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Original Research Article

Land suitability evaluation for maize (Zea mays) production in selected sites of the Mid-Benue valley, Nigeria

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A detailed soil survey was conducted in four locations of Mid-Benue Valley (Central Niger-Benue Trough) namely: Dura Floodplain (DR), Dogo, Katsina—Ala River Bank (DG), Mu River Basin (MU) and University of Agriculture Makurdi Teaching and Research Farm (UAM) all in Benue state. The area is located within Latitude 7º 23' and 07º 44'N and Longitude 008º 9'E and 009º 12'E covering an estimated area of 3250 km². The aim was to evaluate the suitability of the soils for the production of maize and to have a detailed soil data base for effective land use planning. Critical land and soil requirements for maize were collected from past research works and compared with data obtained from field survey. The result showed that the upper horizons of pedons ranged from clay loam to sandy loam; DR1 and MU1 have clay loam which is optimal for maize cultivation. The pH was moderate acid, 5.48 to 5.95. The organic carbon content of the soil was highest in the surface horizons (0.45 – 1.63 %) and decreases down the profile with least values for UAM1 and UAM11 (0.19 – 0.45 %). The available Phosphorus, Exchangeable bases and CEC were generally low. Although land characteristics such as mean annual rainfall and temperature, relative humidity, topography, coarse fragments and base saturation were not major limitations to the production of maize, there was no highly suitable (S1) land for maize cultivation in the area. Sites DG1 (Dogo 1) and UAM1 (University of Agriculture Makurdi 1) were marginally suitable (S3tf) due to topography limitations; the lowlands of MU1 (MU1) with the depression land of DR1 (Dura 1) were marginally suitable (S3wf) due to flooding limitation and low nutrients levels while the midland of UAM11 (University of Agriculture Makurdi 11) was as well limited by its imperfect drainage into marginally suitable (S3wf) subclass for maize production. Thus, the lowland soils (DR/MU) were generally limited by wetness while the uplands (DG/UAM) were limited by their textural arrangements. To raise the productivity level of both lands for optimal maize production, management techniques such as continuous organic matter incorporation and mineral fertilizers application (to adjust the textures and boast fertility levels in the uplands), and efficient of use of mineral fertilizers with low levels of chemical inputs with adaption of appropriate irrigation techniques (in lowlands) would make dry season farming sustainable.

Key words: Land evaluation, maize, suitability, Mid-Benue, production, valley

INTRODUCTION

Land evaluation is a systematic process of identifying and measuring land qualities and assessing them for alternative kinds of use of the land. The broad principles of land evaluation involved comparing the requirements of land use with quality of land thereby assessing the value of each type of land present for each land use (Dent and Young, 1981). Decisions on land use are being based on comprehensive analysis of the production and potentials of natural resources such as climate, soil and hydrology. Land evaluation is very important in this direction as it provides information on the potentials and constraints of land for a defined land use type in terms of crop performance as affected by the physical environment. Soil suitability classifications are based on knowledge of crop requirements, prevailing conditions and applied soil management methods (Ande, 2011). Soil suitability classification quantifies in broad terms to what extent soil conditions match crop requirements under a defined input and management (FAO, 1976). Assessing the suitability of land enables optimum performance and maximum productivity of crop. In evaluation, the specific crop requirements will be calibrated with the terrain and soil parameters (Dent and Young, 1981) so that the identified limiting factors could be managed to suit crop requirements and improve productivity. Land evaluation thus, enables management guidelines in order to promote a more sustainable use of the soil and environmental resources (Maniyunda et al., 2007).

The interest of the farmer in the business of producing crops is mainly on how profitable it is to grow a particular crop and what amendments are necessary to optimize the productivity of the soil for the specified crop (Fasina and Adeyanju, 2006). Thus, the solutions to the farmers' problems are largely dependent on the suitability studies of the land.

According to Badu-Apraku et al., (2012), after the introduction of maize to Africa in the sixteenth century, the crop rapidly gained popularity as a major food crop as well as a trade commodity in much of West and Central Africa (WCA). Today, maize is widely grown in this agro ecological sub region. It is a highly suitable crop, especially well adapted to the savanna zones with their mono-modal rainfall distribution. Maize, as a major source of calories is not only for humans but also for animals in Nigeria as well as other parts of the world. This has resulted to more soil being opened up for large scale production (Udoh and Ogunkunle, 2012). According to Esu (2004), one of the strategies to achieve food security with sustainable environment is to study soil resources in details through soil characterization and land evaluation for various land utilization types.

The pressing demand for food and space from a growing population has created a competition for land. In many developing countries, Nigeria inclusive, fuel-wood, cash crops, timber for construction and grazing for livestock compete with food crops for space, not only on the better quality land but also the marginal areas (Verheye, 2000).

The Mid-Benue Valley sub-region is facing much pressure on the available valuable agricultural land occasioned by Fulani Herdmen invasion, beside other land competitors, thus, the need for evaluation of available land. The study was therefore designed to assess the potentials and limitations of climatic factors and soil properties in the suitability of some selected soils of the sub-humid for maize production.

MATERIALS AND METHODS

The study area

The study areas lie between Latitude 7° 23' and 07° 44'N and Longitude 008° 9'E and 009° 12'E and covered an estimated area of 24 hectares (each farming community or area consists of 200m x 300m = 6000 m^2 plots). Topography is gently undulating and dominant slopes of between 0 and 4%. Elevation varies between 77 and 104m. The study sites have tropical sub humid climate characterized by high humidity (50-85%). Annual rainfall ranges between 1220 and 1500mm with annual maximum mean temperature ranging from 29.5 - 33° C. The original semi-deciduous vegetation has been drastically disturbed by farming and timber logging resulting into secondary vegetation succession like bush re - growth; thick derived savannah has taken over the place. The type of land use is majorly arable cultivation with small sizes of maize, sorghum, yam, cassava, vegetable, oil palm with fruit orchards scattered over the area. The study areas, Dogo, Katsina—Ala River Bank (DG) and University of Agriculture Makurdi Teaching and Research Farm (UAM) have fine Awe and Makurdi sandstones of cretaceous sediment while Dura Floodplain (DR) and Mu River Basin (MU) have alluvium-shale intercalation underlain by undifferentiated basement complex materials (Offodile, 2014)

Soil collection and laboratory analysis

In each location, a representative area of 6 hectares was chosen. The major soil types were identified through the rigid grid soil survey method. Eight profile pits were sunk and morphological characterization of each of the profile pit was carried out using the pattern outlined in the soil survey manual (Soil Survey Staff, 2010; Gutherie and Witty, 1982). Soil samples were collected from identified profile horizons for laboratory analysis. Based on the morphological characteristics, the landscape segments were classified into five mapping units.

Soil samples were air-dried, crushed and passed through a-2mm sieve and analyzed using standard procedure. Soil particle size was determined by hydrometer method (Bouyoucos, 1951) with sodium hexameta-phosphate as the dispersing agent. Soil pH was determined by pH meter in water using a 1:1 soil/water ratio. Total Nitrogen was determined by Microkjeldah method. Organic carbon was determined by Walkley and Black dichromate wet oxidation method (Allison, 1965). Available phosphorus was determined by the ammonium molebdate blue method (Bray and Kurtz, 1945). Exchangeable cations were determined by using 1N NH4OAc (pH 7.0) method. Calcium and magnesium were determined by atomic absorption spectrophotometry. Exchangeable acidity was extracted wit h 1N KCl (Maclean, 1982). CEC was determined by leaching the soil with 1N salt solution buffered at a given pH which was slightly higher than 7. Effective cation exchange capacity (ECEC) was determined by summation of the exchangeable cations and the exchangeable acidity. Base saturation was calculated as sum of total exchangeable bases (TEB) divided by the CEC x 100.

Land Evaluation Procedure

The suitability evaluation of the land was done using the conventional parametric method (FAO, 1976). Pedons were placed in suitability classes by matching their characteristics with the established requirements for maize (Table 1). The final (aggregate) suitability class indicates the most limiting characteristics of the pedons. The parameters used for the land quality calculation include rainfall, mean annual temperature, slope, wetness, drainage while the soil characteristics were texture, coarse fragment, soil pH, depth with fertility indicators: ECEC, base saturation, organic carbon (organic matter) and available phosphorus.

RESULTS AND DISCUSSION

Physical properties

The upper horizons of pedons DR1and MU1 have clay loam which is optimal for maize cultivation (Sys. 1985); pedons DG1 has clay loam to sandy loam; UAM1 sandy loam while UAM11 has clay loam to loam mixed with gravels. The gravelly nature of pedons UAMI and UAMII (11.78 and 15.98 %) posed no major limitation to maize production while the sandy loam texture is sub-optimum for maize cultivation (Table 2). This agrees with the findings of Sys (1985). Though, these are indications of the soils with low infiltration rate and low water and nutrient retention capacity, but not enough limitations to substantially reduce the productivity of maize. Soil moisture may be recharged through capillary action from the wetter zones at lower depth or from ground water table during dry season (Adesemuyi, 2014). The DR1 pedon is the only soil with optimum soil textures (clay loam and loam) for maize performance is in the study area. The coarse texture of the soil associated with high infiltration and low nutrient retention capacity may pose a major limitation to maize cultivation. Proper soil management principles that will insure adequate organic matter buildup in the soil is hereby recommended. Topography was optimal in DR1 and MU1 (0 – 2 %) but sub-optimal in DG1 and UAM1/11 (2 – 5 %) for maize cultivation whereas seasonal flooding has reduced the soils of DR, MU and UAM11 to marginally suitable subclass for the cultivation of maize. Slope sometimes impedes crop production (IAO, 2014).

Chemical properties

The pH of the soil measured in water ranged from 5.48 to 5.95, indicating a moderate acid reaction (James, 2010). This may be due to the acidic nature of the parent material (pm) from which the soils were derived and high rate of leaching of the nutrient down the profile. The organic carbon content of the soil was highest in the surface horizons (0.45 – 1.63 %) and decreases down the profile (Table 2). The organic carbon of the soil is considered low for pedons UAM1 and UAM11 (0.19–0.45 %). Avoiding bush burning and continuous application of organic matter in addition to the bush fallow system will improve organic carbon and eventually improve the aggregate stability of the soil for maize production. The available Phosphorus was low and distributed irregularly with depth in all pedons. This low value may be due to phosphorus fixation and the acidic nature of the soil. Exchangeable bases were generally low. The nature of the underlying parent materials, high rainfall intensity, moderate weathering, leaching and lateral translocation of bases may have been responsible for these low values (Ezenwa, 1988).

The CEC showed marked randomness within the pedons depths, however, higher values were found mostly in horizons with higher clay contents within a profile. The relatively low values of effective cation exchange capacity (ECEC) could be attributed to the low activity clay characteristics of 1:1 clay minerals, probably dominated by Kaolinite (Adesemuyi, 2014). The soils were generally high in base saturation (> 50 %) indicating that the exchange sites of the complexes (clay and humus) were dominated by basic cations (Table 2).

Land suitability evaluation

The matching of Land Characteristics Used for Suitability Ratings of Sites for Maize (Zea mays) Production in Mid-Benue Valleys (Table 2) with Land and Soil Requirements for suitability rating of Maize (Table 1) resulted in the suitability classes of the soil mapping units as shown in Table 3. The region was optimal or near optimal in mean annual temperature, relative humidity, length of dry season, slope and base saturation. . The textural classes of the DG1 soils ranged between clay loams to sandy loam, thus, considered moderately suitable (S2s) for the cultivation of maize. The soil texture for optimum maize performance is clay loam or loam (Sys, 1985) However, topography and low soil fertility levels had limited the soils into the marginally suitable (S3tf) subclass for maize production. The drainage status of UAM11 reduced its suitability for maize cultivation to marginally suitable (S3wf) subclass. These qualities have lowered the suitability of UAM pedons to marginally suitable subclass S3tf and S3wf for the cultivation of maize. The imperfect drainage status of pedons DR1 and MU1 have reduced their productivity to moderately suitable class (S2), while seasonal flooding as the major limitation have further substantially lowered the soils suitability for maize cultivation into a marginally

Table 1. Land and Soil Requirements for Suitability Rating of Maize (Zea mays)

Land/Soil Characteristics	Rate	100 – 95	84 – 40	39 – 20	19 – 0
	Class	**S1**	**S2**	**S3**	**N1**
Climatic (c)					
Mean Annual Rainfall	Mm	850 – 1250	600 – 750	500 – 600	-
			1600 – 1800	>1800	-
Mean Annual Max. Temp.	°C	22 – 26	18 – 16	36 – 30	-
			32+		
Relative Humidity	%	50 – 80	>80	-	-
Length of Rainy Season	Days	150 – 220	110 – 130	90 – 110	-
Topography (t)					
Slope	%	0 – 2	4 – 8	8 – 16	>30 – 50
		0 – 4	8 – 16	16 – 30	>30
Wetness (w)		FO	F1	Aeric	Poor
Flooding		Good	Poor	Poor	Drainable
Drainage	Class				
Soil Phy. Properties (s)					
Texure / Structure	Class	CL, C	LCS	CS, S	S
Coarse Fragments (0-50cm)	%	<3	15 – 35	35 – 55	-
Soil Fertiliy (f)					
CEC	(cmolkg^{-1} clay)	> 24	< 16 (-)	< 16 (+)	-
Base Saturation	%	> 50	20 – 35	< 20	-
OM (0 – 50cm)	%	> 2	0.8 -1.2	< 0.8	-
pH	Water	5.5 - 7.0	5.0 – 8.0	5.0 – 8.0	-
Avail. P	mgkg^{-1}	> 22	7 – 13	3 – 7	< 3
Toal Nittrogen (o/o)	%	> 0.15	0.08 – 0.10	0.04 – 0.08	< 0.08
Exractable K	cmolkg^{-1}	> 0.50	0.20 – 0.30	0.10 – 0.20	< 0.10

Key: FO – No Flooding, F1 – Seasonal Flooding, MR – Flooding Rare; C - Clay, CL – Clay Loam, LS – Loamy Sand, SL – Sandy Loam, LCS- Loamy Clay Sand, CS – Clay Sand, S – Sand S1 – Highly suitable S2 – Moderately suitable S3 – Marginally suitable N1 – Currently not suitable
Source: Adesemuyi, 2014 (modified).

Tabble 2. Land Characeristics Used for Suitability Ratings of Sites for Maize (Zea mays) Production in Mid- Benue Valleys.

Land Characteristics	**Unit**	**DG**	**DR**	**MU**	**UAM1**	**UAM1**
Climatic (c)						
Annual Rainfall	Mm	1220 – 1500	1220 – 1500	1220 – 1500	1220 – 1500	1220 – 1500
Mean Annual Max. Temp.	°C	33	33	33	33	33
Relative Humidity	%	72	72	72	72	72
Length of Dry Season	Days	210	210	210	210	210
Topography (t)						
Slope	%	2 – 4	0 – 2	0 – 2	2 – 5	0 – 3
Wetness (w)	W					
Flooding	Class	FO	F1	F1	FO	FR
Drainage	Class	WD	ID	MD	WD	ID
Soil Physical Properties (s)						
Texture / Structure	Class	CL,SL	CL, L	CL	SL	SL,CL
Coarse Fragments(0-50cm)	%	0.27	0.26	0.24	15.98	11.78
Fertility (f)	F					
CEC	(cmolkg^{-1} clay)	5.26	7.69	7.76	4.06	6.12
Base Saturation	%	96.39	76.56	82.97	98.93	75.94
pH	Water	5.63	5.55	5.71	5.76	5.54
Organic carbon (OM)	(0 - 50) %	0.60	1.63	1.15	0.19	0.45
Avail. P	mgkg^{-1}	9.39	1.75	9.39	1.07	1.32
Extractable K	cmolkg^{-1}	0.23	0.27	0.10	0.20	0.19
Total nitrogen	%	0.05	0.06	0.12	0.03	0.09

Key: DG (Dogo Katsina—Ala River Bank), DR (Dura Floodplain), MU (Mu River Basin) and UAM (University of Agriculture Makurdi Teaching and Research Farm)
FO – No Flooding, F1 – Seasonal Flooding, MR – Flooding Rare; C - Clay, CL – Clay Loam, LS – Loamy Sand, SL – Sandy Loam, LCS- Loamy Clay Sand, CS – Clay Sand, S - Sand

Table 3. Land Characteristics' Suitability Ratings of Sites for Maize (Zea mays) Production in Mid- Benue Valleys

Land Characteristics	**DG**	**DR**	**MU**	**UAM1**	**UAMII**
Climatic (c)					
			100 = S1	100 = S1	100 = S1
Mean Annual Max. Temp. (°C)	100 = S1	100 = S1	100 = S1	100 = S1	100 = S1
Relative Humidity (%)	100 = S1	100 = S1	100 = S1	100 = S1	100 = S1
Length of Dry Season (days)	100 = S1	100 = S1	100 = S1	100 = S1	100 = S1
Topography (t)					
Slope (%)	70 = S3	100 = S1	100 = S1	70 = S3	85 = S2
Wetness (w)					
Drainage	95 = S1	85 = S2	70 = S2	95 = S1	65 = S3
Flooding	100 = S1	70 = S3	65 = S3	100 = S1	85 = S2
Soil Physical Properties (s)					
Texture / Structure	90 = S2	95 = S1	95 = S1	90 = S2	95 = S1
Coarse Fragments (0-50cm)	100 = S1	100 = S1	100 = S1	90 = S2	90 = S2
Fertility (f)					
CEC (cmolkg^{-1} clay)	55 = S3	65 = S3	65 = S3	45 = S3	60 = S3
Base Saturation (%)	100 = S1	100 = S1	100 = S1	100 = S1	100 = S1
pH (water)	95 = S1	95 = S1	95 = S1	95 = S1	95 = S1
OM (%)	90 = S2	90 = S2	80 = S3	25 = S3	39 = S3
Avail. P (mgkg^{-1})	65 = S3	10 = S3	70 = S3	05 = S3	15 = S3
Extractable K (cmolkg^{-1})	60 = S3	65 = S3	35 = S3	60 = S3	55 = S3
Aggregate suitability class	S3tf	S3wf	S3wf	S3tf	S3wf

Key: DG (Dogo Katsina-_Ala River Bank), DR (Dura Floodplain), MU (Mu River Basin) and UAM (University of Agriculture Makurdi Teaching and Research Farm

suitable (S3wf) subclass (Table 3). From the foregoing, none of the pedons was considered highly suitable for maize cultivation in the area. All the soils were classified into marginally suitable (S3f) subclass due to their low nutrients status

Conclusion

The suitability assessment results showed that although, certain qualities or characteristics such as mean annual temperature, relative humidity and base saturation were optimum for maize cultivation, there was however, no highly suitable (S1) land for maize cultivation in the area. All the soils were classified into marginally suitable (S3f) subclass due to their low nutrients levels. The North Bank of River Katsina-Ala at Dogo sections of the area (DG1) was marginally suitable (S3tf) due to topography and low soil fertility. DR1 and MU1 were grouped into the marginally suitable (S3wf) subclass due to seasonal flooding; UAM11 was limited by its imperfect drainage to marginally suitable subclasses S3wf and UAM1 location on high slope limited the soil's to marginally suitable subclasses S3tf for maize production. To enhance the productivity levels of these lands for optimum maize production, farm management techniques that improve soil nutrient levels and structures are recommended

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