Effects of Rubber Cultivation And Associated Land Use Types on The Properties of Surface Soils

*[1]Orimoloye, J. R., [2]Akinbola, G. E., [1]Idoko, S. O., [1]Waizah, Y. and [1]Esemuede U.

[1]Rubber Research Institute of Nigeria, PMB 1049, Benin City, Nigeria
[2]Department of Agronomy, University of Ibadan, Ibadan, Nigeria
* orimoloyej@yahoo.com

Abstract: The effects of rubber plantation of different ages on the surface soil properties were compared with other land use types associated with rubber cultivation in the rubber research Institute of Nigeria. The rubber plantations are young rubber (0- 8 years old), middle aged rubber (10-20 years old), old rubber (>25 years old), while the associated land use types are fallow/forest and arable farm. Soil samples collected at depths of 0-15 and 15-45 cm depths in three replicates were subjected to routine and microbial content analysis. The soils are predominantly sandy-loam textured in the surface layer in all the land use types. Soil acidity (pH) changes significantly from 4.30 in arable farm to 4.7 in young rubber plantations while organic carbon at 13.4 g/kg is significantly lower in arable cropping landuse than fallow/forest with 33.4 g/kg. The forest/fallow and old rubber landuse types are statistically similar on most parameters considered showing that rubber cultivation can be considered as 'planted fallow' and could be employed as a cheap and economically viable means of mitigating land degradation in the rubber belt of Nigeria.

[Orimoloye, J. R., Akinbola, G. E., Idoko, S. O., Waizah, Y. and Esemuede U. **Effects of Rubber Cultivation And Associated Land Use Types on The Properties of Surface Soils.** *Nat Sci* 2012;10(9):48-52]. (ISSN: 1545-0740). http://www.sciencepub.net/nature. 7

Keywords: Rubber; Cultivation; Land; Property; Surface; Soil

Introduction

Assessing land-use-induced changes in soil properties is essential for addressing the issue of agro ecosystem transformation and sustainable land productivity. Land use cannot be improved unless the soil physical and chemical properties match the requirements for the utilization of the land also when two or more land use occur on the same soil type may influence the soil differently, the difference may be insignificant but will have greater effect in future, Ogunkunle (1988), found that traffic induce compaction affect the yield of oil palm and soil compaction cause by farm implements affects the physical property of soil such infiltration rate and bulk density. Agricultural expansion into tropical forest areas has been responsible for at least 50% of deforestation since 1970 (Myers, 1991). From 1970 to 1999, land under arable and permanent crops increased by 1.9 million hectares (Mha), while the areas under forests decreased by 3.1 Mha over the same time (FAO production year book (1970, 1999).

National crop yield averages in tropical Africa rarely show an upward trend despite availability of improved cultivars and agrochemical inputs because of severe soil-related constraints. The low yields have also been attributed to high incidence of pests and diseases and inadequate management of soil and water resources (Lal, 1987).

The fertility status of most soils in the humid tropics, particularly under low input agricultural systems, depends largely upon soil organic matter (SOM), both quantitatively and qualitatively (Agboola and Corey, 1973; Woomer and Ingram, 1990). Numerous studies investigating the effects of cultivation and/or changes in landuse type on soil quality have attempted to develop models of SOM turnover and relate its dynamics to soil fertility: Models, based on density and/or size of organo-mineral fractions, have been amply documented (Anderson *et al*., 1981; Tiessen and Stewart, 1983; Dalal and Mayer, 1986). They showed that clay-size fractions contained predominantly stable and highly mineralized particles, with little contribution to short-term plant nutrition, while sand-size fractions constituted the labile and short-time SOM fractions (Anderson *et al*., 1981; Christensen 1992). The objective of the study to identify land use and management systems that enhance productivity and soil quality for small holder farmers in rubber growing belt of Nigeria.

Materials and Methods

Study area

This study was conducted in 2010 at Rubber research institute of Nigeria Iyanomo near Benin City Edo state., with humid rain forest zone climate. The mean annual rainfall was 2000 mm, with a peak in the months of July and September.The Area is located within the co-ordinates of 5º 34'E and 5º 38'E Longitudes; 6º 08'N and 6º 11'N Latitudes. The soils of this area are mainly Ultisols derived from unconsolidated grits and sand stones containing clay beds of varying proportions.

Land use types

Five land use types were selected for the purpose of this research out of which three of them are rubber plantation of different ages.

1. Arable farm, cultivated annually by mostly slash and burn methods using hoes and cutlasses. crops usually cultivated are yam, (*Discorea spp*), cassava(*mannihot esculenta*) and maize(*zea mays*) in combination with
2. Fallow/Forest plots consisting of multistoried vegetation dominated by trees, climbers and undergrowths typical of the humid tropical rainforest agro ecological zone. Included in this landuse type are secondary forests under fallow which was previously cultivated with arable crops 6-10 years earlier.
3. Young rubber (3-10 years old) plantation, this consists of juvenile rubber plantations including plantations that were recently opened up for tapping
4. Middle age rubber (11-20 years old) plantation, this site has matured rubber trees that are actively under tapping and is characterize by frequent passes of tappers path.
5. Old rubber plantation (> 25 years old). These are old plantations many of which are still under tapping but some have been abandoned and are characterized by several missing stands overtaken by weeds and shrubs.

Sample collection

Three sites each of the land use types within the RRIN mainstation were located and sampled. Soil samples were collected from all the land use type at 0-15cm deep, the samples from each land use at each site were bulked to form composite sample. The samples are air dried and passed through 2mm sieve subsequently analyzed for some soil properties. Cylindrical metal cores were used to obtain undisturbed soil samples for bulk density and porosity determinations.

Soil analysis

Particle size distribution was determined by hygrometer method (Gee and Bauder, 1986), Soil pH was determined at 1:1 soil to water ratio using glass electrode digital pH meter. Organic carbon was measured using the wet oxidation method. Available phosphorous was extracted using Bray-1 solution, and the phosphate in the extract was analysed calorimetrically by the molybdenum blue colour method as described by Murphy and Riley (1962). Exchangeable bases were extracted using 1N neutral ammonium acetate solution. Calcium and magnesium content of the solution were determined volumetrically by EDTA titration procedure, Black (1965). The level of calcium, potassium, and sodium were determined by flame photometry. Total nitrogen was determined by Micro-kjeldahl method as described by Jackson (1962). The exchangeable acidity was determined by the KCl extraction and titration method of Mclean (1965). Viable bacterial and fungal populations were estimated by dissolving one gram of each sample in 9 ml of sterile distilled water. Serial dilutions were made up to 10^{-6}. A 0.1ml portion was pour-plated in 20 ml of potato dextrose agar (PDA) and nutrient agar (NA) in three 9 cm Petri-plate replications. The media used for isolating bacteria and fungi were prepared according to standard procedures (Tuite, 1969).

Result and Discussion

Soil physical and biological characteristics

Table 1 shows the particle size distribution, bulk density, total porosity and microbial populations under the different land use studied. The soils are predominantly loamy sand, clay content in the surface layer varied from 138.8 - 205 while sand fractions ranged from 799 to 853. This clearly shows that sand, silt and clay fractions differed across the five land use types. Soil texture unlike biochemical attributes is an inherent property of the soil that is not easily influenced by agricultural land use types (Bernitez *et al.,* 2006). However certain landuse types may encourage accelerated clay illuviation due to exposure to rainfall, erosion and leaching (Ojanuga, 2006). The clay content in fallow/ forest and in young Rubber plantation landuse were slightly higher probably because the land is either not under cultivation thus clay illuviation brought about by gradual profile development (Lal, 1996). Bulk density within the different land use types varied significantly with values ranging from 1.09 g cm^{-3} in middle aged rubber to 1.23 g cm^{-3} in the arable farm. The higher bulk density in arable farming is an indication of higher soil compaction possibly resulting from cultivation and tillage activities as postulated by Ojima *et al.,* (1994). Motavalli and McConnell (1998) reported increased bulk density due to continuous cultivation over a seven year period in a tropical pacific island environment.

The microbial (bacterial) was population observed in the fallow/forest and old rubber plantations were exceptionally higher than the other land use types while the lowest bacterial counts were observed in the young rubber and arable farm landuse types. This agrees with the observation of Bernitez *et al.,* (2006) that soils developed under organic management in general presented greater biological activity and greater hydrolytic activity than those under integrated or conventional cultivation. Fungi populations are not significantly different among the landuse types with arable farm having the highest of 10.7 cfu.

Landuse also had significant effects on SOM content. Fallow/forest plots had the highest mean SOM of 57.59 g kg^{-1} while the young rubber plantations had the least SOM of 31.90 g kg^{-1}. Soil organic matter (SOM) is a central contributor to soil processes. It mediates many of the physical, chemical and biological processes controlling the capacity of the soil to perform successfully (Quideau, *et al.*, 2000). Previous studies revealed that land use practices influence several soil properties such as SOM concentration and subsequently, soil fertility. Collins *et al*. (1999) observed decline in SOM concentration in cultivated soils as compared to adjacent non-cultivated sites. Soil disturbances, by mixing and inversion, are the primary mechanisms by which organic matter is mineralized and emitted into the atmosphere as CO_2 therefore landuse types with generous vegetation cover are likely to be protected from carbon mineralization. The influence of land use on most soil properties is most drastic in the top few centimeters of soil. Chicacek and Ulmer (1999) observed that SOM concentration is little affected by agricultural activities in soil below 30 cm depth. Table 1 also provides some useful information about temporal changes in the C:N ratio for different land use/cover. The C:N ratio was 21.59 in arable farm but was 4.74 in the young rubber plantation.

Table 1: Effects of different landuse types associated with rubber cultivation on selected physical and biological characteristics of the surface soils

Landuse/rubber age	Sand	Silt	Clay	Bulk density	Total Porosity	bacterial count	fungal count	SOM	C/N ratio
		g kg^{-1}		g cm^{-3}	(%)	cfu*			
Young rubber (3-10 yrs)	853.0	8.50	138.8	1.16^{ab}	55.41^{ab}	3.8^{c}	6.0	31.90^{c}	4.74^{c}
Middle aged rubber (12-20 yrs)	814.0	5.60	180.3	1.09^{b}	58.74^{a}	10.0^{c}	9.8	50.69^{ab}	14.70^{b}
Old rubber (>25 yrs)	824.0	9.90	166.1	1.14^{ab}	56.85^{ab}	41.3^{b}	6.0	51.21^{ab}	11.88^{b}
Fallow/Forest	799.0	7.30	193.6	1.10b	58.49a	84.1a	5.7	57.59^{a}	8.52^{bc}
Arable Farm	799.0	10.60	190.3	1.23^{a}	57.31^{b}	6.0^{c}	10.7	46.90^{bc}	21.59a
SE of Mean	***35.0***	***6.15***	***34.17***	***0.43***	***1.65***	***0.013***	***0.064***	***6.12***	***3.24***

Table 2: Effects of different landuse types associated with rubber cultivation on the chemical properties of the surface soils

Land use/ rubber age	pH	Avail P	Org C	Total N	Exch acid	Ca	Mg	Na	K	ECEC	B sat	Fe	Cu	Mn	Zn
	H_2O	mg kg^{-1}	g kg^{-1}		cmol kg^{-1}						(%)	mgkg^{-1}			
Young rubber (3-10 yrs)	4.7^{a}	13.3	18.5^{bc}	3.90	0.6^{bc}	2.00	0.80^{ab}	0.29	0.40	4.29^{b}	86.6^{ab}	98.0^{bc}	7.86	204.8	29.6
Middle aged rubber (12- 20yrs)	4.5^{abc}	15.6	29.4^{a}	2.00	0.42^{c}	1.95	0.81^{ab}	0.26	0.59	3.83^{b}	90.4^{a}	91.5^{c}	7.77	165.6	25.6
old rubber (>25 yrs)	4.41^{abc}	18.5	29.7^{a}	2.50	1.19^{ab}	2.02	0.91^{a}	0.20	0.26	5.34^{ab}	95.0^{a}	105.4^{abc}	7.80	168.0	31.9
Fallow/Forest	4.48^{abc}	16.5	33.4^{a}	3.92	1.46^{a}	2.40	0.97^{a}	0.20	0.61	5.99^{a}	75.7^{bc}	118.9^{ab}	8.37	175.8	32.5
Arable Farm	4.30^{c}	7.1	27.2^{ab}	1.26	1.16^{ab}	1.77	0.55^{b}	0.25	0.38	4.46^{b}	73.7^{c}	111.0^{abc}	7.13	188.7	30.2
SE of Mean	***0.12***	***5.72***	***4.04***	***0.37***	***0.30***	***0.26***	***0.14***	***0.12***	***0.24***	***0.64***	***5.19***	***10.06***	***0.68***	***22.05***	***5.15***

Soil chemical properties

The soil pH ranges from 4.3 in the arable farm landuse to 4.7 in the young rubber plantations. The data on soil organic carbon Table 2 shows that soil organic C ranged between 14.2 and 19.5gKg-1. Organic C content less than 2% is considered very low (Landon, 1984). Available P content in all landuse types was medium (7.1 mg kg^{-1}) to high (18.5 mg kg^{-1}) according to Sánchez *et al*., (2003) classification. This shows that in spite of the soil acidity, P fixation by Fe- and Al-oxides, as described by Sánchez *et al*., (2003) for tropical soils was very minimal.

However, there is a general decline in soil quality with cultivation and landuse types that exposes the soil surface as is evident by degradation of soil chemical properties (Agele *et al* 2005). This is an important factor in searching for ways to sustainable use of soil resources. Several experiments conducted in Benin and elsewhere in the tropics have demonstrated a rapid decline in soil chemical properties following deforestation and intensive cultivation (Neill *et al*., 1997). Agboola (1981) also reported a rapid decline in soil organic matter content and plant nutrient reserves with intensive cropping. Tiessen *et al*. (2003) observed that rapid decline in soil organic matter content, cation exchange capacity, and exchangeable cations was related to accelerated soil erosion in relation to soil type. McGrath *et al*. (2001) also noted that soil organic carbon and available P decreased with cropping time but Extensive cultivation of perennial crops promotes C gains (Janzen et al., 1998)

In order to understand and predict the impact of an intensive landuse, the factors limiting productivity on each specific site must be understood. It follows therefore that soil management practices that removes large quantities of organic matter from the surface soil, especially on sandy soils, can detrimentally impact on the soil environment. Generally speaking, soils under rubber are found to be rich in organic matter (Krishnakumar and Potty, 1992). In tropical tree-crop ecosystems such as rubber plantations, leaf litter plays an important role in nutrient recycling. Under mature rubber trees, the amount of litter fall is in the range 4620 to 5320 kg/ha/year (Moris, 1993). Most agro-ecosystems result in net exportation of nutrients. The removal of nutrients through crop nutrition is less in rubber than most other crops but latex exploitation (quantity and composition) can affect and be affected by the soil nutrient status (Watson, 1989). Nutrient removal from under rubber plantations through latex tapping is estimated to be 755, 883, 1260 and 945 kg ha^{-1} of N, K, Ca and Mg respectively (Karthikakuttyamma, 1997). In comparison with the nutrient cycling ability, biomass and organic matter generation, rubber cultivation results in a net accumulation of soil nutrients.

Conclusion

Identifying sustainable alternatives to shifting cultivation and related bush fallow systems in the humid and sub-humid tropics is a high priority for achieving food security, and minimising soil and environment degradation. The forest/fallow and old rubber landuse types in this study are statistically similar on most parameters considered showing that rubber cultivation can be considered as 'planted fallow' and could be employed as a cheap and economically viable means of mitigating land degradation in the rubber belt of Nigeria. Intercropping of rubber at juvenile and mature stages of plantation development seems a good alternative. This is suggested as the focus of new research initiatives in the rubber growing world.

REFERENCES

1. Agele, S.O., Ewulo, B.S., Oyewusi, I.K., (2005). Effects of some soil management systems on soil physical properties, microbial biomass and nutrient distribution under rainfed maize production in a humid rainforest Alfisol. *Nutrient Cycling in Agroecosystems* 72, 121–134.
2. Benitez, E., R. Nogales, M. Campos, and Ruano F. (2006). Biochemical variability of olive-orchard soils under different management systems. *Applied Soil Ecology* 32: 221–231.
3. Black C.A. (1965) method of soil analysis Agronomy No 9 part 2 American society Agronomy Madison Wisconsin.
4. Bray R.A and Kurtz L.I (1945). Total organic and available P of soils. Soil science 57: 39-48.
5. Chicacek, L.J., and M.G. Ulmer. 1999. Effects of Tillage on Inorganic Carbon Distribution in soils of the Northern Great Plains of the US. In: Agricultural practices and policies for Carbon sequestration in Soil. An International Symposium 19 – 23 July 1999,Wexner Center for the Arts, The Ohio State University.
6. Collins, H.P., R.L Blevins, L.G. Bundy, D.R.Christenson, W.A. Dick, D.R. Huggins, and E.A. Paul. 1999. Soil carbon dynamics in corn-based agroecosystems: results from carbon-13 natural abundance: In *Soil science society of America Journal*. Vol 63 (3).584 591.
7. Gee, G.W. and J.W. Bauder. 1986. Particle size analysis. In: A. Klute (ed.) Methods of soil analysis. Part 1. Physical and Mineralogical methods. 2nd ed. Agronomy 9:383-411.
8. Jackson M. L. (1962). Soil chemical analysis, prentice hall New York. Journal 42: 940-944.
9. Janzen, H.H., C.A. Campbell, E.G. Gregorich, and B.H. Ellert. 1998. Soil carbon dynamics in Canadian agroecosystems. In: Soil processes and the carbon cycle. 1998. CRC Press Inc; Boca Raton, USA.
10. Karthikakuttyamma, M. (1997). Effect of continous cultivation of rubber *(Hevea brasiliensis)* on soil properties. PhD Thesis, University of Kerala, Trivandrum, India.
11. Krishnakumar, A. K. and Potty, S. N. (1992). Nutrition of *Hevea*. In: *Natural Rubber: Biology, Cultivation and technology* (Eds: M. R. Sethuraj and N. M. Mathews). Elsevier, Amsterdam, pp 239-262.

12. Landon, J.R., 1984. Broker Tropical Soil Manual. A Handbook for Soil Survey and Land Agricultural Evaluation in the Tropics and Subtropics. Booker agriculture international limited, London.
13. McGrath, D., Smith, C., Gholz, H., de Assis, O., (2001). Effects of landuse change on soil nutrient dynamics in Amazonia. *Ecosystems* 4, 625–645.
14. Mclean, E.O (1965) Alumiaum; In method of soil analysis (ed) C.A Black, Agronomy No 9 part 2 American society of Agronomy 978-998.
15. Moris, N. (1993). Nutrient returns via Hevea leaf litter-fall. In: Soil Science Conference of Malaysia 1993. Penang, Malaysia, April 19-21, 1993, Malaysian Society of Soil Science.
16. Motavalli, P, and J. McConnell. 1998. Land use and soil nitrogen status in a tropical Pacific island environment *Journal of environmental quality* 27 (1): 119-123.
17. Neill, C., Piccolo, M.P., Cerri, C.C., Steudler, P.A., Melillo, J.M., Brito, M., 1997. Net nitrogen mineralization and net nitrification rates in soils following deforestation for pasture across the southwestern Brazilian Amazon Basin landscape. *Ecologia* 110, 243–252.
18. Ojanuga A. G. (2006). Agro ecological zones of Nigeria manual (F. Berding and V. O. Chude: Eds.) NSPFS/FAO/ FMA&RD, Abuja, Nigeria. 128pp.
19. Ojima, D.S., Galvin, K.A., Turner, B.L., 1994. The global impact of land-use change. *BioScience* 44, 300–304.
20. Quideau, S.A., Anderson, M. A., Graham, R. C. and Chadwick, O. A. (2000). *Forest Ecology and Management* 138 (1-3): 19-27.
21. Sánchez, P.A., Palma, C.A., Buol, S.W., 2003. Fertility capability soil classification: a tool to help assess soil quality in the tropics. *Geoderma* 114, 57–185.
22. Smith, K., 2008. Soil organic carbon dynamics and land-use change. In: Braimoh, A.K., Vlek, P.L.G. (Eds.), Land use and soil resources. Springer, pp. 9–22.
23. Tiessen, H., Menezes, R.S.C., Salcedo, I.H., Wick, B., 2003. Organic matter transformations and soil fertility in a treed pasture in semiarid NE Brazil. *Plant and Soil* 252, 195–205.
24. Tuite, J. (1969). Plant pathology methods. Burgess publishing co. Minnessota, USA. 239 pp.

4/2/2012