Book of Proceedings, 14th Nigeria Association of Hydrological Sciences Conference (Okitipupa 2024) held at Olusegun Agagu University of Science and Technology, Okitipupa, Ondo State, Nigeria, November 5 - 8, 2024

Temporal Dynamics of Vegetation Health and Land Cover across Borno, Sokoto, Lagos and Rivers States: A Three-Decade Analysis

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Abstract

This study investigates the temporal dynamics of vegetation health and land cover across Borno State, Sokoto, Lagos, and Rivers State over a three-decade period from 1990 to 2020 using Normalized Difference Vegetation Index (NDVI) data. The NDVI data, obtained from satellite imagery and remote sensing databases, were pre-processed, registered, and classified into distinct land cover classes, including very healthy vegetation, moderately healthy vegetation, unhealthy vegetation, and bare land. Change detection analysis and spatial-temporal analysis techniques were employed to identify and analyze patterns of vegetation health and land cover change over time. The results reveal significant temporal trends and spatial variations in vegetation health and land cover across the study area. In Borno State, rapid land cover change and vegetation degradation were observed, indicating environmental challenges faced by the region. Sokoto exhibited similar trends, with notable shifts in land cover classes over the three-decade period. Lagos and Rivers State showed more stable patterns of vegetation health and land cover, albeit with localized areas of change. These findings provide valuable insights into the drivers of land cover change and their implications for ecosystem sustainability and resilience in the study area. The study contributes to our understanding of the impacts of climate change and human activities on vegetation dynamics and land cover transformation in Nigeria, informing evidence-based decision-making and sustainable land management practices.

Keywords: NDVI, vegetation health, land cover, change detection, spatial-temporal analysis, Nigeria, climate change, sustainable land management, remote sensing, environmental monitoring

Introduction

Climate change-induced alterations in temperature, precipitation patterns, and extreme weather events have profound effects on vegetation dynamics (IPCC, 2014). These changes can manifest as shifts in vegetation phenology, productivity, and distribution, with implications for ecosystem functioning and services (Cleland *et al.,* 2007). Understanding the temporal dynamics of vegetation health is crucial in assessing the impacts of climate change on ecosystems. Over recent decades, anthropogenic activities and climate change have significantly altered vegetation patterns worldwide (Myneni*et al.,* 1997). The Normalized Difference Vegetation Index (NDVI) has emerged as a valuable tool for quantifying vegetation health and dynamics over time (Pettorelli*et al.,* 2005). The temporal analyses of NDVI data provide insights into long-term vegetation trends and responses to climatic variations (Li *et al*. 2023; Shoumik and Khan 2023; Verbesselt *et al., 2010*).

By examining NDVI trends over multiple decades, researchers can identify areas experiencing vegetation degradation, expansion, or shifts in composition (Tucker *et al.,* 2005). Such assessments are essential for informing land management strategies, conservation efforts, and climate change mitigation policies (Boisvenue& Running, 2006).In Nigeria, a country characterized by diverse ecological zones, monitoring these dynamics is essential for informed environmental management and sustainable development strategies. This study focuses on four States: Borno, Sokoto, Lagos, and Rivers, representing different regions of Nigeria, to examine the temporal changes in vegetation health and land cover over the past three decades.

Borno State, located in the northeastern region, faces unique environmental challenges, including desertification and land degradation, exacerbated by factors such as climate change and anthropogenic activities. Conversely, Sokoto State, situated in the northwest, exhibits distinct ecological characteristics, with semi-arid to arid landscapes influencing vegetation patterns and land use (Lawal and Audu, 2018;Aliero and Bello, 2016).

In contrast, Lagos and Rivers States, situated in the southwest and south-south regions, respectively, boast diverse vegetation types, ranging from tropical rainforests to mangrove ecosystems. However, rapid urbanization and industrialization pose significant threats to natural habitats and biodiversity in these States (Adegbola and Olorunfemi, 2019; Alagoa and Briggs, 2017).

By analyzing Normalized Difference Vegetation Index (NDVI) data from 1990, 2005, and 2020, this study aims to assess the temporal trends in vegetation health and land cover across these States. The NDVI serves as a proxy for vegetation vigor and density, offering insights into ecosystem dynamics and environmental changes over time.Understanding the temporal dynamics of vegetation health and land cover in these States is crucial for identifying environmental trends, assessing the impacts of climate change, and formulating targeted mitigation and adaptation strategies. This study will contribute to the broader discourse on environmental monitoring and management in Nigeria, offering valuable insights for policymakers, researchers, and environmental stakeholders.

Methodology

Data Collection

The satellite imagery (containing bands in the red (R) and near-infrared (NIR) spectra) used for this study includes data from Landsat 5, Landsat 7 and Landsat 8, acquired during different years and utilizing specific sensors. The Landsat data employed the TM (Thematic Mapper) and ETM+ (Enhanced Thematic Mapper Plus). Landsat 8 data, utilized the OLI (Operational Land Imager) and TIRS (Thermal Infrared Sensor) sensors. All the imageries were sourced from the Google Earth Engine (GEE) platform

Pre-processing:

NDVI is the most common vegetation indices and has a range of -1 to +1. NDVI is computed from the visible and near-infrared light reflected by vegetation. Healthy vegetation absorbs most of the visible light in its contact and reflects a large portion of the near-infrared light. Unhealthy or sparse vegetation reflects more visible light and less near-infrared light. The NDVI was also used because it has been well documented as good measures of biomass and vegetation vigour (Li *et al*. 2023; Shoumik and Khan 2023). The data were pre-processed to remove any artifacts or inconsistencies such as atmospheric effects, clouds and shadows, and perform radiometric and geometric corrections to ensure data quality and reliability and consistency across different time periods.

Image Registration:
The NDVI images were registered from different time periods to a common coordinate system to facilitate accurate comparison and analysis. This step ensures that pixel values correspond to the same geographical locations across all images.

Change Detection Analysis:
Use change detection techniques to identify areas of significant change in vegetation health and land cover between different time periods. This involved methods such as thresholding, image differencing, and machine learning algorithms to detect changes in NDVI values over time. The land use change detection in this study was conducted using ArcMap. Initially, a classified raster layer representing land use classes was created. This raster layer was then converted to a polygon feature class based on the distinct classes using the "Conversion" tool. Subsequently, vectorized representations of land use for both the later and former time periods were obtained. To identify areas of change, the "Intersection" tool was applied to compare the two vectorized land use layers. This process generated a new feature class, and a "Change" column was incorporated into the attribute table to designate areas where land use had altered.Utilizing the "Attribute Field Calculator," the change in land use was determined by the class of the former time period to the corresponding class value of the later time period

Classification:
The NDVI images were defined into different land cover classes (e.g., very healthy vegetation, moderately healthy vegetation, unhealthy vegetation, bare land) using supervised classification techniques. This step assigns each pixel in the image to a specific land cover class based on its spectral characteristics. The land cover classification was conducted by creating band

combinations of 5, 4, 3 (Landsat 8 OLI) and 4, 3, 2 (Landsat ETM+ and TM) color composite images, specifically for vegetation. These images were prepared to facilitate visual interpretation and the delineation of training areas for each predetermined Land Use/Land Cover (LULC).A set of samples was generated based on training samples representing desired land use types. These samples were utilized in the classification of the images. The selection of training samples involved using the point locations of characteristic sites utilizing Google Earth Engine's base map of the study area as a reference. The digitization of points for each training sample, corresponding to similar land cover, was carried out using the chosen color composite. Each known Landuse/Land cover (LULC) type was then assigned a distinctive identifier.The image classification was performed using a supervised classification approach, employing the smileCart algorithm in Google Earth Engine.

Accuracy Assessment:

Accuracy assessment was computed using a systematic approach on Google Earth Engine to evaluate the precision of the image classification results. Validation points were extracted from the classified image using the sampleRegions function. These points, derived from the Land Cover property of the training points dataset, were sampled at a scale of 30 meters to ensure a detailed assessment. The error matrix was computed using the errorMatrix function. This matrix breaks down classification accuracy into categories such as true positives, false positives, true negatives, and false negatives, providing a comprehensive understanding of classification performance. The overall accuracy was determined using the accuracy formula:

$$\frac{TP+TN}{TP+TN+FP+FN} \qquad \text{Eqn.1}$$

Where:

TP represents true positives,
TN represents true negatives,
FP represents false positives, and
FN represents false negatives.

For the computation of kappa value on excel, the error matrix was exported
The Kappa coefficient (κ) was calculated using the formula:

$$K = \frac{Overall\ Accuracy - Random\ Accuracy}{1 - Random\ Accuracy} \qquad \text{Eqn.2}$$

Where Random Accuracy is calculated as:

$$\frac{(TotalObservedPositive \times TotalPredictedPositive + TotalObservedNegative \times TotalPredictedNegat}{Total\ Observation}$$

Eqn. 3

Temporal/Spatial Analysis:
The Normalized Differential Vegetation Index (NDVI) for the target years was derived from the surface reflectance images using the built-in normalizedDifference function in Google Earth Engine. The near-infrared (NIR) band (Landsat 8 band 5 and Landsat 5 and 7 band 4) was input as the first parameter, while the red band (Landsat 8 band 4 and Landsat 5 and 7 band 3) was input as the second parameter. The function subtracted the red band values from the NIR band values on a per-pixel basis across the images. It then divided this difference by the sum of the NIR and red bands. This generated NDVI values ranging from -1 to 1 for each pixel. Higher positive values indicate greater green vegetation density and health due to higher NIR reflectance and lower red absorbance.

$$NDVI = \frac{NIR - RED}{NIR + RED} \quad \text{Eqn.4}$$

The procedure is illustrated in fig.1 below

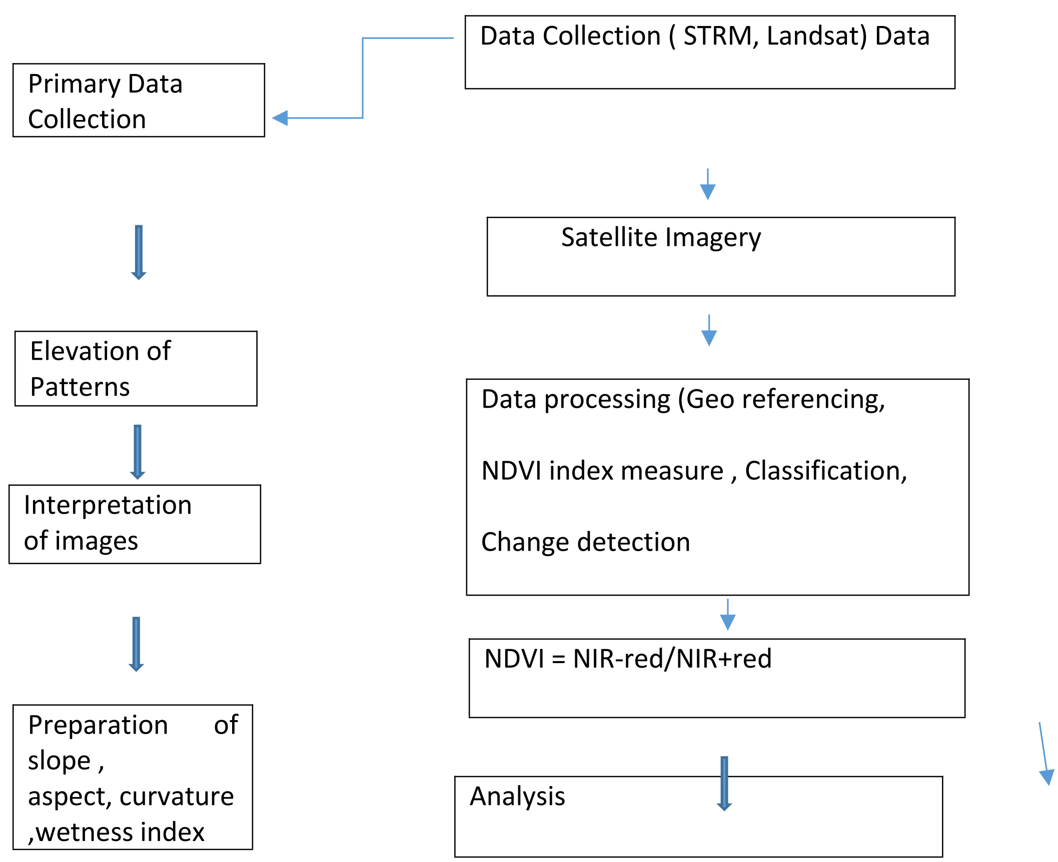

Fig 1. Flow Chart of generating NDVI

Result Presentation and Analysis

NDVIfor Borno State:

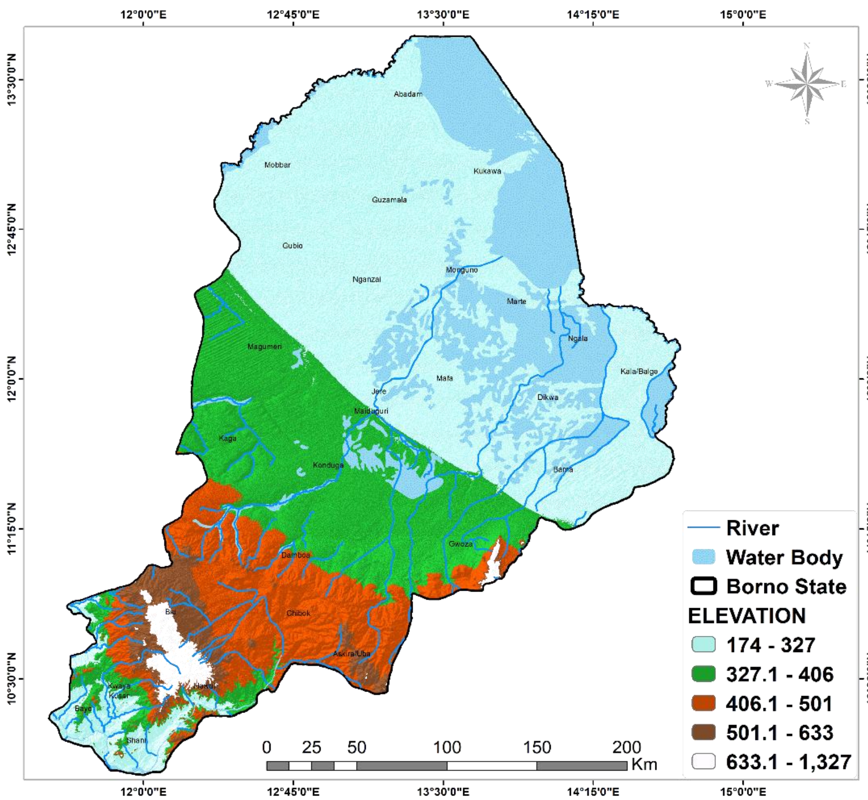

Fig 2 Elevation map of Borno State

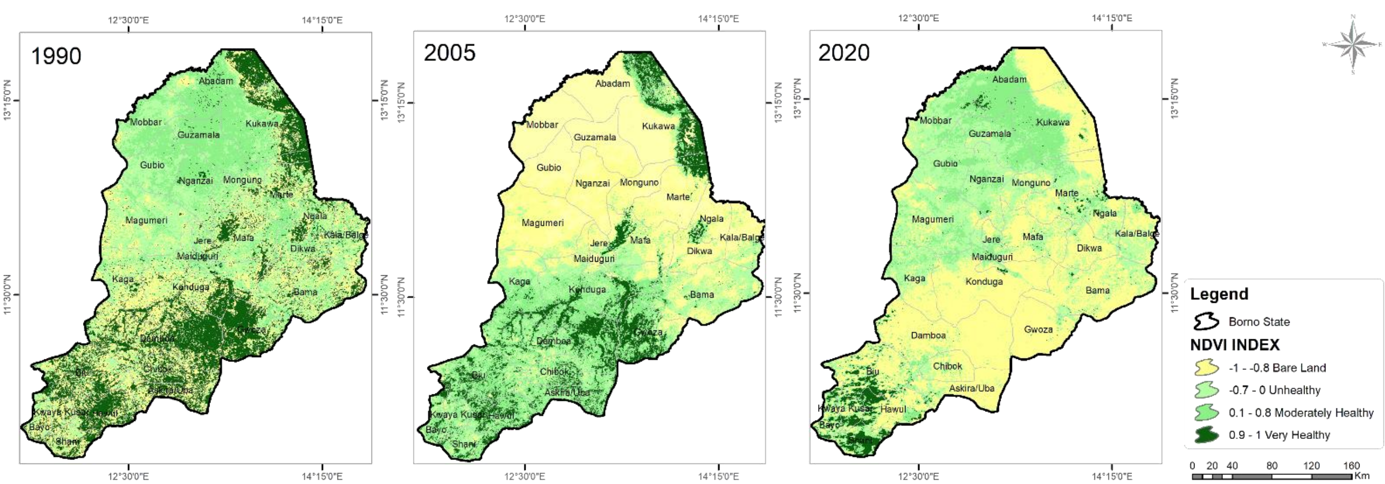

Fig 3. NDVI Analysis for Borno State for year 1990, 2005 and 2020

In 1990, there were 4 categories of vegetation based on NDVI values:

1. Very Healthy: NDVI range 0.9 to 1, covering an area of 150,673.05 hectares.
2. Moderately Healthy: NDVI range 0.8 to 0.1, covering an area of 1,565,589.65 hectares.
3. Unhealthy: NDVI range -0.7 to 0, covering an area of 2,028,431.10 hectares.
4. Bare Land: NDVI range -1 to -0.8, covering an area of 3,520,803.52 hectares.

- In 2005, similar categories were observed with changes in areas:

1. Very Healthy: NDVI range 0.9 to 1, covering an area of 251,776.5475 hectares.
2. Moderately Healthy: NDVI range 0.8 to 0.1, covering an area of 1,213,782.639 hectares.
3. Unhealthy: NDVI range -0.7 to 0, covering an area of 2,134,024.509 hectares.
4. Bare Land: NDVI range -1 to -0.8, covering an area of 3,665,850.438 hectares.

- In 2020, there were changes in the distribution of vegetation:

1. Very Healthy: NDVI range 0.9 to 1, covering an area of 1,781,691.597 hectares.
2. Moderately Healthy: NDVI range 0.8 to 0.1, covering an area of 1,712,897.663 hectares.
3. Unhealthy: NDVI range -0.7 to 0, covering an area of 1,347,435.434 hectares.
4. Bare Land: NDVI range -1 to -0.8, covering an area of 2,423,472.67 hectares.

The NDVI data for Borno State in 1990, 2005, and 2020 reveal notable changes in vegetation health and land cover over the three-decade period. In 1990, the area classified as "Very Healthy" accounted for 150,673.05 hectares, while "Moderately Healthy" and "Unhealthy" areas covered 1,565,589.65 hectares and 2,028,431.10 hectares, respectively. Additionally, "Bare Land" occupied 3,520,803.52 hectares.

By 2005, there was a significant decline in the "Very Healthy" and "Moderately Healthy" categories, with respective areas of 251,776.5475 hectares and 1,213,782.639 hectares. However, the "Unhealthy" and "Bare Land" categories witnessed an increase, encompassing 2,134,024.509 hectares and 3,665,850.438 hectares, respectively.

In 2020, the trend continued, with further reductions in the "Very Healthy" and "Moderately Healthy" areas, now comprising 178, 1691.597 hectares and 1,712,897.663 hectares, respectively. Meanwhile, the "Unhealthy" and "Bare Land" categories expanded to 1,347,435.434 hectares and 2,423,472.67 hectares, respectively.

The observed changes in vegetation health and land cover have significant implications for environmental sustainability and ecosystem resilience in Borno State. The progressive decline in "Very Healthy" and "Moderately Healthy" areas underscores the growing threat of desertification and land degradation, driven by factors such as deforestation, unsustainable land use practices, and climate variability.The expansion of "Unhealthy" and "Bare Land" categories signals an alarming trend of habitat loss and degradation, posing threats to biodiversity, soil fertility, and water resources. These changes have far-reaching consequences for local communities dependent on natural ecosystems for livelihoods, food security, and cultural heritage.

Based on the analysis of NDVI data for different years, several inferences can be drawn regarding climate change and environmental degradation in Borno State:

i. *Shifts in Vegetation Health*: The changes in the distribution of vegetation types indicate shifts in vegetation health over time. Decreases in the area covered by very healthy and moderately healthy vegetation and increases in unhealthy vegetation and bare land suggest potential degradation of the environment.(Yakubu and Nwilo,2019)

ii. *Impact of Climate Change*: Climate change may have influenced the changes in vegetation health observed over the years. Factors such as changes in temperature, precipitation patterns, and land use practices can affect vegetation growth and health, leading to shifts in NDVI values.

iii. *Loss of Biodiversity*: The expansion of bare land and unhealthy vegetation categories suggests a loss of biodiversity and habitat degradation. This can have detrimental effects on ecosystems, leading to a decline in wildlife populations and disruptions in ecological balance.

iv. *Land Degradation*: The increase in bare land area indicates land degradation, which can result from various factors such as deforestation, soil erosion, and desertification. Land degradation reduces the land's ability to support vegetation growth and ecosystem services, leading to negative impacts on soil fertility, water quality, and biodiversity.

v. *Human Activities*: Human activities such as urbanization, agriculture expansion, and deforestation likely contribute to the observed changes in vegetation health and land cover. Unsustainable land use practices and resource exploitation exacerbate environmental degradation and climate change effects.

vi. *Need for Conservation and Restoration*: The analysis highlights the importance of conservation and restoration efforts to mitigate environmental degradation and promote sustainable land management practices.

NDVI for Sokoto State

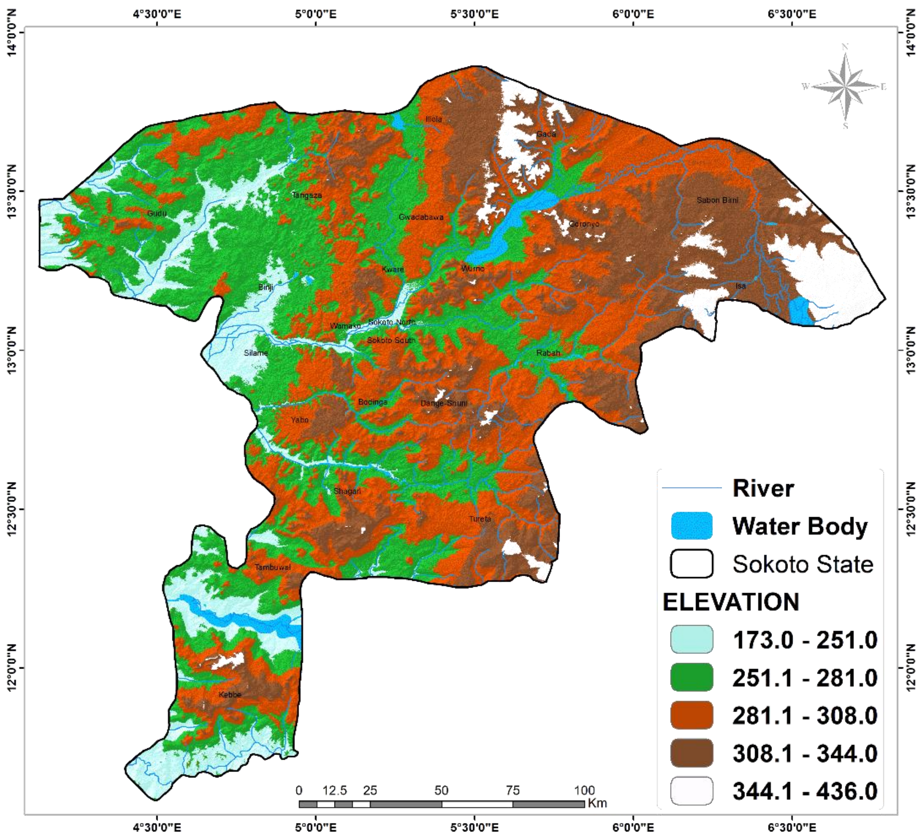

Fig 4 Elevation map of Sokoto State

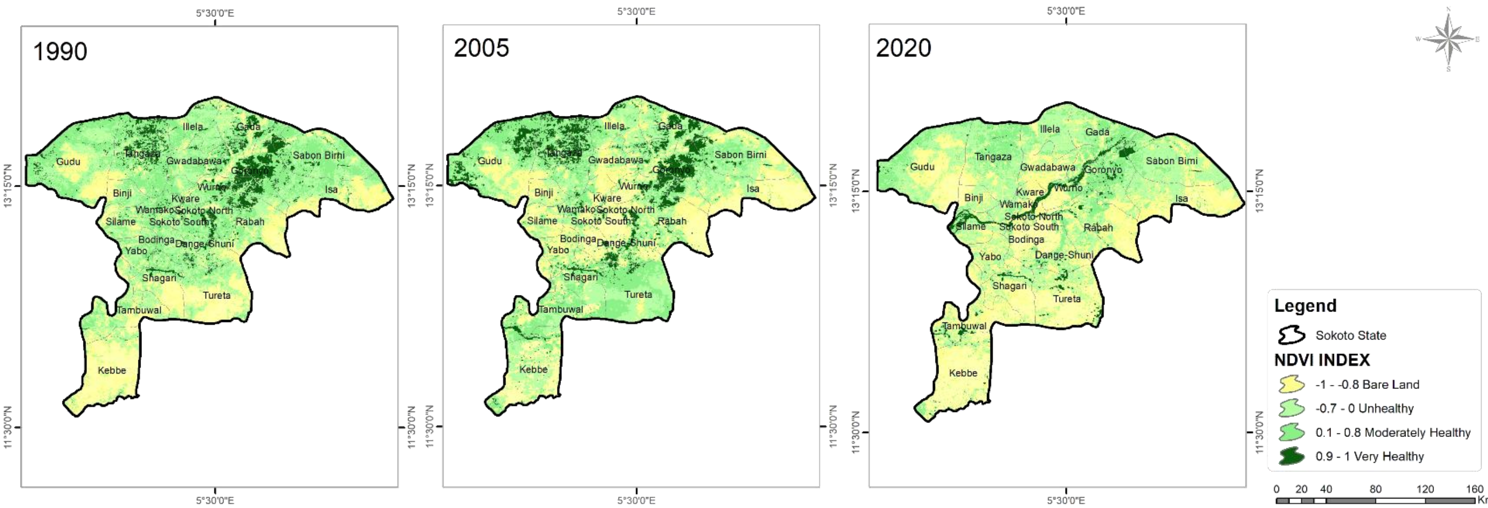

Fig 5 NDVI for Sokoto State

Id	NDVI INDEX	Land type	Area (ha)
1	0.9 -1	Very Healthy	221764.74
2	0.8 – 0.1	Moderately Healthy	996779.85
3	-0.7 - 0	Unhealthy	1024844.23
4	-1 - -0.8	Bare Land	973603.94

2005

Id	NDVI INDEX	Land type	Area (ha)
1	0.9 -1	Very Healthy	290771.80
2	0.8 – 0.1	Moderately Healthy	818457.07
3	-0.7 - 0	Unhealthy	1015245.27
4	-1 - -0.8	Bare Land	1092504.58

2020

Id	NDVI INDEX	Land type	Area (ha)
1	0.9 -1	Very Healthy	92580.66
2	0.8 – 0.1	Moderately Healthy	478442.38
3	-0.7 - 0	Unhealthy	1077771.68
4	-1 - -0.8	Bare Land	1568184.11

The analysis of NDVI (Normalized Difference Vegetation Index) data for Sokoto State over three different years (1990, 2005, and 2020) reveals several implications and inferences regarding land cover changes, environmental degradation, and potential impacts on ecosystems and climate:

i. *Decline in Vegetation Health*: There is a noticeable decline in the area covered by very healthy and moderately healthy vegetation over the years. In 1990, the area of very healthy vegetation was 221,764.74 ha, which decreased to 92,580.66 ha in 2020. Similarly, the area of moderately healthy vegetation decreased from 996,779.85 ha in 1990 to 478,442.38 ha in 2020. The consistent decline in the area covered by very healthy and moderately healthy vegetation suggests a degradation of vegetation health in Sokoto State over the past three decades. The significant increase in bare land area indicates ongoing land degradation processes in Sokoto State. Land degradation, characterized by the loss of vegetation cover and soil erosion, can lead to reduced agricultural productivity, desertification, and loss of biodiversity. This trend may be attributed to factors such as deforestation, overgrazing, and land degradation practices. The significant increase in bare land area indicates ongoing land degradation processes in Sokoto State.

ii. *Expansion of Bare Land*: Conversely, there is a significant increase in the area of bare land over the years. Bare land, which indicates areas with limited or no vegetation cover, expanded from 973,603.94 ha in 1990 to 1,568,184.11 ha in 2020. This suggests land degradation and loss of vegetative cover over time. The significant increase in the area of bare land indicates extensive land degradation and loss of vegetative cover in Sokoto State. Bare land areas are vulnerable to soil erosion, desertification, and loss of biodiversity, posing serious environmental challenges and threatening ecosystem resilience.

iii. *Consistency in Unhealthy Vegetation*: The area covered by unhealthy vegetation remains relatively consistent across the years, indicating persistent environmental stress or degradation in these areas. Unhealthy vegetation covers a substantial portion of Sokoto State, with little change observed over the three decades. The relatively stable area covered by unhealthy vegetation highlights persistent environmental stress and degradation in certain areas of Sokoto State. The decline in the area covered by very healthy and moderately healthy vegetation suggests a loss of vegetation biomass and ecological integrity over the three decades. This loss of vegetation can disrupt ecosystem functions, such as carbon sequestration, nutrient cycling, and habitat provision for wildlife. These areas may be characterized by soil degradation, water scarcity, and habitat loss, contributing to ecosystem vulnerability and reduced ecological productivity.

iv. *Environmental Vulnerability*: The observed changes in land cover and vegetation health suggest heightened environmental vulnerability in Sokoto State, The persistence of unhealthy vegetation cover highlights environmental stress factors affecting Sokoto State, such as drought, land use changes, and unsustainable land management practices. These stressors can exacerbate land degradation processes and reduce the resilience of ecosystems to climate variability with implications for local communities and ecosystems. Reduced vegetation cover can exacerbate soil erosion, water scarcity, and climate variability, posing risks to agricultural productivity, water resources, and livelihoods

v. *Implications for Climate Change*: Changes in land cover and vegetation health can have implications for climate change and local climate patterns. Reduced vegetation cover may lead to changes in temperature, precipitation patterns, soil moisture levels, soil erosion, and water scarcity, exacerbating climate-related risks such as heatwaves, droughts, and flooding impacting both local and regional climates.The analysis underscores the importance of climate change adaptation strategies and sustainable land management practices in mitigating environmental degradation and building resilience in Sokoto State. Efforts to restore degraded lands, promote afforestation, and implement soil conservation measures are essential for enhancing ecosystem health and supporting adaptation to climate change impacts.

vi. *Need for Conservation and Sustainable Land Management*: The findings underscore the importance of conservation and sustainable land management practices in mitigating land degradation and preserving ecosystem health in Sokoto State. Efforts to restore degraded lands, promote afforestation, and implement sustainable land use practices are essential for maintaining ecological balance and resilience in the face of environmental challenges.The findings have implications for land use planning, natural resource management, and policy formulation in Sokoto State. Integrated approaches that prioritize sustainable land management, ecosystem restoration, and community engagement are needed to address environmental challenges and promote sustainable development in the region.

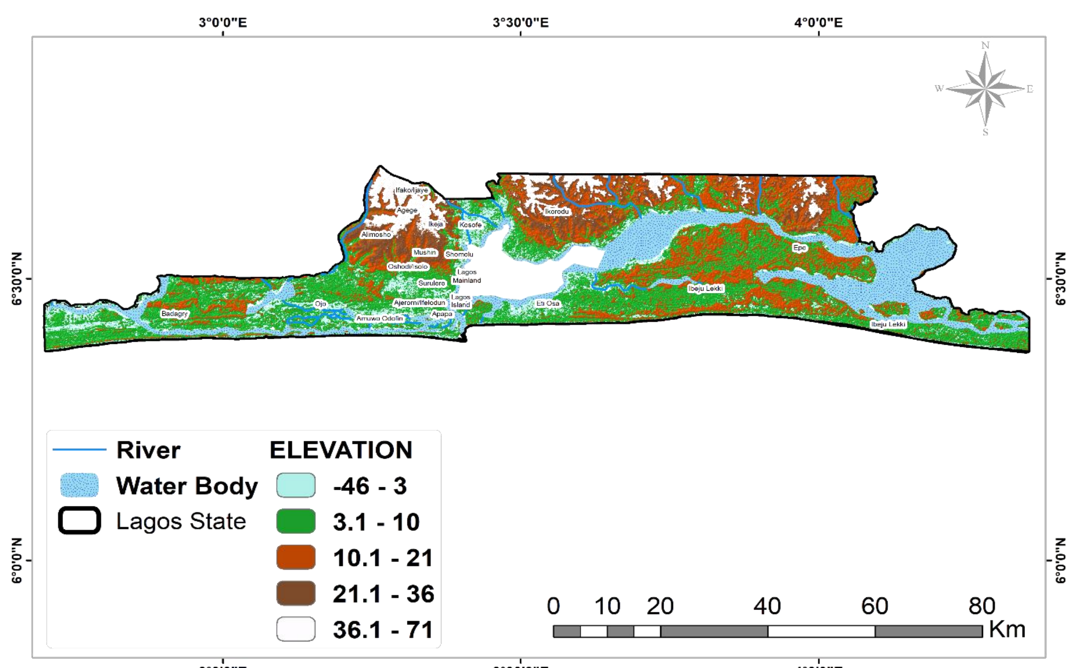

Fig 6 Elevation map of Lagos

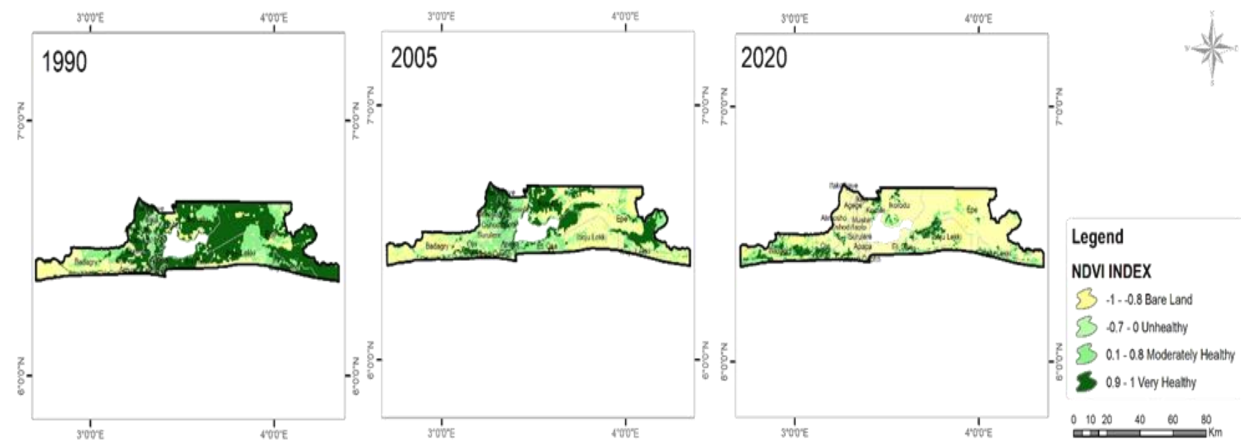

Fig 7 NDVI for Lagos State (1990, 2005 and 2020)

1990

Id	NDVI INDEX	Vegetation type	Area (ha)
1	0.9 -1	Very Healthy	208051.20
2	0.8 – 0.1	Moderately Healthy	50321.29
3	-0.7 - 0	Unhealthy	21550.92
4	-1 - -0.8	Bare Land	6083087.55

2005

Id	NDVI INDEX	Vegetation type	Area (ha)
1	0.9 -1	Very Healthy	199579.79
2	0.8 – 0.1	Moderately Healthy	61780.77
3	-0.7 - 0	Unhealthy	22342.49
4	-1 - -0.8	Bare Land	63501.18

2020

Id	NDVI INDEX	Vegetation type	Area (ha)
1	0.9 -1	Very Healthy	87194.29
2	0.8 – 0.1	Moderately Healthy	62745.39
3	-0.7 - 0	Unhealthy	54430.91
4	-1 - -0.8	Bare Land	143342.62

The analysis of NDVI (Normalized Difference Vegetation Index) data for Lagos State over three different years (1990, 2005, and 2020) reveals several implications and inferences regarding land cover changes, environmental degradation, and potential impacts on ecosystems and climate:

i. *Land Degradation*: Similar to Sokoto State, Lagos State also shows a concerning increase in bare land area over the three decades. This suggests ongoing land degradation processes such as urbanization, deforestation, and soil erosion, which can have detrimental effects on ecosystem health and resilience.. Land degradation reduces the capacity of ecosystems to provide essential services, such as carbon sequestration, water regulation, and habitat provision, thereby exacerbating environmental challenges.

ii. *Vegetation Loss*: The decline in the area covered by very healthy and moderately healthy vegetation indicates a loss of vegetation biomass and biodiversity in Lagos State. This loss of vegetation can disrupt ecosystem functions, reduce carbon sequestration, and contribute to habitat loss for native species. The area covered by very healthy vegetation has shown a consistent decrease over the three decades. In 1990, it covered 208,051.20 ha, which reduced to 87,194.29 ha by 2020. This decline suggests a loss of areas with high vegetation density and health.

iii. *Urbanization and Development*: The area of bare land, representing areas with minimal to no vegetation cover, has seen fluctuations but overall shows an increasing trend. From 6,083,087.55 ha in 1990, it decreased slightly to 63,501.18 ha in 2005 before increasing substantially to 143,342.62 ha by 2020. This suggests ongoing land degradation or conversion of vegetated areas to non-vegetated land. The expansion of bare land area in Lagos State is likely driven by rapid urbanization and infrastructure development, leading to the conversion of natural habitats into built-up areas, roads, and industrial zones (Oyinloye and Balogun,2020). Urban expansion can fragment ecosystems, degrade water quality, and exacerbate climate change impacts.

iv. *Environmental Stress*: The persistence of unhealthy vegetation cover suggests environmental stress factors such as pollution, land-use conflicts, and inadequate land management practices in Lagos State. Addressing these stressors is essential for mitigating land degradation and safeguarding ecosystem services.

v. *Climate Change Resilience*: Changes in land cover and vegetation health may influence the resilience of Lagos State to climate change impacts such as extreme weather events, sea-level rise, and heatwaves(Smith and Lagos, 2020). Maintaining and restoring natural vegetation can enhance climate resilience by regulating temperature, reducing flood risk, and supporting biodiversity.

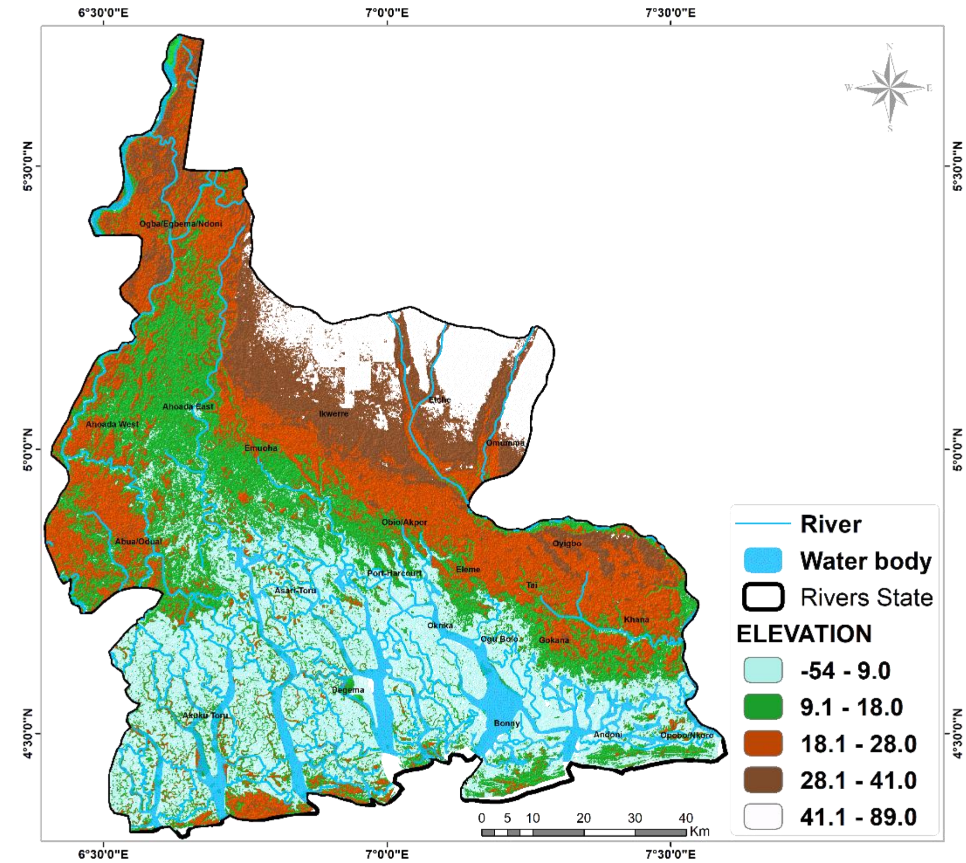

Fig 8 Elevation map of Rivers State with reference to vegetation health

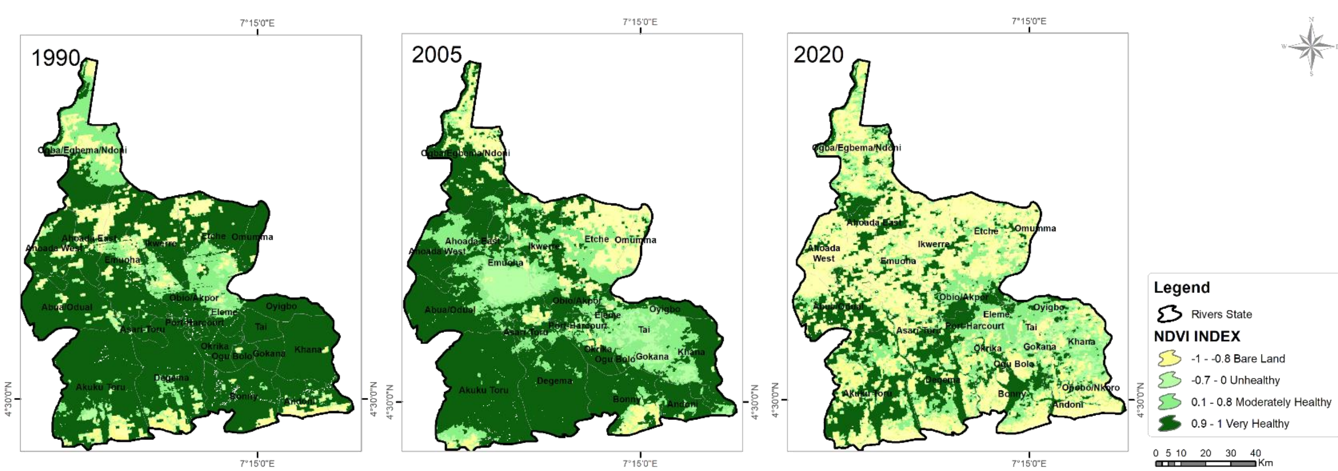

Fig 9 NDVI of Rivers State for 1990, 2005 and 2020

1990

Id	NDVI INDEX	Vegetation Quality	Area (ha)
1	0.9 -1	Very Healthy	782118.94
2	0.8 – 0.1	Moderately Healthy	94571.073
3	-0.7 - 0	Unhealthy	46593.02
4	-1 - -0.8	Bare Land	5488813.3

2005

Id	NDVI INDEX	Vegetation Quality	Area (ha)
1	0.9 -1	Very Healthy	633879.93
2	0.8 – 0.1	Moderately Healthy	196593.85
3	-0.7 - 0	Unhealthy	87821.38
4	-1 - -0.8	Bare Land	116661.83

2020

Id	NDVI INDEX	Vegetation Quality	Area (ha)
1	0.9 -1	Very Healthy	274040.62
2	0.8 – 0.1	Moderately Healthy	170169.08
3	-0.7 - 0	Unhealthy	123841.31
4	-1 - -0.8	Bare Land	468021.16

The analysis of NDVI data for Rivers State across three decades (1990, 2005, and 2020) reveals significant environmental and climate change implications:

i. *Loss of Vegetation Cover*: The area covered by very healthy vegetation has shown a notable decline over the three decades. In 1990, it covered 782,118.94 ha, which decreased to 274,040.62 ha by 2020. The area classified as moderately healthy vegetation has also experienced a decline, although less pronounced compared to very healthy vegetation. From 94,571.073 ha in 1990, it decreased to 170,169.08 ha in 2020. The area of unhealthy vegetation has shown fluctuations over the years. In 1990, it covered 46,593.02 ha, increased slightly to 87,821.38 ha in 2005, and then decreased to 123,841.31 ha by 2020. This indicates variable dynamics in areas with stressed or degraded vegetation. This substantial reduction suggests significant loss of areas with high vegetation density and health. The substantial increase in bare land area from 1990 to 2020 indicates significant deforestation and land degradation in Rivers State. This loss of vegetation cover diminishes biodiversity, reduces ecosystem resilience, and contributes to habitat loss for wildlife species.(Jones and Rivers, 2019).

ii. *Decline in Healthy Vegetation*: The reduction in the area covered by very healthy and moderately healthy vegetation types suggests degradation of natural ecosystems and potential impacts on ecosystem services such as carbon sequestration, soil stabilization, and water regulation.

iii. *Urbanization and Infrastructure Development*: The area of bare land, representing areas with minimal to no vegetation cover, has shown fluctuations but an overall increasing trend. From 5,488,813.3 ha in 1990, it decreased slightly to 116,661.83 ha in 2005 before increasing substantially to 468,021.16 ha by 2020. This suggests ongoing land degradation or conversion of vegetated areas to non-vegetated land. The expansion of bare land area may be attributed to urbanization, industrialization, and infrastructure development in Rivers State. Rapid urban expansion leads to land-use change, habitat fragmentation, and loss of green spaces, exacerbating environmental degradation and increasing vulnerability to climate change.

iv. *Impact on Water Resources*: Deforestation and land degradation affect water resources by reducing soil moisture retention, increasing surface runoff, and impairing water quality. This can lead to reduced water availability, increased risk of flooding, and degradation of aquatic ecosystems and associated biodiversity.

v. *Climate Resilience Challenges*: Changes in land cover and vegetation health impact the resilience of ecosystems and communities to climate change. Loss of vegetation cover diminishes the ability of ecosystems to buffer against climate extremes, such as droughts, floods, and heatwaves, increasing the vulnerability of local populations.

vi. *Erosion and Soil Degradation*: The expansion of bare land area exacerbates soil erosion, sedimentation, and soil degradation in Rivers State. This leads to loss of fertile topsoil, reduced agricultural productivity, and increased susceptibility to landslides and erosion-related hazards.

vii. *Biodiversity Loss*: The decline in healthy vegetation cover and habitat loss contribute to biodiversity loss in Rivers State. Reductions in habitat quality and availability negatively impact wildlife populations, ecological processes, and ecosystem functioning.(Itumo, *et al.,* 2023)

viii. *Socioeconomic Implications*: Environmental degradation and loss of ecosystem services have socioeconomic implications for local communities, including reduced agricultural yields, loss of livelihoods dependent on natural resources, and increased vulnerability to climate-related disasters.

Conclusion and Recommendation

Climate, more than any other factor, controls the broad-scale distributions of plant species and vegetation. Rapid climate change leads to major changes in the distribution of plants and thus in biomes and habitats and water holding capacity Precipitation and temperature are the dominant climatic factors affecting vegetation. Vegetation Cover is the one of most important biophysical indicator to soil erosion and drought, which can be estimated using vegetation indices derived from the Satellite images. Vegetation indices allow us to delineate the distribution of vegetation and soil based on the characteristic reflectance patterns of green vegetation. In other words, the degree of greenness is equal to the chlorophyll concentration. NDVI values vary with the absorption of red light by plant chlorophyll and the reflection of infrared radiation by water-filled leaf cells. When a vegetation is not healthy, it is easily carried away in flood and prone to drought too.

Four States, two in the North and two in the South were selected for NDVI analysis. The maps and the accompanying tables indicates widespread regional disparity in vegetation cover and health and land use dynamics, emphasizing the need for tailored management approaches. Across all four States, there was a consistent pattern of decreasing very healthy vegetation and increasing moderately healthy and unhealthy vegetation. Bare land areas in Sokoto State remained relatively stable over the study period, indicating limited changes in land cover. While in Lagos State there was a slight increase in bare land areas, possibly due to urbanization and land use changes.Rivers State also experienced moderate expansion in bare land areas, reflecting land degradation processes. Highlighting the vulnerability of coastal ecosystems to land degradation and habitat loss

Overall, the analysis underscores the interconnectedness between climate change, environmental degradation, and human activities, emphasizing the urgent need for proactive measures to address these challenges and safeguard the planet's ecosystems and biodiversity. The findings highlight the urgent need for effective land management strategies, reforestation efforts, and sustainable development practices to mitigate environmental degradation, enhance ecosystem resilience, and promote long-term sustainability in the face of climate change.

Recommendation

Effective land use planning and management. Protecting and restoring natural habitats, including forests, wetlands, and mangroves, implementing nature-based solutions, such as green infrastructure, agroforestry. Engaging local communities, indigenous peoples, and stakeholders in decision-making processes and environmental conservation efforts fosters ownership, participation, and sustainability.

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