An analysis of LULC change detection using remotely sensed data; A Case study of Bauchi City

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Abstract. Bauchi is one of the cities in the north eastern part of Nigeria that has witnessed tremendous expansion as a result of rapid urbanization. For the past decade, the city has been known to be relatively small both in size and population. But today, Bauchi is one of the fastest growing cities in northern Nigeria. Therefore, it is paramount to detect the nature and magnitude of these changes in order to determine its direction of future expansion. To achieve that, Remotely Sensed data from Landsat 7 ETM+ and Landsat 8 were utilized for the purpose of LULC change detection in Bauchi city. Landsat 7 image of 2003 and Landsat 8 image of 2013 were obtained for the purpose of the study. Three change detection algorithms were used to detect areas of change. While the unsupervised classification was found to be less effective, the supervised classification produced good results with overall accuracies of 93.5% and 89.7% for the 2003 and 2013 respectively. Finally, “from-to” change was obtained using the post classification comparison.

1.0 Introduction
Cities are dynamic; this is because change is inevitable. These changes can be attributed to one factor or the other depending on socio economic, political and climatic condition of a given area. However, one fundamental factor behind city change both in terms of size and pattern remains the same for most cities, i.e “population growth”. Nevertheless, other factors attributing to Land Use Land Cover (LULC) change are directly or indirectly dependent on population growth. As the population of a given area increase, the demand for land cover such as built up area also increase, while other land cover classes such as bare land, vegetation, decreases as a result of the increased demand for built up area. Consequently, these changes in most cases if not continuously checked comes with certain negativities which may affect not only the environment but also its inhabitants. However, Accurate and up-to-date land cover change information is necessary in understanding and assessing the environmental consequences of such changes [1]. Remote Sensing has the capability of capturing such changes, extracting the change information from satellite data requires effective and automated change detection techniques [2]. The importance of remote sensing was emphasized as a ‘unique view’ of the spatial and temporal dynamics of the processes in urban growth and land use change [3]. Satellite remote-sensing techniques have therefore, been widely used in detecting and monitoring land cover change at various scales with useful results [4]. As land becomes increasingly
important and competition among alternative use intensifies, shift in land use may be affected by further institutional and environmental constraint [5]. Thus, it is imperative to consistently monitor the changes that are taking place so that planners can evaluate the impacts of “from-to” change and plan or suggest alternative land use for development purposes which will in turn help policy making and implementation process. Furthermore, monitoring urban changes leads to forecast of the amount of changes and the location of future built-up areas, which is extremely valuable [6]. This paper seeks to utilize remotely sensed data and GIS tool to analyse the LULC of Bauchi Town for the purpose of detecting change in the area by comparing between two dates images.

2.0 Study area
Bauchi is geographically located in the North Eastern part of Nigeria. It is regarded as the North Eastern gate because it is the only state in the North East that is bounded by at least one state in each of the Northern geo-political zones. Bauchi is located between latitudes 9° 3’ and 12° 3’ north of the equator, while longitudinally it is located between 8° 50’ and 11° east of the Greenwich meridian. It has an altitude of 785.2 meters. The vegetation covers of Bauchi are of two types namely; the Sahel Savanna and the Sudan savannah.

Figure 1. Map showing the study area.
Similarly Bauchi has two distinct types of terrain, namely rocky and flat terrain. The rocky terrain are mostly found in those areas that share boundary with plateau State i.e areas around the southern part of Bauchi, while the flat terrain regions are found mostly in the northern part of Bauchi where the soil type is
generally sandy or semi desert soil. The flat surface of the terrain has been subjected to considerable human interference through farming, grazing and construction activities.

Bauchi experience it’s raining season right from mid-June till mid-October, with August recording the highest amount of rainfall of 340 mm. the total mean annual rainfall stands at 1,091.4 mm. While the hottest temperature is experienced around the months of April and May with the highest temperature of 40.56°C. The coldest temperature (i.e during the harmattan season) is experienced around December and January with the minimum temperature of 6.11°C and 7.22°C respectively.

Bauchi city is the capital of Bauchi state and it is bounded by seven local governments which comprises of Kirfi, Ganjuwa, Alkaleri, TafawaBalewa, Dass and Toro respectively. While as a state, Bauchi share border with seven states that cut across the three different geo-political zones of the Northern Nigeria. These states include Kaduna, Jigawa and Kano State from the North West Zone, Plateau State from North Central Zone and Gombe, Taraba and Yobe State from the North East Zone.

3.0 Methodology
3.1 LULC classifications
The different LULC classes of the study area were grouped into five for easy analysis and assessment of change detection. The LULC classification includes Built up area, Wet land, Farm land, Shrub/grass and Other land. The built up area category includes high, medium and low densities; disperse settlements, and all other man-made structures such as schools, hospitals, industries, bridges and roads. The wet land category includes wet and dry river, river banks, water logged areas and small ponds. The farm land category includes lowland crop and highland crop fields with and without crops. Grass/shrubs were combined into a common class; this was due to the fact that grass and shrubs naturally grows together. Finally, other land category includes ditches, and rocks.

3.2 Image classification
3.2.1 Unsupervised. Unsupervised classification was carried out using the 6 bands of the multi date images in order to classify the image into clusters and to identify the different change classes by using both IsoData and K – Mean. This classification did not produce the needed result because some classes were merged and misclassified.

3.2.2 Supervised. The supervised classification was carried out using the Maximum Likelihood and a composition of band 1, 2 and 3 by applying the false color composite to select Region of Interest (ROI) for features like water body and shrubs/grass, while the true color composite was applied in choosing the ROI of built up area, farm land and other land. The spectral signature of each class was obtained from the images using ENVI. This was done through selection of ROI for each of the LULC category. The ROI helps in producing the map by defining an area in the map based on the color assigned to that category and the spectral homogeneity of the pixels of chosen area. This classification has yielded a good result after subjecting the classified maps to a confusion matrix. An overall accuracy of 93.50% and Kappa coefficient of 0.92 were obtained from the 2003 map, while for the 2013 map, the overall accuracy was found to be 89.66% and a Kappa coefficient of 0.848.

3.3 Change detection
3.3.1 Post classification. The two independently classified images where then ran for post classification comparison in order to produce a change detection analysis. By using the change detection statistical tool of the post classification, the matrix table of “from – to” change class was obtained. Finally, this classification proved to be effective because it presents the advantage of indicating the nature and magnitude of change that has taken place through pixel by pixel comparison.
3.4 Accuracy assessment
The accuracy assessment is a comparison of a classification with ROI or ground-truth data to evaluate how well the classification represents the real world. This is produced in a matrix table showing four different types of accuracies. However, Accuracy assessment requires that an adequate number of samples per map class be gathered when the classified results are compared with actual ground conditions [7].

3.5 Determination of magnitude of change
The magnitude of change is a degree of expansion or reduction in the LULC size. A negative value will present a decrease in LULC size while a positive value will indicate an increase in the size LULC class [5].

- The magnitude of change (K) is calculated by the simple equation

\[ K = F - I \]  

- The percentage of change (A) is calculated by the formula

\[ A = \frac{F - I}{I} \times 100 \]

Where:
- \( K \) = magnitude of change
- \( A \) = percentage of change
- \( F \) = first date (2003)
- \( I \) = Reference date (2013)

4.0 Results
Change detection analysis is performed not only to detect changes that have occurred, but also to identify the nature of those changes and to determine the areal extent and spatial pattern of those changes [8]. The result of the five categorized LULC of 2003 is shown in table 1. A total of 2756 pixels were randomly selected as ROI for the purpose of identifying the different LULC class, the selection of the ROI was aided by the use of aerial photo and the local knowledge of the study area. An overall accuracy of 93.50% and Kappa coefficient of 0.92 were obtained from the accuracy assessment. In terms of producer’s accuracy, all the classes except farm land were over 96.0 %, while for the user’s accuracy all classes were above 92.50%.

Table 1. Confusion matrix table of LULC derived from satellite data (2003).

| Producer’s Class | User’s Class | Built up | Wet land | Farm land | Shrubs/Grass | Other land | accuracy (%) | accuracy (%) |
|------------------|-------------|---------|----------|-----------|--------------|------------|--------------|--------------|
| Built up         | 706         | 6        | 8        | 42        | 0            | 0          | 96.36        | 93.39        |
| Wet land         | 6           | 493      | 16       | 0         | 16           | 0          | 95.17        | 92.84        |
| Farm land        | 18          | 4        | 554      | 22        | 0            | 0          | 86.16        | 92.64        |
| Shrub/Grass      | 3           | 0        | 26       | 361       | 0            | 0          | 94.26        | 92.56        |
| Other land       | 0           | 13       | 5        | 0         | 463          | 0          | 96.66        | 96.26        |
| Total            | 733         | 518      | 643      | 383       | 479          |            |              |              |

Kappa accuracy: 0.92. Overall accuracy: 93.50%.
The table below shows the results obtained from the classified map of 2013. A total of 2581 pixels were randomly selected and checked using aerial photo and local knowledge of the area. An overall accuracy of 89.655\% and Kappa coefficient of 0.85 were obtained. In terms of the producer’s accuracy, all classes were above 83.0\%, while for the user’s accuracy all the classes except farm land were above 76.30\%.

Table 2. Confusion matrix table of LULC derived from satellite data (2013).

| Class        | Built up | Wet land | Farm land | Shrubs/Grass | Other land | Producer Accuracy (%) | User Accuracy (%) |
|--------------|----------|----------|-----------|--------------|------------|-----------------------|------------------|
| Built up     | 1215     | 10       | 2         | 5            | 4          | 89.21                 | 98.30            |
| Wet land     | 43       | 208      | 8         | 0            | 3          | 86.31                 | 76.39            |
| Farm land    | 62       | 19       | 211       | 39           | 3          | 88.44                 | 63.17            |
| Shrub/Grass  | 34       | 1        | 17        | 252          | 0          | 83.44                 | 82.84            |
| Other land   | 8        | 3        | 0         | 6            | 428        | 97.72                 | 96.18            |
| Total        | 1362     | 241      | 238       | 302          | 438        |                       |                  |

Kappa accuracy: 0.85. Overall accuracy: 89.66\%.

Figure 2. The classified map of Bauchi area in 2003, revealing a relatively smaller built up area surrounded by vast farm land.

Figure 3. Change detection map of Bauchi in 2013, indicating the level of urban expansion that has taken place over the period of 10 years.
In the table below, shrub/grass has the highest positive value, indicating high increase of 696.7% from its initial 9.0 km², followed by built up area with a percentage increase of 138.45. On the contrary, farm land has the highest negative value, indicating a high level of conversion to other categories of land cover which reduces its size by 64.1%.

Table 3. Magnitude and percentage of LULC change from 2003 – 2013.

| Class          | 2003 Km² (%) | 2013 Km² (%) | Magnitude of change Km² (%) | Percentage of change (%) |
|----------------|--------------|--------------|-----------------------------|--------------------------|
| Built up       | 26.3 12.9    | 62.7 30.7    | 36.4                        | 138.4                    |
| Wet land       | 5.1 2.5      | 9.7 4.8      | 4.6                         | 90.2                     |
| Farm land      | 144.8 710    | 52 25.5      | -92.8                       | -64.1                    |
| Shrub/Grass    | 9.0 4.4      | 71.7 35.1    | 62.7                        | 696.7                    |
| Other land     | 18.8 9.2     | 7.9 3.9      | -10.9                       | -58                      |
| Total          | 204 100      | 204 100      |                             |                          |

The table below shows the amount of “from – to” change that has taken place over the period of Ten (10) years, where it revealed a great portion of the farm land has been converted to shrub/grass, built up area, wet land and other land respectively.

Table 4. Cross tabulation of LULC classes between 2003 – 2013 in (Km²).

| Class          | Built up | Wet land | Farm land | Shrubs/Grass | Other land | Total |
|----------------|----------|----------|-----------|--------------|------------|-------|
| Built up       | 26.3     | 0        | 28.1      | 1.2          | 7.1        | 62.7  |
| Wet land       | 0        | 5.1      | 4.4       | 0.2          | 0          | 9.7   |
| Farm land      | 0        | 0        | 52        | 0            | 0          | 52    |
| Shrub/Grass    | 0        | 0        | 58.3      | 7.6          | 5.8        | 71.7  |
| Other land     | 0        | 0        | 2         | 0            | 5.9        | 7.9   |
| Total          | 26.3     | 5.1      | 144.8     | 9.0          | 18.8       | 204   |

5.0 Discussion
5.1 Built up area
The built up area which comprises of the low, medium and high densities, road network and other man-made structures has witnessed a significant increase based on the analysis carried out. The total area covered by the built up area was estimated at 26.3 km² in 2003 has increased to 62.7 km² in 2013. This was as a result of the demand for shelter by both city inhabitants and emigrants from rural areas and some neighboring cities especially those who have been troubled by either religious crises in the Jos and TafawaBalewa town or the Boko Haram insurgency in some of the north eastern part of the country.

5.2 Wet land
The wet land which is made up of the river, water logged areas and small ponds has witnessed an increase from the initial 5.1 km² to about 9.7 km² resulting to a net increase of 4.6 km². This is because; over the past few years the amount of rainfall in Bauchi has drastically increased compared to five years back. For
the past few successive years, flooding has been a serious issue both within and around Bauchi town (including peripheral settlements). This particular menace has made Bauchi to be categorized amongst the flood prone zones by the Nigerian Meteorological Agency (NIMET).

5.3 Farm Land
This constitutes the agricultural land which is mostly used for the cultivation of grains such as maize, sorghum and millet; also include cowpea such as beans and groundnut. Others include rice, sugar cane and beverages like tomatoes, onions and cabbage which are cultivated within the Fadama area. The study has shown a drastic decrease in the available agricultural land within the study area. The farm land which has an area of 144.8 km² in 2003 has decreased to 52.0 km² in 2013. This was attributed to the high demand for urban shelter and infrastructural development within the study area, another reason is that, quiet a number of farmers have abandoned farming for other petty businesses in the study area. This has resulted in conversion of some of the abandoned farm land to shrub/grass.

5.4 Shrub / Grass
The shrub/grass which comprises of trees, shrubs and grasses has witnessed an increase over the last decade. This is however not unconnected to the fact that most farmers in the study area have abandoned farming activities and engages in other forms businesses. Even though some shrub/grass land were converted to built up area, still the conversion of farm land to shrubs/grass over the years, has significantly increase its size from the initial 9.0 km² in 2003 to 71.7 km² in 2013.

5.5 Other Land
This comprises of features such as rock outcrops and ditches that are found within Bauchi city and the environs. This study has also revealed a decrease in the amount of other land as a greater portion has been replaced by built up area while some of the ditches were used as waste disposal sites.

6.0 Conclusion
The utilization of Remote Sensing and GIS tools were helpful in detecting the magnitude of LULC change that has taken place in Bauchi over the span of 10 years. The study also revealed a significant expansion of Bauchi city size. All LULC classes except farm land and other land have increased over the years, with the built up area increased to 138% from 2003 to 2013. While farm land, has witnessed a drastic decrease of up to 178% over the period of 10 years. The study has revealed that the expansion of Bauchi city is more concentrated around the north eastern and South Western part of the city. This was as a result of the newly constructed estates that attracted other construction activities around the north eastern part, and also location of higher institutions such as Federal University, Federal Polytechnic and State Polytechnic around the south western part of the city. Meanwhile, expansion around the north western part of Bauchi was constrained by the location of military barracks in the area.

However, based on the LULC change detection algorithms used for the classification, the supervised classification was found to be very effective with overall accuracy of 93.5% and a Kappa coefficient of 0.94% for the year 2003, also an overall accuracy of 89.6% and Kappa coefficient of 0.848% for the year 2013. In general, the maps met the minimum accuracy of 85% as stipulated by the Anderson classification scheme, Anderson et al. [9]. The post classification was found to be helpful in producing the change detection statistics because it provided the matrix table of “from – to” change for the two dates images on the bases of pixel by pixel comparison.
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