Slope Position and Land use Effect on Select Soil Properties, Quality and Carbon Stock in Surface soils at Afaka Forest area, Northern Guinea Savanna of Nigeria

Original Research Paper:

ABSTRACT

Population increase and the need to achieve food security; especially in Nigeria, necessitated encroachment into forests and marginal lands for agricultural land uses in the Savanna ecologies. However, tropical soils are inherently fragile and prone to rapid degradation under intensive agriculture; especially when soil cover is removed and the soil tilled conventionally. Also, Savanna Alfisols are low in inherent fertility, organic matter, cation exchange capacity, dominated by low activity clays and sesquioxides though being intensively cultivated for crops like maize, sorghum, rice, cotton, cowpea, groundnut and soybeans. Increasing incidence of soil degradation and nutrient impoverishment of Nigerian savanna ecologies; especially under intensive cultivation use, resulted in deceasing soil quality, agricultural production and increasing farmer food insecurity that generated this interest in the need to evaluate effect of slope and Land use on soil properties, quality and carbon stock on Afaka soils in Nigerian Guinea Savanna. The study aims to determine potentials of soils in Afaka areas (Forest and Cultivated areas in slope positions) for sustainable crop production. The trial was a Randomized Complete Block Design (RCBD) where treatments were two Land use Types (i.e., Forest and Cultivated land use types) as main treatments, replicated in Slope positions and soil depths were the split-split plots. Data generated were analyzed using ANOVA and significant means were determined using Duncan multiple range test (DMRT). Results obtained reveal that cultivation activities and erosion accounted for increased silt (19.10 %) in cultivated areas than forest areas (14.89 %), while sand fractions (54.44 %) dominate separates in the Forest and the Cultivated land uses. Upper slope positions had the highest sand content (71.67 %), followed by lower slope with 68.00 %, and then middle (67.67 %) slopes. Silt contents at the middle slope positions were significantly higher than at upper (15.33 %) and Lower slope Position (17.00%) and clay values increased in the lower slope terrains. Also, organic carbon varied significantly between the land use types and slope position on the toposequence. At the forest areas, organic carbon was 10.2 gkg^{-1} and higher significantly than Cultivated fields (8.2 gkg^{-1}). At the upper slope fields under cultivation, organic carbon value was 8.7 gkg^{-1} and was significantly lower than Middle slope (9.60 gkg^{-1}) and Lower slope terrains (6.30 gkg^{-1}). Under Forest land use also, Middle slope terrains had significantly higher organic carbon content than Upper slope terrains. The high Carbon stock of the forest middle slope terrain (1.77 $tCha^{-1}$), followed by forest land use type would discourage global warming and climate change within the Afaka environment However, carbon stock in forest Land use type in Afaka areas (1.41 $tCha^{-1}$) was significantly higher than cultivated land use types (1.21 $tCha^{-1}$). At cultivated slope terrains, middle slopes retained significantly higher SOC (1.37 $tCha^{-1}$) than upper and lower slope terrains. Considering soils for prime quality and use for intensive cultivation, soils under forest lower slope terrain ranked best quality (SQ1; prime quality) for sustainable cultivation purposes, followed by Cultivated middle slope and forest land use type that ranked SQ2. Cultivated upper slope soils ranked least (SQ6) in quality for use in crop production and is least advised for sustainable crop production, while Cultivated lower slope and cultivated land use type soils ranked SQ5. However, increasing loss of forests to intensive cultivation activities without adequate soil management practices would portend increase in global warming and climate change in the study area.

Key Words: Soil quality; Carbon stock; Forest land use; Cultivated land use; Sustainable land use.

1. INTRODUCTION:

Population increase and the need to achieve food security; especially in Nigeria, has necessitated encroachment into forests and marginal lands for agricultural purposes in the Nigerian Savanna ecologies [30, 15]. Soil is one of the most important and determinant factors that strongly affects crop production [44]. However, tropical soils are inherently fragile; thus; prone to rapid degradation under intensive agriculture; especially when soil cover is removed and the soil tilled conventionally [36, 33] as is the practice in the Northern Guinea Savanna of Nigeria. Also, Savanna Alfisols are low in inherent fertility, organic matter, cation exchange capacity, is dominated by low activity clays and sesquioxides [29]. Savanna Alfisols also support intensive production of maize, sorghum, millet, rice, cowpea, soybean, groundnut, cotton, tomatoes, pepper, carrot and onion. In the Northern Guinea Savanna of Nigeria, livestock; such as cattle, sheep, goat and donkey, are commonly freely grazed and crop residues are fed to livestock, sourced for fuel or fencing material [40, 5].

Intense cultivation of crops in Savanna ecologies of Nigeria is largely done using poor or wrong management practices that have resulted in accelerated erosion, nutrient depletion and soil degradation [6, 34]. Increasing incidence of soil degradation and nutrient impoverishment; especially under intensive cultivation, results in deceasing soil quality, agricultural production and increasing farmer food insecurity; that generated interest in the need to evaluate the potential of slopes and Land use on soil properties, quality and carbon stock on soils in Afaka area, Nigerian Northern Guinea Savanna for cultivation purposes.

This study therefore aims to:

1. determine the effect of slope on surface soil properties in Afaka forest and agricultural land
2. determine the effect of slope on surface soil quality of Afaka forest areas
3. determine the effect of slope on carbon stock in surface soils in the study area

2. **MATERIALS AND METHODS**:

2.1 Description of the Study Area

The study was conducted in Afaka forest area; located between latitude 10^{o} 37’ and Longitude 07^{o} 15’and at 585 m above sea level (Fig 1) in Kaduna State, Northern Guinea Savanna, Nigeria. Long-term mean annual rainfall amount in the study area ranges from 1011 and 1161 mm between May and October, with peak rainfall occurring in August [35]. Soils in the study area vary from sand in the upper horizons to sandy clay at the sub soils, ironstone concretions at varying depths and crusts in surface layers [14, 19]. Vegetation in the area is commonly *Isoberlina doka* and *Monotesker stigii* in eroded areas. *Uapacato goensis* and *Parinaricu ratellifollia* are also common [14, 19]. Trees planted within Afaka forest include *Eucalyptus rudii, Albizzia lebbek, Cassia siamea, Eucalyptus crebra, Khaya senegalensis, Anogesius leiocarpus, Eucalyptus camadulensis, Cassia siamea* and *Callitris robusta* [19]. Crop production in the area begins in the month of May and ends in October for the rain fed cropping season.

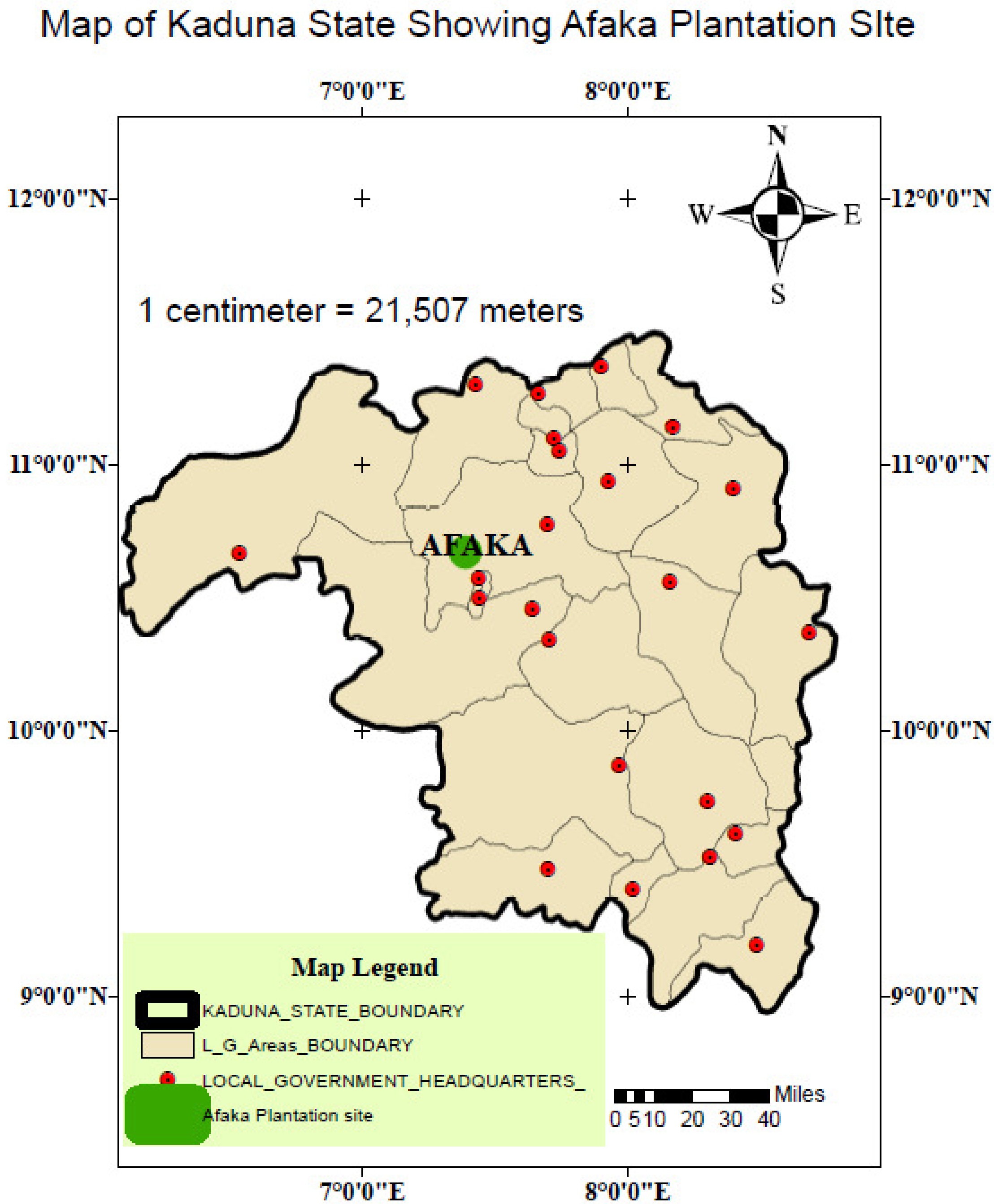

Fig. 1: Map of Kaduna State showing Afaka forest reserve

2.2. Soil Sampling:

Soil samples were obtained at 0-5 cm and 5-10 cm depths from a 1 km by 1 km land area that embraced Afaka forest, forest area recently put into cultivation (Cultivated area) and identified toposequence. Ten traverse lines of 100 km length each, on a rigid grid of 100 m distance between auger sampling points were constructed from a baseline as shown in Fig. 2. The study toposequence was delineated into Upper, Middle and Lower slope positions.

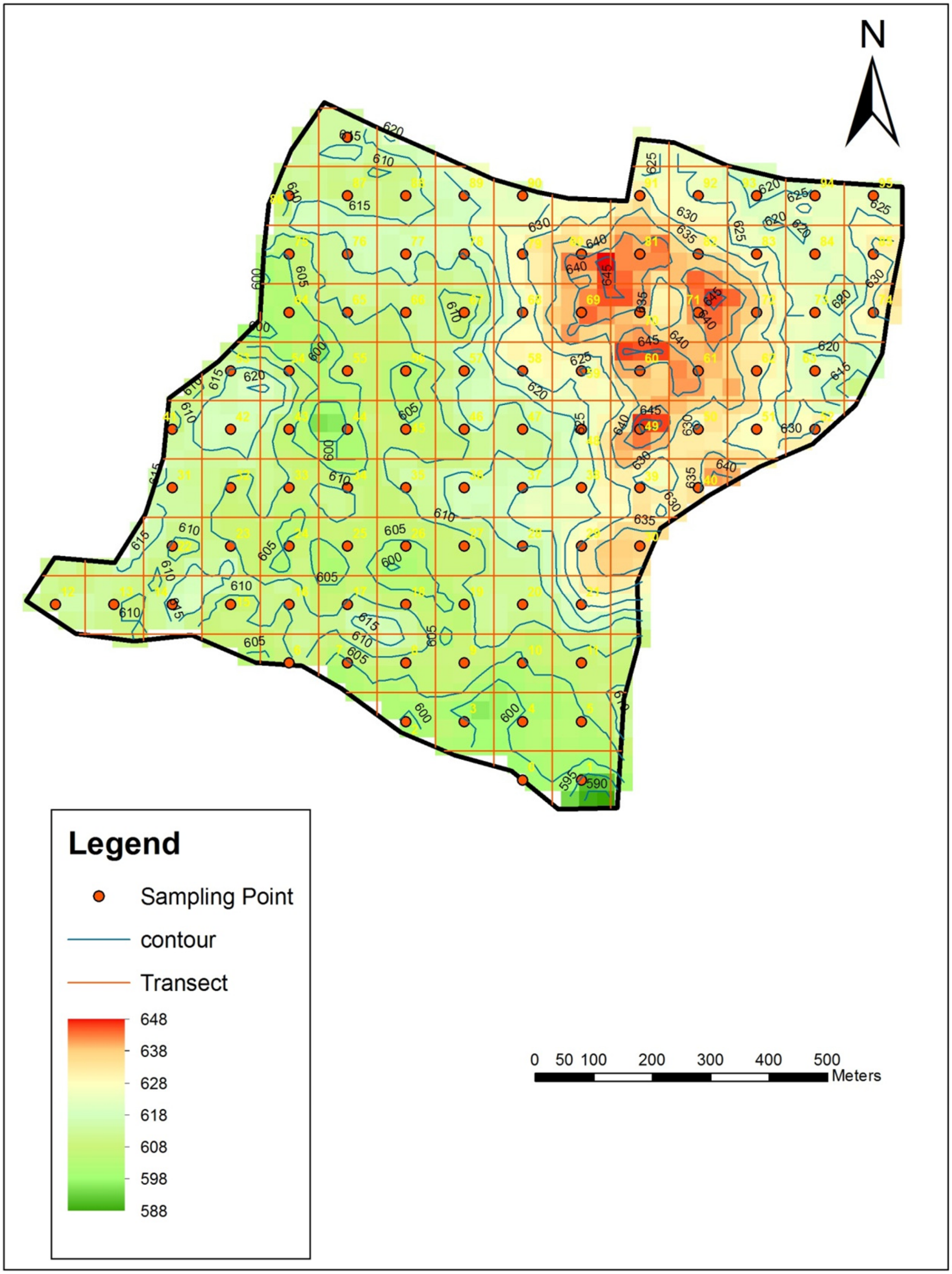
N
Legend
Sampling Point
contour
Transect
648
638
628
618
608
598
588
0 50 100 200 300 400 500
Meters

Fig. 2: Map of Soil Sampling Stations and Toposequence

2.3 **Treatment and Soil Sampling Procedures:**

The trial was a Randomized Complete Block Design (RCBD) treatment, where two Land use types (i. e., Forest land use type and Cultivated Land use types) were replicated in three Slope positions (i.e., Upper slope, Middle slope and Lower Slope positions) and soil depths (0-5 cm and 5-10 cm) served as split-split plots for the study.

Disturbed soil samples obtained from the 0-5 and 5-10 cm depths were air-dried, sieved through 2 mm sieve and the less than 2 mm fractions were analyzed for soil pH, particle size distribution, organic carbon, carbon stock (SOC), total nitrogen, available phosphorus and cation exchange capacity, exchangeable bases. Undisturbed core samples were obtained using 5 cm by 5 cm cores and analyzed for bulk density and hydraulic conductivity.

2.4 Data Acquisition and Analytical Procedures:

Particle size distribution was determined using the hydrometer method [17] and textural classes were obtained from textural triangle using the [41] approach. Soil pH determination followed the [37] while organic carbon was determined by wet oxidation method of Walkley and Black [28]. Soil organic carbon stock (SOC) was measured with the impression:
SOC= Org (C × D × BD × 10000)/1000 (t C ha^{-1})
where C = organic carbon concentration (gkg^{-1}), Bd = bulk density (Mgm^{-3}), depth =d (cm) and
SOC = carbon stock of soil (t C ha^{-1}), 10,000 m^2 =1ha, and 1000 kg=1ton [4, 33, 34]. Also, total nitrogen was determined by the regular micro-Kjeidahl digestion [11] method and available phosphorus was determined by the [10] and [21] extraction method. Exchangeable bases (Ca, Mg, K, & Na) were extracted with 1N NH_40Ac [12]. Exchangeable Calcium (Ca) and magnesium (Mg) were determined by EDTA titration methods [1, 13], while potassium (K) and sodium (Na) were determined using flame photometry [2]. Cation exchange capacity (CEC) was determined by the 1N neutral Ammonium acetate (1N NH_40Ac) method [37]. Bulk density was determined by the by [7] method, while saturated hydraulic conductivity was determined by the constant head permeameter method [38]. Hydraulic conductivity was calculated using Darcy's laws as follows:

$$K_s = \frac{VL}{A\Delta Ht}$$

Where:
K = saturated hydraulic conductivity; cm/min
V = Volume of soil; cm
t = time; minutes
A = Area; cm
L = Length of soil core; cm
ΔH = change in hydraulic head; cm.

Soil quality evaluation was based on soil management assessment framework suggested by [3], with scoring functions for 14 potential soil quality indicators [9]. The minimum data set (MDS) selected in this study include soil functions such as support for plant growth; i.e., bulk density (BD), pH, CEC, total N, and available Phosphorus. Organic carbon and carbon stock were indicators for biological activity in the soil. Indicator ratings were divided into three groups; more is better was applied to N, P, CEC, SOC and organic matter, while less is better was applied to bulk density and optimum is better was applied to pH [22]. Data obtained was subjected to Analysis of Variance (ANOVA), [39] and differences between means were separated using Duncan Multiple Range Test (DMRT) at 5% level of probability.

3. RESULTS AND DISCUSSION:

3.1 Effect of Topesequence and Land use on Bulk Density and Hydraulic Conductivity:

Table 1 shows particle-size distribution of soil in the two locations (Forests and Cultivated land use areas) and slope positions on the toposequence. Mean values for sand, silt and clay fractions were 54.44 %, 14.89 % and 14.00 % at the Forests and 67.11 %, 19.10 %, 13.78 % respectively in the cultivated areas, giving the soil a sandy loam texture. Sand and clay separates were not significantly different between the forest and cultivated areas. However, silt values were significantly different, with more silt (19.10 %) in cultivated areas than forest areas (14.89 %). This suggests that perhaps, cultivation activities and erosion could account for the increased silt fractions in areas under cultivation. Sand fractions dominate the separates in the two land use locations and would cause the soils to be prone to leaching and have low moisture retention capacity that would adversely affect growth of crops because of low moisture and nutrient retention capacity [8].

Upper slope positions had the highest sand content (71.67 %), followed by lower slope with 68.00 %, and then middle (67.67 %) slopes. However, [44] observed that for land use on slopes, the mean value of sand fraction was lowest under the natural forest. Silt content ranged between 15 and 17 % in the slope positions while clay values ranged between 13 and 15 % (Table 1). However, silt contents at the middle slope positions were significantly higher than at upper (15.33 %) and Lower slope Position (17.00%), suggesting that crusting could be prominent at the middle slope terrains. Clay values increased in the lower slope terrains, perhaps resulting from soil depositions following erosion from the upper and middle slope terrains.

Bulk density (Table 1) increased on cultivated land (1.49 and 1.46 Mgm^{-3}) over forest areas (1.42 and 1.34 Mgm^{-3}) at respective depths of 0-5 and 5-10 cm; suggesting perhaps, that crusting/surface sealing due to higher silt content in cultivated areas, trampling, continuous cultivation [31] could have resulted to the higher bulk density values obtained in the cultivated areas. Also,[44] noted that mean value of bulk density was lowest under the natural forest. This result was also in line with the works of [20, 42, 26, 43]). Bulk density at the varying positions in the landscape were not significantly ($P<0.05$) different upper and middle slope positions, but differed significantly with and decreased in lower slope positions. The least (best) bulk density value was obtained at the lower slope positions on the landscape; suggesting least compaction condition in the Lower slope terrains than the Upper and Middle slope positions on the toposequence.

Hydraulic conductivity (Ks) of soil on the study toposequence was higher 5-10 cm depths than the 0-5 cm level in the Forest areas (Table 1). In cultivated areas, Ks was higher at the 0-5 cm level (2.82 $cmhr^{-1}$) than 5-10 cm depth (2.79 $cmhr^{-1}$) and suggests better soil water movement in forest soils than cultivated field soils (Table 1). In slopes, higher Ks was obtained at the upper slope positions 5-10 cm (4.16 $cmhr^{-1}$) that was significantly ($P<0.05$) better the middle (3.05$cmhr^{-1}$) and lower slope terrains (2.06 $cmhr^{-1}$). At the middle slope positions, significantly higher Ks (2.68 $cmhr^{-1}$) than lower (1.97 $cmhr^{-1}$) and upper slope terrains was obtained. Data on Ks shows that Middle slope terrain would water better within 0-10 cm depth than Upper and Lower slope terrains.

Table 1: Effect of Land use and Position on Toposequence on Bulk density and Hydraulic Conductivity of the study area

Treatment	BD_1 ($Mg\ m^{-3}$)	BD_2 ($Mg\ m^{-3}$)	CLAY %	SAND %	SILT %	$Ksat_1$ ($cm\ h^{-1}$)	$Ksat_2$ ($cm\ h^{-1}$)
Land use(**L**)							
Forest	1.42c	1.34d	14.00a	54.44a	14.89b	3.07a	3.39a
Cultivation	1.49a	1.46b	13.78a	67.11a	19.10a	2.82b	2.79b
Slope(S)							
Upper	1.47a	1.47a	13.03c	71.67a	15.33c	1.19c	4.16a
Middle	1.46a	1.41b	13.69b	67.67c	18.67b	2.68a	3.05b
Lower	1.43b	1.31c	15.00a	68.00b	17.00c	1.97b	2.06c

NB: Bulk density 0-5 and 5-10 cm (BD_1 & BD_2 resp.), hydraulic conductivity =Ksat ($Ksat_1$ & $KSat_2$ for 0-5 and 5-10 cm depths resp.). Means with same alphabets in a column are not statistically significant using DMRT.

Table 2 presents information on pH, organic carbon, total nitrogen, available phosphorus and carbon stock content of soils in Afaka area Northern Savanna in Nigeria. Soil pH in forest and cultivated fields range between 6.9 and 7.16. Within the slope terrains in cultivated lands, pH range between 6.8 and 6.93, whereas in forest slope terrains pH range between 6.9 and 7.2. Continuous cultivation practices, excessive precipitation, nature of the topography and application of inorganic fertilizer could partly have attributed as factors responsible for the reduction of pH in the soil. Also, [25] concluded that the lowest value of pH under the cultivated land could be due to the depletion of basic cations in crop harvest and leached to streams in runoff generated from accelerated erosions. Organic carbon varied significantly between the land use types and slope position on the toposequence. At the forest areas, organic carbon was 10.2 gkg^{-1} and was significantly higher than Cultivated fields (8.2 gkg^{-1}), to show that soil organic carbon content was highest under the natural forest land and lowest on the cultivated land [43]. At upper slope fields under cultivation, organic carbon value was 8.7 gkg^{-1} and was significantly lower than Middle slope (9.60 gkg^{-1}) and Lower slope terrains (6.30 gkg^{-1}). At the Forest fields also, Middle slope terrains had significantly higher organic carbon content than Upper slope terrains, but not differ significantly with Lower slope terrains in organic carbon content (Table 2).

Total nitrogen content of soils in the Forest fields (1.20 gkg^{-1}) was significantly higher than those in cultivated fields (1.10 gkg^{-1}). For slopes in cultivated fields, middle slope terrains had significantly higher total nitrogen (1.40 gkg^{-1}) than Upper (1.10 gkg^{-1}) and Lower (0.90 gkg^{-1}) slope terrains (Table 2). Also in Forest areas, middle slope had significantly higher total nitrogen (1.40 gkg^{-1}) than Lower slope areas

(0.90 gkg^{-1}), but similar values with Upper slope terrains. Available phosphorus in Forest land use (8.78 mgkg^{-1}) type was significantly higher than value under cultivated land use (5.40 mgkg^{-1}). Perhaps, this difference was accounted for by forest biomass accumulation and reduced erosion occurrence in Forest land use type. Soils in the savanna ecologies are poor in inherent fertility status, but cultivated areas are further impoverished with nutrient depletions arising from soil erosion, plant uptake and poor management practices adopted by farmers [23, 24, 27, 34]. At cultivated slope terrains, lower slopes had significantly ($P<0.05$) higher available phosphorus (13.40 mgkg^{-1}) than upper and middle slope terrains (Table 2); suggesting perhaps that eroded materials at upper and middle slopes were deposited at the lower slope terrains [22]. At the forest slope areas, upper slope terrains had significantly ($P<0.05$) higher available phosphorus (8.82 mgkg^{-1}) than middle and lower slope terrains (Table 2); suggesting that under forest conditions, soil erosion was minimal at the upper slopes in Afaka area Savannas.

Carbon stock in forest Land use type in Afaka areas (1.41 tCha^{-1}) was significantly higher than cultivated land use types (1.21 tCha^{-1}) perhaps due to forest biomass accumulation and decomposition (Table 2). In cultivated land use type, higher rates of mineralization arising from cultivation activities would account for reduced carbon stock recorded [22, 31, 33, 34]. At cultivated slope terrains, middle slopes retained significantly higher SOC (1.37 tCha^{-1}) than upper and lower slope terrain; due perhaps, to the practice of incorporation of farmyard manure and ridging of fields at land preparation in Afaka. In forest slope terrains, middle slopes also had significantly ($P<0.05$) higher SOC (1.77 tCha^{-1}) than lower slope (1.69 tCha^{-1}) and upper slope (0.88 tCha^{-1}) terrains. Perhaps, middle terrains have inherently higher fertility status than upper slope terrains in Afaka areas.

Table 2: Effect of Land use and Position on a Toposequence on Select Soil Chemical Properties in Afaka, NGS, Nigeria

Treatments	pH	Org. C	Total N	Avail. P	SOC
		← gkg^{-1}	→	mgkg^{-1}	tCha^{-1}
Land use:					
Forest Area	7.16a	10.20a	1.20a	8.78a	1.41a
Cultivated Area	6.90b	8.20b	1.10a	5.40b	1.21b
Cultivated Slope Areas:					
Upper	6.93a	8.70b	1.10b	9.63b	0.88b
Middle	6.93a	9.60a	1.40a	3.20c	1.37a
Lower	6.80a	6.30c	0.90b	13.40a	0.86b
Forest Slope Areas					
Upper	7.20a	6.00b	1.40a	8.82a	0.88c
Middle	6.90a	12.40a	1.40a	5.01b	1.77a
Lower	7.20a	12.30a	0.90b	2.45c	1.69b

Means with same alphabets in a column are not statistically significant using DMRT.

Table 3 presents data on Cation exchange capacity, cation exchange capacity and percent base saturation of soils at Afaka with calcium values being in the range of 4.03 and 5.74 cmolkg^{-1} of soil, but varied significantly ($P<0.05$) between forest and cultivated land use types and slope positions on the toposequence within the land use types. Calcium content was significantly higher under forest conditions (4.92 cmolkg^{-1}) than cultivated land use condition (4.87 cmolkg^{-1}). This reduced calcium value in cultivated land use soils could be attributed to leaching, plant uptake and soil erosion effects [16, 22].

Under cultivated slopes, middle slope terrains contained significantly ($P<0.05$) higher Ca^{2+} value (5.74 $cmolkg^{-1}$) than lower and upper slope terrains that also varied significantly (Table 3). At the forest land use type, upper slope terrains contained 5.74 $cmolkg^{-1}$ calcium to be significantly higher than middle and lower slope terrains, that both also varied significantly.

Magnesium content in forest land use type was also significantly higher than cultivated land use type (Table 3); suggesting perhaps, that leaching, plant uptake, erosion and management practice may account for the reduced Mg^{2+} content in cultivated land use type. Cultivated slopes showed higher Mg^{2+} content at the middle slope and that differed significantly over upper and lower slope terrains. Forest slopes contained Mg^{2+} (2.19 $cmolkg^{-1}$) in middle slope terrain that was significantly higher than values in upper and lower slope terrains (Table 3). Equally, significant higher potassium content in forest land use than cultivated land use type was obtained in Afaka (Table 3). Also, upper slope in cultivated slope terrain and middle slope terrains in forest terrain contained significantly higher K^{+} values than other slope terrains at same positions of the toposequence. Exchangeable sodium was similar statistically between Forest and Cultivated Land use types, but varied significantly within cultivated slopes and forest slopes (Table 3). Middle slope position contained significantly more exchangeable sodium on cultivated slopes and Forest slope areas, than upper and lower slope terrains.

Cation exchange capacity was significantly higher under forest (8.6 $cmolkg^{-1}$) than cultivated (8.54 $cmolkg^{-1}$) land use types, though the soils have low CEC values (<10 $cmolkg^{-1}$). Middle slope terrain had significantly higher CEC in Cultivated Slope terrain than lower (8.13 $cmolkg^{-1}$) and upper slope (7.93 $cmolkg^{-1}$). However in the forest slope areas, upper slope terrain had significantly higher CEC (9.00 $cmolkg^{-1}$) than middle and lower slope terrains (Table 3). Base saturation percent of the soils were high in the land use types and slope terrains; suggesting that the soils have a high potential for exchanging cations for plant uptake.

Table 3: Effect of Land use and position on Toposequence on Exchangeable cations and CEC:

Treatment	Ca	Mg	K	Na	CEC	BS
	←		$CmolKg^{-1}$		→	%
Land use:						
Forest area	4.92a	2.11a	0.58a	0.44a	8.60a	93.61
Cultivated area	4.87b	2.01b	0.40b	0.45a	8.54b	90.94
Slope Cultivated Area:						
Upper	4.03b	1.95b	0.59a	0.43b	7.93c	88.27
Middle	5.74a	2.12a	0.29b	0.51a	9.56a	90.59
Lower	4.84ba	1.95b	0.31b	0.41b	8.13b	92.37
Forest Slope Area:						
Upper	5.74a	2.16b	0.28c	0.39c	9.00a	95.22
Middle	4.89b	2.19a	0.81a	0.48a	8.97a	93.31
Lower	4.12c	1.97c	0.63b	0.43b	7.80b	91.67

Means with same alphabets in a column are not statistically significant using DMRT.

Minimum data set for assessing soil quality (Prime quality agricultural land) in this study include bulk density, organic carbon content, total nitrogen, carbon stock, available phosphorus and pH values obtained from Afaka study area. Mean values of the data set were arranged in Table 4 and scored to obtain totals among the minimum data set (MDS). Prime quality agricultural land is a limited resource defined as soils with the necessary qualities to produce high crop yields when properly managed [18].

The least bulk density value (1.37 Mgm^{-3}) was obtained from forests in the lower slope terrain; suggesting that soils in Forest lower slope terrain were least compacted for cultivation purposes, and was followed by forest land use type (1.38 Mgm^{-3}). Cultivated land use type had the highest bulk density value of 1.47 Mgm^{-3}), suggesting that soil in this land use type were more compact, resulting from effect of cultivation, crust and soil erosion [23]. Among slope positions under cultivation, organic carbon content was highest at cultivated middle slope terrain (12.4 gkg^{-1}), followed by cultivated lower slope (12.3 gkg^{-1}) and forest land use type (10.2 gkg^{-1}). Perhaps, application of farmyard manures by farmers in savanna Nigerian areas and colluviation of soil materials from upper slope positions may account for higher organic carbon value at middle and lower slope terrains [45]. Cultivated upper slope (6.0 gkg^{-1}) and forest lower slope (6.3 gkg^{-1}) terrains would least be advocated for use in sustainable crop production because of very low organic carbon content. Cultivated land use type contained highest total nitrogen value (1.48 gkg^{-1}); perhaps resulting from inorganic N-fertilizer and farmyard manure use by farmers in crop production. Also, forest middle slope, cultivated upper and middle slope terrains contained 1.4 gkg^{-1} nitrogen each, while the least nitrogen content was obtained under forest lower and cultivated lower slope terrains (Table 4). On scoring the land use types and slope terrains against the minimum data set, the least total was that under forest lower slope, followed by cultivated middle slope and forest land use type (Tables 4 and 5). Therefore, soils under forest lower slope terrain were ranked best quality (SQ1) for cultivation purposes, followed by cultivated middle slope and forest land use type that were ranked SQ2. Cultivated upper slope soils were ranked least (SQ6) in quality for use in crop production, while cultivated lower slope and cultivated land use types soils were ranked SQ5.

Table 4: Mean Values Adopted for Soil Quality Assessment in Afaka Study Area

Parameters	Forest	Cultivate	Fu	Fm	Fl	Cu	Cm	Cl
BD (Mgm^{-3})	1.38(2)	1.48(5)	1.47(4)	1.43(3)	1.37(1)	1.47(4)	1.43(3)	1.37(1)
Org. C (gkg^{-1})	10.2(3)	8.2(6)	8.7(5)	9.6(4)	6.3(7)	6.0(8)	12.4(1)	12.3(2)
Total N (gkg^{-1})	1.2(2)	1.1(3)	1.1(3)	1.4(1)	0.9(3)	1.4(1)	1.4(1)	0.9(4)
SOC ($tCha^{-1}$)	1.41(4)	1.21(5)	0.88(6)	1.77(1)	1.69(2)	0.88(6)	1.37(3)	0.86(7)
Avail. P ($mgkg^{-1}$)	8.78(3)	5.4(5)	9.6(2)	3.2(7)	13.4(1)	8.8(4)	5.01(6)	2.45(8)
pH (H_20)	7.16(3)	6.90(2)	6.90(2)	6.90(2)	6.80(1)	7.20(4)	6.90(2)	7.20(4)
Total	16	26	22	18	15	27	16	26
Rank	2	5	4	3	1	6	2	5

NB: Fu=Forest Upper slope; Fm= Forest Middle slope; Fl= Forest Lower slope; Cu= Cultivated upper slope; Cm= Cultivated middle slope; Cl=Cultivated lower slope. Values in red colour are scores aggregated to obtain total score for ranking.

Carbon stock in the study area was highest under forest middle slope terrain (1.77 $tCha^{-1}$), followed by forest land use type and least SOC was obtained under cultivated lower slope terrain (Table 4). The high SOC would discourage global warming and climate change [21, 34] within the Afaka environment. The low carbon stock obtained under cultivated upper, lower and middle slope terrains is attributed to high rate of mineralization of organic matter following cultivation activities and high diurnal temperature of the savanna ecology [33, 34]. Available phosphorus was highest under forest upper slope, followed by cultivated upper slope and forest land use. The least available phosphorus content was obtained under cultivated lower slope terrain. The least soil pH value was under forest lower slope terrain; suggesting least soil acidity under forest lower slope terrain to support sustainable crop production.

Table 5: Soil Quality Ranking for Afaka Forest and Cultivated Savanna Areas in Nigeria

Parameters	Forest	Cultivate	Fu	Fm	Fl	Cu	Cm	Cl
BD (Mgm^{-3})	2	5	4	3	1	4	3	1
Org. C (gkg^{-1})	3	6	5	4	7	8	1	2
Total N (gkg^{-1})	4	5	6	1	2	6	3	7
SOC ($tCha^{-1}$)	4	5	6	1	2	6	3	7
Avail. P ($mgkg^{-1}$)	3	5	2	7	1	4	6	8
pH (H_20)	3	2	2	2	1	4	2	4
Total	16	26	22	18	15	27	16	26
Ranks	2	5	4	3	1	6	2	5

NB: Fu=Forest Upper slope; Fm= Forest Middle slope; Fl= Forest Lower slope; Cu= Cultivated upper slope; Cm= Cultivated middle slope; Cl=Cultivated lower slope

SUMMARY:

Realizing the high rate of population growth in Nigeria, the need to achieve food security, that tropical soils are inherently fragile and prone to rapid degradation under intensive agriculture; especially when soil cover is removed and the soil tilled conventionally as is the practice in the Northern Guinea Savanna of Nigeria, this study 'Slope Position and Land use Effect on Select Soil Properties, Quality and Carbon Stock in Surface Soils at Afaka Forest Area, Northern Guinea Savanna of Nigeria' was initiated. The study aim to determine the effect of slope on surface soil properties in Afaka forest and agricultural land, effect of slope on surface soil quality and the effect of slope on carbon stock in surface soils in the study area. Finding from this study suggests that cultivation activities and erosion could account for increased silt fractions in areas under cultivation. However, sand fractions dominate the separates in the Forest and the Cultivated land uses and would cause the soils to be prone to leaching and have low moisture retention capacity.

On the slopes, silt contents at the middle slope positions were significantly higher than at upper (15.33 %) and Lower slope positions (17.00%), suggesting that crusting could be prominent at the middle slope terrains. Clay values increased in the lower slope terrains, perhaps resulting from soil depositions (Colluviation) following erosion from the upper and middle slope terrains. The least (best) bulk density value was obtained at the lower slope positions on the landscape; suggesting least compaction condition in the Lower slope terrains than the Upper and Middle slope positions on the toposequence studied.

Soil pH in forest and cultivated fields range between 6.9 and 7.2, within the slope terrains in cultivated lands, pH range between 6.8 and 6.93, whereas in forest slope terrains pH range between 6.9 and 7.2. Organic carbon at the forest area land use type was 10.2 gkg^{-1} and differed significantly with Cultivated land use (8.2 gkg^{-1}). At upper slopes under cultivation, organic carbon value was 8.7 gkg^{-1} and was significantly lower than Middle slope (9.60 gkg^{-1}) and Lower slope terrains (6.30 gkg^{-1}). Under Forest land use also, Middle slope terrains had significantly higher organic carbon content than Upper slope terrains.

Carbon stock in forest Land use type in Afaka areas (1.41 $tCha^{-1}$) was significantly higher than cultivated land use types (1.21 $tCha^{-1}$). At the cultivated slope terrains, middle slopes retained significantly higher SOC (1.37 $tCha^{-1}$) than upper and lower slope terrain; due perhaps, due to the practice of incorporation of farmyard manure and ridging of fields at land preparation in Afaka. In forest slope terrains, middle slopes also had significantly higher SOC (1.77 $tCha^{-1}$) than lower slope (1.69 $tCha^{-1}$) and upper slope (0.88 $tCha^{-}$

^{1}) terrains. However, increasing loss of forests to intensive cultivation activities without adequate soil management practices would portend increase in global warming and climate change in the study area.

Cation exchange capacity was significantly higher under forest (8.6 cmolkg^{-1}) than cultivated (8.54 cmolkg^{-1}) land use types, though the soils have low CEC values (<10 cmolkg^{-1}). Middle slope terrain had significantly higher CEC in Cultivated Slope terrain than lower (8.13 cmolkg^{-1}) and upper slope (7.93 cmolkg^{-1}), but in the forest slope areas, upper slope terrain had significantly higher CEC (9.00 cmolkg^{-1}) than middle and lower slope terrains.

Data generated were scored on the minimum data set (i.e., bulk density, organic carbon content, total nitrogen, carbon stock, available phosphorus and pH) for soil quality (Prime quality agricultural land) determination. Therefore, soils under forest lower slope terrain were ranked best quality (SQ1; prime quality) for sustainable cultivation purposes, followed by cultivated middle slope and forest land use type that were ranked SQ2. Cultivated upper slope soils were ranked least (SQ6) in quality for use in crop production, while cultivated lower slope and cultivated land use type soils were ranked SQ5.

CONCLUSION:

In conclusion, the following inferences were reached:

1. cultivation activities and erosion accounted for increased silt fractions in areas under cultivation while sand fractions dominate separates in the Forest and the Cultivated land uses and would encourage leaching and low moisture retention capacity when used for crop production. Also, silt content at the middle slope positions were significantly higher than at upper and Lower slope positions, while clay values increased in the lower slope terrains.

2. Among slope positions under cultivation, organic carbon content was highest at cultivated middle and lower slope terrains and forest land use type. Perhaps, application of farmyard manures by farmers in Nigerian savanna areas and colluviation of soil materials from upper slope positions may account for higher organic carbon value at middle and lower slope terrains. Under Forest land use also, Middle slope terrains had significantly higher organic carbon content than Upper slope terrains.

3. Carbon stock in forest Land use type in Afaka areas was significantly higher than cultivated land use types; suggesting that forest systems would check soil erosion, moderate global warming and climate change. At the cultivated slope terrains, middle slope retained significantly higher SOC than upper and lower slope terrain. Adequate soil management practices to conserve the soils under the Middle slope terrains against erosion, organic matter depletion and nutrient impoverishment are advocated if the soils will be used for sustainable intensive crop production.

4. Soils under forest lower slope terrain were ranked best quality (SQ1; Prime quality agricultural land) for cultivation purposes, followed by cultivated middle slope and forest land use type that ranked SQ2. Cultivated upper slope soils were ranked least (SQ6) in quality for use in crop production, while cultivated lower slope and cultivated land use type soils were ranked SQ5.

REFERENCES:

1. Agbenin, J. O (1995). Laboratory manual for soil and plant analysis (selected methods and data analysis). Aggregate and particle Associated organic carbon under different land uses in Nepal. Soil Science Society of America Journal. 71 (4): 94-1203

2. Anderson, J. M and and Ingram, J. S. I (1993). Tropical Soil Biology and Fertility: A Handbook of Methods 2nd edition. CAB International Wallingford, UK p221.

3. Andrews S. S, Karlen, D. L and Cambardella C. A. (2004). The soil management assessment framework: A quantitative soil quality evaluation method. Soil Science Society of Nigeria. 11(6): 1573-1585

4. Anikwe, M. A. N (2006).Soil quality assessment and monitoring: A review of current research effort.

5. Balasubramania, V and Nnadi, L. A (1980). Crop residue management and soil conservation in savanna areas. In FAO Soils Bulletin No. 43, Rome. P15

6. Bationo , A, Mokwunye, P. L. G, Vlek, S. and Shapiro, B. I (2003). Soil fertility management for sustainable land use in the West Africa Sudano-Sahelian zone. In Soil Fertility Management in Africa: A regional perspective (Gichuru, A. Bationo, M. A, Bekunda, H. C, Gomma, P. L, Mafongoya, D. N, Mugendi, H. M, Murwira, S. M, Nandwa, P, Nyathi and Swift M. J (eds). Tropical Soil Biology and Fertility Institute of CIAT. Nairobi, Kenya. P255-292

7. Blake, G. R and Hartge, K. H (1986). Bulk density. In Klute (ed). Methods of Soil Analysis, Part 1, second edition. Soil Science Society of America. Monograph No. 9 P 363-376

8. Brady N. C and Weil, R. R (2002). The Nature ans Properties of Soils. 13th edition. New Jersey, USA: Prentice-Hall Inc. 960.

9. Brian J. Wienhold, Brian.Wienhold, D. L. Karlen (2009). Protocol for indicator scoring in the soil management assessment framework (SMAF). University of Nebraska-Lincoln DigitalCommons@University of Nebraska–Lincoln, U.S. Department of Agriculture: USDA-ARS, doug.karlen@ars.usda.gov Agricultural Research Service, Lincoln, Nebraska

10. Bray K. H and Kurtz L. T (1945). Determination of total organic and available forms of phosphorus in soils. Soil Science Society of America. 172:1-8

11. Bremner J. M and Mulvaney,C. S (1982) . Nitrogen total. In Page *et al* (ed). Methods of Soil Analysis, Part 2. Chemical and Microbiological properties. Soil Science Society of America, Madison Wisconsin. P 595-642.

12. Chapman H. D (1965). Total exchangeable bases. I Black, C. A (ed). Methods of Soil Analysis part 11. American Society of Agronomy, 56,:902-904

13. Chapman H. D and Pratt F. P (1982). Determination of minerals by titration method. Methods of Analysis for Soils, Plants and Water, 2nd edn. Oakland, CA: Agriculture Division, California University, 169-170

14. Federal Department of Forestry Resources (FDFR) in Afaka, Nigeria (1964) Report

15. Federal Fertilizer Department (FFD, 2012). Fertilizer use and management practices for Nigeria. Federal Fertilizer Department, Federal Ministry of Agriculture and Rural Development, Abuja, Nigeria P 215

16. Gebeyaw T (2007). Soil Fertility Status as Influenced by Different Land Uses in Maybar Areas of South Wello Zone, North Ethiopia. M.Sc. Thesis. Haramaya University, Ethiopia, p 71

17. Gee, G. W and Or, D (2002). Particle analysis. Pp 255-293. Inc: J. H. Dane and G. C Topp (eds). Methods of Soil Analysis Part 4 Physical Methods. Soil Science Society of America. Book Series No. 5 M

18. Gould , William A Frank H. Wadsworth, Maya Quiñones, Stephen J. Fain and Nora L. Álvarez-Berríos (2017). *Forests* **2017**, *8*(7), 242; doi:10.3390/f8070242

19. Hamza, H (2018). Effect of Land use and Slope gradients on selected properties and soil quality of an Alfisol in Afaka Forest, Northern Guinea Savanna of Nigeria.Thesis Report. Department of Soil Science, Faculty of Agriculture, Ahmadu Bello University, Zaria, Nigeria. P. 138

20. Islam KR and Weil RR (2000). Land use effects on soil quality in a tropical forest ecosystem of Bangladesh. Agric Ecosystems Environ 79:9–16, http://dx.doi. org/10.1016/S0167-8809 (99)00145-0

21. Jackson, I. J (1989). Climate, Water and Agriculture in the Tropics. 2nd edition. Longman Scientific and Technical co-published in U.S.A with John Wiley and sons Inc. New York, p 377

22. Larson, W. E and Pierce, F. J (1994). Soil loss tolerance: maintenance of long term soil productivity. Journal of Soil and water Conservation, 39: 136-138

23. Lal, R (1996). Deforestation and land Use Effects on soil degradation and rehabilitation in Western Nigeria. 1 Soil physics and hydrological properties. Land Degradation and Development 7:19-45

24. Lombin,G (1987). Soil and Climate constraints to crop production in the Nigerian savanna region. 15th Annual Conference of Soil Science Society of Nigeria. Kaduna. 21-24th Sept. 1987 p33.

25. Mohammed S (2003). The Effect of Organic Matter on Runoff, Soil Loss and Crop Yield at Anjeni, West Gojjam. M.Sc. thesis. Alemaya University, Ethiopia

26. Mulugeta L (2004). Effects of Land Use Changes on Soil Quality and Native Flora Degradation and Restoration in the Highlands of Ethiopia: Implication for Sustainable Land Management. PhD Dissertation, ISSN 1401–6230, ISBN 91-576-6540-0. Presented to Swedish University of Agricultural Sciences, Uppsala., pp 31–44

27. Mulugeta D, Karl S (2010). Assessment of integrated soil and water conservation measures on key soil properties in south Gondar, north-western Highlands of Ethiopia. J Soil Sci Environ Manage 1(7):164–176

28. Nelson, D. W and Sommers, L. E (1982). Total carbon, organic carbon and organic matter. Methods of Soil Analysis. Part 2. Chemical and Microbiological properties. 2nd edition. In Page et al. (eds). Agron. 9 Am. Soc. Agron. Madison, Wis. USA Pp. 539-580

29. Odunze, A. C**.** (2006). Soil properties and Management Strategies for some sub humid Savanna zone Alfisols in Kaduna State, Nigeria. Samaru Journal of Agricultural Research Vol. 22: 3-14

30. Odunze, A. C and I Kureh (2007). Land use Limitations and Management Option for a Savanna zone Alfisol. Nigerian Journal of Soil and Environmental Research Vol.7: 70-81 (2007).

31. Odunze A. C. Jinshui Wu, Liu Shoulong, Zhu Hanhua, Ge Tida, Wang Yi and Luo Qiao. (2012). Soil Quality Changes and Quality Status: A case study of the Subtropical China Region Ultisols. British Journal of Environment and Climate Change. SCIENCEDOMAIN INTERNATIONAL Vol. 2(1) 37-57, 2012

32. Odunze Azubuike Chidowe (2015). Soil Conservation for Mitigation and Adaptation to a Changing Climate: Sustainable Solutions in the Nigerian Savanna Ecology. International Journal of Plant & Soil Science; 8(4): 1-12, 2015; Article No. IJPSS 19628 SCIENCEDOMAIN International. www.sciencedomain.org

33. Odunze Azubuike Chidowe, Musa, Yusuf Destiny and Abdulkadir, Aisha (2017a). Soil Organic Carbon Concentrations and Stocks under Maize /Legume Cropping System in Alfisols of a Savanna Zone, Nigeria. British Journal of Applied Science & Technology 21(1): 1-12, 2017; Article No.BJAST.32538 ISSN: 2231-0843, NLM ID: 101664541

34. Odunze Azubuike Chidowe, Musa, Yusuf Destiny and Abdulkadir, Aisha (2017b). Soil Quality, Carbon sequestration and Yield of Maize (Zea mays L.) under Maize/Legume Cropping System in Alfisols of a Savanna Zone, Nigeria. American Journal of Climate Change. 6, 622-642. https://doi.org/10.4236/ajcc.2017.64032

35. Oluwasemire, K. O and Alabi, S. O (2004). Ecological impact of changing rainfall pattern, soil process and environmental pollution in Sudan and northern guinea savanna agro ecological zones of Nigeria. Soil Resources 5 Pp23-31

36. Osakwe, U. C. (2014). Effect of land use on chemical properties and soil micro aggregate stability indices in the tropics. Proceedings of the 38th Annual Conference of Soil Science of Nigeria. 2(4):214-215.

37. Rhoades, J. D (1982). Cation exchange capacity. Methods of Soil Analysis. Part 2. Chemical and Microbiological properties. 2nd edition. In Page *et al*. (eds).Agron. 9. Am. Soc. Agron. Madison. Wis. USA Pp 149-158

38. Reynolds W. D and Elrick, D. E (2002). Constant head soil core (tank) method. In J. H Dane and G. C Topp (eds). Methods of Soil Analysis, part 4. Physical methods. Soil Science Society of America. 5:804-808. Madison, Wis.

39. SAS Institute,(2011). SAS/ETS User's Guide. Version 6, second edition. SAS Institute Inc. Cary, NC

40. Tarawali S. A, B. B. Singh, S. C Gupta, R. Tabo, F. Harris, S. Nokoe, S Fernandez-Rivera, A. Bationo, V. M. Manyong, K Makinde and E. C Odion. (2002). Cowpea as a key factor for a new approach to integrated crop-livestock systems research in the dry savanna of West Africa. In Challenges and opportunities for enhancing sustainable cowpea production. Fatokun *et al* (eds). International Institute of Tropical Agriculture, Ibadan, Nigeria. Pp233-251

41. United State Department of Agriculture (USDA, 1975). Soil Taxonomy: A basic System for Soil Classification for Making and Interpreting Soil Surveys. Soil Survey Staff. Soil Conservation Service. Pp 744

42. Woldeamlak B (2003). Towards Integrated Watershed Management in Highland Ethiopia: the Chemoga watershed case study. Tropical Resource Management Papers 44, Wageningen University

43. Yihenew GS, Getachew A (2013). Effects of different land use systems on selected physico- chemical properties of soils in Northwestern Ethiopia. J Agric Sci 5:114–117

44. Yihenew G Selassie, Fentanesh Anemut and Solomon Addisu (2015). The effects of land use types, management practices and slope classes on selected soil physico-chemical properties in Zikre watershed, North-Western Ethiopia. Environmental Systems Research (2015) 4:3 (2-7). DOI 10.1186/s40068-015-0027-0

45. Odunze, Azubuike Chidowe (2015). Conservation Agriculture: A Nigerian Synthesis and Mitigation Measures. Lambert Academy Publishing, Germany.