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Suitability assessment of selected floodplains in Jalingo, Taraba state Nigeria for sugarcane (*Saccharum officinarum* L.) production

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Abstract
The study was carried out in Jalingo area of Taraba State, Nigeria with the sole aim of assessing the suitability of floodplains of Jalingo area for sugarcane production. Five floodplains considered were: Angwan Karofi, Mayo-gwoi, Nukkai, Old Magami, and Sabon gari. Three composite soil samples were collected each at 0–15 and 15–30 cm depth in each of the floodplain areas to determine their physical and chemical properties. The results showed that soils of the floodplain areas were generally clay loam (36.40, 46.80, and 46.40 % of sand, silt, and clay) with moderate porosity (43.66 %), bulk density (1.66 %) and high-water holding capacity (83.70 %). The chemical properties of the soil showed that pH is slightly acidic to neutral (6.47–7.65), moderate organic matter (2.97 %), Medium Nitrogen (0.22–0.70%), Moderate Magnesium (2.42–3.11cmol/kg) and Moderate CEC (17.73 cmol/kg). The soil properties' results across the various floodplain locations were compared individually with the standard suitability ratings for sugarcane production, where the soil suitability was identified as marginally suitable (Ms). The limiting factors identified for sugarcane production were OM, N, K, and Mg. From the result of the study, it could be observed that effective management of these soils will require the application of N, P and K fertilizers and dolomitic lime or magnesium oxide to curb the limiting factors of N, P, K, and Mg respectively for the production of sugarcane in the study area. The growth of sugarcane is recommended within the study areas since the soil conditions are moderately suitable with minimal constraints.

Keywords
Floodplains, Sugarcane, Agriculture, Productivity, Soil

Introduction

Wetlands in Nigeria may be appropriately described as the "breadbasket in the land" because they serve as the primary source for growing crops and water supply to livestock and humankind (Colmer 2003). Nigeria had depended so much on land expansion as a strategy for increasing food production, leaving the potentials of the floodplains untapped. This has led to the rapid degradation of the uplands (Turner, 1991). The efficient management of floodplains offers an acceptable alternative for sustainable food production in Jalingo area (Kefas et al., 2016).

Some of the chemical changes that can occur in flooded soils include variations in soil pH, electrical conductivity, redox potential, denitrification activities and production of organic acids (Unger et al., 2009). Such chemical changes may overtime alter soil properties, including

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soil nutrient availability, enzyme activities, and organic matter dynamics. However, variable results have been reported on the effects of flooding on soil properties. Soil N(NO_3-N), for example, decreased under 5-weeks but increased under 3-weeks inundation. The decrease in NO_3-N was four times greater for stagnant than for flowing water after 5-weeks flooding (Unger et al., 2009).

The floodplains in Jalingo are characterized by continuous yearly flooding from August to November Adashu (2014). No detailed soil fertility studies have been carried out in the area. Therefore, the need to study the fertility status of soils of Jalingo floodplains is imperative. Land that is suitable for agricultural production is a finite and vulnerable resource. Already, there is a widespread decline in the yield of most crops in Nigeria due to poverty and the need to produce more food Essoka, 2013. Consequently, the change in land use and farming practices has resulted in soil organic matter depletion, nutrient mining and soil degradation (Van and Breman, 1990; Onyekwere et al., 2001) observed that apart from the scarcity of upland soils for agriculture, the few available cultivated soils which used to be fertile, have become severely degraded by continuous cropping practices that are prevalent with high population. It is therefore apparent that an indispensable sector of the economy (agriculture) is facing severe constraints of land scarcity and soil fertility decline. This could partly be responsible for the current global food crisis. Pragmatic steps must be taken to save humanity from the impending danger of more severe famine Cornland et al.,2003.

Sugarcane is most suited for a tropical climate and is grown primarily in tropical regions (Hesselmans and Peerbolte 1994). Sugarcane requires a hot, humid climate alternating with dry periods. Most of the world's sugarcane is grown at a latitude between 330N and 330S (Griffee, 2000). Additionally, the elevation is an essential factor determining sugarcane growth success, and typically, the crop is cultivated on land that is up to 1600m above sea level (Griffee, 2000). Studying Jalingo floodplain soils is vital as this would enable the evaluation of the soil's potentials for adequate agricultural production. As the human population is increasing at an alarming rate, there is a pressing need to boost food production by utilizing available land resources. Extending crop production into marginal lands such as flood plains is a promising venture, aimed at increasing food production at a sustainable level. The data generated from this study would equip floodplain users with the necessary information that would be essential for the management of the floodplain soil for sustainable agriculture and the environment. The results of this study, therefore, would be used as baseline data for further research, and it can also be used to advise subsequent users of the floodplains for agricultural production.

Materials and Methods

Study Area

Jalingo is located between latitude 8°47' to 9°01'N and longitudes 11°09' to 11°30'E (Fig. 1a). It is bounded to the North by Lau Local Government Area, to the East by Yorro Local Government Area, to the South and West by Ardokola Local Government Area. It has a total land area of about 198 km^2. Jalingo LGA has a population of 139,845 people, according to the 2006 population census, with a projected growth rate of 3%. The relief consists of undulating plain interspersed with mountain ranges. Between Kwaji-mika to the East and Kona to the West, stretching to Kassa-Gongon to the South exist this compact massif of rock outcrops. The mountain ranges run from Kona area through the border Jalingo and Lau LGAs down to Yorro and Ardo-kola LGAs in a circular form to Gongon area (Fig. 1b); this gives a periscopic semi-circle shape that is almost like a shield to Jalingo town (TSMEUD, 2012).

Soil data collection and physico-chemical analyses

Three composite soil samples were collected each at 0-15 and 15-30 cm in each of the floodplain areas. A total of thirty (30) composite samples were collected. The soil samples were air-dried for 48 hours. After drying, the soil samples were crushed to pass through a 2 mm sieve for analysis.

Saturated hydraulic conductivity (Ksat) was determined based on the method described by Hinga *et al.* (1980). Soil pH was determined with a pH meter in a ratio of 1:2.5 soil/water suspension, while electrical conductivity (EC) was determined on a soil paste using an EC meter. Soil texture was by the hydrometer method, as described by Glendon and Doni (2002). The bulk density was determined by the core method of known soil volume (Fuller and Warrick, 1985). Cation exchange capacity was determined in an ammonium acetate (NH_4OAc) solution at pH7 and NH_4-N concentration in the solution determined by micro-Kjeldhal distillation

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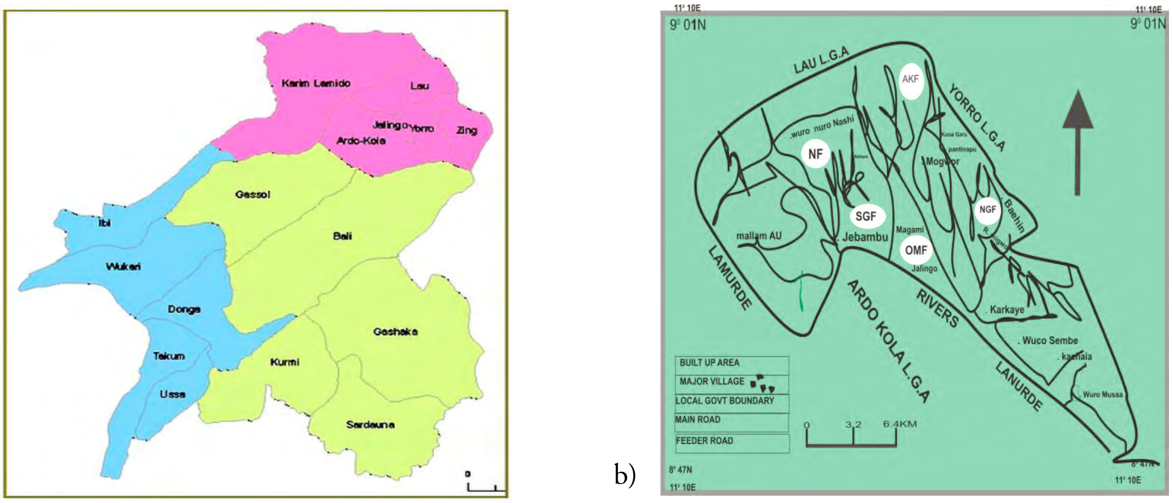
followed by titration with hydrochloric acid. Exchangeable bases (Ca, Mg, Na, and K) were extracted from the soil - NH_4OAc leachate and determined using Atomic Absorption Spectrometry (ASS). Organic carbon was determined following the Walkley and Black (1934) method, as described by Nelson and Sommers (1996). Total N was determined by micro-Kjeldhal distillation method as described by Bremner (1996). The Bray II method was used to determine available P, according to Bremmner (1996).



a) b)

Figure 1. ***a)*** *Map of Taraba State showing Jalingo local government area –* ***b)*** *Map of Jalingo local government area showing floodplain areas. Source: TSMEUD, 2012*
Sites:
MGF = Magwoi floodplain. Latitude 5°07' – 5°13'N and Longitudes 8°25' – 8°41'E.
OMF = Old Magami floodplain. Latitude 4°49' – 5°36'N and Longitudes 6°18' – 7°32'E.
SGF = Sabon-Gari floodplain. Latitude 6°34' – 6°45'N and Longitudes 7°24' -7°46'E.
NF = Nukkai floodplain. Latitude 5°30' – 6°14'N and Longitudes 6°12' – 6°27'E.
AKF = Angwan Karofi floodplain. Latitude 6°22' - 6°38'N and Longitudes 7°18' - 7°25'E.

Results and Discussion

The results of the study sites' soil physical and chemical properties are presented in Tables 1 and 2. The soil texture was across all the locations at both depths were clay loam. Saturated hydraulic conductivity was moderate to moderately rapid across all locations at both depths. The water holding capacity shows very high (73.63 to 84.66) at both the topsoil and subsoil level. The pH of the soil was neutral to slightly acidic (6.35 to 7.65) across all the floodplain locations at both depths. The values of available phosphorus increased with depth at Angwan karofi and Mayo-gwoi area and decreased with depth at Nukkai, Old magami, and Sabon-gari area, respectively, and the ratings were low (5.01 to 5.82). The exchangeable cation ratings of the floodplain soils across all locations at both depths were moderate.

Cation exchange capacity. The CEC values for the soils examined were18.81 Cmol/kg to 19.07 Cmol/kg (moderate) both for the top and subsoil. Mayo-gwoi area had17.73 Cmol/kg and 18.59 Cmol/kg (moderate) for both soil depths. Nukkai area had17.13 Cmol/kg and 17.10 Cmol/kg (moderate) while Old magami had CEC values of 18.34 Cmol/kg and 17.45 Cmol/kg (moderate) respectively for both soil depths. Sabon gari area had 19.38 Cmol/kg and 16.91 Cmol/kg (moderate), respectively. The CEC content in all the 5 locations of the soil assessed indicated moderate (Table 3).

Base saturation. The values of base saturation at Angwan karofi area were 96.30% and 96.40% (very high) for the top and subsoil, respectively. Moyo-gwoi area had 94% and 96% (very high), while Nukkai had 93% (very high for both depths). Old magami had 94% and 93.30% (very high) for both depths, while Sabon gari area had 96% for the top and 93% for the subsoil. The base saturation values for all the soils assessed indicated very high for both the topsoil and subsoil depths, respectively (Table 11).

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Sodium absorption ratio (SAR). Table 2 also showed the SAR contents for Angwan karofi ranged between 0.16 to 0.17 while that of Mayo-gwoi area was 0.18 and 0.13, respectively for both soil depths. Nukkai area had 0.16 for both soil depths. Old magami area had 0.15 for both soil depths while Sabon-gari had 0.18 and 0.15 for both top and subsoils, respectively

Table 1. *Soil physical properties of the study areas.*

Floodplains (see Fig. 2)	Texture				HC	MC	BD	Porosity	WHC
	Sand	Silt	Clay	Class					
	%	%	%	Class		%	g/cm3	%	%
	(0 – 15 cm)								
AKF	36.4	25.4	38.2	Clay-loam	11.2	50.7	1.65	36.7	79.0
MGF	56.4	15.4	28.2	Clay-loam	38.3	56.7	1.63	37.7	75.1
NF	46.8	23.2	29.8	Clay-loam	14.1	58.7	1.57	40.3	83.7
OMF	46.4	25.4	28.2	Clay-loam	9.24	50.3	1.63	37.7	76.3
SGF	56.8	15.4	27.8	Clay-loam	4.68	48.0	1.52	42.7	74.7
	(15 – 30 cm)								
AKF	36.4	25.4	38.2	Clay-loam	11.2	50.7	1.66	38.0	76.3
MGF	56.4	15.4	28.2	Clay-loam	37.0	54.0	1.56	41.3	75.1
NF	46.8	23.2	29.8	Clay-loam	14.4	58.0	1.55	41.3	84.3
OMF	46.4	25.4	28.2	Clay-loam	9.24	50.0	1.64	37.0	76.3
SGF	56.8	15.4	27.8	Clay-loam	4.67	46.7	1.53	43.7	73.6

HC =Hydraulic Conductivity– MC =Moisture Content - BD = Bulk Density - WHC =Water Holding Capacity

The soil suitability ratings for the various floodplain areas were compared individually with the standard soil suitability ratings for sugarcane production.

Soil depth and wetness across all the floodplain locations were moderately suitable (MS) except for Nukkai and Sabon Gari floodplain areas that the suitability ratings were highly suitable. Drainage and soil texture were moderately suitable across the locations except for Mayogwoi soil texture that the ratings were highly suitable (HS). Soil pH across all the locations was highly suitable (HS) for the production sugarcane. Soil organic matter was moderately suitable to produce sugarcane cross all the floodplain locations. Available p across all the floodplain locations were moderately suitable for sugarcane production. Calcium across all the floodplain locations was moderately suitable for rice production, while magnesium and nitrogen were marginally suitable for sugarcane production. The limiting factors identified for sugarcane production were N, K, and Mg.

Conclusions

Careful observations and interpretations of the data generated from this study showed that: The soils of Jalingo floodplains are generally clay loam with particle- size distribution of 36.40% sand, 25.40% silt and 37.15% clay with moderate porosity (43.66%), high water holding capacity (79.33), slight acid reaction and moderate organic matter which does not encourage excessive leaching and loss of basic cations in the soil. The soils of the Jalingo floodplain are generally considered moderately suitable (S2s) for the cultivation of sugarcane production. The soils are generally limited by unfortunate organic matter, Mg, P, N, and K contents.

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Table 2. *Soil chemical properties of the study areas*

Parameters	Unit of measure	Soil Depth (cm)	Floodplains				
			AKF Angwan-Karofi	MGF Mayo-gwoi	NF Nukkai	OMF Old Magami	SGF Sabon-Gari
pH (H_2O)		0 - 15	7.42	7.15	6.80	7.21	7.62
		15-30	7.65	7.36	6.47	6.98	6.35
pH ($CaCl_2$)		0 - 15	17.5	17.1	16.3	16.9	17.9
		15-30	16.8	16.8	17.1	16.5	17.4
Av.P	ppm	0 - 15	5.67	5.21	4.78	5.43	5.82
		15-30	6.03	5.58	4.32	4.86	4.01
K	cmol/kg	0 - 15	0.46	0.33	0.31	0.32	0.48
		15-30	0.38	0.38	0.30	0.30	0.31
Ca	cmol/kg	0 - 15	5.23	4.11	4.07	4.83	5.41
		15-30	5.33	4.87	4.11	4.09	3.98
Mg	cmol/kg	0 - 15	2.81	2.96	2.46	2.89	3.11
		15-30	3.01	2.98	2.42	2.78	2.36
Na	cmol/kg	0 - 15	0.31	0.33	0.29	0.30	0.38
		15-30	0.35	0.36	0.27	0.28	0.26
E.A	cmol/kg	0 - 15	0.33	0.50	0.50	0.50	0.33
		15-30	0.33	0.33	0.50	0.50	0.50
TOC	%	0 - 15	1.76	1.72	1.69	1.73	1.91
		15-30	1.89	1.76	1.67	1.71	1.67
TOM	%	0 - 15	3.02	2.96	2.90	2.97	3.28
		15-30	3.25	3.02	2.87	2.94	2.88
TN	%	0 - 15	0.47	0.42	0.36	0.49	0.70
		15-30	0.53	0.48	0.28	0.35	0.22
CEC	cmol/kg	0 - 15	18.8	17.7	17.1	18.3	19.4
		15-30	19.1	18.6	17.1	17.5	16.9
BS	%	0 - 15	96.3	94,0	93.0	94.0	96.0
		15-30	96.4	96.0	93.0	93.3	93.0
SAR		0-15	0.16	0.18	0.16	0.15	0.18
		15-30	0.17	0.13	0.15	0.15	0.50

Av.P = Available phosphorus - EA = Exchangeable Acidity– TOC = Total Organic Carbon –TOM = Total Organic Matter – TN = Total Nitrogen - CEC = Cation Exchange Capacity– BS = Base Saturatyion

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Table 3. *Organic carbon, total nitrogen, available phosphorus, CEC, Base Saturation, and Hydraulic Conductivity ratings of soils of the study area*

Parameters	Soil Depth (cm)	Floodplains					Standard range	Rating
		AKF Angwan-Karofi	MGF Mayo-gwoi	NF Nukkai	OMF Old Magami	SGF Sabon- Gari		
pH (H_2O)	0 - 15	7.42	7.15	6.80	7.21	7.62	7.4-7.8	Slightly acidic
	15-30	7.65	7.36	6.47	6.98	6.35		
Av.P (ppm)	0 - 15	5,67	5.21	4.78	5.43	5.82	< 8	Low
	15-30	6.03	5.58	4.32	4.86	4.01		
TOC (%)	0 - 15	1.76	1.72	1.69	1.73	1.91	1.5 – 2.0	High
	15-30	1.86	1.76	1.67	1.71	1.91		
TN (%)	0 - 15	0.47	0.42	0.36	0.49	0.70	0.2 – 0.5	Medium
	15-30	0.53	0.48	0.28	0.35	0.22		
CEC (cmol/kg)	0 - 15	18.8	17.7	17.1	18.3	19.4	12 - 25	Moderate
	15-30	19.1	18.6	17.1	17.5	16.9		
BS (%)	0 - 15	96.3	94.0	93.0	94.0	96.0	> 80	Very high
	15-30	96,4	96.0	93.0	93.3	93,0		
Ksat	0-15	11.2	38.3	14.1	9.24	4.68	6.3-12.7	Moderately rapid
	15-30	11,2	37.0	14.4	9,24	4.67		

Av.P = Available phosphorus - TOC = Total Organic Carbon – TN = Total Nitrogen – CEC = Cation Exchange Capacity– BS = Base Saturation – Ksat = Saturated potassium

Table 4. *Land Quality and Factor Rating for Sugarcane. Source: Tarimo and Takamura (1998)*

Land Use Requirement	Factor Rating			
Land quality diagnostic factor	S1(1.0)	S2(0.8)	S3(0.4)	N(0)
Annual rainfall mm	1,600-2,5000	1,200-1,600	900-1,200	<900
Soil(s) s=NAIXPP	0.5	0.1-0.5		<0.1
Nutrient availability index (NAI)	>2.0	-2.0		<1.0
Nitrogen %	>25	6-25		<6
P mg/kg	>0.153	0.076-0.153	0.076	
K mg/kg	6.1-7.3	7.4-8,51-60	7.9-8.4,4.0-4.5	>8.4<4
PH	>0.8	0.4-0.8	0.1-0.4	<0.1
Physical properties (pp)	Very well	Moderately well	Somewhat well	Very poor
P_p = drxtxd	Cl, scl, sil	Sicc,sl sic	Is cgscacs	
Soil range (dr) class (USDA)	Si, cl, 1			
Soil depth (d) cm	>100	50-100	25-50	>25
Salt hazards (sa) salinity	Nonsaline	Low	Medium-high	
Terrain (t) landform & slope & %	combination of landforms and slope			

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Table 5. *Soil suitability of the different locations for Sugarcane cultivation.*

Land properties	Floodplains					
	AKF Angwan-Karofi	MGF Mayo-gwoi	NF Nukkai	OMF Old Magami	SGF Sabon- Gari	
	Limitations					
Soil depth (cm)	S2	S2	S2	S2	S2	
Wetness (%)	S2	S2	S1	S2	S1	
Drainage	S2	S2	S2	S2	S2	
Soil texture	S2	S2	S2	S2	S2	S3 N,K,Mg
pH	S1	S1	S1	S1	S1	
Organic Carbon (%)	S2	S2	S2	S3	S2	
Available P (ppm)	S2	S2	S2	S2	S2	
Exchangeable K	N	N	N	N	N	
Total Nitrogen (%)	S3	S3	S3	S3	S3	
Exch. Mg (cmol/kg)	S3	S3	S3	S3	S2	

S1 = Highly suitable, S2 = Moderately suitable, S3 = Marginally suitable, N = Not suitable

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