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Land Use Management and Nutrient Status of Soils under Tomato (*Lycopersicon esculentum* Mill.) and Oil Palm (*Elaeis guineensis*) Cultivation in Southwestern Nigeria

F. F. Akinola[1*] and O. O. Olubanjo[2]

[1]*Department of Agricultural and Bio-Environmental Engineering, Federal Polytechnic Ado-Ekiti, Nigeria.*
[2]*Department of Agricultural and Environmental Engineering, Federal University of Technology, Akure. Nigeria.*

Authors' contributions

This work was carried out in collaboration between both authors. Authors FFA and OOO designed the study. Author FFA performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Authors FFA and OOO managed the analyses of the study. Author FFA managed the literature searches. Both authors read and approved the final manuscript.

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ABSTRACT

Human-induced soil degradation is a common phenomenon in Nigeria and other sub-Saharan African countries. The study was conducted to determine the effects of rainfall on physico-chemical characteristics of uncultivated bare soil and soils under tomato and oil palm plantation. The effects of the different land uses on soil physical properties such as bulk density (BD), total porosity (PT), soil water content (WC), and particle size distribution) and soil chemical properties namely: organic matter content (SOM), cation exchange capacity (CEC), phosphorus (P) and total nitrogen (TN) were determined. Sediment loss from bare soil plots resulted to loss of soil organic matter (SOM), soil organic carbon (SOC) and in extension loss of soil macro-nutrients such as total nitrogen (TN) and potassium (K). The sand, silt and clay fractions were significantly affected by land uses, soil

**Corresponding author: E-mail: funkeakinola01@yahoo.com, funkeakinola93@gmail.com, akinolafunke93@gmail.com;*

depths and the interaction of land uses ($p \leq 0.001$). Land use management significantly ($p \leq 0.001$, $p \leq 0.01$ and $p \leq 0.05$ respectively) affected the nutrients and fertility status of the land use types. The results of the sediment yield analysis have demonstrated that the three different treatments led to different amounts of soil nutrients loss accompanying the sediments. Soil management has a major impact on agricultural productivity and ecosystem sustainability as soils differ in their response to different management. The study emphasizes the management of soil nutrients through effective runoff and sediment yield analysis.

Keywords: Soil organic matter; bulk density; tomato; oil palm; land uses.

1. INTRODUCTION

Soil fertility decline and reduced soil productivity is a subject of major concern in Africa as it contributes to hunger (famine), food insecurity and reduction in farm or household incomes [1]. Soil physical and chemical properties have been proposed as suitable indicators for assessing the effect of land-use changes and management [2,3]. Soils undergo intensive changes in their physical, chemical, and biological properties during natural soil development and as a result of anthropogenic processes such as ploughing, sealing, erosion by wind and water, amelioration, excavation, and reclamation of devastated land. Different studies have examined the effects of land use/cover change on soil physico-chemical properties, and most concur that despite its consequences vary, land use change frequently leads to nutrient losses and reduction of organic matter inputs in the soil [4]. Soil physical properties could be affected not only by land use changes but also by land management practices [5].

Land use affects soil fertility and productivity. These manifests as changes in soil properties such as nutrient content (N, P, K, Ca, Mg, S etc.), pH, organic matter, CEC, structure etc [6,7] observed increased pH and organic matter for soils under *Gmelina aborea* than those under *Pinus canaborea*, *Treculia Africana*, agro forestry and fallow. They also observed increased P in fallow compared to other land uses. Furthermore, Akamigbo and Asadu [7] reported marked changes in morphological, physical and chemical properties which resulted to accelerated pedogenic processes and a decline in fertility of soil under traditional than forest land use. It has been observed that as the fertility of the soil declines, soil structure weakens and the soil becomes susceptible to erosion [8].

The productive capacity of a soil depends on complex interactions between the biological, chemical and physical properties of soil, which sometimes are little understood. Good farm practice aims to manage the various factors that make up each of these three properties to optimize the yields of crops in environmentally friendly way. Assessment of properties that make up soil fertility is very important components for the ability of soil to supply essential plant nutrients and soil water in adequate amounts and proportions for plant growth and reproduction in the absence of toxic substances which may inhibit plant growth. Achieving and maintaining appropriate levels of soil fertility, especially plant nutrient availability, is of paramount importance if agricultural land is to sustaining crop production at an acceptable level. Therefore, this paper evaluates soil physico-chemical properties of soils under different agricultural land use in an Alfisol of Southwestern Nigeria.

2. METHODOLOGY

2.1 Study Area

The study was carried at the Research and Training Farm of Federal University of Technology, Akure, (FUTA). Akure lies on latitude latitude 7° 17' N and longitude 5° 13' E [9]. Akure has a land area of about 2 303 km^2 and is situated in the western upland area within the humid region of Nigeria. The general elevation is 300 - 700 m above mean sea level. Local peaks rise to 1000 m; other hill-like structures which are less prominent rise only a few hundred meters above the general elevations. The pattern of rainfall is bimodal, the first peak occurring in June and July, and the second in September, with a little dry spell in August. The mean annual rainfall ranges from 1300 mm to1500 mm [10].

The soils of the site are light textured and predominantly sandy clay loam and belong to the Alfisol [11]. The soil is moderately well supplied by organic matter and nutrients. Moisture holding capacity is moderately good [12]. The soil generally becomes dry during the dry seasons which fall within November and March.

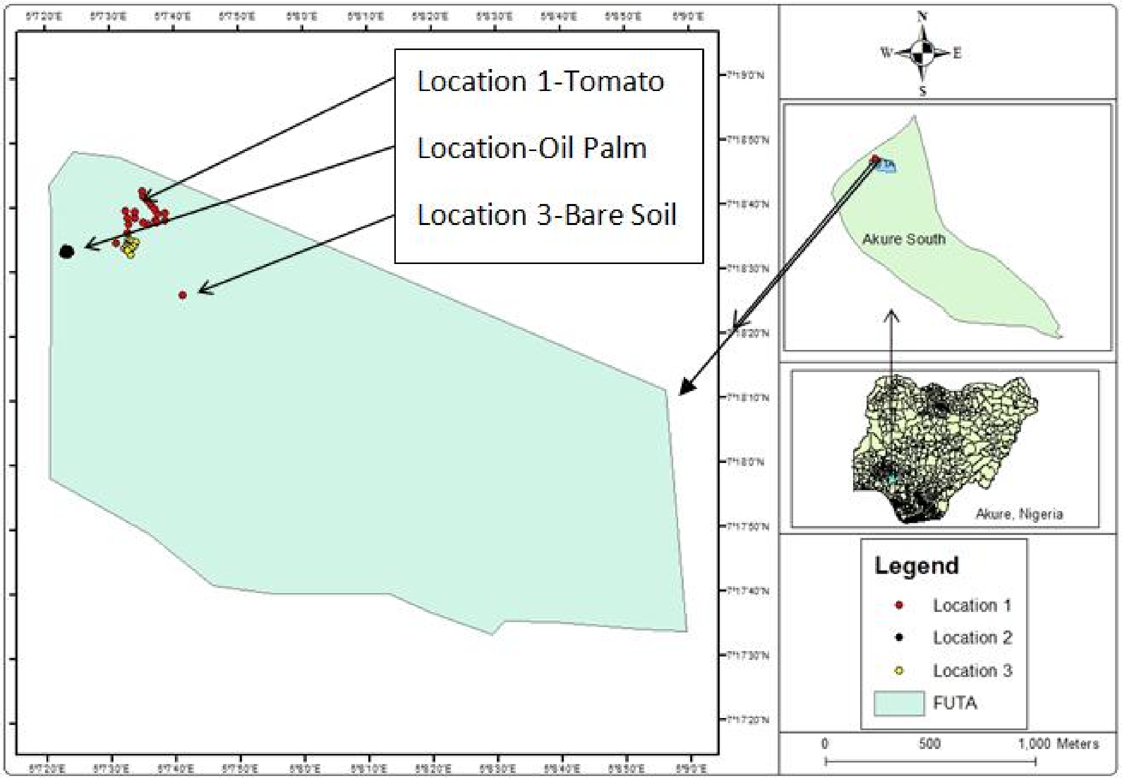


Fig. 1. Map showing selected agricultural land use types at FUTA farm

2.2 Experimental Procedure

The study was carried out during the second modal rainfall season of 2015 (August – November, 2015). Soil sampling and field experiments were carried out at the Research and Training Farm of Federal University of Technology, Akure. Three land uses were selected for the study, which include Tomato cropland, Oil palm plantation and bare soil as control plots. Tomato cropping system has been continuing for the past 7 years under manual tillage operation. Oil palm (*Elaeis guineensis)* plantation (6.4 hectares) has been put to use for about 25 years, with surface covered with litter of fallen palm leaves and bunches, while the bare soil was selected as a reference. Soil sampling and field experiments were conducted on the plots to determine their physico-chemical properties. Completely Randomized Design (CRD) was used where there were "within the treatment variation" and "between the treatment variations". For the determination of soil moisture content, bulk density, total porosity, macro and micro porosity, three (3) sampling points were randomly selected per location and three (3) undisturbed samples were collected at each sampling point. Soil samples were collected to a depth of 0.4 m i.e. 0 – 0.1, 0.1 – 0.2, 0.2 – 0.3 and 0.3 – 0.4 m from all the land uses using soil auger. Three sampling points were randomly selected per plot for each land use treatment and detailed field measurements were carried out. A total of 108 soil samples were collected from the different land uses to a depth of 0.4 m. Soil samples collected were packed in plastic bags, and transferred to the laboratory for physico-chemical analysis.

2.3 Measurements

2.3.1 Physico-chemical characterization of soils

2.3.1.1 Physical characterization

Physical properties of soil of the experimental site such as particle size distribution, moisture content, bulk density, porosity, organic matter and volumetric moisture content were determined in the laboratory using standard procedures. The particle size distribution of the samples was determined using the hydrometer method as described by Agbede and Ojeniyi [13].

The bulk density (BD) was obtained by the gravimetric soil core method described by Blake and Hartge [14] and the particle density (PD) was assumed to be 2.65 g cm^{-3} [15].

The total porosity (PT) was obtained from BD and PD using the equation and relationship developed by Danielson and Sutherland [16].

$$PT = 1 - \frac{BD}{PD} \quad (1)$$

where: BD = Bulk density and PD = Particle density (2.65 Mg m^{-3}). The default value of 2.65 Mg m^{-3} is used as a 'rule of thumb' based on the average bulk density of rock with no pore space [9]. Moisture content was determined using gravimetric core method as described by Fasinmirin and Olorunfemi [9].

2.3.1.2 Chemical characterization of soils

Chemical characterization of the collected soil samples included the analysis of organic matter (SOM), organic carbon (SOC), cation exchange capacity (CEC) at pH 7.0, base saturation, Al^{3+} saturation and soil pH. Six samples were collected at each location for the chemical characterization. The organic carbon was determined using the Walkley - Black wet oxidation procedure and the soil organic matter content was determined from the organic carbon [17]. The cation exchange capacity (CEC) at pH 7.0 was determined following the procedure compiled and described by Reeuwijk [18]. Available phosphorus (P) and exchangeable cations were also determined by Bray-1 extraction followed by molybdenum blue colorimetry [19]. The exchangeable potassium (K^+) and sodium (Na^+) was extracted with HCl solution and their levels determined by flame photometry [20] and exchangeable magnesium (Mg^{2+}) and calcium (Ca^{2+}) by atomic absorption spectrophotometer [21]. Soil pH was determined in distilled water using the pH meter with water ratio of 1:2. Total Nitrogen was analyzed by wet-oxidation procedure of the Kjeldahl method. Exchangeable acidity was determined by saturating the soil samples with potassium chloride solution and titrated with sodium hydroxide as described by Mclean [22]. Available micronutrients (Fe, Cu, Zn and Mn) were extracted by DTPA as described by Sahlemedhin and Taye [23] and all these micronutrients were measured by atomic absorption spectrophotometer.

3. RESULTS AND DISCUSSION

3.1 Soil Physical Properties

3.1.1 Soil particle size analysis

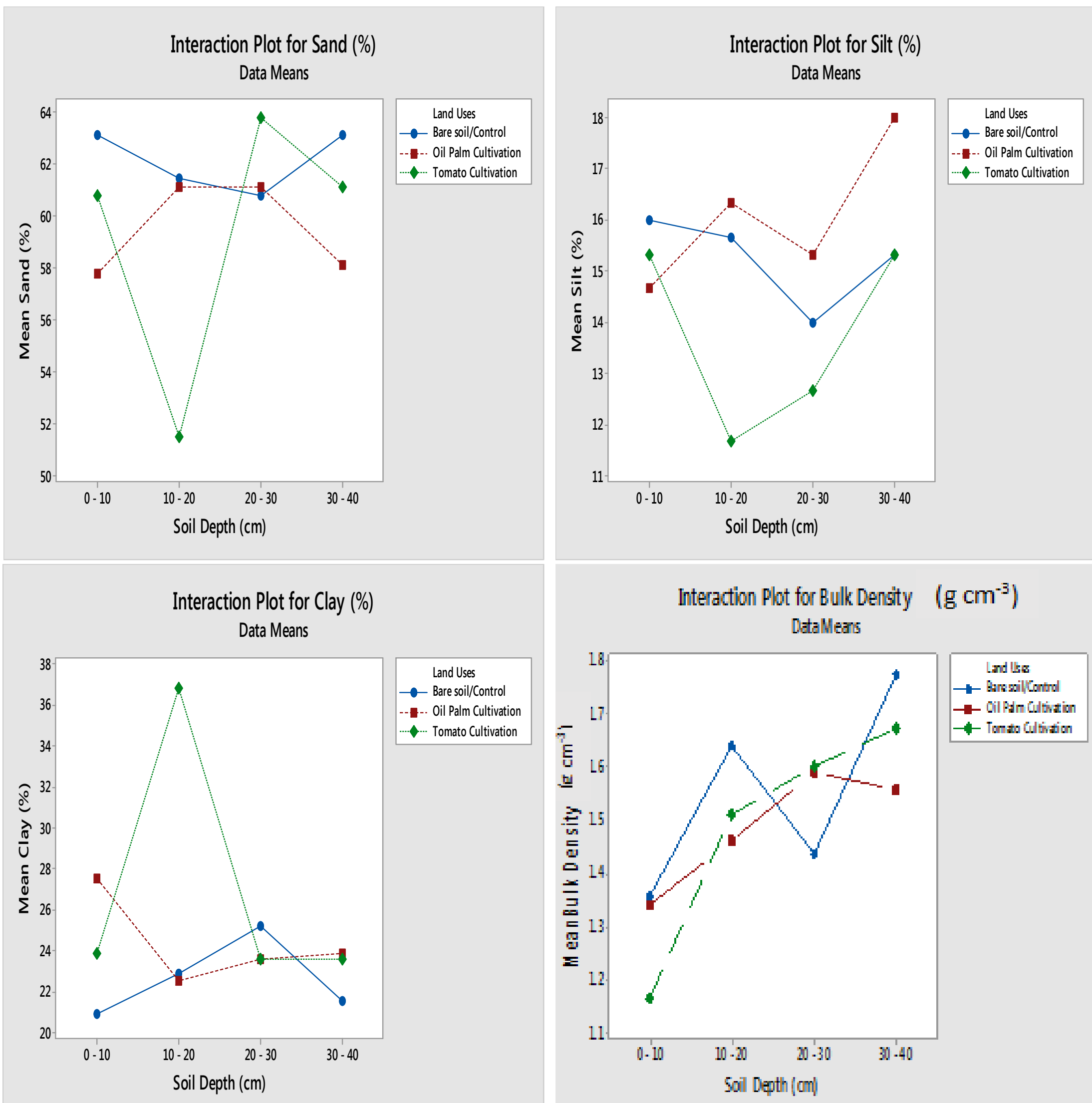
The soils of the experimental sites were predominantly sandy clay loam according to USDA soil textural classification [11]. There was no textural class difference among the land use types. Tables 1, 2 and Fig. 2 show the main effects and the interaction effects of land use type and soil depths on the particle size composition of the collected soil samples. The sand, silt and clay fractions were significantly affected by land uses, soil depths and the interaction of land uses ($p \leq 0.001$). Oil palm cultivation had the highest sand contents (62%) whereas tomato cultivation had the highest clay contents (27%) and lowest silt content (14%). There was no clear distribution in sand contents depth-wise. Highest silt contents (16%) were observed in the 30 – 40 cm soil depth while highest clay contents were recorded in the 10 – 20 cm soil depth (27%).

Considering the interaction effects of land use by soil depths, oil palm cultivation had the highest sand contents at the 10 – 20 cm, 10 – 20 cm and 30 – 40 cm depths of soil. Bare soil/ control had the highest mean clay contents at 0 – 10 cm (28%) and 30 – 40 cm (24%) of soil depths respectively. Bare soil had the highest silt contents at 10 – 20 cm (16%), 20 – 30 cm (15%), and 30 – 40 cm (18%) of soil depths (Table 2 and Fig. 2). Despite the fact that texture is an inherent soil property, management practices may have contributed indirectly to the changes in particle size distribution particularly in the surface layers as result of removal of soil by sheet and rill erosions, and mixing up of the surface and the subsurface layers during continuous tillage activities. Therefore, differences in particle size distribution, which can be attributed to the impact of deforestation and farming practices such as continuous tillage or cultivation and intensive grazing, as equally observed by Yeshaneh [24].

3.1.2 Bulk density, total porosity and moisture content (MC)

Bulk density and total porosity were significantly affected by land use types ($p \leq 0.01$), soil depths and the interaction of land use types by soil depths ($p \leq 0.001$). Bare soil/control had significantly higher mean (0 – 40 cm) bulk density value (1.55 g cm^{-3}) than Tomato (1.49 g cm^{-3}) and oil palm (1.49 g cm^{-3}) cultivation plots which are homogenous. Rain drops impacts and human movements across the field in the bare soil plot might have caused the relatively higher soil BD value. It is generally desirable to have soil with a low BD (<1.5 g cm^{-3}) [25]. High bulk density is an indicator of low soil porosity and soil compaction. Various soil types have different critical values of bulk density restricting root growth [25] but generally bulk densities greater than 1.6 g cm^{-3} tend to restrict root growth [26].

In all the land use types, bulk density showed an increasing trend down the depths (0 – 10 cm, 10 – 20 cm, 20 – 30 cm and 30 – 40 cm) while total pores decrease (Table 2). Increase in bulk density with increasing soil depth for all land use/cover types is consistent with the observation of other researchers [27]. Increase in soil bulk density and decrease in total number of pores with depth increment in all the land uses was due to low organic matter content and compaction from the pressure of the upper layers as equally observed and reported by Datta et al. [28]. Reduced aggregation, root penetration and less pore space of the subsurface layers compared to surface layers equally led to increase bulk density and decrease total porosity down the soil layers [9]. The interaction effects of land use types by soil depths showed that bare



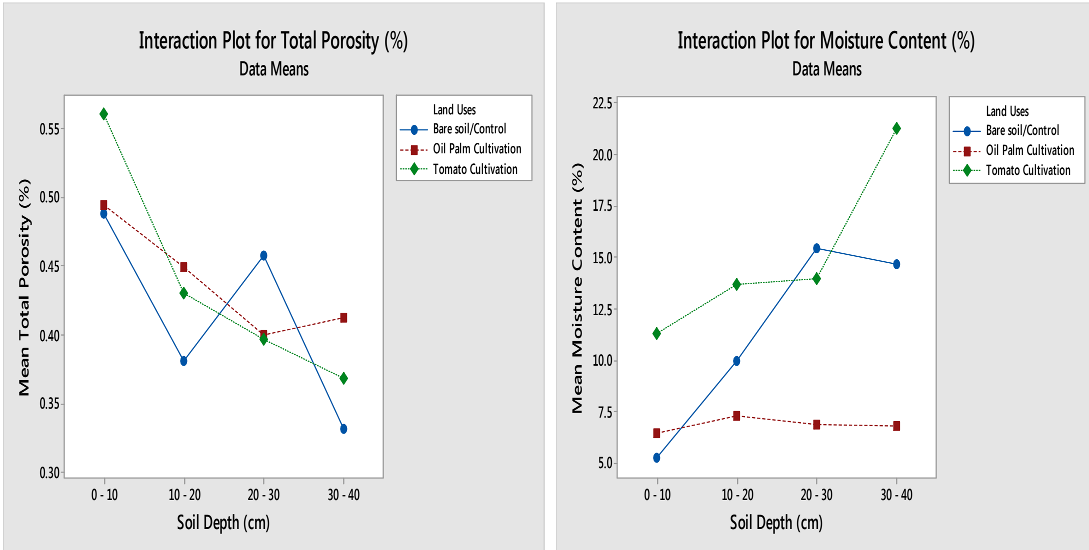


Fig. 2. Interaction plots of land uses types by soil depths for soil physical properties

soil/ control plot had the highest average BD at 0 -10 cm (1.36 g cm^{-3}), 10 -20 cm (1.64 g cm^{-3}) and 30 – 40 cm (1.77 g cm^{-3}) while tomato cultivation had the highest average BD at 20 – 30 cm (1.60 g cm^{-3}) (Table 2). There was a corresponding increase in bulk density down the soil depths at tomato cultivation. It increased till 20 – 30 cm depth of soil at oil palm cultivation whereas there was no clear distribution in the bulk density values of bare soil plots. Total porosity inversely correlated with bulk density in all the land use type and soil depths. Decrease in total number of pores in the bare soil plots is probably due to sealing of soil surface by the impacts of rain drops. Tillage pulverizes the soil, thereby loosening it and increasing the pore sizes. This is because during tillage, hydraulic conductivity is usually high in soils due to high porosity (more open area for the flow of water) [29].

Soil moisture content varied significantly ($p \leq 0.001$) with land use types, soil depths and the interaction of land use types by soil depths. Mean MC (15.05%) of tomato cultivation was significantly higher than that of oil palm and bare soil/ control. The high organic matter content of the tomato cultivation might have influenced its ability to retain more than the other land use types as organic matter is also an important 'building block' for the soil structure and for the formation of stable aggregates [30]. Main and interaction effects of soil depths on moisture content (Tables 1 and 2, Fig. 2) showed that soil moisture content increased with depths. Soil moisture of all the sites varied according to the seasonal distribution of both rainfall and air temperature and this influenced the hydraulic conductivity as high values were obtained in drier soils than in the wetter soils [31,32].

3.2 Soil Chemical Properties

3.2.1 Soil reaction (pH)

Soil pH indicates the degree of acidity and alkalinity in the soil. According to Mokolobate and Haynes [33], the pH value reflects the integrated effect of the acid base reactions taking place in the soil system. The soils pH-H_2O value was significantly affected by land use, soil depth (Table 3) and the interaction of land use by soil depth at $P \leq 0.001$ (Table 3). Duncan Multiple Range Test (DMRT) for the difference of means between the treatments further shows that the corresponding means between the land use types were significantly different. The mean soil pH of Tomato cultivation was significantly higher than that of bare soil which was also significantly higher than that of Oil palm cultivation. The mean soil pH values decreased with increase in soil depth in agreement with Olojugba and Fatubarin [34]. There was however no difference between the corresponding means of 0 – 10 cm, 10 – 20 cm and 20 – 30 cm soil depths. Considering the interaction effects of land use by soil depth, soil pH was significantly different in all the soil depths (0 – 10 cm, 10 – 20 cm, 20 – 30 cm, 30 – 40 cm). Inherent factors such as parent material, rainfall, and type of vegetation were dominant in determining the pH of soils. The pH values under the different land uses were generally strongly acidic based on the pH rating of Horneck et al. [35].

3.2.2 Soil organic matter and organic carbon content

Soil organic matter and organic carbon content were significantly ($P \leq 0.01$) affected by land use, soil depth and the interaction of land use by soil depth. Soil organic matter was highest (2.21%) in Tomato cultivation and lowest (1.34%) in the oil palm cultivation (Table 3). Statistical results showed that Tomato cultivation plots on the overall accumulated more organic matter than oil palm plantations and bare soil plots with organic matter accumulation following in the order Tomato cultivation > bare soil > oil palm plantations. Carter et al. [36] reported that soil organic carbon content is a function of the soil management and tillage practice used on the soil.

Considering the interaction effects of land use by soil depths on SOM and SOC, the soil SOM and SOC content was significantly affected by land use type ($p \leq 0.001$) in 0 -10, 10 – 20 cm and 20 – 30 cm and ($p \leq 0.01$) in 30 – 40 cm soil depth (Table 3). The SOM and SOC was lowest under oil palm plantations in all the depths (0 -10, 10 – 20, 20 – 30 and 30 – 40 cm respectively) while tomato cultivation plots had the highest at 0 10 and 10 – 20 cm soil depths and bare soils had the highest at 20 – 30 and 30 – 40 cm soil depths respectively (Fig. 3). Soil organic matter and organic carbon decreased with increase in soils under tomato and oil palm plantations with bare soil having a temporary increase in the 10 – 20 and 20 – 30 cm depths (Fig. 3). This conforms to the findings of many researchers who reported that the concentration of SOM and SOC in soil decreased with depth. The decrease in SOM and SOC with soil depths is probably due to less microbial activities of soil micro organism down the soil depths. This is because the primary source of organic matter in forest soils is from the litter fall from the trees, which are particularly more on the surface soil than subsoil [37] and this conforms to the findings of the present study. The decrease in SOM of bare soil plots in the 10 – 20 and 20 – 30 cm soil depths might be as result of exposure to rainfall of the soil surface layer thereby depleting the surface soil organic matter.

3.2.3 Total nitrogen (TN)

Total Nitrogen analysis measures N in all organic and inorganic forms. Only 1 to 4 percent of total N becomes plant-available (converts via microbial activity from organic form to inorganic form) during a growing season. Total nitrogen of soils was significantly ($P \leq 0.001$) affected by land use, by the soil depth and the interaction of land use x soil depth (Tables 3 and 4). The two – way ANOVA table gives the F statistics = 11.20, $p \leq 0.001$; 36.00, $p \leq 0.001$ and 8.88, $p \leq 0.03$ for land use, soil depths and land use x soil depths, respectively. In the main effects of land use, TN was highest in soils under tomato cultivation and lowest in soils under oil palm cultivation. DMRT indicated that average values of oil palm plantations were significantly lower than that of bare soils and tomato cultivations plots that are homogenous. The change of total nitrogen content (Tables 3 and 4) followed a similar pattern as the SOM and SOC changes. Since most soil nitrogen is bound in organic matter the result was expected in conformation to the findings of Khresat et al. [38] and Bahrami et al. [39]. Higher rates of microbial decomposition and nitrogen transformation at the oil palm plantations may be responsible for the low average values of TN in the soil samples [39]. The soils under the oil palm plantations were in the lower region, while tomato cultivation and bare soils fell within the medium region of total nitrogen content (%) following the standard TN rating by Landon [40].

Depth wise analysis showed that the mean TN content decreased down the soil depth in the order 0 – 10 cm < 10 – 20 cm < 20 – 30 cm < 30 - 40 cm soil depths respectively (Fig. 4). Total nitrogen was found to be highest under tomato cultivation at 0 – 10 cm and 10 – 20 cm soil depths while bare soils had the highest mean value of TN at 20 – 30 cm soil depth. Oil palm plantation had the lowest average TN values down the soil layers (Fig. 4).

3.2.4 Available phosphorus (P)

Available phosphorus was significantly ($P \leq 0.01$) affected by land uses, soil depths and the interaction of land uses by soil depths (Tables 3 and 4). K was available in 0–10 cm depth as follows: Tomato > Bare soil/Control > Oil palm and was available in the 10 -20 cm depth as follows: Tomato > Oil palm > Bare soil/Control (Table 4). Generally, Tomato cultivation plots slightly have higher mean P values than oil palm and bare soil plots while Depthwise, 10 – 20 cm soil depth has the highest P values (Table 3). An accumulation of P occurs in the upper soil layers and depletion in the deepest sampled as indicated by the results. Oil palm cultivation has the least mean values of available phosphorus among the three land use types. The low mean values recorded in the oil palm plots may be due to nutrients leaching as most of the oil palm root biomass is found within 1 m of the soil, but the distribution of oil palm active roots favours high nutrient uptake in the upper 30 cm, which may increase the potential risk of nutrient leaching [41].

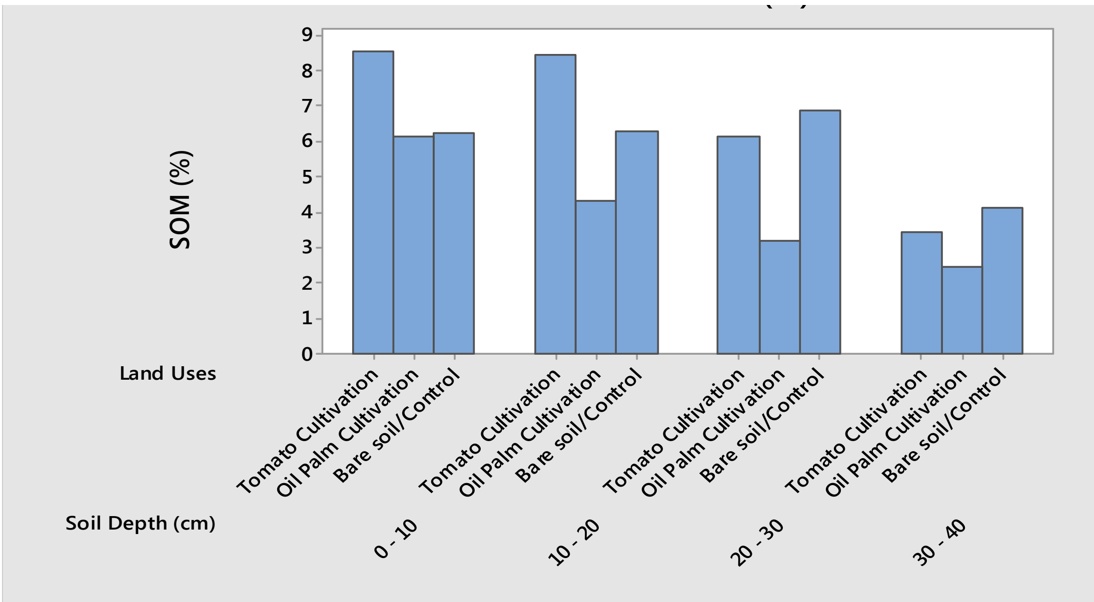


Fig. 3. Mean soil organic matter (SOM %) of the land uses at different soil depths

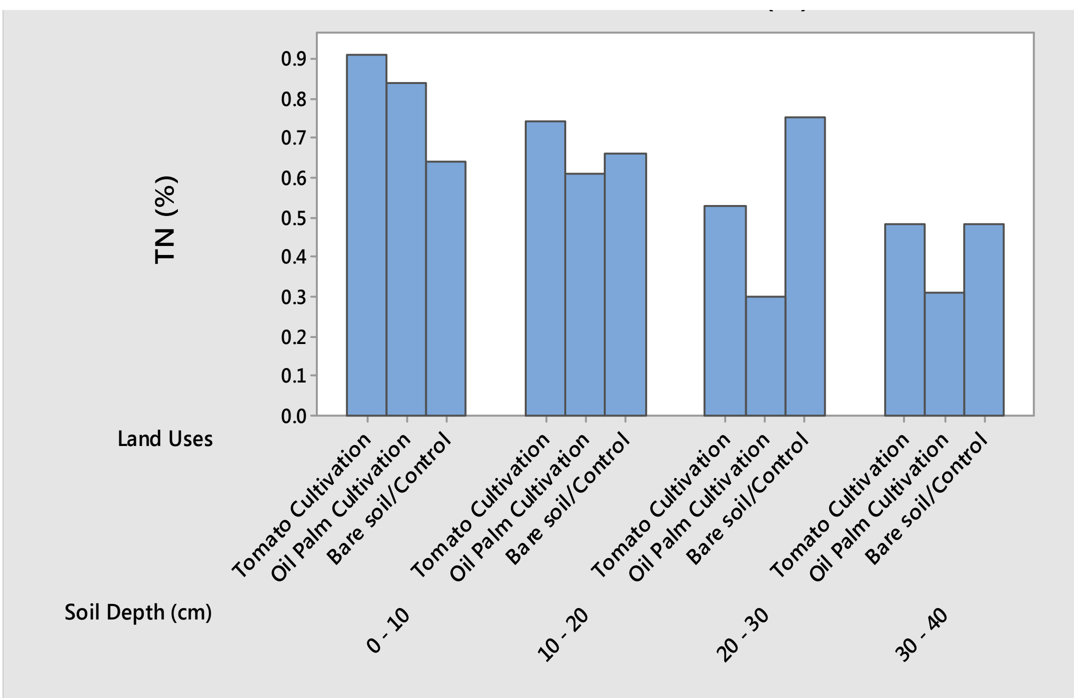


Fig. 4. Mean total nitrogen (TN) of the land uses at different soil depths

Table 1. Main effects of land use and soil depth on soil physical properties

Land uses	Sand (%)	Clay (%)	Silt (%)	BD (g cm^{-3})	PT (%)	MC (%)
Land uses						
Bare soil/control	59.55^a (± 1.82)	24.37^b (± 2.29)	16.08^b (± 1.73)	1.55^b (± 0.18)	0.41^a (± 0.07)	11.30^b (± 4.36)
Oil Palm Plantation	62.13^b (± 1.15)	22.62^a (± 1.78)	15.25^b (± 0.97)	1.49^a (± 0.11)	0.44^b (± 0.04)	6.86^a (± 0.68)
Tomato cultivation	59.30^a (± 4.93)	26.95^c (± 6.03)	13.75^a (± 1.91)	1.49^a (± 0.21)	0.44^b (± 0.08)	15.05^c (± 4.29)
Trt (MS)	29.528	57.028	16.778	0.017	0.002	201.76
SEM (±)	0.556	0.972	1.083	0.003	0.001	1.977
F – Value	53.15	58.657	15.487	6.072	6.072	102.047
P – Value	0.001***	0.001***	0.001***	0.007**	0.007**	0.001***
Soil depth (cm)						
0 – 10	60.58^b (± 2.44)	24.09^b (± 3.10)	15.33^{bc} (± 1.00)	1.29^a (± 0.10)	0.51^c (± 0.04)	7.65^a (± 2.86)
10 –20	58.02^a (± 4.94)	27.42^c (± 7.12)	14.56^{ab} (± 2.24)	1.54^b (± 0.09)	0.42^b (± 0.04)	10.30^b (± 2.81)
20 – 30	61.91^c (± 1.54)	24.09^b (± 1.17)	14.00^a (± 1.41)	1.54^b (± 0.10)	0.42^b (± 0.07)	12.08^c (± 4.08)
30 – 40	60.80^b (± 2.29)	22.98^a (± 1.30)	16.22^c (± 1.86)	1.67^c (± 0.16)	0.37^a (± 0.04)	14.24^d (± 6.59)
Trt (MS)	24.324	33.333	8.398	0.23	0.033	70.101
SEM (±)	0.556	0.972	1.083	0.003	0.001	1.977
F – Value	43.783	34.286	7.752	82.466	82.466	35.456
P – Value	0.001***	0.001***	0.001***	0.001***	0.001***	0.001***

*Note: Columns followed by similar letters are not significantly different at p ≤ 0.05. *** = P ≤ 0.001; ** = P ≤ 0.01; * = P ≤ 0.05 NS = not significant, Trt – treatment, MS – means square effects, SEM – standard error of means*

Table 2. Interaction effects of land use and soil depth (cm) on soil physical properties

Soil parameters	Soil depths (cm)	Significance of the difference between land uses		
		Bare soil/ control	Oil palm plantation	Tomato cultivation
Sand (%)	0 - 10	57.80^{a} (± 1.00)	63.13^{c} (± 0.58)	60.80^{b} (± 1.00)
	10 - 20	61.13^{b} (± 0.58)	61.47^{b} (± 0.58)	51.47^{a} (± 0.61)
	20 - 30	61.13^{a} (± 0.68)	60.80^{a} (± 0.01)	63.80^{b} (± 1.03)
	30 - 40	58.13^{a} (± 1.15)	63.13^{c} (± 0.58)	61.13^{b} (± 0.35)
Clay (%)	0 - 10	27.53^{c} (± 2.08)	20.87^{a} (± 0.52)	23.87^{b} (± 2.31)
	10 - 20	22.57^{a} (± 1.15)	22.87^{a} (± 0.58)	36.86^{b} (± 1.15)
	20 - 30	23.53^{a} (± 0.58)	25.20^{a} (± 0.05)	23.53^{a} (± 1.53)
	30 - 40	23.87^{b} (± 1.15)	21.53^{a} (± 1.57)	23.53^{b} (± 0.58)
	0 - 10	14.67^{a} (± 1.15)	16.10^{a} (± 0.01)	15.33^{a} (± 1.15)
Silt (%)	10 - 20	16.33^{b} (± 0.58)	15.67^{b} (± 0.58)	11.67^{a} (± 0.58)
	20 - 30	15.33^{b} (± 1.13)	14.02^{ab} (± 0.02)	12.67^{a} (± 1.16)
	30 - 40	18.00^{a} (± 2.00)	15.33^{a} (± 1.15)	15.37^{a} (± 1.53)
BD (g cm^{-3})	0 - 10	1.36^{b} (± 0.06)	1.34^{b} (± 0.05)	1.16^{a} (± 0.05)
	10 - 20	1.64^{a} (± 0.05)	1.46^{a} (± 0.08)	1.51^{b} (± 0.03)
	20 - 30	1.43^{a} (± 0.10)	1.59^{b} (± 0.04)	1.60^{b} (± 0.04)
	30 - 40	1.77^{c} (± 0.05)	1.56^{a} (± 0.04)	1.67^{b} (± 0.02)
PT (%)	0 - 10	0.49^{a} (± 0.02)	0.49^{a} (± 0.02)	0.56^{b} (± 0.02)
	10 - 20	0.38^{a} (± 0.02)	0.50^{b} (± 0.03)	0.43^{b} (± 0.01)
	20 - 30	0.46^{b} (± 0.04)	0.40^{a} (± 0.02)	0.40^{a} (± 0.01)
	30 - 40	0.33^{a} (± 0.02)	0.41^{c} (± 0.02)	0.37^{b} (± 0.02)
MC (%)	0 - 10	5.22^{a} (± 0.21)	6.42^{a} (± 1.00)	11.30^{b} (± 0.71)
	10 - 20	9.95^{b} (± 0.59)	7.30^{a} (± 0.79)	13.66^{c} (± 0.30)
	20 - 30	15.41^{b} (± 1.82)	6.87^{a} (± 0.43)	13.97^{b} (± 0.75)
	30 - 40	14.63^{b} (± 0.72)	6.82^{a} (± 0.32)	21.26^{c} (± 4.05)

Note: Rows followed by similar letters are not significantly different at p ≤ 0.05
PT = total porosity and MC = moisture content

However, it was observed that phosphorus values of all the soil sites showed low phosphorus availability (3 – 7 mg kg^{-1}) compared with the standard rating of phosphorus availability for crop production [42,43]. The pH values under the different land uses were generally strongly acidic based on the pH rating of Horneck et al. [35] whereas soils with inherent pH values between 6 and 7.5 and which are equally in moist and warm conditions are ideal for P-availability, while pH values below 5.5 and between 7.5 and 8.5 limits P-availability to plants due to fixation by aluminium, iron, or calcium, often associated with soil parent materials [44]. Phosphorus is essential for growth, cell division, root growth, fruit development and early ripening [45]. It is also required for energy storage and transfer; constituent of several organic compounds including oils and amino acids as stated by Desavathu et al. [45].

3.2.5 Exchangeable potassium (K)

The content of exchangeable potassium (K) was significantly ($P \leq 0.001$) affected by land use, soil depth but not by the interaction of land use by soil depth (Tables 3 and 4). The two – way ANOVA table gives the F statistics = 53.99, $p \leq 0.001$; 20.07, $p \leq 0.001$ and 13.32, $p \leq 0.001$ for land use, soil depths and land use*soil depths, respectively. The mean values of exchangeable potassium (K) under the tomato cultivation, the oil palm and the bare soil/control were 0.27, 0.14 and 0.28 $cmol_c.kg^{-1}$, respectively (Table 3). In all the land uses, exchangeable K fell within the range (0.08 – 0.46 $cmol_c.kg^{-1}$) values showing that K fall within the low (< 0.4 $cmol_c.kg^{-1}$), and medium (0.4 – 0.6 $cmol_c.kg^{-1}$) potassium categories for crop production [35]. Symptoms of potassium deficient plants/crops include slender stem, and brownish leaves margins [46]. Exchangeable Potassium (K) was highest (0.30 $cmol_c.kg^{-1}$) in the 10 – 20 cm soil depth and lowest (0.18 $cmol_c.kg^{-1}$) in 20 – 30 cm depth of soil.

Interaction effects of land use and soil depth (cm) on soil exchangeable K showed that in bare soil, exchangeable K was lowest (0.18 $cmol_c.kg^{-1}$) in 30 – 40 cm whereas in oil palm plantation, K was lowest(0.10 $cmol_c.kg^{-1}$) in 10 – 20 cm and in tomato plantation, it was lowest (0.17 $cmol_c.kg^{-1}$) in 20 – 30 cm depth of soil.

Table 3. Main effects of land use and soil depth on soil chemical properties

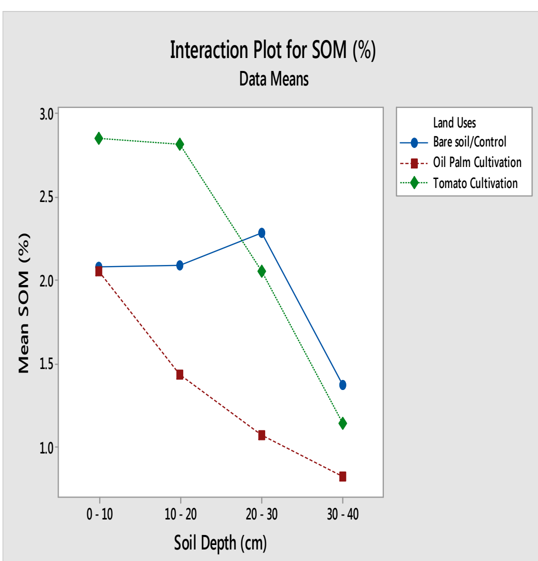
Treatment	pH (%)	SOM (%)	SOC (%)	TN (%)	P (mg kg^{-1})	K (cmolc.kg^{-1})	C/N
Land uses							
Bare soil /control	4.79^{b} (± 0.13)	1.96^{b} (± 0.37)	1.13^{b} (± 0.22)	0.21^{b} (± 0.04)	3.58^{a} (± 0.78)	0.28^{b} (± 0.11)	5.43^{ab} (± 0.73)
Oil Palm Cultivation	4.58^{a} (± 0.14)	1.34^{a} (± 0.49)	0.78^{a} (± 0.28)	0.17^{a} (± 0.80)	3.57^{a} (± 0.27)	0.14^{a} (± 0.50)	4.82^{a} (± 1.04)
Tomato Cultivation	5.04^{c} (± 0.45)	2.21^{c} (± 0.74)	1.20^{b} (± 0.43)	0.22^{b} (± 0.06)	4.28^{b} (± 0.83)	0.27^{b} (± 0.08)	5.79^{b} (± 1.31)
Trt (MS)	0.655	2.419	0.813	0.08	1.988	0.073	2.88
SEM (±)	0.018	0.009	0.003	0.01	0.036	0.001	0.546
F - Value	35.763	276.867	279.755	11.195	55.577	53.988	5.27
P - Value	0.001***	0.001***	0.001***	0.001***	0.001***	0.001***	0.013*
Soil depth (cm)							
0 - 10	4.90^{b} (± 0.55)	2.32^{d} (± 0.40)	1.35^{d} (± 0.23)	0.27^{d} (± 0.05)	4.17^{c} (± 0.70)	0.25^{b} (± 0.08)	5.16^{ab} (± 0.83)
10 - 20	4.89^{b} (± 0.22)	2.11^{c} (± 0.61)	1.23^{c} (± 0.35)	0.22^{c} (± 0.04)	4.31^{c} (± 0.70)	0.30^{c} (± 0.15)	5.49^{bc} (± 1.35)
20 - 30	4.85^{b} (± 0.23)	1.80^{b} (± 0.56)	1.04^{b} (± 0.33)	0.18^{b} (± 0.07)	3.68^{b} (± 0.29)	0.18^{a} (± 0.04)	6.15^{c} (± 1.01)
30 - 40	4.58^{a} (± 0.17)	1.11^{a} (± 0.26)	0.64^{a} (± 0.15)	0.14^{a} (± 0.03)	3.08^{a} (± 0.55)	0.19^{a} (± 0.07)	4.59^{a} (± 0.62)
Trt (MS)	0.205	2.553	0.859	0.027	2.793	0.027	3.812
SEM (±)	0.018	0.09	0.03	0.01	0.036	0.001	0.546
F - Value	11.188	292.249	295.517	35.999	78.091	20.065	6.975
P - Value	0.001***	0.001***	0.001***	0.001***	0.001***	0.001***	0.002**

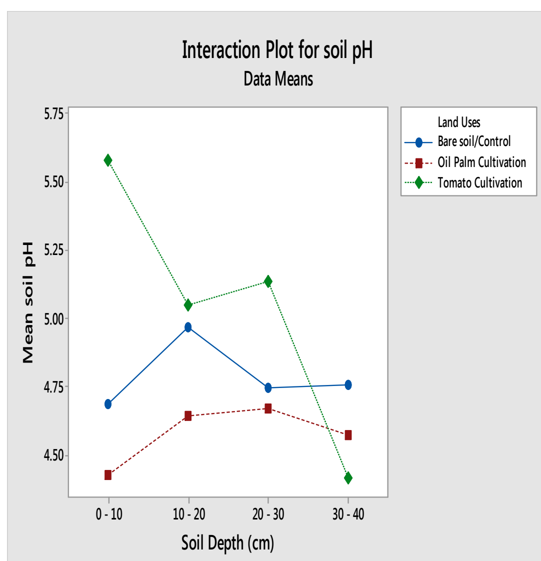
*Note: Columns followed by similar letters are not significantly different at p ≤ 0.05. *** = P ≤ 0.001; ** = P ≤ 0.01; * = P ≤ 0.05 NS = not significant, Trt – treatment, MS – means square effects, SEM – standard error of means*

Table 4. Interaction effects of land use and soil depth (cm) on soil chemical properties

Soil parameters	soil depth (cm)	Significance of the difference between land uses		
		Bare soil /control	Oil palm plantation	Tomato cultivation
pH (%)	0 – 10	4.69^{a} (± 0.17)	4.43^{a} (± 0.10)	5.58^{b} (± 0.26)
	10 – 20	5.00^{b} (± 0.18)	4.64^{a} (± 0.18)	5.05^{b} (± 0.02)
	20 – 30	4.75^{a} (± 0.12)	4.67^{a} (± 0.09)	5.14^{b} (± 0.06)
	30 – 40	4.75^{b} (± 0.07)	4.57^{a} (± 0.08)	4.41^{a} (± 0.12)
SOM (%)	0 – 10	2.08^{a} (± 0.07)	2.05^{a} (± 0.1)	2.85^{b} (± 0.12)
	10 - 20	2.09^{b} (± 0.09)	1.43^{a} (± 0.06)	2.82^{c} (± 0.11)
	20 - 30	2.28^{c} (± 0.06)	1.06^{a} (± 0.09)	2.05^{b} (± 0.07)
	30 - 40	1.37^{c} (± 0.10)	0.82^{a} (± 0.07)	1.14^{b} (± 0.14)
SOC (%)	0 - 10	1.21^{a} (± 0.04)	1.19^{a} (± 0.06)	1.65^{b} (± 0.07)
	10 - 20	1.21^{b} (± 0.06)	0.83^{a} (± 0.04)	1.63^{c} (± 0.06)
	20 - 30	1.32^{c} (± 0.04)	0.62^{a} (± 0.05)	1.19^{b} (± 0.04)
	30 - 40	0.79^{c} (± 0.06)	0.47^{a} (± 0.04)	0.66^{b} (± 0.08)
TN (%)	0 - 10	0.21^{a} (± 0.02)	0.28^{b} (± 0.02)	0.30^{b} (± 0.04)
	10 - 20	0.22^{a} (± 0.05)	0.20^{a} (± 0.02)	0.25^{a} (± 0.02)
	20 - 30	0.25^{c} (± 0.03)	0.10^{a} (± 0.02)	0.18^{b} (± 0.03)
	30 - 40	0.16^{a} (± 0.02)	0.10^{b} (± 0.02)	0.16^{b} (± 0.02)
P ($mg\ kg^{-1}$)	0 - 10	3.90^{b} (± 0.16)	3.57^{a} (± 0.04)	5.05^{c} (± 0.07)
	10 - 20	4.35^{b} (± 0.09)	3.49^{a} (± 0.16)	5.10^{c} (± 0.03)
	20 - 30	3.68^{a} (± 0.14)	3.78^{a} (± 0.52)	3.57^{a} (± 0.09)
	30 - 40	2.37^{a} (± 0.24)	3.47^{b} (± 0.07)	3.41^{b} (± 0.09)
K ($cmolc.kg^{-1}$)	0 - 10	0.33^{c} (± 0.04)	0.16^{a} (± 0.02)	0.26^{b} (± 0.01)
	10 - 20	0.41^{b} (± 0.06)	0.10^{a} (± 0.02)	0.38^{b} (± 0.03)
	20 - 30	0.19^{a} (± 0.02)	0.18^{a} (± 0.07)	0.17^{a} (± 0.03)
	30 - 40	0.18^{b} (± 0.04)	0.11^{a} (± 0.03)	0.27^{c} (± 0.03)
C/N	0 - 10	5.70^{b} (± 0.55)	4.27^{a} (± 0.47)	5.51^{b} (± 0.65)
	10 - 20	5.73^{ab} (± 1.32)	4.11^{a} (± 0.47)	6.65^{c} (± 0.57)
	20 - 30	5.33^{a} (± 0.51)	6.27^{a} (± 0.78)	6.85^{a} (± 1.19)
	30 - 40	4.98^{a} (± 0.28)	4.64^{a} (± 0.72)	4.16^{a} (± 0.65)

Note: Rows followed by similar letters are not significantly different at p ≤ 0.05.





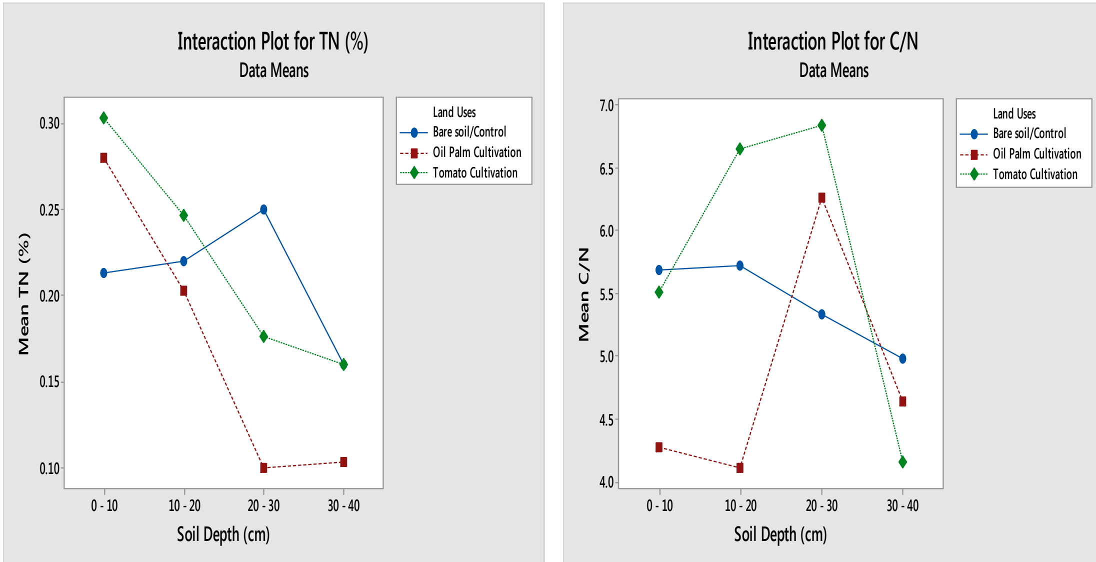


Fig. 5. Interaction plots of land uses types by soil depths for soil chemical properties

3.2.4 Carbon to nitrogen ratio (C/N)

Carbon to nitrogen was significantly affected by land use ($P \leq 0.05$), soil depths and the interaction of land use by soil depth ($P \leq 0.01$) (Tables 3 and 4). The two – way ANOVA table gave the F statistics = 5.25, $p \leq 0.05$; 6.95, $p \leq 0.01$ and 3.73, $p \leq 0.01$ for land use, soil depths and land use x soil depths, respectively. The highest C/N was recorded under tomato cultivation (5.79) while the lowest was observed under oil palm cultivation (4.82) (Table 3). The main effects of soil depth on carbon to nitrogen ratio revealed gradual increase in the mean value of P down the depths of soil to 20 – 30 cm but decrease in the 30 – 40 cm depth of soil. In the interaction effects of land use by soil depth, there was no clear variation in the values of P with depth increment (Table 4 and Fig. 5).

4. CONCLUSION

This research evaluated and characterized physico-chemical properties of soils of similar geological substrate and climatic conditions but under different land uses (i.e. tomato and oil palm cultivation) in Southwestern Nigeria. There was no textural class difference among the land use types. Increase in soil bulk density and decrease in total number of pores with depth increment in all the land uses was due to low organic matter content and compaction from the pressure of the upper layers. Total porosity inversely correlated with bulk density in all the land use type and soil depths. Decrease in total number of pores in the bare soil plots is probably due to sealing of soil surface by the impacts of rain drops. The pH values under the different land uses were generally strongly acidic. Tomato cultivation plots on the overall accumulated more organic matter than oil palm plantations and bare soil plots with organic matter accumulation following in the order Tomato cultivation > bare soil > oil palm plantations. The concentration of SOM and SOC in soil decreased with depth. The decrease in SOM and SOC with soil depths is probably due to less microbial activities of soil micro organism down the soil depths. Higher rates of microbial decomposition and nitrogen transformation at the oil palm plantations may be responsible for the low average values of TN in the soil samples. Overall the soils are moderate in nitrogen, low in phosphorous and potassium content. Hence, the soils require primary nutrients for sustainable crop production. The study provides relevant data for effective land use planning and management and also serves as a useful guide in the choice of appropriate conservation practice. Improvement in the management of land resource for sustainable agricultural use would be one of the most useful strategies that could help to increase overall crop yield.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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