ANALYZING VARIATION IN SOIL PHYSICAL PARAMETERS IN CASHEW PLANTATIONS OF DIFFERENT AGES IN SOUTHWESTERN, NIGERIA

Emmanuel Dada
Department of Geography and Planning Sciences
Adekunle Ajasin University, Akungba-Akoko Ondo State, Nigeria.
E-mail: vissitemma@gmail.com

ABSTRACT: The study analyzed the variation in the soil physical properties under different ages of cashew plantation in the Guinea savanna region of Southwestern Nigeria. The study area was selected as the largest cashew dominant area in the Guinea savanna region of southwestern Nigeria. Multistage sampling technique was adopted to select the cashew plantation study sites and collection of soil data in diagonal format at 3x3 and 30cm depth in privately and institutional managed farms. The selected cashew plantations were classified into three age groups of 0 – 9 years old, 10 – 20 years old, and above 20 years while two fallow lands at 10m distance to the cashew plantations were selected as control plots. The sum of seventy-two (72) samples was collected for the study; nine (9) samples were collected under each age group in eight (8) plots including the two fallow plots. The collected soil data were subjected to particle size analysis and later to different statistical methods to determine the variation in the physical soil parameters under this plantation. The results show no significant variation at different ages except for silt at 34.5% coefficient of variation in 0 – 9 years old in institutional managed cashew plantation. Analysis of Variation results revealed significant interrelationship variation between 10 – 20 years and fallow plot in percentage silt and clay at p-value of 0.004 and 0.001 while cashew plantation of above 20 years and fallow are significant in sand and silt at 0.001 and 0.008 respectively. The study concludes that sandy loam soil is the dominant texture of the soil in the area. while mature and older cashew plantation and fallow lands revealed significant variation at 0.05% critical level.

Keywords: Soil, physical properties, cashew plantation, variation

INTRODUCTION

Cashew plantation is a hardy crop that can be raised in variety of soils and can grow in poor soils that cannot be used for other horticultural crops successfully. It was recorded that cashew cultivation thrives in marginal waste lands, hill slopes, coastal laterite and sandy soils of India, Tanzania, Mozambique, Brazil and even other countries in Africa and Asia. But when grown in lateritic soils with a hard-sub-soil such as in some areas of south India, cashew could show thrift growth (Agnolini and Giuliani, 1977; Luiz et al., 2020). In considering ideal soil for cashew plantation, a well-drained sandy loam soil without hard pan and with sub-soil water content ranging from 5 to 10 meter depth is ideal and also found growing well in coastal sandy or laterite or red soils but to a limited proportion in the black soils. Such of the black soil can be found in parts of south India, volcanic soils of Philippines, Indonesia and Fiji islands, alluvial soils of Sri Lanka and Philippines and the ferruginous and ferralitic soils of east and West Africa, Brazil and Malagasy (Agnolini and Giuliani, 1977 and Ohler, 1979; Steege et al., 2020). Heavy clayey soils though fertile, poorly drained soils or those subjected to stagnation of water, flooding or with high water table are not suitable for cashew cultivation as they restrict its vigorous root system to superficial growth (Agnolini and Giuliani, 1977 and Ohler, 1979; Luiz et al., 2020).

Findings by Rocchetti (1970) opined that plants cannot tolerate more than 2% salinity and the tolerance level varied with the source of seed from which the plant was raised. Cashew cultivation prefers slightly acidic soils of pH 4.5 to 6.5 with low calcium content (Agnolini and Giuliani, 1977; Olatunji and Ewetola, 2015). In a laboratory survey by Ohler (1979), cashew showed very little tolerance to salinity, but was still found to grow well near seacoasts. Badrinath et al. (1990) studied the physical properties of cashew growing soils of coastal Karnataka and observed higher percentage of coarse fractions in the surface layer that decreased with increase in soil depth. However, the finer fractions increased as the depth of the soil increased. This soil condition contributes to the rapid percolation of water and eluviation processes and hence the soils are well drained. The larger proportion of finer fractions of soil therefore separates the sub- surface soils in favour of plant growth by providing the rhizosphere with moisture, nutrients and aeration. Chadha and Nair (1998) studied cashew tree adapted to a wide range of soil and climatic conditions in India.

Cashew plantation covers large area of agricultural land and is basically one of the most typical agro-ecosystems in many countries, including Nigeria (Filipa et al., 2017). The clear importance of cashew nuts as the main commodity for Guinea-Bissau can be depicted by the significantly larger harvesting area for cashew nuts, which has

occurred at the detriment of traditional food crops. Cashew production offers farmers the opportunity of obtaining a higher profitability when compared to cereal, since it allows farmers to reduce their production costs especially in terms of labour inputs (Catarino, Menezes and Sardinha, 2015). Cashew plantations are practiced within semi-natural or savanna woodlands after which the native vegetation is burned for both clarity and for the enhancement of soil fertility (Catarino et al., 2016; Gaurav et al., 2021). Cashew cultivation exists within two cropping systems of ―Ponteiro‖ which is commercially-oriented cropping system. It harbors a great heterogeneity in terms of size and care dispensed to the plantation; and second is ―peasantry‖ which represents the backbone of the African rural economy, comprising small-scale farming for household subsistence and product sale (Ollenburge et al., 2016). The first three or four years of this plantation establishment, cashew cultivation can be maintained under an intercropping system with food crops such as rain fed rice, millet, sorghum, maize or groundnuts, as viable means for smallholder incomes (Filipa et al., 2017). Ensuring the ownership of fallow land by having a cashew plantation can, therefore, be more important than production (Ollenburge et al., 2016). The relatively limited productivity per hectare has been essentially attributed to constraints in the improvement of cashew varieties through conventional breeding, for which there is still a limited understanding concerning vegetative propagation methods and other factors such as pruning and fertilization (Dendena and Corsi, 2014; Paul et al., 2021).

The main objective of this study is to examine the impact of cashew cultivation on variation in the soil physical properties considering different ages of this plantation and uncultivated fallow land in the guinea savanna vegetation zone of southwestern, Nigeria.

THE STUDY AREA

Geographical Location

The study area, Ogbomoso in Oyo state, Southwest Nigeria is the largest producer of cashew nuts in the region (Olatunji and Ewetola, 2015), and an agricultural agrarian community, probably because of its location around the rainforest-savanna transition zone and climate that supports tree cropping (Adeigbe et al., 2015). The area is also characterized by a vast area of land where cashew trees exist at comparable ages and different ownership systems exists – important conditions that made the study area preferred for this study. It is geographically located between latitudes 80 00′N and 80 15′N of the equator and longitudes 40 10′E and 40 20′E of Greenwich Meridian (Figure 1).

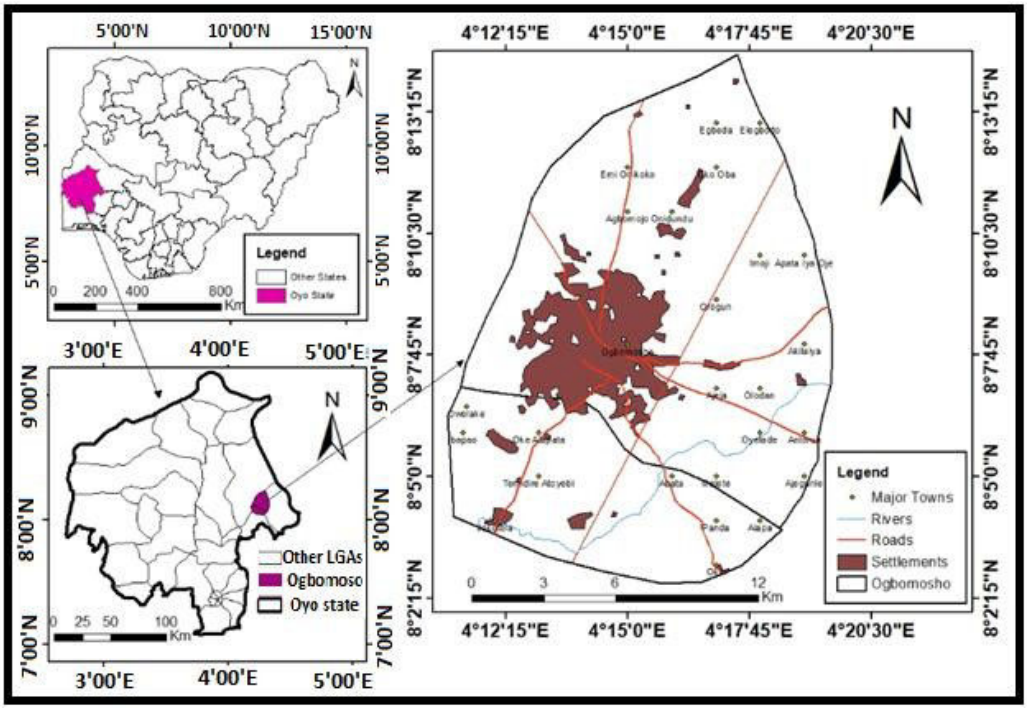

Figure 1. Map of Ogbomoso inset Oyo State and Nigeria.

Physical Characteristics (Climate, Geology and Topography)

The study area exhibits a tropical climate considered to be Aw based on Koppen –Greiger classification. It has an average annual temperature of 26.1oC and average annual rainfall of 1217 mm with relative humidity varied between 36.5 to 85.1%. The settlement has two major distinct seasons of wet and dry, the wet season starts in April and ends in October while the dry season commences in November and ends in March. The mean monthly temperatures are highest at the end of Harmattan averaging at 35oC (Olatunji and Ewetola, 2015).

Ogbomoso lies on the basement complex of Southwestern Nigeria. It is composed of rocks found within the first group of classification as explained by Rahaman (1976). The rocks found in this town are relatively simple; hence, the structural elements indicate more complex events that occurred in the Archean to lower Proterozoic (Afolabi, Kolawole and Abimbola, 2013). The study area is located on the altitude ranges from 150 m to 600 m above sea level. The slopes vary between vertical inselberg flanks to the flat terrain with the mean gradient of about 4% (Rahaman et al, 1970).

Vegetation and Soil

Ogbomoso falls within the southern Guinea Savanna of Western Nigeria. The vegetation is made up of mixture of tall grasses and woody species. The most common savanna trees in this vegetation zone include Daniella oliveri, Lophira alata, Terminalia glaucescens, Adansonia digitata, Afzelia doliana, Vitex grandifolia, and Anogeissus leiocarpus. These species are distinguished by their drought and fire tolerance characteristics which ensure their survival in the savanna environment. The savanna is opened in many areas, but in sparsely populated locations patches of woodlands are found in which not all trees are fire-tolerant species (Richards, 1981). The vegetation of the study area is made up of typical tall grasses and short scattered woody species (shrubs and trees). In the savanna, plants have to adapt to the climatic situation of long dry seasons and short rainy season. The trees are deciduous in nature and are observed to shed their leaves during the dry season to prevent excessive loss of water through transpiration. The woody species in the savanna like Baobabs and bottle trees have long root to search for groundwater or develop broad trunks and tick back to survive in dry season (Adeleke et al., 1981). The traditional agricultural crops raised in Ogbomoso include yam, cassava, maize and sorghum while while cashew plantations dominate its tree or cash crop (Olatunji and Ewetola, 2015).

The soil of the study area is derived from the basement complex rocks (Smyth and Montgomery, 1962). The FAO-UNESCO soil map of the world reveals that Luvisols dominates this area covering about 70% of the entire surface. Among the other notable soils in the area are Arenosols, Fluvisols, Lithosols, Cambisols, and Nitosols. Most of these soils change in texture with depth. They have sandy topsoil over subsoil with clay contents (Murdoch, 1976). The savanna soils have common features of iron and quartz concentrations and are the most important soil groups in Nigeria suitable for cash and food crops production (Areola, 1978). In the savanna, the soil nutrients are low because of high proportion of Kaoline and much of these nutrients are lost with incessant annual bush burning common within this zone (Areola, 1978).

METHODS

Characteristics of Selected Cashew Plantations

Soil samples and vegetation characteristics of cashew trees at different ages were collected from two purposively selected cashew plantations in the study area, each as representative of institutional managed and subsistence individual managed plantations. The Ladoke Akintola University of Technology Cashew Farms (henceforth refers to as LAUTECH Farms in this study) in Ogbomoso North Local Government and Abede Cashew Farms (henceforth refers to as Abede Farms) in Ogbomoso South Local Government were purposively selected, to represent institution and subsistence individual management respectively (Figure 2). The two plantations have been selected for the study due to access to its location and record of its management history.

Determination of Sample Locations

The study adopted multistage sampling method. Purposive and systematic sampling procedures were used to determine the locations from which soil samples. First, each of the selected plantations is stratified into three farm sections based on the ages of the cashew trees (0- 9 years, 10-20 years and above 20 years), and one fallow land of above 15 years old was selected within the farther distance, about 10 m away from each plantation as a control. The control field was sited perpendicular to the plantation as advised by Williams and Lambert (1959). Second, three plots of 100m by 50m dimension each was systematically delineated (diagonally across the farm section- such that the two

extremes and the middle are represented) for representativeness. Also, another 100m by 50m plot is delineated from the control plot, making a total of eight (8) plots, six (6) in the cashew farms and two (2) in the fallow farms at both LAUTECH Farms and Abede farms. Consequently, a total of seventy-two (72) samples locations were configured for the study area. Locational information (northing and easting of each of the sample location was captured using a hand-held Global Positioning System (GPS) (Garmin eTrex-10 version). The description for soil sample collection standard (3x3 x 30 cm) depth was done following the FAO guidelines (FAO, 2006) and USDA guideline (USDA, 2006). The depth of 30cm was used in the study because the roots of plants are usually concentrated in the top 30cm of the profile (Holmes and Rice, 1996) (Figure 3).

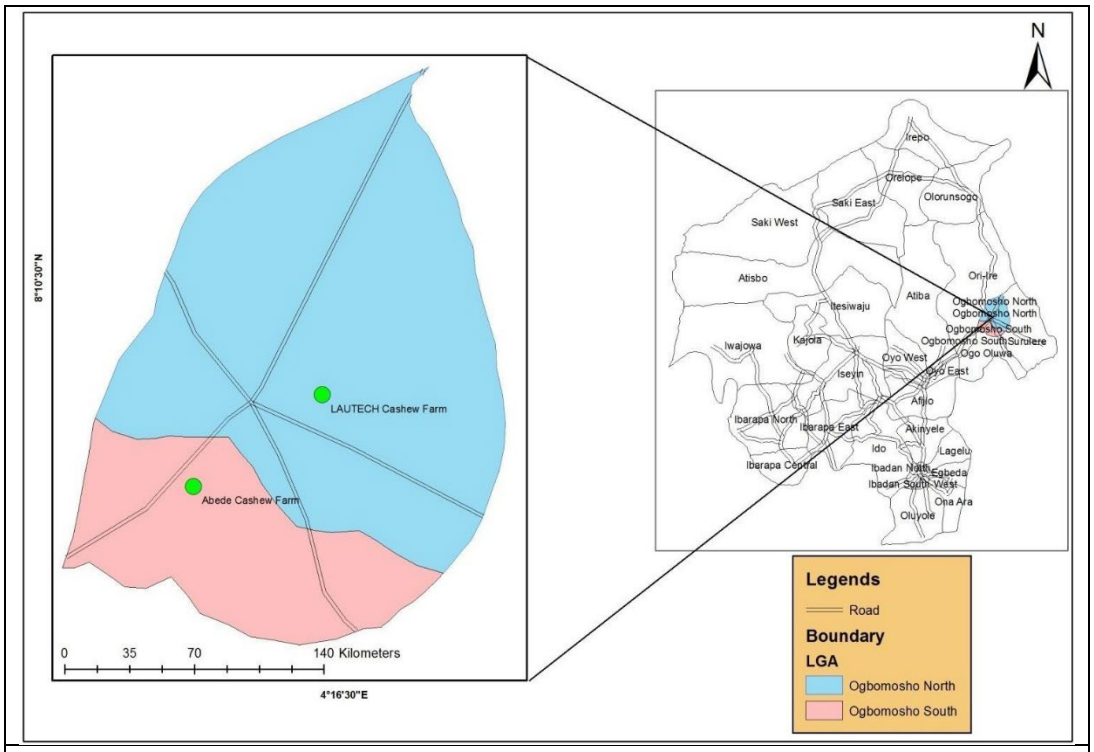

Figure 2. Map of Ogbomoso showing cashew plantation locations.

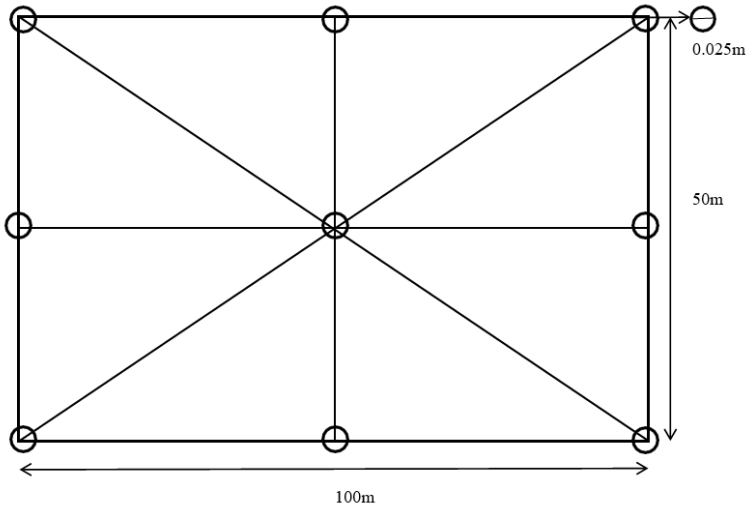

Figure 3. A structural description of the soil sampling points.

Soil Sample Collection

Two sets of soil samples were obtained from each sample location. First, a cylindrical core sampler was used to obtain soil samples for determination of bulk density as described by Don et al., 2011. (Figure 4). According to Throop et al. (2012) the cylindrical core sampler is usually a 3-inch diameter ring constructed with metal. The cylindrical core sampler used in this study was 3-inch diameter ring as described by (Davidson and Ackerman, 1993). Once obtained, the soil samples were kept in a well-labeled black polyethylene bag for onward transfer to the soil laboratory at Sustainable Laboratory Service Limited, Akure where it was analyzed. The soil texture analysis was carried out using hydrometer method by Bouyoucus (1951). The soil sample was crushed to finer than 2 mm, the process was later combined with sedimentation principle referred to as "Stoke's Law". The materials used in addition to soil samples include hydrogen peroxide, sodium hexametaphosphate, 1000 ml graduated cylinders, amyl alcohol, watch glasses and hydrometer. This method has been the popular and reliable method employed by geographers, geologists and engineers (Areola and Faniran, 1978).

In addition, another set of soil samples were obtained using soil sampler. The soil samples were also collected round each sample location at 30 cm soil depth (since the roots of plants are usually concentrated in the top 30 cm of the profile; Holmes and Rice, 1996) area from where the corer was used.

Figure 4. the core samplers used in this study and a part of the procedure for sample collection.

Results and Discussions

Two major physical properties that are vital for the suitability of soil for cashew cultivation considered in this research comprises of particle size distribution and bulk density in which variation occurred at different proportions under cashew plantations of different ages and two considered management system.

Particle Size Distribution

Results show that particle size distribution of the soil mainly consist of sandy loam soil under different management systems, and their fallow lands. The subsistence individual managed cashew plantation consisted of 68.5% sandy loam soil at 3.27 Standard Deviation (S.D) under cashew plantation and 63.3% sandy loam soil at 3.39 S.D. for its fallow land. Clay soil contained 18.5% at 3.3 S.D. under cashew plantation with the minimum and maximum range from 12.2 – 26.6%, while its fallow land soil contained 19.7% at 3.7 S.D. with 13.0% silt at 3.3 S.D. for cashew plantation and 13.6% at 3.7 S.D. in the fallow land soil. However, in the institutionally managed cashew plantations, particle size distribution revealed 58.8% sandy loam soil at 4.27 S.D., 26.4% clay at 4.3 S.D. and 14.7% silt soil at 4.4 S.D. while its fallow land contained 64.0% sandy loam soil at 5.58 S.D., 17.2% clay and 18.8% silt soil

at 2.1 and 6.1 S.D. respectively (Table 1 and Figure 5). It can be deducted from the analysis that the soil particle size in the study area majorly consist of sandy loam soil which is the type of soil mostly suitable for cashew cultivation. This prompted the farmers and different organizations to invest heavily on cashew cultivation in this region. This shows similarity to the research results from Widiatmaka et al., (2014); Olatunji and Ewetola (2015) and Aikpokpodion (2009) all of which established that sandy loam soil of greater than 40% with lesser proportion of clay and silt is very suitable soil for cashew cultivation.

Analysis of variation in soil particle size distribution of cashew plantation of different ages revealed marginal variation in certain ages while some show significant variation determined by standard variation and coefficient of variation. Previous studies on soil properties established that soil is sufficiently homogeneous if the coefficient of variation of particular attribute examined does not more than 33% from the mean (C.V. ≤ 33%). This again was supported by Areola's (1987) research on land facet, Gbadegesin's (1989) findings on land use type and properties and Oriola (1999) on land facet of Southwest Savanna. The result from the subsistence individual cashew plantations ranges from 5.0% coefficient of variation from sand soil of cashew plantations of 0 – 9 years old to 20.3% variation from silt soil of above 20 years old cashew plantations (Table 2). This means that soil particles distribution under this management system of cashew plantations of different ages are homogeneous because coefficient of variation (C.V) values of sand, clay and silt across the three age groups are less than 33%. However, particle size distribution from institutional managed cashew plantation of different ages shows significant variation in %silt soil of cashew plantation of 0 – 9 years with the coefficient of variation value of 34.5% while others cashew plantations age groups and soil types were homogeneous with their coefficient of variation values less than 33%. The relative homogeneity in the soil particle size distribution in Ogbomoso could be part of the reasons for wide cultivation of cashew in the study area without fertilizer application.

Table 1: Summary of Soil Physical Properties of Cashew Plantations and Fallow Land

	Subsistence Individual Managed		**Institutional Managed**	
Parameter	**Cashew Plantation**	**Fallow Land**	**Cashew Plantation**	**Fallow Land**
% Sand	68.5 ± 3.27 (63.8 – 75.4)	63.3 ± 3.39 (58.7 – 68.6)	58.8 ± 4.27 (50.4 – 65.0)	64.0 ± 5.58 (55.1 – 72.9)
% Clay	18.5 ± 3.3 (12.2 – 26.6)	19.7 ± 3.7 (18.3 – 25.7)	26.4 ± 4.3 (18.6 – 34.6)	17.2 ± 2.1 (14.2 – 20.2)
% Silt	13.0 ± 3.3 (12.2 – 26.6)	13.6 ± 3.7 (6.5 – 18.4)	14.7 ± 4.4 (5.4 – 24.4)	18.8 ± 6.1 (11.3 – 28.3)
Bd	1.2 ± 0.2 (0.9 – 1.5)	1.1 ± 0.2 (0.9 – 1.3)	1.3 ± 0.2 (0.9 – 1.7)	1.2 ± 0.2 (0.8 – 1.5)

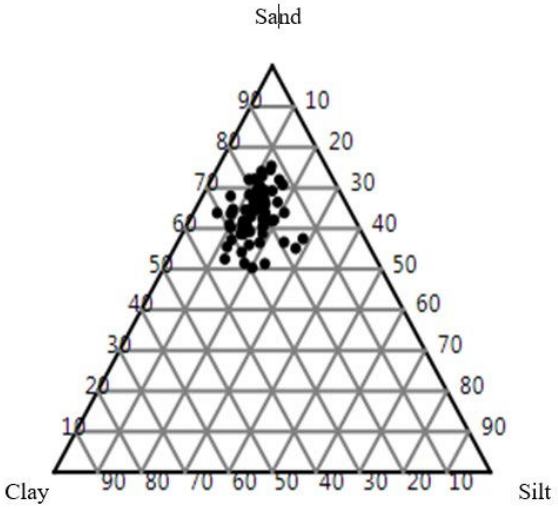

Figure 5. Soil particle size distribution triangle of the study area.

Bulk Density

Bulk density refers to the measure of degree of soil compaction. It is the measure of ratio of the soil weight compared to its volume expressed in grams per cubic centimetre. Result of soil bulk density analysis in this research revealed slight variation in the degree of soil compaction under different ages and management systems as well as comparison with fallow land determined with mean, standard deviation and coefficient of variation. The bulk density in this research ranged between 0.82g/cm3and 1.67 g/cm3. From subsistence individual managed farms, bulk density result reflected mean values ranges from 1.33 g/cm3 for 0 – 9 years cashew plantation, 1.16 g/cm3 for 10 – 20 years and 1.22 g/cm3 for cashew plantation of above 20 years old while the coefficient of variation result varies from 10.5% for 0 – 9 years old plantation to 13.9% for above 20 years old cashew plantation which implies insignificant variation (i.e. C.V. proportion in all ages are less than less than 34% which is the significant level). In the same vein, the bulk density variation was also marginal when comparing cashew plantations to fallow land with the mean value of 1.2 g/cm3 for cashew plantations and 1.1 g/cm3 for fallow land.

In the case of institutionally managed plantations, the bulk density mean values under different ages of cashew plantations consist of 1.20 g/cm3 for cashew plantation of 0 – 9 years, 1.48 g/cm3 for 10 – 20 years and 1.27 g/cm3 for cashew plantation of above 20 years old. While its coefficient ranges from 8.80% for plantation of 10 – 20 years to 31.3% for 0 – 9 years old cashew plantations. The comparison of cashew plantations with fallow land in the institutionally managed farm revealed very close outcome of mean value of 1.3 g/cm3 for cashew plantations and 1.2 g/cm3 for fallow land respectively (Table 2). However, the result indicated that the soil in the area is homogeneous with low level of soil compaction.

Table 2. Mean, Standard Deviation and Coefficient of Variation of Institutional Managed and Subsistence Individual Managed Plantations

Properties	**0 – 9 Years**			**10 – 20 Years**			**Above 20 Years**		
	Mean	**S.D**	**C.V**	**Mean**	**S.D**	**C.V**	**Mean**	**S.D**	**C.V**
Institutional Managed									
% Sand	61.1	2.6	4.3	57.3	4.4	7.7	58.1	4.7	8.1
% Clay	27.0	2.3	8.5	28.5	4.3	15.1	23.8	4.7	19.7
% Silt	11.9	4.1	34.5*	14.2	3.6	25.4	18.1	3.2	17.7
Bulk Density	1.28	0.40	31.3	1.48	0.13	8.8	1.27	0.18	14.2
Subsistence Individual Managed Plantations									
%Sand	68.1	3.4	5.0	68.3	3.7	5.4	69.1	2.9	4.2
%Clay	18.8	2.4	12.8	17.7	4.2	24.6	19.1	3.5	18.3
%Silt	13.1	1.9	14.5	14.0	1.6	11.4	11.8	2.4	20.3
BD	1.33	0.14	10.5	1.16	0.17	14.7	1.22	0.17	13.9

* Significantly vary (C.V. ≤ 33%).

Variation of Soil Properties between Different Ages of Cashew Plantations and Fallow of Subsistence Managed Farms

Result from Table 3 shows the analysis of variation extent between different ages of cashew plantations and fallow land with analysis of variance (ANOVA) inferential statistics. The analysis revealed that the overall ANOVA result varied from 1.325 as minimum recorded in silt to 5.403 as maximum overall ANOVA result recorded sand. The inter ages variation in the soil properties between cashew plantations of 0 – 9 years and 10 – 20 years; 0 – 9 years and above 20 years old cashew plantations show no significant variation at 0.05 critical level. Inter-age soil properties variation between cashew plantation of ages 10 – 20 years old and > 20 years plantations revealed no significant variation while soil of cashew plantations of 10 – 20 years old and fallow land show significant variation in sand at p-values of 0.004 and clay at 0.001 respectively. In the situation of inter-relationship between cashew plantation of > 20 years and fallow land, the result revealed significant variation in sand at p-value 0.001. It is noted from the ANOVA cashew plantation inter-ages and fallow land that physical properties of soil revealed significant variation.

Table 3: Analysis of Variance (ANOVA) for Assessing Variation between Different Ages of Cashew Plantations and Fallow Land in both Subsistence Individual and Institutionally Managed Cashew Plantations

Parameter	Overall ANOVA	F-prob	0 – 9 yrs 10 – 20 yrs	0 – 9 yrs >20 yrs	10 – 20 yrs >20 yrs	10 – 20 yrs Fallow	20 yrs Fallow
Subsistence Individual Managed							
% Sand	5.403	0.004	0.913	0.544	0.618	0.004*	0.001*
% Clay	4.054	0.007	0.489	0.810	0.353	0.001*	0.013
% Silt	1.325	0.283	0.463	0.267	0.70	0.731	0.137
BD	3.115	0.040	0.029	0.165	0.390	0.568	0.157
Institution Managed							
% Sand	4.228	0.013	0.081	0.162	0.712	0.003*	0.008*
% Clay	18.10	0.001	0.385	0.064	0.009*	0.001*	0.001*
% Silt	5.078	0.005	0.267	0.005*	0.068	0.032	0.730
BD	4.528	0.009	0.017	0.878	0.011	0.002*	0.437

Critical level of $p < 0.05$ *Significant variation

Variation of Soil Properties between Different Ages of Cashew Plantations and Fallow of Institutional Managed Farms

Analysis for inter ages variation in the soil physical properties under cultivated cashew plantation and fallow land in the LAUTECH farm using ANOVA revealed overall result ranged from 4.228 – 18.100. The inter age variation between cashew plantation of ages 0 – 9 years and 10 – 20 years show no significant variation while cashew plantation of 0 – 9 years and > 20 years old cashew plantation revealed significant variation at 0.005 p-value in silt. Soil under 10 – 20 years old cashew plantation and >20 years old depicts significant variation clay soil physical parameter at 0.009 and differently varied at 0.003 and 0.001 p-values in sand and clay respectively while comparing relationship with uncultivated fallow land. The relationship between soil under cashew plantation of >20 years old and uncultivated fallow land of institutional managed plantation revealed significant variation in sand and clay at 0.008 and 0.001 p-values respectively (Table 3). It is however obvious that cultivation of mature and old cashew plantation along with other soil formation factors significantly affects the texture of the soil being the cover crops that prevent direct penetration of climatic elements such as rainfall and solar radiation.

CONCLUSIONS

The study analyzed the variation in the soil physical properties under different ages of cashew plantation in the Guinea savanna region of Southwestern Nigeria. The study area was selected as the largest cashew dominant area in the Guinea savanna region of southwestern Nigeria. Multistage sampling technique was adopted to select the cashew plantation study sites and collection of soil data in diagonal format at 3x3x30cm in privately and institutional managed farms. The selected cashew plantations were classified into three age groups of 0 – 9 years old, 10 – 20 years old, and above 20 years while two fallow lands at 10m distance to the cashew plantations were selected as control plots. The study concludes that the particle size distribution of the study area is dominated by sandy loam soil and that there is significant variation in the soil texture between young and mature/old cashew plantations. The finding shows the impact of cover crops like cashew plantation in protecting soil from adverse climatic and environmental effects.

The main goal of this study is to determine the extent of variation in the soil physical properties or parameters as a result of cashew cultivation. The findings revealed homogeneity in the soil texture under cultivated cashew plantation and the fallow plot except at sandy loam soil which showed significant variation. This could be as a result of lack of direct access of the climatic elements to the soil under cashew plantation being a covered tree crop. The study is important because it considered the direct implication of cashew cultivation on soil physical properties with the aim of providing useful information to the agricultural policy maker about the need to increase investment in support of commercial cultivation of this plantation being the major tree crop in the region.

REFERENCES

Adeigbe, O.O., Olasupo, F.O., Adewale, B.D. and Muyiwa, A.A. 2015. A review on cashew research and production in Nigeria in last four decades. *Sci. Res. Essays*, vol. 10(5):196 – 209.

Agnolini, M. and GiulianiI, F. 1977. *Cashew cultivation*, Ministry of Foreign Affairs, Institute Agronomic per Loltremare, Florence, 1-168.

Aikpokpodion, P.E., Uloko, B. and Edibo, G. 2009. Nutrient dynamics in soil and cashew (*Anacardium occidentale* L) leaf and kernel in Kogi state, Nigeria. *Journal of applied biosciences*, 25:1573 – 1578.

Badrinath, M.S., Ramakrishna,V.R., Sudhir, K., Chidanappa, H.M. and Janardhanagowda, N.A. 1990. Percentage distribution of various particle size groups in Oxisol soil profiles of Coastal Karnataka. *The cashew*, 4(2):14-18.

Catarino, L., Menezes, Y. and Sardinha, R. 2015. Cashew culture in Guinea-Bissau—Risks and challenges of the success of a cash crop. *Scice and Agriculture*, 72: 459–467.

Catarino, L., Havik, P.J., Indjai, B. and Romeiras, M.M. 2016. Ecological data in support of an analysis of Guinea-Bissau‘s medicinal flora. *Data Brief*, 7: 1078–1097.

Chadha, K.L. and Nair, M.K. 1998. Managing red and lateritic soils for sustainable agriculture, *Red and lateritic soils*, 1:179-189.

Davidson, E.A., Ackerman, I.L. 1993. Changes in soil carbon inventories following cultivation of previously untilled soils. *Biogeochemistry* 20: 161-193.

Dendena, B. and Corsi, S. 2014. Cashew, from seed to market: A review. *Agronomy for Sustainable Development*, 34: 753–772.

Don, A., Schumacher, J., Freibauer, A.. 2011. Impact of tropical land-use change on soil organic carbon stocks e a meta-analysis. *Global Change Biology,* 17: 1658-1670.

Filipa, M., Luís, C., Dora, B., Bucar, I., Maria, C. D. and Maria, M. R. 2017. Cashew as a high agricultural commodity in West Africa: Insights towards sustainable production in Guinea-Bissau. *Sustainability,* 9, 1666.

FAO. Food and Agricultural Organization of the United Nations Statistics Division. 2006. Available online: http://faostat3.fao.org/download/Q/QC/E (accessed various dates).

Gaurav, M., Avishek, S., Krishna, G., Arun, J.N., Rattan, L. and Rossa, F. 2021. Changes in soil stocks under plantation systems and natural forests in Northeast India. *Ecological modeling*, doi.org/10.1016/j.ecolmodel.2021.109500.

Luiz, A.L., Aline de, H.D and Janderson, P.S. 2020. Hydrophilic polymer changes the water demand in the implementation of a dwarf cashew orchard. *Engineering Agriculture*, 40(3):344- 351.

Noiha, V.N., Zapfack, L.A., Witanou, V.D., Nyeck, B., Ngossomo, J.D., Hamadou, M.R., Chimi, C.D. and Tabue, R.B. 2017. Floristic structure and sequestration potential of cashew agroecosystems in Africa: A case study from Cameroon. *Journal of sustainable forestry*, DOI: 10.1080/10549811.2017.1296776.

Ohler, J.G. 1979. *Cashew*. Department of Agricultural Research, Royal Tropical Institute, Amsterdam, 1-260.

Olatunji, O.O. and Ewetola, E.A. 2015. Spatial variability of soil morphological and physico- chemical properties in Ladoke Akintola University Technology cashew plantation, Ogbomoso. *International journal of applied agriculture and apicultural research*, 11(1&2):137 – 145.

Ollenburger, M.H., Descheemaeker, K., Crane, T.A., Sanogo, O.M. and Giller, K.E. 2016. Waking the Sleeping Giant: Agricultural intensification, extensification or stagnation in Mali's Guinea Savannah. *Agricultural System*, 148, 58–70.

Paul, K.K., Michael, B., Abraham, A., Abu, M.D., Edem, A., Seth, O. and Francis, P. 2021. Broadening the gene pool of cashew (Anacardium occidentale) for survival and precocity. *Agricultural researchs*. Doi.org/10.1007/s40003-020-00521-z.

Rahaman, M.A. 1970. *Review of the basement complex of Southwestern Nigeria*. In C.A. Kogbe ed Gelogy of Nigeria. Elizarbeth Publishing Co. Lagos 41-58 pp.

Rocchetti, G. 1970. Reaction to salinity of cashew during early stages of development. *Rivista Agriculture Sub-tropicale*, 64: 237-353.

Smyth, T.M. and Montgomery, M.A. 1962. A theory of spatial and temporal dynamics of plant communities. *Vegetatio*, 83:49-69.

Steege, H.T., Sabatier, D., Castellanos, H., Andel, T.V., Duivenvoorden, J., Oliver, A., Renske, E., Lilwah, R., Mass, P. and Mori, S. 2000. An analysis of the floristic composition and diversity of Amazonian forests including those of Guiana shield. *Journal of tropical ecology*, 16: 801-282.

Throop, H.L., Archer, S.R., Monger, H.C. and Waltman, S. 2012. When bulk density methods matter: Implications for estimating soil organic carbon pools in rocky soils. *Journal Arid Environments*, 77: 66-71.

United States Department of Agriculture 2006. Soil Standard for Crop Production.

Widiatmaka, A., Wiwin, A., Atang, S., Kukuh, M., Khursatul, M. and Usma D. 2015. Suitable and available land for cashew (*Anacardium occidentale L.* in the island of Lombok, Indonesia. *Journal of applied horticulture*, 17(2: 129-139.