

# Effects of Oil Palm (*Elaeis guineensis*) and Gmelina (*Gmelina arborea*) Plantations on soil properties in the Calabar Environment, Nigeria.

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## ABSTRACT

The study was undertaken in Akamkpa Local Government Area, some 30 – 35 km north of Calabar. The soils are developed from Basement Complex rocks mostly granites inter-bedded with shale under a rainfall regime of over 2,000 mm per annum. One toposequence, each under oil palm and gmelina plantations, was selected for the study. The results showed that the soils under oil palm plantation accumulated more Ca, Mg, K, and P, higher electrical conductivity and exchangeable acidity but lower effective cation exchange capacity, less organic carbon, less total N and was slightly less acidic than the ones under gmelina cultivation. Except for the content of available phosphorus, the nutrient contents in soils of both plantations were higher than similar soils under arable crops, thus confirming both plants as soil improvers.

**KEY WORDS:** soil improvers, *Elaeis guineensis*, *Gmelina arborea*, Basement Complex

## INTRODUCTION

The current industrial demand in Nigeria on timber and pulpwood to the estimated volume of about 10 million m<sup>3</sup> in 1990 compared to 4.3 million m<sup>3</sup> in 1970 is a significant rise (Umeh, 1975; Okorie, 1982). And more than 80% of the demand is *Gmelina arborea*. Out of 198,914 hectares of land put under forest plantations, 89,377 hectares are directly put under gmelina cultivation. Cross River State has 15,000 hectares of *Gmelina arborea* plantations (FORMECU, 1993).

Oil palm, *Elaeis guineensis*, is grown for the production of palm oil, kernel and their by-products which yield high premium thereby contributing significantly to Nigerian economic development. Because of the heavy reliance of our pomade, vegetable oil, margarine and soap industries on palm oil and kernel, many agencies and individuals are investing heavily on its cultivation (Ataga, 1976). Reports show that 2.4 million hectares of wild / natural oil palm grooves and about 200,000 ha of improved varieties (FPDD, 1989) are devoted to oil palm, which had been a major foreign exchange earner for the nation. The National Agricultural Land Development Authority (NALDA) has recently established more than 2000ha of oil palm in various parts of the country.

Botanically, *Elaeis guineensis* is a monocotyledon. It has an elongated trunk of about 20-30 metres and well arranged canopy of fronds. The tree grows best on yellowish brown to reddish brown loamy to sandy clay loam soils. It takes 3 to 4 years to reach reproduction age and remain economical for about 25 years and has a life span of up to 200 years (Purseglove, 1976). *Gmelina arborea* is a dicotyledon. It grows to a height of about 21m, heavily branching with a mean girth of about 50cm. It is deciduous and grows best in yellowish brown to dark brown loamy to sandy clay loam soil (Umeh, 1975; Okorie, 1982).

## JUSTIFICATION AND OBJECTIVES OF THE STUDY

*Gmelina arborea* has become a very important source of pulp wood in Nigeria and the hectareage under cultivation has increased tremendously during the last two decades. However, due to the economic prominence of oil palm, the state governments, organisations and private individuals are expanding their investments in oil palm yearly. Hence many hectares of forest land including gmelina plantations are being cleared for the establishment of oil palm plantations. The trend is ever on the increase.

Forest vegetation is of very great significance in soil formation and in maintaining a high nutrient equilibrium as well as environmental balance. Once the forest is cleared for agriculture land degradation sets-in in various forms depending on the crop type and management. Because gmelina and oil palm are becoming very important in our farming systems and economy, this research project was designed to study the impacts of these two types of ecosystems on the soil physical and chemical properties. It is expected that the results of this research will contribute significantly towards knowledge in the choice of land for agriculture based on their possible impacts on the soil.

## MATERIALS AND METHODS

The study sites were located in Akamkpa LGA about 33km north of Calabar. The oil palm plantation was located at Eyagbam about 2 to 2.5 km away from the gmelina plantations at Awi. They are located in the forest region with the following climatic factors: 5 to 7 hours of sunshine per day, 2000 mm of rainfall per annum, 70 – 80% relative humidity and temperature range of 26-31°C per day (Okorie, 1982; FDALR, 1985).

The soils in Akamkpa form part of the Calabar fasc (Ojanuga et al, 1981). Acid crystalline rocks are found as outcrops at Awi and Eyagbam (FDALR, 1985). The soils are relatively poor in nutrients status (Ahn,

1970; FDALR, 1985). One toposequence was selected from each plantation for the study. Three profile pits were sited on each toposequence, one each at the crest, middle slope and lower slope positions. The six profile pits were described in detail in the field according to the FAO guidelines (FAO, 1976). In addition, the landscape features in the immediate vicinity of the profiles were described.

#### Laboratory Analysis

Samples collected from the field were air-dried for some days, sieved with a 2mm-sized sieve and subjected to selected physical and chemical analysis. The Bouyoucos hydrometer method was used for the particle size analysis (Udo, 1986).

The soil reaction was determined in soil - water paste at a 1:1 ratio and measured with a pH meter (EEL model). The organic carbon was determined by the Walkley-Black (Allison, 1965) wet oxidation method while the total nitrogen was determined by the macro-Kjeldahl procedure (Bremner, 1965). Soil available phosphorus was extracted by the Bray P-1 solution (Bray and Kurtz, 1945) and determined with a Spectronic 20 spectrophotometer.

The exchangeable cations, K and Na, were determined by the flame photometer while calcium and

magnesium were determined by titration with 0.02N EDTA. The exchangeable acidity was determined by the potassium chloride method while the electrical conductivity was determined using an electrical conductivator (Udo, 1986).

## RESULTS AND DISCUSSION

### Morphological and Physical Properties of the Soils

Both areas have good drainage and are located in the thick rainforest zone, therefore, having the implicit capability to support tree crops. At Eyagbam, the toposequence is gently sloping with no exposure to bedrock. *Centrosema pubescens* and other weeds were all over the plantation. The soil is gravelly sandy loam to sandy clay loam with dark greyish brown. At the crest the soil colour was yellowish brown and the texture was gravelly to sandy clay loam but at the lower slope the soil colour was greyish brown with sandy loam texture on the surface, underlain by sandy clay loam sub-soil (Table 1). The sand content was higher in the surface soil than in the subsoil.

At Awi, the toposequence is very gently sloping with no bedrock exposure. Smaller weeds grow all over the plantations. The soil texture is gravelly sand on the surface and changes to sandy clay loam in the subsoil.

Table 1: Particle size analysis for soils under oil palm and gmelina plantations

Profile location	Depth (cm)	% clay	% Silt	% Sand	Textural class
Oil palm plantation					
Crest	0 - 12	2.0	12.2	85.8	Sand
	12 - 32	12.0	28.2	59.8	Sandy loam
	32 - 63	42.0	20.2	37.8	Clay
	63 - 95	32.0	28.2	39.8	Clay loam
	95 - 139	2.0	12.2	85.8	Sand
Middle Slope	0 - 17	2.0	12.2	85.5	Sand
	17 - 56	22.0	13.4	64.6	Sandy clay loam
	56 - 93	24.0	19.4	56.6	Sandy clay loam
	93 - 118	14.0	19.4	66.6	Sandy loam
	118 - 161	16.0	15.4	68.6	Sandy loam
Lower slope	0 - 22	2.0	7.4	90.6	Sand
	22 - 60	2.0	7.4	90.6	Sand
	60 - 89	12.0	5.4	82.6	Loamy sand
	89 - 139	10.0	5.4	84.6	Loamy sand
Gmelina plantation					
Crest	0 - 21	2.0	8.8	89.2	Sand
	21 - 72	22.0	2.8	75.2	Sandy loam
	72 - 100	26.0	6.8	67.2	Sandy loam
Middle Slope	0 - 14	2.0	8.8	89.2	Sand
	14 - 48	22.0	10.8	67.2	Sandy clay loam
	48 - 81	28.0	10.8	61.2	Sandy clay loam
	81 - 125	30.0	12.8	57.2	Sandy clay loam
Lower Slope	0 - 15	2.0	4.8	93.2	Sand
	15 - 36	8.0	08	91.2	Sand
	36 - 89	10.0	4.8	85.2	Loamy sand

Table 2: Chemical properties of soils under oil palm and gmelina plantations

Profile Depth (cm)	pH	Elec. Cond. (uS/cm)	Org. C (%)	Total N (%)	Av. P (mg/kg)	Exchangeable cations (cmol/kg)				Exch. Acidity (cmol/kg)	ECEC (cmol/kg)	Base Sat. (%)
						Ca	Mg	K	Na			
Oil palm plantation												
Crest												
0-12	5.65	66.3	2.73	0.69	7.70	6.40	1.60	5.12	0.20	2.10	15.42	86.4
12-32	5.10	27.1	1.09	0.27	2.67	3.20	2.83	0.21	0.19	0.75	7.18	89.6
32-63	4.71	22.6	1.11	0.28	1.23	3.20	1.92	0.15	0.22	3.42	8.91	61.6
63-95	4.62	13.4	0.73	0.19	0.70	2.88	6.40	0.11	0.20	3.06	12.65	75.8
95-139	4.59	13.6	1.20	0.30	Tr	2.88	2.56	0.13	0.21	0.78	6.56	88.1
Middle slope												
0-17	5.13	116.8	1.78	0.45	4.57	6.40	1.60	1.02	0.18	3.66	12.86	71.5
17-56	5.01	23.4	1.07	0.27	Tr	3.81	2.56	0.12	0.14	1.02	7.68	86.7
56-93	4.88	18.3	1.54	0.39	Tr	5.12	1.92	0.13	0.20	1.44	8.81	83.7
93-118	4.96	16.8	1.36	0.34	Tr	3.52	3.52	0.08	0.15	2.34	9.61	75.7
118-161	4.82	13.1	1.73	0.28	Tr	3.52	4.16	0.15	0.16	1.98	9.97	80.1
Lower slope												
0-22	5.22	34.4	0.99	0.25	5.77	4.10	2.24	1.99	0.27	0.84	8.80	90.5
22-60	5.66	31.9	1.28	0.32	12.20	2.53	4.90	5.82	0.10	0.72	11.31	93.6
60-89	4.91	24.8	1.26	0.32	2.90	3.52	0.64	1.84	0.19	0.84	11.38	92.6
89-139	5.02	20.8	1.34	0.34	3.30	3.20	1.60	0.05	1.02	1.01	5.10	80.0
Mean	5.02	30.0	1.38	0.34	2.93	3.86	2.76	1.20	0.25	1.72	9.73	82.6
Gmelina plantation												
Crest												
0-21	5.17	34.7	1.72	0.43	4.57	4.16	3.20	0.09	0.20	0.84	8.49	90.1
21-72	4.72	24.8	0.75	0.19	0.03	2.88	3.52	0.05	0.20	1.26	7.91	84.1
72-100	4.73	25.8	0.71	0.18	Tr	2.56	2.88	0.09	0.20	1.56	7.29	78.6
Middle slope												
0-14	5.02	39.8	2.21	0.56	6.13	3.58	0.64	0.08	0.20	1.74	6.24	72.1
14-48	4.78	25.4	1.76	0.44	1.27	2.68	5.76	0.04	0.19	0.60	9.27	93.5
48-81	4.71	14.4	1.56	0.39	1.23	2.53	0.96	0.08	0.19	1.98	5.74	65.5
81-125	4.72	19.4	1.34	0.34	0.83	2.51	3.52	1.59	0.26	2.06	9.94	79.3
Lower slope												
0-15	5.02	24.3	2.78	2.78	0.70	Tr	4.18	0.64	0.13	1.21	6.36	81.0
15-36	4.19	19.0	1.52	1.52	0.38	Tr	4.80	0.32	0.10	0.78	6.22	87.5
36-89	4.91	17.4	1.44	1.44	0.36	Tr	3.52	3.52	0.05	0.78	8.04	90.7
Mean	4.80	24.54	1.58	0.40	1.41	3.34	2.50	0.23	0.12	1.28	7.55	82.2

At the crest the colour is dark brown to yellowish red to pale brown with gravelly sandy clay loam texture while at the lower slope it was greyish to dark brown with sandy clay loam texture (Table 1) and poorly drained.

At Eyagbam, the soil was more gravelly at the crest and middle slope, and the consistence was slightly sticky and slightly plastic. At the lower slope, the soil was very sandy and less gravelly but loamy. The structure was very weak and angular blocky while the consistence was slightly sticky, slightly plastic and plastic.

At Awi, the soil at the crest and middle slopes were very stony, and very coarse textured. The soil texture was sandy loamy. The consistence was slightly sticky and slightly plastic but friable when moist. At the lower slope, the soil texture was a slightly coarse sandy clay. The consistence was very sticky and very plastic. Chemical Properties of the Soils

The data given in Table 2 show that the K content was lower in the gmelina plantation (0.04 - 1.59 cmol/kg) than in the oil palm plantation (0.08 - 5.72 cmol/kg). This could have been due to application of

potash fertilizers and potassium recycling from the palm bunches which are littered around the plantation as mulch. Though Mg was generally high, it was higher in the oil palm plantation than the gmelina plantation. Potassium and Mg antagonism was established at Awi, under gmelina plantation (Tinker and Ziboh, 1959; Tinker and Smilde, 1963). Samples with high K contents had low Mg contents and vice versa.

The soils had very low Na content ranging between 0.15 and 0.27 cmol/kg. In the oil palm plantation the values were between 0.10 and 0.27 cmol/kg, and in the gmelina plantation it ranged between 0.17 and 0.26 cmol/kg. Hence, the soils were generally devoid of any dispersing properties which is a pointer to the fertility tendency of the soil (Bohn et al, 1979).

Calcium was high in both plantation with values ranging from 2.53 cmol/kg to 6.40 cmol/kg at Eyagbam (oil palm) and 2.56 to 4.80 cmol/kg at Awi (gmelina plantation). Surprisingly, calcium content was higher in oil palm plantation than in gmelina plantation though gmelina is known to be a calcium accumulator (Sanchez, 1986). This large content of calcium shows

low concentration of potentially acid forming elements (Bohn et al, 1979). At Eyagbam, the figures ranged from 1.00 to 6.40 cmol/kg whereas at Awi it ranged between 0.64 and 5.70 cmol/kg. Tinker (1963) described Calabar fasc soils as being rich in both Ca and Mg. Soils rich in both elements are said to support tree cropping better than arable cropping (Tinker and Gunn, 1962; FDALR, 1985).

Phosphorus content was low in the soils. The amount was decreasing with increasing depth. The values ranged from 0 to 7.70mg/kg in soils under oil palm plantation and 0 to 4.57 mg/kg under gmelina. This may not seriously affect the yield of oil palm and gmelina since they are not grown for root development (Tinker and Smilde, 1963). And due to the low depletive tendency of gmelina on soils, phosphorus tended to accumulate in both the upper and middle slopes but the lower slopes had only traces of phosphorus. This could be due to the occurrence of phosphorus in unavailable forms (Sanchez, 1987), or in organic form rather than inorganic.

High organic carbon content is a good indication of high soil fertility and helps in determining the rate of forest regeneration (Aweto and Areola, 1979; Spaargaren, 1990). Organic carbon contents in the study area generally decreased from the topsoil to the subsoil (from 2.73 to 0.73%) in the oil palm plantation, and from 2.78 to 0.75% in the gmelina plantation. Total nitrogen was generally high and may be explained by the high organic carbon content as well as the leguminous cover crops especially in the oil palm plantation. The N content ranged from 0.19 to 0.69% in soils of oil palm plantation and from 0.18 to 0.70% in gmelina plantation soils.

The exchangeable acidity ranged from 0.78 to 3.66 cmol/kg soil while the pH ranged from 4.62 to 5.65 showing that the exchangeable ion is strictly monomeric aluminium. The pH of the area shows that the soils are very strongly acidic to moderately acidic thereby imposing some restrictive measures on the fertility components of the soil, especially phosphorus.

In the study areas the soils were found to have electrical conductivity (EC) ranging from 13.3 to 116µmho/cm which is less than the acceptable range for normal soils (4000µmho/cm). Therefore, the soils under both plantations were non-sodic and non-saline.

#### SUMMARY AND CONCLUSION

The soil of the study area revealed interesting information regarding the nutrient status as well as the physical and morphological status. From the study, nutritional status of the soils have not been negatively affected. These secondary forests have been able to effectively recycle the major nutrients over the past 25 to 30 years. *Elaeis guineensis* is a heavy feeder of potassium because of its fruit production but since the bunches are used as mulch, they recycle most of the nutrients back to the soil. Magnesium has been low where there is high content of calcium due to calcium antagonism. Calcium content was higher in soils of oil palm plantation than the gmelina soils.

At Awi and Eyagbam, the mean values (Table 2) indicate that the sodium content was low. There was an accumulation of exchangeable acidity under both crops. Hence, the major difference in both plantations are in the contents of organic carbon, available phosphorus, exchangeable K, Ca, electrical conductivity and effective cation exchange capacity. For a continuous maintenance of good oil palm and gmelina plantations in Cross River State, soils with high salinity should be avoided as well as a water-logged soils.

Liming should be used to correct the soil acidity in the area at the beginning of every growing period. Fertilizers should be applied only to young trees and at the beginning of every growing period since older trees are able to recycle nutrients for their use. The soils, however, do not suffer serious depletion of nutrients as a result of growing either *Elaeis guineensis* or *Gmelina arborea*.

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