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COMPARISON OF THE PHYSICAL AND CHEMICAL PROPERTIES OF SOILS UNDER NATURAL FOREST AND GMELINA PLANTATION.

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ABSTRACT

Changes in physical and chemical characteristics of soils as affected by age of Gmelina and position on the slope were studied and compared with those of an adjacent natural forest. There were no significant differences in the effects of Gmelina and natural forest on the physical properties of the soil, though soils under Gmelina had higher bulk densities. The chemical analysis showed that the upper and the lower slopes of the plantations had a higher organic carbon contents, 2.38% and 2.24% and total nitrogen contents, 0.21% and 0.20% than the middle slope with 1.91% and 0.17% organic carbon and total nitrogen respectively. Soils under Gmelina plantations, especially 1982 plantation compared favorably with those of natural forest in N, 0.22%, P, 82.13 mg/kg, organic carbon, 2.59% and mg, 2.42 Cmol kg-1, when compared with 0.23%N, 78.63mg/kgP, 2.5% Organic Carbon and 2.52 CmolK-1Mg values of the natural forest. Phosphorus and contents of soils under Gmelina increased with age while the oldest Gmelina plantation has the highest K content.

Keywords: Gmelina, Toposequence, Bulk density, Nutrients.

INTRODUCTION

It is increasingly becoming accepted that trees are the best option for producing food and fibre on a sustained basis in the tropics since tree plantations resemble the natural ecosystem more closely than do annual crops in arable farming (Budowski, 1981; ICRAF, 1991). Thus, land management where trees are deliberately grown in various combinations and sequence has been reputed to be sustainable management techniques which, apart form increasing the overall productivities of land, are also compatible with the culture of the local farmers (King and Chandler, 1978).

Gmelina arborea, an unbuttressed moderate to large sized deciduous tree belonging to the family verberaceae, is indigenous to very many nations of India, Cambodia, Srilanka, Malaysia etc. and introduced to very many nations including Nigeria *Gmelina arborea* had been found suitable for the purpose of sustained food and fibre production especially as it had been affirmed that soil phosphorus and nitrogen could be improved with Gmelina inclusion in a cropping system (Agbede and Ojo, 1979).

The study reported here was conducted to evaluated the effects of *Gmelina arborea* at various ages and positions on the slope, on the nutrient status of the soil and to compare same with those of a natural forest thereby assessing its usefulness as a fallow crop.

MATERIALS AND METHODS

This study was carried out in Oluwa forest reserve, Epe-Makinde, Ondo State in the guinea savannah ecological zone of Nigeria. The vegetation of the area is of high forest and the average annual rainfall and atmospheric temperature range between 1,500 - 1,6000mm and 25.2 - 29.20C respectively (Periaswamy and Ashaye, 1982). A total of four plantations were sampled. These were, Gmelina plantations established in 1982, 1984 and 1989. There was an adjacent natural forest which served as a reference forest. The reference forest was already established as at the time of planting the 1982 Gmelina plantation which was the pioner plantation of the afforestation project. Infact, it was parts of it that were cleared for the Gmelina plantations. All these were within a radius of about five kilometres. The Gmelina plantation sites were mechanically cleared and packed before establishment. Each of the sample plots was 10m by 10m and were sited randomly in each location along the toposequence i.e. upper, middle and lower slope (A, B and C respectively), at ten metres away from the boundary of each plantation. There were three sample plots, (replicates), in each of the locations.

Soil samples were taken from the top 0 - 15cm of the top soil using a set of core each dimensioned 15cm in height and 10cm in diameter.

Ten samples were taken per replicate such that there were thirty samples per location. These were bulked according to replicate. Samples for analysis were taken from the bulk samples, air dried, sieved to pass through 2mm sieve, and subjected to physical and chemical analyses.

The particle size analysis was done by hydrometer method (Bouyoucos, 1951) while the bulk density was determined by using the core method. The percentage water held was determined by using gravimetric technique with the formula:

$$\% \text{ water held} = \frac{\text{Moist soil weight} - \text{oven dry soil weight}}{\text{Oven dry soil weight}} \times 100.$$

Oven drying was achieved by drying in an Oven at 110oC to a constant weight.

Micronutrient (Cu, Mn, Zn and Fe) were extracted with Na = EDTA extracting solution and then determined in an atomic absorption spectrophotometer.

The pH was determined in 1:2 soil: water suspension using a pH meter. The organic carbon was determined by dichromate oxidation, (Walkley and Black, 1934), total N by the Micro-kjeldahl method, (Jackson, 1964) and available P by the Bray P -

l method, (Bray and Kurtz, 1945). The exchangeable bases were displaced by neutral N NH4 OAC. The displaced K and Na in the extract determined on atomic absorption spectrophotometer. The exchangeable acidity (Al and H) was extracted with NKCL and estimated titrimetrically (Molean, 1965).

The total herbage weight (biomass) under the four plantanions was determined by harvesting at ground level all the plants in each of 3(1m2) quadratis that were randomly placed in each of the sample plots, the plants dried to a constant weight at 800C and expressed as g/m2. The values were then averaged to give value/ location.

Tree parameters such as the Diameter at breast height (DBH) and tree height (Tht), were taken from five randomly selected trees form each of the sample plots The DBH in Centimentres was calculated using the formula calculated using the formula πD = Oce where D = Diameter, Oce = Circumference and π =3.142. Tht was measured in metres using a Haga altimeter. Means were compared using the standard deviation of means (Steel & Torrie, 1980).

RESULTS AND DISCUSSION

The particle size analysis of the sample is presented in Table 1. While silts and clay decreased down the slope, sand content of the soil increased down the slope. There was no significant diference in the effects of Gmelina and natural forest on the textural properties of the soils except silt that significantly increased with age of plantation. The decrease in silt and clay contents and the increase down the slope of sand could be explained in terms of erosion along the toposequence. Stoop slope as a result of the washing down the slope of sand which now makes soils of the lower slope to become deeper than those of the upper slope.

The bulk densities and percentage water held by the soils are presented in table 2. The bulk density was least in the lower slope and highest at the upper slope. The lower slope as the region of illuviation receives more water, and microbial activities is likely to be more, thereby reducing the bulk density. The upper slope due to erosion had lost most of it's top soil to the lower slope thereby exposing the less permeable bulkier clay. Lal (1979) observed that valley bottoms recorded the lowest bulk densities along the slope. He opined this to be as a result of higher microbial activities in this region in addition to erosion deposition. Higher bulk densities associated with the Man-made forests may be due to mechanical clearing and other establishment procedures employed. The significant efectsf both age and location on the slope on the bulk density Table 3, may probably be due to litter accumulation as the plantation as the plantation ages, while locational differences may be to erosion action along the slope. Lal, (1979) and Kilewe (1988) had observed that soils are characterized by heavy bulk densities are low in organic matter content and vice versa.

The chemical analysis, 4 showed that the natural forest was significantly more acidic than the other plantations. Sanchez et al (1985) had reported that *Gmelina arborea* accumulates calcium which is probably dug up from lower soil depths and deposited on the upper layers. Also there was a favourable comparison between the natural forest and Gmelina plantations with respect to N, P and Organic C especially the 1982 plantation. These nutrients increased with age. Magnesium was significantly higher under the Gmelina plantations than natural forest especially at the middle slope. There were significant increases in Mg contents of the soil with the age of plantation, Nitrogen, Phosphorus and Magnesium in 5 - 15 year old Gmelina plantations in Nigeria, Brazil and Beleze. This is attributable to the incorporation of accumulated mineral nutrients into an enlarged plant - litter - soil nutrient cycle by the trees (Nair, 1993).

The micronutrients were affected differently by the tree species. While copper reduced with age, iron increased with age. However copper and Calcium were significantly higher under the natural forest than the Gmelina plantation while there were no significant differences in the iron concentration of the plantations especially with the 1982 and 1984 plantations. Manganese and Zinc were highest in the youngest plantation though manganese was significantly higher under the plantations than under the natural forest at both the upper and the lower slope. Some trees had been reported to selectively accumulate certain nutrients (Nair, 1993). Odum and Pigeon (1970) reported that *cecropia sp* growing on acid soils accumulated calcium and phosphorus. This ability to accumulate nutrients however varies according to sites and soils (Golley, 1986). The reduction in Mn content of the soil as Gmelina ages might be due to Gmelina withdrawal of the element.

Potassium contents of the soil under Gmelina was found to be lower than those of natural forest in contrast to the findings of Emmanuel, (unpublished M. Sc thesis), that the available P and K increased under Gmelina and Teak plantations than under the adjacent natural forest. The disparity might be due to differences between the sites of the two studies.

The phosphorus and nitrogen contents of the soils under Gmelina increased with the age of the plantation while total acidity was not affected by plantation age. Brinson et al (1980) had reaffirmed the recognition of the litter fall as the major avenue for the addition of organic matter to the soil. This probably explained the reason why nitrogen, phosphorus and even potassium were higher in older plantations. The higher organic C and N at both the upper and lower slopes as against increase along the slope as reported by Stoop (1987) bay be due to the differences in the degree and length of slopes on which the study was conducted.

The effects of age and location on the slope on the total herbage and tree parameters were presented in Table 5. The total herbage decreased with the age of plantation, and this may be jointly due to increased shading of the plantation floor and increase in the accumulative litter fall as the plantations age. The natural forest, the oldest most likely the thickest in litter accumulation, had the least biomass. Tree parameters were significantly affected by plantation age. Both plant height and DBH increased with age. This is also responsible for the significant difference which existed between the natural forest and the Gmelina plantations with respect to the parameters.

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Table 1: Particle size analysis of the Soil Samples.

% Soil fraction	Forest type	Location on the slope* A	B	C	Mean
SAND	Gmelina 1982	76.4	82.4	86.4	81.73
	Gmelina 1984	84.4	84.4	84.4	84.4
	Gmelina 1989	76.4	82.4	85.4	81.4
	Natural Forest	84.4	84.4	84.4	84.4
	Mean	80.4	83.4	85.15	82.98
	$S\bar{x}$ **	2.31	0.58	0.48	1.15
SILT	Gmelina 1982	16.0	14.0	10.0	13.35
	Gmelina 1984	10.0	12.0	12.0	11.33
	Gmelina 1989	10.0	8.0	7.0	8.33
	Natural Forest	12.0	10.0	10.0	10.67
	Mean	12	11	9.75	10.91
	$S\bar{x}$ **	1.41	1.29	0.80	1.13
CLAY	Gmelina 1982	7.6	3.6	3.6	4.93
	Gmelina 1984	5.6	3.6	3.6	4.27
	Gmelina 1989	13.6	9.6	7.6	10.27
	Natural Forest	3.6	5.6	1.6	3.60
	Mean	7.6	5.6	4.1	5.77
	$S\bar{x}$ **	2.16	1.41	1.26	1.52

* A = Upper Slope
B = Middle Slope
C = Lower Slope
** Standard deviation of mean

Table 2: Bulk densities and water holding capacities of the soil samples.

% Soil fraction	Forest type	Location on the slope*			Mean
		A	B	C	
Bulk density g/cm3	Gmelina 1982	1.61	1.76	1.39	1.59
	Gmelina 1984	1.64	1.66	1.41	1.57
	Gmelina 1989	1.38	1.81	1.38	1.52
	Natural Forest	1.01	1.25	0.86	1.04
	Mean	1.41	1.62	1.26	1.13
	$S_{\bar{x}}$ **	0.14	0.13	0.13	0.13
% Water held	Gmelina 1982	18.11	13.92	19.78	17.27
	Gmelina 1984	18.00	17.66	19.16	18.27
	Gmelina 1989	14.98	13.25	15.88	14.70
	Natural Forest	21.09	21.30	27.01	23.13
	Mean	18.05	16.53	20.46	18.34
	$S_{\bar{x}}$ **	1.25	1.86	2.45	1.76

* A = Upper Slope
B = Middle Slope
C = Lower Slope
** Standard deviation of Mean.

Table 3: Summary of the Analysis of Variance on the Effects of Age of Plantation and Location on the slope on Bulk density.

Source of Variation	Degree of Freedom	Sum of Square	Mean Square	Fcal
Treatment Total	35	3.75	-	
Replicate	2	0.17	-	
Bulk density	11	2.87	0.26	10.4 **
Age of Plantation	3	2.02	0.67	26.8 **
Location on Slope	2	0.18	0.09	3.6 **
Age and Location Interaction	6	0.67	0.11	4.4 **
Pooled Error	22	0.56	0.03	

** Significant at 5% level.

Table 4: Soil Chemical Analysis.

Analysis	Forest type	Location on the slope*			Mean
		A	B	C	
pH (H2O)	Gmelina 1982	6.90	7.60	6.90	7.13
	Gmelina 1984	7.20	6.60	7.40	7.07
	Gmelina 1989	7.00	7.70	6.90	7.20
	Natural Forest	6.80	6.60	7.00	6.80
	Mean	6.98	7.08	7.05	7.05
	S $\bar{x}$ **	0.09	0.09	0.120	0.03
Organic Carbon (%)	Gmelina 1982	2.68	2.22	2.86	2.59
	Gmelina 1984	2.33	1.40	2.73	2.15
	Gmelina 1989	1.44	1.87	0.86	1.39
	Natural Forest	3.08	1.15	2.49	2.57
	Mean	2.38	1.91	2.24	2.18
	S $\bar{x}$ **	0.35	0.19	0.46	0.28
Total N (%)	Gmelina 1982	0.23	0.19	0.25	0.22
	Gmelina 1984	0.20	0.12	0.24	0.19
	Gmelina 1989	0.12	0.16	0.07	0.12
	Natural Forest	0.27	0.19	0.22	0.23
	Mean	0.21	0.17	0.20	0.19
	S $\bar{x}$ **	0.03	0.02	0.04	0.03
Avail. P (mg/kg)	Gmelina 1982	93.30	96.70	56.40	82.13
	Gmelina 1984	88.80	93.30	83.40	88.5
	Gmelina 1989	68.60	70.90	49.60	63.03
	Natural Forest	93.00	91.10	51.80	78.63
	Mean	85.93	88.00	60.30	78.07
	S $\bar{x}$ **	5.87	5.82	7.83	5.42
Ca (cmolKg-1)***	Gmelina 1982	2.95	15.00	2.30	6.75
	Gmelina 1984	7.50	1.80	14.00	7.77
	Gmelina 1989	10.00	5.50	2.85	6.12
	Natural Forest	4.45	4.60	4.40	4.48
	Mean	6.23	6.73	5.89	6.28
	S $\bar{x}$ **	3.09	2.87	2.74	0.69

ANALYSIS	Forest type	Location on the slope A	B	C	Mean
Mg (cmolKg-1)***	Gmelina 1982	1.93	2.63	2.71	2.42
	Gmelina 1984	2.04	2.30	2.64	2.33
	Gmelina 1989	2.69	2.33	2.17	2.40
	Natural Forest	2.33	2.26	2.95	2.52
	Mean	2.25	2.39	2.62	2.42
	$S\bar{x}$ **	0.22	0.08	0.16	0.03
Na (cmolkg-1)***	Gmelina 1982	0.40	1.40	0.87	0.89
	Gmelina 1984	0.70	0.70	0.70	0.70
	Gmelina 1989	0.74	0.65	0.52	0.64
	Natural Forest	0.61	0.61	0.70	0.64
	Mean	0.53	0.84	0.70	0.72
	$S\bar{x}$ **	0.09	0.19	0.07	0.06
K (cmol Kg-1)***	Gmelina 1982	0.36	0.43	0.18	0.32
	Gmelina 1984	0.19	0.14	0.25	0.19
	Gmelina 1989	0.31	0.16	0.18	0.22
	Natural Forest	0.41	0.38	0.59	0.46
	Mean	0.31	0.28	0.30	0.30
	$S\bar{x}$ **	0.05	0.07	0.10	0.06
Ex.AC(cmolKg-1)***	Gmelina 1982	0.16	0.08	0.08	0.11
	Gmelina 1984	0.08	0.16	0.08	0.11
	Gmelina 1989	0.08	0.08	0.08	0.08
	Natural Forest	0.08	0.16	0.08	0.11
	Mean	0.10	0.12	0.08	0.10
	$S\bar{x}$ **	0.02	0.02	0	0.008
Mn (Mg/Kg)****	Gmelina 1982	82.9	18.8	38.4	46.70
	Gmelina 1984	47.0	39.1	74.5	53.53
	Gmelina 1989	60.8	53.7	66.1	60.20
	Natural Forest	42.2	74.5	41.4	52.70
	Mean	58.23	46.53	55.10	53.28
	$S\bar{x}$ **	9.12	11.76	8.96	2.76

ANALYSIS	Forest type	Location on the slope			Mean
		A	B	C	
Fe (mg/Kg)****	Gmelina 1982	72.9	82.1	91.1	82.03
	Gmelina 1984	72.2	47.1	70.9	63.40
	Gmelina 1989	62.2	71.1	69.7	67.67
	Natural Forest	72.2	89.1	71.1	77.47
	Mean	69.88	72.35	75.70	72.64
	$S\bar{x}$ **	2.56	9.20	5.14	4.11
Cu (mg/kg)****	Gmelina 1982	0.70	0.90	1.10	0.90
	Gmelina 1984	0.80	0.70	0.80	0.76
	Gmelina 1989	1.00	1.00	1.20	1.07
	Natural Forest	1.10	1.20	1.00	1.10
	Mean	0.90	0.95	1.03	0.95
	$S\bar{x}$ **	0.09	0.10	0.09	0.08
Zn (mg/Kg)****	Gmelina 1982	5.10	4.50	4.90	4.83
	Gmelina 1984	6.10	4.20	3.70	4.67
	Gmelina 1989	4.10	7.60	7.70	6.47
	Natural Forest	6.40	7.30	3.70	5.80
	Mean	5.43	5.90	5.00	5.44
	$S\bar{x}$ **	0.52	0.90	0.94	0.43

*A = Upper slope B = Middle slope C = lower slope
** $S\bar{x}$ = Standard deviation of mean
*** Exchangeable cation
**** Extractable micronutrients.

Table 5 Measurements for Tree Parameters and total herbage weight as affected by age of plantation and location on the slope.

	A	B	C	Mean
DBH - (cm)				
Gmelina 1982	42.0	41.0	47.0	43.0
Gmelina 1984	34.0	33.0	30.0	32.0
Gmelina 1989	13.0	15.0	14.0	14.0
Natural Forest	52.0	52.0	51.0	52.0
Mean	35.0	35.0	36.0	35.0
S x **	8.00	8.00	9.00	8.00
Tree height (m)				
Gmelina 1982	19.94	20.74	20.22	20.30
Gmelina 1984	17.96	18.17	21.18	19.10
Gmelina 1989	7.76	08.73	08.59	08.36
Natural Forest	21.22	21.03	25.85	22.70
Mean	16.72	17.17	18.96	17.62
S x **	3.06	2.74	3.67	3.18
Total herbage (g/m2)				
Gmelina 1982	113.6	127.17	108.98	116.58
Gmelina 1984	130.22	134.00	136.00	133.41
Gmelina 1989	134.28	140.60	120.01	131.63
Natural Forest	084.37	107.72	108.47	100.19
Mean	115.60	127.37	118.37	120.45
S x **	11.34	7.10	6.45	7.73

* A,B and C = Upper, Middle and Lower slopes respectively
** S x = Standard deviation of mean.