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An analysis of urban sprawl trend using remote sensing data and GIS techniques in Damaturu town, Nigeria

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***Abstract*: -** *This study investigated the trend of urban sprawl and land use land cover change in Damaturu city between 1986 and 2017 using the tools and techniques of Remote Sensing and Geographic Information Systems with the view to examining the direction of the continuous expansion of the city. Landsat imageries of the area were obtained, processed and classified and later overlaid to determine the pattern of changes in land use, direction and extent of expansion during the study period. Findings revealed that the city grows radially which had unprecedented effects on the agricultural lands close to the city. In view of this, the study suggested effective zoning strategy to check the indiscriminate nature of urban expansion whose effects on land use are prominent in the study area. Adequate monitoring by the Development Control Department and other stakeholders in urban planning is equally suggested to mitigate the incompatible land use change in the area.*

***Keywords*: -** *Remote sensing, Geographic information science, Landsat, Urban Sprawl, Damaturu*

Introduction

The concept of urban sprawl is a situation of illegal and unintended urban development, usually at the peripheral parts of the cities particularly disorganized and unplanned construction of houses, industrial/commercial areas, and other unplanned land-uses. This are usually along the main roads or channels of communications that are close to cities that is often called as the urban sprawl. Urban sprawl seems to generally be a common feature of the metropolitan suburban areas which characterized by circumstances where urban development negatively affects urban environment, thus resulting to unacceptable urban situations (Díaz-Pacheco & García-Palomares, 2014).

Urban sprawl is today viewed as one of the processes of urban development. The incident of urban development and growth is a very broad process with a wide range of concepts. The concept of urban Growth and development is a global phenomenon, however, in developing countries, the rate of urbanization is very fast. Urban growth, especially the encroachment of residential and commercial areas to suburban and typically rural areas around the boundaries of city, has been viewed as a sign of economic growth. Bhatta et al. (2009) is of the opinion that apart from urbanization, urban growth is another processes of urban development, and the characteristics of this incidence are so broad, making its implications to be so extensive. Urban growth encompasses the spatial as well as demographic changes within a particular location whereas urbanization is a social and spatial process that happened in societal dimensions of an urban set up (Hegazy & Kaloop, 2015), as such, the rapid urban growth rate created diversity of urban forms.

Urban planning developed over long period (especially the twentieth century), creating different kinds of urban forms that often gave little consideration of the impacts on the environment. This era experienced the phenomenon of urban sprawl as one of the major sign of urban growth (Daneshpour & Shakibamanesh, 2011). The urban sprawl and the increase in size of the urban areas are the major worries of present-day cities. Nevertheless, when the development is increasing rapidly, the municipality will face new problems that are new to the authorities. Previously, cities had well defined boundaries, but with this trend of urban development, they lose their territories by tremendous rate of urban growth (Habibi & Asadi, 2011).

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Multi-perspective urban sprawl scholars documented the intricate interaction and the driving force of urban development such as the economic, social, cultural as well as political factors as the main cause of sprawl. Among these driving forces consist of the rapid urbanization, population, economic development, traffic conditions, agriculture, government policy, migration, industrialization, income growth, as the key influencing factors (Osman, Nawawi, & Abdullah, 2009).

In Nigeria, one chief feature of cities is urban sprawl, resulting mainly due to unplanned and uncontrolled urban growth and urbanization. At present, there is no city in the Nigeria that is exculpated from this menace of urban sprawl. The urban sprawl in the country is usually characterized by unplanned housing development in the suburbs of the cities, where most of the buildings were done without authorities' consent or planning permit. Oftentimes, these buildings are a product of unlawful resident that choose to settle down at the outskirts due to their inability to acquire houses in the city (Nnaemeka-Okeke, 2016). This objective of this studies is to examine the urban sprawl direction and trend in the study area.

Brief About the study Area

Yobe state is one of the 36 states in Nigeria, with Damaturu as the state capital. The state has 17 local government areas. It is located within latitude 11º44'49 North and longitude 11 º.57'38 East with a total land area of 47, 153 square kilometres. The state shares boundaries with Borno state to the east and south-east, Jigawa state to the north while Bauchi and Gombe states to the south-west. It also shares an international border with the Republic of Niger. This boundary stretches over 180km to the north of the state. Yobe state had the population of 2.3 million in 2006 which was projected to be 3.3million in 2016 (National Bureau of Statistics, 2016).

The vegetation of Yobe state is generally Savannah Grassland. Grasses, sparse dwarf trees and shrubs are the most common features of the state. Human activities such as farming and grazing of animals are the major sources of household wealth and income in the state and are worsen desert encroachment. Yobe state government encourages tree planting campaigns in other to control desert enrichment especially at the northern part of the state. The state is multi-ethnic with Kanuri, Bade, Fulani, Ngizim, Bolawa, Kare-kare, Ngamo, Babur/Maga, Hausa and other Nigerian groups constituting the main groups in the state. The Hausa language is widely spoken in the state.

With regard to the economy the state Yobe is relatively small compared to her counterparts such as Lagos, Kano and Borno in Nigeria. The gross state product (GSP), which evaluate the output of annual economic activities of the state, was estimated to be about US$222.99 compared to the national average for the same year put at US$887.63. The state

economy makes contributes about 0.42% to the National Gross Domestic Product (GDP).

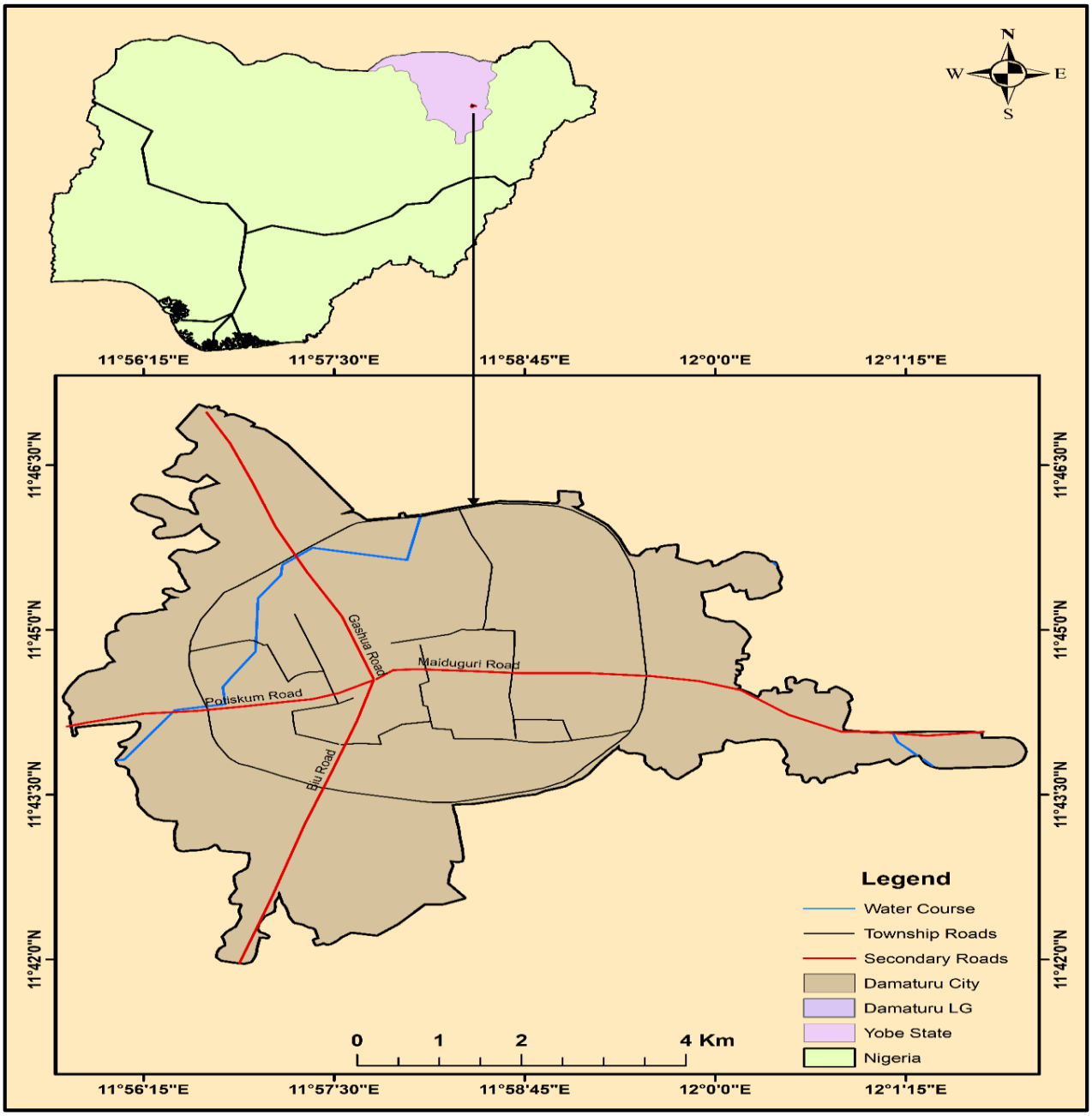

Figure1: The Study Area

Causes of urban sprawl

The causes of sprawl that force unplanned growth and development in the urban zones and the factors that are responsible for unwanted form or manner of urban growth are also fundamentally significant for the investigation of urban growth. The impacts or consequences of urban growth, whether good or bad are also essential to be evaluated towards attaining a sustainable urban development (Basudeb Bhatta, 2010).

The causes of urban growth and those of urban sprawl are relatively the same. In most cases, they cannot be differentiated since both concepts are closely interrelated. Nevertheless, it is imperative to understand that urban growth may be detected without the incidence of sprawl, but urban sprawl cannot be observed without sprawl, as it is this sprawl that persuade urban growth (Bhatta, 2010). Some of the causes of sprawl, for instance the population growth, might produce a coordinated dense growth or inept sprawled growth (Osman et al.,

2009). Also, there are some other causes that are particularly liable for sprawl, as they cannot produced in a compact neighbourhood.

Socio-demographic/Population Growth

According to Couch & Karecha (2006), the factors responsible for urban sprawl can be clustered into two classes: (i) the government planning policies for space and (ii) the general drift of socio-economic transformation in advanced societies. Their study shows that the quest for housing and its characteristic from socio-economic viewpoints is what is essentially persuading the growth of urban sprawl. Citizens living in the municipal will have a propensity to leave the city center and migrate to the neighbouring greener areas majorly due to lesser cost of living (De Ridder, Bertrand, Casanova, & Lefebvre, 2012). This condition is the key motive for urban sprawl occurrences and it was driven by the rapid increase in number of private car owners and the inclination for isolated houses surrounded with gardens (EEA & JCR, 2006).

Again, Jaeger & Schwick (2014) further explained that sprawl is not only the outcome of population increase but similarly the outcome of lifestyles changes that need more urban space. Socio-demographic circumstance involved numerous element such as the economic growth, population upsurge, basic amenities and the proximity to resource base (Boori, Netzband, Choudhary, & Voženílek, 2015). Progress in socio-demographic factor like increasing income and population resulted to increasing demand for housing and other facilities. This condition causes an increase in housing and land prices greatly, resulting in the movement of middle- and lower-class citizens to the outskirt of the urban areas mainly due to a lower property cost (Brueckner & Helsley, 2011; Brueckner & Largey, 2008).

In developed countries, the increase in urban populations will be relatively modest since they have lower growth rates and more than 80% of their inhabitants are already living in urban centers. Whereas in developing nations, they are in the mid of the transition path, where growth rates of urban population are relatively higher. The United Nations report (United Nations Population Fund, 2008), shows that the proportion and number of urban residents will continue to increase rapidly. The global urban population is projected to raise to 4.9 billion by the year 2030. In contrast, the global rural population is anticipated to reduce by about 28 million between the year 2005 and 2030 (UN-HABITAT, 2008). The urban population of Asia and Africa and is projected to be doubled up between the year 2000 and 2030. Hence, globally, the population growth in future will therefore be in cities and towns, quite a number of them will be in developing countries (United Nations, 2015).

Economic Development

The growth of economic base, such as rise in number of working people and higher per capita income, creates the need for more housing space for persons (B. Bhatta, 2009). This development also inspires many developers for more housing construction rapidly. This rapid increase in number of houses and other infrastructure usually creates a diversity of irregular and uncorrelated developments. This is broadly assessed and described based on the key socioeconomic indicators principally, cost of commuting, shift in employment, property tax and change in city revenue, as well as some commercial institutions. Significant number of scholars also agreed that economic factors are among the most important reason for urban sprawl (Habibi & Asadi, 2011).

According to study by Zhao (2016), planning control may not be effectively achieved if economic and political motives are involved. Economic competitiveness and globalization among the countries have instigated the governments in Southeast Asia, to focus attention on economic development in the municipalities to make the cities more economically competitive. This position has however, caused several cities in the region to have higher differences and inequalities between rural and urban areas, at the same time triggering urban sprawl. The rural-urban inequalities reveal that low-income people have limited means of transportation and less job opportunity, thereby affecting their social status (Brueckner & Largey, 2008; Ewing, Hamidi, Grace, & Wei, 2016).

Political

Political factors are among the most significant features of the urban development process (Couch & Karecha, 2006). The lack of strong planning policies at the local and regional level additional leads to the menace of urban sprawl. Bhatta (2010) opined that urban sprawl is not just an unavoidable effect of economic development, but also an outcome of some precise government policies. The spatial planning policy of most government is among the key factors responsible for urban sprawl (Poelmans & Van Rompaey, 2009). Indication revealed that where decentralized and unplanned development dominates, sprawl will inevitably occur automatically. Equally, where development near the fringe of the city is guided by a robust urban policy, a new form of compact urban development will be achieved (EEA, 2006). Though, in many cities, socio- economic, demographic, and physical features are typically viewed as the main causes of urban sprawl disregarding the political factors (Feng, 2008).

Comparison was made of cities in Britain, Brazil and Switzerland Couch & Karecha (Couch & Karecha, 2006) to explore the effect of political factors in inducing the rate of urban sprawl and urban development. They established that urban development rate for a given time is similar to Brazil and Switzerland. But, lacking proper planning policy and implementation, Brazil indicated higher growth rate of urban sprawl. For the same period of time, the highest rate of development was observed in Britain has but with lesser urban sprawl growth chiefly due to the effective implementation of government policies. Thus, based on this comparative analysis, several governments have enhanced their regulatory structures comprised of subdivision regulations, zoning ordinances, and building codes in monitoring urban sprawl (Ewing, Schmid, Killingsworth, Zlot, & Raudenbush, 2008).

Physical Geography

Occasionally the urban sprawl is triggered because of difficult physical terrain (such as wetlands or water bodies, rugged terrain, mineral lands, etc.). This sometimes produces leap-frog sprawl development (Barnes et al., 2001). It is imperative to state that in many cases these problems cannot be handle and thus should be ignored. The types of activities responsible for sprawl increase the size of land required to accommodate people of any given number in another area, which result to sprawl, causing loss of open space especially at the urban boundary (Lichtenberg, 2011). The role of physical geography such as forest planting and zoning requirement are part of the identified essential causes of urban sprawl (Coisnon, Oueslati, & Salanié, 2014).

The process of urbanization caused levels of local traffic jamming to increase thereby causing scarcity of urban open spaces. These trends to progressively create popular opinions against urban growth, normally denoted to as “urban sprawl” and the quest for more compact cities (Chorianopoulos, Pagonis, Koukoulas, & Drymoniti, 2010). In another research, it was also established that urban sprawl is the result of urbanization which is highly related to the physical form of land use (Ngoran & Xue, 2015).

Also, it was recommended that a decent physical organization of land use can not only be used to check urban sprawl but also can be used as a planning control tool. Furthermore, Eid et al., (2007) opine that their theories on the compact neighborhood development may persuade people to use their vehicles less frequently than those in neighborhood were buildings are dispersed. Likewise, areas where houses are integrated with a diversity many shops and local grocery stores may inspire people to stroll more and eat healthier food than in those areas where housing dominate all the lands there (Jain, 2008).

Transportation

Another factor recognized as one of the causes of urban sprawl is transportation. As explained by Anas & Rhee (2006), the affordability of vehicles and the availability of highways and roads are among the key drivers of urban sprawl. According to these scholars, the vehicular-related distortion triggering excessively highway-constructions encouraged by transport planners and engineers, creates urban growth into suburb zones where there is availability and affordability of land (Anas & Rhee, 2006). Even

though there are numerous other factors responsible for urban development, which includes rise in income level, planners and economists agreed that the vehicle ownership is a main contributor but opinions vary widely (Anas & Pines, 2008).

Many scholars appear to agree with the position of Anas & Pines, (2008) on transportation factor as one of the main causes of urban sprawl. Ji et al., (2006) and Brueckner & Helsley, (2011) observed that investment in highway and increasing ownership of automobile as causal to urban sprawl in suburban places. Furthermore, the propensity for people to migrate from cities to areas in the urban peripheral areas led to a substantial damage to natural landscapes and brought about an increased transport demand (De-Ridder et al., 2008).

The construction of highways and expressways creates both congestion in the municipality and rapid development (Harvey & Clark, 1965). Highways are normally considered in planning and projecting sprawl in urban centers (Yang & Lo, 2003), since they are chief promoter of sprawl. It is imperative to realize that transport amenities are vital to cities and its vicinities. Expansion of urban economy and employment opportunities are directly related to the availability of transportation facilities. Thus, transportation amenities can certainly not be inhibited, but rather initiatives to stop linear branch expansion by means of policies and regulations should be encouraged.

Demand of more living space

Residents of the central municipality are dearth in adequacy of living space in many developing nations. This inspires rural area development for additional living space. Societies can acquire new more living space in the fringe of the cities than in the city centers, meanwhile the property cost is not as much as in the suburbs. Conversely, demand for more living space does not always lead to urban sprawl (Deakin et al., 2007). Population density is one of the main worry in this issue related to urban sprawl, especially in cities in developing nations who are several times denser in population than those in industrialized countries (Heberle & Opp, 2008). For that reason, greater per capita consumption of land or living space in urbanized areas is needed in many occasions. In such circumstances, the higher per capita consumption of lands might show enhanced amenities within the boundaries of compact urban areas. Nonetheless, if the need for more living space creates quickly low-density development in the suburb, then that serves as an indication of urban sprawl.

Speculation

Assumption about the potential future growth, or prospective policies and facilities such as transportation may trigger untimely urban growth without appropriate planning (Heberle & Opp, 2008). Numerous election manifestos might also inspire people predicting and speculating the magnitude and direction of future growth and development. Speculation is occasionally attributed to urban sprawl in that speculation creates holding of land for growth and development which is another reason for intermittent expansion. Anticipations of increase in value of land at the urban peripheral cause some property-owners to refuse to give out land sale (Deakin et al., 2007). Expectations may vary, though, between property-owner to property-owner, as does the appropriateness of peri-urban land for improvement, which result is an irregular pattern of land development (UN-HABITAT, 2008).

Development and Property Tax

In general, the costs of development of infrastructure and public services in suburban communities are usually higher comparable to city center (UN-HABITAT, 2008). The costs of maintenance of public services are equally higher in the rural areas. Consequently, the property and development tax is expected to be higher at the fringe of the city. Usually, these taxes are autonomous of a location and in some instances they are lower in the suburb compared the city center (Heberle & Opp, 2008). The main problem of this is that the systems of local tax typically entail developers to pay only a portion of the public-service costs and the community infrastructure cost related to their projects, which exposed development to appear insincerely inexpensive and thereby encouraging urban

expansion and development (Brueckner and Kim 2003).

"Affordable housing" is a word commonly used in referring to housing units whose total amount are considered 'affordable' to those with a relatively lower income. Common way of gauging housing affordability community wide is by determining the number of houses that a family with certain fraction of median income can be able to buy (Glicksman & Lin, 2006). For instance, in a stable housing market, the average household that has half of the households are relatively richer can legitimately acquire the median housing choice, whereas those households poorer than the median income cannot be able to acquire the median house. Thus, according to United Nation, (2015), a balanced market is a situation whereby there is 50% affordability for the median household. Hence, absence of affordable housing in the city push people to the suburb and establish their residences there.

Methodology

Data Acquisition

Data used for this study was primarily Landsat imageries which were acquired from the United States Geological survey (www.earthexplorer.usgs.gov). Landsat data has a global coverage and archive since 1972 and its freely available for public access since 2008 (Wulder, Masek, Cohen, Loveland, & Woodcock, 2012). The images for the study area (Path/Row 186/052) were downloaded free of charge at the end of the rainy season to eliminate the occurrence of clouds.

Table 1: Landsat Data Used in the Study

	Type of Data	Spatial Resolution	Source	Acquisition Date
1.	Landsat 5 (TM)	30m	www.earthexplorer.usgs.gov	21/12/1986
2.	Landsat 5 (TM)	30m	www.earthexplorer.usgs.gov	04/11/1998
3.	Landsat 8 (OLI TIRS)	30m, Pan:15m	www.earthexplorer.usgs.gov	08/11/2017
4.	Google Earth images			

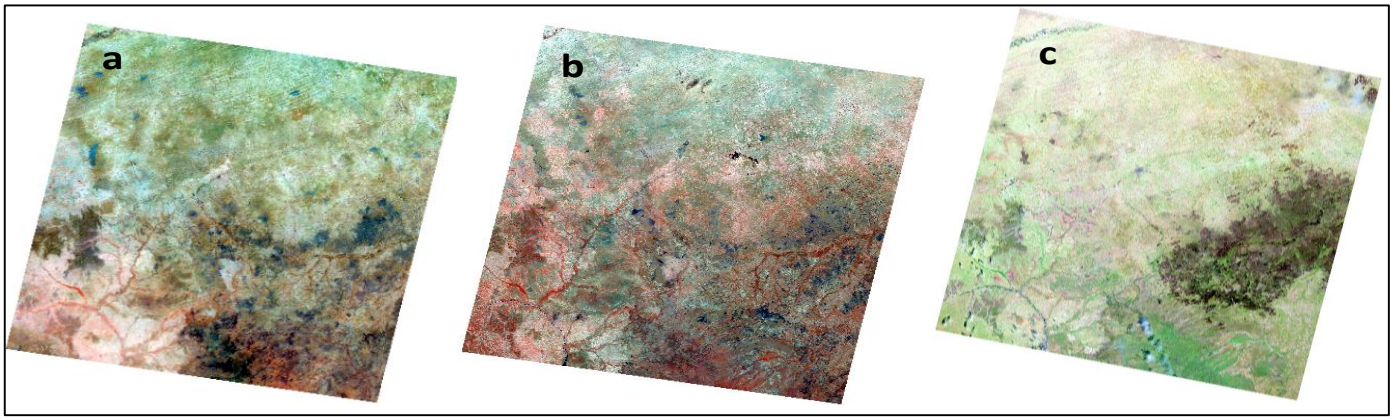

Figure 2: Landsat scenes used in the study: a (1986), b (1998) and c (2017)

Agricultural land use which occupied about 3844.4 hectares (78%) was the major land use around the city in 1986 (Table 4.1). The built-up area occupied 355.14 hectares (7.2%), the open space occupied 534.6 (10.8%) while vegetation occupied 4%. The water bodies and wetland on the other hand made up a very insignificant 2.34 hectares.

Image Processing

The images were first orthorectified to the UTM 33N projection system and the World Geodetic System 1984 (WGS 84) in ArcGIS 10.2. The 1986 and 1998 images were then co-registered to the 2017 (L8 OLI TIRS) image which was taken as the reference image using GCPs collected on the topographic maps. The operation revealed an RMSE of 0.204 which is roughly 6m.

In addition, the images were corrected for atmospheric and radiometric distortions for possible haze, noise and other impurities that may affect the quality of a satellite image (López-Serrano et al., 2016). These operations were carried out using the following equations respectively as obtained from Eastman (2015).

$$L = \left(\frac{Lmax - Lmin}{255}\right) DN + Lmin \quad \text{(Equation 1)}$$

Where L is the radiance expressed in $Wm{-}2sr{-}1$

$$\rho_\lambda = \left(\frac{\pi.\mathrm{L}_\lambda.d^2}{E_{Sun\lambda}.COS\ \theta_s}\right) \quad \text{(Equation 2)}$$

Where

ρ = reflectance

$\boldsymbol{\lambda}$ = spectral band

L = radiance

d = Earth-Sun distance

Esun = the solar atmospheric irradiance and

θ = Solar zenith angle in degree.

By 1998, the built-up area had increased to 570.5 hectares (11.2%) while agricultural lands reduced to 2686.2 hectares (54.4%). This may have been as a result of the creation of Yobe state in 1991 which brought into the city more people with numerous government establishments, parastatals and business activities. Similarly, the government embarked on massive allocation of residential and commercial plots which gave rise to more open spaces. Interestingly, the vegetation also increased to 517.3 hectares which could be attributable to increased planting of trees as more people who moved into the city. Trees were planted on the new residential and commercial areas to provide shade and protection against the harsh winds. The government also complimented these efforts by planting trees to curve the menace of encroaching desertification in the state. The water bodies and wetland increased to 31.4 hectares. This could however be due to increase in the amount of rainfall received in that year.

Table 2: Proportion of Land Use/Land Cover in Damaturu - 1986 to 2017 (Ha)

S/N	LUT	1986	%	1998	%	2017	%
1.	Built-up Area	355.14	7.2	570.51	11.6	1085.6	22.0
2.	Agricultural Land	3844.4	77.9	2686.2	54.4	2238.0	45.4
3.	Open Space	534.6	10.8	1128.6	22.9	1126.5	22.8
4.	Vegetation	197.6	4.0	517.3	10.5	477	9.7
5.	Water Bodies & Wetland	2.34	0.0	31.41	0.6	6.93	0.1

With increased growth of the city due to increase in population and commercial activities as well as improvement in infrastructure, the built-up area further increased to 1085.6 hectares by the year 2017 while the open space increased to 1128.6 hectares. Consequently, the agricultural land use further shrunk to 2238.0 hectares. The vegetation reduced slightly to 477 hectares. These details are shown in figure 4.1 and 4.2.

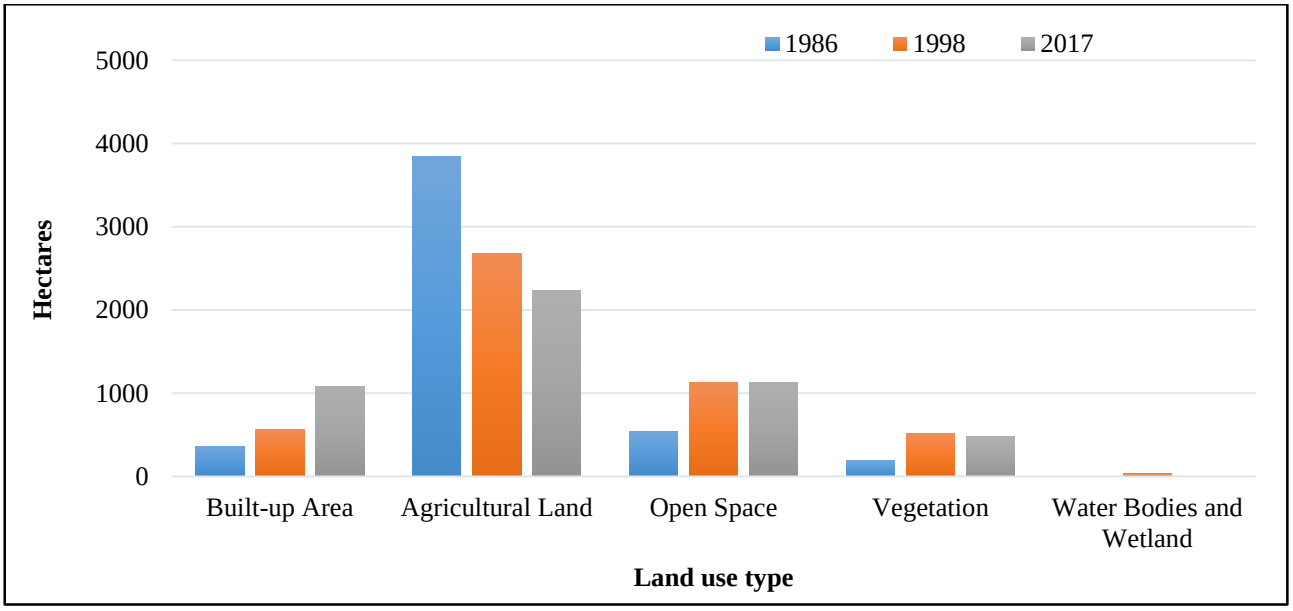

Figure 3: Proportion of Land use/cover in Damaturu between 1986 and 2017

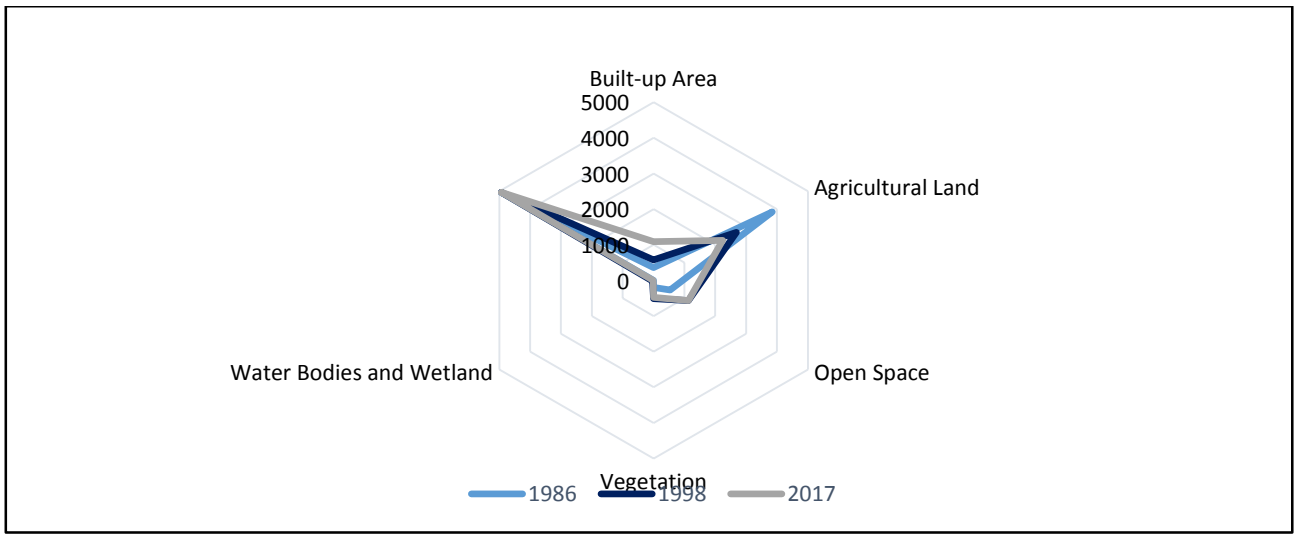

Figure Error! No text of specified style in document.**: Land use/cover change for Damaturu between 1986 and 2017**

The land use/land cover change matrix between 1986 and 1998 (Figure 4.3) revealed that agricultural lands and open spaces were the major land use types that have been converted. These were mostly converted to built-up area. In other instances, these land use types were also converted to vegetation when trees and other vegetation types were planted. Other forms of conversion during this period was from open space to agricultural lands and from vegetation to open spaces when trees were cleared for either agricultural or other purposes.

Results and Discussion

Pattern of Urban expansion

The most practical conversion was between agricultural lands to built-up area. The trend and pattern of this conversion during the 1986 – 1998 study period (Figure 4.9) showed a southward and eastward pattern and direction. The city expanded radially but more intensely towards Maiduguri road where most of the developmental projects and residential plots were allocated. The dark brown areas show the old city while the lighter brown areas show gradual expansion of the city with increasing population and built-up areas. The yellow colour shows areas vulnerable to future expansions while the blue colour shows areas not possibly vulnerable to expansion in the nearest future.

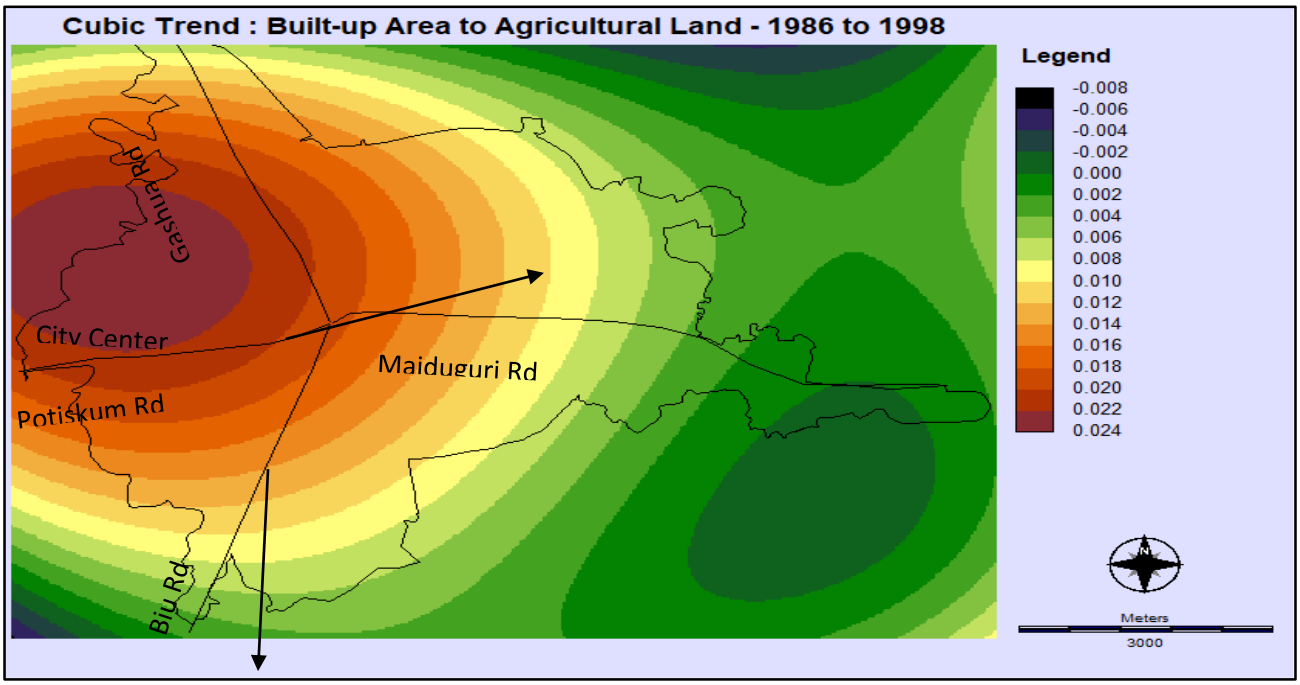

Figure 5: Trend of urban expansion and agricultural lands conversion in Damaturu between 1986 and 1998

The trend of this expansion widened up between 1998 and 2017, encroaching further into the adjacent agricultural lands. During this period however, agricultural lands in the northern and eastern parts of the city were mostly affected by the conversion (Figure 4. 10).

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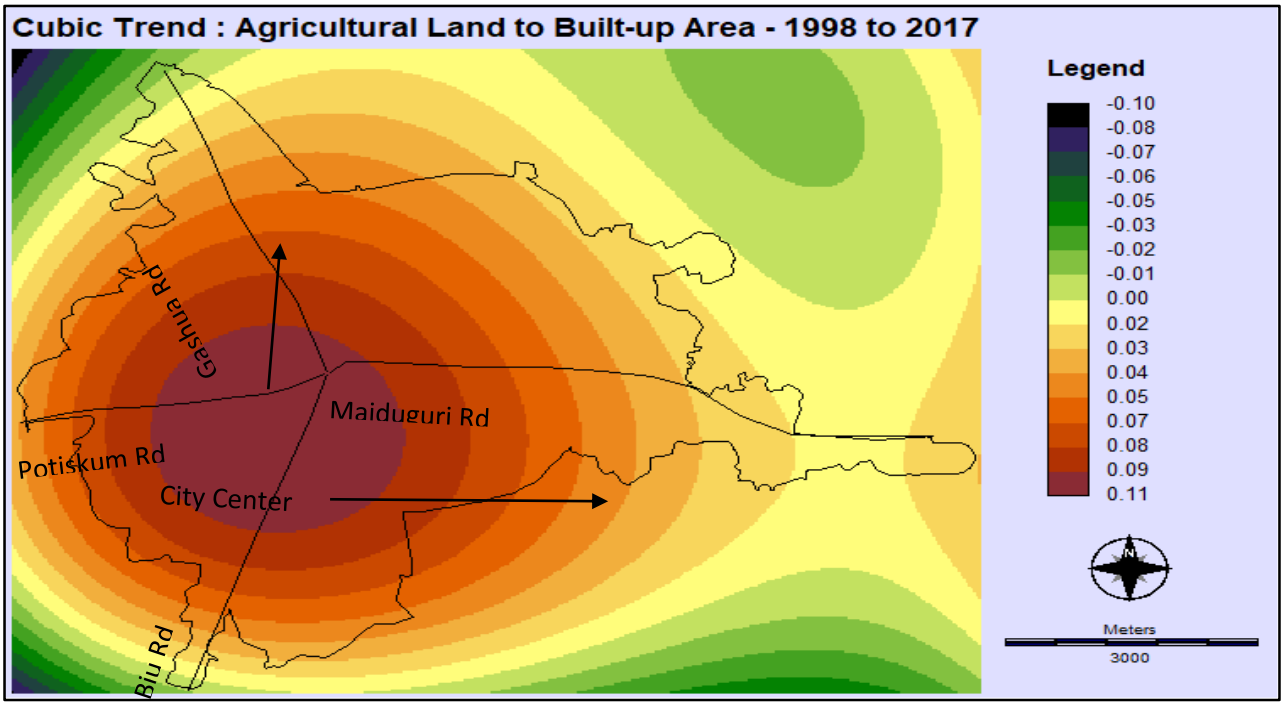

Figure 6: Trend in conversion of Agricultural lands to Built-up area in Damaturu between 1998 and 2017

Urban sprawl researchers with different perspective documented the intricate interaction and manner of urban development causes like social, cultural, economic, and political as the prime cause of sprawl. These driving forces include the socio-demographic/population, political, traffic and transportation conditions, economic development, speculation, and government policy as the main factors (Osman et al., 2009)

Recommendations

In line with the findings of this study, the following recommendations are made:

1. Provision of social amenities and services in line with the pattern of urban growth in the city. Schools, hospitals, water and electricity should thus be provided in the west, south and eastern parts of the city to plan for and accommodate future growth.
2. The agricultural land use is more vulnerable to conversion in the city, there is thus the need to provide farmers with alternative employment opportunities to compensate for loss of their lands.

Assessment of the possible future implications of the urban growth in Damaturu. This may be in form of more studies of urban growth, its causes and consequences are also desirable in the city. This will help policy makers in designing mitigation strategies for the general wellbeing of the people.

Conclusion

The changes of land use/land cover are natural phenomenon which happened in most of the cities of the world. The Yobe State capital Damaturu was not left behind, it is clearly seen that these changes mostly occurred between the various classes of land use/cover at a slower rate between 1986 and 1998 but more accelerated between 1998 and 2017. The conversion was from agricultural lands to built-up areas. The design of the conversion was outspread around the city but more conspicuously towards the eastern and southern part of the city. However, from 1986 and 2017, the agricultural land was reduced by 448.2ha while the built-up area recorded the increase of 515ha. Those conversions were brought about as a result of the creation of Yobe State as well as the location of its headquarter at Damaturu. These developments attracted many businesses to troop in to the city of Damaturu. Also increases the residential, institutional and commercial constructions in the city.

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