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Spatio-Temporal Assessment of Vegetation Health in Relation to Artisanal Crude Oil Refining in Oyigba Community, Rivers State, Nigeria

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ABSTRACT

The Niger Delta region stands as one of the most severely degraded ecosystems from activities such as oil spills, gas flaring, artisanal refining, industrial pollution, etc., which has impacted negatively on the region. This study investigates the impacts of artisanal oil refining on vegetation health in Oyigba community, Rivers State. Landsat images of 2004, 2014, and 2024 were utilized to assess the changes in vegetation cover over time. The vegetation analysis was conducted using the Normalized Vegetation Index (NDVI) for a period of 20 years from 2004 to 2024. The result shows that as of 2004, vegetation cover in this community exhibited a largely healthy vegetation cover, with 42.26% of the land area classified as dense grassland having an NDVI value of 0.29–0.36, and light grassland covered 38.29% with NDVI values ranging from 0.27–0.28. This shows that more than 80% of the land was covered by vegetation**.** By 2014, the percentage of dense vegetation reduced to 1.02%, having NDVI value of 0.29 to 0.31, while light grassland coverage also reduced, occupying 31.19% of the land area, with an NDVI value of 0.27 to 0.28, showing widespread vegetation stress.

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Also, shrub cover expanded notably, covering about 65.72% of the total area of land, revealing a reduction in the quality of vegetation. Bare surface increased slightly to 2.08%. It is worthy to note that dense vegetation increased in 2024 from 1.02% in 2014 to 14.08% in 2024, signaling a recovery stage. The study therefore recommends continuous security monitoring to sustain continued recovery.

Keywords: artisanal refining, hydrocarbon contamination, vegetation impact, Oyigba Rivers State.

1. INTRODUCTION

The environment within the Niger Delta region is an important region to the Nigerian economy, as the exploration and exploitation of crude oil (Aransiola et al., 2024) is hosted in this region and accounts for over 90% of its foreign exchange. Additionally, the Niger Delta region is home to diverse plant and animal species, which has contributed to the ecology and economy of the region (Diagi et al., 2025). Due to the richness of the region in biodiversity, some of its wildlife serves as a source of protein, hides, and skin, while plants provide timbers which are used for construction. Also, Shrubs and herbs are used as medicine for different illnesses (Izah et al., 2018; Izah et al., 2017; Diagi et al., 2025). This region has one of the largest biodiversity in the world, capable of supporting plants and animals with fertile land good for a variety of crops, economic trees, and freshwater fish species (Donwa et al., 2015; Ite et al., 2013), which is gradually depleted as a result of artisanal refining and other harmful environmental practices.

However, the exploration and exploitation of crude oil have resulted in massive degradation of the environment, which has resulted in a decline of its biodiversity (Alagoa, 2004; Chinda & Braid, 2000; Etuk, 2004). Nevertheless, there has been a lot of illegal crude oil refining, theft, and vandalism within the Niger Delta region, thereby leading to the degradation of major biophysical environmental matrices and conditions.

Consequently, the activities from artisanal crude oil refining are harming the vegetation cover, altering the physicochemical and microbial composition of the soil, and releasing hydrocarbons into the environment. When these pollutants are absorbed by vegetation, it leads to harm such as impairing seed germination and stunting plant growth, with negative consequences for local vegetation (Onuh et al., 2008; Oyedeji et al., 2012). Research to determine changes in vegetation is very important when carrying out assessments on the health of the ecosystem, monitoring changes in the environment, providing early warning for natural disaster as well as providing support for making decisions for sustainable development (Guangjie et al., 2023).

Some scholars have investigated the impact of artisanal refining within the Niger Delta region. For instance, Nwankwoala et al. (2017) pointed out that soil and water quality have been affected by artisanal refining activities, causing acid rain contamination on the soil and water bodies due to the release of harmful substances in the atmosphere. Asimiea and Omokhua (2013) highlighted the effect of refineries on vegetation, while Ogwu et al. (2022) reported on how illegal refining activities severely affect biodiversity, the green nature of the forest, regeneration of plant species, and the destruction of wildlife habitat, disrupting the water cycle and loss of medicinal plants. Yabrade, Tanee (2016) reported the reduction in vegetation indices, such as frequency of occurrence, abundance, and total species content, while there was an increase in Total Hydrocarbon Content (THC), Total Organic Carbon (TOC) in refining sites, as against lower THC and TOC in controlled areas.

Suku et al. (2024) reviewed literature to examine the long-term impacts of this unregulated practice, focusing on pollution pathways, community health outcomes, ecosystem degradation, and socioeconomic factors that sustain this illicit artisanal refining, and Diagi et al. (2025) assessed the Impact of Artisanal Refining on Soil and Human Health, highlighting the impact on soil and human health.

Other notable studies conducted have revealed that activities associated with artisanal crude refining are harmful to the germination of seed, which result to stunts growth of plants, which has adverse effects on the vegetation of the locals (Onuh et al., 2008; Oyedeji et al., 2012). These activities of artisanal refining result in the accumulation of pollutants in plants emanating from spent oil, which disrupt the vital metabolic processes, resulting in harm (Okonokhua et al., 2007). These activities also affect the elemental uptake of plants, affecting the nutritional balance and microbial population in the soil (Semhi et al., 2017).

However, petroleum contamination has varying effects on different plant families, with some more sensitive than others (Arellano et al., 2017). Artisanal refining within the Niger Delta region has persisted despite efforts by the government to curtail this menace, which has grown and expanded since the end of the militant crisis in Nigeria in 2009, resulting in several challenges, such as locals losing their farmlands and source of livelihood.

This study, therefore, seeks to assess the impact of artisanal refining on vegetation health in Oyigba community using Landsat-derived NDVI over 20 years (2004–2024) to inform restoration and sustain ecosystem services, as vegetation monitoring aids ecosystem assessments, change detection, disaster warnings, and sustainable decisions. The specific aims are to quantify spatio-temporal declines linked to refining activities and recommend targeted restoration for degraded zones.

2. MATERIALS AND METHODS

Study Area

This study is situated in Oyigba, one of the communities in Ahoada West Local Government Area (LGA) of Rivers State (Fig. 1), and is geographically located between latitudes 4.95° N and 5.15° N, and longitudes 6.50° E and 6.80° E. The LGA comprises approximately 100 communities (National Bureau of Statistics, 2010) and has an estimated population of 249,425 in 2006, which grew to about 435,645 by 2024, according to projections by the National Population Commission (NPC, 2006; NPC, 2024). This population growth reflects an annual growth rate of 3.2%.

The region experiences a tropical climate with a prominent rainy season and a short dry season. The dry season is constrained to December and January, with harmattan conditions that are less pronounced compared to other parts of the country. The highest rainfall is experienced in September, with an average rainfall amount of 370 mm (Rivers State Ministry of Information, 2006). The highest temperature occurrence each month varies within 28°C to 30°C, while the minimum monthly temperature is within the range of 17° C to 24° C (Rivers State Ministry of Information, 2006).

Ahoada West is sedimentary in nature, having a rainforest vegetation that is located in both the wetland and upland regions of Rivers State. The area is distinguished by economic trees, including lianas, grasses, shrubs, and reeds. Food crops such as plantain, rice, banana, yam, cassava, and sugarcane, including cash crops such as palm oil, cocoa, and elastic, which boost the economy and serve as a source of income to farmers (Rivers State Ministry of Information, 2006).

The environment and its ecology favour agricultural activity, which is a means of livelihood for most of the population, supporting a large agricultural economy. The landmass of Oyigba community is primarily farmland and residential areas. However, uncontrolled extraction and artisanal refining of crude oil have led to environmental degradation and health concerns. These issues highlight the need for sustainable management practices in the region.

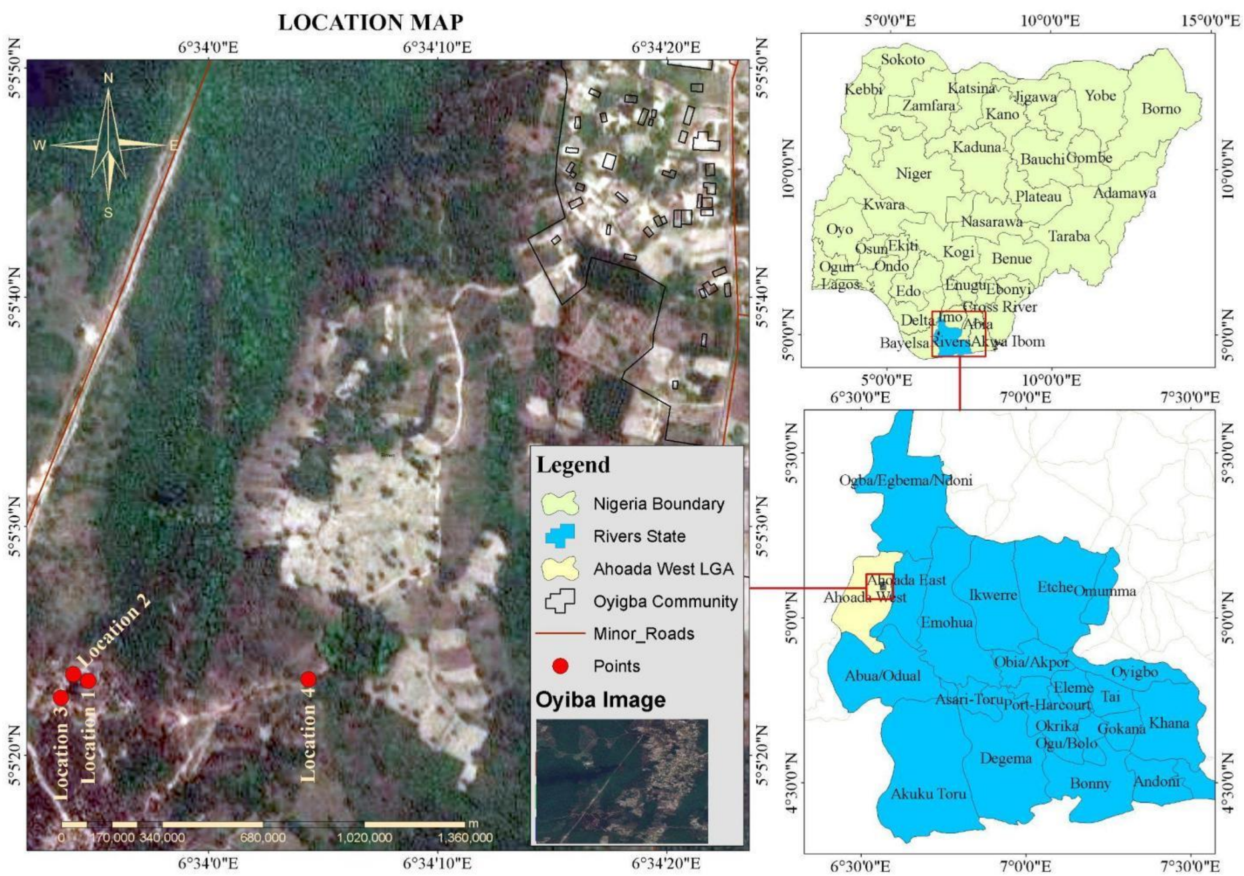

Figure 1. Map Showing the Study Area.

Method of Data Collection

This study made use of ArcGIS10.8 and QGIS 3.22 as the primary Geographical Information System (GIS) tools. Landsat images were retrieved from the United States Geological Survey (https://earthexplorer.usgs.gov/), (USGS) spanning three distinct decades: 2004, 2014, and 2024. The imagery was selected based on its spatial resolution of 30 meters and minimal cloud coverage (<10%). The precise details of the satellite platforms, sensors, and associated parameters are summarized in Table 1.

Table 1. Data Sources.

Data	Date	Satellite	Sensor	Spatial Resolution	Cloud Coverage
Landsat Imagery	30th December, 2004	Landsat 7	ETM	30 m	<10%
Landsat Imagery	23rd December,2014	Landsat 8	OLI/TIRS	30 m	<10%
Landsat Imagery	10th December,2024	Landsat 9	OLI/TIRS	30m	<10%

Method of Data Analysis for NDVI

Landsat imagery of 2004, 2014, and 2024 was processed to derive NDVI, which facilitated the quantitative assessment of vegetation changes in the Oyigba community. Pre-processing involved radiometric calibration, atmospheric correction (e.g., DOS), co-registration to sub-pixel accuracy, and masking of clouds/water bodies (blue classes in NDVI legend).

NDVI

NDVI formula as proposed by John W. Rouse Jr. et al., (1974) while working with NASA EARTH resources Technology Satellite (ERTS-1/Landsat-1) data;

$$NDVI = \frac{(NIR-Red)}{(NIR+Red)} \quad \ldots\ldots\ldots\ldots \quad 1$$

3. RESULT

Figure 2 shows the Normalized Difference Vegetation Index (NDVI) over two decades in Oyigba community. By analysing the vegetation trends in the area, a comprehensive insight into the vegetation health was drawn in order to determine the impact of anthropogenic activities on the health of vegetation and its stress level in the environment.

NDVI analysis in the study area

The NDVI analysis was conducted to assess the vegetation health of the environment by measuring the density and greenness of plant cover over time. Results are presented in tables and graphs.

Table 2. Extent of Changes in Vegetation in (2004).

NDVI Class		Range	Area (%)
Water Bodies	0.01-0.15	47	0.15
Bare Surface	0.16-0.22	521	1.84
Shrubs	0.23-0.26	4911	17.47
Light grassland	0.27-0.28	10750	38.29
Dense grassland	0.29-0.36	11873	42.26
Total		28103	100

The result from Table 2 shows that in 2004, Oyigba exhibited a predominantly healthy vegetation cover, with 42.26% of the area classified as dense grassland with an NDVI value of 0.29–0.36. Light grassland covered 38.29% with NDVI values ranging from 0.27–0.28, meaning that more than 80% of the land was covered by vegetation. Shrubs covered 17.47%, while bare surfaces with NDVI values of 0.16–0.22 and water bodies accounted for only 0.15%, respectively, suggesting stable environmental conditions. These statistics suggest that, before significant artisanal refining activities, the community had a thriving vegetation cover with minimal environmental disturbance.

Table 3. Extent of Changes in Vegetation in (2014).

NDVI Class		Range	Area (%)
Water Bodies	0.01-0.15	4	0
Bare Surface	0.16-0.22	587	2.08
Shrubs	0.23-0.26	18471	65.72
Light grassland	0.27-0.28	8762	31.19
Dense grassland	0.29-0.36	279	1.02
Total		28103	100

Table 3 shows that a significant shift in NDVI values is observed by 2014. The proportion of dense grassland decreased to 1.02% with an NDVI value of 0.29–0.31, while light grassland coverage also declined to 31.19%, having an NDVI value of 0.27–0.28, indicating widespread environmental stress. Conversely, shrub cover increased significantly, covering 65.72% of the total land area, indicating a decline in overall vegetation quality. Bare surfaces expanded slightly to 2.08%, suggesting localized degradation, potentially from increasing artisanal oil refining activities and associated deforestation, oil spills, and land contamination.

Table 4. Extent of Changes in Vegetation in (2024).

NDVI Classes		Count	Area (%)
Water Bodies	0.01-0.15	436	1.46
Bare Surface	0.16-0.22	4260	15.05
Shrubs	0.23-0.26	10895	38.83
Light grassland	0.27-0.28	8553	30.58
Dense grassland	0.29-0.36	279	14.08
Total		28103	100

Table 4 shows that in 2024, NDVI data reveal further environmental deterioration. The percentage of high NDVI values (0.29–0.36) declined to 14.08%, indicating a substantial reduction in dense vegetation. Light grassland with NDVI values of 0.27–0.29 declined to 30.58%, while shrubs, with NDVI values ranging from 0.23–0.26, covered 38.83%, suggesting continued ecosystem stress. Additionally, the area classified as water bodies, with NDVI values of 0.087–0.15, increased slightly to 1.46%, possibly due to oil spills and surface water contamination. The increase in dense vegetation from 1.02% in 2014 to 14.08% in 2024 could be due to efforts made by the military and other security operations in 2024 to dismantle illegal artisanal refineries, targeting oil theft that costs Nigeria billions annually.

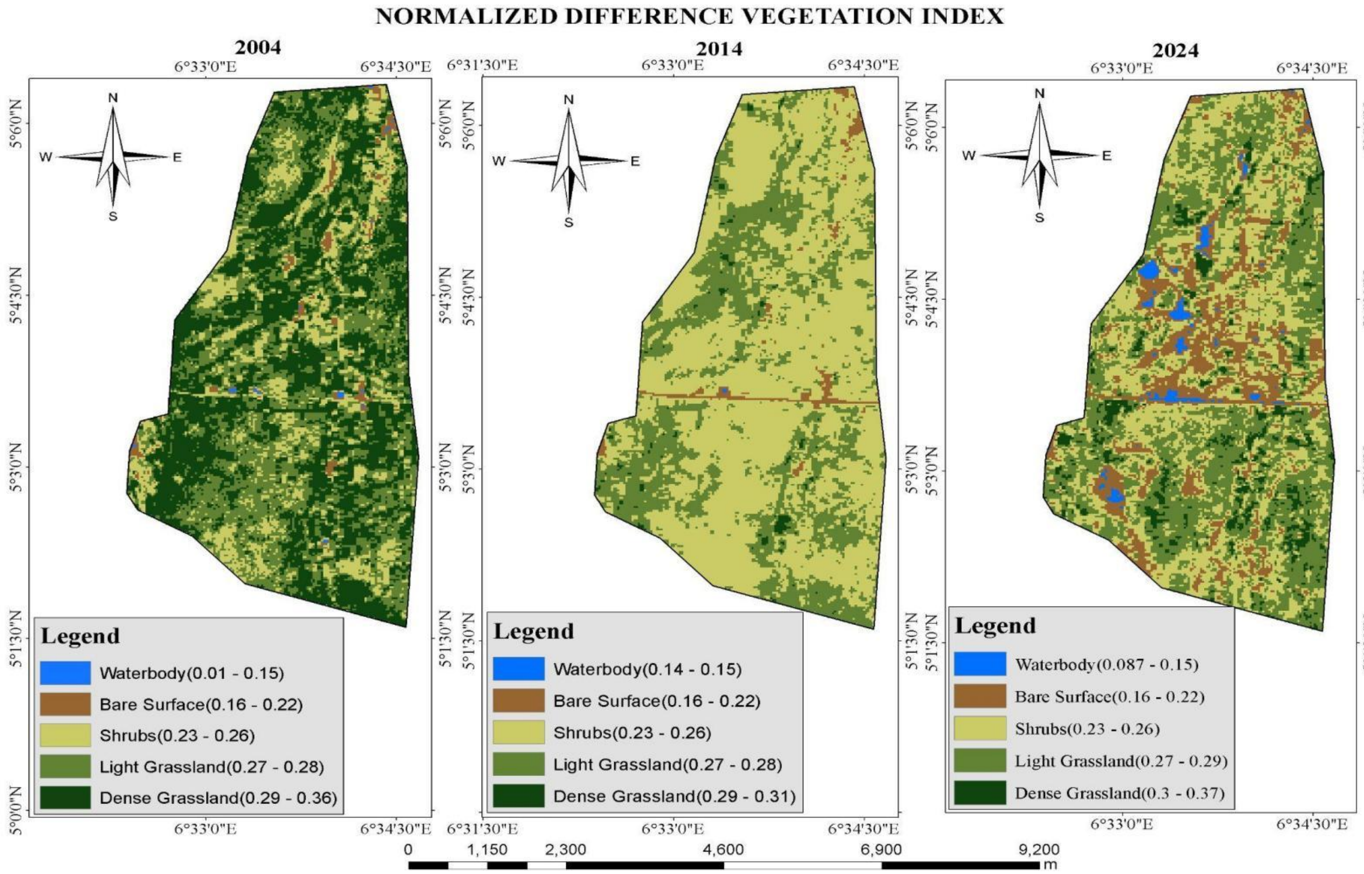

Figure 2. Extent of Changes of Vegetation in 2004, 2014, and 2024.

4. DISCUSSION

The NDVI shown in Fig. 2 indicates a degradation in the health of vegetation in the study area from 2004, which could be linked to artisanal refining activities. In 2004, over 80% of the area was covered by dense (42.26%, NDVI 0.29–0.36), while light grassland covered an area of (38.29%, NDVI 0.27–0.28), signifying a healthy ecosystem before artisanal refining activities in the study area.

By 2014, dense grassland reduced to about 1.02% (NDVI 0.29–0.31), with shrubs reducing to 65.72% and bare surface rising to 2.08%, indicating widespread stress from artisanal refining activities.

The partial rebound to 14.08% dense grassland by 2024 suggests limited natural regeneration in less-impacted southern zones, but persistent low NDVI in central/northern areas underscores ongoing degradation. This study agrees with the study of Suku et al. (2024), who reported a widespread degradation of plant life as a result of artisanal refining in the Niger Delta, especially mangrove trees, from the accumulation of hydrocarbons and heavy metals. Yabrade and Tanee (2016) reported a decline in plant species compositions in sites close to artisanal refining as compared to the control site. Diagi et al. (2025) reported a decline in vegetation health, with 95.1% of the respondents reporting drying or death of plants, 77.0% observing a loss of vegetation cover, and 88.5% indicating reduced crop yields.

This study also agrees with the study conducted by Erebi and Davidson in (2023) that reported that oil-spill areas in Ahoada West LGA have significantly lower vegetation index values (NDVI 0.0665–0.2622, SAVI 0.0333–0.1311) when compared to nearby non-spill areas with (NDVI 0.4523, SAVI 0.2261), confirming that the presence of hydrocarbon contamination can result in reductions in spectral indices.

Similarly, Wekpe (2024) carried out a long-term analysis of oil-spill-impacted vegetation in the Niger Delta. It was discovered that repeated spills produced statistically significant declines in NDVI for about a decade, as seen in this study. Also, a recent NDVI-based assessment of the remediated crude oil area in the Ogoni area of Rivers State revealed an increased reduction in vegetation index values between 1994 and 2014 and a recovery in 2024; for instance, one of the sites improved after bioremediation from an NDVI of 0.0875 in 2004 to 0.1275 in 2024. Another study carried out in the Niger Delta by Chibuike et al. (2022) using NDVI from 2010–2020 shows a marked increase in negative NDVI in areas that were heavily polluted but saw an improvement in areas that were less impacted. This can be compared to the contrast seen between degraded northern/central areas and the healthier southern vegetation in this study.

However, the spatial-temporal variation of vegetation cover in the study area could also be influenced by deforestation activities, conversion of land for various economic activities, as well as climatic factors.

The findings from this study have some serious implications for the environment in Oyigba, as oil contamination and soot from artisanal refining can coat leaves, alter soil properties, and destroy roots, reducing chlorophyll content and leaf area (Adebangbe et al., 2025). These findings have provided baseline information for policymakers to position Oyigba in regional clean-up initiatives towards long-term sustainability.

5. CONCLUSION

This study provided an insight into the impact of artisanal refining on vegetation health in Oyigba community in the Niger Delta. Landsat imagery for 2004, 2014, and 2024 was utilized in the assessment of vegetation changes in the study area as a result of artisanal refining activities. The analysis revealed a decline in vegetation cover across all classes, including shrubs, light grassland, and dense grassland, between 2004 and 2014, reflecting the severe environmental degradation caused by widespread illegal refining and associated pollution. Partial recovery to 14.08% dense grassland by 2024 indicates limited resilience but persistent low-quality cover in refining hotspots. Findings from this work emphasize the need for enforcement agencies to continue in the monitoring efforts that led to recovery in 2024 for sustainable alternatives to restore productive vegetation and ecosystem services for local communities.

Conflict of Interest

Authors declares that no conflict of interest exists that could have influenced this work.

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