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Original Research Article

Selected Physical and Chemical Properties of Soils in Mokwa, Doko and Edozhigi Areas of Niger State, Nigeria

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An assessment was conducted on the selected physical and chemical properties of soils along toposequences in Mokwa, Edozhigi and Doko areas of Niger state. Three profile pits were dug at the upper, middle and lower slope positions, at each of the selected study locations. The soils were described for their physical and chemical properties. All soil samples collected from identified genetic horizons were analyzed in the laboratory using standard laboratory procedures. The results revealed that the soils were predominantly clay in texture, ranging from 0.08 to 1.61 mgm^{-3}. The soil pH was slightly acidic to alkaline in reaction (pH range 6.68-7.69). The organic carbon and total nitrogen were low with values ranging from 5.53-10.9 and 0.62-1.23gkg respectively, while available phosphorus was generally low. It is recommended that, the incorporation of crop residue, addition of organic manure and provision of adequate drainage will improve the physical and chemical properties of the soil, which will in turn enhances suitable crop production.

Keywords: Assessment, Profile, Selected, Sustainable, Toposequence.

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INTRODUCTION

In the past, agricultural systems in Nigeria relied mainly on shifting cultivation to maintain the fertility of the soil through organic and plant nutrient build up during fallow periods. The ever-increasing population pressure on land and the rate at which prime agricultural lands are lost to other non-agricultural uses with the resultant decline in output per hectare of food crops due to continuous cropping, necessitated that every hectare of land should be used in accordance with its capacity and limitations (Ogunkunle, 2005). The degree of land degradation (chemical, physical and biological land degradation) is very high and is on the increase, hence resulting in the dwindling amount of good agricultural land over time (Ayuba, 2004).

Generally, variations in soil properties have been found to have significantly influence soil management and crop production (Fashina, 2003). Soil variability has been seen as a worldwide problem. It does not only cause within field crop growth variability which reduces farmers yields, but also complicates the interpretation of agronomic experiments (Brouwer et al., 2003; Tellen and Yerima, 2018).

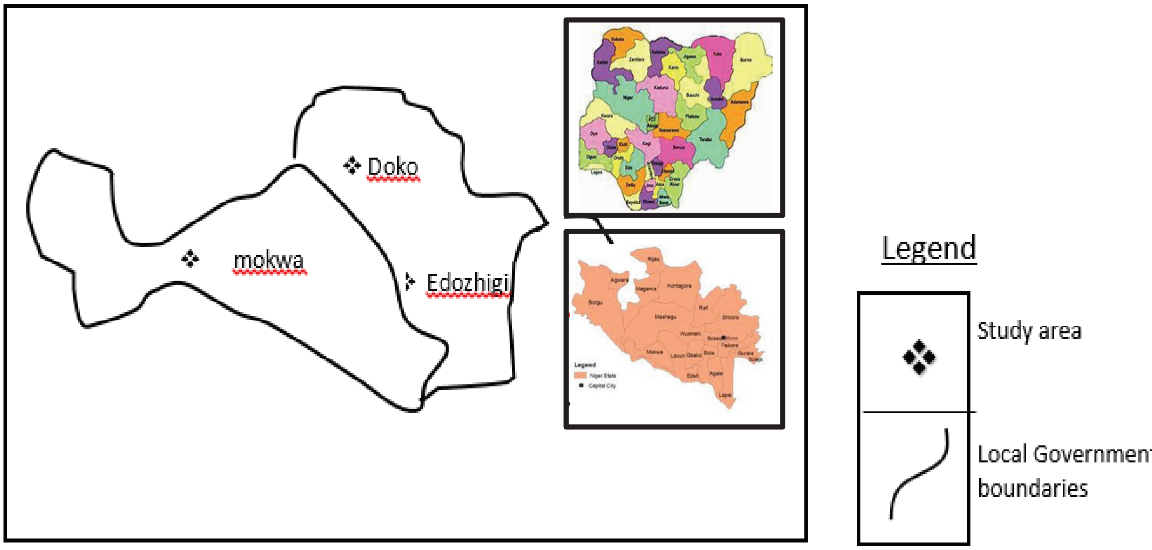

Figure 1. Map of study area.

In Nigeria, there is a gradual drift from traditional to a more scientific agriculture, consequent upon this, the increasing unit cost of fertilizer and the fragility of soils in Nigeria amongst others. The evaluation of the fertility status of soils becomes necessary, such evaluations will ensure prudent and sustainable fertilizer application and utilization. This approach is useful now as efficient fertilizer use, based on recommendations from soil testing that recognizes inherent variability in soil properties is the tool for achieving Nigeria's scientific agricultural rejuvenation (Mustapha and Nnalee, 2007). The recommendation will differ from the blanket rates made over large geographical area which farmers have been encouraged to adopt (Ayodele and Omotoso, 2008). Recent studies have shown that wasteful and inappropriateness of these blanket recommendations are causing environmental pollution among others and irra-tional over use of chemical fertilizers (Sokouti and Mahdian, 2011). Similar research have also been carried out by Umeri et al., (2017); Gisilanbe et al. (2019); Girma (2020).

In the light of this, this study was aimed at assessing the fertility indices of soils at Mokwa, Edozhigi and Doko areas of Niger State, and suggests management practices for optimum and sustainable cropping systems. The land use of the study areas were mostly rainfed and arable crops were cultivated, such crops include maize, rice, cowpea and tuber crops such as yam and cassava.

MATERIALS AND METHODS

The study was conducted at Mokwa, Edozhigi and Doko areas of Niger state within latitude 9.2928^0N and longitude 5.0547^0E and Longitude 9.0797^0N and latitude 6.0097^0E and 9.5076^0N and 7.0391^0E of the southern guinea savannah ecological zone of Nigeria, (Voncir et al., 2007) Figure 1. The geology of Niger state is said to be metamorphic basement complex and sedimentary geological formations, which gives rise to Nupe sand-stone. The second geological formation is the basement complex. The climate is characterized by two distinct sea-sons, wet and dry seasons. The average annual rainfall is about 1000-1500 mm per annum. With mean annual temperature, ranging between 32^0C – 38^0C and a relative humidity of 75 – 80 %. Most of the soils of the study areas were classified according to Food and Agriculture Organization of the United Nations (FAO) as Alfisols and Inceptisols.

Soil Sampling and Handling

Three profile pits, with dimensions 2m long, 1.5m wide, and 1.5m deep, were dug along a toposequence at each of the three study sites. Soil samples and soil clods were collected from each identified genetic horizon of the nine profile pits, using hand trowel.

The collected soil samples were then properly labeled in polythene bags and taken to the laboratory for analysis. In the laboratory, soil samples were separately air-dried ground and passed through a 2mm sieve for laboratory analysis as described by Agbenin (2015), unless otherwise indicated. Particle size analysis was determined using the bouyoucos hydrometer method, after dispersing the soil samples with 5% sodium hexametaphosphate. The bulk density was determined by the core method (Black and Hartge, 1986). Porosity was calculated from bulk density (Db) and standard particle density (Db) data as described by Anderson and Ingram (2008). Soil pH was determined in 1:1 water ratio

Table 1. Physical Properties of the Soils at the three Different Locations, Toposequence and Horizons.

	Sand %	Silt (%)	Clay (%)	Db (Mgm^{-3})	Porosity ($m^{-3}m^{-3}$)
Locations					
Mokwa	32.8	29.9	37.2	1.61	0.40
Edozhigi	25.3	26.3	48.3	1.92	0.30
Doko	12.6	25.6	62.0	1.75	0.30
SE±		2.15		0.08	
LSD (P<0.05)	7.13	NS	3.57	NS	0.01
Toposequence					
Upper	26.1	26.3	47.4	1.85	0.30
Middle	23.9	27.4	49.1	1.70	0.40
Lower	20.7	28.1	51.1	1.73	0.40
SE+	1.96	2.40	3.20	0.08	
LSD (P<0.05)	NS	NS	NS	NS	0.01
Horizons					
Ap	23.7	28.5	47.9	1.79	0.30
Bt	23.5	26.0	50.4	1.72	0.40
SE+	1.60	1.96	2.61	0.06	-
LSD (P<0.05)	NS	NS	NS	NS	0.01

NS: *Not significant*

using a glass electrode pH meter (Page et al., 2002). Determination of organic carbon, and total nitrogen were done by the wet oxidation method and regular micro-kjeldal methods, respectively. Available phosphorous was determined using the Bray-1 method. For the purpose of fertility ratings, the limits given by Esu (2001) were employed.

Data Analysis

The data generated were subjected to analysis of variance (ANOVA) using GenStat 13th edition. Means that are significant are separated using LSD (Harry and Steven, 2005)

RESULTS AND DISCUSSION

Physical Properties

Particle size distribution

The particle size distribution of the soils studied is presented in Table 1. The sand, silt and clay fractions across locations, toposequence and horizons ranged from 12.6 to 32.8, 25.6 to 28.1 and 37.2 to 62.0% respectively. Sand and clay content across locations was significantly different ($P<0.05$), with Mokwa recording the highest means sand content of 32.0%, while Edozhigi recorded the highest mean clay content of 62.0%. Soils of the three locations were predominantly clay in texture. The higher mean value of percentage soil content obtained for Mokwa may be attributed to the secondary product of weathering (Fitzpatrick, 2006), while the dominance in clay fraction of the soils of Edozhigi may be attributed to the natural parent materials (Brady and Weil, 2013).

Bulk density (Db)

The soils investigated had similar distribution of bulk density (Db) values ranging between 1.61-1.92 Mg/m^3 across locations, toposequence and horizons (Table 1). There was no significant differences in soil Db values between locations, toposequence and horizons. However, values exceeding 1.8 Mgm^{-3}. The mean values of soil bulk density obtained for this study are within the range reported in an earlier finding by Folorunso and Ahn (2009) on similar soils, who recorded values of 1.50 to 1.80 Mgm^{-3}, while working on a soil in Borno state. The values of Db obtained for this study are generally considered to be low and may be attributed to low content of organic matter, less aggregation, root penetration as well as compaction caused by the weight of overlying soil layer (Vickers, 2009). Donahue et al. (2000) pointed out that good plant growth is best at bulk densities below 1.40 Mgm^{-3} for clay, and 1.60 Mgm^{-3} for sandy soils.

Porosity

The mean porosity values obtained from this study ranged from 0.30 to 0.40m^{-3} m^{-3} (Table 1). The generally low porosity

Table 2. Soil pH, Organic carbon (OC), total nitrogen (TN) and available phosphorus (AP) at the three different locations, toposequence and horizons.

	pH	OC (gkg^{-1})	TN (gkg^{-1})	Available phosphorus ($mgkg^{-1}$)
Locations				
Mokwa	7.11	9.79	1.23	3.44
Edozhigi	7.26	7.61	0.81	5.75
Doko	7.19	7.34	0.71	20.1
SE±	0.23	2.00	0.18	4.87
LSD (P<0.05)	NS	NS	NS	NS
Toposequence				
Upper	7.33	7.27	0.88	5.68
Middle	7.15	9.23	1.01	16.6
Lower	7.08	8.23	0.86	7.03
SE+	0.16	1.95	0.18	5.48
LSD (P<0.05)	NS	NS	NS	NS
		Horizons		
Ap	6.68	10.9	1.21	11.5
Bt	7.69	5.58	0.62	8.07
SE+		1.59	0.14	4.44
LSD (P<0.05)	0.41	NS	NS	NS

NS: *Not significant*

values recorded in this study falls within the range of 0.31 to 0.51 m^3 m^{-3} as earlier reported by Hassan and Shuaibu (2006), who studied similar soils at Walban Deba in Gombe state.

Mean porosity values significantly (0.40m^3 m^{-3}) (p>0.05) differs with respect to locations, toposequence, and horizons. The subsurface or Bt horizons are significantly (P>0.05) different from the surface or (Ap) horizons (0.30m^3 m^{-3}) (Table 1). This is observed that have high porosity values in the sub-surface horizons and could be attributed to continuous cropping, which often results in a reduction of macro pore spaces on the agricultural plough layer or soil surface (Opeyemi et al., 2020).

Incorporation of organic manure to the soils will decrease the soil bulk density and ultimately increase the percentage porosity value in the sub-surface horizon agrees with an earlier report by Lekwa et al. (2008), who worked on soils of Numan, Adamawa state. Brady and Weil (2013) indicated that a high porosity value in sub surface horizon could be attributed to continuous cropping, which often results in a reduction of macro pore spaces on the agricultural plough layer or soil surface.

Incorporation of organic manure to the soils will decrease the soil bulk density and ultimately increase the percentage pore distribution, thereby enhancing the soil physical condition for optimum crop production and food security (Hassan and Shaibu, 2006).

Soil pH, OC, TN and AVP

The results of selected chemical properties of the studied soils are presented in Table 2. The mean pH values of the soils between locations, toposequence and horizons ranged from 6.68-7.69 (Table 2), which is similar to those earlier reported by Voncir et al. (2007). The pH of the soils can be classified as slightly acidic to alkaline in reaction. Soil pH is the major driver of soil fertility (Brady and Weil, 2013).

Mean values of soil pH increased with soil depth (Table 2). This increase with depth may be attributed to leaching of basic cations and uptake by cultivated crops from the root zones, it may also be attributed to the use of acid forming fertilizer such as urea for agricultural purposes, over a long time (Voncir et al., 2008; Kolo et al, 2009). The above reasons could be responsible for the significant (p>0.05) differences between the surface (Ap) and sub-surface (Bt) horizons (Table 2), but generally, the pH mean values are similar in all the studied soils.

The mean organic carbon values for the studied soils ranged between 7.39-9.79, 7.72-9.23 and 5.53-10.9g/kg for locations, toposequence and horizons, respectively. Mean organic carbon content were all low on the scale of Esu (2001) and not significantly (P>0.05) different between locations, toposequences and horizons (Table 2). The low

Table 3. Critical Limits for Interpreting Levels of Analytical Parameters

Parameters	Rating		
	Low	Medium	High
Organic C (h/kg)	<10	10-15	>15
Total Nitrogen (g/kg)	<2	2-5	>5
Available phosphorus ($mgkg^{-1}$)	<10	10-20	>20

Source: Esu (2001)

value of OC content corroborated with the findings of Mustapha and Nnalee (2007); Vouncir et al. (2007) and Mustapha et al. (2011) for soils in the savanna zones of Nigeria. Aydinalp (2010) attributed the low level of organic carbon content to the prevailing dry conditions, where the biomass production is low and the rate of mineralization high.

Mean values of total nitrogen (TN) of the soils ranged from 0.62-1.23g/kg across locations, toposequence and horizons (Table 2). The TN content of these soils was not significantly different between locations, toposequence and horizons and the total TN content was rated low. The low levels of the total nitrogen obtained in the soils of the study areas could be attributed to rapid rate of organic matter decomposition, high rate of leaching, soil erosion, volatilization and de-nitrification among other factors (Ekwonya and Ojanuga, 2002).

The mean available phosphorus (AP) values of the soils ranged from 3.44-20.1, 5.68-16.6 and 8.07-11.5mg/kg in locations, toposequence and horizons respectively (Table 2). The mean AP content of the soil was not significantly different between locations, toposequences and horizons and was generally found to be low. Brady and Weil (2013), attributed the low value of AP as recorded in this study, to low content in parent materials of most soils, and its propensity to sorption on mineral surface.

The highest mean value of 20.1mg/kg (Table 2) obtained at Edozhigi village, can be attributed to residual application of chemical fertilizer containing phosphorus from the previous farming year. According the Turner et al. (2007), such exceptionally high value of available phosphorus as seen at Edozhigi village which could be attributed to the nature of phosphorus, which is not quite immobile and tends to remain at the surface where it was applied, unless thoroughly ploughed in the soil.

CONCLUSION AND RECOMMENDATIONS

From the result obtained, the physical and chemical properties of the studied soils had very little differences between the three agricultural areas in which the study was undertaken. It was observed, that the main limiting factors regarding soil productivity are low organic matter content, low total nitrogen, high bulk density and high clay contents that can render its workability difficult (Table 3). But generally, the studied soils can be regarded as fertile and good for agricultural production, if well managed.

In line with the above findings, it is recommended that good management practices should be adopted for food sufficiency and security. This management practices should include the provision of adequate drainages, incorporation of crop residue, addition of organic manures, and inorganic fertilizers containing especially nitrogen and phosphorus and finally, proper and periodic monitoring of the physical and chemical properties of such soils is very necessary, so that appropriate preventive measures could be embarked upon as and when due, for optimum agricultural productivity.

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Conflict of Interests

The authors declare no conflict of interest.

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