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VARIABILITY IN SOIL PHYSICO-CHEMICAL PROPERTIES OF HYPOLUVIC ARENOSOLS UNDER MANGO AND CASHEW IN SHIRA, NORTH-EASTERN NIGERIA

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ABSTRACT

To extrapolate the nature of soil nutrient levels under mango and cashew crops in North-eastern Nigeria, the study examined the spatial variability of soil physicochemical properties. A total of twenty four composite soil samples were collected at 0-30cm depth from the fields of mango, cashew and semi-natural Sudan Savanna. From each sampled site, soil samples were collected from 8 quadrats measuring 20 x 20m. The soil samples were tested using standard routine laboratory analysis for particle size composition, OM, TN, soil pH, EA, Ca^{2+}, Mg^{2+}, K^{+}, Na^{+}, P, CEC and BS. One-way analysis of variance was used to assess the variability or otherwise of the soil physicochemical properties under the two crops and semi-natural Sudan savanna. For particle size composition, only silt and clay separates were significantly different ($P \leq .05$) among the three fields. Similarly, all soil chemical properties analysed revealed to be statistically heterogeneous ($P \leq .05$) among the three fields. Most of the soil chemical properties had significantly higher mean values under the semi-natural vegetation, followed by that of cashew and the significantly least mean values were revealed under mango crops. Hence, the study recommends the use of organic manure, and where necessary, the inorganic fertilizer, especially N, Ca, K, Na and P in fields of mango and cashew crops to replenish the increasingly lost soil nutrients. Moreover, farmers in the study area may wish to diversify from mono-cropping to mixed-cropping by juxtaposing mango crops alongside cashew crops and even with perennial crops for sustainable greater returns.

Keywords: Variability, physicochemical properties, mango, cashew, and hypoluvic Arenosols.

INTRODUCTION

Cashew (*Anacardium occidentale*) and mango (*Mangifera indica*) crops are tropical deciduous trees of the same botanical family, *Anacardiceae.* Since cashew was introduced to Nigeria for over 400 years, attention was mainly given to the apple and afforestation practices while no, or at best, little commercial value was attached to it (Aliyu, 2012). Production of cashew nut in Nigeria rose from 7000 tonnes in 1961 to 466000 tonnes in 2000, then skyrocketed to 958860 tonnes in 2016 (FAO, 2017). The statistics on a combined data on yield of mango, though including mangosteens and guava revealed 200000 tonnes in 1961, 730000 tonnes in 2000 and 917617 tonnes in 2016. Hence, there is likely ever-increasing rate of cashew and mango production in the study area under hypoluvic Arenosols and a consequential variability in soil properties; and this might even influence the yield of the crops.

Factors of soil evolution completely define the soil system, in that all various soil properties must depend on climate, organisms, relief, parent material and time (Jenny, 1941). Recent studies by Rhoades (1997); Schaetzl and Anderson (2005); Foth (2006); Das (2011) among others have continued to prove that all these five factors contribute in the spatial variability of soil properties. The major five state factors are responsible for medium and large scale variability in soil properties, but local factors induce small scale differences in soil properties. However, local factors could result from runoff which may lead to soil erosion and deposition of materials. Similarly, different soil management practices among others could also lead to changes in soil properties. Therefore, a localised factor like cultivation of mango and cashew crops on the same soil class likely induces variable impacts on soil physicochemical properties. Even where different cultivation practices of exact same species of tree crops are carried out on a particular soil class, might lead to variation in soil properties and crop yield. According to Das (2011) and Ndakara (2012), tree crops induce profound effect on soil development thereby influencing some of its physicochemical properties. Many of the effects of trees on soils lead to impoverishment of soil fertility (Ekanade, 1991). However, effects of trees on soil properties could increase soil fertility under canopies than the surrounding soils (Young, 2002; Ogunkunle, 2013). Tree species over time, could affect soil properties in either positive or negative way, or might have no effect at all (Oloyede, n.d). Hence, the effects of tree species on soils could vary by many mechanisms, including rates of nutrient inputs, outputs, and cycling (Binkley and Giardina, 1998). Evidence for the effects of trees on soils is revealed when soil properties under tree canopies are compared with those in the surrounding with no tree cover (Russell et al., 2007). Many studies were undertaken to examine the effect of trees on the soil physical and chemical properties, and a growing body of evidence has demonstrated that tree species can differ in their influence on soil properties (Binkley and Giardina, 1998). Despite many researches were carried out on the effects of different trees species on soil properties such as Awotoye et al. (2009); Eni et al. (2012); Dachung et al. (2014); Offiong et al. (2015); Russell et al. (2018) among others, they failed to deduce if there are spatial differences in soil physicochemical properties when both mango and cashew crops are cultivated on same soil class. Although, some researchers like William et al. (2013); William et al. (2015) studied the differences in net income between mango and cashew under different strategies for managing insect pests in Tanzania, but did not assess the variability in soil properties. Similarly, Nalawade (2011); Narayan (n.d) assessed only the variation in yield and income between the two crops. Hence, there was no study carried out to examine the variability in soil physicochemical properties of hypoluvic Arenosols under mango and cashew crops in part of Sudan savanna of North-eastern Nigeria.

Therefore, this study examined the spatial variability of soil physico-chemical properties of hypoluvic Arenosols under mango and cashew crops in the study area. This would assist the farmers in the study area to understand the nature of the soil physicochemical properties in their farmlands and perhaps choose the better cropping system that proffers greater sustainable soil management practices. The study could pave way to carry out further research on the major soil nutrients required to be replenished.

Study Area

The study area extends between Latitudes 11°26'18" and 11°29'58" N and Longitudes 10°01'27" and 10°04'26" E (Figure 1). The elevation of the study area (Shira village) is approximately between 407m to 624m above sea level. The highest elevation is found at the hills which almost surrounded the area. This has given the study area a good drainage system where most of its waters are drained by a network of ephemeral streams south-westerly.

The climate of the study area is tropical continental, classified as 'As' under Köppen's System of Climate Classification. It has a total annual rainfall of about 810mm received between April and October.

Shira village is under Sudan savanna vegetation which is characterized mostly by short grasses, shrubs and few trees. Most of the trees are deciduous, and only few are evergreen. 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*).

Geology of the study area falls under the basement complex of the Hausa Plains of northern part of Nigeria (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. Deposits of fine sands which originated from the Lantewa sand dunes are found alongside these crystalline rocks (Thiemeyer, 2000).

The main soil types of the study area are Arenosols and Plinthosols (FAO/UNESCO, 1988) and soil units include hypoluvic Arenosols and petric Plinthosols (FAO/IIASA/ISRIC/ISSCAS/JRC, 2012; Jones et al., 2013). See Figure 1.

Major crops grown include cereals such as millet (*Pennisetum glaucum*), sorghum (*Sorghum bicolor*), rice (*Oryza sativa*). Other crops grown include groundnut (*Arachis hypogaea)*, cowpea (*Vigna unguiculata*), sesame (*Sesamum indicum*), water melon (*Citrullus lanatus*), tomato (*Lycopersicon esculentum*), and sugarcane (*Saccharum officinarum*) among others. Tree crops that are grown in the area comprise of mango (*Mangifera indica*), cashew (*Anacardium occidentale*) and guava (*Psidium guajava*). Most of the crops are rainfed.

MATERIAL AND METHODS

Soil Sampling

Three sample sites were selected in the study area, which include fields of mango, cashew and semi-natural Sudan savanna. The farmlands were measured approximately 1.04ac and 1.01ac, respectively for cashew and mango plantations. Each sampled field was demarcated using 40 x 80m, and then subdivided into 8 quadrats (20 x 20m). Five representative samples were then collected along a zigzag transect from each quadrat at the depths of 0-30cm). The 5 representative samples of each quadrat were thoroughly mixed and a fraction was obtained as a composite sample. Therefore, a total of 24 composite samples were collected altogether for the three fields (8 composite samples from each field). The composite samples were enclosed in a labelled polythene bags, air dried and ground to pass through a 2mm sieve prior to laboratory analysis.

Laboratory Analysis

Soil physical properties considered for laboratory analysis were the content of sand, silt and clay (particle size composition). In addition, soil chemical properties analysed in the laboratory were organic matter content, total nitrogen, soil pH, exchangeable acidity (EA), exchangeable bases (Ca^{2+}, Mg^{2+}, Na^{+} and K^{+}), cation exchange capacity, base saturation and available phosphorus. Most of these soil chemical properties are those that directly influence soil fertility status and productivity as observed by Brady and Weil (2014).

Therefore, particle size composition was determined using hydrometer method as suggested by Liebens (2007). Walkley Black titration method was used in analysing organic matter content, and total nitrogen (N) was determined by Kjeldahl method. Soil pH was analysed potentiometrically in a solution of 0.01m $CaCl_2$ using a 1:2 soil-to-solution ratio. EA was determined by the use of potassium chloride (Kcl) extraction and titration. Ca^{2+}, K^{+}, and Na^{+} were determined using flame photometry, while absorption spectrophotometer was employed to determine Mg^{2+}. For the determination of CEC, summation of exchangeable cations and exchange acidity was employed. Base saturation was determined by the summation of the exchangeable bases divided by the CEC, and multiplied by 100 as advocated by Das (2011). Available phosphorus was determined using Bray No. 1 method.

Statistical Techniques

One-way Analysis of variance (ANOVA) was used using SPSS package to test the significance of variability in the soil physico-chemical properties among the three selected fields (mango, cashew and semi-natural Sudan savanna). In addition, where a significant variation was revealed in any soil property among the three plots, a post hoc of Honestly Significant Difference (HSD) was conducted to establish the significance of variability between paired plots.

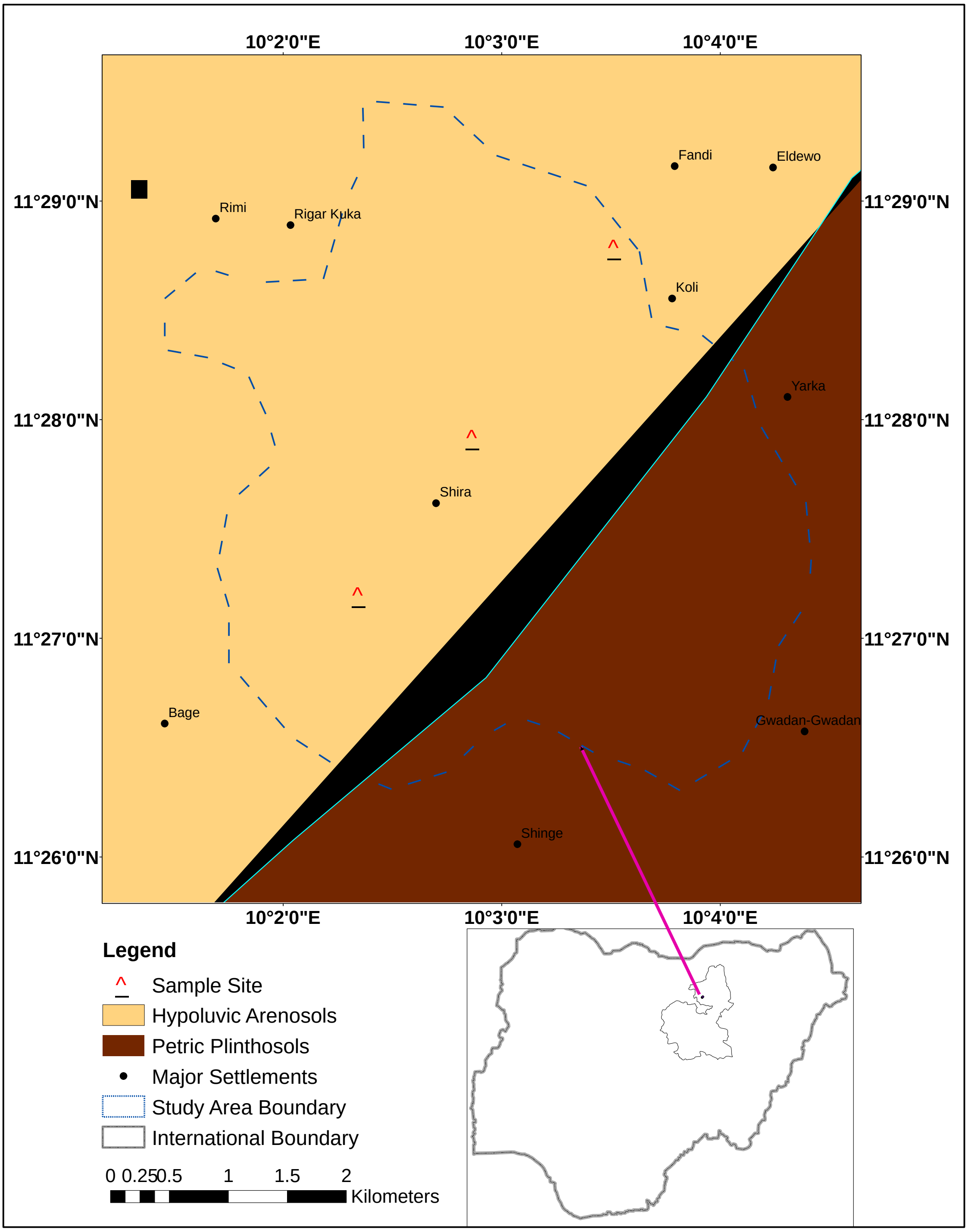

Figure 1: Soil map of the study area

Source: Geoprocessed from FAO/IIASA/ISRIC/ISSCAS/JRC, 2012; Jones et al., 2013.

RESULTS AND DISCUSSION

Soil Physical Properties

Particle Size Distribution

The result in Table 1 reveals homogeneous textural classes among the three sampled sites. Although, result of one-way ANOVA (Table 2) on grain sizes shows that content of sand was not significantly different among the fields, however distinct heterogeneity in the content of silt and clay grains exist (Tables 2 and 3). This is expected, because the Arenosols of the study area are chiefly composed of sands (FAO/IIASA/ISRIC/ISSCAS/JRC, 2012) weakly developed on deposits of fine sands of Lantewa sand dunes (Thiemeyer, 2000). This is coupled with promiscuous deposition of fine sands during the onset of rainy season as observed in the field. Thus, there was a significant variation ($P = .00$) in the mean values of silt and clay separates in the three fields. Soils under cashew had significantly highest silt content (17.87 ± 0.216%) followed by those under semi-natural Sudan savanna (12.42 ± 0.130%) which was also significantly higher than those under mango (11.13 ± 0.295%). In contrast, soils under mango crops were revealed to have had significantly higher clay content (18.87 ± 0.639%) when compared with the other two fields; of which the soils under semi-natural Sudan savanna had mean value of 17.45 ± 0.177%, and those under cashew had the least (11.87 ± 0.325%).

Having significantly higher silt content under cashew and higher clay separate under mango may not be unconnected with the fact that the cashew plantation is situated at the north-eastern part of the study area which experiences most of the silt deposition due to the effect of fine sand and silt-laden storm during the onset of rainy season. This is coupled with the influence of the hilly terrain that shelters the other two fields, to some extent, from silt deposition by the wind. Moreover, the site of mango is located at a slightly lower slope angle than both cashew and semi-natural Sudan savanna fields. In addition, clay content was also significantly higher in the soils under semi-natural Sudan savanna than cashew plantation. 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 cashew than both mango plantation and semi-natural Sudan savanna.

Particle size composition determines the textural class of a soil which influences soil water retention capacity, aeration, and retention of soil nutrient among others. The soils under the two crops are characterized by a homogeneous textural class (sandy loam). However, the presence of higher clay content with heterogeneous sand separates under mango implies greater adsorption capacity of soil nutrients and higher water retention capacity as compared to those under cashew. Hence, these conditions under mango might contribute in better crop root development, greater uptake of soil nutrients; as they are being exchanged between the root surfaces and the colloidal clay surfaces.

Table 1: Descriptive Statistics on Particle Size Composition under Mango, Cashew and Semi-Natural Vegetation in the Study Area

Soil Properties	Sampled Fields					
	Mango Plantation		Cashew Plantation		Control Site	
	Mean	S.D	Mean	S.D	Mean	S.D
Sand (%)	69.98*	0.884	70.26*	0.118	70.13*	0.109
Silt (%)	11.13*	0.295	17.87***	0.216	12.42**	0.130
Clay (%)	18.87***	0.639	11.87*	0.325	17.45**	0.177
Texture	Sandy Loam		Sandy Loam		Sandy Loam	

Note: At 5% confidence level, mean values with different number of asterisks (*) in the same row are significantly different between paired fields and not significantly varied where the asterisks are of the same number. S.D = standard deviation.

Table 2: Result of One-way ANOVA on Particle Size Composition under Mango, Cashew and Semi-Natural Vegetation in the Study Area

ANOVA						
		Sum of Squares	Df	Mean Square	F	Sig.
Sand	B/G	.321	2	.160	.708	.504
	W/G	4.757	21	.227		
	Total	5.077	23			
Silt	B/G	204.943	2	102.472	2.038E3	.000
	W/G	1.056	21	.050		
	Total	205.999	23			
Clay	B/G	218.740	2	109.370	602.590	.000
	W/G	3.811	21	.181		
	Total	222.551	23			

*****B/G = Between Groups, W/G = Within Groups

Table 3: Result of Multiple Comparison of Post Hoc Test on Particle Size Composition under Mango, Cashew, and Semi-Natural Vegetation in the Study area

Multiple Comparisons

Tukey HSD

Dependent Variable	(I) Soil Properties at the Depth of 0-30cm	(J) Soil Properties at the Depth of 0-30cm	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Sand	SPM	SPCa	-.28250	.23796	.474	-.8823	.3173
		SPCo	-.15750	.23796	.788	-.7573	.4423
	SPCa	SPM	.28250	.23796	.474	-.3173	.8823
		SPCo	.12500	.23796	.860	-.4748	.7248
	SPCo	SPM	.15750	.23796	.788	-.4423	.7573
		SPCa	-.12500	.23796	.860	-.7248	.4748
Silt	SPM	SPCa	-6.74500*	.11210	.000	-7.0276	-6.4624
		SPCo	-1.29750*	.11210	.000	-1.5801	-1.0149
	SPCa	SPM	6.74500*	.11210	.000	6.4624	7.0276
		SPCo	5.44750*	.11210	.000	5.1649	5.7301
	SPCo	SPM	1.29750*	.11210	.000	1.0149	1.5801
		SPCa	-5.44750*	.11210	.000	-5.7301	-5.1649
Clay	SPM	SPCa	6.99625*	.21301	.000	6.4593	7.5332
		SPCo	1.42375*	.21301	.000	.8868	1.9607
	SPCa	SPM	-6.99625*	.21301	.000	-7.5332	-6.4593
		SPCo	-5.57250*	.21301	.000	-6.1094	-5.0356
	SPCo	SPM	-1.42375*	.21301	.000	-1.9607	-.8868
		SPCa	5.57250*	.21301	.000	5.0356	6.1094

*. The mean difference is significant at the 0.05 level, SPM = Soil Properties under Mango, SPCa = Soil Properties under Cashew, SPCo = Soil Properties under Control.

Soil Chemical Properties

The results of one-way ANOVA at $P \leq .05$ are presented in Tables 5, 8 and 11. The results show that all the three fields were significantly different ($P = .00$) from each other in almost all the soil chemical properties analysed.

Soil pH and Exchangeable Acidity

Tables 4, 5 and 6 present the result on soil pH and EA. Soil pH was significantly higher in the soils under cashew (6.52 ± 0.024) and mango (6.41 ± 0.016) plantations than those under semi-natural savanna vegetation (6.29 ± 0.011). This corroborates the findings of Duguma et al. (2010) where soil pH values increased under tree plantations and other forms of cultivation as compared to plots used as control. However, Jaiyeoba (1995); Oriola and Adeyemi (1997); Senjobi (2013) observed decrease in soil pH under cultivated lands. More so, Liao et al. (2012) reported no soil pH difference between tree plantations and natural forest; and that where differences exist might be due to peculiar soil reference system under observation. Similarly, soils under cashew had significantly higher pH values than those under mango plantation. This could be as a result of significantly higher contents of all exchangeable bases (Ca^{2+}, Mg^{2+}, K^{+} and Na^{+}) in the soils under cashew than mango crops; perhaps due to faster decomposition of the leaves litter of the former (Pattanayak et al., 2014). Thus, soil nutrients are recycled faster in the soils under cashew crops as compared to those people under mango.

Mango crop requires an optimum soil pH level between 5.5 and 7.0 (QDAF, 2015), 5.5 and 7.5 (USDA NRCS, 2014). Similarly, cashew requires 5.5 to 7.0 soil pH (Wilkinson, 2005). The findings established optimum level of soil pH under both crops. Such soil pH levels could aid in maximizing nutrient availability for both mango and cashew which could enhance crop growth and yield.

Exchangeable Acidity (EA) was revealed to be significantly higher in the soils under semi-natural savanna (0.69 ± 0.014cmol/kg) than in the soils harbouring both cashew (0.57 ± 0.016cmol/kg) and mango (0.41 ± 0.016 cmol/kg) crops. Contrastingly, lower contents of EA were observed by Awotoye et al. (2009) and Yeshaneh (2015) in the soils under natural forest than other land management systems. Hence, this finding establishes lower contents of H^{+} and Al^{3+} in the soils under the two crops (Das, 2015). Although, the content of EA was significantly greater in the soils under cashew than mango, perhaps due to higher uptake of anions under mango as compared to that of cashew. This is because, excess H^{+} is released into the rhizosphere when absorption of cations exceeds that of anions; and OH^{-}/HCO_3 is released when anions exceed cation uptake (Havlin et al., 2005). Increased build-up of H^{+} and Al^{3+} under cashew could dampen the uptake of soil nutrients leading to slow growth of the cashew crops; and this might lead to decline in the crop yield.

Table 4: Descriptive Statistics on Soil pH and Exchangeable Acidity under Mango Cashew and Semi-natural Vegetation in the Study Area

Soil Properties	Sampled Fields					
	Mango Plantation		Cashew Plantation		Control Site	
	Mean	S.D	Mean	S.D	Mean	S.D
Soil pH	6.41**	0.016	6.52***	0.024	6.29*	0.011
Exchangeable Acidity (cmol/kg)	0.41*	0.016	0.57**	0.016	0.69***	0.014

Note: At 5% confidence level, mean values with different number of asterisks (*) in the same row are significantly different between paired fields and not significantly varied where the asterisks are of the same number. S.D = standard deviation, kg = kilogram, cmol = centimole.

Table 5: Result of One-way ANOVA on Soil pH and Exchangeable Acidity under Mango, Cashew and Semi-Natural Vegetation in the Study Area

ANOVA						
		Sum of Squares	df	Mean Square	F	Sig.
Soil pH	B/G	.204	2	.102	327.212	.000
	W/G	.007	21	.000		
	Total	.210	23			
Exchangeable Acidity	B/G	.309	2	.154	649.094	.000
	W/G	.005	21	.000		
	Total	.314	23			

***B/G** = Between Groups, W/G = Within Groups

Table 6: Result of Multiple Comparison of Post Hoc Test on Soil pH and Exchangeable Acidity under Mango, Cashew, and Semi-Natural Vegetation in the Study Area

Multiple Comparisons

Tukey HSD

Dependent Variable	(I) Soil Properties at the Depth of 0-30cm	(J) Soil Properties at the Depth of 0-30cm	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Soil pH	SPM	SPCa	-.11188*	.00882	.000	-.1341	-.0896
		SPCo	.11375*	.00882	.000	.0915	.1360
	SPCa	SPM	.11188*	.00882	.000	.0896	.1341
		SPCo	.22562*	.00882	.000	.2034	.2479
	SPCo	SPM	-.11375*	.00882	.000	-.1360	-.0915
		SPCa	-.22562*	.00882	.000	-.2479	-.2034
Exchangeable Acidity	SPM	SPCa	-.15812*	.00771	.000	-.1776	-.1387
		SPCo	-.27687*	.00771	.000	-.2963	-.2574
	SPCa	SPM	.15812*	.00771	.000	.1387	.1776
		SPCo	-.11875*	.00771	.000	-.1382	-.0993
	SPCo	SPM	.27687*	.00771	.000	.2574	.2963
		SPCa	.11875*	.00771	.000	.0993	.1382

*The mean difference is significant at the 0.05 level, SPM = Soil Properties under Mango, SPCa = Soil Properties under Cashew, SPCo = Soil Properties under Control.

Organic Matter and Total Nitrogen

The analyses on OM and TN are presented in Tables 7, 8 and 9. Organic Matter content (OM) was significantly higher in the soils under semi-natural Sudan savanna (2.56 ± 0.021%) than those under the two plantations. OM content was also significantly higher under cashew (2.39 ± 0.027%) than mango (2.27 ± 0.039%). Higher OM under natural vegetation as compared to cultivated fields was reported by many researchers such as Ayoubi et al. (2011); Oriola and Bamidele (2012); Yitbarek (2013) among others. Similarly, soils under cashew had significantly higher OM when compared to those under mango. Jaiyeoba (1995) reported that lower OM in cultivated fields could be attributed to lower vegetation density and litter cover, the frequency and extent at which soils are being disturbed therein. Higher OM under cashew establishes that there could be higher levels of organic colloids and a richer pool of mineralized organic-bound nutrients than soils under mango crop. These likely enhance plant nutrient availability of the soil under cashew which could enhance growth and ultimate yield of cashew than mango.

Total Nitrogen (TN) significantly varied among the three plots, where soils under semi-natural Sudan savanna recorded higher mean values (0.21 ± 0.004%). Knops and Tilman (2000); Kilic et al. (2012); Nyberg et al. (2012); Yitbarek (2013) reported decrease in TN in the soils under cultivated fields as compared to natural vegetation. This could be as a result of lower rate of mineralisation of lignified litter under mango and cashew crops (Jaiyeoba, 1995; Awotoye, 2009) as compared to that under semi-natural Sudan savanna which is predominantly covered with grasses that have softer stalks and leaves. More so, soils under cashew plot were revealed to have had significantly higher TN than those under mango plantation. This variation might be due to faster mineralisation of litter under cashew than mango for the fact that leaves of the former decompose more readily than those of the latter (Pattanayak, 2014).

Mango crop requires % soil N which is the most vital nutrient element for mango yield and quality, tree vigour, flowering, fruit set, fruit retention, fruit size, and prevention against diseases (QDAF, 2015). Optimum soil N requirement for cashew is 0.1% (Aikpokpodion, 2009). This implies that the available soil N under both crops is within the required level. Hence, there was no shortage in soil N content for the two crops, rather a worrisome significant decline in N level under mango. Similarly, there is seem to be general decline in the content of N in the study area, addition of fertilizer-containing N may be encouraged for sustainable greater yield. Significant improvement in the tree growth, fruit number, size and weight of mango fruit were reported for mango by Nasreen, Kamal, Siddiky, Rannu, and Islam (2014) and for cashew by Ipinmoroti, and Akanbi (2014) due to addition of N alongside other nutrients.

Table 7: Descriptive Statistics on Organic Matter and Total Nitrogen under Mango, Cashew and Semi-Natural Vegetation in the Study Area

Soil Properties	**Sampled Fields**					
	Mango Plantation		**Cashew Plantation**		**Control Site**	
	Mean	**S.D**	**Mean**	**S.D**	**Mean**	**S.D**
Organic Matter (%)	2.27*	0.039	2.39**	0.027	2.56***	0.021
Total Nitrogen (%)	0.16*	0.006	0.20**	0.003	0.21***	0.004

Note: At 5% confidence level, mean values with different number of asterisks (*) in the same row are significantly different between paired fields and not significantly varied where the asterisks are of the same number. S.D = standard deviation.

Table 8: Result of One-way ANOVA on Organic Matter and Total Nitrogen under Mango, Cashew and Semi-Natural Vegetation in the Study Area

ANOVA						
		Sum of Squares	**df**	**Mean Square**	**F**	**Sig.**
Organic Matter	B/G	.345	2	.172	193.612	.000
	W/G	.019	21	.001		
	Total	.364	23			
Nitrogen	B/G	.012	2	.006	304.941	.000
	W/G	.000	21	.000		
	Total	.013	23			

***B/G = Between Groups, W/G = Within Groups

Table 9: Result of Multiple Comparison of Post Hoc Test on Organic Matter and Total Nitrogen under Mango, Cashew, and Semi-Natural Vegetation in the Study Area

Multiple Comparisons							
Tukey HSD							
Dependent Variable	(I) Soil Properties at the Depth of 0-30cm	(J) Soil Properties at the Depth of 0-30cm	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Organic Matter	SPM	SPCa	-.11819*	.01492	.000	-.1558	-.0806
		SPCo	-.29188*	.01492	.000	-.3295	-.2543
	SPCa	SPM	.11819*	.01492	.000	.0806	.1558
		SPCo	-.17369*	.01492	.000	-.2113	-.1361
	SPCo	SPM	.29188*	.01492	.000	.2543	.3295
		SPCa	.17369*	.01492	.000	.1361	.2113
Nitrogen	SPM	SPCa	-.04000*	.00224	.000	-.0456	-.0344
		SPCo	-.05312*	.00224	.000	-.0588	-.0475
	SPCa	SPM	.04000*	.00224	.000	.0344	.0456
		SPCo	-.01312*	.00224	.000	-.0188	-.0075
	SPCo	SPM	.05312*	.00224	.000	.0475	.0588
		SPCa	.01312*	.00224	.000	.0075	.0188

* The mean difference is significant at the 0.05 level, SPM = Soil Properties under Mango, SPCa = Soil Properties under Cashew, SPCo = Soil Properties under Control.

Exchangeable Bases, CEC, Base Saturation and Available Phosphorus

Tables 10, 11 and 12 show the result on exchangeable bases, base saturation and available phosphorus. There is a similarity in the trend of mean values of two exchangeable bases (Ca^{2+} and Na^{+}) and cation exchange capacity (CEC) having significantly higher contents in the soils of semi-natural vegetation than those of mango and cashew crops. This reflects significant decrease in these exchangeable bases and CEC in the study area. Higher CEC was also observed in soils under natural vegetation than cultivated lands by many researchers (Kilic et al., 2012; Yitbarek, 2013; Yeshaneh, 2015). When the soils under the two crops were compared, cashew field recorded significantly higher contents in all the exchangeable bases [Ca^{2+} (1.39 ± 0.013cmol/kg), Mg^{2+} (0.23 ± 0.035cmol/kg), K^{+} (0.20 ± 0.001cmol/kg), Na^{+} (0.79 ± 0.012cmol/kg)], and CEC (3.17 ± 0.018cmol/kg)]. Such significant difference may be partly attributed to greater supply of organic colloids due to substantially higher organic matter under cashew than mango crops, and partly as a result of more readily release of organically bound nutrients, because of faster decomposition of litter under cashew crops. Therefore, higher organic matter reflects greater surface negative charges to adsorb the exchangeable bases (Bohn et al., 2001; Das, 2011; Brady and Weil 2014) and increase in the level of CEC.

Calcium is required to maintain proper root growth (Havlin et al., 2005) in both crops. For mango crop, critical level of soil Ca^{2+} is 3.5 cmol/kg; Ca^{2+} strengthens cell wall, prevents the crop from pathogens and improves fruit quality (QDAF, 2015). Such a critical level is far above the content that is obtainable under mango in the study area. This entails likely poor root development under both crops and perhaps mango crops have significantly greater effect of the loss in Ca^{2+}.

Mg^{2+} is required for chlorophyll production and N metabolism in plants (The Center for Agriculture, Food and the Environment, n.d); it contributes in photosynthetic processes, enhances phosphorus movement in plants and influences the uptake and availability of Ca^{2+} and Mg^{2+} (QDAF, 2015). The content of Mg^{2+} under mango in the study area satisfies the critical level between 0.75 and 1.25cmol/kg to support the production of mango (QDAF, 2015).

Plants utilize K^{+} to open and close stomata, and transfer nitrates from the roots to the leaves (The Center for Agriculture, Food and the Environment, n.d; Havlin et al., 2005). When deficient, plants could not utilize nitrogen and water efficiency, and are vulnerable to diseases (The Center for Agriculture, Food and the Environment, n.d). Mango crops require K^{+} from 0.25 to 0.4cmol/kg (QDAF, 2015) while cashew is best produced at a level above 0.37cmol/kg (Widiatmaka et al., 2014). Hence, the soil K^{+} contents under both crops are significantly lower than the critical level.

Excess content of Na^{+} beyond a given threshold suppresses plants growth and yield (Abo-Rekab et al., 2014), a critical level of <1.0 cmol/kg for mango crop (QDAF, 2015). The content of Na^{+} under the crops satisfies the required threshold. High CEC in a soil suggests high nutrient water retention capacity (QDAF, 2015). Cashew crops grow and yield best at value >12.4 cmol/kg (Widiatmaka et al., 2014), whereas mango produces much better at a critical level above 5 cmol/kg (QDAF, 2015). Hence, the soils under both crops are deficient in the required levels of CEC. Consequently, there is poor nutrient and water retention capacity under both crops which is more pronounced under mango crops.

Percent base saturation was significantly higher in the soils harbouring both mango (85.5 ± 0.51%) and cashew (82.18 ± 0.61%) than soils under semi-natural Sudan savanna (79.73 ± 0.40%). This is in line with the report of Awotoye et al. (2009) where values of BS were revealed to be higher in the control site than tree plantations. In contrast, Yitbarek et al. (2013) observed significantly higher percent base saturation in forest land (used as control) than cultivated fields. Hence, this establishes that exchange surfaces of the CEC in the soils under the two crops adsorb more exchangeable cations than soils in the control site. This difference in base saturation might be due to lower content of the CEC in the soils under mango and cashew than natural savanna, and not as a result of variation in exchangeable bases. Thus, one should not be misguided by the higher contents of all the exchangeable cations in almost all cases (except Mg^{2+} between cashew and control) in the soils under semi-natural Sudan savanna as compared to those under the two tree crops.

A critical soil base saturation level of 80% is required for mango crops (Correia, et al., 2018) while cashew yields best with a base saturation level greater than 66% (Widiatmaka et al., 2014). Higher mango fruit yield was reported by Almeida et al. (2012) when lime was added to a soil to boost the level of base saturation to 72%. Therefore, base saturation levels under the crops are within the critical levels, thus likely to contribute to the growth and yield of the two crops.

Available phosphorus mean value was significantly higher in the soils under semi-natural savanna (11.75 ± 0.092ppm) than those under cashew (10.16 ± 0.069ppm) and mango (9.27 ± 0.262ppm) fields. Findings from other researchers (Bohn et al., 2001; Awotoye et al., 2009; Senjobi et al., 2013) also revealed significantly higher P in the soils under natural vegetation when compared to cultivated fields. This reflects greater uptake of the nutrient by the crops coupled with lower content of exchangeable acidity and higher values of soil pH under the tree plantations. Fe^{2+} and Al^{3+} oxides in soils decrease as soil pH increases (Havlin et al., 2005). It should be noted therefore that phosphorus becomes available to crops when adsorbed on the surfaces of Fe^{2+} and Al^{3+}. From the data on exchangeable acidity (which is the acidity that develops due to adsorbed H^{+} and Al^{3+} on soil colloids), EA content was significantly lower in the soils under the crops as compared to those under semi-natural savanna. Thus, significantly higher content of EA and lower pH in the soils under semi-natural savanna vegetation implies significantly greater availability of P than the soils under the two crops. Hence, there was significant decline in the content of P in the soils under mango and cashew crops in the study area; and such decrease was revealed to be significantly more under mango.

Low phosphorus for most plants leads to impaired vegetative growth, weak root systems, poor fruit and seed quality, hence low yield (The Center for Agriculture, Food and the

Environment, n.d). The best yield of cashew is associated with phosphorus >40 ppm (Widiatmaka, et al., 2014), whereas mango requires a critical level between 60 and 80 ppm (QDAF, 2014). Soils under both crops are deficient in available phosphorus which might lead to significant decrease in their crop yield. More so, mango crops seems to be more severely affected due to greater margin of deficiency in available phosphorus than cashew crops in the study area

Table 10: Descriptive Statistics on Exchangeable Bases, CEC, Base Saturation and Available Phosphorus under Mango, Cashew and Semi-Natural Vegetation in the Study Area

Soil Properties	Sampled Fields					
	Mango Plantation		Cashew Plantation		Control Site	
	Mean	S.D	Mean	S.D	Mean	S.D
Exchangeable Calcium (cmol/kg)	1.33*	0.012	1.39**	0.013	1.41***	0.009
Exchangeable Magnesium (cmol/kg)	0.19*	0.001	0.23**	0.035	0.23**	0.011
Exchangeable Potassium (cmol/kg)	0.17*	0.003	0.20***	0.001	0.19**	0.001
Exchangeable Sodium (cmol/kg)	0.70*	0.009	0.79**	0.012	0.87***	0.010
Cation Exchange Capacity (cmol/kg)	2.80*	0.011	3.17**	0.018	3.39***	0.020
Base Saturation (%)	85.50***	0.505	82.18**	0.627	79.73*	0.399
Available Phosphorus (ppm)	9.27*	0.262	10.16**	0.069	11.75***	0.092

Note: At 5% confidence level, mean values with different number of asterisks (*) in the same row are significantly different between paired fields and not significantly varied where the asterisks are of the same number. S.D = standard deviation, kg = kilogram, cmol = centimole, ppm = parts per million

Table 11: Result of One-way ANOVA on Exchangeable Bases, CEC, Base Saturation and Available Phosphorus on Mango, Cashew and Semi-Natural Vegetation in the Study Area

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Exchangeable Calcium	B/G	.025	2	.013	99.312	.000
	W/G	.003	21	.000		
	Total	.028	23			
Exchangeable Magnesium	B/G	.009	2	.004	9.315	.001
	W/G	.010	21	.000		
	Total	.018	23			
Exchangeable Potassium	B/G	.003	2	.001	479.830	.000
	W/G	.000	21	.000		
	Total	.003	23			
Exchangeable Sodium	B/G	.115	2	.057	552.689	.000
	W/G	.002	21	.000		
	Total	.117	23			
Cation Exchange Capacity	B/G	1.401	2	.701	2.457E3	.000
	W/G	.006	21	.000		
	Total	1.407	23			
Base Saturation	B/G	134.481	2	67.241	249.810	.000
	W/G	5.653	21	.269		
	Total	140.134	23			
Available Phosphorus	B/G	25.407	2	12.703	466.039	.000
	W/G	.572	21	.027		
	Total	25.979	23			

***** B/G = Between Groups, W/G = Within Groups

Table 12: Result of Multiple Comparison of Post Hoc Test on Exchangeable Bases, CEC, Base Saturation, and Available Phosphorus under Mango, Cashew, and Semi-Natural Vegetation in the Study Area

Multiple Comparisons

Tukey HSD

Dependent Variable	(I) Soil Properties at the Depth of 0-30cm	(J) Soil Properties at the Depth of 0-30cm	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Exchangeable Calcium	SPM	SPCa	-.05812*	.00565	.000	-.0724	-.0439
		SPCo	-.07625*	.00565	.000	-.0905	-.0620
	SPCa	SPM	.05812*	.00565	.000	.0439	.0724
		SPCo	-.01812*	.00565	.011	-.0324	-.0039
	SPCo	SPM	.07625*	.00565	.000	.0620	.0905
		SPCa	.01812*	.00565	.011	.0039	.0324
Exchangeable Magnesium	SPM	SPCa	-.04000*	.01079	.004	-.0672	-.0128
		SPCo	-.04062*	.01079	.003	-.0678	-.0134
	SPCa	SPM	.04000*	.01079	.004	.0128	.0672
		SPCo	-.00062	.01079	.998	-.0278	.0266
	SPCo	SPM	.04062*	.01079	.003	.0134	.0678
		SPCa	.00062	.01079	.998	-.0266	.0278
Exchangeable Potassium	SPM	SPCa	-.02569*	.00088	.000	-.0279	-.0235
		SPCo	-.02069*	.00088	.000	-.0229	-.0185
	SPCa	SPM	.02569*	.00088	.000	.0235	.0279
		SPCo	.00500*	.00088	.000	.0028	.0072
	SPCo	SPM	.02069*	.00088	.000	.0185	.0229
		SPCa	-.00500*	.00088	.000	-.0072	-.0028
Exchangeable Sodium	SPM	SPCa	-.08125*	.00510	.000	-.0941	-.0684
		SPCo	-.16938*	.00510	.000	-.1822	-.1565
	SPCa	SPM	.08125*	.00510	.000	.0684	.0941
		SPCo	-.08813*	.00510	.000	-.1010	-.0753
	SPCo	SPM	.16938*	.00510	.000	.1565	.1822
		SPCa	.08813*	.00510	.000	.0753	.1010
Cation Exchange Capacity	SPM	SPCa	-.36469*	.00844	.000	-.3860	-.3434
		SPCo	-.58606*	.00844	.000	-.6073	-.5648
	SPCa	SPM	.36469*	.00844	.000	.3434	.3860
		SPCo	-.22138*	.00844	.000	-.2427	-.2001
	SPCo	SPM	.58606*	.00844	.000	.5648	.6073
		SPCa	.22138*	.00844	.000	.2001	.2427
Available Phosphorus	SPM	SPCa	-.88938*	.08255	.000	-1.0974	-.6813
		SPCo	-2.48688*	.08255	.000	-2.6949	-2.2788
	SPCa	SPM	.88938*	.08255	.000	.6813	1.0974
		SPCo	-1.59750*	.08255	.000	-1.8056	-1.3894
	SPCo	SPM	2.48688*	.08255	.000	2.2788	2.6949
		SPCa	1.59750*	.08255	.000	1.3894	1.8056
Base Saturation	SPM	SPCa	3.32562*	.25941	.000	2.6718	3.9795

	SPCo	5.77625*	.25941	.000	5.1224	6.4301
SPCa	SPM	-3.32562*	.25941	.000	-3.9795	-2.6718
	SPCo	2.45063*	.25941	.000	1.7968	3.1045
SPCo	SPM	-5.77625*	.25941	.000	-6.4301	-5.1224
	SPCa	-2.45063*	.25941	.000	-3.1045	-1.7968

* The mean difference is significant at the 0.05 level, SPM = Soil Properties under Mango, SPCa = Soil Properties under Cashew, SPCo = Soil Properties under Control.

CONCLUSION

How farmlands are managed could influence their impact on soil properties, yield and consequential profits therefrom. The study examined the effect of mango and cashew crops on soils of hypoluvic Arenosols. Hence, it was uncovered that soil physico-chemical properties were disturbed due to the cultivation of both mango and cashew crops in the study area. This is especially reflected in OM, CEC, EA and most of the nutrient elements (N, Ca^{2+}, Mg^{2+}, K^{+}, Na^{+} and P), mostly being significantly lower under the two crops than the semi-natural Sudan savanna. The decline in the soil nutrients was revealed to be higher under mango crops than cashew. However, soil pH and BS were significantly higher under the crops than semi-natural vegetation. Generally, the decline in the plant nutrients and the related soil properties is worrisome, most especially that no fertilizer of any kind was added by the cashew and mango farmers in the study area.

Thus, for greater and sustainable production and profitability, the study advocates that mango and cashew cultivation should be accompanied with addition of the lost soil nutrients that are required by the crops. In addition, the farmers could diversify their practices by adopting mixed cropping - where both crops can be planted alongside each other; and annual crops such as cereals (sorghum and millet), legumes (cowpea, groundnut and soya bean) and other crops like beni seed among others could be grown in the pockets of open spaces.

The Authors declare no conflict of interest whatsoever.

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