IOSR Journal of Environmental Science, Toxicology and Food Technology (IOSR-JESTFT)
e-ISSN: 2319-2402,p- ISSN: 2319-2399.Volume 14, Issue 8 Ser. IV (August 2020), PP 31-36
www.iosrjournals.org

Soil Morphological Properties, Classification, Suitability and Capability Classification on Some Soil of Bali Local Government, Taraba State, Northeastern Nigeria.

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Abstract
Field was carried out to evaluate the soil morphological properties, classification, suitability and capability classification on Bali Local Government toposequence with the opinion to improve the soil management practices and intensify the production of food crops by farmers of the study area. GIS was used to describe the sampling unit and the study area was divided into 3 different slope positions on the topo sequence and each slope position was regarded as a sampling unit. Two soil types were identified and classified into Typic Plinthustalfs and Psammentic Paleudalfs. Mostly, structural development increased alongside the gradient from upper gradient to the bottom slope position. Capability classification occured in the upper slope: as C3 (IIIse) with limit in texture and erosion threat while the soils at the lower slope occured in class C2 (IIsw). Suitability classification showed that these soils had moderate suitability for sorghum at the upper slope while maize was slightly appropriate with restriction in drainage. Measures such as afforestation, land levelling and planting of cover crops will lessen the influence of erosion at the upper slope position.

Keywords: *Psammentic ; Paleudalfs ; morphology; sampling unit; topo sequence*

Date of Submission: 17-08-2020 Date of Acceptance: 03-09-2020

I. Introduction

Soil is one of the natural resources essential for human and animal survival. Human begins depend on it for food production, timber energy crops and fiber. Together with climate, the soil determining factor of which crops be grown, where, and how to quantify the expected yield. Additionally in trying to support our agricultural necessities, we depend on the soils to control the flow of rainwater and to act as a filter for drinkable water. With such an extreme important role, it is imperative that we give a proper management to our soil for its long-standing productivity sustainability and health. The first stage in sustaining soil is to ensure that only suitable crops for the soils are planted on them. Some agricultural soils are suitable for the production of vegetable and grains, while other agricultural soils are suitable for the production of pasture and forage. For this reason, the soils of any area that can support agricultural activities, agricultural development will be expected. The only technique that will help in understanding the soils and their suitability to different crops is soil classification Soil survey information is also the significant to understanding the soil resource (1).Topo sequence is one of the features that have and influence on morphological properties of the soil. The way the soils are arranged on the surface of the land, its gradient angle cause the degree of soil erosion due to the strength of rain water or the speed of surface runoff. As a result of this, soil consistency, soil horizon, soil structure, water infiltration rate and soil texture are changed. These significant soil properties are indispensable in soil taxonomic classification in assessment of the soils based on its ability to support agricultural production. The land capability assessment characterizes and evaluates land development units from a general point of view without considering the nature of its use. The classes are well defined, ranging from I to VIII (Landon LR *et al* 1991). This classification is beneficial as crops specify their soils for optimum growth; so, precision of land use types is indispensable. It could be conveyed not only in terms of types of crop productions, but also the way these specific crops are produced (Sys I *et al* 1991). Land suitability denotes to the capacity of a portion of land to allow the production of crops in a sustainable system. Its assessment provides information on opportunities and constraints for the use of the land and therefore guides decisions on optimal utilizations of resources, whose knowledge is an important prerequisite for land use planning and development. Moreover, such a kind of analysis permits to identify the main restrictive factors for the agricultural production and enables decision makers such as land use planners, land users, and agricultural support services to develop a crop management able to overcome such constraints and increasing the productivity. Land could be classified into spatially distributed agriculture potential zones based on the soil properties, terrain characteristics and analyzing present land use (Bandy opadhyay S, *et al* 2009). Sharu MB *et al*.2010) reported that coupling of soil characterization and classification delivers an influential resource for advantage of mankind especially in the area of food security and environmental sustainability while, (Lekwa MU *et al* 2004) echoed that soil characterization delivers the basic information compulsory to create well-designed soil classification schemes and evaluate soil fertility in order to unravel some special soil problems in a given area. The major occupation of the people along Bali Local government topo sequence is farming. The farmers depend largely on the soils to produce mainly cash crops like maize, sorghum, ground nut and cow pea as a major source of their livelihood. Despite the potentials to produce some cash crops in the study area, farmers are facing problems of declining productivity and nutrient loss through the action of erosion. Apart from these problems, no sufficient work has been done to classify the soils of the area, carry out capability and suitability classification of the major crops cultivated. This study provides useful information on capability and suitability classification of the major crops produced in the area with the view to guide farmers on management practices for optimum production.

II. Materials And Methods

2.1 Location and Extent

The study was carried out in Bali Local government Toposequence in Central part of Tabara State, Northeastern Nigeria. The study area is located between Longitude 10° 57'49. 48"E and Latitude 7° 51'11.89"N.

2.2 Field Work and Sample Collection Sampling units were delineated using the Geographic Information System (GIS) ArcGIS 9.1 software, where the study area was categorized into 3 different slope positions (SP) on the toposequence (SP3, SP2 and SP1) representing 3-5%, 2-3% and 0-2% slope. Each slope position was recognized as a sampling unit, one (1) profile pit was dug in each sampling unit making three (3) profile pits in all and coordinates of the pits were obtained using the GIS, and the exact location of the pits were sited using the German hand held GPS at Bali A SP3 (7.87141N, 10.95848E): Bali A SP2 (7.86475N, 10.6474E) and Bali A 3 SP1 (7.85876N, 10.95095E) respectively. Soil samples were collected and recorded morphological properties. Soil samples were collected in each of the soil horizon, placed in polythene bags and labeled as described by the Soil Survey Field and Laboratory Methods Manual [7].

2.3 Preparation of Soil Samples

Soil samples were air-dried, crushed and passed through a 2 mm sieve for soil chemical analysis as described by the Soil Survey Field and Laboratory Methods Manual [7].

2.4 Laboratory Analysis

Chemical test was carried out for soil base saturation determined by Sum of NH4OAc extractable bases + 1N KCl Al extractable as described by the Soil Survey Laboratory Information Manual [8].

2.5 Soil Classification

Soil classification of the study area was carried out according to the USDA soil taxonomy [9] by considering physical and chemical properties of soils obtained in the field and laboratory studies.

2.6 Land Capability Classification

The criteria for land capability in this study include land quality for rooting condition (s), soil workability (s), erosion hazard (e) and oxygen availability (w). The factor rating used for classification was divided into class I, class II, class III, class IV and class V. These criteria were used to rank the land units based on the severity of the land limitations for general agricultural use. Table 3 presents the summary of the criteria for land capability classification in the study area. These criteria were used to rank the land units based on the severity of land limitations for general agricultural use. Table 4 presents the land unit characteristics of the different soil units of the study area. Matching the land characteristics with the rating of land characteristics produces the land capability classification for the different soil units.

2.7 Land Suitability Classification

Land suitability classification was carried out based on the principles of matching the land use requirements with the land qualities as described by [10] and FAO [11]. The factor for rating land requirement ranged from suitable (S1), moderately suitable (S2), marginally suitable (S3) and not suitable (N).

Table 7 shows the principles of matching the land use requirements with land qualities as described by [10-13]. The data obtained for both land characteristics and qualities of the land units and land use requirements were matched to give land suitability classes [11]. The matching produces suitability classes for each quality. The extreme suitability class for the individual qualities when combined together gives the extent of limitation to productivity. The extent of the combined limitations were used to produce the overall suitability class for each of the crop. The procedure was used to develop suitability classes for the major crops such as sorghum, maize, cowpea and groundnut.

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III. Results And Discussion

3.1 Morphological Properties of the Soils

The morphology of soils 3C (Bali) is presented in Table 1. The soils on the gentle slope of the land (3-5%), have weak, medium, sandy loam with sub angular blocky structure. As these described features found in the area, it might be as a result of the effect of erosion which was more rapid at the upper slope position which destroyed the clay materials and made the soil to be a sandy loose soils. This finding is similar with the finding of (Malgwi WB *et al* 2011) who reported after their experiment on the same soil that the soils were fragile thin epipedons at the upper landscape position because of speedy loss of soil.. The soils were yellowish red 6.5YR (8/4) when dry and moist at the C horizon and contained gravel at >50 cm depth. The same similar results was reported by Fasina AS *et al (*2015) in their experiment on soil of of South Western Nigeria where the soils on upper slope of the landscape had gradients of about 3%. They also indicated that the soils were not poorly drained. Quartz gravels were found at a depth of about 50 cm. The morphological appearance of pedon 2C (Bali) on levelled to almost levelled slope with (2-3%) showed that they were moderate, with sub angular blocky structure, marginally sticky and marginally plastic in consistency, firm when it is moist and soft when it dries. The result of related finding was reported by (Malgwi WB *et al* 2011). Which showed that the soils were pinkish gray 7.5YR 7/2 and brown 7.5YR 4/3 when it is dry, and wet at the medium slope. These might occurred as a result of drainage which induces the oxidation of irons and iron oxides. The morphology of pedon 1C (Bali) on level to approximately levelled (0-25%) slope had gray 6YR 6/2 when it is dry and very dark gray 5YR 3/1 when moist at 0-25 cm depth. Also, yellow 8YR 8/7 when dry and yellowish brown 9YR 7/4 when moist at 34-65 cm depth of the pedon. The soil at 90-129 cm depth was categorized to be light gray and gray 3.5Y7/3 and 4.5YR6/4) when without and with moist respectively. This result showed that the soil had a poor drainage condition. Lawal BA *et al* 2014) reported a comparable results on this aspect.

3.2 Soil Classification

In tabe (2) the soils were classified from order level such as Alfisols due to base saturation was >50%. Taking the presence of argillic horizons and their %base saturation (%BS) >50 into consideration, these soils were at suborder level categorized to be Ustalfs [9]. The soils were additionally classified at the great group level: As Plinthustalfs because of the to the presence of plinthite, humus-poor mixture of clay togather with quartz , iron- richand other minerals. At the subgroup level, the soils were additionally categorized under Typic

On Plinthustalfs (Pedon 2 and 3). The same results were reported by (Yakubu M *et al* 2009). The soils of Dabora (1C) were categorized as Alfisols at order level and as Udalfs when udic soil moisture at suborder level is considered. According to the (Soil survey staff 2014), these soils can equally be classified as Paleudalfs because of the absence densic, lithic or paralithic contact around150 cm at the great group level. The soils can also be classified as Psammentic Paleudalfs because of the presence of sand up to 75 cm of the clay horizon at the subgroup level.

3.3 Land Capability Classification.

Table 3 represented the land capability classification. The soils of Land Unit 3 indicated that the soils were categorized under C3 (IIIse) with the restrictions of erosion hazards texture and depth. The same conditions for soils of Class3 (III) with restrictions of erosion hazard were presented by [19]. The soils of Land Unit 2 showed that the soils were categorized under C2 (IIse) with the restrictions of erosion and hazard rooting condition. Land Unit 1 was classified under C2 (IIsw in) with the restrictions of oxygen availability and rooting condition. This might be as a result of long retention of water in the soils and the udic damp regime (SP1) which caused water logging condition and high clay content at the lower slopes. The same result was reported on soils at the lower slope by (Fasina AS *et al* 2015).

3.4 Rating of land use requirement

Table (4) is the result of rating of land use requirement which showed that in S1 and S2, the soils were well drained with optimum soil PH for sorghum production. But in S3, the soil was poorly drained. This will limit the production of sorghum. Also, in S1 and S2, the soil was well drained with the optimum ph range that is suitable for the cultivation of maize only that in S3, the soils were poorly drained. The rating factor to these soils is that they were poorly drained and not good for the cultivation of either sorghum or maize. This results is in agreement with the result of Yakubu M *et al (*2009). On the structure of the soils, soils in S1 and S2 had moderate structure, but S3 had a weekly develop structure which classified the structure of that soil as structure less. This result is supported by the finding of Sys I *et al* (*1991*) who conducted a similar experiment and came out with the same result.

Table 1. Some morphological properties of soils of the study area

Pedon	HD	Horizon depth (cm)	Colour Dry	Colour Wet	Texture	Structure	Consistency	Inclusions	BS (%)
3 (C)	Ap	0-13	6.5YR 8/4	7.5YR 4/5	SL	Mfsbk	wss,sp,mf,ds	rcf	58.79
3 (C)	E	13-36	8.5YR 5/3	7.5YR 4/3	SCL	Mfsbk	wss,sp,mf,ds	rff	84.65
3 (C)	Bs	36- 57	6.5YR 6/5	7.5YR 5/6	CL	Smsbk	wss,sp,mf,dvh	rff	84.39
3 (C)	Bt	57 -70	7.5YR 7/4	7.5YR 4/6	SC	Mcsbk	ns,np,ml,dh	gcc	80.40
3 (C)	C	70-120	6YR 6/6	5YR 6/5	S	Wcsbk	wns,np,ml,dl	gmc	80.42
2 (C)	Ap	0- 20	4.5YR 6/3	8.5YR 4/3	L	Mfsbk	wss,sp,mf,ds	rff	60.16
2 (C)	E	20-35	3.5YR 7/4	6.5YR 5/4	L	Mfsbk	wvs,vp,mvf,dh	rff	85.83
2 (C)	B	35-58	6.5YR 7/5	7.5YR 4/3	CL	Mmsbk	wvs,vp,mf,dh	rfs	60.72
2 (C)	Bt	58-75	5.5YR 7/	7.5YR 5/4	LS	Mmsbk	wvs,vp,mf,dh	n	82.47
2 (C)	C	75-130	8.5YR 4/6	7.5YR 4/4	SCL	Wmsbk	wns,np,ml,dl	smc	59.66
1 (C)	Ap	0-25	6YR 6/2	5YR 3/1	CL	Sfsbk	wvs,vp,mvf,dvh	rff	78.91
1 (C)	E	25-34	8.5YR 4/5	7.5YR 4/3	CL	Sfsbk	wvs,vp,mvf,dvh	n	86.63
1 (C)	B	34-65	9YR 7/4	8YR 6/5	C	Sfsbk	wvs,vp,mvf,dh	n	65.87
1 (C)	Bt	65-90	7.5YR 7/2	7.5YR 6/2	C	Smsbk	wvs,vp,mvf,dvh	n	67.89
1 (C)	Bw	90-129	3.5Y 7/3	4.5Y 6/4	C	Sfsbk	wvs,vp,mvf,dvh	n	97.78

Source: Field Study, 2019.
HD = Horizon Disignation, Texture: S = Sand, LS = Loamy sand, SL = Sandy loam, L = Loam, SCL = Sandy clay loam, CL = Clay loam, SC = Sandy clay, C = Clay. Structure: Grade; w = weak, m = moderate, s = strong. Class; f = fine, m = medium, c = coarse. Type; sbk = sub angular blocky Consistency: w = wet, ns = non sticky, np = non plastic, ss = slightly sticky, sp = slightly plastic, vs = very sticky, vp = very plastic, m = moist, l = loose, vf = very friable, f = firm, vf = very firm, d = dry, s = soft, vh = very hard, l = loose, h = hard Inclusion: r = roots, s = stone, g = gravel; Abundance of inclusion: f = few, c = common, m = many; Size of inclusion: f = fine, m = medium, c = coarse, n = none, BS = Base saturation

Table 2. Summary of soil classification of the study area

Sampling units	Locations	Classification				
		Order	Sub-order	Great group	Sub group	
					USDA	FAO
SP3	Bali A. 3	Alfisols	Ustalfs	Plinthustalfs	Typic Plinthustalfs	Plinthic Luvisols
SP2	Bali A. 2	Alfisols	Ustalfs	Plinthustalfs	Typic Plinthustalfs	Plinthic Luvisols
SP1	Bali A. 1	Alfisols	Udalfs	Paleudalfs	Psammentic Paleudalfs	Psammentic Luvisols

Table 3. Rating of land characteristics for capability classification

Land quality	Diagnostic factor	Unit	Factor rating				
			Class I	Class II	Class III	Class IV	Class V
Rooting condition (s)	Depth (cm)	Cm	140-200	100-175	75-100	50-75	>60
Soil workability (s)	Texture(class)	Class	L,SCL,SiL	SL,SC	LS,C	S,SC	-
Erosion hazard (e)	Slope (%)	%	0-2	3-5	4-7	7-12	13-19
Oxygen availability (w)	Drainage ( )	Class	W. drained	Mod. Well drained	Poorly drained	V. poorly drained, excessively drained	

Table 4. Characteristic of the land unit

Land quality	Diagnostic factor	Land Unit III SP3	Land Unit II SP2	Land Unit I SP1
Rooting condition (s)	Depth (cm)	117	123	124
Soil workability (s)	Texture (class)	SCL-LS	SL	LS-SCL
Erosion hazard (e)	Slope (%)	4-6	3-4	0-4
Oxygen availability (w)	Drainage ( )	W. drained	Mod. Well drained	Poorly drained

Table 4. Rating of land use requirement

Land quality	Diagnostic factor	Unit	Factor rating			
			S1	S2	S3	N
(a) Sorghum						
Oxygen availability (g)	Drainage	Class	Well drained	Mod. Well drained	Poorly drained	Very poorly drained
Nutrient avail. (a)	Reaction	pH	6.5-7.5	4.8-5.5,7.5-8.0	4.5-7.8,8.0-8.3	<4, >8.3
Nutrient Retention cap (n)	Base saturation	%	>30	30-40	20-30	<20
Rooting condition (r)	Depth	Cm	>123	50-120	30-50	<30
Soil workability(w)	Texture	Class	SL, L	CL, SCL	SC, LS	S
Soil workability (k)	Structure	Class	Mod. Well. Dev. Structure	Mod. Dev. Structure	Structureless	-
Erosion Hazard (e)	Slope	%	0-7	5-9	7-13	➢ 10
(b) Maize						
Oxygen availability (g)	Drainage	Class	Well drained	Mod. Well drained	Poorly drained	Very poorly drained
Nutrient avail. (a)	Reaction	pH	5.5-7	5.-6	5-5.5.7.5-8	<5.6, >8
Nutrient Retention cap (n)	Base saturation	%	>60	40-75	40-60	<30
Rooting condition (r)	Depth	Cm	>120	50-120	40-60	<30
Soil workability(w)	Texture	Class	SL, L	SCL, SiL	LS, CL, SCL	SC, SiL, C
Soil workability (k)	Structure	Class	Mod. Well. Dev. Structure	Mod. Dev. Structure	Weakly dev. Struc.	Structureless
Erosion Hazard (e)	Slope	%	0-3	3-5	5-67	>5
(c) Cowpea						
Oxygen availability (g)	Drainage	Class	Well drained	Mod. Well drained	Poorly drained	Very poorly drained
Nutrient avail. (a)	Reaction	pH	7.0 – 8.0	5.5 – 8.0	5.5 – 9.5	< 4.5 > 8.5
Nutrient Retention cap (n)	Base saturation	%	> 50	40 – 60	20 – 60	< 10
Rooting condition (r)	Depth	Cm	> 95	50 – 90	20 – 40	< 25
Soil workability(w)	Texture	Class	LS, SL, CL	SC, SCL	SCL	S
Soil workability (k) Erosion Hazard (e)	Structure Slope	Class %	Crumb 0 – 5	SBK 5 – 7	SBK 7 – 9	Columnar >8
(d) Ground nut Oxygen availability (g)	Drainage	Class	Well drained	Mod. Well drained	Poorly drained	Very poorly drained
Nutrient avail. (a)	Reaction	pH	6.2-7.25	5.5-5.8, 6.2-6.5	5-5.5, 6-6.7	<5, >7
Nutrient Retention cap (n)	Base saturation	%	>45	35-50	25-35	<25
Rooting condition (r)	Depth	Cm	>95	70-100	40-70	<50
Soil workability(w)	Texture	Class	SL, SiL	SiCL, CL	SiS, SC	<50
Soil workability (k)	Structure	Class	Mod. well. dev. Structure	Mod. dev. Structure	Structure less	C
Erosion Hazard (e)	Slope	%	0-2	2-5	5-8	>7

Key: < = Less than, > = Greater than, Mod.= Moderately, SL = Sandy Loam, L = Loam, SiL= Silty Loam, SiCL = Silty Clay Loam, LS = Loamy sand , SBK = Subangular blocky
Dev. = Develop, S1= Suitable, S2 = Moderately suitable, S3 = Marginally suitable, N = Not suitable

Pedon SP3 and SP2 are moderately suitable for cow pea cultivation with the limitation of soil workability. Whereas pedon SP1 is marginally suitable with the limitation of oxygen. Pedon SP3 and SP2 are moderately suitable for ground nut with limitations of nutrient availability and workability whereas SP1 is marginally suitable with drainage problems.

IV. Summary And Conclusion

The study area was categorized into 3 different slope positions on the toposequence and each slope position was recognized as a sampling unit. Three soil types was identified and classified into Typic Plinthustalfs (Bali) and Psammentic Paleudalfs (Bali).

Capability classification showed that the upper slope are classified as C3 (IIIse) with limitations of texture and erosion hazards while the lower slope in class C2 (IIsw) with limitations of rooting condition and oxygen. The suitability evaluation showed that these soils are moderately suitable for maize and sorghum at the upper slopes while soils at lower slope are marginally suitable. The upper slope is moderately suitable for cow pea cultivation and marginally suitable for ground nut cultivation at the lower slope position.

V. Recommendations

i. Due to the fragile and sandy, loose nature of the soils, mechanical land clearing should be avoided especially at the upper slope because the soils will further be prone to erosion hazards.

ii. Adequate measures should be taken to ameliorate the effect of erosion at the upper slope through the use of proper land leveling, afforestation, terracing and the use of surface running crops in the area. iii. Addition of organic matter will improve the weak and loose nature of the soils of the upper slopes and improve on the soil texture and structure.

iv. Cultivation of the major crops (Maize, sorghum, ground nut and cow pea) on the upper slopes is encouraged: and limitations can be overcome with the use of organic and inorganic fertilizers.

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Abubakar Dauda Jugulde, et. al. “Soil Morphological Properties, Classification, Suitability and Capability Classification on Some Soil of Bali Local Government, Taraba State, Northeastern Nigeria." *IOSR Journal of Environmental Science, Toxicology and Food Technology (IOSR-JESTFT)*, 14(8), (2020): pp 31-36.