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COMPARATIVE ANALYSIS OF SOIL PHYSICO-CHEMICAL PROPERTIES UNDER MANGO AND CASHEW CROPS IN PART OF SUDAN SAVANNA, NIGERIA

Abdulkadir Musa[1], Olufayokemi Rasheedat Oyesanmi[2] & Emmanuel Okunlola Oriola[3]

[1&2]Department of Geography, Federal University Lokoja, P.M.B. 1154, Lokoja, Nigeria
[3]Department of Geography & Environmental Management, University of Ilorin, P.M.B. 1515, Ilorin, Nigeria

Corresponding Author's Email: abdulkadir.musa@fulokoja.edu.ng

Abstract

To understand the dynamics of mango and cashew cultivation on soil fertility for optimum crop productivity, this study examined the spatial variability of soil physico-chemical properties in part of Sudan Savanna, Nigeria. Forty-eight (48) composite soil samples were collected from top and sub-soils at the depths of 0-15 and 15-30cm, respectively. Meanwhile, the samples were collected from 8 selected (20 x 20m) quadrats each in the fields of mango, cashew, and control site of semi-natural vegetation. The samples were analysed using standard routine laboratory tests for soil physico-chemical properties essential for determining soil fertility. One-way analysis of variance was employed to assess the variability of the soil physico-chemical properties among the farmlands and the control site. The result showed that except for percent sand, all other observed soil properties in the topsoil and subsoil were statistically heterogeneous under mango, cashew and control fields. Critical nutrients were therefore significantly higher in the control site than both crop types, though much better under cashew, indicating a negative impact of cultivation on soil health. Thus, the research suggests that mango farmers, especially, can enhance their yields by implementing a long-term soil health monitoring system, collaborating with agricultural research organizations, and implementing best practices like intercropping with cashew and legumes to improve soil health and nutrient content. More so, both mango and cashew farmers could complement for the diminishing soil nutrients through the application of organic fertilizers, and where necessary, the inorganic with special consideration to N, P, K, Ca^{2+} and Na^{+}.

Keywords: *Mango, Cashew, Physico-chemical Properties, Sudan Savanna, Shira*.

Introduction

Crop production involves a complex interaction between the environment, soil parameters, and nutrient dynamics (Ololade et al., 2010; Yang et al., 2020). The most affected elements of the land, in terms of agricultural production, are the plant nutrient elements of the soil. Liao et al. (2012) carried out a meta-analysis of about 73 published field studies across the globe on planted forests and natural forests and observed that soil properties, such as soil pH, bulk density, carbon (C) and nitrogen (N) concentrations greatly affect tree growth when those nutrient elements change in the soil. Continuous cultivation of whatever agricultural production system on a given piece of land affects the soil nutrients availability. Depending on the type of crop and the method of cultivation, there is need for fertility management of the soil. Thus, Tilahun (2007) observed that, rapid population increase makes soil fertility maintenance a great concern in tropical Africa. Failure to understand the complexities of nutrient dynamics due to cultivation has resulted in poor crop production and improper management techniques (Ololade et al., 2010). Therefore, a continuous cultivation of a particular crop on a given field without any conscious effort by farmers to understand the nutrient dynamics, and where necessary, efforts to replenish the soil of the lost nutrients, impoverishes the land for agricultural production. Hence, there could be a decrease in crop yield. This is so, because soil fertility decline leads to low productivity of many soils (Sanchez, 2002; Derpsch et al., 2024). In this regard, Adak et al. (2014) conducted a research in India on the assessment of soil characteristics and guava orchard productivity and observed that, the main focus of farmers in any production system is the level of yield. Thus, the amounts of food and cash income gained from farming are directly related with the yield.

However, the decline or improvement in soil fertility could be differential when varied species of crops are cultivated over a given land. Hence there tends to be spatial variability in available soil nutrients. In view of this, Obalum et al. (2013) stated that, “variability in soil properties at different spatial scales is a key feature of soils”. Several studies have revealed that properties of soils vary across farm fields leading to spatial variability in crop yields (Mzuku et al., 2005; Usowicz & Lipiec, 2017; Nyéki et al., 2022; Abdu et al., 2023; Fowler et al., 2024). Furthermore, Kavianpoor et al. (2012) observed that, soil scientists have carried out researches on spatial changes of soil characteristics about which precise and quantitative information is essential for environmental assessment of soil quality and soil pollution risks among others. Moreover, having knowledge about the compounded role of soil properties and their interactions, as observed by Mzuku et al. (2005), could give an idea about what are the likely causes of variability in crop productivity.

Mango (*Mangifera indica*) and cashew (*Anacardium occidentale*) trees are both evergreen and of the same botanical family (*Anacardiceae*) (Mitchell et al., 2022). These tree crops are grown as cash crops in many parts of Sudan savannah of Nigeria. Despite sharing botanical similarities, the level at which the crops utilize soil nutrients and their effects on soil properties could vary. They are thus likely to influence variability in soil physico-chemical properties in the two fields where they are cultivated. The effect of mango crops could be different from that of cashew crops on the soil properties. Moreover, continuous tree cultivation over a long period could lead to fall in available soil nutrients. On this note, Ekanade (1991), stated that trees have effects on soils, and mainly resulted in impoverishing the soils. Thus, when soils are being impoverished of their nutrients, consequently there could be decrease in the yield of the crops. However, the fall in soil nutrients may vary from one crop to another. In essence, the effect of mango crop may not be the same as that of cashew on the soil and which could lead to variation in their yield.

Therefore, differential tree cropping over a given soil could accentuate spatial variability in soil physico-chemical properties. Thus, the yield from the crops could also vary. On this note, mango and cashew are cash crops grown by some farmers in Shira, a part of Sudan savannah, North-eastern Nigeria. Due to the probable influence of the crops on the soil fertility, productivity may likely reduce due to continuous cultivation over the same field, hence could lead to reduced returns. Although there have been related researches but could not compare soil properties at topsoil and subsoil between mango and cashew crops under savanna vegetation (such as Awotoye et al., 2009; Eni et al., 2012; Dachung et al., 2014; Offiong et al., 2015; Russell et al., 2018; William et al., 2013; William et al., 2015; Usowicz & Lipiec, 2017; Musa & Adamu, 2019; Nyéki et al., 2022; Abdu et al., 2023; Fowler et al., 2024 among others). Most closely related was Musa & Adamu (2019) who observed significant differences in soil physico-chemical properties (at 0-30cm soil depth) under the two tree crops and semi-natural vegetation in the same study area. However, there is no information on soil physico-chemical properties at both topsoil (0-15cm) and subsoil (15-30cm), separately, and the nature of variability therein. Therefore, this research sought to complement the efforts of Musa & Adamu (2019) in order to assist the farmers to improve on nutrient availability and the best practice for better and sustainable crop yield as well as income. Hence, this study seeks to assess the differences in soil physico-chemical properties, at both topsoil and subsoil, under mango and cashew crops in Shira, North-eastern Nigeria.

Study Area

The study area is Shira, a part under Sudan savanna, which extends between Latitudes 11°26'18" and 11°29'58" North of the equator and Longitudes 10°01'27" and 10°04'26" East of the Greenwich Meridian (Figure 1). Its landmass covers about 64 km^2 as reported by Abdulkadir (1978). Relatively, Shira is located in Shira local government area of Bauchi state, Nigeria.

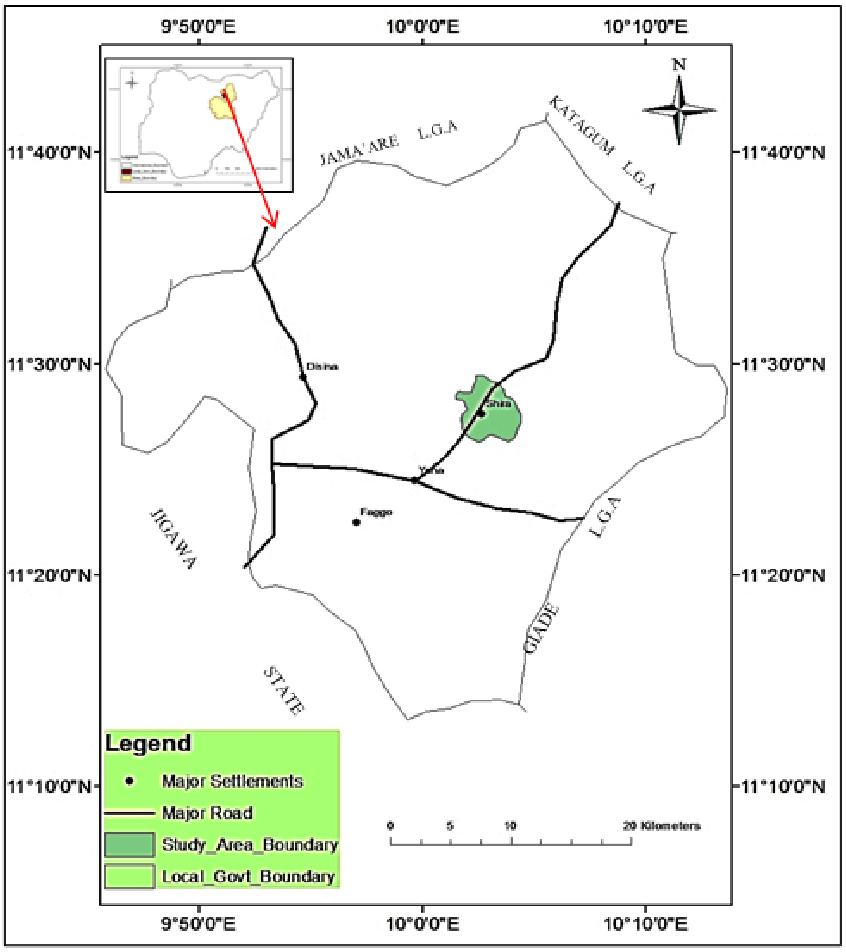

Figure 1: Shira, the Study Area
Source: Ministry of Lands and Survey, Bauchi State/ Google (2024)

The relief of the study area generally ranges approximately between 407m (1335 ft) to 624m (2047 ft) above sea level (Musa & Adamu, 2019), with the highest point being at the peak of one of the inselbergs towards the south-eastern part. The elevated areas are found at the rounded hills and boulders of varying sizes, weathered and superimposed on extensive batholiths, all of granitic origin, and in most parts of the hilly regions, the slope is of varying degrees, with the steepest being at the upper hills and decreases in almost all directions towards the undulating lower regions (Musa, 2017). Due to the rugged nature of the relief, it gives room for sufficient drainage. Thus, the area is well drained by network of some rivulets towards its south-western part (Musa & Adamu, 2019) of which the waters are discharged into farmlands and the tributary of River Zigau which empties its waters into River Jama'are (Musa, 2017; Musa & Adamu, 2019).

The climate of the study area is tropical continental of which according to Köppen's Classification is 'As' in which there are distinct wet and dry (high sun-period) seasons (Gates, 1978). The total annual rainfall of the area of study is about 810mm (Musa, 2017; Musa & Adamu, 2019) where the wettest month is August in which the rainfall totals about 284mm followed by July recording not less than 200mm. In November, the least amount of rainfall (less than 5mm) is received. However, in most cases, rainfall ceases within the first two weeks of October. From December, through January to March, the condition is that of rainfall absence depicting season of dry condition.

Vegetation, coupled with climate of an area determines to some extent the development of soil over the area which consequently influences agricultural activities. Shira and its environs lie under Sudan savanna vegetation. It is characterized mostly by short grasses, shrubs and trees most of which are of deciduous nature. Some of these trees among others include tamarind (*Tamarindus indica)*, *Acacia albida*, baobab (*Adansonia digitata*), neem (*Azadirachta indica*), *Moringa oleifera*, guava (*Psidium guajava*), mango (*Mangifera indica*) and cashew (*Anacardium occidentale*). Some of these trees like the first three mentioned above grow naturally, whereas others are planted by man though could grow naturally when natural forms of seeds dispersal occur (Musa, 2017).

Geology and soils are very important in this research, because the former can influence the development of the latter. Furthermore, soils provide the matrix where crops are grown. Thus, the geology of Shira falls under the basement complex of the Hausa Plains of northern part of Nigeria as described by Bennett et al. (1978). It is chiefly of the precambrian granitic rocks which have been deeply weathered into boulders of varying sizes and colluvium of different sizes. According to Thiemeyer (2000), alongside these crystalline rocks are deposits of fine sands of Lantewa sand dunes.

The area of the study lies within the ferruginous soils of the basement complex origin which is composed of brown and reddish-brown soils as described by D'Hoore (1964) cited in Abdulkadir (1978). The soil type is that of Arenosols and Plinthosols as categorized by FAO/UNESCO (1988). Thus, hypoluvic Arenosols and petric Plinthosols are identified over the study area (FAO et al., 2012; Jones et al., 2013).

Crops grown include cereals like millet, sorghum, rice and in small proportion, maize. Other crops grown include groundnut, cowpea, beni seed, water melon, tomato, pepper, and sugar cane among others. Tree crops that are grown in the area comprise of mango, cashew and guava. Most of the farming activities are rainfed in nature. Irrigation farming complements the other agricultural systems which include the cultivation of sugar cane, vegetables and water melon among others.

Materials and Methods

Sampling Procedure

Three sample sites under mango and cashew crops and control were selected over Hypoluvic Arenosols soils. Each sampled field was demarcated using 40 x 80m which was subdivided into 8 quadrats measuring 20 x 20m (400m^2). Furthermore, the 20 x 20m quadrats were subdivided using grids measuring 10 x 10m from which representative cores were collected. Hence, 5 representative cores as employed by Oriola (2004); and Aweto and Enarubve (2010) were selected from each 20 x

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20m quadrat. The, 5 representative cores were collected along a zigzag transect at the predetermined depths of 0-15cm (topsoil) and 15-30cm (subsoil). The 5 representative cores were thoroughly mixed, and a fraction was obtained to make 1 composite sample representing each 20 x 20m quadrat. The composite samples were enclosed in a labelled polythene bags. Hence, eight composite samples each for the topsoil and subsoil were obtained from the fields of mango, cashew and control making a total of 48 composite samples (24 each for the topsoil and the subsoil). The soil samples were air dried ground and sieved using 2mm mesh, and moved to laboratory for analysis.

Laboratory Analysis

Weil & Brady (2017) pointed out that to select the soil properties for laboratory analysis, the soil chemical properties that directly influence soil fertility status and productivity are soil pH, exchangeable cations (Ca^{2+}, Mg^{2+}, Na^{+} and K^{+}), available phosphorus, cation exchange capacity, base saturation, organic matter content, and total nitrogen. Particle size distribution, which is a physical property, was also tested due to its relative importance in influencing the availability of some chemical properties in the soil (such as the exchangeable cations).

Some of the methods of analysing particle size are pipette and hydrometer methods. However, in this research, particle size was determined using hydrometer method as advocated and employed in the works of many authors (e.g. Liebens, 2007; Ikemura and Shukla, 2009; Aweto and Enarubve, 2010; Eludoyin and Wokocha, 2011; Essoka et al., 2012; Maniyunda et al., 2013; and Saeed et al., 2014).

Some of the notable methods used in determining organic matter (OM) are Walkley Black titration (put forward by Walkley and Black, 1934), and dry combustion (Loss-on-Ignition) methods. According to Liebens (2007), the Walkley Black method is commonly used, especially for research purposes. Thus, the Walkley-Black titration method was adopted in analysing OM in this research. Total nitrogen (N) was determined by the method of Kjeldahl as advocated and/or employed by Aweto and Enarubve (2010); Essoka et al. (2012); Maniyunda et al. (2013); and Ogunkunle (2013) among others. Soil pH was analysed potentiometrically in a solution of 0.01m $CaCl_2$ using a 1:2 soil-to-solution ratio as employed by some authors (e.g. White, 2006; Liebens, 2007; Eludoyin and Wokocha, 2011; and Ogunkunle, 2013 among others). Exchangeable acidity (EA) was determined by the use of potassium chloride (Kcl) extraction and titration as advocated by Hoskins (1997) and Robarge (2016), and employed by Ololade et al. (2010). Exchangeable calcium (Ca^{2+}), exchangeable potassium (K^{+}), and exchangeable sodium (Na^{+}) were determined using flame photometry, while absorption spectrophotometer was employed to determine exchangeable magnesium (Mg^{2+}) as adopted by Aweto and Enaruvbe, (2010); Ololade et al. (2010); Amaral et al. (2011); Eludoyin and Wokocha (2011); Moges et al. (2013); Yitbarek et al. (2013). Available phosphorus was determined using Bray No. 1 method as it was employed by Awotoye et al. (2011); Essoka et al. (2012); and Amouyu et al. (2013) among others. For the determination of CEC, there have been some authors (e.g. Aweto and Enarubve, 2010; Ololade et al, 2010; Eludoyin and Wokocha, 2011 among others) who supported and employed the use of summation of exchangeable cations and exchange acidity. Hence, cation exchange capacity was determined by the summation of exchangeable cations and exchange acidity. Base saturation was determined by the summation of the exchangeable bases divided by the CEC, and multiplied by 100 as noted by Havlin et al. (2005).

Data Analysis

One-way Analysis of variance (ANOVA) accompanied by post hoc test of Tukey's Honestly Significant Difference (HSD) were conducted using IBM SPSS v.29 to test the significance (at 0.05 significant level) of difference in the soil physico-chemical properties among the three selected fields (mango, cashew and control sites).

Results and Discussions

Physical Properties

Particle Size Distribution

The result of ANOVA using table critical f value of 3.47, on physical properties, Table 1 revealed there was no significant variation in sand content in the topsoil of all three fields at p = < 0.05 [F(2,21) = 0.448, p = 0.645]. Similarly, in the subsoil, at p = < 0.05 there was no significant variation in sand content in the three plots [F(2,21) = 0.584, p = 0.566]. This could be the result that soil of the study area is sandy loam with indiscriminate deposition of fine sand particles by wind usually at the onset of rainy season (Musa & Adamu, 2019). Moreover, this is in line with the report of Thiemeyer (2000) that alongside the crystalline rocks of the study area lie some deposits of fine sands of Lantewa sand dunes. The findings are similar to what was observed by Musa & Adamu on a 0-30cm depth in the same field.

Table 1: Summary of ANOVA on Soil Physical Properties under Mango, Cashew and Control Site in the Study Area

Soil Propertie		Result of soil Properties at 0-15cm						Result of soil Properties at 15-30cm					
	Source of Variation	SS	Df	MS	Calculated F value	Table critical F value	Sig.	SS	Df	MS	Calculated F value	Table critical F value	Sig.
Sand	Between Groups	.552	2	.276	.448	3.47	.645	.382	2	.191	.584	3.47	.566
	Within Groups	12.947	21	.617				6.863	21	.327			
	Total	13.500	23					7.245	23				
Silt	Between Groups	206.999	2	103.499	623.251	3.47	.000	203.199	2	101.599	1.190E3	3.47	.000
	Within Groups	3.487	21	.166				1.794	21	.085			
	Total	210.486	23					204.992	23				
Clay	Between Groups	226.137	2	113.069	225.118	3.47	.000	212.604	2	106.302	635.545	3.47	.000
	Within Groups	10.548	21	.502				3.512	21	.167			
	Total	236.685	23					216.117	23				

SS= sum of squares, df= degrees of freedom, MS= mean square, sig.= p value or probability level at < 0.05 significance

Table 2: Summary of Tukey's Post Hoc Analysis on Soil Physical Properties under Mango, Cashew and Control Fields in the Study Area

Soil Properties	Sampled Fields	Descriptive Values for Soil Properties in the Topsoil		Descriptive Values for Soil Properties in the Subsoil		Paired Fields	Significance of Variability in the Topsoil	Significance of Variability in the Subsoil
		Mean	Standard Deviation	Mean	Standard Deviation			
Sand (%)	Mango	69.8250	1.31990	70.1250	.97358	Mango/Cashew	.679 (Non-Significant)	.699 (Non-Significant)
	Cashew	70.1575	.27228	70.3575	.12092	Mango/Control	.998 (Non-Significant)	.571 (Non-Significant)
	Control	69.8475	.18258	70.4175	.13424	Cashew/Control	.713 (Non-Significant)	.976 (Non-Significant)
Silt (%)	Mango	10.9750	.59462	11.2750	.45277	Mango/Cashew	.000 (Significant)	.000 (Significant)
	Cashew	17.6862	.34301	18.0538	.11045	Mango/Control	.000 (Significant)	.000 (Significant)
	Control	12.0875	.16421	12.7575	.19754	Cashew/Control	.000 (Significant)	.000 (Significant)
Clay (%)	Mango	19.1375	1.03777	18.6000	.66332	Mango/Cashew	.000 (Significant)	.000 (Significant)
	Cashew	12.1563	.60701	11.5887	.13054	Mango/Control	.017 (Significant)	.000 (Significant)
	Control	18.0650	.24773	16.8250	.21153	Cashew/Control	.000 (Significant)	.000 (Significant)

The result of ANOVA on percent silt and clay in both the topsoil and subsoil of the three fields revealed that there was a significant variation [$F(2,21) > 3.47$, $p < 0.05$]. Hence, Table 2 of summary post-hoc test for multiple comparisons showed that in the topsoil, percent silt was significantly higher in the soils under cashew crops (17.69 ± 0.34%, p = 0.00) as compared to those in the control site (12.09 ± 0.16%, p = 0.00). In contrast, percent silt was significantly lower under mango crops (10.98 ± 0.60%) as compared to those under control site (p = 0.00). More so, percent silt was significantly higher in the soils under cashew crops (17.69 ± 0.34%, p =0.00) than those under mango crops. The trend is similar in the subsoil, as the mean values of silt under cashew crops and control site were respectively significantly higher (18.05 ± 0.11%, p = 0.00) and (12.76 ± 0.20%, p = 0.00) as compared to those under mango crops (11.28 ± 0.45%). Furthermore, percent silt was also significantly higher in the soils under cashew than that in the control site (p = 0.00).

The result therefore, reveals that there was a significant variation in silt separate among the three fields. The post hoc result established that cashew crops exhibit higher content of silt than both mango crops and control site in the soils at both soil layers. The reason for that may not be unconnected with the fact that the location of the cashew crops is at the north-eastern part of the study area which first receive the influence of north-easterly wind that brings much of the dust storm at the onset of rainy season (Musa & Adamu, 2019). In addition, the ring-like hilly parts of the study area provide shelter to the control site as well as the mango crops leaving the cashew crops more susceptible to the impact of the dust storm, which must have deposited more of fine sand and silt particles. This variation in the silt content is likely, because even the sand separate (though not significantly varied) was found to be more under the cashew crops, at least in the topsoil. In addition, even in the subsoil, sand separate was discovered to be higher in the soils under cashew than mango crops.

The post hoc result of the mean values of clay in the topsoil showed significantly higher under mango (19.14 ± 1.03%, p = 0.00) as compared to those in the control (18.07 ± 0.25%, p = 0.17) and those under cashew crops (12.16 ± 0.61%, p = 0.00). However, percent clay was significantly higher in the soils of the control site than those under cashew crops (p = 0.00). The trend is similar in the subsoil where percent clay was significantly higher in the soils under mango crops (18.60 ± 0.66%, p = 0.00) and control site (16.83 ± 0.21%, p = 0.00) as compared to those under cashew crops (11.59 ± 0.13%).

Hence, the result reveals that in both topsoil and subsoil there was a significant variation in percent clay among the three fields and the post hoc test showed that it was significantly higher under mango crops than both cashew and control sites. More so, the clay content was also significantly higher in the control than cashew crops. The reason for clay separate being significantly lower in the soils under cashew may not be unconnected with the reasons stated above, that there have been more deposits of fine sands and silts under the cashew than both the mango crops and the control site.

Soil Chemical Properties

All soil chemical properties analysed using the one-way ANOVA with table critical f-value of 3.47 and $p > 0.05$ (Table 3), the result revealed that in both the topsoil and subsoil there were a significant variations in the three fields [$F(2,21) > 3.47$, $p < 0.05$].

Organic Matter Content (OM)

The post hoc result for multiple comparisons (Table 4) in the topsoil revealed that OM was significantly higher in the control site (2.56 ± 0.02%, p =0.00) and under cashew crops (2.48 ± 0.04%, p = 0.00) as compared to those under mango crops (2.33 ± 0.08%). However, OM was revealed to be significantly higher in the control site as compared to those under cashew crops (p = 0.024).

Similarly, in the subsoil, the post hoc test revealed that OM was significantly higher in the control site (2.57 ± 0.03%, p = 0.00) and cashew crops (2.30 ± 0.03%, p = 0.00) as compared to those under mango crops (2.21 ± 0.03%). The result also showed that OM was significantly higher in the control site when compared with those under cashew crops (p = 0.00).

This establishes the fact that OM was lower under both crops as compared to the soils under semi-natural vegetation (control site) in both topsoil and subsoil. This revealed a significant decrease in the amount of OM in the study area, perhaps due to the cultivation of both mango and cashew trees. This agrees with the findings of Oriola and Adeyemi (1997) on teak crops in South Western Nigeria; Ayoubi et al. (2011) in Northern Iran and Yitbarek et al. (2013) in Western Ethiopia as they observed higher content of organic matter under the natural forest than cultivated fields. These differences might be due to variation in vegetation density, litter cover, and the degree and frequency of soil disturbance as observed by Jaiyeoba (1995) under semi-arid savanna of Nigeria. The degree and frequency of disturbance could be due to cropping of annual crops at some patches of open spaces in-between the crops as observed in the field. However, in both soil strata, OM was significantly lower in the soils under mango crops than under cashew. This could be the result that the mango crops soils were more disturbed, had lesser vegetation density, hence lower litter cover.

Total Nitrogen (TN)

In the topsoil, the post hoc test (Table 4) revealed that total nitrogen was significantly higher in the control site (0.21 ± 0.01, p =0.00) and under cashew crops (0.19 ± 0.01%, p = 0.00) as compared to those under mango crops (0.14 ± 0.008%). The mean value of TN was also significantly higher in the control site than those under cashew crops (p = 0.03). Similarly, in the subsoil, the post hoc test showed that TN was significantly higher in the control site (0.21 ± 0.01%), p = 0.00) and cashew crops (0.20 ± 0.01%, p = 0.00) as compared to those under mango crops (0.18 ± 0.01%). Furthermore, the contents of TN were significantly higher in the control site than those under cashew (p = 0.28).

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This trend is similar to that of organic matter content in both topsoil and subsoil. Thus, the total nitrogen was lower under both crops as compared to the natural vegetation. The significant variations in total nitrogen among the soils of the three fields agree with the findings of Jaiyeoba (1995). In addition, Knops and Tilman (2000) reported similar outcome in a study of dynamics of soil nitrogen and carbon accumulation for 61 years after agricultural abandonment. Equally, similar results were revealed by Awotoye et al. (2009) in the study of degradation of soil physicochemical properties resulting from continuous logging of tree crops in south-western Nigeria and Yitbarek et al (2013) in the study of impacts of land use on selected physicochemical properties of soils in western Ethiopia. Hence, such significant difference between the crops and the natural vegetation might be due to more lignified litter under tree crops where organically bound nitrogen are associated with leaching and slower mineralisation as observed by Jaiyeoba (1995) and Awotoye et al. (2009). However, there was significant higher total nitrogen in the soils under cashew than mango crops. This variation might be due to the fact that litter was found to be greater under cashew crops than mango. This might likely be coupled with the fact that open spaces between mango trees were greater than those of cashew trees. However, a more reason for the difference may not be unconnected with the fact that cashew litter is more palatable to decomposition by *Perionyx excavatus* (epigeic earthworm) than mango litter as observed by Pattanayak et al. (2014) in the study of changes in growth rate and activities of amylase and cellulose of epigeic earthworm in decomposing leaf of 5 tree species in India. Hence, the process of mineralisation seems to be greater under cashew crops than mango – thus leading to significantly higher total nitrogen under the former in both topsoil and subsoil.

Soil pH

The post hoc test for multiple comparisons (Table 4) in the topsoil uncovered that the soil pH values were significantly higher in the soils under cashew crops (6.43 ± 0.02, $p = 0.00$) and mango crops (6.35 ± 0.03, $p = 0.00$) as compared to those in the control site (6.26 ± 0.02). In addition, it also revealed that the soil pH was significantly higher in the soils under cashew crops than those under mango crops ($p = 0.00$).

Similarly, the post hoc result of the subsoil revealed that soil pH was significantly higher under cashew crops (6.60 ± 0.03, $p = 0.00$) and mango (6.46 ± 0.02, $p = 0.00$) as compared to those in the control (6.32 ± 0.01). The result also revealed that soil pH was significantly higher in the soils under cashew than mango crops ($p = 0.00$).

Therefore, the result of soil pH shows that in both topsoil and subsoil, the mean values were significantly higher in the soils under the crops than the control site. This implies an increase of soil pH towards neutrality (7.0), perhaps due to the cultivation of the cashew and mango trees. Thus, the values of soil pH in all the three fields reflect acidity (values < 7.0) in the soils. In contrast, the observation of Jaiyeoba (1995); Oriola and Adeyemi (1997) revealed significantly lower content of soil pH under tree crops than natural vegetation. The increase in the mean values of soil pH under both crops might be due to greater absorption of anions (H^+ and Al^{3+}) not only the cations (exchangeable bases) by mango and cashew trees as compared to the plants in the control site. This is supported with the fact that exchangeable acidity was found to be lower under both crops in the topsoil (Table 4). This is because decrease in the content of anions or increase in the mean values of cations could lead to increase in soil pH, and the vice-versa is equally the case as observed by Aweto (1986); Havlin et al. (2005); Weil & Brady (2017).

The values of soil pH were also significantly higher under cashew crops than those under mango. This might not be unconnected with greater absorption of the cations by mango trees than those of cashew. This might be coupled with faster decomposition of cashew leaves as observed by

(Pattanayak, 2014) thereby adding greater amount of organic colloids in the soils under cashew (Weil & Brady 2017).

Exchangeable Acidity (EA)

In the topsoil, the post hoc result for multiple comparisons (Table 4) revealed that EA was significantly higher in the control site (0.71 ± 0.02cmol/kg, $p = 0.00$) as compared to those under cashew crops (0.47 ± 0.02cmol/kg) and mango crops (0.45 ± 0.03cmol/kg). However, the result showed that there was no significant variation in the values of EA between the soils under mango crops and those under cashew field ($p = 0.305$). This shows that the values of exchangeable acidity, in the topsoil were significantly lower in the soils under both crops than the control site. In contrast, the observation of Awotoye et al. (2009) and another study on assessment of soil fertility variation in different land uses in Ethiopia by Yeshaneh (2015) reported significantly lower content of EA in the control site. According to Das (2011), EA is the acidity which develops due to adsorbed hydrogen (H^+) and aluminium (Al^{3+}) ions on the soil colloids. This reflects higher H^+ and Al^{3+} in the soils of the control site. However, there was no significant difference between the two crops in the values of EA.

In the subsoil, the post hoc result for multiple comparisons revealed that EA was significantly higher in the soils under both cashew (0.67 ± 0.02cmol/kg, $p = 0.00$) and control sites (0.67 ± 0.02cmol/kg, $p = 0.00$) as compared to those under mango crops (0.37 ± 0.01cmol/kg). However, the result showed that there was no significant difference in the values of EA between cashew crops and the control site ($p = 0.809$). Thus, the trend was similar to that of the topsoil except under cashew crops which had significantly higher EA than the soils under mango, and statistically the same with those in the control site. This is in contrast with the findings of Musa & Adamu (2019) which revealed higher values of EA on the same fields at 0-30cm. Hence, the result implies higher levels of H^+ and Al^{3+} in the soils under cashew and control site as compared to those under mango. This may also reflect higher uptake of anions under mango (Musa & Adamu, 2019). This is because, as cations exceed anions absorption, excess H^+ is released into the rhizosphere, and when anions exceed cation uptake OH^-/HCO_3 is released as reported by Havlin et al. (2005).

Exchangeable Calcium (Ca^{2+})

The post hoc test for multiple comparisons in the topsoil (Table 4), revealed that Ca^{2+} was significantly higher in the control site (1.40 ± 0.01cmol/kg, $p = 0.00$) and cashew crops (1.37 ± 0.02cmol/kg, $p = 0.00$) as compared to those under mango crops (1.27 ± 0.01cmol/kg). The result also revealed that Ca^{2+} was significantly higher in the control site than under cashew field ($p = 0.00$). Hence, in the topsoil, the values of Ca^{2+} were significantly lower in the soils under both crops than the semi-natural vegetation. This is in line with the observations of Jaiyeoba (1995); Oriola and Adeyemi (1997); and Senjobi et al. (2013) in which they reported significantly lower values of Ca^{2+} under tree crops than natural vegetation. The reason for significantly lower values of Ca^{2+} under the crops might not be unconnected with the fact that organic matter content was higher in the soils of the control site. Thus, organic matter likely plays greater role in the soils of the control than the two crops by supplying part of the soil colloids on which cations are adsorbed to as observed by Bohn et al. (2001); Das (2011); and Weil & Brady (2017). More so, the values of Ca^{2+} being significantly lower under mango crops than cashew, also likely reflects the role of the organic matter on the cations. This is because organic matter content was equally higher in the soils under cashew crops than mango.

Table 3: Summary of ANOVA on Soil Chemical Properties under Mango, Cashew and Control Site in the Study Area

Soil Properties		Result of soil Properties at 0-15cm						Result of soil Properties at 15-30cm					
	Source of Variation	SS	Df	MS	Calculated F value	Table critical F value	Sig.	SS	Df	MS	Calculated F value	Table critical F value	Sig.
Organic Matter	Between Groups	.218	2	.109	37.738	3.47	.000	.548	2	.274	364.406	3.47	.000
	Within Groups	.061	21	.003				.016	21	.001			
	Total	.279	23					.564	23				
Nitrogen	Between Groups	.020	2	.010	187.923	3.47	.000	.006	2	.003	39.231	3.47	.000
	Within Groups	.001	21	.000				.002	21	.000			
	Total	.021	23					.008	23				
Soil pH	Between Groups	.118	2	.059	120.235	3.47	.000	.314	2	.157	308.303	3.47	.000
	Within Groups	.010	21	.000				.011	21	.001			
	Total	.128	23					.324	23				
Exchangeable Acidity	Between Groups	.336	2	.168	364.714	3.47	.000	.472	2	.236	918.037	3.47	.000
	Within Groups	.010	21	.000				.005	21	.000			
	Total	.346	23					.478	23				
Exchangeable Calcium	Between Groups	.080	2	.040	123.615	3.47	.000	.001	2	.001	4.964	3.47	.017
	Within Groups	.007	21	.000				.003	21	.000			
	Total	.087	23					.004	23				
Exchangeable Magnesium	Between Groups	.014	2	.007	10.610	3.47	.001	.009	2	.005	8.878	3.47	.002
	Within Groups	.014	21	.001				.011	21	.001			
	Total	.029	23					.020	23				
Exchangeable Potassium	Between Groups	.001	2	.000	44.295	3.47	.000	.008	2	.004	323.632	3.47	.000
	Within Groups	.000	21	.000				.000	21	.000			
	Total	.001	23					.008	23				
Exchangeable Sodium	Between Groups	.033	2	.017	53.779	3.47	.000	.273	2	.136	494.944	3.47	.000
	Within Groups	.006	21	.000				.006	21	.000			
	Total	.040	23					.279	23				
Cation Exchange Capacity	Between Groups	1.105	2	.552	891.504	3.47	.000	1.943	2	.972	1.503E3	3.47	.000
	Within Groups	.013	21	.001				.014	21	.001			
	Total	1.118	23					1.957	23				
Available Phosphorus	Between Groups	19.875	2	9.938	202.263	3.47	.000	31.651	2	15.825	454.998	3.47	.000
	Within Groups	1.032	21	.049				.730	21	.035			
	Total	20.907	23					32.381	23				
Base Saturation	Between Groups	161.901	2	80.951	184.424	3.47	.000	237.922	2	118.961	362.957	3.47	.000
	Within Groups	9.218	21	.439				6.883	21	.328			
	Total	171.119	23					244.805	23				

SS= sum of squares, df= degrees of freedom, MS= mean square, sig.= p value or probability level at < 0.05 significance

Table 4: Summary of Tukey's Post Hoc Analysis on Soil Chemical Properties under Mango, Cashew and Control Fields in the Study Area

Soil Properties	Sampled Fields	Descriptive Values for Soil Properties in the Topsoil		Descriptive Values for Soil Properties in the Subsoil		Paired Fields	Significance of Variability in the Topsoil	Significance of Variability in the Subsoil
		Mean	Standard Deviation	Mean	Standard Deviation			
Organic Matter Content (%)	Mango	2.32750	.082578	2.2132	.02762	Mango/Cashew	.000 (Significant)	.000 (Significant)
	Cashew	2.47962	.037071	2.2975	.02982	Mango/Control	.000 (Significant)	.000 (Significant)
	Control	2.55688	.021649	2.5676	.02460	Cashew/Control	.024 (Significant)	.000 (Significant)
Total Nitrogen (%)	Mango	.1400	.00756	.1750	.01195	Mango/Cashew	.000 (Significant)	.000 (Significant)
	Cashew	.1937	.00744	.2012	.00641	Mango/Control	.000 (Significant)	.000 (Significant)
	Control	.2075	.00707	.2138	.00744	Cashew/Control	.003 (Significant)	.028 (Significant)
Soil pH	Mango	6.3538	.02615	6.4562	.01768	Mango/Cashew	.000 (Significant)	.000 (Significant)
	Cashew	6.4313	.02295	6.6025	.03196	Mango/Control	.000 (Significant)	.000 (Significant)
	Control	6.2600	.01604	6.3225	.01389	Cashew/Control	.000 (Significant)	.000 (Significant)
Exchangeable Acidity (cmol/kg)	Mango	.4500	.02390	.3700	.01309	Mango/Cashew	.305 (Non-Significant)	.000 (Significant)
	Cashew	.4662	.02134	.6700	.01852	Mango/Control	.000 (Significant)	.000 (Significant)
	Control	.7087	.01885	.6650	.01604	Cashew/Control	.000 (Significant)	.809 (Non-Significant)
Exchangeable Calcium (cmol/kg)	Mango	1.2675	.02315	1.3925	.00886	Mango/Cashew	.000 (Significant)	.097 (Non-Significant)
	Cashew	1.3712	.02031	1.4050	.00926	Mango/Control	.000 (Significant)	.016 (Significant)
	Control	1.4025	.00463	1.4100	.01512	Cashew/Control	.006 (Significant)	.662 (Non-Significant)
Exchangeable Magnesium (cmol/kg)	Mango	.1737	.01061	.2062	.00744	Mango/Cashew	.000 (Significant)	.205 (Non-Significant)
	Cashew	.2337	.04138	.2262	.03701	Mango/Control	.044 (Significant)	.001 (Significant)
	Control	.2075	.01488	.2538	.01061	Cashew/Control	.134 (Non-Significant)	.060 (Non-Significant)
Exchangeable Potassium (cmol/kg)	Mango	.18012	.003796	.1629	.00511	Mango/Cashew	.000 (Significant)	.000 (Significant)
	Cashew	.18875	.001909	.2056	.00185	Mango/Control	.000 (Significant)	.000 (Significant)
	Control	.19212	.001642	.1922	.00243	Cashew/Control	.045 (Significant)	.000 (Significant)
Exchangeable Sodium (cmol/kg)	Mango	.1801	.00380	.6225	.01389	Mango/Cashew	.956 (Non-Significant)	.000 (Significant)
	Cashew	.7888	.02031	.7825	.02375	Mango/Control	.000 (Significant)	.000 (Significant)
	Control	.8662	.01685	.8812	.00835	Cashew/Control	.000 (Significant)	.000 (Significant)
Cation Exchange Capacity	Mango	2.85762	.030369	2.7504	.01908	Mango/Cashew	.000 (Significant)	.000 (Significant)
	Cashew	3.04875	.019660	3.2886	.03231	Mango/Control	.000 (Significant)	.000 (Significant)
	Control	3.37712	.023449	3.4030	.02307	Cashew/Control	.000 (Significant)	.000 (Significant)
Available Phosphorus (ppm)	Mango	9.2862	.34413	9.2450	.28320	Mango/Cashew	.000 (Significant)	.000 (Significant)
	Cashew	10.0150	.13512	10.2950	.06887	Mango/Control	.000 (Significant)	.000 (Significant)
	Control	11.4750	.10351	12.0300	.13928	Cashew/Control	.000 (Significant)	.000 (Significant)
Base Saturation (%)	Mango	84.3175	.71428	86.6862	.56381	Mango/Cashew	.481 (Non-Significant)	.000 (Significant)
	Cashew	84.7062	.72206	79.6462	.69525	Mango/Control	.000 (Significant)	.000 (Significant)
	Control	79.0125	.53409	80.4388	.42663	Cashew/Control	.000 (Significant)	.030 (Significant)

There is difference in the trend in the subsoil, where the Ca^{2+} was not significantly lower in the soils under mango crops (1.391 ± 0.01cmol/kg, p = 0.097) and control site (1.410± 0.02cmol/kg, p = 0.662) as compared to those under cashew crops (1.405 ± 0.01cmol/kg). However, Ca^{2+} was significantly lower in the soils under mango crops as compared to those in the control site (p = 0.016). Thus, in the subsoil, exchangeable $Ca^{2+}$was significantly lower under mango, but not significantly lower under cashew when compared with the control site. Still, this may reflect the role of significantly higher organic matter in the control site than under mango crops. However, the reason for no significant variation between the cashew crops and the control is unclear despite having significant variation in terms of organic matter content and per cent clay.

Exchangeable Magnesium (Mg^{2+})

The result of the post hoc test for multiple comparisons (Table 4) in the topsoil revealed that Mg^{2+} was significantly higher under cashew crops (0.23 ± 0.04cmol/kg, p =0.00) and in the control site (0.21 ± 0.02cmol/kg, p = 0.044) than those under mango crops (0.17 ± 0.01cmol/kg). However, there was no significant variation in the values of Mg^{2+} between the soils under cashew crops and those in the control site (p = 0.134).

In the subsoil, the post hoc result unveiled that Mg^{2+} was significantly higher in the control site (0.25 ± 0.01cmol/kg, p = 0.001) than under mango crops (0.21 ± 0.01cmol/kg). On the other hand, the values of Mg^{2+} were not significantly lower in the soils under cashew crops (0.23 ± 0.04cmol/kg) than those in the control site (p = 0.06). Furthermore, there was no significant difference in the values of Mg^{+} between the soils under mango and those under cashew (p = 0.205).

The result therefore establishes that in both topsoil and subsoil, Mg^{2+} was significantly lower under mango crops than control site. Similar findings were reported by Jaiyeoba (1995); Oriola and Adeyemi (1997); Awotoye et al. (2009); Senjobi et al. (2013) and Yeshaneh (2015). However, the values were not significantly different between soils under cashew crops and the control site in both soil layers. The comparison in the soils between cashew and mango crops differs for the topsoil and subsoil. In the topsoil it was revealed to have had significantly lower content of Mg^{2+} under mango crops, while in the subsoil there was no significant difference. The reason for lower values of Mg^{2+} under mango as compared to the control site might be connected with the role of organic matter, being significantly lower under the former. This is likely, because organic matter supplies the organic colloids on which the cations are adsorbed to, as observed by Bohn et al. (2001); Das (2011); Weil & Brady (2017). More so, the significant lower Mg^{2+} under mango than cashew crops in the topsoil could be attributed to the same reason.

Exchangeable Potassium (K^{+})

The post hoc result for multiple comparisons of the topsoil uncovered that the content of K^{+} was significantly higher in the control site (0.192 ± 0.002cmol/kg, p = 0.00) and those under cashew crops (0.189 ± 0.003cmol/kg, p = 0.00) as compared to those under mango crops (0.180 ± 0.004cmol/kg). More so, K^{+} was significantly higher in the control site when compared with those under cashew crops than (p = 0.045).

However, in the subsoil, the post hoc result unveiled that the mean values of K^{+} were significantly higher under cashew crops (0.21 ± 0.002cmol/kg, p = 0.00) and in the control site (0.19 ± 0.002cmol/kg, p = 0.00) as compared to those under the mango crops (0.16 ± 0.005cmol/kg). In addition, the values of K^{+} were also significantly higher under cashew crops than those in the control site (p = 0.00).

The result therefore implies that the values of exchangeable potassium were significantly lower under mango crops than control site in both topsoil and subsoil. This agrees with the observation of Senjobi et al. (2013); and Yeshaneh (2015) on soil fertility variation under different land uses in Ethiopia. In both topsoil and subsoil, the mean values of K^{+} were higher in the soils under cashew crops than those in the control. Similarly, in the subsoil, the values were significantly higher under cashew than mango crops. The reason for the lower K^{+} in the soils under mango crops than both control site and cashew crops might be equally attributed to the role of organic matter and greater absorption of the nutrient by mango trees. Organic matter was lower under the mango crops which reflects less organic colloids to adsorb the cations (Bohn et al., 2001; Das, 2011; Brady and Weil, 2014). However, the reason for higher K^+ under cashew than control site in both the topsoil and might be attributed to less absorption of the nutrient by cashew trees than the plants in the control site.

Exchangeable Sodium (Na^+)

The post hoc test for multiple comparisons (Table 4) in the topsoil revealed that the mean values of Na^+ were significantly higher in the control site (0.87 ± 0.017cmol/kg, p = 0.00) as compared to those under mango crops (0.79 ± 0.015cmol/kg) and cashew field (0.79 ± 0.020cmol/kg). However, there was no significant variation in the content of Na^+ in the soils between mango and cashew crops (p = 0.956).

In the subsoil, the post hoc result showed that the content of Na^+ was significantly higher in the control site (0.88 ± 0.008, p = 0.00) and cashew (0.78 ± 0.024, p = 0.00) when compared with those under mango (0.62 ± 0.014). However, Na^+ was significantly higher in the control site than cashew crops (p = 0.00).

This shows that, in both topsoil and subsoil, the values of Na^+ were significantly lower in the soils under the two crops when compared with the control site. This agrees with the findings of other researchers like Jaiyeoba (1995); Oriola and Adeyemi (1997); Awotoye et al. (2009); and Yeshaneh (2015). In the topsoil, there was no significant difference between the two crops in content of Na^+. However, in the subsoil, Na^+ was significantly lower under mango than cashew crops. The reason for higher Na^+ in the control site might be due to greater absorption of the Na^+ by both crops The significant difference between soils under mango and cashew crops in the subsoil might be due to increased immobilisation under the latter (Jaiyeoba, 1995).

Cation Exchange Capacity (CEC)

The post hoc test for multiple comparisons established that in the topsoil the values of CEC were significantly higher in the control site (3.38 ± 0.02, p = 0.00) and under cashew (3.05 ± 0.02, p = 0.00) as compared to those under mango (2.86 ± 0.03). In addition, the value of CEC was significantly higher in the control site than under cashew crops (p = 0.00).

In the subsoil, the trend is similar, in which the values of CEC were significantly higher in the control site (3.40 ± 0.02, p = 0.00) and cashew (3.29 ± 0.03, p = 0.00) as compared to those under mango crops (2.75 ± 0.02). Moreover, the values of CEC were significantly higher in the control site than under cashew crops (p = 0.00).

Therefore, in both topsoil and subsoil the results show that the values of CEC were significantly lower in the soils under both crops than the control site. The result in the topsoil is in line with the reports of other researchers such as Oriola and Adeyemi (1997); Awotoye et al. (2009); and Yeshaneh (2015) in which they observed significantly higher values of CEC in the control site. In contrast, other authors such as Senjobi (2013) reported lower CEC in the control site as opposed to cultivated fields. Hoskins (1997) and Havlin (2005) referred CEC as the total quantity of negative surface charge on minerals and OM available to attract cations in solution. On this note, the significantly lower content of CEC in the soils under both crops than the control site could be attributed to mostly the role of organic matter content portion of the negative surface charges. This is because the values of organic matter content were found to be significantly higher in both topsoil and subsoil of the control site, even though the values of percent clay were significantly lower, except for soils under cashew. Similarly, the values of CEC were significantly lower under mango than cashew, perhaps due to the same reason, because the content of OM was significantly higher under the latter.

Available Phosphorus (P)

In the topsoil, the post hoc result for multiple comparisons (Table 4) unveiled that the values of available phosphorus were significantly higher in the control site (11.48 ± 0.10, p = 0.00) and cashew (10.02 ± 0.14, p = 0.00) as compared to those under mango crops (9.29 ± 0.34). In addition, the values of P were significantly higher in the control site than cashew crops (p = 0.00).

Similarly, in the subsoil, the post hoc result for multiple comparisons uncovered that the values of available phosphorus were significantly higher in the control site (12.03 ± 0.14, p = 0.00) and cashew (10.30 ± 0.07, p = 0.00) as compared to those under mango crops (9.25 ± 0.28). Moreover, the values of P were also significantly higher in the control site than those under cashew crops (p = 0.00).

This reveals that the values of available phosphorus were significantly lower under both crops than the control in both topsoil and subsoil. Similar results were reported by Awotoye et al. (2009) on degradation of soil physicochemical properties due to continuous logging of tree plantations; and Senjobi et al. (2013) on the assessment of spatial variations of some soil properties under different land uses in south-western Nigeria which revealed significantly higher available phosphorus in the control site. On the other hand, Yeshaneh (2015) in the study of the assessment of soil fertility variation under different land uses in Ethiopia reported lower available phosphorus than the control site. The reason for lower available phosphorus under the crops may be connected with the likely greater absorption of the nutrient by the roots of the crops. Furthermore, phosphorus adsorption by Fe/Al oxides in the soil decreases with increasing pH as reported by Havlin et al. (2005). Thus, the content of soil pH being higher under the crops than the control reflects the observed decrease in the available phosphorus under the former. Similarly, in both topsoil and subsoil, the values of available phosphorus were significantly lower under mango crops than cashew. This might be due to greater absorption of the available phosphorus by mango trees than those of cashew.

Base Saturation (BS)

The post hoc result for multiple comparisons showed that the values of BS in the topsoil, were significantly higher in the soils under cashew (84.71 ± 0.72, p = 0.00) and mango (84.32 ± 0.71, p = 0.00) as compared to those in the control site (79.01 ± 0.53). However, the post hoc result also revealed that there was no significant difference in the values of BS between the soils under mango and cashew crops (p = 0.481).

In the subsoil, the result revealed that the values of BS were significantly higher under mango crops (86.69 ± 0.56) and control site (80.44 ± 0.43, p = 0.03) as compared to those under cashew crops (79.65 ± 0.70, p = 0.00). Unlike in the topsoil, the values of BS were revealed to be significantly higher under mango crops than in the control site (p = 0.00).

The result therefore implies that, in the topsoil, the values of base saturation were significantly higher under both crops than control site. The findings therefore agree with that of Yitbarek et al. (2013) and contradict with that of Awotoye et al. (2009) in which the values of BS were revealed to be higher in the control site than tree crops. However, Senjobi et al. (2013) observed no significant difference between tree crops and the control site. Base saturation indicates the total exchange sites that are occupied by basic cations. However, the values were not significantly lower under mango than those of cashew. The trend is different in the subsoil, in which the base saturation levels were lower under cashew and higher under mango as compared to the control. More so, it was significantly lower under cashew than the control site.

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Conclusion

Aside from soil state factors (climate, organisms, relief, parent material and time), other local factors due to ever-increasing activities of man on the land resource for shelter, clothing, food and medicine among others, exert effects on the soil thereby leading to changes in the soil properties, hence their variability over similar soils under different managements. In this regard, cultivation of mango and cashew in Shira and its environs undoubtedly reflects some degree of variability in the soil physico-chemical properties, and general decline in the soil nutrients, though more pronounced under mango crops than cashew. Thus, mango crops, perhaps absorbs greater soil nutrients than cashew thereby leading to their decline in the study area. Recognising and understanding such variability could aid the farmers to engage in seeking for better strategies to cultivate their farmlands. Considering the findings of this research, mango farmers could improve on a sustainable and more profitable yield by establishing a long-term soil health monitoring system to track changes in physical and chemical properties over time. This can be achieved through collaboration with agricultural research organizations to develop and implement best practices tailored to local conditions of cultivating mango and cashew crops. For example, practicing of intercropping of mango and cashew crops and mixed with other crops that can improve soil health and nutrient content, such as legumes, which can fix nitrogen in the soil.

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