

<sup>1</sup>Udeme N. WILSON, <sup>2</sup>Ifechukwude I. AHUCHAOGU, <sup>3</sup>Unwana I. UDOUMOH, <sup>4</sup>Victor E. NWADIANI, <sup>5</sup>Edikan. M. SAM

## MODELING IMPACT OF LAND USE AND LAND COVER CHANGE IN IBIAKU OFFOT WATERSHED, UYO, NIGERIA

<sup>1,2</sup>Department Of Agricultural And Food Engineering, University Of Uyo, Uyo, NIGERIA

<sup>3,4</sup>Department Of Civil And Water Resources Engineering, University Of Delta, Agbor, Delta State, NIGERIA

<sup>5</sup>Department Of Geology And Mining Technology, University Of Port Harcourt, NIGERIA

**Abstract:** In recent times, the dynamics of Land use / Land cover (LULC) and particularly settlement expansion in the area requires a more powerful and sophisticated system such as remote sensing and geographic information system (GIS). This study examines spatial change in land use and land cover of Ibiaku–Offot, Uyo Watershed. The general patterns of land use/cover as they were recorded in the remotely sensed data were analyzed. For the Landsat TM, ETM+ and OLI, a False Colour Composite (FCC) operation was performed using the ArcGIS 10.5 software and the images were combined in the order of band 4, 3 and 2 for Landsat TM and ETM+ while that of Landsat OLI was in the order of band 5, 4 and 3 due to change in sensor. A supervised classification scheme with the maximum likelihood algorithm was used for the classification. The images were then clipped to the boundary of the study area. The results showed that the natural environments, comprising the forest, shrubland, grassland, agricultural land, wetland, barren land, water body) were being threatened, as they reduced drastically in the area over time and space while the social environment (built–up area) expanded and this may likely be the trend in the future years. The results revealed changes in the landscape in Ibiaku–Offot community from 1986–2024 as there is increase in the built–up area within the 38 years under study. Significant changes in land use within the study area over time have contributed to increasing soil erosion. This study provides decision support tools target, thus, providing conservation needs at both the community and farm scales and hold promise for federal and state agencies as well as other stake holders involved in the management of watershed and maintenance of the ecosystem for productivity and sustainability.

**Keywords:** Land–use, Land–cover, Remote Sensing, GIS, Spatial modelling, Ibiaku Offot

### INTRODUCTION

Significant population increase, migration, accelerated socio-economic activities, increased demands on the landscape for food and shelter and an increased number of products of man's living environment have led to un-parallel changes in land and modification of rural and urban environment; these changes have negatively impacted the environment (Paul and Charles, 2002). Land and water resources are generally depleting due to rapid increase in population, urbanization and industrialization. Just like every other African country, Nigeria is witnessing fast-growing urbanization, with the South western part and some major cities in the South-South part, Uyo inclusive having the highest urbanization level (Aloba, 2004). The urban expansion in Uyo, as is noticed in other parts of Nigeria, occurs in an unguided, unplanned, uncoordinated, and uncontrolled manner (Udumoh *et al.*, 2020).

The advent of geographic information system (GIS) has made it possible for researchers to integrate multisource and multi-data in generating land use and land cover changes. The collection of remotely sensed data facilitates the analysis of Earth-system function, patterning, and change at local, regional and global scales over time. Such data also provide an important link between intensive, localized

ecological research, thus enhancing regional, national and international conservation and management of soil and water resource as well as biological diversity (Wilkie and Finn, 1996). The study sought to articulate the pattern of LULC changes in a fast-growing industrial areas in Akwa Ibom State, South-South Nigeria.

It is a general believe that urbanization has both direct and indirect impacts on land use transformation. In recent times, many researchers have conducted studies on the integration of remote sensing (satellite imageries), geographic information system in modeling land use and land cover change in several parts of the world. Abubakar, *et al.* (2000) in their study on assessment of environmental degradation using satellite remote sensing technologies, had examined land use/land cover changes in Talata-Mafara area of Zamfara State, Nigeria. Their results showed major changes among six land use/land cover classes between 1986 and 1995. The result of the studies showed that cultivated land increased from 117km<sup>2</sup> to 158.5km<sup>2</sup>, while grass, shrub and thicket land cover reduced from 20km<sup>2</sup> to 12.50km<sup>2</sup>. Conversely, there were drastic increase in bare land surfaces from 5.4 km<sup>2</sup> to 27.1km<sup>2</sup>, while settlement revealed a slight decrease from 1.3km<sup>2</sup> to 1.1 km<sup>2</sup> rather than the

expected growth; uncultivated vegetated wetland also revealed a decrease from 14.6 to 8.3km<sup>2</sup> and water bodies increased from 3.9km<sup>2</sup> to 5.0km<sup>2</sup>.

In another study, Bhaduri *et al.* (2000) used Long-Term Hydrologic Impact Assessment (L-THIA) to investigate the long-term hydrologic impacts of land use with special concern to small and low-frequency storms in the Little Eagle Creek in Indianapolis, India. The study made use of daily precipitation data from 1966 to 1995, with 1973, 1984, and 1991 land use data used for the simulations. The results of the study showed that an 18% increase in urban and impervious areas resulted in approximately 80% increase in annual average runoff volume.

The cover management factor reflects the proportion of soil loss occurring under a specific type of vegetation compared to that on bare soil. It serves as an indicator of the extent to which a particular land cover protects the soil from erosion. The value of C depends on vegetation type, stage of growth, and cover percentage. It is obvious that the major negative impacts of the globally recognized rapid land use and land cover changes include land degradation and ecological deterioration. And these are very common experiences in many African countries due to poorly planned human interference with the environment. Therefore, an attempt was made in this study to map out the status of land use and land cover of Ibiaku Offot, Uyo between 1986 to 2024, with the aim of detecting the land consumption rate and the changes that have occurred particularly in the built-up and vegetated areas in order to predict possible changes that might occur in the next 30 years if adequate information and appropriate technology are not employed to ensure environmental management. Thus, the significance of this study was to provide policy makers, land use planners, and natural resources manager with baseline data so they could develop and put into practice successful soil conservation measures.

#### STUDY AREA: GEOGRAPHY, TOPOGRAPHY & CLIMATE

The study area is the Ibiaku Offot community and its environs in the Uyo Local Government Area of Akwa Ibom State. Akwa Ibom state is located in the coastal and southern part of Nigeria and covers a total area of 8,412km<sup>2</sup>, encompassing the Qua Iboe River Basin, the western part of the lower Cross River Basin, and the Eastern part of the Imo River Basin. It has a total population of approximately 5 million people and is the country's highest oil and gas-producing state. The state is bordered in the south by the Atlantic Ocean. The ocean front spans a distance of 129km from Ikot Abasi in the west to Oron in the east. The study area lies between latitude 4° 50' and 5° 10' North of the Equator,

and Longitudes 7° 45' and 8° 05' East of the Greenwich Meridian.

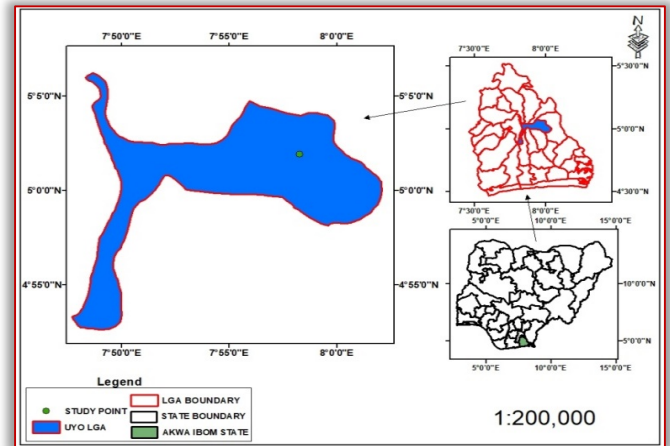


Figure 1: Map of study area

The topography the study area is mostly flat except for some areas which have ravine and gullies. This is as a result of the underlying geology of the state is predominantly coastal plain sediments. The topography of Uyo is characterized by relatively gentle slope and the soil is utisols with a distinct argillic horizon (Okon *et al.*, 2020).

The study area is characterized by two major climatic seasons: the wet season and the dry season. The wet season lasts between the month of March and October and in some years may extend to November. The Annual rainfall averages between 1800-3200 mm per annum. The dry season is usually experienced between the months of December to February. The mean temperature throughout the year is between 22.80°C to 30.13°C. The Relative humidity varies through the year from 70 to 80%. The geographic location of Uyo make the basis of it described as a tropical rain forest region.

#### METHODOLOGY & DATA SOURCE

##### Primary data

Primary data sources include the meteorological record of rainfall variation (monthly) adding up to an annual rainfall data of the study area from the National Aeronautics and Space Administration (NASA) repository and the soil data. The soil data is obtained from the outlook in parts of the study area. The soil data used for this study are based on the field survey. The rainfall data used were retrieved weather data with corresponding meteorological, temporal, and spatial features from the NASA repository (NASA, 2022). The rainfall data used for this work were from 2000 to 2023 monthly average data.

##### Secondary data

##### — Multispectral Satellite Imagery

Optical multispectral imagery from Landsat was used for this study. The LANDSAT data were downloaded from USGS Earth Explorer. The LandSat satellite image used for this work were from 1986 to 2024. The Thematic Mapper (TM)

image was downloaded for 26<sup>th</sup> Dec., 1986. The Enhanced Thematic Mapper Plus (ETM+) image was downloaded for October 2003 and the Operational Land Imager (OLI) for 2016 and 2024, respectively. The image acquisition dates were selected at a similar season to factor in land cover change due to seasonal variation. The Landsat images have 30m resolution. The data was used to determine the Land use Land cover classification of the study area.

#### — Digital Elevation Model

Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) Global Digital Elevation Model (GDEM) version 2, a product of METI and NASA, was used for this study with a 30m resolution.

#### ■ Software

The major software to be used for these studies includes: ArcGIS 10.5 and Microsoft Excel

#### ■ Data processing

#### — DEM

The study area was covered by four scenes of ASTER DEM. The individual DEM covering the study area was merged together using the Raster analysis tool called the mosaic to raster tool build in ArcGIS 10.5.

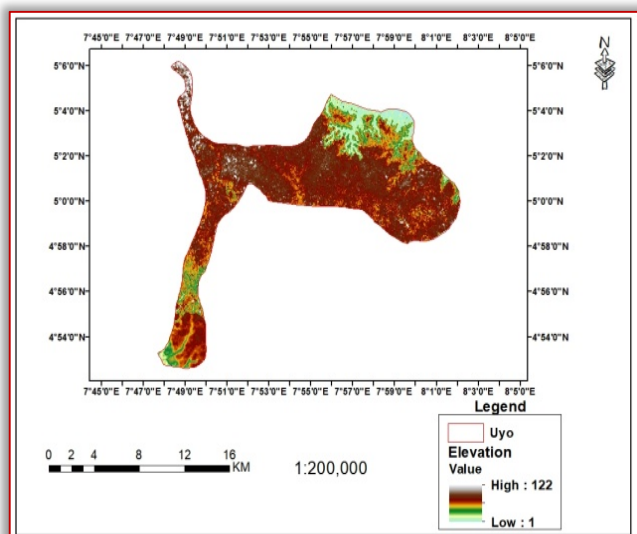


Figure 2: Fill DEM of the study area.

#### — Cover Management Factor (C)

The cover management factor reflects the proportion of soil loss occurring under a specific type of vegetation compared to that on bare soil. It serves as an indicator of the extent to which a particular land cover protects the soil from erosion. The value of C depends on vegetation type, stage of growth, and cover percentage. The estimation of cover factor (C) in this research is based on established values of the C factor inferred from literature reviews, where direct values have been assigned to highly accurate land cover classification maps as other popular methods with satellite data, such as relating the C factor to NDVI (Normalised Differentiated Vegetation Index) by

linear regression methods be weaker in their estimation of the C factor. To derive the C-Factor we used the Land Use Land Cover classification, which was reclassified to adopt the C factor values from the literature.

The land use land cover classification: this was done using the Landsat satellite imagery for 1986, 2003, 2016, and 2024. The LANDSAT data were captured under clear conditions (0% cloud coverage for all the images), hence uniform atmospheric conditions within the images were assumed and no atmospheric corrections were applied. All the images were pre-processed by the USGS to rectify any geometric or radiometric distortions of the image. This correction process employs both Digital Elevation Models and Ground Control Points to achieve a product that is free from distortions related to the Earth (e.g. curvature, rotation), satellite (e.g., attitude deviations from nominal), and sensor (e.g. view angle effects). The USGS also geometrically corrected and georeferenced both images to the WGS1984 datum and Universal Transverse Mercator (UTM) zone 32N coordinate system.

For the Landsat TM, ETM+ and OLI, a False Colour Composite (FCC) operation was performed using the ArcGIS 10.5 software and the images were combined in the order of band 4, 3 and 2 for Landsat TM and ETM+ while that of Landsat OLI was in the order of band 5, 4 and 3 due to change in sensor. The images were then clipped to the boundary of the study area.

A supervised classification scheme with the maximum likelihood algorithm was used for the classification.

The supervised classification was performed by creating a training sample, and based on the spectral signature curve, various land-use classes were identified, namely: Water body, Built-up Area, Bare Surface, Grassland, Forest, and Shrubland.

The maximum likelihood classifier tool considers both the means and covariances of the class signatures when assigning each cell to one of the classes represented in the signature file. With the assumption that the distribution of a class sample is normal, a class can be characterized by the mean vector and the covariance matrix. Given these two characteristics for each cell value, the statistical likelihood is computed for each class to determine the membership of the cells to the class. These classes were observed distinctly on the clipped image and were used for the classification. Table 1 shows the characteristics of these classes and the colours assigned to them. The LULC classification result was reclassified with the corresponding C-value as shown in Table 2.

Table 1: Land Use/Land Cover classes and descriptions

| CLASS | LAND USE<br>LAND COVER | DESCRIPTION                                                                                      | EXAMPLES                                                                                                                                                        |
|-------|------------------------|--------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1     | Water Body             | Surface water bodies                                                                             | River, permanent open water, lakes, ponds, canals, permanent wetlands, marshy land, and swamps.                                                                 |
| 2     | Built-up Areas         | Impervious surfaces that do not allow infiltration of water                                      | All infrastructure—residential, commercial, mixed use and industrial areas, villages, settlements, road network, pavements, and man-made structures.            |
| 3     | Bareland               | Includes all open grounds that are neither vegetated nor built-up, untarred roads and footpaths. | Fallow land, earth and sand land in-fillings, construction sites, developed land, excavation sites, open space, bare soils, and the remaining land cover types. |
| 4     | Forest                 | This includes all plant trees along river channels, forests, parks and reserves etc.             | Trees, natural vegetation, mixed forest, and vegetated lands,                                                                                                   |
| 5     | Grassland              | This includes all grass plants                                                                   | Garden grassland, parks and playgrounds,                                                                                                                        |
| 6     | Shrub land             | This include abandon bushes and shrubs                                                           | Shrubs                                                                                                                                                          |
| 7     | Farmland               | This includes all plants and cultivated lands                                                    | Agricultural lands, and crop fields.                                                                                                                            |

Table 2: Land cover classes and assigned cover (C) factor values

| S/N | LANDUSE LANDCOVER CLASS | C–FACTOR VALUE |
|-----|-------------------------|----------------|
| 1   | Water Body              | 0              |
| 2   | Built-up Areas          | 0.09           |
| 3   | Bareland                | 1              |
| 4   | Forest                  | 0.001          |
| 5   | Grassland               | 0.05           |
| 6   | Shrub land              | 0.014          |
| 7   | Farmland                | 0.15           |

Source: Girma and Gebre (2020), Girmay *et al.* (2020), and Getachew *et al.* (2021))

## RESULTS AND DISCUSSION

### Cover Management Factor (C)

The C-factor maps in Figures 3a, 3b, 3c and 3d clearly reflect the condition of natural vegetation and its positive relationship with soil loss across the study area. A notable feature of these maps is the substantial variation and non-uniform spatial distribution of the C-factor between the four study periods.

Significant changes in land use within the study area over time have contributed to increasing soil erosion. Extensive deforestation has occurred from

1986 to 2024, with forested areas being rapidly converted to agricultural land, urban settlements, and infrastructure developments, as shown in figures 3e, 3f, 3g, and 3h. These changes have intensified the hazards of soil erosion.

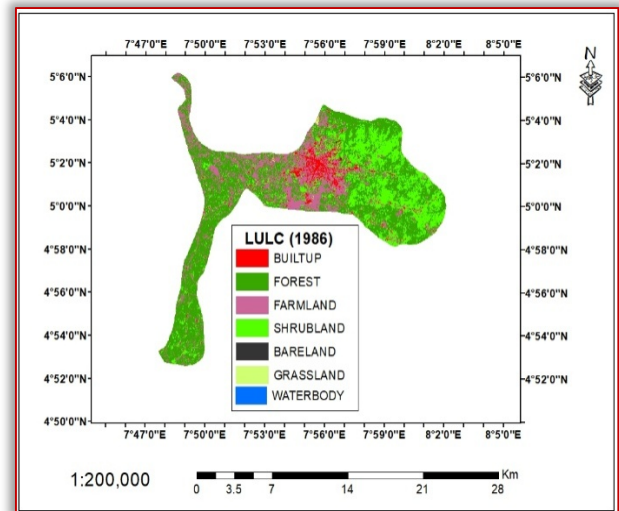


Figure 3a: C-factor map for 1986

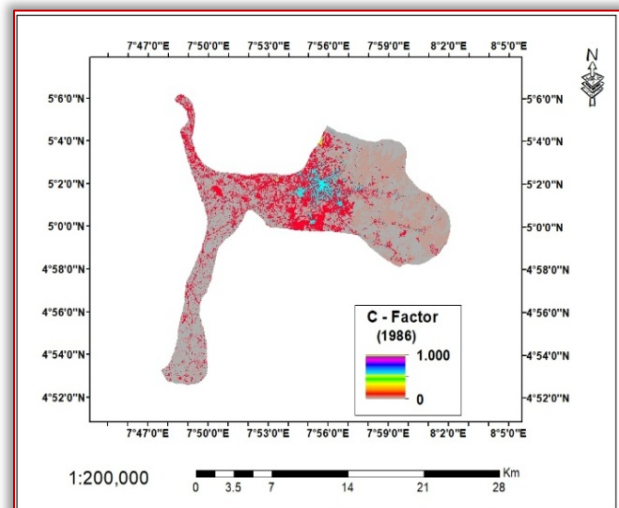


Figure 3e: LULC map of 1986

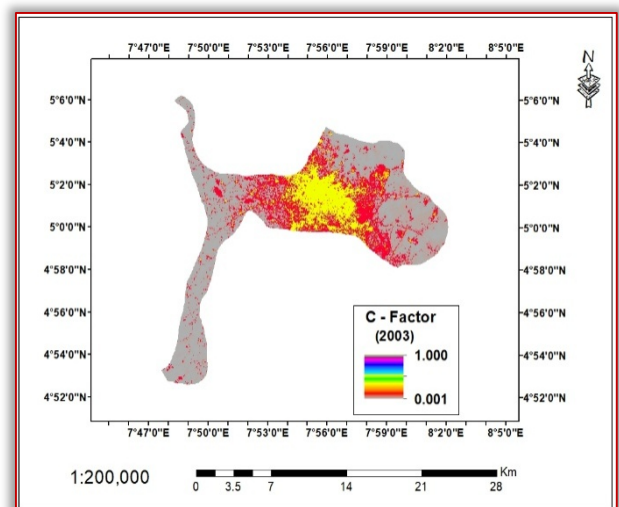


Figure 3b: C-factor map for 2003

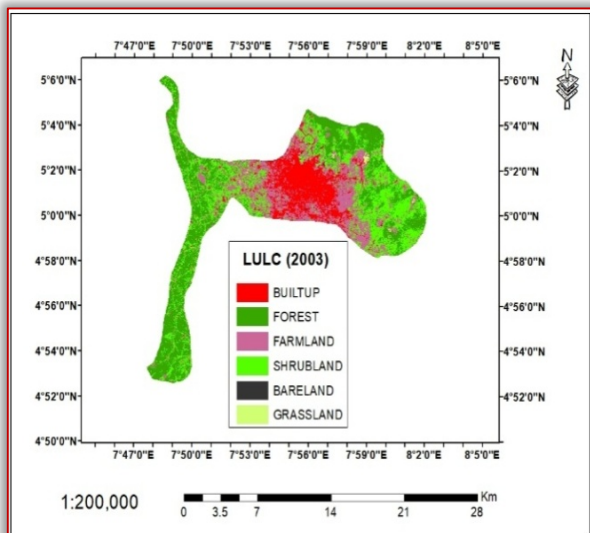


Figure 3f: LULC map of 2003

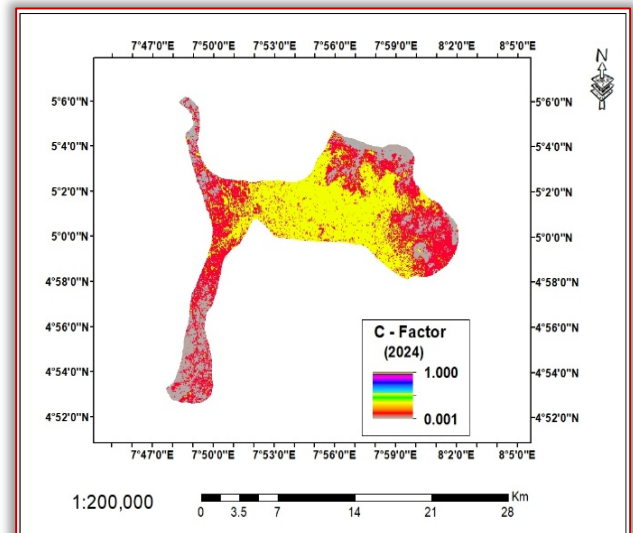


Figure 3d: C-factor map for 2024

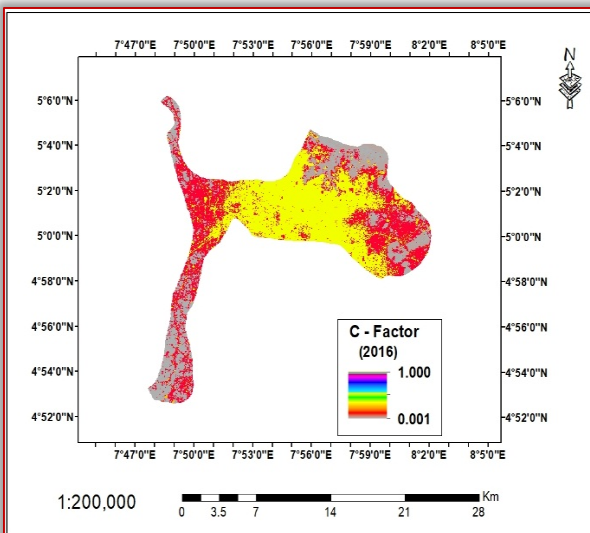


Figure 3c: C-factor map for 2016

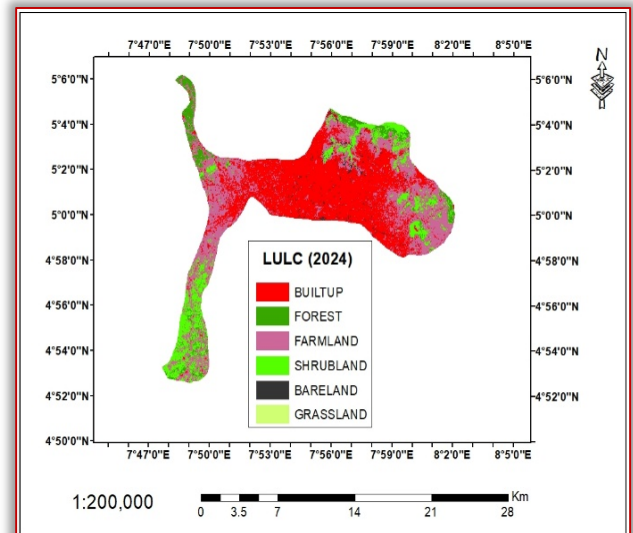


Figure 3h: LULC map of 2024

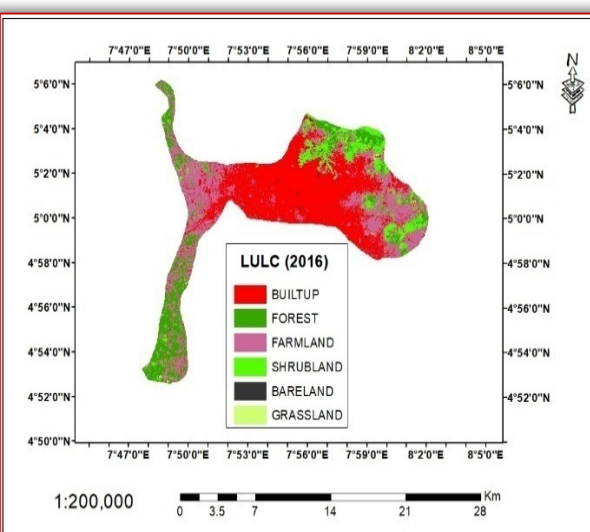


Figure 3g: LULC map of 2016

Based on the 2024 Landsat satellite image analysis, seven different Land use and land cover (LULC) (Table 2) classes were identified. The bareland was accounted for the highest C-value. In such area, it is likely to increase the direct impact of rainfall as compared to perennial and forest cover. This result (Figures 3a-h) showed the absence of vegetation cover over time in the study area, which could help protect soil from erosion by holding the soil in place, reducing the impact of raindrops, and decreasing surface runoff.

A study conducted in Gibe-1 catchment (Central part of Omo-Gibe) found the same trends of LULC (Gizaw and Degifie, 2018). Also, similar trend was found in a study conducted by Girma and Gebre (2020). Different types of vegetation can have different effects on soil erosion. Forests with dense tree covers can provide a better protective layer for the soil than grasslands or crops with sparse vegetation.

The more vegetation there is in a watershed to intercept and transpire water, the less the runoff

there will be. Invariably, the amount and type of vegetation in a given catchment influence the rates of runoff and erosion in that catchment or drainage basin. It is an established fact that plants reduce the impact of raindrops on soil and slow the speed of water flowing across the surface of the land, thereby allowing more water to infiltrate into the soil. A forested or native grass watershed typically delivers its runoff slowly so soil and channel erosion are usually not severe. With the steady loss of vegetative cover over time in the watershed studied, consequent upon urbanization and industrialization, runoff rates and amounts becomes excessive in the watersheds, giving room for more soil loss. Increased runoff means less water is allowed to infiltrate to groundwater or return to the atmosphere through transpiration. More runoff increased erosion of the bare land surface.

### CONCLUSION

The study revealed that data obtained from satellite remote sensing, interfaced with GIS can play an important role in understanding the nature and extent of changes in land use and land cover where these changes are occurring and are being monitored in local scale. The quantitative evidences of land use/land cover changes revealed the dynamic growth of Built-up areas. The trend and extent of urban change is likely to continue with the rapid development of infrastructure (urbanization) due to increasing population. In order to alleviate the dramatic land use/land cover change and adverse environmental impacts of urbanization and increasing built-up surfaces, which negates the principle of sustainable development, this current growth pattern needs to be managed through effective land use/land cover planning and management. This will help ensure the protection of the fragile and important wetland and water body in the area, thereby reducing environmental degradation in the form of erosion and water stress, and ensuring environmental sustainability.

In a nutshell, this study shows change in the landscape in Ibiaku-Offot community from 1986-2024 as there is increase in the built-up area within the 38 years under study. Significant changes in land use within the study area over time have contributed to increasing soil erosion consequently, water bodies have been covered by riparian while wetland while wetland has reduced marginally. However, the land management strategies to be adopted should align with the characterization of the land Use, topography, and interest of the local community. Furthermore, agroforestry, terracing, cut-and carry system can be integrated to successfully and suitably manage the most erosion-prone hotspot as revealed in the maps.

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