Nigerian Journal of Soil Science

Journal homepage:www.soilsjournalnigeria.com

Fertility status of Biakpan rubber (hevea brasiliensis) soils of Cross River State, Nigeria.

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ARTICLE INFO

Article history:
Received September 20, 2020
Received in revised form October 9, 2020
Accepted December 20, 2020
Available online March 21, 2021

Keywords:
Natural rubber
Plantation
Rubber soils
Tropical rainforest.

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https://doi.org/10.36265.njss.2021.310103

ISSN– Online **2736-1411**
Print **2736-142X**

ABSTRACT

A study was carried out at Biakpan rubber estate in Cross River State, Nigeria to evaluate the fertility status of the soils. Three profile pits at random points within the estate were sunk representing the crest, the middle slope, and the valley bottom. Five samples were collected from each profile at 0 – 25cm, 25 – 50cm, 50 – 75cm, 75 – 110cm and 110 – 170cm depth. Fifteen representative soil samples were bulked as composite for each depth and were analyzed using standard laboratory procedures. The result of the study shows that sand, clay, and silt fractions ranged from 52.4% - 67.80%, 18.20% - 36.20%, and 10.00% - 15..40% with means of 57.76%, 28.20%, and 13.24% respectively, decreasing from the top to lower profile. Soil texture for the 0 – 50cm was sandy loam and 50 – 170cm was sandy clay loam. The soil's pH was strongly acid (5.18 – 5.60). Total N, available P, exch. Ca and Base Saturation was low, with a high Exch Acidity. OM was adequate at 0 – 50cm (fertility depth). Exch. K and Mg and ECEC were within adequate limits of rubber trees. With adequate depth and textures of the soils, adoption of agronomic practices with leguminous cover cropping and guided organic and calcium-based fertilizers can overcome the fertility limitations in Biakpan rubber plantation soils.

1.0 Introduction

Rubber (*Hevea brasiliensis*) also called Para rubber, or natural rubber is a commercial tree grown economically in plantations. The product of coagulated latex called rubber is used in the manufacture of industrial products. These include tyres, foot-wears, gloves, balls, containers, and bands in addition to other items. The production and ranking of rubber in Nigeria has been fluctuating between 1986 (60,000 tons) to 1990 (147,000 tons); rose to 142,000 tons in 2004 after dropping in 1995 and 2000 to 125,000 tonnes and 107,000 tonnes respectively (FAOSAT, 2005) Nigeria was the largest producer of rubber in Africa during this period with Liberia at the second position. In 2006 the production dropped with the production of $ 7.4 million placing Nigeria at 16th position in world production with a production of 1.4% of world output with Liberia overtaking Nigeria again. The major producing states in Nigeria are Edo, Delta, Ondo, Ogun, Abia, Anambra, Akwa Ibom, Cross River, Rivers, Ebonyi, and Bayelsa (Aigbekaen *et al;* 2000). Low production factors of rubber in Nigeria can be attributed to the low yield of trees with unknown pedigree, age of trees, poor soil management, and neglect by the government due to crude oil exploration. Adubi (2003) stated that while cocoa is the largest non-oil foreign exchange earner, rubber is the second largest earner if well exploited.

Soil is the basis of all commercial agricultural production especially plantation agriculture. The soil has been described by Liu X et al., (2006) as a vital resource that is not capable of being renewed on the human time scale. The productivity of tropical soils hinges on their maintenance and improvement, particularly physical properties that can hold the trees. Rubber is highly adaptable to different climates and soil conditions of the tropics, including extremely low fertility with a pH of 4.5 -5.5 (Watson 1989). The ideal textural class is loam to silty loam, appropriate structure, and depth of 150cm (Asawalam and Ugwa 1993). These soil properties have earlier been reported by Aweto (1987) who noted that soil fertility is less important than physical properties, but the soils should be deep. The neglect of the para rubber industry by the Nigeria Government due to declining yields that is attributable to poor soil management practices, lack of adequate information on potentials and management practices of our soils among others, formed the thrust of this study to evaluate the fertility status of Biakpan Rubber estate.

2.0. Materials and methods

2.1. Study area and sampling

The study was carried out at Biakpan rubber Estate in Biase Local Government Area by Cross River State. Biase is located in the tropical forest zone of Cross River State on latitude $5^0$00' and $5^0$47' N and latitude $8^0$06' and $8^0$11'E. Characterized by a rainfall range of 1963mm per annum to 27^0 C -33^0C and RH 80-90% (Ayoade 2004). Rainfall in this area commences about March and continues to October / November with the peak in July and October as bimodal. The vegetation is predominantly evergreen characterized by tall trees and bushes. There are also established secondary forest plantations of plantain and oil palm. The common arable crops cultivated by the people are maize, cassava, cocoyam, yam, and vegetables.

2.2 Sampling design

At three random points in the estate representing crest, middle slope, and the valley bottom soil profile pits were sunk with a dimension of 2m x1.5 x 2m. These gave representative soil of the estate.

2.3 Sampling.

From each profile five samples were collected at 0-25cm, 25-50cm,50cm- 75cm, 75cm -110cm and 110cm-170cm.These produced 15 samples which were bulked for composite for each depth. These samples were bagged and labeled in sampling bags then transported to the Federal University of Agriculture, Makurdi soil testing laboratory for analysis.

2.4 Soil analysis

These soil were air-dried and sieved with a 2mm mesh ready for the physicochemical analysis.

2.4.1 Physical Properties

Particle size distribution (PSD) was determined by the Bouyoucos (Hydrometer) method procedure by Udo *et al.,* (2009). This involves the suspension of soil samples with sodium hexametaphosphate (Calgon). The reading on the hydrometer was taken at 40 seconds. The second reading was taken three hours later. The particle size was then calculated using the following formulae:

Sand = 100- $(H_1 + 0.2 (T_1 – 68)-2.0)2$.,

Clay = $(H_2 + 0.2 (T_2 (T_2-68) -2.0)2$

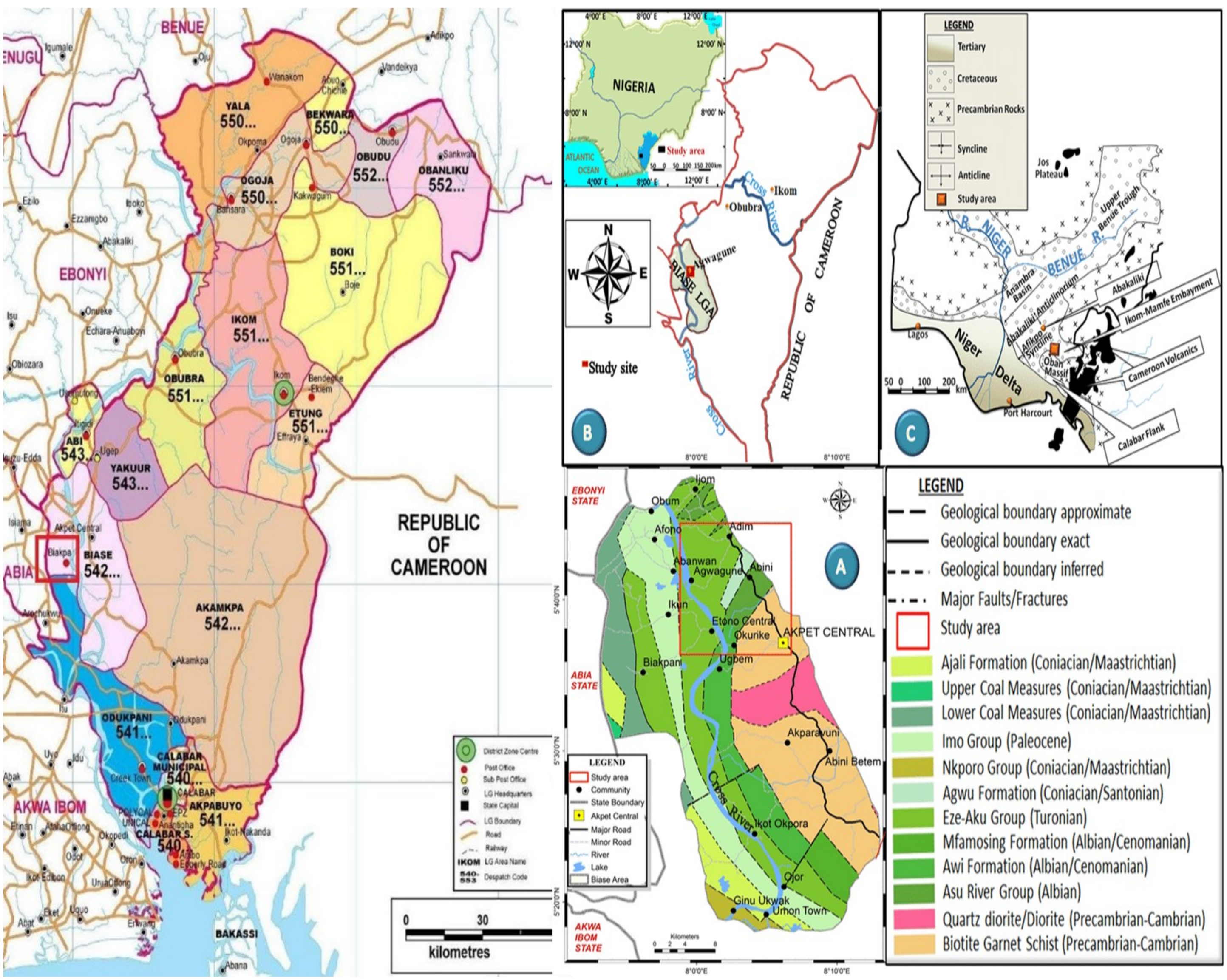

Fig. 1: Map of the study area

Silt= 100 – (% sand + % clay)

Where:

H_1 = Hydrometer first reading at 40 seconds-
T_1 = temperature first reading at 40 seconds
H_2 = Hydrometer second reading after 3 hours
T_2 = Temperature second reading after 3 hours

2.4.2 Chemical Properties

Soil pH. was determined in both water and 0.1 N KCL in a ratio of 1:1 soil: water and 1:2.5 soil: KCl respectively. After stirring the soil suspension for 30 minutes, the pH values were read using the glass electrode pH meter (Mclean, 1982).

i. Organic Matter

This was determined by the Walkley-Black method as outlined by Page *et al*., (1982) which involves the oxidation with dichromate and tetraoxosulphate VI acids ($H_2 SO_4$). The excess was titrated against Ferrous Sulphate. The organic carbon was then calculated using the relationship:

$$\% \text{ org.C} = \underline{N(Vi - V_2)}\ 0.3f$$

Where:

N = Normality of Ferrous Sulphate solution
V_1 = Ml Ferrous Ammonium Sulphate for the black
V_2 = ml Ferrous Ammonium Sulphate for the sample
W = mass of sample = farm
F = correction factor = 1.33
% organic matter in soil = % org.C x 1.729

ii. Total Nitrogen

Total nitrogen in the soil was determined by the macro Kjeldahl method as described by Udo *et al., (*2009). The soil samples were digested with Tetraoxosulphate (Vi) acid ($H_2 S0_4$) after the addition of excess caustic soda. This was distilled into a 2% Boric acid (H_3BO_4) and then titrated with 0.01 HCl. And the nitrogen was obtained from the relationship.

$$\% N = \frac{T \times M \times 14 \times 100}{N}$$

Where:

T = Titre value
M = Molarity of HCl
W = Weight of soil used
N = Normality of H_2SO4

iii. Available Phosphorus

Available P was determined by Bray 1 method as outlined by Page *et al*., (1982). This involved mechanical shaking of the sample in an extracting solution then centrifuging the suspension at 2000 rotations per minute for 10 minutes. Using the Ascorbic acid method, the percentage transmittance on the spectrophotometer at 660 nm wavelength was measured. The optical density (OD) of the standard solution was then plotted against the phosphorus ppm and the extractable P of the soil was then calculated.

iv. Effective Cation Exchange Capacity (ECEC) and Exchangeable acidity (EA)

These were determined by the Kjeldahl distillation and titration method as outlined by IITA (1979) using ammonium acetate solution the soil samples were leached then the soil washed with methyl alcohol and allowed to dry. The soil was then distilled in Kjeldahl operation into a 4% Boric acid solution. The distillate was then titrated with a standard solution of 0.1 N HCl.

v. Exchangeable cations:

This was determined by the ammonium acetate extraction method as described by IITA (1979). The soil samples were shaken for 2 hours then centrifuged at 2000 rpm for 5 -10 minutes after decanting into a volumetric flask, ammonium acetate (30 ml) was added again and shaken for 30 minutes, centrifuged and the supernatant transferred into the same volumetric flask. Atomic Absorption Spectrophotometer (AAS) Buck Scientific 200A model was used to read the cations.

3.0 Results and Discusion

3.1 Physical Properties

Results of soil depth, particle size distribution, and texture are presented in Table 1. The three profile pits were established to the proposed depth of 2m. The surface (0-25 cm) depth has 67.80% sand, 61.80% sand for the 25-50cm depth, and the subsurface Layers of 50 cm -75cm (54.40% sand), 75 cm -110cm with 52.4 % and 110 cm 170 cm depth with a percentage sand composition of 52.40 and a mean value for all the layers of 57.76%. The clay ranged from (in increasing order from the top 0-25cm to 110-170cm profile) 18.20%-36.20% with a mean value of 28.20%. The silt content of the soils ranged from 10.00% - 15.40% in the profile from top 0-25cm to110cm -170 cm with a mean of 13.24% and with no definite order of increment. The textural classes of the soils were sandy loam for the 0 – 50cm and sandy clay loam from 50 cm -170 cm (Table 1).

The profile depth of the soils of up to 170cm was an indication that the soils of the Biakpan rubber estate meet the required depth of 150cm for rubber production (Aweto 1987).

The trend of distribution of sand which showed a decrease down the profile from upper to lower horizons and the increase in the percentage clay with depth in the profile while silt was irregular is in agreement with the observa-

Table 1:Effect of soil depth on the particle size distribution of the study area

	Particles Size Analysis				
Soil. Depth (Cm)	Sand %	Clay %	Silt %	Texture Class	Silt/Clay Ratio
0 – 25	67.80	18.20	10.00	Loamy sand (SL)	0.55
25 – 50	61.80	24.20	14.00	Sandy Loam (SL)	0.58
50 – 75	54. 40	30.20	15.40	Sandy clay loam(SCL)	0.51
75 – 110	52.40	32.20	15.40	Sandy clay loam (SCL)	0.48
110 - 170	52.40	36.20	11.40	Sandy clay loam(SCL)	0.31
Mean	57.76	28.20	13.24		

tion of Esu *et al*, (2015) in Biase soils developed under schist parent materials

The sandy loam and sandy clay loam of the soils are within the recommended texture of loam to silty loam recommended by Asawalam and Ugwa (1993) for rubber production. The physical suitability of these soils in terms of depth and texture was also expressed by Aweto (1987) who stated that soil fertility is less important than physical properties for rubber farming.

3.2 Chemical and fertility properties of Biakpan rubber plantation soils.

The result of the chemical and fertility properties of the soils is presented in Table 2. The soils showed a pH range of 5.18- 5.60 and a mean pH in water value of 5.38. Organic carbon ranged from 0.55-2.85% with a mean of 1.48% while the organic matter was 0.95-4.91% which a mean of 2.50% in a descending order from 0-25cm> 25 cm-50cm>50 cm-75cm. Total nitrogen in the soil ranged from 0.04%(very low) – 0.10% (low) with a mean value of 0.06%. Available phosphorous (P) in the soils ranged from 1.00-7.66 cmol/kg with a mean of 3.29 cmol/kg with an irregular distribution order. The soils exchangeable calcium (Ca) ranged from 1.28-1.92 cmol/kg with a mean value of 1.4 9 cmol/kg. Exchangeable magnesium (Mg) ranged from 0.96 cmol/kg – 1.28cmol/kg with mean value of 1.09cmol/kg with a high concentration in the surface 0 - 50cm soil depth. Exch. Potassium in soil was in the range of 0.26 cmol/kg – 0.69cmol/kg with a mean of 0.52cmol/kg. Exch Na in the soil was 0.26 cmol/kg – 0.39 cmol/kg (mean of 0.33cmol/kg). Exch Acidity (EA) ranged from 9.36 cmol/kg – 19.08cmol/kg with a mean of 13.13cmol/kg. The effective cation exchange capacity (ECEC) of the soils ranged from 13.33 cmol/kg – 22.48cmol/kg with a mean of 16.68cmol/kg while the base saturation of the soils ranged from 15.20 – 29.78% with a mean of 22.12%. The pH of the soils across the horizons indicated that the Biakpan rubber soils are strongly acid in reaction implying that the soils contain a significant amount of exchangeable Al^{3+} and H^{+} that will affect plant growth (Esu, 2010). These acidity levels in the soil could be a result of the low Ca content in the soils. However, rubber is an acid-tolerant plant and so this pH is within the range for rubber plants. Watson, (1989); Ugwa *et al* (2006) stated that the pH range suitable for rubber trees is 4.5 – 5.5 which requires no liming. The organic carbon and organic matter content of the soils at the 0 – 50cm depth of the soils were adequate for fertility ratings of tropical soils (Sims, 2002). The OM of the soils of this depth is capable of reducing runoff and erosion and retains water. The exch. Ca in the soil was below the critical levels (<2.00) as stated by Obigbesan (2009) but this was within the thresh hold of critical limits for deficiencies and the soils can likely give a good response to fertilizer application. Exch. K and Mg in the soils were adequate particularly at the 0 – 50cm depth as these were above critical limits (Enwezor et al; 1989). The high levels of exch K and Mg in this study area are similar to the values observed by Omene et al.,(2015) at Ughelli rubber plantation soils in the Delta State of Nigeria.

The moderate level of OM in the soils could have reduced the leaching of these cations.

Total N and Av. P in the soils were low according to the ratings of Ugwa et al, (2006) for rubber soils. The critical nature of N and P in soils due to their high leachability in soils with low OM and low exch. Ca makes P vulnerable to fixation in low ph soils could be the basis for the low availability of these nutrients. The low (strongly acid) pH, low Ca and OM is implicated in the levels of these nutrients levels.

Exchangeable acidity (9.36 cmol/kg – 19.08cmol/kg) was high in the soil above the critical limits. This level of EA is such that could cause serious problems to crop production. These EA values reflect the reaction of the soils. Effective cation exchange capacity (ECEC) and Base Satura-

Table 2: Chemical and Fertility Properties of the Soils.

Depth (Cm)	**0 – 25**	**25 – 50**	**50 – 75**	**75 – 110**	**110 – 170**	**Mean**
pH in H_2O	5.18	5.31	5.46	5.60	5.36	5.38
pH (KCl)	4.06	4.20	4.33	4.51	4.20	4.26
Organic Carbon %	2.85	2.19	0.55	0.74	0.95	1.46
Organic matter %	4.91	3.77	0.94	1.27	1.63	2.50
Total Nitrogen %	0.10	0.06	0.02	0.06	0.04	0.06
Available phosphorus mg/kg	3.33	7.66	1.00	1.00	3.46	3.29
Exchangeable Ca cmol/kg soil Exchangeable Mg cmol/kg	1.66	1.60	1.60	1.28	1.92	1.49
Exch. Na cmol/kg	1.28	1.28	0.96	0.96	0.96	1.09
Exch. K cmol/kg	0.34	0.34	0.34	0.39	0.26	0.33
Exch. Acidity cmol/kg soil	0.69	0.43	0.63	0.58	0.26	0.52
ECEC cmol/kg	9.36	12.36	11.52	13.32	19.08	13.13
Base Saturation %	13.33	16.01	15.05	16.53	22.48	16.68
	29.78	22.80	23.46	19.42	15.12	22.12

tion were at variance as the ECEC was above the critical limits (< 50%) across all the layers in the profile, (Sys 1985). The high ECEC is attributed to the high clay content and its increase with depth of the profile indicates a correlation with the increasing % clay down the profile. This property indicates the soil's capacity to adsorb basic cations and leaching of anions of N and P. The low base saturation of the soils could be attributed to the leaching of the soluble cations which made them low in solution. This BS will not support continuous arable cropping but can support plantation crops like rubber. The application of calcium-containing fertilizers for the low available nutrients will be ideal as this will improve their retention and increase the soil base saturation. The application of organic-based fertilizers will improve the soil OM content and the nutrient holding capacity.

4.0 Conclusion

This study indicated that Biakpan Rubber plantation soils have the potentials and suitability for improved and sustainable growth and yield of rubber. Adoption of good agronomic practices with leguminous cover cropping and guided organic and calcium-based fertilizers can overcome the fertility limitations in Biakpan rubber plantations.

Acknowledgment

I wish to acknowledge the contributions and services of the following:

Mr. Ekpezu Enun, my colleague and an indigene of Biakpan who introduced me to the Management of the Biakpan Rubber Estate.

I appreciate the Management and Technical staff of the Rubber Estate for the access and the delineation operations carried out by me.

The fieldwork could not have been accomplished without the assistance of my undergraduate students: Lewis Mkpe Anyia, Godwin Itokem, and Emmanuel Ekponoabasi who were my field assistants in soil sampling, labeling, packaging, and sieving for laboratory analysis.

Dr. Tom O. Ojikpong assisted in the design of the experiment and soil data processing.

References

Adubi, A. A. (2002) The Agricultural Sector: Objectives, Priorities, Strategies, and Policies. Book of Readings on policy issues in Nigerian Economy, National Centre for Economic Management and Administration (NCEMA) Abuja.

Aigbekaen, E. O., Imarhiagbe, E. O. and Omokhafe, K. O. (2000) Adoption of some Agronomic Practices of Natural Rubber in Nigeria. Journal of Agriculture for Fish 1: 51-56

Asawalam, D. O. K. and Ugwa, I. K.(1993) Some Soils of Northern Bendel State and their potentials for growing rubber. Indian Journal of Natural Rubber Research 12(1-2): 137-142.

Aweto, A. O.(1987) Physical and Nutrients Status of Soils under Rubber(Hevea brasiliensis) of different ages in South-Western Nigeria. Agricultural Systems Vol.23 (1) 63-72

Ayoade, J. O. (2004) Introduction to Climatology for the Tropics. Wiley John and Sons Incorporated. University of Michigan, USA 274 pp.

Enwezor, W. O. (ed) (1989) Fertilizer use and Management Practices for Crops in Nigeria. Federal Ministry of Agriculture and Rural Development Lagos Nigeria 163Pp.

Esu, I. E. (2010) Soil Characterization, Classification, and Survey. HEBN Publishers Plc. Nigeria 232 pp.

Esu, I. E., Uko, U. and Aki, E.E.(2015) Morphological, Physicochemical and Mineralogical properties of soils developed from Basalt at Ikom, Cross River State Nigeria. Nigeria Journal of Soil Science Vol. 25:168-180.

FAOSAT (2005) Food and Agricultural Organization of the United Nations Statistics; 2005.

IITA (1979) Selected methods for soil and plant analysis. International Institutes for Tropical Agriculture, Ibadan Nigeria. Manual series No. 1.

Liu X, D. G., Herbert, S. J., Hashemi, A. M. and Zhang, X. (2006) Effects of Agricultural Management on soil organic matter and carbon transformation. Soil and Environment, Vol. 53, 531-543.

McClean, E. O. (1982), Soil pH and Lime requirement. In: Page D. C. (eds) Methods of Soils Analysis part 2. Chemical and soil microbial properties. Agronomy series No. 9 ASA, SSSA, Madison.

McClean, E. O. (1982), Soil pH and Lime requirement. In: Page D. C. (eds) Methods of Soils Analysis part 2. Chemical and soil microbial properties. Agronomy series No. 9 ASA, SSSA, Madison.

Obigbesan, G. O.(2009) Ratings for Soil Fertility Classes in Nigeria. Personal Communication.

Ofem, K.I., and Esu, I. E. (2015) Pedological Study of Soil Development on Schist in Biase Local Government Area, Cross River State Nigeria. Nigeria Journal of Soil Science 25: 181-193.

Omene, M. E., Chokor, J. U. and Eyankware, M. O.(2015) Effects of Land Use on Soil Physicochemical Properties in Ughelli and Environs, Delta State Nigeria. International Journal of Research and Review Vol. 2 (11) 656-671

Page, A. L., R. H. Miller, and D. R. Keeney (1982). Methods of Soil Analysis Part 2. Chemical and microbiological properties. American Society of Agronomy, Madison 55 pp.

Sims, J. T. (2000) Soil Fertility Evaluation P. D113-D-153. In Sumner, M. E. (eds). Handbook of Soil Science. CRC Press, Washington DC.

Sys, C. (1985) Land Evaluation. International Training Centre for Post Graduate Soil Scientists. Vol. I, II and III, State University, Ghent

Udo, E. J., T. O. Ibia, J. O. Ogunwale, A. O. Ano and I. Esu (2009), Manual of Soil, Plant and Water Analysis, 183pp., Sibon Books Ltd. Lagos.

Ugwa, I. K., Orimoloye, J. R. and Eskhade, T. U. (2006) Nutrients Status of some soils supporting rubber in Mid-Western Nigeria. Nigeria Agricultural Journal 36: 169-176.

Watson, G. A.(1989) Nutrition in Rubber. C.C. Webster and W. J. Baulkwill (eds.) Longman Scientific and Technical, New York pp 291-348.