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Land Use and Land Cover in Akure City, Ondo State, Nigeria, Using GIS and Remote Sensing

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Abstract

Urbanization and industrial development have intensified pressure on forest reserves in cities and settlement areas, increasing the vulnerability of urban forests to land-use change. This study examines the effects of land-use changes on forest encroachment in Akure City, Ondo State, Nigeria. A remote sensing and GIS-based approach was employed using satellite imagery obtained from the United States Geological Survey (USGS) for 2000, 2010, and 2020. The images were processed and analyzed using ArcMap 10.5 and Environment for Visualizing Images (ENVI) software to assess changes in land-use and land-cover patterns over the study period. The findings rhjeveal notable changes in Akure City's land-use structure, with less dense forest accounting for 41%, 66%, and 58% in 2000, 2010, and 2020, respectively, while built-up areas increased from 1.53% in 2000 to 3.28% in 2010 and 5.28% in 2020. The loss of natural vegetation also increased substantially from 4.4 km² in 2000 to 9.34 km² in 2010 and 12.01 km² in 2020. Surface water bodies were nearly absent in 2000 but accounted for 0.93 km² in 2010 and 0.66 km² in 2020. These findings indicate that continued urban expansion and associated land-use changes are likely to accelerate forest encroachment in Akure City. The study contributes to urban environmental management by highlighting the need for government authorities at all levels to implement sustainable forest conservation strategies and integrated city management policies.

Keywords: Urban Expansion; Forest Encroachment; Land-Use Change; Remote Sensing; GIS Analysis.

INTRODUCTION

A dynamic, pervasive, and quickening process in ecosystems is the change in forest cover. Satellite data is now accessible and helpful for research detecting changes in forest cover. It is possible to identify the state of the forest and track changes in different structural and biophysical factors. One of the primary uses is change detection based on GIS and remote sensing. For specific change detection, a set of temporal images based on the time period of interest can be used, and different maps are produced using GIS.

Forests have a significant impact on the overall balance of carbon in the atmosphere, which can either mitigate or worsen the effects of global warming. Forest carbon sequestration may be able to reduce the atmospheric concentration of greenhouse gases. The US Environmental Protection Agency (2005) states that land-use-land-change and forest activities balance the overall U.S. emissions by 13% and carbon dioxide emissions between 1990 and 2003.

For centuries, millions of people in tropical countries have relied heavily on forest products for their livelihoods, making forests one of the planet's most varied and pervasive ecosystems. Additionally, these goods are essential to the livelihoods of those who live in or close to forests. They also offer a variety of environmental services, the most important of which are the preservation of biodiversity, the protection of watersheds, soil preservation, and the slowing down of climate change. Deforestation and the loss of biodiversity have become widespread occurrences worldwide in the last few decades.

Streams and rivers become silted, the water cycle is disturbed, species are lost, biodiversity and their habitat are destroyed, and deforestation plays a major role in global warming. Thus, the loss of forest resources poses a severe risk to a nation's socioeconomic well-being as well as the stability of the environment. The United Nations Framework Convention on Climate Change (UNFCCC) has identified forests as one of the primary concerns in halting the current global warming, acknowledging the critical role that forests and tree cover play in maintaining environmental stability on a worldwide scale.

Geographic information systems (GIS) and remote sensing (RS) have shown themselves to be among the most accurate tools for determining the degree and trend of changes in land cover patterns over time (Lillesand et al., 2003, Quan et al., 2013). In order to track changes in the land cover, the methods also offer a reliable source of data from which current land cover information can be extracted effectively and affordably (Franklin et al., 2000, Fichera et al., 2012).

The geographic information system, or GIS for short, is a system that enables the collection, updating, and display of several previously disparate datasets, combining them into a single reference system for spatial analysis from which connections can be found and choices made (Sowton 1991).

For a variety of studies, including those involving solid mineral studies, ocean cover, land use cover change, and natural disaster management, remote sensing (RS) has been used to identify variations in land cover. It is a helpful tool for mapping land cover and uses using various adopted techniques and data sets, as well as for classifying land. Particularly, Landsat images have been very helpful in classifying various landscape elements on a larger scale (Ozesmi and Bauer, 2002) (Butt et al. (2015).

Degradation of forests is a major issue for the environment, society, and economy, especially in developing nations. Up to 850 million hectares of forests and forest lands are thought to be degraded (ITTO 2002). However, because different stakeholders with varying goals perceive forest degradation differently at the national and sub-national levels, it is challenging to quantify the scope of the issue.

Nigeria has the highest rate of deforestation in Africa, according to the Food and Agriculture Organization of the United Nations (FAO, 2005). The nation lost 55.7 percent of its primary forests between 2000 and 2005, and the rate of forest change rose from 31.2 percent to 31.2 percent annually (Orga- and Cover, 2010). For a variety of reasons, including the export of timber, vegetation has been cleared in Africa. land for logging, grazing, wood for fuel, and subsistence farming.

In 2005, 12.2% of Nigeria's land area, or 11,089,000 hectares (27,400,000 acres), was covered by forests. An average of 409,700 hectares of forest were lost annually in Nigeria between 1990 and 2000, translating into an average annual deforestation rate of 2.38 percent.

According to Orga- and Cover (2010), Nigeria lost approximately 6,145,000 hectares of forest cover, or 35.7 percent, between 1990 and 2005. Deforestation in Nigeria is becoming one of the country's most serious environmental problems. The northern area is particularly impacted by the effects of deforestation due to its proximity to the vast Sahel savannah, which connects the deserts of Niger and Chard north of the equator. The most harmful practice threatening the nation's forest resources is still the encroachment of forest land for production and other uses.

The purpose of this study was to use geo-spatial analysis to examine the rate of forest encroachment in Nigeria's Akure Forest Reserve in Ondo State. It took into account the following objectives: mapping out the various land uses and land covers and their spatial distribution within the study area; calculating the amount of forest encroachment within the study area; and performing a normalized vegetation index to display the quantity of live green vegetation.

MATERIALS AND METHODS

Study area

Akure is the study area. Situated in the southwest region of Nigeria, this is one of the traditional Yoruba cities. The Forest Reserve under study is located in the Akure South local government area of Ondo State, within the humid rainforest zone of Nigeria. It lies between latitudes 7°16'40" and 7°18'38"N and longitudes 5°9'11" and 5°11'39" (Figure 1), and covers 66 km^2 land area when it was gazetted in 1936. In the northeast, Osun State borders the forest reserve. Oke-Igbo, Ifedore, Akure South, Ile-Oluji, Idanre, and Ondo East are the five local government areas in Ondo State that share a border with the forest. The rainy and dry seasons are the two main seasons in the tropical climate of Akure Forest Reserve. According to Gbiri and Adeoye (2019), the average annual rainfall is 2000 mm in the south and 1500 mm in the north, with mean daily temperatures ranging from 210°C to 290°C and a relative humidity of 80–85%.

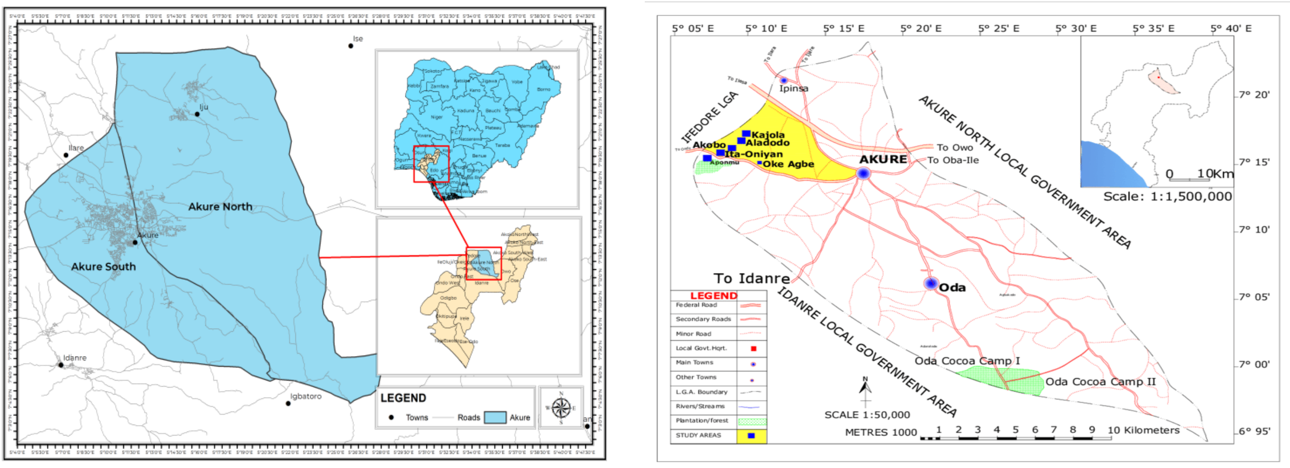

Figure 1: Study Area

In general, the land is gently undulating, with average of 100–270m and some sporadic elevations of up to 1500m in some parts. According to the report, the main rivers in Akure are the Ala, Omi Ebo, Aledi-Moponyin, Ijala, and Ukere. Akure's soils are primarily oxisols and utisols (tropical ferrugineous), and their texture, drainage, and gravel content vary geographically. Akure is covered by forest vegetation, which is divided into three categories: forests, gallery forests, and forest reserves. Rainforest trees like mahogany, obeche, iroko, afara, and others are found in these forests. are found and put to use as lumber. Other profitable trees include coconut, orange, mango, raffia, oil, and African pear. There is now derived forest all around Akure as a result of the ongoing removal of vegetation in the area.

Methods

This study used secondary sources for its data collection. Using a 10-year interval, Landsat satellite images from 2000, 2010, and 2020 were obtained. Online information was taken from the US Geological Survey. The years chosen were determined by taking into account images without clouds in the available Landsat imagery. For this study, Landsat 7 TM data collected on February 15, 2000 (subject imagery) and February 10, 2020 (reference imagery) of the study region were obtained. In February, the data were obtained on a 190/55 path/row in order to reduce the impact of cloud cover on the satellite imagery. Landsat 7 ETM+ (Enhanced Thematic Mapper plus) and Landsat 7 TM (Thematic Mapper) share the same bandwidths. Landsat 7 TM and Landsat 7 ETM+ are both high resolution (30m) and data generated through this are effective for monitoring changes in forest cover. The procedures for the research design for this study are presented in Figure 2. Google Earth Pro, Erdas GIS, and ArcGIS Version 10.3 were used for data analysis after image pre-processing, classification design, and classification for land use/land cover dynamics and comparison of changes between the years under consideration.

Conceptual Clarification

Land evaluation

The use of land for specific purposes, the procedure of evaluating its performance is referred to as land evaluation. According to FAO (1976), it involves conducting and interpreting surveys and studies of landforms, soils, climate, vegetation, and other aspects of the land in order to identify and compare promising land use types that are relevant to the evaluation's goals. Also, FAO (1984) defines land evaluation for forestry as the process of evaluating the performance of land under specific land use types. The comparison of land and land use is its main component, where land is defined as all aspects of the natural environment that have the potential to significantly impact how humans use land. More precisely, assessing land entails contrasting the attributes of the land with the needs of land use. The findings of applying the various land utilization types to each of the mapped land units are predicted using this comparison as the foundation. Better and sustainable land management for the benefit of people is the main goal of land evaluation, which also aims to ascertain whether a piece of land is suitable for other relevant land uses, whether they are current or potential.

The productivity, stability, and sustainability of land use systems serve as the foundation for the suitability evaluation (Huizing et al. (1995). Analyzing information about the land, such as its soils, climate, vegetation, etc., is the main goal of land evaluation. regarding practical options for enhancing that land's use. The land itself, along with its characteristics, uses, and potential, are the main focus (FAO, 2007). The main goal of land evaluation is to determine the best land use for each type of land, taking into account both physical and socioeconomic factors as well as the preservation of environmental resources for future use, since many land use decisions are based on socioeconomic factors (Rossiter, 2001). Thus, a wide range of other disciplines are supported by land evaluation. It can be used for a variety of things, such as land use planning to investigate the possibilities for particular land uses, particularly forestry land use, or the need for better forestry land management or the control of forestry land degradation.

Thailand (Shrestha et al. 1999), Kenya (Fischer and Antoine 1994), and Jamaica (UNEP/FAO 1994) have consistently defined land evaluation that involves land, land mapping unit, major land use, land utilization type, multiple and compound land use, land characteristics, land qualities, diagnostic criteria, land use requirements, imitations, land suitability, land suitability order, class, subclass, unit, and potential suitability classification, based on the evaluation's goals. The majority of the 1976 framework's ideas and tenets are still applicable. As noted by FAO (2007), diagnosis and design framework's socioeconomic procedures are added to the current framework. A thorough evaluation of the performance of land when used for various designated purposes was the impetus behind land evaluation. Basic ideas, guidelines, and protocols for a methodical biophysical and socioeconomic evaluation of the potential for particular land uses that are probably pertinent to the region are outlined in the Framework for land evaluation. It gave specifics on how to assess the land qualities and which factors should be taken into account when evaluating various land uses. Climate and land resources were merged into agro-ecological zones for the purpose of classifying potential productivity at the supranational level. Predicting the most significant changes is the art of land evaluation, according to FAO (1980).

The framework makes it possible to match or compare each type of land's characteristics with the requirements of each possible land use (FAO, 1983). A set of largely independent land qualities that may each restrict the land-use potential are used to assess the overall land suitability of a given land area for a particular land use (Rossiter and van Wambeke, 1997). Land evaluation can be done both economically and physically. Physical factors such as the type and extent of physical limitations or hazards, as well as whether a particular land utilization type can be implemented in a given area, are the basis for physical land evaluation. The economic benefits of a particular land use serve as the foundation for economic land evaluation. Therefore, it is possible to evaluate land in both physical and economic terms. The distinctions between suitability classes in physical evaluation are made using the attributes or features of the land. Physical assessments are referred to as qualitative assessments in the original framework. For quantitative methods, more or less comprehensive models of land performance are required, and these models usually have high data requirements. Recent studies have contrasted quantitative and qualitative assessments of land qualities, using qualitative models to identify which land areas should be further investigated using quantitative models and which areas can be rejected as unsuitable without in-depth investigation (van Lanen et al. 1992).

Van Diepen et al. (1991) offered a thorough analysis of the development of land evaluation practices over time. Furthermore, Bronsveld et al. (1994) and (Rossiter, 1996) opined that there are various methods to enhance the land evaluation process. In order to take into consideration their preferences and limitations, local users should be involved in the plan's creation. Along with the economic, social, and environmental results of putting the land use plans into action, this would also involve evaluating the effects of market interventions. Second, utilizing pre-existing data while modifying data processing techniques through the application of more adaptable data processing techniques.

Thirdly, by making better use of and integrating the different types of data that are available, including remote sensing and field data. Finally, land evaluation and land use plans can be clearly communicated using straightforward language. Assessing land for forest plantations and assessing land for agriculture differs significantly in practice. As a result, one distinctive feature of land evaluation for natural forests is that the types of land use may be more closely linked to conservation than to production, and that the land use is widely distributed, including, among other things, grazing, recreation, wood production, and conservation.

Forestry land evaluation is not valuable if economic and social factors are not taken into account. The purpose of forestland use is to benefit people. Direct benefits included the production of wood products, non-forest products, water, grazing use, etc. as well as intangible advantages like recreation and biological conservation. Additionally, forest land influences work and leisure patterns as well as community social life. Thus, it is clear that the types of land use and management that are most appropriate for a particular location are greatly influenced by socioeconomic analysis in land evaluation (FAO, 1984). Established in land evaluation for forestry (FAO, 1984), the framework—specifically, the principles and methodology to be used for forestry evaluation—has since begun to be widely used in the establishment of forest plantations, the selection of sites for different forest tree species, and the assessment of land potential suitability.

RESULTS

Classifications of land use and land cover imagery in Akure

Band combinations of 2, 3, and 4 from Landsat TM and ETM were used to categorize the images. False color composite applications (FCC) were used to select the region of interest for the land cover categories using band combinations of 3, 4, and 5. The supervised algorithm's maximum likelihood classification (MLC) method was used to assign pixels from the training sample to the class with the highest likelihood by a normal distribution. Four land use/land cover categories—developed land, dense forest, less water body, and bare soil—were identified during the process. Using a temporal scale, the land-use categories were further investigated from 2000 to 2020.

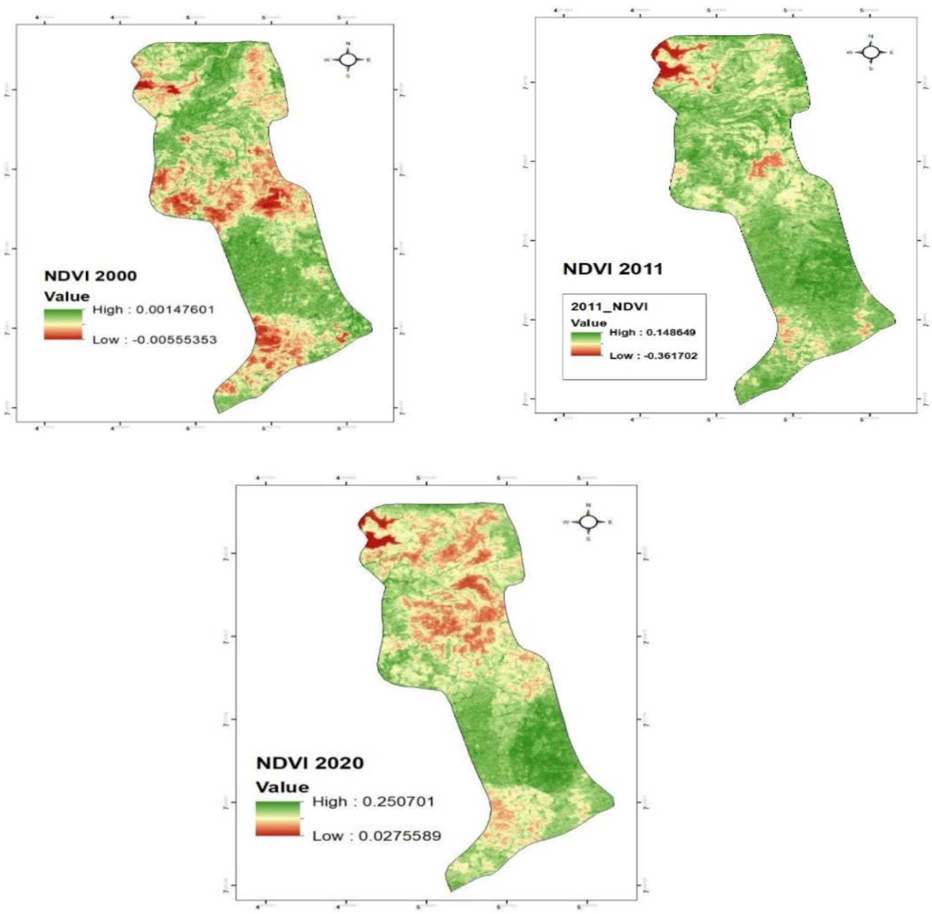

Figure 3: Comparative Analysis of land cover and land use from 2000 to 2020.

The study's classification scheme, which includes built-up area, vegetation cover, barren land, and water bodies, provides a broad classification in which a single digit is used to identify land cover and land use. We refer to all of the roads, buildings, and enclosed spaces identified in the study as built-up areas. According to the definition used in this study, vegetation includes all trees, local season crops, bushes, grasses, and aquatic vegetation that can be found in the study area.

In a similar vein, all open spaces have been declared, including patches of bare soil, abandoned fields, and vacant spaces. Every swampy area, river, and water channel has been designated as a body of water. A mixed class was applied to all objects with spectral resolutions less than 30 meters during the classification process. Subsequently, standard practices for changes in land cover and use have been systematically implemented. Throughout the study area, changes in land cover and use are evident. For each study period, the five types of land cover and land use were identified, and the area was calculated and presented in kilometers. The ENVI Imagine spatial matrix was used to compare the outcomes.

Feature changes by area covered between 2000 and 2020

The acquired data, which were expressed in Sq/Km, demonstrates that the study features in Akure have undergone notable changes. The 2000 processed LULC map showed changes in built-up area, bare soil/space, dense forest, and less dense forest. In the years 2010 and 2020 that followed, it was also observed that a body of water had emerged inside the city. It is clear that there has been a considerable decline in dense forests over time. For example, dense forest covered 14point 6007 square kilometers in 2000, but in 2010 and 2020, it was 9point 39 square kilometers and 12point 0249, respectively. The observed shift that leads to deforestation may be ascribed to human activities, such as built-up areas and industrialization.

Another finding is that between 2010 and 2020, there was an increase in less dense forest. Forest cover was less dense in 2000 by 26.8 sq km, by 43.3 sq km in 2010, and by 38.2 sq km in 2020. In 2010, there was an emergence of a traceable water body at 0.93sq/km, of which 2020 had 0.66sq/km. The observed body of water provides proof that direct rainfall may accelerate overland flow and reach the soil's maximum water-holding capacity, leading to an excessive buildup of water on the surface. Additionally, it was observed that while the observed bare-soil/open space has decreased over time, built-up areas have increased significantly in the study area. For built-up areas, 0.9972sq/km was noted in 2000. In contrast to the higher values of 2.13sq/km in 2010 and 3.433sq/km in 2020, the distance was small. This finding suggests that settlement is growing more quickly in the study area. On the other hand, the effects of urban sprawl in recent years have decreased the observed distance of bare soil.

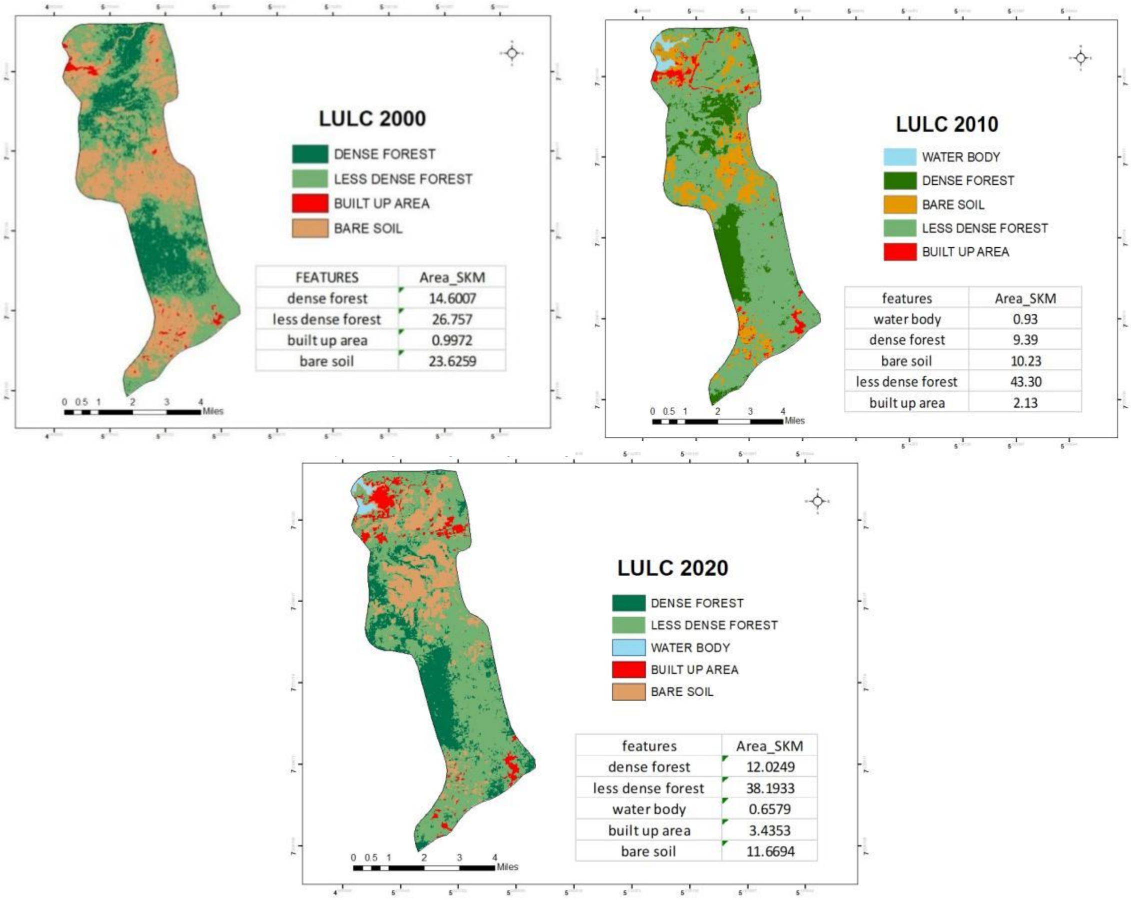

Figure 4: Analysis of area estimate of land cover and land use from 2000 to 2020.

Calculated Change Difference in Landuse from 2000 to 2020

Table 1 shows the computed variations of the chosen characteristics between 2000 and 2020. Every year, there is a noticeable -3 decline in dense forests. Human activity is thought to have a significant impact on natural forests, as evidenced by the yearly changes to the main forest reserves surrounding the city.

Table 6; showing land use and land cover statistics for year 2010 _2020

LULC	2000(km^2)	2010(km^2)	2020(km^2)	Diff(km^2)
dense forest	14.6007	9.3843	12.0249	-3
less dense forest	26.757	43.3017	38.1933	11
water body	-	0.9306	0.6579	0
built up area	0.997	2.1348	3.4353	2
bare soil	23.6259	10.23	11.6694	-12

It may have an impact if trees are cut down and grasses are cleared for construction, industry, or agriculture. Every year, the area of less dense forest increases by 11 square kilometers. This confirms that the study area's land use pattern is continuously changing, with more land being made available for built-up activities at a rate of 2.4382sq/km.

DISCUSSION

Akure City's population is growing at a rapid pace. Images from 2000 and 2020 that were collected and examined showed how cities were growing and how natural habitats were being replaced by settlements. From 2004 to 2020, the extent of this change was significant, particularly in relation to other regions of Ondo State. The decrease in natural habitat was observed with the help of satellite imagery data acquisition, analysis, image classification technique, and land use analysis that were carried out in the study. The findings were in tandem with the recent studies of Alo et al. (2020); Adesoye and Gbiri, 2019). Changes in the LULC were analyzed using a supervised approach to image classification and observed that recent forest alteration brought about by the emergence of other land uses, which caused the reduction in the floristic components of the forest reserves as well as the depletion and disappearance of the forest cover.

Also, the trend in land use and forests that was observed in the current study as a result of growing human population was supported by the work of Alo et al. (2020), who concluded that the cause is attributable to frequently occurring anthropogenic disturbances in most Nigera's forest reserves. Gbiri and Adesoye (2019) recently observed that uncontrolled human entry into the forest reserve is indicated by the increasing rate of development in the forest zones. He further noted, that the undisturbed forest in 1986 was greater than in 2002, which also observed the decline in dense forest from 1984 to 2021.

Additionally, the ongoing migration of people into the forest area for various agricultural purposes may be connected to the sharp rise in less dense forests and the ongoing decline in dense forests. This was further supported by Olayode (2019) research, which found that the Osho Forest Reserve indicates a slow conversion of the natural forest area into plantations and farms. Additionally, Ojo et. al. (2019) added that the 2018 landsat imagery classification indicates that a greater proportion of the land area is covered by light vegetation.

Chukwuka et.al (2020) revealed that the amount of forest area is declining yearly in Ikere's forest assessment using geospatial modeling. In the current study, between 1984 and 2021, the built-up area increased, which is detrimental to the forest reserve. Alo et.al.(2020) in the dynamics of LULCC in Enugu State, where it was also noted that the area built up during the year under study had increased. Water bodies in 2016 and 2021 help to reduce dense forest, which was absent from images taken in 1984 and 2000. However, backdating historical Google Earth imagery was done as a validation check. The emergence of water bodies in the 2010 and 2020 images was consistent with the findings of Gbiri and Adesoye (2019), who dredged the Owena River in order to build a dam.

The greenness levels of the spatial change patterns using the derived Landsat data were compared in this study using the Vegetation Index (NDVI). The prevailing belief was that the NDVI in the past was higher than the one recorded in 2000. Singh et al. (2006) further supported this, wherein their study revealed a notable decline in NDVI values throughout the year. This study provided verifiable evidence of the substantial decline in forest area caused by human activity in different LULC types at the expense of forested land.

Conclusion and Recommendations

Using Landsat images, we were able to successfully evaluate the spatial pattern changes in Akure's land-use and land cover from 2000 to 2020. The findings revealed that the forest had endured substantial vegetation loss during the last 30-year period. The transformation of forests into less dense forests, primarily for agricultural purposes such as cocoa plantations and farmland, is a significant development in the study area.This trend could exacerbate human-induced disruptions to vegetation and intensify climate change effects. In order to address this, regular monitoring of forest reserves is essential. This can be accomplished through the utilization of high-resolution satellite imagery and Unmanned Aerial Vehicles to spot any unauthorized encroachment and disturbances to the ecosystems. Moreover, prioritizing comprehensive land use planning to protect forest reserves is crucial for the government to decrease the rate of deforestation in the study area.

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