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CLASSIFICATION AND EVALUATION OF SOILS UNDER RUBBER (*Hevea brazilliensis* Muell Argo) PLANTATION AT NKO, CROSS RIVER STATE OF NIGERIA

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ABSTRACT

The soils cultivated to rubber at Nko were pedologically investigated. Results of field profile studies showed the soil colours to be brown (7.5YR) in well drained sites and greyish (2.5Y) in poorly drained sites. The surface layers were medium textured and subsurface layers medium to fine textured. Available phosphorus, organic carbon and calcium were deficient. The soils were acidic with pH in water ranging from 4.5 to 4.9 (mean, 4.8). The crests and middle slopes had an udic moisture regime while the lower-slopes had an aquic moisture regime. Based on the above parameters and analytical results, the soils of the crests and middle-slopes were classified as *very gravelly_fine-loamy isohyperthermic Typic Hapludults* while those of the lower-slops fell within the *Very gravelly fine-loamy isohyperthermic Aquic Hapludults* according to USDA *Soil Taxonomy*. The nomenclatures correlate with *Haplic Acriosls for* crests and middle-slopes and *Gleyic Acrisols* for lower-slopes, of FAO – UNESCO Soil Map of the World Legend.

KEYWORDS: Pedological investigation, cretaceous and tertiary sediments, Cross River State, Nigeria.

INTRODUCTION

Geologically Cross River State as a whole is covered by the Calabar flank, the Oban Massif, the Southeastern Benue Trough and the Ikom-Mamfe embayment (Ekwueme, *et al.*, 1995). The study area, Nko, is underlain by a variety of cretaceous and tertiary sediments (shales and sandstones) of Eze-Aku group of Southeastern Benue Trough (Petters, 1995). The Eze-Aku group is made up of two formations, the Amasiri sandstones and Ezillo formations. The study area is located in the Amasiri sandstone area. There was no detailed soil survey information from the southeastern zone of the study area while information on the soil fertility status of the zone was generally scanty and inconclusive (Periaswamy *et al.*, 1983). The main objectives of this study were therefore, to classify the soils according to USDA Soil Taxonomy (Soil Survey Staff, 1998), correlate them with FAO-UNESCO Soil Map of the World Legend (FAO-UNESCO, 1988) and provide basic information about the fertility status of soils formed from sandstone parent material cultivated to rubber in Cross River State.

MATERIALS AND METHOD

The study area is located at Nko in Yakurr Local Government Area of Cross River State. The rubber plantation is situated on the right hand side of the Ikom -Calabar road. Cross River State lies between latitudes 5° 32' and 4° 27' North and longitudes 7° 15' and 9° 28' East. Nko (5° 32' N and 8° 11' E) is 130 km from Calabar. The rainy season starts from April to October with a break lasting two to three weeks (August break) which begins as early as the last week of June or mid July. Mean annual rainfall at Nko is between 2000 to 2250 mm. The annual maximum temperatures range from 29°C to 30°C while annual minimum temperatures range from 16°C to 17°C (Socfinco, 1992).

Soil pattern and relationships were studied along four well identified and selected toposequences. A total of twelve pedons (3 in each toposequence) were identified, described and sampled for laboratory analyses. Three modal profiles representing three geomorphic units of crests, middleslopes and lowerslopes were used for soil classification. Soil samples collected were air dried, gently crushed and screened through a 2 mm sieve. Percentage gravel was calculated with reference to total soil and the gravel discarded. The fine earth separate (< 2 mm) was used for laboratory analyses. Particle size distribution, soil pH, organic carbon, exchangeable bases, cation exchange capacity (CEC), exchangeable acidity, total nitrogen and available phosphorus were determined by the methods described by Page *et al.* (1982).

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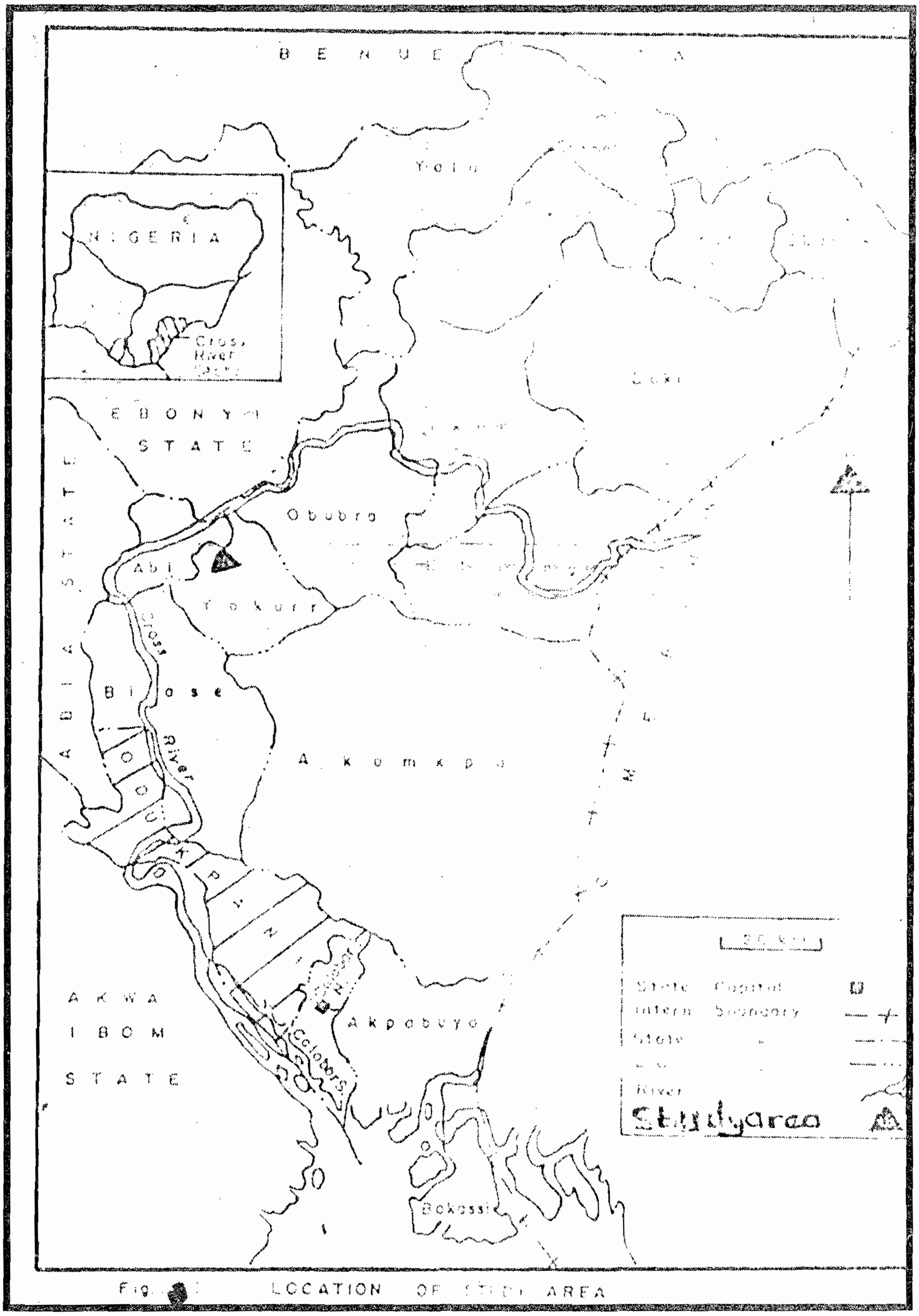

Fig. [illegible]: LOCATION OF STUDY AREA

RESULTS AND DISCUSSIONS

Soil morphological properties

The data on soil morphological properties are presented in Table 1. The soils generally occupy very gently sloping to gently undulating slopes (2 to 7%). The soil colours were brown (7.5YR) in well drained sites and greyish (2.5Y) in poorly drained sites. The structure of the soils varied between crumb surface layers (0 to 30 cm) and sub-angular blocky subsurface layers (30 – 150 cm). The moist consistence for the surface layers was generally friable while wet consistence was non – stocky and non plastic. The moist and wet consistence for the subsurface layers was firm and sticky and plastic respectively because of the increasing clay content with depth. The soils had medium textured surface layers (sandy loams and loams) over medium to fine textured (sandy clay loams, clay loams and clays) subsurface layers. These textures reflect the characteristics of the parent material. The soils were therefore non-cohesive, having relatively high total porosity and low sorption capacity for water and nutrients. They were, however, well aerated with high infiltration rate.

Table 1: Soil morphological properties of representative pedons

Horizon	Depth (cm)	Munsell Colour (Moist)	Mottles	Texture	Structure	Consistence	Boundary	Other Feature
PROFILE CRN-								Many fine, medium and coarse roots,
1	0 - 15	7.5YR $^{3}/_{2}$		SL	1fcr	vfr	cs	common fine mica flakes.
Ap	15 - 30	5YR $^{4}/_{4}$		Sg SL	2m-fsbk	fr	cs	Many medium roots, many fine mica flakes
BA	30 - 60	5YR $^{4}/_{6}$		g SL	3msbk	fi	cs	Few iron modules, many fine mica flakes
Bt1	60 - 64	5YR $^{4}/_{6}$	2.5Y $^{6}/_{4}$	g C	3msbk	fi	cs	Common fine to medium roots, many soft
Bt2	84 - 150	2.5 $^{6}/_{2}$	10R $^{4}/_{8}$	Vg C	3cpr	fi	_	irregular iron nodules, many fine mica
C								flakes
PROFILE MSN-								Few fine & coarse roots, many medium soft
2	0 - 15	10YR $^{3}/_{4}$	10YR	g SL	1fcr	vfr	as	iron nodules, many fine mica, many
Ap	15 - 81	7.5YR $^{4}/_{4}$	$^{6}/_{8}$	Eg C	1msbk	fi	as	fragments of weathered shale.
Brt1	81 - 109	2.5Y $^{6}/_{2}$	2.5YR	Eg C	2msbk	fi	cs	Many fine medium and coarse roots
Brt2	109 –	5Y $^{6}/_{1}$	$^{4}/_{8}$	Vg C	2msbk	fi	_	Common medium roots, many medium &
Crtg	150		2YR $^{4}/_{8}$					coarse irregular shaped shale fragments.
								Few coarse roots, many medium & coarse
								weathered shale fragments.
								Few medium roots, many completely
								weathered reddish and greyish shale layer
PROFILE LSN-								Common fine, medium and coarse roots
3	0 – 14	7.5YR $^{3}/_{2}$	10YR	g L	1fcr	fr	cs	Common medium & coarse roots, many
Ap	14 – 50	7.5YR $^{4}/_{6}$	$^{3}/_{6}$	Eg C	2msbk	fi	cs	medium and irregular shale fragments.
Brt	50 – 80	2.5Y $^{6}/_{0}$	10YR	Eg C	2msbk	fi	gcr	Few very fine roots, many weathered shale
Brtg	80 – 150	2.5Y $^{6}/_{0}$	$^{3}/_{6}$	Eg C	2msbk	fi	_	fragments
Crtg								Few very fine roots, many completely
								weathered shale fragments

1. Texture: Sg - Slightly gravelly, Vg - Very gravelly, Eg – Extremely gravelly, Sl – Sandy loam, L – Loam, Scl – Sandy clay loam, C -Clay.
2. Structure: 1 – weak, 2 – moderate, 3 – strong, F – fine, M – medium, C – coarse, Cr – crumb, sbk – subangular blocky, pr – prismatic.
3. Consistence: vfr – very friable, fi – firm.
4. Boundary: a – abrupt, c – clear, g – gradual, s – smooth, w – wavy.
5. CRN-1 – CREST NKO-1, MSN-1 – MIDDLESLOPE NKO-2, LSN-1 – LOWERSLOPE NKO-3.

Particle size distribution

The data on particle size distribution are shown in Table 2. The gravel content ranged from 8.0 to 35 % (mean, 21.0%) while subsoil layers had a range of 14.0 to 59% (mean, 48%). The data indicate that the soils are generally slightly gravely to very gravely. This agrees with Periaswamy et al (1983) observation that the soils of the area are generally slightly gravely to very gravely except for soils derived from coastal plain sands, which have little gravel. There was a tendency for gravels to increase with depth. The surface and subsoil layers sand fraction ranged from 41.0 to 58.0% (mean, 50%) and 13.0 to 54% (mean, 28.0%) respectively. The sand fraction was the dominant fine earth due to the nature of the parent material. It decreased with depth due to removal and transfer of the finer materials (clay illuviation) vertically and laterally down the slope by subsurface drainage and surface runoff respectively (Akamigbo and Asadu, 1983). The silt fraction had ranges for surface and subsoil layers of 34.0 to 49.0% (mean, 41.0%) and 19.0% to 34.0% (mean, 25.0%). Silt was the lowest fine earth fraction in the subsoil. This is as a result of low content in the soil parent material and intense weathering (Moberg and Esu, 1991). The clay content for the surface and subsoil layers ranged from 8.0 to 10.0% (mean; 9.0%) and 14.0 to 64.0% (mean, 51.0%). There was a progressive increase in clay fraction with soil depth. This is in consonance with the findings of Vine (1995). According to Vine (1995) all soils in the southern part of Nigeria, except some valley bottoms show an increase in clay content with depth. He contended that this was anomalous as there was little clay content in the parent materials of intensely weathered tertiary and upper cretaceous sandstones. He envisaged that there must have been a relative accumulation of clay over a considerable period. He opined that the clay would be derived from sporadic clay beds in sandstones by leaching and eluviation as sandy surface soil was gradually lost by erosion. Akamigbo and Asadu (1983) attributed this phenomenon to clay illuviation vertically and laterally down the slope by subsurface and surface drainage respectively.

Table 2: Physical properties of representative pedons

Horizons	Depth (cm)	Particle size distribution (%)				Textural Class (USDA)
		Gravel	Sand	Silt	Clay	
PROFILE CRN-1						
AP	0-15	8.0	58.0	34.0	8.0	Sandy loam
BA	15-30	14.0	54.0	32.0	14.0	Sandy loam
Bt1	30-60	31.0	46.0	23.0	31.0	Very gravelly sandy clay
Bt2	60-84	29.0	33.0	24.0	43.0	Very gravelly clay
C	84-150	46.0	17.0	19.0	64.0	Very gravelly clay
PROFILE MSN-2						
AP	0-15	35.0	52.0	39.0	9.0	Very gravelly clay
Brt1	15-81	60.0	26.0	23.0	51.0	Very gravelly clay
Brt2	81-109	59.0	25.0	27.0	48.0	Very gravelly clay
Crtg	109-150	40.0	13.0	24.0	63.0	Very gravelly clay
PROFILE LSN-3						
AP		19.0	41.0	49.0	10.0	Gravelly loam
Brt	0-14	85.0	18.0	34.0	48.0	Very gravelly clay
Brtg	14-50	59.0	17.0	20.0	63.0	Very gravelly clay
Crtg	50-80	58.0	29.0	24.0	47.0	Very gravelly clay
	80-150					

Soil chemical properties

The data on soil chemical properties are presented in Table 3. Although there are lower critical values of chemical properties for soils under rubber in Nigeria, they have not been integrated into a table of values in current literature. There is therefore an urgent need to compile the critical units for interpreting levels of parameters in soils for rubber in Nigeria. The categorization of soil nutrient availability (0 – 30 cm soil depth) put forward by Pushparajah *et al.* (1983) is not relevant to the humid tropics because of the extractants used. An attempt is made in Table 4 to compile data on critical values for interpretation are for ad hoc purposes pending such a time the ranges and ratings are worked out. The soil pH determined in H_2O and 0.1 M $CaCl_2$ gave ranges for surface and subsoil layers of 4.8 to 5.3 (mean, 5.0) and 4.1 to 4.9 (mean,4.6) respectively for water and calcium chloride. The data showed the soils to be strongly to very strongly acid due to intense weathering and leaching. Rubber tolerates a pH of 4.3 to 4.6 and at 6.5 growth is retarded (Landon,1991). The soils were deficient in organic carbon, total nitrogen, available phosphorous and calcium (see interpretation in Table 4). The range of values for organic carbon for surface and subsoil layers were 1.78 to 2.37% (mean, 2.44%) and 0.38 to 0.86% (mean, 0.65%) respectively. The surface layers had levels of organic carbon above 1.5% estimated as the lower critical level in similar rubber growing soils of Malaysia (Amalu, 1992). The subsoil layers had substantial deficient levels which fell far below the critical level of 1.5%. If the fertility of the feeder rhizosphere (surface layers) is maintained by conservation of organic matter, organic carbon will not be a limiting factor to rubber growth (Amalu, 1992). The nitrogen levels for surface and subsoil layers were 0.20 to 0.29% (mean, 0.23%) and 0.07 to 0.14% (mean, 0.10%) respectively. The surface layers had values within the requirement for rubber of 0.20% while the subsoil layers had levels below this (Table 4). Maintenance of soil fertility in the feeder root zone by conservation of organic matter will equally mitigate these deficiency levels. Excess of nitrogen should be avoided as it increases vegetative growth and tree weight with greater risks of tree breakage (Webster and Baulkwill, 1989). The available phosphorous for surface and subsoil layers ranged from 3.6 to 6.85mg/kg (mean, 5.72mg/kg) and 0.8 to 2.50 mg/kg (mean, 0.95 mg/kg) respectively. These values are far below the 8.0 mg/kg estimated as the lower critical soil test value (Amalu, 1992). Deficiency of phosphorus is attributed to fixation by sesquioxides in highly weathered soils of the humid tropics (Sanchez, 1976). Single superphosphate fertilizer which has the additional advantage of supplying calcium which was equally deficient as a result of the acidic nature of the soils can be used to correct phosphorous deficiency.

Table 3: Chemical properties of representative pedons

Horizons	Depth (cm)	pH		O/C (%)	TN (%)	AP mg/kg	Exchangeable cations (cmol/kg)				H+ Al cmol kg^{-1}	ECEC cmol kg^{-1}	BS (%)
		$H_2$0	0.01 $CaCl_2$				Ca	Mg	K	Na			
PROFILE CRN-1													
AP	0-15	4.8	4.1	1.96	0.21	6.85	5.0	2.0	0.3	0.2	2.6	10.1	74.3
BA	15-30	4.6	3.5	0.82	0.11	1.45	4.0	1.0	0.3	0.1	7.8	13.2	50.0
Bt1	30-60	4.5	3.5	0.66	0.11	1.05	2.0	4.0	0.3	0.1	12.8	16.2	40.0
Bt2	60-84	4.7	3.6	0.58	0.14	1.05	1.0	2.0	0.3	0.1	16.2	19.6	17.4
C	84-150	4.8	3.4	0.40	0.07	1.50	2.0	3.0	0.3	0.1	20.0	25.4	21.3
PROFILE MSN-2													
AP	0-15	4.8	3.7	1.78	0.20	6.70	3.0	2.0	0.4	0.2	6.2	11.8	47.5
Brt1	15-81	4.7	3.6	0.74	0.10	2.50	2.0	2.0	0.3	0.1	16.3	20.7	21.3
Brt2	81-109	4.6	3.6	0.48	0.10	1.60	1.0	2.0	0.4	0.1	19.6	23.1	15.2
Crtg	109-150	4.7	3.5	0.32	0.10	1.60	1.0	1.0	0.3	0.1	27.4	38.8	7.8
PROFILE LSN-3													
AP		5.3	4.8	2.73	0.29	3.60	15.0	2.0	0.4	0.2	2.6	20.2	87.1
Brt	0-14	4.9	4.0	0.86	0.14	1.40	14.0	8.0	0.4	0.1	10.6	33.7	67.1
Brtg	14-50	4.6	3.7	0.62	0.09	1.60	9.0	4.0	0.4	0.1	18.4	34.7	39.4
Crtg	50-80 80-150	4.1	3.6	0.38	0.07	0.8	8.0	8.0	0.4	0.1	20.0	32.9	32.0

TABLE 4: Critical units for interpreting levels of parameters of soils cultivated to rubber

Parameter	Critical levels (lower)
Ca	5.0
Mg	1.0
K (cmol(+)kg^{-1})	0.20
Na	1.0
ECEC (NH$_4$0Ac) (cmol(+)kg^{-1})	4.0
BS (%)	50.0
Organic carbon (%)	1.5
Total Nitrogen (5)	0.15
Available phosphorous (mg/kg)	8.00

Narrow ranges were observed for exchangeable cations except calcium which had wide ranges. Only calcium was deficient in middle-slope surface layers of all the pedons. The ranges for surface and subsoil layers calcium were 3.0 to 15.0 cmol (+) kg $^{-1}$ (mean, 7.7 cmol (+) kg $^{-1}$) and 1.0 to 14.0 cmol (+) kg $^{-1}$ (mean, 4.2 cmol (+) kg $^{-1}$) respectively. The subsoil layers' values were generally far below the critical value of 5.0cmol (+) kg $^{-1}$ proposed by Taylor and Pohen (1976). Calcium deficiency was due to soil acidity. The application of single superphosphate fertilizer as in phosphorus will take care of calcium deficiency as liming can be deleterious because it can raise pH values above 6.5 (maximum for rubber) leading to retarded growth (Landon, 1991).

The values of magnesium, potassium and sodium for surface and subsoil layers were 2.0 cmol (+) kg $^{-1}$ (constant for surface layers), and 1.0 to 8.0 cmol (+) kg $^{-1}$ (mean, 3.5 cmol (+) kg $^{-1}$) respectively. For magnesium, 0.3 to 0.4 cmol (+) kg $^{-1}$ (mean 0.4 cmol (+) kg $^{-1}$) and for potassium 0.20 cmol(+)

kg $^{-1}$ (constant for surface layers) and 0.1 cmol (+) kg $^{-1}$ (constant for subsoil layers) respectively for sodium, were all within the various critical levels given (Table 4). The soils were therefore deemed suitable in terms of these exchangeable cations for rubber performance. The surface and subsoil layers' values for exchange acidity were 2.6 to 6.2 cmol (+) kg $^{-1}$ (mean, 3.6 cmol (+) kg $^{-1}$) and 10.6 to 27.4 cmol (+) kg $^{-1}$ (mean, 16.9 cmol (+) kg $^{-1}$ respectively. The dominant cation associated with soil acidity in the humid tropics is exchangeable aluminium. Rubber can tolerate up to 85.0% of exchangeable aluminium saturation of the exchangeable sites in soils (Landon, 1991).

According to Sanchez (1976) ECEC values higher than 4cmol (+) kg $^{-1}$ suggest sufficient CEC to prevent serious leaching losses, therefore values for the pedons which ranged from 10.1 to 20.2 cmol (+) kg $^{-1}$ (mean, 14.3 cmol (+) kg $^{-1}$) for surface layers and 13.2 to 38.8 cmol (+) kg $^{-1}$ (mean, 26.8cmol (+) kg $^{-1}$) for subsoil layers were adequate for rubber growth and performance since they were all above this value of 4.0cmol (+) kg $^{-1}$. The percent base saturation by ECEC for surface layers of all the pedons ranged from 47.0% to 87.1% (mean, 63.0 %) while that of the subsoil layers ranged from 7.8 to 67.1% (mean, 31.2%). Base saturation above 50 % is regarded as being adequate for most plants (Landon, 1991). The surface layers had medium to high base status due to litter fall. The subsurface layers had low base status due to leaching. Organic matter additions and conservation should be integrated into the fertilizer programme to reduce cost of inorganic fertilizers to improve on the base status of the soils.

Soil genesis

The soils are derived from the weathering of cretaceous and tertiary sediments of Eze Aku formation (sandstones and alternated beds of sandstones and shales) of Southeastern Benue Trough (Petters, 1975). The soils developed in situ from weathered sandstones and shales parent materials as weathering shale fragments were encountered at about 130cm depth in some pedons.

Soil classification

The soil classification is presented in Table 5. The soils were classified to the family level in the USDA system. Although most of the Ap horizons of the pedons had both low colour value and low chroma they were too thin to be mollic or umbric epipedons. They were therefore classified as ochric epipedons. All the pedons had well developed argillic horizons (Bt) with no fragipans and a base saturation by sum of cations of less than 35% at 125cm below the upper boundary of the argillic horizon. They also lacked an albic E horizon, the distribution pattern of clay and tonguing which is diagnostic of Alfisols and Aridisols and lack an aridic moisture regime. They therefore qualify to be classified as *Ultisols* (Soil Survey Staff, 1998). The moisture regime of the soils at Nko had been inferred to be udic and aquic from information obtained from climatological data of the area (Bulktrade, 1989). The soils inferred to have udic moisture regime include soils of the crests and middleslopes while those of the lowerslopes were usually waterlogged and inferred to have aquic moisture regime. Since in the tropics differences between summer and winter temperatures are small (less than 5%) (Soil Survey Staff, 1992) and the mean annual temperature is greater than 22°C (Bulktrade, 1989) the temperature regime is inferred to be isohyperthermic. The soils of the crests and middleslopes belong to the suborder of udults since they are never saturated with water, have less than .0.9 per cent organic carbon in the upper 15cm of the argillic horizon and have an udic moisture regime (Soil Survey Staff, 1992). They are classified in the great group as Hapludults and the subgroup as Typic Hapludults because they are deep sandy loams with a simple set of horizons. They have more than 15% of the particles by weight as fine sand (diameter 0.25 to 0.1mm) and 18 to 34 per cent clay in the fine earth fraction. They can therefore be classified into the fine-loamy particle size. Because of their high gravel content the soils are therefore classified at the family level as *Very gravelly fine-loamy isohyperthermic Typic Hapludults* for the crests and middleslope soils. The lowerslope soils had the same qualities as the crestal and middleslope soils except that these soils had ground water that fluctuated in the deep layers of the soils and therefore falls into the subgroup of Aquic Hapludults. The soils were therefore fitted into the family of *Very gravelly fine-loamy isohyperthermic Aquic Hapludults*. The soils classify as *Haplic Acrisols* and *Gleyic Acrisols* respectively by FAO – UNESCO Soil Map of the World Legend (FAO-UNESCO, 1992).

TABLE 5: Summary of Classification of Pedons

Geomorphic units	Pedons	USDA Classification	FAO-UNESCO Classification
CRESTS	1 4 7 10	*Very gravelly fine loamy isohyperthermic Typic Hapludults*	Haplic Acrisols
MIDDLESLOPES	2 5 8 11	*Very gravelly fine-loamy isohyperthermic Typic Hapludutes*	Haplic Acrisols
LOWERSLOPES	3 6 9 12	*Very gravelly fine-loamy isohyperthermic Aquic Hapludutes*	Gleyic Acrisols

Limitations to productivity

Low organic carbon content, total nitrogen, available phosphorous and calcium are the major constraints to sustainable rubber production.

Summary and conclusion

These Ultisols developed on sandstones are coarse textured. They are therefore friable and subject to erosion and leaching. They are non-cohesive, having high total porosity and low sorption capacity for water and nutrients. Their fertility can be improved upon by integrating organic matter additions and conservation unto the fertilization programme to reduce cost of inorganic fertilizer.

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