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Morphological, Chemical and Mineralogical Properties of the Soils of Abugi, Nigeria, and their Agricultural Potential

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ABSTRAK

Kajian telah dilakukan ke atas tiga profil tanah di Abugi - dalam dataran banjir Sungai Niger, Negeri Kogi di Nigeria. Tanah di permukaan horizon didapati berasid (pH 4.7 - 6.0). Nilai kation tukargantinya rendah kecuali kandungan kalsiumnya (Ca) yang sederhana dan merupakan kation tukarganti yang dominan dengan nilai dalam julat 0.50 - 7.00 cmol(+)/kg tanah. Mineral lempung yang dominan ialah koalinit, mika terurai dan kuarza, sementara sedikit smektit dan feldspar dikesani. Profil Satu Abugi telah dikelaskan sebagai Eutric Planasol (FAO 1988) atau Fluvaquentic Humaquept (Soil Survey Staff 1992). Profil Dua dan Tiga telah dikelaskan sebagai Eutric Gleysol (FAO 1988) atau Aeric Tropaquept (Soil Survey Staff 1992). Tanah di kawasan Abugi mempunyai potensi baik untuk penghasilan padi dan tebu sekiranya pengawalan banjir dan peningkatan asid dapat dikawal dengan baik.

ABSTRACT

Three soil profiles at Abugi in the flood plains of River Niger, Kogi State, Nigeria were studied. The soils are moderately acidic (pH 4.7 to 6.0) in the surface horizons. Exchangeable cations are low with the exception of calcium which is moderate and is the dominant exchangeable cation with values ranging from 0.50 to 7.00 cmol(+)/kg of soil. The dominant clay minerals are kaolinite, degraded-mica and quartz, while traces of smectite and feldspar were also detected. Abugi profile one was classified as Eutric Planosol (FAO 1988) or Fluvaquentic Humaquept (Soil Survey Staff 1992) while profiles two and three were both classified as Eutric Gleysol (FAO 1988) or Aeric Tropaquept (Soil Survey Staff 1992). The soils of Abugi area offer great potential for rice and sugarcane production if excessive flooding and increasing acidity can be controlled.

INTRODUCTION

Abugi is situated in Kogi Local Government Area of Kogi State, Nigeria. It is the main settlement within the studied area which falls between longitudes 6°10′ and 6°20′ East and latitudes 8°35′ and 8°45′ North (*Fig. 1*). The climate of the area is tropical with pronounced wet and dry seasons and steady high temperatures; it receives a mean annual rainfall of 1,160 mm. The area is a part of the nuclei of rice production centres within the middle belt region of Nigeria south of River Niger. The alluvial soil which covers an exclusive area has not been thoroughly studied previously. The objectives of this study are to describe the morphology of the soils, determine their physical, chemical and mineralogical properties, classify them and make an appraisal of their agricultural potential.

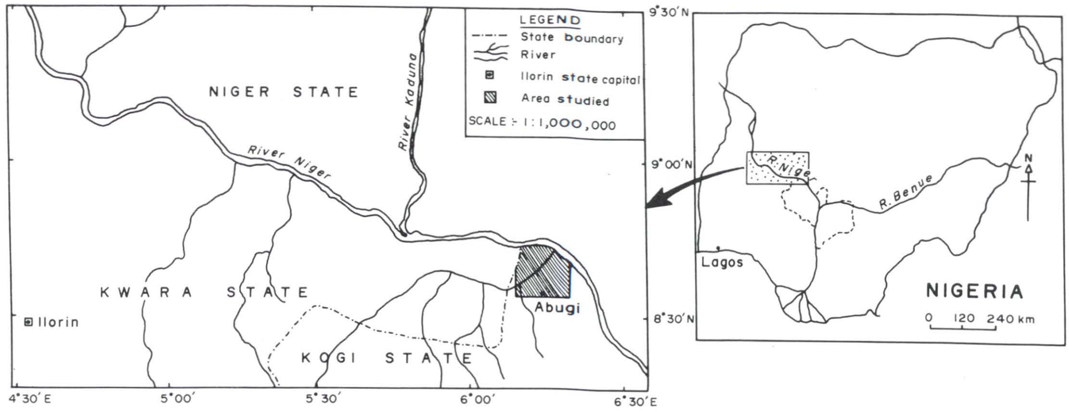

Fig. 1 : Map of parts of Kwara and Kogi States of Nigeria showing the location of Abugi

MATERIALS AND METHODS

Three profile pits sunk in the studied area were morphologically described according to the guidelines for soil description (FAO 1977). The soil samples collected from the genetic horizons of the soils were air-dried, ground and sieved to pass through a 2 mm sieve. These samples were used for chemical and particle size analyses. The particle size analysis was determined by the hydrometer method (Buoyoucos 1962). Exchangeable calcium, magnesium, potassium and sodium were extracted with neutral normal ammonium acetate. Calcium and magnesium in the NH_4OAc solution were determined by atomic absorption spectrophotometry, while K and Na were determined by flame photometry. Available phosphorus (Bray 1) was determined using Murphy and Riley (1962) reagent. Organic matter was determined by Walkey and Black method (Jackson 1958). Effective CEC was the summation of NH_4OAc bases and KCl exchangeable Al and H (Juo *et al.* 1976). The pH was determined with the glass electrode pH meter in soil: water and soil: KCl media, each of ratio 1:2.

Clay fractionation of the soil samples from profiles one and three and preparation of slides for X-ray analysis were carried out as outlined by Jackson (1969), after the hydrogen peroxide pretreatment method of Brewer (1964). X-ray diffraction pattern was obtained for Mg-saturated and glycerol-solvated clay samples. A similar diffraction pattern was obtained for the K-saturated and glycerol-solvated sample after heating to 550°C for 3 h. The samples were run using Cu-K $\propto$ radiation, with goniometer run from 2° 2θ to 40° 2θ at a speed of 2° per minute and 1000 counts per second for each of the slides.

RESULTS AND DISCUSSION

Morphology of the Soils

Buntley and Westin (1965) showed that colour gradation is a good criterion for interpreting drainage conditions among soils. The colour of Abugi soils is black on the surface, changing to different shades of brown in the subsurface horizons. The taints of grey in the subsurface horizons with hues of 7.5 YR or 10 YR, and values less than 4 (Table 1) confirm the imperfect drainage conditions in these soils. The structure of the soils range from structureless to moderate medium sized with granular, subangular blocky or columnar shapes.

The texture of the soils range from loamy sand to sandy loam to sandy clay to clay loam. The three soils exhibited abrupt textural changes with profile depth (Table 1), and this is indicative of different depositional era. The silt/silt + clay weathering indicies of Stewart *et al.* (1970) are very low (< 0.7) (Table 1) in all the horizons of the soils, and they generally decreased with profile depth. These low values of the weathering index indicate that a large proportion of the silt had weathered to clay, either at depositional or at a pre-depositional era.

TABLE 1
Physical and morphological characteristics of the soils of Abugi, Nigeria

Horizon depth (cm)	sand %	silt %	clay %	texture.+	silt / silt + clay	colour *	structure **
Abugi P 1							
0 - 16	66.80	20.88	12.32	SL	0.63	BL (7.5YR 1.7/1)	2 SAB
16 - 30	44.80	30.88	24.32	L	0.56	Br (7.5YR 4/3) (Mott)	3 AB
30 - 52	22.80	38.88	38.32	CL	0.50	Gr Y Br (10YR 4/2) (Mott)	3 C
52 - 94	72.80	12.88	14.32	SL	0.47	Br (10YR 4/4) (Mott)	1 AB
94 - 118	48.80	16.88	34.32	SC	0.33	Br Gr (7.5YR 4/1) (Mott)	3 C
118 - 125	89.68	2.00	8.32	LS	0.19	Br Bl (7.5YR 2/2)	0 G
Abugi P 2							
0 - 4	47.68	26.00	26.32	SCL	0.50	Bl (7.5YR 1.7/1) (Mott)	3 SAB
4 - 13	45.68	22.00	32.32	SCL	0.41	Gr Br (7.5YR 4/2) (Mott)	3 SAB
13 - 42	43.68	22.00	34.32	CL	0.39	Br Gr (7.5YR 4/1) (Mott)	3 SAB
42 - 76	61.68	14.00	24.32	SCL	0.37	Gr Br (7.5YR 6/2) (Mott)	3 SAB
76 - 148	45.68	8.00	46.32	SC	0.15	Br Gr (7.5YR 5/1) (Mott)	3 C
148 - 165	79.68	2.00	18.32	SL	0.10	Gr Y Br (10YR 6/2) (Mott)	1 SAB
Abugi P 3							
0 - 3	67.68	13.00	19.32	SCL	0.40	Br Bl (7.5YR 2/2) (Mott)	2 SAB
3 - 22	71.68	16.00	12.32	SL	0.56	Br (7.5YR 4/3) (Mott)	2 SAB
22 - 55	79.68	9.00	11.32	SL	0.44	D T Or (10YR 7/3) (Mott)	1 SAB
55 - 112	61.68	8.00	30.32	SCL	0.21	L Gr (10YR 7/1) (Mott)	3 SAB
112 - 125	53.68	7.00	39.32	SC	0.15	Br Gr (10YR 6/1) (Mott)	3 SAB

\+ S = Sand, L = Loam, C = Clay
* Bl = Black, Br = Brown, Y = Yellow, L = Light, Gr = Grey, Or = Orange, D = Dark
** AB = Angular Blocky, SAB = Sub angular Blocky, C = Columnar, G = Granular

Chemical Properties

The pH values vary from 4.70 to 6.00 in the surface horizons and from 4.10 to 6.70 in the subsurface horizons (Table 2). Abugi soils are moderately acidic. This could in part be due to the regular flooding of the soils (Young 1976) and the regular and uncontrolled use of ammonium sulphate, urea and other nitrogenous fertilizers for rice production in the area (IADP 1982).

The exchangeable calcium for the surface horizon ranges from 1.20 to 6.10 cmol(+)/kg of soil, and from 0.50 to 7.00 cmol(+)/kg of soil in the subsurface horizons. Magnesium contents vary from 0.70 to 5.95 cmol(+)/kg of soil for the surface horizons and from 0.40 to 7.25 cmol(+)/kg of soil for the subsurface horizons. The potassium values are higher in the surface horizons than in the subsurface horizons and are generally fairly adequate (0.3 to 0.6 cmol(+)/kg of soil) in the surface horizons (Table 2). Sodium values are high for these sedimentary soils deposited by inland river probably because the primary parent material that formed the deposited alluvium was initially high in sodium. These sodium values are higher than the 0.01 - 0.03 cmol(+)/kg of soil recorded for sandstone-derived soils at Iperu, South Western Nigeria (Ogunwale and Ashaye 1975). Exchangeable calcium is the dominant cation and this is followed by magnesium. The effective cation exchange capacity (ECEC) ranging from 2.22 to 12.38 cmol(+)/kg of soil in the surface horizon and from 1.35 to 10.87 cmol(+)/kg of soil in the subsurface horizons indicate that the soils vary in their clay mineral suite.

The organic matter contents vary from 0.45% to 5.60% in the surface horizons and from 0.07% to 0.98% in the subsurface horizons, thus revealing moderate levels for the surface horizons and very low levels for the subsurface horizons. This shows that there is little or no translocation of organic matter within the profiles.

TABLE 2
Chemical characteristics of the soils of Abugi, Nigeria

Horizon Depth (cm)	pH H_2O(1:2)	KCl(1:2)	CA	Mg	K	Exch Na	Acidity	ECEC	OC %	Avail P mg/kg	Total N %	BSP
			cmol(+)/kg									
Abugi P1												
0 - 16	6.00	5.10	5.55	5.59	0.51	0.17	0.20	2.38	1.95	1.52	0.15	98.38
16 - 30	5.35	4.50	2.90	2.10	0.28	0.18	0.20	5.66	0.46	0.00	0.03	96.47
30 - 52	5.20	4.50	7.00	2.20	0.32	0.17	0.16	15.51	0.57	0.00	0.03	98.97
52 - 94	5.20	4.90	2.10	1.10	0.15	0.13	0.20	3.68	0.11	0.00	0.03	94.57
94 - 115	5.40	4.50	4.15	3.85	0.26	0.19	0.12	8.57	0.30	0.70	0.02	98.60
115 - 125	5.75	5.50	0.75	7.25	0.09	0.10	0.12	8.31	0.07	0.00	0.03	98.56
Abugi P2												
0 - 4	4.70	4.00	5.90	1.50	0.77	0.25	0.48	8.90	3.28	0.70	0.25	94.61
4 - 13	5.10	4.20	6.10	2.10	0.34	0.22	0.26	9.02	1.18	0.00	0.02	97.12
13 - 42	5.70	5.10	3.20	6.90	0.41	0.22	0.14	10.87	0.41	0.00	0.02	98.71
42 - 76	6.25	5.50	2.40	6.40	0.15	0.23	0.06	9.24	0.15	0.00	0.04	99.35
76 - 148	6.70	5.80	5.60	2.20	0.44	0.28	0.12	8.64	0.04	7.00	0.09	97.45
148 - 165	4.80	4.00	1.80	1.00	0.21	0.11	0.36	3.48	0.12	0.00	0.05	89.66
Abugi P3												
0 - 3	5.40	5.20	1.30	0.70	0.22	0.14	0.12	2.48	0.83	8.40	0.12	95.16
3 - 22	5.40	4.90	1.20	0.70	0.13	0.11	0.08	2.22	0.24	5.60	0.05	96.40
22 - 55	5.10	4.35	0.50	0.40	0.14	0.11	0.20	1.35	0.04	7.00	0.04	85.19
55 - 112	4.60	3.90	1.80	0.90	0.24	0.16	0.80	3.90	0.04	10.30	0.07	79.49
112 - 125	4.50	4.05	2.60	3.30	0.35	0.19	0.52	6.96	0.20	4.20	0.05	92.53

Clay Mineralogy of the Soils

X-ray diffraction studies showed that the clay fractions were dominated by kaolinite, degraded-mica and quartz (*Fig. 2*). Traces of smectite and feldspar were also detected.

The potassium saturated and glycerol solvated clay sample indicated kaolinite (0.719 nm and 0.357 nm) and was confirmed on heating to 550°C with the disappearance of the peaks. The potassium saturated and glycerol solvated sample gave low intense mica peaks (0.101 nm and 0.499 nm) which became persistent and enhanced on heating the sample to 550°C. These mica peaks were also prominent in the magnesium saturated and glycerol solvated samples. Quartz was indicated in both the potassium and magnesium saturated and glycerol solvated samples with two peaks (0.426 nm and 0.334 nm). Although the 0.334 nm was over two times as intense as the 0.426 nm peak, the latter peak confirmed the presence of quartz in the samples. A trace of smectite (1.82 nm) was observed in the magnesium saturated and glycerol-solvated sample of Abugi profile one. Traces of feldspar (0.324 nm) were also indicated in both the potassium and magnesium saturated and glycerol-solvated samples (*Fig. 2*).

The high kaolinite and quartz contents of the clay fractions of Abugi soils could be attributed to material which is sedimentary in nature, and highly weathered. The presence of quartz in clay fraction is associated with intense degree of weathering. Thus, the alluvium must have been derived from primary basement complex rock probably of the Precambrian age. The presence of micaceous mineral is typical of younger parent material in a tropical environment (Okusami *et al.* 1985) and this is the younger secondary parent material (alluvium) derived from the older primary parent material. The presence of smectite could be adduced to the degradation of part of the micaceous minerals (Ogunwale 1984) or it could have been hydrothermally deposited with the alluvium.

Soil Classification

Profile one at Abugi was classified, using organic carbon and clay distributions with percent base saturation as: order-Inceptisol; sub-order-

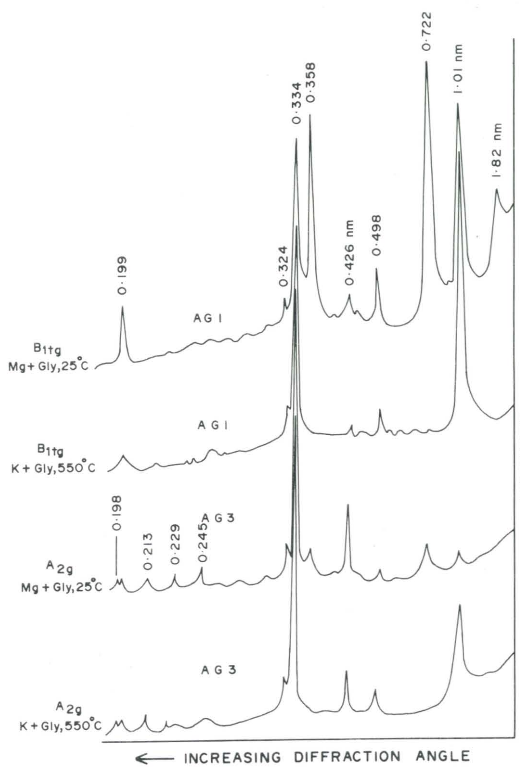

Fig. 2: X-Ray diffractograms of clay fractions in Abugi soils

Aquepts; great group-Humaquepts and sub-group-Fluvaquentic Humaquepts of the Soil Survey Staff (1992). Profiles two and three were also classified as: order- Inceptisol; suborder- Aquepts; great group-Tropaquepts and sub-group Aeric Tropaquepts. According to the FAO/UNESCO (1988) mapping legend, profile one falls within the group Eutric Planosol while profiles two and three fall within the group Eutric Gleysol.

Agricultural Production Potential of Abugi Soils

Young (1976) noted that soils derived from alluvium occupy a distinctive and important place in tropical agricultural while at the same time he observed that the produvtivity of alluvial soils in Africa is more often potential than actual. The flat nature of alluvial soils is one of the factors that confers on it production potential especially in terms of irrigation. Other factors include the suitable textural classes (medium-heavy textured) and its moderate organic matter content. However, the greatest constraint to crop production on alluvial soils is the poor drainage occasioned by a high water table during the rainy season and occasional flood problems. Therefore, in order to tap the immense benefits offered by alluvial soils, a concerted effort towards providing a suitable drainage and flood control system must be attempted.

In Abugi, rice (*Oryza sativa*) is the dominant crop produced since it tolerates water logging. Local varieties are popular, but yields are quite low varying from about 500 kg to 1000 kg per hectare, the average being about 750 kg per hectare. However, increasing usage of improved varieties and other modern agricultural input such as herbicides and fertilizers by a number of farmers have resulted in considerable yield increase from 1,500 to 2,500 kg per ha and more in some cases. Sugarcane (*Saccharum officinarum*) is produced on a very small scale (plots averaging less than 0.1 hectare) in Abugi mainly for home consumption. The varieties are entirely local, yielding less than 50 t/ha cane in the first year. Few efforts are made either at local or national level to encourage or/and improve sugarcane production in Abugi. The reason may be partly due to the great distance and the remoteness of the area from the nearest sugar company in Nigeria. Nonetheless, in the face of the ever increasing cost of sugar in Nigeria, the area offers very great, and realisable financial returns for estate agriculture involving cultivation of mainly rice and sugarcane.

Other crops produced on a small scale in the area include Guinea corn (*Sorghum* spp.) maize (*Zea mays*), cassava (*Manihot* spp.), cowpea (*Vigna* spp.) and yams (*Dioscorea* spp.). Special cultivation practices have to be employed to ensure that these crops do not suffer from the effects of the high water table usually associated with these soils during the rainy season. Such practices include land preparation and/or planting towards the end of the rainy season when the high water table is beginning to recede; making extra-large ridges to keep the roots of crops above waterlogged zones; and provision of crude but functional surface drainage facilities. The high labour and drudgery involved in the provision of these facilities have largely led to fragmentation and much reduced sizes of plots for these crops. Among all these crops, maize is the most important with yields averaging about 1 to 1.5 tonnes per hectare.

CONCLUSION

The physical and chemical characteristics and the location of Abugi soils make them suitable for rice and sugarcare production. Such soils, however, need good drainage if other arable crops such as maize, yam and guinea corn are to be grown. Granular urea should be used on the soils as nitrogen source instead of sulphate of ammonia which has the potential of increasing soil acidity. Moderate applications of inorganic phosphorus and organic manure would boost yields of most crops grown on these soils.

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