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RESEARCH PAPER

Observing land-use/land-cover dynamics in semi-arid environment: Evidence from Damaturu Town and its surrounding lands, Yobe State, Nigeria

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Abstract. The fragile Sudano-Sahelian ecological zone of Nigeria has been classified as a hotspot of land cover change (LCC) that has been suffering from serious anthropogenic and biophysical stresses. Damaturu, being the fastest growing town situated in the region happened to be a victim of this negative development. The purpose of this study is to remotely observe and assess the prevailing land-use/land-cover (LULC) dynamics of Damaturu town and its delicate surrounding lands from the year 1987-2017 study periods. To achieve this, a supervised image classification technique with Maximum Likelihood Classifier (MLC) algorithm was used in ERDAS Imagine version 15 software to classify the three epochs multi-temporal and multi-spectral Landsat imageries (TM 1987, ETM+7 2000 and OLI 2017). The classified LULC maps and their resulting statistics were then used to assess the spatio-temporal aspects of the observed changes by placing the results within the wider context of previous related literature and evidences. Findings revealed that the built-up area has been expanding since 1987 with an annual change rate of 4.5% between 1987-2000, and 5.3% during 2000-2017 respectively. The growth of the town is being accompanied by massive farmlands expansion and vegetal cover (trees and shrubs) lost making the surrounding arable lands seriously disturbed. Thus, if the observed trends continue, the entire studied region will be subjected to severe environmental hazard such as desertification. Overall, the study provides valuable information required for sustainable environmental management.

Keywords: Damaturu; land use/land cover change; remote sensing; multispectral; Landsat imageries

1. Introduction

Human or anthropogenic activities have been for long proven as drivers of environmental change leading to a serious land cover modification across the world. Observing land cover changes (LCC) at local, regional, and global levels could essentially characterize the nature of human-environment relationship. Considerably, the growing

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human population and its activities has a huge impact for altering the original face of the planet earth (Ademiluyi et al., 2008).

The term land cover relates to a physical characterisation of land. In other words it refers to an observable biophysical cover of the earth surface which include water, land, vegetation and built landscapes (Defourny & Bontemps, 2012). While according to Shalaby and Tateishi (2007), viewed land cover change as an extensive term that comprises natural and anthropogenic induced modification of earth's surfaces. In contrast, land use refers to human's definition of land according to suitability and utilization (Ojima et al., 1994), such definition could be residential, agricultural, industrial and many more categorisations (Meyer & Turner, 1992). These two factors are intertwined as they are being used extensively in literature. Environmental change monitoring through land-use/land-cover (LULC) studies have been broadly adopted to derive various information (Geist & Lambin, 2002), which can be used in environmental management and effective decision making processes (Rawat & Kumar, 2015). Information on LULC could provide the fundamental basis upon which the past and present humans interact with the natural environment. Conceptually, drivers of LULC have been classified into proximate and underlying factors (Ojima et al., 1994). Proximate driving forces relates to all human induced activities and practices such as urbanization, agricultural activities, deforestation and other anthropogenic activities which positively alter the virgin state of biosphere, while underlying driving forces refer to socio-political, socio-economic, cultural as well as institutional factors and reasons which directly shape and dictate the proximate-driving factors or processes (Geist & Lambin, 2002), and these factors primarily drives landcover change both regionally and locally. As land cover changes transpired at various periods, rate and magnitude with diverse bio-physical and ecological consequences across regions. Thus, information is required on how such changes happened and at what rate, extent as well as what drives them (Elmore et al., 2000).

Nigeria as a part of developing countries have been seriously lacking information regarding LCC as its population thrive towards rapid urbanization and development. The first ever country-wide Land cover mapping was carried out in 1970s under Nigeria Radar (NIRAD) projects (Ademiluyi et al., 2008). Apart from the NIRAD and Forestry Management, Evaluation and Coordinating Unit (FORMECU) projects, there had never been any attempt to map LCC most especially at national level. Omojola (1997) carried out a LULC mapping and change assessment in a semi-desert region of Nigeria using remote sensing approach, and this could be a follow up to the NIRAD, and FORMECU projects which were carried out earlier. In order to achieve sustainable environmental management, comprehensive land cover monitoring and mapping is required at both local and regional level. For example, north-eastern Nigeria has been earlier classified as a 'hotspot' of land cover change as the semi-arid zone of the country falls more or less within it (Macaulay, 2014). Similar studies conducted by scholars (see, for example, Adams & Mortimore, 1997; Garba & Brewer, 2013; Naibbi et al., 2014; Ogu & Ogbuozobe, 2001) have earlier highlighted that the entire region had suffered seriously from the impact of uncontrolled urbanization, drought, deforestation, unsustainable agricultural expansion and intensification, and this has gravely contributed to serious Land cover modifications that requires periodic monitoring most especially at a local level.

Damaturu being the study area selected from the region (Northeast Nigeria) has been experiencing massive growth without regard to the fragility of the environment. The rapid growth has become significantly noticeable in the last two to three decades. As built-up areas, developmental infrastructures and farmlands extended outwardly from the main town. consequently, the virgin arable lands populated with shrubs and valuable trees were cleared and transformed in a significant way (Babagana-Kyari & Maina-Bukar, 2018; Jajere et al., 2015). Consequently, these developments have led to various conflicting LULC modifications adding much pressure to the entire town and its delicate surrounding virgin land cover in the last two to three decades. Overall, these significant changes have made the environment more susceptible to desertification. However, little attempt has been made in previous studies to observe and evaluate this development within the context of the change drivers. Therefore, the purpose of this study is to observe and assess the general LULC dynamics of the Damaturu town and its delicate surrounding landscape through 1987-2017 study periods using remote sensing technique and GIS.

2. Literature Review

2.1. The drivers of the land use/land cover change

Several related studies have documented and highlighted the potential drivers of the land cover change both regionally and locally in various literature. For example, urbanization and demographic explosion are the key drivers of LULC change across many localities in Nigeria. As in the case of this study, variation in land values and its stratification has greatly led to sprawling out of the town and this consequently expanded the built-up area about four times, from 3.06 km² in 1991 to 12.12 km² in 1999 (Jajere et al., 2015). It was this increase that expanded the built-up area which resulted in a decrease in bare land from about 81 km² to 62 km² and a decrease in shrubland from about 41 km² to 8 km². According to Jajere et al., (2015) highlighted factors such as the siting of the administrative offices and housing estates at the fringes of the town were the primary drivers of the town growth in the past years.

Urbanization which has been defined as economic vitality through increase in built-up pattern or impervious structures of cities and towns has appeared to have serious problems with nature most especially in developing countries of the world (Ojima et al., 1994), and this positively drives-up land cover change through rural-urban land conversions and modifications (Meyer & Turner, 1992). Accordingly, Duraiappah (1998) revealed that 0.3 to 0.5%, which is nearly equivalent to 5-7 million hectares of world arable land is lost per annum due to impact of urbanisation, and Dudal (1982) argued that this is estimated to be doubled by the year 2000 if present trends are continued. In the same vein, Maktav et al. (2005) reported that by the half of 21st century, almost two-thirds of the global population will be dwelling in urban centres and 90% of this will come up from less developed countries. It was reported by Lambin et al. (2001) that this process will substantially lead to serious sprawling out of cities resulting in conflicting land uses across regions and countries which potentially transform existing land uses.

Conversely, in Nigerian urban centres, particularly major towns, where productive socio-economic activities are agglomerated, do attract rural-urban migration and this drives up cities and towns expansion (Cohen, 2006; Farrell, 2018). Similarly, several

scholars around the world have reported factors such as higher income per capita (Seto & Kaufmann, 2003), accessibility to social infrastructures and services (Aduwo et al., 2016; Mundia & Aniya, 2005), rural-urban migration (Lambin et al., 2001; Weber & Puissant, 2003), change in population (Braumoh & Onishi, 2007; Lambin et al., 2001; Serra et al., 2008; Taylor, 1988) as key drivers of urban growth and this, in consequence, translates to unsustainable urban land consumption and conversions.

In the same vein, Opeyemi (2008), Ejaro and Abdullahi (2013), as well as Owoeye & Ibitoye (2016) studied urban land cover change (ULCC) in Nigeria, and they collectively identified factors such as agglomeration of government institutions and functions in state headquarters were main factors that resulted in the city's expansion which massively attracted rural-urban migration leading to a massive expansion of built-up area and paved structures at the detriment of surrounding virgin land and vegetation.

Similarly, government agro-allied policies and programs had seriously impacted on LULC change in most urban centres in Nigeria (Akinsola & Oladele, 2004; Odihi, 2003). Naibbi et al. (2014) highlighted the negative impact of Directorate of Food, Roads and Rural Infrastructure (DFRRI) programs, and policies introduced between 1986 and 1992 has left negative imprints over the study region landscape (Yobe State) as many hectares of virgin lands were deliberately cleared to boost agriculture and improve food and social security. Very meagre studies were conducted to the assess impact of these policies in the environment.

2.2. Remote sensing and land use/land cover

As Landsat imageries provide a long term archive of data for observing the state of the earth, monitoring and assessing land cover changes at both regional as well as in local scale is achievable (Fichera et al., 2012; Macleod & Congalton, 1998), and it is the most cost-effective and reliable technique available when compared to traditional methods of field surveying which is labour intensive and is often inaccurate (Rawat & Kumar, 2015). Many spatio-temporal assessments on LULC in urban or between urban and rural areas had been conducted by researchers across the globe with the launch of first earth resource satellite in the 1970s by the United States. Multiple literatures has proven the efficiency of Landsat data in observing and monitoring land cover dynamics in the semi-Arid environment (Garba & Brewer, 2013; Shalaby & Tateishi, 2007; Zhou et al., 2008).

3. Methodology

3.1. Location of the study

Figure 1 depicts the location of the study area in Nigeria. Like many other Northern Nigerian States, Yobe State was originally carved out from former Borno State on 27th October, 1991, and Damaturu town was chosen as the State headquarters. Relatively, the town lies within the northeast geopolitical region of Nigeria. It is situated geographically on latitude 11°44'48"N, and longitude 11°57'57"E. The town is a nodal settlement connected with various federal highways. The town has a total land area of about 2,366 km² and, a total population of 46,000 peoples according to the 2006 census (NPC, 2016). The main socio-economic activities in the study area are agriculture (peasant farming), civil services, banking and commerce. The study area lies mostly within the Sahel-

Savannah ecological zone of Nigeria which is characterized with savannah-type vegetation. The climate of the area is tropical with two distinctive seasons; rainy season and dry and hot seasons respectively. The rainy seasons set in April and terminate in early September; while the hot-dry seasons last for the rest of the months with an average temperature of 37°C except during harmattan (a dusty cold and dry northeasterly trade wind-blown from the Sahara Desert into the hinterland). During that period the temperature usually drops to about 26°C (Garba & Brewer, 2013).

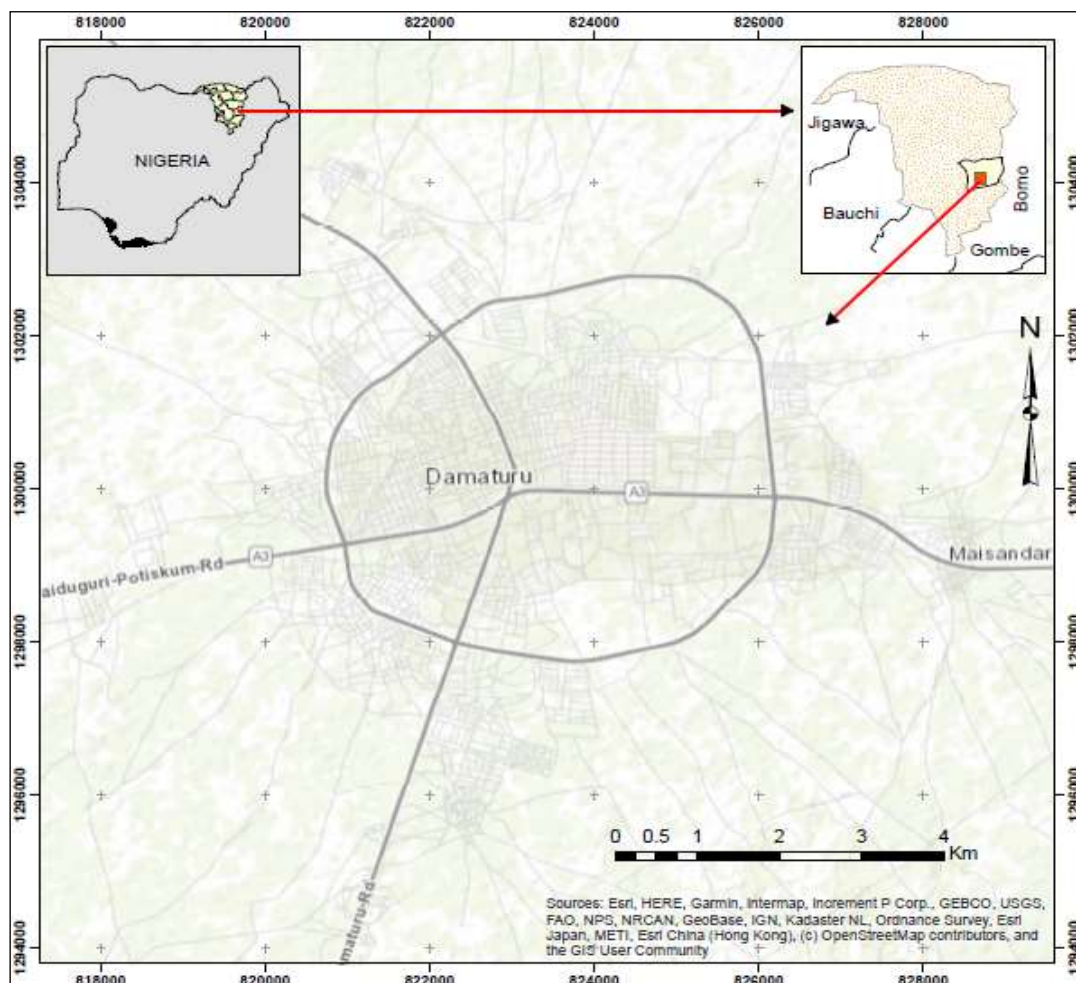


Figure 1. The location of the study Area

The predominant tree species found in the area are Acacia, Dum Palm, Tamarind, and Baobab trees. Shrubs are available all year round while grasses mostly disappear with the termination of rainy seasons due to excessive grazing and fuelwood sourcing mostly carried out by the local inhabitants; and it regenerates at the onset of the wet seasons which usually comes in around April (Naibbi et al., 2014). The Large expanse of areas in the northern part of the state has been engulfed by the menace of desertification, which is sometimes connected to both climate change and man-made activities (Odihi, 2003). The terrain of this area is relatively flat and the elevation approximately ranges between 450

to 480 meters above sea level (Hess et al., 1995). The study area falls within the extensive Mega Chad formation Geologic unit which are characterised with gritty-clays, and loosely un-cemented sands of lacustrine and fluvial origin (El-Nafaty, 2015).

3.2. Datasets

As the principal aim of this study is to observe and assess the LULC change of the study region throughout the selected study periods (1987-2017), three Landsat imageries of the year 1987, 2000, and 2017 were used. The detailed characteristics of imageries used are presented in Table 1. The imageries were sourced from the official website of United States Geological Survey (USGS) via their official site (Earthexplorer.usgs.gov).

Table 1. Characteristics of the Imageries used in the study

Sensor type	Acquisition date	Path	Row	Spatial resolution
Landsat TM	07-Feb-1987	186	52	30
Landsat ETM+7	07-Feb-2000	186	52	30
Landsat 8/OLI	07-Feb-2017	186	52	30

Accordingly, the other datasets used such as the study area polygon shapefiles, the roads shapefiles that are overlaid on the classified thematic map, was sourced from the DIVA-GIS official website (<http://www.diva-gis.org/gdata>). The image tile depicting the study area (Figure 1) was extracted from Landsat seven imagery (February, 2000 scene). The detailed methodology employed to achieve the purpose of the study is presented in Figure 2.

3.3. Data processing and techniques

After areas of interest was cropped from the three acquired Landsat imageries, the panchromatic band (bands 8) of ETM+7 and (bands 8) of the Landsat 8 were used to pan-sharpen the imageries to 15 m resolution from 30 m resolution respectively (Figure 2). This was done using the spatial modeller tools of ERDAS imagine software. This was found necessary because vegetation and buildings in some areas in the study area are sparsely distributed, and it is difficult to be detected accurately in 30 m resolution pixel. Behnia (2005) has highlighted that image pan-sharpening greatly improves the quality of image classification.

Supervised classification approach with Maximum Likelihood Classifier (MLC) algorithms was employed to generate the three land cover maps using the band combinations of 4, 3, 2 (Red, Green and Blue bands) in the Thematic Mapper and ETM+7; and band 3, 4, 5 of the Landsat 8 imagery. Supervised classification of imagery through MLC is the most widely accepted and standard algorithm classifier for assessing land cover change (Emrahoğlu et al., 2003), as it examines both variance and covariance of spectral classes (Lillesand et al., 2004). Using this technique, training samples were selected to generate the land cover classes which are typical representatives of the prevailing land cover types of the study area.

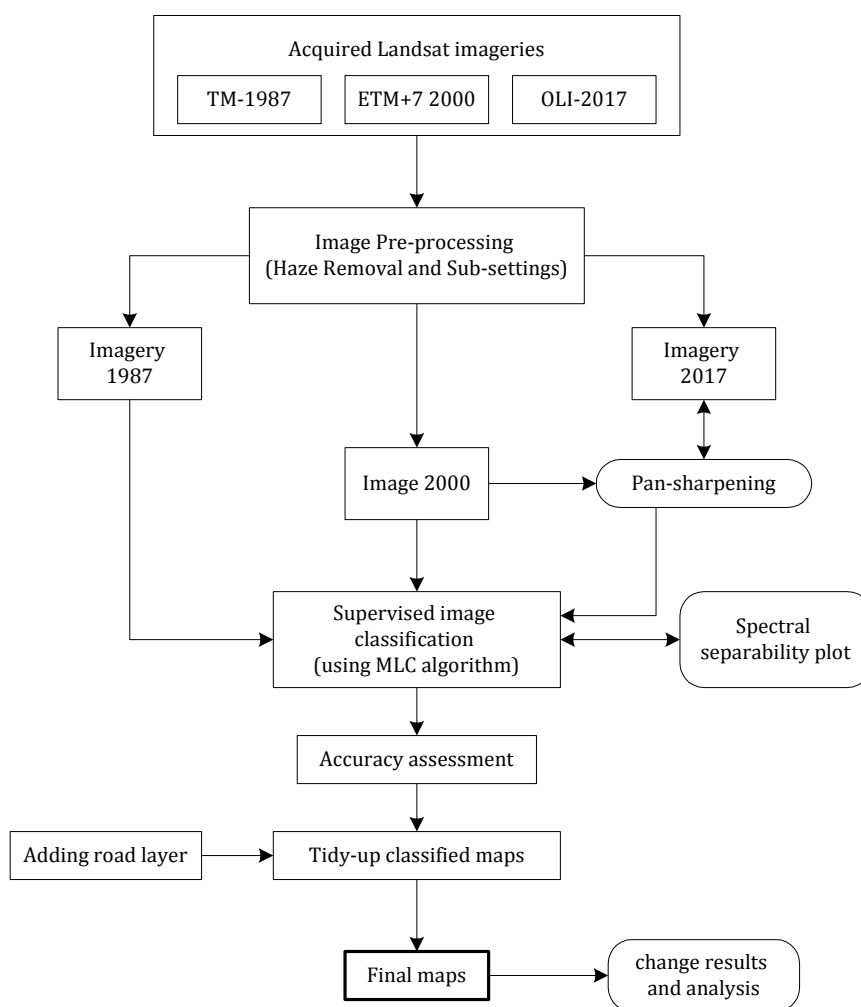


Figure 2. The methodology workflow

Table 2. Detailed definition of the identified land cover types of the study area

Classes	Description
(A) Bare-lands	Represent the undisturbed and uncultivated lands found in between scattered/sparse shrubs and other surrounding virgin land. It also represents fallow fields.
(B) Built-up areas	Comprises all forms of paved structures such as settlements, development infrastructures and tarred roads.
(C) Dry Floodplains and stream beds	Represent seasonally flooded areas and all other forms of dry streambeds and stagnant water surfaces.
(D) Cultivable Fields	These represent all forms of agricultural or cultivable fields (seasonal crop fields).
(E) Vegetation	These represent all forms of vegetation such as Neem trees and other scattered trees, shrubs found in the area regardless of density and heights.
(F) Water	Comprises all forms of stagnant and moving water bodies found in the area.



Figure 3. Google earth images showing the typical representative of the land cover types
 Source: Extracted from Digital Globe (February, 2017 scene).

The six distinctive land cover types were identified and classified based on personal knowledge of the study area, incorporated with aid of the Digital Globe (Google Earth). The statistics of each of the land covers types were generated in hectares (Ha) for quantification so as to detect the Land cover dynamics. These statistics were obtained using ERDAS imagine software version 15. Table 2, and Figure 3 depict the detailed nomenclature and characteristics of the six lands cover types identified.

3.4. Accuracy assessment

Accuracy assessment stands to be a process that must be carried out to determine the correctness of land cover map classification. The accuracy of image classification is generally assessed by comparing the classification with some reference or ground truth data that is believed to be an accurate representation of the actual land covers of the area. The overall accuracy is measured by counting the total number of pixels that were classified consistently in the satellite image, and on the real world and dividing this by the sum/total of sample pixels in each class.

To assess the level of accuracy of the classification for the acquired Landsat (1987, 2000, and 2017) images, for which no aerial photograph or ground-truthing was available; the Simple Equalized Random Assessment Approach (SERAA) was adopted to generate 60 reference points for the whole study area. These points were sourced according to the various classes chosen, and were overlaid on the unclassified imagery to assess if the themes selected falls into the same spectra/group as was used to collect the training samples. A comparison of the Landsat classified images was made with the google earth image. The accuracy assessment statistics are presented in Table 3. Additionally, the use of separability graph (Figure 4, 5, and 6) was also adopted to assess the quality of the image classification carried out.

Table 3. Summary of the classification accuracies (%) for 1987, 2000, and 2017 land cover maps

Classes prod.	1987		2000		2017	
	User	Prod.	User	Prod.	User	Prod.
Built-up	77	60	83	50	78	70
Bared land	90	90	94	92	94	89
Cultivable fields	88	70	88	79	89	80
Dry floodplains and stream beds	70	82	88	78	87	92
Vegetation	86	60	54	77	82	90
Water	70	50	82	90	84	97
Overall accuracy	85		83		85	
Kappa statistics	80		79		82	

Where: Prod. Producer accuracy and User = user accuracy

Herold et al. (2006) highlighted that the choice of land cover types is traditionally determined by actual data capabilities and geography of the study area, hence there is no universally standard system. That is why the above-mentioned classes were selected. Equally, the three classified land cover maps for the following images (1987, 2000 and 2017) were filtered in spatial modeller editor of ERDAS imagine 14 as shown in the workflow chart (Figure 2) in order to eliminate speckling pixels. Focal majority matrix was used with 5x5 low-pass threshold. Area statistics for the land cover types were generated and vector shapefile of the main road networks and existing waterways were overlaid on the final classified maps as shown in Figure 1. Finally, from the land cover maps, the change magnitude, change trend and annual rate change were computed using the following formula (see, for example, Abbas, 2012):

$$\text{Magnitude} = \text{Magnitude of the new year} - \text{Magnitude of the previous year} \quad (1)$$

Percentage change (trend) for each LULC type was then calculated by dividing magnitude change by sum of observed changes between the years concerned and multiplied by 100 as shown in equation:

$$\text{Trend} = \frac{\text{Magnitude of change} \times 100}{\text{Sum of change}} \quad (2)$$

To derive the annual rate of change for each LC type, the trend (percentage change) was divided by 100 and multiplied by the number of study years in between two periods, for example 1986 – 2000, 2000-2017 as shown in equation:

$$\text{Annual rate of change} = \frac{\text{Trend} \times \text{number of study years in between}}{100} \quad (3)$$

3.5. Spectral response of the land covers type

Additionally, spectral separability graph for the six classified land cover types were also generated and plotted using the statistics of the training samples collected. The spectral response of band 2, 3, 4 and 5 was used in all the three Landsat imageries as shown below in Figure 4, Figure 5 and Figure 6 respectively.

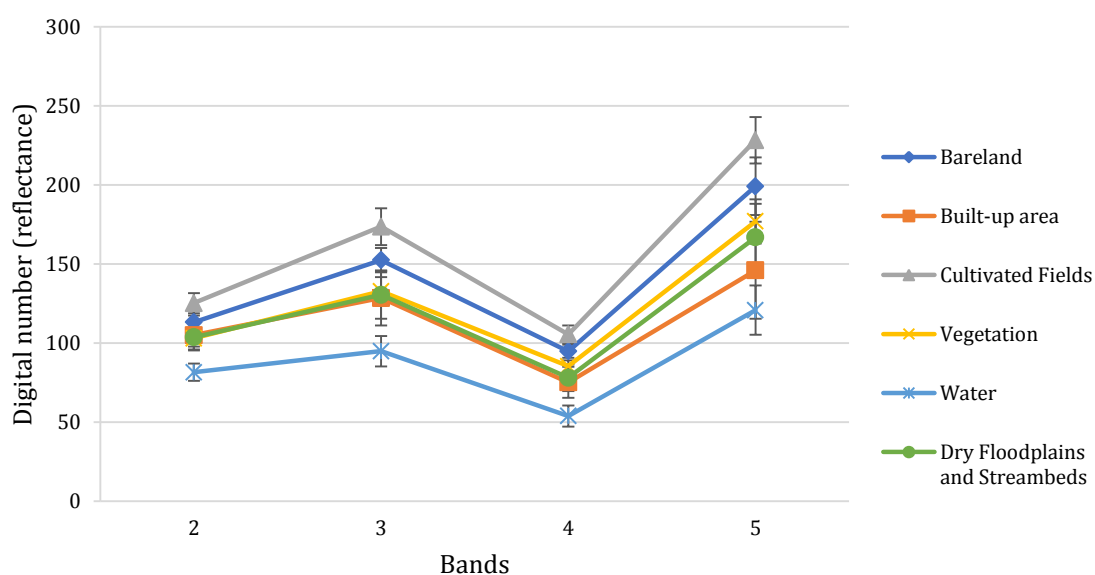


Figure 4. Spectral response plot of 1987 land cover types

The reflectance values (means) and standard deviations of the six land cover classes were used to plot the graph. Stefanov et al. (2001) had applied the use of a spectral graph to assess classification of urban land cover types in semi-arid region of Phoenix Metropolitan Central Arizona.

4. Results

This section present and describe the results and findings obtained in the study. Table 4 present the statistics of the six classified land cover types of the study area as generated from the three LC maps obtained for the year 1987, 2000 and 2017, and these changes are

quantified in hectares' and in percentages. While Table 5 and Table 6 presents the change magnitude and the annual rate of change of the six identified land cover types as well as the change trend from the year 1987-2000, and from 2000-2017 respectively.

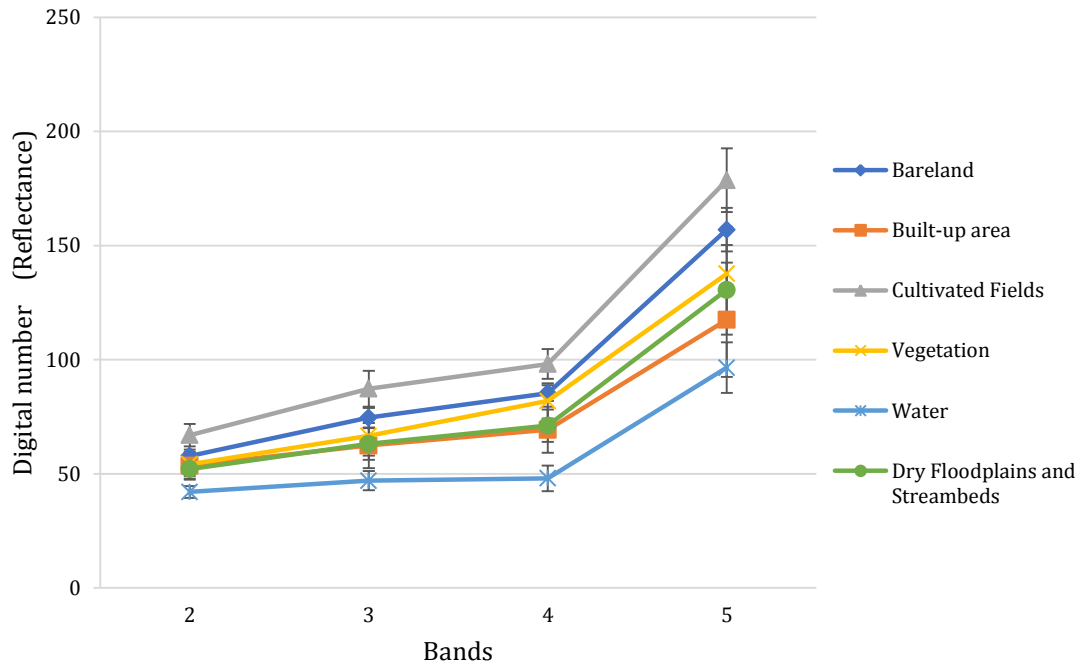


Figure 5. Spectral response plot of 2000 land cover types

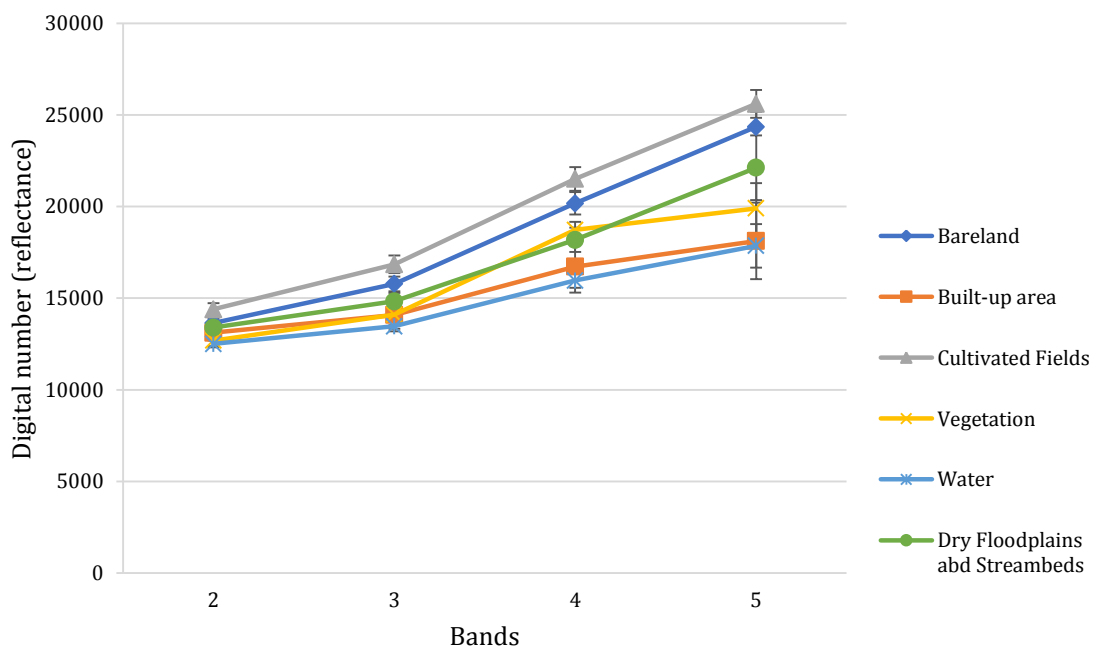


Figure 6. Spectral response plot of 2017 land cover types

Table 2. Change statistics for the six LULC types observed

Land cover types	1987		2000		2017	
	Area(ha)	Area (%)	Area (ha)	Area (%)	Area (ha)	Area (%)
Bareland	17,710.80	41.63	10,707.00	25.10	13,668.70	32.10
Built-up area	461.70	1.10	952.11	2.23	1,905.64	4.48
Cultivated Fields	11,413.20	26.83	16,436.60	38.64	16,003.40	37.65
Dry floodplains and Streambeds	5,322.47	12.51	4,450.68	10.46	3,610.96	8.49
Vegetation	7,392.51	17.37	9,278.64	21.81	7,226.23	17.00
Water	235.44	0.55	711.00	1.67	86.4225	0.20
Total	42,536.12	100,00	42,536.03	100.00	42,501.35	100.00

Table 3. Change magnitude and the annual change rate of the six observed LULC types

Land cover class	1987-2000		2000-2017	
	in hectare	Change rate	in hectare	Change rate
Bare land	-7003.8	3.2	2961.7	2.1
Built-up area	490.41	4.5	953.53	5.3
Cultivated fields	5023.4	2.3	-433.2	0.2
Dry floodplains and streambeds	-871.79	-1.2	-839.72	-1.6
Vegetation	1886.13	1.4	-2052.41	-2.0
Water	475.56	7.0	-624.57	-12.5

Table 4. The change trends from the year 1987-2000, and 2000-2017

Land Cover Class	1987-2000 (in %)	2000-2017 (in %)
Bare land	-37.29	12.15
Built-up Area	34.68	33.36
Cultivated Fields	18.03	-1.33
Dry Floodplains and streambeds	-8.92	-10.41
Vegetation	11.31	-12.43
Water	50.24	-78.32

Figure 8, 9 and 10 depict the thematic land cover maps classified for the three selected epochs, i.e. 1987, 2000 and 2017. While Figure 11, 12 and 13 present the original raw (false colour composites, or popularly known as Red Green Blue combination) multispectral Landsat imageries used for the classification. The red colour represents vegetation, while the brighter areas around the built-up areas represents the cultivated farmlands; and the built-up and floodplains class appeared in grey and black colour as shown in the respective figures earlier mentioned.

The result indicates that cultivated fields (farmlands), bare land (virgin land) and vegetative cover tend to have high areal cover among the six land cover classes identified as graphically presented in (Figure 7). However, the built-up area as the most important land cover class has greatly increased throughout the study periods (1987, 2000, and 2017) as shown in Figure 7 and Table 4 respectively. For example, the built-up area cover-

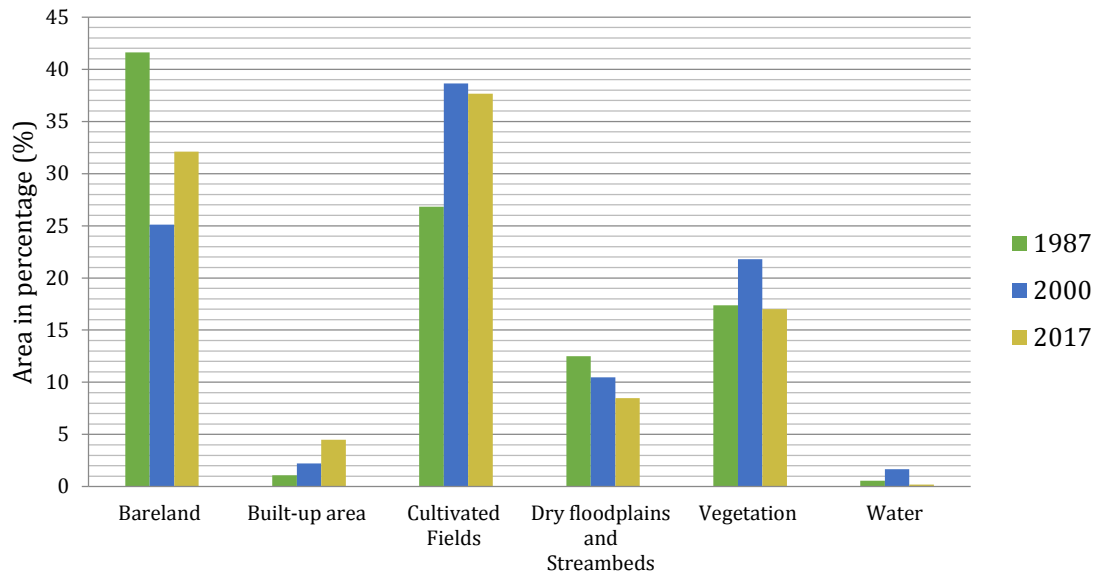


Figure 7. Graphical presentation of the areal cover of the six LULC types

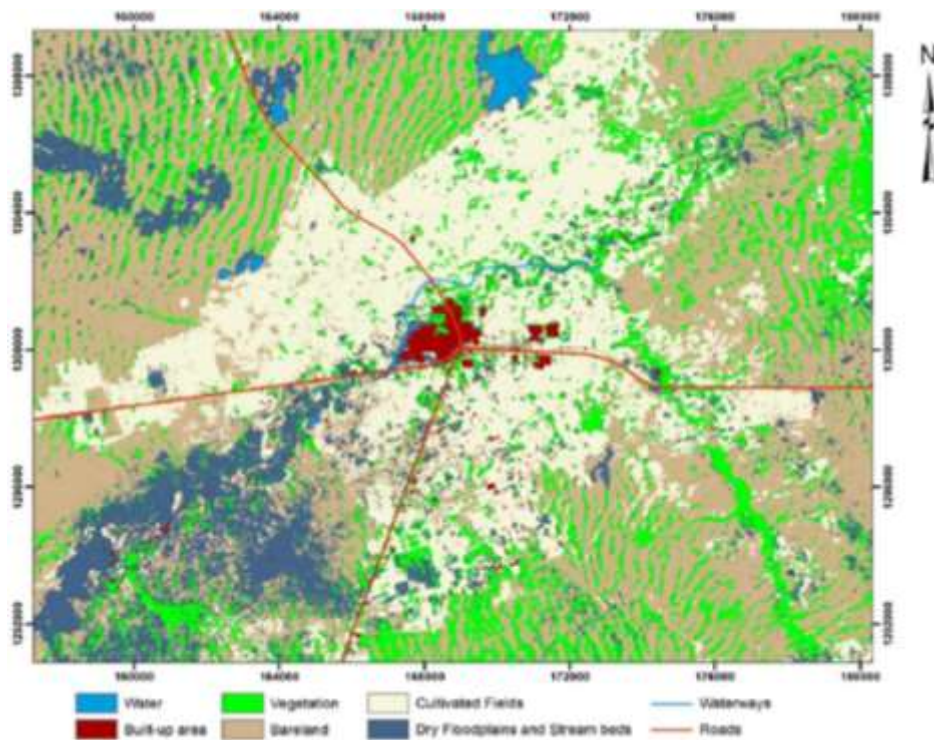


Figure 8. The classified land cover maps of the year 1987

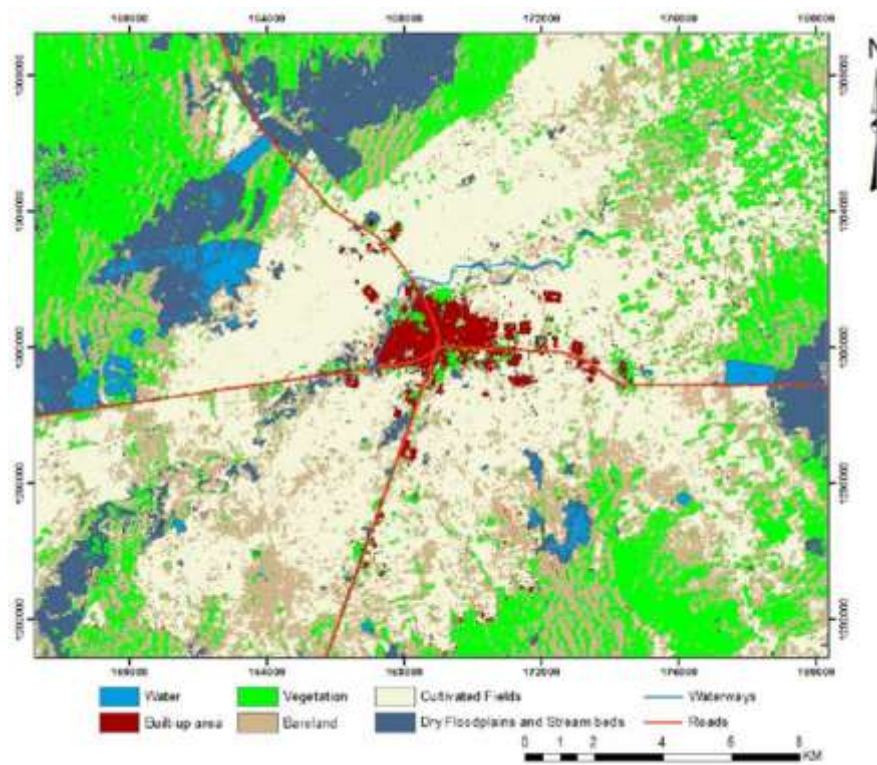


Figure 9. The classified land cover map for the year 2000

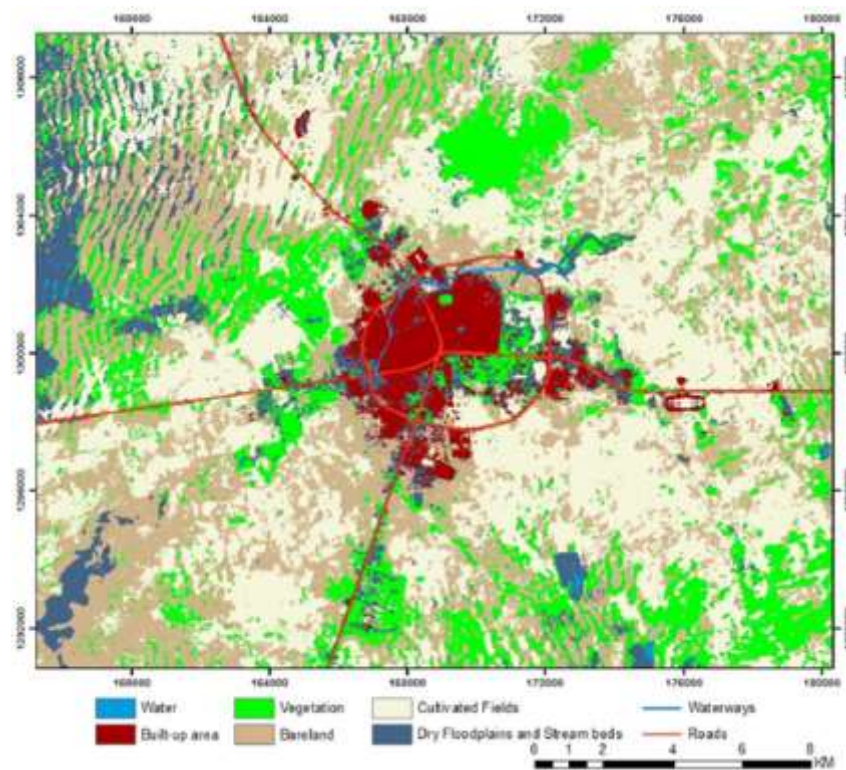


Figure 10. The classified land cover map for the year 2017

ed only 1.1% (461.7 ha) in 1987 but it has significantly increased since then to 2.23% (952.11 ha) in 2000 and 4.48% (1905.64 ha) in 2017 with the annual growth rate of 4.5% and 5.3% between 1987-2000 and from 2000-2017 as shown in Table 4. It can be seen in 2017 (Figure 7) the built-up area has seriously engulfed the cultivable fields (farmlands) areas in the Northern part of the town. Moreover, about 10,000 hectares of arable land have been lost due to the sprawling impact of the town, and what is more frightening is the annual growth of the changes which is placed at the rate of 5.3% between 2000-2017 study periods (Table 4). The impact of these changes is significantly destructive on the general landscape by looking at the rate (Table 5) at which the cultivable areas and built-up areas are expanding at the detriment of the surrounding virgin arable land and vegetation.

It is worth noting that, with the increase in built-up area (paved structures) in 2000 (Figure 7), the cultivated areas were found to have massively expanded, and shifted radically from every axis of the town. While the bareland areas which been defined and classified as undisturbed or stabled virgin land had suffered serious declined from 41.63% in 1987 to as low as 25.1% in 2000 and partly increased to 32% in 2017 (Figure 7). This could be clearly observed from the spectral separability graph presented in Figure 4, 5, and Figure 6, respectively. This is because from the original raw Landsat imagery (Figure 8, 9, and 10) the cultivated areas appeared to have high spectral reflectance particularly in band 4 and 5, unlike the uncultivated areas that are stable. This indicates that the areas have been undergoing serious degradation due to anthropogenic activities (aggressive cultivation), and its growth rate is placed at 2.3% during 1987-2000 study periods (Table 4). However, the patterns of the changes and the annual growth rate have not been the same throughout the study period as depicted in Table 5 accordingly.

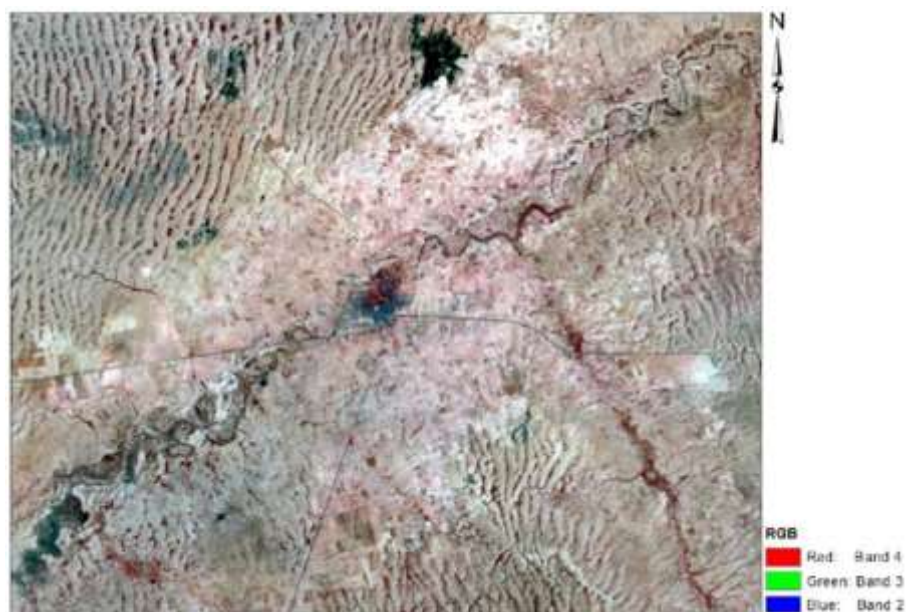


Figure 11. False colour composite of the 1987 Landsat imageries



Figure 12. False colour composite of the 2000 Landsat imageries

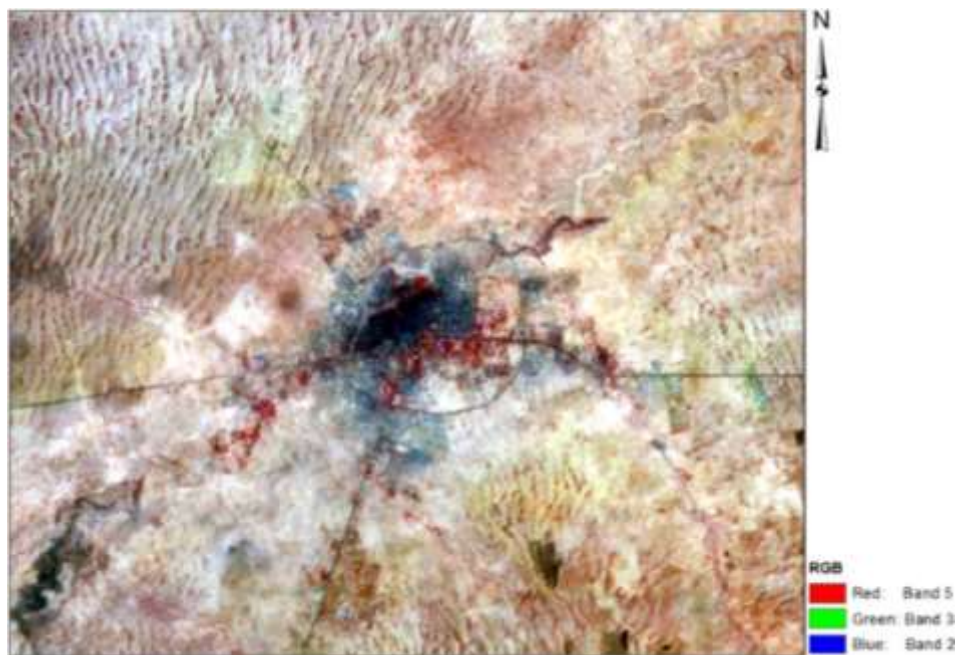


Figure 13. False colour composite of the 2017 Landsat imagery

Furthermore, it was observed that the cultivated lands covered only about 26.83% of the study area but drastically increased to about 38.6% in the year 2000 and slightly reduced to 37% in 2017 resulting in a random pattern of distribution across the whole

study area. A total of about 523.4 ha (Table 5) of cultivable fields was increased from the year 1987-2000 (Table 5). It is also worth observing that water suffered massive decline of about -624.57 ha (Table 5) particularly from 2000-2017 and this has caused the complete disappearance of water bodies in the area.

The natural vegetation cover (trees and shrubs) relatively experienced massive reduction of about -2052.41 ha from the year 2000-2017 and this has happened at the annual growth rate of -12.43% during the 2000-2017 study periods. It could be observed that the sprawling out of the built-up areas and the proliferation of farmlands are the two important land cover modifications observed, and this could have been responsible for the observed dramatic changes on the entire landscape. In overall, there have been complex changes on the fragile land cover of the study region.

5. Discussion

5.1. The change drivers

The results obtained indicate that virtually all the land cover types had changed massively during the whole study periods. As it can be observed from the Land cover change results presented, the town has been experiencing massive urban growth since 1987 with high annual growth rate. The primary reason for this growth could largely be attributed to the administrative status of the town as it was made the state headquarters in 1991 after it was carved out from former Borno State. Accordingly, Jajere et al. (2015) have similarly reported in a related study that the administrative status of the town in line with agglomerations of government functions as sole drivers of massive built-up area expansion and urbanisation. This is very evident across many cities in Nigeria which happened to be an administrative headquarters (see for example, Ejaro & Abdullahi, 2013; Owoeye & Ibitoye, 2016).

This factor is suspected to be the primary cause of the increase of the built-up areas and pave structures of the study region. It should be observed that the built-up area was less in 1987, but it has nearly doubled in size in 2000 as well as in 2017 respectively. It has been reported earlier by Jajere et al. (2015) that it was the variation in land values within Damaturu, and social stratification of the lands within the town that set the pace of the town growth and its outward sprawling. This trend could be seen in the area where the sprawling of the built-up area has engulfed most of the cultivated fields (farmlands), especially in the northern part of the town which was agricultural land in the year 1987 and 2000. It can be adduced that increase in the built-up area of town for the last three decades have far-reaching environmental consequences such as continuous degradation of surrounding arable land of the town, as well as vegetal cover lost (trees and shrubs) as observed in Figure 8 and Figure 9. Thus, if the current annual growth rate for the built-up area of 5.3% as illustrated in (Table 5) are uninterruptedly maintained, in the next coming years the surrounding virgin arable land of the town will be completely put up against the risk of accelerated soil erosion; and this would further facilitate degradation of the general landscape.

Furthermore, demographic factor (population change) might have had an impact on the rapid extension of the built-up area at the detriment of the other land cover types in

the study region as highlighted by Jajere et al. (2015). Nigeria is the most populous country in the entire African sub-regions, its urban centres consumed nearly 10% of total landmass of the country, but still supports 28% of the estimated population (Taylor, 1988), and as well, the urban growth rates were placed at 5.8% per annum in the last three decades (Olujimi, 2009). This point befittingly corroborated with the annual growth rate obtained (Table 4) for the built-up area, for the year 2000-2017, and it is believed that the abovementioned factor had played a significant role in the city's expansion at the expense of the nearby virgin arable land of the town as portrayed in (Figure 13). With this, it could be said that the changing nature and growth of the built-up area of Damaturu ranging from 1987-2000 and 2000-2017 might be connected to change in its population, as reciprocally change in the population leads to increase in the built-up area through the provision of more infrastructures to cater for the growing population needs. This point also corroborated with what Bloch et al. (2014) had reported that the growth of Nigeria's urban population in both absolute and relative terms has been escorted by the increased of existing built-up areas and development of new settlements. This is also demonstrated in the study of (Maktav et al., 2005) who projected that by the half of 21st century, nearly two-thirds of the global population will be living in urban centres; and 90% of this will come up from the under-developing countries. Lambin et al. (2001) added this process would significantly lead to sprawling out of cities resulting to conflicting land use/cover changes across regions. This has evidently manifested in the area under study.

The perceived socio-economic status of the town is what also caused the massive growth of the town as it attracts peoples from neighbouring states, and this is a typical characteristic of most Nigerian urban centres (see, for example, Braimoh & Onishi, 2007; Cohen, 2006). In the same vein, Jajere et al. (2015) have noted this factor as a potential driver which dictates the town growth. Based on personal experience, since the inception of the town as the state headquarter in 1991, it has been receiving an influx of landless seasonal migrants from nearby villages and town just in search of available jobs, and these peoples are popularly referred to as '*Yan chi-rani*' which means seasonal job seekers in the *Hausa* language. This development might have caused the massive expansion of the town, especially in the north-western axis where the main traditional settlement and affordable houses are located. It should be observed in 1987 map (Figure 8), the area occupied by the built-up area was less, but in 2000 (Figure 9) the size of the built-up area was found to have nearly doubled, and relatively basing on personal experience, it could be said that, there is a mutual link between the influx of the peoples from neighbouring state and the built-up area expansion of the town. Moreover, the interconnectivity of the road network infrastructures of the town might have also facilitated the city's growth and built-up area extensions as well. It should be seen in (Figure 1) that the study area is a nodal town which is linked with a trunk 'A' federal highways and this has greatly eased massive inflow of people from nearby neighbouring states of Borno, Jigawa, Gombe and Bauchi States. The transport infrastructures particularly the federal road networks which dissected the town had far-reaching effect on urbanizing the area massively.

5.2. Agricultural land use expansion

Cultivated fields (farmlands) as notable land cover class was found to have changed both in sizes and spatial pattern throughout the study periods (1987, 2000, and 2017)

disrupting the entire landscape. This is in line with the findings of (Ahmed et al., 2015) which reported that West Africa has recorded over 80% increase in cultivated land since 1980. For example, it should be observed in the beginning of the study period 1987 the cultivated fields (farmlands) were centred mostly at the north-western axis of the town while the remaining surrounding lands remained undisturbed and ecologically stable as observed in (Figure 11). But in the year 2000, it was found to have increased as well as in 2017 (Figure 13), leading to a massive reduction of the ecologically-stable bare land. Relatively, this increased in farmlands expansion might be connected to the increased in population of Damaturu town, especially in the last two decades, as increased in population directly necessitates demand for more agricultural lands by the growing population/dwellers. This support the related findings of Madu (2012) which reported earlier that population growth does exerts more pressure on agricultural land use of Northern Nigeria.

Another validity of this point has been found by Lynch et al. (2001) study conducted in Kano city of Northern Nigeria where more surrounding virgin lands are cultivated due to increased demand for agricultural lands which summarily ended up in land degradation. The direct repercussion of this has been seen in the year 2000 map where cultivated fields was found to have expanded at the expense of stable bare lands particularly over the north-western axis of the study region. These areas are being subjected to intense pressure of continuous cultivation by the seasonal subsistence farmers due to its proximity to the low-income high population density residential areas. Consequently, this action is believed to have made the surrounding lands of the town more exposed and vulnerable to soil erosion as seen in (Figure 13); and this is serious environmental concern in nearest future taking into account the annual growth rate of the cultivated field of 0.2%, and the fragile nature of the environment.

Furthermore, change in government agricultural related policies has also triggered and intensified the expansion of the cultivated fields. For example, (Akinsola & Oladele, 2004), study revealed that within the eight years of National Agricultural Land Development Authority's (NALDA) agricultural program in Nigeria, nearly 54,000 hectares of arable land were acquired and cleared for agriculture across various states in Nigeria including Yobe state; and out of these cleared land, only around 15,000 hectares were truly cultivated, while others were entirely abandoned. This action might be suspected to have caused the degradation of the surrounding arable land as well as the massive expansion of cultivated fields at the fringes of the town most especially from 1995 onward.

However, prior to the introduction of this policy in 1992, the study area was still agrarian settlement depending mainly on socio-economic activities of seasonal subsistence agriculture. But with the introduction of the above-mentioned program in line with government programs such as that of Directorate of Food, Road and Rural Infrastructure (DFRRI), the agricultural activities intensified which in turn has disturbed the surrounding fragile environment as practically observed in the year 2000 study period. Naibbi et al. (2014) highlighted this program (DFRRI) as the notable driver of land cover degradation especially the loss of natural vegetal cover over the entire state in his related study conducted in the southern part of the state.

5.3. Critical reflections and future study

In the course of conducting this work, some methodological shortcomings were regrettably encountered. Spectral confusion was noticed in the final classified land cover maps produced using the Maximum Likelihood Classifier algorithm (MLC). For instance, in 2017 classified land cover map (Figure 10), built-up area class was spectrally confused with flooded/dry stream beds and bare land due to the similarity in reflectance in the RGB bands (Figure 13). The similarity could be clearly seen in the sampled representation of the land cover classes extracted from Google Maps as depicted in (Figure 2), where for example, the bare land and cultivated fields (farmlands) look nearly similar in appearances even though they are not the same. This great confounding issue has resulted in the least classification accuracy, and this might have affected the relative statistics generated for the six selected Land cover classes. Future study should improve on this issue.

Generally, the spectral separability graphs presented in (Figure 4, 5, and 6) effectively assesses the classification accuracy. The somewhat overlapping of some of the classes (built-up area and vegetation mostly shrubs) especially in band 2 and 3 are majorly caused by nature of the environment (semi-arid) as well as the small size and sparse distribution nature of the aforesaid features which make it difficult to be detected effectively at the 30m spatial resolutions, and hence spectrally confused. Equally, Stefanov et al. (2001) and Alrababah and Alhamad (2006) highlighted this factor in their study as it influenced training data collection leading to great commission and omission errors and consequently amounting to classification errors. However, the use of higher resolution, multispectral remote sensing imagery (such as IKONOS and Quickbird imagery) could have alleviated the difficulties aforesaid by providing a pure definition of training data samples of the studied area.

Furthermore, lack of more consistent cloud-free Landsat imageries especially those covering the study area in dry season periods have also been identified as a great impediment in this study, as well as the effect Scan Line Corrector failure (SLC-off) of Landsat 7 mission. It was this factor that necessitated the selection and spacing of the three Landsat imageries used. The initial choice preferred was to use four satellite imageries with equal years spacing, but unfortunately, the required imageries were not obtained due to the above mentioned limitations.

6. Conclusion

The current study made an effort to observe and assess the LULC dynamics of Damaturu town, and its surrounding lands using multi-temporal and multispectral Landsat imageries aided with supervised digital image classification techniques. The study has construed the observed changes within the context of the change drivers, and this was effectively done using related literature that were associated with the study region. Although, some studies have earlier struggled to explore the problem, but none of the previous studies had attempted to comprehensively view it from this current perspective.

Overall, the study reveals that in the last three decades, Damaturu and its surrounding landscape had experienced dramatic and unsustainable land cover changes

and transformation. Basically, the built-up/urban area has been expanding increasingly since 1987 with a high annual growth rate of 4.5% and 5.3% between 1987-2000 and from 2000-2017 respectively. Massive natural vegetal cover (Trees and Shrubs) degradation and cultivated fields (farmlands) expansion have accompanied the town's growth making the surrounding landscape of the town ecologically-unstable and fragile. It was found that uncontrolled urbanization in line with administrative status of the town as well as provision of more infrastructures and a shift in government policies and population change was observed as the key drivers of the unsustainable changes observed. However, understanding the main causes of the observed changes appeared to be more complex than expected, but related literature has equally accounted that the aforesaid factors are the culprits. Thus, if the present trend observed continues, the entire landscape of the studied region will be subjected to severe environmental problems such as desertification and accelerated soil erosion. Overall, the outcome of this study has provided an insight on the current condition of the general landscape, and as such it provides the concerned authorities with vital information which will be used especially by the State ministry for environment and other relevant authorities to check the unsustainable practices and actions so as to curb the further degradation of the environment.

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