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# Urban expansion and population growth in Omdurman city, Sudan using geospatial technologies and statistical approaches

Eiman A. Mohammed[1], Hanan M. Alawad[1], Khalid A. Elsayed Zeinelabdein[2], Abdelhafiz G. Ali[3]

[1]Remote Sensing Authority and Seismological Science, National Centre for Research (NCR), Khartoum, Sudan
[2]Depaertment of Geology, Faculty of Petroleum and Minerals, Al Neelain University, Khartoum, Sudan
[3]Department of Geography, Faculty of Arts, Al Neelain University, Khartoum, Sudan

## Email address

eabdalla@hotmail.com (E. A. Mohammed), kalsayed2001@yahoo.com (K. A. E. Zeinelabdein)

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## Abstract

The current study represents an attempt to investigate the status of Omdurman City urban land, Sudan to identify, characterize and quantify the urban sprawl using remote sensing and GIS techniques as well as statistical calculations. The identification, characterization and quantification of sprawl are very important for better urban planning and land resource management. The main objective of this study is to identify and characterize the urban sprawl and population growth of Omdurman City in the period from 1987 through 2000 to 2013 using the powerfulness of remote sensing and GIS technologies to process three Landsat TM, ETM and OLI imageries for the detection, measurement, and analysis of land use/land cover (LULC) changes. The outcome of this study indicated that the total population increased from 552,161 persons in 1983 census to 963,301 persons in1993 census and reached 2,099,751 persons in 2008 census. Omdurman City population is increasing rapidly from 150,000 in 1890 to 3,099,711 in 2014, depending mainly on displacement, migration and natural population growth. As a consequence, the urban land in the study area was increased from 147.8 square km in the year 1987, to 245.5 square km in 2000. This increase may be attributed to the population growth; however, the migration contributes significantly. Two types of displacement and migration occurred: from the rural areas to Khartoum, and that happened during the eighties of the last century due to desertification affected most parts of Sudan, the event that forced many people to migrate to Khartoum. The urban land was increase to 614.9 square km in the year 2013 representing 160% of the urban land in 2000. An increase of about 316% between the years 1987 and 2013 was attained in the period of 26 years. The urban expansion was at the expense of the other land use/land cover types, among which the cultivated areas.

## Keywords

Omdurman City, Urban Growth, Remote Sensing, Landsat Imagery, Land Use/Cover, GIS, Population Growth, Migration

## 1. Introduction

Urbanization is a significant global phenomenon and it becomes a great concern for many parts of the world [1]. Urbanization is an increasing proportion of a population living in settlements defined as urban centers. This usually results from the net movement of people from rural to urban areas or natural increase. However, the definition of what qualifies as urban center differs from one country to another depending on whatever criteria used to define urban [2].

An unplanned urbanization process is now a major problem, especially in the developing countries, where there is lack of dependable and reliable data including spatial data. Factors such as conflicts, political and factional instability, and subsequent internal displacements and migration; population growth; and improved economic opportunities are the driving forces behind the high level of urban growth. This could also be attributed to the absence of an efficient system

for acquiring data about the local urban movements and patterns [1].

Reliable and accurate data are required for development of urban plans. However, such data cannot be easily obtained without using an efficient technology such as satellite imagery [1]. Remote sensing, which is the extraction of information about an object on the earth without making physical contact with it [3], [4] is considered as a powerful tool in the change detection of the land surface. Therefore, urban growth is highly involved in remote sensing and GIS applications ([5] - [7]).

Remote sensing techniques have been proved as a valuable tool in mapping urban areas and becoming data sources for the analysis and modeling of urban growth and land use change [8]. Remote sensing provides spatially consistent data sets with large geographical coverage, high spatial detail, and high temporal frequency [9]. It can also provide consistent historical time series data [8]. There are many techniques that can be used for urban LULC mapping for change detection from satellite data [10]. However, selection of a good change detection method could be sometimes difficult [11] [12] demonstrated that GIS is an appropriate tool for applications in the field of urban planning and management because it integrates information from different sources. Remote sensing and GIS have been proved to be effective and accessible means for extracting and processing spatial information obtained from satellite and aerial images for monitoring urban growth [12]. The correlation between population growth and urban growth can be determined from the Landsat-derived change maps [12].

The main objective of this study is to identify and characterize of the urban sprawl of Omdurman City in the period from 1987 through 2000 to 2013 using the powerfulness of remote sensing and GIS technologies to process three Landsat TM, ETM and OLI imageries for the detection, measurement, and analysis of LULC changes.

Omdurman is the largest city in Sudan, lying on the western bank of the River Nile, opposite to the capital Khartoum. The location of the study area is lying at 15.39 N, 32.29 E (Fig. 1). According to the (2008) census, Omdurman City has the population of 2,395,159 persons.

The study area is flat surface gently sloping towards the White Nile and the River Nile to the west. The elevation ranges between 350 and 510 m above sea level (Fig. 2). The drainage system is dominated by the lower most reaches of the White Nile, River Nile and local systems of ephemeral streams, which flow mostly from northwest and west to southeast and east (Fig. 2). The area is characterized by its scanty vegetation that can be increased along seasonal drainage pattern and river banks.

Omdurman area is regarded as semi-arid climate zone with only the months of July and August seeing significant precipitation. Omdurman area is one of the hottest major cities in the world. Temperatures may exceed 53°C in middle summer. The average monthly temperature is 37.1°C, with six months of the year seeing an average high temperature of at least 38°C.

Geologically, the surveyed area is covered by Cretaceous Omdurman Formation, which is underlain by Precambrian basement rocks including gneisses, marbles, foliated batholithic granites and sheared acid dykes. The formation is covered by Tertiary volcanic rocks (basic and acidic) and Quaternary deposits.


***Fig. 1.*** *Location map of the study area*

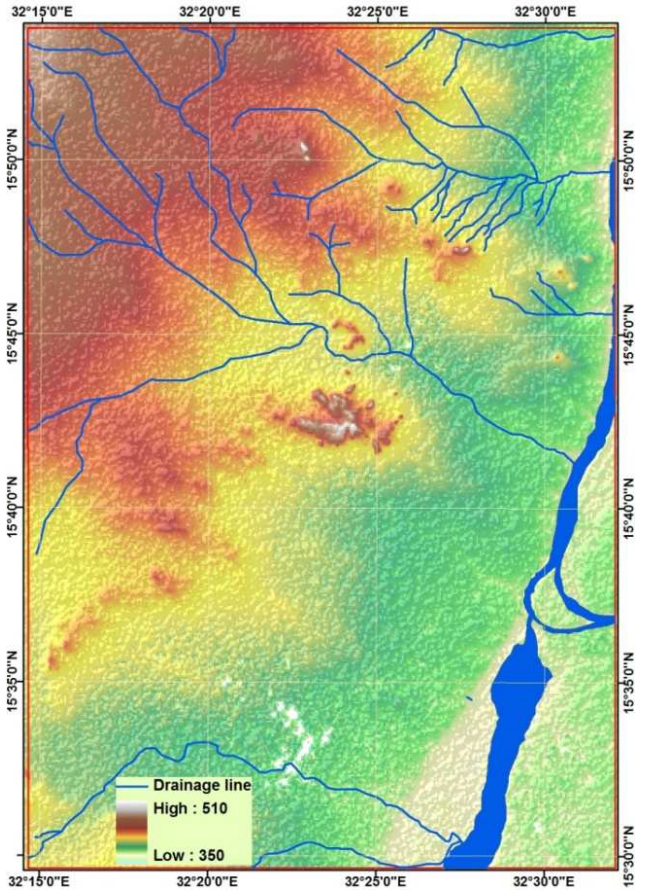


***Fig. 2.*** *Digital Elevation Model and drainage system of Omdurman area.*

## 2. Data Types

The present study is based on multi-temporal Landsat imageries with the path 173/row49 acquired in different dates. The Landsat data were obtained from the USGS Earth Resources Observation and Science Data Centre. Details of the satellite imageries together with the acquisition date are provided in Table (1). All of the datasets are orthorectified and registered to a common coordinate system, UTM zone 36N with WGS 84 datum. The population information was obtained from the Central Bureau of Statistics, Sudan [13].

***Table 1.*** *Detail of the used Landsat imageries.*

| Sensor type | Acquisition date | Spatial resolution |
|---|---|---|
| Landsat 5 TM | November 1987 | 30 |
| Landsat 7 ETM+ | December 2000 | 30 |
| Landsat 8 OLI | December 2013 | 30 |

## 3. Methodology

Landsat TM, ETM and OLI imageries were used in this study. These images were separately stacked and a subset covering the study area from each image was prepared. The images were digitally enhanced and then classified into various land cover/land use types. The adopted classification methods were both the unsupervised and supervised classification. The shape file of the study area was produced to be further checked against a digital version of the LULC map of Sudan produced by FAO [14]. Then calculations were done to compute the total area and the percentage of each LULC for the various Landsat subsets. Overlay analysis was performed in the GIS context.

## 4. Result and Discussion

### 4.1. Omdurman Population Growth

The importance of some knowledge about future population as an aid in social and economic development planning is beyond discussion. In most less developed countries, statistics for any such planning; including a statistical basis for population projections are either very week or completely lacking. As far as population estimates are concerned the former is true of Omdurman City. Nevertheless, it is felt that this attempt is justified as from census data the growth of population for the census year is known and this is the basis for some estimation as to know the deceive factors will developed in the future, resulting in a rough approximation of the population growth which may be expected. Of the three factors that determine growth of population, that is fertility, mortality and internal migration, the effect of migration is the most major factor that affects the growth of Omdurman population.

Omdurman was developed from small village to a national town when Mahdi chosen it as to be the national capital of the Sudan in 1885. Its population grew rapidly from 150,000 in 1885 to 3,099,711 in 2014 (Table 2). The new capital and the religious status of Omdurman attracted a large number of different ethnic groups and tribes from all over the country. The rapid growth of the town was attributed to the huge influx of rural migrants than natural increase.

***Table 2.*** *Omdurman population growth 1890*-2014***

| Year | Population | % of 2014 population |
|---|---|---|
| 1890 | 150,000 | 4.8% |
| 1900 | 150,000 | 4.8% |
| 1910 | 43,000 | 1.4% |
| 1920 | 50,000 | 1.6% |
| 1930 | 104,000 | 3.4% |
| 1940 | 116,000 | 3.7% |
| 1950 | 125,000 | 4.02% |
| 1955/56 © | 116,231 | 3.74% |
| 1960 | 153,522 | 5% |
| 1970 | 267,833 | 7.3% |
| 1973 © | 316,499 | 10.2% |
| 1980 | 467,260 | 15.1% |
| 1987 | 689,858 | 22.29% |
| 1983 © | 552,163 | 17.8% |
| 1990 | 815,180 | 26.3% |
| 1993 © | 963,301 | 31.1% |
| 2000 | 1,422,160 | 45.8% |
| 2008 © | 2,219,751 | 71.6% |
| 2013 | 2,931,917 | 94.59% |
| 2014 | 3,099,711 | 100% |

Sources: [16], **estimated, and *projected from 1955/56 census as a base, © census.

According to Table (2), the population of Omdurman City decreases from 150000 persons to 43000 persons between 1890 and 1900 for the effect of drought and famine occurred at that time. The population stability of Omdurman from 1900 to 1930 was attributed to the rigid measures applied by the colonial administration to control the influx of rural population. The rapid population growth of Omdurman, 1940-1960 were also mentioned by [14] and they stated that "…the population expanded rapidly after the independence period…". Since the independence the same process of growth has continued. At the same time the prevailing difficulties in rural areas have acted as "push" factors leading to an influx into Omdurman.

According to 1983 National Census (Table 2), Omdurman population totaled to 552,163 persons, while in the 1990 Capital Region Census the population in Omdurman City increased to 815,180 persons. [15] explained the phenomenon of rural population of Omdurman as a considerable urban over spilling. Moreover, they explained the phenomenon of the large increase in population around Omdurman urban fringes as a large influx of migrants coming from west. Since 1993 census, the population of Omdurman City increased rapidly to reach more than two million persons in 2008 census.

The total population increased from 552,161 persons in 1983 census to 963,301 persons in 1993 census and reached 2,099,751 persons in 2008 census. At last one can conclude that, Omdurman City population is increasing rapidly in one hundred and twenty five years from 150,000 in 1890 to 3,099,711 in 2014, depending mainly on migration displacement and natural population growth.

## 4.2. Land Use/Land Cover Classification

Multispectral image classification is used in remote sensing to categorize all pixels in an image to produce thematic maps of the existing land cover [17]. Two types of classification (unsupervised and supervised) are used for processing satellite images. Each of these methods groups the pixels of an image into homogeneous classes in order to portray the spatial distribution of different features detected by the satellite sensor [18]. Through this way, the various land covers within the study area were defined into five land cover classes: namely, sand, water body, built-up land, vegetation and soil (Table 3).

***Table 3.*** *Land covers classes of Omdurman.*

| Class | Sub-class |
|---|---|
| 1. Urban or Built-up Land | Commercial and Services, Residential, Industrial, Transportation, Communication and Utilities and Other Urban or Built-up Land. |
| 2. Water Bodies | Streams and Canals, Artificial Canals |
| 3. Light soil | Sand dune land |
| 4. Dark soil | Rock and Lateritic soil |
| 5. Agriculture and Vegetation | Farms ,Natural Vegetation along Urban or Built-up Land, Spar Vegetation Forest |

Using the unsupervised classification, the subsets of three Landsat images of Omdurman area were classified. The result of this classification is the production of three thematic maps portraying the LULC in the years 1987, 2000 and 2013 for Omdurman City (Fig. 3). Summary of the total areas occupied by each LULC types and their percentages in each date are presented in Table (4).

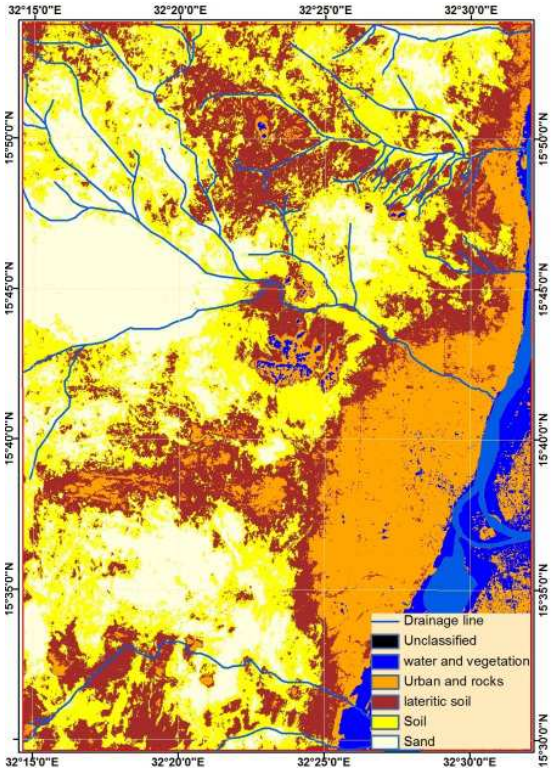


***Fig. 3a.*** *Results of the application of unsupervised classification upon Landsat TM image of Omdurman City, 1987.*

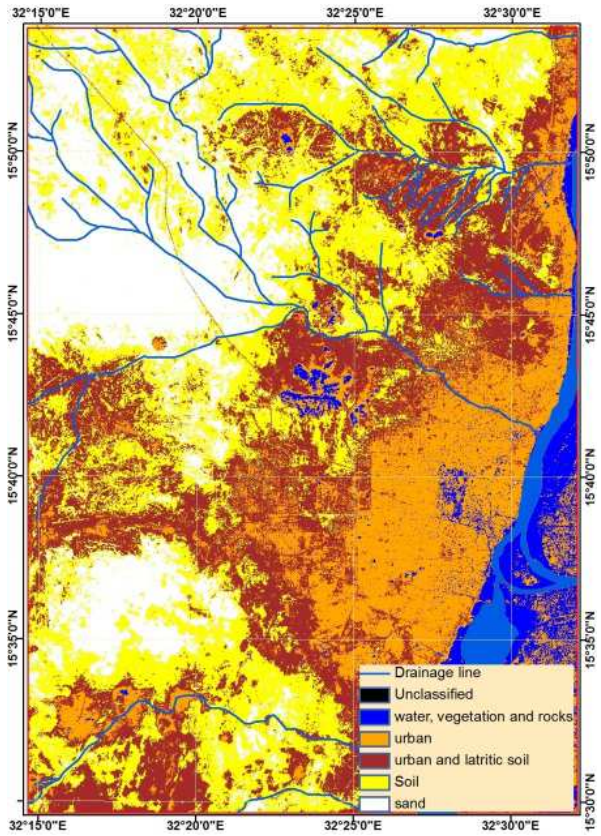


***Fig. 3b.*** *Results of the application of unsupervised classification upon the Landsat ETM of Omdurman City, 2000.*

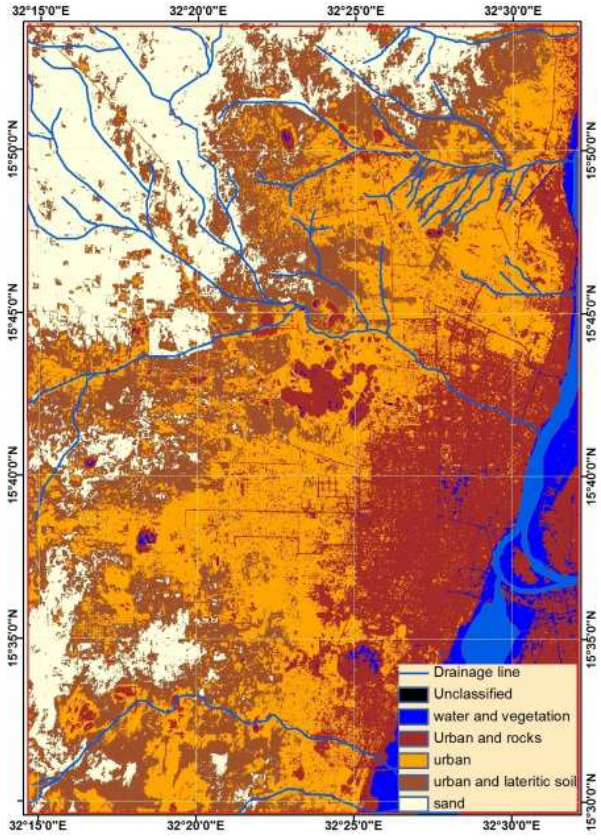


***Fig. 3c.*** *Results of the application of unsupervised classification upon the Landsat OLI image of Omdurman City, 2013.*

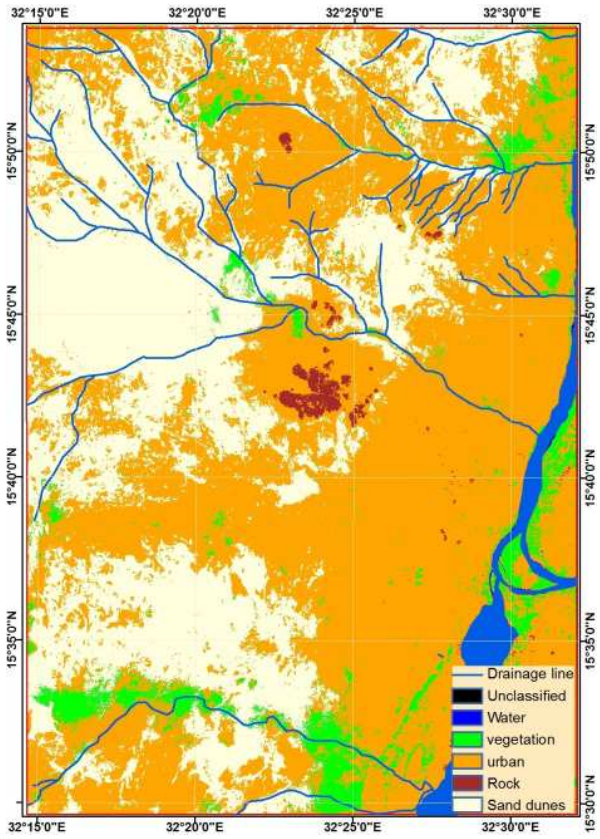


***Fig. 4a.*** *Results of the application of supervised classification upon the Landsat TM image of Omdurman City, 1987.*

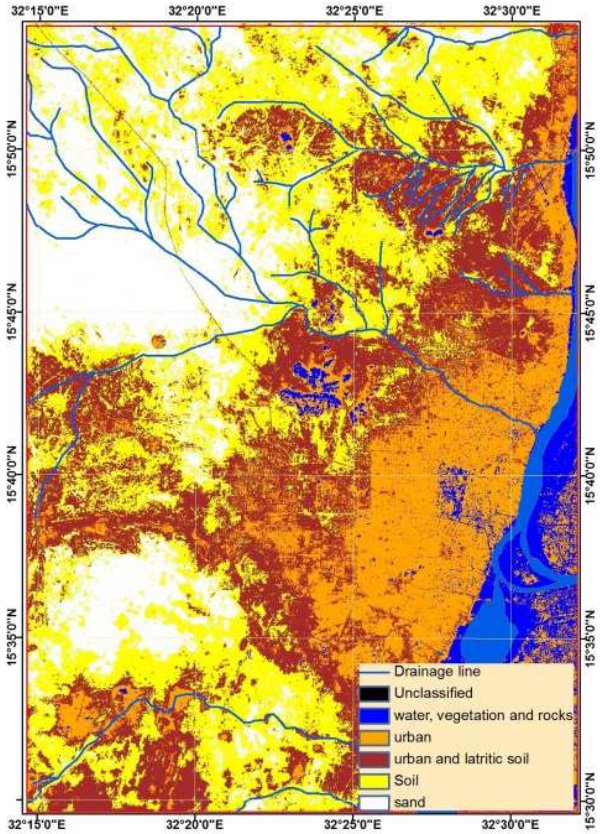


***Fig. 4b.*** *Results of the application of supervised classification upon the Landsat ETM image of Omdurman City, 2000.*

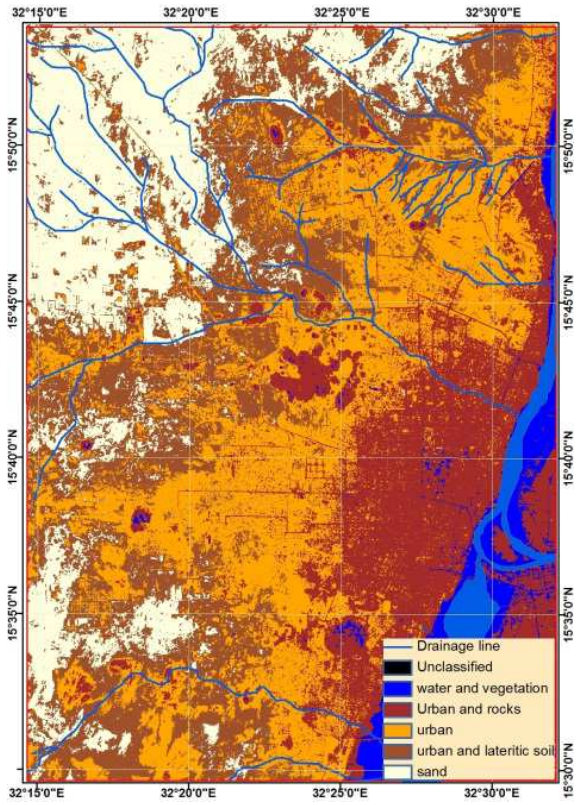


***Fig. 4c.*** *Results of the application of supervised classification upon the Landsat OLI image of Omdurman City, 2013.*

As can be noticed from Figure 3 and Table 4, the results of the unsupervised classification are not adequately accurate. This can be deduced from the mixed classes, such as urban, which is mixed with soil and vegetation, which is mixed with water. This indicates that the natural grouping was unable to separate the different LULC classes accurately. This imposes a problem in determining the percentage of the urban area from the total area, especially in the year 1987. Despite this fact, an overall increase in the urban land can be observed.

The unsuccessful implementation of the unsupervised classification suggests the use of another technique, i.e. the supervised classification. Accordingly, the supervised classification was performed upon the three subsets representing Omdurman in the years 1987, 2000 and 2013. The reference data were the LULC map of Sudan [14] accompanied by adequate knowledge about the investigated area. The result of this process is presented in Figure (4). Table (5) summarizes the total areas occupied by each LULC types and their percentages for each date.

In contrast to the unsupervised classification, the supervised classification managed to separate the different LULC classes. According to this classification, the percentage of the urban land increased form 56.84% in 1987 to 62.56% in the year 2000 and reach 67.39% of the total area in 2013. A remarkable increase was disclosed for the urban land in parallel to decrease in the soil and vegetation during the period 1987-2013.

Although the obtained results from the supervised classification gave good clues about the overall urban

expansion, the final output do not seem to be accurate enough. This is attributed to many factors, among which the types of building materials used by most of the inhabitants. In the peripheries of Omdurman most people use the loamy and ferruginous soils to construct their houses. Accordingly, the built houses to a great extent have the same spectral characteristics as the soil land cover. This introduces some errors in the classification process. Therefore, the obtained results from the supervised classification though are better than the results of the unsupervised one, have error borne.

Due to this reason, a shape file for the urban was manually on-screen digitized utilizing the on-screen mode of digitization in the GIS environment. A shape file of the urban land was produced from each subset to compare the change in urban land through the period 1987-2013. The obtained shape files were superimposed and presented in Figure (5).

***Table 4.*** *The unsupervised classification for each Landsat image of the study area.*

| Class | Area | | | | | |
|---|---|---|---|---|---|---|
| | 1987 | | 2000 | | 2013 | |
| | Sq. km | % | Sq. km | % | Sq. km | % |
| Urban and Soil | - | - | 349.40 | 25.02 | 355.49 | 25.47 |
| Vegetation and Water | 106.88 | 7.68 | 121.59 | 8.71 | 94.08 | 6.74 |
| Soil | - | - | - | - | - | - |
| Sand | 418.83 | 30.1 | 400.43 | 28.68 | - | - |
| Sand dunes | 297.85 | 21.40 | 277.62 | 19.88 | 275.15 | 19.72 |

***Table 5.*** *The supervised classification for each Landsat image of the study area.*

| Class | Area | | | | | |
|---|---|---|---|---|---|---|
| | 1987 | | 2000 | | 2013 | |
| | Sq. km | % | Sq. km | % | Sq. km | % |
| Urban | 790.96 | 56.84 | 873.57 | 62.56 | 940.44 | 67.39 |
| Vegetation | 71.39 | 5.13 | 101.73 | 7.29 | 26.58 | 1.90 |
| Water | 26.67 | 1.92 | 33.08 | 2.37 | 33.80 | 2.42 |
| Rock | 9.95 | 0.72 | 21.17 | 1.52 | 9.45 | 0.68 |
| Soil | 492.69 | 35.40 | 366.83 | 26.27 | 385.31 | 27.61 |

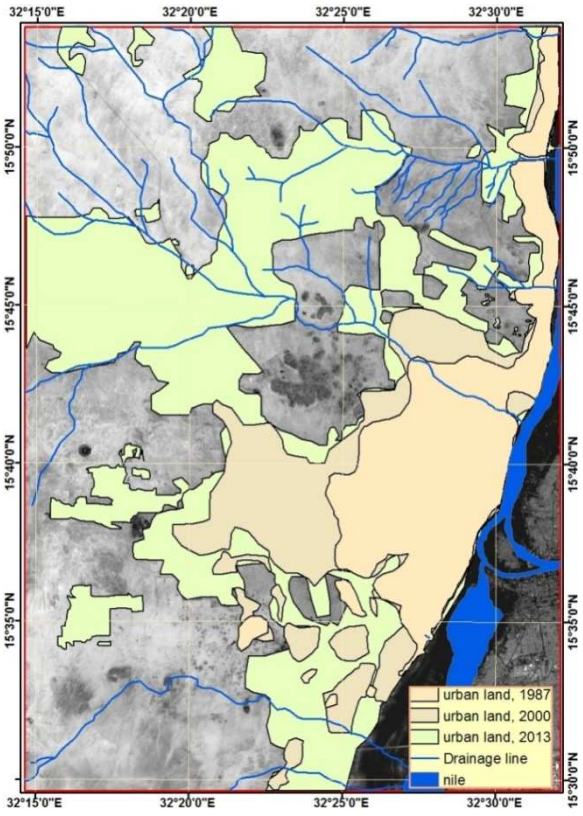


***Fig. 5.*** *Superimposition of the urban land of the years 1987, 2000 and 2013.*

The areas covered by urban land and their percentages in the three different years are summarized in the Table (6) and illustrated in Figure (6).

***Table 6.*** *Summary of the urban land area and percentage of increase in 1987, 2000 and 2013.*

| Year | Urban Land (km2) | Increase % |
|---|---|---|
| 1987 | 147.7954 | - |
| 2000 | 245.5256 | 66 |
| 2013 | 614.9032 | 150 |

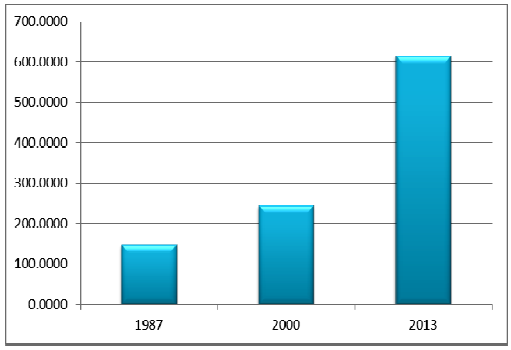


***Fig. 6.*** *The increase in the urban land between 1987 and 2013.*

The increase in the urban land in the study area is clearly noticeable from Figure (6) that indicates an increase from 147.8 $km^2$ in the year 1987 to 245.5 $km^2$ in 2000. This increase may be attributed to the population growth; however, the migration, as mentioned earlier, contributes significantly. There are two types of migration: from the rural areas to urban centres, mainly Khartoum, in quest of better living conditions beside the education and health service. The other type of migration was occurred during the eighties of the last century, whence desertification affected most parts of Sudan,

especially the central and western regions. This event forced many people to move to Khartoum. As a consequence, the urban land increased in the period.

Referring to Table (6), the urban land was increase to 614.9 $km^2$ in the year 2013, by 160%. Comparing this area to the area of urban land in 1987, it can be estimated that an increase of about 316% was attained in the period of 26 years. The urban expansion was at the expense of the other land use/land cover types, among which the cultivated areas.

## 5. Conclusions

This study represents an attempt to investigate the status of Omdurman area, Sudan to identify, characterize and quantify the urban sprawl using remote sensing and GIS techniques as well as statistical calculations. This approach is effective in detecting LULC change and assessing the extent of the urban growth without depending on costive and inefficient land surveys. The identification, characterization and quantification of sprawl are very important for better urban planning and land resource management.

The outcome of this study indicated that the total population increased from 552,161 persons in1983 census to 963,301 persons in 1993 census and reached 2,219,751 persons in 2008 census. Omdurman City population is increasing rapidly from 150,000 in 1890 to 3,099,711 in 2014, depending mainly on displacement, migration and natural population growth. As a consequence, the urban land in the study area was increased form 147.8 $km^2$ in the year 1987, to 245.5 $km^2$ in 2000. This increase may be attributed to the population growth; however, the migration contributes significantly. Displacement and migration from the rural areas to Khartoum, and that occurred during the eighties of the last century due to desertification affected most parts of Sudan, the event that forced many people to move to Khartoum. The urban land was expanded to 614.9 $km^2$ in the year 2013 representing 160% of the urban land in 2000. An increase of about 316% between the years 1987 and 2013 was attained in the period of 26 years. The urban expansion was at the expense of the other land use/land cover types, among which the cultivated areas.

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