African Journal of Plant Science Vol. 5(10), pp. 565-569, 27 September, 2011
Available online at http://www.academicjournals.org/AJPS
ISSN 1996-0824 ©2011 Academic Journals

Full Length Research Paper

Assessment of soil quality under various land use practices in a humid agro-ecological zone of Nigeria

Olusegun O. Awotoye[1], Clement O. Ogunkunle[2]* and Sunday A. Adeniyi[3]

[1]Institute of Ecology and Environmental Studies, Obafemi Awolowo University, Ile-Ife, Nigeria.
[2]Department of Plant Biology, University of Ilorin, Ilorin, Nigeria.
[3]Department of Geography, Osun State University, Osogbo, Nigeria.

Accepted 12 July, 2011

In this study, soil samples were collected from 0 to 15 cm and 15 to 45 cm of secondary forest, mixed plantation, natural fallow and sole plantation. Soil samples were chemically analyzed using standard methods for organic matter, nitrate-nitrogen, pH, bulk density and available phosphorus. The results were statistically analyzed and index of deterioration was also calculated for the soil properties. Mixed plantation appeared to resemble the secondary forest in soil properties except available phosphorus. There is significant degradation of available phosphorus in mixed plantation which was probably due to the high uptake of nutrients for production of pods, nuts and beans of cocoa and kola trees that co-exists to form the mixed plantation. The results suggested that establishment of sole plantation was not a viable ecological approach to soil management and conservation but mixture of trees proved advantageous to soil. Natural fallow in the absence of incessant bush fire also appears to be a sound land-use technique in conserving soil properties.

Key words: Index of deterioration, soil productivity, organic matter, litterfall, natural fallow, mixed plantation.

INTRODUCTION

Soil properties deteriorate with change in land use especially from forest to arable land (Oguike and Mbagwu, 2009). The cropping system may lead to erosion and leaching of soil nutrients which in turn adversely affect the physico-chemical properties of the soil. Soil structure can be affected by the intensity of land use and this has effect on the distribution of microbial biomass as well as microbial processes within the aggregates (Gupta and Germida, 1988). Mbagwu and Auerswald (1999) have shown that land use influenced structural stability more than intrinsic soil properties and that percolation stability of soil increased with organic matter content. Land use change is also known to be an important factor controlling soil organic matter storage since it affects the quantity and quality of litter inputs, the litter decomposition rate and the processes of soil organic matter stabilization (Shepherd et al., 2001). Land use changes, especially cultivation of natural lands in tropical areas have led to negative effects on soil organic matter components (Fallahazade and Hajabbasi, 2011). With continuous cultivation, physical properties and productivity of soils commonly decline due to decrease in organic matter content (Oguike and Mbagwu, 2009) and soil pH. Intensive cropping has also been recorded to lead to disaggregation in surface soil due to decrease in organic matter. But bush fallowing has been proved by Juo et al. (1995) as an inevitable method to restore the physico-chemical and biological properties of soil while Ewel (1986) considered it to be efficient for nutrient recycling and biomass accumulation because it consist of many plant species with different type of root system. Yemefack and Nounamo (2002) also put the role of fallow phase as to facilitate the repositioning of soil productivity. Yemefack and Nounamo (2002) in their work on the effect of fallow period on topsoil in Southern Cameroun stated that humus content increases and consequently

*Corresponding author. E-mail: seyeogunkunle@yahoo.com. Tel: +2348062176518.

Abbreviations: DI, Index of deterioration; **SOM,** soil organic matter.

increased the organic carbon and this correlated with the result of Kirchlof and Salako (2000) in Southern Nigeria.

The system of monocropping of trees has been discouraged because of the rate of nutrient uptake with fewer returns to the soil (Padley and Brown, 2000). In a homogenous plant community, the stage of development of plant communities affects both the nutrients uptake and nutrient return which causes differentiation of soil properties (Ogunkunle and Awotoye, 2011). Nutrient dynamics has been noted as important in the understanding of ecosystem functioning and ecological status and in monocropping system, more uptake and less returns to the soil is evident, leading to deterioration of soils. But intercropping of trees or mixed planting produces better soil quality due to mixing of litter components and the synergistic interactions that are beneficial to the soil (Ekanade, 1990). Bernhard-Reversat and Loumeto (2002) affirmed that the most relevant parameter for soil organic matter binding up could be the amount of standing litter on the soil which integrates litter fall and decomposition and also essential in the soil aggregate stability (Emadi et al., 2008). Hence, the study assessed the soil properties of secondary forest, natural fallow, sole plantation and mixed plantation sites in the topsoil and subsoil layers of a humid agro-ecological zone of Nigeria.

MATERIALS AND METHODS

Study area- humid agro-ecological zone

The study area is located between latitude 7° 55′ N and 8° and longitude 4° 50′ E and 4° 53′ of Osun State, Southwestern region of Nigeria. The vegetation could be classified as lowland rainforest as stated by Keay (1959) but some of the present vegetation may be described as secondary forest which is as a result of agricultural colonization. The climate is humid sub-equitorial type, characterized by distinct rain and dry season and mean annual rainfall ranges between 1300 and 1600 mm (Aweto, 1981; Anuforom, 2009). The monthly humidity is at least 70% and temperature ranges between 24°C and 28°C. The soils are acidic and easily degraded without vegetation (Anuforom, 2009).

Selection of the study sites

The study area consists of four sites and they are as follow:

1. Secondary forest: this is a site consisting of relatively intact forest serving as the control;
2. Natural fallow: this is a site under fallow and the year of fallow could not be estimated;
3. Sole plantation: this is a site consisting of *Tectona grandis* solely that has been established since 1976 and still under non-selective harvesting;
4. Mixed plantation: this is a site with interplant of *Theobrom cacao* and *K. nitida* of more than 30 years and is still productive.

Soil sampling techniques

Each study site was randomly divided into four blocks of area 400 m^2 and three soil samples collected at the topsoil depth of 0 to15 cm and subsoil depth of 16 to 45 cm, respectively using bucket soil auger (Ekanade, 1991a). The soil samples were put into polythene bags and transported to the laboratory for air-drying. Each sample was homogenized, sieve through 2 mm sieve and stored for chemical analysis.

Laboratory analysis

The soil samples were analyzed chemically for the following properties; soil pH was measured in 0.01 M $CaCl_2$ (at soil to solution ration 1:2), organic matter was determined by the Walkley and Black method (Walkley and Black, 1934), nitrate-nitrogen by the Kjeldahl method (Black, 1965), available phosphorus using Bray No. 1 method (Bray and Kurtz, 1945) and bulk density was determined by the Core method (Blake, 1965).

Data analysis

Analysis of variance (ANOVA) was used to compare the influence of the land use types on the measured soil properties in the study area. Duncan Multiple Range test was also employed to differentiate the means at probability level of 5% (Ogunkunle and Ogunkunle, 2011). Index of deterioration (DI) was applied according to Ekanade (1991b) to compute the rate of deterioration of the soil properties in the study.

$$DI = \frac{\overline{X} - \overline{X}i}{\overline{X}}$$

$\overline{X}$ = mean value of soil parameters in Secondary forest (reference site), X_i = mean value of soil parameter in compared site.

RESULTS

Tables 1 and 2 show the mean value of the topsoil and subsoil properties in the secondary forest, mixed plantation site, natural fallow site and the sole plantation site. There is significant different in the mean values of the soil properties across the soil levels. Table 2 shows that the bulk density of the mixed plantation site was the same with that of the secondary forest in the topsoil while available phosphorus in mixed plantation site rated the least in both topsoil and subsoil levels (8.17 and 8.01 ppm, respectively). Organic matter and nitrate-nitrogen contents in mixed plantation site were close to the values in the secondary forest (7.12 and 6.18%, respectively) (Table 2). The pattern of soil properties distribution in the subsoil appears similar to the topsoil. It is very important to note that organic matter and nitrate-nitrogen contents were least in the sole plantation site. Table 3 shows the index of deterioration of the soil properties under mixed plantation, natural fallow and sole plantation. Deterioration indices of organic matter and nitrate-nitrogen contents were highest in the topsoil and subsoil of sole plantation but it is evident in Table 3 that available phosphorus was most degraded in the mixed plantation. Bulk density in the topsoil of secondary forest

Table 1. Mean values of topsoil and subsoil properties in each plot of the study area.

Plots	pH ($CaCl_2$)	Bulk density (g/cm^3)	Organic matter (%)	Nitrate-nitrogen (ppm)	Available phosphorus (ppm)
A_i	5.92/5.65	1.1/nd	9.22/9.10	9.46/9.10	18.21/12.86
A_{iI}	5.75/5.63	1.0/nd	8.82/9.08	9.42/8.90	18.66/12.80
A_{iII}	5.86/5.55	1.0/nd	9.34/9.06	9.48/8.90	18.39/12.79
A_{iV}	5.91/5.61	0.9/nd	9.10/8.80	9.44/8.70	18.58/12.75
B_i	5.56/5.50	1.0/nd	7.46/6.20	7.88/7.20	8.20/8.09
B_{ii}	5.54/5.52	1.0/nd	7.01/6.18	8.01/7.00	8.18/8.12
B_{iii}	5.56/5.54	1.1/nd	7.22/6.18	7.93/6.96	8.14/8.00
B_{iv}	5.62/5.52	0.9/nd	6.70/6.16	7.91/6.84	8.16/7.83
C_i	5.33/5.12	1.3/nd	6.43/5.33	6.19/5.79	16.79/10.19
C_{ii}	5.44/5.08	1.2/nd	6.39/5.31	6.15/5.71	16.83/10.07
C_{iii}	5.31/5.11	1.1/nd	6.37/5.40	6.12/5.76	16.81/10.14
C_{iv}	5.30/5.09	1.2/nd	6.35/5.20	6.18/5.58	16.85/10.16
D_i	5.46/5.35	1.8/nd	4.44/3.10	5.10/4.16	10.37/9.84
D_{ii}	5.49/5.31	1.6/nd	4.45/3.02	5.34/4.12	10.38/9.86
D_{iii}	5.33/5.32	1.4/nd	4.35/3.06	5.30/4.14	10.39/9.84
D_{iv}	5.48/5.34	1.6/nd	4.43/3.06	5.18/4.14	10.38/9.82

Numerator represents the mean value of soil property in the topsoil layer, denominator represents the mean value of soil property in the subsoil layer.

Table 2. Mean values of soil properties in the topsoil and subsoil of the study sites soil properties.

Soil properties	Topsoil				Subsurface			
	A	B	C	D	A	B	C	D
pH ($CaCl_2$)	5.86^a	5.57^b	5.73^c	5.44^d	5.61^a	5.52^b	5.60^c	5.33^d
Bulk density (g/cm^3)	1.0^a	1.0^a	1.2^b	1.6^c	nd	nd	nd	nd
Organic matter (%)	9.12^a	7.12^b	6.39^c	4.42^d	9.01^a	6.18^b	5.31^c	3.06^d
Nitrate-nitrogen (ppm)	9.45^a	7.93^b	6.16^c	5.23^d	8.9^a	7.0^b	5.71^c	4.14^d
Available Phosphorus (ppm)	18.46^a	8.17^d	16.82^b	10.38^c	12.80^a	8.01^d	10.14^b	9.84^c

A- secondary forest (reference site), B- mixed plantation site, C- natural fallow site, D- sole plantation site, nd- not determined. Values with different letters are significantly different according to Duncan multiple range test at 5% probability level.

and mixed plantation showed the same value but highest in sole plantation topsoil. The natural fallow appears to be less degradation than the sole plantation.

DISCUSSION

High fertility under the secondary forest (organic matter, nitrate-nitrogen and available phosphorus) is possibly due to the accumulation and decay of leaf litter and root within the secondary forest and tree canopy could possibly contributed to the high fertility. Craswell and Lefroy (2001) note that an important aspect of organic matter management is to mimic natural systems that have constant input of carbon of varying quality Ogunkunle and Awotoye (2011) Muoghalu and Awokunle (1994) attributed higher organic matter under tree canopy to litterfall and its decay and decaying tree roots around the trees. The decrease in organic matter and consequent reduction in inorganic elements with depth may be due to decrease in the abundance of fine roots (Post and Kwon, 2000). Oriowo (1989) reported abundance of fine roots in 0 to 20 cm depth in a regrowth forest and this possibly enhances organic matter content in the topsoil. Secondary forest is a simulation of natural forest and enjoys all natural forms of ecological interaction involving the biotic and abiotic components. The high fertility indices asserts to the fact that it is a simulation of natural forest and increase in nitrate-nitrogen and available phosphorus is a resultant of the improved organic matter content via litterfall decomposition and mineralization. This assertion corroborated the work of Shukla (2009) and Ratnayake et al. (2011) on the e ffect of cultivation on soil organic

Table 3. Deterioration Indices (DI) of Top and Subsoil properties.

Soil properties	Topsoil DI (%)			Subsoil DI (%)		
	A	B	C	A	B	C
pH	4.9	2.2	7.1.	1.6	0.2	5.0
Bulk density	0	-20.0	-60	nd	nd	nd
Organic matter	21.9	29.9	51.5	31.4	41.1	66.0
Nitrate-nitrogen	16.1	34.8	44.7	21.3	33.6	53.5
Available Phosphorus	55.7	8.9	43.78	37.4	20.8	23.1

A- mixed plantation site, B- bush fallow site, C- sole plantation site, DI- represent deterioration index and it is presented in percentage. Values above 50% show high deterioration and negative indices for bulk density depict degradation of bulk density.

carbon content in soil. The introduction of different tree species has remarkable improvement in the soil properties of the mixed plantation and allowed it to appear similar to the secondary forest. Mixing of litter components produce synergistic interactions that are beneficial to the soil which makes it to resemble secondary forest soils.

The relatively high organic matter content maintained through accumulation of litters assisted in lowering the bulk density and improving the soil nitrate-nitrogen (Ogunkunle and Awotoye, 2011). The low available phosphorus content both in the topsoil and subsoil layers could be attributed to the uptake of nutrients by cocoa and kola in producing pods, beans and nuts in an immobilized form (Ekanade et al., 1991). But recorded high values in the remaining properties is due to decomposition of varieties of leaves emanating from the mixed plantation leading to release of nutrients at various stages of decomposition (Ekanade, 1990). The amount of organic matter stored in the soil results from net balance between the rate of soil organic matter inputs and rate of mineralization (Schlesinger, 1990). Fisher (1995) outlined five ways that trees can ameliorate soil conditions at a given site; these include N-fixation, surface soil nutrient enrichment through litterfall and root turnover, increase in soil organic matter (SOM) through additional litter and root inputs, changes in above and below ground microclimate (moisture and temperature extremes, aeration, etc), and through the increase in organism activity within the rhizosphere of perennial roots. The natural fallow showed significant enrichment of organic matter and available phosphorus, both in the topsoil and subsoil layers because of biological activities and the amount of litter production and decomposition on the soil surface. The improvement could be the result of vegetal organic particles introduced into the soil (Yemefack et al., 2002).

The increased available phosphorus noted in the natural fallow was due to the seasonal burning processes of the vegetal materials in the natural fallow. Also, the increase in pH in the natural fallow is ascribed to the effect of ashes from burnt vegetation biomass which acts as lime fertilizer. The decreased bulk density in the natural fallow could be the result of several years of plants regrowth; Yemefack et al. (2002) discovered that as natural fallow duration increased, bulk density decreased in his work on effect of natural fallow on soil properties in Southern Cameroun. Decrease in bulk density has been reported by Yemefack et al. (2002) to be beneficial for plant regrowth and desirable for rehabilitation. Lower bulk density increases infiltration, perolation, aeration and also shown to promote seedling survival in neotropical forest (Pedrazza and Williams-Linera, 2003). Soil degradation in sole plantation was significantly high and this could possibly be as a result of the incessant fire that occurs in the plantation; large amount of nitrogen and sulphur are released as gaseous and thus are no longer available in the soil (Van Scholl and Nieuwehuis, 2004). Regular burning of litters decrease the supply of fresh organic material and this result in a decreased level of organic matter in the soil (Van Scholl and Nieuwehuis, 2004).

The lack of understory vegetation in sole plantation due to fire management technique and actions of wood fetchers leaves the soil exposed and vulnerable to erosion that washes away topsoil nutrients (Boley et al., 2009). Inorganic elements degradation in the sole plantation also resulted from the high rate of nutrient uptake that did not commensurate with the returns through litterfall because of the incessant fire occurrence. Shukla (2009) puts that 8 to 10% of the total potassium and phosphorus absorbed by teak and sale are returned through litterfall. The high bulk density was the consequence of frequent trampling of soils by loggers and leaf-fetchers; also lack of canopy closure in the sole plantation attributed to the high bulk density. Fisher (1995) also found that bulk density increased under *Pinus tecunumanii* plantations without canopy closure. Nutrients dynamics is very important for the understanding of ecosystem functioning and ecological status in sole plantation; more uptakes and less returns to the soil led to deterioration of soil as reported by Ogunkunle and Awotoye (2011) in the sole plantation. Similarly, Amponsah and Meyer (2000) found decreased soil organic matter in monocropped teak plantation of 16 to 27 years when compared to undisturbed forest.

Conclusion

The study has been able to demonstrate clearly that monocultural cropping of trees (sole plantation) is less beneficial to the soil than mixed plantation and natural fallow. It is also evident that soils mixed plantation compares quite well with those under secondary forest. This is thus an indication that mixed plantation and natural fallows might be more effective in sustaining soil properties for quite a longer time than sole plantation. Previous works (Ogunkunle and Awotoye, 2011; Ekanade et al., 1991) have affirmed this fact in relation to timber-yielding tree species such as *Gmelina arborea* and *T. grandis.* Proper combination of tree species appears promising as an effective economic and biological method of sustaining soil productivity in tree crop production and land management. Natural fallows have appeared less beneficial than mixed plantation because of the frequent fire management technique adopted in clearing which demonstrated to be more destructive to soil properties than slash method used in mixed plantation.

REFERNCES

Amponsah I, Meyer W (2000). Soil characteristics in teak plantations and natural forests in Ashanti Region, Ghana. Comm. Soil Sci. Plant Anal., 31: 355-373.

Anuforom AC (2009). Climate change impacts in different agro-ecological zones of West African humid zones. A paper presented at the International workshop on adaptation to climate change in West African agriculture at Ouagadougou, Burkina Faso from 27-30 April, 2009.

Aweto AO (1981). Organic carbon diminution and estimates of carbon dioxide release from plantation soil. Environmentalist, 15: 10-15.

Bernhard-Reversat F, Loumeto JJ (2002). The litter system in African forest-tree plantation. In Reddy, M. V. (ed) Management of tropical plantation, forest and their soil litter system. Science Publishing Inc, New Hampshire, USA., pp. 11-39.

Black CA (1965). Method of soil analysis II. American Society of Agronomy, Madison, WI., pp. 573-590.

Blake GR (1965). Bulk Density. In: methods of Soil Analysis, Part 1. Physical and Mineralogical Properties including Statistics of Measurement and sampling. No. 9. Agron. Am. Soc. Agron., Inc. Publisher Madison, Wisconsin, USA, pp. 374-377.

Boley DJ, Drew AP, Andrus RE (2009). Effects of active pasture, teak (*Tectona grandis*) and mixed native plantations on soil chemistry in Costa Rica. For. Ecol. Manage., 257: 2254-2261.

Bray RH, Kurtz LT (1945). Determination of total organic and available forms of phosphorus in soils. Soil Sci., 59: 39-46.

Craswell ET, Lefroy RDB (2001). The role and function of organic matter in tropical soils. Nutrient Cycling Agroecosyst., 61: 7-18.

Ekanade O (1990). An evaluation of soil productivity in interplanted cocoa and kola environmental systems in Southwestern Nigeria. Int. J. Environ. Stud., 35: 253-259.

Ekanade O (1991a). Degradation of the physical elements of the rural environment resulting from tree crops cultivation in the Nigerian Cocoa belt. Singapore J. Trop. Geogr., 12: 83-94.

Ekanade O (1991b). The nature of soil properties under mature forest and plantations of fruiting and exotic trees in the Tropical Rainforest fringes of Southwestern Nigeria. J. World For. Res. Manage., 5: 101-114.

Ekanade O, Adesina FA, Egbe NE (1991). Sustaining tree crop production under intensive land use: An investigation into soil quality differentiation under varying cropping patterns in Western Nigeria. J. Environ. Manage., 32: 105-113.

Emadi MM, Baghernejad G, Emadi M (2008). Effect of shifting cultivation on distribution of nutrient elements and carbohydrates within water-stable aggregates in Northern Iran. Pak. J. Biol. Sci., 11: 195-201.

Ewel JJ (1986). Designing agricultural ecosystems for the humid tropics. Ann. Rev. Ecol. Syst., 17: 245-271.

Fallahazade J, Hajabbasi MA (2011). Soil organic matter status changes with Cultivation of overgrazed pastures in semi-dry west central Iran. Int. J. Soil Sci., 6(2): 114-123.

Fisher RF (1995). Amelioration of degraded rain forest soils by plantations of native trees. Soil Sci. Soc. Am. J., 59(2): 544-549.

Gupta VV, Germida JJ (1988). Distribution of microbial biomass and its activity in different soil aggregate size classes as affected by cultivation. Soil Biol. Biochem., 20: 777-786.

Juo ASR, Franzluebbers K, Dabiri A, Ikhile B (1995). Changes in soil properties during long-term fallow and continuous cultivation after forest clearing in Nigeria. Agric. Ecosyst. Environ., 56: 9-18.

Keay RWJ (1959). An outline of Nigerian vegetation. Federal Government Printer, Lagos, p. 52.

Kirchlof G, Salako FK (2000). Residual tillage and bush fallow effects on soil properties and maize intercropped with legumes on a tropical Alfisol. Soil Use Manage., 16: 183-188.

Mbagwu JSC, Auerswald K (1999). Relationship of percolation stability of soil aggregates to land use, selected properties, structural indices and simulated rainfall erosion. Soil Till. Res., 50: 197-206.

Muoghalu JI, Awokunle HO (1994). Spatial patterns of soil properties under tree canopy in Nigeria Rainforest Region. Trop. Ecol., 35(2): 219-228.

Oguike PC, Mbagwu JSC (2009). Variations in some physical properties and organic matter content of soils of coastal plain sand under different land use types. World J. Agric. Sci., 5(1): 63-69.

Ogunkunle CO, Awotoye OO (2011). Soil fertility under different tree cropping system in a southwestern zone of Nigeria. Not. Sci. Biol., 3: 123-128.

Oriowo TI (1989). Soil characteristic and root distribution pattern in a regrowth forest. B.Sc Thesis. Obafemi Awolowo University, Ile-Ife, Nigeria.

Padley D, Brown C (2000). Teak: A global overview. Int. J. For. Ind., 51: 1-15.

Pedrazza RA, Williams-Linera G (2003). Evaluation of native tree species for the rehabilitation of deforested areas in the Mexican cloud forest. New For., 26: 83-99.

Post WA, Kwon KC (2000). Soil carbon sequestration and land use change: process and potential. Global Change Biol., 6: 317-3238.

Ratnayake RR, Seneviratne G, Kulasooriya SA (2011). The effect of cultivation on organic carbon content in the clay mineral fraction of soils. Int. J. Soil Sci., 6: 217-223.

Schlesinger WH (1990). Evidence from chronosequence studies for a low carbon storage potentials of soils. Nature, 348: 232-234.

Shepherd TG, Saggar S, Newman RH, Ross CW, Dando JL (2001). Tillage-induced changes to soil structure and organic carbon fractions in New Zealand soils. Aust. J. Soil Res., 39: 465-489.

Shukla PK (2009). Nutrient dynamics of teak plantation and their impact on soil productivity- A case study from India. Proceeding of the 8th World Forestry Congress, Oct. 18-23, Buenos Aires, Argentina, pp. 1-11.

Van S, Nieuwenhuis LR (2004). Soil fertility management. Agromisa Foundation, 4th Edition, Wageningen, pp. 1-80.

Walkley A, Black IA (1934). An examination of the Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. Soil Sci., 37: 29-38.

Yemefack M, Nounamo L, Njomgang R, Bilong P (2002). Effects of natural fallow on topsoil properties and subsequent crop yield in a forest oxisol of Southern Cameroun. A paper presented at the 17th WCSS between 14-21 August, 2002, Thailand.