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ASSESSMENT OF VARIABILITY OF SOIL PROPERTIES UNDER DIFFERENT VEGETATIONS IN AN ULTISOL IN IFE AREA, OSUN STATE, NIGERIA

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ABSTRACT

Soil variability leads to undesirable effects on crop yield. Knowledge of soil variability is necessary to estimate reliable average values for soil properties. A field trial was conducted at the Teaching and Research Farm of the Obafemi Awolowo University, Ile-Ife, to assess the variability of some soil properties under citrus, cacao and oil palm plantations in an Ultisol with a view to documenting the effects of vegetation on the variability of the selected soil properties.

Soil samples were collected from the surface (0-20 cm) and subsurface (20-50 cm) horizons with the aid of a Dutch auger. These were processed and analysed for selected physical and chemical properties. The results showed that there were no significant differences (p>0.05) among the physical properties across the plantations at the surface and subsurface horizons. At the surface horizon, sand and clay contents were least variable, irrespective of the plantation; silt content was highly variable in the citrus and oil palm plantations with CV of 40.86% and 37.88%, respectively but was least variable in the oil palm plantation. The pH was least variable in all the plantations. Organic matter (OM) content was least variable in the oil palm plantation but moderately variable in the citrus and cacao plantations. The Na content was moderately and least variable in the surface and subsurface horizons, respectively in the plantations while K, Ca and Mg contents were highly and moderately variable at the surface and subsurface horizons, respectively across the plantations. Compared with the previous works on the variability of soil properties, vegetation was found to have a mitigating effect on soil variability.

Key Words: Variability, Soil Properties, Vegetation, Ultisol, Ife Area and Southwestern Nigeria.

INTRODUCTION

Soil is a natural landscape resource that supports plants and animal life. However, its properties vary over time and space. Soil variability is a product of soil-forming factors that interact over a continuum of temporal and spatial scales.

Soil variability could be spatial or temporal; however, spatial variability is often larger (Dahiya, *et al.*, 1984), and relates to variations in soil properties with distance while temporal variations are those due to season or time, depending on the activities taking place on them over time. Spatial variability could be due to variations in the natural landscape, cultivated landscape or vegetation type (Wilding and Drees, 1978). Beckett and Webster (1971) have also reported variability of soil properties with depth. They stated that different treatments affect the soil to different depths and nutrient uptakes are not always from the same depth as for all soils and crop types. Soils in the landscape differ in their properties and potentials for crop production. High degree of variability in tropical soils gives rise to soil heterogeneity, resulting in poor predictability of potentials, difficulty in management and agro-technology transfer (Ogunkunle 1987; 1993; Ettema and Wardle, 2002; Akinbola *et al.*, 2006; Akinbola *et al.*, 2010). Availability of information on the degree of variability of soil properties improves the quality of soil survey, enhances land use and its management and guides the design and location of agronomic experiments. Better sampling efficiency also results from recommendations based on such studies (Ogunkunle, 1986). The need to take due cognizance of the extent of spatial variability in estimating reliable "field average values" of soil properties is widely recognized (Babalola, 1978; Oyedele and Amusan, 2000). The objective of this study, therefore, was to assess the degree of variability of soil properties as influenced by vegetation.

Materials and methods

The experiment was conducted at the Teaching and Research Farm (T&RF), Obafemi Awolowo University, Ile-Ife. The T&RF is situated within the rain forest zone, between latitudes 7^{o} $32^{'}$ and 7^{o} $33^{'}$N and longitudes 4^{o} $32^{'}$ and 4^{o} $40^{'}$E, at about 200 m above sea level. The climate of the area is tropical with annual rainfall of about 1400 mm (Okusami and Oyediran, 1985). The parent rock of the soils is coarse-granite gneisses and pegmatites, giving rise to coarse-textured soils. The experimental plots consisted of three plantations namely; citrus, cacao and oil palm which were established in 1974. No form of soil amendment (fertilizer, manure or lime) was used on the plots, except occasional application of fungicide (commonly copper sulphate) to control black pod disease in the cacao plantation.

Soil samples were collected with the aid of a Dutch auger at the depths of 0 - 20 and 20 - 50 cm, top and subsoil, respectively at five locations arranged diagonally. Ten samples were taken on each plantation, making a total of thirty samples. The soil samples were bagged and taken to the laboratory for processing and analysis. In the laboratory, the samples were air-dried, crushed gently and sieved to separate the fine earth (< 2 mm) fraction from the gravel portion (> 2 mm). The fraction less than 2 mm in diameter was retained for laboratory analysis. Particle size distribution analysis was carried out using the hydrometer method described by Bouyoucos (1965). The soil pH was determined in water and 1 M potassium chloride (KCl) solution, using a glass electrode pH meter (Peech *et al.*, 1953). Organic carbon was determined by the Walkley-Black method (Nelson and Sommers, 1996), available phosphorus by Bray P1 method (Bray and Kurtz, 1945) and exchangeable cations (Ca, Mg, K and Na) contents of the soil were determined by extracting the soils with 1 N neutral ammonium acetate solution. The concentrations of Ca, Mg, K and Na in the filtrate were then determined, using a flame photometer for Ca, K and Na while Mg was by atomic absorption spectrophotometer (IITA, 1979). Exchangeable acidity was determined by 1 N KCl extraction and titrated with 0.05 N NaOH solution (McLean, 1965) while the effective cation exchange capacity (ECEC) was evaluated by the summation of the exchangeable cations and exchangeable aluminum.

The data generated were analysed using the means, standard deviation and analysis of variance. The means were separated using the Duncan's Multiple Range Test at 5% level of probability (SAS, 1999). Coefficient of variation (CV) was calculated for each of the properties under the different vegetations. The variability was then classified after Wilding and Drees (1978) and Wilding (1988) method as follows:

i CV of < 15%: least variable
ii CV of 15- 35%: moderately variable
iii CV of > 35%: highly variable

Results and discussion

The soils of the experimental site occupy gently sloping sites at the intermediate position in the topography and were reportedly developed from coarse-grained granite and gneisses and classified as Ultisol (Iwo series) by Okusami and Oyediran (1985). All other soil-forming properties were relatively uniform except the vegetation (citrus, cacao and oil palm) which differed from one site to the other. Table 1 shows the mean, standard deviation and coefficient of variation of the physical and chemical properties of the top soil. The sand content was 71, 65 and 67% for the surface soils (0 - 20 cm) of the citrus, cacao and oil palm plantations, respectively. However, the values were not significantly different from one another at 95% probability. The sand content was least variable (with CV ranging from 6.11-14.50%), irrespective of the plantation. Babalola (1978) also recorded a low CV value (3.2%) for the soils of Ibadan, southwestern Nigeria while Idowu *et al.* (2003) reported a CV values of 2 to 9% for sand fraction in the surface soils under different land use types. The silt and clay contents ranged from 7 to 10% and 22 to 27%, respectively across the plantations. Furthemore, the differences among them were not significant ($p< 0.05$). The silt contents in the citrus and cacao plantations were highly variable with the CV of 40.86% and 37.88%, respectively, but was least variable in the oil palm plantation (CV: 14.10%) while clay contents were least variable (CV: 8.86 to 14.60%), irrespective of the plantation. In the subsoil (20-50 cm), however, sand and silt contents were lower while that of the clay was higher compared to the surface soil. They ranged from 57 to 62%, 7 to 8% and 30 to 36% for sand, silt and clay, respectively. The lower values of sand and silt contents at the B-horizon were possibly due to the dilution effect of the illuvial clay. Lower silt content had been reported for most soils derived from the basement complex in southwestern Nigeria (Okusami and Oyediran, 1985; Mbagwu *et al.*,1985; Ojetade *et al.*, 2014) while Ojanuga and Nye (1969) attributed the increase in the clay content in the subsurface horizons to the differential sorting of clay from the surface horizon to the subsurface horizon. Smyth and Montgomery (1962) had earlier attributed biological, physical, and at times, chemical processes as major causes of clay eluviation from the surface horizon to the subsurface horizon. However, the differences among the particle sizes were not significant ($p<0.05$). The sand content varied moderately (CV: 11.94 - 17.85%) in all the plantations, silt content was least variable (CV: 11.13%) in the citrus, moderately variable (CV: 25.63%) in the oil palm plantation and highly variable (CV: 49.14%) in cacao plantation. Clay content was moderately variable in the citrus and oil palm plantations, but highly variable in the cacao plantation (Table 1). Soil pH in water and KCl solution varied from 5.1 to 6.5% and 4.3 to 5.8% in the citrus, cacao and oil palm plantations, respectively. The mean of the pH in water for the cacao plantation was significantly different from those of the citrus and oil palm plantations, whereas the means of the pH in KCl solution for all the plantations were not significantly different ($p>0.05$). However, irrespective of the plantation, pH in both water and KCl solution were consistently least variable (CV<15%). This was in agreement with the work of Ogunkunle (1986; 1993) and Akinbola *et al.* (2006) (Table 1). Organic matter content (OM) content of the soils was relatively high following Adepetu (1986) classification of soil organic matter (SOM) content into low (0 - 1.5%), medium (1.5 - 2.5%) and high (>2.5%) for soils of SW-Nigeria. The OM contents varied between 4.66 and 5.94%. Visual field observation revealed litter layer on the soils of the plantations which subsequently decayed and mineralized to yield OM (Olayinka, 2009). This possibly explains the high OM content of the soils. The differences in OM content of the soils among the plantations were not significant ($p<0.05$) irrespective of the plantation and depth of sampling. While the SOM content of the oil palm plantation was least variable (CV=10.82%), those of the citrus and cacao plantations were moderately variable with the CV values of 25% and 17%, respectively. Available P of the soils varied from low to medium (4.84 – 7.06 ppm). Ataga (1978) classified the soil test value of available P for oil palm in acid and basement complex soils of southern Nigeria into low (< 5 ppm), medium (5-10 ppm) and high (>10 ppm). The differences among the available P values for the soils of the plantations were significant ($p<0.05$). However, irrespective of the plantation, the available P values were consistently moderately variable. Ojetade *et al*. (2013) observed similar trend. The CV values ranged between 17.99 and 21.88%. With respect to the exchangeable cations, K and Mg contents in the soils of the oil palm plantation were significantly different ($p<0.05$) from others, while only Mg in the citrus plantation was significantly different. However, this did not reflect in the total exchangeable bases which showed no significant difference. This was so because Ca contributed the most to the exchangeable bases. Within the plantations, K, Ca and Mg were highly variable. Irrespective of the plantations and depth of sampling, Na content was consistently least variable.

Conclusion

The study investigated the degree of variability of soil properties under different tree crop plantations. While some properties were consistently least variable, irrespective of the nature of the vegetation in the plantations, others exhibited different levels of variability across the plantations. In conclusion, vegetation was found to have mitigating effect on the degree of variability when compared with previous works on the variability of soil properties in the upland area of southwestern Nigeria.

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Table 1: Means, Standard deviation and CV of physical and chemical properties of the top soil (0 - 20 cm)

	Sand	Silt	Clay	pH		OM	Av. P	Exchangeable bases				TEB	EA			ECEC	BS
	←	(%)	→	H_2O	KCl	(%)	(ppm)	Na	K	Ca	Mg	←	Al	H	TA	→	
								←		cmolkg^{-1}				(%)		→	
Citrus plantation																	
Mean	71.0a	7.0a	22.0a	5.6b	5.0b	4.99a	5.89ab	0.11a	0.27a	2.00a	0.30b	2.68a	0.30a	0.30b	0.62a	3.26a	33.52a
SD	4.34	2.86	1.95	0.83	0.70	1.28	1.06	0.02	0.11	1.09	0.09	1.21	0.07	0.11	0.11	1.34	40.79
CV	6.11	40.86	8.86	14.82	14.00	25.65	17.99	15.94	40.89	54.50	54.66	45.13	23.57	34.23	31.03	41.03	121.69
Cacao plantation																	
Mean	65.0a	8.0a	27.0a	6.5a	5.8a	5.94a	7.06a	0.14a	0.28a	3.58a	0.69a	4.68a	0.24a	0.48b	0.72a	5.40a	5.40a
SD	5.29	3.03	3.49	0.29	0.27	1.06	1.55	0.02	0.13	1.70	0.33	1.87	0.11	0.08	0.18	2.03	2.03
CV	8.14	37.88	12.93	4.49	4.72	17.83	21.88	11.15	45.44	47.46	47.54	39.89	47.51	16.67	24.85	37.66	37.66
Oil palm plantation																	
Mean	67.0a	10.0a	23.0a	5.1b	4.3c	4.66a	4.84b	0.10a	0.12b	2.50a	0.54ab	3.27a	0.36a	0.22b	0.58a	3.85a	3.85a
SD	9.72	1.63	3.36	0.27	0.31	0.50	0.96	0.02	0.04	1.08	0.25	1.25	0.15	0.11	0.04	1.30	1.30
CV	14.50	14.10	14.60	5.34	7.17	10.82	19.93	16.11	30.50	43.36	46.37	38.18	42.13	49.79	15.50	33.81	33.81

Means on the same column with the same alphabets are not significantly different ($p > 0.05$).

OM = organic matter, Av. P = available phosphorus, TEB = total exchangeable bases, EA = exchangeable acidity, TA = total acidity, BS = base saturation

Table 2: Means, Standard deviation and CV of physical and chemical properties of the top soil (20 - 50 cm)

	Sand	Silt	Clay	pH		OM	Av. P	Exchangeable bases				TEB	EA				
				H_2O	KCl			Na	K	Ca	Mg		Al	H	TA	ECEC	BS
	← (%) →					(%)	(ppm)	← cmolkg^{-1} →									(%)
							Citrus plantation										
Mean	62.0a	8.0a	30.0a	5.0b	4.4a	2.52a	6.55a	0.10a	0.13a	2.07b	0.57a	2.89a	0.30a	0.34a	0.64a	3.45b	82.96a
SD	7.40	0.89	6.18	0.48	0.47	1.71	1.47	0.00	0.04	0.68	0.21	0.76	0.10	0.19	0.25	0.70	5.57
CV	11.94	11.13	20.60	9.60	11.75	67.71	22.42	0.00	31.93	32.88	37.18	26.23	33.33	57.33	39.22	20.14	6.71
							Cacao plantation										
Mean	57.0a	7.0a	36.0a	5.86a	4.82a	2.67a	5.89a	0.10a	0.19a	2.97a	0.57a	3.86a	0.46a	0.44a	0.90a	4.76a	80.97a
SD	9.74	3.44	13.08	0.50	0.89	0.63	1.50	0.00	0.07	0.75	0.29	1.08	0.21	0.22	0.31	1.25	4.39
CV	17.09	49.14	36.33	8.50	18.52	23.66	25.40	0.00	34.50	25.41	50.04	28.02	45.08	49.79	34.25	26.26	5.42
							Oil palm plantation										
Mean	59.0a	8.0a	33.0a	5.02b	4.38a	3.36a	5.35a	0.10a	0.18a	2.89a	0.69a	3.85a	0.44a	0.34a	0.78a	4.63a	83.24a
SD	10.53	2.05	10.33	0.41	0.41	1.75	0.80	0.00	0.08	0.16	0.18	0.24	0.05	0.17	0.16	0.34	2.71
CV	17.85	25.63	31.30	8.14	9.33	52.09	14.98	0.00	46.61	5.66	25.87	6.27	12.45	49.22	21.07	7.35	3.25

Means on the same column with the same alphabets are not significantly different ($p > 0.05$).
OM = organic matter, Av. P = available phosphorus, TEB = total exchangeable bases, EA = exchangeable acidity, TA = total acidity, BS = base saturation.