

Plant Species Response to Coal Mining Sites in Kogi State

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ABSTRACT

Coal mining activities are widely recognized for their capacity to alter species composition and ecological stability. This study assessed plant biodiversity responses to coal mining disturbance in the coal belt areas of Kogi East, Kogi State, Nigeria, using species diversity indices as ecological indicators. Vegetation data for this study were collected using line transects and nested quadrats. A total of 48 quadrats (50 × 50 m) were systematically laid along four parallel transects at 10 m intervals across Sites A, B, and C. From these, 24 quadrats were randomly selected using a table of random numbers, with eight quadrats chosen from each site, resulting in a total sample size of 24. Plant species diversity was quantified using the Shannon Wiener diversity index (H'), species richness, and Pielou's evenness index (J'). Differences in diversity metrics among plot categories were evaluated using one-way analysis of variance (ANOVA). Results revealed that the control site (Plot C) consistently recorded the highest median values for Shannon diversity ($H' \approx 3.65$), species richness (47.5 species), and evenness ($J' \approx 0.960$), accompanied by relatively low variability (IQRs ≈ 0.180 , 8.25, and 0.015, respectively), indicating a stable and well-structured plant community. In contrast, mined plots exhibited lower median diversity values and greater dispersion, with Shannon diversity medians of 3.59 (Plot A) and 3.51 (Plot B), richness medians of 45.5 and 43.5 species, and evenness medians of 0.938 and 0.955, reflecting heterogeneous recovery and ecological instability. However, one-way ANOVA results indicated no statistically significant differences among plot categories for Shannon diversity ($F_{2,21} = 0.78$, $p = 0.472$), species richness ($F_{2,21} = 0.37$, $p = 0.696$), or Pielou's evenness ($F_{2,21} = 2.48$, $p = 0.108$). The study provides baseline ecological data critical for vegetation restoration and biodiversity management in coal mining landscapes of Kogi East. It is recommended that targeted ecological restoration programs be implemented alongside long-term monitoring to mitigate the impacts of coal mining on vegetation.

Keywords: Coal mining disturbance, Plant biodiversity, Shannon diversity index and Species richness

INTRODUCTION

Mining significantly affects plant species diversity by altering habitat structure, soil properties, and ecological processes. Recent studies have shown that

mining activities lead to substantial biodiversity loss, particularly through vegetation removal and land degradation (Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services,

2022; Sonter et al., 2020). Among the major drivers of changes in species diversity are habitat loss and fragmentation, overexploitation of natural resources, introduction of invasive species, and the compounding effects of climate change (El-Ghanim et al., 2010; Alsherif & Fadl, 2016; Newbold et al., 2020; IPBES, 2022). Quantifying species richness remains essential not only for comparing ecological communities but also for understanding colonization dynamics and biodiversity patterns at local and regional scales (Cornell, 1999; Chase et al., 2020). Maximizing species richness continues to be a central goal in conservation biology, particularly in the context of accelerating global biodiversity loss (May, 1988; Díaz et al., 2020). Vegetation clearance associated with mining poses one of the most severe threats to biodiversity conservation globally. Contemporary evidence indicates that mining contributes significantly to deforestation and ecosystem degradation, particularly in tropical regions (Sarma, 2005; Adjei, 2007; Sonter et al., 2020). Beyond exposing soils to higher temperatures, vegetation removal disrupts nutrient cycling, reduces soil fertility, and impairs ecosystem recovery processes (Lu et al., 2002; Wang et al., 2021). Furthermore, mining activities intensify habitat fragmentation, resulting in smaller, isolated patches that limit species dispersal and regeneration (Saunders et al., 1991; Haddad et al., 2015; Newbold et al., 2020). Coal remains one of the most abundant fossil fuels globally and continues to play a major role in energy production despite increasing environmental concerns (Rashid et al., 2014; International Energy Agency, 2023). However, coal mining has been widely associated with severe ecological disturbances, including vegetation loss and the proliferation of invasive species (Huang et al., 2014; Hapsari et al., 2020; Li et al., 2021). Recent studies have shown that post-

mining landscapes are often dominated by disturbance-tolerant and invasive plant species, which hinder natural succession and reduce native biodiversity (Zhang et al., 2021; Prach & Walker, 2020). Similar findings have been reported across coal mining regions worldwide, where species such as *Chromolaena odorata*, *Ageratum conyzoides*, and *Panicum maximum* frequently colonize degraded mine sites. The study area the Coal Belt of Igala Land in Kogi State, Nigeria is notable for its high-quality coal deposits and long history of mining activities. Despite its economic importance, coal mining in the region through surface, tunnel, and high-wall mining methods has led to extensive environmental degradation. The regeneration of these mined landscapes is often constrained by insufficient baseline ecological data, particularly regarding native plant species composition and diversity. Recent ecological restoration studies emphasize the importance of site-specific biodiversity data in guiding effective reclamation strategies (Prach & Walker, 2020; Wang et al., 2021).

Although some studies in the region have examined mining-related impacts on water quality and soil degradation (Ameh et al., 2021; Oloche et al., 2019; Ekwule et al., 2021; Enock, 2023), there remains a notable gap in empirical research on plant species diversity and community responses to coal mining disturbances. Globally, recent studies (e.g., Saikat et al., 2020; Sonter et al., 2020) have highlighted the ecological consequences of mining on biodiversity, while local studies (Imade et al., 2021; Ogbonna et al., 2019) provide limited insights without detailed species-level analyses. Therefore, this study addresses this gap by evaluating plant species responses to mining disturbances, with a focus on species diversity and richness within coal mining sites.

METHODOLOGY

Study Area

Ankpa LGA lies between longitude 7°36'E to 7°39' E and latitude 07°23' N to 07°26' N, while Omala LGA lies between longitude 7°42'59.99''E and latitude 07°32'59.99'' N (Figures 1 and 2). Ankpa has an area of 1,200km² while Omala has an area of 1.667 km² and a population of 267,353 at the 2006 census. The projected population for 2023 is 644,326. The climate of the study area based on Koppen's classification model, falls within the tropical wet and dry (Aw) climatic region. With a mean temperature of about 25°C, rainfall in the area is high during the wet season. It ranges between 1600-2000mm, lasting for about seven months (i.e between April and October), (Ocholi, 2015).

The study area spans the rainforest belt and the southern Guinea savanna. The rainforest vegetation is characterized by rich, semi-deciduous forests with dominant tree species such as Iroko (*Milicia excelsa*) and Mahogany (*Khaya* spp.) (Akinyemi & Adebawale, 2021; Food and Agriculture Organization, 2020). The Guinea Savanna belt is dominated by tall grasses interspersed with scattered trees, exhibiting strong seasonal variation, lush and green during the rainy season but largely dry and fire-scarred during the dry season

(Abdulrahman et al., 2022; World Bank, 2021). Trees in this zone typically grow in clusters, reaching heights of up to 6 m, while grasses may attain heights of about 3 m.

Common tree species in this region include locust bean (*Parkia biglobosa*), shea butter tree (*Vitellaria paradoxa*), and *Isobertinia* spp., which are widely reported as characteristic species of the West African savanna (Sosef et al., 2021; Abdulrahman et al., 2022). Other plant species commonly associated with this ecological zone include *Carissa edulis*, *Pterocarpus erinaceus*, and *Triplochiton scleroxylon*, all of which are important components of tropical African vegetation (Akinyemi & Adebawale, 2021; Sosef et al., 2021). In the floodplains, vegetation is dominated by species such as oil palm (*Elaeis guineensis*) and various riparian plants including ferns, which thrive in moist environments (FAO, 2020; Sosef et al., 2021).

Vegetation distribution in this area follows a pattern that is similar to that of rainfall distribution, Ukwedeh (2003). The study area is known for its rich source of a variety of medicinal, cultural and edible wild plants, such as; *Abrus precatorius* Linn, *Allophylus africanus*, *Butyrospermum paradoxum* (Gaerrn, f.) Hepper/ *vitellaria paradoxum* (Gaertn,f), *Dennettia tripetala* and *Cola nitida* (Aniama et al, 2016).

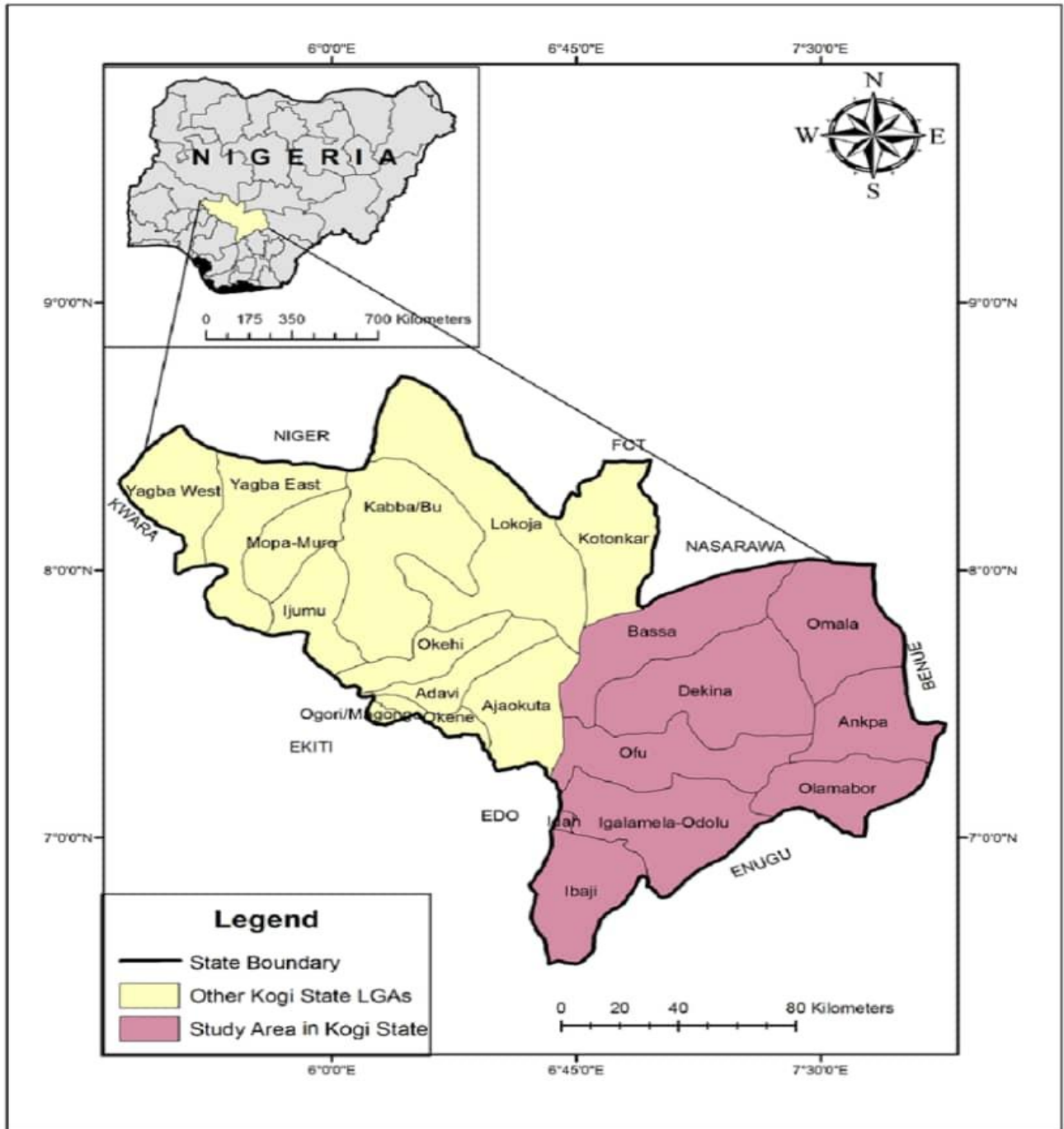


Figure 1: Nigeria showing Kogi State, Kogi State showing study areas
Source: Department of Geography, GIS Lab, University of Abuja.

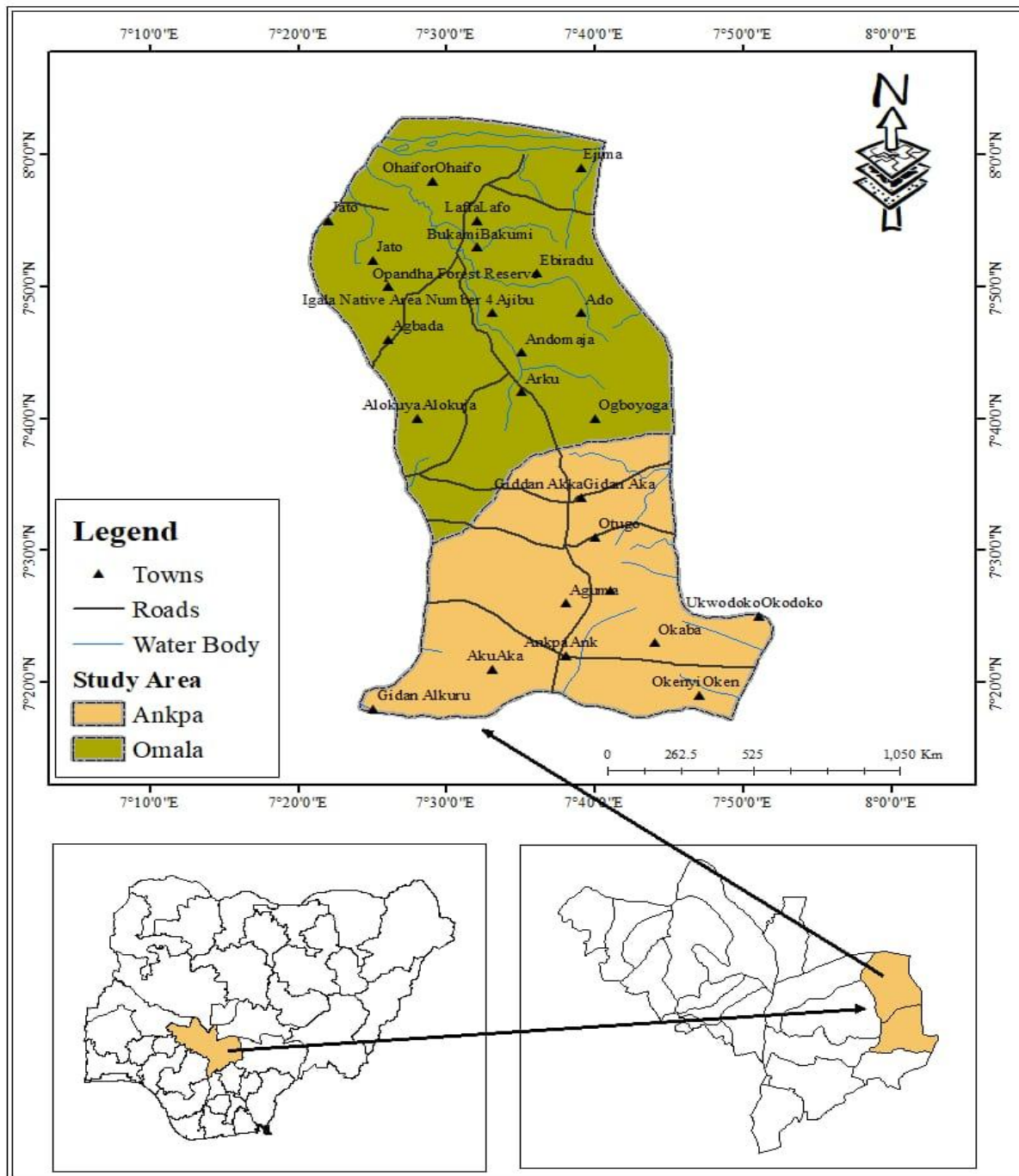


Figure 2: The Study Area (Ankpa and Omala Districts)
Source: Department of Geography, GIS Lab, University of Abuja.

MATERIALS AND METHODS

Data management

The sampling frame of this study comprises of all woody and herbaceous plant species in the Coal mining sites of the study area and these include; Okaba, Odagbo (Ojoku district), Ogboyaga (Ika)

and Okobo (Enjema). However, Ogboyaga (Ika) and Okobo (Enjema) mine sites were selected for this study. This was done with the use of the table of random numbers. This is presented on table 1.

Table 1: Table of random numbers for identified communities

Communities	Random Numbers
Odagbo	4
Okobo	2
Okaba	3
Ika-Ogboyaga	1

Source: Microsoft Excel, 2019 Version

In this study, vegetation data was collected using both a line transects and a nested quadrat. A total of 16 quadrats, each measuring 50 x 50 meters, were strategically placed on both sides of four parallel transect lines with an interval of 10 meters between each quadrat. The length of each of the four parallel transect lines is 230 meters and was spaced 100 meters apart, so as to capture the variability in the vegetation and include the gradients of environmental factors present in the study area. Also, this provided a systematic and comprehensive coverage of the study area.

Within the quadrats, an alternative grid system was employed. This comprised of a 10 x 10 meters grid for sampling tree species and a nested 5 x 5 meters grid for sampling shrub and herb species (Sarma and Barick, 2011) see (figure 3). This hierarchical approach ensured detailed and fine-scale data collection, allowing for a thorough examination of both tree, shrub and herb species composition in the study area

The nested-quadrat technique was used for vegetation sampling, where total counts was employed for studying shrubs and herbs in the subplots (Aigbedion and Iyayi, 2007; Sarma and Barick, 2011).

The table of random numbers was used to obtain a sample of 8 plots from each

study site for detailed investigation, and their GPS locations was recorded (Table 2). Therefore, a total of 24 plots was used in this study to assess the variation in floristic composition and diversity in the study area. Fig. 3 shows the layout of plots in the study area.

To enhance the robustness of the study, this sampling design was replicated in both the mined and unmined sites in the study area. By employing this systematic and nested sampling approach, the study aims to provide a comprehensive understanding of the vegetation dynamics in relation to the mine site, shedding light on species distribution and diversity patterns at various spatial scales. The data was quantitatively analysed to show variation in species diversity between the various plots.

In each plot, the species in the respective life forms was identified using vernacular and scientific names, Standard literatures and floras such as Flora of West Tropical Africa (Hutchinson and Dalziel, 1968); Nigerian Trees (Keay *et al.*, 1964); Guide to West African Weeds by Akobundu and Agyakwa (1987), Handbook of African Medicinal Plants by Iwu (1993) and Ethnobotanical documentation of some plants among Igala people of Kogi State by Aniaya *et al* (2016) were consulted for their proper identification.

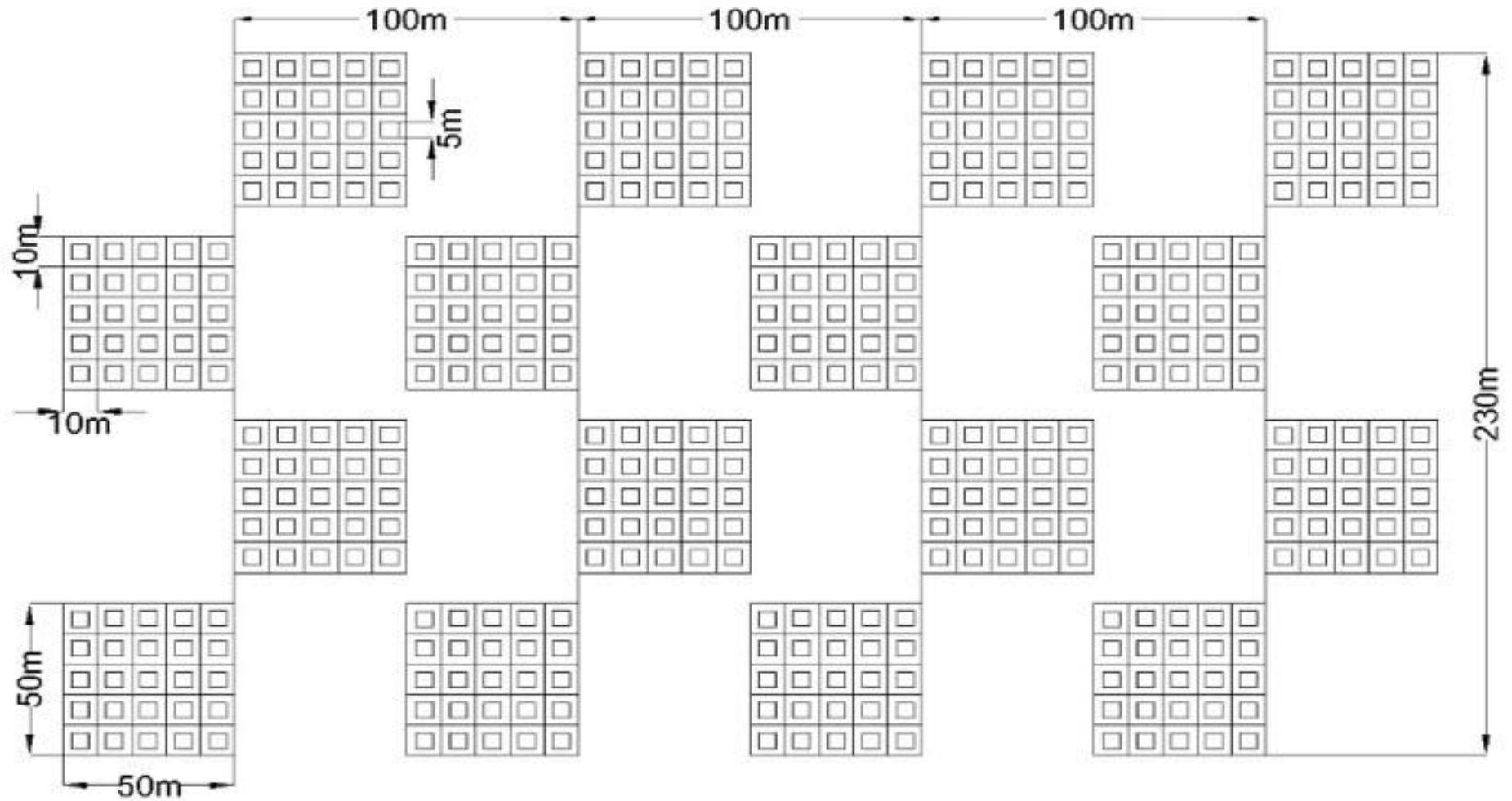


Figure 3: Layout of plots within the study area.

Source: Author's Design using Autocard Software, Version 2022

Table 2: Geo Location of Sampled Plots

ENJEMA-OKOBO (PLOT A)				IKA-OGBOYAGA (PLOT B)			OJOKU (PLOT C, CONTROL)		
QUADRATS	COORDINATES		SELECTED PLOTS	COORDINATES		SELECTED PLOTS	COORDINATES		SELECTED PLOTS
	Latitude	Longitude		Latitude	Longitude		Latitude	Longitude	
Q1	7.587533	7.687306	A5	7.666292	7.710331	-	7.444481	7.708578	-
Q2	7.586814	7.687733	-	7.665386	7.71035	B6	7.443772	7.708619	C1
Q3	7.586178	7.688033	-	7.664697	7.710358	B1	7.443089	7.708658	-
Q4	7.585747	7.688267	A7	7.664142	7.710381	-	7.44245	7.708686	-
Q5	7.588117	7.688064	A3	7.666375	7.711181	B3	7.444528	7.709464	-
Q6	7.587269	7.688478	-	7.665444	7.711189	-	7.443811	7.709508	C3
Q7	7.586717	7.688714	A8	7.664833	7.711192	-	7.443117	7.709553	C8
Q8	7.586231	7.688914	-	7.664292	7.7112	B5	7.442478	7.709597	C4
Q9	7.588722	7.688819	A2	7.666425	7.712131	-	7.444589	7.710367	C5
Q10	7.587942	7.689164	-	7.665517	7.712075	B7	7.443908	7.710397	-
Q11	7.587328	7.689397	-	7.664942	7.712064	-	7.443247	7.710425	-
Q12	7.586814	7.689625	A4	7.664369	7.712033	B8	7.442542	7.710467	C7
Q13	7.589281	7.689567	A1	7.666514	7.713025	B2	7.444631	7.711247	-
Q14	7.588631	7.689847	-	7.665653	7.712964	-	7.443936	7.711261	C2
Q15	7.587886	7.690128	-	7.665075	7.712925	B4	7.443317	7.711261	C6
Q16	7.587292	7.690319	A6	7.664469	7.712889	-	7.442572	7.711267	-

Source: Author's Field Work, 2025

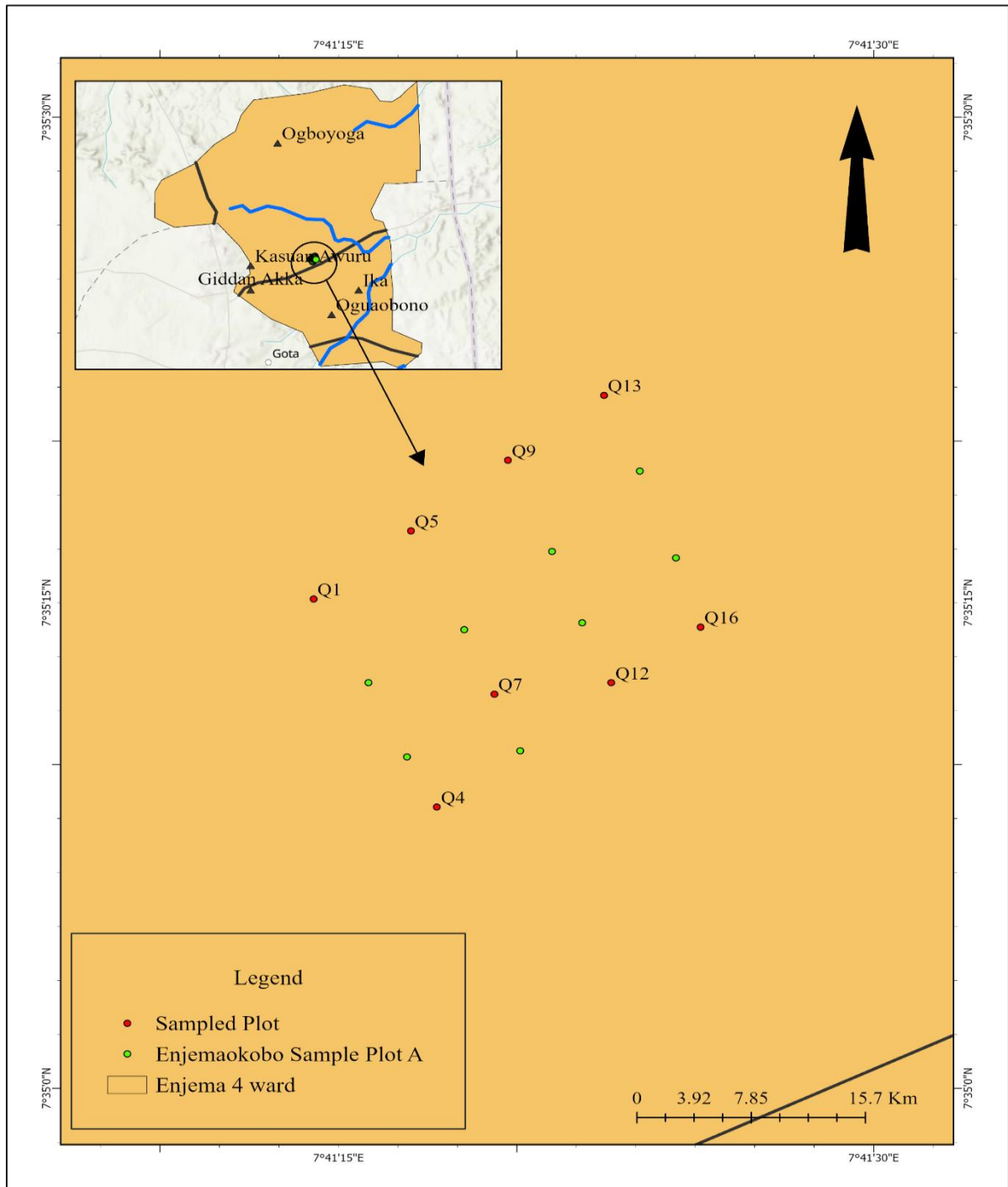


Figure 4: Sample Plot A (Enjema Okobo)

Source: Department of Geography, GIS Lab, University of Abuja.

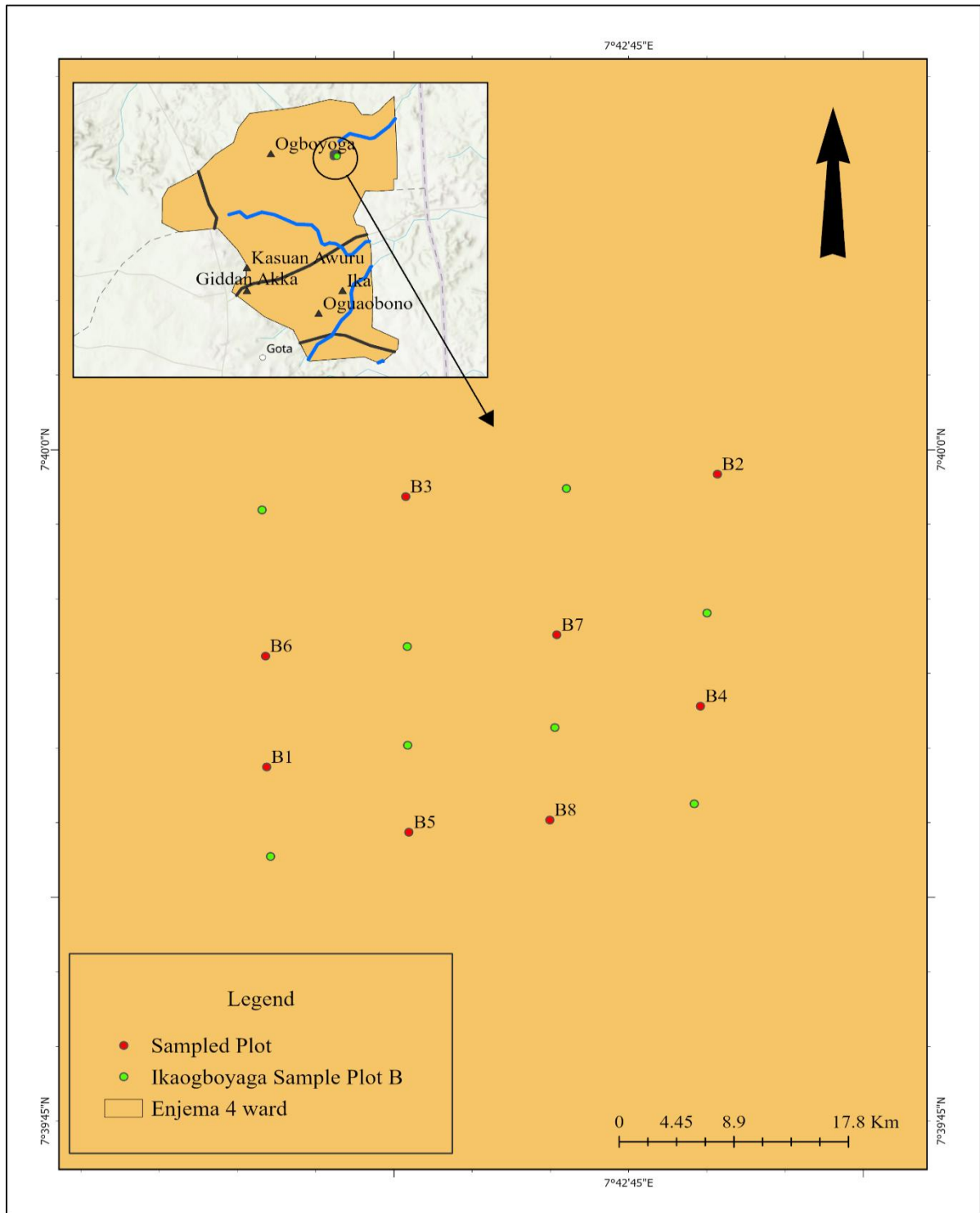


Figure 5: Sample Plot B (Ikaogboyaga)

Source: Department of Geography, GIS Lab, University of Abuja.

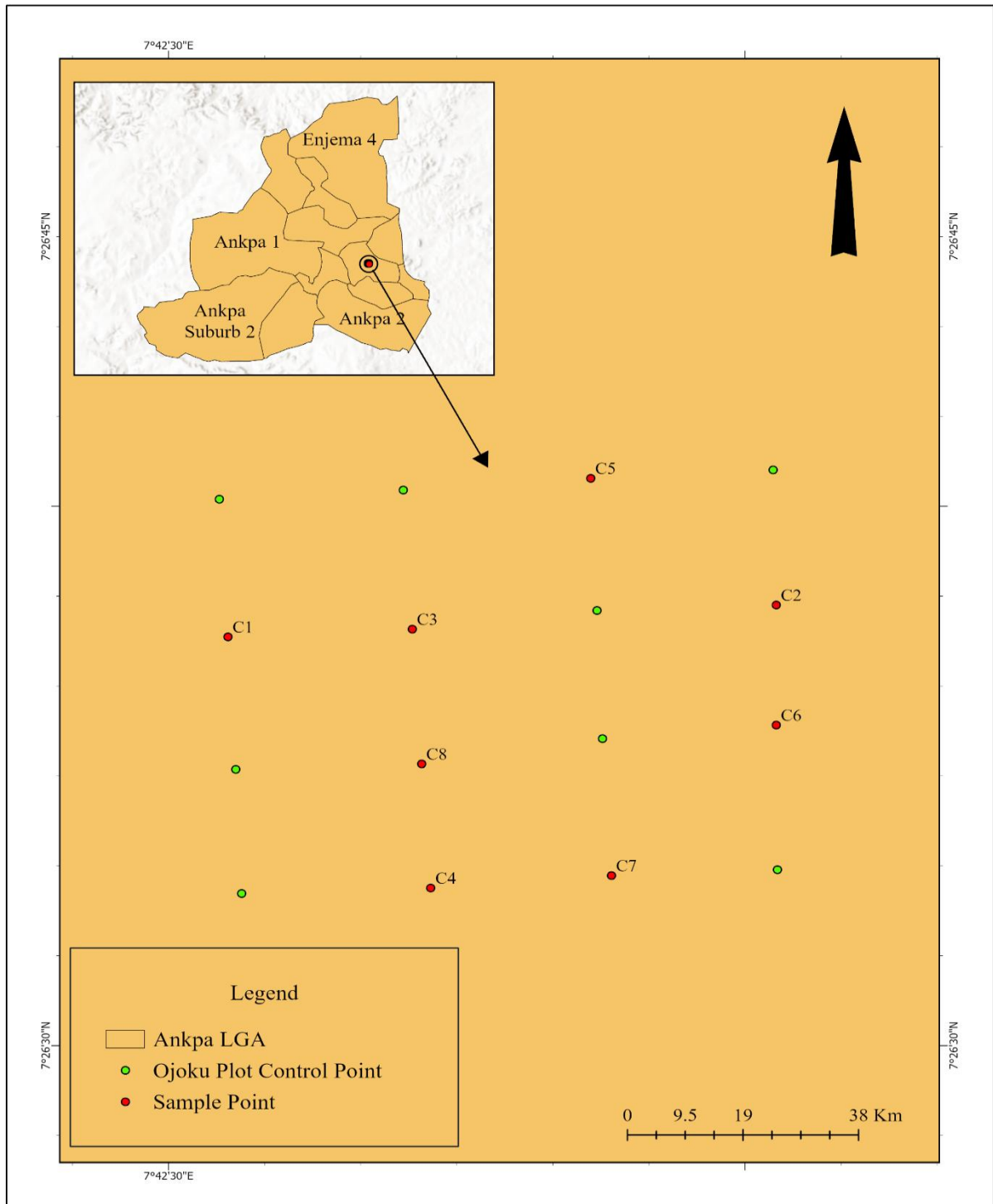


Figure 6: Control Plot A (Ojoku)

Source: Department of Geography, GIS Lab, University of Abuja.

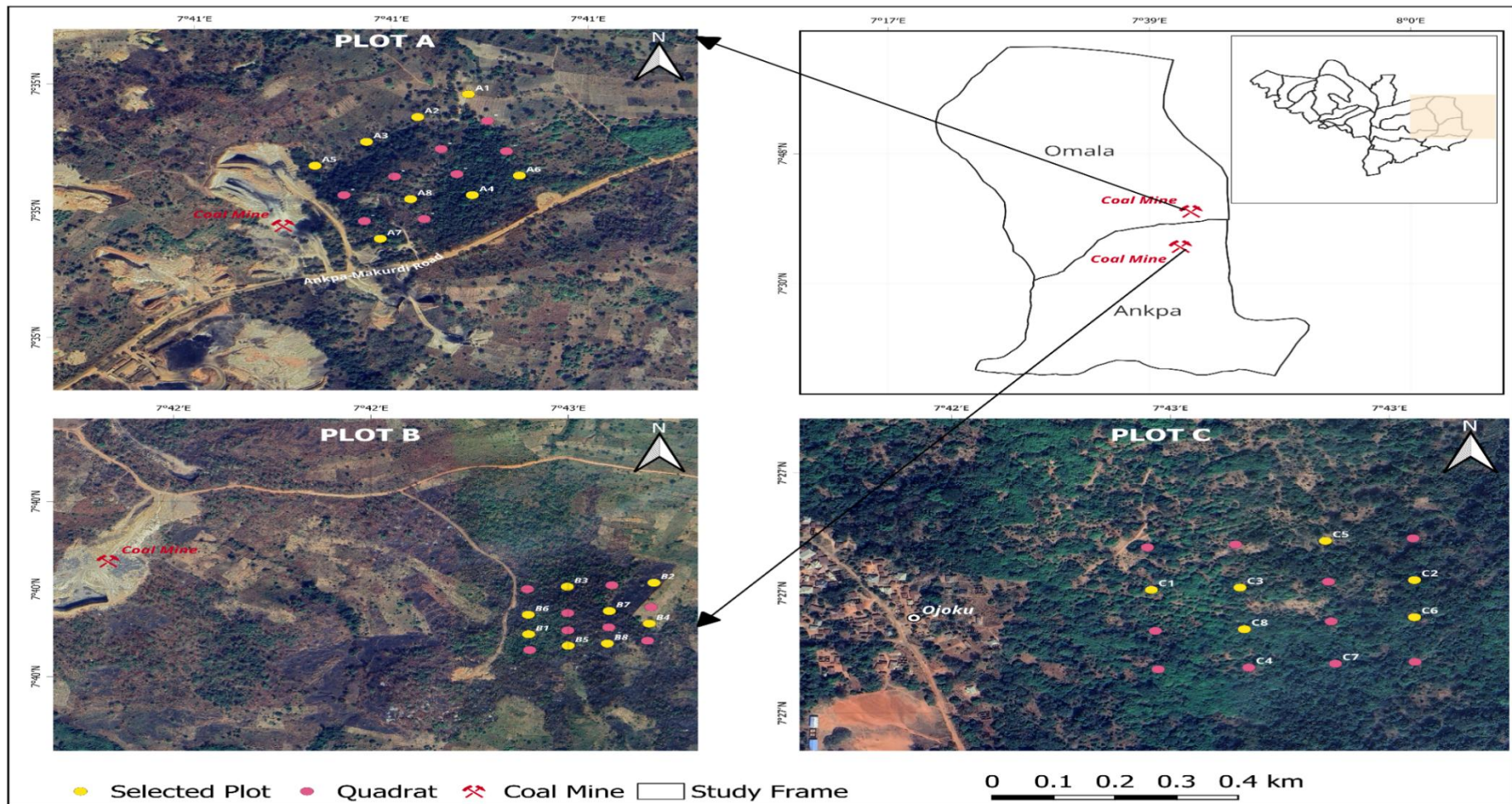


Figure 7: Aerial View of Sampled Plot

Source: Department of Geography, GIS Lab, University of Abuja.

Species diversity and richness across the study plots (Plot A and B: mine sites, and Plot C: control site; Figures 4,5,6) were assessed using widely accepted ecological indices. The Shannon–Wiener diversity index (H') was employed to quantify species diversity, as it accounts for both species richness and relative abundance within a community (Magurran, 2004). Species richness was determined as the total number of species recorded per plot. Pielou’s evenness index (J') was used to measure the equitability of species distribution across plots, providing insights into how evenly individuals were distributed among the recorded species.

To evaluate whether significant differences existed in plant diversity metrics among the three plot categories (A, B, and C), a one-way analysis of variance (ANOVA) was computed. The ANOVA was applied separately to the Shannon–Wiener diversity index, species richness, and Pielou’s evenness index, with plot category treated as the independent factor. This analysis enabled the assessment of variations in plant diversity metrics attributable to mining disturbance across the study plots. Statistical significance was evaluated at $p < 0.05$.

For visualization, boxplots were used to represent the Shannon–Wiener index, Richness and Pielou’s evenness index across the three plot types. In addition to the central tendency, variability in diversity metrics across plots was accounted for by computing descriptive quartiles (Q1, Q2, Q3) and the interquartile range (IQR). All analyses and visualizations were performed in R Studio (version 4.4.2) using standard ecological and statistical packages.

Table 3: The list of equations used for calculating biodiversity indices of the vegetation in the study area.

Biodiversity indices	Formula
Shannon–Wiener’s index (H')	$H' = -\sum_{i=1}^S p_i \ln p_i$
Pielou’s evenness index (E)	$E = (H'/\ln S)$

Source: Adapted from Shannon (1948) and Pielou (1966)

Here; $P_i = p_i$ is the proportion (n/N) of individuals of one particular species found (n) divided by the total number of individuals found (N); S = numbers of species encountered, n = the total number of individuals of a particular species, N = the total number of individuals of all species, S = total number of species.

RESULTS AND DISCUSSION

Figure 7 shows that the evenness index of Plot C, the control site, recorded the highest median evenness (0.960), reflecting a more balanced distribution of individuals among species in the undisturbed plots. Its interquartile range (IQR ≈ 0.015) is identical to that of Plot B (IQR ≈ 0.015), showing that both plots experience a similar degree of variability in evenness despite differing disturbance histories. Plot A, however, displayed a notably lower median (0.938) and the smallest IQR (≈ 0.009), suggesting that species abundances are distributed less evenly yet more consistently across its samples. This reduced variation may reflect community homogenization, a condition often associated with disturbed ecosystems where disturbance-tolerant taxa dominate (Cristescu et al., 2012; Newbold et al., 2020). Recent studies further indicate that disturbance can lead to reduced variability in evenness where dominant species consistently exploit similar ecological niches (Hui et al., 2023; Blowes et al., 2022).

Despite these observable differences in central tendency and dispersion, the one-way ANOVA for Pielou’s evenness index indicated no statistically significant variation among the three plot categories ($F_{2,21} = 2.48, p = 0.108$). This suggests that although mining disturbance influences species distribution patterns, the magnitude of these differences was insufficient to produce statistically distinct evenness values.

Similar findings have been reported in recent post-mining and restoration studies, where evenness changes were ecologically meaningful but statistically non-significant due to overlapping community structures and high within-site variability (Prach & Walker, 2020; Wang et al., 2021).

For Shannon diversity (H'), Plot C again depicts the highest central tendency with a median of about 3.65, coupled with the lowest variability (IQR ≈ 0.180), indicating a stable and well-structured community. In contrast, Plots A and B (mine sites) showed greater heterogeneity, with medians of 3.59 and 3.51 respectively, and wider IQRs (≈ 0.316 and ≈ 0.302). These broader spreads suggest that disturbed sites exhibit fluctuating diversity patterns, likely driven by uneven recovery and patchy recolonization processes. Recent studies in post-mining landscapes have similarly reported that disturbed ecosystems may display comparable mean diversity values to control sites but exhibit significantly higher variability due to ongoing succession (Zhang et al., 2021; Li et al., 2021).

However, the ANOVA results for Shannon diversity revealed no significant difference among the plots ($F_{2,21} = 0.78$, $p = 0.472$). This suggests that Shannon diversity may recover relatively quickly or remain comparable to control conditions, especially in areas undergoing secondary succession. Similar observations have been reported in recent studies of coal-mined landscapes, where diversity indices in disturbed sites approached those of reference ecosystems despite differences in species composition and functional structure (Wang et al., 2021; Zhang et al., 2021).

Species richness further illustrates these dynamics. Plot C held the highest median richness (47.5 species) and the narrowest IQR (≈ 8.25), indicating a consistently rich assemblage. Plot A showed the lowest median (45.5) and the widest IQR (≈ 14.5), while Plot B displayed intermediate values but with some plots exceeding the control site in species counts. This pattern may reflect colonization by opportunistic and disturbance-resilient species, a phenomenon widely reported in recent

ecological studies of degraded landscapes (Prach & Walker, 2020; Newbold et al., 2020). Contemporary research also shows that disturbed ecosystems can exhibit transient increases in local richness due to species influx, even though long-term stability remains compromised (Blowes et al., 2022).

Nevertheless, the one-way ANOVA for species richness revealed no statistically significant difference among plot categories ($F_{2,21} = 0.37$, $p = 0.696$), reinforcing the notion that richness alone may be an insensitive indicator of disturbance effects, particularly where species turnover compensates for local losses. This aligns with recent biodiversity research emphasizing that compositional change and variability are often more informative indicators of disturbance than richness alone (Chase et al., 2020; Blowes et al., 2022).

This apparent discrepancy underscores the importance of interpreting biodiversity metrics alongside measures of variability and distribution rather than relying solely on mean comparisons. Recent studies similarly emphasize that disturbed ecosystems may maintain comparable diversity indices to undisturbed systems while remaining ecologically unstable and compositionally distinct (Prach & Walker, 2020; Wang et al., 2021).

The control site consistently supported higher median diversity, evenness, and richness with lower variability, reflecting a more stable and mature ecosystem. In contrast, the mined plots exhibited greater dispersion in biodiversity metrics, highlighting ecological instability and heterogeneous recovery trajectories. These findings align with contemporary ecological theory on secondary succession and disturbance dynamics, which predict uneven recovery following disturbance events (Prach & Walker, 2020; Chase et al., 2020). They also support recent refinements of the intermediate disturbance hypothesis, which suggest that disturbance can enhance localized diversity while increasing variability across landscapes (Newbold et al., 2020; Blowes et al., 2022).

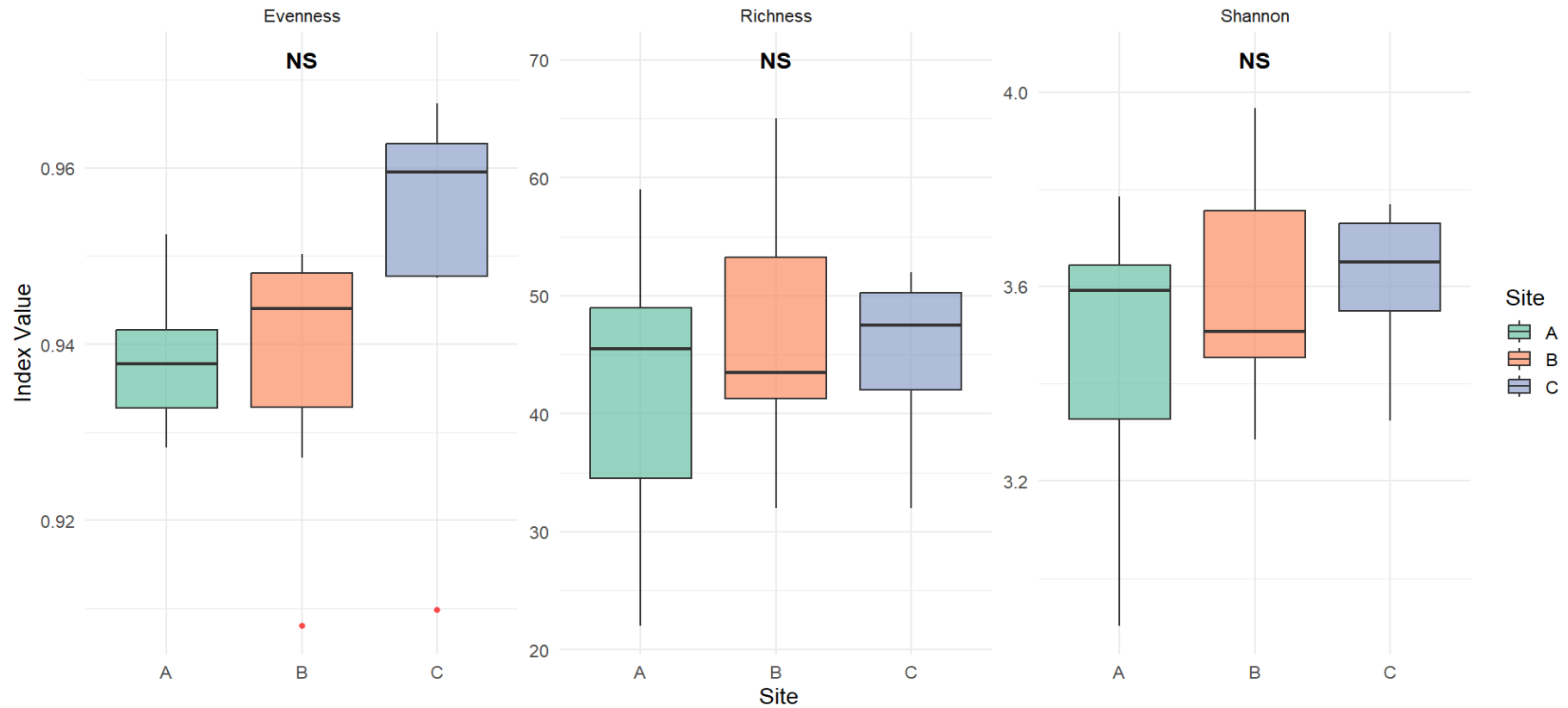


Figure 8: Diversity Metrics Across Site (A, B, C)

ANOVA Significance (* or NS)

Source: Author's Field Survey, 2025

CONCLUSION

This study evaluates plant biodiversity responses to coal mining disturbance in the coal belt areas of Kogi East, Kogi State Nigeria, using Shannon diversity, species richness, and Pielou's evenness as key ecological indicators. The findings demonstrate that undisturbed control plots consistently supported higher median diversity, richness, and evenness values with lower variability, reflecting greater ecological stability and structural maturity. In contrast, mined plots exhibited increased dispersion in plant diversity metrics, indicating heterogeneous vegetation recovery and community instability associated with mining disturbance.

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