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BASELINE ASSESSMENT OF VEGETATION COVER ALONG THE ABUJA – KADUNA RAIL CORRIDOR USING GEOSPATIAL TECHNIQUES.

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Abstract
This study assessed the baseline vegetation cover along the Abuja–Kaduna Rail Corridor prior to railway construction using geospatial techniques. Establishing pre-construction vegetation conditions is essential for monitoring environmental changes associated with infrastructure development and for distinguishing natural vegetation dynamics from anthropogenic disturbances. The study employed remote sensing and Geographic Information Systems (GIS) techniques using Landsat satellite imagery acquired for the year 2011. Image preprocessing involved radiometric and atmospheric corrections to improve spectral accuracy and consistency. Vegetation conditions within a 200m buffer zone along both sides of the rail alignment were evaluated using the Normalized Difference Vegetation Index (NDVI). The processed NDVI imagery was classified into five vegetation density classes: very low, low, moderate, high and very high vegetation. Spatial analysis and supervised classification were conducted in ArcGIS, while accuracy assessment was performed using field observations and GPS validation points. Results revealed that moderate vegetation constituted the dominant land cover class, accounting for 42.6% of the study area, followed by high vegetation at 28.3%. Very high vegetation occupied 5.4%, representing dense forest patches, wetlands and riparian vegetation, while low and very low vegetation covered 18.5% and 5.2% respectively, mainly around built-up and agriculturally disturbed areas. The findings indicate that the corridor was largely characterized by stable and productive vegetation cover prior to railway development. Spatial distribution patterns further revealed higher vegetation density in rural and less accessible areas, whereas lower vegetation classes were concentrated near urbanizing zones around Abuja. The study establishes a reliable environmental baseline for future monitoring and assessment of vegetation changes associated with railway construction and related land-use transformations.

Keywords: Baseline Assessment, Vegetation Cover, NDVI, Remote Sensing, Geographic Information System (GIS), Landsat Imagery, Geospatial Techniques, Abuja–Kaduna Rail Corridor, Vegetation Dynamics, Environmental Monitoring.

1.0 Introduction

Baseline environmental assessment is a critical component of infrastructure impact studies, particularly in regions experiencing rapid development. Vegetation cover plays a vital role in ecosystem stability, carbon sequestration, soil protection and biodiversity conservation. Establishing pre-construction vegetation conditions allows for accurate detection of anthropogenic disturbances over time (Turner et al., 2003).

Remote sensing and Geographic Information Systems (GIS) have become indispensable tools for environmental monitoring due to their ability to provide spatially continuous and multi-temporal data (Weng, 2012). Among the various vegetation indices, the Normalized Difference Vegetation Index (NDVI) is widely used to assess vegetation health, density and productivity (Tucker, 1979). NDVI values range from -1 to +1, where higher values indicate dense and healthy vegetation.

Prior to railway construction, vegetation patterns are primarily influenced by natural climatic conditions and human activities such as agriculture and settlement expansion. Therefore, understanding the baseline vegetation structure is essential for distinguishing between natural variability and construction-induced changes. This study establishes the pre-construction vegetation conditions along the Abuja–Kaduna rail corridor using geospatial techniques, providing a benchmark for subsequent environmental impact analysis.

Materials and Method

2. Study Area

The study area covers the Abuja–Kaduna rail corridor in north-central Nigeria, extending approximately 186 km from Idu in Abuja to Rigasa in Kaduna. The corridor lies within the Guinea Savannah ecological zone, characterized by a mix of grasses, shrubs and scattered trees as seen in figure 1. The region experiences a tropical climate with distinct wet and dry seasons, with annual rainfall ranging between 1000 mm and 1500 mm. Land use in the area is dominated by agriculture, with crops such as maize, millet and sorghum cultivated extensively. Urban expansion is prominent near Abuja, leading to increased land pressure and vegetation modification. To capture localized environmental changes, a 200m buffer was created along both sides of the rail alignment. This buffer zone enables the analysis of edge effects and direct impacts of infrastructure development on vegetation dynamics.

Data Source/Collection

This study adopted a geospatial analytical approach integrating remote sensing and Geographic Information Systems (GIS) techniques to assess vegetation conditions along the study area. Satellite imagery from the Landsat series for the year 2011 (pre-construction phase) was acquired due to its reliability and widespread application in long-term environmental monitoring. The dataset was selected based on minimal cloud cover and seasonal consistency to ensure comparability. Pre-processing of the imagery involved radiometric correction to normalize sensor errors and atmospheric correction to remove distortions caused by atmospheric particles. These steps are essential for improving the accuracy of spectral reflectance values used in vegetation analysis and ensuring consistency across multi-temporal datasets (Liu et al., 2025; Burton et al., 2024). Vegetation condition was assessed using the Normalized Difference Vegetation Index, which remains one of the most widely used indices for monitoring vegetation health, productivity, and spatial distribution in environmental studies. NDVI is particularly effective due to its sensitivity to chlorophyll content and vegetation vigor across different ecosystems (Zhao & Qu, 2024; Nițu et al., 2025).

The NDVI was computed using the standard formula:

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

Where:
NDVI: Normalized Differences Vegetation Index
NIR: Reflectance in the near-infrared band (typically between 0.76 µm and 0.90 µm).
RED: Reflectance in the red band (typically around 0.63 µm to 0.69 µm).

NDVI values range between -1 and +1, where higher values indicate dense and healthy vegetation, while lower values represent sparse vegetation, bare surfaces, or non-vegetated areas. Recent studies emphasize that NDVI remains a robust and reliable indicator for assessing vegetation dynamics under varying environmental and climatic conditions (Rahimi et al., 2025).

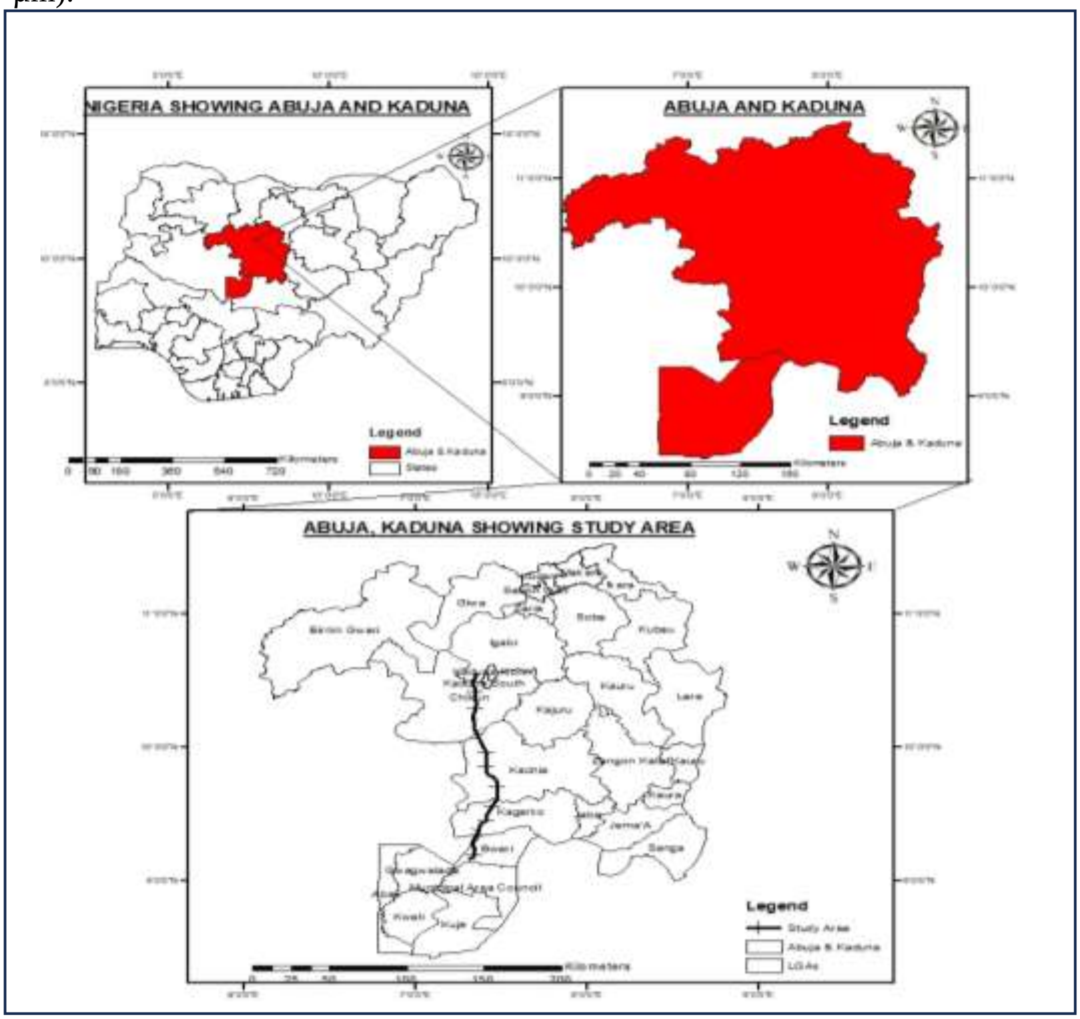

Figure: 1 Map of the study Area
Source: Author's Research (2025)

Data Analysis

The processed NDVI imagery was classified into five vegetation density categories: very low, low, moderate, high and very high vegetation. This classification scheme provides a detailed representation of vegetation conditions and enables effective comparison of spatial patterns within the study area. A supervised classification approach was employed whereby training samples representing each vegetation class were selected based on spectral characteristics. This method enhances classification accuracy and allows for precise differentiation between vegetation densities. To ensure the reliability of the classification results, an accuracy assessment was conducted using ground truth data collected through field surveys and Global Positioning System (GPS) observations. The comparison between classified outputs and actual field conditions improves confidence in the results and aligns with best practices in remote sensing analysis. Spatial analysis was performed using ArcGIS to quantify the areal extent of each vegetation class and examine their spatial distribution patterns. GIS-based analysis further enabled the identification of dominant land cover types and the detection of spatial trends in vegetation distribution. Recent advancements in remote sensing emphasize the importance of integrating multi-temporal NDVI datasets with GIS techniques for accurate monitoring of vegetation dynamics and environmental change (Li et al., 2023; Liu et al., 2024).

The remote sensing data capture Landsat satellite imagery for the year 2011 was acquired from the United States Geological Survey (USGS) Earth Explorer platform, with multiple scenes (Path/Rows 189/054, 189/055 and 189/056) required to provide complete coverage of the 186 km Abuja-Kaduna rail corridor. All scenes were acquired during the September-October 2011 window to ensure phenological consistency, as this period represents the transition from the wet to dry season when vegetation biomass is generally at its peak in the Guinea Savannah ecological zone. This temporal consistency is critical for ensuring comparability across scenes, as vegetation vigor varies significantly between wet and dry seasons. To ensure data quality, only scenes with less than 10% cloud cover were retained for analysis, and all selected scenes underwent uniform preprocessing including radiometric calibration (conversion of digital numbers to top-of-atmosphere reflectance), atmospheric correction using the Dark Object Subtraction method to remove scattering effects, and geometric registration to UTM Zone 32N projection with WGS84 datum. Following preprocessing, individual scenes were mosaicked to create a continuous, gap-free image covering the entire corridor, ensuring that vegetation analysis could be conducted uniformly across the full study area without scene boundary artifacts.

The NDVI was computed for each 30m × 30m pixel (900 m^2 ground resolution) using the standard formula NDVI = (NIR - RED) / (NIR + RED), where NIR represents reflectance in the near-infrared band (Band 4, 0.76–0.90 µm for Landsat 5) and RED represents reflectance in the red band (Band 3, 0.63–0.69 µm). For the 200m buffer zone along both sides of the rail alignment (total width of 400m), this resulted in approximately 48,000+ individual pixels being analyzed across the entire mosaic, covering approximately 120 km^2 of buffer area. To derive corridor-wide vegetation statistics, the following aggregation approach was applied: each 30m pixel within the 200m buffer was classified into one of five NDVI classes, all pixels within the same class across the entire mosaic were grouped together, and the area per class was computed by multiplying the number of classified pixels by 900 m^2 (0.0009 km^2). The percentage distribution was then derived by dividing the class area by the total buffer area (120 km^2) and multiplying by 100. This aggregation approach ensures that the vegetation statistics presented represent the entire corridor rather than localized sampling points.

To ensure comparability and reliability of the NDVI analysis, several parameters were held constant across the entire study. The satellite sensor (Landsat 5 Thematic Mapper) was consistent across all scenes, providing uniform spectral and spatial resolution. The temporal window of September-October 2011 ensured consistent vegetation phenology, while the cloud cover threshold of less than 10% per scene minimized atmospheric interference. Atmospheric correction using the DOS method was applied uniformly across all scenes, geometric registration to UTM Zone 32N with WGS84 datum ensured consistent spatial referencing, and the Maximum Likelihood Classifier algorithm was used consistently for classification. Additionally, a minimum of 50 training samples per vegetation class were selected to ensure sufficient spectral representation. Several methodological assumptions underpin the data analysis, consistent with established practices in remote sensing. It is assumed that atmospheric conditions across the corridor are sufficiently comparable after atmospheric correction such that NDVI values are not systematically biased by localized atmospheric variations. All imagery was acquired within the same seasonal window, ensuring that observed differences in NDVI reflect actual vegetation density rather than seasonal growth stage variations. NDVI is relatively insensitive to soil color variations in vegetated areas; however, in sparsely vegetated areas (NDVI <0.2), soil background may influence NDVI values, which is acknowledged in the interpretation of the "very low" and "low" vegetation classes. While 30m resolution pixels may contain mixed land cover types, the supervised classification approach using spectral signatures minimizes misclassification, with training samples selected from homogenous areas representing each class to improve classification accuracy. Field validation points collected via GPS represent the vegetation class at the time of ground observation during the validation campaign, and it is assumed that vegetation conditions during validation were consistent with 2011 baseline conditions in areas not affected by significant land-use changes between 2011 and the validation period.

The accuracy assessment was conducted using ground truth data collected through field surveys conducted between November 2015 and February 2016, with a total of 250 validation points randomly distributed across the corridor, ensuring a minimum of 50 points per vegetation class. GPS observations with ±3m positional accuracy were used to record field conditions at each validation point. An error matrix (confusion matrix) was generated by comparing the classified NDVI classes against the ground truth observations, and overall classification accuracy, producer's accuracy (omission error), user's accuracy (commission error), and the Kappa coefficient were computed to quantify classification reliability. This rigorous validation approach, which aligns with established best practices in remote sensing analysis (Congalton & Green, 2019), provides quantitative evidence of classification accuracy and strengthens confidence in the vegetation distribution patterns reported in this study.

Results and Discussion

The Normalized Difference Vegetation Index (NDVI) analysis conducted for the year 2011 provides a comprehensive assessment of the baseline vegetation condition within the Abuja–Kaduna rail corridor prior to the commencement of railway construction activities. The classification results in Figure 2 revealed that moderate vegetation, accounting for 42.6% of the total study area, constitutes the dominant land cover category along the corridor. This vegetation class generally represents areas characterized by active plant growth and moderate biomass accumulation, including cultivated farmlands, fallow agricultural lands, grasslands and natural savannah vegetation. The predominance of this category reflects the agricultural character of the Abuja–Kaduna region, where farming activities constitute a major land-use practice. Seasonal cultivation of crops such as maize, millet, sorghum and legumes contribute significantly to the NDVI values observed within this class. The dominance of moderate vegetation indicates that the ecological conditions of the corridor were generally favorable for plant growth and productivity during the period under investigation.

The high vegetation category covers approximately 28.3% of the study area and represents zones with relatively dense and healthy vegetation cover, typically associated with woodlands, gallery forests, dense shrublands and areas experiencing limited anthropogenic disturbance. The substantial proportion of high vegetation suggests that significant portions of the corridor maintained relatively intact natural ecosystems before the implementation of railway infrastructure, providing numerous ecological services including habitat provision for wildlife, regulation of local climatic conditions, enhancement of soil fertility and protection against erosion. The analysis also identified very high vegetation areas, which account for 5.4% of the total land area, corresponding to dense forest stands, riparian vegetation along rivers and streams, wetlands and protected natural ecosystems. Although this class occupies the smallest proportion among the vegetation-rich categories, its ecological importance is disproportionately high, with riparian vegetation stabilizing riverbanks, reducing sediment transport, maintaining water quality and supporting aquatic biodiversity, while wetland ecosystems contribute significantly to groundwater recharge, flood regulation and carbon storage. These environmentally sensitive zones require careful monitoring during subsequent phases of infrastructure development.

In contrast, the low vegetation class, representing 18.5% of the study area, indicates regions characterized by reduced vegetation density and lower photosynthetic activity, commonly associated with intensive agricultural use, overgrazed lands, sparse grass cover, partially exposed soils and transitional landscapes undergoing land-use modification. The very low vegetation category occupies 5.2% of the corridor and represents the most degraded or sparsely vegetated portions of the landscape, typically associated with built-up settlements, transportation infrastructure, exposed rock surfaces, bare soil, construction sites and heavily disturbed lands. The concentration of very low vegetation around urban and peri-urban centers, particularly near Abuja, reflects the influence of population growth, urban expansion and increasing anthropogenic pressure on natural vegetation resources. However, the relatively small proportion of this class suggests that extensive environmental degradation had not yet occurred across the majority of the corridor during the baseline period.

Spatial analysis of the NDVI distribution reveals a distinct pattern of vegetation density variation across the study area. Higher vegetation classes are predominantly concentrated in rural and less accessible portions of the corridor where human activities remain comparatively limited, while low and very low vegetation classes tend to cluster around major settlements, transportation routes and rapidly urbanizing zones. The vicinity of Abuja demonstrates particularly noticeable reductions in vegetation density due to increasing urban development and associated land conversion processes. This spatial pattern highlights the significant role of human activities in shaping vegetation dynamics even before the railway project commenced and underscores the vulnerability of vegetation resources located near expanding urban centers.

When the moderate, high and very high vegetation categories are combined, they account for approximately 76.3% of the total study area, indicating that more than three-quarters of the Abuja–Kaduna rail corridor was covered by vegetation exhibiting moderate to high levels of health and productivity in 2011. Such extensive vegetation cover reflects a relatively stable ecosystem characterized by active biological productivity and functional ecological processes, consistent with the environmental characteristics of Nigeria's Guinea Savannah ecological zone where vegetation growth responds strongly to seasonal rainfall patterns and climatic variability. The dominance of moderate and high vegetation classes observed in this study aligns with previous research on savannah ecosystems, as documented by Tucker and Anyamba (2005), who reported that savannah environments typically exhibit intermediate NDVI values resulting from seasonal fluctuations in vegetation greenness, particularly during transitions between wet and dry seasons. The NDVI distribution observed in 2011 therefore reflects the natural ecological characteristics of the region while also capturing the influence of existing land-use practices.

Furthermore, the relatively low proportion of sparsely vegetated and degraded land classes suggests that the corridor had not yet experienced significant large-scale environmental disturbances prior to railway construction. This condition enhances the reliability of the 2011 dataset as a baseline reference for temporal change analysis, providing a quantitative benchmark against which future vegetation changes can be measured. By comparing subsequent NDVI datasets with the 2011 baseline, it becomes possible to identify areas of vegetation loss, recovery, fragmentation, or transformation associated with railway development, urban expansion, agricultural intensification and other anthropogenic activities. Consequently, the 2011 NDVI assessment forms a critical foundation for evaluating long-term environmental change and supporting sustainable management of the Abuja–Kaduna rail corridor ecosystem.

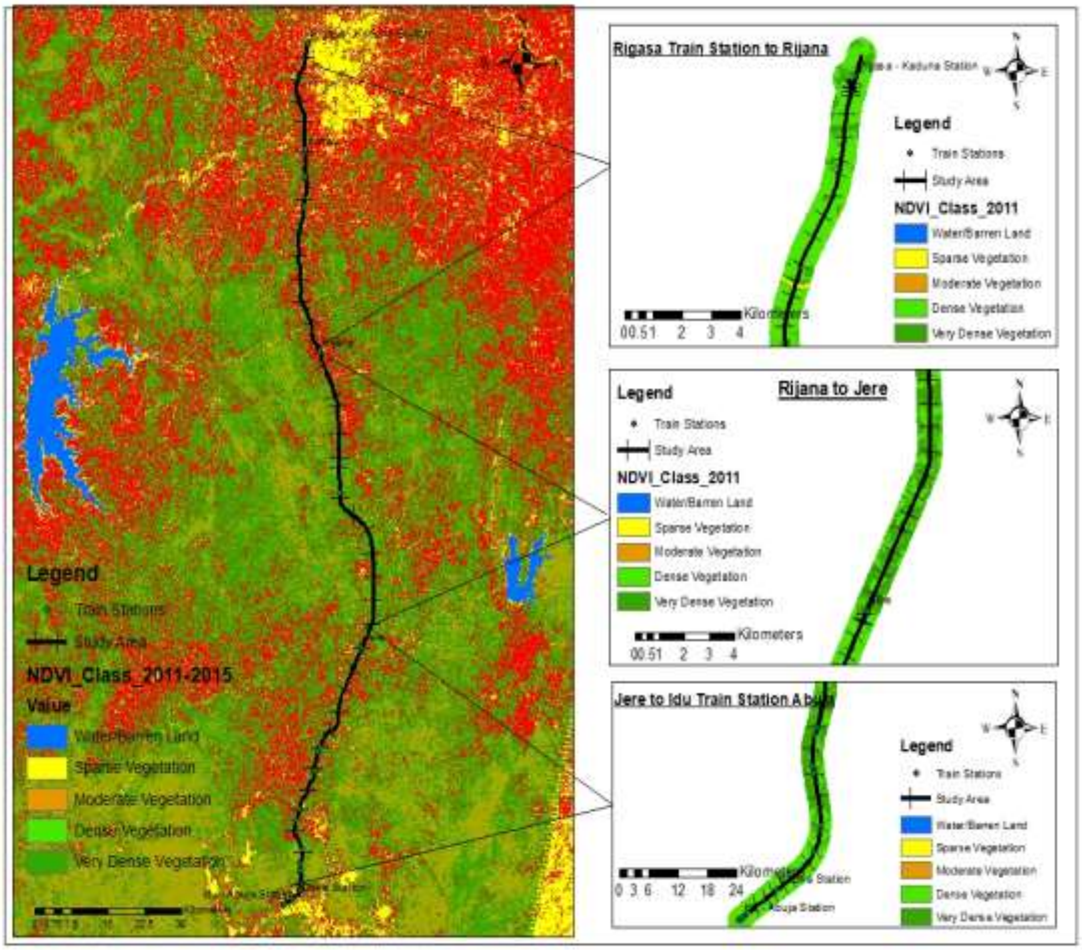

Figure 1 NDVI Pre - Construction Phase (2011)
Source: Author's Research (2025)

Table 1: NDVI Classification and Areal Distribution for 2011 (Pre-Construction Phase)

S/N	NDVI Range	Vegetation Class	Area (km²)	Percentage (%)	Description
1	-1.00 – 0.10	Very Low Vegetation	6.24	5.2	Bare surfaces, built-up areas, exposed soil
2	0.11 – 0.25	Low Vegetation	22.20	18.5	Sparse vegetation, degraded lands, light farming
3	0.26 – 0.50	Moderate Vegetation	51.12	42.6	Croplands, mixed vegetation, savannah grasses
4	0.51 – 0.70	High Vegetation	33.96	28.3	Dense vegetation, woodland areas
5	0.71 – 1.00	Very High Vegetation	6.48	5.4	Forest patches, wetlands, riparian vegetation
	Total		**120.00**	**100%**	

Source: Author's Research (2025)

Table 1 presents the NDVI classification and areal distribution of vegetation cover within the Abuja–Kaduna rail corridor for the year 2011, representing the pre - construction phase of the railway project. The classification provides valuable information on the health, density and spatial extent of vegetation across the study area and serves as a benchmark for assessing future environmental changes associated with railway development. The results reveal a landscape predominantly covered by moderate to high vegetation, indicating that the corridor maintained a relatively stable ecological condition before the commencement of major construction activities.

The Very Low Vegetation class, with NDVI values ranging from 1.00 to 0.10 occupies 6.24 km², representing 5.2% of the total study area. This category consists mainly of built - up areas, exposed soil surfaces, rocky outcrops, transportation routes and other non - vegetated land covers. The relatively small proportion of this class suggests that highly disturbed or completely barren surfaces were limited within the corridor during the baseline year. Areas within this category are commonly associated with urban settlements, construction sites and locations experiencing intensive human activities that suppress vegetation growth. The low percentage recorded indicates that extensive urbanization and land degradation had not yet become dominant features of the corridor environment in 2011.

The Low Vegetation class, characterized by NDVI values between 0.11 and 0.25 covers approximately 22.20 km², accounting for 18.5% of the total area. This category represents sparsely vegetated surfaces, degraded lands, lightly cultivated farmlands and areas subjected to moderate anthropogenic pressure. The presence of this class reflects localized environmental disturbances arising from agricultural activities, grazing, fuelwood collection and settlement expansion. Although the proportion of low vegetation is notable, it remains significantly lower than the moderate and high vegetation classes, indicating that vegetation degradation was not widespread across the study area. The occurrence of this class also reflects the transitional nature of some landscapes where vegetation cover fluctuates seasonally due to farming practices and climatic variability.

The Moderate Vegetation class emerges as the dominant land cover category, occupying 51.12 km² and representing 42.6% of the total study area. NDVI values within this range (0.26 – 0.50) are generally associated with croplands, mixed vegetation communities, fallow lands and savannah grasslands. The predominance of this class highlights the agrarian nature of the Abuja–Kaduna corridor, where agricultural activities coexist with natural vegetation systems. Moderate vegetation cover indicates active photosynthetic processes and healthy plant growth, reflecting favorable environmental conditions for vegetation development. The large spatial extent of this class suggests that much of the corridor was characterized by productive landscapes capable of supporting both ecological functions and human livelihoods. This finding is consistent with the characteristics of the Guinea Savannah ecological zone, where mixed vegetation and agricultural lands constitute major components of the landscape.

The High Vegetation class, with NDVI values ranging from 0.51 to 0.70, occupies 33.96 km², accounting for 28.3% of the study area. This category represents dense vegetation, woodland ecosystems and areas with substantial biomass accumulation. High

NDVI values indicate vigorous vegetation growth, high chlorophyll concentration and favorable environmental conditions. The significant proportion of this class demonstrates that large sections of the corridor retained relatively intact natural vegetation prior to railway construction. These areas contribute substantially to ecosystem services such as carbon sequestration, biodiversity conservation, soil protection and climate regulation. The presence of extensive woodland vegetation also suggests limited disturbance in certain portions of the corridor, particularly in rural and less accessible locations where human activities are comparatively low.

The Very High Vegetation class records the highest NDVI values (0.71–1.00) and covers 6.48 km², representing 5.4% of the total area. Although this category occupies the smallest spatial extent among the vegetated classes, it is ecologically significant because it corresponds to forest patches, wetlands and riparian vegetation. These ecosystems are characterized by dense canopy cover, high biomass productivity and strong ecological resilience. Riparian vegetation found along rivers and streams performs essential environmental functions, including erosion control, water quality maintenance, habitat provision and flood mitigation. Wetland ecosystems within this category also contribute to groundwater recharge and biodiversity conservation. The existence of these highly vegetated areas indicates that portions of the corridor still maintained relatively undisturbed ecological habitats before the onset of railway development activities. A broader examination of the vegetation distribution reveals that the Moderate Vegetation, High Vegetation and Very High Vegetation classes collectively occupy 91.56 km², representing 76.3% of the entire study area. This finding demonstrates that more than three quarters of the Abuja – Kaduna rail corridor was covered by vegetation exhibiting moderate to high levels of health and productivity during the pre - construction period. Such extensive vegetation cover is indicative of a stable and functioning ecosystem capable of supporting diverse ecological processes and providing essential environmental services. The dominance of these vegetation classes further suggests that anthropogenic disturbances had not significantly altered the natural vegetation structure of the corridor before railway construction commenced.

The NDVI classification presented in Table 1.1 above indicates that the Abuja–Kaduna rail corridor was characterized by relatively healthy vegetation conditions in 2011. The prevalence of moderate and high vegetation classes, coupled with the limited extent of low and very low vegetation categories, suggests that environmental degradation was relatively minimal during the pre-construction phase. Consequently, the 2011 vegetation distribution provides a robust baseline against which subsequent changes resulting from railway construction, urban expansion, agricultural intensification and other land - use transformations can be accurately assessed. The findings therefore establish an essential reference point for evaluating the magnitude and spatial patterns of vegetation change throughout the different phases of railway development within the corridor.

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