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Chemical Compositions of Soils in Parts of Edo State, Southwest Nigeria and their Relationship to Soil Productivity

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ABSTRACT: Thirty eight (38) soil samples taken from locations accessible to the Benin – Oluku – Ifon – Uzebba – Afuze – Auchi – Ukpilla – Okene highway, covering a distance of approximately 185 kilometres and an area of about 12,000 square kilometers were subjected to chemical and mineralogical analyses with a view to determining the variability of their fertility status within the rainforest and savannah vegetational zones. Results show that the soils of the area consist predominantly of quartz, kaolinite, feldspar and **sesquioxides** of aluminium and iron, including goethite. They are generally acidic with very low cation retention and buffering capacities. Higher concentrations of the major oxides MgO, CaO and K_2O were recorded in soils of the savannah zone while the soils of the rainforest zone are relatively deficient in these oxides. A chemical productivity index (CPI) of MgO + CaO + K_2O/Al_2O_3 is proposed for the soils of the area of study. @ JASEM

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The mineralogical and chemical characteristics of any soil are known to influence the performance of the soil in agriculture and engineering (Imasuen et al 1989b). Clay mineral composition and such physical characteristics as particle size distribution, organic matter content and geologic history also influence their agricultural productivity and engineering performance. (Onyeobi, et al 2013). In agricultural terms, this is because the soil's capacity for ion – exchange, water retention and sustained fertility are dependent on the nature and quality of clay minerals (Kronberg et al, 1979; Gillman, 1980; Fyfe et al, 1982).

The amount and nature of the various forms of iron and aluminium oxides as well as organic complexes had also been reported by Ashaye (1969) to greatly influence the physical and chemical properties of some soils in Nigeria. Furthermore, the growth and development of plants in soil is a function of the micronutrients available.

Previous work in the area under investigation (IITA, 1975) had noted aluminium to be the dominant exchangeable cation in the soils. Further investigation into the exchangeable aluminium status and effect of liming on nutrient availability and balance in the soils indicated that aluminium toxicity and lack of calcium and magnesium are the major limiting factors affecting crop growth in the acidic soil. (IITA, 1975). However, the conventional liming of acid soils to neutrality which is practised in the temperate region has not significantly improved soil productivity in the area of investigation.

In this contribution, we explore the chemical and mineralogical compositions of soils in parts of Edo State and their relations to productivity based on a chemical productivity index (CPI).

MATERIALS AND METHODS

Thirty eight (38) soil samples were collected from different locations accessible to the Benin – Oluku – Ifon – Uzebba – Afuze – Auchi – Ukpilla – Okene highway (Figure 1). The sampling protocol covered a distance of approximately 185 kilometers and an area of approximately 12,000 square kilometers which falls within a typical rainforest (III), mixed rainforest – savannah (II) and savannah (I) belt. The samples were subjected to bulk mineralogical and chemical analyses for major elemental oxides. The chemical analyses were carried out in the Geochemistry Laboratory of the University of London, Eghan Hill, Surrey, England using a Philips 45 – channel Inductively Coupled Plasma (ICP) emission spectrometer. ICP analysis can be compared with Atomic Absorption Spectrometer (AAS) analysis, having comparable (or better) detection limits for many elements.

The ICP programme, KI employed in these analyses involved hydrofluoric and perchloric ($HF/HClO_4$)

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acid dissolution of the samples and simultaneous determination of aluminium, magnesium, calcium and potassium (quoted as weight percent oxides). Additionally, mineralogical analysis of selected samples was carried out by X-ray diffractometry. A Phillips ADP-10 computer controlled diffractometry with CuK radiation at 45KV, 55MA, 1^0 divergence and receiving slits and proportional detector fitted with a graphite monochromator was used to record diffractograms of selected randomly oriented samples. The temperature and pH of the soils were also determined.

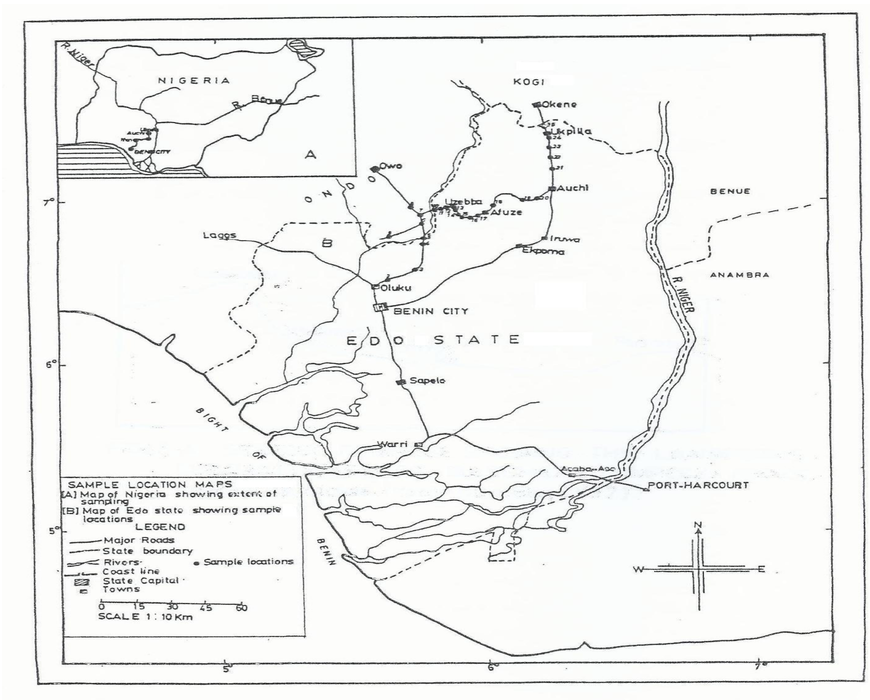

Fig1: Maps of Nigeria and Edo State showing extent of Sampling

RESULTS AND DISCUSSION

Results of mineralogical analysis of representative soils of the soils are shown as diffract grams in Figure 2.

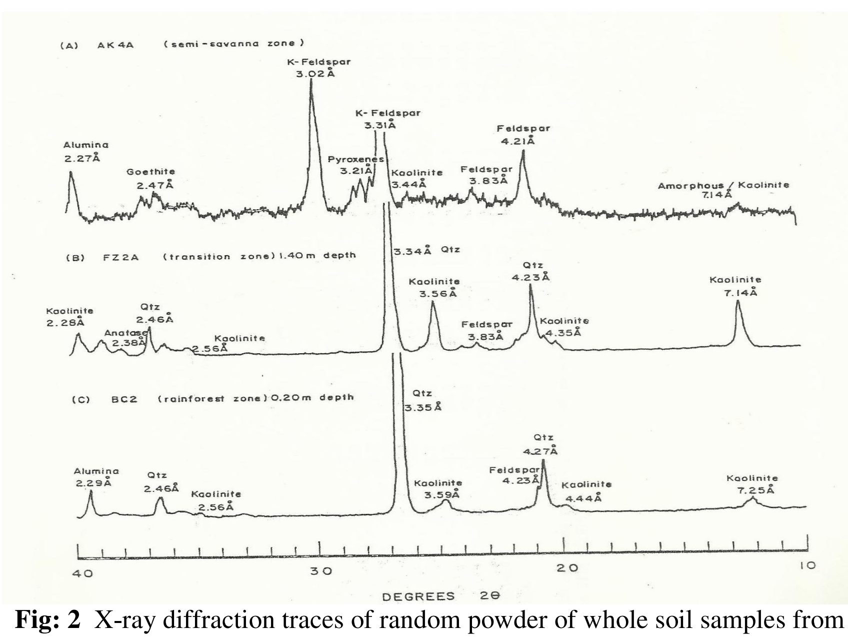

Fig: 2 X-ray diffraction traces of random powder of whole soil samples from Edo State, Nigeria.

The diffractograms show that virtually all the soils contain quartz, kaolinite and goethite. K-feldspar is present only in the soils of the semi-savannah zone with a conspicuous absence of smectites which is indicative of free-draining soils.

The major oxide compositions, temperature, pH, and chemical productivity index of soil samples from parts of Edo State, Nigeria are given in Table 1, in three groups comprising (I) savannah zone, (II) mixed savannah and rainforest zone, and (III) samples from the rainforest zone. The concentration of the major oxides are relatively high in the samples from the savanna zone (Group I) and very much depleted in the samples from the rainforest zone (Group III).

It is interesting to note that in a sweet potato yield trial under ten different locations varying from savanna to the high rainfall rainforest zones in Nigeria, the performance became poorer from the savanna to the high rainfall areas (Table 2 and Figure 2).

The variation pattern of MgO, CaO, K_2O content of soil samples across Edo State from the savanna group to the rainforest zone has a similar trend of depletion (Figure 3). In other words, the zones of high concentration of the oxides MgO, CaO and K_2O would be more productive than the zones that are highly depleted in these oxides. Since aluminium toxicity and lack of calcium and magnesium have been identified as the major limiting factors affecting crop growth in acid soils (IITA, 1975), a chemical productivity index (CPI) can be defined for the soils from this area as follows:

$CPI = MgO + CaO + K_2O/Al_2O_3$

The higher the CPI value, the more productive the soil. CPI is plotted against alumina composition of soils of Edo State and compared with soils from other areas in Figure 4. Most of the soils from the area investigated plot closer to the so-called impossible soils from Niger Delta (Olorunfemi, 1983) and the Amazon (Kronberg et al, 1979). A few of the soil samples from Group I plot close to quoted values for fertile soil, basalt, granite, average crust etc (Fig. 4).

The temperatures and pH values of the soil samples are also shown alongside the major oxides in Table 1. The temperatures range between 27.5^0C and 32^0C while the pH values are in the range 5.3 – 6.8 in distilled water except for sample AK4A with a much higher value of 8.5. Not surprisingly, AK4A was collected near the marble deposit in Ukpilla area where high MgO is commonplace.

On the addition of $Mg(OH)_2$, the pH of the soil samples were generally raised to values between 8.6 and 9.8 (Table 1).

Figure 5 shows that both the temperature and pH values of soils across Edo State, Nigeria, correlate with the magnesia composition of the soils. The more the MgO content of the soil, the higher the pH, a fact which is in consonance with the findings of (Imasuen et al., 1989b). It is quite clear from the data obtained in this study that most soils in Edo State, Nigeria are acidic and hence are characterized by low cation retention and buffering capacities, probably due to their high leaching potentials. This also implies that to manage these acidic soils, a significant amount of magnesia is required to attain a suitable pH level.

Liming a soil attempts to raise the base saturation by adding more of the basic cations, primarily Ca^{2+} and Mg^{2+} to the soil matrix (Mary – Howell, 2001). It has also been suggested that one way of managing highly weathered and intensely leached acid tropical soils is to raise the pH by liming (IITA, 1975). However, it is arguable that liming could result in a sharp decrease in the Mg concentration of the soil. On the other hand, the application of the kaolinite – smectite conversion mechanism (Imasuen et al., 1989b) will not only provide the suitable pH condition in the soil system but will also increase the capacity for cation retention and eliminate aluminium toxicity (Imasuen, et al., 1989a). The only snag with the conversion is that it is expensive to apply on a large – scale transformation under typical tropical soil temperature conditions; also it is achievable within a duration of over 25 years

However, the use of rock powder from Mg-bearing rocks e.g serpentinite and olivine basalt with the clay soils acting as inert carriers would be cheaper while effecting a good degree of in situ conversion.

Table 1: The Major Oxide, Chemical Productivity Index (CPI), Temperature, pH and other Parameters of Soil Samples from Edo State, Nigeria

Sample No	MgO	CaO	K_2O	Al_2O_3	CPI	pH H_2O	$Mg(OH)_2$	Temp
Soil Sample from Zone I								
AK5B	1.10	2.42	3.15	17.12	0.39	6.5	-	31
AK4A	1.96	16.24	1.96	10.48	1.92	8.5	9.7	-
AK3B	0.24	1.20	3.34	11.65	0.41	6.6	9.8	31
AK2B	0.84	1.80	2.68	13.89	0.36	6.8	9.8	29.5
AK1C	0.13	0.30	0.18	8.07	0.08	6.1	9.5	29.5
AK1B	0.08	0.18	0.14	8.20	0.14	5.3	9.5	29.5
AK1A	0.09	0.19	0.13	9.58	0.09	5.8	9.1	31
Soil Sample from Zone II								
ZC9B	0.07	0.32	0.06	6.23	0.07	5.9	9.6	30
ZC8A	0.03	0.18	0.02	3.55	0.06	-	-	28
ZC8B	0.03	0.12	0.02	3.47	0.05	-	-	29
ZC8C	0.04	0.16	0.03	5.04	0.05	-	-	29
ZC7C	0.13	0.52	0.06	6.73	0.11	6.0	9.4	30
ZC6A	0.19	0.60	0.12	12.90	0.07	-	-	30
ZC5A	0.05	0.21	0.10	6.00	0.06	-	-	30.5
ZC3B	0.13	0.36	0.11	11.17	0.05	-	-	30.5
ZC2B	0.23	0.43	1.52	11.04	0.20	6.1	9.5	32
ZC1B	0.21	0.37	0.05	20.29	0.04	-	-	31
ZC10A	0.11	0.27	0.05	10.95	0.04	-	-	31.5
FZ2AA	0.06	0.27	0.09	12.07	0.03	6.5	8.6	-
FZ2A	0.04	0.30	0.14	14.46	0.03	-	-	-
FZ2B	0.06	0.25	0.20	30.26	0.02	-	-	-
FZ2C	0.06	0.29	0.22	30.69	0.02	-	-	-
FZKA	0.12	0.29	0.10	13.34	0.04	5.8	-	-
FZK	0.07	0.34	0.32	26.89	0.03	-	-	-
Soil Sample from Zone III								
FZ1C	0.09	0.32	0.06	9.92	0.05	5.9	-	-
FIB	0.06	0.26	0.03	5.94	0.06	6.4	-	30
FWA	0.82	3.43	1.41	16.5	0.34	-	-	-
L9T	0.17	0.63	0.13	9.07	0.10	6.2	9.5	-
L9S	0.50	0.55	0.53	26.06	0.06	-	-	-
FB1B	0.54	0.73	3.01	12.80	0.33	6.1	9.7	32
FB2B	0.45	0.58	0.27	11.73	0.11	5.9	9.5	29
FB3A	0.15	0.27	0.16	17.22	0.03	5.5	-	29.5
FB3B	0.16	0.26	0.16	18.95	0.03	5.5	8.6	30
FB3C	0.18	0.27	0.17	24.33	0.03	5.4	8.8	-
FB3	0.06	0.26	0.17	16.42	0.03	-	-	-
FB4B	0.10	0.77	0.07	12.66	0.07	6.2	9.7	30
FD5B	0.12	0.34	0.08	11.40	0.05	5.9	9.5	29
BC2	0.15	0.29	0.08	19.72	0.03	5.2	9.7	27.5
Other Area								
Fertile Soil[1]	0.92	1.61	1.80	11.3	0.3			
Average Crust[2]	4.57	6.51	2.22	15.8	0.84			
Basalt[3]	3.64	7.77	1.37	14.5	0.88			
Granite[4]	1.43	1.68	3.95	1.44	4.88			
Amazon[5]	0.12	0.02	0.29	29.30	0.02			
Niger Delta[6]	0.14	0.01	0.16	9.2	0.03			

1 Bear (1964)
2 Bear (1964)
3 Mitchelle (1976)
4 Fyfe et al. (1983)
5 Kornberg et al (1979)
6 Olorunfemi (1983)

Table 2: Sweet Potato Yield Performance under 10 Different Locations in Nigeria

	Savannah						High Rainfall Area				
Entry	Olorunda	Fashola	Apata Oloro	Mokwa	Ajia	Jago	Warri*	Warri**	Umudike	IITA	Mean
TIb2	8.6	7.9	8.4	25.0	28.1	6.6	6.5	3.1	2.5	18.0	11.64
TIb4	4.3	4.0	8.6	19.8	15.0	5.7	5.1	3.6	3.3	13.0	8.40
TIS1145	14.8	12.8	13.5	20.6	20.9	13.8	4.0	2.1	2.3	19.4	12.93
TIS1176	7.6	8.1	21.0	28.7	26.1	2.7	9.9	8.6	9.1	24.7	16.94
TIS1354	9.0	9.6	22.1	24.4	26.0	8.3	9.6	6.6	0.6	14.0	13.42
TIS1439	11.6	8.7	11.6	17.8	20.9	2.0	13.4	10.8	6.1	11.4	11.60
TIS1487	16.8	18.9	19.2	23.4	30.7	7.9	19.1	13.4	11.7	13.4	17.81
TIS1487	22.3	17.8	16.0	30.4	30.5	3.8	9.4	6.1	9.8	23.0	17.70
TIS1491	10.5	10.5	14.5	19.4	18.6	3.3	6.2	3.8	5.4	21.9	11.80
TIS1499	7.5	8.8	9.5	29.2	34.8	9.6	5.4	4.0	8.0	28.2	14.38
Mean	11.3	10.71	14.44	23.87	25.16	6.37	8.80	6.15	5.82	18.70	13.47

* 2,000 mm annual rainfall, ** 2,600 mm annual rainfall
Source IITA (1975).

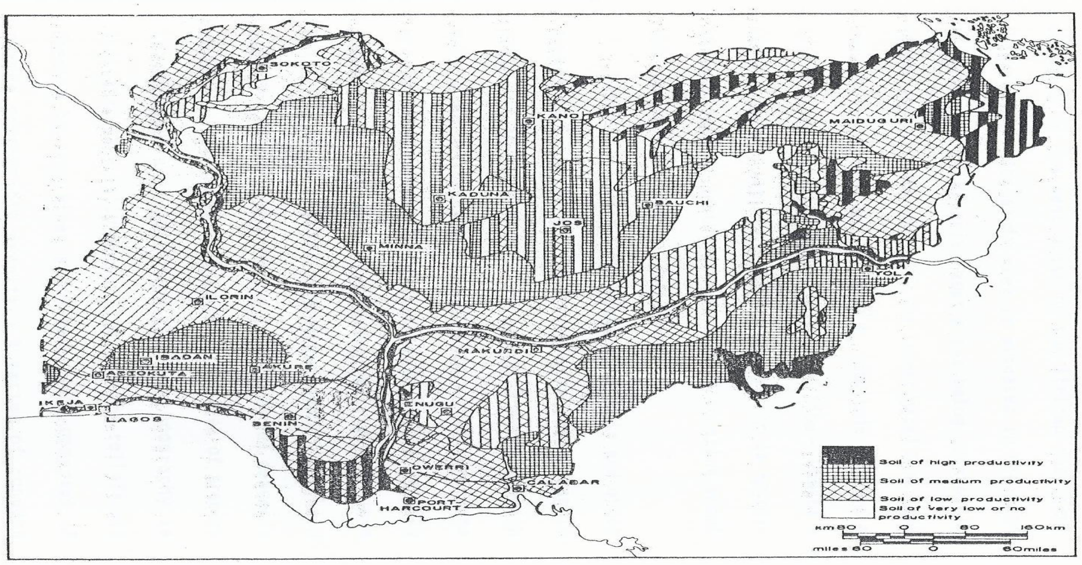

Fig: 3: Nigeria Soil Productivity FROM AGBOOLA (1979)

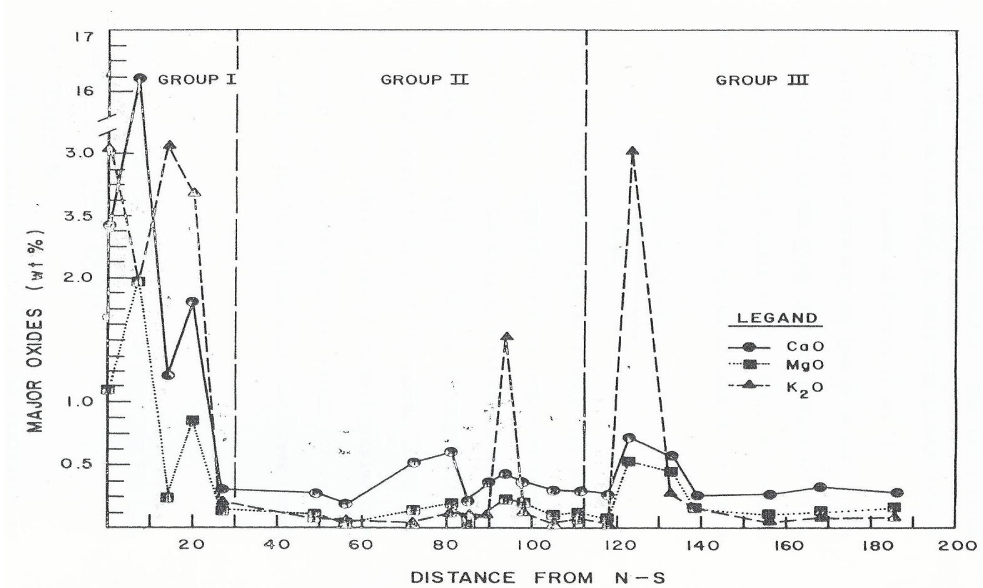

Fig:4: Profile of some Major Oxides in Soils across Edo State, Nigeria

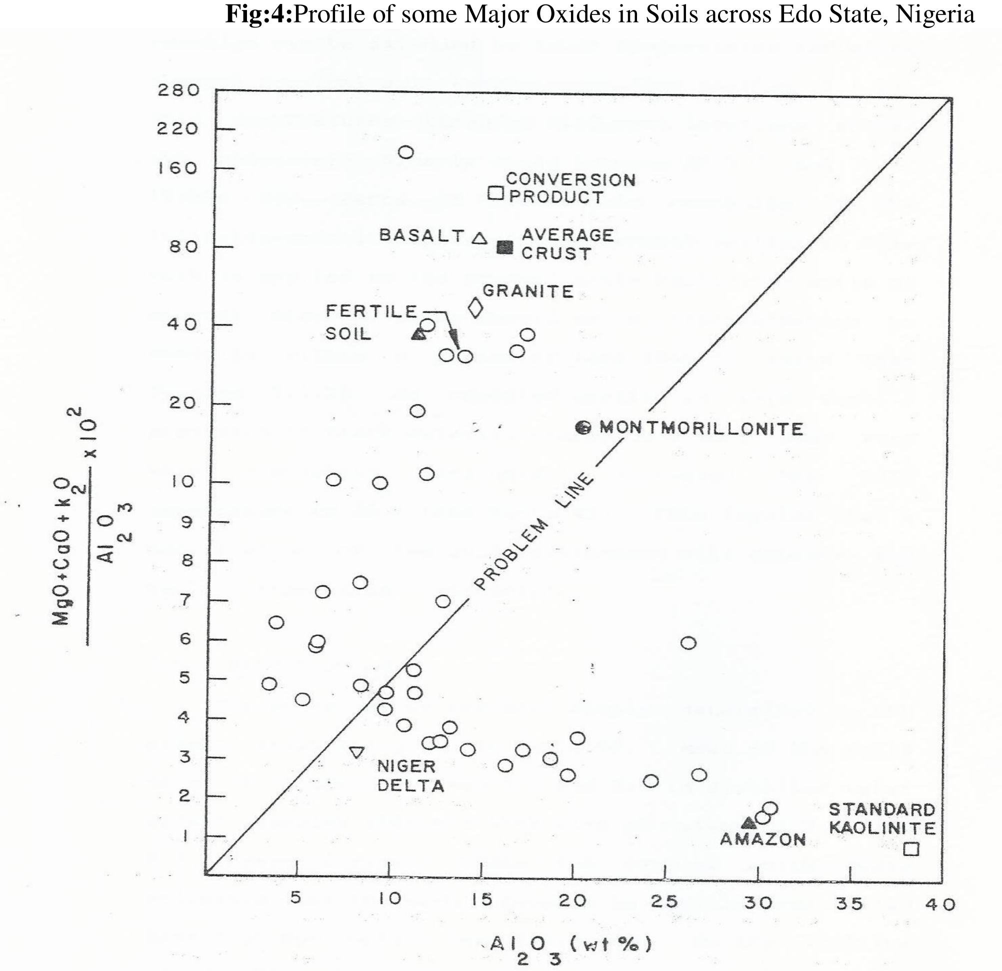

Fig: 5: CPI for Soil from Edo State, Nigeria and other Areas
Product of Kaolin-Smectite transformations [Imasuen, (1987)]

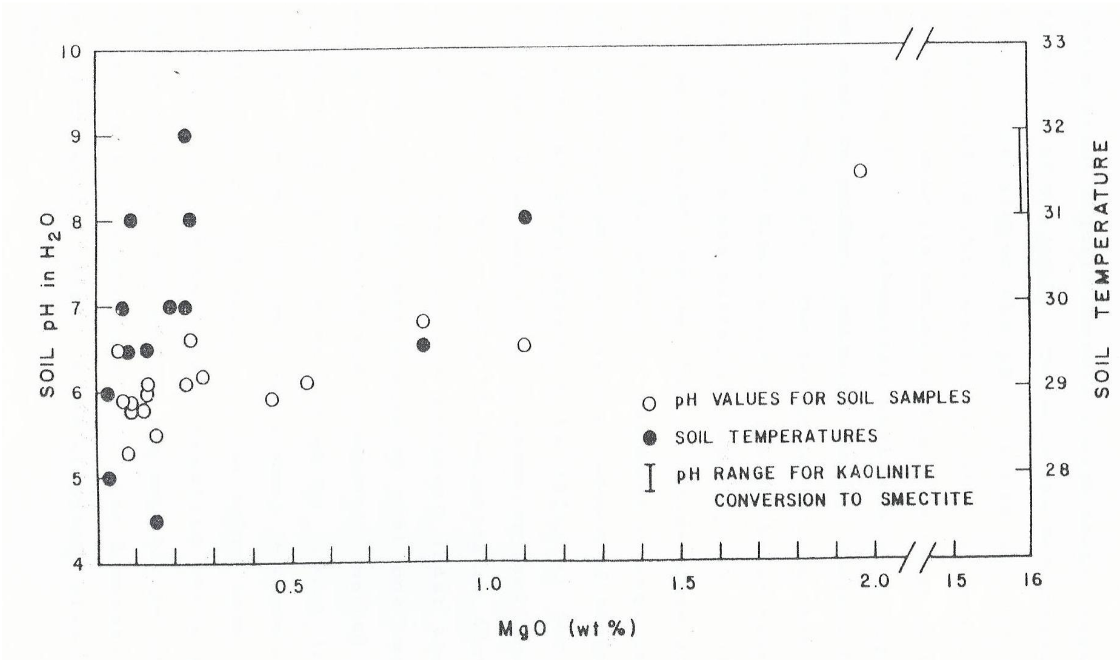

Fig: 6: Correlation between Soil Temperature/pH and MgO Composition of Soils across Edo State, Nigeria

Conclusions: Analytical results of the mineralogical compositions of soils across parts of Edo State, Southwestern Nigeria, show them to consist predominantly of kaolinite, quartz and sesquioxides of Fe and Al, particularly goethite with small amounts of k-feldspar in the semi-savannah zone.

Geochemically, the major oxides MgO, CaO and K_2O which are of agricultural importance, vary from one vegetational zone to the other.

With the notable exception of K_2O at a localized distance of between 125 and $130 Km$ south, there is a general depletion of MgO, CaO and K_2O from the savannah (group I) to the Rainforest (group III) zone which could be ascribed to greater weathering and leaching in the latter zone.

The soils are generally acidic with low cation retention and buffering capacities.
Assessment of the fertility status of the soils based on a proposed chemical productivity index (CPI) indicates that group I soils are relatively more productive than the group III soils. Because of the reported difficulties of enhancing the productivity of intensely leached acid soils, the use of rock powder from Mg-bearing rocks is recommended as a means of improving the fertility of the soils.

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