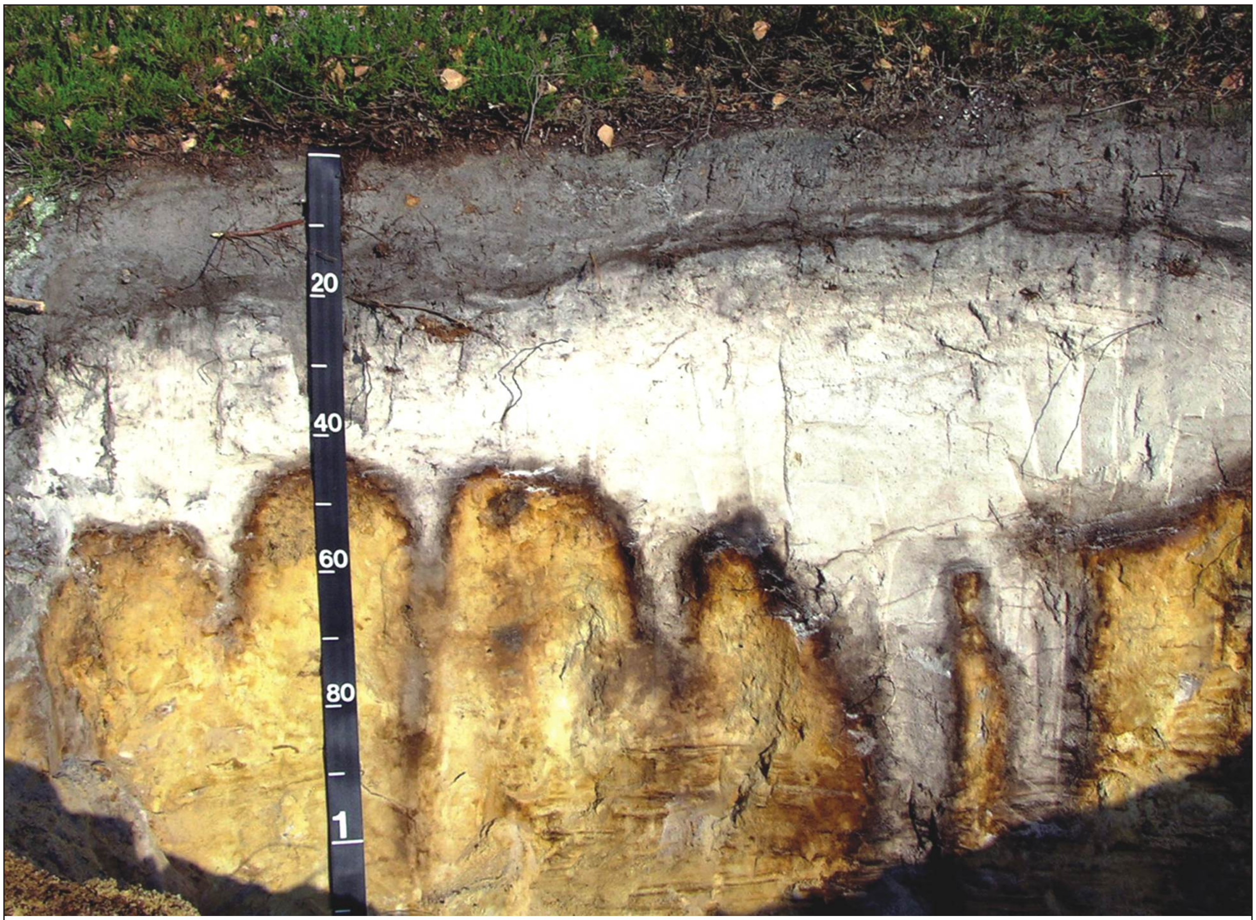

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Variability of Soil Properties at the Transition Zone Between Two Parent Materials in South Western Nigeria

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Abstract: A rigid grid soil survey was carried out on a 1,295 hectares land at the transitional zone between Basement complex and Sedimentary soils of southwestern Nigeria at Atuagbo-Ekhilor, Edo State. Six mapping units were established. A fertility evaluation of the soils was carried out by examining and sampling the soils at 0-20 cm depth. The number of observation point was dependent on the areal coverage of the mapping units identified. Sample were processed and analyzed for eighteen parameters. Thevariability of individual property as indicated by coefficient of variation differed widely: Silt, clay and gravel, organic C, total N, Avail. P, Mn, B, Zn and K were highly variable (CV>35%) while sand, Ca, Mg, N and ECEC were moderately variable (CV 15-35%). Three properties pH, Exch acidity and Base saturation were least variable (CV<15%). The variance ratio test indicate that some properties which are most influenced by management significantly (p<0.01) affected the variability of the soil. Data of this kind would give a better understanding of the soil fertility of the area and planning of management practices to be employed for optimum output. Also, data of this kind should accompany soil survey report so that soil map users can have a better understanding of the soils they are working with.

Key words: Soil properties, variability, mapping units, southwestern Nigeria

INTRODUCTION

Soil variability has been extensively studied at both small and large scales. This is evident in the reviews by Wilding and Drees (1978), Ogunkunle (1986 and 1993), Fasina (2002) and Zebarth *et al.* (2002). Much of the existing information on soil variability, including the few on tropical soils (Babalola *et al*., 2007; Areola, 1982), concentrates on soil variability. This is the component of total variability observed over a considerable distance of between two distinctly different units such as parent materials or land facets (Van wambeke and Dual, 1978).

Knowledge of the degree of variability of soil over an area and the factors responsible for this variability is essential for practical, commercial and experimental agriculture. Little information has been published to document variability at the transition zone between two parent materials and within mapping units with reference to soil nutrient status.

Soil exhibits tremendous variations both laterally and vertically. The result of some previous soil variability studies (Ogunkunle, 1986) have revealed very high variations between soil properties of two closely spaced spots 10 m apart on a uniform terrain on the Basement complex of southwestern Nigeria. Variations in soil properties have also been found to influence soil management and crop production (Fasina, 2005). Significant crop yield differences between plots on the same soil series due to differences in the native potassium have been encountered (Costigan *et al*., 1983; Shittu and Fasina, 2006). Soil variability study across the landscape prior to cropping would have revealed such differences and hence better informed landuse planning and management.

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It has also been established that for most arable crops, the control of crop performance is mainly in the plough layer (0-20 cm) where most plant roots concentrate, Similarly, Sopher and McCracken (1973) found that 70% of corn yield variation was due to soil nutrient or properties of the plough layer. Lal *et al*. (1975) also observed that the removal of 2.5 and 7.5 cm of the topsoil resulted in 50 and 90% reduction in maize yield.

Spatial variability in soils occurs mostly naturally from pedogenetic factors. Also, variability can occur as a result of the type of land use and management (Shittu *et al*. (2006). This can influence soil fertility, crop growth and yield. There is need to generate information on soil variability on farms which can be of use to farmers. This study was therefore undertaken to examine the spatial variability of soil properties in six mapping units at the transition zone between two parent materials in southwestern Nigeria.

MATERIALS AND METHODS

Description of Project Site

The project site is about 1,295 ha, located about 3 km northwest of Atuagbo town in the Esan Central local government of Edo state, Nigeria. It is about 10 km from Irua. It lies centrally within latitudes 6° 30'N and 7° 00'N and longitudes 6°00'E and 6° 30'E on the Topo sheet Ubiaja 285 SE of 1964. It is in the transition zone between rainforest and guinea savanna, generally referred to as forest-savanna mosaic. The mean monthly temperature ranges between 20.1 and 33°C. The project site is underlain by sedimentary deposition and Basement complex metamorphic rock. It has a humid climate with marked wet and dry seasons.

Soil Survey Method, Sampling and Analysis

A rigid grid method of soil survey was adopted at a scale of 1:10,000 to establish the mapping units (soil series). Auger observations were made at intervals of 200 m along each transects. Six mapping units were identified and demarcated on the base map. The area coverage of each of the mapping units was estimated (Iweke 75.85 ha, Mesan 34.42 ha, Iju 359.18 ha, Molo 315.50 ha, Agege 355.40 ha and Kulfo 155.65 ha). Surface soil (0-20 cm) samples were collected with the aid of soil auger from the mapping units. The number of sampling locations was proportionate to the areal coverage of each of the mapping units. The classification of the soils of the six mapping units is presented in Table 1.

The soil samples were air-dried, ground and sieved to separate the fine earth fraction (≤2 mm) from coarser fragments. Gravel content was determined gravimetrically as the percentage of particles with diameter >2 mm to the whole soil sample. Particle size analysis was done by the hydrometer method (Day, 1965). Soil pH was determined electrometrically in water (1:1 soil to water ratio). Organic carbon was analyzed by the dichromate wet oxidation method of Walkley-Black (1934). Total nitrogen was determined by Micro-kjedahl method. The exchangeable cations (Ca, Mg, Na and K) were extracted in 1 N neutral NH_4OAC. Na, K contents were determined by flame photometer while Ca and Mg were by atomic absorption spectrophotometer.

Table 1: Soil classification

Pedon	Local classification	USDA soil classification	FAO soil classification	Mapping unit areal (ha)
NW	Iweke series	Oxic dystropept	Luvic arenosol	75.85
DP	Mesan series	Alfic udarent	Haplic gleysol	34.42
AB	Iju series	Plinthic kandiudalf	Plinthic lixisol	359.18
ML	Molo series	Plinthic kandiudalf	Plinthic lixisol	315.50
AG	Agege series	Typic kandiudalf	Haplic lixisol	355.40
KF	Kulfo series	Ustoxic dystropept	Eutric cambisol	155.65

Statistical Analysis

The variability of the soil properties within and between the different mapping units was measured by estimating the mean (x), the standard deviation (SD) and coefficient of variation (CV). The variance ratio test was also calculated to test the between /within unit ratio of the mean square (i.e., F-ratio) for significance.

RESULTS AND DISCUSSION

The Table 1 shows the classification of the pedons and their local and international names. The local names were according to Moss (1957). Their appropriate taxonomic classifications were according to USDA soil taxonomy (Soil Survey Staff, 1994) and FAO/UNESCO (1988) soil map of the world revised legend. The areal covered of each of the mapping units were indicated.

Variation of Soil Properties Using Coefficient of Variation (CV)

The coefficient of variation of the properties for individual mapping unit as presented in Table 2 indicated that some soil properties are more variable than others. The mean sand content appears to be more homogenous with all the mapping units, having CV <15% (Wilding and Dress, 1978). The CV of sand ranges from 4.33-18.4%. High CV were recorded for silt (16.56-68.04%), clay (1.25-39.28%) and gravel (2.82-76.58%) content. With respect to gravel content, all the mapping units are extremely variable except for Iju and Kulfo soils, indicating that the soils are more heterogeneous in gravel content when mineral fractions are considered.

Chemical properties for different mapping units indicted that total N, available P, B organic C, K and Mg with CVs, range of 40.4-75.7, 52.8-88.9, 27.6-70.5, 33.8-75.2, 28.0-51.2 and 21.6-43.7%, respectively are more variable while Ca, Na, Exch. Acidity, ECEC, Base. Saturation, Zn with CVs range of 0.93-28.5, 15.8-39.8, 0.00-15.2, 14.9-26.8, 0.00-1.47 and 5.9-25.3%, respectively are less variable. These values obtained when grouped together by the method of Wilding and Drees (1978) puts Iju, Agege, Kulfo series as least variable while Iweke and Molo series are moderately variable while Mesan series is most variable.

Table 2: Variability of soil properties among mapping units 0-20 cm depth

Mapping		pH	Sand	Silt	Clay	Gravel	Mn	Ca	Mg	K	Na	E.A	CEC	BS	C	N	B	P	Zn
unit		(H_2O)	(%)	(%)	(%)	(%)	(ppm)	------------------ Cmol/kg ----------------						(%)	(%)	(%)	-------	(ppm)	---------
Iju	CV	3.08	13.20	16.56	16.29	14.47	19.77	28.56	21.69	51.18	39.84	5.83	26.85	0.59	42.80	40.65	28.52	89.02	25.26
	SD	0.16	3.65	3.99	2.34	4.890	5.46	0.8	0.33	0.20	0.23	0.01	1.45	0.58	0.47	0.05	2.11	5.14	1.41
	X	5.30	27.66	24.10	14.38	33.81	27.63	2.79	1.51	0.39	0.58	0.14	5.41	97.50	1.11	0.11	7.40	5.78	5.58
	S^2	0.03	13.33	15.91	5.48	23.92	29.82	0.63	0.11	0.04	0.05	0.00	2.11	0.33	0.22	0.00	4.45	26.45	1.98
Iweke	CV	2.87	11.63	68.04	39.28	45.56	37.56	10.4	32.14	52.90	26.61	7.09	18.18	0.73	40.70	40.66	28.69	65.47	25.38
	SD	0.16	5.62	4.52	2.38	8.640	3.45	0.25	0.42	0.19	0.12	0.009	0.85	0.71	0.42	0.04	1.57	1.85	0.93
	X	5.50	48.30	6.65	6.05	18.96	9.18	2.39	1.33	0.36	0.45	0.13	4.65	97.00	1.02	0.10	5.48	2.83	3.66
	S^2	0.03	31.55	20.45	5.64	74.62	11.89	0.06	0.18	0.04	0.01	8E-05	0.72	0.50	0.17	0.002	2.47	3.43	0.86
Mesan	CV	0.68	4.33	44.47	1.25	39.35	8.93	45.13	30.14	41.59	38.57	0.00	39.28	1.47	47.10	47.14	28.28	47.14	132.30
	SD	0.04	1.65	11.31	0.14	9.810	1.69	1.06	0.28	0.14	0.21	0.00	1.69	1.41	0.71	0.71	0.14	0.71	6.15
	X	5.23	38.23	25.44	11.30	24.94	19.00	2.35	0.92	0.34	0.55	0.15	4.31	96.00	1.50	1.50	0.50	1.50	4.65
	S^2	0.00	2.74	128.00	0.02	96.33	2.88	1.13	0.08	0.02	0.04	0.00	2.86	2.00	0.50	0.50	0.02	0.50	37.85
Molo	CV	5.18	9.52	47.86	36.05	76.58	25.86	0.93	43.71	27.86	21.36	15.23	14.98	0.00	75.20	75.78	70.50	76.45	5.95
	SD	28.00	3.27	7.65	3.19	34.03	2.41	0.03	0.58	0.10	0.12	0.02	0.82	0.00	0.42	0.04	0.61	2.16	0.15
	X	5.32	34.30	15.97	8.84	44.43	9.33	3.12	1.33	0.37	0.55	0.14	5.49	98.00	0.56	0.05	0.87	2.83	2.57
	S^2	0.08	10.66	58.44	10.15	1158	5.82	8E-04	0.34	0.10	0.13	4E-04	0.68	0.00	0.18	0.002	0.37	4.68	0.02
Agege	CV	1.38	18.43	31.26	26.67	45.94	39.86	14.58	42.83	30.05	15.81	3.27	23.48	0.84	36.00	40.41	54.71	58.23	35.10
	SD	0.07	7.22	5.74	2.99	23.92	7.72	0.38	0.79	0.08	0.06	0.005	1.21	0.82	0.24	0.03	0.19	1.93	1.62
	X	5.14	39.19	18.37	11.22	52.08	19.38	2.63	1.85	0.25	0.40	0.15	5.29	97.00	0.68	0.07	0.35	3.31	4.63
	S^2	0.005	52.19	32.98	8.96	572.2	59.63	0.14	0.63	0.006	0.004	3E-05	1.54	0.67	0.05	0.008	0.04	3.70	2.64
Kulfo	CV	2.49	5.23	49.37	28.36	2.820	33.84	23.17	25.08	28.04	17.94	9.42	18.80	0.92	54.50	51.40	27.66	52.88	22.18
	SD	0.13	1.85	5.32	2.88	1.040	3.43	0.54	0.37	0.12	0.10	0.01	0.93	0.89	0.39	0.04	1.79	3.89	2.41
	X	5.42	35.45	10.77	10.15	36.90	10.14	2.31	1.48	0.43	0.58	0.13	4.94	97.40	0.71	0.07	6.48	7.37	10.88
	S^2	0.02	3.44	28.27	8.29	1.080	11.77	0.29	0.14	0.01	0.01	2E-04	0.86	0.80	0.15	0.001	3.21	15.18	5.82

8E-05 = 5×10^{-8}, 4E-04 = 4×10^{-4}, 3E-05 = 5×10^{-5}, 2E-04 = 4×10^{-2}

Soils between the mapping units are more uniform in those properties which are genetically important such as textural properties, (% sand, silt, clay and gravel), pH, exch. acidity and percentage base saturation while those properties which are related to management e.g., (Ca, Mg, Na ECEC, organic C, Total N, Avail P, Mn, B and Zn) are more variable (Table 3).

The observed difference in the variability of physical properties can be attributed to rock weathering, biological action, micro relief and parent material from which the soils are formed. The high CVs for gravel in some mapping units e.g., (Iweke, Yampere, Molo and Agege) indicate that the soils are not uniform with respect to gravel content (Table 3).

The CV result obtained (Table 3) when all the mapping units are pulled together shows that some chemical properties are less variable than others, pH, Exch. Acid, B. saturation, Ca Mg, Na ECEC are less variable while exchangeable K, Organic C, Total N, Avail P, Mn, B and Zn appear to be more variable with CVs >35%. The CV values obtained in this study when grouped together by method of Wilding and Drees (1978) put Iju, Agege and Kulfo as least variable. Iweke and Molo are moderately variable while Mesan is most variable. Also the CV value obtained (Table 4) for soil properties put pH, Exch. Acidity, Base saturation as least variable having CV <15% while sand, clay, Ca, Mg, Na, ECEC. are moderately variable (CV 15-35%) and silt, gravel, K, organic C, Total N, Avail P, Mn, B, Zn are extremely variable having CV >35%.

The high level variation observed could be attributed to soil management practice employed in the area. At the time of survey, apart from some arable crops like cocoyam, cassava yam, that were grown, it was noted that oil palm trees were very common in the area. It has been noted that oil palm do have remarkable influences on soil chemical properties, Kang (1977) and Ogunkunle (1986). Zebarth *et al.* (2002) noted that human induced changes in soil can fundamentally alter the natural pattern of soil distribution in landscape even over relatively short time scales. Also Becket and Webster (1971) showed that in cultivated area, contrasting crops, soil amelioration and addition of fertilizer super impose differences between fields in addition to the variation already present in the native soils.

Table 3: Estimate of variability between the mapping units

Soil properties	CV	- X	SD	S^2	F-value	Significance
pH (H_2O)	3.5	5.3	0.2	0.04	4.70	*
Sand (%)	21.1	37.6	7.9	63.4	0.02	**
Silt (%)	55.4	15.4	8.5	73.5	0.23	**
Clay (%)	35.7	10.1	3.6	13.1	0.63	**
Gravel (%)	55.0	35.3	19.4	378.5	17.31	ns
Ca (cmol kg^{-1})	21.1	2.5	0.6	0.3	36.00	ns
Mg (cmol kg^{-1})	34.8	1.4	0.5	0.2	40.15	ns
K (cmol kg^{-1})	40.0	0.4	0.2	0.02	64.47	ns
Na (cmol kg^{-1})	28.3	0.5	0.2	0.02	34.58	ns
Exch. Acidity (cmol kg^{-1})	10.1	0.1	0.01	0.0	2.11	*
ECEC (comol kg^{-1})	21.1	5.0	1.1	1.1	75.78	ns
Base sat (%)	0.8	97.2	0.9	0.7	14.65	ns
Org. C (%)	66.1	0.9	0.6	0.4	0.15	**
Total N (%)	49.7	0.1	0.04	0.0	19.41	ns
Avail P (ppm)	76.4	4.1	3.1	9.6	15.61	ns
Mn (ppm)	54.3	15.2	8.3	68.5	0.01	**
B (ppm)	79.3	4.1	3.3	10.5	0.01	**
Zn (ppm)	55.6	5.9	3.3	10.9	0.01	**

*p<0.05, **p<0.01, ns = Not significant

Table 4: Grouping of soil properties using CV values

Group of properties	Range of CV value	Soil properties
Least variable	<15%	pH, Exch acidity, B. sat
Moderately variable	15-35%	Sand, Ca Mg, Na, ECEC
Extremely variable	>35%	Silt, clay gravel, K, org C, total N, Avail P, Mn, B, Zn

Adopted from Wilding and Drees (1978)

Variance Ratio Test (F-Ratio Test)

The result in Table 3 indicate that for soil properties considered, 50% of the mapping units are homogenous with reference to nine out of the eighteen properties studied showing significance difference between the mapping units. All the physical properties except gavel content significantly ($p<0.01$) affect the homogeneity of the soil (Table 3). The high variability within the mapping unit obtained for available P in this study was however not significant, despite the high CVs obtained. This can be explained from the view expressed by Becket and Webster (1971) that the variability in these properties which are largely affected by management introduced by differences in crops and management practice within a soil series could be as high as or higher than the variability introduced between series.

CONCLUSION

The high level of variability associated with these soils can be accounted for in term of their complex nature arising from their parent materials, landuse and management practices. The soils lie on the fringes of two-parent materials (Sedimentary and Basement complex). Mesan (highly variable), Iweke and Molo series all differed significantly in most of their chemical properties, Hence they should be managed differently. They cannot be representative enough or uniform for the whole land area for agricultural purpose.

In order to achieve optimum crop production, there is need to embark on the use of recommended cultural practices, rational use of fertilizers accompanied with optimum soil and crop management inputs that will take into cognizance, the variability of the soils. Since agronomic trials are measured by yield produced and such yields are highly dependent on soil fertility, the result will be affected by high soil variability as demonstrated in this study. Minimum tillage operation is recommended here, in order to effectively control water erosion and hence land degradation.

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