IMPACT OF LAND USE CHANGES ON SOIL QUALITY OF A BIOSPHERE RESERVE IN SOUTHWESTERN NIGERIA

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ABSTRACT

Many primary forests in the tropical regions of the world have been converted into degraded secondary or intensively used agricultural areas. Using the Spatial Analogue technique of studying ecosystem dynamics, soil impact of deforestation and conversion was evaluated by comparing soil properties under the natural forest, secondary regrowth of a logged-over forest, monoculture plantation of Cedrela odorata (Linn), and maize/cassava farm at 0 10, 10 20 and 20 30cm soil depths. % sand decreased with soil depth in all the land use types and was significantly different between the natural forest and each of the logged-over forest regrowth, monoculture plantation and farmland except at 0 10cm depth. % Clay increased with soil depth but did not vary significantly among land use types except at 20 30cm depth. Available phosphorus decreased gradually with soil depth in all land use types with the natural forest and farmland having the highest and lowest mean values respectively. Organic matter varied significantly between each of the natural forest, logged-over forest regrowth and monoculture plantation, with the farmland at the three soil depths. Total nitrogen was generally low in all land use types, though, the natural forest compared better than the others. Soil pH, calcium, magnesium, effective cation exchange capacity, and percentage base saturation decreased with soil depth in all land use types with the natural forest having higher mean values than the others. Indices of change computed for organic matter, total nitrogen, available phosphorus, calcium, magnesium, potassium, effective cation exchange capacity and percentage base saturation, showed that soil management in the introduced land use types, is tending away from sustainability. Inter-cropping with nutrient-regenerating agroforestry trees on the farmland and the use of low-impact logging techniques are suggested for soil conservation.

Keywords: ***Omo Biosphere Reserve, Monoculture, Logging, Farming, Soil quality.***
Impact of Land Use Changes on Soil Quality of a Biosphere Reserve in Southwestern Nigeria.

INTRODUCTION

Many primary forests in the tropical regions of the world have been converted into degraded secondary or intensively used agricultural areas. Human poverty and continuous decline in the amount of agricultural land per person (Mahtab and Karim, 1992), and increasing demand for firewood, timber, pasture, shelter and food crops (Hall *et al*, 1993), are identified causes of indiscriminate exploitation, degradation and conversion of natural land covers, particularly tropical forests.

The Nigerian tropical rainforest, which was estimated to cover a total area of 170,000km^2 (Sutter, 1979), has been overwhelmingly reduced in size, degraded and converted to other land uses. Even the reserved areas are not left out, as they mainly exist on paper today and hold little or no evidence of their original flora and fauna. Salami (2006) in his study to ascertain the feasibility of the use of NigeriaSat-1 and other satellites in monitoring Nigerian forests, reported that deforestation in Nigeria is occurring at the rate of 1.36% per annum. Although, this is less than the 3.5% per annum being used by the Federal Department of Forestry, it is still on the high side.

An interdisciplinary committee (Oyinloye *et al*, 2004) of the National Research Council (NRC) recently identified some important environmental research challenges over the next 20 to 30 years. One of the challenges is land use dynamics, which calls for the development of a comprehensive understanding of challenges in land use and land cover that are critical to bio-geochemical cycling, ecosystem functioning and services, and human welfare. The report concluded that "improved information on, and understanding of land use and land cover dynamics are essential for society to respond effectively to environmental challenges and to manage human impacts of environmental systems".

Several authors (Nwoboshi, 1970; Ola-Adams, 1981; Jordan, 1985; Oyeniyi and Aweto, 1986; Chapman and Reiss, 1992; Islam and Weil, 2000) have given credence to the fact that vegetation modification alters the soil/vegetation equilibrium needed to sustain the productivity of the tropical rainforest ecosystem.

The success in soil management to maintain soil quality depends on an understanding of how soil responds to agricultural practices and other land uses over time. Consequently, a systematic understanding and knowledge of soil nutrient dynamics due to land use and land cover changes are paramount in predicting the ecological consequences of disturbing natural ecosystems, and the soil impact of current utilization and management practices.

This paper gives a quantitative account of the impact of land use/land cover changes on soil quality, using Omo Biosphere Reserve as a case study. These effects were examined by comparing soil condition currently observable in the farming areas, logged areas, and the areas dominated by tree cropping; with those of the climax vegetation. It is hoped that the findings will foster management decisions that will improve soil conservation and introduce sustainable farming and forestry practices that will ensure long-term productivity of the soil.

MATERIALS AND METHODS

Description of the Study Area

Omo Biosphere Reserve is located between latitudes 6°35' to 7°05' N and longitude 4°19' to 4°10' E in the Ijebu area of Ogun State (Badejo and Ola-Adams, 2000*);* about 135km northeast of Lagos, about 120km east of Abeokuta and about 80km east of Ijebu Ode (Ola-Adams, 1999). The reserve shares a common boundary in its northern part with two other reserves Ago Owu and Shasha, in Osun State. It also has a common boundary with Oluwa Forest Reserve in Ondo State (Karimu, 1999); and covers 130,500 hectares of land (see Fig. 1).

The reserve lies within a typical

lowland rainforest. The soils are predominantly ferruginous tropical (Hall, 1977); and are of the Ferric Luvisols type of the higher category of classification (Chijioke, 1980). The reserve is made up of several soil types but all the soils sampled are derived from ferruginous sand stones.

The climate of the reserve has been extensively described by Ola-Adams (1999). The reserve falls within the tropic wet-and-dry climate characterised by two rainfall peaks separated by relatively less humid period usually in the month of August. The mean annual rainfall is about 1750mm, and mean relative humidity is 80%. The mean daily temperature is 26.4°C. Compared with the mean of 25.8°C recorded by Evans (1939), an increase in temperature of 0.6°C is evident.

Selection and Description of the Study Sites

To gain an insight into the differences in soil properties both in the modified portions of the study area as well as the protected nature reserve within it, four study sites A, B, C and D, of one hectare each, were chosen to reflect the current vegetation patterns induced by anthropogenic activities.

Site A (6.96598°N and 4.36245°E), which served as the reference ecosystem, was drawn from the core of the Strict Nature Reserve (SNR). The site represents part of the study area that has not been modified either by agricultural activities of the smallholders, plantation establishment or timber exploitation. Tree species in the site include: *Rinorea dentate, Drypetes principum, Octolobus spectabilis, Diospyros dendo, Strombosia pustulata, Diospyros viridens, Funtumia elastica, Drypetes gilgiana, Holoptelia grandis, Drypetes floribunda, Celtis milbraedii, Anthonotha macrophylla, and Hunteria nitida.* The shrubs include *Heisteria paroifolia, Dichapetalum madagascariens,* and *Memecylon zenkeri,* while lianes were represented by *Salacia nitida* and *Rutidea paveettoides.*

Site B (6.87608°N and 4.42397°E) was selected from a secondary regrowth of a logged-over forest between Temidire and Ajebandele camps along the road leading to Oloji camp. The vegetation comprises tree species of *Hunteria umbellata, Diospyros dendo, Celtis philippensis, Musanga cecropioides, Ficus exasparata, Enanthia chlorentha, Irvingia gabonensis, Funtumia africana, Cordia millenii, Zanthoxylum leptrieurri, Albizia zygia and Drypetes gilgiana,* with undergrowth of saplings of *Ficus exasparata*, *Theobroma cacao, Funtumia africana, Elaeis guineensis and Diospyros dendo.*

Site C (6.81163°N and 4.41640°E) is a monoculture plantation of *Cedrela odorata* with undergrowth of mainly *Chromanaela odorata,* and scanty saplings of *Ficus exasparata, Funtumia africana* and *Melicia excelsa*. The plantation is situated about 100 metres before Fiyalana camp.

Site D (6.88744°N and 4.38893°E) is an arable farmland located about 100 metres after Abakurudu Camp along the road to Oshoko. The site, which has been under arable cropping since 1986, was covered with *Manihot escluenta* and *Zea mays*.

Collection of Soil Samples

Each of the one-hectare study sites

was divided into sixteen 25 x 25m^2 quadrats. Ten out of the sixteen quadrats were randomly selected in each study site for sampling. Soil samples were collected (using soil auger) from the ten randomly selected quadrats at three depths: 0 - 10; 10 20 and 20 30cm, in triplicates. Each set or the triplicate samples was bulked for each depth, enclosed in polybags and immediately taken to the laboratory for analysis. All the soils sampled, are derived from ferruginous sand stones.

Laboratory Analyses

Prior to the analyses, all air-dried samples were broken mixed and sieved using 2mm mesh. The particle size analysis was done using the hydrometer method (Bouyoucous, 1951); the exchangeable bases were determined by the summation method (lITA, 1979); available phosphorus was determined by Bray No. I method (Bray and Kurtz, 1945); exchangeable acidity was determined by extraction with IN Kcl and titrating with NaOH; organic carbon was determined by Walkley Black wet oxidation method (Allison, 1965) and organic matter derived there from by multiplying with 1.72; total nitrogen was determined by Kjedahl method (Bremner, 1965); Soil pH was measured in 1:1 soil: water ratio; effective cation exchange capacity was determined as the sum of exchangeable bases and exchangeable acidity; while percentage base saturation was computed by dividing the sum of the charge equivalents of the base forming cations (Ca, Mg, K and Na) by the effective cation exchange capacity of the soil and multiplying by 100 (Lemenih, 2004).

Data Analyses

A one-way analysis of variance was used to test for significant differences in soil properties among the land use/land cover types for each soil depth using the Statistical Package for Social Sciences (SPSS) as described by Oloyo (2001). Duncan Multiple Range Test (DMRT) was used for mean separation for those soil properties that differed significantly at 0.05 level of significance.

Change indices were computed for selected soil properties of the introduced land use/land cover types according to Ekanade (1987); Adejuwon and Ekanade (1988); Salami (1998); and Islam and Weil (2000). The calculation of the change index was based on the assumption that the tropical rainforest represented by the SNR, is the stable vegetation cover in the area. The value of each soil property in the SNR (Site A) was taken as an approximation of the optimal value. Consequently, the index of change was derived from the difference between the value of a determined property in Site A and each of Site B (logged-over forest regrowth), Site C (monoculture plantation) and Site D (arable farmland). The computed difference was then expressed as a percentage of the property in Site A. Furthermore, the computed change indices for the three sampled depths were added and averaged for each soil property.

RESULTS

Soil physical properties

The particle size distribution of soils under different land use types arc shown in Table 1. % Sand decreased with soil depth while % Clay increased with soil depth in all the land use types. % silt did not show any regular pattern of distribution with soil depth. % Sand varied significantly between Site A and each of the modified sites (B, C and D) at the different soil depths except 0 - 10cm where no significant difference was observed among Sites A, C and D, % Silt varied significantly among land use types especially at 0 - 10cm depth with Site C having higher mean value than the other sites at lower soil depths. % Clay did not vary significantly among most of the land use types except at 20 30cm depth where significant difference exists between each mean pair compared.

Soil Chemical Properties

Table 2 shows Available P, Organic C, Organic matter, and Total N in soils under different land use types. Available P decreased gradually with soil depth in all land use types with Site A and Site D having the highest and lowest mean values respectively. Organic matter decreased sharply with soil depth in all the land use types with Site A having higher mean value than each of the modified sites (B, C and D). Also, Organic matter varied significantly between each of Sites A, B and C, with Site D at the three soil depths. Total N was generally low in all the land use types, though, Site A compared better than the other land use types at the three depths.

Soil pH, exchangeable cations, effective cation exchange capacity (ECEC) and percentage base saturation (PBS) of soils under the different land use types are shown in Table 3. Soil pH, Ca, Mg, ECEC and PBS decreased with soil depth in all the land use types with Site A having higher mean values than sites B, C and D. PBS was fairly high at 0 10cm depth in all the land use types except in site B. K was generally low in all the land use types.

Soil Deterioration

Table 4 shows indices of change for organic matter, total N, available P, Ca, Mg, K, ECEC and PBS in the modified sites (B, C and D). Site C had lower change indices than each of

Sites B and D while Site D had the highest change indices in almost all the soil attributes considered.

Table 1:Particle size distribution of soils under different land use/land cover types

		%		
Soil Depth (cm)	Site	Sand	Silt	Clay
0 10	A	79.40^{a}	9.80^{cd}	10.80^{bcd}
	B	71.20^{cd}	11.40^{b}	17.40^{a}
	C	75.80^{ab}	10.00^{c}	14.20^{ab}
	D	75.20^{abc}	13.40^{a}	11.40^{bc}
10 20	A	75.40^{a}	8.80^{d}	15.80^{d}
	B	61.20^{cd}	12.40^{ab}	26.40^{a}
	C	61.80^{bc}	14.00^{a}	24.20^{ab}
	D	66.60^{b}	12.00^{abc}	21.40^{bc}
20 30	A	70.40^{a}	9.60^{bcd}	20.00^{d}
	B	53.20^{cd}	10.20^{bc}	36.60^{a}
	C	53.80^{c}	14.00^{a}	32.20^{b}
	D	65.40^{b}	11.20^{b}	23.40^{c}

Values are means of triplicate samples

Means with the same alphabet on the same column for each soil depth are not significantly different (P > 0.05).

Table 2:Available P, Organic C, and Total N under different land use/land cover types

Soil Depth (cm)	Site	Av.P (mg/kg)	OC	% OM	TN
0 10	A	44.80^{a}	4.19^{a}	7.21^{a}	0.22^{a}
	B	30.30^{bc}	2.98^{bc}	5.13^{bc}	0.16^{abc}
	C	31.50^{b}	3.00^{b}	5.16^{b}	0.18^{ab}
	D	18.30^{d}	1.50^{d}	2.58^{d}	0.12^{bcd}
10 20	A	36.60^{a}	1.78^{a}	3.06^{a}	0.14^{a}
	B	24.15^{c}	1.62^{ab}	2.79^{ab}	0.12^{ab}
	C	28.95^{b}	1.56^{abc}	2.68^{abc}	0.12^{abc}
	D	16.35^{d}	0.90^{d}	1.54^{d}	0.08^{bcd}
20 30	A	25.10^{ab}	1.28^{a}	2.20^{a}	0.10^{a}
	B	23.85^{abc}	1.04^{ab}	1.79^{b}	0.08^{ab}
	C	25.75^{a}	1.03^{abc}	1.77^{bc}	0.08^{abc}
	D	15.15^{d}	0.35^{d}	0.60^{d}	0.06^{abcd}

Values are means of triplicate samples

Means with the same alphabet on the same column for each soil depth are not significantly different (P > 0.05).

Table 3: Exchangeable cations and pH under different land use/land cover types

Soil Depth (cm)	Site	pH (H_2O)	Ca	Mg	K	Na	H+Al	ECEC	PBS
0 10	A	6.00^{a}	4.86^{a}	2.65^{a}	0.12^{a}	0.47^{b}	0.11^{cd}	8.21^{a}	98.66^{a}
	B	4.50^{d}	1.90^{c}	0.93^{c}	0.07^{c}	0.26^{bcd}	1.08^{a}	4.24^{c}	74.53^{d}
	C	5.90^{ab}	4.03^{b}	2.00^{b}	0.11^{ab}	0.89^{a}	0.14^{c}	7.17^{b}	98.05^{ab}
	D	5.20^{c}	1.84^{cd}	0.79^{cd}	0.05^{cd}	0.37^{bc}	0.24^{b}	3.29^{d}	92.71^{c}
10 20	A	4.70^{b}	1.88^{a}	0.89^{a}	0.05^{a}	0.54^{a}	0.99^{c}	4.35^{a}	77.24^{a}
	B	4.10^{d}	1.22^{cd}	0.72^{ab}	0.04^{ab}	0.25^{c}	1.21^{a}	3.44^{c}	64.83^{cd}
	C	5.50^{a}	1.70^{ab}	0.60^{bc}	0.04^{ab}	0.40^{b}	1.10^{b}	3.84^{b}	71.35^{b}
	D	4.70^{bc}	1.25^{c}	0.50^{cd}	0.04^{ab}	0.23^{d}	0.95^{d}	2.97^{d}	68.01^{bc}
20 30	A	4.80^{b}	1.67^{a}	0.81^{a}	0.04^{ab}	0.48^{a}	0.95^{cd}	3.95^{a}	75.95^{a}
	B	4.10^{d}	1.11^{c}	0.66^{b}	0.03^{bc}	0.22^{cd}	1.24^{a}	3.26^{bc}	61.96^{cd}
	C	5.40^{a}	1.44^{b}	0.51^{c}	0.04^{ab}	0.38^{b}	1.10^{b}	3.47^{b}	68.30^{b}
	D	4.70^{bc}	1.05^{cd}	0.50^{cd}	0.05^{a}	0.24^{c}	0.96^{c}	2.80^{d}	65.71^{bc}

Values are means of triplicate samples

Means with the same alphabet on the same column for each soil depth are not significantly different (P > 0.05).

Table 4:Index of change for selected soil properties in the introduced land use types

		%		
Soil property	**Site A**	**Site B**	**Site C**	**Site D**
Organic matter	-	18.75	20.13	62.21
Total nitrogen	-	20.52	17.49	42.78
Available P	-	23.77	16.00	51.37
Calcium	-	43.18	13.47	44.26
Magnesium	-	34.17	31.38	50.76
Potassium	-	28.89	9.44	17.78
ECEC	-	28.92	12.18	39.85
PBS	-	19.65	6.11	10.49

Values are means for the three soil depths.

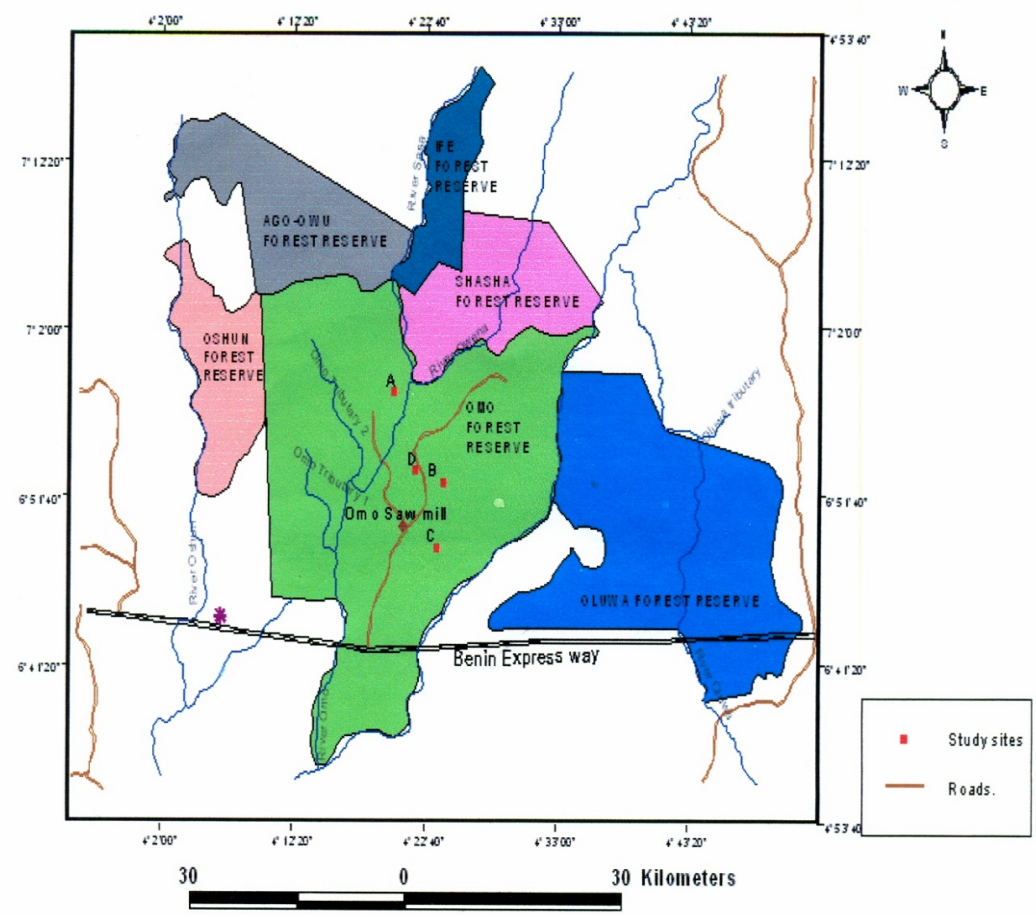

Fig. 1:Map showing Omo Biosphere Reserve, the study sites and surrounding areas.

DISCUSSION

The increase in the % Clay with soil depth could be attributed to leaching of the fine clay particles to lower soil depths while the decrease in % Sand with depth could be attributed to the inability of the larger sand particles to be leached to lower depths by percolating water. Similar trends in particle size distribution have been reported by Muoghalu and Awokunle (1994) in the Nigerian rainforest region. Although, texture is an intrinsic soil property, vegetation modification could probably have contributed to the variations observed through the associated operations. For example, higher % Sand in Site A, could be due to the ability of the natural forest to trap more aeolian materials than the modified sites.

The lowest level of available P recorded for Site D could be as a result of vegetation removal through continuous cultivation and the inability of the impecunious smallholders to procure and apply inorganic phosphorus fertilizers. Hatton and Smart (1984) have reported higher phosphorus content under tree canopy and that organic fraction of phosphorus is returned to the soil via litter and is an indication of the increased decomposition of organic material occurring under regenerating canopy.

The decrease in % Organic matter with soil depth may be due to the decrease in the abundance of fine roots with depth; at greater depths, larger diameter roots predominate. The significant difference in organic matter between each of Sites A, B, and C. with Site D is probably due to the accumulation and decay of leaf litter and root within the tree canopies. Garakis and Tsangarakis (1970) attributed the highest organic matter under tree canopy to litter fall and its decay and decaying tree roots around the trees. However, higher organic matter in Site A than each of Sites B and C, could be attributed to higher litter production under the natural forest. Ola-Adams (1999) noted that mean nitrogen contents are generally low for tropical forest soils and this is also the case in this study. Although, leaching loss was not directly assessed in this study and soil nitrate was not distinguished, the low total N especially at the cultivated land is probably due in part, to soil leaching losses of the mobile nitrate ion.

The lower PBS recorded for Site B is attributable to the higher exchangeable acidity in the Site. This is also indicative of the fertility level of the site. According to Tisdale and Nelson (1975) "for a soil of any given organic matter and mineral composition, the pH and fertility increase with an increase in the base saturation". The generally low K content recorded in the study may be due to immobilisation. Preferential immobilisation of the basic nutrients by the Verbenaceae has been reported by Nwoboshi (1972) and Chijioke (1978); and other hardwoods by Rennie (1957) and Golley *et al* (1975). Chijioke (1980) also reported that K was the element immobilised to the greatest extent by *Gmelina arborea* in Omo Ajebandele area of the study area. Generally, the pH values show that soils of the study area are acidic. This is in conformity with earlier reports by Okali and Ola-Adams (1987) and Isichei (1995). However, the higher pH values at the surface layer of the sites could be attributed to higher concentrations of the exchangeable bases at this layer. Muoghalu and Awokunle (1994) reported that the accumulation of these cations is likely to increase pH.

The change indices computed for the modified sites indicated that soil management practices in these sites are unsustainable. The relatively high change indices recorded for Site D support Chapman and Reiss (1992) assertion concerning the unsuitability of the tropical rainforest for the cultivation of agricultural crops, and explain why there could be a dramatic decline in crop yield when such cultivation is attempted without adequate soil conservation measures.

CONCLUSION

Soil quality under the SNR was better than in the other land use types. The change indices for the modified sites, showed a better soil quality under the *Cedrela Odorata* monoculture than in the logged-over forest regrowth and the farmland; with the latter being the poorest. Although, this could give credence to earlier assertions on the restoration capabilities of fast-growing monocultures (e.g. Lugo, 1997; Fan and Peng, 1997), conclusion with *Cedrela odorata* needs additional research, as the undergrowth of *Chromanaela odorata* a good compost material, under it in the study, might have enhanced the higher nutrient content. However, soil quality under the modified sites drifted from sustainability.

RECOMMENDATION

Inter-cropping with nutrient-regenerating agroforestry trees on the farmland and the use of low-impact logging techniques are suggested for soil conservation.

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