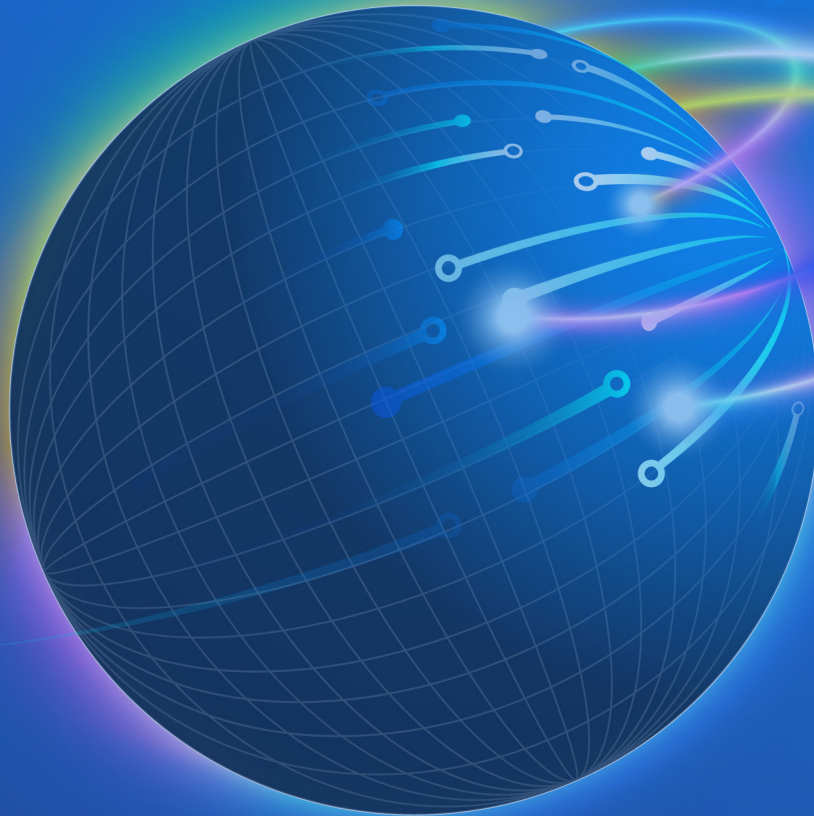




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Detection of Human Induced Land Use and Land Cover Change in Nagi Forest Reserve in Gwer-West Local Government Area of Benue State, Nigeria

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ABSTRACT

Land cover and land use are often conflated concepts but have distinct definitions and implications. Land cover refers to the physical surface of the Earth, encompassing natural and artificial features, while land use describes the human activities and purposes for which land is utilized. Land Use and Land Cover Change (LULCC) represents human-driven modifications of Earth's terrestrial surface, significantly impacting environmental conditions. This study focuses on detecting human-induced land use and land cover changes in the Nagi Forest Reserve in Benue State, Nigeria. Utilizing Geographic Information System (GIS) and Remote Sensing techniques, the research analyzes changes in land cover from 1980 to 2020 to provide insights into sustainable forest management. Multi-temporal Landsat satellite imagery was employed, using supervised classification methods to identify five land use categories: built-up areas, forest, grassland, and agricultural land. Image processing and change detection analyses revealed significant deforestation and forest degradation, primarily driven by human activities such as oil palm expansion, population growth, and logging. The study identified a cumulative loss of forest cover, with the most alarming rate observed in 2020. To mitigate ongoing deforestation, this study recommends implementing guided forest conservation policies, frequent eco-guard monitoring, community involvement in forest management, and capacity-building for policymakers and resource managers. These measures aim to ensure the sustainable management and conservation of the Nagi Forest Reserve, preserving its ecological balance and biodiversity for future generations.

INTRODUCTION

Land cover and land use are two interrelated concepts that are often confused but differ fundamentally in their definitions and implications. Land cover refers to the Earth's physical surface, including natural vegetation, water bodies, rock formations, and other visible physical features, whether natural or man-made (Njike *et al.*, 2011; Saleh *et al.*, 2014). It describes the total physical features that cover a particular land area, while land use refers to the human purposes for which land is utilized, such as agriculture, settlement, or conservation (Ellis, 2011). Land Use and Land Cover Change (LULCC), also referred to as land change, represents the human modification of Earth's terrestrial surface, often driven by a combination of natural and anthropogenic factors, with the latter generally being predominant (Selvaraj *et al.*, 2013).

The dynamics of Land Use and Land Cover (LULC) have become increasingly significant in recent years, particularly in the Niger Delta region of Nigeria, where rapid changes in land use and cover are leading to widespread environmental degradation (Abah, 2013). As global demand for land resources, particularly for agriculture, continues to rise, the need for decisions that optimize land use is becoming more urgent. Such decisions should be based on evidence to ensure the optimal utilization of limited land resources while conserving them for future use. Furthermore, the activities carried out on the land surface contribute significantly to changes in

its cover, impacting both biotic and abiotic components and their interactions (Ronchi, 2018; Bekele *et al.*, 2019). Accurate forecasting of LULC changes and predicting their consequences depend on understanding the past, present, and future states of land use and cover, which is facilitated by the use of multi-temporal data (Dalil *et al.*, 2016).

LULCC plays a crucial role in contributing to variations in climate at all scales by altering the balance of greenhouse gases (GHG) in the atmosphere. For instance, LULCC can lead to increased carbon dioxide emissions through deforestation and subsequent agricultural activities that disturb terrestrial soils and vegetation (Ellis, 2013). While human activities are increasingly disturbing the Earth's surface, some areas remain relatively undisturbed (Dadson, 2016). However, with time, human activities such as deforestation and sand mining are likely to further degrade these areas. Evidence from a study on the Owabi river catchment area demonstrates the rapid conversion of forest cover to built-up areas due to human encroachment (Frimpong, 2011).

The rapid and often unplanned changes in LULC have emerged as a critical concern worldwide, significantly contributing to global environmental changes such as ecosystem degradation, water scarcity, and declining food security (Venter *et al.*, 2016). As the global population grows and environmental issues become more prominent, studying the effects of land use and cover changes is

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increasingly vital (Lambin & Meyfroidt, 2011). Notably, substantial areas of forest, including economically valuable trees, have been destroyed in various regions, such as the Nagi forest reserve in Benue State, Nigeria. Given this context, this study aims to detect human-induced land use and land cover changes in the Nagi forest reserve. The research will address several key questions, including the magnitude and rate of land use and cover changes in the study area, the human activities contributing to these changes, and the current state of the Nagi forest reserve. By employing Geographic Information System (GIS) and Remote Sensing approaches, this study seeks to provide the data needed for sustainable forest management and promote community-based forestry practices in Benue State. The focus will be on generating LULC maps of the Nagi forest reserve for the periods 1980, 2000, and 2020, and determining the magnitude, rate, and human-induced factors contributing to these changes, thereby informing measures for sustainability.

LITERATURE REVIEW

Forests

Forests are defined as extensive areas characterized by dense woodland, non-woody vegetation, and diverse communities of plants and animals that exist in mutually supportive associations (Orobator *et al.*, 2020). They play a crucial role in the global ecosystem as “the lungs of the planet” (Mohammed, 2014) and offer a variety of ecosystem services, including supporting, provisioning, regulating, and cultural functions. At the local level, they provide essential resources such as food, timber, and medicine to indigenous communities (Eguiguren *et al.*, 2019). In their natural state, forests are relatively stable, self-regulated systems (Oludotun, 2011). However, they are increasingly affected by human activities and environmental changes, particularly in semi-arid regions where they are managed as forest reserves to stimulate rainfall, reduce wind erosion, and combat desertification. Globally, forests are among the most vital natural resources after air and water, providing significant ecological services such as carbon sequestration, oxygen production, and maintaining the hydrological cycle (Mohammed, 2014). Moreover, forests act as protective barriers against soil erosion, drought, and floods, and serve as habitats for diverse wildlife. In recognition of their importance, the United Nations mandates that at least 25% of every country’s surface area should be maintained under permanent forest cover to ensure ecological balance and socio-economic stability. However, forests and forest reserves in certain regions, such as Northern Nigeria, have become security concerns due to their use as hideouts for insurgents, armed robbers, and other criminals. This situation poses significant challenges to forest management and conservation efforts in these areas (Tudunwada, 2012).

Forest Reserves

Forest reserves are areas specifically designated by

governments to protect forest ecosystems for their ecological benefits and other purposes (Usman & Adefalu, 2010). These areas are managed to conserve specific habitats and their associated flora and fauna, particularly those considered rare or endangered (Farlex, 2014). Forest reserves are also vital for supporting local livelihoods and serving as safety nets for the rural poor in Nigeria. However, the increasing human encroachment and development activities have led to significant biodiversity loss, reduction in forest reserves, and the extinction of flora and fauna (Tudunwada, 2012). Forest management in Nigeria is primarily the responsibility of the State Forestry Departments, which manage forest resources on behalf of their respective states. However, several unresolved issues, such as ownership disputes, unclear roles, and management rights, have hindered effective forest conservation efforts. Moreover, anthropogenic activities such as illegal logging, poaching, and overgrazing by Fulani herdsmen continue to degrade forest reserves. Insufficient personnel, inadequate equipment, and poor remuneration further exacerbate these challenges (Tudunwada, 2012).

Causes of Land Use and Land Cover Change in Forests

Rapid population growth, increased human activities, and urbanization are major drivers of land use and land cover change (LULCC) in forests. In Nigeria, these changes are driven by a range of factors including a mono-cultural economy reliant on crude oil, soil erosion, deforestation, loss of biodiversity, and urban expansion. Urbanization, for example, has led to the conversion of approximately 400,000 hectares of vegetative cover in recent decades (Etim & Dukiya, 2013). Human activities such as forest exploitation, hunting, and farming have led to significant forest depletion (Kiki & Akpor, 2012). These activities alter the structure and function of forest ecosystems, affecting their biogeochemical properties and contributing to environmental degradation. Illegal activities such as unauthorized logging, corruption, and misuse of forest resources also pose serious threats to the sustainability of forest ecosystems, resulting in loss of government revenues, increased poverty, and social conflict (Leadley *et al.*, 2010).

Effects of Land Use Changes

Land use changes significantly impact environmental functions, both in the short and long term. For example, urbanization leads to the destruction of biodiversity, land degradation, and alterations in the hydrological cycle (Malaiki, 2017). These changes reduce the land’s ability to perform essential ecological functions, such as supporting human settlements, providing raw materials, and preserving cultural heritage. Additionally, changes in land use can exacerbate water shortages, which are already a pressing concern in many African states (Bronstert *et al.*, 2012).

Land Use and Land Cover Change (LULCC)

LULCC studies are critical for monitoring human-induced environmental changes. These studies reveal that LULCC is often the result of complex interactions between human and environmental factors (Goswami *et al.*, 2019). Changes in land cover are influenced by both direct human activities, such as agriculture and urban development, and indirect factors, such as acid rain from fossil fuel combustion and other pollutants (Pervez *et al.*, 2016). Remote sensing (RS) and Geographic Information Systems (GIS) are essential tools for monitoring LULCC, allowing for the collection and analysis of spatial data on land use patterns (Rai *et al.*, 2017). Understanding the driving forces behind LULCC is essential for explaining past trends and predicting future patterns. These driving forces may include cultural, economic, environmental, and policy-related factors. Human activities, particularly those driven by socio-economic and cultural forces, are the primary causes of environmental changes, such as land degradation and ecosystem alteration (Panwar & Malik, 2017). Effective management and intervention strategies are necessary to mitigate these impacts and ensure sustainable land use practices.

Remote Sensing and GIS in LULCC

RS and GIS are widely used to analyze LULCC and predict future trends. Various models, such as the Markov chain and Cellular Automata (CA-Markov) models, have been developed to simulate land cover changes. These models combine long-term prediction capabilities with dynamic simulation functions, allowing for effective monitoring and management of LULCC (He *et al.*, 2018). Studies using RS and GIS have shown significant urban expansion and land cover changes in various regions, highlighting the need for effective land

use planning and management strategies (Manju *et al.*, 2011). The review highlights the critical importance of forests and forest reserves for ecological balance, socio-economic development, and environmental sustainability. However, increasing human activities, population growth, and urbanization pose significant threats to forest ecosystems. Effective management strategies, including the use of advanced technologies such as RS and GIS, are essential for monitoring and mitigating the impacts of land use and land cover changes on forest resources. Policymakers and stakeholders must prioritize sustainable forest management practices to ensure the continued provision of ecosystem services and the conservation of biodiversity.

MATERIALS AND METHODS

The study was conducted in the Nagi Forest District, which spans approximately 12.5 km² and is situated at longitude 80° 91' E and latitude 70° 411' N. The district is located about 12 km along the Naka-Agagbe road, Gwer West local government area, Benue state, Nigeria. The area falls within the tropical sub-humid climate zone, characterized as a tropical wet and dry (Aw) climate. Two distinct seasons are observed: the dry season, lasting from late November to March, dominated by tropical continental air mass and harmattan winds that are typically dry, cold, and hazy; and the wet season, from April to October, marked by rainfall and moist conditions, peaking in August/September. A brief transitional period with sparse rainfall occurs in early November. The annual mean rainfall is approximately 1200 mm, with a mean annual temperature of about 32.5°C. The region is identified with Guinea savannah vegetation, where trees such as *Daniella olivera*, *Prosopis africana*, and *Vitex doniana* grow alongside tall grasses. The forest types

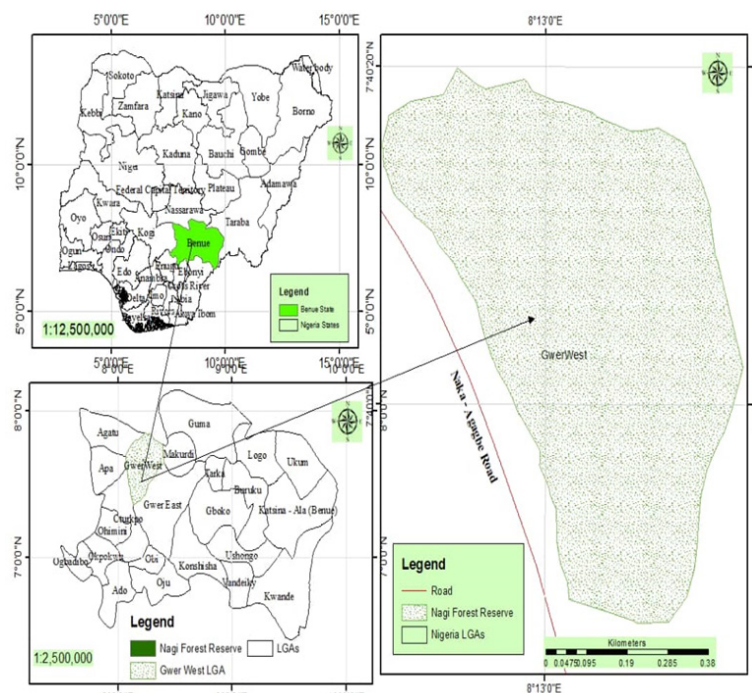


Figure 1: Map of the Study Area

include naturally occurring wild forests, gallery forests, village forests, and reserved forests. The topography of the area is undulating, characterized by interfluvies with hills averaging 30-40 meters, while the majority of the terrain lies below 183 meters (600 feet) above sea level. The Nagi and Kpukujembe streams drain the area. The soil is primarily tropical ferruginous, formed from different parent materials, with clay-loamy soil as the dominant type, and sandy lateritic soil occurring in the vicinity of Nagi town (Mage & Hula, 2015).

Data Collection

To assess the land use and land cover changes in the study area, remote sensing data were utilized. The analysis was based on three multi-date Landsat satellite imageries: the Enhanced Thematic Mapper (ETM+) for the years 1985 and 2000, and the Operational Land Imager (OLI) for 2020. The study area was extracted from the scenes, and a supervised classification method was applied using a Level 1 classification scheme, as proposed by Anderson *et al.* (1976). Five land use and land cover categories were

Table 1: Characteristics of Landsat Images used for the study

Date of Acquisition	Sensor	Path	Row	Multispectral Band	Thermal Band	Spectral Range (micrometers)	Spatial Resolution (pixel spacing)	Source
1985	TM	188	55	1to5 and 7	6	10.45-12.45	30	
2000 & 2010	ETM+	188	55	1to5 and 7	6	10.45-12.45	30	USGS
2020	OLI and TIRS	188	55	1to7 and 9	10 and 11	10.60-12.51	30	

identified and classified: built-up areas, forest, grassland, and agricultural land.

Image Processing and Classification

Image processing was carried out using Idrisi Image Processing software. The images, initially in single bands, were layer-stacked, and geometric corrections were applied using change detection analysis to remove possible noise and scan lines. Geometric errors were corrected using ground control points to geocode the images, which were then used to register other images for photo-interpretation. Four basic pre-processing operations were conducted:

1. Image reconstruction to extract the area of interest

from the general satellite scene.

2. Image enhancement to improve visual interpretation by increasing apparent contrast among various features.

3. Radiometric correction to adjust for the sun's elevation on the raw data.

4. Band combinations of 2,3,4 were used for the 1985 and 2000 images, and 3,4,5 for the 2020 Landsat 8 (OLI), due to the sensitivity of bands 4 and 3 to vegetation cover and band 4 to water content.

Following classification, a histogram of the classified images was generated, displaying the areas of the different land use and land cover classes, facilitating comparison and inference.

Table 2: Software Components of the Research

S/N	Software	Purpose
1	Idrisi & ArcGIS 10.3	GIS analysis & classification of the Landsat images
2	Microsoft Excel	Statistical analysis for the calculation of percentage
3	Global Positioning System	For picking geographic co-ordinates

Data Analysis

Analysis of Extent, Rate, and Magnitude of Forest Degradation

To determine the extent of land use change, the analysis was conducted by subtracting the reference year (2020) from the base year (1985). The extent of change is represented mathematically as:

$$E_T = B - A$$

Where:

A = Base year (1985)

B = Reference year (2020)

ET = Total extent of forest land

different years. Simple percentage tables were employed for statistical analysis. Change analysis was conducted to examine the alterations in built-up areas from 1985 to 2020 to determine the extent of land use and land cover changes.

Change Detection Techniques

Three change detection methods, as previously applied by Ikusemoran *et al.* (2013), were utilized to analyze land use and land cover changes:

Change Detection by Area Calculation

This method involves three key steps:

- i. Magnitude of Change Calculation: The magnitude of change was calculated by subtracting the observed change of each period from the previous period.

ii. Trend Calculation: The trend, or percentage change for each land use, was determined by subtracting the percentage of the previous land use from the recent land use, dividing by the previous land use, and multiplying by 100:

$$\text{“Percentage Change”} = \left(\frac{B-A}{A} \right) \times 100$$

Where:

A= Base year (1985)

B = Reference year (2020)

iii. Annual Rate of Change Calculation: The annual rate of change was calculated by dividing the percentage

change by 100 and multiplying by the number of study years, which is 35 years (1985-2020).

RESULTS AND DISCUSSION

Classification of Land Use/Land Cover Dynamics (1985, 2000, and 2020)

The land use and land cover (LULC) dynamics of the Nagi Forest Reserve were classified for the years 1985, 2000, and 2020 to illustrate and interpret the changes in the various land use categories. The classification results are presented using maps, charts, and tables.

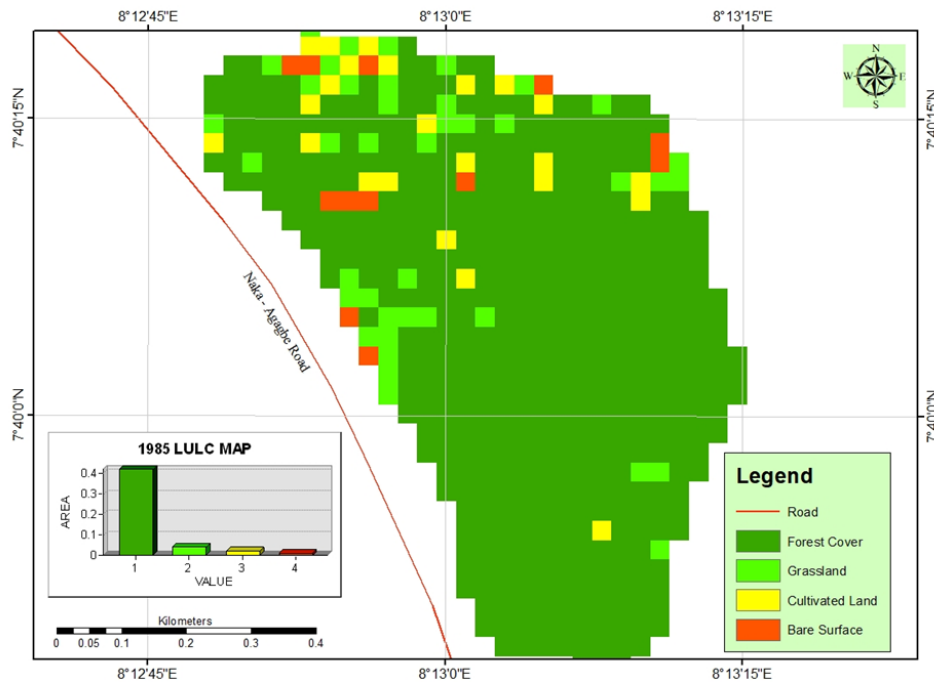


Figure 2: 1985 Land use/Land cover distribution map generated from LandSat 4 TM

Source: Author's Analysis, 2020

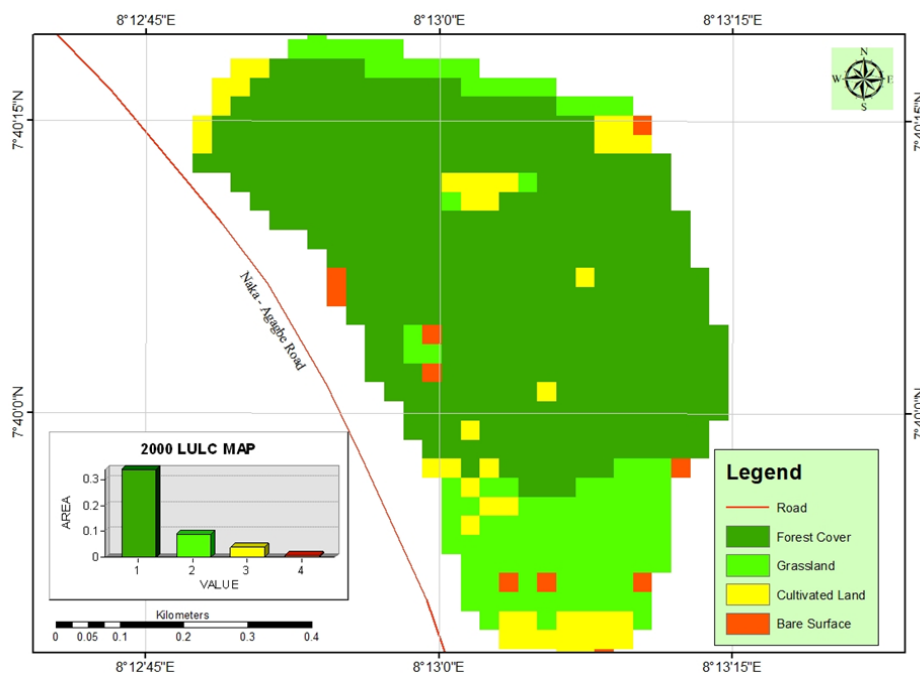


Figure 3: 2000 Land use/Land cover distribution map generated from LandSat 4 TM

Source: Author's Analysis, 2020

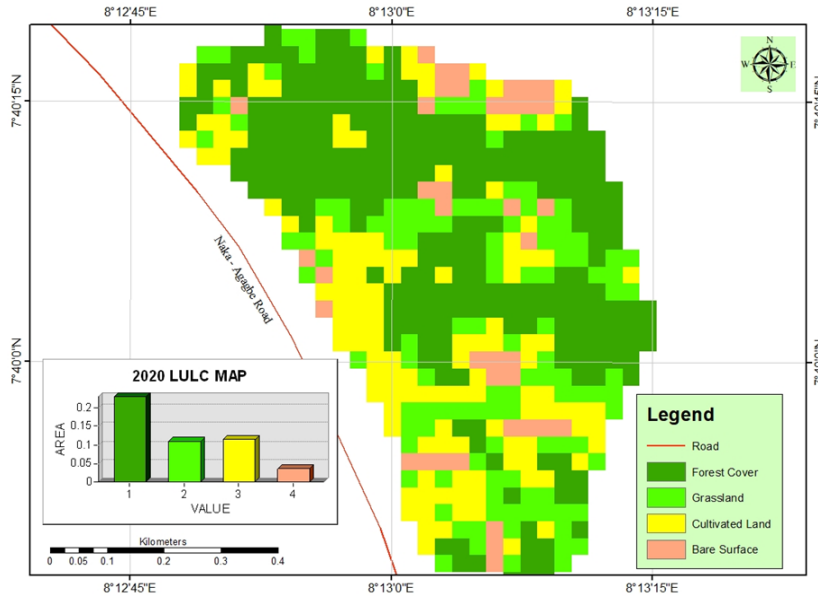


Figure 4: 2020 Land use/Land cover distribution map generated from LandSat 4 TM
Source: Author's Analysis, 2020

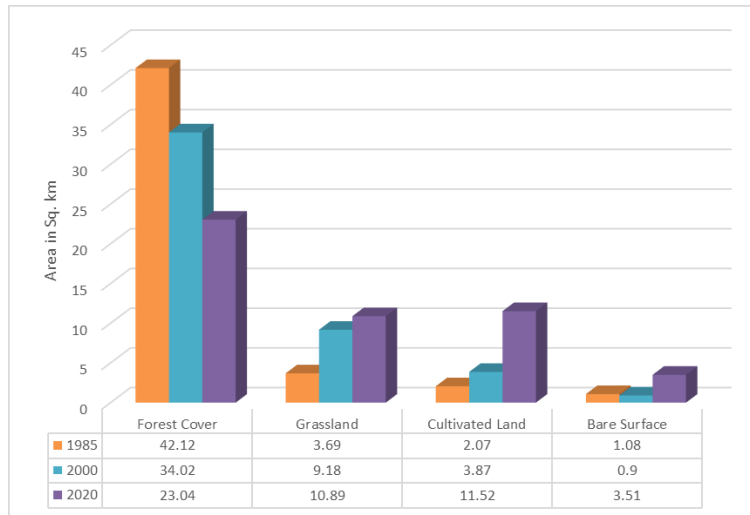


Figure 5: Land use and land cover comparative chart

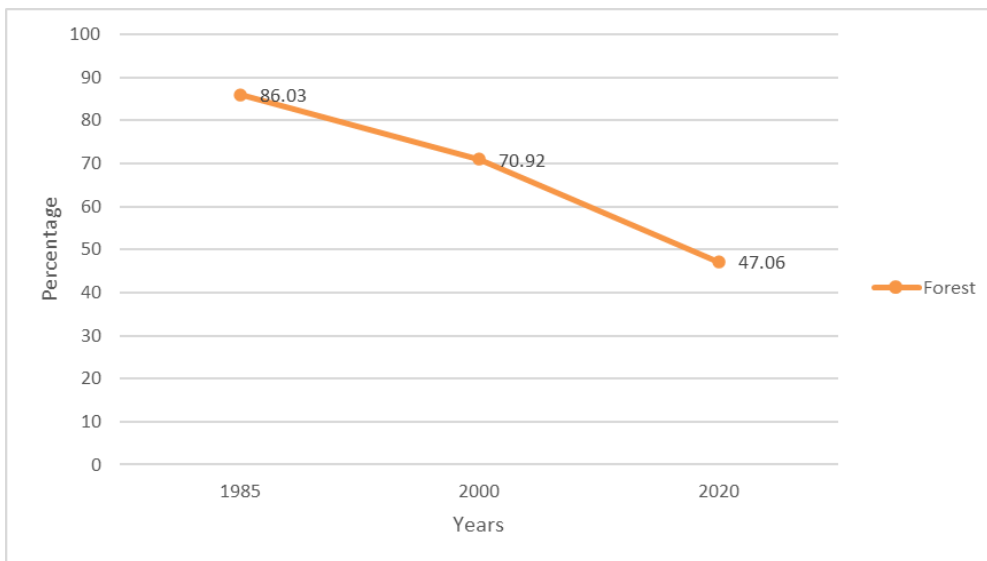


Figure 6: Trend analysis of forest decline

Table 3: Magnitude and Percentage of Change in Land Use/Land cover between 1985 and 2000

LULC Class	1985 Extent (Sq. km)	2000 Extent (Sq. km)	Magnitude of Change (Sq. km)	Percentage of Change	Annual Rate of Change %
Forest	42.12	34.02	-8.1	-52.02	7.80
Grassland	3.69	9.18	5.49	35.26	5.29
Cultivated land	2.07	3.87	1.8	11.56	1.73
Bare surface	1.08	0.9	-0.18	1.16	0.14
Total	48.96	47.97	15.57	100	15

Table 4: Magnitude and Percentage of Change in Land Use/Land cover between 2000 and 2020

LULC Class	2000 Extent (Sq. km)	2020 Extent (Sq. km)	Magnitude of Change (Sq. km)	Percentage of Change	Annual Rate of Change %
Forest	34.02	23.04	-10.98	47.84	9.57
Grassland	9.18	10.89	1.71	7.45	1.49
Cultivated land	3.87	11.52	7.65	33.33	6.67
Bare surface	0.9	3.51	2.61	11.37	2.27
Total	47.97	48.96	22.95	100	20

Table 5: Magnitude and Percentage of Change in Land Use/Land cover between 1985 and 2020

LULC Class	1985 Extent (Sq. km)	2020 Extent (Sq. km)	Magnitude of Change (Sq. km)	Percentage of Change	Annual Rate of Change %
Forest	42.12	23.04	-19.08	50	17.5
Grassland	3.69	10.89	7.2	18.87	6.60
Cultivated land	2.07	11.52	9.45	24.76	8.67
Bare surface	1.08	3.51	2.43	6.37	2.23
Total	48.96	48.96	38.16	100	35

Analysis of Classified Land Use and Land Cover Map of 1985

The classified LULC map for 1985 (Figure 2) shows that forest was the dominant land use and land cover type, covering approximately 42.12 hectares (ha) or 86.03% of the area. This forested area was predominantly located in the Nagi Forest Reserve and extended towards the northern, southern, and some sections of the study area. Grassland was the next most significant cover type, occupying about 3.69 hectares (ha) or 7.54% of the total land area. These grasslands were primarily found in the northwest and southeastern sections, as well as in patches across various parts of the study area.

Analysis of Land Use/Land Cover Classification for 2000

The LULC map for 2000 (Figure 3) reveals notable changes in the spatial distribution and areal extent of the various land use categories. Forest areas, while remaining the most dominant class, decreased from 42.12 hectares (86.03%) in 1985 to 34.02 hectares (70.92%) in 2000. This decline in forest cover was primarily due to increased farming activities and settlement expansion in many sections of the map. Conversely, grassland areas increased from 3.69 hectares (7.54%) in 1985 to 9.18 hectares (19.14%) in 2000, mainly in the southeastern region

and spreading towards the northern section. Cultivated land also saw an increase from 2.07 hectares (4.23%) in 1985 to 3.87 hectares (8.07%) in 2000, particularly in the southern sections of the study area.

Analysis of Land Use/Land Cover Classification for 2020

The LULC map for 2020 (Figure 4) indicates further significant changes in the study area. The forested areas experienced a marked decline, decreasing from 34.02 hectares (70.92%) in 2000 to 23.04 hectares (47.71%) in 2020. This decline is attributed to increased human activities and the expansion of built-up areas across the region. Cultivated land areas also continued to increase, rising from 3.87 hectares (8.07%) in 2000 to 11.52 hectares (23.53%) in 2020, particularly in the northwestern part and expanding towards the central and southern sections of the study area. Bare surface areas increased from 0.9 hectares (1.88%) in 2000 to 3.51 hectares (7.17%) in 2020, further reflecting the intensification of land use changes.

Trend Analysis of Forest Decline in the Study Area

The trend analysis (Figure 4.5) shows a continuous decline in forest cover in the study area over the years. Between 1985 and 2000 (a period of 15 years), forest cover decreased by -15.11%. From 2000 to 2020 (a period

of 20 years), the forest decreased further by -23.86%. Overall, the forest lost -38.97% of its coverage between 1985 and 2020, indicating a continuous conversion of forest land to other land use types.

Magnitude and Percentage of Change in Land Use/ Land Cover

1985 to 2000

The magnitude of change in forest area between 1985 and 2000 shows a decrease of -8.1 sq. km, representing 52.02% of the total change during this period (Table 3). Forests had the highest annual rate of change at 7.80%, while bare surfaces had the lowest at 0.14%. The period also witnessed an increase in grassland (5.49 sq. km, 35.26% of the total change) and cultivated land (1.8 sq. km, 11.56%), reflecting urbanization pressures.

2000 to 2020

Between 2000 and 2020, the forest area further declined by -10.98 sq. km, representing 47.84% of the total change (Table 4). The forest had an annual rate of change of 9.57%, while bare surfaces remained the least changed. In contrast, cultivated land increased by 7.65 sq. km (33.3%) at an annual growth rate of 6.67%, driven by agricultural expansion, fuel wood collection, and logging activities.

1985 to 2020

Over the 35 years from 1985 to 2020, the forest area declined by -19.08 sq. km, accounting for 50% of the total change in the study area (Table 5). Forests had the highest annual rate of change at 17.5%, whereas bare surfaces had the lowest at 2.23%. Grassland areas also underwent changes of 7.2 sq. km (18.87%) with an annual growth rate of 6.60%.

The use of Landsat satellite imagery for change detection, despite limitations like weather effects and noise from passive sensors, remains effective in monitoring LULC changes. The data reveal a substantial decline in forest and grassland areas in the Nagi Forest Reserve between 1985 and 2020, signifying a shift towards other land use types such as agriculture and settlement expansion. The continuous loss of forest cover (from 86.03% in 1985 to 47.71% in 2020) and the conversion to other uses indicate ongoing habitat loss and declining forest resources, consistent with findings from previous studies (Audu & Shola, 2016; Uloko & Yager, 2017; Yager *et al.*, 2018). The reduction in vegetation cover has led to decreased productivity, increased soil erosion, and long-term degradation. These changes also affect vegetation composition, leading to bush encroachment, reduced floral biodiversity, and habitat loss for fauna (Vogel & Strohbach, 2009). The disturbed forest canopy has resulted in a higher amount of understory, signaling that the Nagi Forest has been significantly altered. This aligns with Uloko & Yager's (2017) report on the decline in range vegetation cover due to farming activities, indicating the current habitat is less suitable for wildlife.

CONCLUSION

The study reveals a significant threat to the Nagi Forest Reserve, primarily driven by human-induced deforestation and forest degradation. Through the application of advanced remote sensing and GIS technologies, substantial deforestation has been quantified over the past decades, offering detailed insights into the spatial and temporal dynamics of land use and land cover changes in the study area. The use of satellite imagery and ground-based data allowed for precise mapping of deforestation, forest degradation, disturbances, and their corresponding drivers. The analysis showed a cumulative loss of forest cover due to clearings for farms and other uses from 1985 to 2020, with the most alarming rate of forest loss occurring in 2020. Key drivers identified for this decline include oil palm expansion, population growth, increased built-up areas, and settlement-related activities such as logging. Faced with these rising threats, it is evident that only a concerted and comprehensive approach can guide sustainable forest management and conservation efforts in the Nagi Forest Reserve. Immediate intervention is required to mitigate the ongoing deforestation and ensure the long-term preservation of forest resources.

Recommendations

To effectively address the challenges of deforestation and promote sustainable forest management, the following recommendations are proposed:

1. **Development and Implementation of a Guided Forest Conservation Policy:** There is a need for a well-structured forest conservation policy that incorporates community sensitization and education on the importance of forest conservation. This policy should emphasize sustainable land-use practices and discourage activities that lead to forest degradation.

2. **Frequent Monitoring by Eco-Guards:** Regular patrols and monitoring by eco-guards should be enforced to prevent illegal logging and other unauthorized activities that contribute to forest degradation. The presence of eco-guards would help in deterring illegal activities and ensuring compliance with forest conservation regulations.

3. **Community Involvement and Participatory Forest Mapping:** Incorporating local communities in forest management through participatory forest mapping and decision-making can enhance community ownership and reduce conflicts. This approach can also foster cooperation and commitment towards sustainable forest management and conservation efforts.

4. **Capacity Building for Policymakers and Resource Managers:** Training and capacity-building programs should be organized for policymakers, resource managers, and stakeholders on the use of remote sensing and GIS technologies. This will enable them to effectively monitor land use and land cover changes, identify critical areas for intervention, and implement appropriate management strategies.

By adopting these recommendations, sustainable

forest management can be achieved in the Nagi Forest Reserve, thus safeguarding it for future generations while also maintaining ecological balance and biodiversity conservation.

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