International Journal of Academic Research and Development
ISSN: 2455-4197, Impact Factor: RJIF 5.22
www.academicsjournal.com
Volume 2; Issue 2; March 2017; Page No. 96-101

Aggregate stability and organic carbon as affected by different landuse in kwali local government of Abuja, F.C.T, Nigeria

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Abstract

Aggregate stability of soil is an indicator of soil quality. This study was carried out on Alfisol soil to describe the relationships between soil properties related to aggregate stability, and effects of landuse on aggregate stability of soil in North central of Nigeria. Bulk and core samples were collected from 0-20 cm depth from the fields, in order to determine soil structural stability parameters. Soil organic carbon, iron, aluminum, WSA, and DR have effect on landuse type: $P = 0.002$, $P = 0.034$, $P = 0.042$, $P = 0.001$, $p=0.050$ respectively. Aggregate stability parameters were more stable cashew and mango plantations followed by landuse under cowpea and cassava plantation compare to rice plantation which has the lowest soil aggregate stability among all the ten different land use types studied. The results indicated that land use types had a significant effect on soil aggregate stability, that there are relationships among soil aggregate stability parameters and organic carbon, iron and aluminum content of the soil studied.

Keywords: Aggregate stability, Landuse, soil quality

Introduction

In major parts of the world, agriculture is the primary cause of land use change. Much of the pressure on the conversion of forests to agricultural uses comes from increasing population growth and developmental demands. During the 1990s, 14.6 million hectares (ha) of forest per year was converted to agricultural or urban usage. However, 5.2 million ha per year was gained in plantations, reforestation, and natural forest expansion, for a net loss of 9.6 million ha of forest per year (FAO 2001). Although soil structure is the soil property most sensitive to tillage (Hamblin, A.P. 1985), it is one of the least understood, despite its significant effect on agricultural productivity and environmental quality (Lal, 1991) [20]. A good soil structure for crop growth depends on the presence of aggregates between 1 to 10 mm diameter. Such aggregates should be stable when wetted and should have a good proportion of pores with diameter greater than 75 mm to allow good drainage and aeration during the rainy season, and at the same time have an adequate volume of medium size pores (30 – 0.2 mm) to store available water for dry periods (Tisdall, 1996). Cultivation subjects soil aggregates to fragmentation by rapid wetting, raindrop impact and the direct impact of tillage implements, and exposes protected soil organic matter (SOM) to microbial attack. The consequent decrease in SOM reduces the percentage of water stable aggregates (Lal, 1993) [19].

The objectives of this study were to describe the relationships between soil properties related to aggregate stability and effects of landuse type on soil stability of North central of Nigeria.

Material and Methods

Site Characterisation

The study was conducted Abuja 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) [27]

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 180 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; Geeand Bauder, 1986,) [22, 11]. The hydrometer method of silt and clay measurement relieson the effects of particle size on the differential vertical velocities of the particlesthrough a water column (i.e., the sedimentation rate). Sedimentation rate isdependent 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) modified technique (Whitbread, *et al*., 1996; Oku, 2004) [33, 28] using set of graduate
.d 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) [16].

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

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) [11]

Dispersion ratio

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

Clay dispersion index

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

Clay flocculation index

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

(Oku E E 2004) [28]

Chemical Properties
Soil Carbon
Soil carbon was determined simultaneously using the dry combustion technique (Wright and Bailey, 2001) [34]. 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) [17] 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. DUNCAN at $P < 0.5$ level was used to separate the mean where applicable.

Result and Discussion

Table 1: Effect of Land Use on particles size distribution of Soil in 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) [10]. 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) [10], Bradly N.C and Weil RR 2002) [6].

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

Land Use Type	Bulk Density g/cm^3	Water Stable Aggregate %	MWD Mm	CDI	CFI	DR
Mango	1.68	12.18	5.69	1.80	2.92	53.01
Rice	1.67	8.83	4.04	1.36	2.04	38.50
Maize	1.67	10.89	4.98	1.67	2.52	47.49
Sorghum	1.67	9.59	4.38	1.46	2.21	41.81
Cashew	1.68	12.77	5.84	1.89	2.95	55.69
Yam	1.68	12.16	5.54	1.85	2.80	52.82
S.F	1.67	9.22	4.21	1.42	2.13	40.19
Cowpea	1.68	11.89	5.43	1.81	2.76	51.96
Cassava	1.68	11.89	5.43	1.81	2.75	51.84
Pepper	1.67	11.57	52.26	1.77	2.66	55.29
SEM	0.11	1.24	2.85	1.09	1.73	4.23
Significant	0.040	0.001	0.87	.96	.872	0.05

MWD= Mean Weight Diameter, DR= Dispersion ratio, CDI= Clay Dispersion Index, CFI = Clay Flocculation Index

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) [24], 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) [35] 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) [15], Spaccini R.A *et al.* (2002) and Igwe (1995) [14].

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.

Table 3: Effects of Land Use on Selected pH, Organic Carbon, Iron oxide and Aluminum of Soil in 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) [21] rating the overall pH of the studied soil was found to be moderately acidic. This result is in agreement with Steanwerth *et al.* (2002) [31].

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) [36] and Girma G. *et al.* (2008)) [12]. The result is in agreement with Khresat S. *et al.* (2008) [18] but contradict Moges A and Holding N.M (2008) [26].

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) [17], 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_20_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) [29]. 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) [29] 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 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 and aggregation in soils. Landuse type has effect on the aggregate stability of soil. Over grazing by Fulani herdsmen and mismanagement of secondary forest of Abuja has negative implication on the soil stability and speedy action is needed to safe the soil from agent of erosion.

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