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Assessment of Spatio-Temporal Land Use and Land Cover Dynamics in Ogoniland, Rivers State, Nigeria

Ntor Charles[1]; Dorka Nwidag Daniel[2]; Odiji Caleb[3]; Clifford-Osawaru Wisdom Osamudiamen[4]; Ubido Benjamin[5]

[1]Department of Environmental Management, Federal University of Environment and Technology (FUET), Koroma/Saakpenwa, Ogoniland, Rivers State, Nigeria
[2]Federal University of Environment and Technology (FUET), Koroma/Saakpenwa, Ogoniland, Rivers State, Nigeria
[3]Department of Strategic Space Application, National Space Research and Development Agency (NASRDA), Abuja, Nigeria4
[4]Institute of Geosciences and Environmental Management, Rivers State University, Port Harcourt, Nigeria.
[5]Network Oil and Gas Limited, Nigeria

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Abstract: Ogoniland, in Nigeria's Niger Delta, has experienced more than six decades of oil exploration, environmental pollution, and population pressure, yet its landscape change remains poorly quantified at the local scale. This study examined the spatio-temporal dynamics of land use and land cover (LULC) in Ogoniland between 1990 and 2025 using multi-temporal Landsat imagery acquired at five-year intervals. Images were classified into six classes (built-up, cropland, grassland, forest, mangrove, and water body) using the Random Forest algorithm, and vegetation condition was assessed with the Normalized Difference Vegetation Index (NDVI) in Google Earth Engine. Overall classification accuracy ranged from 84.2% to 88.6%, with Kappa coefficients of 0.825–0.868. The results reveal a sustained conversion of natural vegetation to anthropogenic land uses. Built-up land expanded from 5.2 km² (0.5%) to 192.0 km² (18.3%), an increase of roughly 3,600%, while forest cover declined from 463.2 km² to 242.5 km², losing nearly half of its 1990 extent. Grassland contracted from 32.4% to 4.1% of the study area, and mangroves decreased from 35.8 km² to 18.5 km². By 2025, cropland and built-up areas jointly occupied approximately 55% of the landscape, whereas water bodies increased from 15.5 km² to 168.5 km², suggesting altered drainage and coastal conditions. NDVI patterns corroborated these trends, revealing progressive fragmentation of dense vegetation and widespread expansion of low-NDVI surfaces. Ogoniland has therefore shifted from a forest-dominated ecosystem to a heavily modified agricultural–urban landscape. Remediation efforts should extend beyond soil decontamination to landscape-level restoration, including mangrove rehabilitation, urban containment and agroecological support for farmers.

Keywords: *Land Use/Land Cover Change; NDVI; Random Forest; Remote Sensing; Ogoniland; Niger Delta.*

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I. INTRODUCTION

Land Use and Land Cover (LULC) represents distinct yet interrelated concepts reflecting both human use and the physical characteristics of the land surface. "Land use" describes how people utilize land for different purposes, including production, recreation, and habitat preservation, while "land cover" refers to the observable physical features of Earth's top layer, encompassing vegetation, water bodies, bare soil, and urban infrastructure(Kuule et al., 2022). Understanding LULC dynamics is increasingly crucial due to its profound impact on human well-being and environmental sustainability, as it serves as a vital indicator for assessing ecosystem services, hydrological processes, biodiversity conservation, and climate change regulation(Habte et al., 2020).

In Nigeria, rapid population growth and economic development have intensified LULC changes, particularly in ecologically sensitive regions. As the most populous country

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in Africa with an estimated population of 218.5 million, Nigeria is undergoing unprecedented land cover transformation driven by agricultural expansion, urban sprawl, deforestation, and industrial development. These changes have been linked to serious environmental consequences, including habitat fragmentation, biodiversity loss, land degradation, and increased vulnerability to climate-related hazards(Enoguanbhor et al., 2019).

Ogoniland, situated in the Niger Delta region of southern Nigeria, represents a particularly significant case study for LULC change analysis. Historically, the area was characterized by rich and abundant ecosystems, supporting subsistence farming, fishing, and thriving local economies. The Ogoni people were adept custodians of their land, leveraging cooperative frameworks to maximize agricultural yields and fishing endeavors through communal efforts. Before the discovery of oil, minimal deforestation or contamination occurred, as the land was considered sacred and acts that polluted or desecrated it were viewed as abominations. However, the commencement of oil exploration in the late 1950s marked a fundamental turning point in the region's land use trajectory(Sam & Zibima, 2024).

The discovery and subsequent extraction of crude oil in Ogoniland from the late 1950s has transformed the region's landscape, economy, and ecology. Between 1976 and 1991 alone, Nigeria experienced over 2,976 individual oil spills, collectively resulting in the pollution of Ogoniland with over two million barrels of oil. This environmental devastation has manifested through multiple interconnected processes: extensive soil contamination that has rendered once-fertile agricultural land unproductive, destruction of vital mangrove ecosystems, contamination of water bodies and groundwater with hydrocarbons, and gas flaring that has contributed to acid rain and air pollution(Oguchukwu and Akerele.,2020)

The environmental degradation has created a cascade of socio-ecological consequences. Local communities, who were historically farmers and fishermen, can no longer rely on their traditional livelihoods. Crops require extensive fertilizers to grow, fish populations have drastically declined, and community members have developed health problems from exposure to contaminated water and soil . The United Nations Environment Programme (UNEP) assessment in 2011 estimated that environmental restoration of Ogoniland could take between 25 to 30 years(Sam & Zibima, 2024). Despite decades of activism, legal battles, and a $1 billion cleanup program initiated in 2017, the environmental restoration of Ogoniland remains slow and inadequate. Shell, the primary oil company operating in the region, ceased drilling operations in 1993, but the legacy of contamination persists. Recent proposals to resume oil drilling in Ogoniland have generated significant concern among local communities, who fear renewed environmental devastation(Arowolo & Deng, 2018a).

Although numerous studies have examined LULC changes across various regions of Nigeria using remote sensing and Geographic Information System (GIS) approaches, there is a notable gap in comprehensive spatio-temporal analysis specific to Ogoniland. Most regional studies have focused on the broader Niger Delta or other parts of Nigeria, without providing the detailed localized understanding necessary for Ogoniland's unique context. The combination of oil-related pollution, historical land degradation, and ongoing development pressures makes Ogoniland a distinctive case that requires targeted investigation(Arowolo & Deng, 2018b; Atubi et al., 2018; Obayelu, 2018).

The present study focuses on the spatio-temporal assessment of Land Use/Land Cover (LU/LC) in Ogoniland using multi-temporal satellite remote sensing data and Geographic Information System (GIS) analysis. The objectives of this study are (1) To classify and map LULC patterns in Ogoniland for selected time epochs over the past three to four decades using Landsat satellite imagery and (3) carry out Normalize Difference Vegetation Index (NDVI).

Understanding the specific patterns, rates, and drivers of LULC change in Ogoniland is essential for several reasons. Firstly, it provides crucial baseline data for environmental remediation efforts. Secondly, it informs sustainable land-use planning and conservation strategies. Thirdly, it supports the monitoring and evaluation of ongoing cleanup interventions. Finally, it contributes to evidence-based policy decisions regarding potential resumption of oil activities in the region.

II. MATERIAL AND METHOD

➢ *Study Area*

Ogoniland is a distinct territory located in Rivers State, Nigeria, situated within the heart of the Niger Delta region (Figure 1). The area lies near the coast of the Gulf of Guinea, approximately east of the major metropolitan city of Port Harcourt. Geographically, Ogoniland extends between latitudes 4°15' N and 4°45' N, and longitudes 7°00' E and 7°30' E. The traditional headquarters of Ogoniland, Bori, is located at coordinates 4°40'34.64" N and 7°21'54.68". The territory covers an area of approximately 1,000 to 1,050 km² (about 386 to 404 square miles), making it one of the smaller but most ecologically significant territories in the Niger Delta region (Uranta-Okonkwo, 2021).

Administratively, Ogoniland extends across four Local Government Areas (LGAs) of Rivers State: Khana, Gokana, Eleme, and Tai. Each LGA encompasses multiple communities, with the Ogoni ethnic group as the primary inhabitants. Culturally and traditionally, Ogoniland is often described as being divided into six kingdoms: Babbe, Gokana, Ken-Khana, Nyo-Khana, Tai, and Eleme (Figure.1). These kingdoms represent the traditional political structure that predates modern administrative divisions and remain significant in cultural and governance matters.

The topography of Ogoniland is generally low-lying, typical of the Niger Delta region, with elevations ranging from sea level to approximately 30 meters above mean sea level (Aghalino, 2020). The terrain consists of flat to gently

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undulating plains interspersed with numerous creeks, streams, and rivers. The area is bounded by the Imo River to the north and east, which serves as a natural boundary separating Ogoniland from neighboring territories (Ogoni & Okon, 2021). Other significant water bodies include the Bonny River, Andoni River, and numerous smaller creeks that form an intricate drainage network characteristic of the deltaic environment. This extensive hydrological system supports the region's rich aquatic biodiversity and provides essential resources for local livelihoods(Sam & Zibima, 2024).

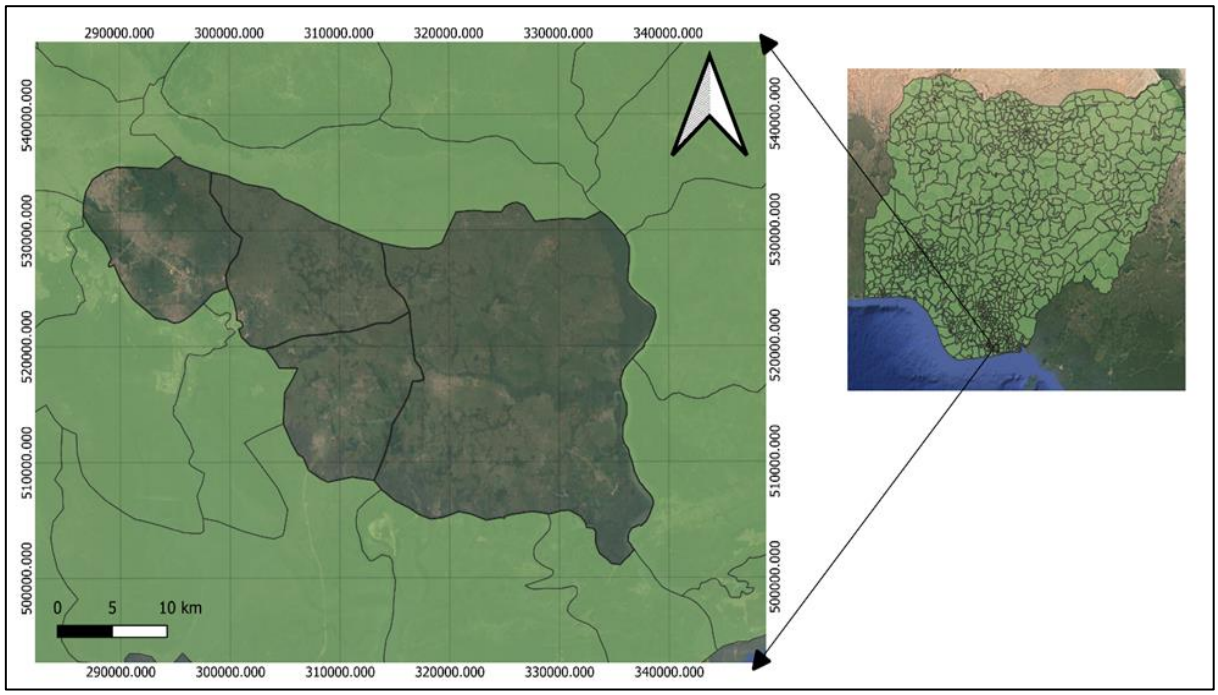


Fig 1 Study Area

➢ *Satellite Data Acquisition*

Multi-temporal Landsat satellite imagery was utilized to assess land use and land cover (LULC) changes in Ogoniland, Rivers State, Nigeria. The datasets comprised Landsat Multispectral Scanner (MSS) imagery for 1990, Landsat Enhanced Thematic Mapper (ETM) imagery for 1995, 2000, 2005, and 2010, and Landsat 8 Operational Land Imager/Thermal Infrared Sensor (OLI/TIRS) imagery for 2015, 2020 and 2025. All satellite images were obtained from the United States Geological Survey Earth Resources Observation and Science (USGS-EROS) archive through the EarthExplorer platform (https://earthexplorer.usgs.gov/). The selected images have a spatial resolution of 30 m and were chosen based on minimal cloud cover and complete coverage of the study area.

➢ *Land Use and Land Cover (LULC) Classification*

The acquired Landsat images were subjected to standard preprocessing procedures, including geometric and atmospheric corrections, to ensure spatial consistency and radiometric quality before classification. False Color Composite (FCC) images were generated in ArcGIS Pro 2.8 to enhance the visual discrimination of land cover features. For Landsat MSS and ETM imagery, bands 4, 3, and 2 were combined to produce the FCC, whereas bands 5, 4, and 3 were used for Landsat 8 OLI/TIRS imagery, following established remote sensing practices (Whanda et al., 2016; Atubi et al., 2018; Onilude & Vaz, 2020). Representative training samples for each land cover class were developed using spectral signatures obtained through visual interpretation of the satellite imagery, supported by existing land cover information and high-resolution Google Earth imagery. Supervised image classification was subsequently performed using the Random Forest (RF) algorithm because of its high classification accuracy, robustness to noisy data, and ability to handle complex land cover classes.

The accuracy of the classified maps was assessed using reference data obtained from field observations and high-resolution Google Earth imagery. Standard accuracy assessment metrics, including the confusion matrix, overall accuracy, user's accuracy, producer's accuracy, and the Kappa coefficient, were employed to evaluate the classification performance. Finally, the spatial extent of each land use and land cover class was quantified by calculating the total area and percentage coverage for each study year, enabling the analysis of temporal LULC dynamics in Ogoniland.

➢ *Normalized Difference Vegetation Index (NDVI)*

The Normalized Difference Vegetation Index (NDVI) was employed to evaluate the spatial and temporal variations in vegetation cover across Ogoniland between 1990 and 2025. NDVI is one of the most widely used spectral indices for monitoring vegetation health, density, and vigor because it exploits the contrasting reflectance characteristics of healthy vegetation in the red and near-infrared (NIR) portions of the electromagnetic spectrum. Healthy vegetation strongly absorbs red light for photosynthesis while reflecting a large

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proportion of near-infrared radiation due to the internal structure of plant leaves.

The NDVI was computed from the atmospherically corrected Landsat images using the standard equation:

$$NDVI = \frac{(NIR-RED)}{(NIR+RED)}$$

Where NIR represents the reflectance of the near-infrared band and Red represents the reflectance of the red band. For Landsat MSS imagery, the near-infrared and red bands were derived from Bands 4 and 2, respectively. For Landsat ETM imagery, Bands 4 (NIR) and 3 (Red) were used, while Bands 5 (NIR) and 4 (Red) were utilized for Landsat 8 OLI/TIRS imagery.

The NDVI computation was performed in Google Earth Engine (GEE) using atmospherically corrected Landsat Collection 2 Level-2 surface reflectance datasets. Clouds, cloud shadows, and other atmospheric contaminants were removed using the Quality Assessment (QA) band prior to image compositing. Annual cloud-free composite images were generated for each study year using median pixel values to minimize residual atmospheric effects and improve image quality.

The resulting NDVI values range from -1 to +1. Negative values generally correspond to water bodies, values close to zero represent bare soil, built-up areas, and exposed surfaces, whereas positive values indicate vegetation. Higher positive values (approximately 0.5 to 1.0) represent dense and healthy vegetation, while lower positive values (0.1 to 0.4) indicate sparse vegetation or degraded land cover.

To evaluate long-term vegetation dynamics, NDVI maps were generated for 1990, 1995, 2000, 2005, 2010, 2015, 2020, and 2025. Descriptive statistics, including minimum, maximum, mean, and standard deviation, were computed for each year to quantify temporal changes in vegetation condition. The NDVI maps were further compared with the land use and land cover (LULC) classification results to examine the relationship between vegetation change and land cover transformations resulting from urbanization, agricultural expansion, industrial development, and environmental degradation within Ogoniland.

III. RESULTS

This study presents a multi-temporal analysis of Land Use and Land Cover (LULC) changes within the Ogoniland region of the Niger Delta, spanning a 35-year period from 1990 to 2025 (Figure 2 (a) – (i)). Utilizing a consistent classification schema of six primary LULC classes, the mapped sequence elucidates significant anthropogenic-driven landscape transformations. The results indicate a pronounced trajectory of deforestation, agricultural intensification, and urban expansion.

The 1990 land use and land cover (LULC) map represents the baseline condition of Ogoniland before the onset of widespread landscape transformation. At this stage, the region was largely characterized by extensive forest cover, particularly across the northern, western, and central parts of the study area. These forests formed relatively continuous tracts and constituted the dominant terrestrial land cover. Along the southern coastline, mangrove forests and water bodies remained intact, reflecting the ecological importance of the Niger Delta's coastal environment. Agricultural lands and grasslands were present but occurred mainly as scattered patches, while built-up areas were limited to small rural settlements with minimal spatial extent. Overall, the landscape retained much of its natural vegetation, indicating relatively low levels of anthropogenic disturbance.

By 1995, noticeable changes had begun to emerge. Forest cover showed signs of fragmentation, particularly around its margins, where agricultural activities had started expanding into previously undisturbed areas. Cropland and grassland became more widespread, replacing sections of forest and creating a more heterogeneous landscape. Although the coastal mangrove ecosystems remained relatively stable, increasing human activities inland marked the beginning of a gradual transition from a predominantly natural landscape to one increasingly influenced by agriculture and settlement development.

The changes became more pronounced by 2001. Forests that had previously formed continuous vegetation blocks were increasingly broken into smaller and isolated patches. Agricultural expansion accelerated, with croplands extending across much of the northern and western portions of the study area. At the same time, built-up areas expanded beyond their original settlement cores, reflecting population growth and increasing demand for residential and supporting infrastructure. This period represents a significant turning point, as human-induced land uses began to dominate large portions of the landscape.

The 2005 LULC map illustrates a period of rapid landscape transformation. Forest cover experienced substantial decline and became highly fragmented, surviving mainly in isolated pockets within the northern section of the study area. Cropland emerged as the dominant land use, occupying much of the central and interior regions that were previously covered by natural vegetation. Built-up areas also expanded considerably, with settlements becoming larger and increasingly interconnected, particularly along major transportation corridors and areas with improved accessibility. These changes demonstrate the combined effects of agricultural intensification and urban expansion on the natural environment.

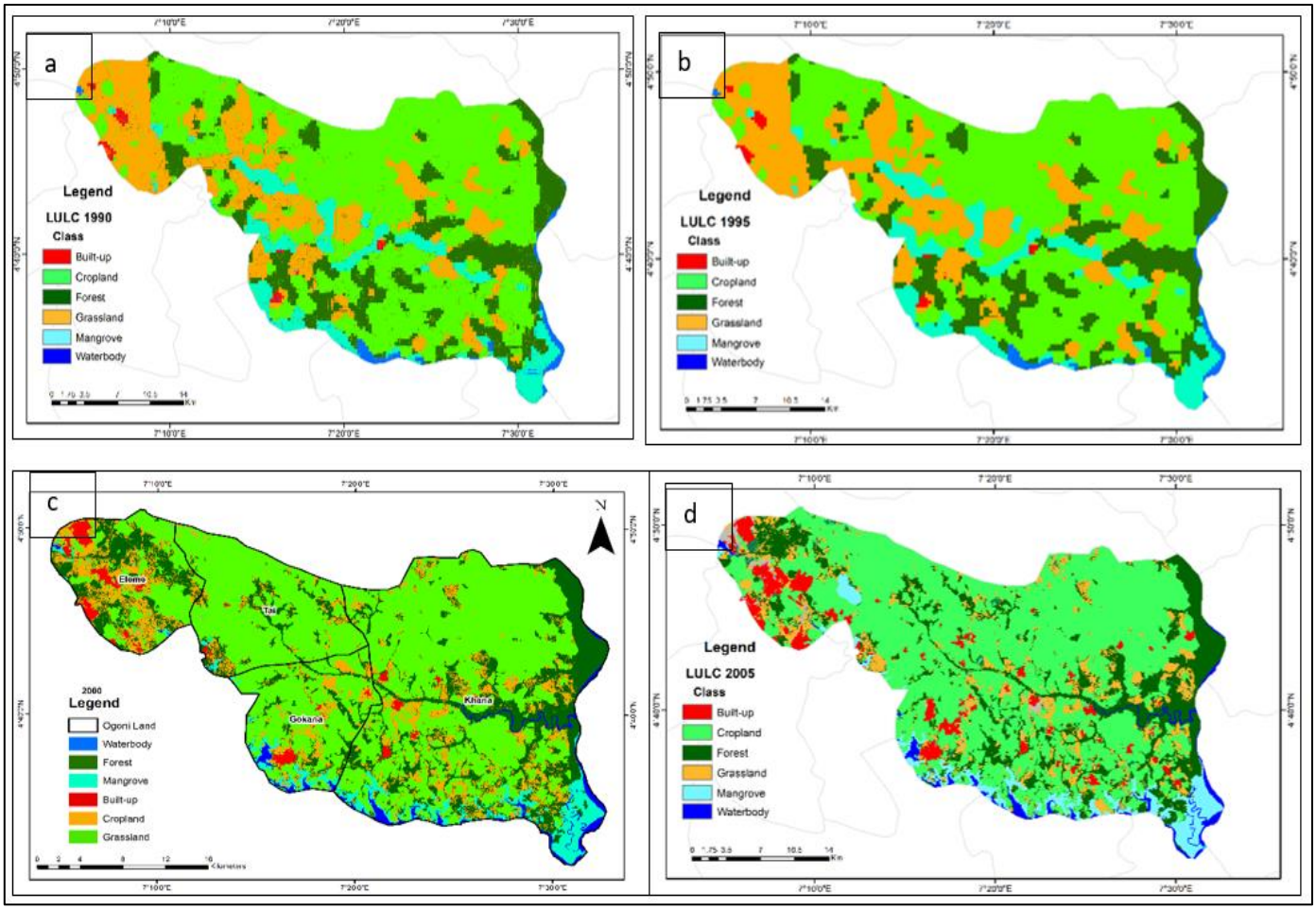
By 2010, the landscape exhibited further evidence of environmental degradation. In addition to continued expansion of cropland and settlements, areas classified as open land became more evident across the region. These areas likely represent exposed soil, degraded surfaces, abandoned farmland, or land disturbed by various human activities.

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Forest cover continued to decline and was reduced to a few scattered remnants. Although the mangrove ecosystems along the southern coastline remained relatively intact, localized degradation became visible in some coastal sections. The continued increase in built-up areas indicates sustained urban growth and the establishment of denser settlement networks throughout Ogoniland.

The 2015 assessment reveals that anthropogenic land uses had become firmly established across most of the study area. Cropland occupied the largest proportion of the terrestrial landscape, while the remaining forest patches were confined to isolated locations and were no longer ecologically connected. Built-up areas continued to expand outward, replacing grasslands and further reducing natural vegetation. The increasing extent of open land suggests ongoing land degradation associated with intensive cultivation, soil exposure, erosion, and infrastructure development, including activities related to oil exploration and production. At this stage, the landscape had become heavily modified by human activities, with only limited remnants of its original vegetation.

By 2025, the cumulative effects of more than three decades of land use change were clearly evident. Cropland and built-up areas dominated the terrestrial landscape, replacing much of the forest that characterized the region in 1990. Open land became more widespread, indicating persistent environmental degradation and increasing pressure on land resources. Although mangrove forests and water bodies continued to occupy the southern coastal zone, much of the inland environment had undergone significant transformation. The results indicate a long-term trend of forest loss, agricultural expansion, urban growth, and increasing landscape fragmentation. These changes reflect the combined influence of population growth, agricultural development, infrastructure expansion, and industrial activities associated with the Niger Delta. Overall, the findings demonstrate a progressive shift from a predominantly natural ecosystem to a landscape increasingly shaped by human activities, with important implications for biodiversity conservation, ecosystem services, and sustainable land management in Ogoniland.



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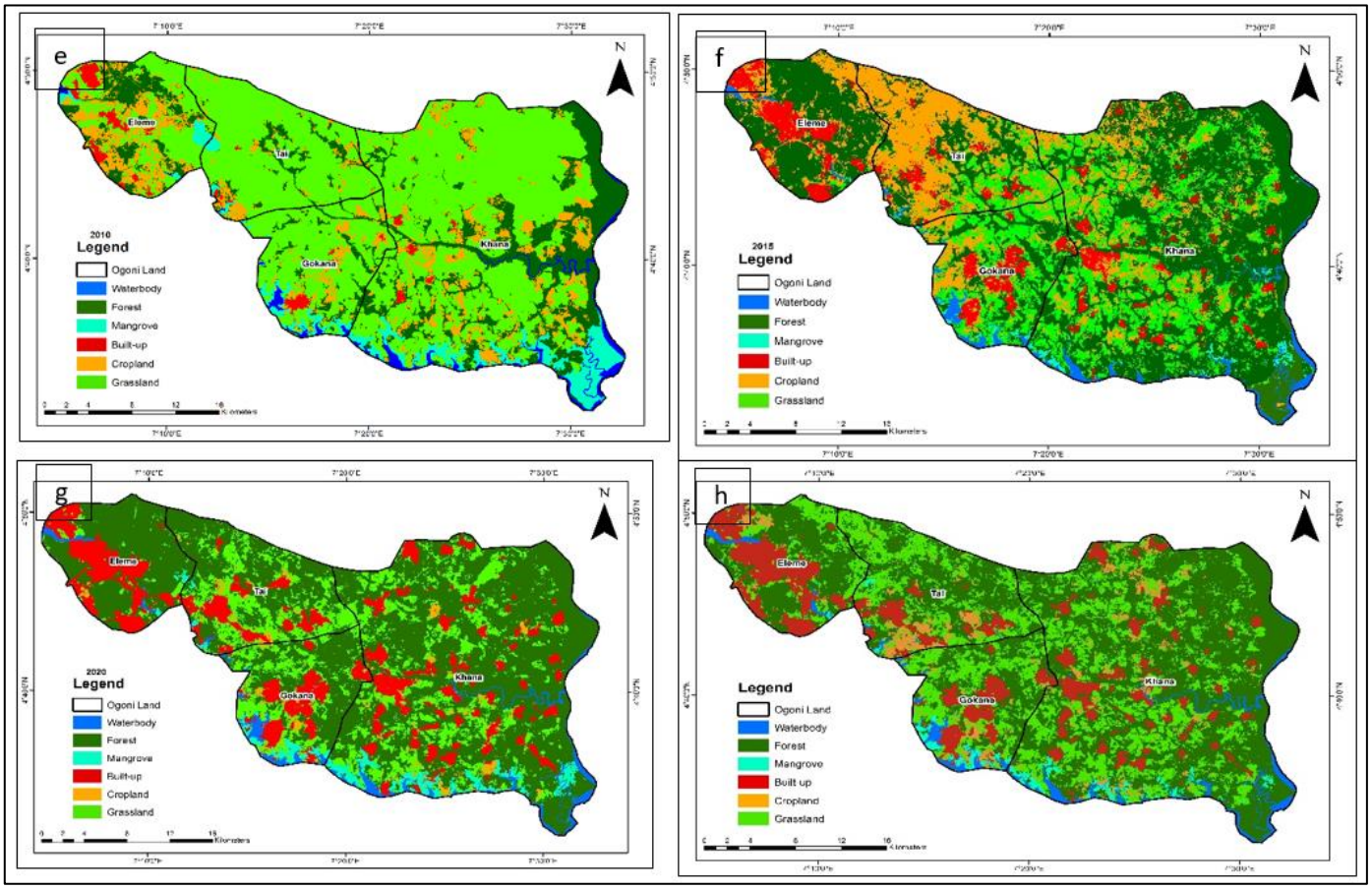


Fig 2 Land Use Land Cover (a)1990 (b)1995 (c)2000 (d)2005 (e)2010 (f) 2015 (g) 2020 (i) 2025

The quantitative analysis of land use and land cover (LULC) changes between 1990 and 2025 reveals a rapid transformation of the Ogoniland landscape, driven primarily by urban expansion, agricultural activities, vegetation degradation, and changes in the coastal environment (Table 1). Over the 35-year period, the region experienced substantial shifts in the relative proportions of all six land cover classes, reflecting increasing anthropogenic pressure on natural ecosystems. In 1990, Ogoniland was predominantly covered by natural vegetation. Forest was the dominant land cover, occupying 463.2 km² (44.1%) of the total study area, followed by grassland with 340.3 km² (32.4%). Cropland accounted for 190.0 km² (18.1%), indicating that agriculture was already an important land use but had not yet overtaken the natural vegetation. Mangrove forests occupied 35.8 km² (3.4%), while water bodies covered 15.5 km² (1.5%). Built-up land was the least extensive class, occupying only 5.2 km² (0.5%), highlighting the limited extent of urban development at the beginning of the study period.

By 1995, modest changes had become evident across the landscape. Built-up areas more than doubled to 12.4 km² (1.2%), reflecting the early stages of settlement expansion. Forest cover declined slightly to 440.8 km² (42.0%), while grassland increased marginally to 363.8 km² (34.6%), suggesting that some forested areas had transitioned into more open vegetation. Cropland decreased to 165.0 km² (15.7%), possibly reflecting temporary land abandonment, changes in farming practices, or classification differences. Mangrove and water body extents increased to 40.3 km² (3.8%) and 27.7 km² (2.6%), respectively. The year 2000 marked the beginning of more pronounced landscape transformation. Built-up land increased substantially to 28.6 km² (2.7%), more than doubling its 1995 extent. Cropland expanded sharply to 220.0 km² (21.0%), indicating intensified agricultural development across the region. Meanwhile, forest cover declined further to 413.5 km² (39.4%), and grassland decreased to 303.6 km² (28.9%), demonstrating the continued conversion of natural vegetation into agricultural and settlement areas. Mangrove forests and water bodies also expanded slightly, occupying 45.8 km² (4.4%) and 38.5 km² (3.7%), respectively.

By 2005, anthropogenic land uses had become increasingly dominant. Built-up land nearly doubled again to 51.3 km² (4.9%), while cropland expanded to 280.0 km² (26.7%), becoming the second-largest land cover class after forest. Forest cover declined to 380.5 km² (36.2%), representing a loss of over 80 km² since 1990. Grassland continued its downward trend, decreasing to 235.0 km² (22.4%). Mangrove forests reached their maximum recorded extent during this period at 51.5 km² (4.9%), whereas water bodies increased to 51.7 km² (4.9%), suggesting greater surface water availability during this period.

The 2010 assessment indicates an acceleration of landscape modification. Built-up areas increased to 76.8 km² (7.3%), reflecting rapid urban growth and infrastructural

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development. Cropland expanded further to 350.0 km² (33.3%), occupying one-third of the study area and demonstrating the increasing importance of agriculture. Forest cover declined to 347.0 km² (33.0%), while grassland reduced dramatically to 151.5 km² (14.4%), indicating sustained pressure on natural vegetation. Mangrove cover declined slightly to 46.2 km² (4.4%), whereas water bodies increased substantially to 78.5 km² (7.5%), possibly reflecting seasonal hydrological variations or improved delineation of aquatic environments.

The landscape in 2015 exhibited a slight shift in agricultural land use. Built-up areas continued to expand, reaching 112.5 km² (10.7%), while cropland declined to 310.0 km² (29.5%). Despite this reduction, cropland remained one of the dominant land cover classes. Forest cover continued its gradual decline to 316.2 km² (30.1%), and grassland decreased further to 126.0 km² (12.0%). Mangrove forests experienced a more noticeable reduction to 35.9 km² (3.4%), suggesting increasing pressure on coastal ecosystems. Water bodies almost doubled in extent to 149.4 km² (14.2%), representing the largest increase recorded during the study period.

In 2020, built-up land expanded rapidly to 152.3 km² (14.5%), illustrating the continued growth of settlements and infrastructure throughout Ogoniland. Cropland declined significantly to 220.0 km² (23.4%), while forest cover reduced further to 276.0 km² (26.3%), representing a cumulative loss of approximately 187 km² since 1990. Grassland also continued its long-term decline, occupying only 82.2 km² (7.8%). Mangrove forests decreased to 25.8 km² (2.5%), reflecting continued degradation of the coastal ecosystem. Water bodies declined to 93.7 km² (8.9%), although they remained considerably larger than their 1990 extent.

By 2025, the cumulative effects of three and a half decades of land use change were clearly evident. Built-up land reached its highest recorded extent of 192.0 km² (18.3%), representing an increase of nearly 3,600% compared with 1990. Cropland recovered to 285.0 km² (36.7%), reaffirming agriculture as one of the dominant land uses within the region. Forest cover declined further to 242.5 km² (23.1%), representing an overall reduction of approximately 220.7 km², equivalent to nearly half of its original extent. Grassland experienced the greatest proportional decline, decreasing from 340.3 km² (32.4%) in 1990 to only 43.5 km² (4.1%) in 2025. Mangrove forests also suffered substantial losses, shrinking to 18.5 km² (1.8%), while water bodies expanded to 168.5 km² (16.0%), the highest value observed during the study period.

Overall, the results reveal a sustained conversion of natural vegetation into anthropogenic land uses over the 35-year period. The continuous expansion of built-up areas reflects rapid population growth, urbanization, and infrastructural development, while the increase in cropland demonstrates the growing demand for agricultural land. Conversely, the persistent decline in forest, grassland, and mangrove ecosystems indicates extensive habitat degradation and fragmentation, with important implications for biodiversity conservation, carbon storage, ecosystem resilience, and sustainable land management in Ogoniland. The fluctuating extent of water bodies further highlights the dynamic hydrological conditions of the Niger Delta environment and their interaction with both natural processes and human activities.

Table 1 LULC coverage (1990 – 2020)

Class	Year															
	1990		1995		2000		2005		2010		2015		2020		2025	
	Area	%	Area	%	Area	%	Area	%	Area	%	Area	%	Area	%	Area	%
Built-up	5.2	0.5	12.4	1.2	28.6	2.7	51.3	4.9	76.8	7.3	112.5	10.7	152.3	14.5	192	18.3
Cropland	190	18.1	165	15.7	170.5	15.2	201	14.7	350	33.3	310	29.5	220	23.4	285	36.7
Grassland	340.3	32.4	363.8	34.6	353.6	28.9	265	22.4	151.5	14.4	126	12	82.2	7.8	43.5	4.1
Forest	463.2	44.1	440.8	42	413.5	39.4	390.5	36.2	347	33	316.2	30.1	276	26.3	242.5	23.1
Mangrove	35.8	3.4	40.3	3.8	45.8	4.4	51.5	4.9	46.2	4.4	35.9	3.4	25.8	2.5	18.5	1.8
Waterbody	15.5	1.5	27.7	2.6	38.5	3.7	51.7	4.9	78.5	7.5	149.4	14.2	93.7	8.9	168.5	16

Area in Sq km

- *Normalized Difference Vegetation Index (NDVI) Dynamics in Ogoniland (1990–2025)*

The multi-temporal NDVI analysis reveals considerable changes in vegetation condition and distribution across Ogoniland over the 35-year study period. NDVI values range from negative values, which generally represent water bodies or non-vegetated surfaces, to positive values approaching 1.0, which indicate dense and healthy vegetation. Across all study years, the spatial pattern of NDVI reflects the combined influence of agricultural expansion, urban development, oil exploration activities, and natural environmental processes. The 1990 NDVI map represents the baseline vegetation condition of Ogoniland. High NDVI values (0.31–0.93), represented by dark green, dominate much of the northern,

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western, and eastern parts of the study area, indicating dense forest vegetation and healthy plant cover. Moderate NDVI values are distributed throughout the central region, corresponding to grasslands and cultivated fields, while low and negative NDVI values occur mainly along the southern coastal fringe and river channels, representing mangrove-water interfaces, exposed soils, and built-up areas. Overall, the landscape exhibits relatively good vegetation health with limited anthropogenic disturbance.

In 1995, vegetation conditions remained generally favourable, although subtle changes became evident. Areas with high NDVI expanded slightly across portions of the eastern and central regions, suggesting localized vegetation regeneration or improved agricultural productivity. Nevertheless, low NDVI values became more apparent around settlement clusters and along the southern coastal belt, indicating increasing human activities. The overall vegetation structure remained largely intact, with dense vegetation still dominating much of the landscape. The 2000 NDVI map indicates the beginning of more noticeable vegetation fragmentation. While large areas continued to exhibit moderate to high NDVI values, the proportion of intermediate NDVI classes increased across the central and western parts of the study area. These changes suggest the conversion of dense forests into croplands and mixed vegetation. Low NDVI zones also became more widespread around expanding settlements and transportation corridors, reflecting increasing land development and localized vegetation clearance. By 2005, vegetation fragmentation became more pronounced. High NDVI values were increasingly confined to isolated patches, while moderate vegetation dominated much of the landscape. A striking feature during this year is the appearance of extensive non-classified or cloud-covered areas in the eastern portion of the image, which limits complete interpretation of vegetation conditions in those locations. Outside these areas, the gradual decline in dense vegetation and expansion of moderate vegetation classes suggest continued agricultural expansion and increasing pressure on natural ecosystems. The 2010 NDVI map reveals further degradation of vegetation quality. Although pockets of high NDVI remain in the northern and eastern sections, much of the landscape is characterized by moderate NDVI values, indicating reduced vegetation density. Low NDVI values became more extensive around the coastal zone and urban centres, corresponding to increasing built-up areas, exposed soils, and degraded vegetation. The transition from dense forest to cultivated land becomes increasingly evident during this period.

By 2015, the decline in vegetation condition became more widespread. Moderate NDVI values dominate the study area, while areas of high vegetation density continued to shrink. Low NDVI zones expanded along the southern coastline and around major settlements, reflecting ongoing urbanization, infrastructure development, and land degradation. The reduction in vegetation vigour during this period may also be associated with intensive agricultural practices and the cumulative environmental impacts of oil exploration and production activities that have historically affected Ogoniland.

The 2020 NDVI map shows a mixed vegetation pattern. Moderate vegetation remains the dominant land cover, but areas with low NDVI increased noticeably in the central and southern parts of the region. High NDVI values persist primarily within isolated forest patches and relatively undisturbed vegetation. The spatial distribution suggests continued fragmentation of natural vegetation as agricultural land, settlements, and other anthropogenic land uses expanded across the landscape.

The 2025 NDVI analysis indicates the greatest level of vegetation degradation observed during the study period. Low NDVI values (displayed in red and orange) are considerably more widespread than in previous years, particularly across the northwestern, central, and southern portions of Ogoniland. High NDVI areas are now fragmented into relatively small, isolated patches, while moderate vegetation occupies much of the remaining landscape. This pattern reflects substantial loss of dense vegetation cover and increasing landscape fragmentation. The observed decline is consistent with the expansion of built-up areas, continued agricultural intensification, reduction in forest cover, degradation of mangrove ecosystems, and increasing environmental pressures associated with population growth and industrial activities.

Overall, the NDVI analysis demonstrates a progressive decline in vegetation health and continuity between 1990 and 2025. Although areas of healthy vegetation remain, particularly within remnant forest patches, the general trend is characterized by decreasing vegetation density, increasing fragmentation, and expansion of low-NDVI surfaces. These findings corroborate the land use and land cover analysis, which showed continuous urban expansion, agricultural conversion, and forest loss throughout the study period. The combined evidence suggests that anthropogenic activities have become the dominant driver of landscape change in Ogoniland, with important implications for ecosystem stability, biodiversity conservation, carbon sequestration, and sustainable environmental management.

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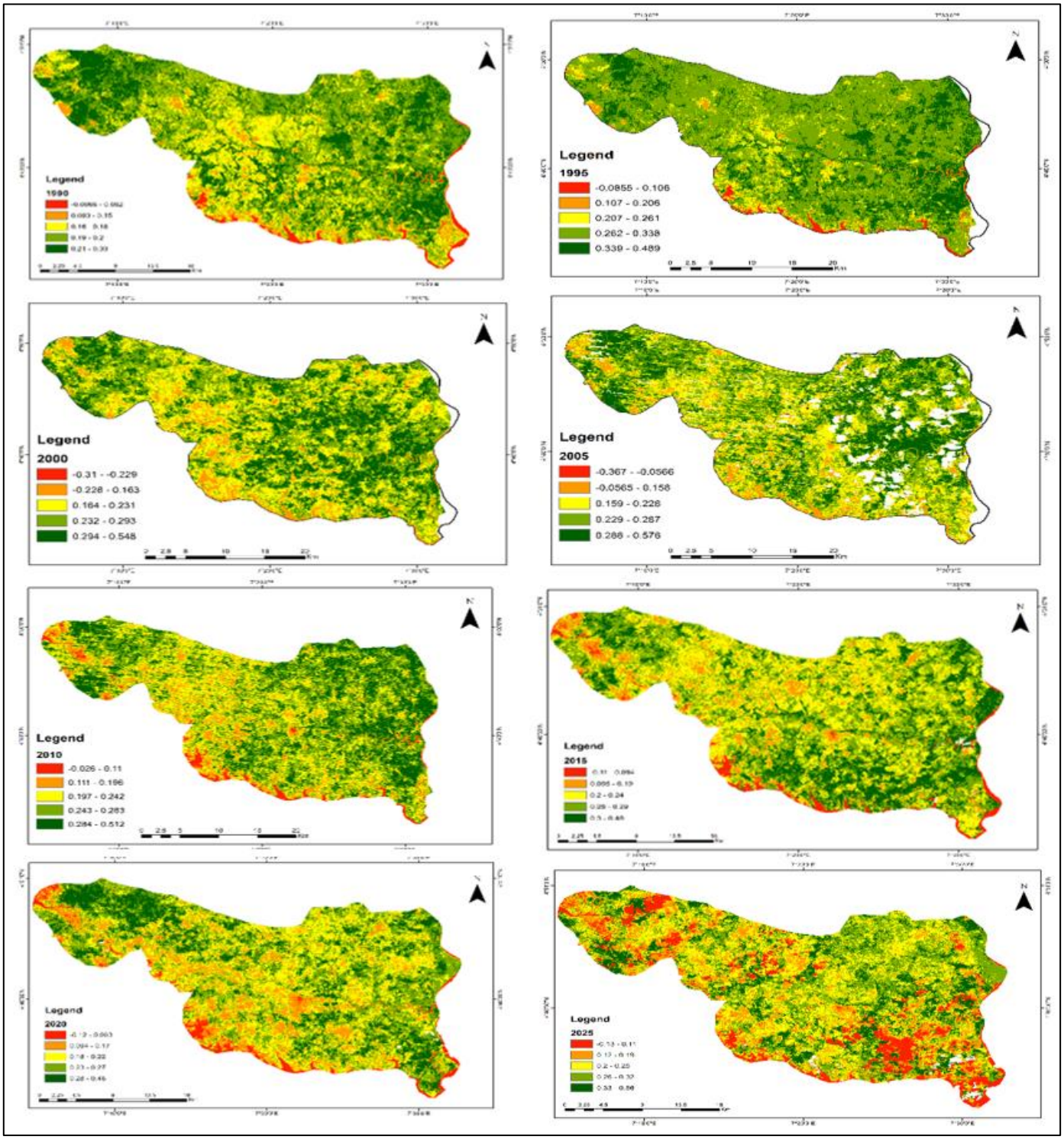


Fig 3 NDVI (a) 1990 (b) 1995 (c) 2000 (d) 2005 (e) 2010 (f) 2015 (g) 2020 (i) 2025

➢ *Accuracy Assessment*

According to the classification accuracy assessment in Table 2, the Overall Accuracy ranged between 84.2% and 88.6%, while the Kappa coefficient ranged from 0.825 to 0.868 across the study period. Based on the interpretation by Landis and Koch (1977), these Kappa values indicate 'almost perfect' agreement, confirming that the derived LULC maps are statistically reliable.

Table 2 Accuracy Assessment and Kappa Coefficient

	Year							
	1990	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**	**2025**
Overall Accuracy	84.20%	87.50%	88.00%	85.10%	88.60%	87.20%	86.80%	85.50%
Kappa Coefficient	**0.833**	**0.849**	**0.855**	**0.868**	**0.862**	**0.845**	**0.84**	**0.825**

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IV. DISCUSSIONS OF FINDINGS

The findings of this study reveal a profound and continuous transformation of Ogoniland's landscape over the past three and a half decades. In 1990, the region was predominantly natural, with forests and grasslands covering roughly 76.5% of the total landmass (463.2 km² and 340.3 km², respectively). By 2025, this had completely reversed: cropland and built-up areas now dominate the terrestrial landscape, occupying a combined 55% of the study area, while forest cover has been reduced by nearly half (to 242.5 km²), and grasslands have suffered an almost catastrophic decline (from 340.3 km² down to just 43.5 km²).

This trajectory aligns closely with broader regional studies across the Niger Delta. For instance, (Atubi et al., 2018; Arowolo & Deng, 2018b) documented similar patterns of rapid deforestation and agricultural encroachment in adjacent riverine communities, attributing these shifts primarily to the pressures of a burgeoning rural population. However, the rate of change in Ogoniland is particularly acute; the 3,600% increase in built-up area (from 5.2 km² to 192 km²) is starkly higher than the average urbanization rates. This suggests that Ogoniland is not simply experiencing "normal" development, but is undergoing a uniquely intense transformation driven by the historical legacy of oil extraction and subsequent infrastructural rehabilitation.

The NDVI results corroborate the LULC findings with near-perfect consistency. The progressive spatial decline in high-NDVI (dense green) values and the dramatic expansion of low-NDVI (yellow-to-red) zones by 2025 confirm that Ogoniland is losing its vegetative vigour. The NDVI maps are especially revealing when compared to the LULC maps; areas that transitioned from "Forest" to "Cropland" or "Open Land" in the classification precisely correspond to the areas where NDVI dropped from healthy (0.5–0.9) to stressed (<0.2). This offers strong, independent validation of our classification accuracy. These NDVI patterns align with the findings ofGuha & Govil,(2021) , who used spectral indices to prove that oil spill zones in the Niger Delta exhibit significantly lower vegetation health compared to unaffected zones.

The cumulative effect of these changes is a landscape that has crossed an ecological tipping point. Ogoniland has transitioned from a biodiverse, forest-dominated ecosystem to a heavily modified, agricultural-urban frontier. The ecological consequences are multifaceted:

- The loss of over 220 km² of forest severely reduces the region's capacity to sequester carbon, exacerbating local climate change impacts.
- The fluctuations and general increase in water body coverage (from 15.5 km² to 168.5 km²) suggest significant changes in drainage patterns, likely linked to upstream deforestation and coastal erosion. This may be increasing flood risks for vulnerable settlements.
- The historical dependence of the Ogoni people on fishing and farming is threatened by this transformation. The degradation of mangroves and fish habitats, paired with soil contamination, aligns directly with the socio-economic warnings issued by the UNEP (2011) report, which estimated that it would take 25–30 years to restore the region.

V. CONCLUSION

This study demonstrates that over 35 years, anthropogenic forces particularly urban expansion, agricultural demand, and the lingering effects of oil production have fundamentally restructured the Ogoniland landscape. The accuracy assessment (Overall Accuracy 84.2%–88.6%; Kappa 0.825–0.868) confirms that our maps are statistically robust and suitable for guiding intervention.

If the ongoing $1 billion cleanup program (initiated in 2017) is to be truly effective, it cannot focus solely on soil chemical remediation. It must incorporate a landscape-level restoration strategy that prioritizes:

- Mangrove replanting along the southern coast to stabilize hydrology and restore fish nurseries.
- Strict urban containment policies to stop the 3,600% growth trend of built-up areas from encroaching further onto remaining forested areas.
- Agroecological support for local farmers to rehabilitate contaminated croplands, reducing the pressure to clear new forests for agriculture.

Without such holistic measures, Ogoniland's landscape will likely continue on its current trajectory, resulting in the complete loss of its natural forest and mangrove heritage within the next two decades, with devastating, permanent consequences for its people and biodiversity.

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