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Conversion of Forests to Arable Land and its Effect on Soil Physical Properties in Enugu State South Eastern Nigeria

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Abstract
Population increase and low input agriculture in south eastern Nigeria has resulted to forest conversion to arable land. A study was conducted in six locations; Ugbo-IyOkpara (L1), Ugbo-nabo (L2) , Ugwogo-Nike (L3) , Iyi-Ukwu (L4) , Edem(L5) and Ngwo (L6) in Enugu State, southeastern Nigeria to determine the changes in selected soil physical properties (particle size distribution, bulk density, hydraulic conductivity, macro porosity micro porosity and total porosity) as a result of converting forests to arable land..Cultivation resulted to significant ($P \leq 0.05$) increase in the sand fractions and bulk density. Result showed decline in silt fraction, hydraulic conductivity, macro, micro and total porosity by 4, 17.5, 38, 26, 19 and 21% respectively. Interaction of location and land use indicated that 67% of the locations were adversely affected by cultivation while 33% of the locations indicated improvement in soil properties in favor of cultivation expressed by a significantly ($P \leq 0.05$) lower bulk density in Ugbo-Okpara , higher micro and total porosity in Ugbo-nabo , higher clay content in Ugbo-Okpara and Ugbo-nabo , while 19 % and 13 % higher silt content were observed in Ugbo-Okpara, and Ugwogo-Nike respectively..The study revealed that the magnitude and direction of change was location specific.

Keywords: Forest Conversion, Cultivation, soil properties, low-input agriculture,
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Introduction

Population increases, national food shortages and economic recession across Nigeria have increased anthropogenic activities on the soil. Enugu State has a land area of 800,240ha and a population of 2.1million (NPC 1991) and this population has risen to 3.3million (NPC, 2007) showing an increase in population density. This places a high demand on agriculture, compelling farmers to engage in continuous cultivation to increase food production and achieve food security. Odemene *et.al.,(*2010) in an analysis indicated that the exponential growth in human population is one of the major interacting drivers for land use change and that arable agriculture was the most important (24%) form of human economic activity in which there was woodland conversion.

Agriculture in Southeastern Nigeria is on subsistence level with low input return and to meet food demand, farmers clear more virgin forest in search of more fertile soil. The implication of this is shrinkage and degradation of agricultural land thus posing a threat to food security in the near future. Land- use change such as cultivation is known to result to changes in the ecosystem function, yet the magnitude of these changes varies from one location to another Mojiri *et al.(* 2011). Variations in some soil physical properties such as particle size distribution, hydraulic conductivity, bulk density, macro, micro and total porosity have been used by many researchers to infer change in the soil environment with forest conversion to arable land . Carter, (2002); Brady and Weil, (2008) observed that attributes of inherent quality such as particle size distribution are mainly static and usually showed little change over time But Lal and Kimble, (1997); Fearnsider and Barbosa, (1998) remarked that decrease in clay content because of selective erosion is one of the changes known to result from forest conversion. However, Krishnaswamy and Ritcher, (2002) indicated that there was no evidence of any selective erosion of clay or other textural changes after forest conversion concluding that differences in inherent properties after forest conversion is not large. Emadi *et al*., (2008) quantified the effect of forest conversion into crop land during an 18year period found out that the bulk density increased by 16% percent resulting to disruption of pores leaving the soil more susceptible to soil erosion. Benjamin (2008) observed in an experiment that plots with permanent vegetation had greater hydraulic conductivity than those under cultivation and this may indicate greater pore continuity and stability. Celik (2004) investigated 3 land use types (Pasture, cultivated and forest) on some physical properties of the soil. He found that cultivated land gave the lowest saturated hydraulic conductivity regardless of soil depth whereas the highest values were measured on samples from forest soil.

The major objective of this research was to use some physical characteristics of some forest and cultivated soils of Enugu State, Southeastern Nigeria to assess the level of physical changes that occur in the soil due to forest conversion to arable land.

Materials and Methods1

Site Description: The study locations (Ugbo-Okpara (L1), Ugbo-Nabo(L2), Ugwogo- Nike [L3], Iyi-Ukwu [L4] , Edem [L5] and Ngwo (L6)) are in Enugu State and within the same agro – ecological zone of southeastern Nigeria. The area lies between latitude 6^{o} 10' N to latitude 6^{o} 24' N and logitude 7^{o} 25' E to 7^{o} 29' E The study area has a tropical wet and dry climate with the rainy season lasting from April to October and the dry season from November to March. The average annual precipitation is between 1600 - 1800 mm with average temperature of 28^{o}C. The vegetation is derived savannah with patches forest. Farming is done with traditional tools like hoes and machete and on subsistent level. Preliminary information from farmers in all locations revealed that they practice shifting cultivation and some common crops planted include cassava (*Manihot esculenta*), cocoyam (*Colocasia spp*.), melon (*Citrilus viligaris*) and maize (*Zea mays*). Also, information from the indigenes showed that the forests have never been cleared, cultivated or burnt for about 100 years. The soils of Enugu State are ferrasols and are of sedimentary origin, (Balogun, 2000).

Soil Sample collection: Soil samples from 0 – 20 cm depth were collected in triplicate from cultivated and adjacent forest lands. The different locations were selected based on the identification of virgin forests, with corresponding adjacent cultivated land and relatively with the same slope and aspect. At every sampling location, core samples were taken in triplicates and used for determination of particle size distribution, bulk density, hydraulic conductivity, macro porosity, micro porosity and total porosity.

Particle size distribution of less than 2 mm fine earth fraction, was measured by the hydrometer method as described by Gee and Bauder (1986) .Bulk density (BD) was measured by the core method, as described by Blake and Hartge (1986). Total porosity was calculated as follows;

Total porosity (Pt) = $1 - \left\{\frac{Bd}{Pd}\right\} x\, 100$ Eqn (1)

Total porosity (Pt), the percentage of bulk volume not occupied by solids was calculated from bulk density (Bd) value assuming a particle density (Pd) of 2.65g cm^{-3}

Macroporosity (Pma) = $\frac{\text{volume of water drained at 60cm tension}}{\text{Volume of soil}} X\, 100$ Eqn (2)

Microporosity (Pmi) = Pt – Pm Eqn (3)

Micro porosity was calculated as the difference between total porosity (Pt) and macro porosity (Pm)

The hydraulic conductivity was determined using the Klute and Dirksen (1986) method. The saturated hydraulic conductivity was calculated as.

Ksat = $\frac{Q}{At} \bullet \frac{L}{\Delta H}$ Eqn (4)

Where K_{sat} = Saturated Hydraulic Conductivity (cm^{3} hr^{-1}),
Q = volume of water per unit time,
L = length of soil column (cm),
A = the cross sectional area of the soil column (cm^{2}),
ΔH = change in hydraulic head (dimensionless)
t = time of flow (hr.).

Statistical Analysis: Data generated from the study were subjected to a 6 x 2 factorial analysis of variance (ANOVA) using Genstat Discovery edition software. These numbers represent the two (2) land use types and six (6) locations. Where the F - values were significant at P=0.05, the means were separated by the least significance difference (LSD) test.

Results and Discussion

Particle size distribution: Change in particle size distribution due to cultivation is shown in Table 1 The result showed that average value of clay, silt and sand in the six locations varied between 7 -31%, 6-33% and 36-87% respectively. The significant difference among locations apparently suggests that differences in values are due to location effect. Also land use significantly ($P \leq 0.05$) affected the clay content evidenced by 8% higher value in the cultivated land use compared to the forest land use. The interaction of land use and location also showed 13 and 40% higher clay particles in cultivated sites of L1 and L2 respectively compared to the adjacent forest land. An experiment carried out on Ugbo-nabo (L2) by Osakwe (2010) revealed that percentage aggregate stability and clay dispersion index were 10% higher and 28% lower in the cultivated soils respectively suggesting more loss of clay in the forest soil compared to the adjacent cultivated site. Perner-Debuyser *et al*., (2003) demonstratesd increase in clay content in cultivated plots treated with manure and Shresher *et al.,((*2007) have demonstrated. that the forest soils studied in Nepal contained fewer clay particles (49–95 g kg^{-1}) than the cultivated soils. However the interaction of land use and location revealed that 50% of the locations (L3, L5 and L6) had 6%, 12%, 25% significantly ($P \leq 0.05$) higher clay content in the forest location compared to the adjacent cultivated land This is in agreement with the work of Klimowicz and Uziak, (2001) and Krishnaswamy and Ritcher, (2002) which showed selective loss of clay due to forest conversion to arable land. Also cultivation significantly ($P \leq 0.05$) reduced silt content by 27.6 %, 5 %, 45.7 % and 50 % in L2, L4, L5 and L6, respectively while 19% and 13 % increase in silt content were observed in L1 and L3 of the cultivated land use respectively. Osakwe (2010) demonstrated 30% higher aggregated silt +clay in cultivated site of L3 inferring loss of more silt in the forest site. .In 50% of all location (L1 ,L2 andL3) it appeared that there were higher fine particles in the cultivated land use with the consequent 22, 8 and 5% reduction in sand fraction respectively compared with the adjacent forest sites which is in agreement with the work of Shresher *et. al.* (2007) which demonstrated that the forest soils studied in Nepal contained more sand (639–834 g kg^{-1}) than the cultivated.

Bulk Density: The result of the bulk density (BD) is presented in Table 2. Average values in the six locations varied between 1.28 g cm^{-3} and 1.72 g cm^{-3}. There were significant ($P \leq 0.05$) differences among locations except between L4 and L5, and between L2 and L6. Significant effect shows that variations in values were due to location.

The effect of land use was significant ($P \leq 0.05$). This means that cultivation affected bulk density hence an increase of about 17.5 % was recorded compared to the forest land use (Table 2). This is consistent with the result of Oguike and Mbagwu, (2009). Also Emadi *et al.,* (2008) in quantifying the effect of forest conversion into crop during 18year period found that bulk density was increased by 16% which is in agreement with the result obtained in this study. The significant interaction of land use and location on bulk density of the soils showed that values in each land use were dependent on location and vice versa. A consistently higher value of about 9.7, 17.6, 31.5, 33.5 and 12 % was indicated in the cultivated sites of L1, L3, L4, L5 and L6, respectively compared to the adjacent forest sites.. Many researchers have shown that increases in BD as a result of forest conversion to arable land were a reflection of the extent of soil degradation that has occurred (Guilser, 2006; Mbagwu *et al.*, 1984).The implication of higher bulk density in cultivated land use is the reduction in total porosity causing poor aeration which physically restricts root growth (Mbagwu *et al.,* 1984).

Hydraulic conductivity: The hydraulic conductivity of both land uses is shown in Table 2. Average values in the six locations varied from 2.1 cm hr^{-1} to 11.90 cm hr^{-1}. Significant ($P \leq 0.05$) differences existed among locations . The effect of land use was significant ($P \leq 0.05$). This shows that cultivation significantly ($P \leq 0.05$) affected hydraulic conductivity evidenced by a decline of 38 % compared to the forest land use. Such difference might be ascribed to the increased bulk density and reduced porosity (Table 3) in the cultivated land use. Silva *et al,* (2005) have found that some soils cultivated with sugar cane showed increased compaction leading to reduction of the hydraulic conductivity of the soil, while Lorimer and Douglas (2000) studied the effect of different management practices on hydraulic conductivity of the soils, revealed that the soil cropped every year had much less than the hydraulic conductivity under native forest.

The interaction of land use and location on saturated hydraulic conductivity values was significant ($P \leq 0.05$) resulting to about 46, 21, 85, 93 and 91% declines in hydraulic conductivity in L1, L2, L3, L4 and L5 of the cultivated land use, respectively compared to their adjacent forest sites. On the contrary, saturated hydraulic conductivity was significantly ($P \leq 0.05$) higher in the cultivated site of L6 compared to the adjacent forest site. In general terms, reduction in hydraulic conductivity in sandy or coarse textured soils is encouraged because of high leaching of plant nutrients which is prevalent in such texture, therefore increase in hydraulic conductivity in L6 with very high sand fraction is undesirable because of high leaching of nutrients associated with such soils However, such decline as observed in other locations is a demonstration of serious degradation of the physical condition of the cultivated site. These results (except L6) is in agreement with the work of Celik (2005) which showed that cultivated land gave the lowest saturated hydraulic conductivity whereas the highest values were measured on samples from forest soils, concluding that cultivation of forest degraded the physical properties, making the soil more prone to soil erosion by water.

Soil porosity: Data on the macro porosity, micro porosity and total porosity (Table 3) showed that average values in the six locations ranged from 6.9 % to 16.5 %, 26.6 % to 40.7 % and 35.3 % to 51.9 %, respectively. The overall result demonstrated that porosity depended on bulk density of the soil (Table 2). Celik (2005) has indicated that depending upon increases in bulk density, total porosity decreased accordingly.

Table 1: Particle Size Distribution of Cultivated and Forest Soils

Parameter	CLAY(%)			SILT (%)			SAND (%)		
Land use	FR	CL	Mean	FR	CL	Mean	FR	CL	Mean
Location L1	26.0	30.0	28.0	29.0	35.0	32.0	45.0	35.0	40.0
L2	14.0	27.0	20.5	27.0	19.0	23.0	59.0	54.0	56.5
L3	32.0	30.0	31.0	31.0	35.0	33.0	37.0	35.0	36.0
L4	28.0	28.0	28.0	35.0	18.0	26.5	37.0	54.0	45.5
L5	32.0	28.0	30.0	31.0	17.0	24.0	37.0	56.0	46.5
L6	8.0	6.0	7.0	8.0	4.00	6.0	84.0	90.0	87.5
Mean	23.0	25.0	24.0	27.0	21.0	24.0	50.0	54.0	51.0
LSD (0.05)									
Location		0.97		1.19			1.19		
Land use		0.56		0.69			0.69		
Location x land use	1.38			1.69			1.88		

From the result in Table 3, a significant ($P \leq 0.05$) decline due to cultivation in the magnitude of about 26 %, 19 % and 21 % was observed in the value of the macro-porosity, micro-porosity and total porosity respectively suggesting that land use was significant. The pore size mostly affected by tillage practice was the macro pores hence the highest decline compared to the micropores. Raisiah *et al.,* (2004) have reported that tillage activities tend to decrease total porosity, most at the expense of large pores. The implication of this adverse effect is that infiltration and percolation might be limited and hence favor an increase in surface run-off. There is also the added problem of toxic accumulation of gases and insufficient supply of oxygen for plant roots and other soil organisms. Considering the combined effect of land use and location on the total porosity (Table 3), result indicated significantly ($P \leq 0.05$) lower values in all locations of the cultivated land use except L2 in the magnitude of about 9, 30, 36, 33 and 16 % in L1, L3, L4, L5 and L6 of the cropped land respectively. The contrary result of higher porosity in the cultivated site of L2 might be due to higher bulk density (Table2) in the forest location.

Table 2 Bulk Density (BD) and Saturated Hydraulic Conductivity (Ksat) in Forest and Cultivated Land Use

Parameter	Bulk Density (gm/ cm3)			Ksat (cm/hr)		
Land use	FR	CL	Mean	FR	CL	Mean
Location L1	1.21	1.34	1.28	15.4	8.4	11.9
L2	1.54	1.48	1.51	7.5	5.9	6.7
L3	1.55	1.88	1.72	4.0	0.6	2.3
L4	1.12	1.62	1.37	6.0	0.4	3.2
L5	1.11	1.67	1.39	3.8	0.4	2.1
L6	1.42	1.62	1.52	10.3	13.4	11.9
Mean	1.33	1.60	1.47	7.8	4.9	6.4
LSD (0.05)						
Location	0.05			0.29		
Land use	0.03			0.17		
Location x Land use	0.07			0.41		

Furthermore, this trend of lower total porosity in the cultivated sites was also observed in the macro and micro porosity in all locations, except that in the macro porosity, a non significant ($P \leq 0.05$) effect (L2) and a significantly ($P \leq 0.05$) higher value in the cultivated site of L1 was indicated compared to the adjacent forest site. Other workers have reported serious decline in the soils pore volume as a result of forest conversion to arable land (Arauyo *et al.,* 2004). Decline in macro-porosity implies reduction in aeration capacity which affects the activities of soil micro organisms.

Conclusion

This research showed that there were variations in soil properties as a result of land use. The study demonstrated decline in soil properties in 67% of the locations as a result of cultivation while about 33% of the locations revealed a contrary result indicating enhanced soil property as a result of cultivation. The direction and magnitude of change in soil properties due to cultivation of forest lands was site specific. Hence, as a result of the variability in soil property observed in the different locations, the use and choice of management to which soils are subjected to should be based on an understanding of the prevailing or inherent soil property in such location.

Table 3: Soil Porosity Under Forest and Cultivated Land Use

Parameter		Pma (%)			Pmi (%)			Pt (%)		
Land use		FR	CL	Mean	FR	CL	Mean	FR	CL	Mean
Location	L1	15.7	17.2	16.5	38.6	32.2	35.4	54.3	49.4	51.9
	L2	16.5	16.4	16.5	25.4	27.8	26.6	41.9	44.2	43.1
	L3	10.0	5.0	7.5	31.5	24.1	27.8	41.5	29.1	35.3
	L4	14.4	4.2	9.3	43.3	34.7	39.0	57.7	38.9	48.3
	L5	9.8	4.0	6.9	48.3	33.0	40.7	58.1	37.0	47.6
	L6	13.0	12.0	12.5	33.4	26.9	30.1	46.4	38.9	42.7
Mean		13.2	9.8	11.5	36.8	29.8	33.3	50.0	39.6	44.8
LSD (0.05)										
Location		0.67			1.67			1.93		
Land use		0.39			1.00			1.11		
Location x Land use		0.95			2.46			2.73		

Pma - Macro-porosity Pmi - Micro-porosity Pt - Total-porosity

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