Soil Macronutrients and Micronutrients assessment under different Land Use Types in University of Benin, Benin City, Nigeria

[1]EDMOND OSEMWENGIE AIRUEGHIAN and [2]RACHAEL ISIUWA OSAKUE
[1]Department of Soil Science and Land Management, University of Benin, Benin City.
[2]Department of Soil Science and Land Resource Technology, Federal College of Land Resource Technology, Kuru, Jos, Plateau State
e-mail: osemwengie.airueghian@uniben.edu

Abstract
Land use change is a critical driver of soil nutrient dynamics, particularly in rapidly developing regions. This study assessed the macronutrient and micronutrient status of soils under four distinct land use types (Arable, Fallow, Residential, and Silviculture) within the University of Benin, Benin City, Nigeria. Soil samples were collected from three replicated sites per land use at depths of 0-15 cm and 15-30 cm. Standard labouratory procedures were employed to analyze soil for; pH, total organic carbon (TOC), total nitrogen (TN), available phosphorus (Av. P), exchangeable bases (K, Ca, Mg, Na), and sulphate-sulphur (S-SO_4). Data were subjected to analysis of variance and means were separated using Duncan's Multiple Range Test, at 5% level of probability. Results indicated that sand fraction dominated all soils, classifying them as Loamy Sand. Soil pH ranged from strongly acidic (5.20) in the arable land to moderately acidic (5.70) in silviculture area at the surface. TOC was highest in silvicultural area (21.07 g/kg) and lowest in Arable land (16.93 g/kg). TN was generally low, with the highest value in Silviculture (1.05 g/kg). Available P was significantly higher ($p<0.05$) in silviculture (16.00 mg/kg) compared to residential area (11.23 mg/kg). Exchangeable K, Ca, and Mg were generally low across all land uses, with the highest K concentration in silvicultural area while highest Ca, Mg and Na concentrations often found in Residential areas. Furthermore, the micronutrients (B, Cl, Cu, Fe, Mn, Mo and Zn) were more concentrated in the silvicultural area than the other land uses. Nutrient (macro and micro) contents decreased with depth across the land uses. The study concludes that continuous disturbance of soil leads to nutrient depletion, while silvicultural systems showed better nutrient content. **Keywords:** Land Use, Soil Fertility, Macronutrients, Micronutrients, Ultisol.

Introduction

Land is a predominant factor influencing soil properties and processes at a local scale. The conversion of natural ecosystems to managed systems is a global phenomenon with profound implications for soil health and nutrient cycling (Tellen and Yerima, 2018). In Nigeria, rapid population growth and urbanization have intensified pressure on land resources, leading to extensive changes in land use patterns, often with adverse effects on soil quality (Ufot *et al.,* 2016). These changes can alter the distribution and availability of essential plant nutrients, potentially leading to land degradation and threatening agricultural sustainability (Ramankutty *et al*., 2018).

The soil's nutrient status comprising macro-nutrients: nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sulphur (S) and micro-nutrients: boron (B), chlorine (Cl), copper (Cu), iron (Fe), manganese (Mn), molybdenum (Mo), zinc (Zn) is a fundamental indicator of its fertility and capacity to support plant growth. Land use management practices directly impact these nutrients by influencing soil organic matter dynamics, pH, erosion rates, and microbial activity (Yang *et al*., 2018). For instance, continuous arable cultivation without adequate nutrient replenishment is widely reported to deplete soil organic carbon and total nitrogen more rapidly than other land uses (Airueghian *et al*., 2018). Conversely, land uses that maintain permanent vegetation cover, such as silviculture (tree plantations) or fallow systems, often promote the accumulation of organic matter and associated nutrients (Ofor *et al.,* 2015). In Southern Nigeria, where Ultisols are the dominant soil order, understanding these dynamics is crucial. These soils are inherently acidic and have low inherent fertility, making them particularly susceptible to degradation (Okunsebor and Umweni, 2021). While several studies have examined effect of land use on nutrients in Nigeria (e.g., Onwudike *et al*., 2016; Ufot *et al.,* 2016; Airueghian *et al*., 2018), but information about the macronutrient status of different land uses in University of Benin, Benin City is scarce.

Therefore, this study was initiated to bridge this knowledge gap by providing a comparative assessment of the macronutrient and micronutrients status of soils under Arable, Fallow, Residential, and Silviculture land uses within the University of Benin, Benin City. The findings will provide valuable insights for sustainable land use planning and soil management strategies.

Materials and Methods

Description of the Study Area

The study was conducted at the University of Benin, Benin City, Edo State, Nigeria. The area is geographically located between latitudes 6° 23' 53" and 6° 24' 40" N and longitudes 5° 37' 24" and 5° 37' 34" E. The region falls within the humid tropical rainforest zone of Nigeria, characterized by a bimodal rainfall pattern (Floyd *et al*., 2016). The annual rainfall averages about 2000 mm, and the mean annual temperature is approximately 27°C (Balogun *et al*., 2023). The distinct seasons are the rainy season (March to October) and the dry season (November to February). The underlying soil is classified as Ultisol (Rhodic Paleudult), derived from coastal plain sands, often referred to as "Benin Formation" (Okunsebor and Umweni, 2021). The vegetation of the area include: *Panicum maximum, Mimosa pudica, Sporobolus pyramidalis and Sida acuta*, for the arable land, it was, *Sporobolus pyramidalis, Axonopus compressus a*nd *Eleucine indica* in the fallow land; while residential area had *Sporobolus pyramidalis, Eleucine indica* and *Sida*

acuta. The dominant weeds in silvicultural area wee area; were; *Sporobolus pyramidalis* and *Eleucine indica*

Experimental Design and Soil Sampling

A Randomized Complete Block Design (RCBD) was employed for this study. Four land use types were identified: Arable land (Faculty of Agriculture Experimental Field), Fallow land (uncultivated lawns), Residential land (Student Halls of Residence), and Silviculture land (Forestry Arboretum and Orchard). For each land use type, three representative sites (replicates) were selected. At each site, soil samples were collected at two depths: 0-15 cm and 15-30 cm, using a soil auger. A total of 24 soil samples were collected. The samples were air-dried, crushed, and passed through a 2 mm sieve for labouratory analysis.

Labouratory Analysis

Standard analytical procedures were used to determine the soil physical and chemical properties. Particle size distribution was determined by the hydrometer of Buoyoucos (1962) as modified by Gee and Bauder (1986). Soil pH was measured in a 1:1 soil-to-water ratio using a glass electrode pH meter (McLean, 1982). Total Organic Carbon (TOC) was determined by the Walkley and Black (1934) wet oxidation method (Nelson and Sommers, 1996). Total Nitrogen (TN) was analyzed using the micro-Kjeldahl digestion method (Bremner, 1996). Available Phosphorus (Av. P) was extracted using (Houba *et al*., 2000) method and determined colorimetrically by (Bray and Kurtz, 1945). Exchangeable bases (K, Ca, Mg, and Na) were extracted with 1N ammonium acetate (NH4OAc) at pH 7.0. Potassium and Sodium were determined by flame photometry, while Calcium and Magnesium were determined by EDTA titration (Black, 1965). Sulphate-Sulphur (S-SO_4) was determined using method of Blair *et al*., (1991). Boron was extracted using hot water by and determined by the method of Karen (1996), chlorine was determined by the method of Frankenberger *et al* (1996). Copper, iron, manganese and zinc were extracted by DTPA extraction method. Copper and zinc were determined by the method of Reed and Marten (1996) while iron and manganese were determined by using Courchesne and Turmel (2007) method. Molybdenum was extracted using ammonium oxalate and determined by the method of Johnson and Fixen (1990).

Statistical Analysis

The data generated were subjected to Analysis of Variance (ANOVA) using GENSTAT 12th Edition. While treatment means were separated using Duncan's New Multiple Range Test (DMRT) at 5% probability level.

Results and discussion

Soil Physical Properties

Particle Size Distribution

The textural class (Table 1) across all land uses was Loamy Sand, with sand fraction dominating (867.70 - 887.70 g/kg). The highest sand content was in Residential land, while Silviculture had the highest clay content. The similarity in textural class is expected, as soil texture is an inherent property less influenced by land use management in the short to medium term (Tallen and Yerima 2018). The slightly higher clay content in the sub-soil of Silviculture and Fallow lands could be attributed to less disturbance and illuviation processes. Sand content decreased with depth while clay content increased with depth across the land uses sampled. This is due to illuviation of clay particles from top soil to sub soil (Zhang *et al*., 2023). Okunsebor and Umweni (2021) reported similar occurrence with soils in University of Benin

Soil Chemical Properties

Soil pH

The soils in sampled were generally acidic. This is typical of Ultisols in the region, resulting from intense leaching of basic cations due to high rainfall in the area (Okunsebor and Umweni, 2021). The pH ranged from strongly acidic (5.20) in arable farm land to moderately acidic (5.70) in silvicultural land at the 0-15 cm depth. pH reduced with depth across the four land uses sampled.

Total Organic Carbon (TOC)

TOC was highest in silvicultural area (21.07 g/kg) and lowest in Arable land (16.93 g/kg). This agrees the finding of Airueghian *et al*. (2018) who reported that silvicultural area have higher TOC than cultivated lands. The low TOC in arable land confirms the detrimental effect of continuous cultivation on soil organic matter (Yu *et al*., 2017); while the higher TOC in the silvicultural area could be due to less disturbance and litter cover on the forest floor (Ufot *et al*., 2016; Airueghian *et al*., 2018; Yang *et al*., 2018).

Soil Macronutrient

Total Nitrogen (TN)

Total nitrogen followed a similar trend, with the highest value in Silviculture area (1.05 g/kg). This may be due to decomposition of organic matter from litter fall (Shafreen *et al*., 2021). The lower total nitrogen content in arable land (0.77 g/kg). may be due to crop removal and enhanced mineralization from tillage (Yang *et al*., 2018), while the least total nitrogen content in the residential area may be due to excessive disturbance of the soil, resulting from human activities (Tolessa *et al*., 2017).

Available Phosphorus (Av. P)

Silviculture land had the highest Av. P (16.00 mg/kg), which was significantly ($p<0.05$) greater than that of Fallow land (11.23 mg/kg). The higher P in silvicultural area could be linked to the recycling of nutrients from tree litter and the reduced erosion under canopy cover (Ofor *et al*., 2015). The moderate levels across all lands, despite the acidic conditions that favor P fixation, suggest some organic matter-mediated P availability (Jindo *et al*., 2023)

Exchangeable Bases (K, Ca, Mg, Na)

The concentrations of these bases were generally low according to fertility ratings for Nigerian soils (Chude *et al.,* 2011). Residential land consistently had the highest values, particularly for Ca, Mg and Na. This may likely be as a result of external inputs from construction and domestic activities (Gupta, 2025). The low K content across all land uses, can be attributed to leaching in these sandy, acidic soils (Paramisparam *et al*., 2021).

Sulphate-Sulphur (S-SO_4)

The Silviculture land had the highest S-SO_4 content (9.94 mg/kg), while Arable land had the lowest (8.58 mg/kg). The depletion in arable land can be attributed to crop removal and leaching losses, a phenomenon also reported by (Degryse *et al*., 2016).

Table 1. Particle size distribution of soils under the different land uses in University of Benin

Land Use	Sand	silt	clay	Textural class
	← (g/kg) →			
	0-15 cm depth			
Arable	885.70[a]	63.33[c]	51.00[a]	Loamy sand
Fallow	879.00[b]	70.67[b]	50.33[a]	Loamy sand
Residence	887.70[a]	70.33[b]	42.00[b]	Loamy sand
Silviculture	870.30[c]	74.33[a]	55.33[a]	Loamy sand
LSD (0.05)	3.811	3.648	5.719	
	15-30 cm depth			
Arable	881.70[ab]	59.33[a]	58.33[b]	Loamy sand
Fallow	876.70[b]	58.33[a]	65.00[b]	Loamy sand
Residence	883.00[a]	57.00[a]	60.00[b]	Loamy sand
Silviculture	867.70[c]	57.67[a]	74.67[a]	Loamy sand
LSD (0.05)	5.317	6.465	7.77	

Means with same letter in the same column and same depth are not significantly different at $p < 0.05$.

Table 2. Macronutrient status of soils under different land uses in University of Benin

Land Use	pH (1:1 H_2O)	T.O.C. (g/kg	T.N. (g/kg)	Av. P (mg/kg)	K (cmol/kg)	Ca (cmol/kg)	Mg (cmol/kg)	Na (cmol/kg)	S-SO_4 (mg/kg)
0 - 15 cm Depth									
Arable	5.20[a]	16.93[a]	0.77[a]	11.94[ab]	0.25[a]	0.91[a]	0.23[a]	0.15[a]	8.58[a]
Fallow	5.03[a]	18.33[a]	0.84[a]	11.23[b]	0.24[a]	0.81[a]	0.20[a]	0.14[a]	8.67[a]
Residence	5.33[a]	17.77[a]	0.69[a]	11.03[b]	0.23[a]	1.02[a]	0.27[a]	0.17[a]	8.59[a]
Silviculture	5.70[a]	21.07[a]	1.05[a]	16.00[a]	0.31[a]	0.65[a]	0.16[a]	0.12[a]	9.94[a]
LSD (0.05)	1.96	7.58	0.284	4.322	0.15	0.582	0.123	0.057	2.037
15-30 cm Depth									
Arable	4.97[a]	8.81[a]	0.63[b]	7.83[ab]	0.24[a]	0.77[ab]	0.25[a]	0.13[a]	3.42[b]
Fallow	4.73[a]	10.18[a]	0.65[b]	6.88[b]	0.21[a]	0.63[ab]	0.15[a]	0.11[a]	3.86[ab]
Residence	4.40[a]	8.83[a]	0.56[c]	7.82[ab]	0.32[a]	0.93[a]	0.25[a]	0.16[a]	3.90[ab]
Silviculture	5.92[a]	10.29[a]	0.79[a]	9.34[a]	0.23[a]	0.58[b]	0.15[a]	0.12[a]	4.87[a]
LSD (0.05)	1.739	3.016	0.068	2.037	0.134	0.327	0.104	0.059	1.126

*Means in the same column for each depth followed by the same letter are not significantly different at $p<0.05$.

Table 3. Micronutrient status of soil under different land uses in University of Benin

Land Use	Boron	Chlorine	Copper	Iron	Manganese	Molybdenum	Zinc
	← (g/kg) →						
	0-15 cm depth						
Arable	9.65[a]	5.42[b]	21.80[bc]	272.75[b]	8.23[ab]	0.87[a]	19.32[ab]
Fallow	5.64[b]	5.00[b]	20.23[c]	264.23[c]	6.77[b]	0.76[b]	17.56[b]
Residence	5.99[b]	4.40[c]	22.71[b]	284.41[a]	7.67[b]	0.75[b]	18.74[b]
Silviculture	10.86[a]	6.74[a]	25.80[a]	279.40[a]	10.56[a]	0.90[a]	20.41[a]
LSD (0.05)	3.19	0.55	1.921	5.621	2.71	0.06	1.29
			15-30 cm depth				
Arable	4.33[a]	3.04[a]	15.87[a]	249.36[ab]	5.46[a]	0.55[ab]	12.24[a]
Fallow	3.48[a]	2.81[a]	15.64[a]	247.13[b]	4.45[b]	0.49[b]	11.51[a]
Residence	3.65[a]	2.71[a]	15.43[a]	246.89[b]	4.75[ab]	0.44[b]	11.63[a]
Silviculture	4.74[a]	3.52[a]	16.37[a]	252.70[a]	5.56[a]	0.59[a]	12.76[a]
LSD (0.05)	1.29	1.02	2.14	4.231	1.05	0.067	2.34

*Means in the same column for each depth followed by the same letter are not significantly different at $p<0.05$.

Soil Micronutrients

Boron (B) and Chlorine (Cl)

The boron and chlorine contents of the soils (Table 3) in the land uses were highest in the silvicultural area (10.86 mg/kg and 6.74 mg/kg) in the 0-15 cm depth and 4.74 mg/kg and 3.52
mg/kg in the 15-30 cm depth. The higher boron content in the silvicultural area may be due to decomposition of plant litter on the floor of the silvicultural area (Kot *et al*., 2016; Takoutsing *et al*., 2016; Zhang *et al*., 2020). The least boron concentrations were recorded in the fallow area (5.64 mg/kg and 3.48 mg/kg) respectively in the 0-15 cm and 15-30 cm depths. While the least chlorine contents were recorded in the residential area (4.40 mg/kg and 2.71 mg/kg) respectively in the 0-15 cm and 15-30 cm depths. Boron and chlorine contents in the silvicultural area were significantly ($p<0.05$) higher than their corresponding values in the fallow and residential areas in the 0-15 cm depth. The higher chlorine content in the silvicultural area may not be unconnected with organochlorine replenishment from forest litter (Vodyanitskii and Makarov, 2017; Svenson *et al*., 2022) and forest filtration of chlorine from rainfall (Zhao *et al*., 2017). While the less chlorine in residential area may be due to leaching of chlorine from the soil as a result of human activities Svenson *et al*., 2021)

Copper (Cu) and iron (Fe)

Copper content of the silvicultural area (25.80 mg/kg) was significantly ($p<0.05$) higher than the 22.72 mg/kg, 21.80 mg/kg and 20.23 mg/kg recorded respectively for residential, arable and fallow lands at the 0-15 cm depth. Litter cover and less erosion in the silvicultural area favour the accumulation of copper (Tella *et al*., 2016; Zolotova and Ryabinin, 2019). There was no significant difference ($p<0.05$) between the copper contents of the land uses at the 15-30 cm depth.

Iron content of the residential area (284.41 mg/kg) was significantly ($p<0.05$) higher than the 246.23 mg/kg recorded in the follow area at the 0-15 cm depth. The high iron content in the residential area may be due to sand filling of the area with laterite during construction (Jones *et al*., 2020) and decomposition of organic matter (Zhao *et al*., 2016). While the iron content of the 15-30 cm depth was significantly ($p<0.05$) highest in the silvicultural area.

Manganese (Mn), Molybdenum (Mo) and zinc (Zn)

Manganese, molybdenum and zinc contents of the silvicultural area were significantly ($p<0.05$) higher than those recorded in fallow and residential areas in the 0-15 cm depth. Manganese content varied from 6.77 mg/kg in the fallow area to 10.56 mg/kg in the silvicultural area at the 0-15 cm depth and varied from 4.45 mg/kg in the fallow area to 5.56 mg/kg in the silvicultural area at the 15-30 cm depth. Manganese contents in the silvicultural area was significantly ($p<0.05$) higher than those of the fallow area at 0-15 cm and 15-30 cm depths. According to Bravo *et al*. (2017); Li *et al*. (2021) manganese bio accumulate in acidic soils.

Molybdenum contents of silvicultural area was significantly ($p<0.05$) higher than those in the residential area at both depths. The highest (0.90 mg/kg) and least (0.75 mg/kg) molybdenum content in the 0-15 depth were recorded in the silvicultural area and residential area respectively. Similarly, the highest (0.59 mg/kg) and least (0.44 mg/kg) in the 15-30 cm depth were recorded respectively in the silvicultural area and residential area. High pH as well as Phosphorus and Sulphur availability increase molybdenum availability (Sun *et al*., 2020; yang and Wang, 2021).

Zinc contents of the silvicultural area was significantly ($p<0.05$) higher than those recorded in the fallow land at both depths. The highest zinc contents (20.41 mg/kg and 12.76 mg/kg) at both depths were recorded in the silvicultural area while the least contents (17.32 mg/kg and 11.51 mg/kg) at both depths were recorded in the fallow area. Higher zinc content in silvicultural area may be due to decomposition of organic matter (Prasad *et al*., 2016; Noulas *et al*., 2018)

Conclusion

This study demonstrates that land use type significantly influences the macronutrient and micronutrients status of the Ultisols in the University of Benin. The residential area exhibited the most pronounced nutrient depletion, particularly for total nitrogen, available phosphorus, potassium and sulphur, arising from high rate of disturbance from the residents. The silvicultural area showed a relatively better nutrient conservation status, especially for total organic carbon, total nitrogen, available phosphorus, and the micronutrients; boron, chlorine, copper, iron, manganese, molybdenum and zinc, highlighting the role of permanent vegetation in maintaining soil fertility. Nutrient (macro and micro) contents decreased with depth across the land uses. The study concludes that continuous disturbance of soil leads to nutrient depletion, while silvicultural systems showed better nutrient content

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