DISTRIBUTION OF EXCHANGEABLE CATIONS IN SOILS UNDER DIFFERENT AGRICULTURAL LAND USES OF SIMILAR LITHOLOGY IN EDO STATE, NIGERIA

UGWA, I. K., *EKPENKHIO, E. AND OROBATOR, P. O.

Department of Geography and Regional Planning, Faculty of Social Sciences, University of Benin, PMB 1154, Benin City, Nigeria

**Corresponding author's email: aigbounited@gmail.com; +2349052308940*

ABSTRACT

This study was carried out to examine the distribution of exchangeable cations in soils under cassava-cultivated land use, mixed-tree plantation and secondary forest of similar lithology in Edo State, Nigeria. The study sought to determine the concentrations of exchangeable cations under each land use; evaluate the distribution of exchangeable cations across the different land uses; examine the impact of the different land uses on exchangeable cations; and ascertain if significant relationships exist among the exchangeable cations under each land use. Using transect sampling design, a total of 54 soil samples were collected for the study. The soil samples were prepared and analyzed for exchangeable cations: pH, calcium (Ca) magnesium (Mg) potassium (K), sodium (Na), exchangeable acidity (EA), effective cation exchange capacity (ECEC) and base saturation (BS) in the laboratory using standard methods. The results revealed heterogeneous effects of land use and soil depths on the exchangeable cations (Ca, Mg, Na and K), especially as Na and K showed significant ($p < 0.05$) variations. The values of Ca, Na, K and BS were rated as moderate and adequate in all the test soils, but Mg concentrations were deficient. Soil pH was rated slightly acidic to neutral in all the soils. Effective cation exchange capacity values revealed that the soils of the studied sites had a low capacity to hold cations. Pearson correlation analysis indicated significant correlations ($p < 0.05$) between some soil properties at the 0-15 and 15-30 cm soil depths in the different land uses. The study concluded that exchangeable Mg was the most adversely impacted soil property in the studied land uses and recommended liming and incorporation of organic manure to soils to boost their ECEC.

Keywords: Cassava, Exchangeable cations, Land-use, Mixed-Tree plantation, Similar lithology

INTRODUCTION

Land use which can be described as human-driven activities on land is defined as the arrangements, activities and inputs people undertake in a certain land cover type to produce, change or maintain it (Ufot *et al*., 2016). Land use conversion is a major component of environmental change that alters soil properties, water resources and biodiversity, affecting ecosystem services in many parts of the world (Newbold *et al*., 2015). Soils vary in time and space and these variations may be features of changes in the lithological origin and land use. Hence, the distribution of nutrients in soils under similar lithology can be traced mainly to the dominating factors of land use types and soil management practices which could deteriorate soil quality. Change in land use cover, such as from forests to agricultural fields is one of the utmost concerns in environmental degradation assessment and have significant effects on soil quality, particularly at the surface horizons (Wali *et al*., 1999). The intensity of soil erosion and the measure of soil nutrient loss varies depending on the vegetation type at a particular place and time. Therefore, unsustainable land use types and soil management practices which lead to soil degradation can be seen as a serious challenge to food security and environmental quality.

Sustainable farming entails proper use of soil resources since soil can easily lose its quality and quantity within a short period of time for various reasons such as soil erosion, leaching, intensive cultivation etc. Inappropriate land use change and loss of forest cover associated with anthropogenic actions are growing concerns in many parts of the world. This problem is mostly occurring in developing countries of the tropical landscape perhaps due to increases in human population, biophysical, and socio-economic activities where the conversion of natural forests and grasslands to other land uses such as tree plantations and arable farmlands have degraded the soil properties (Valera *et al*., 2016). Approximately 50 % of the tropical closed-canopy forest had been removed and the land converted to other uses (Wright, 2005). Plantation forests and other associated arable cropping lands are significant elements of land use change. The Food and Agriculture Organization (FAO, 2005) predicted a global annual expansion rate of approximately 2 % of plantation forest areas which may be a result of the demand for food and wood products. This might affect the soil properties of a given area when it is changed from natural forest to other land use types. Maddonni (1999) stated that land use impacts soil processes such as leaching, carbon sequestration, soil structure and aggregate stability, nutrient cycling, erosion and other similar biophysical and chemical processes.

Soil nutrients make up the chemical basis of soil fertility and they come from both organic and inorganic sources. The minerals inherited from the soil parent materials over time release chemical elements that go through different changes and transformations within the soil due to varying land use systems. This in turn may influence the properties of the soil. White (1997) opined that parent materials are the principal sources of Ca in soil but their concentrations vary significantly on the basis of the land use type. Calcium deficiency may include interveinal chlorosis and necrosis of young leaves as well as stunted plants. Magnesium is an essential nutrient for crop production and it is a constituent of chlorophyll. Long-term soil sustainability requires balancing the Mg supply with removal from crop harvest, leaching and erosion.

Foth and Ellis (1997) opined that K is the major constituent of soil parent rock and becomes exchangeable as weathering occurs. It is important for plant food formation as well as the transport and storage of plant food. Sposito (1989) stated that high levels of Na indicate salinity problems and alter soil properties by causing enlargement and dispersal of organic and clay particles which restricts water absorption, and airflow and causes nutrient deficiency. Effective cation exchange capacity (ECEC) represents the capability of the soil to attract, hold and exchange cations. Thus, the ECEC of soil depicts the total amount of exchangeable cations that the soil can adsorb. It is a critical soil parameter because it gives insight into the storage of nutrient cations (Ulery *et al*., 2017). Specifically, a high ECEC value is one of the indicators of good quality soils because it connotes the optimum capacity of the soil to hold on to more cations. Effective cation exchange capacity is also affected by land use conversions and soil management activities.

In Nigeria, various studies have attempted to quantify the effects of different agricultural land uses on soil properties (Ugwa *et al*., 2005; Ihem *et al*., 2014; Onwudike *et al*., 2017; Ekpenkhio, 2018; Adebo *et al*., 2020; Orobator and Ekpenkhio, 2021; Solomon *et al*., 2022; Ekpenkhio, 2022). Some investigations compared the effects of natural forests and monocropped plantations on soil properties (Ogunkunle and Awotoye, 2011; Gideon *et al*., 2016; Ota *et al*., 2019). Other studies examined the impact of cultivated lands of different ages on soil quality (Orimoloye *et al*., 2012; Onijigin *et al*., 2016; Orobator *et al*., 2020). But, only very little scientific report is so far documented on the distribution of soil exchangeable cations in relation to soil fertility and with particular reference to mixed permanent and annual arable cropping systems. Although Orobator and Odjugo (2015) evaluated the influence of parent materials and land use on exchangeable cations in a tropical environment and found significant differences in the values of Ca, Mg, K and Na between secondary forest and plantain plantation and between plantain and oil palm plantations, their focus was on the effect of monocropped plantation forests on soil exchangeable cations and not a combination of mixed permanent and arable cropping systems.

Empirical knowledge of exchangeable cations in soils under different agroecosystems is fundamental in enhancing sustainable crop production and productivity. However, practically oriented basic information on the status and management of these soil indicators in different farming land use systems to give recommendations for the optimal utilization of soil resources remains scanty.

Therefore, the results of this study are expected to add value to the existing literature on exchangeable cations as it pertains to soil fertility under different farming systems and to fill the locational gap in knowledge in Edo State as well as other similar agro-ecological environments in Nigeria. Thus, this study was carried out to examine the distribution of exchangeable cations in soils under cassava-cultivated land use, mixed tree plantation and secondary forests of similar lithology in Edo State, Nigeria. The specific objectives were to: (i) determine the concentrations of exchangeable cations under each land use, (ii) evaluate the distribution of exchangeable cations across the different land uses, (iii) examine the impact of the different land uses on exchangeable cations, and (iv) ascertain if significant relationships exist among the exchangeable cations under each land use.

MATERIALS AND METHODS

Study Area

The study sites are located in the Odighi community of Ovia North-East Local Government Area, Edo State, Nigeria. Odighi was chosen for this study because it is largely an agrarian community that is endowed with diverse agricultural land use types. Geographically, Odighi is located between Latitudes 6° 37' 5.24" N and 6° 36' 46.97" N and Longitudes 5° 45' 53.88" E and 5° 45' 49.16" E (Figure 1). Odighi is spatially bounded by Uhiere, Owan and Agbanikaka villages to the north, and Igbakhue and Osasimwinoba villages to the south. The area has a relatively flat topography with an average elevation of 237 m above sea level and is drained by river Okhuo, a tributary to the Ovia River which is the largest and longest river in Edo State. Because the study area is approximately 37 km north of the capital city of Benin, they share similar climatic conditions. According to Köppen’s climate classification scheme, Odighi falls within the tropical rainforest climate zone. It is characterized by a distinct dry and wet season, with a mean annual rainfall and temperature of 2,040 mm and 34°C respectively. These climatic variations are suitable for cassava farming.

The soils in Odighi community have been classified by Imadojemu *et al.* (2018) as Typic Kandiudults with deep sandy horizons. The geology indicates the Benin rock formation, underlain by limestone which is generally of lateritic clay sand with reddish-brown colouration (Edema *et al.*, 2002). Although Odighi is located in the rain forest vegetation, typical of dense ever green, multi-layered high tropical forest with thick plant life, human activities are fast depleting the natural vegetation. Some of the dominant trees include teak (*Tectona grandis* L. f.), cacao (*Theobroma cacao*) and gmelina (*Gmelina arborea* Roxb.); dominant grasses consist of elephant grass (*Pennisetum purpureum*), guinea grass (*Panicum maximum*), giant star grass (*Cynodon plectostachyus*) etc; while arable crops cultivated comprise cassava (*Manihot esculenta* Crantz), yam (*Dioscorea spp*), plantain (*Musa paradisiaca*) and others.

Field Work

Soil sampling was conducted purposively under three different agricultural land uses viz. mixed tree plantation comprising gmelina (*Gmelina arborea* Roxb.) and teak (*Tectona grandis* L. f.) species, cassava (*Manihot esculenta* Crantz) cropland and secondary forest (uncultivated). Mixed tree plantation was 10-15 years old, cassava cultivated land use was 7-10 years old, while the secondary forest was 25 years old and above. Three transects of 100 m and at intervals of 25 m were mapped on each sample area measuring 100 m × 100 m (Johnson, 1961; Ahukaemere *et al.*, 2021). Soil samples were collected once during the rainy season from three sampling points at intervals of 50 m along each transect and at predetermined depths of 0-15 (topsoil) and 15-30 cm (subsoil) from each of the study sites.

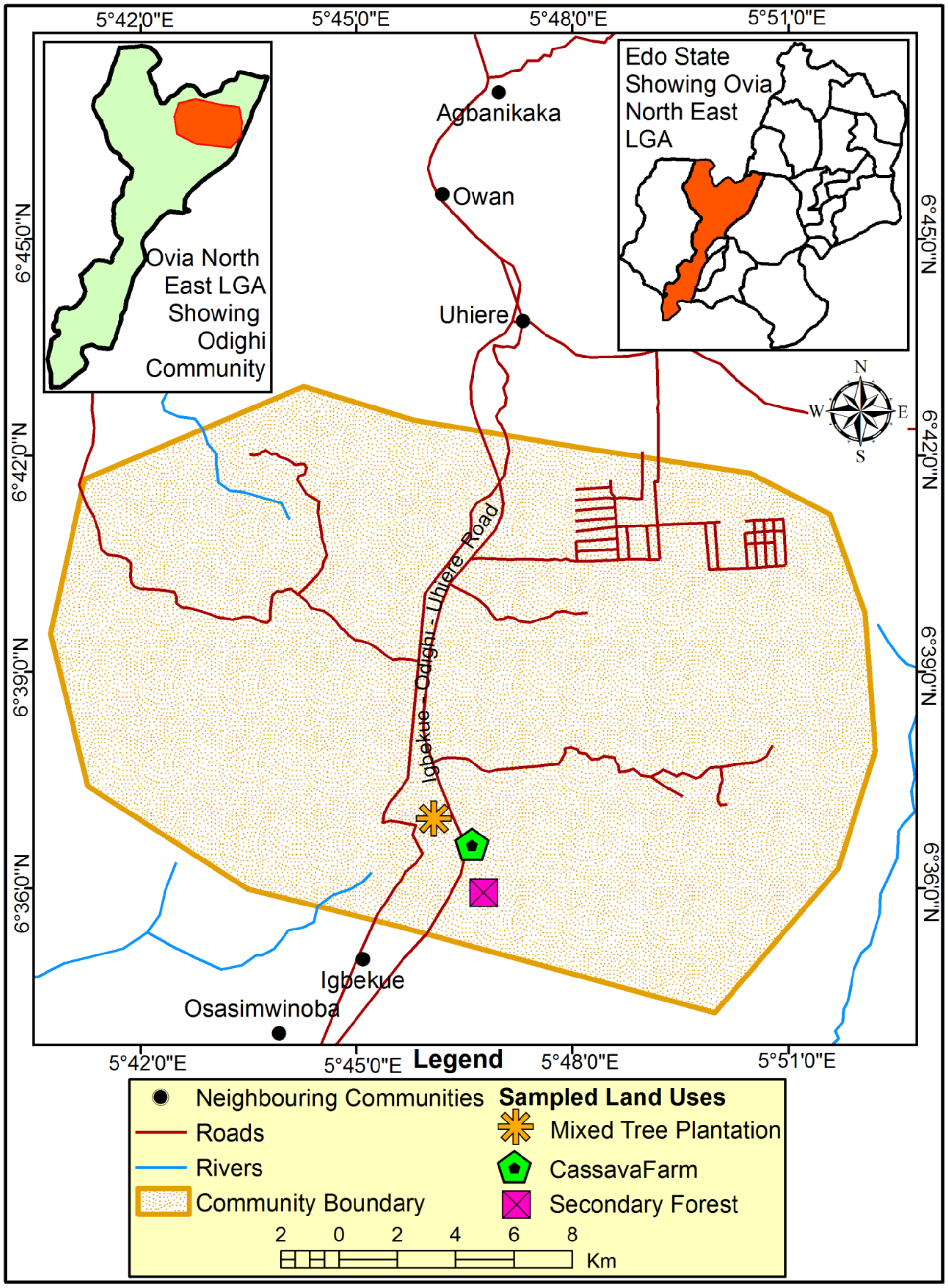

Figure 1: Odighi Community showing Sampled Land Uses

Source: Compiled using Open Street Map Database and Field Work

Beyond the fact that 85 % of plant roots are concentrated in the first 30 cm of the soil column where soil mineralization mainly occurs (De Oliveira and Valle, 1990; Webb *et al*., 2013), these depths were also chosen to examine the distribution of exchangeable cations between the topsoil and subsoil. Consequently, 18 soil samples each were collected from the sample sites thereby giving a total of 54 samples for the study. All sampling points were geo-referenced using a handheld Global Positioning System (GPS) receiver. The study sites have similar soil-forming environments in respect of lithology, topography and macro-climate but differed in their respective agricultural land use activities.

Soil Laboratory Test

Soil samples collected from the study sites were air-dried, gently crushed and sieved through a 2 mm mesh to remove impurities and homogenize the samples before analysis. Soil pH was measured in 1:1 (soil to water), using a glass electrode pH meter. Exchangeable cations: calcium (Ca) magnesium (Mg) potassium (K) and sodium (Na) were extracted using 1 M ammonium acetate solution at pH 7.0 through the leaching technique. Calcium and magnesium in the extracts were determined using atomic absorption spectrophotometer while Na and K were analyzed by a flame photometer (Malo *et al*., 2005). Exchangeable acidity (EA) was determined by leaching the soils with 1 M KC1 and titrating aliquots with 0.01 M NaOH. Effective cation exchange capacity was determined by the summation of Ca, Mg, K, Na and EA (Anderson and Ingram, 1993). Base saturation (BS) was calculated as the sum of the exchangeable cations divided by ECEC and expressed as a percentage.

Statistical Analysis

Descriptive statistics were computed for all soil properties in the 0-15 and 15-30 cm soil depths which included range, mean, standard deviation and coefficient of variation (CV). The distributions of exchangeable cations across the three agricultural land uses were depicted using bar charts. Variability of soil properties was assessed using Wilding and Dress, (1978) classification scheme in which CV < 15 % = less variable, CV = 15 - 35 % = moderately variable and CV > 35 % = highly variable. Threshold values for selected soil properties adapted from Landon (1991) and Waskom *et al*. (2014) were used to determine the status of exchangeable cations in the three land uses (Table 1). Analysis of variance was used to determine if any significant variation exists in the selected soil properties among the examined land uses. Pearson correlation analysis was tabulated to identify if significant relationships exist between the soil properties under each land use. All statistical procedures were performed using Microsoft Excel (2010) and SPSS version 16.0 statistical software packages.

RESULTS AND DISCUSSION

Soil pH

Table 2 revealed that pH values in soils of mixed tree plantations were 6.34 (0-15 cm) and 6.12 (15-30 cm). In cassava farms, it was 6.48 (0-15 cm) and 6.12 (15-30 cm) while in the secondary forest it was 6.96 and 7.31 for 0-15 and 15-30 cm soil depths respectively. The pattern of pH distribution was; mixed tree plantation > cassava farm > secondary forest in both the 0-15 and 15-30 cm soil depths. pH exhibited significant interaction effects with the three land uses and soil depths ($p \leq 0.05$). The pH means values recorded in all the soils were rated slightly acidic to neutral (Foth and Ellis, 1997). The lower pH means values observed in cassava soils compared to the control soils may be due to intensive cultivation of the land which increases water infiltration, runoff and leaching of basic cations. However, this pH status is acceptable for crop cultivation in the tropics where the soil may be subjected to regular leaching of bases and often replenished by crop residues. These pH values suggest that the soils in the three land uses have sufficiently balanced nutrient levels and are good for agricultural use (Brito-Vega *et al*., 2018).

Table 1: Threshold Values for the Selected Soil Properties

Soil parameter	Very low	Low	Moderate	High	Very high
pH		< 5.5	5.5 - 7.0	> 7.0	
Ca (cmol kg^{-1})		< 4	4 - 10	> 10	
Mg (cmol kg^{-1})		< 3	3 - 8		> 8
Na (cmol kg^{-1})	< 0.1	0.1 - 0.3	0.3 - 0.7	0.7 - 2	> 2
K (cmol kg^{-1})		< 0.2	0.2 - 0.6	> 0.6	
EA (cmol kg^{-1})		<2.1	2.1 - 4.0	>4.0	
ECEC (cmol kg^{-1})	< 5	5 - 15	15 - 25	25 - 40	> 40
BS (%)	< 20	20 - 40	40 - 60	60 - 80	> 80

Source: *Modified from Landon (1991) and Waskom et al. (2014)*

Exchangeable Calcium

Table 2 showed that the distribution of Ca in soils of mixed tree plantation was 5.71 cmol kg^{-1} (0-15 cm) and 4.05 cmol kg^{-1} (15-30 cm). In the cassava farm, the Ca mean values were 4.84 cmol kg^{-1} (0-15 cm) and 4.72 cmol kg^{-1} (15-30 cm) while in the secondary forest it was 4.72 cmol kg^{-1} and 3.94 cmol kg^{-1} for 0-15 and 15-30 cm soil depths respectively. These results revealed that the sequence of Ca concentrations in topsoil was in the order mixed tree plantation > cassava cultivated land use > secondary forest, but in subsoil, it was cassava cultivated land use > mixed tree plantation > secondary forest. The value of exchangeable Ca was higher at the topsoil (0-15 cm) than at the subsoil (15-30 cm) in all the different land use types. This may be a result of abundant biological activities as well as plant and animal residues at the topsoil than the subsoil of the studied sites. White (1997) reported that soil parent materials also play a major role in determining its Ca concentration. This outcome corresponds with the work of Kiflu and Beyene (2013) but was at variance with Bore and Bedadi (2015).

The lower mean Ca values recorded in both top- and sub-soils of secondary forest may be due to higher proportions of the element being retained in the diverse plant biomass and not being returned to the soil (Yamashita *et al*., 2008). Also, Brady and Weil (2007) opined that high tropical rainfall and harvesting of timber as it is prevalent in the control (secondary forest) site leaves the soil open to erosion and nutrient leaching that lead to rapid loss of Ca. However, since the Ca values in soils of both depths and across all the land uses were within 4 to 10 cmol kg^{-1}, they were categorized as moderate rate and adequate for most plants. The interaction effects of land use and soil depths displayed a non-significant ($p > 0.05$) impact on Ca. Generally, the results show that Ca was the most dominant exchangeable cation followed by Mg, K and Na respectively (Table 2). The high level of exchangeable Ca over Mg, K and Na agreed with Pitty (2014), who stated that Ca is the most predominant cation in soil due to its strong adsorption and rapid release into the soil system through soil mineral weathering.

Exchangeable Magnesium

The distributions of Mg mean values in mixed tree plantations were 2.25 cmol kg^{-1} in the topsoil and 1.33 cmol kg^{-1} in the subsoil. In cassava land use it was 1.90 cmol kg^{-1} (topsoil) and 1.72 cmol kg^{-1} (subsoil), while in the secondary forest it was 1.94 cmol kg^{-1} (topsoil) and 1.46 cmol kg^{-1} (subsoil) (Table 2). Results indicated that the concentrations of Mg were in the order of mixed tree plantation > secondary forest > cassava cultivated land use for topsoil while the order in subsoil was cassava cultivated land use > secondary forest > mixed tree plantation. There was an insignificant impact ($p > 0.05$) of land use types and soil depths on soil Mg. However, on a comparative basis, the higher level of Mg in topsoil of mixed tree plantation (2.25 cmol kg^{-1}) may be due to the dense overhead canopy and more undergrowth that protects the soil from rain drop impact and accelerated soil nutrients decomposition which might have enhanced the accumulation of Mg.

The lowest Mg value (1.90 cmol kg^{-1}) observed in cassava soils may be related to the low percentage foliage cover under cassava farmland thereby exposing the soil surface to erosion and soil Mg depletion. The intensity of cultivation and annual crop harvest with little or no inputs in soils of cassava farms may have accounted for the low Mg status. Meanwhile, tuber crops are known to rapidly diminish soil Mg (Mikkelsen, 2010). This result aligns with that of Ufot *et al.* (2016) who noticed a lower mean value for Mg in the topsoil of cassava land use compared to the other land use types. The proportions of Mg were rated low in all the studied sites implying a deficiency of the element in the soils of the study area. Similar results were reported by Orobator and Odjugo (2015). However, the ratio of exchangeable Ca to Mg in the three land uses was within the critical values (3:1 to 5:1), which may not cause nutrient imbalance under the different land use types of the study area.

Exchangeable Sodium

Regarding the distributions of Na concentrations, the mean values of mixed tree plantation, cassava cultivated land use and secondary forest both at the topsoil and subsoil were (0.29, 0.21) (0.56, 0.33) and (0.28, 0.19) cmol kg-1 respectively (Table 3). The sequence of Na concentrations was in decreasing order of cassava cultivated land use > mixed tree plantation > secondary forest in both soil depths. These results revealed the positive influence cassava cultivation had on Na concentrations in both soil depths compared to the other sites. Variability of Na with soil depths indicated that Na declined down the soil in all the examined land uses.

Table 2: Summary of Selected Soil Chemical Properties under the Different Agricultural Land Uses

Soil Parameter	Depth (cm)	Mixed Tree Plantation				Cassava-Cultivated Land Use				Secondary Forest				p-value
		Range	Mean	SD	CV (%)	Range	Mean	SD	CV (%)	Range	Mean	SD	CV (%)	
pH	0 - 15	5.80 - 6.80	6.34	0.28	4.53	6.00 - 6.90	6.48	0.27	4.21	6.60 - 7.60	6.96	0.30	4.32	0.00*
	15 - 30	5.70 - 6.60	6.12	0.25	4.15	5.40 - 6.90	6.12	0.53	8.71	6.90 - 7.90	7.31	0.34	4.66	0.00*
Ca ($cmol\ kg^{-1}$)	0 - 15	3.60 - 7.50	5.71	1.14	20.04	2.80 - 6.70	4.84	1.42	29.48	3.41 - 7.60	4.72	1.39	29.49	0.25
	15 - 30	2.30 - 5.80	4.05	1.26	31.26	2.90 - 6.80	4.71	1.13	24.14	2.60 - 6.40	3.93	1.44	36.73	0.39
Mg ($cmol\ kg^{-1}$)	0 - 15	1.61 - 2.80	2.25	0.51	22.71	1.10 - 2.60	1.90	0.48	25.62	0.90 - 2.60	1.94	0.52	27.19	0.30
	15 - 30	0.12 - 2.20	1.33	0.70	53.50	1.18 - 2.20	1.72	0.35	20.51	0.71 - 2.80	1.46	0.74	50.98	0.41
Na ($cmol\ kg^{-1}$)	0 - 15	0.12 - 0.42	0.29	0.10	37.02	0.21 - 2.40	0.56	0.69	124.28	0.15 - 0.41	0.28	0.11	39.25	0.28
	15 - 30	0.10 - 0.36	0.21	0.10	48.51	0.18 - 0.60	0.33	0.14	43.06	0.10 - 0.40	0.19	0.10	54.49	0.03*
K ($cmol\ kg^{-1}$)	0 - 15	0.38 - 0.62	0.45	0.10	22.09	0.32 - 0.62	0.49	0.09	19.88	0.16 - 0.41	0.33	0.09	29.61	0.00*
	15 - 30	0.12 - 0.46	0.29	0.12	44.73	0.31 - 0.64	0.47	0.10	22.88	0.12 - 0.60	0.27	0.14	52.34	0.00*
EA ($cmol\ kg^{-1}$)	0 - 15	0.04 - 0.05	0.05	0.00	7.22	0.01 - 0.07	0.04	0.01	34.35	0.01 - 0.04	0.05	0.00	7.46	0.90
	15 - 30	0.035 - 0.095	0.05	0.01	35.88	0.01 - 0.07	0.05	0.01	37.04	0.042 - 0.055	0.05	0.00	8.34	0.85
ECEC ($cmol\ kg^{-1}$)	0 - 15	7.13 - 11.36	8.75	1.22	14.04	4.88 - 10.27	7.64	1.87	24.49	5.05 - 11.03	7.32	1.86	25.50	0.19
	15 - 30	4.09 - 8.82	6.42	1.67	26.14	4.95 - 9.57	7.27	1.31	18.15	4.06 - 9.96	5.90	2.18	36.98	0.27
BS (%)	0 - 15	99.19 - 99.56	99.41	0.12	0.12	98.98 - 99.85	99.33	0.28	0.29	98.00 - 99.55	99.14	0.46	0.47	0.34
	15 - 30	98.38 - 99.55	99.15	2.029	0.40	93.21 - 99.88	98.28	0.39	2.34	98.77 - 99.84	99.17	0.37	0.38	0.30

It was observed that the concentration of Na was the least on the exchange complex (Table 2), and was rated low to moderate in all the sites and soil depths. Possible reasons for this low to moderate status could be that the parent material on which the soils have developed is poor in Na.

The lower Na concentrations in the control (secondary forest) site compared to treatment (mixed tree plantation and cassava farm) sites may be explained by the fact that in the forest ecosystem, the majority of soil nutrients are found in the biomass than in soils, been that their biomass could be larger than that of other vegetal ecosystems. The study of Ota *et al*. (2019) is at variance with this result and found that Na was lower in the *Gmelina* plantation compared to the control site. The high variability (CV > 35 %) of Na contents may have justified the significant variation ($p < 0.05$) noted in the subsoil across the land uses.

Exchangeable Potassium

Potassium concentrations in soils of mixed tree plantations recorded mean values of 0.45 cmol kg^{-1} in 0-15 cm depth and 0.29 cmol kg^{-1} in 15-30 cm depth. In cassava soils, K content mean values in topsoil and subsoil were 0.49 and 0.47 cmol kg^{-1} respectively while under secondary forest, a mean of 0.33 and 0.27 cmol kg^{-1} were observed in topsoil and subsoil respectively (Table 2). Similar to Na, the sequence of K contents was in the order of cassava cropping land > mixed tree plantation > secondary forest at both soil depths. Comparative to Ca and Mg (Table 2), the result showed that K concentrations declined with decreasing soil depths. The higher K values observed in cassava soils suggest that cassava cultivation absorbs less K compared to mixed tree plantation and secondary forest. A similar trend was also observed for Na. This finding is in consonance with the work of Onwudike *et al*. (2017) who reported higher K values in soils under cassava farmland than in maize and forest land use types. Despite the significant variation ($p < 0.05$) observed across the land uses and soil depths, K proportions were within adequate levels for most plants in all the land use types.

Exchangeable Acidity

The exchangeable acidity in the top and sub-soil of mixed tree plantation indicated mean values of 0.05 cmol kg^{-1} and 0.05 cmol kg^{-1} respectively. In the cassava cultivated land use, it was 0.04 cmol kg^{-1} (topsoil) and 0.05 cmol kg^{-1} (subsoil) while in the secondary forest it was 0.05 cmol kg^{-1} (topsoil) and 0.05 cmol kg^{-1} (subsoil) (Table 2). The EA status was rated low in the study area as their values were below the moderate range of 2.1 - 4.0 cmol kg^{-1} for crop production. This low status reflects the pH, albeit H and Al may be the principal contributors to EA in the soils. No significant variation ($p > 0.05$) was observed across the different land uses and soil depth levels for exchangeable acidity. This finding was in contrast with the work of Endalew *et al*. (2014) who reported highly significant ($p < 0.01$) variation between land use types on exchangeable acidity.

Effective Cation Exchange Capacity

Mean values for ECEC concentrations in mixed tree plantation, cassava cultivated land use and secondary forest both at the topsoil and subsoil were (8.75, 6.42) (7.64, 7.27) and (7.32, 5.90) cmol kg^{-1} respectively (Table 2).

The order of ECEC values was mixed tree plantation > cassava cultivated land use > secondary forest in topsoil while the order in the subsoil was cassava cultivated land use > mixed tree plantation > secondary forest. ECEC values decreased with increasing soil depth in all the investigated land uses. This finding agrees with Gideon *et al*. (2016) who found that ECEC content declined down the soil horizon under the different land uses. Topsoil mixed tree plantation recorded the highest mean ECEC value (8.75 cmol kg^{-1}) compared to the other land uses.

This result is not surprising because, unlike the monoculture type of vegetation in cassava farms, mixed tree plantations had the highest diversity of plant species which possess different quality and decay rates of litter. Besides, the frequent supply of basic cations by microbial decomposition of organic residues would have contributed to the higher values of ECEC in the topsoil of mixed tree plantation. This result disagrees with the work of Woldeamlak and Stroosnijder (2003) who found that ECEC was higher in forest soils than in cultivated soils. However, ECEC was not significantly impacted by the interaction effects of the land uses and soil depths ($p > 0.05$). The result obtained was not consistent with the findings of Jemal (2020) who reported that ECEC was significantly ($p < 0.05$) affected by land use. Similar to EA, the ECEC values for soils in all the examined sites were classified as low (Landon, 1991; Waskom *et al*., 2014). This outcome could imply that all the soil tests have low clay fractions. Also, the low classification of ECEC in this study indicates a low reservoir of soil nutrients in the area.

Base Saturation

As shown in Table 2, the mean concentrations of base saturation in mixed tree plantations were 99.41 % in the topsoil and 99.15 % in the subsoil. Under cassava-cultivated soils, base saturation mean values were 99.33 % in 0-15 cm depth and 98.28 % in 15-30 cm depth. Regarding secondary forest, the topsoil base saturation mean value was 99.14 % while it was 99.17 % in the subsoil. Base saturation was non-significantly ($p > 0.05$) impacted by the different land uses and soil depths. This result disagrees with the work of Kiflu and Beyene (2013) who reported significant differences ($p < 0.05$) in base saturation under grassland, wild banana and maize land use systems. The high per cent base saturation (> 80 %) in the area may be due to the ease with which adsorbed cations are released to plants. Exchangeable acidity was extremely low and that may have accounted for the high BS as ECEC was almost made up of basic cations. Soils with a high per cent base saturation are generally more fertile.

Correlation Study among Soil Properties at 0-15 and 15-30 cm Soil Depths under Different Land Use Types

In order to determine the extent of the relationships among the selected soil properties in all the investigated land uses, the Pearson correlation coefficient was computed for the 0-15 and 15-30 cm soil depths (Table 3). Significant correlations were observed in 3 of the 21 soil properties in the topsoil of mixed tree plantation. Significant positive correlations were detected for Ca with ECEC, and Na with Mg, while BS significantly and negatively correlated with EA. As for the subsoil, 5 significant associations were observed. Significant positive relationships were noted for Ca with ECEC and BS; K with Na and BS with ECEC. Contrastingly, BS correlated significantly and negatively with EA. In the topsoil and subsoil of the cassava cultivated site, 3 significant relationships each were detected within the 21 soil attribute pairs. Significant positive relationships were exhibited for Ca with ECEC; Mg with EA and ECEC with Mg. In the subsoil, K correlated significantly and positively with Na and ECEC with Ca. However, a significant negative correlation was revealed between BS and EA. Secondary Forest topsoil displayed 5 significant correlations among the 21 soil property pairs. Significant positive associations were revealed for Ca with Mg and ECEC; Mg with ECEC and BS; and ECEC with BS. For subsoil, the 6 significant correlations found within the 21 soil attribute pairs were all positively correlated. They were Ca with Mg and ECEC; Mg with ECEC and BS; Na with BS; and ECEC with K. Similar significant positive and antagonistic relationships among soil chemical properties were reported by Orimoloye *et al*. (2018), Tufa *et al.* (2019) and Solomon *et al*. (2022). Generally, the correlations observed among the exchangeable cations suggest that the soils were from similar lithology. The significant positive correlations observed between Ca and ECEC in both the topsoil and subsoil of all the land uses infers that at higher Ca concentrates, the capability of the soils to hold on to cations will improve. Ca is an important element to ECEC because of its positive influence.

CONCLUSION

Distribution of exchangeable cations in soils under cassava cultivated land use, mixed tree plantation and secondary forest of similar lithology in Edo State, Nigeria were examined during the rainy season using analysis of variance and correlation statistical tools. It was noticed that the different agricultural land uses and soil depths had varied impacts on the examined soil properties. Considering the distribution of exchangeable cations with soil depths, this study showed that Na, Ca, Mg and K decreased down the soil in all the land uses. While Ca, Na, K and BS were rated as adequate in all the test soils, EA and Mg concentrations were rated as low and deficient. Generally, it was observed that soils in the three land use types reflect the ease with which adsorbed cations are released to plants due to the high base saturation level, but lacked adsorptive capacity for nutrients due to the low ECEC values. The study recommended the use of Mg containing fertilizer and Epsom salts as cheap and readily available solution to ameliorate Mg deficiency in the soils. Also, liming and incorporation of organic matter were suggested to boost the cations holding capacity of the soil.

Table 3: Pearson's Correlation Coefficient Matrix of Selected Chemical Properties for Topsoil (0-15 cm, Above Diagonal) and Subsoil (15-30 cm, Below Diagonal)

Variables	pH	Ca	Mg	Na	K	EA	ECEC	BS
Mixed Tree Plantation								
pH	-	0.157	-0.126	-0.280	0.207	-0.606	0.085	0.283
Ca	0.126	-	-0.190	-0.186	0.259	-0.088	0.856**	0.458
Mg	-0.129	0.260	-	0.680*	0.372	0.452	0.330	-0.440
Na	-0.458	0.449	0.427	-	0.611	0.278	0.247	0.056
K	-0.580	0.284	0.316	0.929**	-	-0.260	0.530	0.477
EA	-0.542	-0.301	0.181	0.305	0.425	-	0.112	-0.684*
ECEC	0.084	0.985**	0.131	0.462	0.306	-0.303	-	0.286
BS	0.504	0.772*	-0.057	0.121	-0.054	-0.799**	0.776*	-
Cassava-Cultivated Land Use								
pH	-	0.115	0.168	0.270	-0.027	-0.080	0.126	0.080
Ca	-0.245	-	0.595	0.521	0.340	-0.001	0.965**	0.647
Mg	0.146	0.118	-	0.416	0.536	0.712*	0.775*	-0.100
Na	0.235	0.288	0.011	-	0.540	0.116	0.571	0.245
K	0.302	0.235	0.404	0.692*	-	0.274	0.494	0.202
EA	0.141	-0.413	-0.382	0.480	0.002	-	0.224	-0.725
ECEC	-0.220	0.966**	0.350	0.338	0.359	-0.414	-	0.482
BS	-0.367	0.273	0.251	-0.065	0.293	-0.716*	0.308	-
Secondary Forest								
pH	-	-0.008	-0.430	-0.335	0.172	-0.155	-0.138	-0.660
Ca	-0.001	-	0.780*	-0.036	0.204	-0.182	0.975**	0.549
Mg	0.209	0.782*	-	0.177	0.236	0.122	0.887**	0.861**
Na	0.557	-0.010	0.326	-	0.528	-0.051	0.111	0.196
K	-0.385	0.583	0.641	-0.007	-	-0.495	0.302	0.205
EA	0.182	-0.759	-306	0.186	-0.259	-	-0.129	-0.084
ECEC	0.072	0.964**	0.915**	0.152	0.669*	-0.613	-	0.674*
BS	0.325	0.435	0.796*	0.789*	0.451	0.001	0.626	-

*** = correlation is significant at the 0.05 level (2-tailed), ** = correlation is significant at the 0.01 level (2-tailed)**

REFERENCES

Adebo, B., Aweto, A. and Ogedengbe, K. (2020). Assessment of soil quality under different agricultural land use systems: a case study of the Ibadan farm settlement. *International Journal of Plant and Soil Science*, 89-104.

Ahukaemere, C.M., Onweremadu, E.U. and Akamigbo, F.O.R. (2021). Erodibility of soils of varying land utilization types and lithologic materials in central southeastern Nigeria. *Agro-Science*, 20(3): 104-109. https://dx.doi.org/10.4314/as.v20i3.14.

Anderson, J.M. and Ingram, J.S. (1993). *Tropical soil biology and fertility*: A handbook of Methods, 2nd ed. CAB International, Wellingford, UK., 35 pp.

Bore, G. and Bedadi, B. (2015). Impacts of land use types on selected soil physico-chemical properties of Loma Woreda, Dawuro Zone, Southern Ethiopia. *Science, Technology and Arts Research Journal*, 4(4): 40-48.

Brady, N.C. and Weil, R.R. (2007). *The nature and properties of soils*, (13th ed.) New Jersey, Prentice Hall Inc., USA. 450 pp.

Brito-Vega, H., Salaya-Domínguez, J.M., Gómez-Méndez, E., Gómez-Vázquez, A., Antele-Gómez, J.B., (2018). Physico-chemical properties of soil and pods (*Theobroma cacao* L.) in cocoa agroforestry systems. *Journal of Agronomy*, 17(1): 48-55.

De Oliveira, L.J. and Valle, R.R. (1990). Nutrient cycling in the cacao ecosystems: Rain and through fall as nutrient sources for the soil and the cacao tree. *Agricultural Ecosystem and Environment*, 32: 143-154.

Edema, C.U., Ayeni, J.O. and Aruoture, A. (2002). Some observations on the zooplankton and macrobenthos of the Okhuo River, Nigeria. *Journal of Aquatic Sciences*, 17(2): 145-149.

Ekpenkhio, E. (2018). Land Use Effects on Soil Quality in Ososo Mountain Region, Edo State, Nigeria. Unpublished B.Sc. Thesis, Department of Geography and Regional Planning, Faculty of Social Sciences, University of Benin, Benin City, Nigeria.

Ekpenkhio, E. (2022). A comparative analysis of the effects of mixed tree (*Gmelina arborea* Roxb. and *Tectona grandis* L. f.) plantation and cassava crop (*Manihot esculenta* Crantz) cultivation on soil quality in Odighi, Edo State, Nigeria. Unpublished M.Sc. Thesis, Department of Geography and Regional Planning, Faculty of Social Sciences, University of Benin, Benin City, Nigeria.

Endalew, B. A., Adgo, E. and Argaw, M. (2014). Impact of land use types on soil acidity in the highlands of Ethiopia: The case of Fagetalekoma District. *Journal of Environmental Sciences*, 2(8): 124-132.

Faniran, A. and Areola, O. (1978). *Essentials of Soil Study*. Ibadan: Heinemann Educational Books, 350 pp.

Food and Agriculture Organization (FAO). (2005). Global Forest Resources Assessment 2005. FAO Forestry paper 140 Rome, Italy.

Foth, H. D. and Ellis, B. G. (1997). *Soil fertility*, (2nd ed.). Lewis CRC Press LLC., USA, 290 pp.

Gideon, I.K., Ogbonna, A.N. and Nzebgule, E.C. (2016). Soil physicochemical properties in three land-use sysytems (*Theobroma cacao*, *Gmelina arborea* and secondary forest) in Umuahia north of Abia State, Nigeria. *Canada Journal of Agriculture and Crops*, 8(1): 12-21.

Ihem, E.E., Osuji, G.E., Onweremadu, E.U., Onwudike, S.U., Nkwopara, U.N., Ndukwu, B.N., Uzoho, B.U. (2014). Variability in properties of soils under three land use types in a humid tropical environment. *International Journal of Development and Sustainability*, 3(4): 923-930.

Jemal, K. (2020). Effects of different land use systems on physicochemical properties of soil in Wudma Sub Watershed District, southern Ethiopia. *Global Advanced Research Journal of Agricultural Science*, 9(6): 151-159.

Johnson, W.M. (1961). Transect methods for determination of composition of soil mapping units. Soil Survey Technical Notes, SCS/USDA.

Kiflu, A. and Beyene, S. (2013). Effects of different land use systems on selected soil properties in South Ethiopia. *Journal of Soil Science and Environment Management*, 4(5): 100-107.

Landon, J.R. (1991). Booker tropical soil manual: A Handbook for Soil Survey and Agricultural Land Evaluation in the Tropics and Subtropics. Longman Scientific and Technical, Essex, New York. pp 474.

Maddonni, G.A., Urricariet, S., Ghersa, C.M. and Lavado, R.S. (1999). Assessing soil fertility in the rolling Pampa, using soil properties and maize characteristics. *Journal of Agricultural Research and Science*, 91: 280-286.

Malo, D.D., Schumacher, T.E. and Doolittle, J.J. (2005). Long-term cultivation impacts on selected soil properties in the northern Great Plains. *Soil and Tillage Research*, 81, 277-291.

Mikkelsen, R. (2010). Soil and fertilizer magnesium. *Better Crops*, 94(2), 26-28.

Newbold, T., Hudson, L.N., Hill, S. and Contu, S. (2015). Global effects of land use on local terrestrial biodiversity. *Nature*, 520(7545): 45-50. https://doi: 10.1038/nature1432.

Ogunkunle, C.O. and Awotoye, O.O. (2011). Soil fertility status under different tree cropping systems in a southwestern zone of Nigeria. *Notulae Scientia Biologicae*, 3(2): 123-128.

Onijigin, E. O., Fasina, A. S., Oluwadare, D. A., Ogbonnaya, U. O., Ogunleye, K.S. and Omoju, O.J. (2016). Influence of fallow ages on soil properties at the forest-savanna boundary in southwestern Nigeria. *International Journal of Plant and Soil Science*, 10(1): 1-12. doi: 10.9734/ijpss/2016/23551.

Onwudike, S.U., Agbani, L., Ihem, E. and Onyegbule, U. (2017). Influence of land use types on soil properties and micronutrient concentrations on soils of similar lithology in Owerri, southeastern Nigeria. *MAYEB Journal of Agricultural Science*, 4: 1-9.

Orimoloye, J.R., Akinbola, G.E., Idoko, S.O., Waizah, Y. and Esemuede, U. (2012). Effects of rubber cultivation and associated land use types on the properties of surface soils. *Nature and Science*, 10(9): 48-52.

Orimoloye, J.R., Alasa, I.R. and Umweni, A.S. (2018). Characterization and classification of some flood plain soils at Weppa, Edo State, Nigeria for sustainable agricultural productivity. *Ife Journal of Agriculture*, 30(3): 1-18.

Orobator, P.O. and Odjugo, P.A.O. (2015). Influence of parent materials and land use on exchangeable cations in a tropical environment. *Journal of Geography, Environment and Earth Science International*, 3(4): 1-12.

Orobator, P.O., Ekpenkhio, E. and Noah, J. (2020). Effects of rubber (*Hevea brasiliensis*) plantation of different age stands on topsoil properties in Edo State, Nigeria. *Journal of Geographic Thought and Environmental Studies*, 15(2): 21-35.

Orobator, P.O. and Ekpenkhio, E. (2021). Land use effect on quality of plateau soils: a case study of Ososo in northern Edo State, Nigeria. *Ghana Journal of Geography*, 13(3): 22-41.

Ota, H.O., Aja, D., Okolo, C.C., Oranu, C.O. and Nwite, J.N. (2019). Influence of tree plantation *Gmelina arborea* and *Gliricidia sepium* on soil physicochemical properties in Abakaliki, Nigeria. *Acta Chemica Malaysia*, 2(2): 23-28.

Solomon, R.I., Abdulkareem, J.H. and Mamzing, D. (2022). A multivariate approach to assessing variability in some soils of the Nigerian Savanna, *Ife Journal of Agriculture*, 34 (1): 14-31.

Sposito, G. (1989). *The chemistry of soils*. Oxford University Press, New York. 64 pp.

Tufa, M., Melese, A. and Tena, W. (2019). Effects of land use types on selected soil physical and chemical properties: The case of Kuyu District, Ethiopia. *European Journal of Soil Science*, 8(2): 94-109. https://doi:10.18393/ejss.510744.

Ufot, U.O., Iren, O.B. and Njoku, C.U. (2016). Effects of land use on soil physical and chemical properties in Akokwa area of Imo State, Nigeria. *International Journal of Life-Sciences Scientific Research*, 2(2): 273-278.

Ugwa, I.K., Orimoloye, J.R. and Esekhade, T.U. (2005). Nutrients status of some soils supporting rubber (*Hevea brasiliensis* Arg. Muell) in midwestern Nigeria. *Nigeria Agricultural Journal*, 36: 169-176.

Ulery, A.L.,Graham, R.C., Goforth, B.R. and Hubbert, K.R. (2017). Fire effects on cation exchange capacity of California forest and woodland soils. *Geoderma*, 286 (2): 125-130.

Valera, C.A., Valle Junior, R.F., Varandas, S.G.P., Sanches Fernandes, L.F. and Pacheco, F.A.L. (2016). The role of environmental land use conflicts in soil fertility: a study on the Uberaba River basin, Brazil. *Science of the Total Environment*, 562: 463-473. https://doi.org/10.1016/j.scitotenv.2016. 04.04.

Wali, M.K., Evrendilek, F., West, T., Watts, S., Pant, D., Gibbs, H. and McClead, B. (1999). Assessing terrestrial ecosystem sustainability: usefulness of regional carbon and nitrogen models. *Nature and Resources*, 35(4): 20-33.

Waskom, R.M., Bauder, T., Davis, J. and Andales, A.A. (2014). Diagnosing saline and sodic soil problems. Colorado State

University Extension. A division of the Engagement; 2014. Available:www.ext.colostate.edu/../00521.html

Webb, M.J., Nelson, P.N., Bessou, C., Caliman, J.P. and Sutarta, E.S. (2013). Sustainable management of soil in oil palm plantings (eds). *Proceedings of a workshop held in Medan, Indonesia. Australian Centre for International Agricultural Research*: Canberra, 70 pp.

White, R. E. (1997). *Principles and practice of soil science: The soil as a natura.* Blackwell Science, Vistoria, 45 pp.

Wilding, L.P. and Dress, L.R. (1978). Spatial Variability: A Pedologist's View Point In: Diversity of Soils in the Tropics. ASA Special Publication, 34: 1-12.

Woldeamlak, B. and Stroosnijder, L. (2003). Effects of agro-ecological land use succession on soil properties in the Chemoga watershed, Blue Nile basin, Ethiopia. *Geoderma*, 111: 85-98.

Wright, S.J. (2005). Tropical forests in a changing environment. *Trends in Ecology and Evolution*, 20(10): 553-60. doi: 10.1016/j.tree.2005.07.009.

Yamashita, N., Ohta, S. and Hardjono, A. (2008). Soil changes induced by *Acacia mangium* plantation establishment: comparison with secondary forest and *Imperata cylindrica* grassland soils in south Sumatra, Indonesia. *Forest Ecology and Management*, 254: 362-370.