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Site-Specific Nutrients Cycling in Manage Recreational Ecosystem of Sarius Palmetium Botanical Garden, Maitama, Abuja, Nigeria.

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Abstract

The study examines site-specific variation of soil nutrients in a managed recreational ecosystem at Maitama, Abuja, the federal capital territory of Nigeria, which is Sarius Palmetus Botanical Garden. The focus of the study was to evaluate the soil nutrients dynamic and the existence of heavy metal considering the utilisation of the garden as a recreational service. Soil samples were collected from site specific locations in both wet and dry seasons for elements such as N, K, P, SOM, OC, exchangeable cations, textural properties, Fe, pb among other nutrients. A total of sixty soil samples were in both seasons from six site specific locations using a quadrat sampling technique of size 50cm by 50cm which was further subdivided into small cells of 10cm by 10cm. The soil samples were taken at the intersection of each cell and homogenised into six sampling for both top soils and sub soils at the depths of 0-15cm and 16cm -30cm, respectively the soil samples were analyzed using standard laboratory procedures. The results obtained from the field were analyzed using descriptive statistics such as means and tables. From the analysis, there exists soil nutrient dynamic across all sites in all the depths in both seasons. Furthermore, the presence of heavy metals such as iron and lead are present in the managed recreational park, though not at elevated values, and therefore, the safety limit is within human safety. Consequently, recommendations were made to ensure sustainable ecological service of the managed ecosystem.

Keywords: ecosystem, soil nutrients, recreational service.

1. Introduction

Nutrient cycling is a fundamental ecological process that regulates the movement and transformation of essential elements within terrestrial ecosystems. It governs the circulation of macronutrients such as nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), and magnesium (Mg), as well as micronutrients like iron (Fe), manganese (Mn), zinc (Zn), and copper (Cu) within the soil–plant–atmosphere continuum (Guo et al., 2020; Steinauer, Chatzinotas & Eisenhauer, 2020). These nutrients are vital for plant growth, soil fertility, and overall ecosystem productivity, and their availability is influenced by complex biological, chemical, and physical processes within the soil (Schröder et al., 2016; Suleiman, Jimoh & Aliyu, 2017). This cyclical movement connects the abiotic environment with living organisms, ensuring continuous nutrient reuse to sustain vegetation, microbial activity, and ecosystem function (Chapin et al., 2011; Schlesinger & Bernhardt, 2013).

Natural ecosystems such as forests and savannas function as nearly closed systems where nutrients are recycled through litter fall, root turnover, and decomposition. However, managed ecosystems like agricultural lands and recreational parks often experience nutrient imbalances due to human interventions, although the fundamental processes of nutrient cycling remain the same (Havlin et al., 2014). In botanical gardens and urban parks, activities such as planting, pruning, mowing, and fertilizer application modify soil structure, organic matter content, and microbial activity, thereby influencing nutrient availability and cycling (Zhao et al., 2019). Unlike natural forests where litter decomposition dominates nutrient return, managed ecosystems depend on anthropogenic nutrient inputs to sustain soil fertility and plant growth (Edmondson et al., 2014). Additionally, urbanization and recreational activities such as foot traffic, waste deposition, and irrigation affect soil compaction, pH, and nutrient distribution, creating localized nutrient surpluses or deficiencies (Pouyat et al., 2007). Organic matter from leaf litter, grass clippings, and ornamental vegetation further contributes to the nutrient budget, with decomposition rates varying according to plant species and microclimatic conditions (Lorenz & Lal, 2009).

Human activities such as deforestation, overgrazing, intensive cultivation, and urbanization alter natural nutrient pathways, leading to nutrient depletion, imbalances, or contamination (Ramprasad & Bhattar, 2018; Bahram et al., 2020). In urban and managed environments, irrigation, fertilization, and atmospheric deposition modify soil–nutrient dynamics, while heavy metal accumulation from pollution sources can disrupt microbial activity, reduce nutrient bioavailability, and impair ecosystem functioning (Feng et al., 2021; Yu et al., 2021; Vitousek & Sanford, 1986; Scholes & Walker, 1993).

The availability of macro- and micronutrients in managed ecosystems is often variable due to changes in soil chemistry, microbial communities, and seasonal variations (Marschner, 2012; ludwig, 2001). Nutrient bioavailability is further influenced by soil pH, temperature, moisture, and microbial interactions, which are frequently altered in urban and managed landscapes (Barber, 1995; Vance et al., 2003). These fluctuations can create nutrient limitations or toxicities that affect plant growth and ecosystem stability (Elizabeth, 2009; Brown et al., 2022).

A growing concern in urban green spaces is the accumulation of heavy metals and other contaminants in soil. Anthropogenic activities and atmospheric deposition can introduce toxic elements such as lead (Pb), cadmium (Cd), and mercury (Hg), posing risks to soil organisms, vegetation, and human users (Christian et al., 2022). However, the extent of heavy metal contamination in urban botanical gardens and similar environments remains underexplored in Abuja and comparable tropical urban settings.

Extending to urban and managed ecosystems, Guo et al. (2020) observed that anthropogenic inputs such as fertilizers and soil amendments modify microbial community structure and function. While these inputs can enhance nutrient cycling, imbalances occur when management practices are suboptimal. (Chen et al. 2020) found that nutrient stoichiometry in urban green spaces is influenced by vegetation type, litter quality, and management intensity. Managed parks exhibited higher phosphorus levels due to fertilizer use but lower nitrogen content from biomass removal, demonstrating how human activities shape nutrient dynamics. Luo et al. (2019) also emphasized the role of plant species composition in determining soil organic matter and nutrient retention.

From an ecological standpoint, this study aims to enhance understanding of nutrient cycling in managed ecosystem. It bridges the gap between natural forest systems and urban green spaces, allowing for meaningful comparisons and the development of sustainable management strategies Therefore, this research seeks to address critical gaps in understanding the nutrient status in site-specific managed ecosystem in the study area, and the potential of heavy metal contamination in the wet season and dry season of soil the nutrients of managed recreational ecosystems, using Sarius Palmetum Botanical Garden in Maitama, Abuja..

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2. Materials and Methods

2.1 **Study Area**

The study was conducted at Sarius Palmetum Botanic Garden, located within the Ministers' Hill area of Maitama District, Abuja, Nigeria. Maitama is one of the districts under the Abuja Municipal Area Council (AMAC) in the Federal Capital Territory (FCT).

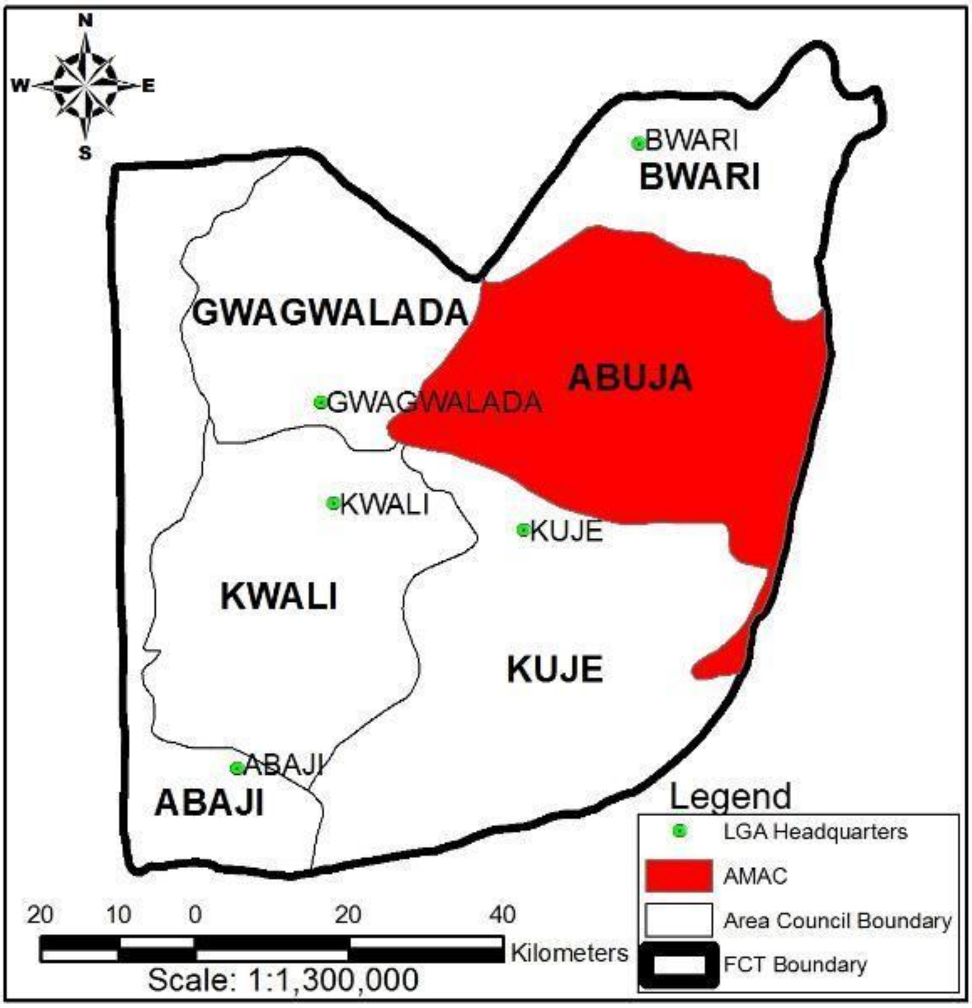

Fig 1: Map of FCT showing AMAC

Source: Abuja Guide (2023).

Geographically, Sarius Palmetum Botanical garden is located at $9^{0}05'47''$N and $7^{0}29'25''$E. The terrain is characterized by gently undulating plains with interspersed hills, with elevations ranging between 456m and 757m above sea level, and an average elevation near 512m just like that of Maitama in general. The soil is predominantly ferruginous tropical, formed under humid tropical conditions and characterized by moderate to high iron and aluminum oxide content. It is generally well-drained and slightly acidic, supporting the growth of a wide range of indigenous and exotic plant species, including palms, shrubs, and ornamental trees (FineLib, 2023). The topsoil is rich in organic matter from decomposed plant residues, which enhances soil structure, nutrient supply, and microbial activity (Sarius Palmetum, 2024). The study area experiences the same climatic conditions as the Federal Capital Territory (FCT), to be hot and humid tropical climate (Balogon 2001). The study area records its highest temperatures and greatest diurnal variations during the dry season, when maximum temperatures range between 30°C and 35°C. During the rainy season, maximum temperatures fall between 25°C and 30°C (Balogun 2001). Rainfall begins around april and ends by October and dry season is November to March, the rainy season lasts for approximately 190 days. The mean annual rainfall ranges between 1,100 mm and 1,600 mm (Ishaya et al 2017). The area is interspersed with both natural and human grown vegetation. The canopy cover can best describe as continues canopy. , there are also variety of exotic trees, shrubs, and indigenous nursery plants, with over 30 native species grown alongside ornamental plants to enhance biodiversity and ecological stability (FineLib, 2023). Aside the palm trees, other common tree species found are, *Daniella oluveri, Delonxi regia, Azaldica indica, traminalia catappa, polyaltia longfolia* among others.

2.2 Method of the Study

This study employed an inferential and comparative research design to investigate soil nutrient dynamics within the managed recreational ecosystem of Sarius Palmetum Botanical Garden, Maitama, Abuja. Primary data were used, focusing on soil physical properties (sand, silt, clay, bulk density, and moisture), chemical properties (nitrogen, phosphorus, organic carbon, pH, exchangeable cations Ca^{2+}, Mg^{2+}, K^{+}, Na^{+} cation exchange capacity (CEC), and effective cation exchange capacity (ECEC)), and micronutrients (Zn, Cu, Fe, Mn, and Co). Based on a reconnaissance survey, three sampling points were purposively selected within relatively undisturbed forested areas of the garden, each spaced about 50 meters apart to ensure spatial coverage and ecological uniformity. At each point, a 50 cm × 50 cm quadrat was established, and soil samples were collected from two depths 0–15 cm (topsoil) and 16–30 cm (subsoil) using a soil auger. The top soil at site one is labeled as A1TS, while the sub soil at site one is labelled as A1SS. The rest are A2TS and A2SS for top soil and sub soil at site two. while A3TS and A3SS are top soil and sub soil for site three. Composite samples were formed by mixing five randomly collected cores within each quadrat to minimize variability and enhance representativeness. In total, 30 soil samples were collected per season (wet and dry), amounting to 60 samples overall. From the 30 samples in each season, 6 homogenized samples were formed from each season from al the sites in both seasons. Each soil sample was preserved separately for verification during laboratory analysis to detect potential outliers. The soil samples were collected in October, 2024 for wet season and February, 2025 for dry season. All samples were subsequently analyzed at the Soil Science Laboratory, Federal University of Technology, Minna, to determine the physicochemical and nutrient characteristics across seasons and soil depths.

Table 1: GPS Coordinates of sites Where Samples were collected

S/N	Sample Points	Latitude	Longitude
1	A1TS and A1SS	$9^0$05’47’’N	$7^0$29’25’’E
2	A2TS and A2SS	$9^0$05’48’’N	$7^0$29’26’’E
3	A3TS and A3SS	$9^0$05’49’’N	$7^0$29’28’’E

Source: Author’s field work 2025

The techniques employed for Laboratory analyses is summarize in table 2

Table 2: Methods of laboratory Analysis

S/N	Parameters	Methods
1	Particle size distribution	Particle size distribution (PSD) was determined by using the Bouyoucos (Hydrometer) method as described by Udo *et al*., (2009).
2	Bulk density	The soil dry bulk density was determined using the core method.
3	Soil p^H	The soil p^H in water (1:1) and in CaCl (1:1) were determined by electrometric method as described by Mclean, (1982).
4	Organic Carbon/ soil organic matter	Organic carbon was determined by the modified Walkley – Black method as described by Nelson and Summers (1982),
5	Total Nitrogen	Total Nitrogen was determined by the macro-Kjeldahl digestion and distillation procedures as described by Bremner (1965).

6	Available Phosphorus	Sodium bicarbonate {Na $(HCO_3)_2$} extracting solution was used in this analysis (Olsen and Dean, 1965).
7	Cation Exchange Capacity (CEC)	This was determined by neutral 1N ammonium acetate method.
8	Exchangeable Cations and Percentage Base Saturation	This was determined by ammonium acetate extraction method as described by IITA (2015).
9	Exchangeable Acidity	The exchangeable acidity was determined using barium chloride tri-ethanolamine method as described by Peech (1965).

Source :Author's fieldwork, 2025

In addition to laboratory analysis, the data obtained from the field were analysed using descriptive techniques such as tables and means.

3 Results and Discussion

3.1 Site-specific Characteristics of Soil Nutrients in the study area.

In order to examine the location specific characteristics of the soil nutrients in the study area, table 3 provides the data in line with the focus of the study.

The mean values of the soil characteristics for both top soil and sub soil in the study area is provided in table 4.1

Table 3: Site-*specific Characteristics of Soil Nutrients of Top Soil and Sub Soil in dry Season in the study area.*

S/N	PROPERTIES	TOP SOILS	SUBSOILS
1	Sand	61.3	60.3
2	Silt	17.7	18.3
3	Clay	21.0	21.3
4	P^H	6.9	6.7
5	$CaCL^2$	6.1	6.0
6	SOM	0.84	0.82
7	OC	0.28	0.27
8	TN	0.39	0.38
9	Available P	29.2	28.12
10	Na^+	1.71	1.73
11	K^+	1.67	1.69
12	Mg^{2+}	3.98	3.89
13	Ca^{2+}	4.94	4.68
14	(EA)	0.82	0.82
15	ECEC	12.98	12.68
16	Bulk density (g/cm^3	1.74	1.80

Source: Field work, 2025

From table 3, the textural analysis showed that sand content was higher in the topsoil (61.3%) compared to the subsoil (60.3%). Conversely, silt was lower in the topsoil (17.7%) and higher in the subsoil (18.3%), while clay was 21.0% in the topsoil and slightly higher in the subsoil (21.3%). The soils were generally classified as sandy clay loam (SCL), with sand dominating the particle size distribution during the dry season. This finding agreed with Raji and Mohammed (2000), who reported that Nigerian savanna soils were mainly sandy with few loam or clay surface horizons, and with Lungmuana et al. (2016), who also argued that sand particles dominated soil fractions, followed by clay and silt. The dominance of sand in this study was likely linked to the influence of parent material and weathering processes typical of savanna soils.

Soil p^H was higher in the topsoil (6.9) than in the subsoil (6.7). These results indicated that the soils were moderately acidic (USDA, 2001; USDA, 2008). The slightly higher acidity in the subsoil was attributed to leaching of basic cations down the profile, which is common in tropical soils. However, this result disagreed with Karwade et al. (2019), and Mandal et al. (2021), who observed in their study higher p^H value in sub soils. Such differences may be attributed by variations in land use, soil management practices, and rainfall intensity, which influence leaching and nutrient redistribution.

The SOM content was higher at the top soil with (0.84%) and lower at the sub soil with (0.82%). The SOM was considered to be low according to (USDA NRCS, 2014). However, this result agrees with that of (Houque et al 2020) whose study revealed SOM was higher at the top soil. The study of (Zhoa et al 2019) also showed higher amount of SOM at the top soil. According to sun et al (2020), soil nutrients decline with soil depth due to reduced organic matter and microbial biomass.

With respect to Organic carbon (OC) as shown in table 3, it was higher in the topsoil (0.28%) and slightly lower in the subsoil (0.27%). Both values were classified as low (USDA NRCS, 2001; USDA NRCS, 2011). This observation agreed with the works of Karwade et al. (2019), Choudhury et al. (2019), Mandal et al. (2021), and Lungmuana et al. (2018), who also found higher OC in top soil due to surface litter accumulation and root activity. The low OC in this study could be attributed to rapid decomposition under high temperatures in the FCT, coupled with low organic inputs which may be due to high mineralization and other biotic activities in managed recreational ecosystems as well as potential soil nutrient immobilizations which was observed in the study area as the area consist of well develop higher plants which rapidly immobilize nutrients with little being returned to the soil.

Total nitrogen (TN) was higher in the topsoil (0.39%) compared to the subsoil (0.38%), and both values fell within the range of (0.2–0.5%) as reported by USDA NRCS (2011) and FAO (2006). This finding was consistent with Mandal et al. (2018), Zhao et al. (2021), and Weng et al. (2020), who recorded higher TN in top soils as a result of surface organic matter decomposition and root activity.

Available phosphorus (P) was also higher in the topsoil (29.2 mg/kg) compared to the subsoil (28.12 mg/kg), indicating moderate availability (USDA NRCS, 2008; USDA NRCS, 2019; Havlin et al., 2014). The relatively higher P concentration in the topsoil of this study was likely due to surface litter input combined with reduced leaching during the dry season.

Among exchangeable bases, Na^+ was slightly higher in the subsoil (1.73 cmol/kg) compared to the topsoil (1.71 cmol/kg). These values were within safe limit as reported by USDA NRCS, 2008; Soil Survey Staff, 2014). This pattern corroborated with the works of James et al. (2016), Okoro et al (2023), who attributed higher subsoil concentrations of exchangeable bases to downward leaching.

Potassium (K^+) was also higher in the subsoil (1.69 cmol/kg) compared to the topsoil (1.67 cmol/kg). These values reflected excess levels that may cause nutrient imbalances (USDA NRCS, 2001; Havlin et al., 2014). This finding agreed with James et al. (2016), Okoro et al (2023), who reported greater K^+ accumulation in deeper horizons due to leaching. However, it contradicted with the works of Karwade et al. (2019) and Kocak (2022), who recorded higher K^+ in topsoil. The difference could be explained by rainfall intensity, soil mineralogy, and vegetation type, age of vegetation which regulates nutrient distribution in the soil profile.

Magnesium (Mg^{2+}) was higher in the topsoil (3.98 cmol/kg) compared to the subsoil (3.89 cmol/kg), suggesting adequate availability of Mg^{2+} (USDA NRCS, 1999; Havlin et al., 2014). This finding is not in consonance with James et al. (2016), who observed higher Mg^{2+} in deeper horizons. The higher topsoil concentration in this study could be attributed to nutrient cycling processes, as noted by Cole and Rapp (1981), Stark and (1994), where nutrients absorbed by roots were translocated to aboveground biomass and recycled back to the surface through litter fall, through fall, and stem flow.

Calcium (Ca^{2+}) was higher in the topsoil (4.94 cmol/kg) compared to the subsoil (4.68 cmol/kg), reflecting moderate Ca^{2+} availability (USDA NRCS, 1998). This agreed with Zhang et al. (2023), who reported higher Ca^{2+} in top soils due to litter decomposition and nutrient recycling.

Exchangeable acidity (EA) was equal in both depths (0.82 cmol/kg), suggesting low acidity, since the values were below 1.0 cmol/kg (USDA NRCS, 1999; Havlin et al., 2014).

Effective Cation exchange capacity (ECEC) was higher in the topsoil (12.98 cmol/kg) compared to the subsoil (12.68 cmol/kg). These values reflected moderate nutrient-holding capacity (USDA NRCS, 1999; Havlin et al., 2014), with higher topsoil levels linked to greater organic matter and nutrient cycling at the surface.

Bulk density was lower in the topsoil (1.74 g/cm³) compared to the subsoil (1.80 g/cm³). Both values exceeded the USDA threshold (<1.40 g/cm³), indicating compaction that may restrict root penetration, reduce aeration, and hinder water infiltration. Higher bulk density in sub soils was typical, as also reported by USDA (2025), due to overburden pressure and reduced organic matter content.

Furtherance to the study, the mean location specific characteristics of soil nutrients of top soil and sub soil in wet season was investigated and this is presented in table 4

Table 4: Mean of Site-s*pecific Characteristics of Soil Nutrients of Top Soils and Sub Soil in wet Season in the study area*

S/N	PROPERTIES	TOP SOILS	SUBSOILS
1	Sand	60.3	59.0
2	Silt	18.3	19.7
3	Clay	21.3	21.3
4	P^H	6.8	6.8
5	$CaCL^2$	5.9	6.0
6	SOM	0.82	0.82
7	OC	0.27	0.27
8	TN	0.40	0.39
9	Available P	29.18	28.02
10	Na^+	1.70	1.72
11	K^+	1.66	1.70
12	Mg^{2+}	3.98	3.89
13	Ca^{2+}	4.96	4.69
14	(EA)	0.82	0.81
15	ECEC	12.98	12.51
16	Bulk density (g/cm^3	1.74	1.80

Source: field work, 2025

The particle size distribution showed that sand content was higher in the top soil (61.3%) compared to the sub soil season (60.3%). Silt was slightly higher in the sub soil with (18.3%) than in the top soil with (17.7%), while clay was also slightly higher in the sub soil with (21.3%) compared to the top soil (21.0%). Based on the USDA classification (2008), the soils were sandy clay loam (SCL). The dominance of sand in top soil and sub soil confirmed that soils of the study area were sand-dominated, which aligned with Edicha (2010), who reported sandy soils in the Federal Capital Territory, Abuja in the study conducted on the relationship between soil particle size and soil carbon sequestration.

Soil p^H in was slightly higher in the sub soil (6.9) compared to the top soil (6.8). These values indicated moderately acidic conditions according to USDA, 2001; USDA, 2008). This result agreed with Houque et al. (2020), Lungmuana et al. (2018), and Mandal et al. (2021), who observed in their study higher p^H value in sub soils. Such differences may be attributed by variations in land use, soil management practices, and rainfall intensity, which influence leaching and nutrient redistribution.

Soil Organic Matter was at state of equilibrium with (0.82%) at both top soil and sub soil. This value is considered to be low according to (USDA NRCS, 2014)

Similarly, Organic Carbon also recorded the same value of (0.27%). Which is considered low according to (USDA NRCS, 2001; USDA NRCS, 2011), suggesting limited nutrient supply and reduced microbial activity.

Total nitrogen was higher in the top soil (0.40%) than in the sub soil (0.39%). Both values fell within the moderate fertility range (0.2–0.5%) required (USDA NRCS, 2011). The higher top soil nitrogen content could be attributed to increased mineralization of organic matter at the top soil. This agreed with Zhao et al. (2021), Weng et al. (2020), Mandal et al. (2018), and Mandal et al. (2021), who reported higher nitrogen availability at top soil due to enhanced microbial activity.

Available phosphorus was higher at the top soil (29.18 mg/kg) compared to the sub soil (28.02 mg/kg). This indicates moderate availability of phosphorus (USDA NRCS, 2008; USDA NRCS, 2019; Havlin et al., 2014). The slight reduction in the sub soil may have been due to leaching losses. This finding disagreed with Kocak (2022), Mandal et al. (2018), and Choudhury et al. (2019), who reported higher phosphorus in top soils, often linked to increased mineralization. The difference in this study could be due to site-specific factors such as vegetation cover and intensity of rainfall as well as nutrient immobilization

Among the exchangeable bases, sodium was slightly higher at sub soil with (1.72 cmol/kg) compared to the top soil with (1.70 cmol/kg). Both values were within safe limits for plant uptake (Soil Survey Staff, 2014). The reduction in the subsoil season was likely caused by leaching of sodium from the surface layer.

Potassium was also slightly higher in the top soil (1.70 cmol/kg) compared to the sub soil season (1.66 cmol/kg). These values indicated excess potassium that could lead to nutrient imbalance

(Havlin et al., 2014; USDA NRCS, 2001). This could be due to litter decomposition. This agreed with Kocak (2022), Kumar et al. (2024), and Mandal et al. (2018), who reported higher potassium concentrations at top soil, often attributed to rapid mineralization and recycling of surface litter.

Magnesium recorded higher values at the top soil (3.98 cmol/kg) and lower at (3.89 cmol/kg). These values indicated adequate availability (USDA NRCS, 1999; Havlin et al., 2014). The study of sun et al (2020) argued that nutrient availability declined with soil depth due to reduce organic matter

Calcium was slightly higher at top soil (4.96 cmol/kg) compared to sub soil with (4.94 cmol/kg), indicating moderate availability (USDA NRCS, 1999). The higher Ca^{+} at the top soil could be due to increased mineralization of organic matter during moist conditions. This finding agreed with Zhang et al. (2023), who also observed higher Ca^{2+} concentrations in surface soils enriched by decomposition processes.

Exchangeable acidity was higher at the top soil with (0.82 cmol/kg) and lower at the sub soil with (0.81 cmol/kg) . These values were below 1.0 cmol/kg, indicating low acidity (Havlin et al., 2014; USDA NRCS, 1999).

Effective cation exchange capacity (ECEC) was also higher at the top soil with (12.98 cmol/kg) and lower at the sub soil with (12.51 cmol/kg). This reflected moderate nutrient-holding capacity (USDA NRCS, 1999; Havlin et al., 2014). The lack of variation suggested limited seasonal changes in organic matter and clay contributions to nutrient retention.

Bulk density was higher at the sub soil with (1.80 g/cm³) and lower at top soil with (1.74 cmol/kg). Both values exceeded the USDA threshold (<1.40 g/cm³), indicating compaction that may restrict root penetration, reduce aeration, and limit water infiltration. As noted by USDA (2025), bulk density often remains stable seasonally but generally increases with depth due to overburden pressure.

Table 5: Mean soil analysis of heavy metals between the topsoil and subsoil *in dry season, in the study area*

Serial Number	Properties	Top soils	Sub soils
1	Zn^{2+}	3.35	3.07
2	Cu^{2+}	1.89	1.49
3	Fe^{2+}	5.18	5.17
4	Mn^{2+}	0.85	0.82

Source: Field work, 2025

Zinc (Zn^{2+}) was higher in the topsoil (3.35 mg/kg) compared to the subsoil (3.07 mg/kg). The zinc content at both depths was considered low, as values below 5 mg/kg are classified as deficient (Lindsay & Norvell, 1978; USDA-NRCS, 2004; Alloway, 2008). The relatively higher concentration in the topsoil may be attributed to surface organic inputs and limited downward mobility. This finding agrees with Wuana and Okieimen (2011), who reported that stable zinc levels with slight enrichment at the surface, as well as Abenu and Yusufu (2021), who observed higher Zn^{2+} in the topsoil across different land uses in the savanna region of North Central Nigeria.

Copper (Cu^{2+}) was also higher in the topsoil (1.89 mg/kg) than in the subsoil (1.49 mg/kg). The decline with depth agrees with the findings of Wuana and Okieimen (2011), Abenu and Yusufu (2021), and Obasi et al. (2022), who all reported that copper concentrations were highest in the surface horizon and decreased with depth due to its strong affinity for organic matter, which is typically concentrated in topsoil layers.

Iron (Fe^{2+}) showed very little variation between depths, with 5.18 mg/kg in the topsoil and 5.17 mg/kg in the subsoil, indicating a uniform distribution. Nevertheless, the slightly higher concentration in the topsoil is consistent with the findings of Abenu and Yusufu (2021) and Obasi et al. (2022), who reported that iron tends to accumulate in surface horizons and plough layers before decreasing significantly with depth.

Manganese (Mn^{2+}) was measured at 0.85 mg/kg in the topsoil and 0.82 mg/kg in the subsoil. Both values are below the commonly cited sufficiency threshold of 1.0 mg/kg (Lindsay & Norvell, 1978; Havlin et al., 2014), indicating low Mn availability. The near-consistent values across depths suggest limited vertical movement of Mn, and this observation is supported by the findings of Abenu and Yusufu (2021) as well as Obasi et al. (2022), who also reported relatively low Mn concentrations across soil horizons.

Table 6: Mean soil analysis of heavy metals between the topsoil and subsoil in wet season, in the study area

S/N	Properties	Top Soil	Sub Soil
1	Zn^{2+}	3.36	3.08
2	Cu^{2+}	1.90	1.51
3	Fe^{2+}	5.19	5.39
4	Mn^{2+}	0.89	0.87

Source: Field work, 2025

Zinc (Zn^{2+}) increased slightly to 3.36 mg/kg in the topsoil and 3.08 mg/kg in the subsoil. This shows that zinc was consistently higher in the topsoil, while seasonal variation remained negligible. These values are still considered low, as the sufficiency threshold is 5 mg/kg (Lindsay & Norvell, 1978; USDA-NRCS, 2004; Alloway, 2008). The higher concentration in the topsoil could be attributed to organic matter deposition and limited leaching. This finding agrees with Abenu and Yusufu (2021), who reported higher Zn^{2+} levels in the topsoil under various land uses in the savanna region, as well as with Rahman et al. (2021), who observed Zn enrichment in surface soils around disposal sites in developing countries. Similarly, Wuana & Okiemen (2011) reported a comparable trend, confirming the topsoil as the dominant zone of Zn accumulation.

Copper (Cu^{2+}) followed a similar trend, with higher concentration in the topsoil (1.90 mg/kg) than in the subsoil (1.51 mg/kg), as copper levels above 0.6 mg/kg are considered adequate (Sparks, 1995; 1995; Colorado State University, 2023). The higher surface concentration can be linked to the affinity of copper for organic matter and surface deposits. This finding supports the results of Abenu and Yusufu (2021) and Obasi et al. (2022), who also observed copper enrichment in topsoil layers.

Iron (Fe^{2+}) was unique in showing higher concentrations in the subsoil (5.39 mg/kg) compared to the topsoil (5.19 mg/kg). Both values were above the critical threshold of 4.5 mg/kg reported by Lindsay and Norvell (1978) and Havlin et al. (2014). The greater accumulation in the subsoil may be associated with iron's mobility and binding to clay minerals, which are often more concentrated at deeper horizons. However, this disagrees with the study of Sneha et al. (2020), who found that Fe^{2+} concentrations were generally higher in surface soils.

Manganese (Mn^{2+}) was slightly higher in the topsoil (0.89 mg/kg) than in the subsoil (0.87 mg/kg). Both values fell below the sufficiency threshold of 1.0 mg/kg (Lindsay & Norvell, 1978; Havlin et al., 2014), indicating low Mn availability. The slightly higher topsoil concentration could be linked to organic matter input, which influences Mn cycling. This observation agrees with Kocak (2022) and Choudhury et al. (2019), who both reported higher Mn^{2+} levels in surface soils compared to deeper layers.

Conclusion

The study established that the soils of Sarius Palmetum Botanical Garden which is a managed recreational ecosystem exhibited clear vertical variation in nutrient distribution and the presence of trace levels of heavy metals. Nutrient concentrations were generally higher in the topsoil (0–15 cm) than in the subsoil (16–30 cm), reflecting greater organic matter accumulation, microbial activity, and root influence at the surface. This pattern indicates that the managed recreational ecosystem maintains relatively stable soil fertility under minimal disturbance. The detected heavy metals were largely within permissible limits, suggesting that their occurrence is primarily geological factor and poses no immediate ecological risk. Overall, the soil nutrient status demonstrates the capacity of the ecosystem to sustain healthy vegetation growth, while continued monitoring is recommended to ensure long-term soil quality and ecological integrity.

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