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TREE SPECIES DIVERSITY AND SOIL MACROFAUNA IN RELATION TO SOIL PHYSICOCHEMICAL PROPERTIES IN FOREST RESERVE AND DISTURBED SITE OF MALADUMBA, BAUCHI STATE, NIGERIA

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ABSTRACT

Human disturbance is one of the major threats to Maladumba Forest Reserve. Assessing tree species and macro soil fauna diversity associated with soil properties in protected and disturbed sites can inform sustainable management for conserving biodiversity and ecosystem functions in tropical forest. Woody plants with a diameter at breast height of ≥10 cm were identified, recorded; the tree basal area were calculated. Soil samples were collected using a soil auger at 1-15 cm depth during the peak rainy season in 2024 for examined physical and chemical properties. Soil macro fauna was identified, counted and recorded based on morphological characteristics. Shannon Diversity Index was used to calculate the Soil Macro fauna while T. Test was employed to compare soil properties between sites, and correlation analysis to determine relationships between the soil properties and tree species distribution and soil macro fauna diversity. A total of 53 individuals (13 families) and 12 individuals (12 families) tree species were recorded from the protected and disturbed sites respectively. Tree diversity was higher in the protected area (3.93) compared to the disturbed site (1.63), with the highest tree distribution (41.51%) found in the 81cm and above. Soil macrofauna counts were 282 (11 families) in the protected and 202 (11 families) in the disturbed sites while Soil macrofauna diversity was 2.60 and 1.32 respectively. Soil pH and aluminum showed significance across sites, while the dominant soil type in both are sandy loam. Protected sites showed higher tree diversity and soil macrofauna diversity compared to disturbed sites. Enforcement of protection strategies and sustainable management practices will maintain biodiversity, ecosystem health, and soil quality.

Keywords: Tree Species Diversity, Soil Macrofauna, Soil Physicochemical, Protected and Disturbed

INTRODUCTION

Forests play an important role in protecting the soil, water resources and ameliorating the environment (Raj *et al,* 2020; Salami and Akinyele, 2023). Forest soils in particular play a vital role in determining the sustainable productivity of the forest ecosystems (Cui *et al.,* 2026). Soil fertility changes and the nutrient balances are taken as key indicators of forest ecosystem quality (Zhang *et al.,* 2026). Hence, forest lands with good physical and chemical characteristics are essential in maintaining productivity in terrestrial ecosystems and driving processes that maintain environmental quality (Locke *et al.,* 2026) and sustainability. Presently, forest is a threatened natural resource. Anthropogenic activities such as over-exploitation, overgrazing, inappropriate clearing techniques and unsuitable land-use practices have resulted in severe soil nutrient decline and decrease in productivity (Gupta *et al.,* 2026). It is further widely established that, human activities are increasingly altering the ways in which energy and elements cycle within and between ecosystems including forests (Tonkin *et al.,* 2026). Human-driven deforestation causes increased losses of carbon, nitrogen, phosphorus, and Tetraoxo-sulphate (vi) oxide from terrestrial ecosystems. Losses of these elements following deforestation are most rapid in sites with high decomposition rates, especially on fertile soils (Popin *et al.*, 2026).

Over the past century tropical forests have been suffering from exceptional rates of change as they are degraded or destroyed by human activities (Gaikwad and Vijayalakshmi, 2026). Over harvesting of timber could have significant ecological consequences including losses in biodiversity and soil quality (Zaman *et al,* 2010). In recent years, much attention has been paid to understanding the impact of timber harvesting on soil physical and chemical properties in general and on soil fertility in particular. Many studies have reported that cutting of forests deteriorates soil physical and chemical properties including losses of organic matter nitrogen (N), phosphorus (P), potassium (K) and minerals (Dymov, 2023). As a result, the savanna of northern Nigeria continues to experience major biophysical environmental degradations closely associated with such activities as commercial and artisanal logging, large scale land conversion, fuel wood and charcoal production, slash and burn agriculture, grazing, harvesting of non-timber forest products, hunting and mining (Isah, 2023). Macro fauna is the most conspicuous group of organisms which have great potential to modify the soil environment through their activities. Earthworms and termites are widely recognized for their role in soil structure formation, organic matter incorporation and decomposition and nutrient mineralization (Bonini *et al.,* 2023). Byers, (2024) considered these organisms as "ecosystem engineers'', which are defined as organisms that directly or indirectly modulate the availability of resources to other species, by causing physical state changes in biotic or abiotic materials; in so doing they modify, maintain and create habitats. Soil biota plays an essential role in ecosystem functioning, especially in biogeochemical cycles (Zaman *et al,* 2025) with feedback on tree species, diversity, abundance, succession (Bardgett and Van der Putten, 2014) and productivity. In

Nigeria, forested area consisting of a single tree species has decreased annually over the last 15 years (Yahaya, 2026) and today about 70 percent of European forests are dominated by two or more tree species (Retez *et al.,* 2026). However, information about the effects of land use changes on soil physico-chemical properties is essential in order to present appropriate recommendations for optimal and sustainable utilizations of land resources.

MATERIALS AND METHODS

Description of the Study Area

Maladumba forest reserve is located in Maladumba-Misau, Misau local Government Area of Bauchi State. It is approximately 18 km South-West of Misau town, in Bauchi State. It has an area of approximately 120 km^2. It has a Sudan type of climate with two distinct seasons, a short, wet season that span across May –September and a longer dry season from October- April. Its average annual rainfall is about 800mm with unimodal distribution during the rainy season July and August marks the highest peak of the wet season and the rainfall is characterized by storm with high intensity mean temperature ranges from 26-34^{o}C during the hot months as April and May (Olanipon *et al.,* 2025). The dry season is dominated by dusty north easterly Harmattan winds. Vegetation of Maladumba forest reserve is the Sudan savannah vegetation type which is characterized by open deciduous woodland with common species such as *Isoberlinia doka, Anogeissus leiocarpus, Balanites spp* and *Combretum spp*. The region has been much affected by clearance for agriculture, fire and cutting for wood and charcoal. Most of the remaining natural habitat is found only in the protected area, there are areas and should contribute to the conservation of such areas (Arbain et al., 2026).

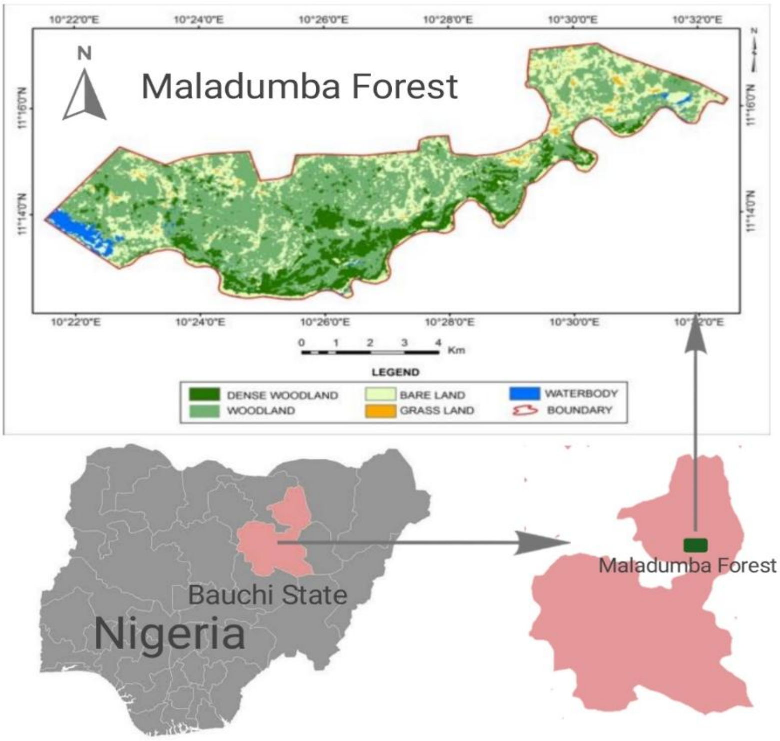

Figure 1: Map of the Study Area
Source: Bauchi Ministry of Environment, 2023

Data Collection

Species Identification and Diameter at the Breast Height Measurement

Measurement and identification of all woody plants with diameter at breast height of 10 cm and above were assessed. The tree growth variables were limited to diameter at breast height of all the standing trees in the forest. The botanical name of every living tree encountered in each sample plot was recorded. Where a tree's botanical name is not known immediately, such a tree was identified by its commercial or local name. Such commercial or local names were translated to correct botanical names using (Gbile and Soladoye, 2002). Trees that could not be identified were tagged 'unknown. Each tree species was recorded individually in the field forms and possible effort was made not to omit any eligible stem in a sample plot. Mean volume for sample plots was calculated by dividing the total plot by the number of sample plots.

Soil Sample Collection

Dutch auger was used to collect soil samples from the study sites, and the samples were collected in peak rainy season in the year 2024 and used for the soil sampling. The samples were collected at depths (1-15cm depth) each. Soil samples were determined in Maladumba Forest Reserve and a disturbed site by establishing a sub plot (1 x 1m) in each plot during inventory period. (Hendershort *et al,* 1993; Salami *et al,* 2022).

Soil Macro Invertebrates

The soil macro invertebrates encountered in each of the sites were counted and recorded. Identification was done using literature/manual keys which described by Delcourt *et al.,* (2026). Soil Biology Guide by Abera *et al.,* (2026). Guide to Soil Macro Fauna Sampling. Pictures of unidentified soil macro invertebrates were taken for the purpose of identification. The computation of species diversity indices was done. Through the following formula; $H^1 = -\Sigma Pi In Pi$ (Yager *et al,* 2017, Shannon and Weaver, 1948)

Sampling Design and Layout
A kilometer line transect was laid with four sample plots established (30 × 30 m) which was used for measuring the tree on interval of 100m from each plot. 1×1 m subplots was also used to determine soil sample (Richard, 1994).

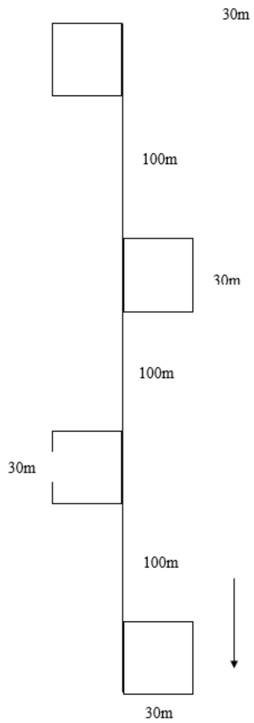

Figure 2: Plot Layout with Systematic Line Transet Sampling Technique
Source: Salami and Akinyele, 2018

Soil Sample Preparation to Laboratory Analysis
Soil samples collected from the study sites were spread on a drying tray to remove roots and other debris and air-dried for 3 days and ground with a wooden pestle and mortar to loosen the aggregates. After grinding, the soil was screened through a 2mm mesh and mixed thoroughly. The prepared samples were taken to the laboratory for the Standard analytical methods were subjected in the analysis of soil samples according to (Motsara and Roy, 2008).

Physicochemical Analysis
Particle Size Analysis
The particle size analysis was determined by the Bouyoucos hydrometer method described by (Ge and Bauder, 1986). Fifty (50) grams of the soil was shaken with 50 ml of 5% Calgon Sodium hexa-metaphosphate) for 30 minutes for proper and complete dispersion. The suspension was then transferred into a 1000 ml graduated cylinder and made to volume with distilled water. Hydrometer readings were taken at 40 seconds and 2 hours. A blank containing no soil was carried out through the same procedure to correct the reading that was taken in the soil suspension.

Determination of Silt and Clay
Silt and clay contents wre determined using the hydrometer method based on the principle of sedimentation of soil particles in suspension. Hydrometer readings were taken at specified time intervals, and the percentages of silt and clay were calculated using standard equations.

Determination of Sand
Sand content was determined as part of soil particle size analysis using the hydrometer method. The proportion of sand was obtained from the weight of course particlesremaining after dispersion and sedimentation of finer soil fractions, following standard laboratory procedures.

Chemical Properties
Determination of Soil pH
Soil pH was determined using a calibrated glass electrodw pH meter. A soil- water suspension was prepared at a standard rtio and allowed to equilibrate before measurement. The pH meter was calibrated using standard buffer solutions and readings were recorded to determine soil acidity or alkalinity.

Determination of Electrical Conductivity (EC)
The electrical conductivity of the soil saturation extract was determined at a 1:2 soil/water ratio (Udo *et al,* 2009). Ten (10) grams of the soil samples was soaked with 20 ml of distilled water for 1 hour. The suspension was then read using a Wheatstone bridge at 25°C.

Determination of Organic Carbon
Organic carbon contents of the soil samples were determined using dichromate wet oxidation method of Walkley-Black as described by Black (1965).

Determination of Organic Matter (%)
Value of organic matter was obtained by multiplying the organic carbon content of the soil by a factor of 1.724 (Black, 1965).

Determination of Nitrogen

Total nitrogen was determined by the micro Kjeldahl technique (Harold *et al,* 2020). One (1) gram of soil was digested with 10 ml of concentrated Teteroxo sulphate (vi) acid; the digested was then diluted with 100 ml of distilled water. 10 ml of the aliquot was distilled with sodium hydroxide. The distillate was then titrated with 0.01N H_2SO_4 to a pink endpoint.

Determination of Phosphorus

Available phosphorus was determined following the procedure described by IITA (1979) using the Bray-1 extraction method (Bray and Kurtz, 1945). Available phosphorus was extracted from Ten (10) grams of soil using ammonia fluoride in hydrochloric acid. Phosphorus in solution was then determined calorimetrically.

Determination of Exchangeable Cations

Exchangeable cations (Ca, Mg, K and Na) were determined using the NH_4OAc saturation method at pH 7.0 as described by (Thomas, 1982). Ten (10) grams of soil samples were leached with NH_4OAc solution. Potassium and Sodium were read from the flame photometer, while Calcium and Magnesium in the solution were determined using the titrimetric method. By the modified single solution procedure using ascorbic acid (Koralage *et al,* 2015).

Determination of Exchangeable Acidity

The soil samples were leached with 1M KCl solution. Total exchangeable acidity (H+Al) was determined by titration of the extract with standard NaOH solution (Thomas, 1982). The difference between total exchangeable acidity and exchangeable aluminium gives the amount of exchangeable hydrogen.

Data Analysis

Tree identified was recorded to determine tree composition ecosystems of the reserve. The following community indices were used to calculate woody plant species composition such as:

Frequency = $\frac{Number\ of\ individual\ species\ ocurrence}{Total\ number\ of\ all\ species}$ (1)

Relative frequency = $\frac{species\ frequency\ of\ individual\ species}{Sum\ of\ frequency\ values\ for\ all\ species}$ x100% (2)

Density = $\frac{Number\ of\ individual\ species}{Area\ sampled}$ (3)

Basal Area Calculation

The basal area of all trees in the sample plots were calculated using the formula

BA= $\frac{\pi D^2}{4}$ (4)

Where BA = Basal area (m^2), D = Diameter at breast height (cm) and π (3.142)

$H^1 = -\Sigma Pi In Pi$ (Yager *et al,* 2017) (5)

Where: H1 = Shannon Diversity Index; ni = number of individuals in species; N = total number of all individuals; Pi = relative abundance of each species, calculated as the proportion of individuals of a given species to the total number of individuals in the community: ni/N, and In = natural logarithm

Frequency tables were used in presenting the list of macro species.

Frequency = $\frac{\text{No.of individual specie occurrence}}{\text{Total number of all species}}$ x 100%. (6)

Data on macro faunal diversity was determined using Shannon Diversity Index:

Sorensen's Similarity Index = (2C) / (A + B) (7)

Pair sample T test was used to compare the different chemical and physical properties of soil nutrients based on location and depth using SPSS Version 17.

Correlation analysis was used to determine the relationship between the soil properties and tree species indicators and diversity of macro soil fauna.

RESULTS AND DISCUSSION

Table 1 presents a comparison of floristic composition, basal area, and plant diversity between protected and disturbed areas. The results show that the protected area has a significantly higher quantity of individual plants (53) compared to the disturbed area (12). Both areas have a similar number of families, with 13 and 12 families represented in the protected and disturbed areas, respectively. In comparing the protected and disturbed areas, the total diameter at breast height (DBH) and total basal area were higher in the protected area (39.01 and 35.19, respectively) compared to the disturbed area (12.04 and 14.50). However, the mean DBH and mean basal area were lower in the protected area (0.73 and 0.66) versus the disturbed area (1.0 and 1.20). Notably, the diversity index is significantly higher in the protected area (3.93) compared to the disturbed area (1.63), indicating a greater level of plant diversity in the protected area.

Table 1: Floristic Composition, Community Structure and Plant Diversity in Maladumba Forest Reserve and Disturbed Site

S/N	Variables	Protected Site	Disturbed Site	Standard Deviation	Standard Error
1.	Number of Individual Plant	53.00	12.00	28.99	20.50
2.	Number of Family	13.00	12.00	0.71	0.50
3	Total DBH (m)	39.01	12.04	19.08	13.49
4	Mean DBH(m)	0.73	1.00	0.19	0.13
5	Total Basal Area	35.19	14.50	14.65	10.36
6	Mean Basal Area	0.66	1.20	0.38	0.27
7	Diversity Index (H^I)	3.93	1.63	1.63	1.15

DBH: Diameter at the Breast Height

Table 2 presents the percentage diameter distribution of trees in protected and disturbed sites. In the protected area, the majority of trees (41.51%) have a diameter of 81 cm and above, followed by trees with diameters between 21-40cm (35.85%). In contrast, the disturbed area has a more even distribution, with 33.33% of trees in both the 21-40 cm and 41-60 cm diameter ranges. Notably, the protected area has a higher proportion of larger trees (81 cm and above), while the disturbed area has a higher proportion of smaller to medium-sized trees. The frequency distribution also shows that the protected area has a greater number of trees in the larger diameter classes, with 22 trees having diameters of 81 cm and above, compared to only 3 trees in the disturbed area.

Table 2: Percentage Diameter Tree Species Distribution in Maladumba Forest Reserve and Disturbed Site

SN	Diameter Range (cm)	Protected Site Frequency	Percentage (%)	Disturbed site Frequency	Percentage (%)
1	10-20	01	1.89	-	-
2	21-40	19	35.85	04	33.33
3	41-60	05	9.43	04	33.33
4	61-80	06	11.32	01	8.33
5	81 and above	22	41.51	03	2.5
Total		53	100	12	100

Table 3 present the diversity and density of various insect and invertebrate species in protected and disturbed sites. The table shows 11 families and species, with the number of individuals and density (Pi) calculated for each site. The protected site has a higher total number of individuals (282) compared to the disturbed site (202). The Formicidae family (ants) is the most abundant in both sites, with a density of 0.2837 in the protected site and 0.4554 in the disturbed site.

Table 3: Checklist of Soil Macrofauna in Maladumba Forest Reserve and Disturbed Site

S/No.	Family Name	Scientific Name	English Name	Protected Site Frequency	Disturbed Site
1	Acrididae	*Caelifera spp*	Grasshopper	34	18
2	Achipteriidae	*Trombidium holosericeum*	Velvet mite	34	-
3	Formicidae	*Formicide species*	Ant	80	92
4	Spirostreptidae	*Archispirostreptus gigas*	Millipede	31	-
5	Gryllidae	*Gryllus bimaculatus*	Cricket	30	12
6	Scolopendridae	*Scolopendra morsitans*	Centipede	16	2
7	Lumbricidae	*Lumbricus terrestris*	Earthworm	5	-
8	Achatinidae	*Achatina fulics*	Land snail	55	6
9	Pentatomidae	*Nazara viridula*	Stink Bug	25	-
10	Rhinotermitidae	*Heterotermes species*	Subterranean termite	56	69
11	Stephylinidae	*Bisnius blandus*	Rove beetle	16	3
	Total			282	202

The data show that Maladumba Forest Reserve (Table 4) has higher abundance, diversity, and ecological stability than the disturbed site. The protected site recorded 282 individual macro soil fauna compared to 202 in the disturbed site, indicating greater species abundance under conservation. Biodiversity is also substantially higher, with a Shannon-Weiner Index of 2.60 in the protected site versus 1.32 in the disturbed site, meaning species are more varied and the community is more complex. Species evenness of 0.96 in the protected site shows that individuals are more evenly distributed across species, while the lower 0.68 in the disturbed site suggests dominance by a few tolerant species. Species richness is also higher at 2.3 over 1.94, reflecting more unique species in the protected area. The Sorensen similarity index of 77.78% indicates that about 78% of the species are shared between both sites, but the protected site still maintains a richer and more balanced community. Disturbance reduces both the quantity and diversity of macro soil fauna, highlighting the importance of forest protection for maintaining soil ecosystem health and function.

Table 4: Abundance, Density and Diversity of Macro Soil Fauna in Maladumba Forest Reserve and a Disturbed Site

SN	Measures	Protected Site	Disturbed
1	Total Number of Individual/ species abundance	282	202
2	Shannon-Weiner Index	2.60	1.32
3	Species evenness	0.96	0.68
4	Species richness	2.3	1.94
5	Sorensen	77.78 %	

Table 5: presents the mean physiochemical parameters of soil in protected and disturbed areas. The results show that the protected area has a higher clay content (11%) compared to the disturbed area (7%), while the silt content is lower in the protected area (28%) compared to the disturbed area (34%). The sand content is slightly higher in the protected area (61%) compared to the disturbed area (59%). The pH level is higher in the protected area (7.34) compared to the disturbed area (6.68), indicating a more alkaline soil in the protected area. The electrical conductivity (EC) is also higher in the protected area (0.225 ds/m) compared to the disturbed area (0.185 ds/m). The organic carbon (OC) and organic matter (OM) contents are higher in the protected area (0.58% and 1%, respectively) compared to the disturbed area (0.19% and 0.31%, respectively). However, the available phosphorus (P) is lower in the protected area (1.40 mg/kg) compared to the disturbed area (3.13 mg/kg). The protected area also has lower levels of nitrogen (N), sodium (Na), and calcium (Ca) compared to the disturbed area. The cation exchange capacity (CEC) is slightly higher in the protected area (3.274 cmol(+)/kg) compared to the disturbed area (2.722 cmol (+)/kg.

Table 5: Mean Physiochemical of Soil Parameter in Maladumba Forest Reserve and Disturbed Site

Parameters	Clay %	Silt %	Sand %	pH	Ec ds/m	O.C %	O.m %	P mg/kg	N %	Na	K	Ca	Mg	AL+H	TEB	CEC
										Cmol (+)/kg						
Protected Site	11	28	61	7.34	0.225	0.58	1	1.40	0.021	0.025	0.10	1.32	1.25	0.55	2.722	3.274
Disturbed Site	7	34	59	6.68	0.185	0.19	0.31	3.13	0.045	0.067	0.04	1.75	0.37	0.5	2.222	2.722
P value	0.139	0.061	0.011	0.030	0.062	0.298	0.312	0.233	0.242	0.273	0.291	0.089	0.317	0.030	0.064	0.058

Source: Field survey, 2024

Table 6 the correlation results in show how different soil properties relate to tree characteristics and soil macrofauna. Tree species diversity, tree density, and basal area exhibit strong positive correlations with soil pH, potassium (K), calcium (Ca), and magnesium (Mg). Conversely, these tree parameters negatively correlate with clay, silt, electrical conductivity (EC), and sodium (Na), implying that heavier, more saline soils may hinder tree growth and diversity. Notably, soil macrofauna diversity shows strong negative correlation with sodium (−0.94) and sand (−0.74), but a positive correlation with silt (0.74. Macrofauna richness and evenness display strong positive correlations with organic carbon (0.94), organic matter (0.94), nitrogen (0.89), potassium (0.89), and cation exchange capacity (CEC).

Table 6: Correlation of Physiochemical Properties Associated with Tree and Soil Macrofauna Diversity in Maladumba Forest Reserved and a Disturbed Site

Variables	Clay	Silt	Sand	pH	Ec	Oc	Om	P	N	Na	K	Ca	Mg	Al	T	CEC
Tree Species Diversity	-0.32	-0.31	0.20	0.80	-0.80	0.63	0.63	0.00	0.00	-0.40	0.80	0.80	0.40	0.20	0.00	0.00
Tree Density	-0.22	-0.11	0.15	0.65	-0.70	0.54	0.45	0.00	0.00	-0.40	0.73	0.73	0.40	0.20	0.00	0.00
Basal area of the tree	-0.4	-0.29	0.31	0.63	-0.75	0.63	0.63	0.00	0.00	-0.40	0.52	0.80	0.50	0.30	0.01	0.01
Soil Macro Fauna Diversity	0.00	0.74	-0.74	0.32	0.21	0.38	0.38	0.14	0.09	-0.94	0.32	0.21	0.55	-0.74	0.11	0.11
Richness Soil Macro Fauna	0.70	-0.45	0.45	0.89	0.00	0.94	0.94	-0.89	0.89	0.00	0.89	0.00	0.89	0.45	0.89	0.89
Evenness Soil Macro Fauna	0.70	-0.45	0.45	0.89	0.00	0.94	0.94	-0.89	0.89	0.00	0.89	0.00	0.89	0.45	0.89	-0.89

Discussion

Tree Species Composition, Distribution and Diversity in Maladumba Forest Reserve and a Disturbed Site

The savannah is a complex and dynamic environment characterized by a mixture of grasslands and open woodlands (Mbanefo *et al.,* 2026), with tree species playing a crucial role in shaping its structure and function. Understanding the composition and distribution of tree species in savannahs is essential for appreciating the ecological and conservation significance of these ecosystems. The comparison of floristic composition, basal area, and plant diversity between protected and disturbed areas reveals clear ecological benefits of conservation in protected zones. Findings from the study reveal that Fabaceae is the most prominent plant family in Maladumba Forest Reserve and a disturbed site, aligning with previous research by Salami *et al,* (2022) and Salami *et al,* (2024), which also identified Fabaceae as dominant in various forest ecosystems across Nigeria. The protected area exhibited a significantly higher number of individual plants (53) than the disturbed area (12), indicating greater plant density. Although both areas recorded a similar number of families (13 and 12 respectively), the diversity index was markedly higher in the protected area (3.93) than in the disturbed area (1.63), signifying richer species diversity. The low plant diversity observed in the disturbed area corresponds with similar trends reported by Salami and Lawal (2018) which was reported at Orchard of Federal University Dutse, Jigawa State (1.35) and Salami *et al,* (2022), at Kurba Forest Reserve in Bauchi state where human disturbances and inadequate conservation measures led to reduced species richness. In contrast, the high diversity index recorded in the protected area, comparable to the diversity value of 4.28 observed in the Kano Zoological Garden, confirms that well-managed protected areas support richer and more stable plant communities. This consistency in findings across different studies underscores the ecological importance of protection status in influencing species composition and diversity. It also highlights the need for increased attention to the management of disturbed areas to restore biodiversity and ecosystem functions.

This has important implications for biodiversity conservation, as it underscores the need to preserve both areas to maintain regional species diversity. According to Whittaker (1972), spatial variation in species composition (beta diversity) is key to understanding ecosystem health and resilience. The low Sorensen index here may also signal habitat fragmentation or degradation, which can reduce connectivity and species dispersal (Legendre and Legendre, 2012). While the total diameter at breast height (DBH) and basal area were higher in the protected area (39.01 and 35.19 respectively), the disturbed area showed slightly higher mean DBH (1.0) and basal area (1.20), possibly due to fewer but larger remaining trees. These findings align with studies in Nigeria that highlight the ecological value of protected areas in conserving biodiversity and maintaining forest structure (Onyekwelu and Olajiire, 2014). They also emphasize the impact of anthropogenic pressures, such as logging and land conversion, which significantly degrade disturbed forests across Nigeria (Adekunle *et al,* 2011). This underscores the need for stronger protection policies and sustainable management strategies to conserve forest ecosystems in the country.

The diameter distribution of trees in protected and disturbed sites highlights the ecological maturity and structural integrity of conserved forests. In the protected area, a significant proportion of trees (41.51%) fall within the 81 cm and above diameter class, indicating the presence of older, well-established trees. This is followed by 35.85% of trees in the 21–40 cm range, suggesting a balanced regeneration pattern. In contrast, the disturbed area exhibits a more even but limited distribution, with 33.33% of trees in both the 21–40 cm and 41–60 cm classes, and only 3 trees (compared to 22 in the protected area) reaching 81 cm and above. This implies that human disturbed such as logging and land conversion, have restricted tree growth and reduced structural complexity in disturbed areas. The greater presence of larger diameter trees in the protected area signifies better forest stability and long-term ecological value. These findings are consistent with research in Nigeria, which emphasizes the role of protected forests in conserving tree diversity, promoting natural regeneration, and maintaining ecosystem services (Agbelade, 2022; Onyekwelu and Olajiire, 2014). The data supports the need to strengthen forest protection policies to preserve Nigeria's remaining mature forest stands.

Diversity and Abundance of Macro Soil Fauna in Maladumba Forest Reserve and a Disturbed Site

The diversity and abundance of macro soil fauna are crucial indicators of soil health and ecosystem functioning. These organisms, including earthworms, termites, ants, beetles, and millipedes, play vital roles in nutrient cycling, organic matter decomposition, soil aeration, and structure formation. High diversity and abundance of soil fauna enhance microbial activity and improve soil fertility, which directly supports plant growth and agricultural productivity. Their presence helps in the breakdown of organic matter, releasing essential nutrients like nitrogen and phosphorus. In addition, diverse macrofauna populations contribute to pest control and increased soil resilience against erosion and climate stress. Low diversity or abundance may signal soil degradation due to pollution, over-cultivation, or deforestation.

The results on macro soil fauna reveals a varied composition and abundance of species, indicating a relatively healthy and functioning soil ecosystem. Formicidae species (ants) recorded the highest abundance (80), reflecting their dominant role in soil structure maintenance and nutrient cycling. *Heterotermes species* (termites) and *Achatina fulica* (giant African snail) also showed high numbers (55 and 6 respectively), both of which are key decomposers contributing to organic matter breakdown. Caelifera (grasshoppers) and *Trombidium holosericeum* (velvet mites) were equally abundant (34 each), suggesting their ecological relevance in soil and surface food webs. Other moderately abundant species include Ahispirostreptus gigas (millipede) and *Gryllus bimaculatus* (cricket), both important in litter decomposition. Low counts of Lumbricus terrestris (earthworm) and Scolopendra morsitans (centipede) might indicate some level of soil disturbance or unsuitable habitat conditions.

The recent Sorenson Similarity Index (SSI) from the recent study indicates a high degree of similarity in micro-fauna composition between the study site and other forest ecosystems in Nigeria, suggesting a relatively stable and diverse micro-fauna community. Research in Nigerian forests, including northern regions, has shown that micro-fauna plays a crucial role in ecosystem functioning, contributing to decomposition, nutrient cycling, and soil health (Devi *et al.,* 2023). For instance, studies by Awazi *et al.* (2025), in northern Nigeria's savannah forests have reported similar macro-fauna diversity patterns, highlighting the importance of these organisms in maintaining ecosystem balance and resilience. The high SSI value indicates similar environmental conditions and micro-fauna composition, often found in undisturbed or protected areas, consistent with findings from other Nigerian forests (Senterre *et al.,* 2020). In Ngel Nyaki Forest, studies on soil macrofauna diversity reveal the impact of human disturbance on soil ecosystems. The protected areas recorded a Shannon-Wiener diversity index (H′) of approximately 1.65, indicating a relatively moderate level of species richness and evenness. In contrast, disturbed areas exhibited a lower diversity index of 1.40, suggesting a reduction in macrofauna variety likely due to land degradation, deforestation, or agricultural activities. The maximum possible diversity (H_{max}) was higher in protected soils (3.69) compared to disturbed areas (3.18), highlighting a greater potential for biodiversity in undisturbed environments (Asongo *et al,* 2012). These findings emphasize the ecological value of conservation efforts in maintaining soil health and biodiversity. Reduced macrofauna diversity in disturbed sites signals ecosystem stress, which may compromise vital soil functions such as nutrient cycling, decomposition, and aeration. Therefore, protecting forested areas is critical to sustaining soil biodiversity and overall ecosystem stability.

Physico-chemical Properties of Soil in Maladumba Forest Reserve and a Disturbed Site

The significant difference in sand content between the two sites is supported by the p-value of 0.011, indicating a statistically significant difference. According to a notable scientist, soil texture plays a crucial role in determining soil fertility and productivity (Ifeanyi-Onyishi *et al.,* 2024). For instance, soils with high sand content tend to have poor water-holding capacity, while those with high clay content tend to have better nutrient retention (Ezeaku, 2015). Further research could investigate how these differences in soil texture impact crop yields and soil management practices in Nigerian agricultural systems.

The soil pH values of 7.34 at the protected site and 6.68 at the disturbed site show a significant difference (p-value = 0.030). Soil pH affects nutrient availability and microbial activity, with a pH range of 6.5-7.5 considered optimal for most crops. According to (Ifeanyi-Onyishi *et al,* 2024), Nigerian soils tend to be slightly acidic to neutral, highlighting the importance of pH management for optimal crop production. Effective pH management can enhance nutrient uptake, promote beneficial microbial activity, and ultimately improve crop yields. Electrical Conductivity values (0.185-0.225 dS/m) indicate marginally significant differences in soil salinity, which can impact plant growth and soil structure. According to Ojanuga (2006), high EC values can signal soil degradation, particularly in areas with poor drainage. The low levels of organic carbon (0.19-0.58%) and organic matter (0.31-1%) underscore the importance of conserving and adding organic matter to enhance soil fertility, structure, and water-holding capacity (Wichman, 2024). Phosphorus levels (1.40-3.13 mg/kg) are crucial for plant growth, and adequate levels are necessary for optimal crop production. Emmanuel *et al,* (2020). Emphasize the significance of phosphorus in Nigerian soils, particularly for crops like maize and cowpea. Nitrogen levels (0.021-0.045%) are critical for plant growth, and adequate management is necessary for optimal crop production. Oikeh *et al,* (2004) highlight the importance of nitrogen management for improving crop yields in Nigerian agriculture. The varying levels of exchangeable cations (Na, K, Ca, Mg) impact soil fertility and plant nutrition, emphasizing the need for balanced nutrient management (Agbenin, 2003). Total Exchangeable Bases (TEB) and Cation Exchange Capacity (CEC) values indicate marginally significant differences, highlighting their impact on soil fertility and nutrient retention. According to Esu (2010), CEC is a vital soil property that affects nutrient availability and soil management in Nigerian agriculture.

The correlation analysis underscores the intricate relationships between soil properties, tree characteristics, and soil macrofauna diversity. Tree species diversity, density, and basal area exhibit strong positive correlations with soil pH, potassium (K), calcium (Ca), and magnesium (Mg), indicating that nutrient-rich, neutral to slightly alkaline soils foster robust forest structures. This aligns with findings by Lavigne, (2025), who reported that tropical tree growth is positively related to soil base cation and phosphorus availability. Conversely, negative correlations with clay, silt, electrical conductivity (EC), and sodium (Na) suggest that heavier, saline soils may impede tree growth and diversity. Soil macrofauna diversity shows a strong negative correlation with sodium (−0.94) and sand (−0.74), but a positive correlation with silt (0.74), indicating a preference for finer-textured soils with lower salinity. This is supported by studies highlighting that soil salinity adversely affects soil biodiversity (Singh, 2022). Furthermore, macrofauna richness and evenness display strong positive correlations with organic carbon (0.94), organic matter (0.94), nitrogen (0.89), potassium (0.89), and cation exchange capacity (CEC), emphasizing the role of nutrient-rich soils in enhancing soil biological health. These findings highlight the interconnectedness of soil quality, vegetation, and faunal diversity in maintaining ecosystem health.

CONCLUSION

The study revealed that forest disturbance negatively affects tree species diversity, soil macrofauna abundance, and soil physichochemical parameters in Maladumba Forest reserve. The protected site recorded higher biodiversity and better soil quality than the disturbed area, indicating the importance of forest conservation. Human activities such as logging, grazing and agricultural expansion were major drivers of ecosystem degradation in the disturbed site. Soil macrofauna showed strong relationships with vegetation cover and soil properties, confirming their value as indicators of ecosystem health. These findings highlight the need for effective conservation and sustainable forest management maintain ecological integrity.

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