FERTILITY EVALUATION AND MANAGEMENT STRATEGIES OF SOILS OF IJEBU IGBO, NIGERIA FOR RUBBER (*HEVEA BRASILIENSIS*) AND OIL PALM (*ELAEIS GUINEENSIS*) AGRO-FORESTRY

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ABSTRACT

This study was conducted to evaluate the soil fertility status of the undulating topography of Lamina Village, Ijebu North Local Government Area of Ogun State and its implication for utilization in rubber and oil palm-based farming system. The land was mapped using visual appraisal of the area such as soil colour, texture, topography and vegetation. Samples were collected at two depths (i.e. 0 - 30 cm and 30 - 60cm) and subjected to standard laboratory procedures. The soil analysis results and the field observations formed the bases for the recommendation of fertilizer rates and other agronomic practices for optimum rubber and oil palm agro-forestry systems. The results indicated that the area had been under secondary forest for about 20 years. The soils of the area ranged from loamy sand to sandy loam on the surface overlying a slightly heavier textured sub-soil ranging from sandy loam to sandy clay loam. The soils were slightly acidic and low in most essential nutrients. Total Nitrogen (0.13 – 0.17%), Phosphorous (0.46 – 2.34%), and Exchangeable Cation Exchange Capacity (6.91 – 11.22mg/kg) were generally low. The organic carbon content of 3.09% is moderate while potassium content (0.25 – 1.36Cmol/kg) is of good supply in the soils. Fertilizer recommendations were made for the different stages of rubber growth while other management strategies were suggested aimed at reducing organic matter losses and minimizing soil erosion as well as control of termite infestation.

Key words: Rubber (*Hevea brasiliensis*), oil palm (*Elaeis guineensis*), soil properties, soil fertility, Nigeria.

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INTRODUCTION

Nigerian economy has recently suffered grave consequences of over-dependent on oil as a single source of income. The current effort to diversify the nation's economy with emphases on agriculture and solid minerals is therefore necessary. The current effort in agriculture is placing too much emphasis on grain production, as was the case in previous government efforts. To avoid the pitfalls of the past, there is need for government to focus her attention on the agricultural diversification plans that is holistic to meet food, income as well as environment and social needs. Diversification strategy through agriculture should put into account the peculiar needs of all the agro-ecological zones of Nigeria.

Rain forest belt of Nigeria covers land area of about 7.6 million ha of land that lies in the southern part of Nigeria extending from Ogun State to Cross Rivers State (Michael, 2006). The soils of the area are predominantly coarse textured ultisols and oxisols derived from cretaceous sandstones and Pleistocene unconsolidated coastal sediments (FDALR, 1995) characterized by high acidity, low nutrient status, low activity clay and are subjected to rapid fertility decline on land clearing for cultivation (Asawalam and Ugwa, 1993; Eshett, 1991; Juo 1981; Kang and Juo, 1986). The physical characteristic of the soil makes it susceptible to degradation especially by erosion and leaching when exposed.

Sustainable land utilization in these areas requires that the land be perpetually kept under vegetation cover. To this end, economic tree cultivation especially (rubber and oil palm) has been promoted in the area for climate change adaptation and mitigation (Omokhafe and Eguavoen, 2014). They are also suitable for the amelioration of the challenges of social dislocation, as they can check rural-urban migration and youth restiveness, because their cultivation and processing are labour intensive.

Ijebu Igbo in Ijebu North Local Government Area of Ogun State is located within the rubber and rainforest belt of Nigeria. It has an undulating topography and there are efforts to encourage cultivation of rubber in the location, but record of the fertility evaluation of the area for economic utilization for rubber and oil palm are not available. The objective of the study therefore was to evaluate the fertility potentials of the soils of Ijebu Igbo for possible rubber and oil palm cultivation and recommend appropriate fertilizer and agronomic management strategies for a sustainable rubber and oil palm cultivation in the area.

METHODOLOGY

Soil fertility evaluation study was carried out at the proposed 20ha rubber and oil palm based agro-forestry farm located at Lamina settlement, 15 to 16 km along Ijebu-Igbo/Osun highway, Ijebu North Local Government Area of Ogun State. The study area is an irregular shaped land area lying approximately within the co-ordinates Lat 7^{o} 05314'' and 07^{o} 05057'' N and Long 04^{o} 12085'' and 04^{o} 12118'' E. The area covers about 20 hectares of land. The Ijebu-Igbo area lies essentially in the rain forest zone with two distinct seasons (raining and dry seasons) which alternate annually. Mean annual rainfall is about 1950mm distributed in about 9 months of the year with a peak between July and September each year. The vegetation in its natural state falls within the rainforest zone. However, the study area is mostly secondary forest re-growth, which has been fallow for upward of 20 years. The land is in 3 storey vegetation cover consisting of tall forest trees at the top, luxuriant perennial shrubs in the middle and undergrowths of mainly broad leaves such as *Aspilla africana*, *Chromolaena odorata*. Grass species were not common in the area. Some bamboo trees grow luxuriantly close to the streams and lowland areas in the vicinity. The area has large concentration of mainly wild oil palm trees and forest trees, which farmers in the area harvest, process and market in addition to engagement in mixed cropping of various crops especially, cassava, plantain, maize and yams.

The land was mapped out based on field observations such as soil colour, texture, topography and vegetation covers. The hill is in form of ridges and they show similar patterns in shape and orientation. Soil samples were collected at the Hillcrest, Middle slope and the Valley bottom. Samples were collected at two depths i.e. 0 – 30 cm and 30 – 60cm depths as the sampling points. A composite sample was collected for each depth at each of the sampling area. A total of 24 composite samples were collected, bagged, labeled and transported to the laboratory for analysis. Soil pH was determined at 1:1 soil/water ratio using glass electrodes pH meter. Organic carbon was determined by chromic acid oxidation method. Available P was extracted using Bray 1 solution and the phosphate in the solution assayed by the Molybdenum blue colour method. Exchangeable cations were extracted with neutral normal ammonium acetate solution. Ca and Mg were determined by EDTA titration, while Na and K were determined by flame photometry. Effective cation exchange capacity (ECEC) and base saturation were computed.

Particle size analysis was by the modified Bouyoucous Hydrometer method as modified by Black (1965). The interpretation of the results for fertility evaluation was based on the interpretation rules for tropical and subtropical soils as adopted by FDALR (1995). With respect to rubber cultivation, the information contained in Watson (1989), Orimoloye *et al.* (2004) and Orimoloye *et al.* (2005) was utilized at arriving at the conclusions and recommendations. Other criteria used for soil data interpretation and the sources of information are presented in Tables 1 and 2 below.

Criteria for interpretation of Results:
The interpretation of the results for fertility evaluation was based on the interpretation rules for tropical and subtropical soils as adopted by FDALR (1995). With respect to rubber cultivation, the information contained in Watson (1989), Orimoloye *et al.*, (2005) and Ugwa *et al.*, (2006) was utilized at arriving at the conclusions and recommendations as in indicated in Tables 1-3.

Table 1: Criteria use in identifying the soil textural class

Physical Characteristics	**Textural Class**
Coarse textured soils	Sand (S), Loamy Sand (LS)
Moderately textured soils	Sandy Loam (SL), Sandy Clay Loam (SCL).
Fine textured soils	Loam (L), Sandy Clay (SC) and Clay (C).

Textural class names were as defined by USDA: Soil Survey Staff (1975)

Table 2: Classification of soil acidity

Soil acidity	**pH Values**
Extremely acidic	≤ 3
Very Strongly acidic	3.5 – 4.5
Strongly acidic	4.5 – 5.0
Moderately acidic	5.5 – 6.5
Slightly acidic	6.5 – 6.9

Source: FDALR (1995)

RESULTS AND DISCUSSIONS

Geology: Field observations in the study area showed that they consist entirely of highly deformed and metamorphosed sedimentary rocks. However, very few fragmented rocks of the mica and granite gneiss were encountered, the area consists principally of quartz and quartzite schists characterized by ridges and steep slopes with no visible rock outcrop within the whole area. Within 0-60 cm depth there were stony obstructions mainly quartzite origin, which are evidence of incomplete weathering processes. These impediments were observed not to obstruct plant root development and growth. The study site is characterized by a remarkably undulating topography with slope gradients measuring between 3 – 5%. Global Positioning System (GPS) elevation averaged about 121m. The area appears to be a watershed with depressions towards the slopes ending invariably in a stream (Teleba stream) that emptied into the Osun River.

Soil Physical Properties
The soils of the study area has texture ranging from Loamy Sand to Sandy Loam on the surface overlying a slightly heavier textured sub-soil ranging from Sandy Clay loam (Table 2). This result is similar to those of Iyanomo (Orimoloye *et al*, 2012) and Northern Cross River State (Orimoloye *et al.*, (2010).

Table 3.Criteria for interpretation of soil data

Soil Parameter	Very poor	Low	Moderate	Good	Sources
Ca (Cmol kg^{-1})	1.0	1.0-2.3	2.3-5	7.0	FDALR (1995)
Mg (Cmol kg^{-1})	0.4	0.5-1.0	1.1-1.5	3.0	FDALR (1995)
K (Cmol kg^{-1})	0.01	0.01-0.2	0.2-0.4	0.4-0.8	FDALR (1995)
ECEC (Cmol kg^{-1})	<4	4-9	9-12	>12	Ugwa *et al* (2006)
Available P (mg/kg)	< 5	5-8	8-10	>10	FDALR (1995)
Total N (%)	<0.04	0.05-0.12	0.12-0.24	>0.24	Watson (1989)

This shows a degree of profile development and it is desirable for rubber and oil palm cultivation. The two crops, but rubber in particular, has an extensive root system with taproots that could be as deep as 3 – 4m and lateral roots that can extend from 15 – 20m. Accordingly, a fairly deep, well drained soil with good physical structure on a gently sloping terrain with minimal soil erosion is required by rubber for optimum growth. Sandy clay loams and clay loams are among the most suitable textural classes for rubber cultivation. Some of the soils of the study area have gradients that are higher than the recommended degrees for rubber but they are not under any serious threat of erosion due to the stability of the underlying parent material. Hard pans and stoniness can greatly restrict root growth. Most areas of the soils studied have gravelly layers less than 100 cm from the surface. With proper management, this will not affect the survival of the two crops on the field. For instance, pruning of the rubber trees to reduce canopy weight is suggested. In the case of oil palm, it is a shallow rooted plant, hence will not be affected by the concretions observed.

Soil Chemical Properties

The results of the chemical characteristics of the soil are presented in Table 4. The soils of the study area have a pH range of 4.8 - 5.9 which is within the suitable range for rubber and oil palm without any need for liming. The two crops are essentially adapted to high rainfall areas which are often associated with leaching and acidity. The crops tolerate soils with an acid reaction. Most suitable soils for rubber and oil palm are strongly to moderately acid with pH (in H_2O) ranging from 4.0 - 6.5 (Ugwa *et al*., 2006). The exchangeable bases (Ca, Mg, Na and K) are generally moderate to good (FDALR, 1995) in the study area. The Effective Cation Exchange Capacity (ECEC) was also modrate (between 7.00 to 11.22 Cmol kg^{-1} of dry soil). An optimal value for ECEC for rubber and oil palm is 15 Cmol kg^{-1} and soils that have less than 5 Cmol kg^{-1} requires supplementary fertilizer programme for optimum rubber development (Ugwa *et al.*, 2006). Hence the mean ECEC value of 8.98 Cmol kg^{-1} obtained for the area may therefore not need fertilizer intervention at planting. Considering the potential losses that may arise as a result of leaching, erosion and consumption by other crops to be intercropped the oil palm and rubber, subsequent fertilizer application will be necessary (Orimoloye *et al.,* 2010). The base saturation recorded in the land between 91.43 – 96.97% was satisfactory. As soils with base saturation above 80% indicates that the exchange complex of the soil particles are occupied by bases rather than reserved acidity (Al^{3+} and H^+). The observed base saturation might be attributed to the fact that the land area has been under vegetation cover for a very long period. The status of the soil exchange complex is desirable for long term fertility management. The soil available P of 1.04 mg/kg is very poor and the total N and organic carbon contents of 0.16% and 3.09% respectively are moderate in the soils. These nutrients are mainly influenced by vegetation cover, bush burning and organic matter management. However, Nitrogen is easily lost through several processes in the soil while Phosphorous is easily immobilized by microbial activities as well as chemical reactions. The mean organic carbon content of 2.60 – 3.45 % is high (Ugwa *et al.,* 2006). This is understandable as the land has been under vegetation cover for a long period of time. To sustain this, agronomic management practices that allow for quick vegetation cover especially food based cropping system will be beneficial. This was also suggested by Orimoloye *et al.,* 2010 and Orimoloye *et al.,* 2012.

Fertility Evaluation and Fertilizer Calculations: Soil distribution was very heterogeneous mainly due to the undulating topography. The recommendations were therefore based on the averaged soil properties on the Hill tops, middle slopes and the valley bottoms for easy interpretation. Fertilizer calculations are based on the interpretation rules for tropical and subtropical soils as adopted by FDALR (1995). With respect to rubber cultivation, the information contained in Watson (1989), Orimoloye *et al*., (2004) and Orimoloye *et al*., (2010) were adopted.

The major nutrients required for rubber and oil palm growth at planting and juvenile growth stages are Nitrogen (N), Phosphorus (P_2O_5), Potassium (K_2O) and Magnesium (MgO). They are also required for optimum growth until harvesting. They are also required for maintenance of plant yield stability and vigor. In the case of N, care should be taken to avoid excess as this may lead to excessive vegetative growth that may bring about a greater risk of lodging and trunk breakage.

Nitrogen is a dynamic soil nutrient. It is lost in the soil as NH_4^+, NO^{3-}, N and NO through the process such as leaching, volatilization, de-nitrification, microbial uptake and clay fixation. Application of Nitrogen as ammonium phosphate is well encouraged in immature rubber trees. They are necessary for root and shoot growth, because of the added advantage of phosphate. Nitrogen applications to rubber and oil palm in splits are recommended at six monthly intervals from the 1st year to the 5th year after planting. Recommendations of N fertilizer usually consider added N from leguminous covers or crop residue management. Critical level of N equivalent to 0.15% represents a supply of 168kg N/ha. At 0.16% soil content, a supply of native 179.2 kg N/ha is available thus, needing no nitrogen interventions in the soil natural state at planting. Considering losses after land clearing and component crop consumption, basic N fertilizer intervention as recommended by Orimoloye *et al*., (2010) is necessary at the second year (Table 5).

Phosphorous (P) is an important constituent of nucleic acids and complexes needed for respiration and photosynthesis in plants. It is necessary for seed germination, plant metabolism and efficient utilization of N. Phosphorous is an active ingredient of protoplasm and gives stability to rubber and oil palm stems. Phosphorous is a pH dependent nutrient whose availability and uptake sometimes are influenced by other nutrients or soil conditions. At the pH obtained from the study area, liming is not required and P will be very active. Phosphate is very important at rubber establishment to stimulate rooting. Therefore, it is advised that at least 100-120g/tree of ground rock phosphate be applied to the planting hole. The soil contains an average of 1.04 mg/kg which amounts to 2.06 kg/ha. Minimal requirement for optimal rubber development is about 25.70kg/ha. This requires an additional 13.64 kg/ha. This could be supplied as 127.95 kg Single Super Phosphate (SSP) per hectare (or 213g/tree).

Potassium (K) enhances the resistance of rubber and oil palm to diseases and it balances excess magnesium in the trees. Adequate supply of K helps in plant tissue regeneration, increase yield and stability of trees. The need for K depends mainly on soil type and constitution. The mean K level of 0.7Cmol kg-1 soil obtained for the soils of the area could be classified as good (FDALR, 1995). The soil could be said to have good supply of K, which is quite remarkable considering the parent material. However, some level of K has to be applied to maintain a good nutrient balance in the soil especially in the presence of low magnesium. An application of 20.94kg K_2O could be applied per year is recommended for the first 5 years of rubber establishment. This could be supplied as muriate of potash (MOP) at 50 kg/ha or 83g per tree.

Magnesium is an essential ingredient of chlorophyll. It aids the translocation and utilization of phosphorus in rubber. Excessive uptake of Mg is associated with adverse effects on latex composition leading to pre-coagulation. A good balance therefore should be maintained between Mg and K in the soils for rubber. The soils of the study area do not have threat of Mg deficiency. The optimum Mg requirement is 120.96kg/ha However, the soil has an average of 168kg/ha at 0.70 C mol/kg soil content leaving an excess of 47.04kg/ha. This level Mg in the soil needs no fertilizer intervention in its natural state (FDALR, 1995). After cropping, application of MgO at 20g/ha or less may be necessary. If deficiency symptoms are observed subsequently, dolomitic limestone at about 120g per tree could be applied to correct Mg deficiency during the juvenile stages of the trees.

Table 4: Average soil chemical properties at three physiographic locations on the farm at Lamina, Ogun State, Nigeria

Physiography	Depth (cm)	Sand %	Silt %	Clay %	Textu	pH (H2O)	Org C (%)	Av P (mg/kg)	Total N (%)	Exch Acidity	Ca	Mg	Na	K	ECEC	BS (%)
											Cmol kg-1					
Hill crest	0-30	51.52	18.84	29.64	SCL	5.61	3.14	2.34	0.16	0.42	2.13	5.07	1.74	1.36	10.72	96.08
	30-60	55.52	16.84	27.64	SCL	5.91	2.60	1.15	0.13	0.34	2.40	5.47	1.74	1.27	11.22	96.97
Middle slope	0-30	79.52	6.84	13.64	SL	4.99	3.04	0.76	0.15	0.54	1.17	3.73	1.15	0.32	6.91	92.19
	30-60	83.52	2.84	13.64	SL	4.79	2.94	0.98	0.15	0.60	3.07	1.73	1.15	0.45	7.00	91.43
Valley Bottom	0-30	63.52	11.84	24.64	SCL	4.81	3.45	0.56	0.17	0.56	2.80	2.67	1.45	0.54	8.02	93.02
	30-60	55.52	14.84	29.64	SCL	4.82	3.38	0.46	0.17	0.52	2.40	4.53	2.32	0.25	10.02	94.81
Mean	-	64.85	12.00	23.14	SCL	5.16	3.09	1.04	0.16	0.50	2.33	3.87	1.59	0.70	8.98	94.08

Table 5: Schedule of fertilizer application for the first 5 years of rubber planting at Ijebu Igbo in g/tree

At Planting: 80g of NPK + 100g rock phosphate/planting hole				
Months after planting	**N**	**P_2O_5**	**K_2O**	**MgO**
6	18.00	11.35	17.45	10.63
12	18.00	11.35	17.45	10.63
18	18.00	11.25	17.45	10.63
24	28.40	14.25	22.68	10.63
36	56.00	28.50	34.9	14.40
42	100.0	84.00	40.00	21.00
54	120.0	80.00	45.00	25.00
66	120.0	80.00	45.00	25.00

CONCLUSIONS

- The undulating topography soils of Lamina Village, Ijebu North Local Government Area of Ogun State ranged from loamy sand to sandy loam on the surface overlying a slightly heavier textured sub-soil ranging from sandy loam to sandy clay loam.
- The soils were slightly acidic and low in most essential nutrients. Total Nitrogen (N), Phosphorous (P) and Exchangeable Cation Exchange Capacity (ECEC) were generally low.
- The land also had sloped gradient slightly above the recommended level for rubber cultivation; but with effective agronomic and fertilizer management strategies, these limitations could be tilted in favour of economic rubber and oil palm based agro-forestry.

RECOMMENDATIONS

Based on field observations and soil analysis, the following recommendations are presented for rubber and oil palm:

1. 100g rock phosphate per plant should be thoroughly mixed with top soil and applied to the planting holes 1-2 weeks before planting.
2. Application rate of 33kg N/ha, 13.64 kg P_2O_5 /ha, 20.94 kg K_2O per ha and 12.96 kg MgO /ha in two split applications is advised for the first years. While a schedule for the first 5 years in Table 5 should be followed.
3. To ensure maximum nutrient capture, fertilizers should be applied in a ring form a few centimeters from the base of rubber during the first year. The radius of the ring should be increased progressively to 80 - 90cm at the end of the second year. From year 3 to 4, band placement along a clean weeded strip at 80 - 250 cm from the base of the tree till year 5 is recommended.
4. Frequent dressings and split application at 6 monthly interval is encouraged. Time of application should be adjusted to avoid periods of excessive rainfall or very dry periods of the year.
5. Due to stoniness and the soil depth observed, regular pruning to avoid dense foliage should be carried out. In the alternative, rubber clones with light crowns should be planted. The clone GT 1 is an example of a clone with light canopy.

6. Fertilizer application to mature rubber trees take 2 - 3 years before the effects are felt and are mainly for stability and yield maintenance. Application of 320kg/ha (equivalent of 550g/tree) per year of NPK Mg mixture of ratio 10:7: 9:4 of N, P_2O_5, K_2O, and MgO respectively is recommended from year 7 – 15. Fertilizer application for matured tree could be modified based on responses obtained from the above and fertilizer regimes maintained at the immature phase.

Other soil management suggestions

a. A smallholder plantation development plan of 2ha each per year of rubber and oil palm is hereby recommended for proper management.
b. Creeping legume cover crops like melon may be beneficial to rubber and oil palm in the study area. Mulching around the base of the trees is well encouraged. Other intercrops include water melon, maize, cassava, plantain and other common food crops in the environment is encouraged during the first four (4) years of rubber and oil palm immaturity. Other suitable crops include pineapple, okra, cassava, yam, leafy vegetables, plantain, paw-paw, pepper, garden egg etc. This will bring early return on investment and ensure proper maintenance of the plantation. The high value trees will be additional source of income at maturity and these include bush mango, cherry, bitter kola, kola spp, pepper fruit, irvingia, moringa etc. Planting arrangement should be such that rubber is not choked up and fertilizer should be adjusted to accommodate the food crops and/or high value trees according to Esekhade *et al.,* (2014).
c. Contour terracing or contour planting is recommended in view of the slope observed.
d. The rides of rubber should be kept clean of weeds before and after planting.
e. Termite control by destroying the termite hills and drenching with DEVAP or any of its variants at 2% concentration is highly recommended in the termite prone areas.
f. At canopy closure, mixed farming is necessary and this includes bee keeping and snailery.

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