Available online at www.elixirpublishers.com (Elixir International Journal)

Agriculture

Elixir Agriculture 131(2019) 53211-53216

ISSN: 2229-712X

Land Capability classification of soils in a lithosequence within forest and savannah zone of Nigeria

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ARTICLE INFO

Article history:
Received: 16 April 2019;
Received in revised form: 25 May 2019;
Accepted: 3 June 2019;

Keywords
Soil; Production,
Evaluation,
Limitation,
Use,
Management

ABSTRACT

It is important to evaluate the capacity of soils to support arable crop production for proper land use planning and sustainable management. The soils developed on schists in southern guinea savannah zone (Kabba) and older granites in dry upland rainforest zone (Ado-Ekiti) were mapped and classified with Land Capability Classification. Profile pits were dug and described in sixteen pedons delineated at both locations. Soils samples were collected from the pedons for the analysis of some soil physico-chemical properties. Data on climate and physiographic features were also collected. The capability groupings of the soils are as follows: KA-$III_S^{3,4}$; KB, KF, AB and AF- II_S^{4}; KC, KD, KE, KG KH and AA- III_S^{4}, while AC, AD, AE and AG were V_S^{4}, $V_S^{3,4}$, IV_S^{4} and $VW^{2}{}_S^{4}$.The capabilities of the 16 pedons were limited by low nutrient capacity, shallow depth and wetness due to high water table. Appropriate fertility management scheme and land use were suggested for both sites.

Introduction

There is high demand on land for food and industrial needs of the world increasing population. There has been inability to match food production with the population increase especially in the sub-Saharan Africa (SSA). Increasing agricultural production is a global issue and a critical issue in the SSA. Two options had been suggested (Idoga et al. 1995):

1. Increasing land hectrage under cultivation
2. Increasing production per unit area.

Increasing land hectrage does not give consideration to sustainable production and may cause land degradation. On the other hand increasing production per unit area is conservative in nature; it involves sustainable land use towards optimum production.

Sustainable land use involves proper land use planning and an essential part of land use planning is land evaluation (Oluwatosin et al. 2006). There are several methods of land evaluation and they are all used for assessing land qualities or suitability of land for specific use as conditioned by the soil and environmental conditions (Beek 1978).

Land capability classification is a land evaluation method involving the systematic grouping of soils into categories based on nature of the potential and constraints to sustainable use. It involves classifying land based on physical constraints and potential hazards that can limit productivity (Satriawan et al. 2014). It determine and gives general direction for specific use to which a land can be put such as arable cropping, plantation, forestry, pasture and recreation (Samranpong et al. 2009). It is therefore necessary to conduct land capability classification to determine the ability of an area for effective land use planning as well as sustainable production. The objective of this study is to carry out land capability classification of soils formed in a lithosequence located within two agro-ecological zone of Nigeria.

Materials and Methods

Description of the study area: Ado-Ekiti is situated in Ekiti State of South Western Nigeria. The research site lies between latitude 7.710802N and 7.713800N and longitude 5.243230E and 5.246470E. The climate is of the upland Tropical Rain Forest type with distinct wet and dry seasons. The dry season comes up between November and March while the wet season prevails between early April and October with double maxima rainfall occurring in July and September with mean annual rainfall of 1470.1mm and average number of rainy days of 119.3.

Kabba this is located in the western part of Kogi State of the North Central Nigeria and The research site lies between latitude 7.860376N and 7.862225N and longitude 6.069576E and 6.074468E. The area is within the southern guinea savanna zone of Nigeria. It has an average annual rainfall of 1,329mm. The rainy season begins in late April/early May, with maximum precipitation occurring towards the end of the rainy season and is followed almost immediately by drought condition. July is the wettest month with over 203.2mm of rain, but in November, the area is already so dry that all parts receive less than 25.4mm of rain. Both locations are shown on map in figure 1.

Soil Survey, Sampling and determination of land characteristics: Each of the location (Ado-Ekiti and Kabba) was mapped. The conventional method of soil survey involving rigid grid procedure was adopted. For both sites, observations were made along traverses of 50 m apart with soil auger. The drainage classes, presence/absence of stones and boulders, flooding, erosion and slope angle were determined in the field following the procedure described in

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the guideline for soil description (FAO 2006). Areas with same soil type were mapped together and plotted on a base map. An area of 12.4395 and 12.1841 hectares of land were mapped in Ado Ekiti and Kabba respectively. Soil map of the two locations are presented in figure 2 and 3. Soil samples were collected within each soil boundary and taken to the laboratory for analysis.

Electrical conductivity (salinity) was determined at a 1:2.5 soil/water ratio using a wheatstone bridge at 25°C.

The soil texture was determined with textural triangle from the result of particle size distribution carried out with hydrometer method (Bouyoucos 1951).

ECEC of clay fraction was calculated using the method of Sombroek and Zonneveld (1971) as follows:

$$\text{ECEC (Clay)} = \frac{\text{ECEC (Soil)} - (3.5\ \%\text{Carbon})}{\%\ \text{Clay}} \times \frac{100}{1}$$

Land Capability Classification: Land Capability Classification was carried out following the system of Klingebiel and Montgomery (1961) and Modified from USDA (2017). The land capability classification rating in Table 1 was matched with the land characteristics of the study area in table 2 to produce land capability grouping in table 3.

Results and Discussion

Erosion hazard (e): There were no traces of erosion at both locations and the slope angle values ranged from 0.9 to 2.3, all the pedons understudy were grouped into class 1 in terms of erosion hazard.

Excess water (w): Pedons AG, KC, KG, KH and KI are somewhat poor to poorly drain. This occasioned pedons AG, KC and KI to be seasonally flooded most especially during the raining season and made them to be rated in class III in terms of excess water. This implies that rain-fed arable crops production will be impeded in these soils.

Soil limitation (s): Electrical conductivity values ranged from 0.050 to 0.67ds/m. These values are below the critical level of 4.00ds/m rated for saline soils (Brady and Weil, 2005) therefore the soils are non-saline and rated as class I in terms of salinity.

There was high percentage of stones in pedons KA, KB, KC, KD, KE and KF with ratings that ranged from 1 to 2. This could constitute a major impediment to tilling the soils with machineries and impede root penetration of crops and it occasioned the pedons to be grouped into class II in terms stones and boulders content.

Table 1. Land capability classification system.

Properties	Land capability class- Degree of limitations, Restrictions or harzards						
	I	II	III	IV	V	VI	VII	VIII
Erosion harzard (e)								
[1]Erosion	None or Slight	Moderate	Severe	Very Severe	None or Slight	Not class-determining		
[2]Slope Angle (%)	1	3	5	10	18	35	≥35	
Excess Water (w)								
[1]Drainage class	Well or Moderately	Moderately or Somewhat poorly	Somewhat poorly or poorly	Poor	Not class-determining			
[2]Flooding	None	Rare	Occasionally moderate	Frequent Severe	Frequent –Prevents normal production of crops			
Soil Limitation (s)								
[1]Salinity (EC-dS/m)	<1	1-2	≤3	>3	4-8	8-16	>16	
[2]Rock outcrop, stone and Boulders	<0.1	≥0.1 to <3	≥3 to <15	≥15 to <50	≥15 to <50	≥15 to <50	≥50 to <90	≥90
[3]Effective Soil depth (cm)	>90	45-90	22.5-45	7.5-22.5	<7.5		0	0
[4]ECEC (Cmol/kg) Clay	25-40	12-25	6-12	>5	≤5	2	1	0
[5]Surface Texture Class	SL, SCL, CL or LS (if less than 20in thick)	LS, S or SC, C (if <60% clay)	C (≥60% clay i.e HC)	COS, HC	VCOS		Not class-determining	
Climate (c)								
[1]Effective precipitation (mm)	≥1117.6	≥787.4 to <1117.6	≥635 to<787.4	≥482.6 to <635	Not class-determining	≥284 to 482.6	<284	Not class-determining
[2]Nature of Climate	Humid climate. Rainfall evenly distributed	Humid Climate. Dry spells occassionally occur	Crop yield frequently reduced by drought in subhumid climate	Crop yields frequently reduced by drought in semi arid climate	Semi Arid climate	Arid Climate		

Modified from: USDA (2017)

SL= Sandy loam, L= Loam, SCL= Sandy clay loam, CL= Clay loam, LS= Loamy sand, S= Sand, SC= Sandy clay, C= Clay, COS= Coarse sand, VCOS, Very coarse sand, HC= Heavy clay.

The soils depth of the pedons ranged from 40cm to 200cm. Deepest soil depth in soils on older granite is 130cm at pedon AA while on schists it is 200cm at pedons KB and KC. Generally the soils on schists are deeper than older granites, major restriction to depth in soils on the two parent materials are high water table around the lowland areas at profile AG (60cm), plinthites and concretions at profile KA and AA (40cm). Pedons AD and AG were rated into class II while KA was rated into class III in terms of soil depth.

Effective cation exchange capacity clay (ECEC Clay) values ranged from 2.67 to 22.22cmol/kg clay. The values recorded are below the boundary of 24cmol/kg clay set by Juo (1980) for limit between high activity clay and low activity clay. This implies that the soils studied are dominated by low activity clay (FAO 2014; Soil Survey Staff 2014). The high presence of low activity clay in the soils implies that nutrients may likely be lost through leaching (Sanchez 1976) this conditioned the soils to be rated in class below class I. Pedons AB, AF, KB, KF, KH and KI were grouped into class II, AD, KA, KC, KD, KE and KG into class III while the other pedons are in class IV in terms of ECEC clay.

Aggregate land capability rating: Based on the limitations observed in the soils studied, all the pedons were rated below class I. S indicates soil limitation; superscripts 2 is limitation due to high presence of stones and boulders, 3 is shallow effective soil depth and 4 is low nutrient holding capacity due to moderate to low ECEC clay. W indicates Excess water; superscript 1 is somewhat poor to poorly drained soil, 2 is occasionally flooded condition. Pedons AA was rated IIIs^{4}, AB and AF- IIs^{4}, AC and AE- IVs^{4}, AD- IIIs^{3,4} AG-IVw^{1,2}s^{3,4}, KA- IIIs^{2,3,4}, KB and KF- IIs^{2,4}, KC- IIIw^{1,2}s^{2,4}, KD and KE- IIIs^{2,4}, KG and KH- IIIw^{1}s^{4}, and KI-IIIw^{1,2}s^{4}.

According to the ratings of Mary and Nowshaja (2016) the soils grouped into class II are good cultivable land but require conservative measures for sustainable arable crop production. Class III soils are moderately good cultivable soils that can be cultivated with precaution against permanent land damage. Class IV soils are fairly good land, suited for occasional or limited cultivation in rotation.

Conclusion and recommendation

All the soils studied fell below capability class 1 due to shallow soil depth, seasonal flooded and poor drainage condition, high stone content and low nutrient holding capacity.

Soil depth restriction due to plinthites observed in this study could be managed by construction of contour ridges and bunds to improve the soils to quality seedbed and increase rooting depth. Construction of contour ridges along with the maintenance of plant cover will conserve the soils against surface runoff by erosion that might expose the plinthitic horizons to harden irreversibly and render the soil unsuitable for crop production. The wetland area can be utilized for fisheries and dry season farming in other to optimize production and land use of the soils. There is need to employ practices such as use of organic matter and appropriate inorganic fertilizers to raise the ECEC of the soils.

Table 2. Land characteristics of the study areas.

Pedons	Location	Soil type	Rainfall (mm)	Nature of climate	Flooding	Erosion	Slope (%)	Drainage	Texture	Depth (cm)	ECEC Clay	Stones and Boulders	Salinity
AA	7.711121N 5.243230E	Plinthic Kandiustalfs/Plinthic Lixisols/Iwo	1470.1	Humid	None	None	2.1	Perfect	SCL	130	10.75	0	0.065
AB	7.710876N 5.245183E	Plinthic Paleustalfs/Plinthic Lixisols/Iwo	1470.1	Humid	None	None	1.9	Perfect	SL	114	13.08	0	0.053
AC	7.712567N 5.244153E	Arenic Kandiustalfs/Haplic Lixisols/Iwo	1470.1	Humid	None	None	1.7	Perfect	SL	94	2.67	0	0.080
AD	7.713800N 5.244635E	Typic Durustalfs/Petroplinthic Lixisols/Iwo	1470.1	Humid	None	None	1.6	Perfect	SL	64	8.33	0	0.060
AE	7.713694N 5.245869E	Typic Kandiustalfs/Haplic Lixisols/Iwo	1470.1	Humid	None	None	1.6	Perfect	SCL	120	5.46	0	0.059
AF	7.712131N 5.246052E	Arenic Paleustalfs/Haplic Lixisols/Iwo	1470.1	Humid	None	None	1.8	Perfect	SL	105	13.80	0	0.050
AG	7.710802N 5.246470E	Typic Epiaqualfs/Oxyaquic Arenosols/Matako	1470.1	Humid	Occasionally	None	0.9	Poor	SL	60	3.98	0	0.051
KA	7.859302N 6.069769E	Typic Durustalfs/Petroplinthic Lixisols/Gambari (Iron pan)	1329	Humid	None	None	2.3	Perfect	SCL	40	9.25	2	0.090
KB	7.859440N 6.070209N	Arenic Kandiustalfs/Ferric Lixisols/Gambari (Very concretional soil)	1329	Humid	None	None	2.1	Perfect	SCL	200	12.10	1	0.35
KC	7.860822N 6.069576E	Aquic Arenic Paleustalfs/Gleyic Lixisols/Adio	1329	Humid	Occasionally	None	1.2	Somewhat poor	SL	200	7.62	1	0.58
KD	7.860376N 6.072108E	Typic Kandiustalfs/Ferric Lixisols/Gambari (Very concretional soil)	1329	Humid	None	None	2.0	Moderate	SCL	145	9.90	2	0.67
KE	7.860811N 6.072108E	Kandic Paleustalfs/Ferric Lixisols/Gambari (Very concretional soil)	1329	Humid	None	None	1.9	Perfect	SCL	150	7.68	1	0.51
KF	7.861024N 6.073063E	Plinthic Kandiustalfs/Gleyic Lixisols/Gambari (Very concretional soil)	1329	Humid	None	None	1.9	Perfect	SL	120	21.10	1	0.53
KG	7.861874N 6.073964E	Typic Plinthaqualfs/Gleyic Lixisols/Adio	1329	Humid	None	None	1.7	Somewhat poor	SCL	150	10.25	0	0.39
KH	7.862225N 6.074468E	Aquic Kandiustalfs/Gleyic Lixisols/Adio	1329	Humid	None	None	1.7	Somewhat poor	SCL	150	22.22	0	0.37
KI	7.862129N 6.072258E	Aquic Arenic Kandiustalfs/Gleyic Lixisols/Adio	1329	Humid	Occasionally	None	1.3	Somewhat poor	SL	130	15.72	0	0.61

Texture: SL- sandy loam, SCL- sandy clay loam

Table 3. Land capability classification of soils studied.

Pedons	Climate (c)		Excess water (w)		Erosion hazard (e)		Soil limitation (s)					Aggregate Capability
	[1]Rainfall (mm)	[2]Nature of climate	[1]Drainage	[2]Flooding	[1]Erosion	[2]Slope (%)	[1]Salinity	[2]Stones and Boulders	[3]Effective soil depth (cm)	[4]ECEC Clay (Cmol/kgclay)	[5]Texture	
AA	I	I	I	I	I	I	I	I	I	III	I	IIIs^{4}
AB	I	I	I	I	I	I	I	I	I	II	I	IIS^{4}
AC	I	I	I	I	I	I	I	I	I	IV	I	IVS^{4}
AD	I	I	I	I	I	I	I	I	II	III	I	IIIS^{3,4}
AE	I	I	I	I	I	I	I	I	I	IV	I	IVS^{4}
AF	I	I	I	I	I	I	I	I	I	II	I	IIS^{4}
AG	I	I	III	III	I	I	I	I	II	IV	I	IVW^{1,2}S^{3,4}
KA	I	I	I	I	I	I	I	II	III	III	I	IIIS^{2,3,4}
KB	I	I	I	I	I	I	I	II	I	II	I	IIS^{2,4}
KC	I	I	III	III	I	I	I	II	I	III	I	IIIW^{1,2}S^{2,4}
KD	I	I	I	I	I	I	I	II	I	III	I	IIIS^{2,4}
KE	I	I	I	I	I	I	I	II	I	III	I	IIIS^{2,4}
KF	I	I	I	I	I	I	I	II	I	II	I	IIS^{2,4}
KG	I	I	III	I	I	I	I	I	I	III	I	IIIW^{1}S^{4}
KH	I	I	III	I	I	I	I	I	I	II	I	IIIW^{1}S^{4}
KI	I	I	III	III	I	I	I	I	I	II	I	IIIW^{1,2}S^{4}

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