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Comparative Assessment of Forested and Cultivated Soils for Sustainable Crop Production in Mubi Environment, Northeastern Nigeria

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ABSTRACT

An assessment of physico-chemical properties of 22 soils samples (at composite surface and horizon depths) from forested and cultivated fields within Mubi, Nigeria, was conducted between June and August, 2008. There was a significant difference ($P<0.05$) between the compared soil properties. Both soil types were sandy clay loam textured with moderate compactions (1.56/1.50 Mg m^{-1}) and porosities (41.23/43.21%) marked by slightly saline (0.17/0.16 dS m^{-1}) conditions. The soils were slightly acidic (pH 6.45) and alkaline (pH 7.46) in forested and cultivated soils, respectively. Total N (0.16/0.05%) and organic matter (2.09/1.13%) contents, respectively had medium and low rates in forested and cultivated soils. The available K and Mg were high, while available P and exchangeable Na had medium and low rates in both soil types. The exchangeable Ca and CEC (cation exchange capacity) were moderate in forested and low in cultivated soils, while the PBS had very high (93.66/91.70%) concentrations in the soil types. Generally, the soils still pose good potentials for sustainable crop production, particularly the forested soil that indicated high nutrient edge over cultivated soils. It is recommending that the forested fields may be converted into arable land uses in the study area. © Friends Science Publishers

Key Words: Assessment; Forested; Cultivated; Soil potentials; Sustainable; Crop production; Nigeria

INTRODUCTION

The heterogeneous nature of land makes it variable in both physical and chemical compositions that largely depend on the nature of soil and pattern of land use. This difference in land application generates variation in the agricultural production potentials and system of crop management (Gliessman, 1990; Baumer, 1990; Mengel & Kirkby, 2006). Forest lands consist of trees and shrubs of modest heights that competitively utilize oxygen, water and soil nutrients to attain desired maturity compared to most depleted cultivated soils (Vergara & Nair, 1995). Several years of land cultivation could lead to sharp decline in nutrient reserves that are often reclaimed through bush fallow and other soil fertility enrichment options, such as planting trees, shrubs and green manure crops on the degrading lands (Montagnini, 1990; Vergara & Nair, 1995; Mengel & Kirkby, 2006).

Forest vegetation conserves soil properties through organic matter additions and soil aggregate stability against erosion devastation, as well as protecting soils from direct impacts of rain splash and solar radiations compared to cultivated soils (Vergara & Nair, 1995; Brady & Weil, 2002; Mengel & Kirkby, 2006). Plant roots generally promote stable granulation of the surface aggregates, thereby improving soil porosity and infiltration capacities (King, 1997; Brady & Weil, 2002). Continuous cultivation of farm lands appears necessary for the production of food crops, fiber and employment sources to most farmers. In recent years, over-cultivation ignited from intensive land uses beyond the threshold limits of soil natural fertility to compensate for the nutrient depletions, have necessitated supplemental soil fertilization and nutrient recycling (Dahl, 1980; Bottrell, 1998) thereby, predisposing soils to limited fertility statuses (Mengel & Kirkby, 2006). This continuous cultivation practices further exposes soils to variable degradation factors. The amount of harm done often depends on the system of practices adopted and how the farmer handles his land and the type of crop/s grown (Parkinson, 1993; Clarke, 1995).

Mubi environment is one area that is still afflicted by erosion hazards with sparse tree vegetations, routinely subjected to intensive soil cultivation and marked by sharp nutrient depletion. This study was therefore, designed to asses the fertility potentials of the forested over the cultivated soils towards recommending suitable land

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management practices compatible to the study area.

Methodology

Study area: Mubi local government area is situated in the northeastern part of Adamawa state and located between latitudes 9º 26″ and 10º 11″ N and between longitudes 13º 10″ and 13º 44″ E. It has a land area of 506.40 km^2 and a population size of 759,045 with a density of 160.5 people per square kilometer. The local government shares boundaries with Michika to the North, Askira-Uba to the West and Hong local government to the South. It also shares international boundary with the Republic of Cameroon to the East.

The climate of the area is characterized by alternating dry and wet seasons. The rain lasts from April to October with a mean annual rainfall ranging from 700 mm to 1,050 mm (Udo, 1970; Adebayo, 2004). The vegetation is of typical Sudan Savannah, which implies grassland interposed by shrubs and few trees mostly, acacia, locust-beans and eucalyptus trees among others (Adebayo, 2004; Tekwa & Usman, 2006). The land use types are mainly arable farming and livestock production threatened by soil erosion at varying extent of devastations, from sheet and rill erosion to the spectacular gully erosion known for colossal loss of soil and soil nutrients (Tekwa *et al.*, 2006).

Field study: Two land use types (forests & cultivated) were investigated in Mubi area between June and August, 2008. The forested vegetation (Yellow-Cassia) and cultivated sites with establishment history of between one and two decades were sited and from, which the soils were sampled for this study.

Soil sampling: Soil samples at the surface (0-15 cm) and sub surface (15-30 cm) depths and from soil pedons were collected using a bucket soil-auger and core samplers, respectively. Two composite samples were collected at the top (0-15 cm) and sub-surface (15-30 cm) soil depths each, while the pedogenic samples were collected at observed horizon depths in each soil pedon dug on both fields. A total of 22 composite soil samples were collected, air dried, crushed and sieved through a 2 mm sieve and kept in well labeled polythene bags for routine laboratory analysis.

Determination of soil physical properties: The determinations of soil physical properties were conducted in the laboratory. The particle size distribution (PSD) was determined using Bouyoucous hydrometer method (Trout *et al.*, 1987) in sequence, the textural class of the soil was determined by subjecting the obtained particle size distribution to Marshall's textural triangle. The bulk density was determined by clod method, while the water holding capacity was determined by gravimetric water content of a given quantity of soil fully saturated with water.

Determination of soil chemical properties: The soil pH was measured in a 1:2.5 soil to water suspension ratio with the use of a glass electrode pH meter. The electrical conductivity (EC) of a saturation extract was determined in sequence alongside the pH in same suspension. The organic carbon (OC) was determined using potassium dichromate wet-oxidation method of Walkley and Black (1934), from which the soil organic matter was obtained by multiplying the OC with a conversion factor of 1.724. Total nitrogen (N) was determined by Kjedahl method, while the available phosphorus (P) by Bray 1 method (Bray & Kurtz, 1945; Wolf, 2003). The available potassium (K) and sodium (Na) were determined by flame photometry (Jackson, 1965; Wolf, 2003). The exchangeable calcium (Ca) and the magnesium (Mg) were determined by tetrimetric method, while the cation exchange capacity (CEC) and the total exchangeable bases (TEB) were computed from the analyzed result of the soil bases.

Data analysis: The student t-test was used to compare some of the properties analyzed in both the forested and cultivated soils.

RESULTS AND DISCUSSION

The vegetation of the study sites were made of dense yellow-cassia tree vegetation established over two decades on the forested field, while arable crops (e.g., maize, cowpea, sorghum, rice, millet & groundnut) were grown on the cultivated field having a land use history of over a decade. Both fields occupied almost flat laying topography. Presented in Table I is the result of investigation of the soil physical properties of both the forested and cultivated soils, which indicated a predominance of sand skins constituting the observed sandy clay loam soil textures. The soils exhibited differing soil structures of between sub-angular blocky and massive structural stabilities, with moderate compactions in both the forested (1.49-1.64 Mg m^{-3}) and cultivated (1.45-1.55 Mg m^{-3}) soils (Table III). The soil porosity estimates of both soil types were medium ranging (38.11-45.28%). These estimates are comparable with the earlier findings (sandy clay loam textures, massive soil structures, moderate porosities & soil compactions) reported by Tekwa *et al.* (2006) for soils in the same environment.

Results on investigation of the soil chemical properties is presented in Table II, it revealed that the soil reaction (pH) differed among the soils, the forested soil was slightly acidic (pH 6.45), while the cultivated soil was slightly alkaline (pH 7.46) in reactions. These ranges are within the adequate pH (6.5-8.5) for most crop production (Wolf, 2003). However, both soil types were only slightly saline/acidic (Table III), suggestive of the soils as still un-saturated with harmful salts (e.g., Sodium), which limits irrigation farming potentials (Brady & Weil, 2002; ICAR, 2006). The soil organic matter (OM) content ranged lower (0.90-1.36%) in cultivated soil and with medium ranges (1.85-2.50%) in forested soils. Further statistical test (t-test) indicated a significant difference ($P<0.05$) between the OM content of both soil types (Table IV). This low ranges of OM content in the cultivated soils appeared similar to the range (0.27-1.05%) earlier reported by Tekwa *et al.* (2006) for some locations within same Mubi area, while the OM content of the forested soils compared slightly higher than

Table I: Soil physical properties

Soil Sample Type	Sampling Depth (cm)	Particle Size Distribution (%) Sand	Silt	Clay	Soil Texture (Class)	Bulk Density (Mg/m^3)	Porosity (%)
Forested Soil							
Surface samples TS_1	0-15	63-70	14.25	22.05	Sandy clay loam	1.52	42.67
SS_1	15-30	53.70	21.75	24.55	Sandy clay loam	1.58	40.38
TS_2	0-15	64.60	13.50	21.90	Sandy clay loam	1.49	43.77
SS_2	15-30	55.40	20.80	23.80	Sandy clay loam	1.64	38.11
Pedogenic samples	0-16	58.70	19.25	22.05	Sandy clay loam	1.45	45.28
	16-27	46.20	19.25	34.55	sandy clay	1.66	37.36
	27-67	36.20	24.55	39.25	clay loam	1.66	37.36
	67-96	26.20	32.05	41.76	clay loam	1.68	36.60
	96-128	38.70	27.05	34.25	clay loam	1.65	37.74
	128-200	38.70	26.75	34.55	clay loam	1.67	36.98
Cultivated Soil							
Surface samples TS_1	0-15	53.70	16.55	29.55	sandy clay loam	1.45	45.28
SS_1	15-30	66.20	11.75	22.05	Sandy clay loam	1.54	41.89
TS_2	0-15	54-25	17.10	28.65	Sandy clay loam	1.48	44.15
SS_2	15-30	65.50	12.50	22.00	Sandy clay loam	1.55	41.51
Pedogenic samples	0-9	61.20	16.75	22.05	Sandy clay loam	1.45	45.28
	9-15	66.20	13.80	20.00	sandy loam	1.64	38.11
	15-22	66.20	15.50	18.30	sandy loam	1.59	40.00
	22-30	43.70	19.25	37.05	sandy clay	1.62	38.87
	30-55	81.20	7.05	17.75	loamy sand	1.54	41.89
	55-68	31.20	29.25	39.55	clay loam	1.45	45.28
	68-78	58.70	19.25	22.05	sandy clay loam	1.46	44.91
	78-135	21.20	34.25	44.55	clay loam	1.45	45.28

Key: TS = top surface; SS = sub-surface

Table II: Soil chemical properties

Soil sample Type	Sampling Depth (cm)	Soil pH 1:2.5 (soil:water)	EC ($dS\ m^{-1}$)	OM (%)	Total N (%)	Ave P (ppm)	Exch. K	Exch. Na	Exch. Ca	Exch. Mg	Exch. (Al+H)	CEC	PBS (%)
							(Cmol (+)/kg)						
Forested soil													
Surface TS_1	0-15	7.660	0.024	1.983	0.167	7.700	0.627	0.274	6.008	5.800	0.900	13.609	93.387
samples SS_1	15-30	5.290	0.273	1.845	0.146	6.350	0.550	0.226	4.810	4.200	0.600	10.390	94.225
TS_2	0-15	5.500	0.025	2.500	0.160	7.500	0.650	0.301	5.100	6.500	0.950	13.500	92.963
SS_2	15-30	7.300	0.350	2.050	0.150	7.800	0.680	0.365	4.550	5.500	0.700	11.800	94.068
Pedogogic Samples	0-16	7.520	0.163	1.917	0.020	8.430	0.648	0.278	3.806	5.600	0.500	10.830	95.383
	16-27	8.580	0.124	1.412	0.013	12.650	0.588	0.226	4.810	4.000	1.000	10.620	90.584
	27-67	7.130	0.103	0.976	0.016	9.100	0.422	0.218	6.613	3.800	0.600	11.653	94.851
	67-96	6.940	0.088	0.505	0.013	11.250	0.550	0.222	4.008	3.600	0.800	9.18	91.285
	96-128	8.250	0.107	0.438	0.012	16.800	0.499	0.287	6.012	4.000	0.900	11.698	92.306
	128-200	7.450	0.123	0.202	0.008	5.600	0.422	0.252	4.609	3.000	0.600	8.883	93.246
Cultivated soil													
Surface TS_1	0-15	6.970	0.158	1.362	0.124	9.150	0.640	0.196	5.812	5.200	0.900	12.748	92.940
samples SS_1	15-30	7.170	0.158	0.941	0.014	7.780	0.346	0.187	3.006	6.200	0.800	10.539	92.409
TS_2	0-15	6.980	0.156	1.301	0.105	9.200	0.660	0.205	3.950	4.100	0.880	9.800	91.020
SS_2	15-30	7.500	0.155	0.902	0.050	8.100	0.450	0.210	3.100	3.800	0.800	8.360	90.431
Pedogogic Samples	0-9	7.040	0.135	1.581	0.165	11..920	0.397	0.283	3.407	4.400	0.500	8.987	94.436
	9-15	7.380	0.154	1.075	0.014	8.450	0.448	0.205	4.008	2.400	0.800	7.861	89.823
	15-22	8.310	0.143	0.772	0.014	14.000	0.461	0.226	4.008	2.600	1.200	8.495	85.874
	22-30	7.370	0.154	0.976	0.016	17..500	0.512	0.248	4.409	2.600	0.600	8.369	92.831
	30-55	7.510	0.159	0.537	0.012	12.600	0.294	0.200	3.006	5.00	0.800	9.300	91.398
	55-68	6.810	0.045	1.681	0.015	18.200	0.397	0.283	3.006	1.200	0.700	5.586	87.469
	68-78	6.720	0.073	1.377	0.150	13..300	0.589	0.239	5.611	1.400	1.000	8.839	88.687
	78-135	6.620	0.044	1.748	0.017	20.300	0.358	0.357	3.808	2.800	0.800	8.123	90.151

Key: Exch = exchangeable, EC = Electrical Conductivity, OM = Organic Matter, N= Nitrogen, P = Phosphorus, K = Potassium, Na = Sodium, Ca = Calcium, Mg = Magnesium, Al = Aluminium, H = Hydrogen, CEC = Cation Exchange Capacity, PBS = Percentage Base Saturation

the range (1.23-2.46%) reported by Ekwue and Tashiwa (1992) for some soil sites in the same environment. The low OM values observed in the cultivated soils could probably be due to the sparse vegetation, overgrazing and marginal land usage as influenced by human activities (Tekwa & Belel, 2008).

The result on statistical contrasts between the mean OM content of the forested and cultivated surface soils is presented in Table IV. The student t-test showed that the calculated t-value (22.803) is greater than t-critical (2.447), then H_o is rejected, implying that there exist a significant difference ($P<0.05$) between the OM content of forested and cultivated soils, suggestive of higher fertility rates in forested than cultivated soils as observed in this study.

Table III: The soil physico-chemical characteristics and rates within plant rooting depth (0-30 cm)

Soil properties	Forested soil				Cultivated soil		
	Units	Ranges	Mean content	Ratings	Ranges	Mean Content	Ratings
			Physical Properties				
Particle Size Distribution							
Sand	%	53.70 – 64.60	59.35	Coarse textured	54.25-66.20	51.91	
Silt	%	13.50 – 21.75	17.58		11.75-17.10	14.48	Medium textured
Clay	%	21.90 – 24.55	23.08		22.00-29.55	25.56	
Soil texture	Class	Sandy clay loam	Sandy clay loam	Sandy clay loam	Sandy clay loam	Sandy clay loam	Sandy clay loam
Soil structure	Class	Sbk/m	Sbk	Sbk	Sbk/m	Sbk/m	Massive
Bulk density	Mgm^{-3}	1.49 – 1.64	1.56	Moderate compaction	1.45-1.55	1.50	Moderate compaction
Soil porosity	%	38.11 – 43.77	41.23	Medium	41.51-45.28	43.21	Medium
			Chemical properties				
Soil reaction (pH)	-	5.29 - 7.66	6.45	Slightly acidic	6.97-7.50	7.46	Slightly alkaline
Electrical conductivity (EC)	dSm^{-1}	0.024 – 0.350	o.17	Slightly saline	0.155-0.158	0.16	Slightly saline
Organic matter (O.M)	%	1.845 – 2.500	2.09	Medium	0.902-1.362	0.13	Low
Total Nitrogen (N)	%	0.146 – 0.167	0.16	Medium	0.014-0.105	0.05	Low
Avail. Phosphorus (P)	Ppm	6.350 – 7.800	7.35	Medium	7.780-9.200	8.56	Medium
Exch. Potassium (K)	Cmol(+)/kg	0.550 – 0.680	0.53	High	0.346-0.660	0.63	High
Exch. Sodium (Na)	Cmol(+)/kg	0.220 – 0.365	0.29	Low	0.187-0.210	0.20	Low
Exch. Calcium (Ca)	Cmol(+)/kg	4.550 – 6.008	5.12	Moderate	3.006-5.812	3.97	Low
Exch. Magnesium (Mg)	Cmol(+)/kg	4.200 – 6.500	5.50	High	3.800-.6.200	4.83	High
Percentage Base saturation (PBS)	%	92.960 – 94.225	93.66	Very high	90.431-92.940	91.70	Very high
Cation Exchange Capacity	Cmol(+)/kg	10.390 -13.609	12.33	Moderate	8.360-12.748	10.36	Low

Key: Exch = exchangeable, Sbk = sub-angular blocky, m = massive

Table IV: Student t-test of the mean OM content of the forested and cultivated surface soils

S/N	Soil type	∑	X	SS	N	Degree of freedom (df)	t-calculated	t-critical	Remark
1	Forested	7.77	1.943	15.783	4				
2	Cultivated	4.50	1.125	5.233	4	6	22.803	2.447	Reject H_o

Tested at 0.05 level of significance; Legend: ∑ = Sum of CEC Content; X = Mean of CEC Content; N = Number of observation; SS = Sum of Squares

Table V: Student t-test of the mean CEC values of the forested and cultivated surface soils

Soil type	∑	X	SS	N	Degree of freedom (df)	t-calculated	t-critical	Remark
Forested	49.30	12.33	614.67	4				
Cultivated	41.45	10.36	439.58	4	6	2.763	2.447	Reject H_o

Tested at 5% level of significance

Several changes in soil quality especially OM content occur, when virgin soil is routinely cultivated (Saviozzi *et al.*, 2001).

The total soil nitrogen (N) content was low ranging (0.02-0.12%) on cultivated field and medium ranging (0.12-0.17%) on the forested field. Both N ranges in this study compared lower than the range (0.14-0.21%) earlier observed in some soil locations in the same environment (Tekwa *et al.*, 2006). This low N estimates could likely be due to N mobility in tropical soils (Sanchez & Leaky, 1997) or perhaps due to poor N returning capacities of yellow-cassia tree vegetations with prolonged N uptakes by the plants without proper compensations with N enriching fertilizer sources (Ekwue & Tashiwa, 1992; Wolf, 2003; Mengel & Kirkby, 2006).

The available phosphorus (P) was of medium rates in the cultivated (8.56 ppm) and forested (7.35 ppm) soils. The exchangeable potassium (K) was high in both soil types, which is characteristic of the Mubi soils (Ekwue & Tashiwa, 1992; Tekwa & Usman, 2006; Tekwa & Belel, 2008). The sodium (Na) content was generally low ranging in both the cultivated (0.19-0.21 Cmol (+)/kg) and forested (0.22-0.37 Cmol (+)/kg) soils as reflected in the soils mild salinity levels (Table III). The calcium (Ca) content differed noticeably, a moderate rate (5.12 Cmol (+)/kg) was observed in the forested soil and lower rates (3.97 Cmol (+)/kg) in the cultivated soil. This variation could have been due to differences in crop consumption of Ca, leaching effects and physical degradation of the cultivated soils than it was on the forested soils.

Mg content of the soils were high, alongside the other basic cations, thereby yielding a very high percentage base saturation (PBS) in both the forested (93.66%) and cultivated (91.70%) soils. The result indicated impressive agricultural potentials of both soil types for variable crop supports (Wolf, 2003; Tekwa *et al*., 2006). Another student t-test comparison between the CEC content of forested and cultivated surface soil is presented in Table V. Since the calculated t-value (2.763) is greater than the t-critical (2.447), then H_o rejected, implying that there exist a significant difference ($P<0.05$) between the CEC content of forested and cultivated soils observed in this study. This occurrence is likely contributed by periodic accumulation of soil bases, characteristic of forest soils (Saviozzi *et al.*, 2001).

Generally, the cation exchange capacity (CEC) recorded moderate (12.33 Cmol (+)/kg) in the forested soil and lowly (10.36 Cmol (+)/kg) in the cultivated soil. As it was with the OM content, the CEC amounts also statistically differed with significant differences ($P<0.05$) between the forested and cultivated soil types (Table IV). The relatively higher values of soil bases in the forested soil than on cultivated soil, possibly contributed to the higher CEC in the forested soil observed in this study. This adequate estimate of both the PBS and CEC certainly explains the relative potentials of especially the forested soils in contrast to the cultivated soils for sustainable crop production in the study area. This outcome similarly agreed with the earlier reports of Tekwa *et al.* (2006) for some soils within the same Mubi region. Likewise, it equally compares with the reports of Saviozzi *et al.* (2001), that long term corn production at an intensive level caused a marked decline in valuable soil qualities in Pisa, Italy.

CONCLUSION

The physico-chemical properties of the soils under test are still within ample crop support limits. The soil reaction (pH) and EC were moderate in the forested soil and lower in cultivated soil. The available P, soil porosity and bulk density were generally of medium rates, while K and Mg were all high in both soil types. Only PBS recorded very high rates in both soil types. Hence, the forested soil compared richer in nutrient stocks than the routinely cropped arable or cultivated field in the study area. It is recommended that the forested field should henceforth be converted into arable land-uses in order to utilize its high nutrient reserves. Also, the cultivated soils should further be supplied with soil fertilizing sources, such as organic and inorganic fertilizer materials, coupled with compatible crop husbandry practices capable of conserving the soils for sustainable crop production in the study area.

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