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Land use conversion effects on aggregation and erodibility of Alfisol soil of Abaji, FCT of Nigeria

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Abstract

Land use conversion can affect natural ecological processes such as surface runoff and erosion. Therefore, it has potential to change soil stability. The study was carried out in Abaji local government of Federal Capital Territory. The objective was to determine the effects of land use conversion on soil properties, soil erodibility and the relationships among soil properties and some erodibility indices. Duplicate topsoil samples were taken by using steel cylinders auger at 60 different sampling points from three different land use types; 20 of them are in farmlands, 20 in rangelands and 20 in forestlands. Soil particle size distribution, loss of ignition and three erodibility indices were determined. Data were analyzed by using Pearson correlation analysis (at 95% significance level), and ANOVA. According to the study results, land use conversion affects some properties of soils significantly. Loss of soils in forests was significant higher than soils in farmlands and rangelands. Soil aggregate stability percentage in rangelands and farmlands were significantly different. The study results showed that there was significant difference between pH of soils in forests and farmlands ($p < 0.05$). Pearson correlation analysis results showed significant correlations among erodibility.

Keywords: Land, conversion effects, Alfisol soil, Nigeria

Introduction

In the Federal Capital territory of Nigeria, Aifisols is the predominant soils. The people of Federal Capital Territory engaged themselves in multiple land use types. Alfisols occur on basalt and crystalline rocks (Jungeruis, 1975). Alfisol is one of the soils referred to as low activity clay (LAC) soils (Juo, 1980, 1981). Low activity clay soils are soils with effective cation exchange capacity (ECEC) of less than 14 meg100 g of soil in the diagnostic horizon where the influence of organic matter is least. Based on the mineralogical and surface characteristics Alfisols are referred to as Kaolinitic LAC soils (Juo, 1981).

Under natural vegetation Alfisols possesses favorable soil properties. All soil properties are continuously influenced by land use at various levels of management such as cropping system and the farming system. Also soil structure, amount of soil organic matter (SOM), water and nutrient holding capacity are all affected by land use (Lal, 1995).

Intensive land use may cause important changes in soil physical and chemical characteristics and can affect soil fertility, increase soil erosion or cause soil compaction (Geissen, 2009). Land use changes through cultivation may rapidly diminish soil quality, as ecologically sensitive components of tropical soils are not able to buffer the effect of intensive agricultural practice (Islam and Weil, 2000) [6]. Most areas of land previously developed from tropical rainforest have been degraded because of land misuse. Nutrient mining and soil degradation are presently considered as problems in arable farms (Ande and Onajobi, 2009). Severe deterioration in soil quality may lead to a permanent degradation of land productivity (Kang and Juo, 1986; Islam and Weil, 2000) [6].

In recent years, many authors have used the USLE-K factor as an indicator of soil erosion (e.g. Evrendilek *et al.*, 2004; Khormali *et al.* 2009) [9], because it is a measure of soil susceptibility to erosion. Although the effects of conversion of natural grassland ecosystems to arable land on different soil properties have been studied widely throughout the world, the long-term (>10 years) effects of tillage practices on aggregate size distribution, aggregate stability and soil erodibility have not been extensively studied, especially in agro-ecosystems under rainfed conditions.

An assessment of the degree and extent of degradation of farmers' fields at a particular point in time is useful to create awareness and alert farmers and other land users of the need to halt further degradation which is a poverty reduction strategy. Also, assessment of the effects of land use and soil management practices on soil properties is of importance to detect changes in soil quality. These effects on soil properties also provide essential information for assessing sustainability and environmental impact (Ishaq and Lal, 2002; Ceyhum, 2009). Effect of land use types on the determination of soil quality has been reported (Amhakhian *et al.*, 2003). In this research I hypothesized that soils under secondary forest and conventional tillage would behave differently in terms of aggregate size distribution, aggregate stability and erosion. Therefore, the major objective of this research was to evaluate the effects of different land use on soil structure and erodibility in Abaji, Federal Capital Territory

Material and Methods

Site Characterisation

The study was conducted in Abaji Local Government within the Federal Capital Territory of Nigeria. The

Federal Capital Territory (FCT) and its environments experiences three weather conditions annually.
The rainy season begins from April and ends in October, when daytime temperatures reaches 28º C to 30º C and night time around 22º C to 23º C. In the dry season, daytime temperatures can soar as high as 40º C and night time temperatures can dip to 12º C. Even the chilliest nights can be followed by daytime temperatures and undulating terrain of FCT act as a moderating influence on the weather of the Territory. Rainfall in the FCT reflects the territory's location on the windward side of the Jos Plateau and the zone of rising air masses. The annual total rainfall is in the range of 1100 mm to 1600 mm. The FCT falls within the Guinea forest savannah mosaic zone of the West Africa sub-region. Patches of rainforest, however, occur in the Gwagwa plains, especially in the gullied train to the south and the rugged south eastern parts of FCT form one of the surviving occurrences of the mature forest vegetation in Nigeria (Najmoon Farm, 2010) [28]

Field/Soil Sampling
Traditional farmers' field were used for the study. Samples were taken to a depth of 0 – 20cm. In each field, core samples were randomly collected and bulked to obtain composite samples that were used for the laboratory analysis. The samples were analysed for physical and few chemical properties of the soil. A total of 60 composite samples were collected for this study.

Field and Laboratory Analysis
Physical Properties of Soils
Soil texture
Soil texture was determined using the hydrometer method (Landon, 1984; Gee and Bauder, 1986,) [23, 12]. The hydrometer method of silt and clay measurement relies on the effects of particle size on the differential vertical velocities of the particles through a water column (i.e., the sedimentation rate). Sedimentation rate is dependent upon liquid temperature, viscosity, and the diameter and specific gravity of the falling soil particles. Soil was dispersed into individual particles after pretreatment with hydrogen peroxide to destroy organic matter, and addition of sodium hexametaphosphate to aid dispersion, then dispersed throughout a water column and allowed to settle. Hydrometer measurements quantified the amount of material remaining in suspension at specific time intervals. This was then related to the amounts of sand, silt and clay in the soil.

Soil bulk density analysis
It was determined by the core method (Burke *et al.*, 1986) [7].

Macro aggregate stability: Water stable aggregate 0 - 20 cm soil depth was evaluated with air-dried samples. The aggregates was wet sieved using Yoder (1936) [39] modified technique (Whitbread, *et al.*, 1996; Oku, 2004) [35, 29] using set of graduated nest of sieves 4.75 mm, 2 mm, 1mm and 0.25 mm. The percentage water stable aggregate was calculated as stipulated by Kemper and Rosenau (1986) [17].

$$\% \text{ WSA} = \frac{\text{weight of soil retained on sieve - weight of sand}}{\text{Total sample weight - weight of sand}} \times \frac{100}{1} \quad (1)$$

Mean Weight Diameter (MWD): The MWD or size distribution was determined using Anger and Mehuys (1993) method.

Micro aggregate stability: This was calculated from the amount of silt and clay in calgon-dispersed as well as water-dispersed samples using Bouyoucos hydrometer method of particle size described by Gee and Bauder (1986) [12]

Dispersion ratio

$$(\text{DR}) = \frac{(\% \text{ silt + clay } (H_20)}{(\% \text{ silt + clay (calgon)}} \times 100 \quad (2)$$

Clay dispersion index

$$(\text{CDI}) = \frac{[\% \text{ clay } (H_20)]}{[\% \text{ clay (calgon)}]} \times 100 \quad (3)$$

Clay flocculation index

$$(\text{CFI}) = \frac{[\% \text{ clay (calgon)}] - [\% \text{ clay } (H_20)]}{[\% \text{ clay (calgon)}]} \times 100 \quad (4)$$

(Oku E E 2004) [29]

Soil Erodibility Analysis t
The soil erodibility (USLE-K factor) was based on the equation suggested by Wischmeier and Smith (1978) and calculated from mean analytical results determined from soil samples.

Chemical Properties
Soil Carbon
Soil carbon was determined simultaneously using the dry combustion technique (Wright and Bailey, 2001) [36]. The samples were air-dried and finely ground into a flour-like texture which were then weighed and packaged into tin capsules for analysis.

Iron Oxide (Fe_2O_3) and Aluminum Oxide
These were estimated by using Atomic Absorption Spectrophometre (AAS).

Soil pH: Soil pH was measured using Kemper method (1996) in soil water solution.

Statistical Analysis
Correlation and regression were used to analyses the relationships between land use and some soil parameters of the samples. Analysis of variance (ANOVA) for randomized complete block design (RCBD) was used to compare the influence of the land use types on the measured soil parameters.

Result and Discussion

Table 1: Effect of Land Use on particles size distribution of Soil in Abaji, Federal Capital Territory

Land Use Type	Sand %	Silt %	Clay %
Mango	73.50	7.89	18.61
Rice	75.28	6.89	17.83
Maize	73.06	7.33	19.61
Sorghum	74.28	8.00	17.72
Cashew	74.11	6.83	19.06
Yam	73.78	6.61	19.61
S.F	74.78	7.39	17.83
Cowpea	73.50	7.06	19.44
Cassava	73.50	8.00	18.50
Pepper	74.11	5.89	20.00
SEM	1.08	2.53	2.88
Significant	0.981	0.671	0.910

Soil Texture

The soil texture of the study area was not influenced by land use. Data presented in table 1 shows the variation in sand, silt and clay fraction of the soil.

The result shows that the textural class across all the land use types of the study area is sandy loam, indicating the homogeneity of forming processes and similarity of parent material. The result is in agreement with (Foth H.D 1990) [11]. However, over a very long period of time, paedogenesis processes such as erosion, deposition, eluviations, and weathering can change the soil texture (Foth H.D 1990) [11], Bradly N.C and Weil RR 2002) [6].

Table 2: Effect of Land Use on Soil bulk density, aggregate stability and erodibility in Abaji, Federal Capital Territory

Land Use Type	Bulk Density g/cm^3	Water Stable Aggregate %	MWD Mm	CDI	CFI	DR	USLE – K factor
Mango	1.68	12.18	5.69	1.80	2.92	53.01	0.48
Rice	1.67	8.83	4.04	1.36	2.04	38.50	0.33
Maize	1.67	10.89	4.98	1.67	2.52	47.49	0.37
Sorghum	1.67	9.59	4.38	1.46	2.21	41.81	0.38
Cashew	1.68	12.77	5.84	1.89	2.95	55.69	0.46
Yam	1.68	12.16	5.54	1.85	2.80	52.82	0.40
S.F	1.67	9.22	4.21	1.42	2.13	40.19	0.39
Cowpea	1.68	11.89	5.43	1.81	2.76	51.96	0.44
Cassava	1.68	11.89	5.43	1.81	2.75	51.84	0.45
Pepper	1.67	11.57	52.26	1.77	2.66	55.29	0.36
SEM	0.11	1.24	2.85	1.09	1.73	4.23	0.09
Significant	0.040	0.001	0.87	0.96	0.872	0.05	0.04

MWD= Mean Weight Diameter, DR= Dispersion ratio, CDI= Clay Dispersion Index
CFI = Clay Flocculation Index, USLE – K factor**,** SEM= Standard Error of Mean

Soil Bulk Density and Aggregate Stability

Bulk Density (gcm-^{3}): Bulk density was highly affected by land use ($P<0.05$). This was in agreement with works of Sintayehum (2006), Lemenih M. *et al.* (2005) [25], and Monges A et al (2005) who postulated that the significant difference is due to differences in the land management and land use history but contradict Yifru A *et al.* (2011) [37] who found out that bulk density was not affected by land use.

Aggregate Stability

Water Stable Aggregate (WSA)

At the Macro aggregate level cashew plantation has the highest value of WSA (12.77mm) and this may be due to application of organic fertilizer or the cashew which usually prevent direct impact of rain on the soil, followed by mango plantation with the same reason as that Camp bell *et al.* (2001) mentioned that the WSA content of the agricultural soils may increase as a result of adding organic fertilizer. Rice plantation (8.83mm) has the lowest WSA as expected. Secondary forest falls below expectation (9.22mm) and this may be due to over grazing by Fulani herdsmen and cutting of the leaves by the same people during dry season to provide forage for their cattle's. The higher the WSA the higher the strength of soil texture against erosion agents. Land use greatly influence WSA ($P<0.001$)

Mean Weight Diameter (MWD)

MWD helps in determining the textural quality of soil.

The higher the MWD of soil sample the better the stability of the soil to break down cause by erosion agents and degradation. Data shows that cashew plantation as the highest MWD 5.84mm, followed by mango plantation 5.69mm, followed by yam farm 5.54mm while cowpea farm and cassava farm have the same MWD of 5.43mm followed by secondary forest 4.21mm while Rice plantation has the lowest MWD of 4.04mm. This result proof that erosion is not likely to occur in mango, cashew plantations, cowpea, cassava, yam farms but erosion is likely to occur in Rice, sorghum farms and Secondary Forest due to their low values of MWD. Statistical analysis shows that MWD has effect on land use ($p\leq0.05$), the result support the result of Spaccini *et al.* (2002).

CDI, CFI and DR

At the micro level of aggregation, table 9 shows the value range of CFI, CDI and DR. Cashew plantation has the highest followed by the mango plantation. The analysis follows the WSA and MWD result which shows the Rice plantation to have the lowest value. The values obtained with these indices of micro aggregate stability under the Rice plantation showed that its stability was lower than that of other land use types. This may be connected with the lower organic carbon content observed under the Rice plantation which supported the reports by Igwe *et al.* (1999) [16], Spaccini R.A *et al.* (2002) and Igwe (1995) [15].

Although, no significant differences existed between the land uses types, except for DR, cashew plantation appear to be the best at the micro aggregation level irrespective of the level organic carbon observed in soils of cashew and mango plantation. It may therefore mean that other soil parameters, apart from organic carbon influenced aggregate stability of the soils studied.

Soil Erodibility Factor Analysis

As shown in Table 2, the USLE K-factor, as an indicator of soil erodibility, differed significantly among different land use soils. This factor is lower in the rice farm (0.38) than in the 0–30cm layer in the adjacent Mango plantation soils (0.46). The lower the K-factor values, the higher the potential of the soil to erode. The magnitude of changes in the USLE K-factor observed in our study is supported by the values reported by Evrendilek *et al.* (2004) [9] for Mediterranean highland soils (46.2%). The erodibility of a certain soil is closely related to its particle size distribution, organic matter content, permeability, and structure. The Alfisols under all the land use had similar contents of sand, silt and clay in the 0–30cm layer. For the investigated Alfisol, the difference in soil erodibility is mainly the result of variations in soil structure of which changed distribution and stability of soil aggregates are the most important factors. The higher K-factor values in the tree plantation soils, therefore, could be mainly due to the higher aggregate stability and organic matter content.

Table 3: Effects of Land Use on Selected pH, Organic Carbon, Iron oxide and Aluminum of Soil in Abaji, Federal Capital Territory

Land Use Type	PH	OC g/kg	Fe cmolc/kg	AL cmolc/kg
Mango	5.32	9.31	1.27	0.11
Rice	5.18	3.63	1.14	0.12
Maize	4.94	4.16	1.23	0.12
Sorghum	5.22	4.63	1.16	0.12
Cashew	5.28	8.89	1.30	1.12
Yam	5.13	5.02	1.06	0.11
Secondary forest	5.32	8.35	1.27	0.12
Cowpea	5.15	5.24	1.31	0.11
Cassava	5.01	6.32	1.22	0.12
Pepper	5.31	3.66	1.22	0.12
SEM	0.56	1.15	1.90	0.000
Significant	0.711	0.002	0.034	0.042

pH

The soil Chemical data of the representative soil samples are presented in table 3. The soil ranges from (4.94-5.32) and all the soils have pH values below 7.0.

Soil pH did not show any significant variation across land use type (P>0.05, table 10). According to Landon E.d (1991) [22] rating the overall pH of the studied soil was found to be moderately acidic. This result is in agreement with Steanwerth *et al.* (2002).

Organism carbon

The overall soil organic carbon content showed significant variation with land use types (p=0.002,). The overall SOC content was higher under mango plantation (9.31g/kg) followed by cashew plantation (8.89g/kg) and secondary forest (8.35g/kg) compared to other land use. The lower SOC content of other land uses apart from mango, cashew plantation and secondary forest could be due to the reduced amount of organic material being returned to the soil system and high rate of oxidation of soil organic matter as a result of continuous cultivation for long period of time without following, loss of organic matter by water erosion and removal of green materials (Yimer F *et al.* (2007) [38] and Girma G. *et al.* (2008) [13]. The result is in agreement with Khresat S. *et al.* (2008) [19] but contradict Moges A and Holding N.M (2008) [27].

Iron Oxide

The study shows that the concentration of Iron oxide in the soil (table 3) significantly varied with land use types (P=0.03), higher in soil under cowpea plantation (1.31cmolc/kg) followed by both mango and cashew plantation 1.27Cmolc/kg while rice plantation has the lowest Iron oxide content (1.14Cmolc/kg). The finding is in agreement with those obtained by Dimoyiannis (2011) [8].

Aluminum

There was no significant difference variation in the overall concentration of aluminum with land use types (p>0.05, table 3) seven land use types has the same value of aluminum content in the study area (0.12 cmolc/kg) namely Rice plantain, maize, sorghum, cashew, S.F, cassava and pepper land uses, while other land uses have 0.11cmolc/kg as the value of aluminum content.

Table 4: Relationship between Water Stable Aggregate and Organic Carbon, Aluminum and Iron Oxides

Parameters		Regression Equation	R^2	P
WSA	Against OC	Y =4.440+ 1.163x	0.36	0.01
WSA	Against Iron Oxide	Y =5.136 + 0.035x	0.19	0.01
WSA	Against Aluminum	Y= 5.121 + 0.048x	0.09	0.04
WSA	Against CFI	Y= 19.297 -1.156x	0.08	0.01

Relationship between Aggregate stability and Organic Carbon, Iron and Aluminum Oxides of the Soil

Aggregate stability is related to soil texture, organic carbon, iron oxide content (Kemper and Koch 1996), and Aluminum oxide content (Bartoli *et al.* 1988a,b) [4, 5]

The coefficients of determination of soil chemical properties with WSA are shown in Table 4. The correlation found between soil properties was rather weak even if statistically significant. The weakness of correlations may be explained by joint effect of more properties that may support or inhibit the influence of each other.

The study shows that concentration of Fe_2O_3 in the soils has a significant correlation with WSA with R^2 value of 0.19 (table 4). The result shows that iron oxide can increase the stability of aggregates. This is because the Iron oxide acts as a binding agent in the arid & tropical soils and it affects the edge charge and the variable surface charge on clays and minerals (Shepherd *et al.* (2001) [30]. The finding is in agreement with those obtained by Dimoyianis (2011) [8]. Water stable aggregate is affected by soil organic carbon by reason of the binding agent of hyoric materials and other Mirabel by product (Shepherd *et al.* (2001) [30] and this is shown by the significant positive coefficient of determination between WSA and the organic carbon (R^2 = 0.36). The strong relationship between organic materials and aggregation has been reported by Barthes *et al.* (2008) [3]. Aluminum also shows positive correction to WSA with coefficient of determinant value of 0.09. This result shows that aluminum has effects on soil aggregation though at a lower level compared to Iron oxides and organic carbon. Clay flocculation index has a negative relationship with WSA (R^2=0.08 Table 4) and thus shows that increase in clay flocculent index will lead to decrease in WSA of soil.

Conclusion

Changes in soil aggregate stability and erodibility with respect to land use were investigated in federal capital territory, Abuja, Nigeria. Aggregate stability, organic carbon, iron and aluminum oxides are all correlated. Aggregate stability test is therefore useful for assessing organic carbon, iron oxide, aluminum oxide, erodibility and aggregation in soils. Land use type has effect on the aggregate stability and erodibility of soil. Over grazing by Fulani herdsmen and mismanagement of secondary forest of Abaji has negative implication on the soil stability and speedy action is needed to safe the soil from agent of degradation.

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