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Soil Morphological Properties, Classification, Suitability and Capability Classification on Dabora-Yelwa Toposequence, Adamawa State, Northeastern Nigeria

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Authors' contributions

This work was carried out in collaboration between all authors. Author SAG designed the study, carried out field and laboratory work and wrote the first draft. Author SAM participated in the field work, laboratory work and helped write the draft copy. Author IJL wrote the protocol and managed the literature searches. Author SSB helped with hue and croma and the experiment. Author HDA helped with the discussion and tables. All authors read and approved the final manuscript.

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ABSTRACT

This study was conducted to assess soil morphological properties, soil classification, suitability and capability classification on Dabora-Yelwa toposequence with the view of improving soil management practices and increase the productive capacity of the farmers of the study area. Soil sampling units were delineated using GIS and the study area was categorized into 3 different slope positions on the toposequence and each slope position was recognized as a sampling unit. Two soil types were identified and classified into Typic Plinthustalfs (Yelwa and Sangba'a respectively) and Psammentic Paleudalfs (Dabora). Generally, structural development increased along the slope

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from upper slope to the bottom slope position. Capability classification resulted in the upper slope: as C3 (IIIse) with limitations in texture and erosion hazards while the soils at the lower slope resulted in class C2 (IIsw). Suitability classification indicated that these soils were moderately suitable for sorghum at the upper slope while maize was marginally suitable with limitation in drainage. Measures such as land leveling, afforestation and use of cover crops will reduce the effect of erosion at the upper slope position.

Keywords: Land use; limitation; morphology; sampling unit; toposequence.

1. INTRODUCTION

Soil is essential to human survival. We rely on it for the production of food, fiber, timber and energy crops. Together with climate, the soil determines which crops can be grown, where, and how much they will yield. In addition to supporting our agricultural needs, we rely on the soil to regulate the flow of rainwater and to act as a filter for drinking water. With such a tremendously important role, it is imperative that we manage our soils for their long-term productivity, sustainability and health. The first step in sustainable soil management is ensuring that the soil will support the land use activity. Some better agricultural soils will support grain and vegetable production, while some marginal agricultural soils will support forage and pasture-based production. For this reason, agricultural development should only occur in areas where the soil resource will support the agricultural activity. The only way to do this is to understand the soil resource that is available. Soil survey information is the key to understanding the soil resource [1].

One of the features that influence morphological properties of the soil is the soil toposequence. The arrangement of soils on the surface of the land, its slope angle causes the degree of soil detachment due to the intensity of rain water or the velocity of surface runoff through the action of erosion, changes in the soil horizon, soil texture and structure, infiltration rate and soil consistency. These important soil factors are essential in soil taxonomic classification and in rating the soils based on its capability in supporting agricultural production.

The land capability evaluation characterizes and appraises land development units from a general point of view without taking into consideration the kind of its use. There are defined classes ranging from I to VIII [2]. This classification is useful as some soils can be suitable for specific crops and unsuitable for others; therefore precision of land utilization types is necessary. It cloud be expressed not only in terms of types of crop productions, but also how these specific crops are produced [3].

Land suitability refers to the ability of a portion of land to tolerate the production of crops in a sustainable way. Its evaluation provides information on the constraints and opportunities for the use of the land and therefore guides decisions on optimal utilizations of resources, whose knowledge is an essential prerequisite for land use planning and development. Moreover, such a kind of analysis allows identifying the main limiting factors for the agricultural production and enables decision makers such as land users, land use planners, and agricultural support services to develop a crop management able to overcome such constraints and increasing the productivity. Land could be categorized into spatially distributed agriculture potential zones based on the soil properties, terrain characteristics and analyzing present land use [4].

Sharu MB et al. [5] reported that coupling of soil characterization and classification provides a powerful resource for benefit of mankind especially in the area of food security and environmental sustainability while, [6] reiterated that soil characterization provides the basic information necessary to create functional soil classification schemes and assess soil fertility in order to unravel some unique soil problems in a given area.

The major occupation of the people along Dabora-Yelwa toposequence 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.

2. MATERIALS AND METHODS

2.1 Location and Extent

The study was carried out in Yelwa-Dabora Toposequence in Ganye Local Government Area in the Southern part of Adamawa State, Northeastern Nigeria. The study area is located between Longitude 11° 58'0"E to 12° 40'0"E and Latitude 8° 26'0"N to 8° 30'8"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 co-ordinates of the pits were obtained using the GIS, and the exact location of the pits were sited using the German hand held GPS at Yelwa SP3 (940542N, 828461E): Sangba'a SP2 (939973N, 170527E) and Dabora SP1 (936781N, 169991E) 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 NH_4OAc 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 ground nut.

3. RESULTS AND DISCUSSION

3.1 Mophological Properties of the Soils

The morphology of soils 3C (Yelwa) is presented in Table 1. The soils on gently sloping or undulating land (3-5%), have weak, medium, sandy loose and sub angular blocky. This might be due to the effect of erosion more rapid at the upper slope position which removes the clay materials leaving sandy loose soils. A similar finding was reported by [14] that the soils were weak thin epipedons at the upper landscape position due to rapid erosion. The soils were yellowish red 7.5YR (5/6) when dry and moist at the C horizon and gravelly at >50 cm depth. [15] recorded similar results in their study of South-Western Nigeria where the soils on upper slope of the landscape with gradients of about 3%. They also stated that the soils were well drained. Quartz gravels were encountered at a depth of about 50 cm.

The morphology of pedon 2C (Sangba'a) on level to nearly level (2-3%) slope shows moderate, sub angular blocky, slightly sticky and slightly plastic, firm when moist and soft when dry. Similar finding was reported by [14]. The soils were pinkish gray 7.5YR 7/2 and brown 7.5YR 4/3 when dry and moist at the middle slope. This might be due to the drainage and oxidation of iron oxides.

The morphology of pedon 1C (Dabora) on level to nearly level (0-2%) slope have gray 5YR 6/1 when dry and very dark gray 5YR 3/1 when moist at 0-23 cm depth. Also, yellow 10YR 7/8 when dry and brownish yellow 10YR 6/8 when moist at 34-61 cm depth of the pedon. The soils at 88-121cm depth were characterized by light gray and gray 2.5Y (7/1 and 6/1) when dry and moist respectively. This result indicates the poor drainage condition of the soils. Similar results were reported by [16,17].

3.2 Soil Classification

The soils were classified (Table 2) at order level as Alfisols due to base saturation >50%. Considering the presence of argillic horizon and their %base saturation (%BS) >50, these soils are at suborder level classified as Ustalfs [9]. These soils are further classified at the great group level: As Plinthustalfs due to the presence of plinthite, iron-rich, humus-poor mixture of clay with quartz and other minerals. At the subgroup level, these soils are further classified as Typic Plinthustalfs (Pedon 2 and 3). Similar findings were recorded by [18].

The soils of Dabora (1C) are classified under Alfisols at order level and as Udalfs considering udic soil moisture at suborder level. According to the [9], these soils are further classified as Paleudalfs due to no densic, lithic or paralithic contact within 150 cm at the great group level. The soils are further classified as Psammentic Paleudalfs due to the sand upto 75 cm of the argillic horizon at the subgroup level.

3.3 Land Capability Classification

The land capability classification is presented in Table 5. The soils of Land Unit 3 showed that the soils were classified as C3 (IIIse) with the limitations of depth, texture and erosion hazards. Similar criteria for soils of Class3 (III) with limitations of erosion hazard were presented by [19]. The soils of Land Unit 2 indicated that the soils were classified as C2 (IIse) with the limitations of rooting condition and erosion hazard. Land Unit 1 is classified as C2 (IIsw) with the limitations of rooting condition and oxygen availability. This could be due to the water retained in the soils for long and the udic moisture regime (SP1) which led to the water logging condition and high clay content at the lower slopes. Similar result was reported for soils at the lower slope by [15].

3.4 Land Suitability Classification

Table 6 shows land qualities for suitability classification of the study area. The step involve is to first classify or decide which factors should be used to define each suitability class. Pedon SP3 and SP2 were well drained and moderate to weakly developed while pedon SP1 is strongly structured.

3.4.1 Land evaluation for sorghum, maize, cow pea and ground nut

Table 8 presents the suitability rating of soils for sorghum, maize, cow pea and ground nut. These soils are evaluated as moderately suitable for sorghum (SP3) with the limitations of nutrient retention and texture whereas SP2with limitations of workability and marginally suitable SP1 with oxygen availability and workability. Pedon SP3 and SP2 are moderately suitable for maize production with the limitations of nutrient retention capacity, rooting condition and soil workability. Pedon SP1 is marginally suitable with drainage problems.

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

Pedon	HD	Horizon depth (cm)	Colour		Texture	Structure	Consistency	Inclusions	BS (%)
			Dry	Wet					
3 (C)	Ap	0-11	7.5YR 8/2	7.5YR 5/4	SL	Mfsbk	wss,sp,mf,ds	rcf	58.79
3 (C)	E	11-34	7.5YR 6/3	7.5YR 4/4	SCL	Mfsbk	wss,sp,mf,ds	rff	84.65
3 (C)	Bs	34- 55	7.5YR 7/6	7.5YR 4/6	CL	Smsbk	wss,sp,mf,dvh	rff	84.39
3 (C)	Bt	55 -68	7.5YR 7/4	7.5YR 5/8	SC	Mcsbk	ns,np,ml,dh	gcc	80.40
3 (C)	C	68-110	5YR 5/6	5YR 4/6	S	Wcsbk	wns,np,ml,dl	gmc	80.42
2 (C)	Ap	0-10	7.5YR 6/2	7.5YR 3/3	L	Mfsbk	wss,sp,mf,ds	rff	74.17
2 (C)	E	10-28	7.5YR 7/2	7.5YR 4/3	L	Mfsbk	wvs,vp,mvf,dh	rff	75.89
2 (C)	B	28-40	7.5YR 7/2	7.5YR 4/3	CL	Mmsbk	wvs,vp,mf,dh	rfs	80.62
2 (C)	Bt	40-60	7.5YR 7/3	7.5YR 5/4	LS	Mmsbk	wvs,vp,mf,dh	n	83.37
2 (C)	C	60-120	7.5YR 4/6	7.5YR 4/4	SCL	Wmsbk	wns,np,ml,dl	smc	57.62
1 (C)	Ap	0-23	5YR 6/1	5YR 3/1	CL	Sfsbk	wvs,vp,mvf,dvh	rff	74.59
1 (C)	E	23-34	7.5YR 6/4	7.5YR 4/3	CL	Sfsbk	wvs,vp,mvf,dvh	n	76.65
1 (C)	B	34-61	10YR 7/8	10YR 6/8	C	Sfsbk	wvs,vp,mvf,dh	n	62.82
1 (C)	Bt	61-88	7.5YR 7/2	7.5YR 6/2	C	Smsbk	wvs,vp,mvf,dvh	n	69.80
1 (C)	Bw	88-121	2.5Y 7/1	2.5Y 6/1	C	Sfsbk	wvs,vp,mvf,dvh	n	95.75

Source: Field Study, 2015.

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 unit	Location	Classification				
		Order	Sub-order	Great group	Sub group	
					USDA	FAO
SP3	Yelwa	Alfisols	Ustalfs	Plinthustalfs	Typic Plinthustalfs	Plinthic Luvisols
SP2	Sangba'a	Alfisols	Ustalfs	Plinthustalfs	Typic Plinthustalfs	Plinthic Luvisols
SP1	Dabora	Alfisols	Udalfs	Paleudalfs	Psammentic Paleudalfs	Psammentic Luvisols

Source: Field study, 2015

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	150-200	100-150	75-100	50-75	>50
Soil workability (s)	Texture	Class	L,SCL,SiL	SL,SC	LS,C	S,SC	-
Erosion hazard (e)	Slope	%	0-2	2-4	4-7	7-12	12-18
Oxygen availability (w)	Drainage	Class	W. drained	Mod. Well drained	Poorly drained	V. poorly drained, excessively drained	

Table 4. Land unit characteristics of the land units

Land quality	Diagnostic factor	Unit	Land Unit III SP3	Land Unit II SP2	Land Unit I SP1
Rooting condition (s)	Depth	Cm	116	120	121
Soil workability (s)	Texture	Class	SCL-LS	SL	LS-SCL
Erosion hazard (e)	Slope	%	3-5	2-3	0-2
Oxygen availability (w)	Drainage	Class	W. drained	Mod. Well drained	Poorly drained

Source: Field study, 2015.

Table 5. Matching land characteristics with land rating

Land quality	Diagnostic factor	Land Unit 3	Land Unit 2	Land Unit 1
Rooting cond.	Depth (s)	C2	C2	C1
Soil workab.	Texture (s)	C2	C1	C2
Erosion hazard	Slope (e)	C3	C2	C1
Oxygen avail.	Drainage (w)	C1	C1	C2
Overall Capab.		C3(IIIse)	C2(IIse)	C2(IIsw)

Source: Field study, 2015.

Table 6. Land unit characteristics and quality for suitability classification

Land quality	Diagnostic Frt.	Unit	SP 3	SP 2	SP 1
Oxygen availability (g)	Drainage	Class	Well drained	Well drained	Poorly-M drnd.
Nutrient availbty. (a)	Soil reaction	pH	6.5	6.5	6.5
Rooting condition (r)	Depth	Cm	116	120	121
Soil Workability (w)	Texture	Class	SCL-LS	Sandy loam	LS-SCL
Soil Workability (k)	Structure	Class	Mod.Developed	M-Weakly Developed	Strongly-M Developed
Erosion Hazard (e)	Slope	%	3-5	2-3	0-2
Nutrient Retn. (n)	Base sat	%	<70	<70	>75

Source: Field study, 2015.

Table 7. 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	5.5-7.5	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	%	>40	30-40	20-30	<20
Rooting condition (r)	Depth	Cm	>120	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	%	0-4	4-8	8-12	>12
(b) Maize						
Oxygen availability (g)	Drainage	Class	Well drained	Mod. Well drained	Poorly drained	Very poorly drained
Nutrient avail. (a)	Reaction	pH	6-7	5.5-6	5-5.5.7.5-8	<5.6, >8
Nutrient Retention cap (n)	Base saturation	%	>70	50-70	30-50	<30
Rooting condition (r)	Depth	Cm	>120	50-120	30-50	<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	%	0-2	2-4	4-6	>6
(c) Cowpea						
Oxygen availability (g)	Drainage	Class	Well drained	Mod. Well drained	Poorly drained	Very poorly drained

Land quality	Diagnostic factor	Unit	Factor rating			
			S1	S2	S3	N
Nutrient avail. (a)	Reaction	pH	6.0 – 7.0	5.5 – 8.0	4.5 – 8.5	< 4.5 > 8.5
Nutrient Retention cap (n)	Base saturation	%	> 60	40 – 60	10 – 40	< 10
Rooting condition (r)	Depth	Cm	> 100	50 – 90	25 – 50	< 25
Soil workability(w)	Texture	Class	LS, SL, CL	SC, SCL	SCL	S
Soil workability (k)	Structure	Class	Crumb	SBK	SBK	Columnar
Erosion Hazard (e)	Slope	%	0 – 4	4 – 6	6 – 8	>8
(d) Ground nut						
Oxygen availability (g)	Drainage	Class	Well drained	Mod. Well drained	Poorly drained	Very poorly drained
Nutrient avail. (a)	Reaction	pH	5.8-6.2	5.5-5.8, 6.2-6.5	5-5.5, 6-6.7	<5, >7
Nutrient Retention cap (n)	Base saturation	%	>50	35-50	25-35	<25
Rooting condition (r)	Depth	Cm	>100	70-100	40-70	<40
Soil workability(w)	Texture	Class	SL, SiL	SiCL, CL	SiS, SC	<40
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	>8

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

Table 8. Matching land use requirement with land qualities for sorghum, maize, cow pea and G. nut

Land use requirement / land quality	Suitability ratings of sampling units											
	Sorghum			Maize			Cow pea			Ground nut		
	SP1	SP2	SP3	SP1	SP2	SP3	SP1	SP2	SP3	SP1	SP2	SP3
Oxygen availability (g)	S1	S1	S3	S1	S1	S3	S1	S1	S3	S1	S1	S3
Nutrient availability (a)	S1	S1	S1	S1	S1	S1	S1	S1	S1	S2	S2	S2
Nutrient retention cp (n)	S2	S1	S1	S2	S2	S1	S1	S1	S1	S1	S1	S1
Rooting condition (r)	S2	S1	S1	S2	S1	S1	S1	S1	S1	S1	S1	S1
Soil wrk (texture) (w)	S2	S2	S2	S3	S1	S1	S2	S1	S2	S2	S1	S1
Soil wrk structure (k)	S1	S1	S1	S2	S2	S1	S2	S2	S2	S2	S2	S1
Erosion hazard (e)	S2	S1	S1	S3	S2	S1	S2	S1	S1	S2	S2	S1
Overall suitability	S2nre	S2w	S3gw	S2nke	S2nke	S3g	S2wke	S2k	S3gwk	S2ake	S2ke	S3g

Source: Field Study, 2015

Key: SP = Slope position, cp = Capacity, wrk = Workability, S1 = Suitable, S2 = Moderately suitable, S3 = Marginally 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.

4. 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 (Yelwa and Sangba'a, respectively) and Psammentic Paleudalfs (Dabora).

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.

5. 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 (sorghum, maize, ground nut and cow pea) on the upper slopes is encouraged: and limitations can be overcome with the use of organic and inorganic fertilizers.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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