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Impact Of Oil-Related Activities on the Abundance, and Diversity of Herbaceous Plants in Delta State, Nigeria

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ABSTRACT

This research was necessary to establish a baseline understanding of how oil-related activities in Delta State, Nigeria, impact the abundance, diversity, and conservation status of herbaceous plants, which is crucial for developing effective environmental management strategies. This study provided a detailed analysis of plant diversity and distribution patterns across five sampling locations: MW1, MW2, OE1, OE2, and CT. The inventory revealed the area's rich botanical diversity, documenting numerous plant families and species, many of which have reported medicinal uses, highlighting their value to local communities. However, the conservation status of several species remains uncertain, with many classified as "Data Deficient" or "Not Evaluated" by the IUCN, underscoring the urgent need for further conservation assessments. The quantitative analysis showed clear variations in plant abundance and community structure across the sites. The *Poaceae* family was the most abundant, with specific species like *Eleucine indica*, *Euphorbia aphylla,* and *Ipomoea eriocarpa* also showing high individual abundances. Diversity indices revealed that site MW1 generally had the highest diversity and evenness, suggesting a more balanced and complex plant community compared to other locations. Principal Coordinate Analysis (PCoA) and cluster analysis were used to explore relationships between plant species and sampling locations, providing insight into community composition and patterns of similarity and dissimilarity among sites. The study's findings provide a crucial ecological baseline for the area, informing future conservation strategies, resource management, and ongoing ecological research, particularly regarding the factors influencing plant distribution and diversity in this specific ecosystem.

1. INTRODUCTION

Indiscriminate disposal of waste petroleum hydrocarbons, particularly from mechanic workshops and oil exploration activities, significantly threatens terrestrial ecosystems. The presence of petroleum hydrocarbons disturbs the intricate balance of soil properties, affecting its physical, chemical, and biological attributes (Wang *et al*., 2009; Wang *et al*., 2013). This alteration is detrimental to soil health, resulting in increased hydrophobicity, reduced permeability, and changes in microbial

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community dynamics, ultimately leading to an inhospitable environment for plant communities (Wang *et al*., 2009; Aislabie *et al*., 2004; Klamerus-Iwan *et al*., 2015). Such contamination sets off complex weathering processes where easily degradable compounds are preferentially broken down while more persistent, toxic residuals linger, compounding the detrimental effects on soil quality (Wang *et al*., 2009; Wang *et al*., 2013).

Herbaceous plant communities, which are vital to many terrestrial ecosystems as they provide foundational ecological functions, are particularly vulnerable to these alterations. The species richness, abundance, and overall composition of these communities are often used to gauge ecological integrity, but the specific impacts of oil contamination remain underexplored, especially in regions like the Niger Delta where oil-related activities are prevalent (Olubode, 2023; Mittelbach *et al*., 2001). Studies suggest that improved understanding of these relationships is critical, as the persistence and diversity of herbaceous plants can directly affect overall ecosystem health and functionality (Olubode, 2023; Mittelbach *et al*., 2001). For instance, oil contamination can enhance competition among various species, leading to detrimental growth outcomes, where the presence of certain herbaceous species may inhibit the establishment and growth of others (Rahmadhani *et al*., 2020).

Considering the direct impact of hydrocarbon pollutants on microbial populations, there is a notable disruption of native soil microbiomes that play essential roles in nutrient cycling and organic matter decomposition (Jirasripongpun, 2002; Das and Chandran, 2011). While certain microbial communities adapt and thrive in contaminated environments, this often results in reduced overall biodiversity, as less tolerant species diminish in numbers (Aislabie *et al*., 2004). Therefore, the question of how oil-related activities affect the diversity of herbaceous plant communities becomes crucial, not only for assessing ecological damages resulting from oil pollution but also for predicting potential local extinctions of these herbaceous species due to altered habitats and diminished diversity (Olubode, 2023; Mittelbach *et al*., 2001).

The proposed study carries substantial ecological and practical relevance, offering critical insights into the environmental consequences of oil-related activities. Ecologically, the findings will furnish empirical data detailing the specific effects of oil contamination originating from disparate sources – mechanic workshops and oil exploration sites – on the diversity of herbaceous plant communities. This will contribute significantly to a more comprehensive understanding of the ecological footprint associated with these activities in the Ibadan region and potentially other similar tropical ecosystems (Connell and Sousa, 1983). Furthermore, by meticulously documenting the impacts on species richness and identifying potential declines or losses of specific herbaceous species, the study will directly address biodiversity conservation concerns, highlighting areas requiring urgent attention and informing the development of targeted strategies to mitigate the detrimental effects of oil pollution on local plant biodiversity (Myers *et al*., 2000).

Beyond immediate ecological assessment, understanding the alterations in herbaceous plant communities holds the key to predicting the long-term ecological stability and resilience of affected areas. Declines in plant diversity are often associated with reduced ecosystem functionality and increased vulnerability to subsequent disturbances,

potentially hindering natural recovery processes (Tilman, Wedin, and Knops, 1996). The identification of plant species exhibiting tolerance or sensitivity to oil contamination within this study can also directly inform the development and implementation of more effective remediation and ecological restoration strategies tailored to the specific context of oil-polluted sites in the region (NRC, 2003). This knowledge can guide the selection of appropriate plant species for revegetation efforts and the design of phytoremediation approaches.

On a broader societal level, the scientific evidence generated by this research can be instrumental in supporting the formulation and enforcement of stricter environmental regulations concerning the disposal of oil-related wastes and the management practices at oil exploration sites, potentially leading to improved environmental protection in Nigeria (UNEP, 2011). Moreover, the study has the potential to raise crucial awareness among local communities and stakeholders in Ibadan and surrounding areas regarding the often-underappreciated impacts of oil pollution on the herbaceous layer, which directly influences their local environment, agricultural practices, and access to plant-based resources, including grazing land and traditional medicines (Scoones, 1999). Finally, this research will contribute to the broader scientific understanding of the ecological impacts of hydrocarbon contamination on plant communities within tropical ecosystems, with a specific focus on the herbaceous stratum, thereby advancing ecological knowledge in this critical area (Lal, 2003).

This study aims to investigate the impact of oil-related activities by first assessing the level of petroleum hydrocarbon pollution in the soil and vegetation around mechanic workshops and oil exploration sites. It will then determine how this pollution affects herbaceous plant diversity, examining changes in species richness, evenness, and composition. The research will identify the most sensitive herbaceous species to this pollution and assess their vulnerability, while also evaluating the relationship between hydrocarbon levels and the overall plant community structure, including shifts in species abundance and dominance. Finally, the findings will be used to provide recommendations for mitigating the environmental impact and promoting sustainable ecosystem management.

2. MATERIALS AND METHODS

2.1 Site Selection

The selection of study sites was a crucial initial step in this investigation into the ecological impacts of oil-related activities on plant diversity. For the purpose of assessing these impacts, two categories of sites were designated: impacted sites and a control site. The impacted sites comprised two mechanic workshops, labeled MW1 and MW2, which exhibited clear visual evidence of indiscriminate disposal of waste petroleum hydrocarbon products on the surrounding land. Additionally, two oil exploration sites, identified as OES1 and OES2, were included due to the presence of known or readily observable oil-related activities. These activities encompassed features such as wellheads, storage facilities for petroleum products, and areas where spills or leaks may have occurred, indicating potential contamination of the surrounding environment.

In contrast to the impacted locations, a single control reference site, designated CT1, was carefully chosen to serve as a baseline for comparison. The primary criterion for selecting this control site was its location at a considerable distance from any known oil-related industrial or commercial activities,

thereby minimizing the likelihood of direct or indirect petroleum hydrocarbon contamination. Furthermore, efforts were made to ensure that the control site shared similar ecological characteristics with the impacted sites. This included matching, as closely as possible, the dominant vegetation type, soil composition, and overall topography to provide a robust basis for discerning the specific effects of oil-related activities on plant diversity at the impacted locations.

2.2 Location

The location of sampling was the following as presented in the Table below;

S/N	Sample location Code	Description	Location	GPS Coordinate
1	MW1	Mechanic workshop	Uvwie	Lat5.562860''N Long 5.811310''E
2	MW2	Mechanic workshop	Airport Road	5032'30.51744''N 5045'20.62152''E
3	OE1	Oil exploration site	Oben	6º0.5026'N/5053.0220'E
4	OE2	Oil exploration site	Oghara	Lat5º56'58'N Long5º39'58''E
5	CT	Control site	Okpe	Lat 5º38'14.89''N Long 5º 53'24.47''E

2.3 Sampling Method

The study commenced with the selection of five distinct study sites to assess the impact of oil-related activities on plant diversity. Two sites were chosen to represent impacted mechanic workshops (MW1 and MW2), exhibiting visible signs of indiscriminate dumping of waste petroleum hydrocarbon products. An additional two sites were selected to represent impacted oil exploration areas (OE1 and OE2), characterized by observable oil-related activities such as wellheads or potential spill zones. Finally, one control reference site (CT1) was carefully identified at a distance from any known oil-related activities, ensuring they shared similar vegetation types and general environmental conditions (soil type, topography) with the impacted locations. At each of these five pre-selected sites, two parallel transects were established. These transects ranged in length from 20 to 30 meters and were positioned approximately 10 to 15 meters apart to capture potential plant variations. The placement of transects at the impacted sites was guided by a perceived gradient of oil-related impact, with one end positioned within or near the area of highest visible contamination and extending outwards. For the control site, transects were placed in representative areas of the prevailing vegetation. The starting and ending points of each transect were clearly demarcated in the field using permanent

markers to ensure accurate relocation for subsequent sampling.

Following the establishment of transects, quadrat sampling was conducted systematically along each marked line. Quadrats of a standardized size, typically 1 meter by 1 meter, were placed at regular intervals along the length of each transect. The specific sampling interval was random. A total of 3 quadrats were placed on each transect, making a total of 6 quadrats per sampling location. The data obtained were pooled and mean for quadrant (per meter square) was used in the study at each designated quadrat location, all plant species present within the quadrat boundaries were carefully identified. When possible, scientific names were recorded directly in the field. For any unidentified plant specimens, voucher samples were collected, labeled with location and date, and preserved for later identification using field guides, local floras, or expert consultation. Concurrently with species identification, the abundance of each identified plant species within each quadrat was recorded. This was primarily achieved through visual estimation of the percent aerial cover, representing the proportion of the quadrat area covered by the live parts of each species. In some instances, depending on the vegetation structure, other measures of abundance such as frequency or density were also noted.

This comprehensive sampling procedure, involving the establishment of transects and systematic quadrat sampling along with detailed recording of plant species and their abundance, was consistently repeated across all five study sites, providing a dataset for comparative analysis of the impact of oil-related activities on plant diversity. A total of 5 quadrants were randomly sited within the 2 transects and data obtained were pooled to obtain a representative mean.

2.4 Data Collection within Quadrats

Within each established quadrat, a systematic data collection process was followed. The initial step involved meticulous plant identification. All plant species encountered within the boundaries of each quadrat were carefully identified. This process utilized field guides and local floras as primary resources. When necessary, consultations with a botanist were planned for verification or identification of particularly challenging specimens. To ensure accurate identification beyond the immediate field assessment, voucher specimens of all unknown species were collected. These specimens were carefully labeled with the date and location of collection and preserved for subsequent detailed examination. For each identified species, the scientific name was recorded whenever possible. In instances where the scientific name could not be immediately determined, a clear and detailed local name, accompanied by a thorough morphological description, was documented to facilitate later identification.

Following plant identification, the abundance of each recorded species within the quadrat was estimated. To ensure consistency and comparability across all sampling units, a primary method for abundance estimation was selected and strictly adhered to. Several potential methods were considered, including percent cover, frequency, and density. Percent cover, involving a visual estimation of the percentage of the quadrat area covered by the aerial parts of each species, was deemed the most practical approach for the anticipated diverse vegetation. During this estimation, care was taken to account for overlapping canopies, ensuring that the total estimated cover within a quadrat did not exceed 100%. In some instances, depending on the specific characteristics of the plant community within a given quadrat, supplementary methods such as recording the

frequency (presence or absence) of each species or counting the density (number of individual plants) of clearly distinguishable individuals (like herbs and seedlings) were also employed to provide a more comprehensive understanding of species abundance. The chosen method(s) for abundance estimation were applied uniformly across all quadrats sampled throughout the study.

2.5 Data Analyses

Using data from a total of six randomly placed quadrants within two transects, a quantitative assessment of plant diversity was conducted by calculating several key ecological indices. The Shannon-Wiener Index (H′) was used to measure species diversity by considering both the number and relative abundance of species, with a higher value indicating greater diversity. The Dominance Index (D), or Simpson's Index, was calculated to measure the probability of two randomly selected individuals belonging to the same species, where higher values indicate greater dominance by a few species; this was often expressed as the Simpson's Index of Diversity (1−D) for clearer interpretation. Species Richness (S) was determined by simply counting the total number of unique plant species identified in each sampling unit. Species Abundance was quantified using consistent methods such as percent cover, frequency, or density. All of these indices were calculated with precision using the statistical software package PAST (Paleontological Statistics Software) version 4 to ensure accurate analysis of the collected data.

3. RESULTS

Table 1 serves as a foundational inventory of the plant biodiversity within the sampled area, revealing a rich tapestry of plant families and species. This catalog underscores the variety of plant life present, which is crucial for understanding the ecological dynamics of the area and for broader conservation efforts. The detailed listing of each plant's botanical name, alongside its family, habit, and common name, provides essential taxonomic and ecological context. Such information is vital for accurate identification in future studies and for assessing the functional roles these plants play within their ecosystem.

Furthermore, the table highlights the significant potential of this flora for local communities, as evidenced by the numerous plants with documented medicinal uses. This observation suggests a long-standing relationship between the local people and the plant resources, with potential implications for traditional medicine, pharmacological research, and the sustainable use of natural resources. However, the varying IUCN statuses, ranging from "Least Concern" (LC) to "Data Deficient" (DD) and "Not Evaluated" (NE), point to a critical need for increased conservation attention. While some species are currently considered to be of lower concern, the lack of sufficient data for others underscores the urgency of conducting thorough conservation assessments to inform effective strategies for preserving this valuable plant diversity.

Table 2 presents a quantitative overview of plant distribution across the sampled locations, offering valuable insights into species abundance and community composition. Notably, several species exhibit high abundance values, suggesting their ecological dominance or adaptation to the prevailing conditions.

Eleucine indica demonstrates a considerable presence with a total abundance of 42, while *Euphorbia aphylla* and *Ipomoea eriocarpa* show even greater abundance, with 62 and 68 individuals respectively. These figures

highlight the relative success of these species within the sampled area. Furthermore, the *Poaceae* family, which includes grasses, exhibits the highest overall abundance at 242, indicating the significant role of grasses in the plant communities of these locations.

However, the table also reveals substantial variation in total abundance across the different sampling locations. This disparity implies that there are notable differences in plant density, which could be attributed to variations in environmental factors, habitat heterogeneity, or even sampling effort. Such differences in plant abundance across locations can have important ecological implications, influencing primary productivity, nutrient cycling, and overall ecosystem function. Further analysis, incorporating environmental data and spatial considerations, would be necessary to fully understand the factors driving these observed patterns in plant distribution and abundance.

Table 3 provides a quantitative assessment of plant diversity across the five sampling sites, utilizing several ecological indices to capture different facets of community structure. Notably, species richness, a fundamental measure of diversity, varies among the sites, with MW1 exhibiting the highest richness (50 species) and OE2 the lowest (39 species). This disparity suggests that MW1 harbors a more diverse array of plant species compared to OE2. However, diversity is not solely determined by the number of species; their relative abundance also plays a crucial role. The Shannon diversity index (Shannon_H), which incorporates both species richness and evenness, further supports this observation, with MW1 demonstrating the highest Shannon diversity (3.733), indicative of a more diverse community structure, while OE2 shows the lowest (3.32).

In addition to species richness and Shannon diversity, the table also highlights differences in evenness among the sampling sites. Evenness, quantified here as Evenness_e^H/S, reflects the equitability of species distribution, with values closer to 1 indicating a more even distribution of individuals among species. MW1 displays the highest evenness (0.8361), suggesting a relatively balanced community where no single species dominates In contrast, OE1 exhibits the lowest evenness (0.6344), implying that certain species are more dominant, leading to a less equitable distribution. Overall, the suite of diversity indices presented in Table 3 paints a picture of MW1 as consistently exhibiting higher diversity and evenness, indicative of a more complex and balanced plant community structure, whereas OE2 tends towards lower diversity and less even distribution.

Figures 1 and 2 employ Principal Coordinate Analysis (PCoA) to provide a visual representation of the relationships between plant species and sampling locations, offering insights into community composition and distribution patterns. PCoA is a dimensionality reduction technique that transforms complex ecological data into a more easily interpretable graphical format, allowing for the visualization of similarities and dissimilarities.

Specifically, Figure 1 uses PCoA to illustrate the relationships between individual plant species and their distribution across the various sampling locations. In this type of plot, each point represents a plant species, and the proximity of points to one another reflects the similarity in their occurrence patterns. If species points are clustered together, it suggests that these species tend to be found in similar locations, indicating shared habitat preferences or ecological associations. Conversely, if the species points are widely scattered, it implies that different species exhibit distinct distribution patterns, with some being more prevalent in certain

locations and less so in others. This visualization aids in identifying groups of species that co-occur and those that are more spatially segregated.

Figure 2, on the other hand, utilizes PCoA to depict the relationships between the sampling locations themselves,

Table 1: List of plants present in the sample area, their uses and IUCN statuses.

Botanic Name	Family	Habit	Common name	Use	IUCN Status
Abelmoschus esculentus	Malvaceae	Herb	Okro	Vegetables	LC
Abrus precatorius	Fabaceae	Herb	Crab's Eye	Medicine	NA
Acrostichum aureum	Pteridaceae.	Herb	Golden leather	Used for trapping crayfish	NA
Aeschynomene indica	Fabaceae	Herb	Curly indigo	fodder	LC
Aframomum daniellii	Zingiberaceae	Herb	Alligator pepper	Ornamental, medicine	LC
Ageratum conyzoides	Asteraceae	Herb	Goat Weed	Medicine	NA
Amaranthus viridis	Amaranthaceae	Herb	Amaranthus	Vegetables	LC
Amaranthus spinosus	Amaranthaceae	Herb	Amaranthus	Vegetables	LC
Ananas comosus	Bromeliaceae	Herb	Pine Apple	Food, medicine	NA
Anchomanes difformis	Araceae	Herb	Forest Anchomanes	Medicine	NA
Argemone Mexicana	Papaveraceae	Herb	Mexican Poppy	Medicine	NA
Arthraxon hispidus	Poaceae	Herb	Hairy Joint grass	Medicine	NA
Aspilia Africana	Asteraceae	Herb	Haemorrhage Plant	Medicine	NA
Athyrium otophorum	Athyriaceae,	Herb	Large leaf Fern	Medicine	NA
Axonopus compressus	Poaceae	Herb	Carpet grass	Grasses	LC
Bambusa vulgaris	Poaceae	Herb	Bamboo	Building, furniture, fodder	LC
Boerhavia diffusa	Nyctaginaceae	Herb	Pig weed	Weed	LC
Calathea lutea	Marantaceae	Herb	Cuban cigar	For wrapping food	NA
Calopogonium mucunoides	Fabaceae	Climber	Calapo	Legumes	NE
Capsicum annuum	Solanaceae	Herb	Red pepper	Food	LC
Cardiospermum halicacabum	Sapindaceae	Herb	Baloon Vine	Medicine	NA
Carica papaya	Caricaceae	Herb	Pawpaw	Food, Medicine	NA
Centrosema pubescence	Fabaceae	Herb	Centro	Legumes	LC
Cercestis afzelii	Araceae	Herb	Cercetis	Medicine	NA
Cissus populnea	Amplidaceae (Vitaceae)	Herb	Stemmed Vine	Medicine	NA
Colocosia esculenta	Araceae	Herb	Cocoyam	Food	LC
Commelina benghalensis	Commelinaceae	Herb	tropical spiderwort	Weed, Medicine	LC
Corchorus capsularis	Malvaceae	Herb	Jute	Fiber	NE
Costus afer	Costaceae	Herb	Ginger Lilly	Medicine	LC

Cymbopogon citratus	Poaceae	Herb	Lemon grass	Medicine	DD
Cynodon plectostachyus	Poaceae	Herb	Giant Star Grass	Grasses	LC
Cyperus articulatum	Cyperaceae	Herb	Guinea Rush	Weed, grasses, lawn	NA
Cyperus esculentus	Cyperaceae	Herb	Nut Grass	Weed, grasses, lawn	NA
Cyperus ligularis	Cyperaceae	Herb	Mbew	Weed	NA
Cyrtosperma senegalense	Araceae	Herb	Swamp-arum	Weed	NA
Dioscorea bulbifera	Dioscoreaceae	Herb	Aerial Yam	Food, Medicne	NA
Dioscorea dumetorum	Dioscoreaceae	Herb	Wild Yellow Yam	Food, Medicne	NA
Eleucine indica	Poaceae	Herb	Stubborn grass	Grasses	LC
Elipta alba	Asteraceae	Herb	Field aster	Medicine	NE
Emilia coccinea	Asteraceae	Herb	Tassel flower	Medicine	DD
Euphorbia aphylla	Euphorbiaceae	Herb	Euphorbia	Medicine	NA
Euphorbia hirta	Euphorbiaceae	Herb	Garden spurge	Medicine	NE
Fimbristylis ferruginea	Cyperaceae	Herb	Rusty sedge	fodder	LC
Fimbristylis littoralis	Cyperaceae	Herb	Fimbry	fodder	LC
Fuirena ciliaris	Cyperaceae	Herb	Umbrella grass	fodder	LC
Gomphrena serrata	Amaranthaceae	Herb	Globe Amaranth	Medicine	DD
Icacina trichantha	Icancinaceae	Herb	False Gum	Medicine	DD
Imperata cylindrica	Poaceae	Herb	Spear grass	Grasses	LC
Indigofera spicata	Fabaceae	Herb	Creeping indigo	fodder	NE
Ipomoea aquatica	Convolvulaceae	climber	Swamp morning glory	fodder	LC
Ipomoea cordatotriloba	Convolvulaceae	climber	Purple bindweed	fodder	LC
Ipomoea eriocarpa	Convolvulaceae	climber	Tiny morning glory	fodder	LC
Ipomoea involucrata	Convolvulaceae	Herb	Close to the ground	Medicine	NA
Marantochloa cuspidata	Marantaceae	Herb		Medicine	NA
Mimosa pudica	Fabaceae	Herb		ornamental	LC
Musa sapientum	Musaceae	Herb	Banana	Food	NA
Musa paradisiaca	Musaceae	Herb	Plantain	Food	NA
Nephrolepis biserata	Nephrolepidaceae	Herb			NE
Nymphaea lotus	Nymphaeaceae	Herb		fodder	NA
Nymphaeaceae salisb	Nymphaeaceae	Herb	Water lilies	Weed	LC
Panicum maximum	Poaceae	Herb	Guinea grass	Grasses	NE
Panicum repens	Poaceae	Herb	Torpedo grass	fodder	LC
Paspalum orbiculare	Poaceae	Grass	Rice Grass	-	NA
Paspalum vaginatum	Poaceae	Grass	Biscuit Grass	-	NA
Passiflora foetida	Passifloraceae	Herb	Stinking Passion Flower		NA
Pennisetum purpureum	Poaceae	Herb	Elephant grass	Grasses, fodder	NE
Phyllanthus amarus	Euphobiaceae	Herb	Carry me seed	Medicine	NA

Phyllanthus niruri	Euphorbiaceae	Herb	Stone breaker	Medicine	NA
Rottboellia cochinchinensis	Poaceae	Grass	Alligator weed	Fooder	NA
Saba florida	Apocynaceae	Liana	Saba		NA
Setaria sp.	Poaceae	Grass	Bristle Grass	Fodder	NA
Sida acuta	Malvaceae	Herb	Hornbean Leaf	Medicine, Weed	NA
Smilax kraussiana	Smilacaceae	Liana		Medicine	LC
Talinum triangulare	Portulacaceae	Herb	Waterleaf	Food	NA
Telfairia occidentalis	Cucurbitaceae	Herb	Pumpkin	Food, medicine	NA
Thaumatococcus daniellii	Marantaceae	Herb	Miracle berry	Medicine, packaging	NA
Tridax procumbens	Asteraceae	Herb	Tridax	Weeds	NE
Xanthosoma sp.	Araceae	Herb	Cocoyam	Food	NA

based on their overall plant species composition. In this plot, each point represents a sampling location, and the distance between points reflects the degree of similarity or dissimilarity in their plant communities. If location points are situated close to each other on the plot, it indicates that these locations share similar species composition, suggesting similar environmental conditions or connectivity. Conversely, if location points are far apart, it implies that their species composition is markedly different, reflecting distinct ecological characteristics or spatial separation. This visualization is valuable for understanding landscape-scale patterns in community structure and for identifying locations that are ecologically similar or distinct.

The analysis of the plant community's structure and diversity was visualized through three key figures. A cluster diagram (Figure 3), or dendrogram, was used to display the relationships between sampling locations. This diagram groups sites based on the similarity of their plant species composition, with locations joined at lower branches indicating greater similarity due to shared ecological characteristics. Conversely, sites connected at higher branches are more dissimilar, allowing for the identification of distinct ecological groupings.

A rarefaction curve (Figure 4) and a diversity family plot (Figure 5) provided a more detailed look at species richness and overall diversity. The rarefaction curve, by plotting the number of species against the number of individuals sampled, indicated the completeness of the sampling effort; if the curve plateaued, it suggested that most species had been identified. The diversity family plot offered a comprehensive view of community structure by simultaneously presenting multiple diversity indices, such as richness, evenness, and dominance. This approach allows for a more nuanced understanding of how different aspects of biodiversity vary across sites.

Table 4 summarizes the abundance of plants at the family level across all sampled locations. The Poaceae family (grasses) was the most abundant overall, highlighting its ecological importance. Other families with high representation included Araceae,

Euphorbiaceae, and Cyperaceae. In contrast, families like Costaceae and Solanaceae had very low abundances. Interestingly, some families, including Poaceae, Araceae, and Asteraceae, were found at every site, indicating their widespread distribution.

Table 2: Plant abundance within the sampling areas

Botanic Name	MW1	MW2	OE1	OE2	CT	TOTAL
Abelmoschus esculentus	3	0	5	2	0	10
Abrus precatorius	1	3	2	0	4	10
Acrostichum aureum	0	3	11	25	1	40
Aeschynomene indica	2	4	0	5	0	11
Aframomum daniellii	6	2	35	0	0	43
Ageratum conyzoides	5	0	11	0	0	16
Amaranthus viridis	0	2	24	0	5	31
Amaranthus spinosus	0	4	0	0	0	4
Ananas comosus	1	2	3	0	0	6
Anchomanes difformis	2	1	6	0	5	14
Argemone Mexicana	5	0	0	0	0	5
Arthraxon hispidus	0	3	0	0	5	8
Aspilia Africana	2	0	1	0	7	10
Athyrium otophorum	3	5	11	0	0	19
Axonopus compressus	0	6	0	0	0	6
Bambusa vulgaris	0	0	0	0	14	14
Boerhavia diffusa	3	7	3	0	8	21
Calathea lutea	0	8	6	0	2	16
Calopogonium mucunoides	0	13	2	0	0	15
Capsicum annuum	5	0	0	0	0	5
Cardiospermum halicacabum	0	2	1	0	0	3
Carica papaya	6	0	1	1	5	13
Centrosema pubescence	0	4	0	2	7	13
Cercestis afzelii	0	4	0	4	24	32
Cissus populnea	7	6	0	2	0	15
Colocosia esculenta	0	0	0	2	0	2
Commelina benghalensis	8	6	0	6	2	22
Corchorus capsularis	6	0	0	0	32	38
Costus afer	0	3	0	0	4	7
Cymbopogon citratus	0	4	22	2	6	34
Cynodon plectostachyus	6	0	31	0	2	39
Cyperus articulatum	0	1	15	0	0	16
Cyperus esculentus	0	4	3	2	31	40
Cyperus ligularis	6	0	3	3	6	18
Cyrtosperma senegalense	3	3	1	14	6	27
Dioscorea bulbifera	3	0	6	2	9	20
Dioscorea dumetorum	5	0	0	31	0	36
Eleucine indica	17	12	4	6	3	42
Elipta alba	6	4	0	0	3	13
Emilia coccinea	0	0	3	11	0	14
Euphorbia aphylla	6	5	43	6	2	62

Euphorbia hirta	0	22	0	2	0	24
Fimbristylis ferruginea	4	0	8	7	0	19
Fimbristylis littoralis	0	4	5	0	11	20
Fuirena ciliaris	2	0	0	9	4	15
Gomphrena serrata	5	6	0	0	0	11
Icacina trichantha	0	4	0	5	3	12
Imperata cylindrica	5	2	4	3	0	14
Indigofera spicata	3	6	2	0	7	18
Ipomoea aquatica	1	0	0	0	0	1
Ipomoea cordatotriloba	2	6	0	0	13	21
Ipomoea eriocarpa	0	6	6	3	53	68
Ipomoea involucrata	1	0	33	8	0	42
Marantochloa cuspidata	3	6	9	0	7	25
Mimosa pudica	5	0	0	0	5	10
Musa sapientum	0	1	7	7	7	22
Musa paradisiaca	3	0	0	3	0	6
Nephrolepis biserata	0	0	5	0	3	8
Nymphaea lotus	3	3	6	3	0	15
Nymphaeaceae salisb	2	0	0	4	7	13
Panicum maximum	0	0	4	8	9	21
Panicum repens	2	4	0	7	2	15
Paspalum orbiculare	2	1	0	4	0	7
Paspalum vaginatum	2	0	5	3	2	12
Passiflora foetida	3	0	0	3	7	13
Pennisetum purpureum	0	0	0	0	3	3
Phyllanthus amarus	8	12	0	0	0	20
Phyllanthus niruri	2	23	12	9	14	60
Rottboellia cochinchinensis	5	0	5	4	5	19
Saba florida	0	3	5	11	4	23
Setaria sp.	4	0	0	0	4	8
Sida acuta	2	2	5	0	5	14
Smilax kraussiana	5	5	7	0	0	17
Talinum triangulare	8	0	0	0	5	13
Telfairia occidentalis	3	5	0	3	0	11
Thaumatococcus daniellii	0	0	6	0	0	6
Tridax procumbens	0	3	4	2	6	15
Xanthosoma sp.	2	4	2	0	0	8
TOTAL	204	249	393	234	379	

Table 5 presents a quantitative analysis of the dissimilarity between plant communities using Euclidean distance. A larger distance value indicates a greater difference in species composition between two sites, while a smaller value suggests higher similarity. For example, the distance between locations MW1 and MW2 was 57.507, which is less than the distance between MW1 and OE1 (79.881), showing that MW1 and MW2 are more similar. The highest dissimilarity was found between MW2 and CT, with a distance of 100.27, indicating these two sites had the most distinct plant communities.

4. Discussion

This study provides a comprehensive overview of plant diversity and distribution within the sampled area, highlighting key

Table 3: Diversity indices of plant species available in the 5 sampling sites

	MW1	MW2	OE1	OE2	CT
Taxa_S	50	48	45	39	47
Individuals	204	249	393	234	379
Dominance_D	0.02859	0.03624	0.04972	0.05099	0.04953
Simpson_1-D	0.9714	0.9638	0.9503	0.949	0.9505
Shannon_H	3.733	3.601	3.352	3.32	3.433
Evenness_e^H/S	0.8361	0.7631	0.6344	0.7092	0.6591
Brillouin	3.368	3.299	3.156	3.055	3.22
Menhinick	3.501	3.042	2.27	2.55	2.414
Margalef	9.214	8.518	7.365	6.966	7.747
Equitability_J	0.9543	0.9302	0.8804	0.9062	0.8917
Fisher_alpha	21.13	17.69	13.11	13.36	14.13
Berger-Parker	0.08333	0.09237	0.1094	0.1325	0.1398

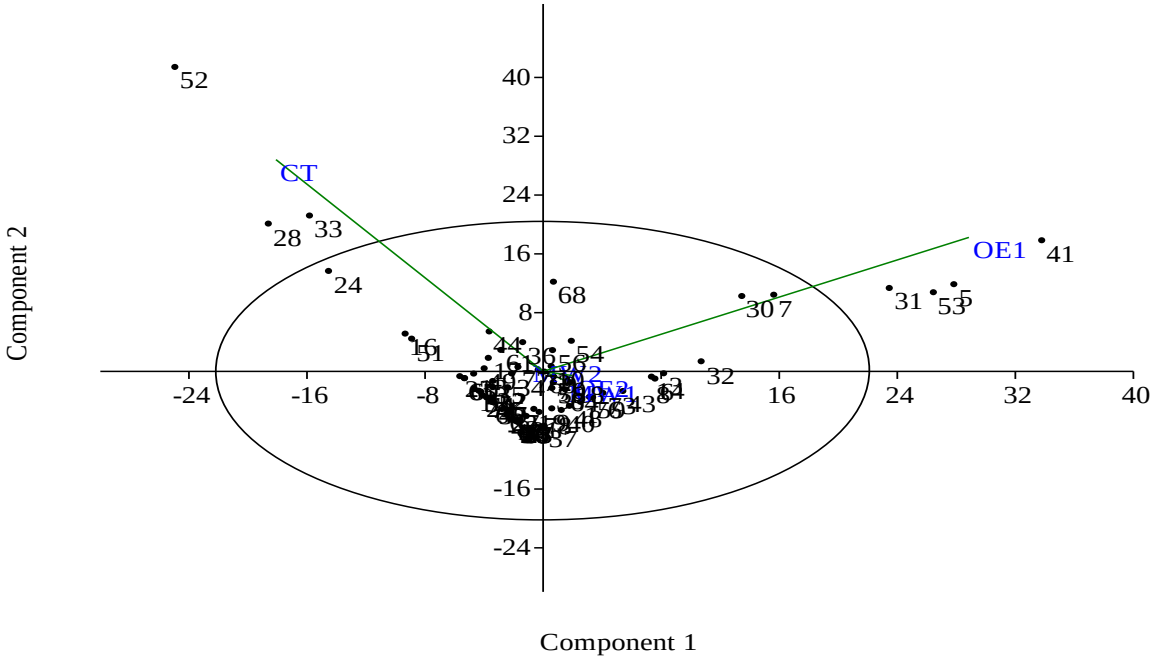

Figure 1: Principal coordinate scatter diagram showing relationship between plant species and their sampling locations

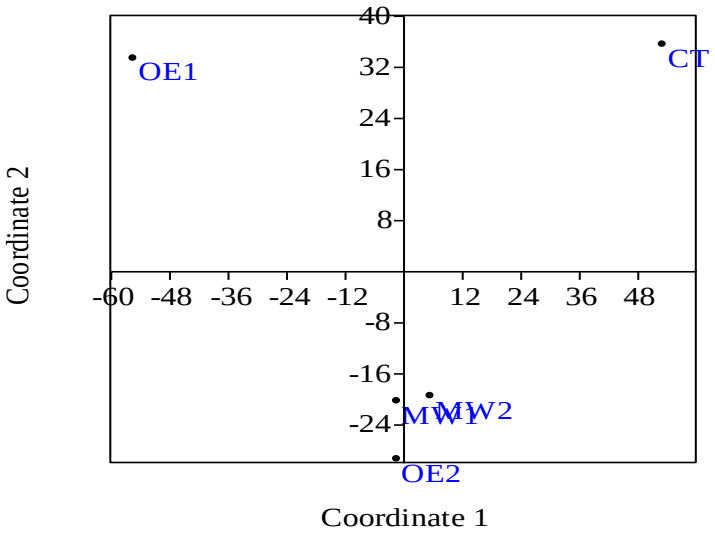

Figure 2: Principal coordinate scatter diagram showing relationship between sampling locations

ecological patterns and potential conservation concerns. The foundational inventory reveals a rich tapestry of plant families and species, underscoring the variety of plant life crucial for understanding the area's ecological dynamics. The detailed listing of botanical names, families, habits, and common names offers essential taxonomic and ecological context, vital for future identification and functional assessments within the ecosystem. Such inventories are fundamental to ecological research and conservation planning, as they establish a baseline for monitoring changes in plant communities over time (Magurran, 2004).

The prevalence of plants with documented medicinal uses indicates a potentially significant relationship between local communities and plant resources. This observation aligns with studies highlighting the importance of traditional ecological knowledge and the role of plants in local healthcare practices (e.g., Cox, 1994). Traditional medicine often relies heavily on locally available plant species, and documenting these uses can have implications for pharmacological research and the sustainable use of natural resources. However, the varying IUCN statuses, from "Least Concern" to "Data Deficient" and "Not Evaluated," underscores the need for increased conservation attention to ensure the preservation of this valuable plant diversity. The lack of sufficient data for some species highlights the urgency for thorough conservation assessments, as species with insufficient information may be at risk of decline or extinction without proper management (IUCN, 2022).

The quantitative overview of plant distribution reveals variations in species abundance and community composition across sampling locations. The high abundance of species like *Eleucine indica*, *Euphorbia aphylla*, and *Ipomoea eriocarpa* suggests their ecological dominance or adaptation to local conditions. Dominance by a few species is a common pattern in plant communities, often influenced by resource availability and disturbance regimes (Whittaker, 1972). The *Poaceae* family's overall abundance indicates the significant role of grasses in these plant communities,

which is consistent with the global importance of grasses in many ecosystems (Gibson, 2009). The substantial variation in total abundance across sampling locations points to differences in plant density, potentially influenced by environmental factors, habitat heterogeneity, or sampling effort. These variations can have important ecological implications, affecting primary productivity, nutrient cycling, and ecosystem function, emphasizing the need for further analysis incorporating environmental data.

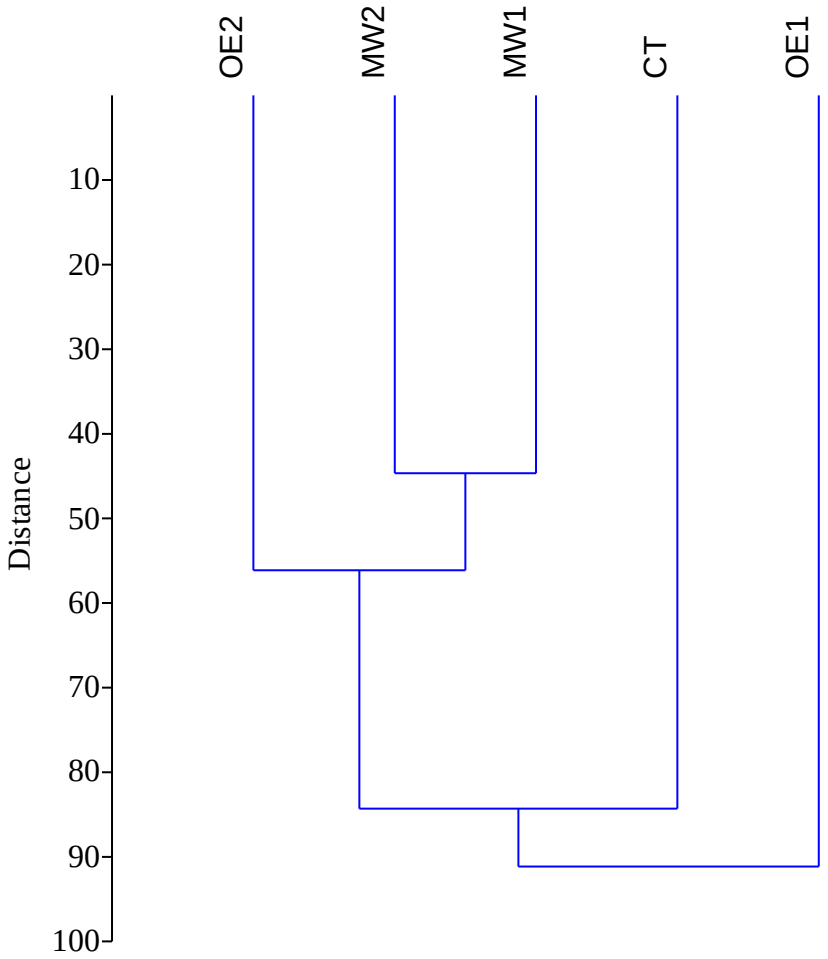

Figure 3: Cluster diagram showing relationship between sampling locations

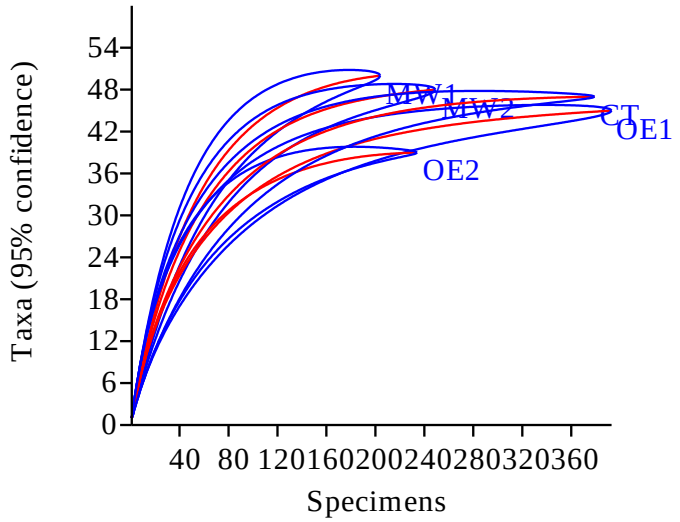

Figure 4: Rarefraction curve

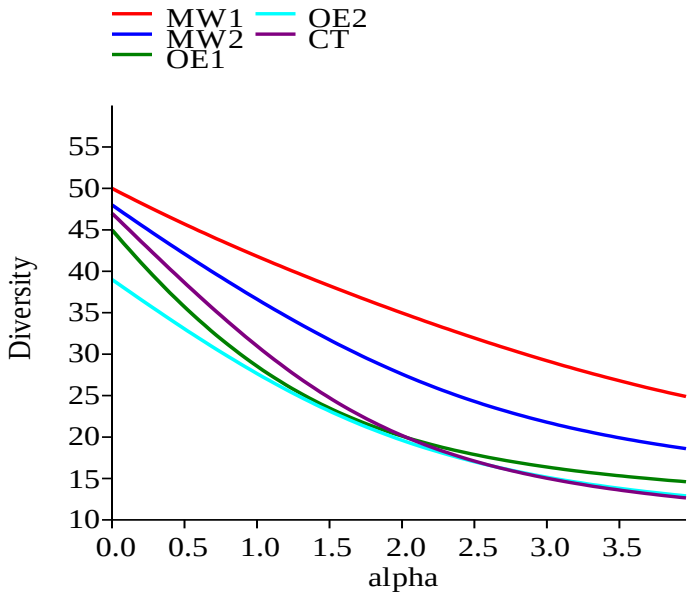

Figure 5: Diversity family

Table 4: Species abundance st the level of plant family

Family	**MW1**	**MW2**	**OE1**	**OE2**	**CT**	**Total**	**Freq. of occurrence**
Amaranthaceae	5	12	24	0	5	46	0.8
Amplidaceae (Vitaceae)	7	6	0	2	4	19	0.8
Apocynaceae	0	3	5	11	5	24	0.8
Araceae	7	12	9	20	30	78	1.0
Asteraceae	13	7	19	13	16	68	1.0
Athyriaceae,	3	5	11	0	0	19	0.6
Bromeliaceae	1	2	3	0	5	11	0.8
Caricaceae	6	0	1	1	2	10	0.8
Commelinaceae	8	6	0	6	0	20	0.6
Convolvulaceae	4	12	39	11	70	136	1.0
Costaceae	0	3	0	0	0	3	0.2
Cucurbitaceae	3	5	0	3	0	11	0.6
Cyperaceae	12	9	34	21	61	137	1.0
Dioscoreaceae	8	0	6	33	0	47	0.6
Euphorbiaceae	16	62	55	17	20	170	1.0
Fabaceae	11	30	6	7	22	76	1.0
Icancinaceae	0	4	0	5	32	41	0.6
Malvaceae	11	2	10	2	7	32	1.0
Marantaceae	3	14	21	0	14	52	0.8
Musaceae	3	1	7	10	3	24	1.0
Nephrolepidaceae	0	0	5	0	8	13	0.4
Nyctaginaceae	3	7	3	0	0	13	0.6
Nymphaeaceae	5	3	6	7	7	28	1.0
Papaveraceae	5	0	0	0	7	12	0.4
Passifloraceae	3	0	0	3	5	11	0.6
Poaceae	43	32	75	37	55	242	1.0
Portulacaceae	8	0	0	0	1	9	0.4
Pteridaceae.	0	3	11	25	0	39	0.6
Sapindaceae	0	2	1	0	0	3	0.4
Smilacaceae	5	5	7	0	0	17	0.6
Solanaceae	5	0	0	0	0	5	0.2
Zingiberaceae	6	2	35	0	0	43	0.6
Total	204	249	393	234	379		

Table 5: Similarity and distance indices (by Euclidean distance)

	MW1	MW2	OE1	OE2	CT
MW1	0	57.507	79.881	46.519	95.755
MW2	57.507	0	75.379	71.056	100.27
OE1	79.881	75.379	0	87.023	84.546
OE2	46.519	71.056	87.023	0	93.354
CT	95.755	100.27	84.546	93.354	0

The diversity indices offer a quantitative assessment of plant diversity. The differences in species richness, with MW1 exhibiting the highest richness and OE2 the lowest, suggest variations in community complexity across sites. Species richness is a fundamental component of biodiversity and is often used as an indicator of ecosystem health (Hooper *et al*., 2005). MW1's higher Shannon diversity compared to OE2 further supports this observation, indicating a more diverse community structure. The Shannon index incorporates both species richness and evenness, providing a more comprehensive measure of diversity (Shannon and Weaver, 1949). The higher evenness observed in MW1 suggests a more balanced community, while the lower evenness in OE1 implies greater species dominance. High evenness is often associated with more stable and resilient communities (Tilman, 1996).

Principal Coordinate Analysis (PCoA) visually represents the relationships between plant species and sampling locations, providing insights into community composition and distribution patterns. Figure 1 illustrates species distribution across locations, with clustered points indicating similar occurrence patterns and scattered points suggesting distinct distributions. This visualization is valuable for identifying co-occurring species and those with spatial segregation. Figure 2 depicts the relationships between sampling locations based on species composition, with closer points indicating similar communities and distant points reflecting distinct ecological characteristics. These PCoA results contribute to understanding landscape-scale patterns in community structure. PCoA is a useful tool for visualizing complex ecological data and identifying underlying gradients in community composition (Legendre and Legendre, 2012).

The cluster diagram further elucidates the relationships between sampling locations based on plant community similarity. Locations clustered closer together exhibit greater similarity, suggesting shared ecological characteristics, while those in distant branches are more dissimilar. This hierarchical representation aids in identifying distinct groups of locations and broad-scale patterns in community structure. Cluster analysis is a common method for classifying ecological communities and identifying groups of sites with similar species composition (McCune and Grace, 2002).

The rarefaction curves provide insights into species richness and sampling completeness. The plateauing of a curve suggests that sampling has captured most species, while a rising curve indicates that more species could be found with further sampling. Comparing curve heights allows for relative richness comparisons between locations. Rarefaction is a crucial technique for comparing species richness across samples with different sample sizes (Gotelli and Colwell, 2001). The diversity family visualizes different diversity measures, offering a nuanced comparison of diversity patterns using various indices. Comparing the values and trends of different lines representing different indices allows for a more robust assessment of biodiversity. Using a diversity family provides a more comprehensive view of diversity than relying on a single index (Hill, 1973).

The summary of plant abundance at the family level reveals dominant plant groups and their distribution patterns. The *Poaceae* family's high abundance highlights the ecological significance of grasses. Other families with high abundances include *Araceae*, *Euphorbiaceae*, and *Cyperaceae*. Some families, such as *Costaceae* and *Solanaceae*, have low abundances and

limited distribution, while families including *Poaceae*, *Araceae*, *Asteraceae*, *Convolvulaceae*, *Cyperaceae*, and *Euphorbiaceae* occur at every site. Plant families often have distinct ecological traits, and analyzing abundance at this level can provide insights into ecosystem function and evolutionary relationships (Cronquist, 1981).

The analysis of dissimilarity between plant communities at different sampling locations using Euclidean distance quantifies the differences in species composition. Larger distance values indicate greater dissimilarity. For example, the distance between MW1 and OE1 is greater than that between MW1 and MW2, indicating that MW1 and MW2 are more similar. The highest distance between MW2 and CT suggests these sites have the most distinct plant communities. Euclidean distance is a commonly used metric for measuring ecological dissimilarity (Legendre and Legendre, 2012).

This study's findings contribute to a broader understanding of plant diversity and distribution patterns, providing a basis for conservation planning and future ecological research. Further investigations should explore the environmental factors influencing community structure and the functional roles of different plant species within this ecosystem.

5. CONCLUSION

Based on the analysis of plant diversity, distribution, and community structure across the sampled locations, this study reveals significant ecological patterns and highlights areas of conservation importance. The inventory of plant species underscores the richness of plant life, with many species having medicinal uses, indicating their potential value to local communities. However, the varying IUCN statuses, including Data Deficient and Not Evaluated, point to the need for further conservation assessments to ensure the preservation of this plant diversity. Variations in plant abundance and community composition were observed across the sampling sites, with some species exhibiting ecological dominance. Diversity indices revealed differences in species richness and evenness, suggesting variations in community complexity and structure. Principal Coordinate Analysis and cluster analysis provided further insights into the relationships between plant species and sampling locations, highlighting patterns of community similarity and dissimilarity.

The findings of this study contribute to a broader understanding of plant diversity and distribution, providing a basis for conservation planning and future ecological research. Further investigations are recommended to explore the environmental factors influencing community structure and the functional roles of different plant species within the ecosystem.

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