Agro-Science
Journal of Tropical Agriculture, Food, Environment and Extension
Volume 3, Number 1, January 2002 pp. 41 - 46

ISBN 1119-7455

CHARACTERIZATION AND SUITABILITY EVALUATION OF REPRESENTATIVE RUBBER-GROWING SOILS OF NIGERIA

V. E. Osodeke, O. J. Kamalu and A. A. Omenihu
Department of Soil Science & Agroclimatology
Michael Okpara University of Agriculture, Umudike

ABSTRACT

This study was conducted to characterize the soils supporting rubber in Nigeria with a view to evaluating their suitability and constraints for rubber production. The results obtained showed that the soils of the rubber belt are very deep and well-drained with sandy to sandy clay loam texture. The soils are acidic with pH ranging from 4.0 to 5.5. There are no hardpans or impermeable layers and the terrains are almost flat to gently sloping (0-5%). The structure are weak to moderate granular, sub-angular and angular blocky with friable soil consistence. They are generally of poor nutrient status. The suitability ranking of the soils for rubber production was of the order:- Okhuo and Iyanomo> Akwete. Odagwa> Calabar while the productivity ranking was in the order Calabar> Okhuo and Benin> Akwete> Odagwa.

Keywords: Rubber, Productivity ranking, Latex.

INTRODUCTION

The Rubber growing belt of Nigeria, comprises the southeastern and Southwestern parts of the country extending from southern part of Ondo State to Cross Rivers State. The area is situated within longitude 4^{o} 20^{1} to 8^{o} 30^{1} E and latitude 4^{o} 50^{1} and 5^{o} 20^{1} N. Annual rainfall usually exceeds 2000mm and the mean temperature is about 26^{o}C. The soils are underlain by Cretaceous and Tertiary sediments of the Abeokuta, Ewekoro, Ibaro, Benin, Nsukka, Imo and Ameki formations (Kogbe, 1975). A greater part of this area is generally termed as "Acid Sands" and is derived from unconsolidated sedimentary deposits of the Miocene-Pleistocene periods (ILACO-NEDECO, 1966).

The soils are generally characterized by deep, well-drained pedons with sandy texture and diffused horizons. Although these soils naturally support a luxuriant vegetation, yet they have been described as poor soils due to the excessive leaching (Tinker and Ziboh, 1959; Enwezor *et al.*, 1981; Lekwa and Whiteside, 1986 Okoye, 1995). Despite these very widely held views of poor fertility the soils have been rated as having immense agricultural potentials for tree crops (Ataga *et al.*, 1981, Eskhade *et al.*, 1996).

Several characterization studies exist for these soils with emphasis on chemical and pedological parameters (Lekwa and Whiteside, 1986; Omenihu, 1989, Okoye 1995, Ojanuga 1995). However, most of the schemes used in characterizing the soils do not properly highlight the suitability and constraints of these soils to the cultivation of specific crops. This work is therefore aimed at characterizing the soils supporting rubber in Nigeria with a view to evaluating their suitability and constraints. Relationship between the suitability ratings of the soils to latex yield obtained was also established.

MATERIALS AND METHODS

A preliminary inventory of soil and agronomic resources of large and small holder rubber estates was conducted across the study area. Detailed morphological study of soils of representative estates was done in each of the following locations : Iyanomo, Okhuo, and Urhonigbe in Edo State; Sapele in Delta State; Odagwa in Rivers State; Akwete in Abia State; Nekede in Imo State and Calabar in Cross Riivers State as shown in Figure 1. Auger borings were made to cover all possible physiographic or landform units to a control section of 1.25m. Physical and morphological properties of representative pedons were evaluated and samples taken from genetic horizons in addition to composite surface samples. An inventory of climatic data at Benin, Port Harcourt and Akwete were also made.

Routine laboratory chemical and physical properties were determined by standard procedures – pH in 2:1 soil water ratio by calomel pH meter, organic carbon by modified Walkley and Black (1934) method, available phosphorus by Bray and Kurtz-1 (1945) method, total nitrogen by Kjeldahl method, effective cation exchange

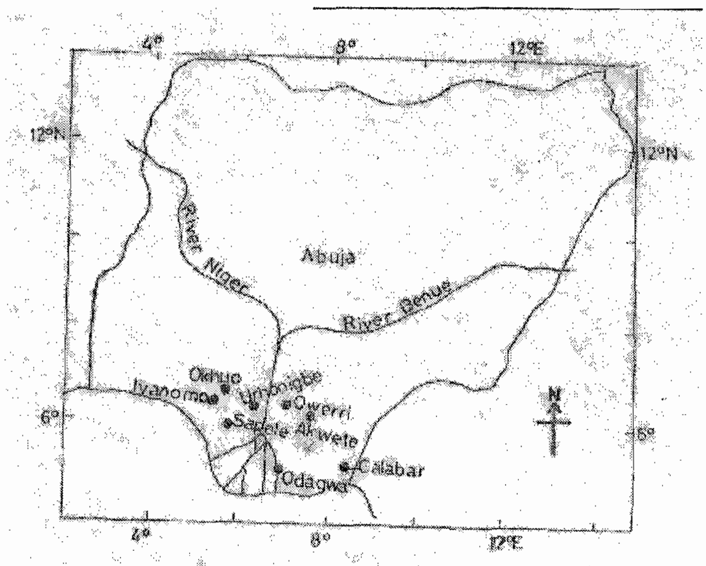

Fig. 1. Map of Nigeria showing the Pedon locations.

capacity (CEC) by summation of cations and particle size analysis by Hydrometer methods of Bouyoucos (1951).

A suitability evaluation of the soils was done using a combination of schemes suggested by Sys (1975); Rubber Research Institute of Malaysia (1979); Yew (1979) and Dent and Young (1981). The schemes are based on the limitations of soil properties on rubber performance. The limitations identified by the scheme are; soil depth, soil texture, soil consistency, soil aeration, soil structure, drainage, depth to water table, slope and its effect on erosion, nutrient status and soil acidity. Based on the levels of the parameters, the scheme identified suitability classes ranging from class 1 with no serious limitations to class 5 with at least one very serious limitation to rubber production. Slight local modifications on nutrient status was made due to observed performance of rubber under various soil types in the studied plantations.

RESULTS AND DISCUSSIONS

Chemical Properties

Results for chemical properties of representative pedons are given in Table 1. The soils are generally very acid (p^H 4.2) to moderately acid (pH 5.5). Soil pH was highest in the surface horizons of soils of the western part of the country. The general trend was a decrease in pH towards the southeastern part of the country. Rubber grows well on a majority of acid soils of the humid tropics with a pH of 4.0 to 6.0 (Sys. 1975; Watson, 1989). Though Rubber thrives optimally within the above pH range, most plant nutrients are, however, fixed resulting in low nutrient availability in the soils. The low pH values of the soils have been attributed to the intensely leached unconsolidated sedimentary parent material and the dominance of sesquioxides in the exchange complex (Lekwa and Whiteside, 1986).

Exchangeable acidity also had a trend similar to that of pH. A range of 0.80 to 6.90 $Cmolkg^{-1}$ soil was observed for the entire study area. The variation was quite wide between the southwestern and southeastern parts of Nigeria. Variations of 0.80 to 3.20 and 1.60 to 6.90 $Cmolkg^{-1}$ soil were observed for the southeastern and southwestern zones respectively. The trend of the effective cation exchange capacity (ECEC) was similar to that of exchangeable acidity. A range of 1.56 to 8.93 $CmolKg^{-1}$ soil was obtained in the study area with higher values occurring in the southwestern areas. The generally low levels of ECEC could be ascribed to the dominant sandy texture of the soils. Juo (1981) related the low ECEC of the soils to the predominant kaolinitic mineralogy.

The range for organic carbon was 0.11 to 4.27 gkg^{-1}. The range for the surface horizons was 0.67 to 4.27 gkg^{-1} while that of the sub-surface was 0.11 to 0.97 gkg^{-1}. The soils of southwestern areas had higher values (0.70 to 4.27 gkg^{-1}) with a mean value of 2.22 gkg^{-1} for surface soils while the range for the surface soils of Southeastern parts was 0.67 to 1.13 with a mean value of 0.89 gkg^{-1}. Total nitrogen and available phosphorus content had distribution patterns similar to that of organic carbon. The range for total N for surface soils was 0.06 to 0.12 gkg^{-1} with a mean value of 0.09 gkg^{-1} for the southwestern part and 0.11 to 0.28 gkg^{-1} with a

Table 1: Properties of Representative Pedons of Rubber Growing Soils of Nigeria

Pendon Location	pH (H₂O)	Org. C.($_{gkg^{-1}}$)	Total N ($_{gkg^{-1}}$)	Avail. P($_{mgkg^{-1}}$)	Ca	Mg	K	Na	Ex. Ac	ECEC	Base Sat. %	Sand %	Silt %	Clay %	Texture
					←		Cmol kg^{-1}		→						
Iyanomo	5.0	8.6	0.9	3.93	1.70	0.60	0.12	0.11	6.90	8.93	22.7	71.04	12.96	16.0	SI
0-43	4.8	4.7	0.4	9.75	1.22	0.48	0.08	0.02	5.10	6.91	26.2	60.04	11.96	18.0	SI
43-124	4.7	2.5	0.3	2.53	1.40	0.51	0.04	0.02	5.50	7.47	26.3	69.04	9.96	20.0	SCI
124-165	4.6	2.9	0.4	3.61	1.00	0.52	0.08	0.04	4.90	6.54	25.1	66.04	9.96	40.0	SCI
165-200	4.6	1.3	0.4	2.71	1.30	0.44	0.11	0.02	2.52	4.39	42.6	66.04	9.96	24.0	SCI
Okhuo															
0-18	5.1	11.3	1.2	9.30	2.40	1.22	0.21	0.05	1.68	5.58	70.1	82.80	11.20	10.0	SI
18-80	5.2	3.9	0.6	3.00	2.89	1.46	0.32	0.15	3.04	7.90	61.0	60.80	8.20	31.0	SCI
80-120	5.5	2.4	0.6	6.30	2.94	1.20	0.16	0.02	1.96	6.30	68.9	59.80 .	7.00	33.2	SCI
Sapele															
0-30	4.4	8.4	0.6	7.22	0.98	0.63	0.07	0.03	0.92	2.73	66.30	95.40	3.00	1.6	S
30-66	4.8	4.8	0.2	9.08	0.62	0.23	0.05	0.03	1.32	2.25	41.33	82.40	7.00	10.6	S
66-103	4.8	4.6	0.3	8.36	1.25	0.64	0.06	0.07	2.44	4.37	44.16	76.40	7.00	16.6	S
103-148	4.5	2.8	0.3	7.35	1.26	0.88	0.21	0.05	1.88	4.34	56.68	75.40	6.00	18.6	IS
148-200	4.7	2.7	0.2	7.09	0.16	0.10	0.01	0.01	1.28	1.56	17.95	78.40	7.00	14.6	IS
Urhonigbe															
0-10	4.8	6.7	0.6	10.26	0.20	0.12	0.06	0.03	0.84	1.23	31.71	93.40	5.80	2.8	IS
10-35	5.0	5.4	0.5	4.18	1.60	0.54	0.16	0.06	1.12	2.88	61.71	92.40	3.80	4.8	SI
35-70	5.0	3.9	0.3	6.80	0.96	0.24	0.11	0.04	1.44	2.79	48.39	89.40	3.80	6.8	SI
70-125	5.2	3.7	0.4	5.07	3.67	1.24	0.25	0.10	1.68	6.94	75.79	96.40	4.80	8.8	SCI
125-150	4.8	2.0	02	9.63	0.32	0.49	0.09	0.07	1.36	2.03	33.00	94.40	6.80	8.8	SCI
Odawa															
0-12	5.1	42.7	2.8	22.40	1.0	0.42	0.15	0.05	2.48	4.10	39.50	86.00	2.00	12.0	
12-32	4.4	9.7	0.4	18.60	0.36	0.11	0.05	0.06	3.22	3.78	14.80	72.00	8.00	20.0	12
32-72	4.4	4.6	0.3	17.10	0.31	0.20	0.03	0.02	2.27	3.83	14.60	72.00	8.00	20.0	--
72-126	4.4	3.0	0.2	19.50	1.10	0.28	0.04	0.01	2.03	3.45	17.90	68.00	6.00	26.0	IS
126-200	4.5	2.5	0.04	12.00	0.17	0.11	0.05	0.03	2.48	2.82	12.00	68.00	7.00	25.0	IS
Akwete															
0-15	4.6	18.1	1.3	13.40	1.22	0.21	0.10	0.04	1.68	3.25	43.30	95.60	2.20	2.2	IS
15-18	4.5	8.5	1.0	13.00	0.88	0.35	0.13	0.09	0.88	2.30	61.70	90.60	5.20	4.2	SI
18-40	4.5	7.6	0.9	17.60	0.76	0.45	0.11	0.10	2.88	4.30	34.90	90.60	2.20	7.2	IS
40-86	4.5	4.6	0.8	24.40	1.23	0.64	0.22	0.05	2.72	4.76	42.90	85.60	2.20	12.2	IS
86-127	4.7	2.2	0.7	15.20	0.78	0.42	0.16	0.06	1.52	2.60	41.50	87.60	2.20	10.2	IS
127-200	4.6	1.1	0.6	17.60	1.00	0.24	0.04	0.10	1.40	2.78	49.60	97.60	3.20	11.2	IS
Nekede															
0-20	5.1	7.0	1.0	4.90	0.67	0.30	0.11	0.04	0.80	1.94	35.60	80.00	3.00	17.0	IS
20-38	5.1	5.1	0.8	2.80	1.35	0.65	0.21	0.10	2.00	4.35	44.90	65.00	10.00	25.0	SI
38-57	5.1	5.1	0.8	2.80	1.41	0.71	0.13	0.16	2.00	4.45	44.90	66.00	9.00	25.0	IS
57-101	4.8	2.6	0.6	2.80	0.42	0.31	0.12	0.11	1.20	1.93	13.40	76.00	10.00	13.0	IS
101-162	4.3	2.3	0.4	2.80	0.51	0.29	0.09	0.10	1.20	1.93	15.50	76.00	10.00	13.0	IS
162-200	4.5	1.5	0.4	5.90	0.37	0.24	0.10	0.09	1.20	1.87	20.50	76.00	10.00	13.0	IS
Calabar															
0-11	4.4	19.7	1.4	2.4	1.51	1.10	0.21	0.11	2.20	4.50	51.10	87.80	5.20	7.0	S
11-42	4.6	3.3	0.8	5.6	0.96	0.58	0.10	0.13	1.76	3.22	45.30	72.80	11.20	16.0	SI
42-80	4.6	4.5	0.8	5.2	1.39	0.76	0.09	0.13	2.60	4.80	45.80	72.80	11.20	16.0	SI
80-117	4.6	6.2	0.9	6.4	1.00	0.55	0.11	0.08	1.00	2.40	58.30	74.80	9.20	16.0	SI
117-164	4.6	8.3	1.0	5.2	1.31	0.64	0.09	0.06	1.84	3.28	43.90	75.80	7.90	18.1	SI
164-200	4.7	3.0	0.7	4.4	1.33	0.81	0.06	0.12	2.08	3.60	42.20	74.00	8.90	18.1	SI

Table 2: Suitability evaluation of representative soils supporting rubber (*Hevea brasiliensis*) in Nigeria

Location	Effective soil depth cm	Texture	Consistency (moist)	Porosity	Structure	Slope (%)	Drainage	Summary of constraints to rubber cultivation	Suitability
Iyanomo	Very deep (>200)	Sandy loam to sandy clay Loam	Friable to slightly sticky	Abundant macro and micro pores	Weak to medium sub-angular blocky	Almost flat (0-2)	Moderately well drained to	Low fertility	I
Okhuo	Deep (>150)	Sandy loam to sandy clay loam	Friable to slightly sticky	Abundant macro and few micro pores	Medium angular blocky	Almost flat (0-3)	Perfectly well drained well drained	Low fertility	I
Sepele	Very deep (>002)	Sand to sandy loam	Friable	Many macro and micro pores	Weak to medium sub-angular blocky	Almost flat (0-2)	Well drained	Sandy texture, low fertility	II
Akwete	Very deep (>200)	Sandy to loamy sand	Loose to friable	Abundant macro pores	Weak granular to medium angular blocky	Almost flat (0-3)	Well-drained	Sandy texture and low fertility	II
Nekede	Moderately deep (about 150)	Loamy sand	Friable	Abundant macro and micro pores	Weak fine granular to weak fine sub-angular blocky	Gently sloping (2-5)	Moderately well drained (ground water level at 180 cm)	Sandy texture and low fertility	II
Calabar	Deep (about 150)	Sandy to sandy loam	Friable to sticky	Few macro and abundant micro pores	Medium crumb to angular blocky	Medium slopes (3-9)	Moderately well drained to well drained	Steep slopes, threatening erosion surfaces, low fertility	III
Odagwa	Very deep (>200)	Loamy sand to sandy clay loam	Friable to slightly sticky	Many fine to medium interstitial pores	Weak to moderate sub-angular blocky	Almost flat (0-2)	Well drained low fertility	Sandy texture and low fertility	II
Urhonigbe	Very deep (>200)	Loamy sand to sandy clay loam	Friable	Abundant macro and micro pores	Weak fine sub-angular blocky	Almost flat (0-2)	Well drained	Sandy texture low fertility	II

mean value of 0.16 gkg^{-1} for the Southeastern part.

Available phosphorus ranged between 2.4 and 24.4 ugg^{-1} with a mean of 10.66 ugg^{-1} for Southeastern zone and 2.53 to 10.26 ugg^{-1} with a mean value of 6.57 ugg^{-1} for the Southwestern zone. The values observed for organic carbon, total nitrogen and available phosphorus were within the range reported by others in the area (Agboola and Fagbenro, 1985; Omenihu, 1989, Osodeke and Kamalu, 1999).

Generally, soils of the study areas are highly leached due mainly to duration and amount of rainfall and the dominant sandy texture. Preliminary studies on nutrition of Hevea (Onuwaje and Uzu, 1980; Osodeke and Kamalu, 1999) have revealed that all the soils under Hevea cultivation in Nigeria require the application of N P K and Mg as nutrients during the establishment stage. Although the poor inherent fertility of the soils is not considered a threat to the suitability of the soils for Hevea cultivation, it is a constraint to its optimal production. The yield and performance of Hevea will, therefore, be greatly improved by the application of appropriate fertilizer to control nutrient deficiencies in the soils and the adoption of other soil fertility management practices such as erosion control at the early stages of plantation establishment.

Morphological Properties and the Suitability of the Soils to Hevea Cultivation

A summary of the parameters evaluated and the suitability classification of representative pedons of the rubber growing soils of Nigeria are shown in Table 2. All the soils studied are deep to very deep with mean effective depth greater than 150 cm. Shallow pedons were only observed in depressions along stream banks.

The texture of the soils was usually sandy; changing from loamy sand on the surface to sandy clay loam in the subsurface. Clay content in the soils generally varied from 1.6% on the surface of most pedons to 33.25% in the subsurface horizons. The higher clay content in the lower horizons have been attributed to illuviation, a process of clay transfer from overlying horizons. Only a few subsurface horizons of Okhuo, Iyanomo, Odagwa and Nekede have greater than 20% clay. The general low clay content and predominant sandy texture was noted to be a major constraint of the soils to rubber cultivation. According to Sys (1975) optimum rubber growth is obtained in soils having sandy clay, clay loam, silty clay and loam textures. Clay content in such soils is usually between 25 and 45%. However, there were no stones and gravels within 200 cm of the soils except in restricted pedons near stream banks.

The structure of the soils was weak to moderate granular or crumb on the surface and sub- angular to angular blocky in the sub-soils. The angular blocky to crumb structure on the surface enhance infiltration of water and ensure good drainage. The medium angular and sub-angular blocky structures are suitable for good anchorage of tree crops. There are generally no massive structures. The peaty soils are restricted to marshy or swampy areas along river banks and creeks and within the mangrove swamps and meander belt deposits.

The soils have common to abundant micro and macro-pores which are evenly distributed , continuous and inerstatial. Soil consistency in the area varied greatly between non sticky to non plastic on the surface to slightly sticky and slightly plastic in the sub-soils.
The rubber growing soils of Nigeria are generally level to gently sloping (1 to 3% slopes). Incidence of erosion is therefore minimal. However, some parts of Calabar and its environs are undulating with occasional deep slopes greater than 8%. There is the threat of soil erosion in such areas if not subjected to good soil management measures. Soils of the study areas are also perfectly well drained to moderately well drained. The groundwater table in most areas was below 150 cm. Table 2 also outlines the constraints of representative pedons to the cultivation of rubber.

Data on latex yield collected from major experimental stations in Nigeria whose soils have been characterized show a productivity trend different from the suitability rating. Yield studies over a six month period in five experimental stations just opened for tapping revealed a yield range of 1734 to 2870kg /ha/year. The productivity ranking was in the order: Calabar (2870kg) > Okhuo (2566kg) and Iyanomo(2560kg) > Akwete (1992kg) > Odagwa (1734). However, the suitability evaluation of the soils in the representative stations was of the order: Okhuo and Benin> Akwete> Odagwa> Calabar.

The observed discrepancy between soil suitability evaluation and latex yield ranking could be attributed to short term better moisture use efficiency in the Calabar area and more favourable environmental conditions (temperature and relative humidity) on latex yield of individual trees. In the long run, more trees will be lost to erosion hazards and wind effects in the Calabar area. The area has greater slopes (usually between 5 and 10%) and are, therefore, prone to both wind destruction of mature rubber trees and accelerated erosion. The apparent higher latex yield on the short term would be difficult to sustain for a long term. Greater soil management inputs would be required for soils of the Calabar area than the other rubber growing soils for sustainable latex production hence its relative placing in the suitability rating.

CONCLUSION

The study showed that the soils of the rubber growing area of Nigeria are suitable for rubber cultivation with only slight constraints in form of low soil fertility, sandy texture and threatening erosion in limited area. In terms of suitability ranking, soils around Benin (Iyaomo and Okhuo) are best suited for rubber cultivation while soils of Akwete are least suited.

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