

FERTILITY STATUS AND AGRICULTURAL POTENTIAL OF BASEMENT COMPLEX ROCK-DERIVED SOILS IN SOUTH WESTERN BAUCHI STATE, NIGERIA

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ABSTRACT

This study was conducted in the year 2005 to 2007 to assess the fertility status and agricultural potential of basement complex rock-derived soils in south-western Bauchi state, Nigeria. Due to continuous cultivation and removal of plant nutrients, most cultivated soils have been depleted of the nutrients and therefore unable to produce good yield. A sound knowledge therefore, of the kind and distribution of soils, their outstanding characteristics, classification and management system is essential for attaining sustainable production as well as facilitating agro-technology transfer programmes. (Khan et al, 1998). Soils samples were taken from five local government areas of South Western Bauchi state, namely: Bauchi, Dass, T/Balewa, Bogoro and Toro. Five different samples were collected from each location at 0-15 and 15-30cm depths of the soils. A total of 50 soil samples were taken and used for the study. Mechanical analyses of particle size were determined using the hydrometer method (Day, 1965). Organic carbon and total Nitrogen content were analysed using the procedure of wet oxidation method and micro Kjeldahl method respectively. Available P was extracted by Bray-1 method. Statistical differences obtained were separated using DMRT as described by Steel and Torrie. The results indicated that the texture of the soils ranged from loam to sandy loam. Organic carbon, total N and available P ranged from low to medium hence, the soils are of low fertility and consequently the need for appropriate fertilizer application, involving organic manuring and adequate inorganic fertilizer for sustainable crop production.

KEYWORDS: soil, sample, location and fertility status.

INTRODUCTION

The study area is in the northern guinea savanna zone of Nigeria and is characterized by distinct rainy (April - October) and dry (November - March) seasons. The area receives a mean annual rainfall of about 1,014.7mm and the mean daily maximum temperature of 26°C (Kowal and Knabe, 1972). The soil temperature regime is isohyperthermic which suggests less than 5°C difference between mean summer and mean winter soil temperature (Soil Survey Staff, 1998) while the soil moisture regime is dominantly Ustic in the uplands and Aquic in the fadamas. The arable lands are mostly upland with some few fadama. The soil orders are mostly Ultisol, Alfisol, Inceptisols and Entisols which have developed mainly from basement complex rock parent materials.

Soil fertility, according to Brady (1984) is defined as the inherent capacity of a soil to supply nutrients to plants in adequate and in suitable proportions. It is the quality that enables a soil to provide adequate nutrients in a proper balance for specified plant growth, other factors such as light, moisture, temperature and the physical condition of the soil being favourable. If the required amounts of nutrients are not available in the soil, the crop yield remains low, and in most cases, farming becomes uneconomical. Essential nutrients, particularly primary macronutrients: N, P, and K as well as Ca and Mg, are the major determinants of soil fertility (Singh, 1999). The level of primary nutrients in African soils is generally very low, particularly in the areas where farmers practices intensive cultivation. Majority of the soils,

particularly sandy and sandy loam soils, have poor nutrient retaining capacity hence need repeated application of nutrients, from external sources such as organic and inorganic fertilizers. The study was undertaken with the aim of evaluating the fertility status of the soils for the production of maize, sorghum, groundnut and rice in South Western Bauchi State.

MATERIALS AND METHODS

The study area is located in the South Western part of Bauchi State, latitudes 9° 40' and 10° 18'N, and longitudes 8° 58' and 9° 50' E. The entire State lies on high plains with elevation exceeding 500m above sea level. (Kowal and Knabe 1972). The geology of the area is made up of basement complex rocks (Kowal and Knabe 1972; Lombin, 1983). The study area is on granite basement complex rock formation. Along the area are mountains that extend to the edge of Plateau State in the west Sandstone is medium to coarse grained in texture in many areas with clay beds lies in few places.

Soil samples were taken from five local government areas of south-western Bauchi state, namely: Bauchi, Dass, T/Balewa, Bogoro and Toro. Five composite samples were collected from each location at 0-15 and 15-30cm depths of the soils using soil auger and stored in plastic bags. A total of 50 soil samples were taken and used for the study. The samples were dried in air, and ground, using a porcelain pestle and mortar and passed through a 2mm sieve. The sieved soil samples were stored in polythene bags and used for all laboratory analyses using standard procedures.

Particle size distribution was determined using Boyoucos hydrometer method as described by Day (1965). The textural class determined using the USDA textural triangle.

Organic Carbon was determined using the dichromate oxidation method of Walkley-Black (1965) while the total nitrogen contents of the soil samples were determined using the macro-kjeldahl method respectively. Moreover, available phosphorus was extracted by Bray-I method as provided by Bray and Kurtz (1945). The data obtained were statistically analyzed in a nested design using the *Minitab* software F-test. Means that were significantly different were separated using the Duncan's Multiple Range Test (DMRT) as described by Steel and Torrie (1981).

RESULTS

Table 1 shows the particle size distribution of the soils in the study areas. Sand, silt and clay contents ranged from 55.94 - 70.23 (mean = 65.07%), 9.93 - 24.65 (mean = 15.27%) and 18.47 - 21.70 (mean = 19.73%) respectively. The result indicate that there is a significant ($p < 0.05$) difference in the sand distribution between the different locations considered. The sand fractions in soil from Tafawa Balewa (mean = 69.82%), Bogoro (mean = 65.36%) and Toro local government areas (mean = 70.23%) were significantly ($p < 0.05$) highest, while it was least in soils from Bauchi local government area (mean = 55.94%). The silt content ranged from 8.4 to 26.5% within all locations. The percent silt content in Bauchi (mean = 22.65%) was significantly higher than in all other locations followed by Dass, Toro and T/Balewa local government areas which had the least silt content in the soils with means of 9.93% and 10.64% respectively. The clay content on the other hand ranged from 16-21%, 16-22%, 17-23%, 19-26% and 17-23% at the Bauchi, Dass, T/Balewa, Bogoro and Toro respectively. The percent clay content in Bogoro (mean = 21.70%) was significantly higher than in the T/Balewa (mean = 19.55%) and Toro (mean = 19.85%), while the T/Balewa and Toro clay fraction were also significantly higher than the Bauchi (mean = 18.42%) and Dass soils (mean = 19.15%) clay fractions.

Table 2 shows the particle size distribution as influenced by soil depths in the study areas. There were no significant differences in the contents of sand, silt and clay with depth

in all the locations although generally the sand content decreased with depth while the silt and clay contents increased with depth.

Table 3 shows the content of organic C, total N and available P of the soils of the study areas at all locations in g/kg^{-1} and mg/kg^{-1} respectively. The organic carbon content ranged from 0.24 - 0.99 g/kg^{-1} in all locations. Tafawa Balewa (T/Balewa) soils had significantly higher organic carbon content (mean = 0.70 g/kg^{-1}) than all the other soils while the organic carbon in Bogoro soils (mean = 0.64 g/kg^{-1}) was significantly higher than that of Bauchi (mean = 0.55 g/kg^{-1}) and Dass soils (mean = 0.43 g/kg^{-1}) which were also significantly higher than the Toro soils (mean = 0.50 g/kg^{-1}). The total N in the soils under study varied from 0.047 - 0.068 (mean = 0.06 g/kg^{-1}). Toro soils had significantly higher total N content (mean = 0.068 g/kg^{-1}) than the Bauchi soil (mean = 0.066 g/kg^{-1}) which was also significantly different from T/Balewa and Bogoro soils (mean = 0.061 and 0.047 g/kg^{-1}) respectively. Dass soils recorded the lowest total N content (mean = 0.058 g/kg^{-1}). Available P in the soils of the study areas varied within the ranged of 4.76 - 8.95 (mean = 7.28 mg/kg^{-1}) for all locations. The available P in Bauchi (mean = 8.05 mg/kg^{-1}) and Toro soils (mean = 8.95 mg/kg^{-1}) were significantly higher in available P than the soils from Dass (mean = 7.68 mg/kg^{-1}) and Bogoro (mean = 6.98 mg/kg^{-1}) which also had significantly higher available P value than the soils from T/Balewa (mean = 4.7 mg/kg^{-1}).

Table 4 shows the content of organic C, Total N and Available P as influenced by soil depth in the study area. The organic C content varied significantly ($p < 0.05$) with depth at all the locations ranging between 0.81 g/kg^{-1} to 0.55 g/kg^{-1} (Dass) at 0 - 15cm depth and 0.61 g/kg^{-1} (T/Balewa) to 0.31 g/kg^{-1} (Dass) at 15 - 30cm depth. The total N content of the soils was also significantly affected by soil depth in some of the locations. There were significant ($p < 0.05$) differences between the total N contents at 0 - 15cm and 15 - 30cm depths in Bauchi, Dass and Toro locations while in T/Balewa and Bogoro there were significant differences. The available P contents of soils in the study area varied between 4.42 and 9.60 mg/kg^{-1} but there was no significant difference in the content between depths in all the locations studied. However, available P was observed to decrease with depth in all the locations.

Table 1: Particle size distribution of the soils of the study areas

Particle Size Distribution (%)				
Location	Sand	Silt	Clay	Textural Class
Bauchi	55.94c	22.65a	18.42c	Loam
Dass	63.98b	16.87b	19.15c	Sand loam
T/Balewa	69.82a	10.64d	19.55b	Sand loam
Bogoro	65.36a	13.25c	21.70a	Sand loam
Toro	70.23a	9.93d	19.85b	Sand loam
SE±	0.74	0.64	0.41	

Means followed by the same letter(s) within column are not significantly different $p < 0.05$ (DMRT).

Table 2: Particle size distribution as influenced by soil depth

Particle Size Distribution (%)					
Location	Depth (cm)	Sand	Silt	Clay	Textural Class
Bauchi	0 - 15	58.9a	24.8a	16.3a	Loam
	15 - 30	53.0a	26.5a	20.6a	Loam
Dass	0 - 15	67.6a	15.0a	17.4a	Sandy Loam
	15 - 30	60.4a	18.7a	20.9a	Sandy Loam
T/Balewa	0 - 15	70.8a	10.4a	18.7a	Sandy Loam
	15 - 30	68.8a	10.9a	20.4a	Sandy Loam
Bogoro	0 - 15	67.5a	12.3a	20.2a	Sandy Loam
	15 - 30	63.2a	14.2a	23.2a	Sandy Loam
Toro	0 - 15	71.4a	9.6a	19.0a	Sandy Loam
	15 - 30	69.0a	10.3a	20.7a	Sandy Loam
SE±		1.04	0.90	0.56	

Means followed by the same letter(s) within column are not significantly different
 p < 0.05 (DMRT).

Table 3: Organic C, Total N and Available P contents of soils

Location	Organic C (g/kg ⁻¹)	Total N (g/kg ⁻¹)	Available P
Bauchi	0.55c	0.066b	8.05a
Dass	0.43c	0.058d	7.68b
T/Balewa	0.70a	0.061c	4.76c
Bogoro	0.64b	0.047c	6.98b
Toro	0.50d	0.068a	8.95a
SE±	0.24	0.003	0.24

Means followed by the same letter(s) within column are not significantly different
 p < 0.05 (DMRT).

Table 4: Organic C, Total N and Available P contents as influenced by depth of soils

Location	Depth (cm)	Organic C (g/kg ⁻¹)	Total N (g/kg ⁻¹)	Available P (mg/kg ⁻¹)
Bauchi	0 - 15	0.67a	0.08a	7.25a
	15 - 30	0.43b	0.05b	8.84a
Dass	0 - 15	0.55a	0.08a	6.79a
	15 - 30	0.31b	0.04b	8.39a
T/Balewa	0 - 15	0.79a	0.07a	4.42a
	15 - 30	0.61b	0.05a	5.10a
Bogoro	0 - 15	0.81a	0.06a	6.06a
	15 - 30	0.48b	0.04a	7.91a
Toro	0 - 15	0.61a	0.08a	8.30a
	15 - 30	0.40b	0.05b	9.60a
SE±		0.03	0.01	0.34

Means followed by the same letter(s) within column are not significantly different
 p < 0.05 (DMRT).

DISCUSSION

Data on particles size distribution are presented in Table 1. The results indicated that the soils of the study area are generally loamy to sandy in texture. The sand content of the soils ranged from 55.9% - 70.2% (mean = 65.1%). The results revealed that sand fraction was the dominant in the soils. Fitzpatrick (1998) noted that the chemical and mineralogical composition of parent material are important properties which are responsible largely for the coarse nature of soil formation and the resulting chemical and physical composition of the soil, including the secondary products of weathering. Esu (1999) reported that Nigerian Savanna soils are generally coarse textured. The high values of sand fraction were obtained from the soils of Toro while Bauchi soils recorded the least sand content. However, values of silt content ranged from 8.4% to 26.5%. Bauchi soils had higher percent silt content while least values were obtained from Toro soils with

mean of 9.9%. The high silt contents have been ascribed to low intensity of weathering in the semi-arid environment (Esu, 1991). The soils are generally free from coarse materials. The clay content of the soils was generally low, with a range of 16% - 26% (Table 1). The highest value was recorded in soils of Bogoro, this may be due to alluvial deposition. This indicates the intensity of weathering of the silt and clay size particles, which agrees with the report of Jones and Wild (1975) that tropical soil and indeed Bauchi state soils have undergone intense weathering.

Data presented in table 2 shows that the sand fraction was dominant at all locations and decreased slightly with depth in most soils. This corresponds the findings of Esu, 1998 and Malgwi, 2001), who reported that sand fraction decreased with depth down profiles. The nature of parent material also influences soil characteristic.

A soil might inherit a sandy texture from a coarse, quartz-rich parent material such as granite or sandstone. While percent silt was low at all locations (ranged of 8 to 13%) except at Bauchi which had higher percent silt (24%). The silt content increased with depth, which may be due to the action of erosion and leaching processes. The highest silt content is recorded in Bauchi soils which were also increased with an increase in depth down the profile. The clay content for all the soils ranged from 16.3 to 23.2% with higher value in soils of Bogoro and increased apparently with depth in most soils. The irregular profile depth distribution of the clay fraction especially in the surface and sub-surface soils indicated stratification of the illuvial parent materials. This increase in clay content with depth could be probably due to illuviation process and this conforms to the findings of Singh (1999). This indicated the intensity of weathering of the silt and clay size particles.

In respect of the organic carbon, it ranged from 0.49 to 0.63, 0.36 to 0.58, 0.42 to 0.88, 0.50 to 0.71 and 0.39 to 0.60g/kg⁻¹ at Bauchi, Dass, T/Balewa, Bogoro and Toro respectively. Bogoro local government had the highest organic carbon contents (0.50 to 0.71g/kg⁻¹) while Dass soils recorded the least value of organic carbon (0.36 - 0.58g/kg⁻¹). The values of organic matter content of the soils were generally low as indicated in table 3. These low values of organic matter are in agreement with data reported for the drier Savanna, (Jones and Wild, 1975; Esu, 1983: 1989). The low levels of organic matter might be partly attributed to the rapid organic matter mineralization thereby preventing any appreciable level of humification. It may also indicate the sparse natural vegetation of the semi-arid climate and the cultural practices of crop residuals removal (Jones and Wild, 1975). However, the value of total N content ranged from 0.065 - 0.09, 0.04 - 0.08, 0.04 - 0.08, 0.04 - 0.06 and 0.05 - 0.08g/kg⁻¹ at Bauchi, Dass, T/Balawa, Bogoro and Toro respectively. The overall values ranged from 0.03 - 0.11g/kg⁻¹ (Table 3). The soils were low in total N. This is probably associated with the low organic matter content of the soil, which resulted in low mineralization. Similar results were obtained in some fadama elsewhere (Singh, 1999, Akamigbo and Asadu, 1983). The low value of total Nitrogen could be due to low vegetation cover especially leguminous this crops and activity of nitrification process by nitrobacter. Total nitrogen varies significantly between locations suggesting that it is associated with organic matter contents of the soils. Nevertheless, the available phosphorous content is rated low to moderate and ranged from 4.76 to 8.95 (mean = 7.3mg/kg⁻¹) except in some locations such as Bauchi and Toro where moderate values are obtained. The low contents of available P in these soils could be attributed to the generally low total P in savanna soils and the interaction of P

and soil constituent. This conforms to the result adopted for the Nigerian Savanna soils by Esu (1991). Available phosphorous in the soil was low at all locations considered. Akamigbo and Asadu. (1983) gave two reasons that might be responsible for that. The first reason may be due to low phosphate potential of the parent rock while the second reason might be due to high fixation rate of the phosphate ion in the soil. This result conforms with the findings of Malgwi (2001). This may be related to the organic matter content of the soil which was found to be low.

The organic carbon content in all the soils decreased irregularly with soils depth and was low generally less than the critical limit given by Esu (1991). Organic matter was higher at 0 - 15cm and decreases in the 15 - 30cm depth (Table 4). The low level organic matter attributed to rapid decomposition and mineralization characteristics of the hot semi and climate. The frequent burning of farm residue commonly carried out by farmers also destroys much of the organic materials that could have been added to the soils from the sparse vegetation (Yakubu, *op cit*). Organic carbon content decreases with profile depth in the surface and subsurface correspondingly with decreases in total nitrogen content. According to the rating scale (Esu, 1991), the soils were all low in total N content with values decreased with increased in depth and varied significantly. This is probably associated with the low organic matter content of the soil, which resulted in low mineralization and decreasing with depth. Jones and Wild (1975), reported that soils of the arid and semi-arid regions, generally contain less than 1.0gNkg⁻¹ at the top 1.5cm and many contain less than 0.2gNkg⁻¹ soil. Moreover, the available P was moderately distributed in the soils of the area. Depth wise, the surface soils tend to be lower than the sub-surface in respect of available P content but statistically remains the same at all depths. Toro soils had higher value of available P, while T/Balewa soils recorded the least value of available P.

CONCLUSION

The study concluded that the soils of the study area were generally classified as poor soils. This is because they are virtually low in such nutrients as total N, available P, and organic matter respectively. The soils are therefore regarded as poor in fertility for most arable crops. The continuous production led to degradation of soil and also the constant usage of land for intensive cultivation made the land to be scarce and thus depletion of its natural resources. Increased population and consequently increased pressure on land use may have resulted into the degraded nutrients of depleted soils. Organic manuring and the use of inorganic fertilizer are recommended to could improve the soil fertility and productivity.

REFERENCES

- Akamigbo, F. O. R. and C. L. A. Asadu, (1983) Influence of parent materials on soil of southeastern Nigeria. *East Africa Agric*, for J. 48; 81-91.
- Brady, N. C. (1974). The Nature and properties of soils (9th Ed). Macmillan Publishing Company, New York. 12-18 Pp 416-420.
- Bray, R. H. and Kurtz, L. T. (1945). Determination of total organic and available forms of phosphorus in soil. *Soil science*. 59:39-45.
- Esu, I. E. (1983). Characterization and classification of dark clay soil of Biu plains, *Nigeria journal of soil science* 4:80-91.
- Esu, I. E. (1989). A pedological characterization soils of the Hadejia alluvial complex in the semi- and region of Nigeria pedological xxxix: 171-190.
- Esu, I. E. (1991). Detailed soil survey of NOHORT format Bunkure, Kano state, Nigeria. Institution for agricultural research, Ahmadu Bello University Zaria p.7.
- Esu, I. E. (1999). *Fundamentals of penology. Stirling Horden*, Ibadan, Nigeria, pp.87-98.
- Fitzpartrick, E. A. (1986), An Introduction to Soil Science; 2nd edition-John Wiley and Sons Inc. New York pp 225.
- Fussel, L.K. Serafini, P.G Bationo, A. and Klainji, M.C. (1987). Management practices to increase yield and yield stability of millet in Africa. Pp.255.
- Jones, M. J. and A. Wild (1975). Soil of the West Africa Savannah. Technical Communication no. 55, Common Wealth Bureau of Soils, Harpenden, pp-9-50.
- Juo, A. S. R. (1979), Selected Method for Soil and Plain Analysis. Manual Series. No.2 Pp.55.
- Kowal, J. M and Knabe, D. T. (1972), An Agro climate Logical Atlas of Northern States of Nigeria with Explanatory Notes. ABU Peers, Zaria, Nigeria.
- Kowal, J. R. and F. Kasam (1978), Agricultural Ecology of Savannah: A Study of West Africa Clarendon Press Oxford pp 6-90.
- Lombin, G. (1985), Evaluating the Micronutrient Fertility of Nigerian semi and Savannah Soils. 1 Boron and Molybdenum. *Soil Science and Plant Nutrition*. 31:12-25.
- Malgwi, W. B. (2001). Characterization of salt affected soils in some selected locations in the north-western zone of Nigeria. Unpublished PhD Thesis. ABU Zaria. 230 Pp.
- Singh, B. R. (1999), Fertility and Salinity/Sodicity Status of Fadama Soil in North - Western Nigeria I. Kebbi State *Nigerian Journals of Basic and Applied Science*. 8:1-14.
- Soil Survey Staff (1998). Keys to Soil Taxonomy, USDA, Soil Conservation Services. 8th Edit. Washington, D. C.
- Steel, R. C. and Torrie, J. H. (1981), Principles and Procedures of Statistics. Macmillan, New York, U.S.A.255pp.
- Walkley, A. and Black, A. (1934). An examination of Degtjareff Method of Determining Soil Organic Matter and a proposed modification of the chromic acid titration method. *Soil Science*. 37: 29-38.