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Spatial Variability of Soil Morphorlogical and Physico-Chemical Properties in Ladoke Akintola University of Technology Cashew Plantation, Ogbomoso.

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Abstract

To study the spatial variability of soil morphological, physical and chemical properties in the Cashew plantation of Ladoke Akintola University of Technology, Ogbomoso, Oyo State of Nigeria eight profile pits were dug, described and examined. The result of the analysis and the variability grouping put colour value in AP and B_1 as least variable. Stoniness (AP) and structure (AP and B_1) were moderately variable properties. Colour (AP, B_1 B_2 and B_3), structure (B_2 and B_3), stoniness (B_1, B_2 and B_3), concretion (AP B_1, B_2 and B_3) and boundary forms (B_1, B_2andB_3) have extremely variable properties. pH (H_2O and KCl), Na^+ base saturation were least to variable. Fe^{2+}, cu $^{2+}$, Mg^{2+}, k^+, CEC, Ex. Acidity, extractable Mn^{2+} , organic carbon (g/kg), organic matter (g/kg), and available phosphorus were extremely variable soil properties.
The available moisture of soil was very low thus water holding capacity (WHC) and wilting point (WP) of the soil was very low. .The gravel content of the land was high at the surface and reduced down the slope... Bulk density parameter of the land was very high at the surface. The land was very low in plant nutrients, this result show that the soil of the cashew plantation is highly variable and that management techniques that would be flexible enough to carter for the variation noticed should be adopted, such as organic fertilizer application.

Keywords: Spatial variability, management strategy, soil fertility and land underutilization.

Introduction

Spatial variation is a natural phenomenon in soil that measures the differences in physical and chemical properties of soil from one point to another, soil variation can either be of a small or wide range. It could also be linked to soil formation factors such as, parent materials, climatic (rainfall, temperature), the nature of landscape relief, other factors include biological and human activities (Ojanuga, 1978, Ogunkunle, 1987). Soil is the living medium which is highly variable in sizes, functions, properties and compositions; however, it is highly heterogeneous in nature (Dahiya *et al*., 1984). Soil variability is therefore the changes that occur within the soil as a result of the reactions happening within it day in day out and from time to time (Becket and Webster, 1971).

The pertinent question raised by researchers is to how best to cope with spatial distribution of soil properties and its effect on crop production. Thus, the study of soil variability can serve as an important feature in the identification of soil properties relative to crop production, irrigation scheduling, land drainage, land reclamation, runoff pollution, ground water contamination, pesticides management, liquid waste disposal from municipalities, industries, nuclear power plants and mapping and classifying of soils (Dobermann *et al*., 1995).

Soil variability poses a number of problems to farm owners, their productivity, existence and livelihood. They face or overcome the variation via complex farming system i.e. the more diverse the environment and the smaller the farm the more complex are the farming systems adopted to cope with such soils (Cassel, 1983, Ford, 1990). To solve these challenges, farmers uses different technologies and practices such as bush follows, mix-cropping, farm rotation, planting cover crops, planting legumes, mulching system (Brouwner and Bouma, 1995) etc. The precision of agriculture depends on how much knowledge a farmer have on the soil in which he is working with for optimum production. The knowledge of spatial variability of soil physical and chemical properties is essential for optimum and sustainable agriculture (Wilding, 1985).

Variation in soil properties imposed limitation on the potentiality of the soil and productivity status. This had hindered the yield performance of cashew production in Ladoke Akintola University of Technology cashew farm, Ogbomoso. The cashew (*Anacadium occidentale*) trees had been found growing stunted with no improvement over years. The LAUTECH Teaching and Research Farm had been used extensively for experiments and research works and the production of cash crops which generate economic value within the University community. Soil variability may influence the result obtain from the experiments no matter the kind of experimental design used. Results obtain from Laboratory or Greenhouse analysis carried out on the soil samples taken is also influenced by soil variability. In view of the potentials of this farm, little or no information has been provided on the LAUTECH cashew farm soils, even though it has been in operation over the last twenty years. Thus necessitating the need to assess or evaluate the nutrient status of the land been used for production.

The objects of this study were to:

- evaluate the soil physical and chemical properties of LAUTECH cashew plantation.
- suggest management and soil fertility improvement strategies that could be adopted to improve productivity.

Materials and Methods

Characteristics of the Study Area

The study area was, LAUTECH Cashew Plantation affiliated to LAUTECH Teaching and Research Farm located at Ogbomoso North Local Government Area in Oyo state, Nigeria. Ogbomoso lies on latitude $8^0$10’N and longitude 40^0 10’E. Ogbomoso is in southern Guinea savanna zone. The Climate is equatorial, notably with dry and wet seasons with relatively high humidity. The dry season lasts from November to March while the wet season starts from April and ends in October. Average daily temperature ranges between 25 °C (77.0 °F) and 35 °C (95.0 °F), almost throughout the year.

The mean annual rainfall is about 1200 mm, with average range of 786.2 to 1513 mm. The raining season occur between April and November. It has bimodal monthly distribution that assumes the first peak in June and second in September with July/August break during this period. The dry season follows immediately starting by November and terminating by February with associated harmattan.

Soil Sampling and Analysis

The study field covers a total area of 8 hectares. The field was divided into three different parts according to the landscape gradient; the upper slope position, middle slope position and the lower or bottom base slope position. Samples were taken in three replicates across the slope for physico–chemical properties using systematic sampling method. Eight profile pits were dug in all using two transverses and four pits each, samples were taken in each identified horizon, horizon replicate samples were also taken for physical properties making a total of 84 core samples.

The description and sampling was done using standard profile pit of 1.5 x1.5 x 1.5 m depth, Morphological description was done following the FAO guidelines (FAO, 2006) and USDA guideline (USDA, 2006). The morphological properties considered were colour (hue, value and chroma) using Munsel soil colour chart. Soil consistence and texture were done using hand feels. Pore size and root growth abundance and distribution were described using hand lens. The other properties examined were mottles, cutans, boundary form, drainage, water table, moisture condition, soil structure, stoniness, biological activities i.e presence of insects or animal burrowing and concretions.

The samples were air dried ground and sieved to separate the fine earth particle fraction (less than 2 mm) from coarse fragments using ceramic mortar and pestle with a 2 mm sieve. The gravel content was the weighed and it percentage was calculated as percentage gravel content.

Laboratory Analysis

Particle size distribution was determined using Hydrometer method (Gee and Or, 2002), pH in ratio 1:2 (Soil: H_2O), Organic carbon was by Nelson and Sommers (1982) method.

Extractable phosphorus was determined in Mehlich-3 extractant (Mehlich, 1984). The exchangeable cations and the cation exchange capacity (CEC) of the soil were determined using the ammonium acetate method (McKeague 1978).Soil bulk density was determined using minimally disturbed core samples for each depth as described by Blake and Hartage, (1986). The saturated hydraulic conductivity (Ks) was obtained using a constant head parameter placed on undisturbed core samples. The permanent wilting point was carried out using the pressure plate apparatus method (Klute, 1986).

Statistical Test of Variability

The parameters (morphology) described on site were coded for statistical analysis and the set of data from laboratory was analyzed statistically. The mean ($\bar{X}$), standard deviation (S.D.) and Coefficient of variation (CV%) for each soil property were calculated for each site in order to compare them.

Results and Discussions

Variation in Morphological Properties

Field work was carried out in eight different pits with three to five layers in each pit. Generally the soils at the upland had higher depth than the soils at the lower landscape. Pit 1 had five layers, pits 2, 3, 4, 7, and 8 had 3 layers each while pit 5 and 6 had four layers each. This difference in horizon differentiations was due to age of maturity for the majority of the soils and depth to underlining parent materials. The mean, standard deviation and coefficient of variation of morphological properties across the horizons is shown in Table 1.

Moist consistency increased with depth ranging from loose to firm. AP horizon was friable. Consistence increased down the profile across the slope. The variability may be due to alterations caused by cultural practices. The high variability in the subsoil is a reflection of the combined action of soil forming factors and human interference (cultivation of land) which is likely to be encountered with topographic positions.

Table 1: The mean, standard deviation and coefficient of variation of morphological properties of lautech cashew farm.

properties	range	SDVE	X	CV%
		AP		
Mottles	1-3	0.5995	2.125	28.21
stoniness	2-3	0.4841	2.625	18.44
soil structure	31-35	1.0897	2.125	3.29
consistency	1-4	0.4841	3.625	13.3
roots abundance	31-34	0.7071	32	2.21
concretions	31-33	0.927	32.12	52.89
boundary forms	23-24	0.4841	24.62	51.97
		B1		
Mottles	1-2	0.484	11.625	29.79
stoniness	2-3	0.4841	2.65	18.44
soil structure	34-35	0.433	34.25	1.261
consistency	1-4	0.9922	2.65	37.44
roots abundance	31-34	3.1524	31.25	10.09
concretions	31-33	4.6904	30	15.63
boundary forms	23-24	4.9738	26.375	18.86
		B2		
Mottles	1-3	0.5995	1.875	31.97
stoniness	2-4	0.6614	2.25	29.4
soil structure	34-46	3.6997	36.25	10.21
consistency	1-3	0.5995	1.875	31.97
roots abundance	31-34	0.8292	32.75	2.53
concretions	20-33	5.2426	28.625	18.31
boundary forms	21-34	4.9101	25.125	19.54
		B3		
Mottles	1-2	0.4714	1.6667	28.28
stoniness	2-3	0.4714	2.3333	20.21
soil structure	35	35	0	0
consistency	2	2	0	0
roots abundance	33-34	0.4714	33.333	1.41
concretions	22-31	4.0277	25.333	15.9
boundary forms	22-23	0.9428	21.667	4.35

Soil texture ranges (hand feel method) from loam sandy to clay. Clay content increased down the profile in all the profile pits with decreasing sandy content. This is expected as increases in depth tend to show more accumulation of clay at the subsoil and it is in agreement with the findings of Fasina *et al.*, (2007). Soil structure ranges from granular to blocky. A_P horizon was predominantly granular. The soil structure became more stable with increase in horizon depth (i.e. B_1, B_2 and B_3).

Concretion was highly variable across the slope and down the depth. Concretions were majorly ferruginous and unidentified. This is due to the activities of Fe in reduction and oxidation reaction in the soil which is a characteristic of tropical soils. Boundary forms include smooth, wavy, abrupt, clear, gradual and diffuse. However, none of it could be said to be dominant in all. There is moderate variability from A_P to B_4

Table 2: Percentage Gravel Content for the soil profiles.

S/N	SAMPLES	PERCENTAGE GRAVEL CONTENT
1	P_D1_A	31.00
2	P_D1_B	69.95
3	P_D1_C	63.44
4	P_D1_D	54.62
5	P_D1_E	59.89
6	P_D2_A	41.48
7	P_D2_B	45.22
8	P_D2_C	47.59
9	P_D3_A	45.50
10	P_D3_B	65.78
11	P_D3_C	67.48
12	P_D4_A	31.81
13	P_D4_B	49.28
14	P_D4_C	57.74
15	P_D5_A	62.00
16	P_D5_B	31.85
17	P_D5_C	49.57
18	P_D5_D	62.94
19	P_D6_A	46.38
20	P_D6_B	58.51
21	P_D6_C	62.24
22	P_D6_D	57.00
23	P_D7_A	30.37
24	P_D7_B	45.21
25	P_D7_C	60.90
26	P_D8_A	38.56
27	P_D8_B	45.96
28	P_D8_C	76.49

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Variation in Physical Properties

Percentage gravel content for AP horizon range from 30.37 to 62% with overall mean, SD and CV% of 3.65, 0.6822 and 36.48% respectively.

Generally, the high gravel content may be attributed to the parent material and agents of soil formation. The high gravel content at crest and upper slope can be attributed to the action of run-off of water that carries fine particle and leave the gravel behind and the steepness of the slope.

Table 3: Distribution of some soil physical properties using standard deviation, mean and percentage coefficient of variation down the profile.

	Bulk density			Field capacity			Plant available water		
Profile	std	mean	% CV	std	mean	% CV	std	mean	% CV
1	0.11	1.50	7.33	0.05	0.21	23.44	0.01	0.09	7.86
2	0.02	1.54	1.12	0.01	0.18	3.15	0.00	0.08	0.00
3	0.16	1.39	11.26	0.10	0.29	35.00	0.01	0.10	10.00
4	0.15	1.50	9.85	0.08	0.22	37.59	0.02	0.09	19.25
5	0.12	1.45	8.58	0.07	0.24	28.04	0.01	0.09	10.35
6	0.11	1.43	7.48	0.06	0.25	23.18	0.01	0.10	9.82
7	0.05	1.63	2.77	0.02	0.16	13.29	0.01	0.09	13.32
8	0.07	1.51	4.52	0.03	0.21	14.29	0.02	0.09	24.74

The mean distribution of bulk density in Table 3 range from 1.43– 1.63 mg/m^{3}while the standard deviation range from 0.02 – 0.16 and CV range from 2.77 – 11.26%. This is a reflection of moderate to high soil compaction on the studied area. The high compaction that was noticed down the profile is indicative of mechanical impedance to root penetration, the root of cashew trees will find it difficult going down to deeper depth where it could tap more nutrient and have better stability. Thus cultivation of arable crop could be more suitable for profitable crop production since surface rooted crops may not adequately tap into the subsoil beyond certain level. The use of heavy machinery should be discouraged as much as possible to reduce soil compaction.

The mean distribution of field – capacity as shown in Table 3 ranged from 0.16m^3 – 0.29m^3, while the standard deviation ranged from 0.01 – 0.08 and the field capacity CV range from 3.15 – 37.59.Plant available water is the amount of water available for plant uptake at a particular time to successfully complete its life cycle without water stress.

The mean distribution of plant – available water ranged from 0.08mg/m^3 to 0.10mg/m^3 – while the standard deviation of plant available water range from 0.00m^3 – 0.002m^3 and the coefficient (CV) range from 0.00 – 24.74%. This clearly shows that planted crops can thrive well if the field capacity can supply the required plant available water to the planted crops.

Table 4: Range, Standard Deviation, Mean and Coefficient of Variation of Chemical Properties of Soil on LAUTECH Cashew Farm.

properties	range	SDVE	X	CV%
pH (KCI)	4.2-6.9	0.71	5.88	1.2
pH(H2O)	4.9-7.6	0.69	6.49	10.59
E.C25(mmho/cm)	0.0-9.0	1.81	2.14	84.33
Av.P(ppm)	0.99-7.03	1.27	1.98	64.28
Ca(me/100g	1.26-18.79	45.1	4.72	86.8
Mg(me/100g)	0.06-2.19	0.51	1.05	48.82
Na(me/100g)	0.05-0.89	0.32	0.36	88.24
K(me/100g)	0.05-0.97	0.3	0.71	42.1
E.Ac(me/100g)	0.20-3.20	0.67	0.6	111.01
CEC(me/100g)	2.81-22.51	4.83	7.45	64.75
B.sat (ppm)	82.76-98.67	4.63	91.82	5.05
Mn (ppm)	4.10-88.00	21.302	5.35	84.06
Fe (ppm)	16.8-36.5	4.85	23.35	20.8
Cu(ppm)	0.86-4.85	0.96	2.07	46.46
Zn (ppm)	1.71-36.30	6.84	5.85	117.05
Sand(%)	39.8-87.6	13.56	68.21	119.89
Silt(%)	5.4-17.4	3.09	10.36	29.79
Clay(%)	6.0-50.4	12.072	1.15	57.07

Variation in Chemical Properties

pH is consistently the least variable chemical properties (Table 4), it ranges from 4.9 to 7.6 for pH in water and 4.9 to 6.9 for pH in KCl which could be classified as strongly acidic to neutral. Organic matter (0.M) was highly variable. Organic matter was least abundant at upper slope and most abundant at the lower slope. The types of vegetation cover and cropping system could account for this variability observed at the topographic positions; most of the organic materials are washed down the slope. Available phosphorus was very highly variable and ranges from 1.06 to 7.03 mg/kg with mean, SD and CV% of 1.272, 1.979 and 64.28% respectively.

The lower available P at certain point could have been due to some loses through plant uptake or leaching away of the plant nutrient. Okusami and Oyediran (1985) observed that soil test for phosphorus and potassium had cyclic variation with topography and that the degree of this variation increases with slope degree.

The exchangeable cations include Ca^{2+}, Mg^{2+}, K^{+} and Na^{+} ions. Calcium value ranged from 1.26 to 18.79 Cmol/kg. Calcium increases with increases in organic matter and thus explains the higher range of calcium. However, the high variation shown by calcium could have been due to formation of calcium complexes with soil organic matter.

Magnesium ranges from 0.06 to 2.19 Cmol/kg with mean value, SD and CV% of 4.10, 4.72 and 86.8% respectively. Sodium ranges from0.05 to 0.89Cmol/kg with mean, SD and CV% of 0.32, 0.36 and 88.24% respectively. Potassium ranges from0.05 to 0.97Cmol/kg with mean, SD and CV% of 0.67, 0.60 and 111.01. Exchangeable acidity ranged from 0.2 to 3.2Cmol/kg with mean, SD and CV% of 4.83, 7.45 and 64.45% respectively. Manganese ranges from4.10 to 88 mg/kg with mean, SD and CV% of 21.3, 91.8 and 84.6% respectively. This high range can be attributed to the low pH of the soil. Cu^{2+}ranges from 0.86 to 4.5 mg/kg with mean, SD and CV% of 0.96, 25.3 and 46.46 respectively. Zinc and iron and moderately variable with range of 1.71 to 36.3 and 16.8 to 36.5 mg/kg respectively. Cation exchangeable capacity was highly variable with range of 2.81 to 22.51cmol/kg.

Variability Grouping of Soil Properties

According to Wilding and Drees (1978), soil properties variability can be divided into three groups based on their coefficient of variation (CV %) values. The grouping of soil properties is shown in table 5 the groups are: least variable with CV less than (<) 15%, moderately variable with CV% between 15-35% and highly variable with CV greater than 35%.

Table 5: Variability grouping of soil properties according to Wilding and Drees (1978)

CV%	Groupings
Least variable	<15%
Moderately Variable	15-35%
Extremely Variable	>35%

Variability grouping of some of the measured Soil Properties

In reference to Table 5, the grouping put colour value in $A_P$to B_3at least variable. Stoniness (A_P) and structure (A_P and B_1) are moderately variable soil properties. Colour (A_P, B_1 B_2 and B_3), structure (B_2 and B_3), stoniness (B_1, B_2 and B_3), concretion (A_P, B_1, B_2 and B_3) and boundary forms (B_1, B_2 and B_3) were extremely variable. pH (H_2O and KCl), Na^+, base saturation were least variable. Fe^{2+}, cu $^{2+}$, Mg^{2+}, k^+, CEC, Ex. Acidity, extractable Mn^{2+}, organic carbon (g/kg), organic matter (g/kg), and available phosphorus were extremely variable.

Conclusions

The result showed a complexity in variation. The dominant spectral colour (hue) were 2.5YR, 5YR, 7.5YR and 10YR, illustrating the changes in organic matter content with depth and the various effect of drainage both lateral and horizontal. Morphological properties show a complex pattern and no single property was consistently variable at all depth. Stoniness, colour value, structure, boundary form, consistence and texture were least variable to highly variable in AP and B_1 horizons. At horizon $B_{2,}$ B_3 all the morphological properties are extremely variable including.

Soil chemical properties also show a complex pattern of variation; pH, Na^+ and base saturation were least variable. CEC and exchangeable acidity were extremely variable. $Ca^{2+,}$ $Mg^{2+,}$ organic carbon, organic matter and Phosphorus were extremely variable.

There is substantial difference in gravel content between the upper, middle and lower slope positions. This must be taken into consideration for further stratification. The various soil regions existing may require different management system for the same or different crops because of the basic differences in their characteristics. From the result obtained from this study, transfer of management methods adopted can be done for the slope of the upper regions but not for the lower region or the valley bottom.

References

Backett, P.H.T and R. Webster, (1971). Soil variability review Soil fert 34, 1-15

Brouwner, J. and J. Bouma . Soil and crop growth variability in the Sahel highlights of research (1995) at ICRISAT Sahelian center . ICRISAT – information – Bulletin 1997, No 49, 42pp Cassel,O.K

(1983). Spatial and temporal variability of soil physical properties following tillage of Norfolk loamy sand. Soil Sc. Soc. Am. J. 39:247-50

Cramptom, C.B. (1983). Variation in pH with annual precipitation in loamy forest soils Can J. Soil Sc. 63:401 – 403.

Dahiya, I.S, J. Ritcher and R.S malik (1984). Soil spatial variability a review. Intern. J. Trop. Agric, vol 11, No 1 pp 1-102.

Dobermann A. P. Goovaerts and T. Geoge (1995). Sources of soil variation in an acid ultisol of the Philippines. Geoderma 68:3, 173-191:41 ref.

FAO-ISRIC-ISSS. (Food and Agriculture Organization of the United Nations, International Soil Reference and Information Centre, International Society for Soil Science), (2006). World Reference Base for Soil Resources. Report No. 103, FAO, Rome.

Fasina, A.S., F.O. Omolayo, A.A. Falodun and O.S Ajayi. (2007). Granitic derived soils in humid forest of south-western Nigeria-Genesis classification and sustainable management. American-Eurasian journal of Agiculture and Environmental Science. 2 (2): 189-195.

Ford, R.E (1990). The dynamics of human environmental interaction in the tropical montane agrosystems of Rwanda: implication for economic development and environmental stability. Mountain Research and Development 10, 43 –63

Gee, G.W. and D. Or, (2002). Particle Size Analysis.Pp.255 -293. In J.H. Dane and G.C. Topp (eds) Methods of Soil Analysis, Part 4, Physical Methods. Soils Science Society of America. Book series No.5, Madison, Wisconsin, USA.Graham, R.C., K.R.

Tice, and W.R. Guertal. (1994). Thepedologic nature of weathered rock. p.21–40. *In* D.L. Cremeens *et al.*, (ed.) Whole regolith pedology. SSSA Spec. Publ. 34. SSSA, Madison.

Mehlich, A. (1984). Mehlich-III soil test extractant: A modification of Mehlich II extractant. Communication in Soil Science and Plant Analysis.15:1409–1416.

Murphy, J. and J.P. Riley. (1962). A modified single solution method for the determination of phosphate in natural waters.Anal.Chim.Acta.27: 31–36.

Nelson, D.w. and L.E. Sommers (1982).Total carbon, organic carbon and organic matter. In: page, A.L. Miller, R.H. and Kenney, D.R. (eds.). Methods of soil analysis, part 2. American society of Agronomy, Madison, Wisconsin Pp 539-579

Ogunkunle, A.O. (1987). Influence of Micro Topography and Sampling on the Variability of Some Chemical Properties in Southern Nigeria. Tropical. Agriculture (Trinidad) 64:111-114.

Ojanuga, A.G. (1978). Genesis of soils in the metamorphic forest region of Southwesthern Nigeria. Pedolomor-phic Pedologie xxviii., 1: 105-117.

Okusami, T.A and G.O. Oyedran. (1985). Slope-soil relationship on an Aberrant toposequence in Ife area of Southwestern Nigeria: Variabilities in Soil Properties. Ife J.Agric.7:1-5.

Soil Survey Staff. (2006). Keys to Soil Taxonomy, US Department of Agriculture, NRCS (9th Edn.), pp: 281.

Webster, R. 1985. Quantitative spatial analysis of soil in the field Adv. Soil Sci. Vol .3 Springer-Verlag, New York.

Wilding, L. P. (1985). Spatial variability: Its documentation, accommodation and implication to soil survey. Soil variability. Nielsen, D. R. and Bouma, J. Eds. PUDOC, Wageningen. 166-189.

Wilding, L.P and L.R. Drees, (1978). Spatial variability: A pedologist view point in Diversity of soil in the tropics. ASA Special publ. 34: 1-12.