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Morphogenesis and classification of the yellowish-brown soil at Agbarho, Bendel State, Nigeria

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Abstract

Two profiles of Agbarho soil were analysed chemically, physically and mineralogically. The soil is located in the heavy rainfall, thick vegetation zone of Nigeria (average annual rainfall 2500mm).

The soil has a yellowish-brown colour, sandy loam to loamy sand texture with low silt content. The heavy rainfall has effectively contributed to the leaching of the basic cations from the soil. Calcium is the dominant exchangeable cation with values ranging from 0.1 to 1.8 m. eq/100g soil.

Kaolinite is the dominant clay mineral. Considerable quantities of mica, vermiculite, quartz and interstratified materials are present in the clay fraction of the soil. The silt fraction is dominated by quartz with some feldspars.

It is probable that the parent sediment of Agbarho soil was arkosic, and that the weathering of this parent sediment resulted in the formation of the minerals present in the clay and silt fractions.

Agbarho soil would classify as Etinan series following Vine's description; as Sols Ferrallitiques Lessives of the French classification system; as Oxisol of the Soil Taxonomy; and as Xanthic Ferralsol of the FAO/UNESCO mapping legend.

Introduction

Agbarho is a town situated in the Bendel State of Nigeria (5°34′N; 5°54′E). It is about 18.5 km northeast of Warri, on Warri-Ugbelli road (Fig. 1). It receives an average annual rainfall of about 250cm. The intensity of the rainfall on this sandstone-derived soil is such that caused a marked colour change from red to yellowish-brown, when compared with the red sandstone-derived soils from Benin, Iperu, Agege, Mokwa and Gombe, which receive less rainfall in the year (Ogunwale, 1973).

This soil, on which rubber, sugar cane, cassava and cowpeas are grown, has not been thoroughly studied. The objectives of this work were to determine some aspects of the chemistry and mineralogy of the soil, to attempt an explanation on its genesis and to classify it.

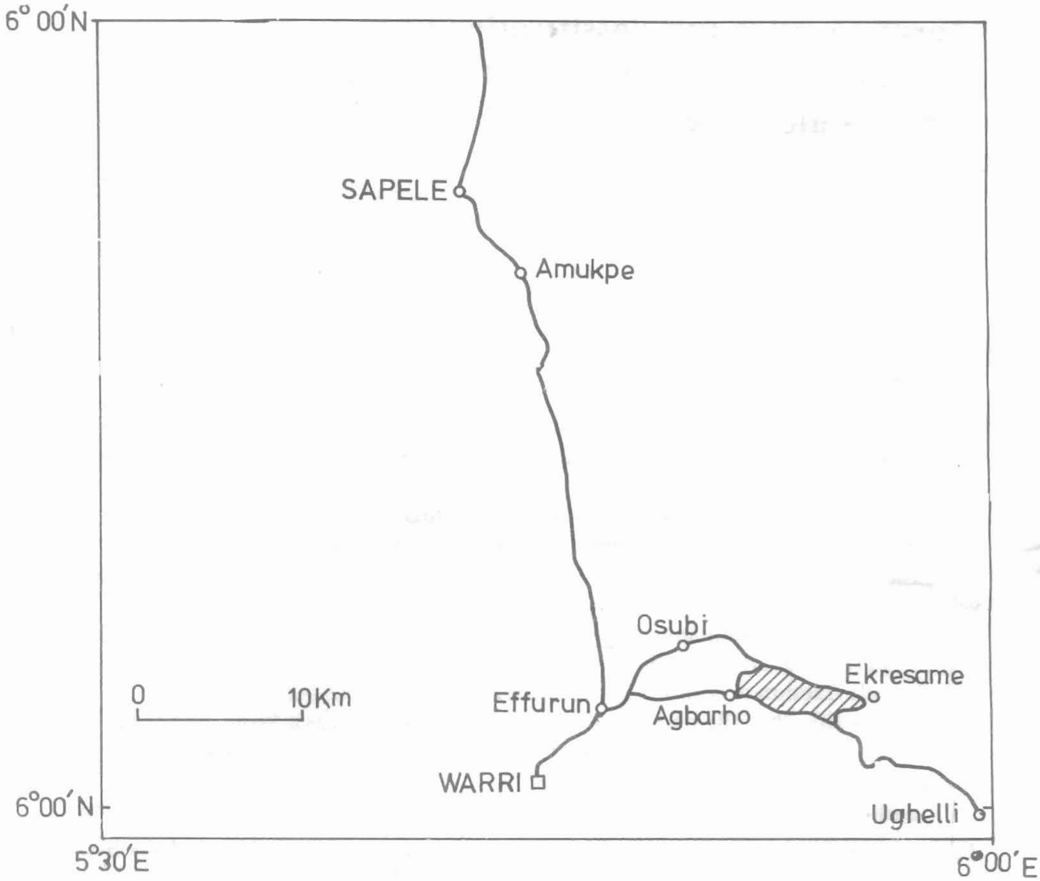

Fig. 1: A location map of Agbarho in Bendel State of Nigeria

Materials and Methods

Two profile pits were dug in the old farm settlement at Agbarho. Soil profile pits were sited on drainage basis. The soil was described according to the "Guidelines for soil description" (F.A.O., 1965).

The soil samples were air-dried and sieved to pass through a 2mm sieve. The air-dried soil samples were used for chemical, particle size and mineralogical analyses. The soil was chemically analysed for exchangeable calcium, magnesium, potassium, sodium and acidity; and also for available phosphorus (Bray and Kurtz PI) and organic matter following the methods outlined by Jackson (1958). Cation exchange capacity of the soil was determined by ammonium saturation and distillation method (Metson, 1961). Iron was extracted by the D-C-B method, and analysed on an atomic absorption spectrophotometer (Jackson, 1969).

Particle sizes were determined by the pipette method of Kilmer and Alexander (1949), using sodium hexametaphosphate as dispersant.

Pretreatment method of Brewer (1964) was followed in the mineralogical analysis. Fractionation and preparation of slides for X-ray analysis was carried out as outlined by Jackson (1969). X-ray diffraction pattern was obtained for Mg-saturated and glycerol solvated clay samples. Similar diffraction pattern was obtained for K-saturated and glycerol solvated clay sample, after heating to 550°C.

Silt sample was packed in an aluminium box mount for X-ray analysis. A Philip's diffractometer using graphite monochromator, with Cu-Ka radiation, and a scanning speed of 2°/min. was employed.

Subsample of clay fraction was treated for electron microscope investigation as outline by Rich and Kunze (1964).

Results

Morphology of the soil:

Agbarho Profile 1

Profile 1 was sited very close to a sugar cane experimental plot on a gently sloping land. This profile was moderately well-drained, moist throughout the horizons and particularly wet at a depth of 162 cm. The vicinity of the profile had neither stones nor rock outcrops; and the vegetation was primarily dominated by Siam weed *(Eupatorium odoratum)*, with some *Alchornea* species.

Profile Description:
Depth (cm).

0 – 8	A1	Dark grayish brown (10YR 4/2 moist); loamy sand; fine granular, weak structure; loose moist; abundant fine roots; few earthworm and millipedes; diffuse wavy boundary; pH 5.0
8 – 28	E	Dark brown (10YR 3/3 moist) with about 5% medium (10YR 4/3) mottles; sand; fine granular, weak structure; loose moist; common medium roots; sharp wavy boundary; pH 4.5

28 – 63	B1	Brown (10YR 4/3 moist) with about 5% medium (10YR 3/3) mottles; loamy sand; medium subangular blocky, weak structure; friable moist; few medium roots; diffuse smooth boundary; pH 4.3
63 – 85	B21	Brown (10YR 4/3 moist) with about 10% medium (10YR 4/1) mottles; loamy sand; medium columnar/ subangular blocky weak structure; friable moist; abundant burnt palm kernel shells; few medium roots; common medium vesicular pores; clear wavy boundary; pH 4.3
85 – 117	B22	Dark yellowish–brown (10YR 4/4 moist) with about 10% medium (10YR 5/6 mottles; loamy sand; medium subangular blocky, weak structure; friable moist; common burnt palm kernel shells; few medium roots; common medium vesicular pores; clear wavy boundary; pH 4.2
117–163	B23	Yellowish brown (10YR 5/5 moist) with about 15% medium (10YR 5/6) mottles; loamy sand; medium subangular blocky, moderate structure; friable moist; few burnt plam kernel shells; few medium roots; many medium vesicular pores; diffuse smooth boundary; pH 4.1
163–180	B3	Yellowish brown (10YR 5/8 moist) with about 15% medium (10YR 5/6) mottles; sandy loam; subangular blocky, moderate structure; slightly sticky wet; few medium roots; few medium vesicular pores; very thin clay skin on root channels; water table below; pH 4.0

Agbarho Profile II

This profile was sited close to a stream on a landform gently sloping to the West. The profile is poorly drained, moist/wet throughout the horizons studied. There were no stones or rock outscrops in the vicinity of the profile. The vegetation consisted of Siam weed (*Eupatorium odoratum*), *Selaginella* sp. and *Pteridophytes* (Ferns).

Profile Description
Depth (cm).

0 – 8	Ap	Black (10YR 2/1) moist; loamy sand; fine granular weak structure; loose moist; abundant medium woody with abundant fine fibrous roots; many earthworm casts; sharp wavy boudary; pH 5.0
8 – 15	A-1	Dark brown (10YR 3/3) moist; loamy sand; fine granular, medium subangular blocky, weak structure; friable moist; common fine roots; few earthworms with their burrows; diffuse wavy boundary; pH 4.6
15 – 38	B1	Dark grayish brown (10YR 4/2) moist, with about 5% medium (10YR 6/6 wet mottles; loamy sand; fine columnar/subangular blocky, weak structure; friable moist, slightly sticky wet, few medium interstitial pores; few medium roots; few earthworms with their burrows; water-table below; pH 4.9.

Particle size distribution:
Sand percentages were highest in both the surface and subsurface horizons ranging from 79 to 87.

The silt content of the two profiles constituted the least percentage of the fine earth materials (<2mm fraction). The values were less than 5.0 percent in the B horizons. The clay content of the soil was less than 20 percent in the two profiles. There was a general trend of gradual clay increase with depth in the two profiles (Table 1).

The texture of the soil was sandy, and the prominent texture of the horizons was either loamy sand or sandy loam.

TABLE I: PARTICLE SIZE DISTRIBUTION IN AGBARHO SOIL (IN PER CENT).

Depth in cm.	Horizon Designa.	Coarse + Medium sand	Fine sand	Silt (50-2um)	Clay (<2um)	Texture
PROFILE I						
0–8	A1	42.3	44.1	6.0	7.6	Loamy sand
0–28	E	51.9	35.8	3.9	8.3	Sand
28–63	B_1	59.7	23.0	4.3	13.0	Loamy sand
63–85	B_{21}	61.1	21.1	4.9	13.0	Loamy sand
85–117	B_{22}	63. 9	18.5	3.6	14.0	Loamy sand
117–162	B_{23}	63. 5	19.0	2.8	14.7	Loamy sand
163–180	B_3	45. 9	33.6	3.6	16.9	Sandy loam
PROFILE II						
0–8	A_p	44.6	40.0	7.0	8.3	Loamy sand
8–15	A_1	41.2	43.9	6.6	8.3	Loamy sand
15–38	B_1	38.3	43.8	4.4	13.5	Loamy sand

Chemical properties:

The pH values of the soil ranged from 5.0 in the surface horizons to a minimum of 4.0 in the subsurface horizons. The exchangeable acidity values ranged from 5.8 m. eq/100g soil in the surface to a minimum of 2.2m. eq/100g soil in the subsurface horizons (Table 2).

The distribution of cation exchange capacity was irregular in the two profiles. The values which ranged from 6.6 to 8.8 m. eq/100g soil in the surface horizons dropped to a minimum range of 3.2 to 3.5 m. eq/100g soil in the subsurface horizons. Exchangeable calcium was the dominant cation, and this was followed by magnesium. The values for potassium and sodium were extremely low, and could be negligible for sodium, especially in some of the subsurface horizons. Percent base saturation usually ranged from a maximum value in the surface horizons to a minimum value in the subsurface horizons. These values varied from 39.2 to 4.0 in profile I; and 21.9 to 3.5 percent in profile II. The generally higher base saturation percentages for the upper portions of the profiles may be attributed to the organic matter effect. The concentration of nutrients in the surface soil is, usually, due to the re-cycling process by plants through their growth and subsequent decay (Carson and Kunze, 1967).

The organic matter content of the surface horizon of profile II was higher than that of profile I. The higher value of organic matter in Agbarho profile II may be due to poorer drainage. The organic matter values decreased with depth in this soil (Table 2).

Percent extractable Fe_2O_3 increased with profile depth. except for one horizon in profile I. The values of Fe_2O_3 were comparatively higher in profile I than in profile II. The values were however fairly low when compared with other sandstone-derived soils with red colours (Ogunwale and Ashaye, 1975). In Agbarho profiles I and II, the iron oxide content increased from a low of 0.1% in the surface to a high of 1.2% in the subsurface horizons.

TABLE 2: CHEMICAL PROPERTIES OF AGBARHO SOIL

Depth in cm.	pH Water	C.E.C.	Ca^{2+}	Mg^{2+}	K^{+}	Na^{+}	Exch. Acidity	Base Satur.	O.M.	Fe_2O_3	Avail. P
		m.eq/100gm. soil						%	%	%	ppm.
PROFILE I											
0–8	5.0	6.6	1.8	0.8	0.02	0.01	3.1	39.2	2.9	0.3	4.8
8–28	4.5	3.8	0.4	0.2	0.01	–	2.5	13.4	1.2	0.4	3.1
28–63	4.3	4.2	0.3	–	0.01	–	2.9	6.2	0.7	0.9	1.3
63–85	4.3	4.0	0.1	0.1	0.01	–	3.4	4.0	0.7	0.8	1.9
85–117	4.2	3.7	0.2	–	0.01	–	2.9	4.4	0.5	0.9	1.1
117–163	4.1	3.2	0.2	0.1	0.01	0.01	2.2	6.9	0.3	0.9	–
163–180	4.0	3.5	0.1	–	0.01	–	2.5	4.7	0.3	1.2	0.8
PROFILE II											
0–8	5.0	8.8	1.3	0.6	0.02	0.01	5.8	21.9	5.1	0.1	4.2
8–15	4.6	6.7	0.5	0.1	0.01	–	5.5	8.4	2.7	0.1	2.2
15–38	4.9	4.8	0.1	0.1	0.01	–	3.8	3.5	1.2	0.2	3.3

Mineralogy of the Soil:

X-ray diffraction studies show that the silt fractions of Agbarho soil were dominated by quartz (4.26°A and 3.34°A), with moderate quantities of feldspar (6.7°A and 3.23°A) in all the horizons. Traces of kaolinite (7.2°A) and mica (10.0°A) occurred in some of the surface horizons (Fig. 2).

The <2um fraction of the soil was dominated by kaolinite (7.2°A and 3.58°A) with appreciable quantities of mica (10.0°A and 4.9°A), vermiculite (14.1°A), quartz and vermiculite–smectite interstratified materials. The presence of vermiculite was confirmed by the collapse of the 14.1°A peak to 10.0°A on heating the potassium saturated and glycerol solvated clay to 550°C as indicated in the last horizon of profile 1 (Fig. 3).

Electron micrograph of clay (<2um) revealed the moire pattern characteristic of mica, vermiculite and related materials (Gard, 1871). The waviness of the edges of the mica-vermiculite-like materials indicates that weathering of mica-vermiculite to kaolinite is still going on in Agbarbo soil. Kaolinite crystals are shown by their hexagonal shapes (Fig. 4).

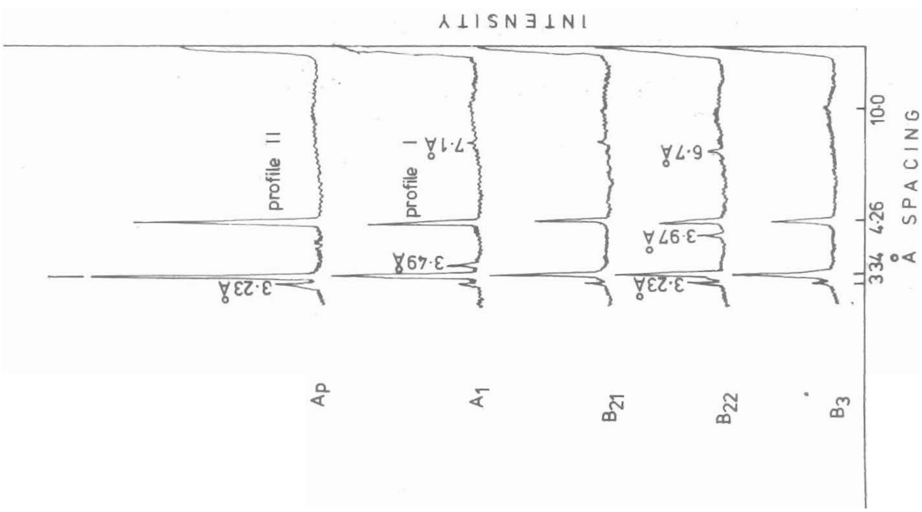

Fig. 2: X–ray diffractograms of silt fractions in Agbarho soil.

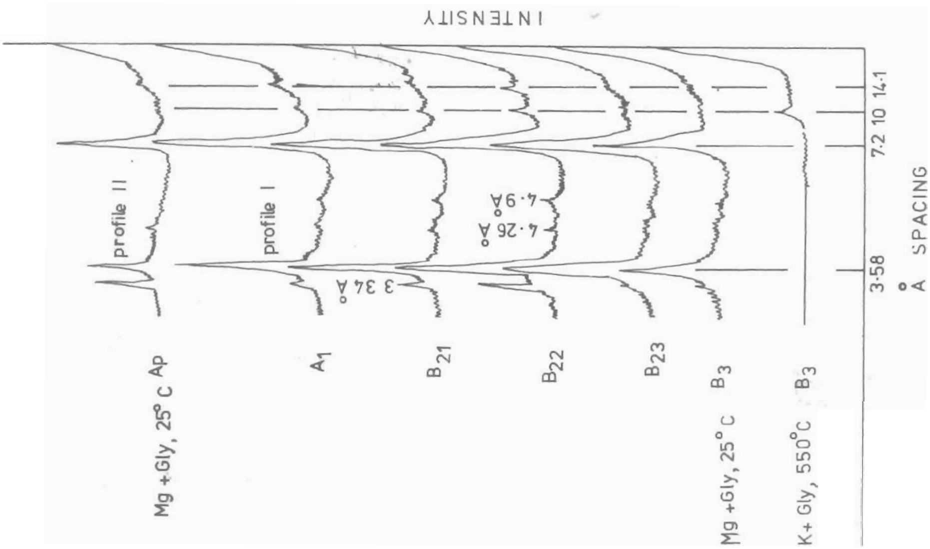

Fig. 3: X-ray diffractograms of clay fractions in Agbarho soil.

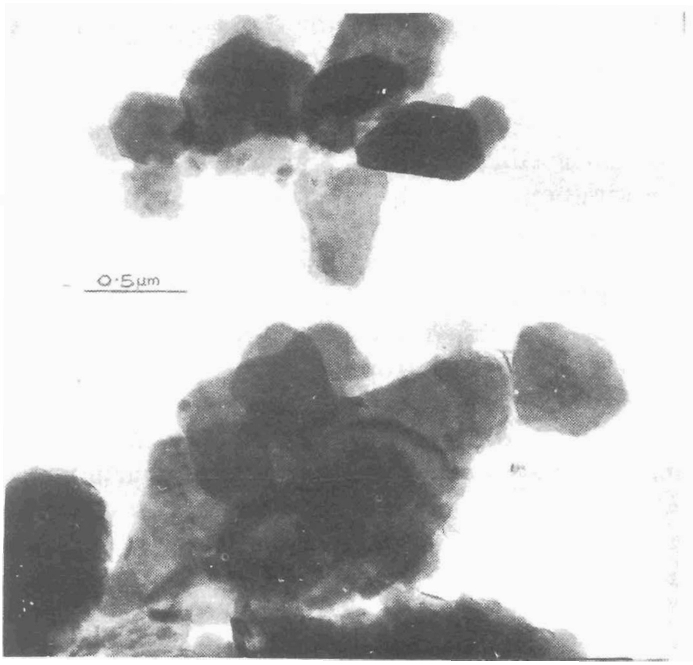

Fig 4. Electron micrograph of clay fraction from Agbarho Soil

Discussion

Genesis:

The colour of the soil (Brown-Yellowish brown) could be attributed to the intense leaching effect of heavy rainfall peculiar to Agbarho and Warri area. This was evidenced by the low values of iron oxide in the soil, when compared with other sandstone-derived soils which receive less rainfall in the year (Carson and Kunze, 1967; Ogunwale and Ashaye, 1975).

The presence of appreciable amounts of quartz in the clay fraction and the increase in the mica content of the clay fraction with depth indicate that the parent material of Agbarbo soil could have been arkosic sandstone rich in mica and feldspar. The heavy rainfall of the area coupled with the thick vegetation cover, led to intense weathering conditions whereby most of the cations became depleted. It is probable that the abundance of kaolinite and the presence of mica, as revealed by the x-ray data, might be due to the weathering of the feldspar present in the parent sediment to kaolinite, and the resistance of micaceous minerals to harzadous weathering. The degradation of part of the micaceous minerals could probably have resulted in the formation of vermiculite and vermiculite-smectite interstratified materials as shown on the x-ray diffraction patterns of the clay fraction of Agbarho soil.

Classification:

Etinan series is similar to Ahiara series in texture, but similar to Uyo series in colour. The Ahiara series, according to Vine (1956) and Moss (1960), have variations of sandy loam or sandy clay loam textures at and below 90cm. of the surface. The sand fraction of the Ahiara series is not dominated by coarse sand. The Uyo series occur in areas of higher rainfall ($>$200cm average annual) and are thus generally strongly leached, a feature associated with a yellowish-brown colour in the subsoil, and a greyish-brown topsoil. The Uyo series is, however, similar to Alagba series in textural characteristics in that sandy clay texture is usually encountered at and below 50cm of the surface. Both Ahiara and Alagba series are commonly found in areas of less intense rainfall ($\simeq$150cm average annual) than the area associated with Uyo series. Moss (1960) observed that no examples of Etinan series have been seen in the Western Region of Nigeria, but that they exist in Southern Benin and Delta provinces (now Bendel State of Nigeria). Agbarho soil would tend to classify as *Etinan series* for its texture, colour, base status and mineralogy.

Agbarho soil is highly leached and would classify as the *Sols Ferrallitiques Lessives* of the French system (Aubert, 1964). The soil shows all the properties characteristic of the Oxisols of the Soil Taxonomy (1975), especially with very low values of silt; but is extremely sandy. Agbarho soil profile I would therefore belong to the order Oxisol, suborder *Humox*, great group *Acrohumox* and subgroup *Psammentic Acrohumux*. Agbarho profile II was sited very close to a stream where the drainage was poor. This profile would classify as order Oxisol, suborder Aquox, great group Umbraquox, and subgroup *Psammentic Umbraquox* (Soil Survey Staff, 1975).

According to the FAO/UNESCO mapping legend (Dudal, 1970), Agbarho soil would fall within the group *Xanthic Ferralsols*. This however, is a broad classification whose classes at the lower levels of abstraction should be properly defined.

Acknowledgements

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