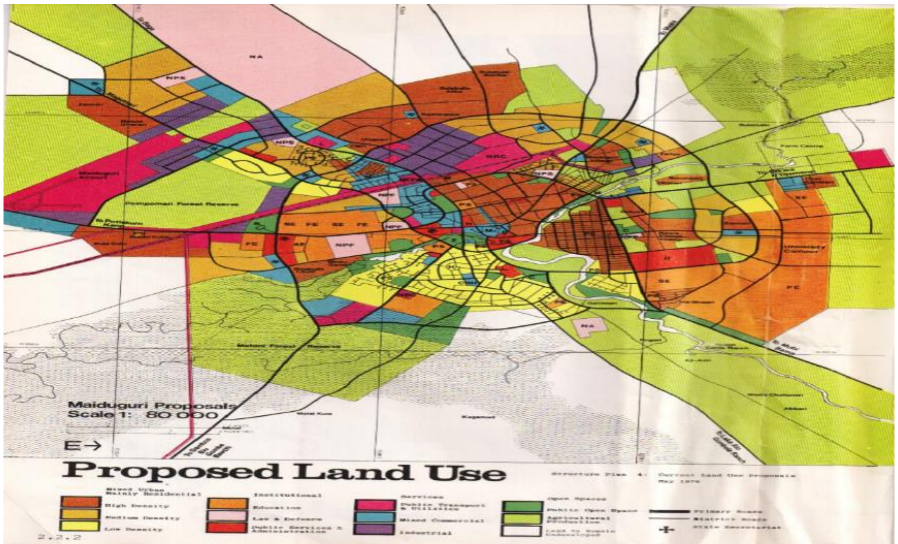


Fig. 10: Maiduguri proposed land use.
Adopted from Max Lock, 1976.

By classifying Maiduguri into wards, this political mapping of the settlement has succeeded in bringing together both planned and unplanned areas, making it difficult to conveniently categorize these wards in accordance with their characteristics. This rapid urbanization within these planned areas has made their drainage systems ineffective because the flood water is beyond their carrying capacity. The expansion of these wards is uncontrolled and disorganized because there are no regards for building standards, drainage, sanitation, road access and public utility services.

Refuse Generation and Disposal by Residents

The issue of dumping refuse indiscriminately may not be unconnected with the lack of planning. The perception of residents on poor refuse management, reveal that the suburb of Dala Lawanti recorded the highest percentage value of 50% pertaining to poor refuse management. Those between the values of 20% and 40% were Bale Galtimari, Gwange III, Mashamari, Hausari, Bolori II and Shehuri North. Wards that were 20% and below are Mairi, Gwange I, Gwange II, Gamboru, Limanti, Bulabulin, Maisandari and Old Maiduguri. Others are Ngomari AP, Bolori I, Mafoni, Fezzan and Jabbamari. It is difficult to establish whether the distribution of this response has taken a particular pattern in terms of the densities in the wards. However, the lowest value of 0% was recorded at the center wards of Limanti and Fezzan, which may suggest disparity between suburbs and city centre. The findings also showed that residents dispose their refuse in any available points which include drainages. Most collection centers have been converted to other uses thereby giving rise to the problem of ineffective refuse disposal in the city. The less efficient a city's refuse collection method, the greater the load on the surrounding environment. In all the sampled wards, waste materials are improperly disposed of near large storm water drainages and road sides. The effort of personnel responsible for the evacuation of refuse from the areas was found to be ineffective (34.3%). It was not until recently that vehicles and containers for refuse collection and disposal were provided by government according to a respondent. The vehicles were, however, inadequate to serve the whole metropolis. Large solid waste dumps are noticed all over the metropolis both during the dry and rainy season. The situation is worst during the rainy season where water running off these impervious surfaces tends to pick up gasoline, motor oil, heavy metals, trash and other pollutants from roadways and parking lots, as well as fertilizer and pesticides from lawns and contaminates water sources. This has been confirmed by Laws and Lauren, 2004 and EPA, 2005.

Urban Heat Island

One major problem of urbanization in Maiduguri is the urban heat island. The main cause of the urban heat island effect is from the modification of land surfaces (Solecki, Rosenzweig, Parshall, Pope, Clark, Cox, and Wiencke, 2005). As a population center grows, it tends to expand its area and increase its average temperature. There are concerns raised about possible contribution from urban heat islands to global warming. Research on China (Huang, 2015) indicates that urban heat island effect contributes to climate warming by about 30%. For example, dark surfaces absorb significantly more solar radiation, which causes urban concentrations of roads and buildings to heat more than suburban and rural areas during the day materials commonly used in urban areas for pavement and roofs, such as concrete and asphalt, have significantly different thermal bulk properties (including heat capacity and thermal conductivity) and surface radiative properties (albedo and emissivity) than the surrounding rural areas. This causes a change in the energy budget of the urban area, often leading to higher temperatures than surrounding rural areas. Surfaces in the urban areas tend to warm faster than those of the surrounding rural areas. By virtue of their high heat capacities, urban surfaces act as a giant reservoir of heat energy. For example, concrete can hold roughly 2,000 times as much heat as an equivalent volume of air. UHIs have the potential to directly influence the health and welfare of urban residents. Within the United States alone, an average of 1,000 people dies each year due to extreme heat. Studies has shown that the mortality rate during a heat wave increases exponentially with the maximum temperature, an effect that is exacerbated by the UHI (Buechley et al, 1972). Major areas where heat islands were observed in the metropolis are the Post Office, Monday Market, Custom and West end Round About due to traffic congestions as the areas serves as convergence zones for a lot of vehicles and tricycles and use of generators for various business more especially during the day in the dry season. Such phenomenon has been confirmed by several studies (Oluseyi, 2007; Adinna *et al,* 2009; Adebayo *et al,* 2017; Tanko *et al,* 2017 and Jimme *et al*, 2018).

Effects of urban expansion on flash floods

Urbanization generally has the effect of increasing the volume of runoff coupled with inadequate urban drainage facilities or poor drainage management. Urbanization generally increases the size and frequency of floods and exposes communities to increasing flood hazards. Flooding in the metropolis is therefore not just related to heavy rainfall alone but, it is also related to changes in the built-up areas which increases runoff from hard surfaces, inadequate waste management, inadequate and silted up drainage systems. The rapid growth and development of Maiduguri has brought about land use changes which also affected hydrological regimes resulting in frequent flooding as shown in Table 5. Furthermore, there was the problem of lack of waste collection sites which also contributed to dumping of waste into drainage channels. The most important structure of expansion that was noticed in the map (Fig. 8), was that Maiduguri urban is rapidly expanding towards the periphery areas of the city.

The DEM based generated flood map shows that the total land mass of Maiduguri metropolis is 145.4 square kilometers, out of which 40.17 square kilometers are categorized as a very high risk flash flood and inundation area, 41.92 square kilometers, moderately risk area, while 63.31 square kilometers, as a low risk area. This is also attributable to the process of urbanization, lack of drainages, blocked drainages and entrapment of flood water even on higher elevations.

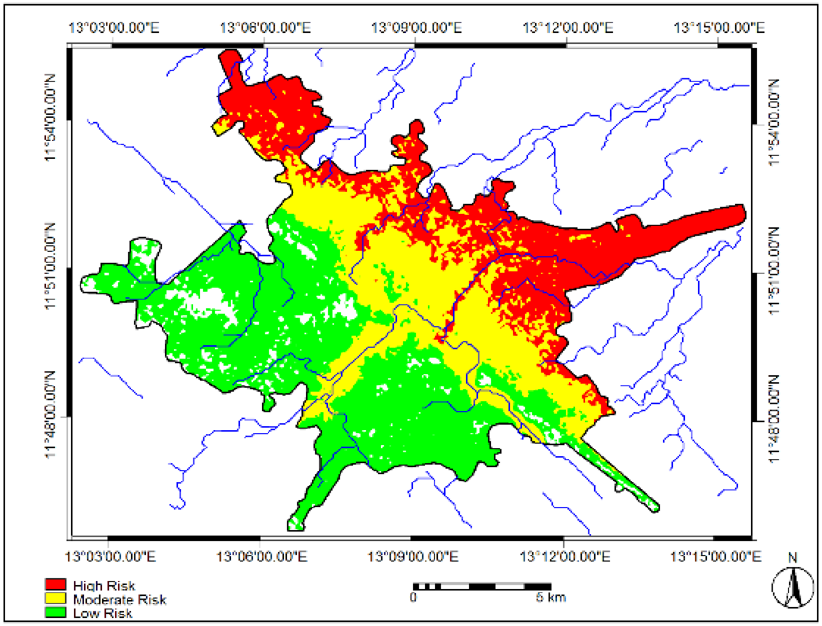


Fig.11 Flood Risk Vulnerable Areas

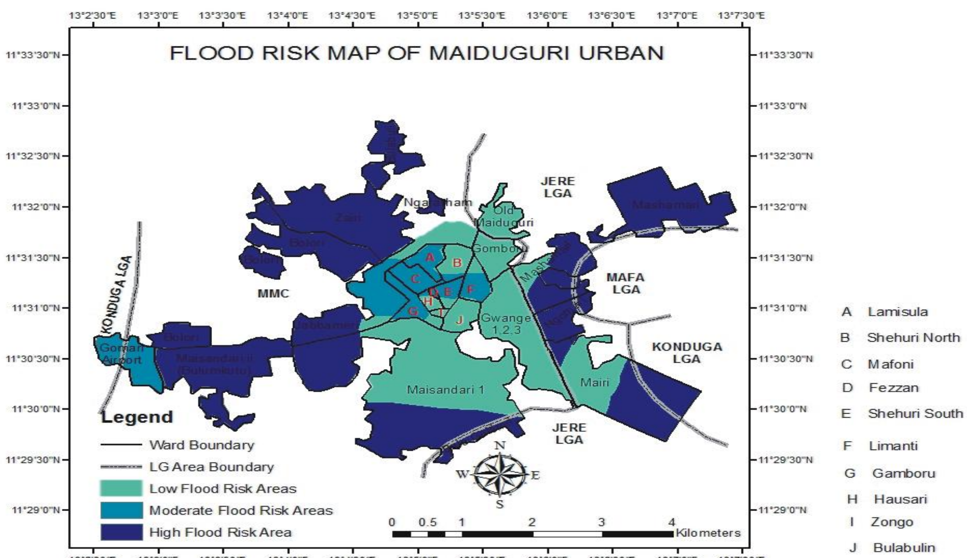


Fig.12 Flood Risk Wards

Table 5: Spatial growth of Maiduguri over the years in km^2

Year	Area(ha)	Area km^2	Percentage Change
1975	4260	42.60	-
1987	8868.47	88.69	51.96
1999	11026.71	110.27	19.57
2012	14540	145.4	24.16
TOTAL	34435.18	344.36	-

Source: Data Analysis, (2014)

From 1975, the metropolis has expanded by 52% in 1987, 20% in 1999 and 24 % in 2012 (Table 5). The increase in the surface runoff is may be due to increased anthropogenic activities over the years from 1975 to 1987, 1999 and 2012 in these area in the form of development of infrastructures and residential buildings in once forested and marshy areas. The percentage changes within the years 1975 to 1987, 1999 and 2012 clearly explain the effect of land cover changes in the area (Fig. 8 and Table 5). Jimme and Bashir (2009) had reported that some areas that were marked as green zones which were considered unsuitable for even farming have all now been occupied by people and it is now associated with devastating flash floods and inundations; forcing people to look towards the periphery for the construction of their houses. Human use of land in the urban environment has increased both the magnitude and frequency of floods. In the process of urbanization, raw land is converted and covered with pavement. This causes an increase in the amount of runoff after rainfall leading to flash floods. As an urban area, much of the land surface is covered by roads and buildings have less capacity to store rainfall. The permeable soil is replaced by impermeable surfaces such as roads, roofs, parking lots, and sidewalks that store little water, reduce infiltration of water into the ground, and accelerate runoff. It has been proved by earlier studies (WMO, 2008) that urbanization increase runoff from 2 to 6 times over what would occur on natural terrain because rain water has less chance to be absorbed. Thus, storm water rushes down the streets and areas that were never known to be frequently under water. According to Hollis (1975), small floods may be increased by 10 times by urbanization and floods with a return period of 100 years may be doubled in size by 30%.

The spatial growth of the metropolis has restricted where floodwaters flow covering large parts of the ground with roofs, roads and pavements, thus obstructing natural channels, slowing water movement to the rivers Ngadda and Ngadda Bul, more rapidly than it did under natural conditions. In old colonial Maiduguri, for example, the urban area increased between 1951 and 1989 from 7.4 to 12.2%. This high degree of surface sealing in the metropolis produces large amounts of instantaneous runoff during rainstorms. Despite the increasing population, governments have not provided adequate planning in terms of drainage and land use for the present and future developments of these areas (Jimme *et al*, 2016). The population of Maiduguri has equally grown from 653,401 people in 1991 to 1.275 million people in 2006 thereby aggravating flash flood and inundation in the low lying parts of the city due to increased surface runoff during torrential rainfall. The combine effects of population growth and urbanization on land use was found to have aggravated flash floods and inundation in most of the newly developed wards.

Conclusion

This study has examined urbanization in Maiduguri and the effects of urbanization on the environment. The findings of the study indicated that the areal extent of the city has increased from $43km^2$ in 1975 to $145.4km^2$ in 2012. This urbanization has generally induced flash floods, solid waste, distorted landuse and environmental pollution. The causes of the floods were largely due to excess solid waste generated and encroachment of large development into natural drainage channels in the metropolis. This encroachment, it is believed, were done without adequate provision for alternative drainage systems. Therefore, poor residential planning and inadequate management strategies could be responsible for escalating flash floods and inundation and other related problems in the city.

Recommendations

Based on the findings of the study, the following recommendations were suggested:

i. The Borno State Urban Development Board (BSUDB) should monitor and ensure land use compliance by the residents in the metropolis and discourage them from building on water ways and in flood prone areas.
ii. There is a strong need for the state government to embark on rapid drainage redesigning and expansion and proper channelization of urban drainages and ensure all drainages covered with strong covers or slaps.
iii. The government should make plans such as drainages and culverts in the newly formed areas to curtail flash floods and inundation in the metropolis.
iv. The Borno State Environmental Protection Agency should live up to their task of timely evacuation of solid waste from the communities.

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