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Land Use Effects on Rhizosphere Soil Physical and Chemical Characteristics of an Ultisol in Rivers State

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Abstract: *The rhizosphere soil health plays a vital role the productivity of plant and lasting sustainability of land. This study was carried out to assess the physical and chemical properties of rhizospheres of soils under Gnetum africanum (Ukazi), Ananas comosus (Pineapple), Musa × paradisiaca (Plantain) cultivations, and a five-year fallow soil cosidered as the control. Soil samples were randomly and uniformly collected from four points within each land use type. A total of twelve composite samples were properly labeled, transported to the laboratory, and prepared for standard soil analyses. Standard laboratory techniques were used to determine soil pH, organic carbon, total nitrogen, available phosphorus, total exchangeable acidity, and exchangeable bases (Na^+, K^+, Ca^{2+}, and Mg^{2+}). The results showed significant differences in soil properties among the different land use types. Rhizosphere soils under plantain cultivation exhibited relatively higher pH, organic carbon, nitrogen, phosphorus, and cation exchange capacity. These properties suggest improved soil fertility and a better environment for microbial activity and nutrient cycling. In contrast, the control (fallow) and Ukazi soils recorded relatively lower values for these soil properties including higher bulk density suggesting poor soil structural and biological activity. Generally, the study emphasizes the strong impact of land use type on rhizosphere soil quality and that continuous cultivation under suitable crops, such as plantain, can improve soil nutrient status and biological functioning, while fallow soil or certain crop systems may not adequately support soil fertility. To improve rhizosphere soil health particularly in the control and Ukazi land use types, the sustainable land management practices adoption is recommended. These practices include the organic amendments incorporation, use of microbial inoculants and crop rotation. These soil fertility management methods will promote lasting soil productivity and environmental sustainability.*

Keywords: Rhizosphere soil, land use type, soil productivity, environmental sustainability.

INTRODUCTION

The crop productivity and ecological sustainability of any agricultural land depends largely on the soil quality of that land. Tropical regions of southern Nigeria, are characterized and dominated by heavy weathering, low base saturation, and limited natural fertility soils known as ultisols (Akande *et al.,* 2023). Ultisols are naturally restricted making them particularly sensitive to changes in land use (Adesemuyi *et al.,* 2021). The narrow zone of soil surrounding plant roots and mediates vital biological, chemical, and physical interactions is and influence nutrient cycling, soil structure, and microbial dynamics is known as the rhizosphere (Zhang *et el.,* 2023). Rhizosphere soil properties can be significantly altered by land use practices (Adeyemi *et al.,*2026). Cultivating continuously without sufficient soil management can reduce soil organic matter, increase bulk density, and reduce nutrient availability, decline soil quality and crop performance (Adeniyan *et al.,* 2020). Perennial and mixed cropping systems equally often maintain and improve soil quality by boosting organic inputs, stabilizing soil aggregates, and supporting diverse microbial communities (Balogun & Abiola, 2023).

Plantain (*Musa × paradisiaca*) and pineapple (*Ananas comosus*) are some of the crops widely cultivated for both subsistence and commercial markets in Nigeria. (FAO,2024) Plantain (*Musa × paradisiaca*) cropping typically involve massive biomass return and ground cover, which increase soil organic carbon and improve rhizosphere conditions (Ibrahim & Eze, 2024). Pineapple, having fibrous root system and moderate residue contribution, also influences rhizosphere dynamics, however its influence on soil chemical fertility depends on management practices (Nwokoro & Chukwu, 2022). In contrast, ukazi (*Gnetum africanum*) being a not widely studied perennial leafy crop often grow under scarcely managed or wild conditions, with insignificant soil disturbance but potentially incomplete nutrient recycling due to frequent harvesting of leaves (Okafor & Nnamani, 2023). Land left undisturbed for years, serve reference systems since it often exhibits noticeable soil biological and chemical profiles compared to cultivated lands (Osondu & Ugwu, 2021). Understanding how these varied land uses influence rhizosphere soil physical and chemical characteristics is essential for sustainable land management. Ihese insights can inform practices that improve soil fertility, crop resilience, and ecosystem services in subsistence agricultural lands.

MATERIALS AND METHODS

Study Area

This study was conducted in Umuahiagu Community of Etche Local Government Area of Rivers State. The community lies within the coastal lowlands of the Niger Delta, between latitude 5°8′20″N and longitude 7°8′20″E, and is predominantly occupied by subsistence farmers within area (Nwankwoala & Nwaogu, 2023).

Soil Sample Collection

Four land-use types were chosen for this research. These are Ukazi, plantain, pineapple, and fallow (control). For each land use, three 10 m × 10 m quadrats were placed in relatively non-uniform areas with different slope and elevation to enclose 5-6 plants. Soil samples were collected by shaking off loosely attached soil and brushing the soil that adhered to the roots into sampling bags. This gave three replicate samples per land use and a total of 12 samples. Visible roots and debris were removed by hand. The soils were air-dried, sieved through a 2-mm mesh, gently ground, and stored at room temperature prior to laboratory analysis.

Laboratory Analysis

Soil pH was determined electrometrically in soil–water and 0.01 M $CaCl_2$ suspensions (1:2.5 ratio) using a glass electrode pH meter. Particle size distribution was determined using the

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hydrometer method with sodium hexametaphosphate as a dispersant, and soil texture was assigned using the textural triangle. Total nitrogen was determined using the semi-micro Kjeldahl digestion and distillation method. Nitrate was analyzed using the phenol disulphonic acid method after extraction with 1 N K_2SO_4. Available phosphorus was determined using the Bray and Kurtz No. 1 method, with absorbance read at 660 nm after color development. Exchangeable bases were extracted using ammonium acetate. Potassium and sodium were determined by flame photometry, while calcium and magnesium were measured using atomic absorption spectrophotometry. Total exchangeable bases were obtained by summing Na^+, K^+, Ca^{2+}, and Mg^{2+}. Exchangeable acidity was determined using 1 M KCl extraction, and cation exchange capacity (CEC) was calculated as the sum of exchangeable bases and exchangeable acidity. Organic carbon was determined using the Walkley and Black wet oxidation method, and organic matter was calculated by multiplying organic carbon by 1.724.

RESULTS

The results of some soil chemical and physical properties under four Agricultural land-use types: control (fallow), plantain, pineapple, and Ukazi are shown on Table 1. There were significant differences ($P < 0.05$) observed in some soil properties across the different land use types, showing the impact of cropping systems on soil quality. Soil pH ranged from 5.3 in the control to 6.6 under plantain cultivation. Plantain had a significantly higher pH than the other land use types, suggesting a reduction in soil acidity under this system. The control soil showed higher acidity, while pineapple and Ukazi land use type showed slight acidity with 5.7 and 6.0 respectively. Organic carbon and organic matter followed a similar trend, with plantain recording the highest values (1.60% OC and 2.77% OM), significantly different from the control (1.01% OC and 1.31% OM) which had the lowest values. Pineapple also showed relatively high values (1.51% OC and 2.60% OM). This implies that there’s a better organic matter accumulation under plantain cultivation, probably due to greater litter return and root biomass. Total nitrogen was significantly higher under plantain (0.24%) and pineapple (0.23%) land use type compared to the control and Ukazi (0.14%). Available phosphorus was highest in plantain soils (29.16 mg/kg), followed by the control, while Ukazi recorded the lowest value (19.39 mg/kg). The higher nutrient levels under plantain show improved soil fertility status relative to the other land uses. Exchangeable bases (Ca, Mg, K, and Na) did not differ significantly among land use. However, plantain generally recorded higher mean values for calcium and magnesium. Particle size distribution showed sandy dominance across all land use types, with sand content ranging from 82.10% to 87.57%, confirming the coarse-textured nature of the soils. Silt and clay fractions varied slightly but showed no major significant differences.

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Table 1: Soil chemical and physical properties Under different land use type

Land use	pH	Org.C	Org M	N	A.P	Ca	Mg	K	Na	E.A	Sand	Clay	Silt
		→ % ←			mg/kg	→ cmol/kg ←					→ % ←		
Control	5.3c	1.01b	1.31b	0.14b	23.68b	1.52b	0.70a	0.15a	0.61a	0.70a	82.10a	37a	6.72ab
Plantain	6.6a	1.60a	2.77a	0.24a	29.16a	2.95a	0.96a	0.17a	0.39a	0.62a	86.91a	5.70a	7.38a
Pineapple	5.7bc	1.51ab	2.60ab	0.23a	21.33c	1.81b	0.71a	0.12a	0.48a	0.70a	86.91a	7.04a	5.38ab
Ukazi	6.0b	1.02b	1.76ab	0.14b	19.39d	1.62b	0.68a	0.18a	0.50	0.72a	87.57a	7.71a	4.72b
L.S.D P<0.05	0.5	0.54	1.35	0.02	1.87	0.61	0.35	0.10	0.22	0.27	6.10	4.85	2.40

Means followed by the same letter(s) in the same column are not significantly different from one another at 5% level of probability using least significant different (L.S.D)

DISCUSSION

The results clearly show that land-use type significantly influenced the soil chemical and physical properties in the study area. The variations observed among plantain, pineapple, Ukazi, and fallow land which control reflect differences in vegetation cover, litter input, nutrient cycling, and management practices. Similar studies have reported that land-use change alters soil fertility status of different agroecological zones. (Alabi *et al.,* 2024; Ogunleye & Agele2025).

The higher pH recorded under plantain implies that there's an improved base status and reduced acidity, maybe due to higher organic matter inputs and nutrient recycling. (Smith & Adewale 2025) opined that in the humid tropics, continuous cropping without adequate organic input often leads to soil acidification. However, perennial cropping system such as plantain plantations tend to maintain better soil reaction because of regular litter deposition and canopy cover, which reduce nutrient leaching (Agbede, 2009). The generally acidic nature of the soils aligns with reports that soils of the Niger Delta coastal plain sands are inherently acidic and low in buffering capacity (Udom *et al.,* 2023).

Organic carbon (OC) and organic matter (OM) were significantly higher under plantain and pineapple compared to the control and Ukazi plots. This finding suggests that perennial cropping systems enhance organic residue return to the soil. Increased organic carbon under tree and plantation crops in southern Nigeria has been widely documented (Udom *et al.,* 2023). Organic matter is central to soil productivity because it improves aggregation, nutrient retention, and microbial activity (Lal, 2020). According to (Wu, 2025) lower OC in the fallow and Ukazi plots may be attributed to rapid decomposition under high rainfall and temperature conditions characteristic of rainforest soils, consistent with recent evidence that elevated temperatures increase, soil respiration and accelerated carbon loss. Ukazi also produces relatively low above ground biomass compared to other crops native forest vegetative, less organic residue enters the soil. (Xiao *et al.,* 2022) The low organic matter level in the fallow maybe due to a previous land use history of intensive cultivation and continuous cropping which may have depleted carbon pool. This corroborates with the findings of (Ogunleye and Agele 2025).

Total nitrogen followed a similar pattern to organic carbon, with significantly higher values under plantain and pineapple. This is expected because soil nitrogen is largely associated with organic matter fractions (Agbede, 2009). Reduction in microbial activity will slow organic matter decomposition and N mineralization. The improved nitrogen status under plantain may therefore be linked to enhanced organic matter accumulation and reduced erosion losses (Onyegbule *et al.,*2023).

Available phosphorus (P) was highest under plantain and lowest under Ukazi. In highly weathered tropical soils, phosphorus availability is often constrained by strong adsorption and fixation onto iron and aluminum oxides, which bind phosphate and make it less available for plant uptake (Mabagala & Mng'ong'o, 2022; Amenkhienan *et al.,* 2025). According to (Agbede 2009) organic matter can form complexes with these oxides, thereby increasing phosphorus availability. Similar improvements in available P under plantation crops have been reported in southwestern Nigeria (Ojo *et al.,*2018). The lower P under Ukazi may reflect higher nutrient uptake or limited replenishment. Exchangeable bases (Ca, Mg, K, and Na) showed no significant differences across land uses, although plantain recorded relatively higher mean values. Particle size analysis showed that sand content in all land use types had more than 80%, confirming that they are sandy soil texture which is typical of the Niger Delta soils. These soils are highly permeable, prone to leaching, and generally low in nutrient retention capacity (Onyekwere *et al.,* 2023). This emphasizes the importance of sustainable land management practices, particularly organic matter addition, in conserving soil productivity in the area (Lal, 2020). These findings support earlier studies that emphasized the importance of appropriate land-use management in sustaining soil quality in the tropics (Agbede, 2009; Ojo *et al.,*2018).

CONCLUSION

This study suggest that plantain soils had the best physical and chemical properties**,** including higher pH, organic Carbon, Nitrogen, Phosphorus and cation exchange capacity**.** This reflects the improved soil structure and nutrient availability under plantain cultivation. But Pineapple soils, displayed moderate fertility while control and Ukazi soils had lower nutrient levels**,** higher bulk density**,** and reduced microbial biomass, indicating poorer soil health**.** The results confirm that land use influences soil structure, water retention and nutrient cycling, with perennial crop systems enhancing soil quality. The results also indicate that plantain land use improved soil fertility indicators compared to pineapple, Ukazi, and fallow systems. The improvements are largely associated with greater organic matter input, enhanced nutrient cycling, and better soil structural stability.

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