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Analysis of Land Use Land Cover Changes Using Remote Sensing Data and Geographical Information Systems (GIS) at an Urban Set up of Damaturu, Nigeria

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Abstract: Change detection is useful in many applications related to land use and land cover change (LULCC), such as shifting cultivation and landscape changes. Land degradation and desertification. Remote sensing technology has been used for the detection of the changes in land use land cover in Damaturu town Nigeria. The main objectives of this research is to derive the land use/cover change map of Damaturu town from 1986 to 2017 and to quantify land use/ land cover change in the study area. Methodology employed while carry the research includes three satellites images for the year 1986, 1998 and 2017 were downloaded from USGS websites and used for detecting the land cover changes. Ground truth points were collected using google images and used for verification of image classifications. The accuracy of images classification was checked using ground truth point which showed the overall accuracy of 84.6% and a kappa coefficient of 0.89 which indicated that the method of classification was accurate. In the process of the research work, an increased was recorded in the built-up area which rose from 7.2% to 22.0%, open space increased from 10.8 to 22.8%, vegetation from 4.0% to 9.7%, water bodies from 0.0% to 0.1% while agricultural land decreased from 78% to 45.4% due to increase in interest of building as a result of the expansion of the town. The study arrived at the conclusion that there has been a significant land use change due to increase in population and development interest in built up areas which resulted in increased of amount of agricultural land being converted to build up areas over the period of 31 years.

Keywords: Remote Sensing, Geographic information systems, Landsat, Land use, Land Cover

1. Introduction

The concepts of land use and land cover change, which is fundamental to the sustainable development discussion is considered as one of the major driving forces for changes on the global environmental. Land use/land cover change has been studied from different standpoints in order to ascertain the exact causes of land use/land cover change, and their consequences. Urban growth, especially the transfer of commercial areas as well as the residential land to rural areas at the fringe of city areas, has been considered one of the great signs of economic development [1].

The land use/ land cover shape of an area is a result of socio-cultural and natural factors. Research on land use/cover and the potentials for their maximum use is necessary for the planning and application of land use programs to meet the growing need for the basic welfare and needs of the people.

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One of the key driving forces of change on the global environment is the Land use and land cover change (LULCC), which is principal in the sustainable development debate. The rapid changes of land use and land cover, especially in developing countries like Nigeria, are usually characterized by land degradation and widespread urban sprawling, or the conversion of agricultural land to other uses that result in huge cost to the surroundings [2], [3].

Two distinct terms which are used interchangeably in relation to urbanization are Land use/cover [4]. The first concept 'land cover' refers to the physical features of earth's surface, comprising of soil, water, distribution of vegetation, and some other physical features of the earth surface, including those produced solely by human activities such as residential settlements. On other hand, the term 'land-use' refers to the way in which humans use their lands, on the basis of their functions for various social and economic activities. The natural as well as socio-economic features of the land is the outcome of the utilization of the land use/ land cover of given place by man in space and time. Providing vital information regarding land use and land cover and opportunities for their maximum use is important for the choice, planning and execution of various land use programs to meet the ever-increasing demands for basic man' welfare and need. Provision of such information would also help in monitoring the changing aspects of land use, especially the emerging demands of population increase [5].

Land use and land cover change is usually described as an important instrument for assessing diverse global change in spatiotemporal scales [6][7]. This concept is a dynamic and endless practice [8], thus, wider study on LULCC pattern is imperative together with their environmental and social consequences at different temporal and spatial scales [9]. It is a general, and important process that is driven by human activities, which in some instances, it as well pushes changes that affect society [10]. Research on the modifications taking place in different land uses are imperative for overall environmental monitoring and evaluation [11].

There are significant number of methods available for assessing and detecting land use and land cover change. Prominent among them and most widely used by researchers in the field is the GIS and remote sensing technique [12]. With the discovery of remote sensing and Geographical Information System (GIS) as tools for land use change detection, it gave land use/cover mapping a useful and comprehensive way of enhancing the choice and selection of areas designed for urban, agricultural and industrial areas of a city [13]. The use of remotely sensed data has made it possible to examine various changes taking place on land at low cost, in a lesser time, and also with high degree of accuracy [14], [15]. Furthermore, this remote sensing, together with the GIS provides an appropriate platform for spatial data acquisition, update, analysis, and retrieval [16][17].

With the discovery of higher spatial resolution satellite images, more innovative image processing and GIS tools has occurred. Remote sensing technique has been extensively used in updating land use and land cover maps, which has become one of the most important applications of remote sensing. In this study, remote sensing and GIS techniques are also applied to detect urban sprawl and LULCC in Damaturu for the purpose of exploring how the land use has been changed in Damaturu for the period of 1986 to 2017. The specific objectives of this research were to derive the land use/cover change map of Damaturu town from 1986 to 2017 and to quantify land use/ land cover change in the study area.

The evolution of cities can be traced to the beginning of human civilization. Urbanization refers to the intricate spatial and physical change in urban areas that influences a different facet such as demography, social, political, economy, and the environment at large. In many parts of the world, many municipalities face the problem of disproportionate growth that usually resulted to 'urban sprawl'. Urban sprawl is generally recognized by many as uncontrolled and unplanned outward growth from the center to the periphery, primarily due to increased human population and resulting to serious burden on the boundary which largely contributes to adverse effects on the city and its environment [18], [19]. These increases in turn require corresponding increase in residential and institutional spaces, urban infrastructure such as hospitals, schools, roads and other commercial establishments. Urban sprawl is thus a response to confusing sets of social, economic, physical and political forces irrespective of the level of urban development [20].

The rate of urbanization is high in Asia and Africa with Nigeria having the highest contribution to the global urban population by the year 2030 [21]. Cities in Nigeria therefore face the challenge of increasing and unregulated expansions. Damaturu which is the focus of this study became the capital city and seat of government of Yobe state, north-eastern Nigeria when the state was created in August 1991. Since then, the city has been experiencing urban sprawl due to mass influx of people from rural areas in search of greener pasture. The government has at various points, constructed offices and residential accommodations to carter for public official, businessmen and other government employees of the state. This is in addition to the low-cost housing estates, schools, hospitals and roads the government constructed in its bid to provide infrastructure to the people. In addition, private organizations such as banks as well as individuals have also invested heavily in private constructions which cumulatively contributed to the rapid expansion of the city.

2. Literature Review

2.1 Concept of Land use/Cover change

The concept of Land use and land cover change, which is fundamental to the sustainable development discussion is considered as one of the major driving forces for changes on the global environmental. Land use/land cover change has been studied from different standpoints in order to ascertain the exact causes of land use/land cover change, and their consequences. Urban growth, especially the transfer of commercial areas as well as the residential land to rural areas at the fringe of city areas, has been considered one of the great signs of economic development [2]. The land use/ land cover shape of an area is a result of socio-cultural and natural factors. Research on land use/cover and the potentials for their maximum use is necessary for the planning and application of land use programs to meet the growing need for the basic welfare and needs of the people. Land use and land cover change detection is very important for greater understanding of the dynamics of landscape changes within a particular period of time. Land use/cover changes is an extensive and rapidly growing process, majorly caused by anthropogenic activities as well as some natural phenomena that in turn, causes changes that affect the ecosystem [22], [23]. The significant changes associated with land use and cover, especially in developing countries, are usually related to widespread urban sprawling and land degradation and the conversion of agricultural land at the expense of environmental quality [2]. It is believed that anthropogenic activities have greatly altered the land cover many cities in the last 30 years. Land, is considered as one of the important natural assets that sustain agricultural productions. Entirely, the eco-system, which encompasses water, soil, and plant provide communities with energy source, food, shelter and other necessary things for human survival. It is therefore necessary to observe the changes in land use/cover, with the sole aim of determining its effect on ecosystem such that adequate for sustainable land use can be design [24][25].

Land use and land cover change is described as a significant instrument for evaluating spatial changes at different time scales. The effects of Land use and land cover change on the survival of the ecosystems are gradually becoming significant issues in research. Human activities appear to be the important factor causing the changes that resulted in the current state of the environment. Changes in the land cover create changes to the balance of water, energy and the geochemical parameters at the local, national and global level. These changes will unavoidably affect the sustainability of environmental resources [26]. Thus, understanding changes to landscape patterns and relationship between human activities and natural environment are vital for effective land use planning management decision.

2.2 The GIS and Remote Sensing as LULCC Detection Tools

From the numerous available techniques for assessing and detecting land use and land cover change, the most widely used among them is the GIS and remote sensing technique [27][28]. A GIS (Geographical Information System) is a decision support system that can aid in municipal planning. The use of GIS technique has become very widespread within the discipline of urban studies. Some scholars employed GIS technique to examine the effects of urban sprawl on the landscape. The GIS shows the pattern of urban sprawl by computing the distances of new suburban and the sprawled areas from roads and city centers [29].

With the discovery of Geographical Information System (GIS) and remote sensing techniques, land use and the cover mapping has been providing a detailed and vital information as well as useful approach to enhance the choice of areas designated for urban, agricultural, and/or industrial region of a city (Selcuk et al., 2013). The advent of remotely sensed data made promising to examine the changes in land cover in a lesser amount of time, and at very low cost (Kachhwala, 2008). This technique together with GIS tool, offers an appropriate platform for spatial data analysis (Chilar, 2010). The introduction of spatially high-resolution satellite imagery with more advanced image processing and GIS tools has led to a shift to more consistent and routine monitoring of land use change and land cover patterns [30].

The remote sensing appears to be a suitable means of urban data to support spatial studies [31]. It is undisputable fact that the study of the earth as a modern science, which examine the earth's changing environment through remote sensing tools (by means of aerial photographs and satellite imagery) [32]. Exploring the pattern and process of urban growth using the remote sensing data, assist us to understand how changes is taking place over time on the urban landscape. This understanding comprises of: the rate of urban growth, the spatial configuration of urban growth, whether there is any disparity in growth spatially or temporally, whether there is any inconsistency in the experimental and predicted growth, and lastly whether there is sprawling in the growth or not [33].

3. Description of 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 11^o 44' North and longitude 12 ^{o}57' East with a total land area of 47,153 square kilometres as in Fig . 1. 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 180 km 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 [34]. 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 by desert encroachment. Yobe state government encourages tree planting campaign in other to control desert encroachment especially in the northern part of the state. The state is multi-ethnic with Kanuri, Bade, Fulani, Ngizim, Bolewa, 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. And, economically, the state is relatively small compared with states like 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 contributes about 0.42% to the National Gross Domestic Product (GDP).

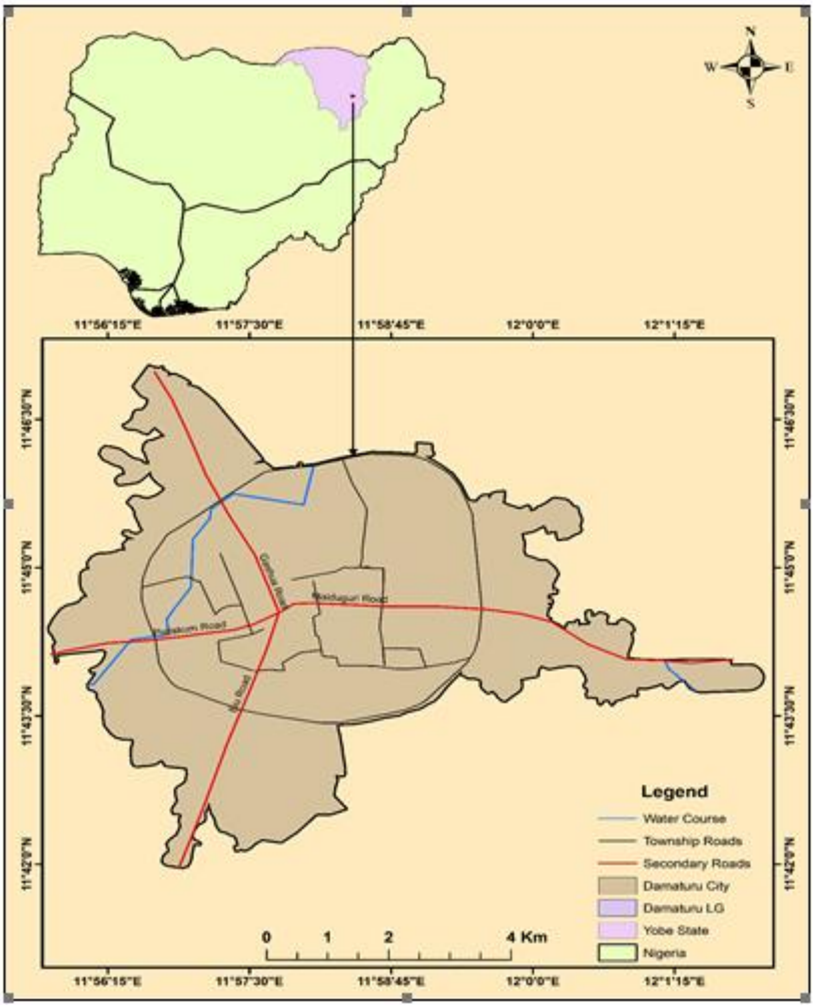

Fig. 1 - The study area

4. Data and methodology

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 has been freely available for public access since 2008 [35]. 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. These are presented in Table1 and Fig. 2.

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			

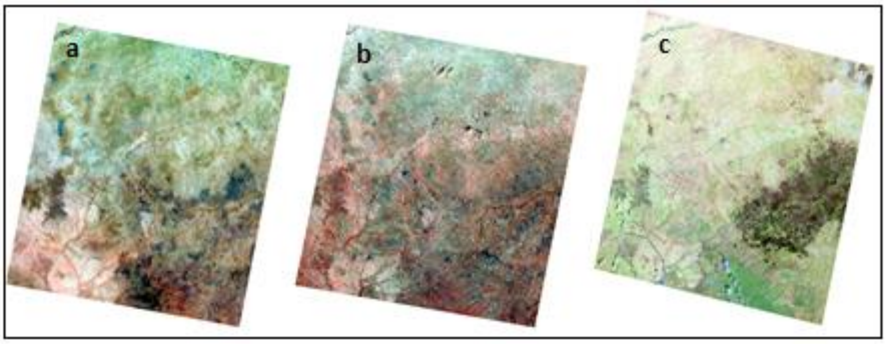

Fig. 2 - Landsat scenes used in the study: a (1986), b (1998) and c (2017)

Other data used include land use and topographic maps of the area obtained from the Department of lands and survey, Yobe state as well as historical Google Earth images which were used for verification and accuracy assessment.

4.1 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 6 m. 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 [33]). 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
λ = spectral band L
= radiance
d = Earth-Sun distance
Esun = the solar atmospheric irradiance and θ
= Solar zenith angle in degree.

4.2 Accuracy Assessment

The classification accuracy was established with an error or confusion matrix. The error matrix quantitatively compares the relationship between the classified maps and reference data [36]. The accuracy assessment was calculated based on User Accuracy (UA), Producer Accuracy (PA), Overall Accuracy (OA) and the Kappa Index of Agreement (KIA) as derived from the formula given by [37] as follows:

$$UA = \frac{nii}{Gii} \quad \text{(Equation 3)}$$

$$PA = \frac{nii}{Cii} \quad \text{(Equation 4)}$$

$$OA = \frac{\sum_{i=1}^{k} nii}{n} \quad \text{(Equation 5)}$$

$$KIA = \frac{N \sum_{i=1}^{n} m_{i,i} - \sum_{i=1}^{n} (G_i C_i)}{N^2 - \sum_{i=1}^{n} (G_i C_i)} \quad \text{(Equation 6)}$$

where:

i = class number

n = total number of classified pixels that are being compared to ground truth,

nii = number of pixels belonging to the ground truth class i, Ci
= total number of classified pixels belonging to class i and Gi
= total number of ground truth pixels belonging to class i.

4.3 Change Detection

Change detection (CD) implies comparing the state of objects or phenomena at two or more different times in order to identify differences (Singh, 1986). This study used the Post Classification Comparison (PCC) which is the most widely used and most accurate approach to change detection in remote sensing[15]. The proportion of each of the land use/land cover classes was calculated for each year (1986 and 1998, between 1998 and 2017 and between 1986 and 2017 as the overall change). The Land Change Modeler (LCM) of IDIRISI was also used to analyse land cover changes, the proportion of change from each land cover type and the overall losses and gains. The rate and pattern or direction of change were also determined.

4.4 Land Use Maps

The resultant land use/land cover maps of Damaturu city in 1986, 1998 and 2017 are presented in Fig. 3.

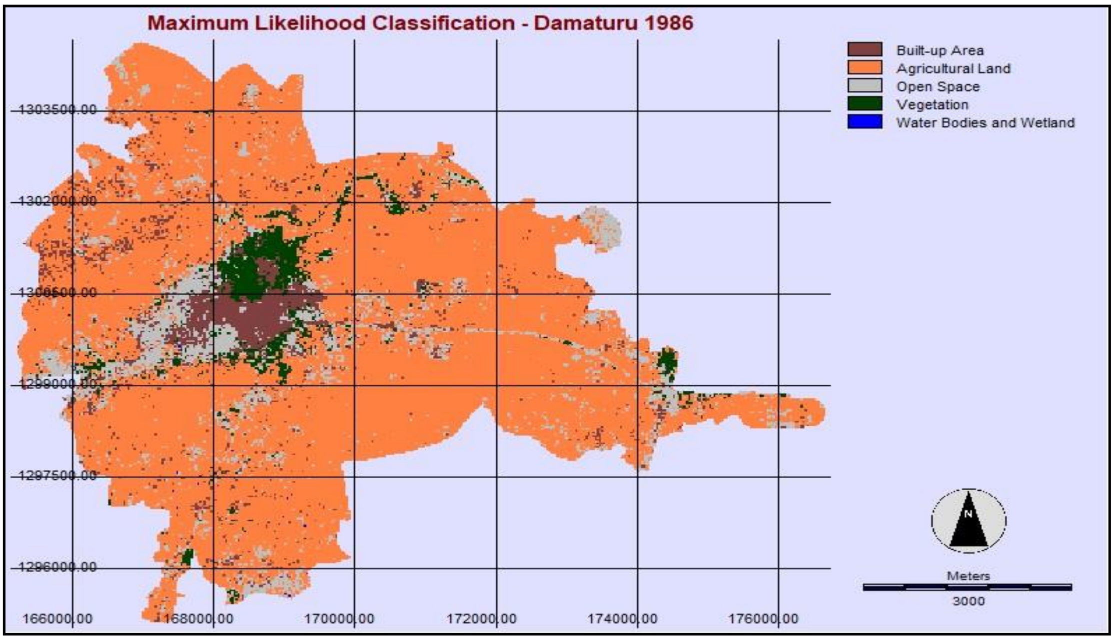

Fig. 3 - Land use/cover map for Damaturu 1986

In 1986 (Fig. 3), the city was practically small, surrounded by vast areas of agricultural lands, scanty vegetation and some open spaces. By 1998 after the state was created, the city expanded to the west, south and eastern parts. The builtup area and vegetation increased noticeably towards the southern and eastern directions (Fig. 4). The open space also expanded in all directions as new layouts were created by the government. Increases have also been spotted in the water bodies and wetlands in and around the city.

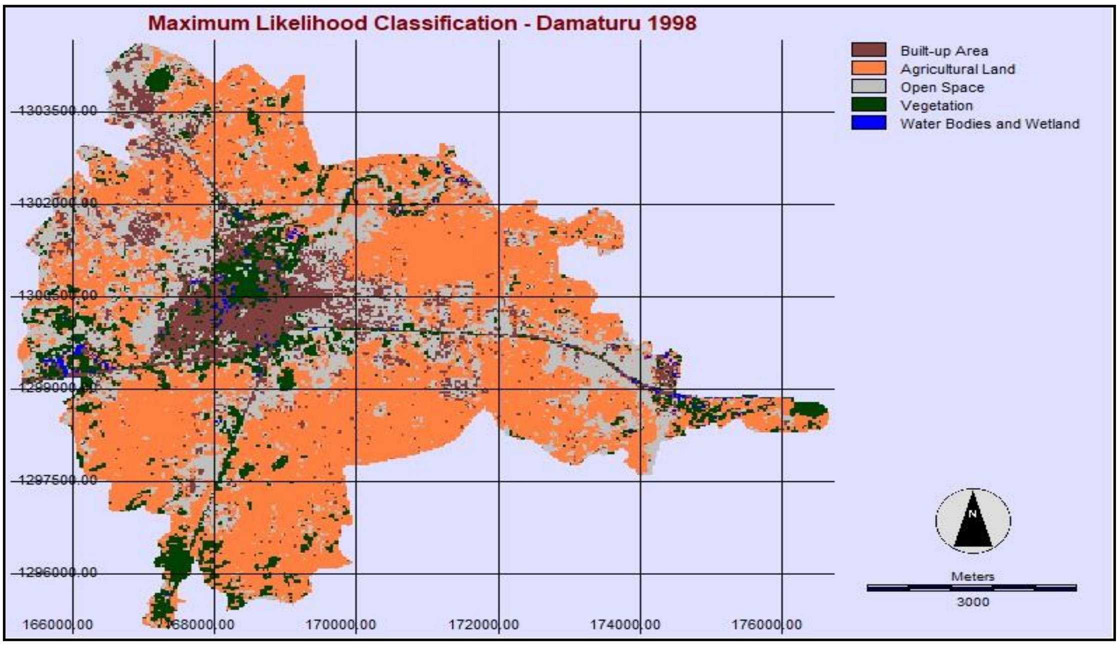

Fig. 4 - Land use/cover map for Damaturu 1998

By 2017 (Fig. 5), the city further expanded down south and to the east along Maiduguri road. The expansion of vegetation was seen to follow expansion in the built-up area.

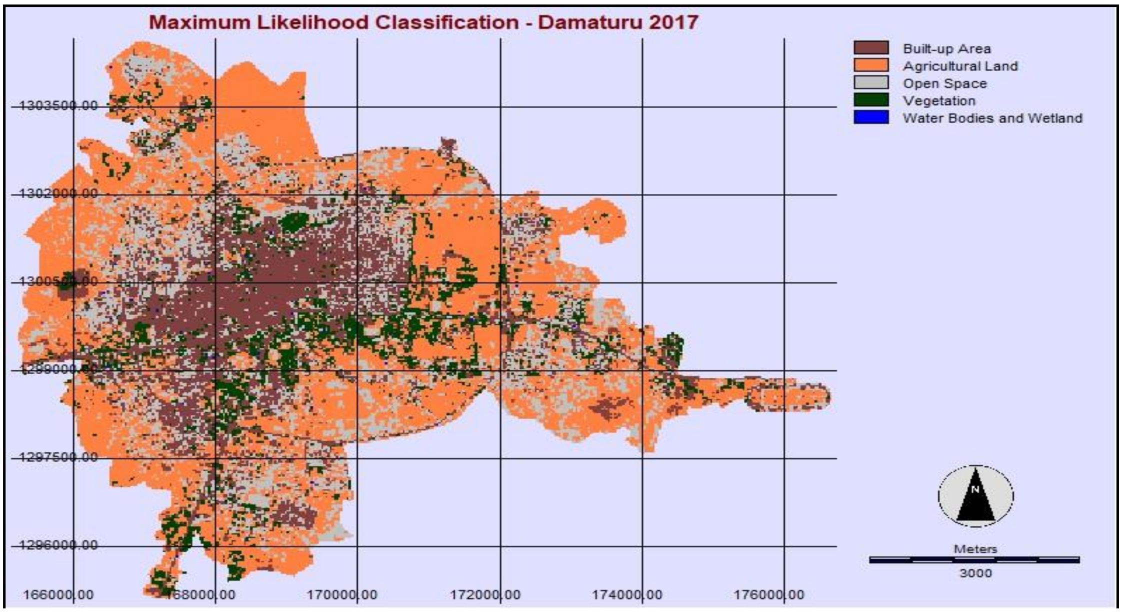

Fig. 5 - Land use/cover map for Damaturu 2017

5. Results and Discussion

5.1 Land use/land cover classification

The land use/land cover classification exercise generally revealed 5 classes of land use. These include the Built-up Area, Agricultural lands, Open Space, Vegetation and Water bodies and wetland. These classes are described in Table 2.

Table 2 - Land Use/Land Cover Classes

S/N	Land use type	Description
1.	Built-up Areas	These include all built-up areas including houses, schools, shops, religious buildings, industrial premises and roads.
2.	Agricultural Land	These are farmlands and other cultivable lands for both dry and rainy season farming activities
3.	Open Space	These are Bare surfaces, rocks, sandy areas and uncompleted buildings
4.	Vegetation	These include trees, shrubs and other vegetation
5.	Water bodies and wetland	All water bodies, wetlands and marshy areas

5.2 Land use/land cover change

Agricultural land use which occupied about 3844.4 hectares (78%) was the major land use around the city in 1986 (Table 3). 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. 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 3 - 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 Fig. 6 and 7.

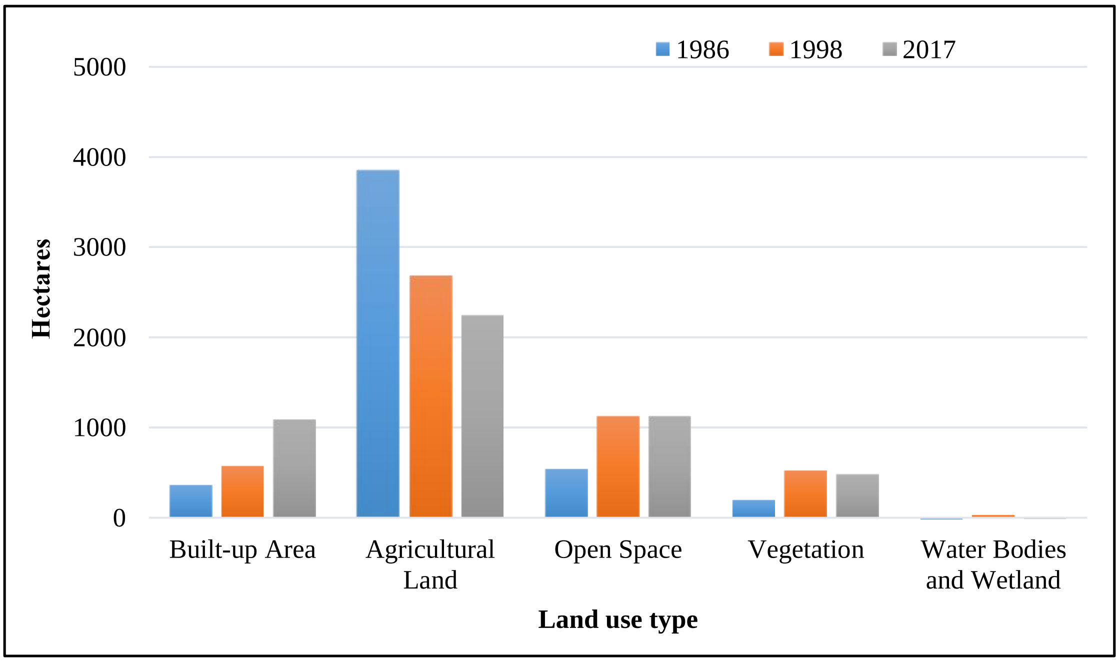

Fig. 6 - Proportion of Land use/cover in Damaturu between 1986 and 2017

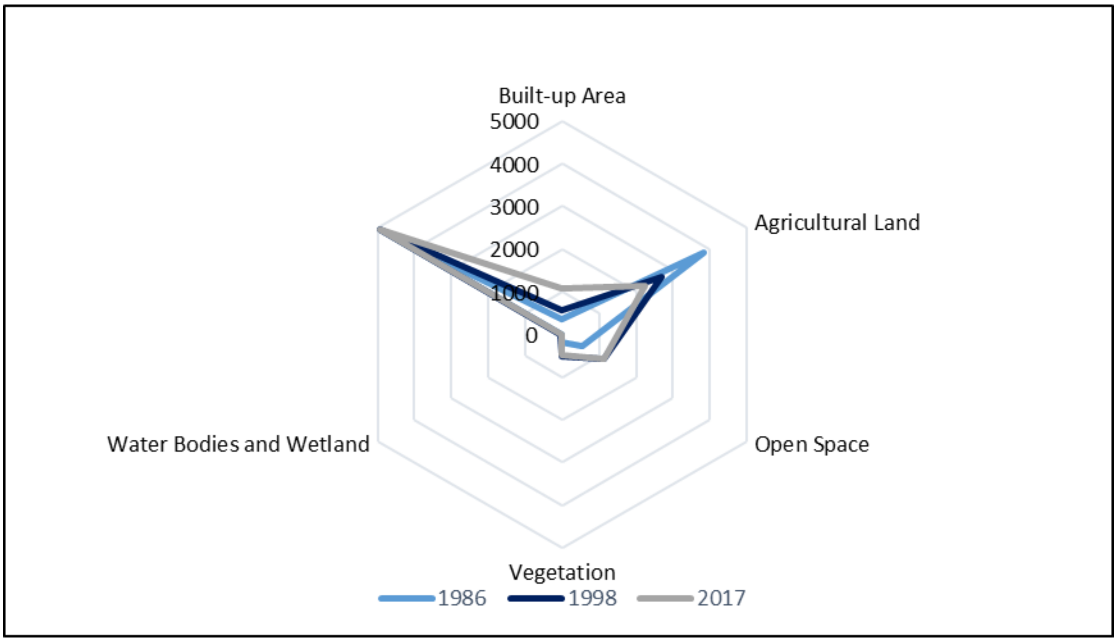

Fig. 7 - Land use/cover change for Damaturu between 1986 and 2017

The land use/land cover change matrix between 1986 and 1998 (Fig. 7) 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.

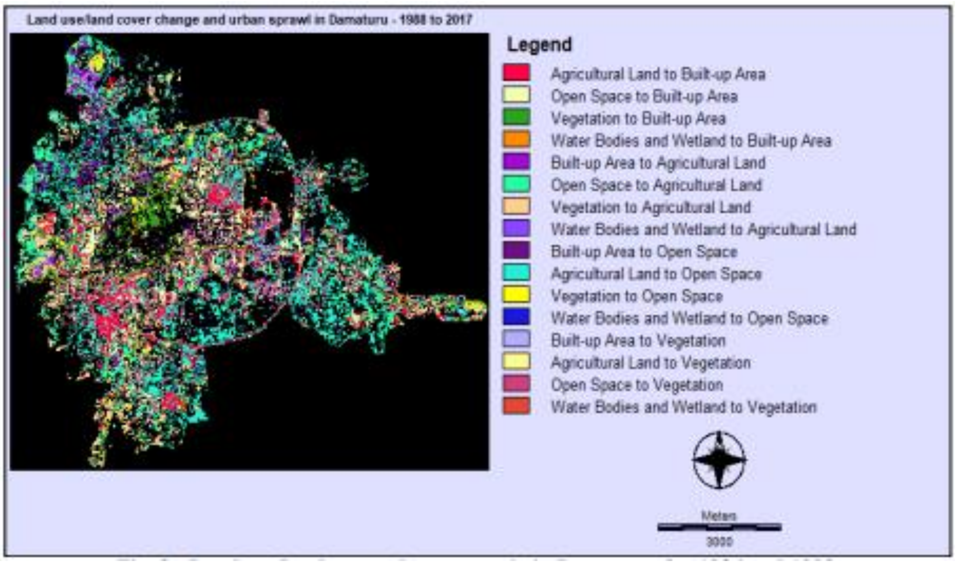

Fig. 8 - Land use/land cover change matrix in Damaturu for 1986 and 1998

Net change (Fig. 8) show an increase of 594 hectares for open space, 319.7 hectares for vegetation and 215 hectares for the built-up area. On the other hand, agricultural lands reduced by 1158.2 hectares.

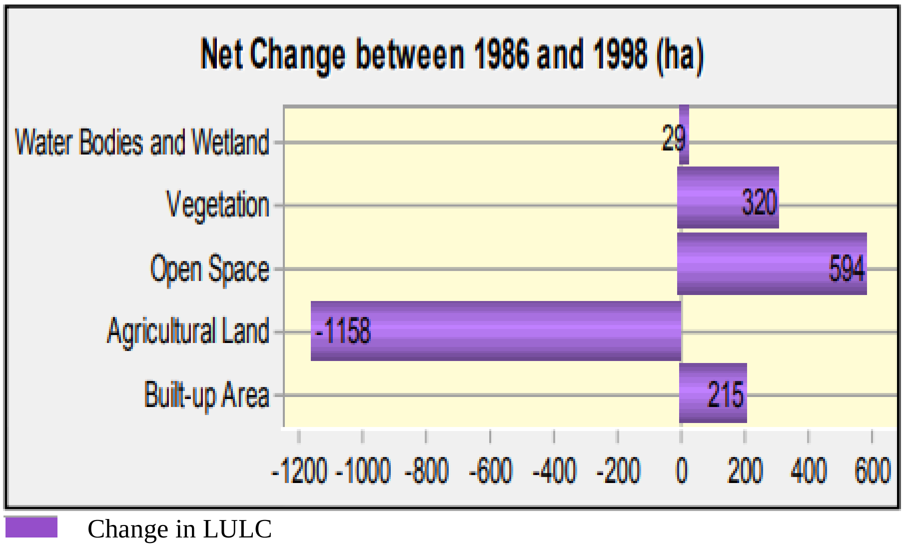

Fig. 9 - Net change of land use for Damaturu between 1986 and 1998

Net gains and losses during the period (Fig. 10) therefore show that the highest increase was recorded in the open space while the highest loss was recorded in the agricultural lands. The built-up area and vegetation also appreciated remarkably during this period.

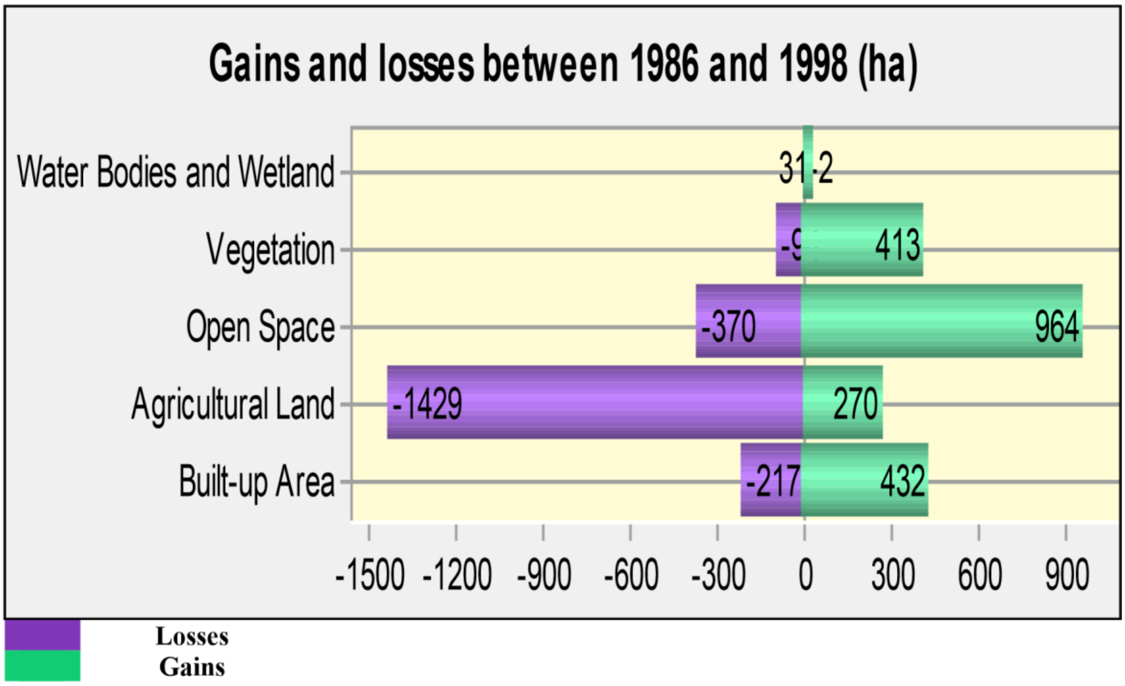

Fig. 10 - Gains and losses between land use types in Damaturu (1986 to 1998)

Between 1998 and 2017, the built-up area expanded dramatically to 1085.6 hectares which was 22% of the total land area of the city. This resulted to a further reduction of about 448 hectares of agricultural lands. The open space remained almost unchanged during this period but vegetation and water bodies reduced by 40.3 and 24.5 hectares respectively.

The change matrix (Fig. 11) show that most of the changes were from agricultural lands, open space and vegetation to built-up area. There were also some parcels of water bodies and wetlands that have been converted to the built-up areas. Similarly, some open spaces and vegetation were also converted to agricultural lands while agricultural lands, open spaces and some built-up areas were converted to vegetation. This however does not imply total conversion but symbolizes the appearance or growth of trees and other vegetation to cover the soil in these areas. The satellite sensors will thus capture vegetation as the prevailing land use class.

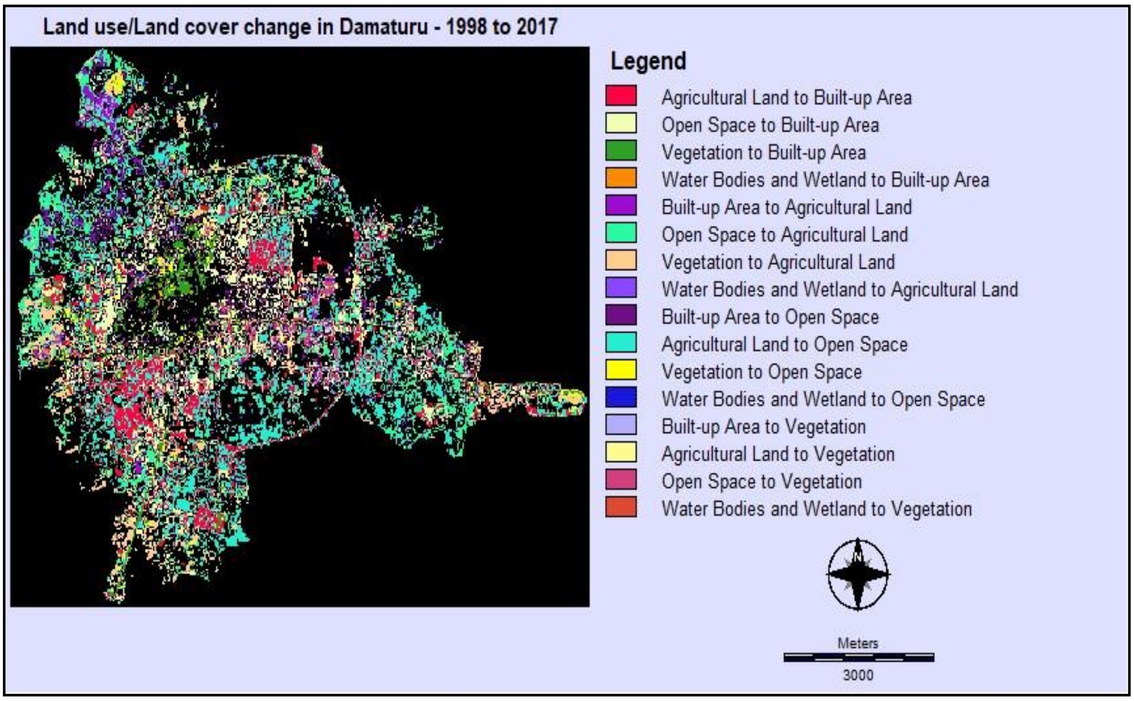

Fig. 11 - Change matrix between land use types for Damaturu from 1998 to 2017

Gain and losses between land use types during the period 1998 to 2017(Fig. 12) show that the built-up area and vegetation had the highest gains while the highest losses were recorded in the agricultural lands and water bodies and wetlands. The open space remained almost unchanged.

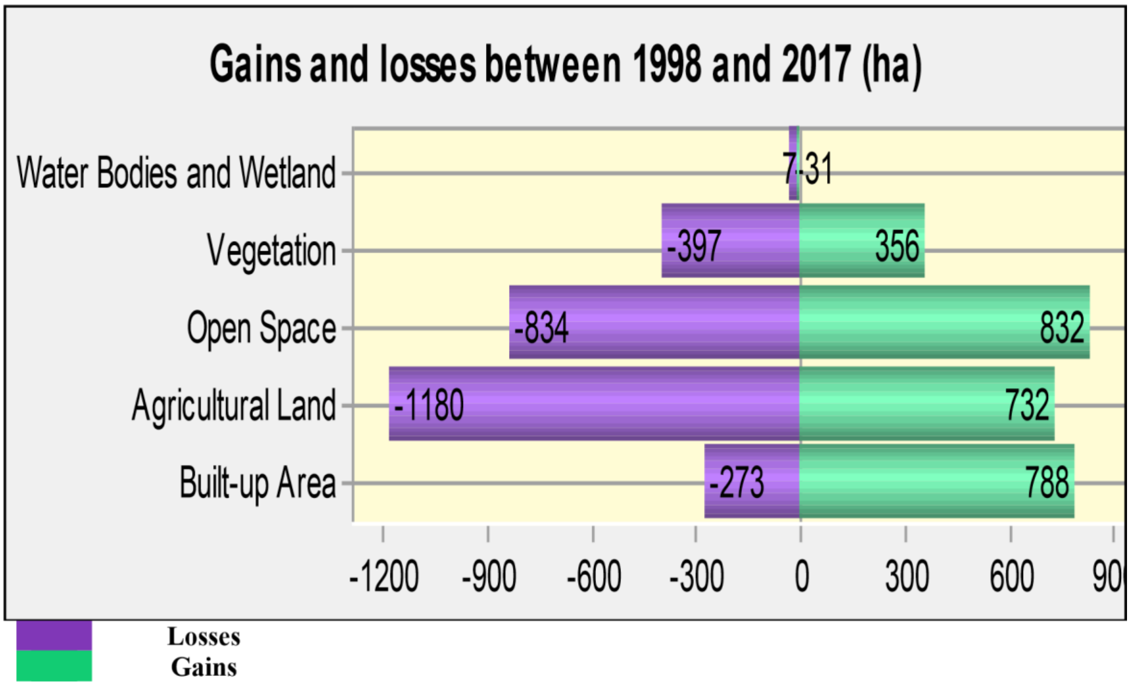

Fig. 12 - Gains and losses in land use for Damaturu from 1998 to 2017

Overall changes between 1986 and 2017 (Fig. 13) show that the built-up area appreciated most, followed by the open space and the vegetation. The highest losses on the other hand were recorded in the agricultural lands. This shows that agricultural lands were more vulnerable to conversion while the built-up areas increased almost exponentially throughout the study period.

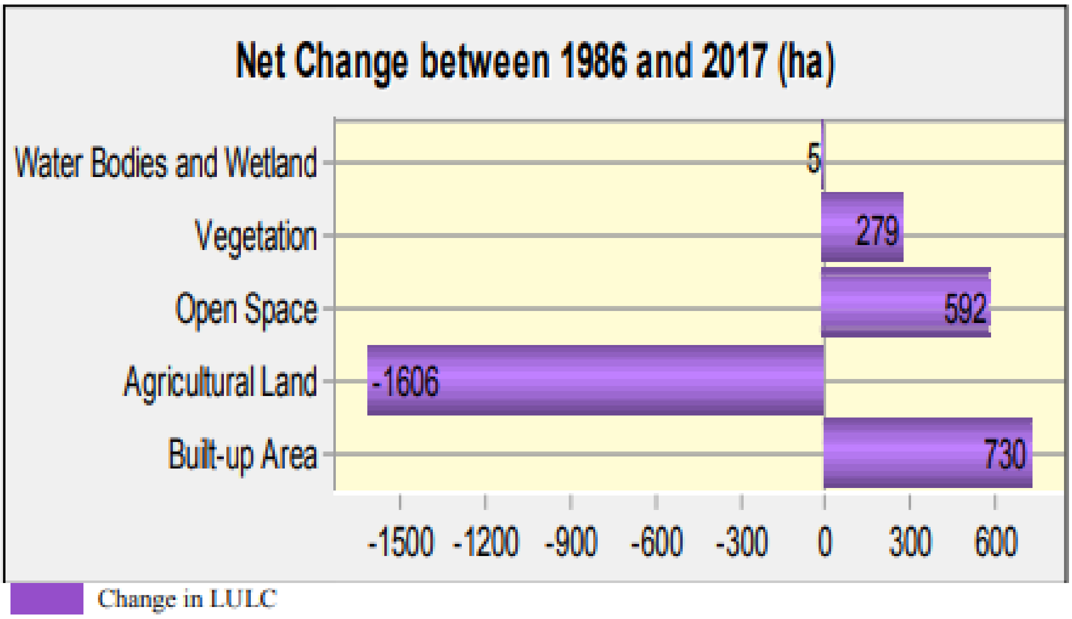

Fig. 13 - Overall land use/land cover changes in Damaturu from 1986 to 2017

6. Conclusion

Land use and land cover changes are natural phenomena which occur in most cities around the world. In Damaturu, these changes took place between the various land use/cover classes at a slower rate between 1986 and 1998 but accelerated between 1998 and 2017. The most practical conversion was from agricultural lands to built-up area. The built-up area recorded the highest increased of 515ha while the agricultural lands reduced by 448.2ha between 1986 and 2017. These conversions were generally brought about by the creation of Yobe state and the location of its headquarters in Damaturu. This attracted a lot of people and their businesses to the city, hence the increase in institutional, residential and commercial constructions in the city.

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