MODELLING URBAN GROWTH FROM MEDIUM RESOLUTION LANDSAT IMAGERIES OF AKURE, NIGERIA

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Abstract

The city of Akure has experienced rapid growth in the past 2 to 3 decades which has led to the expansion of the core urban areas of the city into adjoining rural lands. The paper analyses the urban growth of Akure using medium resolution Landsat imageries. Landsat (MSS), Landsat Thematic Mapping(TM) and Landsat Enhanced Thematic Mapper (ETM$^+$) images for 1972, 1986 and 2002 respectively were used in a post-classification comparison analysis to map the spatial dynamic of land cover changes and identify the urbanization process in Akure. The land cover statistical results revealed a rapid growth in the built-up area of Akure from 997.2 hectares in 1972 to about 3852.70 hectares in 2002 due to increase in population of Akure within this period. Results of the prediction showed that the built-up area of the city has increased in size from 977.2 hectares in 1972 to 5863.66 hectares in 2022 corresponding to 500% at the rate of 13.1% per annum. Implications of growth include loss of open space, pressure on limited infrastructure, overcrowding, traffic congestion and poor standard of living. The study recommends regular monitoring of urban area, development of small towns around the city area to avoid overcrowding, training of planners and administrators to acquire more knowledge in the use of GIS and remote sensing to enhance efficiency.

Keywords: Urban growth, Landsat, Imageries.

1 Introduction

The World's urban population has being growing by four times the rate of the rural population since last decade (U.N. 1999), and will increase in most continents, including Africa and Asia, where urban areas have developed at the expense of the rural areas, as expressed in the context of core periphery model. The model explains that the rural areas that are mostly the resource base often get worse off by resource depletion and trickle down effect of the urban vices. With an increase in the urban population in developing countries from about 30 million in 1950 to 1.7 billion in 1998 (United Nations, 1999), and relatively poor technological development in most of these countries, the pressure increased on the largely insufficient resources to the increasing population pressure. This problem is more prominent in the developing countries, including Nigeria, where growth and development of settlements have proven difficult to monitor because of relatively lower technological status compared to many developed countries in Europe and Americas.

The mechanisms of Rapid City expansion on the developing countries are rural-urban migration and natural increase. The former is enhanced by the skewed in equality in the location of socio-economic activities in favour of the cities. In any case, expansion is gradual and in some cases rapidly encroaching into immediate rural farmlands thereby overwhelming the natural environment and destroying the ecosystem. The strain on natural environment is compounded by the unplanned or uncontrollable city growth in the context of rising consumption levels in terms of increasing demand for land for urban uses vis-a-vis industrial constitutional, commercial, recreational and other urban-based uses, with the resultant effects that land hitherto used for primary production activities are now encroached upon (Mohammed, 2007).

Housing development on the rural-urban fringe has been happening at a very fast pace, often spontaneous, without much planning and coordination. The consequences of such over-sized, uncoordinated growth of the sub-urban area include negative ecological effects, massive traffic problems, inadequate and lack of infrastructural provision. Therefore, an important planning aim of such urban and sub-urban development must be the reduction of such negative consequences (Balogun, 2007).

Planning for the urban environment has been a major phenomenon since the ancient Greece. However, the problems created by the industrial city during the industrial revolution have exerted greater concerns on the need to adequately cater for the urban environment in order to protect its quality and enhance living conditions. Management of the urban environment therefore, involves procedures of monitoring and modeling which require reliable information base and robust analytical technologies.

To adequately plan for Akure city, Nigeria, it is necessary to effectively monitor and model the growth of the city, know the rate of growth, direction of growth for the future. The outdated nature of topographical map and the general lack of urban landuse map in Nigeria, which are planning and monitoring tools, informed the need for this study.

A vague understanding of how cities grow results in meddled and misguided solutions to urban problems and vague awareness of opportunities that arise from that growth. Effective planning of cities relies on accurate and up-to-date information of the existing land cover and landuse. The timely detection of trends in landuse change and a quantification of such trends are of specific interest to planners. It is pertinent to note that the techniques used in acquiring information and presenting such information goes a long way at determining how useful such information can be to planners and decision makers for effective urban management, the heterogeneous landscape of the urban environment accompanied with its high dynamic nature has posed serious challenges to the application of conventional methods which, however, technologies and theories in the wider field of remote sensing and social sciences alike have valuable insights (Yang, 2005). It is against this background that this study applied the use of GIS and remote sensing in modeling urban growth of Akure.

Several studies have been conducted with integration of remote sensing and geographical information system to monitor and analyze urban growth. Sedigueh (2001) used aerial photograph and satellite stereo images to provide an urban growth map. Here, stereoscopic analysis was done on the satellite data using a second-level classification procedure. A digitalized map of the study area was incorporated in the stereo analysis to differentiate all areas with known information. This was quite a simple method adopted. In a similar way, Moeller (2005) used satellite images (ASTER, ETM^+, TM, MSS) from different sensors to analyze growth directions and distances. The approach was quite complicated due to the data from different sensors hence the image analysis approach before classification which led to reliable results. Similar approach were found in Herold, el at (2003), where the spatiotemporal form of urban growth was established suing a data set compiled from interpreted aerial photography and IKONOS imagery. By the method of image interpretation and classification, the deviation of the extent of built –up areas was delineated for each of the data set. One of the methods that integrate the Integration Remote Sensing and geographic information system to monitor urban growth is the post classification comparison analysis by Musaoglu (2005), He incorporated Remote Sensing and GIS to create overlays of two or more independently produced classified images. This was used to detect change, trend, location and amount of changes that have occurred.

Application of Remote Sensing with the use of Satellite data has proved to be one of the fastest means for the development of administrative maps and mapping/modeling/monitoring of the growth of urban cities. An urban growth model that can make appropriate projective about future urban growth and expansion will serve as an educational tool for the general public, politicians and city planners who can take advantage of the

visualization of different growth scenarios (Wu, 1988; Strange et al 1999). Research or urban growth and land use change may have one or two objectives:
(i) To develop an understanding of urban dynamics, both spatial and temporal (Allen, 1997); or (ii) to provide a better decision support for urban planning (Brail and Klosterman, 2000). The application of urban growth models is in its infancy in Africa particularly in Nigeria and one of the significant bottlenecks in addressing urbanisation issues in the continent using these models is the dearth of information. This could be the result of unavailability of appropriate databases, unreliability of existing information, and lack of economic resources for research and data collection (Stren, 1994).

The aim of this paper therefore is to use the technique of satellite remote sensing and geographic information system to analyze the urban growth of Akure between 1972 and 2002 with a view for improving urban landuse planning and management in the study area. The objectives are to:

(i) Assess landuse changes in Akure, using remote sensing;
(ii) Investigate the spatial attributes which influence landuse change; and
(iii) Predict future urban growth using alternative scenario.

2. The study area

The study can be achieved in any area using the approach, but for specifics, the present study focused on a fast growing administrative city in Nigeria, Akure. Previous study by Akinbode et al (2012) has shown that the level of urban heat island in Akure compares well with those of well older cities (Ibadan and Benin), and it is a representative of more than 10 other administrative State capitals that were created in Nigeria in 1976. Akure is situated on $7^0$15'N, 5^0 15'E and roughly lies on 370m above sea level. It is situated in the humid tropical region of Nigeria (see figures 1a, 1b). Its population has increase from 71,006 people in 1963 to 340,021 in 2006 (NPC, 2006), and has been estimated to increase annually by more than 5%. The increase in annual growth of the population has been tied to the administrative role of the town and its long standing role as a centre of economic activities attracting a large spectrum of immigrants into it.

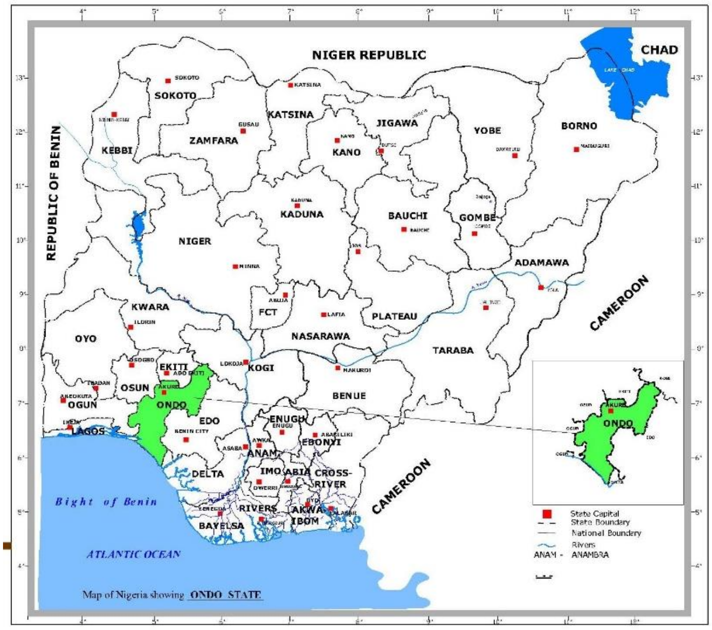


Figure 1a: Map of Nigeria Showing Ondo State

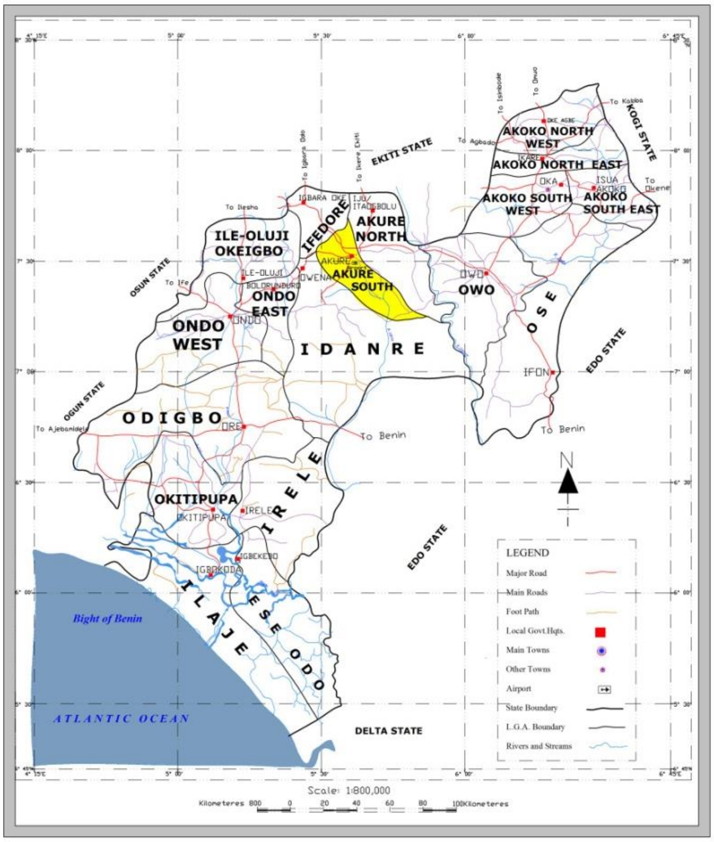


Figure 1b: Ondo State showing Akure South Local Government

(3) Data acquisition and Method

The approach adopted in this study of urban growth analysis was the post-classification comparison analysis which is a GIS approach of overlaying two or more produced classified images. The main aim of the study is to analyze the urban growth of the city, direction of change; trend and amount of changes that have occurred have to be deduced. So with the use of multi-date remote sensing images and ability to create overlays in the GIS environment, the post classification comparison method appears to be the best approach for this study. Three remote sensed data namely Landsat Multispectral Scanner (MSS), Thematic Mapper (TM) and Enhanced Thematic Mapper plus (ETM^+) covering the study area were used to monitor the urban growth for two periods (1972-1986; 1986-2000) giving a total period of 30 years. The image processing procedure includes image-processing, classification design scheme, image classification results analysis. Since the study involved the use of multi-temporal image data, the image pass through geometric correction. This is to allow pixels of each image align to a common map projection or coordinate system. This metric correction includes georeferencing and resampling. A supervised classification was performed on false colour composites (bands 4, 3 and 2) into the following landuse and land covers classes. Built –up area, vegetation, bareland, exposed rocks and water bodies. Information collected during the field surveys was combined with the digital topographic map which was developed for the city and was used to assess the accuracy of the classification. The digitalized topographic map and images together are manipulated in map to allow for GIS overlay creation for the purpose of comparison and qualitative visual assessment of the possible factors influencing urban growth. The urban growth model adopted for this study was based on exponential modeling approach developed by Hoftee and Bussels (2002). The exponential model states that:

Exponential Model: An A_0 *Exp (perc/100*n)
Where
'A0' is the amount in year 0
'An' is the amount of years
Perc is the growth rate as a percentage per year
'n' is the number of years. The model was quantified using data from 1972 and 1986 and verified using the 2002 data. Maps of future urban growth were generated by setting some urban growth scenarios (Table 4).

4 Results and Discussion

In order to analyze the nature, rate and location of the urban landuse changes; image of the built –up area was extracted from each of the original images. The overlay of the classifications results provided actual change detection analysis. To allow for comfortable examination of the overlay result the class values of the three images were recorded before the overlay process. The statistics of the extracted images are recorded to obtain an urban growth data. Figures 2, 3 and 4 showed the results of the image classification and the statistics. The statistics derived from the classification tables 1, 2, and 3are graphically represented in figures 2, 3 and 4. Figures 5 showed the overlay of the three maps while figure 6 showed the prediction map of the study area for 2002 to 2022. Table 4 was used to quantify and model the landcover change based on the landuse classification. The model suggests that by 2022, urban spatial will fill in all the areas as show in figure 6. Most of the city's growth, however, will be towards the northwest and southwest. These are the areas that present favourable physical environment for construction. The topography is generally flat and that will not require much erosion or physical obstacles during and after construction. Figure 6 plays a major role in determining the extent and direction of growth, most of the urban expansion is along the roads, a phenomenon that is coming to most developing cities.

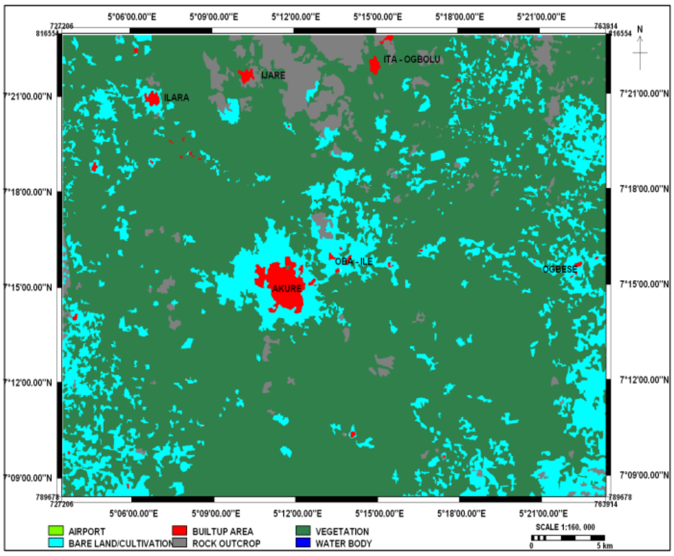


Figure 2: Supervised Classification of Landsat MSS 1972 Image of Akure and Environs

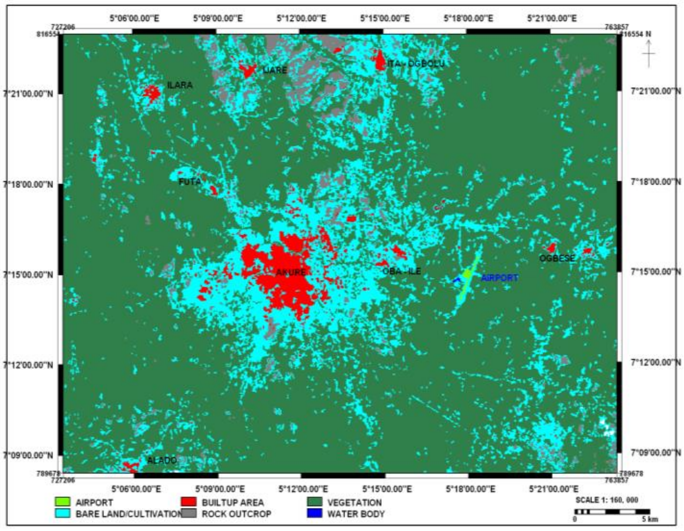


Figure 3: Supervised Classification of Landsat TM 1986 Image of Akure and Environs

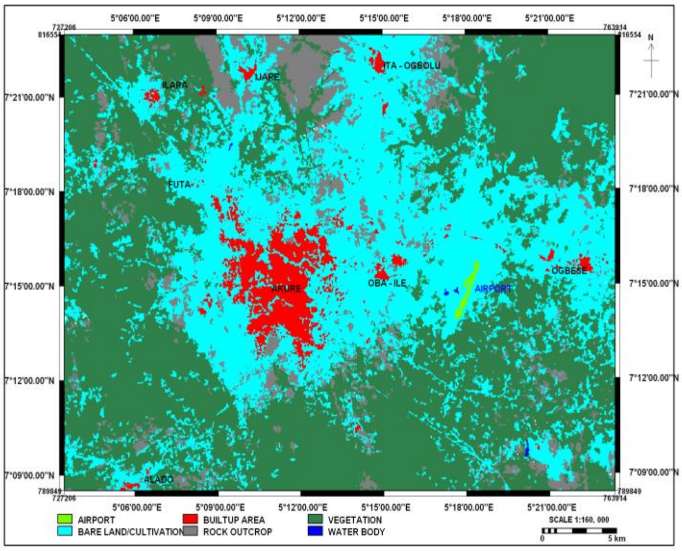
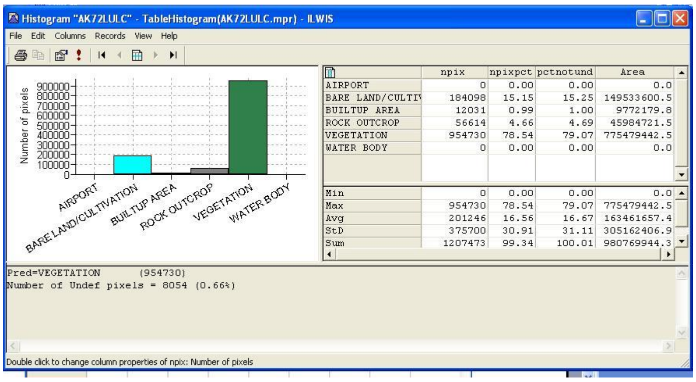


Figure 4: Supervised Classification of Landsat ETM$^+$ 2002 Image of Akure and Environs

Table 1: Statistical Result of Classified Landsat MSS Data of Akure in 1972



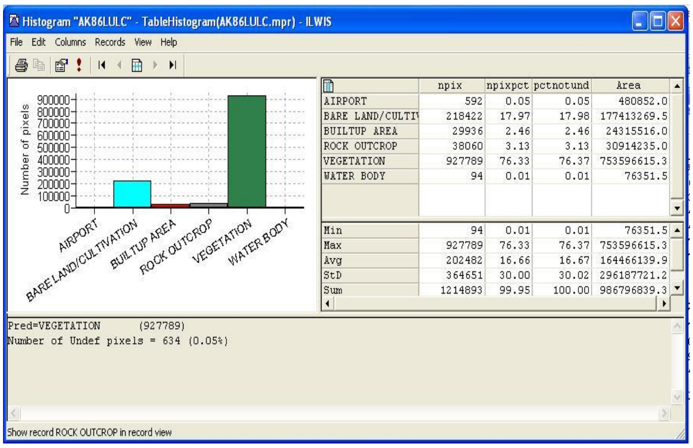
Histogram "AK72LULC" - TableHistogram(AK72LULC.mpr) - ILWIS

	npix	npixpct	pctnotund	Area
AIRPORT	0	0.00	0.00	0.0
BARE LAND/CULTIV	184098	15.15	15.25	149533600.5
BUILTUP AREA	12031	0.99	1.00	9772179.8
ROCK OUTCROP	56614	4.66	4.69	45984721.5
VEGETATION	954730	78.54	79.07	775479442.5
WATER BODY	0	0.00	0.00	0.0
Min	0	0.00	0.00	0.0
Max	954730	78.54	79.07	775479442.5
Avg	201246	16.56	16.67	163461657.4
StD	375700	30.91	31.11	305162406.9
Sum	1207473	99.34	100.01	980769944.3

Pred=VEGETATION (954730)
Number of Undef pixels = 8054 (0.66%)

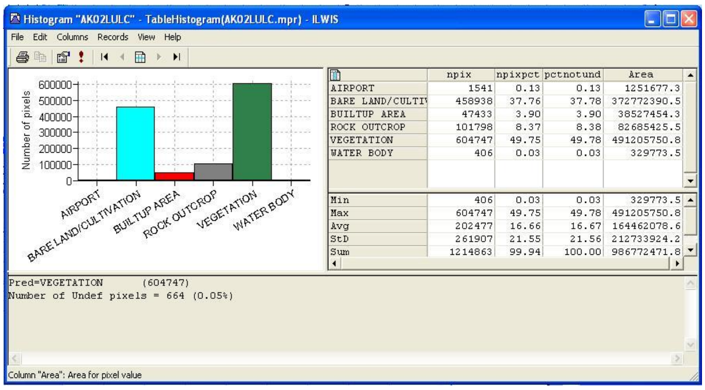
Double click to change column properties of npix: Number of pixels

Table 2: Statistical Result of Classified Landsat TM Data of Akure in 1986



	npix	npixpct	pctnotund	Area
AIRPORT	592	0.05	0.05	480852.0
BARE LAND/CULTIV	218422	17.97	17.98	177413269.5
BUILTUP AREA	29936	2.46	2.46	24315516.0
ROCK OUTCROP	38060	3.13	3.13	30914235.0
VEGETATION	927789	76.33	76.37	753596615.3
WATER BODY	94	0.01	0.01	76351.5
Min	94	0.01	0.01	76351.5
Max	927789	76.33	76.37	753596615.3
Avg	202482	16.66	16.67	164466139.9
StD	364651	30.00	30.02	296187721.2
Sum	1214893	99.95	100.00	986796839.3

Table 3: Statistical Result of Classified Landsat ETM$^+$ Data of Akure in 2002



	npix	npixpct	pctnotund	Area
AIRPORT	1541	0.13	0.13	1251677.3
BARE LAND/CULTIV	458938	37.76	37.78	372772390.5
BUILTUP AREA	47433	3.90	3.90	38527454.3
ROCK OUTCROP	101798	8.37	8.38	82685425.5
VEGETATION	604747	49.75	49.78	491205750.8
WATER BODY	406	0.03	0.03	329773.5
Min	406	0.03	0.03	329773.5
Max	604747	49.75	49.78	491205750.8
Avg	202477	16.66	16.67	164462078.6
StD	261907	21.55	21.56	212733924.2
Sum	1214863	99.94	100.00	986772471.8

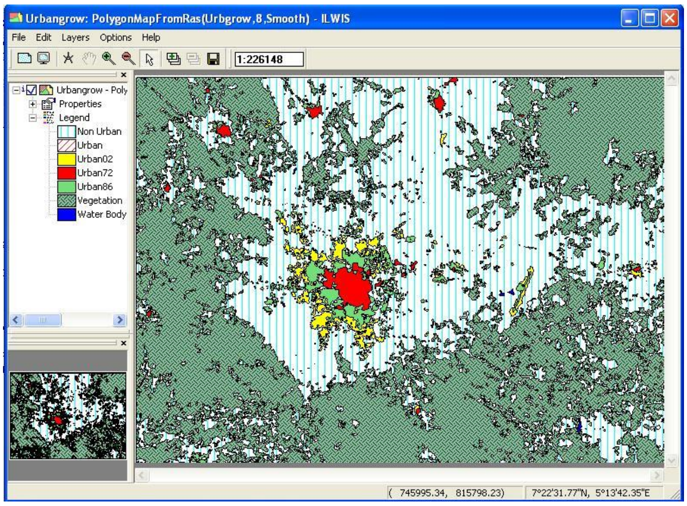


Figure 5: Overlay Maps (Landcover changes) of Akure between 1972, 1986 and 2002

Table 4: Landuse Changes in (Ha/year) and (%/year)

Year	Land cover area (ha) Bareland	Change (ha)	Change (%)	Time span (years)	Arithmetic mean change (ha/year)	Arithmetic mean change (%/Year)	Period
1972	14,953.40	2,787.90	18.64	14	199.14	1.33	1972-1986
1986	17,741.30						
		19,535.90	110.12	16	1,220.99	6.88	1986-2002
2002	37,277.20						
		40,230.86	107.92	20	2,011.54	5.40	2002-2022
2022	77,508.06						

Year	Land cover area (ha) Built-up	Change (ha)	Change (%)	Time span (years)	Arithmetic mean change (ha/year)	Arithmetic mean change (%/Year)	Period
1972	977.2	1,454.40	148.83	14	103.89	10.63	1972-1986
1986	2,431.60						
		1,421.10	58.44	16	88.82	3.66	1986-2002
2002	3,852.7						
		2,010.96	52.20	20	100.55	2.61	2002-2022
2022	5,863.66						

Year	Land cover area (ha) Vegetation	Change (ha)	Change (%)	Time span (years)	Arithmetic mean change (ha/year)	Arithmetic mean change (%/Year)	Period
1972	77547.90	-2,188.20	2.82	14	-156.30	0.20	1972-1986
1986	75,359.70						
		-26,239.10	34.82	16	-1,639.94	2.18	1986-2002
2002	49,120.60						
		-45,176.27	91.97	20	-2,258.81	4.60	2002-2022
2022	3,944.33						

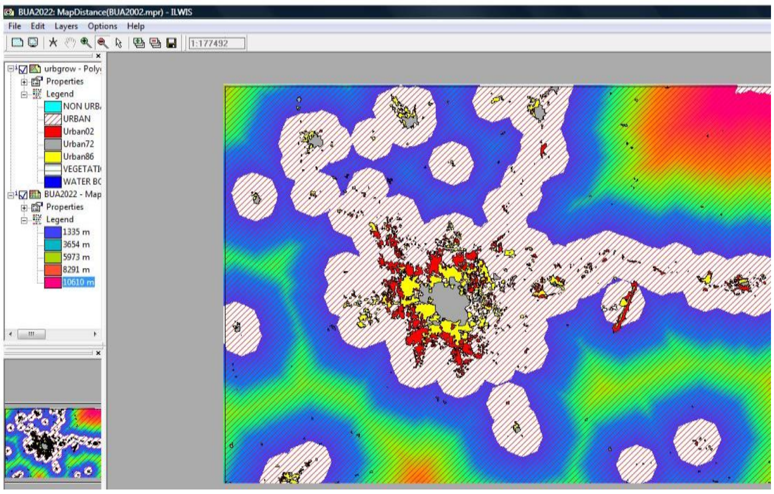


Figure 6: Predicting Modeling Urban Expansion of Akure to 2022

A supervised classification was performed on these false colours composite (bands 4, 3 and 2) into the following land use classes; Built up area, vegetation, bare land, Exposed rocks, and water bodies. The classification results of Figures 2, 3 and 4 however shows remarkable differences as evidenced on Tables 1, 2 and 3. On comparing the figures 2, 3 and 4 and tables 1, 2 and 3, it was observed that the built-up area covered 977.20 hectares (1.0%) in 1972, 2431.60 hectares (2.46%) in 1986 and increased to 3852.70 hectares (3.90%) in 2002. Furthermore, vegetation decreased gradually from 77547.90 hectares (79.07%) in 1972 to 75359.70 hectares (76.36%) in 1986 and further decreased drastically in 2002 to 49120. 60 hectares (49.78%). The bare land on the hand due to massive cultivation of land and population increase had also increased from 14953.40 hectares (15.25%) in 1972 to 17741.30 (17.98%) in 1986 and further to 37277.20 hectares (37.78%) in 2002. Also rock outcrop due to encroachment and quarry activities had increased from 4598.50 hectares (4.69%) in 1972 to 5002.90 hectares (5.07%) in 1986 and further increase to 8268.50 hectares (8.38%) in 2002. Water bodies are not well discernible in 1972 due to vegetation cover until 1986; it increased from 7.60 hectares (0.01%) to 33.00 hectares (0.03%) in 2002. This was probably as a result of massive encroachment and farming activities. Table 4 was used to quantify and model the land cover change based on the land use classifications. It was observed that the city expanded from 9772 hectares in 1972 to 2431.60 hectares in 1986 (1972-1986). Between 1986 and 2002, the built-up area had increased from 2431.60 hectares to 3,852.7 hectares. The built-up area changed at the rate of 88.2 hectares (3.66%) per year during the period (1986-2002) which was used to compute and predict the likely changes in 2022. This indicates that urban expansion could increase probably to about 5863.66 hectares in 2022. Likewise all the three maps were overlaid on each other to produce one composite thematic map that clearly showed the stages of expansion and their extent in figure 5. While figure 6 shows the predicting future expansion of Akure for 2002 to 2022. The expected total built-up area after 20 years (of current built up area of 3852.7ha) with an estimated growth rate of 3.6% is 3852.7* EXP ((3.6/100) * 20) = 5863.66ha.
The urban expansion in 2022 will be 5863.60 hectares. Figure 6 shows the expansion up to 2022 using the above scenario. It is noted that growth is expected to avoid physical obstacles of this great rocks in the study area. The prediction should be taken into consideration of the new master plan.

5 Implications of urban Growth

The tremendous expansion that most capital cities in developing countries shave often created environmental degradation consequent upon their rapid growth. Consequently, effect of this development include social ills such as poverty, poor quality housing and traffic congestion and overcrowding which pressure on government to provide the basic amenities and infrastructure for the growing population.

Another serious consequence of this growth is the loss of biodiversity (i.e. deforestation within the city and in surrounding areas). Most of the urban dwellers and rural dwellers used wood harvested from the neighbouring village as firewood and for construction purposes. This extensive wood harvesting leaves the land surface denuded making them vulnerable to erosion.

In an area where unsuitable agricultural lands are limited, conversion of prime agricultural lands into urban dwellings will have serious repercussions on food production. This has led many developing countries importing virtually food from developed countries to meet the growing population. Another consequence of urbanization is the sand and gravel mining for the construction of roads and houses (Andrew et al, 2005). The unsystematic excavation on the sideslopes for the sandy clay loam soil material results in the creation of holes and channels that initiate further removal of soil material during the high intensity of rainfall characteristics of the study area.

6 Conclusion

One of the biggest obstacles for development in the developing countries is rapid population growth. This, together with continuing poverty and lack of basic needs of acceptable life (e.g food, clean water, shelter, basic health care, security of tenure) imposes a great challenge for sustainable development. The negative social and environmental consequences of the uncontrolled urban expansion have been documented. Therefore, in order to enhance the functionality of the city and to reduce its social problems, there is need to control urban spreading out to agricultural land as this will have serious repercussions on food production. Various development and legislative measures should be adopted as to regulate growth and associated sprawl in the study area. It is also necessary to embark on the regional development planning to make other surrounding areas more conducive living, thus discouraging the sprawl unnecessarily. Public and private partnership to create housing schemes particularly for low income scheme should be encouraged. Newly city concept planning should be adopted in developing small towns around Akure. This will absorb the excess population of Akure and reducing spatial expansion of this city to adjoining agricultural lands. Appropriate urban growth simulation models will also be necessary to compare present landuse to future scenarios. The purpose of this paper was to use Remote Sensing and Geographical Information System (GIS) to study the temporal landuse changes, investigate the spatial attributes which influence urban expansion, and predict future urban growth for the city of Akure, Nigeria.

Data for the landuse of the city was obtained from satellite imagery of 1972, 1986 and 2002. The images were geometrically corrected and ground control point obtained through intensive ground surveys that permitted the co-registration of all images to a Universal Transverse Mercator (UTM). Other images were obtained from extensive GPS mapping; exponential model of Hoffee and Brusells (2002) was used to predict future trend of expansion of the city. Simulated maps of future urban growth were subsequently generated.

This study reveals that the urbanized areas of the city will increase by 2431.60 hectares between 1972 and 1986 and 3852.7 hectares between 1986 and 2002, based on the model the city will expand to 5863.66 hectares between 2002 and 2022. It also indicates that city's expansion will be mostly towards Northwest and Southwest respectively.

The implications of the expansion of the city include traffic congestion, overcrowding and the accompanied problems, destruction of fertile farm lands and deforestation of the surrounding rural areas. Results of this study could serve as a guide to city planners, policy makers and land developers and users to maintain an internal balance between economic activity, population growth infrastructures and services.

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