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Examining Deforestation and Forest Degradation in North-Eastern Nigeria

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Abstract

Deforestation and forest degradation pose significant environmental and socio-economic threats to North-Eastern Nigeria. This region, ravaged by insurgency (such as Boko Haram) and climate change, has witnessed unprecedented forest loss, compromising biodiversity, water resources and livelihoods. This study examines the pattern, consequences and drivers of deforestation and forest degradation in North-Eastern Nigeria. Using mixed-methods approach, combining satellite remote sensing, Geographic Information Systems (GIS), Normalise Differential Vegetation Indices (NDVI) and field data, this research analyze forest cover changes over time and the impact of human activities such as agricultural expansion, illegal logging and urbanization. The findings reveal alarming rates of forest loss with significant implications for environmental sustainability, food security and human well being. Moreover, it emphasizes the importance of high resolution satellite imagery and machine learning techniques in detecting subtle vegetation changes. The study recommends sustainable forest management practices, conflict sensitive conservation approaches and climate resilient agriculture to mitigate deforestation and forest degradation. It also highlights the need for policy reforms, community engagement and international cooperation to protect North-Eastern Nigeria’s fragile forest ecosystems and promote sustainable development.

Keywords: *Deforestation, Forest Degradation, Satellite Remote Sensing, Gis, Ndvi, Forest Conservation, Policymakers.*

I. INTRODUCTION

Forests are crucial ecosystems that provide a range of environmental, economic and social benefits, including carbon storage, biodiversity support, water regulation and livelihood resources for millions of people worldwide (FAO, 2020). However, forest ecosystems across the globe are under severe threat due to deforestation and forest degradation, primarily driven by human activities and increasingly by climate change. Deforestation involves the large-scale conversion of forested land to non-forest uses such as agriculture, settlements and infrastructure development. In contrast, forest degradation refers to the reduction in forest quality, often caused by selective logging, fire and other activities that do not entirely eliminate forest cover but severely impact forest structure and biodiversity (Curtis et al., 2018). Examining these changes is essential for the sustainable management of forest resources and for the broader goals of climate mitigation and biodiversity conservation.

A. Study Area

Nigeria is one of the countries most affected by deforestation in Africa, with forest cover shrinking by nearly 4% per year, which is among the highest rates globally (Ogunleye et al., 2021). The pressures on Nigeria’s forests stem from various factors, including population growth, agricultural expansion and a high dependence on fuel wood for energy (FAO, 2020). North-Eastern Nigeria, a region comprising states like Adamawa, Bauchi, Borno, Gombe, Taraba and Yobe, is particularly vulnerable to forest degradation due to its semi-arid Sahelian climate, high levels of poverty and longstanding conflicts such as Boko Haram, Herders and Farmers.

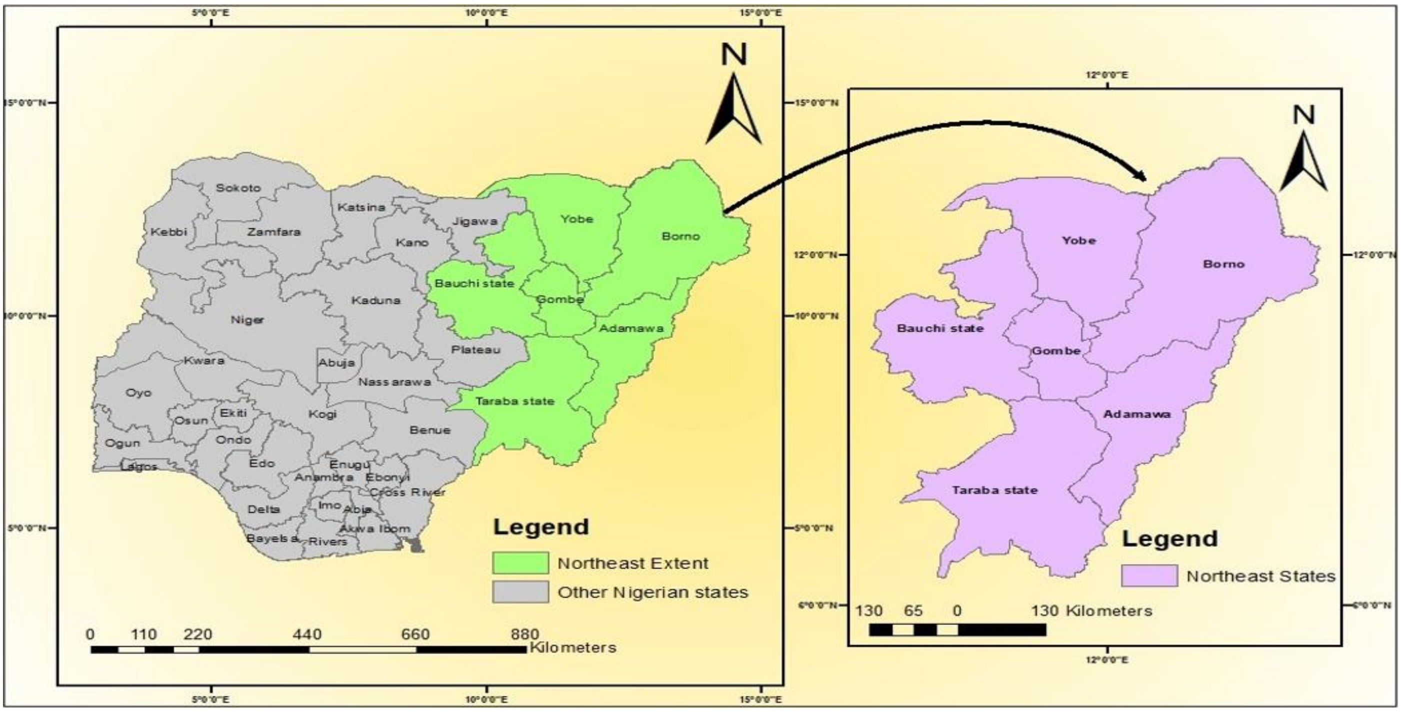

Fig 1 Examining Site

The forests in this region are part of an ecologically sensitive zone that transitions between the humid forests of southern Nigeria and the desert regions of the Sahara. Consequently, forests here play a vital role in soil stabilization, biodiversity conservation and as a buffer against desert encroachment (Baba, 2021).

The region's dependence on forest resources is further intensified by socio-economic challenges. In North-Eastern Nigeria, where many rural communities live below the poverty line, forests provide essential resources, such as fuelwood, medicinal plants and food (Zahradeen et al., 2019). Moreover, insurgency and violent conflicts in the area have forced many displaced populations to rely heavily on forests for shelter and daily survival needs, further accelerating forest degradation (Baba, 2021). As such, North-Eastern Nigeria exemplifies the complex and interrelated drivers of deforestation and forest degradation in developing regions, where environmental and socio-political challenges intersect.

B. Problem Statement

Monitoring forest changes is challenging, especially in regions like North-Eastern Nigeria where security concerns, limited funding and inadequate technical resources hinder effective conservation efforts. Traditional field-based assessments of deforestation are often impractical and costly in such areas, given the risks and logistical challenges involved. Consequently, remote sensing and satellite-based monitoring systems have become indispensable tools for tracking forest cover and degradation patterns in inaccessible regions (Hansen et al., 2013). These technologies allow for systematic and continuous observation of large forested areas, providing critical data for identifying trends, hotspots and drivers of deforestation.

However, monitoring deforestation and degradation in North-Eastern Nigeria faces additional challenges due to the region's distinctive socio-political dynamics and environmental conditions. The semi-arid landscape of this region requires specific analytical techniques, as forest degradation may manifest differently compared to more humid forest regions. Moreover, satellite data resolutions may be insufficient to detect subtle forms of forest degradation, such as selective logging or gradual canopy thinning, which are common in North-Eastern Nigeria (Curtis et al., 2018). Furthermore, limited technological infrastructure and capacity in Nigeria hinder the consistent and accurate processing of remote sensing data. Therefore, while remote sensing has great potential for forest monitoring, its effective application in North-Eastern Nigeria is constrained by the need for higher-resolution imagery, advanced analytical tools and institutional support.

Deforestation and forest degradation in North-Eastern Nigeria also have severe socio-economic and environmental implications. The continued loss of forest cover exacerbates soil erosion, reduces agricultural productivity and affects water availability, posing direct threats to local food security and livelihoods (Zahradeen et al., 2019). Additionally, deforestation contributes to carbon emissions and reduces the region's ability to sequester carbon, which has implications for Nigeria's climate commitments and global efforts to mitigate climate change (FAO, 2020). These interconnected challenges underscore the need for a robust, comprehensive approach to forest monitoring that accounts for the unique circumstances of North-Eastern Nigeria.

C. Objective

The primary objective of this study is to examine effective methods for monitoring deforestation and forest degradation in North-Eastern Nigeria, with an emphasis on utilizing remote sensing technology and geographic information systems (GIS). The study aims to identify suitable satellite data sources, such as Landsat and to assess their effectiveness in detecting forest cover changes in a semi-arid context (Hansen et al., 2013). Additionally, the study seeks to explore the potential of advanced remote sensing technologies, Geographic Information Systems (GIS), Normalise Differential Vegetation Indices (NDVI) and field data for providing more detailed insights into forest degradation, despite their higher costs and technical demands (Curtis et al., 2018).

The study also aims to highlight the socio-economic implications of forest loss in North-Eastern Nigeria and to assess the role of current policies in addressing deforestation and degradation challenges. By exploring both technological and policy approaches, this research seeks to contribute to the development of sustainable forest management strategies tailored to the specific conditions and needs of North-Eastern Nigeria. Ultimately, this study hopes to inform policymakers, conservation practitioners and local stakeholders about effective monitoring practices that can support long-term forest conservation and sustainable development in the region.

II. METHODOLOGY

To effectively monitor deforestation and forest degradation in North-Eastern Nigeria, an integrated methodology combining remote sensing and field surveys will be employed. This methodology is structured into four key phases: data collection, processing, analysis and validation. Figure 2, shows the methodology flow chart for the all processes.

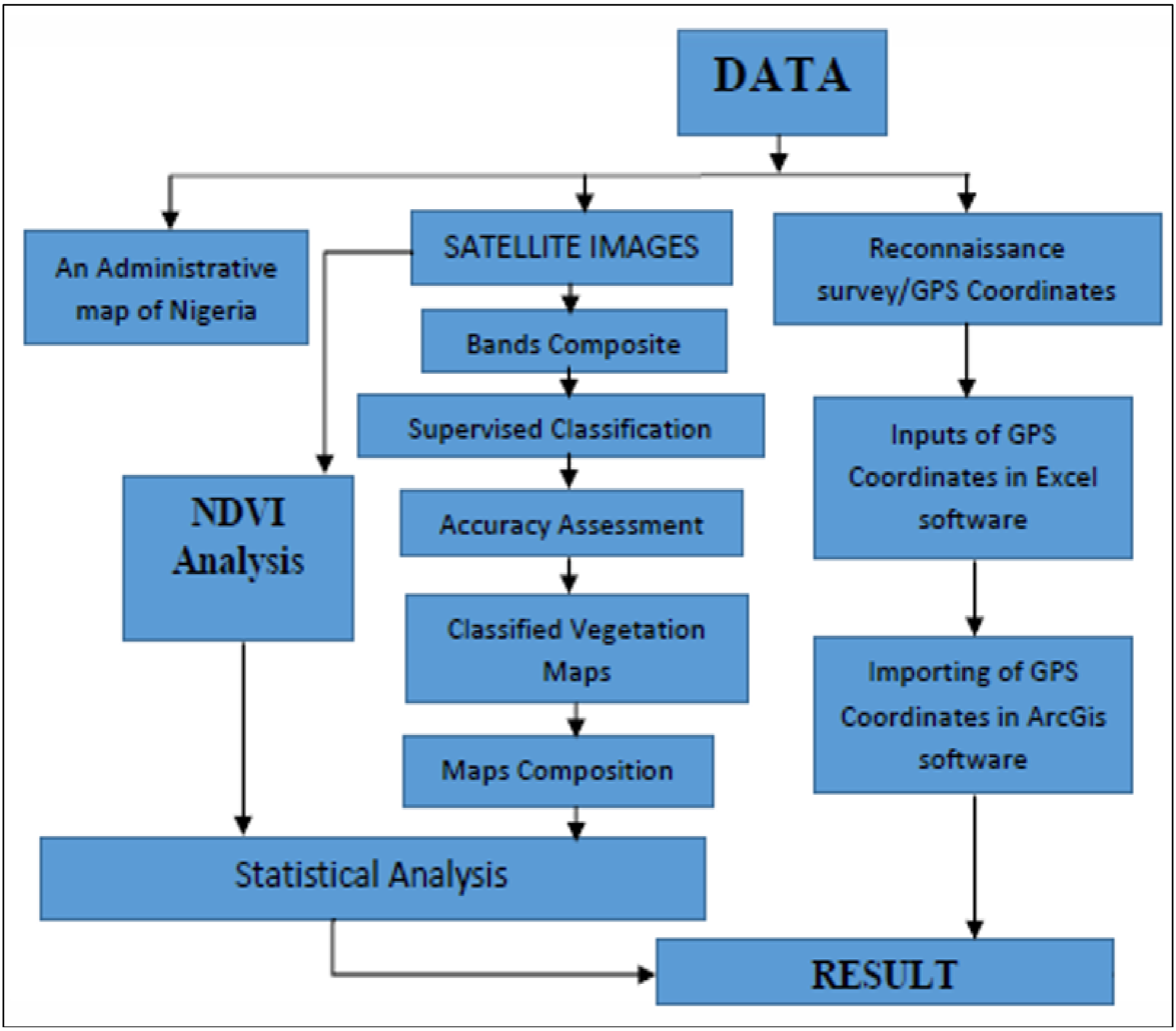

Fig 2 Methodology Flow Chart

A. Data Collection

High-resolution satellite imagery from sources such as Landsat retrieved from https://earthexplorer.usgs.gov/ was acquired to detect changes in forest cover. These images will provide data on vegetation indices, land cover changes and forest health. Multi-year datasets spanning at least the last 30 years to analyze trends in the entire North-Eastern region, with higher resolution focus on known hotspots of deforestation.

The area falls within the overlapping of fifteen Landsat scenes of World Reference System order two (WRS-2). The two set of data were acquired between the year 1988 and 1991 (Landsat TM), and in the year 2020 (Landsat OLI); all the images have 30 m spatial resolution. Land use data maps indicating agricultural, urban and industrial development together with Socio-economic data which gives the Information on local community activities impacting forests, such as logging, farming and grazing. Figure 3 shows the spatial distribution of the Landsat scenes superimposed on the delineated North-Eastern Nigeria map; the scene identification number and the specific date of acquisitions of each were also embedded on it. Lastly, ground-truthing will be conducted to validate remote sensing data to obtain detailed information and tools like GPS and mobile data collection apps were used.

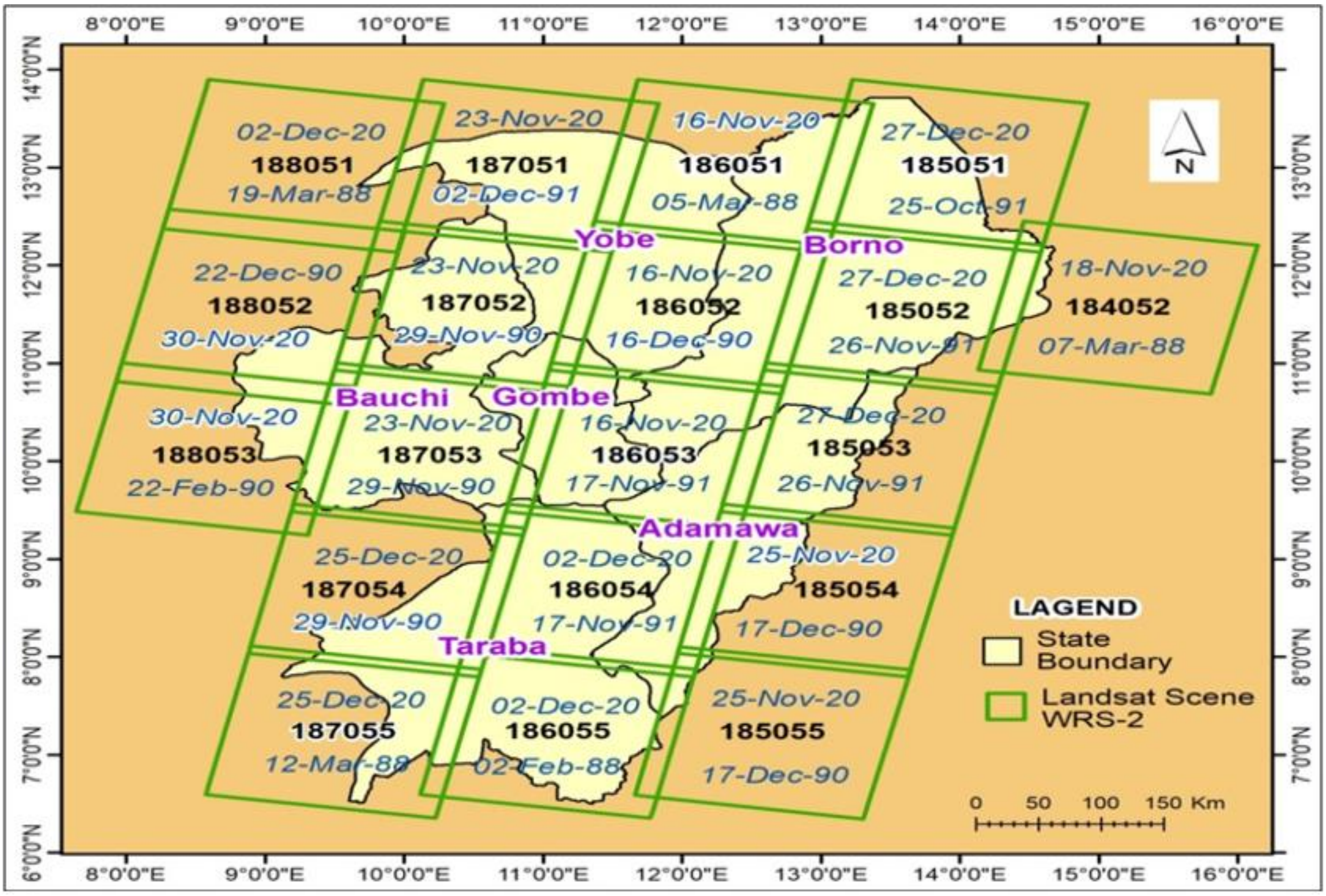

Fig 3 Spatial Distribution of the used Landsat Scenes

B. Data Processing and Analysis

In the Pre-processing of Satellite Data, a radiometric and geometric corrections method was used to ensure consistency across images. Cloud masking was utilised to removal of noise from cloud cover and image normalization to standardizing imagery for temporal comparisons. Supervised classification using algorithms like Random Forest or Support Vector Machines to classify land cover types and Change Detection employing techniques such as Normalized Difference Vegetation Index (NDVI) to identify deforestation and degradation patterns.

Spatiotemporal Analysis using trends and patterns of deforestation will be analyzed across years and regions. This includes Hotspot identification using GIS tools and Analysis of drivers of deforestation, such as proximity to roads or settlements. To validate the analysis, accuracy assessment using validation of classified maps was conducted using Normalized Difference Vegetation Index (NDVI) and GPS. Moreover, a cross-validation with local knowledge was utilised by engaging local communities and forestry officials to verify findings and gather insights on undocumented activities impacting forests. Reports and maps will be generated to share findings with stakeholders, including policymakers, conservation groups and local communities to educate communities on the importance of sustainable forest management and the results of the monitoring process.

C. Tools and Techniques

The software used in the analysis of the data is ArcGIS 10.8 version and Microsoft Excel. The Hardware used includes the GPS devices and smart phones for data collection. The techniques used was machine learning for classification, participatory mapping for local input and for detailed structural analysis. This methodology ensures a comprehensive and systematic approach to monitoring deforestation and forest degradation in North-Eastern Nigeria. By integrating advanced technology with local knowledge and field data, the project aims to provide actionable insights for sustainable forest management and conservation efforts.

III. RESULTS AND DISCUSSION

A. Deforestation Trends

In this section, results obtained from the analysis are presented and discussed using tables and figures. The analysis of satellite imagery revealed significant forest loss in North-Eastern Nigeria over the past three decade that is the Land Use Land Cover (LULC) as shown in figures 4 and figure 5 below. Key findings include annual deforestation rates with an average annual forest loss of approximately 3.5%, with peaks in deforestation observed between 2016 and 2018, this however coinciding with intensified agricultural expansion and conflict-related displacement. Hotspots of Deforestation in states like Adamawa, Borno and Yobe showed concentrated deforestation around urban centres, agricultural zones and along major roads.

Furthermore, the result of the supervised classification displays the spatial distribution of LULC within the North-Eastern Nigeria in the year 1990 and 2020 as well as the magnitude of each LULC class. Moreover, the result of the LULC classification reveals the five dominant classes covering North-Eastern Nigeria which include vegetation, farmland, bare surface, built-up area and water body.

As shown in figure 4 and figure 5, areas with vegetation cover displayed in green colour, farmland in yellow, bare surface in orange colour, built-up land displayed in red and water body in blue. The visual interpretation of the classified images portrayed that vegetation class is found at each part of the study. Similarly, farmlands are found at each corner however are more pronounce at central and northern parts of the study area. Bare surface are also more pronounce at central and northern parts and lastly, the water body found at central areas.

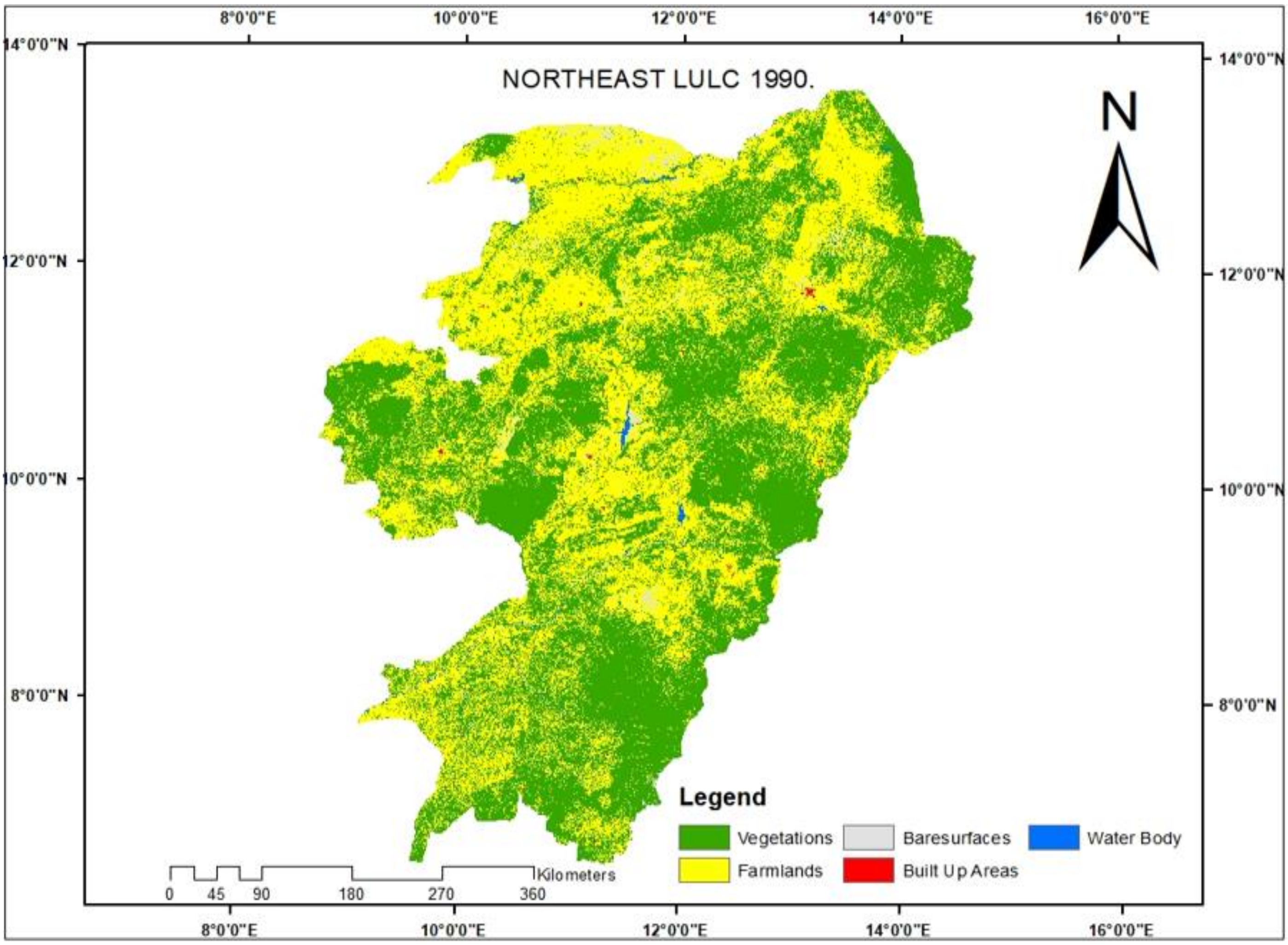

Fig 4 North-Eastern Nigeria LULC 1990

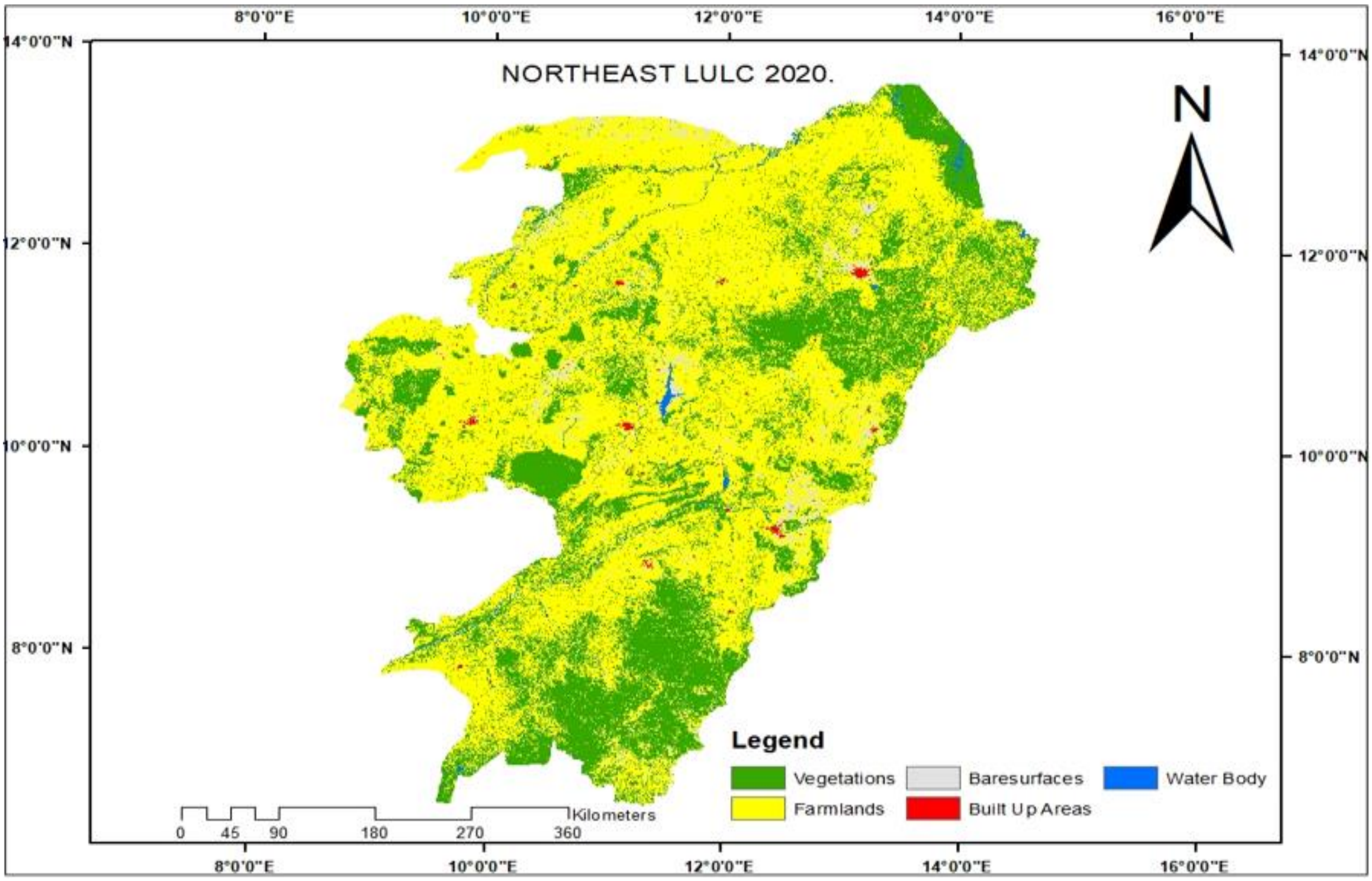

Fig 5 North-Eastern Nigeria LULC 2020

This table I below also provide a summary of land cover maps produced from 1990 to 2020, providing the distribution of land cover types in kilometres and percentages of each land cover class.

Table 1 Analysis of Changes in LULC (1990 – 2020)

LULC CLASS	1990		2020		Change 1990 - 2000		Rate of Change
	Area (km^2)	%	Area (km^2)	%	Area (km^2)	%	%
Vegetation	146103.86	52.09	87192.09	31.08	-58911.77	-40.32	-1.34
Farmland	128646.21	45.86	180941.36	64.50	52295.15	40.65	1.36
Bare Surface	3996.06	1.42	9073.88	3.23	5077.82	127.07	4.24
Built-up Area	496.64	0.18	1404.98	0.50	908.34	182.90	6.10
Water body	1265.62	0.45	1896.09	0.68	630.47	49.82	0.08
TOTAL	280508.40	100.00	280508.40	100.00			

The result portrayed in Table I shows that vegetation cover experienced a great decrease in size throughout the study period. At initial 1990 vegetation cover occupied 146103.86 km² and by the year 2020 it grown to 87192.09 km² indicating a decline in area coverage of 58,911.77 km² which is equivalent to 40.32 % growth decrease and with 1.34 % rate of annual decrement. This was accredited to pressure on searching farmlands and fuel wood as the population of the study area is rapidly increasing as indicated by 1991, 2006 census and the projected 2022 population.

Moreover, the result of the temporal land use and land cover classifications as given in Table I also shows that the size of arable land in 1990 was estimated at 128646.21 km² which was 45.86% of the total study area. By the year 2020, the size becomes 180941.36 km² with indicates a high growth in farmlands of about 52297.15 km²; that is to say arable land use got an additional area of 40.65 % of its baseline value as in 1990. Also, the rate of increment of farmland throughout the study period was calculated as 1.36 % per year.

Similarly, Table I, figures 4 and 5 shows that bare surface is increasing throughout the study period. At initial 1990 bare surface cover an area of 3996.06 km² and rise with 5077.82 km² to 9073.88 km² in year 2020, indicating a rise of 127.07 % and annual growth rate of 4.24 %.

Furthermore, the result shows that built-up area experienced an increase in size within the study period. In the year 1990, built-up area only occupied 496.64 km² which is 0.18 % of the total area under study and by the year 2020 it grown to 1404.98 km² with a rise of 908.34

km² which is equivalent to 6.10% annual growth rate. This revealed that there is more than 182.90 % increase in built-up area. This indicates that urban area in 2020 approximately multiplied itself by three times when compared to the 1990.

Lastly, the analysis indicates that water body increases in the study area. It was estimated at 1265.62 km² in the 1990 and growth to 1896.09 km² in the year 2020. This indicates a growth of 630.47 km² of land corresponding to 49.82 % of its baseline value and which increases at an annual rate of 0.08 %. This was mainly due to the construction of Kashimbila Dam in Taraba state.

B. Land Use Land Cover Change Trends from 1990 to 2020

The following graph provides a summary of the land use land cover change trends of vegetation, farmland, bare surface, built-up areas and water body in the North-Eastern Nigeria from 1990 to 2020 as shown in figure 6 to figure 10 respectively.

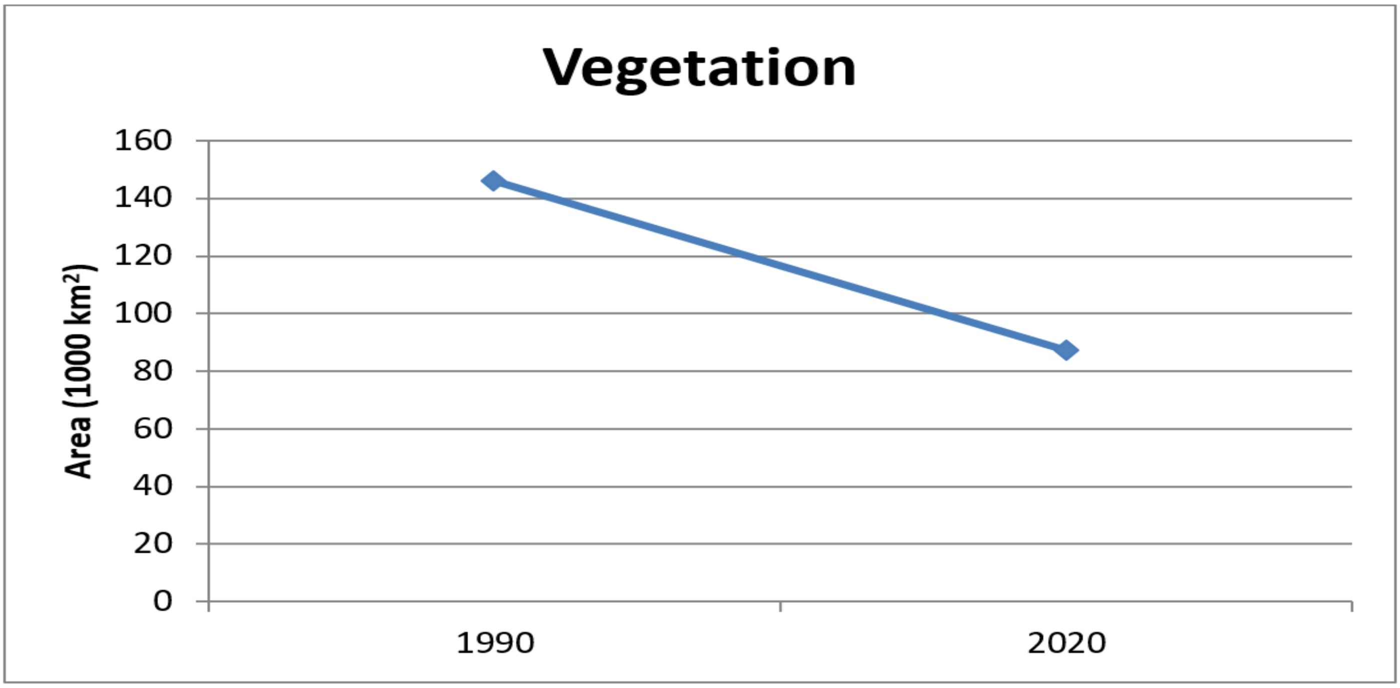

Fig 6 Vegetation LULC Change Trends in the North-Easter Nigeria from 1990 to 2020

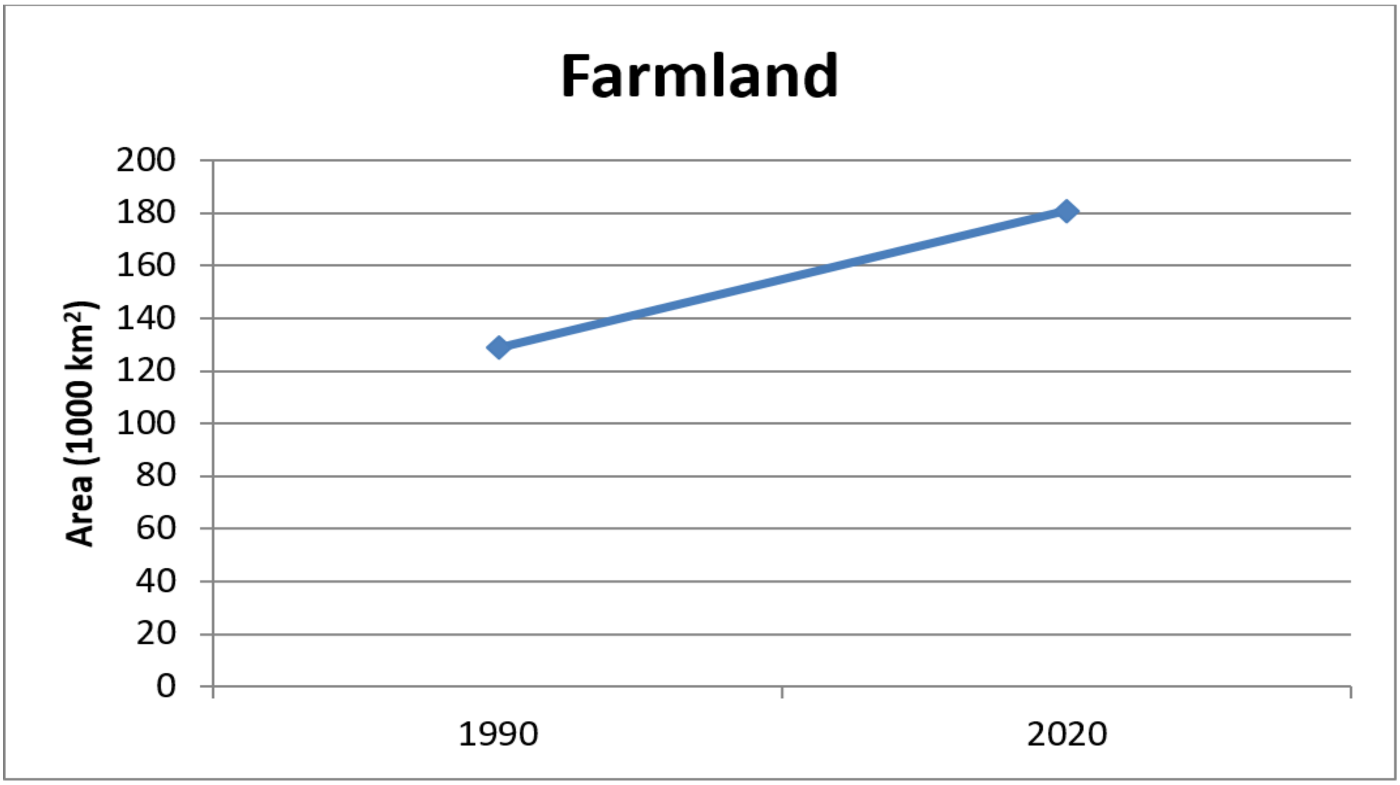

Fig 7 Farmland LULC Change Trends in the North-Eastern Nigeria from 1990 to 2020

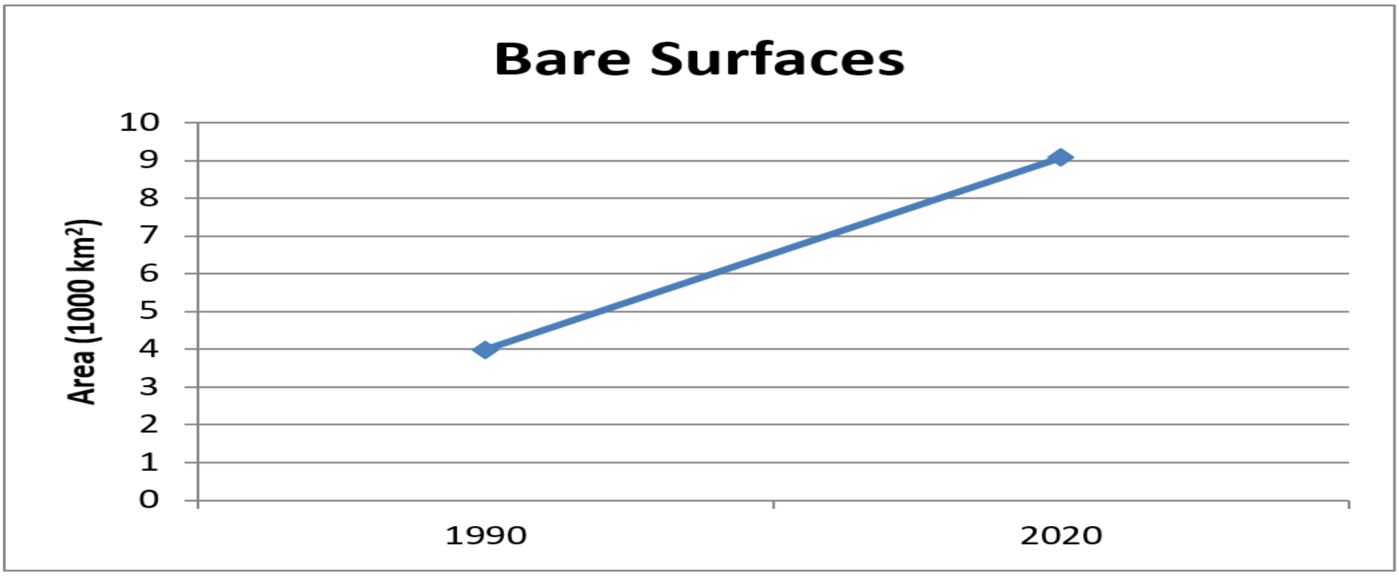

Fig 8 Bare surfaces LULC change trends in the North-Eastern Nigeria from 1990 to 2020

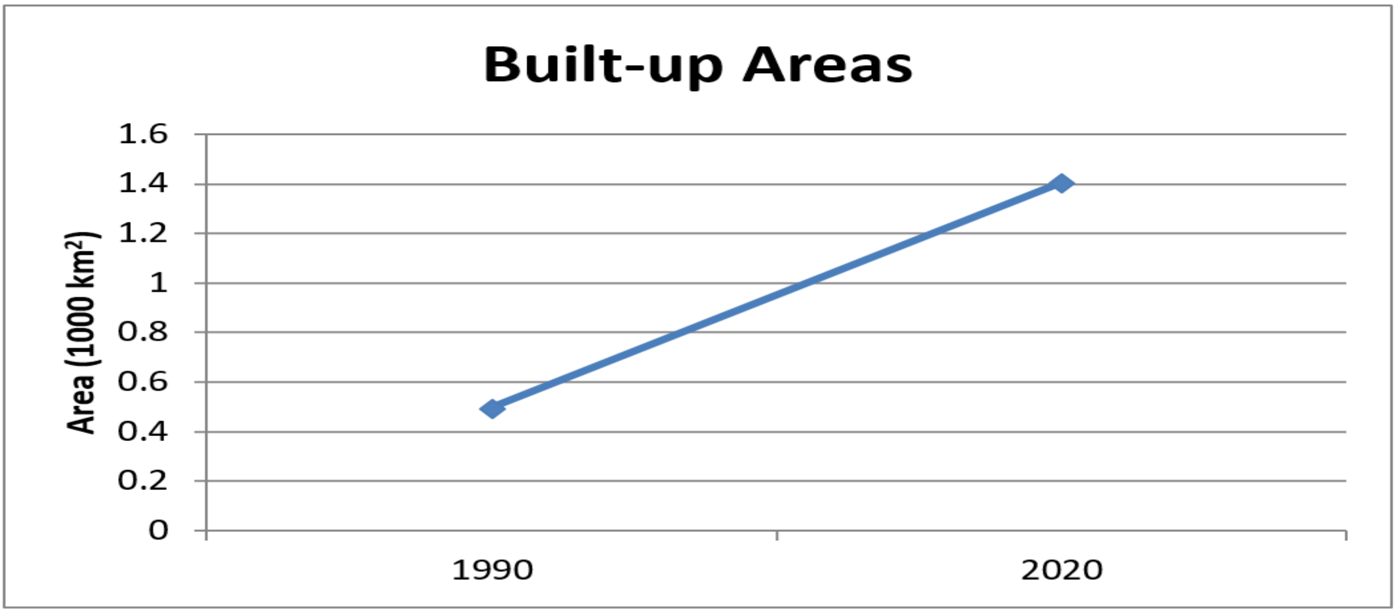

Fig 9 Built-up areas LULC change trends in the North-Eastern Nigeria from 1990 to 2020

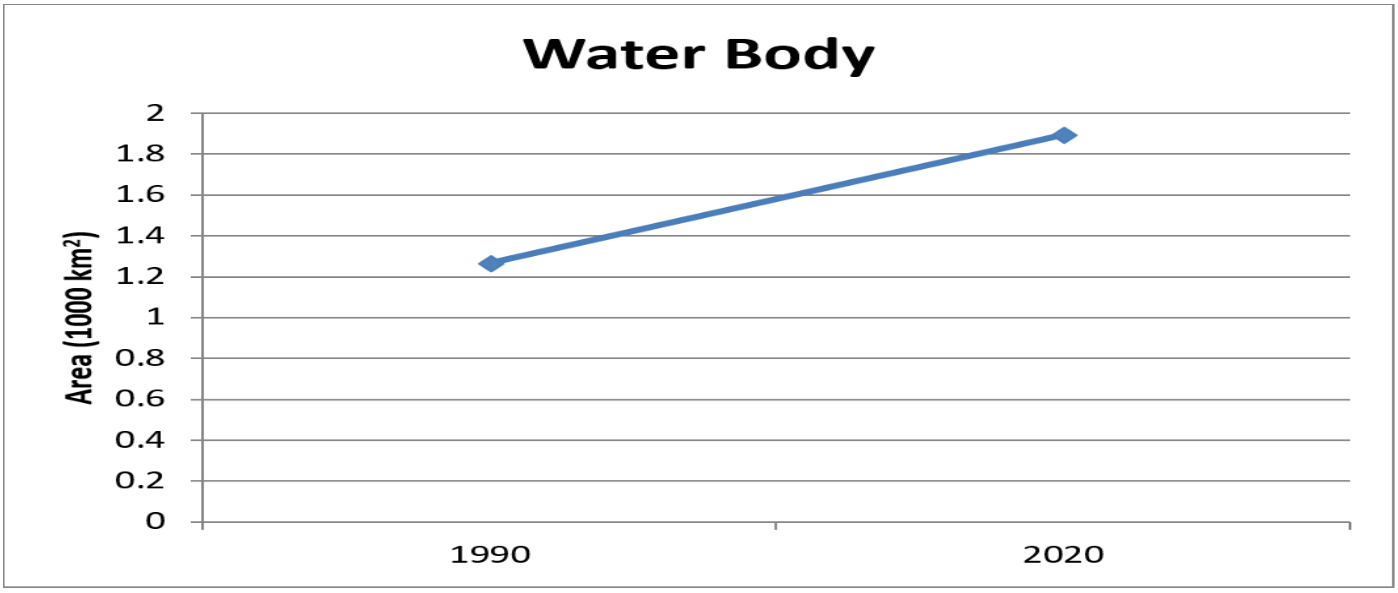

Fig 10 Water body LULC change trends in the North-Eastern Nigeria from 1990 to 2020

C. Socio-Economic and Environmental Sustainability Impact Analysis

Our approach to deforestation and forest degradation monitoring reveal that the forest lost every year in North-Eastern Nigeria is at the rate of 1.34% and table II shown the Socio-Economic and Environmental Sustainability Impact Analysis.

Table 2 Socio-Economic and Environmental Sustainability Impact Analysis

Socio-Economic Impacts of Deforestation and Forest Degradation	**Environmental Sustainability Impacts of Deforestation and Forest Degradation**
Exacerbation of Conflicts.	Increased greenhouse gas emissions due to Slash and burn methods.
Increased Rural Poverty Levels.	Reduction of climate regulation.
Displacement and Forcing of Rural-Urban Human Migration.	Disruption of water cycles
Food Insecurity, Higher unemployment, Nature and Energy Crises.	Biodiversity loss and species extinction.
Loss of livelihoods for communities that depend on forests.	Soil degradation and erosion due to Shifting Agriculture, Increased under brushing/felling.

D. Drivers of Deforestation

➢ *The Spatial Correlation Analysis Identified the Primary Drivers of Deforestation as:*

- Agricultural Expansion: Conversion of forested areas to farmlands, particularly near riverbanks and fertile zones.
- Wood Extraction: Unsustainable logging for fuel wood and charcoal production.
- Conflict: Forced displacement due to insurgencies led to unregulated resource exploitation in some regions.

E. Normalise Differential Vegetation Indices (NDVI)

Areas near settlements exhibited signs of forest degradation due to overgrazing, selective logging and firewood collection. Vegetation indices NDVI shown in figure 11 indicated a steady decline in forest health, with an average reduction of 12% in heavily utilized zones over thirty years.

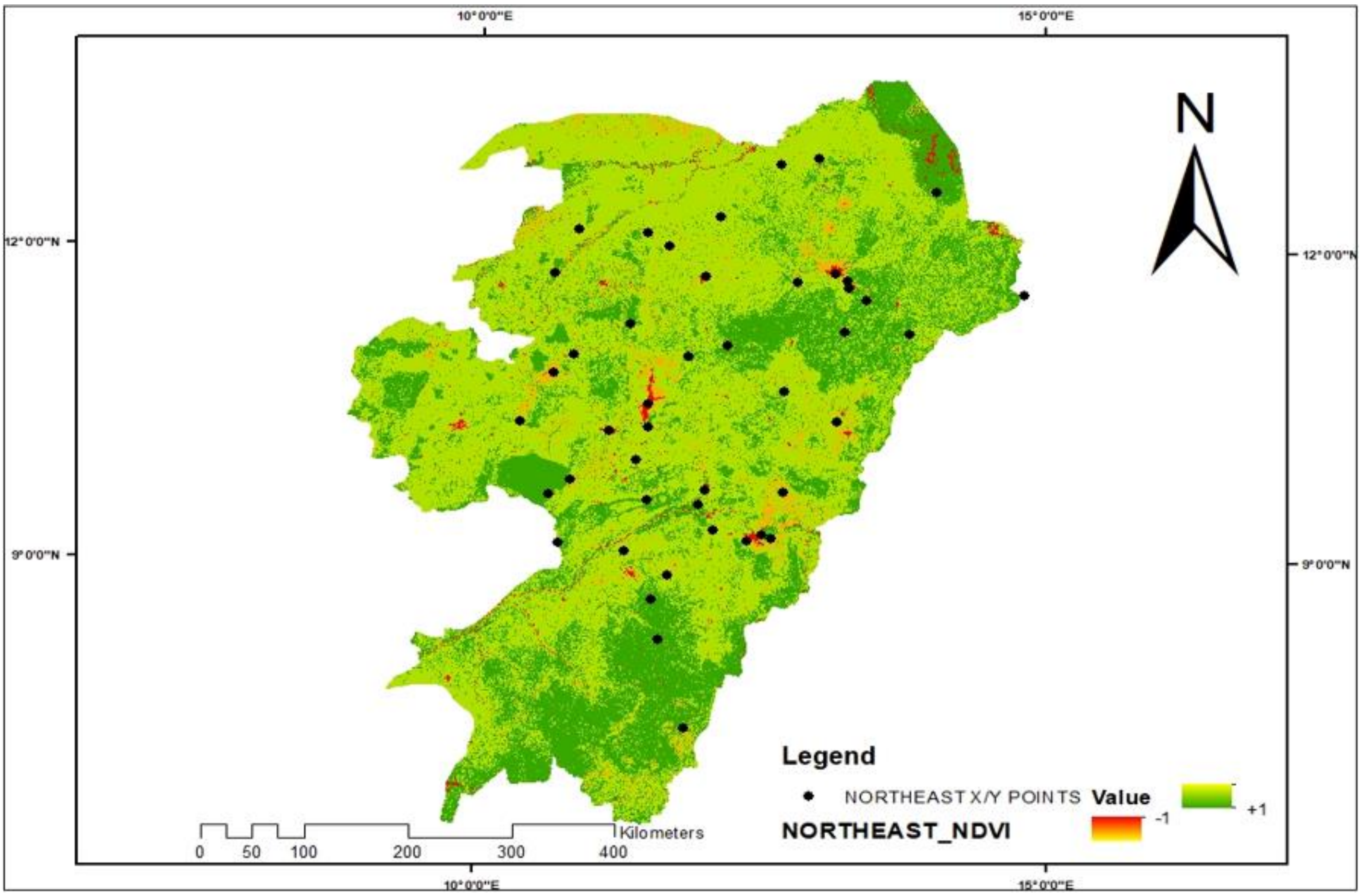

Fig 11 NDIV map of North-Eastern Nigeria with superimposed GPS coordinates points for validation.

Normalize Difference Vegetation Index (NDVI) of North-Eastern Nigeria consists of the following colors scale:

Green shades implies high NDVI values (closer to +1), indicating healthy, dense vegetation and yellow to red shades implies low NDVI values (closer to -1), representing areas with sparse vegetation, unhealthy vegetation, bare soil, or non-vegetated surfaces.

The map covers an area with geographic coordinates ranging from approximately 9°00'N to 12°00'N latitude and 10°00'E to 15°00'E longitude. With the following features such as densely vegetated areas are prominently green and yellow and red zones highlight degraded vegetation or land use like urban areas or exposed soil. The black dots represent validation points where field data are collected to corroborate the NDVI analysis. These are critical for comparing satellite-derived NDVI data with actual vegetation conditions, enhancing the accuracy of vegetation mapping and refining models for environmental monitoring.

The references and field validation steps includes, NDVI References is calculated using satellite imagery with the formula in equation 1.

NDVI = (NIR-R) / (NIR+R) …………………………………………….. Equation 1

Where NIR is near-infrared reflectance and R is red light reflectance. The value of +1 is healthy vegetation, 0 is bare soil and -1 is the water or non-vegetated features.

In the field validation, the coordinate mapping using GPS devices to locate the black dots on the ground was utilized and observation was used to measure vegetation characteristics (e.g., canopy cover, species type). Comparison indicates cross-check field data with NDVI values to ensure consistency. The area of applications includes land cover classification, agricultural monitoring and environmental conservation. However, the estimation of biomass revealed a decline indicating the environmental cost of deforestation.

IV. DISCUSSION

Impacts of deforestation on ecosystem services is that deforestation and degradation have led to a reduction in ecosystem services, including biodiversity loss, soil erosion and decreased water regulation capacity. Satellite imagery revealed an increase in barren and degraded lands, exacerbating vulnerability to desertification and climate change. In the socio-economic and conflict dynamics, the socio-political context, particularly the insurgency in the region, significantly contributed to forest exploitation. Displacement of communities increased dependence on forest resources for survival, underscoring the need for integrated humanitarian and environmental strategies.

Effectiveness of remote sensing tools by the integration of remote sensing and field surveys proved effective in identifying spatial and temporal deforestation trends. However, challenges such as cloud cover in rainy seasons and limited ground-truth data in conflict zones impacted the accuracy of some classifications.

Lastly, policy and management implications is as a results of weak enforcement of forest laws, despite existing regulations, enforcement remains inadequate due to limited resources and corruption. Also, opportunities for reforestation by identified degraded areas present opportunities for reforestation and afforestation projects. Leveraging several initiatives which can align local efforts with broader regional goals. Furthermore, findings highlight the importance of engaging local communities in sustainable forest management practices. For example, agroforestry and alternative livelihoods can reduce pressure on forest resources.

V. RECOMMENDATIONS FOR FUTURE EXAMINING

Improved Data Integration by combining LiDAR and hyperspectral imagery with current satellite data could provide more detailed assessments of forest structure and health. Capacity building by training local stakeholders in data collection and interpretation will enhance monitoring efforts. Conflict sensitive approaches by addressing the underlying drivers of resource overexploitation in conflict zones is essential to achieving long-term sustainability. Also, to adopt advanced satellite based remote sensing technology by integrating community based monitoring and establishes early warning systems. Furthermore, to develop a centralised forest monitoring system and implement drone technology. Strengthen policy, legal frameworks and address corruption. Lastly, to promote reforestation, afforestation program and foster multi stakeholder collaborations/partnerships and address socio-economic drivers, better farming techniques, promoting sustainable forestry practices and regular reporting and transparency

The results underscore the urgent need for comprehensive interventions to curb deforestation and forest degradation in North-Eastern Nigeria. By leveraging technology, strengthening policies and fostering community participation, it is possible to mitigate environmental impacts and promote sustainable land use in the region.

VI. CONCLUSION

The examining of deforestation and forest degradation in North-Eastern Nigeria revealed alarming trends of forest loss and degradation driven by human activities and environmental challenges. Using an integrated approach of remote sensing, field surveys and stakeholder engagement, the study provided critical insights into the extent, drivers and impacts of forest changes in the region. Key conclusions include:

The region is experiencing significant deforestation driven primarily by agricultural expansion, wood extraction and conflict-related displacement. These activities have resulted in severe environmental consequences, including loss of biodiversity, soil erosion and reduced carbon sequestration capacity. Deforestation hotspots were identified around urban centres, agricultural zones and conflict-affected areas, highlighting the need for targeted interventions. Forest degradation is primarily driven by overgrazing, selective logging and unsustainable fuel wood collection. The interplay between socioeconomic factors and environmental pressures is evident. The conflict in the region exacerbates resource exploitation, while the resulting deforestation intensifies vulnerabilities to climate change, desertification and food insecurity. The use of satellite imagery and vegetation indices proved effective in detecting forest cover changes, while field surveys added valuable context. However, challenges such as data gaps in conflict zones and limited access to advanced technologies remain. Weak enforcement of forest conservation policies, coupled with inadequate community engagement, has contributed to the unsustainable use of forest resources. Opportunities exist to leverage degraded areas for reforestation and sustainable land management practices.

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