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Full Length Research Paper

Degradation of the soil physicochemical properties resulting from continuous logging of *Gmelina arborea* and *Tectona grandis* plantations

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This study assessed the changes in soil properties in sites subjected to continuous logging in exotics plantation sites of *Gmelina arborea* and *Tectona grandis* with the aim to evaluate the deterioration level of the soil productivity in respect to human disturbance. Thirty five sampling plots, each measuring 40 m x 25 m were used for soil sampling. Standard field and laboratory methods were employed in the collection of data for 18 soil characteristics (sand, silt, clay, water holding capacity, electrical conductivity, bulk density, total porosity, pH, organic matter , total nitrogen, available phosphorus, exchangeable calcium, magnesium, potassium, sodium, exchangeable acidity, cation exchange capacity and base saturation) at depths of 0 - 15 cm and 15 - 30 cm. The results indicated that values of soil and plant parameters decreased with length of continuous logging (1, 5 and 10 years respectively). The soil deterioration indices of the logged plots showed high deterioration of all the soil properties except electrical conductivity, bulk density exchangeable acidity and in exchangeable sodium, percent silt and sand at both levels of soil depths. The two exotic species were impacted differently on the soil properties on the study area as a result of adverse logging. If these plots area are left to fallow for a considerable period of time, the lost soil nutrients may be replaced.

Key words: Deterioration level, soil productivity, textural properties, electrical conductivity, *Gmelina* species, *Tectona* species, continuous logging and sustainable productivity.

INTRODUCTION

In the last 25 years, Southwestern Nigeria has suffered increasing ecological damage, with floristic and edaphic changes taking place over time. The current concern in the environment stems from evidence that natural processes are being disrupted by uncontrollable /unproductive means of forest extraction (Salami, 2006). The southern rainforest the source of the country's timber resources, covers about 2% of the total land area is currently being depleted at an estimated rate of 3.5% per year. This carries with it, loss of biological diversity. Many species in the tropics are disappearing because they are being harvested beyond their capacity to regenerate.

The artificial tree plantation sites that were established to act as buffer within the ecosystem are not spared from uncontrolled wave of logging which has made the natural the fast growth rate of plantation trees depicts a depletion resources to be vulnerable to degradation. A number of workers (Khanna 1998; Kumar et al., 1998) opined that of nutrient base of the site which presages danger for both the ecosystem and sustainable production. Another school of thought associated productivity in plantation to poor management practices, specifically, soil compaction during site clearing and top soil litter positioning among others (Mathers and Xu, 2003; Chen et al., 2004). However, changes in the structure of vegetation are followed by changes in the chemical make-up of the soil. Although, the productivity of the ecosystem of such areas is mainly functional, secondarily compositional, it largely depends on efficient mineral cycling.

If the vicious cycle of overexploitation and consequent degradation continues, it is inevitable that it will lead to the detriment of our environment. Timber extraction, at the non sustainable rate at which it is being carried out, would not only affect the biological resources but produce

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a primary effect on the productive base. (Onyekwelu, 2006) predicted an upsurge in global wood supply through an increase rate of forest plantation establishment and reestablishment within the next decades. If this prediction is something to go by, then the already fragile productive base of the forest ecosystem will be facing a very serious threat.

Plantations are expected to increasingly supply most of Nigeria's timber needs. *Tectona grandis* and *Gmelina arborea* have been a source of timber in the last decade. Although, these fast growing exotics species have been found to be more productive than plantations of indigenous species such as *Triplochiton scleroxylon*, the depletion of resource base may prevent achieving the goals for a sustainable productivity of the plantations.

One of the topical issues in the restoration of biological resources is the management of areas of secondary vegetation and degraded soil for sustainable productivity. Sustainability of forest resource base is a key to ecosystem structure development and functioning. Onyekwelu et al. (2006) opined that for plantation to be sustainable, the nutrient depletion level should be inconsequential to the ecosystem. In order words, no pronounced effect is observed on both the soil chemical and physical parameters. Properly managed planted plantation will add substantial ground cover against erosion and improve soil physical conditions (Rocheleau et al., 1988).

Understanding the changes and magnitude of the deterioration of the soil under exotic tree species plantation resulting from exploitation may provide a template for the management of the resource base of the ecosystem. As observed by Turner et al. (1990), the demand for forest resources will continue to increase as long as they remain the basis for development with severe consequence on environment resources and development. This study was therefore designed to assess the changes and the magnitude of deterioration in the soil characteristics resulting from the opening up of exotic tree species plantations by logging in a tropical environment.

SITE AND METHODS

The study site was Omo - Osun Forest Reserve which consists of undulating land with pockets of hills within thick forest which rise in height from 3 m in some places to 12 m above sea level in others. The underlying parent materials is Precambrian basement complex rocks with gneisses, quartzites and schists and are directly overlain by the maestrichatian sediments (Jones and Hockey, 1964).

Weathering has produced ferruginous tropical soils (Ferric Livisols: FAO-UNESCO, 1977) as the typical upland soil of this part of Nigeria. Local heterogeneity is indicated by the presence of sandy loam in texture which is Egbeda and Iwo series (Smyth and Montgomery, 1962). The climate is humid tropical (Sensu Thornthwaite, 1948) with seasonal variation in the relative humidity due to spatio-temporal variation in temperature.

The vegetation of the study area is the moist Tropical Rainforest (Keay, 1989). It belongs to the lowland evergreen forest type with abundant forest tree species of different families and genera.

Two main sites were selected from the study areas to enable a comparison of the situation in the protected environment of the forest and the highly degraded impacted environment where forest lumbering practices dominate. The first site was in Osun Forest Reserve (unlogged plot) located in the Northwestern part of the study area. The second site was Omo forest reserve area selected from the eastern part of the study area. Plots comprising *G. arborea* and *T. grandis* subjected to continuous logging for 1 year (logged for a year), 5 years (logged for a period of five years) and 10 years (logged for ten years) were selected. An area of one hectare was demarcated from the study sites. Each demarcated area was divided into 40 m × 25 m rectangles which were regularly spaced at 10 m. Within each 1.0 ha, 5 rectangles were randomly selected using a table of random numbers, thus making 35 sample plots.

Soil data

A transect was placed across each 40 m × 25 m rectangles, of which 1 m × 1 m rectangles were demarcated and uniformly spaced at 9 m. A 1 m × 1 m rectangles was randomly selected, whose centre served as the soil sample point. Soil samples were collected at constant layers of 0 - 15 cm topsoil and 15 - 30 cm (subsoil) using soil layer.

Laboratory analysis

The soil properties examined and related to vegetation patterns were water holding capacity, bulk density, total porosity, electrical conductivity, organic matter, available phosphorus, total nitrogen, total exchangeable acidity and cation exchange capacity. The soil samples were passed through a 2 mm sieve after they had been air-dried. Field moisture capacity (in percentages) was determined by saturating soil samples with water and allowing them to drain for 48 h before oven-drying at 150°C. Bulk density was determined by the core method (Blake, 1965) while total porosity (%) was computed from those of bulk density value of 2.65 gcm^{-3} (Vomocil, 1965). Electrical conductivity (ds/m) of the soil was measured in saturated soil paste extract read at 25°C by conductivity meter (Hanna, 1968) and pH was determined potentiometrically in 0.01 m calcium chloride solution ratio 1:2. The soil organic matter content was derived by first determining soil organic carbon through the Walkley Black dichromate method and then converted to organic matter by multiplying by a factor of 1.724 (Walkley and Black, 1934). Phosphorus was extracted using Bray No.1 method and the P content was determined colorimetrically using a Spectron $20D^+$ spectrophotometer (Bray and Kurtz, 1945). The total nitrogen (%) was determined by Kjeldahl digestion and by using a Technicon autoanalyser (Jackson, 1962). Total exchangeable acidity (meg/100 g) was determined by titration method that is by residue carbonate method (McLean, 1982), and the cation exchange capacity was determined by summation method expressed in meg/100 g (Chapman, 1965). The base saturation (%) was determined as the sum of the exchange cations divided by the cations exchange capacity expressed in percentage (Fitzpatrick, 1986).

Statistical analysis

Descriptive and inferential statistics were used to analyze the data. The means and standard errors of vegetation and soil variables were calculated for each of the sampled quadrants. One way ANOVA and New Duncan multiple range test were used to find out whether the differences among the means of the vegetation and soil variables on the forest and each of the logged tree sites were significant or not. An index of deterioration was determined for the vegetation and soil variables according to the procedure outlined by Ekanade (1987). The computation of the index was premised on the assumption that the status of any property whether vegetation or soil under an exotic species was once the same as that under the forest. In effect, the mean level of a vegetation or soil parameter under the forest is regarded as the optimal level. It depicts the extents of biotic and edaphic degradation.

RESULTS

Table 1 depicts the characteristics of the topsoil under 1 year, 5 year and 10-year continuously logged plots of *G. arborea* and *T. grandis* as well as in the natural forest. The textural properties of the soil appear homogenous under both logged plantations plots and forest and could be regarded as loamy sand. The average sand percentage was about 70% while percentage silt + clay was 30%. These apparent similar textural properties may be a result of the same parent material.

There was no definite pattern of distribution of all the soil properties under logged plots of Gmelina arborea which is an indicative that the pattern of change over time for each soil property varies. The mean values of topsoil properties in the natural forest plots were higher than those of the logged plots except in the case of electrical conductivity (3.33 $Hdsm^{-1}$), bulk density (0.75 Hgm^{-3}) exchangeable sodium (0.41 Hgm^{-3}/100 g) and exchange acidity (0.64 meq^{-1}/100 g) where lower values were found, when compared to the logged plots, as shown in Table 1.

The subsoil properties (Table 2) under different logged plots and tree species exhibited similar pattern of distribution as the topsoil. The results of the particle size analysis still justified the classification of the soil as loamy sand, although it was observed to be more sandy than topsoil.

As evident in Tables (for *Gmelina*) and (for *Tectona*), the present study showed that while soil textural classes indicated low deterioration values, water holding capacity, organic matter content, available phosphorus, total nitrogen, exchangeable calcium, magnesium, potassium, cation exchange capacity and base saturation indicated high deterioration values of these soil properties under 1 year, 5 year and 10 year logged plots of the selected species.

The pattern of deterioration in the soil as indicated in Tables 3 and 4 seems to be similar among the tree species irrespective of the logging periods in the plots. The deterioration overtime of the soil properties showed a diagonal deterioration pattern with an initial deterioration in the 1 year plots followed by continuing decline in each property up to the 10 year logged plots.

The analysis of variance test shows that all the soil properties measured in the topsoil and subsoil are significantly different (F = 0.05) between the natural forest and logged plots (Table 5). It reveals that there are significant differences among the mean values of the soil properties under the logged plots as well as between the soil of the logged plots and the natural forest. However, for total porosity the mean values are significantly higher under the forest than under the logged plots. At both topsoil and subsoil horizons, the mean values of the soil chemical characteristics were significantly lower at the logged plots than in the forest except for the exchangeable acidity.

DISCUSSION

The temporal changes of soil properties under a disturbed ecosystem are mainly functional, secondarily compositional and largely depend on efficient mineral cycling and regeneration of the vegetation. Soil - plant stability and resilience are central to how many disturbances can be tolerated before they are irretrievably degraded. The specific interaction of plant growth with soil properties depends on the species, site conditions and the age of the species (Prichett, 1979).

In plantation forests, like most other ecosystems, there are more sources of nutrient inputs including fertilizer application, use of pesticides, and other management practices. In this present study, a very broad homogeneity in edaphic features was observed between sites in respect of percentage sand, silt and clay; organic carbon content on the other hand was nearly homogeneous. A comparison of the soil textural properties among the different sampled plots showed that there are differences in the mean values of these parameters. This is as a result of differences in humus-clay colloid particles formed from high supply of vegetal properties. Soil texture has again been implicated in the nutrient storage capacity, chemical activity, and soil management for plant growth (Cai et. al., 2002).

Mean values of electrical conductivity are found to be lower in the forest soils than in the logged plots. The higher values of electrical conductivity under the logged plots may be due to exposure to solar radiation resulting to dry soils. According to Rhoades (1993) and Brady (1974), electrical conductivity was a product of neutral soluble salts. Hence, salts become concentrated in the soil solution, thereby increasing salt stress. Similar observations have been made by Tanji (1990) and Ogidiolu (1997). Kotuby-Amacher et al. (1997) opined that as salinity level increases, plants extract water less easily from the soil. This situation aggravates water stress condition, causes nutrient imbalance, results in accumulation of elements toxic to plants and reduces water infiltration. Conversely, the enhanced mean values of electrical conductivity in the logged plots could be attributed to high dissolved concentration of inorganic ion in solution particularly during the dry season.

Values of total porosity, water holding capacity, pH, organic matter, total nitrogen available phosphorus, exchangeable calcium, magnesium, potassium and cation exchange capacity are respectively higher than in the logged plantations. There seem to indicate withdrawal of

Table 1. Summary of descriptive statistics of topsoil properties (0 - 15 cm) under natural forest and logged plots.

				Gmelina arborea									*Tectona grandis*								
Soil properties	**Natural forest**			**1-year logged**			**5-year logged**			**10-year logged**			**1-year logged**			**5-year logged**			**10-year logged**		
	Mean	**S.D.**	**C.V.**	**Mean**	**S.D.**	**C.V.**	**Mean**	**S.D.**	**C.V.**	**Mean**	**S.D.**	**C.V.**	**Mean**	**S.D.**	**C.V.**	**Mean**	**S.D.**	**C.V.**	**Mean**	**S.D.**	**C.V.**
Sand (%)	69.20	2	2.89	67.06	4.96	7.28	74.80	4.77	6.38	75.6	2.97	3.92	65.96	3.84	6.82	70.20	3.85	5.48	65.5	3.03	4.67
Silt (%)	9.90	0.89	9.13	12.26	3.12	25.21	9.40	1.22	13.03	8.56	1.85	21.63	14.08	1.79	13.15	13.04	1.45	11.13	14.30	2	13.89
Clay (%)	20.90	1.52	7.29	20.68	4.25	20.57	15.80	3.91	24.76	15.84	3.33	21	19.96	2.66	13.45	16.68	2.55	15.28	20.7	4.52	21.82
WHC (%)	61.46	3.36	5.47	44.16	4.15	9.40	40.72	8.46	20.78	20.8	3.80	18.25	48.86	1.31	2.69	41.56	8.98	21.6	21.64	4.49	20.75
E.C. (dS/m)	3.33	0.05	1.4	3.52	0.53	15.08	3.58	0.37	10.2	4.23	0.32	7.49	3.75	0.27	7.21	3.94	0.25	6.29	4.08	0.16	4.03
B.D. (g/cm^3)	0.75	0.18	23.78	1.19	0.05	4.20	1.35	0.04	2.64	1.42	0.01	2.7	1.16	0.03	2.69	1.31	0.05	4.15	1.40	0.05	3.56
T.P. (%)	71.84	6.68	9.01	55.24	1.86	3.37	49.12	1.34	2.73	46.32	1.41	3.12	56.28	1.3	2.31	50.54	2.09	4.13	47.22	1.88	3.97
pH	6.44	0.42	6.46	6.14	0.32	5.23	5.5	0.21	3.86	4.92	0.15	3.01	6	0.22	3.73	5.56	0.34	6.05	5.12	0.11	2.14
Org. matter (%)	8.77	2.78	31.69	3.66	0.36	9.72	3.42	0.37	10.82	1.75	0.33	18.99	4.13	0.19	4.72	3.61	0.32	8.75	1.64	0.37	22.33
Total N (%)	1.23	0.18	14.51	1.17	0.05	4.24	0.49	0.11	21.65	0.09	0.03	30.43	1.14	0.03	2.8	0.38	0.07	19.74	0.09	0.03	30.43
P (ppm)	26.86	3.36	12.52	9.25	1.36	14.69	8.46	1.23	14.48	1.13	0.21	20.7	13.16	1.13	8.59	9.25	0.96	10.33	1.15	0.20	17.70
Ca^{++} (meq/100g)	7.23	0.75	10.32	4.34	0.59	13.69	1.08	0.11	9.78	0.28	0.08	27.31	5.13	0.33	6.38	1.19	0.11	9.11	0.25	0.09	35.72
Mg^{++} (meq/100g)	2.34	0.58	25.02	1.18	0.12	9.96	0.95	0.11	11.34	0.06	0.01	21.03	1.25	0.07	5.72	1.09	0.05	4.54	0.04	0.02	62.83
K^{+} (meq/100g)	1.05	0.3	28.49	0.69	0.07	9.83	0.52	0.05	10.22	0.04	0.01	31.04	0.78	0.1	13.01	0.56	0.06	10.82	0.04	0.02	45.80
Na^{+} (meq/100g)	0.41	0.11	26.42	0.09	0.06	64.01	0.37	0.03	8.89	0.43	0.43	101.59	0.05	0.03	60	0.48	0.04	9.72	0.26	0.3	119.02
E.A. (meq/100g)	0.64	0.22	34.23	0.94	0.17	17.8	1.06	0.09	8.41	0.86	0.11	13.26	1.00	0.10	10	1.10	0.12	11.13	0.84	0.26	31.04
C.E. C. (meq/100g)	11.66	1.17	10	7.58	0.46	6.12	3.96	0.31	7.76	1.33	0.09	7.03	8.41	0.44	5.21	4.37	0.75	3.33	1.22	0.36	29.58
B.S. (%)	94.46	1.92	2.03	87.6	2.55	2.91	74.32	3.29	4.43	35.14	7.49	21.3	88.28	1.02	1.16	74.76	3.49	4.67	31.56	3.76	11.92

E.C. - Electrical Conductivity, B.D. - Bulk Density T.P. - Total Porosity, E.A. - Exchangeable Acidity, CEC - Cation Exchangeable Capacity, B.S. – Base Saturation, Total N – Total Nitrogen, P – Available phosphorus , S.D. - Standard Deviation, C.V. - Coefficient of Variation.

Table 2. Summary of descriptive statistics of subsoil properties (15 - 30 cm) under natural forest and logged plots.

				Gmelina arborea									*Tectona grandis*								
Soil Properties	**Natural forest**			**1-year logged**			**5-year logged**			**10-year logged**			**1-year logged**			**5-year logged**			**10-year logged**		
	Mean	**S.D.**	**C.V.**	**Mean**	**S.D.**	**C.V.**	**Mean**	**S.D.**	**C.V.**	**Mean**	**S.D.**	**C.V.**	**Mean**	**S.D.**	**C.V.**	**Mean**	**S.D.**	**C.V.**	**Mean**	**S.D.**	**C.V.**
Sand (%)	67.80	4.45	6.56	64.92	6.69	10.3	70.8	4.77	6.74	79.6	1.67	2.1	65.46	2.64	4.04	65	5.4	8.11	71	4.15	5.8
Silt (%)	11.20	1.92	17.17	11.8	2.07	17.57	11	1.52	13.79	8.40	1.41	16.84	13.9	0.89	6.48	14.36	1.85	12.05	12	1.19	9.8
Clay (%)	21	3.65	17.37	23.28	5.68	24.59	18.20	3.70	20.34	12	1.67	13.94	20.64	2.93	14.48	20.64	4.77	23.11	17	3.51	21
WHC (%)	73.90	4.10	5.55	42.54	3.70	8.70	37.80	6.63	17.54	27.8	6.61	23.79	48.28	1.39	2.88	39.38	9.01	22.88	20.62	4.46	22
E.C. (dS/m)	3.35	0.04	1.1	3.55	0.53	14.79	3.24	0.37	10.67	4.36	0.34	7.71	3.9	0.26	6.58	3.98	0.23	5.86	4.16	0.14	3.5
B.D. (g/cm^3)	0.79	0.18	29	1.2	0.05	4.01	1.37	0.04	3.03	1.47	0.07	4.64	1.18	0.03	2.59	1.34	0.05	3.61	1.42	0.04	3.1
T.P. (%)	70.1	6.67	9.51	55.22	2.94	5.33	48.14	1.06	3.32	44.5	2.59	5.81	55.62	1.14	2.04	49.56	1.81	3.66	46.56	1.68	3.6
pH	6.22	0.49	7.83	5.82	0.13	2.24	5.28	0.29	5.42	4.46	0.21	4.65	5.86	0.11	1.95	5.2	0.38	7.32	4.82	0.2	4.8
Org. matter (%)	5.49	4.25	77.6	3.41	0.38	11.10	2.57	0.26	10.07	1.41	0.42	29.73	3.83	0.2	5.29	3.39	0.25	7.38	1.42	0.23	16
Total N (%)	1.06	0.54	50.47	0.94	0.1	10.06	0.22	0.12	56.21	0.07	0.03	43.38	0.78	0.06	8.15	0.33	0.08	23.76	0.07	0.03	36
P (ppm)	19.88	6.35	31.94	6.76	3.29	48.72	6.26	2.14	34.13	0.93	0.18	19.48	12.06	1.02	8.45	9.32	0.63	6.76	0.98	0.17	18
Ca^{++} (meq/100g)	4.40	0.41	9.24	4.00	0.44	10.9	0.96	0.07	7.76	0.23	0.05	20.43	4.91	0.29	5.93	1.08	0.08	7.63	0.21	0.05	23
Mg^{++} (meq/100g)	1.90	0.55	26.44	1.13	0.12	10.95	0.88	0.11	12.42	0.06	0.02	43.01	1.20	0.08	6.64	1.13	0.22	19.43	0.04	0.02	42
K^{+} (meq/100g)	0.99	0.19	19.11	0.66	0.06	9.03	0.45	0.04	9.04	0.1	0.07	66.23	0.74	0.09	12.56	0.52	0.08	14.96	0.02	0.01	28
Na^{+} (meq/100g)	0.24	0.04	14.86	0.08	0.07	89.01	0.33	0.04	10.5	0.48	0.36	74.84	0.03	0.04	15.97	0.30	0.03	11.08	0.22	0.27	119
E.A. (meq/100g)	0.60	0.19	31.18	0.96	0.21	21.6	1.00	0.12	12.25	1.06	0.11	10.76	1.04	0.13	12.9	1.22	0.13	10.69	0.92	0.23	25
C.E. C. (meq/100g)	8.16	0.91	11.09	7.24	0.19	2.61	3.63	0.31	8.59	1.51	0.11	7.02	8.11	0.41	5.07	4.23	0.28	6.52	0.22	0.29	24
B.S. (%)	92.68	1.99	2.15	86.64	3.22	3.72	72.48	1.77	2.45	30.2	7.44	24.62	87.2	1.12	1.29	56.7	31.4	55.43	24.82	2.5	10

E.C. - Electrical Conductivity, B.D. - Bulk Density, T.P. - Total Porosity, E.A. - Exchangeable Acidity, CEC - Cation Exchangeable Capacity, B.S. - Base Saturation, Total N - Total Nitrogen, P - Available phosphorus, S.D. - Standard Deviation, C.V. - Coefficient of Variation.

Table 3. Deterioration indices of soil properties under logged *Gmelina arborea* plantation.

	Topsoil (%)			Subsoil (%)		
Soil Properties	**1 year**	**5 years**	**10 years**	**1 year**	**5 years**	**10 years**
Sand (%)	3.09	-8.09	-9.25	4.25	-4.42	-17.40
Silt (%)	-23.83	5.05	13.53	-5.36	1.79	25
Clay (%)	1.05*	24.40•	24.21°	-10.86	13.33*	42.86°
WHC (%)	28.15*	33.75°	66.16•	42.44*	48.85°	62.38•
Electrical Conductivity (dS/m)	-5.83	-7.70	-27.18	-6.03	-2.09	-30.15
Bulk Density (g/cm^3)	-59.00	-80.7	-90.6	-52.02	-73.48	-85.86
Total porosity (%)	23.11*	31.63°	35.52•	21.23*	31.33°	36.58•
pH	4.66*	14.60°	23.60°	6.43*	15.11°	28.30•
Organic matter (%)	58.26*	61.02°	80.01•	37.87*	53.20°	74.26•
Total Nitrogen (%)	4.88*	60.16°	92.68•	11.32*	79.25°	93.40•
Availability phosphorus (ppm)	65.56*	68.50°	95.79°	65.98*	68.52°	95.33°
Exchangeable Ca% (meq/100g)	39.97*	85.12°	96.18•	9.91*	78.33°	94.86°
Exchangeable Mg% (meq/100g)	49.40*	59.33°	97.35•	40.30*	53.59°	96.73°
Exchangeable K% (meq/100g)	34.16*	50.76°	95.99•	33.13*	54.34°	89.90•
Exchangeable Na% (meq/100g)	78.05°	9.80*	-4.88	66.67*	-37.50	-100.00
Exchangeable Acidity (meq/100g)	-46.88	-65.63	-34.38	-60	-66.67	-76.67
CE C. (meq/100g)	35.02*	66.03°	88.63•	11.35*	55.55°	81.50•
Base Saturation (%)	7.26*	21.32°	62.80•	6.52*	21.80°	67.41•

Note: Positive indices for sand, electrical conductivity, bulk density and electrical conductivity and negative indices for other soil properties show that no degradation occurs under logged plantation plots.
* Low or significant pattern of deterioration.
° High or more significant pattern of deterioration.
• Higher or most significant pattern of deterioration.

soil nutrient by the growing plant and logged plantations while accumulation of nutrients is taking place under the rainforest. Earlier studies by FAO (1997) and Osuntogun (2001) have shown a decline in organic matter either in the short term or long term basis in a logged plantation.

The mean values of total nitrogen are higher in the natural forest when compared to the logged plots. These differential effects could be attributed first, to the fact that forest community consists of varied leguminous plant species that are known to fix nitrogen there by enhancing the build up of nitrogen components (Awotoye et al., 1992). Secondly, the organic matter which is a major source and store of nitrogen components is higher under forest than the logged tree species thus, total nitrogen will respond to the level of organic matter content in the soil. The role of organic matter in the build up of soil nutrients appears crucial in all ecosystems and depends on the high foliage cover and vegetation biomass and higher rate of litter production and subsequent decomposition. In effect, more nutrients are stored in the forest biomass, than in the exotics. Hence, it can be deduced that the nutrient return from vegetation to the soil would depend on the nutrient uptake by the biomass of each plant community.

In a homogenous environment, the stages of development of the plant species communities may affect both the nutrient uptake and the nutrient return of the vegetation, which could cause differentiation of soil properties as encountered under the exotics (*Gmelina* and *Tectona*). In this study, it seems the rate of nutrient uptake by these rapidly growing exotics outmatched the rate of nutrient return to the soil thereby causing a decline in soil nutrient status, since nutrient immobilization in the tissues of these logged tree species does not correspond to the nutrient return to the soil through the fall and mineralization of litter (Ekanade, 1991), thereby affecting their levels in the nutrient cycling process. This does not agree with the observation made by Onyekwelu et al. (2006) that soil nutrient depletion under *Gmelina* is independent of age of the trees. Our study shows that nutrient demand under the two tree species is rather influenced by years of logging. This was implicated particularly on the soil total N and available phosphorus under both tree species. *Gmelina* and *Tectona* are fast growing trees that will be expected to extract more nutrients for biomass development. Although, efficient internal re-use of nutrient as a result of rapid recharge of soil exchangeable nutrient (Evans, 1999) may occur, this will depend on the amount and quality of the foliage shed for recycling. The buffering capacity against disturbance

Table 4. Deterioration indices of soil properties under logged *Tectona grandis* plantation.

Soil Properties	Topsoil (%)			Subsoil (%)		
	1 year	5 years	10 year	1 year	5 years	10 years
Sand (%)	4.68	-1.56	6.07	3.45	4.13	-4.72
Silt (%)	-42.22	-31.72	-44.44	-24.11	-28.2	-7.14
Clay (%)	4.50°	20.19•	0.96*	1.71*	1.71*	19.04°
WHC (%)	20.50*	32.38°	64.79•	34.67*	46.31	72.10•
Electrical Conductivity (dS/m)	-15.51	-18.34	-22.67	-16.42	-18.81	-24.47
Bulk Density (g/cm^3)	-55.23	-75.60	-87.40	-48.48	-68.69	-78.79
Total porosity (%)	21.66*	29.65°	34.27•	20.66*	29.30°	33.58•
pH	6.83*	13.66°	20.50•	5.79*	16.40°	22.51•
Organic matter (%)	52.95*	58.81°	81.31•	30.23*	38.24°	71.14•
Total Nitrogen (%)	7.31*	69.11°	92.68•	26.42*	68.87°	93.40°
Availability phosphorus (ppm)	51.01*	65.58°	95.71•	39.34*	53.10°	95.09°
Exchangeable Ca% (meq/100g)	29.05*	83.49°	96.49•	-10.50	75.72*	95.18°
Exchangeable Mg% (meq/100g)	46.66*	53.34°	98.37•	36.8*	40.40°	98.10°
Exchangeable K% (meq/100g)	25.57*	47.33°	95.99•	24.85*	47.47°	97.53•
Exchangeable Na% (meq/100g)	87.80°	-4.87	36.59*	87.50°	-25.00	8.33*
Exchangeable Acidity (meq/100g)	-56.25	-71.88	-31.25	-73.33	-103.33	-53.33
CE C. (meq/100g)	27.87*	62.53°	89.50•	0.61*	48.17°	85.03•
Base Saturation (%)	6.54*	20.86°	66.59•	5.91*	38.82°	73.22•

Note: Positive indices for sand, electrical conductivity, bulk density and electrical conductivity and negative indices for other soil properties show that no degradation occurs under logged plantation plots.
* Low or significant pattern of deterioration.
° High or more significant pattern of deterioration.
• Higher or most significant pattern of deterioration.

Table 5. Results of ANOVA comparing soil properties under forest and the logged plantation in Omo-Osun forest reserve.

Soil properties	Calculated F	
	Topsoil (0 - 15 cm)	Subsoil (15- 30cm)
Sand	5.87	6.32
Silt	7.50	9.48
Clay	2.47	4.32
WHC	34.00	45.84
Electrical Conductivity	5.41	7.85
Bulk Density	44.00	40.95
Total porosity	44.08	37.94
pH	20.59	23.49
Organic matter	23.59	5.92
Total Nitrogen	26.64	107.89
Availability phosphorus	156.54	26.84
Exchangeable Calcium	253.68	332.17
Exchangeable Magnesium	57.41	46.23
Exchangeable Potassium	43.82	69.24
Exchangeable Sodium	3.12	3.97
Exchangeable Acidity	4.52	6.53
Cation Exchange Capacity	259.78	241.48
Base Saturation	222.00	25.54

ANOVA: $F_{0.05}$ (6.28) = 2.45. All soil properties are significantly different between the ecosystems at 5% level.

appears to be determined in part, by the structure of the ecosystem. The implication of an index of deterioration in this study indicates that status of soil in the plantation species appears to be stable before the area was exposed to human activities, in other words, the effects of logging on the edaphic component is being reflected. Thus, the impact of continuous logging in the 10 year logged plots of the exotic species on the soil component of the study area was demonstrated. Achieving sustainability of forest biomass and resources in the tropical area, forest activities should be regulated so as to enhance conservation and environmentally sound management practices. There is need to introduce restriction on the number of trees felled, set girth limits for cutting down trees, ensuring pre-felling and post felling inspection as well as ensure good road network in the forest reserve in order to reduce area spoilage.

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