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Fertility Status of Soils of the two major cocoa producing Local Government Areas (Etung and Ikom) in Cross River State, Nigeria

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ABSTRACT

Fertility studies were carried out on the status of Basalt soil of Etung and Ikom Local Government Areas of Cross River State for Cocoa production. Stratified – random sampling technique was used in taking soil samples at 0-25cm and 25-50cm depth at different locations in Etung and Ikom Local Government Areas of Cross River State. Analytical results indicated that the soils in these areas are clay loam. The sand content of the soil ranged from 34.20 % to 84 %. Etung Local Government Area had the highest mean sand fraction of 50.54% compared to Ikom having 49.71%. Sand content of the soil generally decreased with increased in soil depth while the silt and clay content ranged from 9.80 % to 16.00 % and 8.00 % to 48.00 % respectively. The silt and clay content of the soils were higher in the surface soil than the subsurface soil in both Local Government Areas having a textural class of sandy loam in the surface soil and clay in the subsurface soil. The soil organic matter content of the surface soils in both Local Government Areas was generally higher than those of the subsurface soils with a mean value of 2.56 % and 3.07 % in the surface soil and 2.90 % and 2.94 % in the subsurface soil respectively. The soil pH decreased with depth; at 0-25 cm it ranged from 5.46 and decreased to 5.29 at 25-50 cm. The effective cation exchange capacity ranged from 5.09 cmol/kg to 10.6 cmol/kg with a mean value of 7.00 cmol/kg and 7.86 cmol/kg for surface and subsurface soils respectively. The exchangeable bases (Ca Mg, k, and Na) and ECEC of these soils were below the critical value required for cocoa production.

1. Introduction

Since the discovery of crude oil in Nigeria in the late sixties, there has been a drastic shift from agriculture which was the central hub of Nigeria economy to crude oil production. Since the oil boom, agriculture, which was the major contributor to the Gross Domestic Product (GDP) of the country, has been relegated to the background (Jimoh, 2005). Nigeria dependence on oil revenue as the primary source of income to the nation has been described as unhealthy because of the widespread agitation for a cleaner source of energy than fossil fuel. As such, the government is now considering the revitalization of the agricultural sector of the economy.

Some of the major tree crops that had contributed immensely to the external earnings of the country in the past included Oil palm, Rubber, Cocoa, and Coffee. The focus of the government is to revitalize the production of some of these crops, especially cocoa and oil palm. Due to years of neglect, there has not been a major improvement in Cocoa production technology. This has brought down the ranking of Nigeria as the world's fourth largest producer of Cocoa. Statistical record in 2005/2006 production season indicated that Nigeria produced 170,000 tons of Cocoa which accounted for about 5% of global production (ICCO, 2006).

One of the possible reasons for this low yield may among other things, be due to nutrient depletion of Cocoa plantation soils as a result of "nutrient mining" through Cocoa pod harvest without nutrient replacement as more than 85% of smallholder Cocoa farmers in Nigeria do not use fertilizer on Cocoa, old and poor planting material, depletion of humid rainforest and decline in soil fertility, lack of good agricultural practices in the management of Cocoa plantation (Iremiren *et al*., 2012) and the prevalence of malaria fever among farmers which has been reported to account for about 3% loss in the GDP from the agricultural sector (Jimoh, 2005).

There is an urgent need for improvement in all the series of activities from site selection to initial processing that will ensure sustainable Cocoa farming in Nigeria. The objective of the study was to assess the fertility status of the soils of Etung and Ikom Local Government Areas of Cross River State which are the two major cocoa producing areas and to suggest possible management practices that could enhance high productivity and sustainability of Cocoa production in these local government areas.

2. Materials and Methods

This study was carried out in Cross River State, Nigeria in October, 2015. Two high cocoa producing Local Government Areas were selected for the study. The selected Local Government areas were; Etung and Ikom Local Government Areas in the Central Senatorial district of Cross River State. (fig.1). The selected Local Government Areas have several villages including Ajassor 1, Ajassor mission, Agbokim, Bendeghe, Last motor, and Apparating. Composite soil samples were collected in Cocoa plantation farms from different locations in the two Local Government areas using the soil auger. Soil samples were taken at two depths; 0-25cm and 25 - 50cm at established reference point positioned along North-South and East-West transects at a different topographical location of the landscape. The samples were put in labeled polyethylene bags and transported to the Soil Science laboratory for processing before laboratory analysis.

2.1 Laboratory Analyses

The soils were analysed for physical and chemical properties. Particle size was determined by Bouyoucous hydrometer method (Bouyoucous 1951). Soil pH was measured in 1:1 soil-water ratio using an EDT BA350 digital pH meter. Organic matter was determined by the dichromate wet oxidation method as described by Nelson and Sommer (1996). Total N was determined using the micro Kjeldahl method as described by Jackson (1965). Available P was determined using Bray P-1 method (Bray and Kurtz, 1945).

Electrical Conductivity was measured in the extract obtained from 1: 2.5 soil: water suspension using a conductivity bridge.

Exchangeable Cations (Ca^{2+}, Mg^{2+}, K^{+}, and Na^{+}) were extracted with 1N ammonium acetate (NH_4OAc) buffered at pH 7.0 (Thomas, 1996). Exchangeable K and Na in the extracts were read through the Jenway flame photometer (Model PFP7). Ca and Mg were read on Atomic Absorption Spectrophotometer (AAS). Exchangeable acidity was extracted with I N KCl and determined by titration with 0.05 N NaOH using phenolphthalein indicator (McClean 1982). Effective Cation Exchange Capacity was obtained by the summation method while Percent Base Saturation was calculated as follows:

$$\% \text{ Base Saturation} = \frac{\text{Exchangeable Bases}}{\text{ECEC}} \times \frac{100}{1}$$

3. Results and Discussion

3.1 *Physical properties*

Across the two Local Government Areas (Etung and Ikom), sand fraction ranged from 34.20% to 84% as shown in Tables 1 and 2. Etung had the highest mean sand fraction of 50.54% compared with Ikom (49.71%). The sand fraction in most of the soils decreased with increase in soil depth. The silt fraction of the soils ranged from 7.80% to 19.20% with a mean value of 14.45 % in Etung Local Government and 14.11% in Ikom Local Government Areas respectively. The silt fraction was higher in the surface soil with the mean value of 14.40% and 14.23% in the subsurface in Etung Local Government Area and 13.75% in the surface soil and 16.15% in the subsurface soil in Ikom Local Government Area respectively.

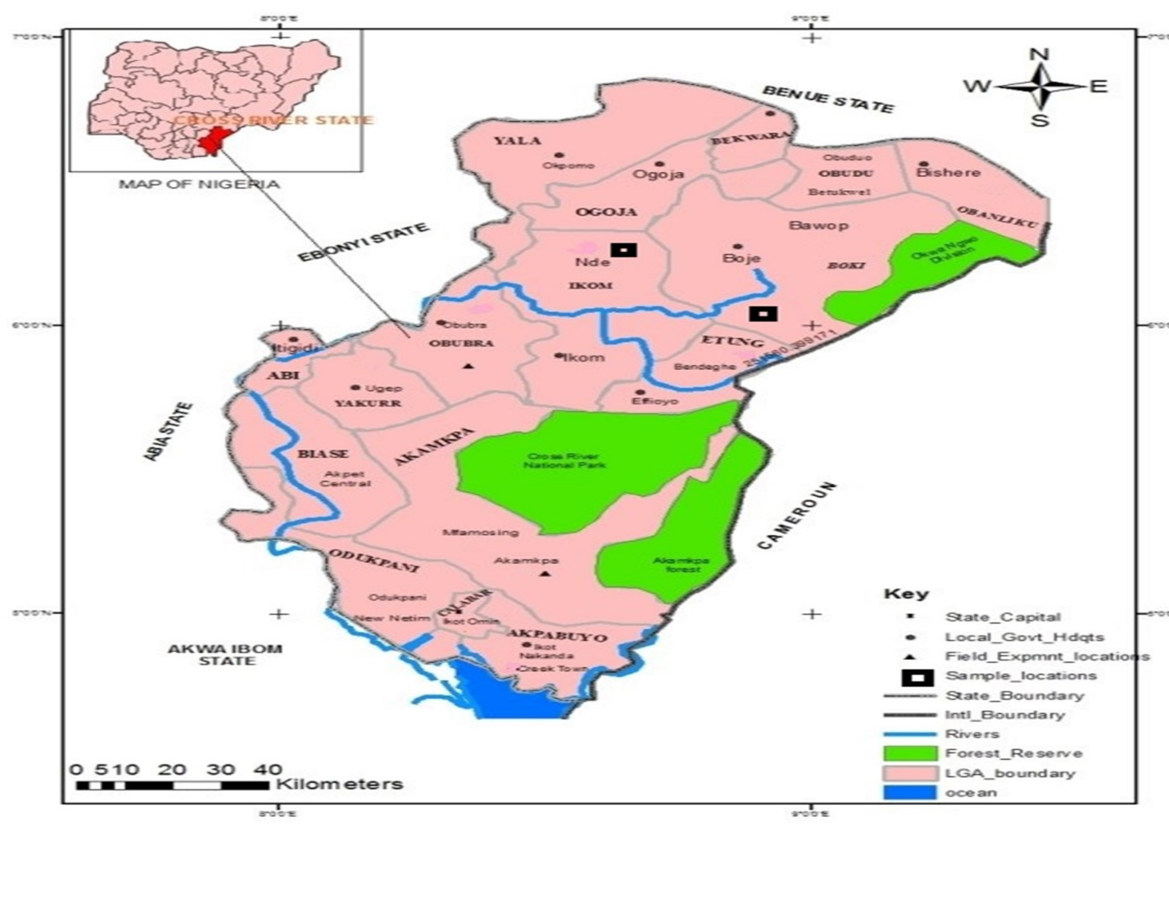

Table 1: Physical and Chemical Properties of Soils Sampled at Etung Local Government Area.

			Physical Properties				Chemical Properties											
S/N	LOCATION	Depth (cm	Sand %	Silt %	Clay%	TEXTURAL CLASS	pH	EC ds/m	OM %	TOTAL N%	AV.P mg/kg	Ca	Mg	Na Cmol/Kg	K	EA	ECEC	% PBS
		0 – 25	54.00	17.80	28.20	scl	7.10	0.021	2.89	0.07	1.67	3.20	1.40	0.05	0.12	1.03	5.80	82.24
1	Bendeghe I	25 -50	50.00	19.80	30.20	scl	5.90	0.018	2.90	0.08	1.60	4.00	1.30	0.07	0.09	1.20	5.66	78.8
		0 – 25	70.00	7.80	22.20	scl	5.80	0.013	4.59	0.12	4.50	4.40	1.40	0.06	0.10	1.30	7.26	82.09
2.	Bendeghe II	25 -50	64.00	7.80	28.20	scl	6.40	0.014	4.30	0.11	5.36	8.90	2.80	0.05	0.10	1.20	13.05	90.80
		0 – 25	54.00	13.80	32.20	cl	5.00	0.020	3.64	0.10	5.50	2.40	1.20	0.06	0.13	1.40	5.09	72.50
3.	Agbokim I	25 -50	50.00	13.60	36.40	cl	4.80	0.023	2.38	0.06	2.34	2.80	1.30	0.06	0.09	1.50	5.74	73.87
		0 – 25	46.00	13.60	40.40	cl	5.20	0.040	2.89	0.07	2.01	2.80	1.20	0.06	0.09	1.50	5.65	73.45
4	Agbokim II	25 -50	46.00	13.00	40.00	cl	4.90	0.042	1.87	0.05	1.17	4.00	1.30	0.07	0.11	1.60	7.07	77.37
		0 – 25	45.40	14.20	40.40	sl	4.90	0.030	2.89	0.07	1.50	3.20	1.50	0.04	0.16	1.82	6.72	72.92
5.	Ajassor I	25 -50	39.40	18.20	42.40	sl	4.80	0.031	2.58	0.06	1.00	2.70	1.40	0.06	0.10	1.79	6.05	70.41
		0 – 25	50.20	17.80	32.00	cl	4.90	0.032	2.61	0.07	5.00	3.20	1.40	0.06	0.13	1.60	6.38	75.08
6.	Ajassor II	25 -50	64.20	10.80	25.00	ls	5.00	0.030	2.00	0.06	2.17	4.00	1.50	0.05	0.14	1.66	7.35	77.41
		0 – 25	40.20	15.80	44.00	si	5.30	0.042	3.71	0.09	7.34	4.80	1.70	0.05	0.13	1.70	8.38	79.62
7.	Ajassor III	25 -50	34.40	17.80	48.00	scl	5.20	0.041	1.87	0.05	3.84	4.40	1.50	0.04	0.12	1.78	7.84	77.30
		Mean	50.54	14.45	35.00		5.37	0.028	2.93	0.08	3.21	3.91	1.60	0.06	0.12	1.51	7.00	77.42

scl = sandy clay loam; cl = clay loam; si = silty clay; ls = loamy sand, EC = electrical conductivity, OM = organic matter, EA = exchangeable acidity

The clay fraction in the subsurface soil was higher than those of the surface soil in both Local Government Areas. In the two Local Government Areas, the soils were deep enough for proper development of cocoa roots. Hardy (1960), proposed a general rule of 1.5m as minimum soil depth for optimum cocoa growth. Nevertheless, where all other aspects of soil suitability parameter are met, soils with only 1m depth may be acceptable. The textural composition of the soils in the various locations studied indicated that the level of sand and clay fractions was adequate for cocoa production. The texture of the soil ranged from sandy loam in the surface soil to clay in the subsurface soil.

3.2 *Chemical properties*

The soil pH in Etung Local Government Area soil at 0 -25cm depth was 5.46 and decrease with depth to 5.29 at 25-50cm indicating that the soil is moderately acidic in the surface soils and strongly acidic in the subsurface soils compared to that of Ikom Local Government Area with mean value of 5.20 on the surface soils and 5.23 on the subsurface soils. The lower pH value observed in the soils of Etung Local Government is as a result of the long-term average annual rainfall ranging from 2500 - 3500mm (Cyprian *et al.,* 2014, Grace *et al.,* 2013). This high rainfall is probably the cause of excessive leaching of soluble bases leading to the low pH observed in the soils. This trend has been reported by some researchers (Onweremadu and Uhuegbu, 2007; Yesin *et al.,* 2010). The low pH of these soils has implications for the management of applied phosphorus fertilizers. At pH below 5.5, it has been reported that most of the applied P are fixed by iron and aluminum oxide (Agbenin, 2003, Igwe *et al.,* 2005).

The soil organic matter varies appreciably in the soils of the study areas. The mean value of organic matter ranged from 2.56% to 3.07 % in the surface soil and 2.90 % to 2.94 % in the subsurface soil respectively. Organic matter is high in the surface soil than the subsurface soil due to the accumulation of leaf droppings and decayed plant residues. The total nitrogen content of the soil was low with a mean of 0.07% and 0.06% for both surface and subsurface soils respectively.
The soil nitrogen levels were below the critical level of 0.9 % that has been established as ideal soil for cocoa cultivation in Nigeria (Egbe *et al.,* 1989).

The available phosphorus content of the soils was low with a mean value of 3.21mg/kg in Etung and 5.64 mg/kg in Ikom Local Government Areas respectively. However, the available P was generally very low in the two Local Government Areas due to excessive leaching and was below the critical value of 10 mg/kg meant for ideal cocoa production in Nigeria (Wood, 1989). This is an indication that P-fertilizer is needed on cocoa farms across the various locations in Nigeria for good growth and sustainable optimum pod production.
The total exchangeable acidity of the soils had a range of 1.03 to 1.82 cmol/kg with a mean value of 1.51cmol/kg and 1.41cmol/kg for both surface and subsurface soils respectively. Exchangeable acidity in Etung Local Government Area was higher in the surface soil with a mean value of 1.48 cmol/kg. The calcium content of the soils had values that ranged from 3.20 cmol/kg to 8.9 cmol/kg with mean values of 3.91cmol/kg and 4.67cmol/kg respectively. The value was lower in the surface soil, and higher in the subsurface soil in both Local Government Areas and these values were below the critical value of 5 cmol/kg for ideal cocoa soil (Smyth,1966).

The value of Mg in the soils ranged from 1.20 cmol/kg to 2.80 cmol/kg with the mean value of 0.12 cmol/kg and 1.67 cmol/kg for surface and subsurface soils respectively. Mg is also higher in the subsurface soil than the surface soil. This could be as a result of excessive leaching caused by high rainfall and might also be due to continuous pod harvesting (nutrient mining) without replacement in the form of fertilizer application, as 95% of farmers in the study area do not use fertilizer on cocoa (Agbeniyi *et al*., 2009). Potassium in the soils ranged from 0.09cmol/kg to 0.16cmol/kg with mean value of 0.12cmol/kg and 0.08cmol/kg respectively. K was higher in the surface soil of Etung Local Government Area with the mean value of 0.12cmol/kg than the subsurface soil 0.11cmol/kg and higher in the subsurface soil of Ikom Local Government 0.12cmol/kg than the surface soil 0.11cmol/kg. K in these soils is higher than the critical value of 0.03cmol/kg. This is an indication that K - fertilizer would not be needed on the cocoa farms for optimum cocoa growth on the soils in the first two years. This is consistent with the views expressed by Ipinmoroti *et al.,* (2005).

The value of Na ranged from 0.04 cmol/kg to 0.08 cmol/kg with the mean value of 0.06 cmol/kg and 0.07cmol/kg surface and subsurface soils respectively. The effective cation exchange capacity ranged from 5.09 to 10.6cmol/kg with a mean value of 7.00cmol/kg and 7.86cmol/kg for surface and subsurface soils respectively. The exchangeable bases and ECEC of these soils were generally below the critical requirement for cocoa production. Base saturation ranged from 70.41% to 90.80% with a mean value of 7 7.42% and 81.76% for both surface and subsurface soils respectively. Base saturation was higher in the subsurface soil than surface soil. This is as a result of excessive leaching of the bases elements

Table 2: Physical and Chemical Properties of the Project Site at Ikom L.G.A.

S/N Location	Depth Cm	Physical Properties				Chemical Properties											
		SAND %	SILT %	CLAY %	TEXTURAL CLASS	pH	EC ds/m	OM %	TOTAL N%	AV.P Mg/kg	Ca	Mg	Na cmol	K /kg	EA	ECEC	BASE SAT. %
	0 - 25	54.00	9.60	36.40	cl	5.10	0.022	3.37	0.08	7.01	3.02	1.40	0.06	0.01	1.30	5.96	78.19
Aparabong 1	25- 50	42.00	13.60	44.40	cl	5.30	0.040	3.81	0.10	11..51	6.00	2.00	0.05	0.11	1.20	9.36	87.18
	0 -25	44.00	15.60	40.40	cl	5.10	0.041	2.72	0.06	3.50	4.00	1.40	0.07	0.13	1.60	7.30	78.08
Aparabong 2	25 -50	46.00	15.60	38.40	cl	5.20	0.031	2.21	0.08	5.00	4.40	1.50	0.08	0.14	1.30	7.42	82.48
	0 -25	58.00	16.00	26.00	cl	5.40	0.026	3.13	0.08	3.40	5.20	1.80	0.06	0.10	1.54	8.70	82.30
Last Motor 3	25-50	54.15	14.24	31.61	cl	5.20	0.026	2.79	0.07	3.40	5.21	1.60	0.06	0.12	1.50	8.49	82.33
	Mean	49.71	14.11	36.20		5.22	0.031	3.01	0.08	5.64	4.67	1.67	0.07	0.12	1.41	7.86	81.76

scl = sandy clay loam; cl = clay loam; si = silty clay; ls = loamy sand, EC = electrical conductivity, OM = organic matter, EA = ex changeable acidity.

3.3 Coefficient of correlation

There was a significant positive relationship between sand and clay (0.966* *) in the surface soil and a negative significant relationship between sand and silt (-0.658*) in the subsurface soils of both Etung and Ikom Local Government Areas. Sand is also significant and positively correlated with electrical conductivity in surface soil (0.874*). Total nitrogen in the soil was positively correlated with sand on the surface soil (0.680*) but is not on the subsurface soil. Nitrogen correlated negatively on surface soil (-0.648*) but not on the subsurface soil. This shows that as nitrogen increases in the surface soil, it decreases in the subsurface. Organic matter was negatively correlated with clay (- 0.644*) indicating that soil organic matter has higher water holding capacity than clay thereby promoting aggregation of heavy clays. Mineralization of organic matter releases essential mineral elements including nitrogen, potassium, phosphorus, calcium. Organic matter in the subsurface soil was positively correlated with total nitrogen (0.925**), available P (0.772**), calcium (0.795**), magnesium (0.841**) and ECEC (0.724*). This is an indication that the exchangeable bases in the subsurface soil were higher than the surface soil in most of the soils as a result of excessive leaching of soluble bases leading to low pH observed in the soils (Onweremadu and Uhuegbu, 2007). pH was positively correlated significantly with organic matter (0.732*), total nitrogen (0.774**), availa ble phosphorus (0.790**), calcium (0.647*), magnesium (0.736*) and ECEC (0.675*) respectively on the subsurface soils as shown in Table 4.

4. Conclusion and Recommendation

The nutrient holding capacities of these soils as indicated by the CEC were low 7.00 cmol/kg and 7.86 cmol/kg for both surface and subsurface soils respectively. The rainfall both in amount and intensity was higher in Etung Local Government Area. These two factors combined with the low pH of the soils will require special management technique to obtain optimal productivity of cocoa and will also require caution in the type and method of fertilizer application on the soils. Fertilizer having an appreciable amount of CaO and MgO in addition to N, P and K will be of uttermost benefit for Cocoa production in these Local Government Areas.

Therefore, the recommended rate of N, P and K for low fertility soils (FFD, 2011) could be adopted using non-acidifying fertilizer sources with quantities of MgO and CaO that will be sufficient to raise the pH of the soils above 5.5 and a good supply of Ca and Mg. From several studies on soils, the use of organic manure and partially acidulated phosphate rocks as fertilizer sources is highly recommended. Concerning the application of the mineral fertilizers, a split application is recommended to prevent leaching that may result from the high rainfall amount and intensity in these areas.

Table 3: Coefficient of Correlation at 0 – 25cm Depth

Pearson correlation	Sand	Silt	Clay	p^H	EC	OM	Total N	AV.P	Ca	Mg	Na	K	EA	ECEC	Base Sat.
Sand	1	-.523	.966**	.369	.874**	.606	.680*	-.246	.166	-.050	.209	-.265	-.576	-.075	.468
Silt	-.523	1	.483	.146	.495	-.727	-.648*	.161	.036	.251	-.157	.568	.214	.083	-.060
Clay	.966**	.483	1	-408	.782**	-.644*	-.702*	.267	-.269	.011	-.178	.123	.506	-.047	-.523
pH	.369	.146	-408	1	-.394	.116	.077	-.212	.112	.043	-.196	-.017	.767 **	.104	.667*
EC	.874**	.495	.782**	-.394	1	-.538	.617	.414	.126	.147	-.055	.279	-.655*	.334	-.301
OM	.606	-.727	-.644*	.116	-.538	1	-.966**	-.070	.302	.049	.016	-.205	-.248	-.064	.343
Total N	.680*	- .648*	-.702*	.077	.617	-.966**	1	-.087	.213	-.013	.223	-.122	-.252	-.202	.243
AV.P	-.246	.161	.267	-.212	.414	-.070	-.087	1	.282	-.045	.218	-.312	.047	-.113	-371
Ca	.166	.036	-.269	.112	.126	.302	.213	.282	1	.856**	.068	.077	.234	.788**	.727*
Mg	-.050	.251	.011	.043	.147	.049	-.013	-.045	.856**	1	-.270	.101	.349	.741	.572
Na	.209	-.157	-.178	-.196	-.055	.016	.223	.218	.068	-.270	1	-366	-.197	-.093	.114
K	-.265	.568	.123	-.017	.279	-.205	-.122	-.312	.077	.101	-366	1	.466	-.036	-.249
EA	-.576	.214	.506	.767 **	-.655*	-.248	-.252	.047	.234	.349	-.197	.466	1	.299	-.467
ECEC	-.075	.083	-.047	.104	.334	-.064	-.202	-.113	.788**	.741	-.093	-.036	.299	1	.589
Base Sat.	.468	-.060	-.523	.667*	-.301	.343	.243	-371	.727*	.572	.114	-.249	-.467	.589	1

* Correlation is significant at the 0.05 level. (2-tailed)
** correlation is significant at 0.01 level. (2-tailed)

Table 4: Coefficient of Correlation at 25 – 50 cm Depth

Pearson correlation	Sand	Silt	Clay	p^H	EC	OM	Total N	Av. P	Ca	Mg	Na	K	EA	ECEC	Base Sat.
Sand	1	-.658*	.976**	.213	-.447	.093	.159	.279	.367	.257	-.448	.317	-.103	.251	.000
Silt	-.658*	1	.485	-.260	.211	-.389	-.387	-.662*	-.630	-.670*	.380	-.181	.223	-.710*	-.155
Clay	.976**	.485	1	-.193	.485	-.009	-.085	-.148	-.262`	-.111	.437	-.293	.079	-.094	.053
pH	.213	-.260	-.193	1	.624	.732*	.774**	.790**	.647*	.736*	-064	-.257	.701	.675*	.307
EC	-.447	.211	.485	.624	1	-.491	-.477	-507	-.377	-.360	.426	.407	.474	-.219	.048
OM	.093	-.389	-.009	.732*	-.491	1	.925**	.772**	.795**	.841**	-.388	-410	-.715*	.724*	.211
Total N	.159	-.387	-.085	.774**	-.477	.925**	1	.743	.622	.816**	-404	-162	-.866**	.714*	.334
AV.P	.279	-.662*	-.148	.790**	-507	.772**	.743	1	.748	.952**	-144	-198	-.485	.900**	.369
Ca	.367	-.630	-.262	.647*	-.377	.795**	.622	.748	1	.790**	-.300	-349	-414	.763*	.051
Mg	.257	-.670*	-.111	.736*	-.360	.841**	.816**	.952**	.790**	1	-.142	-.071	-.504	. .965**	.307
Na	-.448	.380	.437	-064	.426	-.388	-404	-144	-.300	-.142	1	.165	.451	-.041	.054
K	.317	-.181	-.293	-.257	.407	-410	-162	-198	-349	-.071	.165	1	.214	.088	-.107
EA	-.103	.223	.079	.701	.474	-.715*	-.866**	-.485	-414	-.504	.451	.214	1	-.422	-.307
ECEC	.251	-.710*	-.094	.675*	-.219	.724*	.714*	.900**	.763*	.965**`	-.041	.088	-.422	1	.195
Base Sat.	.000	-.155	.053	.307	.048	.211	.334	.369	.051	.307	.054	-.107	-.307	.195	1

* Correlation is significant at the 0.05 level. (2-tailed)
** correlation is significant at 0.01 level. (2-tailed)

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