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EVALUATION OF PHYSICO-CHEMICAL PROPERTIES OF SOILS UNDER SELECTED AGRICULTURAL LAND UTILIZATION TYPES

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ABSTRACT

A comparative study of the effects of cassava monocropping, cassava + maize intercropping, cassava + maize + pepper intercropping, maize + pepper intercropping and natural forest agricultural land utilization types on soil physical and chemical properties were investigated under farmer – managed conditions. Monocropping and/or inter cropping were unable to conserve soil physical and chemical properties. Soils under cultivation were significantly ($P < 0.05$) higher in bulk density but lower in total porosity, macro-porosity, water retention and saturated hydraulic conductivity relative to forest soil. Soil pH, base saturation and available P were significantly ($P < 0.01$) lower in the forest soil but organic carbon, total nitrogen, total exchangeable acidity and cation exchange capacity were higher in forest soil relative to cultivated soils. Significant differences ($P < 0.01$) were observed among cultivated soils in available P and total N.

Key words: Land utilization types, Soil physico-chemical, Soil conservation.

INTRODUCTION

The increase in population pressure and food requirement have in recent years led to the shortening of fallow periods as well as intensive use of land (FAO, 1965). There is a shift from subsistence farming to growing of cash crops as farmers attempt to increase their income through farming. People through their crop production practices influence the course of soil formation and the physico-chemical status of the soil at any given time (Asadu and Enete, 1997). Land use intensification practices such as organic manuring and continuous cultivation are special cases of these influences.

Under similar agroecological environments land use and cultural practices become the dominant factors affecting soil properties and crop production. Land use as defined by Vink (1975) is any kind of permanent or cyclic human intervention to satisfy human needs from complex of natural and artificial resources, which together constitute 'land'. Akamigbo (2001) noted that at any given time land use is a resultant interplay of available land resources with cultural, social and economic conditions of the past and present development. When two or more land use types occur on the same soil type, they influence the soil differently. The differences in their effect may be small and insignificant, but may affect future uses. Many researchers have studied the influence of land use on soil properties. Chijoke (1980) reported soil differences resulting from growth of Gmelina and pinus. Ogunkunle and Eghaghara (1992) reported significant differences between the land use types studied (fallow, Gmelina, arable, secondary forest and cocoa plots) in soil pH, K, Ca, Mg, extractable P, total N, organic matter and bulk density. Kang (1977) also reported that in uncultivated secondary forest, surface soil samples taken from areas close to palm trees had lower bulk density and higher moisture retention, organic matter and nutrient status than the soil from else where. Hall et al. (1977) observed that the main properties of soil varying with land use were bulk density and organic matter content and also that forest soils were better nutrient accumulators than grassland soils because forest soils have good potentials for storage of nutrients in biomass. In another study on influence of land use on soil properties of the humid tropical agroecology of Southeastern Nigeria, Akamigbo (1999) observed that there was a marked difference between forestland use and traditional cultivated land use in morphological, physical and chemical properties. He noted that cultivation accelerated certain pedogenic processes and influences certain soil properties, which may lead to soil deterioration

Not much research on the long-term influence of intensive cultivation of some crops (under mixed or monocropping farming systems) on soil physico-chemical properties has been done, especially, in southeastern Nigeria. Observation made in Nsukka area revealed that farmers in the area have over the years grown some particular crop/crop mixtures on particular pieces of land. The crop/s involved yellow pepper, cassava and maize in different combinations. Economic returns in terms of income derivable from sales of such cash crops after harvest is the major driving force propelling them to continue practicing these land utilization types. The long-term effects of such practices on soil physical and chemical properties have not been investigated. For sustainability of yield and effective soil conservation, there is need to study the influences of cultivation of such crops and crop combinations on soil properties. The objective of this study was to evaluate the changes in soil physical and chemical properties due to some identified agricultural LUTs in Nsukka area and comparing them with those of the forest.

MATERIALS AND METHOD

Study area

The research was carried out during the 1995/96 cropping season at Nsukka (Nru), Southeastern Nigeria. The area is located by latitude 6^0 52^1 N and longitude 7^0 23^1 E and has a humid tropical climate. There are two distinct seasons with a characteristic bimodal distribution of rainfall, which peaks during the months of July and September. The mean annual rainfall ranges from 1600 to 2000 mm (Inyang, 1975). The temperature is uniformly high throughout the year (Asadu, 1990). It rarely falls below 21 ^{o} C except during harmattan weather (December through January) when temperatures below 21 ^{o} C may be recorded. Annual mean maximum temperature does not exceed 35 ^{o} C. The soil was derived from falsebedded sandstone parent material. The properties of soil formed from such parent material are shown in Table 1. It is a sandy loam and had been classified as Typic Kandpaleustult or Dystric Nitosol, belonging to Nkpologu series (Nwadialo, 1989). The vegetation is described as derived savanna. There are areas where no farming have been done. Some of these areas have natural forest.

Experimental design

The study involved the identification of fifteen plots of farmlands. These plots are located within the same area and are at close proximity. For over fifteen years each of the plots have been consistently, under one of the following LUTs - cassava monocropping, cassava + maize intrercropping, cassava + maize + pepper intercropping maize + pepper intercropping and natural forest. Adequate care was taken to ensure that fields selected for a particular LUT have been subjected to similar cultural practices (e.g. uniform tillage system, application of manure, etc.) over the years. The farmers whose fields were selected were generally within the same social setting, hence the great uniformity found in their farming practices. These practices associated with each LUT are given in Table 2.

The experiment was managed entirely by the farmers. The researcher's input was restricted to provision of technical advice and data collection. The experiment was a randomized complete block design with the five LUTs as the treatments. Three farmers' plots were used as replicates for each LUT. Each plot measured 652 m^2 in area (25 m x 25m). All data were taken from the inner 15 x 15 m^2 of each plot.

Sampling and analytical procedure

Soil composite samples were collected at two periods (March and December) from each plot during the study. During each period of soil sample collection, samples were taken from each plot at 0-20 cm depth, bulked and subsampled to produce one composite sample used for chemical analysis. A total of 30 composite samples were collected from all the plots for chemical analysis. Similarly core samples were collected from each experimental plot and were used to determine soil physical properties.

Laboratory analysis

Soil bulk density was determined according to Blake and Hartge (1986). Total porosity was estimated from bulk density and assumed particle density of 2.65 g/cm^3. Macroporosity (Ma. P) was calculated thus

$$\text{Ma P} = \frac{\text{Volume of water drained at 60cm tension}}{\text{Volume of bulk soil}}$$

Saturated hydraulic conductivity (Ks) was determined by the constant pressure head method (Klute and Dirksen, 1986). Soil pH was determined in duplicate in both distilled water and 0.1N KCL solution (1:2.5), exchangeable bases were determined by the complexometric titration method (Jackson, 1958), cation exchange

Table 1: Some properties of soil formed from falsebedded sandstone in Nsukka

Soil properties		Value
PH (H_2O)		5.4
Tot. exch. Bases	(Meq 100g $soil^{-1}$)	2.11
Exchan. Acidity	,,	0.80
CEC	,,	3.3
Tot. N	(%)	0.063
Org. C	,,	0.74
Avail. P	(ppm)	5.8

Source: Akamigbo and Asadu (1983)

Table 2: Cultural practices associated with each land utilization type (LUT)

Cassava monocropping (C sole)	Land clearing and preparation	Traditional method of slashing, tillage, bed and ridge making were done using hoes, pick axe and cutlass
	Soil amendments applied	Yearly and manual application of organic manure (compost farmyard manure) during land preparation. The application is done between the months of December and February. Inorganic fertilizer application was occasional and irregular over the years. Wood ash was occasionally applied to the field.
	Weeding	This was done manually using hoes and cutlasses. The plots were weeded 2 times during the growing season
Cassava + maize (C+M)	Land clearing and preparation	As in sole cassava monocropping
	Soil amendment applied	As in sole cassava monocropping
	Weeding	As in sole cassava monocropping
Cassava + maize + pepper (C+M+P)	Land clearing and preparation	As in sole cassava monocropping
	Soil amendment applied	Yearly and manual application of farmyard manure and poultry droppings during land preparation. Also post germination split application of NPK fertilizer are practiced by farmers.
	Weeding	Manual weeding using hoes and cutlasses was done three times during the growing season.
	Other practices	Burning of plant debris/residues remaining after harvest.
Pepper + maize (P+M)	Land clearing and preparation	As in sole cassava monocropping
	Soil amendment applied	As in C+M+P
	Weeding	As in C+M+P
	Other practices	As in C+M+P
Natural forest (FS)	Land clearing and preparation	Has never been done
	Soil amendment applied	None
	Weeding	None

capacity (CEC) was determined by the neutral ammonium acetate (NH_4OAC) leachate method (Jackson, 1958). Total N was determined by the Kjeldahl digestion method (Bremner and Mulvaney, 1982) and organic carbon by Walkley and Black method (1934) as modified by Alison (1965). Exchangeable acidity was determined by the method outlined by Barnhisel and Bertsch (1982). Available P was determined by the Bray 2 method (Bray and Kurtz, 1945).

Statistical analyses were carried out using the procedure for a randomized complete block design (RCBD). Mean differences were detected using Fisher's Least Significant Difference (F-LSD).

RESULTS

Effects of LUTs on soil physical properties

The physical properties of soils under the studied LUTs are given in Table 3. Soil bulk densities of maize + pepper intercropping (M+P), cassava monocropping (C sole), cassava + maize + pepper intercropping (C+M+P) and cassava + maize intercropping (C+M) were significantly higher (P=0.01) than bulk density of forest soil (FS) by 64%, 55%, 54% and 37%, respectively. Total porosity and macroporosity were higher in forest soil than the cultivated soil. Only soil under M+P significantly (P=0.05) differed from forest soil in total porosity. Water content at field capacity followed this trend FS > C+M > M+P > C+M+P > C sole. Saturated hydraulic conductivity (Ks) of soils under forest was more than 200% higher (P = 0.001) than Ks of cultivated soils. These cultivated soils did not differ significantly (P> 0.05) from each other.

Effects of LUTs on soil chemical properties

Soil pH in water was significantly lower (P < 0.05) in forest soil relative to cultivated soils (Table 4). There were no differences within cultivated soils in pH. The nitrogen content of the soil of the forestland was the highest and significantly (P = 0.001) differed from those of the soils under other LUTs. The mean value (0.053%) of N obtained from the soil under C+M+P intercrop was the lowest and significantly (P= 0.001) differed from the N content of the soil of the forest LUT. There was, however, no significant difference between the N content of soils under other LUTs.

Organic carbon content was moderate in all the soils (mean values range from 1.15% to 1.29%) under the different crops. These values were significantly lower (P < 0.001) than that obtained from the forest soil (2.4% - Table 4). No significant differences were observed within cultivated soils in their organic carbon content (P > 0.05).Available P ranged from 37-62 ppm. Soils of the M+P, C+M+P, C sole and C+M were 68%, 27%, 14% and 11%, respectively higher than forest soil in available P.

Exchangeable Na and Ca contents of soil under the different LUTs were low (Table 5) and did not significantly differ (P > 0.05).

Cation exchange capacities of soils of the different LUTs were low. The CEC followed this order - FS > C+M+P >C+M>MP > C sole. The CEC of soils under forest differed significantly (P < 0.01) from those of the cultivated soils (Table 5). There were no significant differences between cultivated soils in CEC contents.

DISCUSSION

Physical properties

The lower bulk density obtained in soils of the forest may be attributed to the modification of some forest soil structural properties by its higher organic matter content compared to the values obtained from the cropped land. Furthermore, intensive cultivation of the soil leads to compaction; it also accelerate leaching and sheet erosion processes which wash away finer particles leaving the denser sand particles behind. The higher total porosity values obtained from the forest soil was as a result of improvement of forest soil structure, which may be due to its higher OC content. The lower values of macroporosity obtained from cropped soils relative to the soils of the forest supports this inference and suggest greater structural degradation in the soils of cropped lands. The influence of forest roots as well as the increased organic matter content of forest soil could have also contributed to its higher macro-porosity. Land clearing and preparation as well as weeding operations in cultivated soils can compact soil, thereby reducing its total and macroporosity.

The higher water retention at field capacity value obtained from the soils of the forest than from the soils of the cropped areas may be attributed to the higher organic matter contents of forest soils. Wood (1971) reported that organic matter improves soil water holding capacity. The higher macroporosity of the soils of the forest land and its lower bulk density consequent on its better structure gives it higher saturated hydraulic conductivity values than other soils. Mbagwu et al. (1983) observed that macroporosity more than the total porosity influences saturated hydraulic conductivity of some soils of southern Nigeria. In his studies of soils formed from the same parent material and within the same climate,

Table 3: Effects of selected LUTs on some soil physical properties and

Treatment	Bulk density (gcm^{-3})	Total porosity (%)	Macroporosity (%)	Water content at field capacity (%)	Saturated hydraulic conductivity ($cm\ hr^{-1}$)
C sole	1.46	45.10	9.75	23.42	7.07
C + M	1.29	51.01	7.65	30.71	4.81
C + M + P	1.45	45.10	6.08	24.24	4.80
M + P	1.54	41.79	5.31	24.85	6.50
FS	0.94	58.30	22.15	39.07	21.06
F-LS $D_{(0.05)}$	0.60	13.58	9.45	12.54	7.07

Table 4: Effects of LUTs/treatments on some soil chemical properties

Treatment	pH (in H_2O)	Total N (%)	Organic carbon (%)	Available P (ppm)	Tot. exch. acidity Meq 100 g $soil^{-1}$
C sole	4.36	0.105	1.22	42.00	2.10
C + M	4.39	0.099	1.15	41.00	2.24
C + M + P	4.71	0.053	1.29	47.00	1.63
M + P	4.45	0.110	1.28	62.00	1.90
FS	3.84	0.15	2.4	37.00	4.60
F-LSD $_{(0.05)}$	0.51	0.067	0.64	6.48	1.64

Table 5: Effects of LUT/treatments on soil exchangeable base, CEC and base saturation.

Treatment	Na	K	Ca	Mg	CEC	Base saturation
	Meq 100g $soil^{-1}$					(%)
C sole	0.112	0.033	0.70	0.53	5.08	41.75
C + M	0.110	0.040	0.83	0.77	6.00	44.36
C + M + P	0.100	0.048	1.12	0.75	6.08	52.15
M + P	0.080	0.043	1.00	0.90	5.08	49.92
FS	0.105	0.043	0.83	0.75	9.00	27.30
F-LSD $_{(0.05)}$	NS	NS	NS	NS	1.66	16.04

relief and time of soil formation, Akamigbo (1999) observed a higher bulk density and lower total porosity of cultivated soil relative to forest soil. The lower bulk density and higher total porosity of forest soil might have relatively increased its saturated hydraulic

Chemical properties

The lowest pH value obtained in forest soil relative to other soils show that management and cultural practices modified the effect of parent material. This is also reflected by the slight variation in pH values as noticed in the cropped lands. Higher leaching in forest soil as well as microbial production of acidic substances during decomposition of accumulated forest litters can also contribute to the higher acidity level of forest soil. The generally low organic matter content of the soils (especially in cropped lands) is due to the high rate of organic matter decomposition. Such decomposition processes are favoured by high temperatures and good soil aeration and are influenced by the physical manipulation of the soil through tillage. The lower organic matter content of cropped soils relative to that of the forest soil supports the observation by Ofomata (1965), that an interruption of vegetation disrupts the build up of organic matter. Also, Akamigbo and Asadu (1983) observed that human activity has a substantial influence on soil organic matter in addition to vegetation.

The low organic matter content and the predominately low adsorption capacity clay minerals (e.g. kaolinite and quartz) of the soil of the area (Akamigbo and Igwe, 1990) are responsible for the low CEC of the soils. However, it could be said that the relatively higher organic matter content of the soils of forest and C+M+P LUTs gave rise to their respective higher CEC values compared to soils of other LUTs.

The low values of total exchangeable bases obtained from different soils may be due to the mineral composition of the parent rock (parent material and climatic factors). However, the significant differences in these properties between the soils of the forest and soils of the other LUTs could be as result of the amendments farmers added to the soil and higher leaching in the forest. Although forest soils were better nutrient accumulators (Hall et al., 1977), the value of exchangeable bases obtained for the forest soil in this study did not reflect that.

The high available P in all the soils of the different LUTs may be partly due to the fact that P is returned through soil organic matter mineralization. It may also be due to the effect of P-rich organic and inorganic fertilizers (e. g. poultry dropping, compost manures and NPK fertilizers) added to the soil at varying rates. This also explains the reason for the relative lower available P in the forest soil. The higher acidity level of forest soil may have resulted in the fixation of some soil P making it unavailable. Variation in the quantity and rates of uptake of P nutrient by the different crop/crop mixture over the years may also have given rise to variation in P content within cultivated soils.

Unless for the conservation of soil available P, which M+P LUT was relatively better than other cultivated soils in doing, soils under cultivation have similar statistical effects on most of the soil properties investigated. The non-significant differences between cultivated LUTs in most soil properties determined is an indication that putting the soil under either of the cultivated LUTs, if not for the conservation of available P will be based on other farmers' considerations. These may include the influence of the cultivated LUTs on other soil properties not investigated as well as farmers' social, economic and religious interests derivable from a particular LUT.

CONCLUSION

In Nsukka area of southeastern Nigeria, the evaluation of the physico-chemical properties of soils under farmers-managed sole cassava, cassava + maize, cassava + maize + pepper, maize + pepper and natural forest LUTs showed that the cultivation of sole cassava in combination with maize and or pepper leads to soil degradation.

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