Original Research Article

Effect of land use on soil quality in Afaka forest northern guinea savannah of Nigeria

ABSTRACT

Land use changes from forest into cultivated ecosystems result in negative impact on soil structure and quality. The purpose of this study was to determine effect of land use on soil quality in Afaka forest northern guinea savannah of Nigeria. Land use systems, including natural forest and cultivated land were identified. Eighteen (18) composite disturbed and undisturbed samples were collected from depth of 0-5 and 5-10cm for analysis of pertinent soil properties in the laboratory using grid procedure. Most physical and chemical properties show relative variations in response to land use types and geomorphic positions. Results indicate that the soils had high degree of weathering potentials, low to moderate bulk density at 0-5cm depth values between 1.42 to 1.49 Mg m^{-3} in forest and cultivated land, bulk density of 1.34 and 1.46 1.Mg m^{-3}at 5 -1ocm depth for forest and cultivated land respectively. The soil water at 0-5cm depth is from 4.20 to 2.63 cm^3/cm^3 , while at 5-10cm depth these values vary from 4.32 to 2.13 cm^3/cm^3 under forest and cultivation land use. The pH (H_2O) is 6.9 to 7.16 with low electrical conductivity of 0.13 dS/m(forest) and 0.12 dS/m (cultivation). The CEC of soils is recorded as 8.60 cmol kg^{-1} (forest) to 8.54 cmol kg^{-1} (cultivated)whereas total nitrogen content of 1.21 g kg^{-1} and 1.11 g kg^{-1} and available phosphorus of 8.78 mg kg^{-1} (cultivated)and 5.47 mg kg^{-1} (forest).. Results indicate that soil fertility parameters were moderate to low for cultivated land and at all slope positions, suggesting that soil fertility management is required in order to make agriculture sustainable on Afaka area.

Introduction

Land use-induced changes in nutrient availability may influence secondary succession and biomass production[1] and reduce soil organic carbon (SOC); which plays a crucial role in sustaining soil quality, crop production and environmental quality[2]. Such changes directly affect soil physical, chemical and biological properties such as soil water retention and availability, nutrient cycling, gas flux, plant root growth and soil conservation [3]. Maintenance of SOC is especially important due to its effect on soil nutrient status and structural stability.

Soil quality is defined as the capacity of a specific soil to function within natural or managed ecosystem boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality, and support human health and habitation [4]. Thus, soil quality assessment reflects biological, chemical and physical properties, processes and their interactions within each resource unit [5].

Soil quality evaluation was based on the soil management assessment framework (SMAF) suggested by [6], and scoring functions for 14 potential soil quality indicators [7]. A general guideline has been the use of a minimum of five indicators with at least one each for biological, chemical and physical properties or process [5] as suggested by[8], and with which a minimum data set (MDS) was established. The MDS selected in this study include soil functions such as ease of tillage, salinity support for plant growth, bulk density (BD), CEC, total N, available P, and exchangeable K were used as indicators for plant growth support, while organic carbon was the indicator for biological activity in the soil and mean weight diameter (MWD) to assess erodibility of the soils.

Afaka study area is facing the problem of deforestation, over grazing, poor soil management and severe erosion. Combating and minimizing ongoing soil degradation and to enhance land productivity through sustainable use of soil resources, it is required proper understanding of soil quality under different land use systems. However, very little information is available about the study area. Therefore the present study was undertaken to evaluate effect of different land use systems and slopes on soil quality of different land use system in Alfisols of Afaka area

MATERIALS AND METHOD

Site description

The study area is Afaka forest reserve, established in 1946 and situated 24 kilometers in north – west of Kaduna and bisected by Kaduna-Tegina road (Figure 1). The area lies between Latitude 10^0 $37^{'}$, N and Longitude $07^0 15^{'}$ E, and covers an area of 129 ha [9].The altitude is approximately 585 m above mean sea level. The area is virtually flat with running very gentle sloping towards the south. The mean annual rainfall is 1011-1161 mm; between May and September, with peak rainfall in August [10]

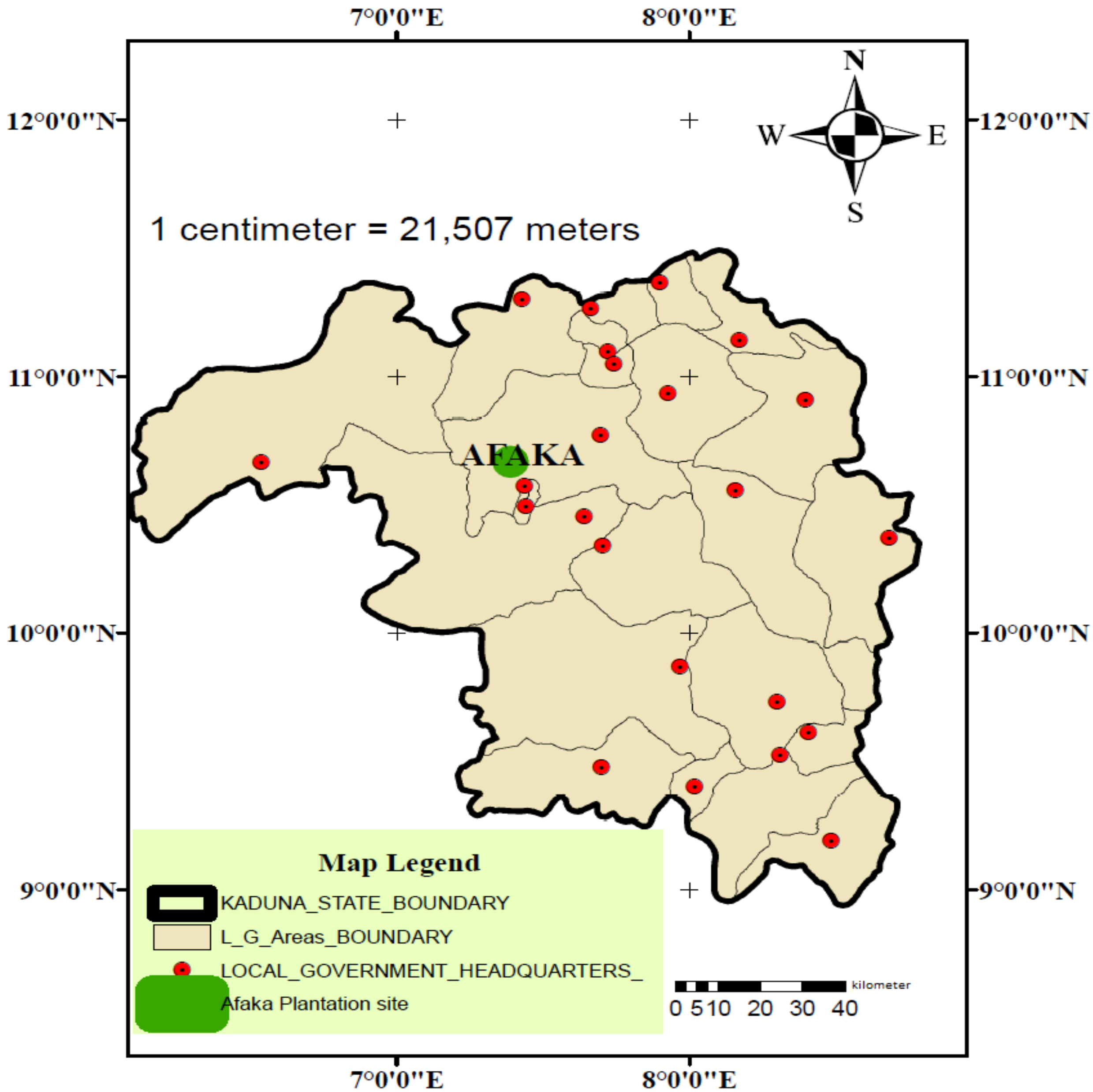

Figure 1: Map of Kaduna State showing Afaka forest reserve

Sampling plan: Soils on geomorphic positions were sampled on grid survey. Soil samples from 0- 5 cm (top soil) and 5 -10 cm (lower layer) were collected at auger points determined along traverses from cultivated land and in adjacent forest, in each delineated geomorphic position of the study area. The sample area covered 1 km by 1 km as shown in Figure 2. In all, ten traverse lines were proposed, such that augering was done at 100 m interval along each transverse.

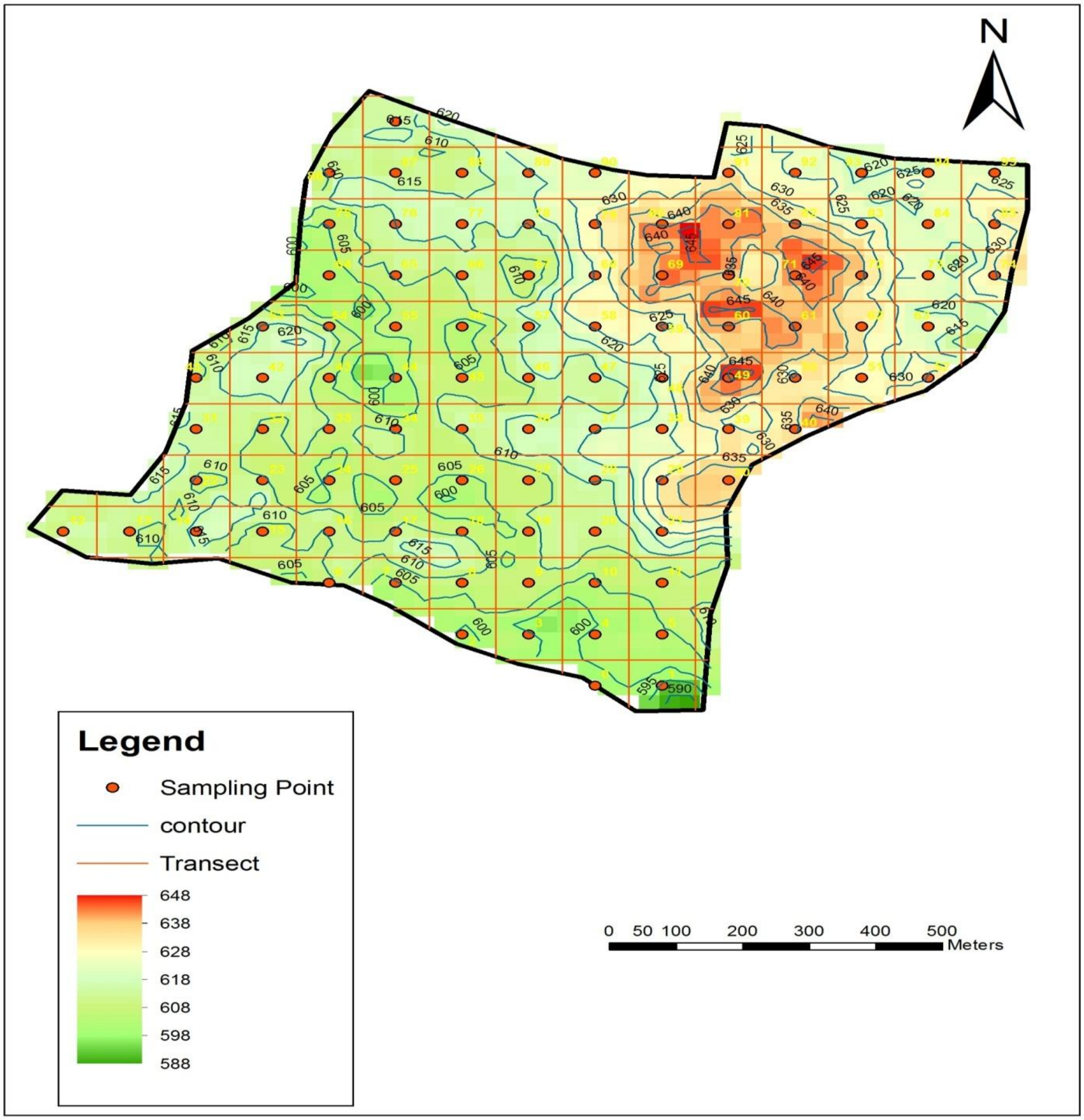

Fig 2: Map showing sampling grid points in Afaka Forest Reserve

Laboratory analysis

Particles Size Distribution

Particle size analysis of soil samples was used to determine percentage of sand, silt and clay in the soil samples. These percentages were used to determine textural classes of soil samples. The analysis was performed using the hydrometer method [11].

Aggregates stability indices

Composite soil samples previously dried and wet-sieved through 5-mm mesh were used to calculate Macro-aggregate stability indices such as: Mean Weight Diameter (MWD), Water Stable Aggregates (WSA) and Degree of Aggregation (DOA) [12]; [13]

Bulk density

Three undisturbed soil core samples were collected with metal cylinders that measured 45 mm diameter and 50 mm height from the designated soil depths, (0-5 and 5-10 cm) at three geomorphic units (upper, middle and lower slopes) in each of the two land use types, for the determination of bulk density[14].

Bulk volume was obtained by measuring internal diameter and height of the cylinder, so that volume of the soil was expressed as:

$V = \pi r^3 h$ Where

V is volume of the core (cm3), r is the radius (cm), h is the height of the core and π is 3.142

Bulk density was calculated as:

$$\rho_p = \frac{weight\ of\ oven\ dry\ soil}{volume\ of\ soil} \quad (\frac{g}{cm^3})$$

pH

Soil pH of each soil sample was determined both in water and 0.01M$CaCl_2$ solution, using a soil to solution ratio of 1:2.5[15]

Cation exchange capacity (CEC)

The cation exchange capacity (CEC) was determined after extracting the soil samples by ammonium acetate (1N NH4OAc) at pH 7.0,

Total Nitrogen

The total nitrogen determination was done using macro kjeldahl method as described by [16].

Available phosphorus was determined by Bray-1 extraction method [17].

Organic carbon

Soil organic carbon was determined by the Walkley-Black wet oxidation method by [18]. The organic carbon (OC) was determined by titrating this digest with 0.5 N ferrous ammonium sulphate $[NH_4)_2SO_4.FeSO_4.6H_2O]$ to a red (maroon) end point. The organic carbon content was calculated using the following formulae:

$$OC\ \% = \frac{(\text{Blank titre} - \text{Actual titre}) \times 0.3 \times m \times f}{\text{Weight of air dried soil taken}}$$

Where f =correction factor =1.33,

m =concentration of $FeSO_4$= <u>Concentration of $K_2Cr_2O_7$ × Volume of $K_2Cr_2O_7$</u>

Blank titre

Organic carbon (OC) (g/kg) = OC (%) ×10

Indexing soil quality indicators

This is due to temporal and variability of soil, complexity of an ecosystem and differences in soil management practices available. [6]Andrews *et al.,* 2001 postulated that once the systems management goal are identified, soil quality indexing involve three main step

i. Choosing appropriate soil quality indicator for minimum data set
ii. Transforming indicators score
iii. Combining indicators the scores into the index.

Choosing appropriate soil quality indicator for minimum data set

The important step in indexing soil quality indicators is to choose appropriate soil quality indicators to efficiently and effectively capture the effect of critical soil functions as determined by management goal for which the evaluation is being made. [8] proposed a minimum set of data, which is the smallest set of soil properties or indicators needed to measure soil quality, identifying key soil properties or attribute that are sensitive to change in soil functions established a minimum data set

Table 1 show Soil quality indicators selected for minimum data set and its function

Indicators of soil condition	Relationship to soil condition and function
Less is better	**physical**
Texture	Retention and transport of water and chemical,

Bulk density and infiltration	Potential for leaching ,productivity and erosivity
Water holding capacity	Related to water retention ,transport and erosivity, available water texture and organic matter
Indicator more is better	**chemical**
Soil organic matter	Fertility and stability
Electrical conductivity	Plant and microbial activity
Extractable N, P, and K	Plant loss available and for N
Optimum is better	**biological**
pH	Biological and chemical activity threshold
Potentially mineralization	Soil productivity and N supplying potential
Soil respiration, water content and temperature	Microbial activity

[8]

Transforming indicators score

This involve selecting MDS for assessing a particular management objective, [5] explained that this step is required so that biological, chemical and physical indicator measurement with totally different measurement unit can be combined. [19] emphasized simplicity of design and use by developing a linear scoring techniques that relies on the observed of data to determine the highest possible score for each indicator and non- linear score technique involve the use of curve linear scoring functions with a y-axis ranging from 0 to one and x axis representing a range of site of function

a) More is better: total nitrogen, cation exchange capacity organic carbon content microbial biomass
b) less is better: bulk density
c) optimum is better: porosity electrical conductivity, water filled pore space phosphorus, pH, would electrical conductivity [20]

Statistical Analysis

Analysis of variance (ANOVA) test was done to determine significant difference among treatments. In conditions where there was significant difference, mean comparison was performed with least significant difference (LSD) at 0.05% level of probability using statistical analysis software (SAS) [21]. Correlation analysis was also used to determine level of relationship between soil properties of the slopes and the land uses.

RESULTS AND DISCUSSION

Bulk density

The BD under cultivated land is 1.49 Mgm^{-3} at 0-5 cm (1.49 Mg m^{-3}) and 1.46Mgm^{-3} at 5-10 cm (1.46 Mg m^{-3}),but low BD values at 0-5 cm (1.42 Mg m^{-3}) and 5-10 cm (1.34 Mg m^{-3}) are recorded under forestland (Table 2). The relatively high bulk density under cultivated lands is attributed to trampling effects, continuous cultivation and soil surface sealing/ crusting.[22] observed that bulk density rapidly increased with depth in the surface, but remained uniform at depth more than20 cm. [23] observed that reduction of bulk density in forest soils is due to restricted movement of machine as against continuous cultivation.. Forest litter and roots' decompose over time to improve quality of surface soils and reduce bulk density.[24] also reported that conversion of forestland into cultivated land during a 12-year period increased bulk density and decreased total porosity. Perhaps, forest soils have higher organic matter (OM) content in making the soil loose, porous and well-aggregated and in reduction of soil bulk density. The result also shows that bulk densities decreases with slope. The variation of soil bulk density among slope gradients might be attributed to variation of disturbance of soil particles by erosion. Suspended finer particles were transported down the slope where they accumulate at the bottom; thus increasing clay and silt content at the bottom slope positions with higher micro porosity and lower bulk density [25].

Available soil water content

Available moisture content was determined at two depths (0-5 cm and 5-10 cm). Results show that forest retained more water of 4.20 cm^3/cm^3 at 0-5 cm and 4.32 cm^3/cm^3 at 5-10 cm, than cultivated soils with values of 2.82 cm^3/cm^3 at 0-5 cm and 2.79 cm^3/cm^3 at 5-10 cm. (Table 2). The results are in agreement with the statement of forest soils hold more water as compared to cultivated lands due to clay and organic carbon (OC) [26]. .

This confirms that cultivation deteriorates soil structural aggregation and reduces soil water retention capacity [27]. Soil water at field capacity (FC) for all land use systems shows decreasing trend with depth [25]

Table 2: Effects of Land Use and Slope on Dry and Wet Mean Weight Diameter,bulk density, and available moisture content.

	BD (Mg m^{-3}) 0-5cm	BD(Mg m^{-3}) 5-10cm	AMC 0-5 cm(cm^3/cm^3)	AMC 5-10 cm (cm^3/cm^3)	dmwd	wmwd
Land use						
forest	1.42[a]	1.34[a]	5.96	5.79	1.19	1.19
cultivation	1.49[a]	1.46[a]	3.17	3.84	1.24	1.27
SE±	0.05	0.06	0.2	0.33	0.08	0.12
Cultivated slope						
upper	1.43	1.40[a]	1.3	1.6	1.22	1.00
middle	1.46	1.40[a]	4.2	3.2	1.04	1.51
lower	1.36	1.23[a]	2.3	1.5	1.32	1.05
Forest slope						
upper	1.50	1.53[a]	4.03	4.06	1.21	1.36
middle	1.46	1.43[a]	4.5	5.53	1.18	1.04
lower	1.50	1.40[a]	4.06	3.36	1.31	1.36
SE±	0.06	0.06	0.28	0.03	0.10	0.15

AMC= available moisture content, dmwd =dry mean weight diameter and wmwd =wet mean weight diameter

Conventional ploughing; which is commonly practiced in Afaka areas, causes damage to soil structure. [28] reported a loss of intermediate aggregate size classes after long term cultivation with more pronounced negative effects of cultivation on macro aggregate size classes. This finding supports that the conversion of native forest to cultivation leads to deterioration of soil structure [29] as applicable to Alfisols in Afaka forest reserve in Northern Guinea savanna of Nigeria.

Table 3: Effects of Land Use and Slope on Total Nitrogen, Available Phosphorus, Exchangeable Sodium Concentration, cation exchange capacity

	TN (g kg^{-1})	AP (mg kg^{-1})	NA (cmol kg^{-1})	CEC (cmol kg^{-1})
Land use				
forest	1.2	8.78	0.44	8.60
cultivation	1.1	5.4	0.45	8.54
SE$\pm$	0.01	2.1	0.04	0.5
Cultivated slope				
upper	1.1	9.60	0.43	7.93
middle	1.4	3.2	0.51	9.56
lower	0.9	13.4	0.41	8.13
Forest slope				
upper	1.4	8.82	0.39	9.00
middle	1.4	5.01	0.48	9.00
lower	0.9	2.45	0.43	7.80

SE±	0.41	2.57	0.05	0.60

TN = total nitrogen, AP = available phosphorus, Na = sodium and CEC = cation exchange capacity.

Dry means weight diameter (dmwd)

Forestland had mean dry aggregate fractions of 1.24 mm; while cultivated land had 1.19 mm cultivated land has 1.22 mm, 1.04 mm and 1.32 mm for upper, middle and lower slopes. Similarly, forestland had 1.21 mm, 1.18 mm and 1.31mm for upper, middle and lower slopes respectively depth of 0 -10 cm (Table 2). This implies a negative impact of tillage on aggregate size distribution when compared with values in forest land use. Dry aggregate size distribution is one of the major physical characteristics of soil that strongly affects soil quality, fertility and its resistance to erosion and degradation and is also considered an indicator of soil structure [22]

Wet mean weight diameter (WMWD)

.Cultivated land recorded 1.19 mm; which was lower than forested land with 1.26mm. Similarly, cultivated land recorded 1.00 mm, 1.51 mm and 1.05 mm for upper, middle and lower slopes while forest recorded 1.36 mm, 1.04 mm and 1.36 mm for upper middle and lower slopes respectively at depth of 0-10cm (Table 2). The mean water stable aggregates were highest at forest than cultivated land though not statistically significant ($p > 0.05$). The low wet MWD recorded in cultivated land may be associated with degradation of large macro-aggregate fractions in the dry soil when immersed in water [23]

Total nitrogen

Total N contents were highly affected by the different land use systems. Total soil nitrogen at 0-10 cm depth had mean of 1.11 g kg^{-1} under cultivated land, while 1.2 g kg^{-1} was recorded under natural forest land, cultivated land had mean of 0.9 g kg^{-1}, 1.4 g kg^{-1} and 1.05 g kg^{-1} of total nitrogen for upper, middle and lower slopes respectively, while forestland had mean of 1.4 g kg^{-1}, 1.4 g $kg^{-1}$and 0.9 g kg^{-1} total nitrogen in upper, middle and lower slopes respectively (Table 3). [30] reported that presence of dense vegetation affords the soil adequate cover, thereby reducing loss in macro and micro nutrients that are essential for plant growth and energy fluxes. The total nitrogen status was low in cultivated land and high under natural forest land use in Afaka northern guinea savanna of Nigeria. [31] reported that natural forest soils had more total nitrogen compared to cultivated lands. [32] reported highest total N on surface soil layers of virgin lands compared to cultivated and farmers' fields. Total nitrogen decreased consistently with depth under land use systems corresponding to the findings of [33, 34, and 35]

Available phosphorus (AP)

Available phosphorus (AP) concentration of land use systems had mean values of 8.78 mg kg^{-1} and 5.47 mg kg^{-1} for forest and cultivated land, Lower slopes recorded 13.4 mg kg^{-1} available phosphorus, followed by upper slope with 9.60 mg kg^{-1} and middle slope with 3.2 mg/kg in cultivated land. Forestland at upper slopes recorded 8.82 mg kg^{-1} available phosphorus, followed by middle slope with 5.01 mg kg^{-1} and lower slope with 2.45 mg kg^{-1} in (Table 3). [36] reported that natural forestland contained relatively higher concentration of AP as a result of high organic matter turnover in soils, which released phosphorus during its mineralization and is in conformity with findings from this study. The difference in available phosphorus might be due to increased clay and reduced organic matter concentration in cultivated land. Organic compounds in soils increase P availability by the formation of organophosphate complexes that are more easily assimilated by plants, anion replacement of H_2PO_4 from adsorption sites, the coating of Fe/Al oxides by humus to form a protective cover and reduced phosphorus fixation [36]. Also, decomposing of organic matter releases acids that increase solubility of calcium phosphates [37, 38 and 39]. Available P was positively correlated with organic carbon [36].

Differences of slope gradient among the areas did not significantly ($P > 0.05$) affect available P (Table 3). The lowest (4.12 mg kg^{-1}) and highest (9.31 mg kg^{-1}) contents of available P were recorded in soils of middle slope and upper slope terrains respectively (Table 3). [40] also reported low available P within soils having low content of OM, but [41] stated that available P content of Tropical soils did not necessarily decrease with decrease of organic matter. The low contents of available P observed in soil of the study area were in agreement with reports by some authors [42]; that availability of P under most soils of savanna Alfisols decline by the impacts of fixation, abundant crop harvest and erosion.

Cation exchange capacity (CEC):

Forestlands recorded CEC value of 8.60 cmol kg^{-1} compared to cultivated land with mean value of 8.54 cmol kg^{-1} while the lower slopes in forestland showed decrease in CEC with 7.80 cmol kg^{-1} and 9.00 cmol kg^{-1} for upper and middle slope respectively. The upper slope of cultivated land showed decrease in CEC with 7.93 cmol kg^{-1}, 9.56 cmol kg^{-1} for middle slope and 8.13 cmol kg^{-1} for lower slope (Table 3). Cation exchange capacity (CEC) of the study area was not affected by land use. [42] Reported higher CEC value in soils under natural forest than soils under cultivation. [43 reported lower CEC values obtained in cultivated land and could be partly attributed to erosion, nature of soils and low organic matter content of the soils.

Soil pH (H_2O) **and $CaCl_2$**

The highest soil pH in water (pH 7.16) was recorded in forestland and pH 6.9 in cultivated land.

The upper slope had pH (H_2O) 6.9, middle slope had pH (H_2O) 6.9 and lower slope had pH (H_2O) 6.8 in cultivated land, while forestland had pH (H_20) 7.2, 6.9 and 7.2 for upper, middle and lower slopes respectively. Values of soil pH ($CaCl_2$) were 6.49 and 6.22 for forest and cultivated land use types respectively. Upper slopes had pH ($CaCl_2$) 6.13; middle slope had pH ($CaCl_2$) 6.16 and lower slope had pH ($CaCl_2$) 6.36 in cultivated land, while 6.5 pH ($CaCl_2$), 6.3 pH ($CaCl_2$) and 6.6 pH ($CaCl_2$) values were recorded in forest land (Table 4). It however increased slightly down the topographic positions in soils of both cultivated and forested lands. The increasing trends in pH from middle to lower slope positions may be due to higher deposition of basic cations in lower slope positions. This agrees with [44], [45] and [46] who independently reported low pH value in soils of high altitude and steeper slopes are associated with washing out of solutes from these parts.

Table 4: Effects of Land Use and Slope on pH in water and in $CaCl_2$

	pH (H_2O)	pH ($CaCl_2$)
Land use		
forest	7.16	6.49
cultivation	6.90	6.22
SE$\pm$	0.1	0.12
Cultivated slope		
upper	6.9	6.13
middle	6.9	6.16
lower	6.8	6.36
Forest slope		
upper	7.2	6.5
middle	6.9	6.3
lower	7.2	6.6
SE$\pm$	0.12	0.14

Criteria for Soil Quality Monitoring and Evaluation in Afaka reserve, Nigeria

Table 5 shows that mean weight diameter dry for forest soil (1.24mm) is greater than for cultivated land (1.19mm). The pH in H_2O and $CaCl_2$ shows that pH decreased slightly under cultivation and increased under forest. Both pH in H_2O and $CaCl_2$ followed the same trend. The results further shows increase in organic carbon contents under forest (10.2 g kg^{-1}) while cultivated land show decrease in organic carbon content (8.21 g kg^{-1}). The total N content of (1.2 g kg^{-1}) is more in forestland, than cultivated land with 1.1 g kg^{-1}.

Table 5 shows that forestland had the highest content of available P (8.78 mg kg^{-1}), Cultivated land had the least (5.47 mg kg^{-1}) and this could be attributed to crop uptake of phosphorus since it has been proven that legumes use up phosphorus more and the presence of legume facilitates the utilization of soil phosphorus by crops in the low P soil of Northern Guinea Savanna of Nigeria [36].

Cation Exchange Capacity (CEC) decreased slightly under cultivation (8.54 cmol kg^{-1}), and increased slightly with forest 8.60 cmol kg^{-1} in CEC would imply that soil health/quality over the years had been positively impacted upon by the management practices [47];[48]. The data shows that lower slope had the least bulk density (1.37 Mg m^{-3}) while upper had the highest bulk density 1.47 (Mg m^{-3} then 1.44 (Mg m^{-3}) record in the middle slope, it's also shows that there was increase in organic carbon contents under middle slope 11.0 g kg^{-1} fallowed by upper slope with 9.30 g kg^{-1} then lower slope 7.40 g kg^{-1}. Total N content of 1.20 g kg^{-1} was observed at upper slope, 1.4 g kg^{-1} and 0.9 g kg^{-1} at middle and lower slope respectively.

The results shows that upper slope had the highest content of available P among the other slopes, this could be attributed to crop uptake of phosphorus and the presence of legume facilitates the utilization of soil phosphorus by crops in the low P soil of Northern Guinea Savanna of Nigeria [49]. It shows that CEC decreased slightly under lower slope 7.97 cmol kg^{-1}, 8.46 cmol kg^{-1} at upper slope and increased under middle slope 9.28 cmol kg^{-1} . Table 5 shows that lower slope increased in dry mean weight diameter with 1.32mm while upper slope had 1.22 mm. Lower slopes show least in wet mean diameter (1.19 mm) and upper slope (1.21mm), middle slope shows increase with (1.28 mm) table 5. It shows that pH in water decreased slightly under middle slope and increased under lower slope. Decrease in soil pH however, was not sufficient to hamper crop growth. Both pH in H_2O and $CaCl_2$ did not followed the same trend. Management practices which were superior by improving soil quality were ascertained from results and a summary of the threshold limits using soils (Table 5).

Table 5: Threshold limits of soil quality assessment for the land uses in Afaka Alfisols Using Minimum Data Set

Soil parameter	**Forest**	**Cultivated land**
Bulk density (Mg m^{-3})	1.34	1.46
Organic carbon (g kg^{-1})	10.2	8.21
Total nitrogen (g kg^{-1})	1.2	1.1
Available phosphorus (mg kg^{-1})	8.78	5.47
CEC (cmol kg^{-1})	8.60	8.54
Dry mean weight	1.24	1.19
Wet mean weight	1.27	1.19
pH (H_2O (1:2.5)	7.16	6.90
pH ($CaCl_{2)}$ (0.01M)	6.49	6.22

Table 7: Threshold limits of soil quality assessment for the slope in Afaka forest reserve savanna Alfisols.

Properties	upper	middle	lower
Bulk density (Mg m^{-3})	1.47	1.44	1.37
Organic carbon (g kg^{-1})	9.30	11.0	7.40
Total nitrogen (g kg^{-1})	1.20	1.4	0.9
Available phosphorus (mg kg^{-1})	9.31	4.12	7.94
CEC (cmol kg^{-1})	8.46	9.28	7.97
Dry mean weight	1.22	1.11	1.32
Wet mean weight	1.21	1.28	1.19
pH (H_2O (1:2.5)	7.03	6.97	7.08
pH ($CaCl_{2)}$ (0.01M)	6.38	6.37	6.32

Table 8: Soil Quality Monitoring and Evaluation in Afaka forest, Nigeria

	Soil of Afaka		
Soil parameter	High	Medium	Low
Bulk density(Mg m^{-3})	≥ 1.4	1.2– 1.4	< 1.2
Organic carbon (g kg^{-1})	> 15	10 – 15	< 10
Total nitrogen (g kg^{-1})	0.3	0.2-0.3	<0.2
Available phosphorus(mg kg^{-1})	≥ 4.0	2.5 – 4.0	< 2.5
CEC(cmol kg^{-1})	>8.0	7.0 – 8.0	< 7.0
Dry mean weight	≥1.5	1.3 – 1.5	< 1.3
Wet mean weight	≥1.5	1.3 – 1.5	< 1.3
pH (H_2O(1:2.5)	>5.5	4.8 – 5.5	< 4.8
pH ($CaCl_{2)}$ (0.01M)	>4.5	4.0 – 4.5	< 4.0

Note: > is greater than, < less than, ≥ greater than or equal to, ≤ less than or equal to

Table 9: combining indicators the scores into the index (SMAF protocol)

Functions	Indicators	forest			Cultivated		
		upper	middle	lower	upper	middle	lower
Ease of tillage	Bulk density	0.015	0.014	0.015	0.014	0.014	0.013
Biological activities	Organic matter	0.12	0.12	0.123	0.087	0.096	0.06
Support plant growth	Total N	0.014	0.014	0.009	0.011	0.014	0.009
Support plant growth	Available p	0.08	0.05	0.024	0.096	0.032	0.134
Plant nutrient	CEC	0.09	0.09	0.078	0.079	0.095	0.081
Resistance to air erosion	Dry mean weight	0.012	0.012	0.013	0.012	0.010	0.013
Resistance to water erosion	Wet mean weight	0.013	0.010	0.013	0.01	0.015	0.010
Salinity	pH (H_2O(1:2.5)	0.072	0.062	0.072	0.069	0.069	0.068
Salinity	pH ($CaCl_2$) (0.01M)	0.065	0.063	0.066	0.061	0.061	0.063
	Total (Index)	0.481	0.435	0.413	0.439	0.406	0.451

Table 10: Ranking of soil quality under different land use and slopes

Slope positions	Total score	Percentage	Ranking
F upper	0.481	48.1	1
C lower	0.451	45.1	2
C upper	0.439	43.9	3
F middle	0.435	43.5	4
F lower	0.413	41.3	5
C middle	0.406	40.6	6

A score scale of 1 to 6 was used in the assessment of parameters; where 1 is best and 6 is the worst condition.

Summary

The study was conducted with the aim to determine Effect of land use on soil quality in afaka forest northern guinea savannah of Nigeria and assess quantitatively, effect of forest and cultivation land uses on soil quality. Rigid grid detailed survey was employed. Soils on geomorphic positions were sampled on grid survey. Soil samples from 0- 5 cm (top soil) and 5 - 10 cm (lower layer) were collected at auger points determined along traverses from cultivated land and in adjacent forest, in each delineated geomorphic position of the study area. The sample area covered 1 × 1 km, data collected was analyzed with SAS software [21] computer package to test for significant difference among treatments. In conditions where there was significant difference, mean comparison was performed with least significant different (LSD). However, The results also show no significant difference between these land use types and slope positions ($p<0.05$) on cation exchange capacity, total nitrogen, available phosphorus, Soil quality evaluation was based on the soil management assessment framework (SMAF), scoring functions for 14 potential soil quality indicators and a minimum data set (MDS) was established. The MDS selected in this study include soil functions such as ease of tillage, salinity support for plant growth, bulk density (BD), CEC, total N, available P, and exchangeable K were used as indicators for plant growth support, while organic carbon was indicator for biological activity in the soil, MWD was used to assess erodibility of the soils. Alfisol at the upper forest land had better soil quality than those at the slope positions. Slight change in CEC would imply that soil health/quality over the years had been positively impacted upon by the management practices.

Conclusion

From the study, it was concluded that soil quality significantly varied among land use systems and slope positions in the study site. Shift in land use systems from natural forest to agricultural land use systems had detrimental effect on soil quality. The result indicates that organic matter concentration declined particularly in the upper slope of cultivated land, when compared to forest land. The result also indicates impact of forest on compaction of soils by the relatively high bulk density values recorded in soils under cultivated land use type on almost all the topographic positions. However, slope position affected most selected soil properties under different land use types considered in this study. The study indicates that cultivation led to increased bulk density, reduced organic carbon, aggregate stability and water retention, total nitrogen, available phosphorus and potassium compared to forest land. The soil quality management should address the problem of land degradation which will help in mitigating the effects of climate change and global warming.

Recommendations

It is recommended that integrated land management should be practiced that involving long term research and evaluation on land uses and slope on soil quality changes, Long-term experiments (10–30 years) should be conducted to establish the positive and negative effects of different land uses on soil quality for developing models so that appropriate action could be taken accordingly

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