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Characterization of Some Selected Soils Based on Fertility Capability Classification. In Madagali Local Government Area of Adamawa State, Nigeria

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Abstract

Characterization of soils using a scientific procedure is essential to assess the potential and constraints of a given land for agricultural purposes. The knowledge of soil limitations arising from land evaluation reports aims to provide practical approaches to ameliorating such limitations before or during the cropping period. This study was conducted to characterize selected soils in Madagali Local Government Area based on fertility capability classification. A reconnaissance soil survey was conducted in the study area. Ten auger point soil samples from each ward were randomly collected at depths of 0-20cm and 20-50cm using a digger, hoe, spade, and polyethylene bag. For each surface and sub-surface, ten samples were collected, making twenty samples representative of each ward. The twenty auger points collected from each ward were taken to the laboratory for analysis. Based on the laboratory results of selected soil properties, the fertility capability classification system classified the soils of Madagali Local Government into one FCC class (LLaedmk) for Hymbula, Gulak, Duhu, Kirchinga, and Palam. The fertility capability classification (FCC) revealed that all the soils in the study area were facing major constraints such as soil moisture stress (d), low organic matter (m), aluminium saturation (a), and low nutrient reserve (k). However, in the studied area, it is necessary to add potassium fertilizers or organic amendments with a significant K content, irrigate for dry-season farming, and add lime to overcome aluminum toxicity.

Keywords: Characterization, Soils, Fertility, Capability, Classification.

Introduction

Human disturbance of the earth's ecosystem to generate food and fiber will impose a larger strain on soils to provide important nutrients as the human population continues to rise (Vonciret *al.*, 2006). Soils are the basis of life on Earth. They provide the foundation that plants rely on to remain upright. Soils provide a habitat for a vast biodiversity and biomass of soil organisms and serve as the repository for most of the carbon and nutrient elements that support life (Mayer et al; 2018). Soil fertility capability classification (FCC) is a system of characterizing soils based on a collection of physical and chemical features, specifically fertility-related restrictions of topsoil and subsoil, which directly affect plant development and production. The Soil form, Characteristics, and Classification (SFCC) is a classification of soil based on constraints measured by condition modifiers (Rao and Jose, 2003). The SFCC system was developed to bridge the gap between sub-disciplines of soil classification and soil fertility. The diversity and abundance of soil and rhizosphere microorganisms influence plant composition, productivity, and sustainability (Monther et al., 2020). Its purpose is to interpret soil taxonomy and additional soil attributes in a manner directly relevant to plant growth (Sancheze *etal,*2003). The use of different soils for agricultural purposes and the appropriate management strategies required to maximize agricultural productivity largely depend on soil variability.

The soil fertility capability classification system was developed to interpret soil taxonomy and additional soil attributes in a way that is directly relevant to plant growth (Sanchez *et al.*, 2003). It is a technical system of grouping soils with similar limitations and management problems in terms of the nutrient supply capacity of the soils, which has been widely used in the tropics (Sanchez *et al.*, 2003). The FCC considers topsoil parameters as well as specific subsoil properties that are related to plant growth. While many consider the FCC to be a land evaluation system, it is actually a soil classification system that does not rank soils (Tabi et al., 2013). Basic soil resource information is essential for planning sustainable agriculture (Ekwoanya and Ojanuga, 2002). Sustainable agriculture requires both direct and indirect knowledge of soil capabilities and nutrient status (Dickson *et al.*, 2002). In Nigeria, low soil nutrient reserves due to the predominance of low activity clays and declining soil fertility have been major problems for smallholder farmers. However, Mutsaers (1990) stated that a strategy for replenishing soil fertility to enable sustainable agricultural productivity has not yet been developed. The need for soil surveys and land evaluation reports prior to crop cultivation and other agricultural land uses has been emphasized (Orimoloye, 2011).

The FCC modifiers (letters) can be directly related to individual land qualities. Therefore, in effect, the soil 'name' as given by its FCC class is meaningful for soil fertility management and appears to be a suitable framework for agronomic soil taxonomy, acceptable to both pedologists and agronomists (Lin, 1989). Through knowledge of FCC classes, farmers and land users can identify fertility, rooting, and moisture limitations of land for specific crops and plan their activities to circumvent the drawbacks (Sanchez *et al.*, 2003).

Therefore, soil characterization using a scientific procedure is essential to assess the potential and constraints of a given land for agricultural purposes (FAOSTAT. (2021). The knowledge of soil limitations, arising from land evaluation reports, aims to provide practical approaches to ameliorate such limitations before or during the cropping period (Lin *et al.*, 2005). In addition, sustainable agricultural production can only be achieved when information on soil characteristics is carefully collected, assembled, and interpreted. Therefore, understanding soil fertility capability classification is crucial in this study to help farmers manage their land resources, maximize crop production, sustain the ever-growing population, and improve their income and standard of living.

Materials and Methods

Location of the Study Area

The study was carried out in Madagali Local Government Area of Adamawa. Madagali Local Government Area is located in the northern part of Adamawa State, Nigeria. Madagali Local Government area is situated between longitude 13°37′. 42″to the east of the Greenwich Meridian and 10°53′31" north of the Equator. It is bordered by Borno State to the north, Cameroon Republic to the east, Michika Local Government to the south, and Askira/Uba Local Government Area to the west. The majority of the population are farmers who produce different varieties of crops such as sorghum, maize, groundnuts, cowpea, rice, sugarcane, sweet potato, vegetables, as well as various species and types of tree crops. Livestock such as cattle, sheep, goats, pigs, poultry, and rabbits are also raised in the study area.

Soil Sampling Technique

A reconnaissance soil survey was conducted in the study area which was aided by topographic maps and vital information. Ten auger point soil samples from each ward were collected at depths of 0-20 cm and 20-50 cm using a digger, hoe, spade, and polyethylene bag. For each surface and sub-surface, ten samples were collected, making twenty samples representative of each ward. The twenty auger points collected from each ward were sealed in clean polyethylene bags, labeled, and then taken to the laboratory for analysis.

Sample Preparation and Laboratory Analysis

The soil samples collected were air-dried and crushed using a pestle and mortar to pass through a 2mm mesh sieve. Some samples underwent further analysis by passing through a 0.5 mm sieve for chemical analysis. The soil samples collected were analyzed for their physical and chemical properties using standard laboratory procedures. The laboratory analysis results of the selected soil properties in the study area were used to classify the soil's fertility.

Results and Discussion

Some Selected Soil Properties for Fertility Capability Classification

The results of some selected soil properties are presented in Table 1. The mean values for particle size distribution for surface and subsurface soils of Hymbula were (63.80%,62.00%), (24.80%, 26.60%), and (11.40%, 11.40 %) for sand, silt, and clay, respectively. The sand content decreases with depth, silt content increases with depth, and the silt content remains constant. This might be due to the sorting of silt and clay particles by water. This result is in conformity with that reported by Osujieke *et al.* (2016). This gives the textural class of sandy loam for both surface and subsurface layers. The mean values of pH, organic carbon, and total nitrogen for surface and subsurface soils of Hymbula were (6.12, 6.22), (11.45 g/kg, (12 g/kg, 13 g/kg), respectively, all of which increase with soil depth. This might be due to the leaching of basic cations by water and the sandy nature of the soil. This is in conformity with the result reported by Musa (2015). The mean values of potassium content for surface and subsurface soils remain constant (0.14 cmol/kg). This might be due to the uniformity of the soil types and management practices in the study area. The mean values of available phosphorus, ECEC, and exchangeable sodium percentage were (8.0 mg/kg), (5.48 cmol/kg), and (3.91%, 4.67%), respectively, all of which decrease with depth. This might be due to low organic matter at the soil surface and low rainfall in the study area.

The mean values of particle size distribution of Gulak soils were (62.20%, 62.30%), (23.50%,4.30%), and (13.40%,14.30%) for sand, silt, and clay, respectively. Sand and silt decrease with depth, while clay content increases. This might be due to the sandy nature of the study area and soil types. This gives the textural class of sandy loam for both the surface and subsurface layers. The mean values of pH, organic carbon, total nitrogen, available phosphorus, and ECEC for the surface and subsurface were (6.2, 6.25), (12.54 g/kg, 14.10 g/kg), 14 g/kg, and 6.68 cmol/kg, respectively. All of these values decreased with depth. The mean values of potassium and exchangeable sodium percentage for the surface and subsurface were 0.80 mg/kg,6.00%, and 3.27%, respectively. Both of these values increased with depth. This may be attributed to the parent material and leaching of the basic cations by water. This finding is also consistent with the work of Shobayo (2010).

Table 1: Selected Soil Properties for Fertility Capability Classification.

LOCATIONS	DEPTH	SAND	SILT %	CLAY	TC	pH 1:2 (Soil:H_2O)	OC (g/kg)	TN (g/kg)	AvP (mg/kg)
HymbuLa	0-20cm	63.80	24.80	11.40	SL	6.12	11.54	12	9.11
	20-50cm	62.00	26.60	11.4	SL	6.22	13.14	13	8.02
Gulak	0-20cm	62.30	24.30	13.40	SL	6.25	14.10	14	11.24
	20-50cm	62.20	23.50	14.30	SL	6.21	12.54	12	8.80
Duhu	0-20cm	56.90	29.90	13.20	SL	6.41	12.0	12	7.45
	20-50cm	58.40	25.40	16.20	SL	6.30	13.12	12	8.25
Kirchinga	0-20cm	66.00	23.40	10.60	SL	6.09	14.20	12	10.25
	20-50cm	58.80	25.40	15.80	SL	6.03	12.83	12	10.26

Palam	0-20cm	67.00	20.60	12.40	SL	6.17	12.50	12	8.57
	20-50cm	59.60	25.10	15.30	SL	6.23	12.23	11	8.65

SL= Sandy, LS= Loamy Sandy, OC= organic carbon, TN = total nitrogen, AP = available phosphorus, ECEC = Effective cation exchange capacity, ESP =Exchangeable Sodium Percentage. The mean values of particle size distribution for Duhu's surface and subsurface soils were 56.90%, 25.40%, and 13.20% for sand, silt, and clay, respectively. For subsurface soils, the mean values were 40%, 29.90%, and 16.20% for sand, silt, and clay, respectively. The sand and clay content increase with depth, while silt content decreases with depth. This might be due to the nature of Harmattan dust, which contributes to silt accumulation at the soil surface of the study area. This is in conformity with the results obtained by Kpamwang (2008), who worked on the soils of the Savannah region of northern Nigeria. This gave the textural class of sandy loam for both surface and subsurface layers. The mean values of pH and potassium content were 6.30 and 6.41, respectively, and both values decreased with soil depth. The potassium content was 0.16 cmol/kg.

The mean values of organic carbon, available phosphorus, ECEC, and exchangeable sodium percentage were 12.00 g/kg), (7.45 mg/kg, 6.23cmol/kg, and 4.50%, 4.50%), respectively, for subsurface soils. Both values decrease with soil depth. The total nitrogen remained constant at 12g/kg. The increase in effective cation capacity in subsurface soils compared to surface soils might be due to the leaching of basic cations by water to subsurface soils and the low organic carbon content of the soils in the study area. This result corroborates that reported by Malgwi (2007).

The mean values of particle size distribution for surface and subsurface soils were 58.80%, 66.00%), (23. In subsurface soils, the mean values were 66.00%, 29.6%, 15.80%) for sand, silt, and clay particles, respectively. The sand content decreases with depth, while silt and clay content increase with depth. This might be affiliated with the sorting of clay and silt particles by water to subsurface soils of the study area, Osujieke *et al.* (2016). This gave the textural class of loamy sand and sandy loam for surface and subsurface layers. The mean values of pH and organic carbon were 6.03, 6.09, respectively, for surface soils, and 6.09 and 14.2 g/kg), respectively, for subsurface soils. Both pH and organic carbon values decreased with soil depth due to the low organic carbon content of the soils in the study area (Saddiq et al., 2019). Both values decreased with soil depth due to the low organic carbon content of the soils in the study area (Saddiq *et al.*,2019). Total nitrogen remained constant (12g/kg). The mean values of available phosphorus, potassium, ECEC, and exchangeable sodium percentage content for surface and subsurface soils were 10.25 mg/kg), (0.14%, 0.16%), (6.02cmol/kg, 7.05cmol/kg), and 3.22%,3.97%, respectively. These values increased with depth due to the leaching potential of the soils in the study area (Shehu *et* al., 2005).

The mean values of the particle size distribution for the surface and subsurface soils of Palam were 59.60%, 67.00%), (20.60%, 25.10%), and (12.40%,15.30%) for sand, silt, and clay, respectively. The sand content decreases with depth, while silt and clay content increase with depth due to illuviation and eluviation processes. This gives the textural class of sandy loam for both the surface and subsurface layers. The mean values of pH, organic carbon, available phosphorus, ECEC, and exchangeable sodium percentage were 6.17, 6.23), (15.50 g/kg), (8.57 mg/kg), (6.38, 6.43 cmol/kg), and (3.09%, 34.46%, respectively. All values increase with soil depth due to leaching caused by the high sand content of the study area. The mean values of total nitrogen and potassium for surface soils were 12 g/kg) and 0.11 cmol/kg,0.13 cmol/kg and decreased with depth. The decrease in total nitrogen and potassium with soil depth may be attributed to the sandy nature of the soil (Maniyunda *et al.*, 2014) and low organic matter content at the soil surface in the study area.

The Soil Fertility Capability Classification of the Study Area

The results of the fertility capability classification of the soils of Madagali Local Government area were summarized and presented in Table 2. The soils were generally sandy loam in texture at both the surface and subsurface for all five wards. In the first category type, all the soils were classified as L. This indicates that the soils have loamy topsoil with moderate to well-drained soil and good water holding capacity. While at the substrata type category, L was also observed, this also indicates that the subsoils of the study area have loamy textures as well. All soils were rated using d, k, a, and m modifiers based on laboratory results, indicating their fertility capability classification according to Sanchez's (2003) guidelines. This classification implies that the soils have a ustic moisture regime, low nutrients, aluminum saturation, and low organic matter, according to Sanchez's (2003) guidelines for fertility capability classification. Table 2 lists the soil fertility capability classification units. The table shows that the soils in the study area share the same FCC unit, potential, limitations, and management practices, which places them into one fertility capability class.

Table 2: The Capability Classification of the Study Area.

Location	Type	Sub strata type	Condition Modifiers					FCC Units	Interpretations	Management
	L	L	d	e	m	k	a			
Hymbula	L	L	*	-	*	*	*	LLadmk	Loamy surface and sub surface soil saturated with aluminium, formed under ustic	Potassium fertilizers or organic amendments with a significant content of K need to be applied. Crops

									moisture regime, having low organic matter and low nutrient reserve.	should be closely monitored for K deficiency symptoms. Irrigation is necessary for dry season farming and addition of lime to surmount aluminium toxicity.
Gulak	L	L	*	-	*	*	*	LLad mk	Loamy surface and subsurface soil saturated with aluminium, formed under ustic moisture regime, having low organic matter and low nutrient reserve.	Potassium fertilizers or organic amendments with a significant content of K need to be applied. Crops should be closely monitored for K deficiency symptoms. Irrigation is necessary for dry season farming and addition of lime to surmount aluminium toxicity.
Duhu	L	L	*	-	*		*	LLad mk	Loamy surface and sub surface soil saturated with aluminium, formed under ustic moisture regime, having low organic matter and	Potassium fertilizers or organic amendments with a significant content of K need to be applied. Crops should be closely monitored for K deficiency symptoms. Irrigation is

									low nutrient reserve.	necessary for dry season farming and addition of lime to surmount aluminium toxicity.
Kirchinga	L	L	*	-	*		*	LLadmk	Loamy surface and sub surface soil saturated with aluminium, formed under ustic moisture regime, having low organic matter and low nutrient reserve.	Potassium fertilizers or organic amendments with a significant content of K need to be applied. Crops should be closely monitored for K deficiency symptoms. Irrigation is necessary for dry season farming and addition of lime to surmount aluminium toxicity.
Palam	L	L	*	-	*	*	*	LLadmk	Loamy surface and sub surface soil saturated with aluminium, formed under ustic moisture regime, having low organic matter and low nutrient reserve.	Potassium fertilizers or organic amendments with a significant content of K need to be applied. Crops should be closely monitored for K deficiency symptoms. Irrigation is necessary for dry season farming and addition of lime

										to surmount aluminium toxicity.

Key: L= Loamy, a= aluminium saturation, k = low nutrient reserve, e = leaching potential, m=low organic matter.

The soils of Hymbula have a loamy (L) texture for both the type and sub-strata type, with condition modifiers (d) ustic moisture regime, (m) low organic matter, and (k) low nutrient reserve, which gives the fertility capability class (LLadmk). Duhu soils have (L) surface and sub-surface texture for both type and sub-strata,with condition modifiers (a) aluminium saturation, (d) for ustic moisture regime, (k) low nutrient reserve, and (m) low organic matter (LLadmk).Gulak and Pallam have a loamy (L) texture for both type and sub-strata,with condition modifiers (a) aluminium saturation, (d) ustic moisture regime, (m) low organic matter, and (k) low nutrient reserve that gave the FCC class (LLadmk) respectively. The soils of Kirchinga have a loamy (L) texture for both type and sub-strata, with condition modifiers (a) aluminium saturation, (d) ustic moisture regime, and (m) low organic matter. This gave the soil FCC class (LLadmk) according to the fertility capability classification guidelines of Buol, 1975 and Sanchez, 2003), this capability classification guidelines.

Conclusion

The soil fertility capability classification units coded in Table 2 above placed soils of the study area into one fertility capability class, indicating that soils of Madagali have the same FCC unit and the same potentials, limitations, and management practices. However, it could be observed that condition modifiers (d) ustic moisture regime, (a) aluminium saturation, (k) low nutrient reserve, and (m) low organic matter were found to be the major constraints in all the FCC classes. These conditions cause soil dynamics such as a slowing down of nitrogen mineralization and leaching, as well as the death of many soil microorganisms (Sanchez *et al.*, 2003). Conversely, it may limit year-round production of crops unless supplementary water is supplied through irrigation and a sufficient amount of organic manure is added to the soil. This implies that the soils are saturated with aluminium which may affect aluminium sensitive crops, be poor in fertility, and have low water retention. These are the major constraints of the study area. Therefore, these soils would require supplementary water through irrigation for crop production during the dry season. Additionally, compound fertilizers and organic amendments containing significant amounts of nitrogen, phosphorus, potassium, and other cations like magnesium would be necessary for effective crop production.

Recommendation

- Compound fertilizers and organic manuer should be added for effective crop production.

- The soils should be supplemented with water through irrigation for crop production during the dry season.

Conflict of interest by the authors

The authors declare that there is no conflict of interest.

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