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(RESEARCH ARTICLE)

Edaphic status along altitudinal gradients of Bagale hills forest reserve, Adamawa State, Nigeria

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Abstract

An extensive soil survey of the Bagale Forest Reserve, an old reserve in North East Nigeria was conducted, to ascertain its soil status because of exposure and vulnerability to various anthropogenic activities which have been exacerbated by climate change over time. Five fragments within the altitudinal gradients were selected using LANDSAT ETM+ satellite imagery from Google earth. The fragments selected as samples include Tudunwada (<200m), Holin (200-300m), Modire (300-400m), Lugga (400-500m) and Wurodole (>500m) above sea level. Composite soil samples were collected and sent to the laboratory for analysis. Physical properties of the soil revealed a preponderance of sand (84%), and low percentages of silt (4%), clay (6%) while pores spaces ranged between 28.80-39.49% in both surface and sub-surface. Chemical properties revealed low pH (5.4-6.09), EC (0.06-.10m_3m^{-1}), percentage base saturation ranged between (54.08-85.38). The results showed variations in soil properties in the lower, mid and high elevations of the gradient. However, the ANOVA revealed no significant difference in same. The soil of this area will require adjustments and interventions to be able to sustain this forest reserve.

Keywords: Edaphic; Fragments; Interventions; Altitudes; Reserve; Bagale

1. Introduction

Bagale Hills Forest Reserve is an old ecosystem situated between Latitude 9° 11' N and 9°N and Longitude 12° 20" and 12° 30'E in Adamawa state, North East Nigeria. It was gazetted as a forest reserve by the state government in December, 1954, [1] long after it had existed as a forest. However, according to [2] (2014) Fufore area of the state that was once dominated by good vegetation and extensive forest as revealed by the 1972 satellite images has by 2014 been alarmingly deforested with significant loss in natural vegetation, increase in bare surfaces, farmlands and built up areas. Common activities carried out in the forests include indiscriminate cutting of trees, intensive farming using wrong approaches, removal of non-forest tree products (NFTP),herding of cattle through the forests for grazing, [3].These practices also cause soil degradation of forest reserves.

One of the most important factors that have effect on the diversity and growth of trees is edaphic, [4]. Forest soils are the initial source of nutrients to plants, store nutrients and serve as habitat to soil microorganisms [5].Many studies on forest soils have showed increased importance of soil physical properties over chemical properties in relation to tree growth.

Soil physical and chemical properties include measurements such as infiltration rates, bulk density, porosity, total nitrogen and available phosphorus. These properties relate with each other and are influenced by other factors such as

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environmental factors and vegetation. Infiltration of water which refers to the downward flow of water from the surface increases water storage for plants and ground water recharge and also reduces erosion [6]. Increased moisture, organic matter and acidity are said to correspond with increasing elevation. Macro and micro nutrients revealed variable responses with nitrogen increase and other macro nutrients decreasing with altitude, [7]. Infiltration is governed by two forces, gravity and capillary action, while smaller pores offer greater resistance to gravity, every small pores pull water through capillary action in addition to and even against the force of gravity. Bulk density has also been reported to be inversely related to total porosity [8]. Bulk density has also been related to natural soil characteristics such as texture, organic matter, soil structure and gravel content [9]. Less than optional bulk density (high porosity) leads to poor water relation and high bulk density (low porosity) reduces exertion and increases penetration resistance limiting plant growth. In grazing areas, infiltration rate has been reported to decrease with increase in stocking of animals while bulk density does not significantly differ with rate of stocking.

Due to the importance of the soil in promoting and sustaining tree growth[10]; [11], the need to assess the current "health" status of forest reserves cannot be overemphasized. Hence the diagnostic soil survey of Bagale forest Reverse (the study area) in different fragments at various altitudes was carried out to access its current status as it has unavoidably been vulnerable to various forms of anthropogenic activities through its current life span of over sixty years. In addition results from such survey should provide baseline information for related future researches and help in the development of agroforestry, management plans. The results can also be used as a template in assessing the status of other forest reserves within the North East sub-region.

2. Material andmethods

2.1. Study Location

Bagale Forest Reserve is an old reserve located within latitude 9^{o}11'N-9^{o}and longitude 12^{o}20'E-12^{o}30"E in North East Nigeria (Fig 1) with a total area of about 18,000 hectares.

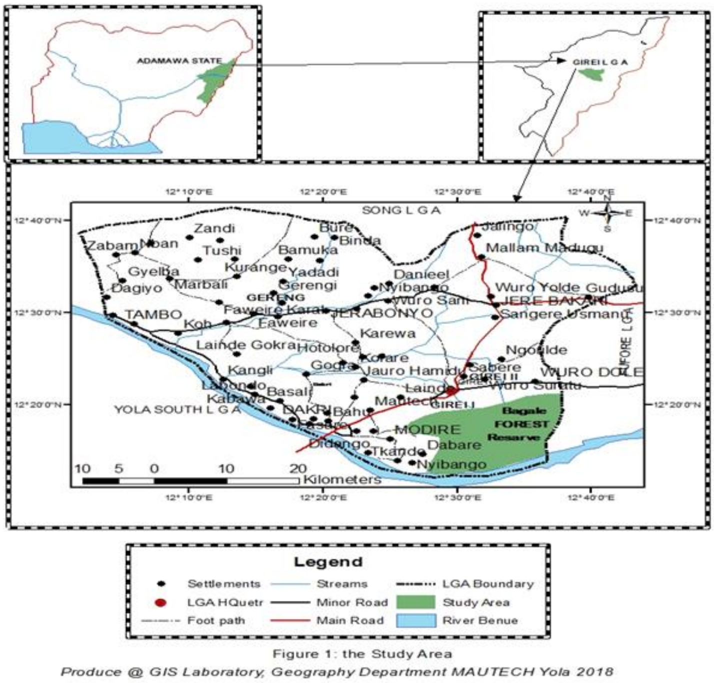

Figure 1 Study area1

The physiography of the reserve is typically undulating, generally of flat plain and a deep to gentle slope surface. The most important landforms are small mountains and flood plains along the River Benue.

The area experiences two distinct seasons, the rainy and dry and two distinct types of temperature, hot and cold [12]. The vegetation is savannah woodland with grass association more or less interspersed with shrubs and trees. It has the characteristics of open biotype with common tree species which include *Burkea africana*, *Tamarindus indica*, *Acacia* *senegal*, V*itex doniana*, *Adansonia digitata*; common grasses include *Ipomeatriloba*, *Andropogon gayanus*, *Panicum maxicum*, *Tridax procumbens*, *Desmodium salicifolium*, [13], [14].

2.2. Digital Maps of the Study Area

A contour map (fig.2) and the cross section of the study area along a section line from SW to NE (Fig. 3) were produced following the polynomial models adopted by [15]. Elevation above sea level and the distance between plots were measured using a Garmin GPS. The fragments selected and sampled included Tudunwada (<200m), Holin (200-300m), Modire (300-400m), Lugga (400-500m) and Wurodole (>500m) above sea level.

2.3. Procedure for Data Collection

Soil sample collection was done at three points within each quadrat in each quadrat in each of the fragments at 0-40 and 40-80 centimetres depths. The samples were collected at the centre of the plots and at 10cm on two sides of a depth at a line drawn passing through the centre of the plots were formed into a composite sample and put in airtight containers and transported to the laboratory for analysis.

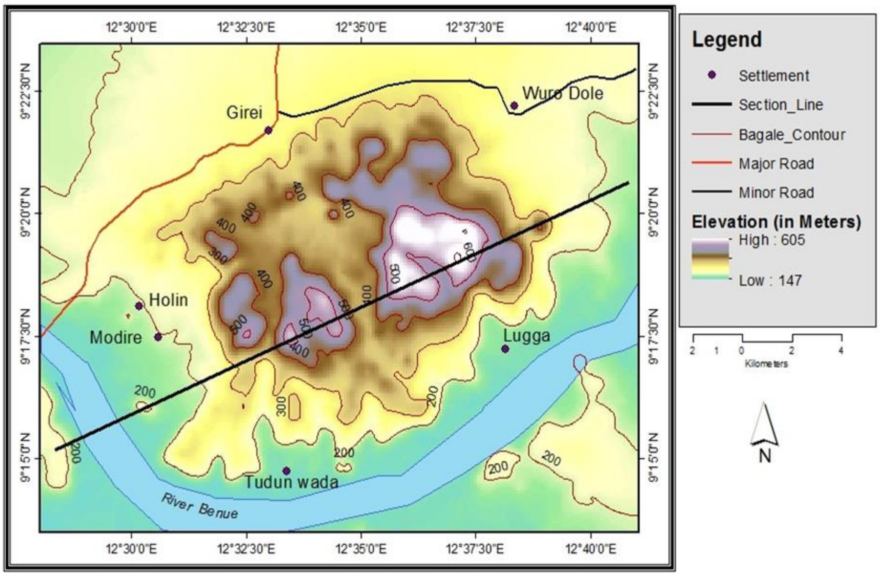

Figure 2 Contour of study area
Source: Department of Geography, Mautech, Yola (2018).

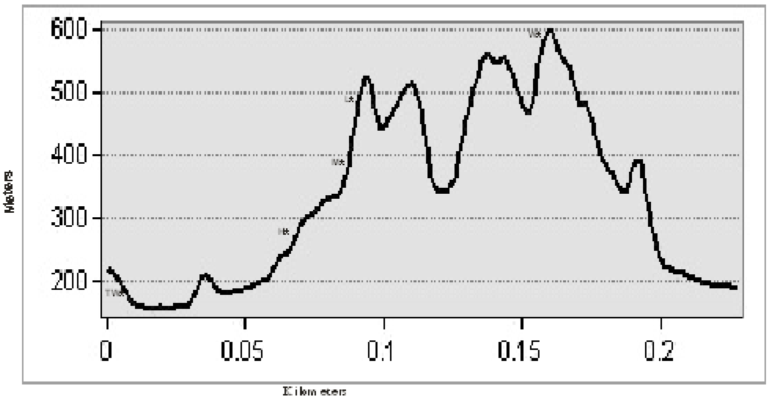

Figure 3 The Cross Section of Bagale Hills Forest Reserve along a Section from SW to NE
T/W=Tudun Wada, H=Holin, M=Modire, L=Lugga,, W=Wurodole
Source: GIS Laboratory, Geography Department MAUTECH, Yola (2018)

2.4. Laboratory Analysis

Physical properties analysed in the surface and sub-surface depths in the fragments included sand (%), clay (%), silt (%) bulk density, (gm/cm^3), particle density (g/cm^3), porosity (%), chemical properties analysed in the surface and sub-surface included, P^H (1:1) H_20, EC M_3M^{-1}, OCgk^{-1}, OM, TN(Cmol/kg^{-1}), AVP (PPM), Ca(Cmol/kg^{-1}), Mg(Cmol/kg^{-1}), K(Cmol/kg^{-1}), Na (Cmol/kg^{-1}), TEB, TEAC, ECEC (Cmol/kg^{-1}), %BS.

Analysis in the laboratory was carried out following the procedures of [16], [17],[18] , [19],[20] , [21], [22], in the determination of soil P^H, particle size analysis, bulk density, total porosity, electrical conductivity, organic carbon, total nitrogen, total phosphorus, extractable potassium in soils respectively.

3. Results

The 0-40cm depth of the Tudun-wada, Holin, Modire, Lugga and Wurodole yielded 86.0, 12,2,2.7, 1.8,31.5; 84.0,10.0, 6, 2.8, 39.5; 84.0, 10.0, 6.0, 2.5, 1.7, 33.2; 91.0, 6.0, 3.0, 2.9, 1.8, 37.8; 92.0,4.0, 4.0, 1.7, 2.7, 34.8; 90.0,8.0,2.0,2.7,1.8,31.1; percent of sand, silt, clay ,particle density, bulk density and porosity respectively (Table 1) while 40-80cm depth of Tudun-wada, Holin, Modire, Lugga and Wurodole exhibited 86.0, 6.0, 2.7, 39.0; 80.0, 6.0, 6.0, 2.0, 50.0, 1.7, 32.8; 90.7,3.0, 3.0, 1.8, 28.8; 91.0, 6.0, 3.0, 2.9, 1.8, 37.8; 94.0, 4.0,2.0, 2.7,1.9, 30.7; percent of sand, silt, clay, particle density, bulk density and porosity respectively,(Table 2).Both surfaces had a textural class of loamy sand.

Table 1 Surface (0-40) soil physical properties of the various fragments

Soil parameter	Depth (cm)	F1	F2	F3	F4	F5	$\bar{X}$	SD	%CV
% Sand	0-40	86	84	84	91	90	87	3.32	3.81
% Silt	0-40	12	10	10	6	8	9.2	2.28	24.79
% Clay	0-40	2	6	6	3	2	3.8	2.05	53.93
Textural Class	0-40	LS	LS	LS	Sand	Sand	Sand	-	-
Bulk density (g/cm^3)	0-40	1.83	1.67	1.67	1.78	1.84	1.758	0.08	4.75
Particle density (g/cm^3)	0-40	2.67	2.76	2.5	2.86	2.67	2.692	0.13	4.94
% porosity	0-40	31.46	39.49	33.2	37.76	31.09	34.6	3.81	11.01

Source: Field survey, 2016

F1 = Tudun Wada (<200m) above sea level, N09^{0}15'32.1'', E12^{0}22'51.4''; **F2** = Holin (200-300m) above sea level, N09^{0}42.1', E12^{0}29'54.7''
F3 = Modire (300-400m) above sea level, N09^{0}17'31.7'', E12^{0}31'08.7''; **F4** = Lugga (400-500m) above sea level, N09^{0}21'13.4'', E12^{0}35'52.3''
F5 = Wurodole (>500m) above sea level, N09^{0}22'24.6'', E12^{0}34'56.3''

Table 2 Surface soil (40-80cm) physical properties of the various fragments

Soil parameter	Depth (cm)	F1	F2	F3	F4	F5	$\bar{X}$	Sd	CV%
% Sand	40-80	88	86	90	92	94	90	3.2	3.5
% Silt	40-80	6	6	7	4	4	5.4	1.3	24.9
% Clay	40-80	6	8	3	4	2	4.6	2.4	52.4
Textural Class		LS	LS	LS	Sand	Sand	-	-	-
Bulk density (g/cm^3)	40-80	1.7	1.6	1.8	1.7	1.9	1.7	.09	4.9
Particle density (g/cm^3)	40-80	2.5	2.7	2.5	2.7	2.7	2.6	.09	3.6
% porosity	40-80	32.8	39.0	28.8	34.8	30.7	33.2	3.9	11.8

Source: Field survey, 2016

F1 = Tudun Wada (<200m) above sea level N09^{0}15'32.1'', E12^{0}22'51.4''; F2 = Holin (200-300m) above sea level N09^{0}42.1', E12^{0}29'54.7''
F3 = Modire (300-400m) above sea level N09^{0}17'31.7'', E12^{0}31'08.7''; F4 = Lugga (400-500m) above sea level N09^{0}21'13.4'', E12^{0}35'52.3''
F5 = Wurodole (>500m) above sea level) N09^{0}22'24.6'', E12^{0}34'56.3''

The chemical properties of soils at 0-40 cm depth of Tudun- wada, Holin, Modire, Lugga and Wurodole revealed $P^{H(1:1)H_20}$ Electrical conductivity (ds/m), Organic carbon (g/kg), Organic matter (g/kg),Total Nitrogen(g/kg), Available phosphorus (ppm), Calcium (cmol/kg), Magnesium (cmol/kg), Potassium (cmol/kg), Sodium (cmol/kg), Total Exchangeable Base (cmol/kg), Total Exchangeable Acidity (cmol/kg), Effective Cation Exchange Capacity (cmol/kg), Percentage Base Saturation of 5.5,0.06,6.1, 10.5,0.61,6.6,0.96,0.21,0.77,0.17,2.1,1.8,3.9 and 54.1; 5.5, .08,12.5,21.5,1.3,6.5,1.9,.41,0.44,0.22,3.0,2.0,5.0,60.0;6.3,0.07,10.8,18.6,1.1,6.5,1.6,0.28,0.31,0.26,2.46,2.0,4.5,55.2;5.3,0 .11,5.0,8.6,0.50,6.7,2.6,0.21,0.44,0.26,3.5,1.8,5.3,65.9;6.1,0.09,8.1,14.0,0.81,6.5,2.6,0.15,0.26,0.26,3.2,0.8,4.0and 80.2 respectively, (Table 3), while the 40-80cm depth of the fragments exhibited 6.1,0.10,11.5,19.8,1.2,6.7,2.3,0.09,0.21,0.17,2.7,1.2,3.9,69.4;5.6,0.09,10.3,17.8,1.1,6.5,0.64,0.24,0.33,0.22,1.43,2.40,3.8,3 7.3;6.0,0.08,6.4,11.0,0.64,6.6,3.9,0.06,0.36,0.22,4.5,1.8,6.3,71.4;5.9,0.07,6.1,10.3,0.61,6.7,2.3,0.22,0.77,0.26,3.5,0.6,4.1,8 5.4; 5.9,0.08,4.8,8.3,0.48,6.6,1.6,0.02,0.21,0.17,2.0,1.2,3.2 and 62.6 respectively (Table 4).

Table 3 Surface (0-40) chemical properties of soils in the various fragments

Parameter	Depth (cm)	F1	F2	F3	F4	F5	Mean	SD	%CV
pH (1:1)H_2O	0-40	5.54	5.54	6.26	5.34	6.09	5.73	0.42	7.27
EC(ds/m)	0-40	0.06	0.08	0.07	0.11	0.09	0.08	0.02	23.46
OCgkg^{-1}	0-40	6.10	12.50	10.80	5.00	8.10	8.50	3.14	36.95
OM(gm/kg	0-40	10.52	21.50	18.62	8.62	13.96	14.64	5.40	36.87
TN Cmol kg^{-1}	0-40	0.61	1.25	1.08	0.50	0.81	0.85	0.31	36.95
AVP Cmol kg^{-1}	0-40	6.56	6.49	6.49	6.71	6.49	6.55	0.10	1.46
Ca Cmol/kg^{-1}	0-40	0.96	1.93	1.61	2.57	2.57	1.93	0.68	35.39
Mg Cmol/kg^{-1}	0-40	0.21	0.41	0.28	0.21	0.15	0.25	0.10	39.52
K Cmol kg^{-1}	0-40	0.77	0.44	0.31	0.44	0.26	0.44	0.20	44.78
Na Cmol kg^{-1}	0-40	0.17	0.22	0.26	0.26	0.26	0.23	0.04	16.99
TEB(gm/kg	0-40	2.12	3.0	2.46	3.48	3.24	2.86	0.56	19.59
TEA(gm/kg	0-40	1.80	2.0	2.0	1.8	0.8	1.68	0.50	29.88
ECEC Cmol kg^{-1}	0-40	3.92	5.0	4.46	5.28	4.04	4.54	0.59	13.03
%BS	0-40	54.08	59.96	55.15	65.91	80.2	63.06	10.66	16.91

Source: Field survey, 2016

F1 = Tudun Wada (<200m) above sea level N09^{0}15'32.1'', E12^{0}22'51.4''; F2 = Holin (200-300m) above sea level N09^{0}42.1', E12^{0}29'54.7''
F3 = Modire (300-400m) above sea level N09^{0}17'31.7'', E12^{0}31'08.7''; F4 = Lugga (400-500m) above sea level N09^{0}21'13.4'', E12^{0}35'52.3''
F5 = Wurodole (>500m) above sea level N09^{0}22'24.6'', E12^{0}34'56.3''

Table 4 Sub-surface (40-80 cm) chemical properties of soils in the five fragments

Parameter	Depth (cm)	F1	F2	F3	F4	F5	Mean	SD	%CV
pH (1:1)H_2O	40-80	6.12	5.59	6.00	5.88	5.87	5.88	0.21	3.40
ECM$_s$m^{-1}	40-80	0.10	0.09	0.08	0.07	0.08	0.08	0.01	16.29
OCg/kg^{-1}	40-80	11.5	10.3	6.4	6.1	4.8	7.82	2.91	47.65
OM(gm/kg	40-80	19.83	17.76	11.03	10.25	8.28	13.48	5.01	47.63
TN Cmol/kg^{-1}	40-80	1.15	1.10	0.64	0.61	0.48	0.78	0.29	47.65
AVP Cmol/kg^{-1}	40-80	6.71	6.49	6.64	6.71	6.64	6.64	0.09	1.34
Ca Cmol/kg^{-1}	40-80	2.25	0.64	3.86	2.25	1.61	2.12	1.17	52.17
Mg Cmol/kg^{-1}	40-80	0.09	0.24	0.06	0.22	0.02	0.13	0.10	44.72
K Cmol/kg^{-1}	40-80	0.21	0.33	0.36	0.77	0.21	0.38	0.23	99.95
Na Cmol kg^{-1}	40-80	0.17	0.22	0.22	0.26	0.17	0.21	0.04	14.75
TEB(gm/kg	40-80	2.72	1.43	4.49	3.5	2.01	2.83	1.21	34.55
TEA(gm/kg$^-$	40-80	1.20	2.40	1.8	0.6	1.2	1.44	0.68	114.02
ECEC Cmolkg^{-1}	40-80	3.92	3.83	6.29	4.10	3.21	4.27	1.18	28.73
%BS	40-80	69.41	37.33	71.39	85.38	62.61	65.22	17.65	20.68

Source: Field survey, 2016

F1 = Tudun Wada (<200m) above sea level N09^{0}15'32.1'', E12^{0}22'51.4''; F2 = Holin (200-300m) above sea level N09^{0}42.1', E12^{0}29'54.7''
F3 = Modire (300-400m) above sea level N09^{0}17'31.7'', E12^{0}31'08.7''; F4 = Lugga (400-500m) above sea level N09^{0}21'13.4'', E12^{0}35'52.3''
F5 = Wurodole (>500m) above sea level 09^{0}22'24.6'', E12^{0}34'56.3''

4. Discussion

Most Nigerian Savannah soils are highly weathered and fragile with low activity clays, thus making their fertility decline under continuous arable cropping [23]. Generally, soil productivity decline rapidly when vegetation cover is lost and inappropriate management practices are adopted [24], thereby resulting in soil organic matter depletion and reduced agricultural productivity.

High percentage of sand was recorded in both depths of the study area. This agrees with findings of [25], who reported that the dominance of sand contents in Northern Nigeria soils (lithosols) is as a result of sorting, of materials by clay eluviations and surface wind erosion. This report also agrees with the findings of [26] who revealed a high percentage of sand with increase in altitudes in the area he studied which is in the same ecological zone as the study area. These findings also agree with those of [27] who reported a preponderance of sand over sandy loam in his study area. A preponderance of sand in a forest ecosystem could also be related to the parent material from which the sand is developing[28]. The implication of high percentage of sand in an ecosystem is that soil nutrients are leached out of the reach of the trees and hence not available to them for sustainable development.

There was a low percentage of clay with a range of 2 – 8% and silt 4 – 12% with a clay/sand ratio of 1:18. This does not agree with the results of [29] who reported a clay range of between 18 – 24%; silt 20 - 24%; sand 51 – 59% respectively. Also the mean values of sand, silt and clay factions which were 88.5%, 7.3%, 4.2% (in both depths) respectively, which gave the soil a sandy loam texture agrees with the result of [30] who recorded similar trend in a related agroecological zone as the study area. This suggests that the soil at the study area would be prone to leaching due to the high presence of macropores of the dominating sand fraction. This could adversely affect the growth, yield and development of the trees in the study area, because of probable low water and nutrient retention capacity which also aid in high leaching of soil nutrients. This scenario is further exercabated by uncontrollable removal of trees from the forest which further exposes the soil to leaching and erosion. Furthermore, due to intense continuous cultivation as well as the sandy nature of the soils, cations such as Ca^{2+}, Mg^{2+} , and K^+ are continuously removed resulting into acidity, as exhibited by the very low and negative values for pH and ECEC. This invariably explains the reason for the observed low pH, ECFC and OC status of the soil in the study area. The decrease in silt/clay ratio with depth is an indication that sub-soils depths are more weathered than surface depths [31]. Silt/clay ratio are relative higher in the surface depths and decrease with increased depth in the pedons. The relative high bulk density values which ranged between 1.63 – 1.85g/cm3 is attributed to compaction caused by grazing animals which is a common activity in the study area. Plants perform best in bulk densities below 1.4mgm-3 and 1.6mgm-3 for clayey and sandy soils respectively [32]. One reason for the variation in bulk density on forest floors is the variation in biomass of live small and fine roots (<5mm diameter) and the extent to which they were removed before bulk density was calculated[33]; [34]. The results of the bulk density in the study area which ranged between 1.63 – 1.85g/cm3 agree with [36] that also recorded almost similar values in bulk density in a similar ecosystem. The least bulk density value obtained under fallow at the soil surface level compared to those obtained under agro forestry species. This could be as a result of mart layer formed by low quality liter which does not decompose easily, thereby lowering soil compaction by rain drops. The implication is that soils under agro forestry tree species are more compacted, thereby increasing the water holding capacity of the soil than the soil under natural forest which drain and dry fast due to high porosity [37]. Generally, the observed mean range of bulk density in the study area (1.63 – 1.85gm/cm3) is ideal for optimum root growth and this agrees with the findings of [37]. The soils of the area are found to contain relatively appreciable amount of clay content between 2 – 8%, this may be attributed to eluviations and pedoturbation processes. The silt content of the soil was observed to slightly increase with increasing depth in almost all the profiles. [38] and in their studies of soils in the Savannah region of Northern Nigeria mentioned the influence of harmattan dust in contributing silt to soil. The silt/clay ratio ranged from 0.35 to 2.19, 0.35 to1.27 and 1.11 to 1.46. [39] reported that “old” parent materials usually have a silt/clay ratio below 0.15 while silt/clay ratios above 0.15 are indicative of “young” parent materials. Results of the study from this study area show that all the soils have silt/clay ratio above 0.15 indicating these soils have high degree of weathering potential.

Growth could also be inhibited due to high bulk density because of soil resistance to root penetration, poor aeration, slow movement of nutrients and water and build-up of toxic gases and root exudates,[40]; [41]; [42], reported that particle size density values increase with soil depth. Similar results were also reported by [43] in soils of Samaru area, a location also in the Northern Guinea Savannah as the study area. Porosity values ranged from 25 – 40% (35% average), 34 to 47% (41% average), [44] reported similar values in the soils of Zaria, Kaduna State also in the Northern Guinea Savanna,.[45], recommended that soils having porosity of over 50% and 45 – 50% of volume are good agricultural soils. Soil porosity is lower in the study area and this may be attributed to the clayey nature of the soils.

PH value of the soils in the study area ranged between 5.34 and 6.26, and was observed to increase or decrease irregularly with increasing depth. Similar trends were observed and reported by [46] According to [47] a pH range of

5.5 to 7.0 is the preferred range for most crops. This might be due to irrigation activities going on in an area. Organic matter is generally low in the soils. According to [48] organic matter in the soil is rated as; >20% very high, 10 – 20% high, 4 – 10% medium, 2 – 4% low and <2% very low. Low organic matter content of the soils in Sokoto State has been attributed to factors such as continuous cultivation, frequent burning of farm residues commonly carried out by farmers in the area which tends to destroy much of the organic materials that could have been added to the soil [49]. Furthermore, [50] stated that low organic matter content in soils of Sokoto area could be due to rapid decomposition and mineralization of organic materials contributed by sparse vegetation in the hot semi-arid climate as promoted by radiation.

Total nitrogen ranged between 0.50 to 1.81g/kg. This result agrees with that of [51] whose study in Bauchi State gave total nitrogen values that ranged from .084 to .09g/kg, (0.09g/kg-1 average); 0.05 to 0.06g/kg-1 (0.05g/kg-1 average), and 0.7 to 0.09g/kg-1 (0.082g/kg-1 average), in different depths TLL1, TLL2, and TLL3 respectively. The total nitrogen values of the soils in the area changed irregularly with depth which could be attributed to influence of continuous cultivation, a common practice in the area that is accompanied by crop residue removal and deforestation [52]

Electrical conductivity ranged between 0.06 and 0.11ds/m which was low. Low values of EC indicate non-saline status of the soil. This finding is not agreeing with the results of [53] who obtained EC ranging from 1.88 to 3.30dsm-1, (3.3dsm-1 average); 0.88 to 2.60dsm-1 (1.50dsm-1 average) and 0.90 to 1.08dsm-1 (1.30dsm-1 average) in three profiles respectively in studies carried out in sites within the same ecological zone as the study area.

The values of exchangeable sodium percentage (ESF) were generally below15% which is the critical limit for sodicity [54]. The Sodium Adsorption Ratio (SAR) values in the study area are rated low, below the threshold value of 13 for sodic soils [55].

The exchangeable basis of the soils in the study area was generally low. Similar results were obtained by [56]. Calcium and magnesium are the predominant basic cations in the soils. Similar observations have been made in the past for West African soils in general [57]. The findings also agree with those of [58].

The effective cation exchange capacity (ECEC) of the soil is low, an indication that the soils at their natural pH levels, remain low in CEC and therefore have a low capacity to retain nutrients.

5. Conclusion

The soil survey of Bagale hills Forest Reserve was conducted to ascertain its current edaphic status because of its vulnerability to different anthropogenic activities over the many years of its existence. The composite soil samples collected from two depths, 0-40cm and 40-80cm, were assessed for physico-chemical properties. Physical properties revealed a preponderance of sand and low percentages of silt and clay. Chemical properties showed that the soil is acidic. Although results varied at the lower, mid and high elevations along the altitudinal gradients, the ANOVA showed no significant difference in the edaphic status of this reserve. The soil of this reserve will therefore require adjustments and intervention to enhance its sustainable development.

Extension activities and capacity building, should be carried out to sensitise the people especially those proximal to this reserve, on its proper utilization. Deforestation, wrong farming methods, bush burning and many other forms of anthropogenic activities detrimental to this ecosystem, could be discouraged as these could lead to soil degradation.

This study can be used as a template in conducting further researches in this category to evaluate the “health status” of other forest reserves in Northern Nigeria and in the whole country.

Compliance with ethical standards

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Disclosure of conflict of interest

If two or more authors have contributed in the manuscript, the conflict of interest statement must be inserted here.

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