AN ASSESSMENT OF THE EFFECT OF SOIL DEGRADATION ON SOILS OF LAPAI AREA, NIGER STATE, NIGERIA

By

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ABSTRACT

The research was carried out to assess the effect of soil degradation on soils of Lapai area. One hundred samples comprising of four sub-samples taken from five different land uses (plantation, 'fadama', cultivated, scrubland and badland) were analysed for key soil properties. Descriptive statistics were used to summarise the data while Analysis of variance and student t-test were used to analyse the data. The particle size distribution tests show that sand fractions in the soils are higher over scrubland at 77.3% and least over 'fadama' (51%). The highest bulk density value is in badland (1.62g/cm^3) and least over plantation (1.37 g/cm$^{3.}$). Results also show that soil pH is highest over plantation (6.51) and lowest over badland (5.40). The analysis of variance for Ca shows that significant difference exist at 0.05 level in the respective landuses. Mean value of total nitrogen is highest in the plantation (0.79%) and least over bad land (0.23%). Comparison of results to critical values of soil fertility ratings show that soils in the study area have undergone degradation resulting to higher bulk densities, lower porosity, lower soil moisture contents, low organic matter content, higher pH values and low CEC values of soils, particularly over badland and cultivated landuses. Recommendations include formulating policies which eliminate discriminatory land ownership rights, rehabilitation of degraded lands and encouraging sustainable soil management practices such as tree planting, mulching, fallowing and intercropping.

Key words: Analysis, Degradation, Indicators, Landuse, Soil

1NTRODUCTION

Soil degradation is a serious and multi-facetted environmental problem characterized by physical, chemical and biological deterioration of soils. Soil degradation processes can occur naturally or accelerated by human activities such as over cultivation, deforestation, and so on (Gessess, Klik and Hurni, 2009; Aminu and Jaiyeoba, 2015). Soil degradation contributes to the depletion of biodiversity, directly through the degradation and destruction of lands and indirectly by accentuating the need to expand cropping into natural forests and rangelands (Pagiola, 1999) and also causing extensive damages to the environment.

Soil degradation result in reduced soil quality and consequent poor soil health. The concept of soil quality describes ability of a soil to function in a sustainable manner. For example, Doran and Parkin (1994) defined soil quality as the capacity of a soil to function within ecosystem boundaries to sustain biological productivity, maintain environmental health and promote plant and animal health. An assessment of soil health and quality is necessary to evaluate and monitor the degradation status of soils over various land uses (Lal, 1993). Sensitivity and resilience are measures of vulnerability of soils and are affected by factors such as topography, soil properties and human influence (Stocking and Murnaghan, 2000). Soil resilience is defined as the ability of a soil to restore its living systems after disturbance while sensitivity is the degree to which a soil undergoes change due to natural forces, human intervention or a combination of both (Bridges and Van Baren, 1997; Stocking and Murnaghan, 2000).

Soil degradation assessment is a complex phenomenon and is often exacerbated by the high levels of variation in the properties of African soils (Swift and Shephard, 2007). Landuse conversions associated with increasing population have been observed in the study area (Dadzi, 2013). Although several studies on soil degradation have been carried out in Lapai area (Dadzi, 2013; Aminu and Bamidele, 2015) using remote sensing/GIS and perception studies, observation shows that there is a dearth of information on the effect of soil degradation on soil health in the study area. Therefore, this study aims at an assessment of the effect of soil degradation on soils in Lapai area. Specifically, the objectives of the study are determination of key soil properties with a view of establishing a link between landuse types and the magnitude of soil degradation in the area.

THE STUDY AREA

Lapai area is located in the southern part of Niger State between latitude $9^0$02´ -$9^0$06´ N and longitude $6^0$31´ -$6^0$38´E. Geologically, Lapai area (Fig.1) is underlain by sedimentary rocks and undifferentiated Basement Complex of mainly Gneiss, magmatite and schist (Obaje, 2009). It is characterized by sandstones and alluvial deposits. The study area is also characterized by low relief with minor rock outcrops and has a gentle undulating surface. Soils in the study area are ferruginous tropical soils and are hydromorphic in depressions and valley bottom positions, while those around the inselbergs and other residual hills, and at the bed of rivers, are weakly developed soils (Jaiyeoba and Essoka, 2006).

The area is drained by river Ndakotsu and its tributaries, Audu Sanbi, Danbugi, Kun Yan Tsaiwa which discharge into River Gurara. The area is sub-humid and experiences distinct wet and dry seasons with a mean annual rainfall value ranging between 1400mm to 1600mm. The rainy season starts from April to October. The cold harmattan is between November and February. The maximum air temperature of about 27^0C is recorded between March and June, while the minimum air temperature of about 23^0C usually occur between December and January. The study area lies within the Southern Guinea Savanna zone characterized by woodland vegetation type although most of the natural vegetation cover have undergone anthropogenic modification (Jaiyeoba and Essoka, 2006).

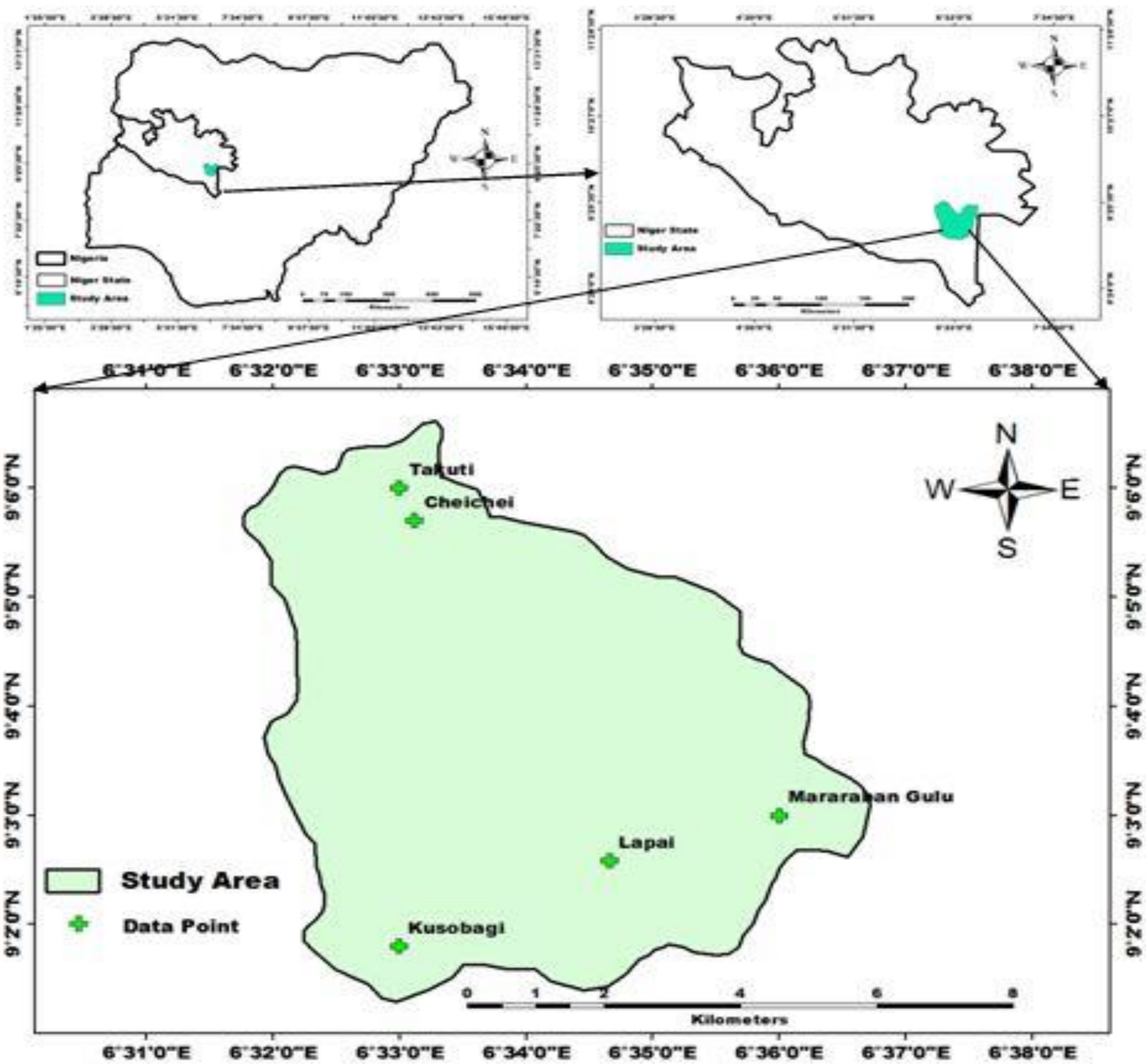

Figure 1: Geographical Location of Study Area

MATERIALS AND METHODS

Soil samples used for the determination of soil physico - chemical properties were drawn from the five land use categories in five villages namely, Lapai, Mararaban Gulu, Kusobagi, Cheche and Takuti (all located 15km from Lapai town, as the central point). The choice of the locations is to reduce climatic and physiographic variations as much as possible. Dominant landuses identified for the study are plantation, 'fadama' (wetlands), badland, scrubland and cultivated landuses. For each identified land use category, surface soil samples at 0-15 cm depth were taken at four equi-distant points along transects. A total of 100 samples were drawn from 5 land uses across 5 locations and used for the study (that is, 4 points × 5 landuses × 5 locations= 100).

Each soil sample was air- dried, crushed and sieved through a 2mm sieve. Each sample was analysed for water content gravimetrically. Bulk density was determined using the core method while percentage porosity values were determined from bulk density values (using a particle density of 2.65g/cm^3). Particle size distribution was determined using Bouyoucos hydrometer method. Soil pH was determined potentiometrically in water and $CaCl_2$, using a soil to solution ratio of 1:2.5. The Walkley-Black digestion method was used to determine soil organic carbon. Total Nitrogen was determined using macro Kjedahl method while Available Phosphorous was determined using Bray No.1 method. The cation exchange capacity (CEC) was determined using the ammonium acetate saturation method. The leacheate preserved during CEC determination was used to determine exchangeable bases. The base saturation was derived by dividing sum of values of exchangeable bases by the CEC value and expressed as percentage. Similarly, exchange acidity was determined by extraction with KCl (Agbenin, 1995).

Descriptive statistics such as mean, standard deviation and coefficient of variation (CV), analysis of variance (F-ratio) and student t-test were used to analyse the data generated.

RESULTS AND DISCUSSION

Physical and Chemical Characteristics of Soils under Different Land uses

Table 1 summarizes mean values, standard deviation, coefficient of variation and Analysis of Variance (ANOVA) performed to test for significant differences amongst the various land uses while Table 2 summarizes results of t-test performed to detect soil physico -chemical properties which vary significantly between pairs of land uses.

The mean value of sand over scrubland is highest (77.3%) and ranged between 67% over plantation, 68% over cultivated land and 69% over badland landuse. However, mean value over ‘fadama’ landuse is lowest (51%). Analysis of variance shows statistically significant variation in sand fractions as indicated in ‘fadama’ landuse. Similarly, variation in silt fractions is statistically significant at $p > 0.05$. The mean value is highest over ‘fadama’ landuse (31%) and lowest over the scrubland (14.7%). The coefficient of variation for silt is highest over fadama landuse (39.9%) and is followed by scrubland with 35.5%. Analysis of variance shows statistically significant difference at 0.05 level in silt fraction of soils over the different landuses. Similarly, clay fraction shows significant variation in soils over the different land use types. The mean values of clay are higher in the ‘fadama’ landuse (17.9%) and lowest over scrubland (8.0%). Similar studies by Afolabi *et al*., (2014) attributed low silt and clay fractions in soils to slow rate of weathering and the relatively young age of the soils.

The result from Table 1 shows statistically significant differences at $p \geq 0.05$ in soils over the different landuses. The highest bulk density value is in badland (1.62 g/cm^3), followed by cultivated land (1.58 g/cm^3), scrubland (1.51 g/cm^3), ‘fadama’ (1.47 g/cm^3) and least over plantation (1.37 g/cm^3). There is relative homogeneity in bulk density values over the landuses as indicated by the generally low coefficient of variation (between 2.46 to 6.56 %). The result of t-test analysis shows significant difference in bulk density between the different land uses. Generally, soils of the study area have high bulk density values than the recommended value of 1-1.45 g/cm^3 for tropical soils (Brady, 1990; Esu, 1991; Malgwi, 2007). Similar studies by Aminu and Jaiyeoba (2015) observed high bulk density values across all the dominant land use categories in the Zaria area of Northern Nigeria. High bulk density values in the soils reduce porosity and have implications for infiltration and plant rooting depths (Brady, 1990; Malgwi, 2007; Madaki, 2011).

Similarly, soil porosity values over the different land uses are generally less than 50%. The value is lowest over badland (38.9%), cultivated land (40.4%), scrubland (43%) and highest over plantation (48.3%) and 'fadama' (44.5%). The analysis of variation shows that there is a significant difference at 0.05 level in porosity over the different land use categories. The low porosity may be a reflection of the high bulk densities across the respective land use categories.

Mean values of gravimetric moisture content over the respective land uses are generally low and range between10.7% to 23.3%. It is highest over 'fadama' landuse (22.3%), plantation (18%), cultivated land (13.9%) and lowest over scrubland (10.7%) and badland (9.86%). The coefficient of variation across the landuses range between 51.6% (over badlands) and 24.4% ('fadama'). Although the analysis of variance indicates significant difference at $p \geq 0.05$, t-test results show no significant difference between pairs of land uses.

The analysis of variance shows statistically significant difference in the respective land uses at $p \geq 0.05$. The mean value of soil pH is highest over plantation (6.51), followed by 'fadama' (6.49), cultivated land (6.33), scrubland (6.00) and least over the badland topography (5.40). This may be due to granitic lithology the study area or leaching of soil cations which have been found to increase soil acidity (Afolabi *et al.,* 2014; Aminu and Jaiyeoba, 2015).

Mean values of soil exchangeable acidity ($H \pm Al^{3+}$) is highest over the badland (0.40 cmol/kg^{-1}). The values over the remaining landuses are homogeneous (between 0.08 and 0.09 cmol/kg^{-1}).). Analysis of variance reveals significantly different values amongst the various landuses and is supported by the high coefficient of variation of soil exchangeable acidity ($H \pm Al^{3+}$) among the respective landuses categories. The values range between 77.8% ('fadama'), 75% (scrubland), 50% (cultivated land), 44.4% (plantation) and 30% (badland). Result of t-test show no significant difference between most pairs of land uses. However, exchangeable acidity ($H \pm Al^{3+}$) varied significantly between plantation/badland, scrubland/badland, badland/cultivated and cultivated/ 'fadama' land uses.

The mean value of soil base saturation is highest over plantation (69%) and lowest over badland (29%). The coefficient of variation is 50% over badland and intermediate over other landuses. Although the analysis of variance did not reveal significant difference in the base saturation amongst the various landuses, t-test result shows significant differences between most pairs of land uses. The lower base saturation over cultivated and badland uses may be attributed to absorption of ions by plants and leaching (Madaki, 2011).

The mean value of soil organic matter is highest over the plantation landuse (1.66%), followed by 'fadama' (1.28%) and scrubland (1.23%). The values are lowest over cultivated land (1.11%) and badland (0.80%). Although coefficient of variation in the different landuses is consistently low (less than 40%), analysis of variance shows a significant difference in soil organic matter at 0.05 level. Similarly, t-test analysis show significant difference between pairs of land uses. However there is no difference between the pairs of scrubland/cultivated land and scrubland/'fadama'. The generally low levels of soil organic matter across respective land uses is confirmed by similar studies (Afolabi *et al*., 2014) which attributed low organic matter of the study area soils to rapid mineralization of organic matter.

The analysis of variance for Ca shows significant difference exist at 0.05 level in the respective land uses. The mean value is highest over cultivated land (2.80 cmol/kg^{-1}), plantation (2.60 cmol/kg^{-1}), scrubland (2.40 cmol/kg^{-1}) and least over badland (0.71 cmol/kg^{-1}). Results also show significant differences of exchangeable Mg over respective landuses. Mean value was highest over 'fadama' (1.17 cmol/kg^{-1}) and lowest over badland (0.21 cmol/kg^{-1}). The values of exchangeable Na over various land uses were similar and showed no significant differences among landuses. The mean values display relative homogeneity with 0.17 cmol/kg^{-1} over plantation, scrubland and badland, while cultivated and 'fadama' landuses have 0.19 cmol/kg^{-1} and 0.23 cmol/kg^{-1} respectively. The mean value of exchangeable K shows statistically significant differences at 0.05 level amongst the landuse types. Generally, results of t-test show significant differences in exchangeable bases between most pairs of landuse categories.

The analysis of variability for CEC shows significantly different amounts amongst the landuse types. The value is highest over cultivated land (7.16 cmol/kg^{-1}) and 'fadama' (6.43 cmol/kg^{-1}), and lowest over badland (4.27 cmol/kg^{-1}). The CEC values across different land use categories are generally low. The higher CEC values over cultivated and 'fadama' land uses may be attributed to direct application of NPK fertilizer which has been found to increase the CEC content of soils (Oluwadare, Voncir, Mustapha and Mohammed, 2013).

Results show mean values of total nitrogen (TN) range between 0.79 - 0.23%. The highest mean value was in the plantation and cultivated land uses (0.79% and 0.56%), while the least values were over badland and scrubland (0.23% and 0.24%). The analysis of variance shows no significant difference among the different landuse categories. The area generally shows low levels of TN and may be due to loss of nitrogen through mineralization as a result of high diurnal temperatures (Madaki, 2011). Result of t-test analysis shows that with the exception of the pair of scrubland and badland, all other pairs of land uses showed significant difference in their total nitrogen content.

Table 1: Variations of Soil Physical and Chemical Properties Over Different Land Uses

Land uses	Sand %	Silt %	Clay %	Bulk density (g/cm^3)	Porosity %	MC %	pH (1:2.5) (soil:H_2O)	Organic matter (%)	TN (%)	AP (mg/ kg-^{1})	Ca	Mg	K	Na	CEC	H+AL	BS %
							Soil Properties				← (cmol/kg^{-1})				→		
Plantation																	
$\bar{x}$	67.0	24.7	8.30	1.37	48.3	18.0	6.51	1.66	0.79	3.85	2.60	0.92	0.10	0.17	5.46	0.09	69.1
SD	9.36	6.7	4.22	0.09	4.01	5.35	0.44	0.33	0.23	1.51	0.80	0.34	0.03	0.02	1.10	0.04	15.6
CV%	13.9	27.2	50.8	6.56	8.30	29.7	6.75	19.9	29.1	39.2	30.8	37.0	30.0	11.8	20.0	44.4	22.6
Scrubland																	
$\bar{x}$	77.3	14.7	8.0	1.51	43.0	10.7	6.00	1.23	0.24	4.03	2.40	0.92	0.07	0.17	5.38	0.08	66.2
SD	8.24	5.2	4.01	0.08	3.67	5.20	0.14	0.31	0.21	1.50	0.83	0.32	0.02	0.02	1.11	0.06	15.5
CV %	10.7	35.5	50.1	5.29	8.50	48.6	6.83	25.2	87.5	37.2	34.6	34.8	28.6	11.6	20.6	75.0	23.4
Cultivated																	
$\bar{x}$	68.1	20.6	11.3	1.58	40.4	13.9	6.33	1.11	0.56	5.98	2.80	0.89	0.07	0.19	7.16	0.08	55.2
SD	3.82	4.1	3.83	0.07	3.42	5.34	0.36	0.30	0.20	1.46	0.64	0.36	0.03	0.02	1.12	0.04	15.2
CV%	5.6	20.0	34.0	4.43	8.46	38.4	5.68	27.0	35.7	24.4	22.9	40.4	42.9	10.5	15.6	50.0	27.5
Fadama																	
$\bar{x}$	51.0	31.1	17.9	1.47	44.5	22.3	6.49	1.28	0.36	7.18	2.20	1.17	0.11	0.23	6.43	0.09	57.7
SD	18.1	12.4	8.16	0.09	4.22	5.44	0.65	0.47	0.31	2.35	0.88	0.41	0.04	0.03	1.18	0.07	15.7
CV%	35.5	39.9	45.6	6.12	9.48	24.4	10.0	36.7	86.1	32.7	40.0	35.0	36.4	13.0	18.4	77.8	27.3
Badland																	
$\bar{x}$	69.0	16.0	15.0	1.62	38.9	9.86	5.40	0.80	0.23	3.85	0.71	0.21	0.16	0.17	4.27	0.04	29.3
SD	5.5	3.65	2.46	0.04	3.25	5.09	0.21	0.26	0.15	1.39	0.43	0.14	0.03	0.01	1.08	0.12	14.7
CV%	7.91	22.8	16.4	2.46	8.35	51.6	3.88	32.5	65.2	36.1	60.6	66.7	18.8	5.88	25.3	30.0	50.3
ANOVA	1.74	3.11	7.29	3.24	3.69	6.83	6.03	6.88	0.23	5.01	7.02	4.78	4.27	0.23	4.68	4.25	1.46
Level of sig	**	**	**	**	**	**	**	**	-	**	**	**	**	-	**	**	-

$\bar{x}$ = mean, SD= standard deviation, CV%= coefficient of variation, Level of significance: **=0.05

Source: Laboratory Analysis (2016)

Table 2: Result of Student's t-test Analysis between Pairs of Land Uses

Land Uses	Sand %	Silt %	Clay %	BD g/cm^3	Porosity %	MC %	OM (%)	Ca (cmol/kg^{-1})	Mg (cmol/kg^{-1})	K (cmol/kg^{-1})	Na (cmol/kg^{-1})	CEC (cmol/kg^{-1})	PH soil:H_2O	H+AL cmol/kg^{-1}	BS %	N (%)	AV.P (mg/kg-^{1})
PL/SL	-0.36	1.04	0.997	-6.80*	1.26	1.33	5.73*	5.39*	0.00	3.37*	0.00	0.30	9.86*	0.30	0.71	9.65*	-049
PL/BL	-0.42	0.95	-0.53	-10.9*	1.40	1.45	11.5*	9.40*	8.16*	-6.74*	0.00	4.46*	10.96*	-9.39*	10.9*	9.82*	0.00
PL/CL	-0.43	0.74	-0.71	-9.13*	1.34	1.03	7.33*	-4.62*	5.14*	3.37	-3.17*	-6.36*	9.35*	0.30	3.82*	4.04*	-5.77*
PL/FL	0.57	-0.49	-0.45	-4.35*	1.22	-0.64	5.07*	5.88*	-9.04*	-1.12	-9.52*	-3.63*	9.11*	0.00	3.13*	7.54*	9.02*
SL/BL	0.48	-0.57	-0.51	-4.78*	1.24	0.86	5.73*	8.41*	8.16*	-10.1*	0.00	4.16*	10.1*	-9.69*	10.1*	0.18	0.49
SL/CL	0.49	-0.44	-0.68	-3.04*	1.20	-0.61	1.60	-4.26*	5.14*	0.00	-3.17*	-6.67*	-8.62*	0.00	3.02*	- 5.61*	-5.28*
SL/FL	0.66	-0.29	-0.43	1.74	-1.09	-0.38	-0.67	5.43*	-9.04*	-4.49*	-9.52*	-3.93*	-8.40*	-0.30	2.34*	- 2.10*	-8.54*
BL/CL	0.44	-0.48	-1.28	1.74	-1.08	-0.56	-4.13*	-1.26	-2.71*	-10.1*	-3.17*	-10.8*	-7.76*	9.70*	-7.12*	-5.79	-5.77*
BL/FL	0.59	-0.32	-0.81	6.52*	-0.98	-0.35	-6.40*	-0.61	-2.06*	5.62*	-9.52*	-8.09*	-7.56*	9.39*	-7.81*	-2.28	-9.02*
CL/FL	0.58	-0.41	-0.61	4.78*	-1.02	-0.50	-2.27*	6.33*	-8.74*	-4.49*	-6.35*	2.73*	-8.87*	-0.30	-0.69	3.51	-3.25*

PL= plantation, CL= cultivated land, SL= scrubland, FA= fadama, BL= Badland
Level of significance: *=0.05
Source: Laboratory Analysis (2016)

For available phosphorous, the highest mean value is in the 'fadama' land use (7.18 mg/ kg^{-1}) and cultivated land (5.98 mg/ kg^{-1}) while badland and plantation have the lowest mean value of 3.85 mg/ kg^{-1} each. The CV for Available P over all the land uses is less than 40%. However, the analysis of variance indicates a statistically significant difference for Available P amongst the land use types. The higher mean values over the 'fadama' and cultivated landuses may be attributed to the addition of nitrogen and phosphorous bearing fertilizers (Aminu and Jaiyeoba, 2015). Although t-test result show no significant variation between three pairs of land uses (plantation and scrubland, plantation and badland, scrubland and badland), there was however, significant difference between all other pairs of landuses.

Severity of Soil Degradation

To assess the severity of soil degradation in the study area, the soil physico-chemical properties were compared to soil fertility ratings for tropical soils and are summarised in Table 3.

Table 3: Ratings for Interpreting Selected Soil Physico-Chemical Properties

	Soil Properties								
Range	Organic matter (%)	TN (%)	AP (mg/ kg^{-1})	Ca	Mg	K	Na	CEC	BS %
				←	(cmol/kg^{-1})		→		
Low	< 2	0 – 0.15	0-10	0-2	0- 0.3	0 0.15	0-0.1	6-12	< 40
Medium	2-3	0.15-0.20	10-20	2-5	0.3- 1.0	0.15-0.3	0.1-0.3	12- 25	40-60
High	>3	> 0.20	>20	> 5	> 1	> 0.3	> 0.3	25-40	60-80
Very high	> 6	> 0.30	-	>20	>8	>1.2	>2	>40	80-100

Source: Soil Survey Staff (1975) and Landon (1991)

Soil texture is a fundamental soil property which influences a soil's susceptibility to erosion, its infiltration capacity, moisture and nutrient retention (Madaki, 2011; Afolabi *et al*., 2014). Generally, mean values of sand, silt and clay indicate that soils in the study area are sandy clay loam. Although they are well drained, the dominance of sand fractions predisposes the soil to erosion due to the macro pores in the soil (Afolabi *et al*., 2014). These macro pores result in low moisture retention by the soils and nutrient loss through translocation by soil wash and leaching. Similarly, sandy soils have been found to be slightly acidic owing to the silica-rich parent material and the strong leaching regime associated with soils of the tropics (Jim, 2003; Afolabi *et al*., 2014).

Bulk densities of the soils are generally high over the respective landuses. For a normal soil, the critical limits for bulk density is 1-1.45mg/m^3 (Brady, 1990). The lower bulk density value in the plantation land use could be attributed to the higher organic matter due to litter addition from the vegetal cover. Porosity values are also lower than the critical limits of >50% in top 30cm for normal mineral soils (Malgwi, 2007). However, the overall high bulk density in all the soils may be due to the sandy texture of the soils. Compaction by cultivation, trampling by humans and cattle may also be responsible for the high bulk density and low porosity, particularly over cultivated and badlands.

The higher moisture content in the ‘fadama’ and plantation land uses could be attributed to the higher silt and clay content of the soils. The proximity of the ‘fadama’ landuse to water bodies and the high fraction of soil fines may be responsible for its high moisture content (Aminu and Jaiyeoba, 2015). For example, Brady and Weil (2002) observed that fine-textured soils are poorly drained and retain more moisture than coarse-textured soils. Similarly, the high soil moisture over the plantation land use may be attributed to protection of its soil from excessive solar radiation by the vegetal cover and the higher organic matter content of the soils. On the other hand, lower soil moisture in the cultivated and badland topograghy could be due to the low organic matter content, high evaporation rates over exposed soil surfaces and low porosity of the soils.

The critical limit of organic matter content for soils under natural conditions in the Savannah is ≥ 2% (Esu, 1991; Landon, 1991; Malgwi, 2007). This indicates that all soils over the different landuses are low in organic matter. However, the higher organic matter content over plantation land use could be attributed to continuous litter deposition and minimum disturbance, while the lower organic matter content over badland and cultivated lands may be attributed to the effect of sparse vegetation cover and persistent cultivation (Aminu and Jaiyeoba, 2015). For example, studies have shown that intensive cropping and tillage practices destroy soil structure through compaction, loss of soil moisture, increased bulk density and make such soils susceptible to soil wash and loss of basic cations (Jaiyeoba, 1995; Afolabi *et al*., 2014; Aminu and Jaiyeoba, 2015; Amuyou and Kotingo, 2015). Loss of soil organic matter is directly related to intensive use of these soils and the rapid mineralization of humus under Savannah climate (Jaiyeoba, 1995; Aminu and Jaiyeoba, 2015).

Total nitrogen over the respective land uses were generally within the favourable limits of >0.20 % for tropical soils (Esu, 1991; Landon, 1991; Malgwi, 2007). This could be attributed to the presence of vegetation which enhances nitrogen fixation and humification. However the lower total nitrogen over the badland maybe attributed to loss of total nitrogen through leaching and rapid mineralization due to exposure to solar radiation and to high temperatures which characterize the study area. Available phosphorous content in soils over the respective land uses is low. Even the highest mean of value of 7.18 mg/ kg^{-1} over fadama landuse is lower than the recommended values for tropical soils (Esu, 1991; Malgwi, 2007). The low available phosphorous maybe due to low phosphate solubility which is enhanced by the acidic nature of the soils (Amuyou and Kotingo, 2015). However, the higher mean values of available phosphorous over fadama’ and cultivated landuses may be attributed to the addition of phosphate-bearing fertilizers (Aminu and Jaiyeoba, 2015).

In productive soils exchangeable bases in the soil are in the order of Ca>Mg>Na>K (Brady and Weil, 2002) and indicate the fertility status of soils. In comparison to the critical limits for tropical soils, all soils over the respective land uses are low in exchangeable Mg, K and Na (Esu, 1991). This may be attributed to excessive soil wash and high level of leaching that has taken place in the soils. However, the exchangeable Ca is moderately available in the soils except over the badland. Low levels of exchangeable bases as indicated over the badland topography have severe implications for soil health. For example, cation imbalance affect soil reaction, soil structure and organic matter content (Madaki, 2011; Oluwadare, *et al*., 2013). Similarly, various studies have shown that CEC values reflect the productive capacity of soils (Oluwadare, *et al*., 2013). Soil quality ratings of CEC levels in tropical soils consider CEC values under 6 cmol/kg to be low (Esu, 1991; Landon, 1991; Malgwi, 2007). The higher CEC values over cultivated and ‘fadama’ landuses may be attributed to the addition of fertilizers to the soils to enhance productivity. Studies have shown that directly applied NPK fertilizer is rapidly mineralized and enhances ionic exchange by soil cations

(Oluwadare, *et al*., 2013). However, the generally low CEC values in the soils is a reflection of the sandy texture and generally low organic matter content of the soils (Aminu and Jaiyeoba, 2015) and also indicates that the soils have been subjected to various degree of degradation.

The critical limits of pH values for soils of the Savannah region is 5.5-6.5 (Esu, 1991; Malgwi, 2007). The range of the pH values over the different landuses show that the soils are moderately to slightly acidic. This may be associated with the granitic lithology as well as the strong leaching regime associated with tropical soils which drain the soils of basic cations. However studies have shown that in the Savannah soils, pH values over 6.0 result in micro-nutrient deficiency (Ojonuga, 1987; Oluwadare, *et al*., 2013), while lower pH values lead to increased Al toxicity. The base saturation values over all, but for the badland, are above the critical value of >50%, with the base saturation over other land uses within the moderate- high range. However, the low base saturation over the badland could result from a dominance of exchangeable acidity over the exchangeable bases (Afolabi *et al*., 2014). The lower pH and CEC values over the badland use are indicative of the intense leaching regime associated with the Savannah soils, which could result in loss of basic cations and overall soil fertility.

CONCLUSION

Soil fertility assessments showed that soils over the study area have undergone varying degrees of degradation with significantly differentiated soil properties over the respective land uses. For example, the higher bulk densities, lower porosity, lower soil moisture contents and low organic matter content, higher pH values and low CEC values which characterize soils, particularly under cultivated and badland landuses, are signs of soil degradation. Drawing from the findings of this research, it is recommended that government provides adequate incentives through policies which eliminate discriminatory land ownership rights, rehabilitation of degraded lands and enhanced public enlightening campaigns for a sustainable environment through adoption of soil management practices such as tree planting, mulching, fallowing and intercropping and minimum tillage.

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