sciendo DOI: 10.2478/ats-2020-0009 AGRICULTURA TROPICA ET SUBTROPICA, 53/2, 81–92, 2020

Original Research Article

Assessment of inland valley soils for sugarcane (*Saccharum officinarum* L.) production in some floodplains in central Nigeria

Julius Romiluyi **Orimoloye**[1], Harrison Ugochukwu **Nkwocha**[1], Ibrahim **Adamu**[1,2]

[1]*Department of Agronomy, Faculty of Agriculture, University of Ibadan, Ibadan, Nigeria*
[2]*Department of Soil Science, Faculty of Agriculture, University of Maiduguri, Nigeria*

Correspondence to:
J. R. Orimoloye, Department of Agronomy, Faculty of Agriculture, University of Ibadan, Ibadan, Nigeria,
e-mail: juliusorimoloye@gmail.com

Abstract

Sugarcane is an energy crop with great economic potentials. Information on soil evaluation for sugarcane in central Nigeria is very scanty. This study was carried out to evaluate the suitability of some soils of the floodplains in central Nigeria for sugarcane cultivation. A semi-detailed soil survey was carried out on 18,500 hectares of land straddling the floodplains of Rivers Niger and Benue in Korton-Karfe Local Government Area of Kogi State. Land resource survey was carried out using a 500 m×500 m grid pattern. Identified soil types were further examined with standard soil profiles. Samples were collected from the soil genetic horizons as well as surface (0–30 cm) soils at selected sampling points for fertility analysis. Parametric and non-parametric suitability evaluation methods were used to relate land qualities with land use requirements for commercial sugarcane cultivation. Relationships between evaluation methods were assessed using Spearman's rank correlation coefficients. Nine soil mapping units were identified in the study areas which were mainly Inceptisols (55.4%) and Alfisols (22.5%) which correlates with Fluvisols (40.4%), Cambisols (15.1%) and Lixisols (22.5%) in the World Reference Base (WRB) classification system. The evaluation methods used revealed that 0%, 4.95%, 49.48%, 23.55% of the soils were highly suitable (S1), moderately suitable (S2), marginally suitable (S3) and not suitable (N) for sugarcane cultivation, respectively. Potentially, 0%, 9.52%, 44.91% and 23.55% of the soils were found to be highly suitable (S1), moderately suitable (S2), marginally suitable (S3) and not suitable (N) for sugarcane cultivation, respectively. The soils were strongly limited by low soil nutrient availability, soil acidity and flood hazard. Soil management practices such as application of organic manures, fertiliser and liming could be adopted to ameliorate the soil acidity and supply deficient nutrients while land development strategies such as drainage, flood control and possibly sub-soiling would mitigate other major limitations to sugarcane cultivation.

Keywords: land; suitability; evaluation; sugarcane; soil texture; colour; consistency; mottles; physical and chemical properties

INTRODUCTION

The floodplains defined as a strip of relatively smooth land bordering a stream and overflows at a time of high water (Leopold et al., 1964) is referred to as *Akuro* in South Western Nigeria and *Fadama* in Northern Nigeria. The floodplains cover an estimated area of four million hectares in Nigeria and is the most exploited for agricultural production in Africa (Fasina, 2005). This 'strip' could be several kilometers wide in many parts of the Northern Nigeria holding high potentials for commercial agricultural development (Uzu et al., 2003). The major soils in Nigerian floodplains have been classified as Alfisols, Inceptisols, Entisols, Histosols and Vertisols (Olaleye, 1998; Akamigbo, 2009; Ogbaji, 2010). The floodplains usually adjoining major rivers consist mostly of soils formed under conditions of poor drainage with active or passive erosional and depositional features (Schmudde, 1968; Fasina, 2005). They are characterised by seasonal superficial flooding or shallow, seasonally fluctuating groundwater table (Okusami, 1985).

Sugarcane cultivation is a key provider of income and employment in many countries, particularly in developing economies with a high proportion of poor and unemployed groups thereby enhancing the economic growth of developing economies (Gopinathan, 2010). With the increase in electricity demand in recent years, and the imminent risk of blackouts as a result of insufficient capacity, bioelectricity generation through sugarcane processing has been advocated for (Olivério and Ferreira, 2010). With crisis and environmental concerns associated with the use of fossil fuels, the trend towards biofuels and renewable energy has further positioned sugarcane to play an increasing role in producing bioethanol. The generation of surplus electricity from bagasse (a byproduct of sugarcane processing) is already well established while rapidly advancing technologies based on biotechnology and bioprocess engineering has converted bagasse into a wide range of other products (Rogers et al. 2001; Olivério and Ribeiro, 2006). Sugarcane production if properly managed is expected to lead to a shift in the demand-supply situation of sugar and associated products in favour of the Asian, South East and African countries within a foreseeable future (Gopinathan, 2010). With the inauguration of the sugar policy for Nigeria, it is expected that Nigeria will key into the wide range of opportunities available in sugarcane agriculture.

Appropriate protection and judicious utilisation of the floodplains is essential to enable these ecosystems survive and continue to provide sustainable sugarcane productivity. It is therefore necessary that appropriate strategies are developed for the sustainable use and management of floodplains for sugarcane cultivation and other agricultural purposes. Development of such policies and strategies can only be possible where information, on the characteristics and functioning of floodplains is carefully collected, assembled and interpreted. Land evaluation is thus necessary to assess the potentials for sugarcane in the floodplains as the basis for proper land use planning (Fasina and Adeyanju, 2007).

This work was carried out in the floodplain soils in the Dangerri area in Kogi State to contribute to the information database required for the understanding of floodplain resources in Nigeria with a view to develop management strategies for the exploitation of this vast resource for agricultural productivity. Therefore the objectives of this study are to characterise the soils of the floodplains of Rivers Niger and Benue around Dangerri area in Central Nigeria, evaluate the suitability of the floodplain soils of the area for sugarcane cultivation and suggest management practices to ameliorate possible limitations to the sustainable use of the soils for sugarcane production.

MATERIALS AND METHODS

Study Location

This study was carried out on a parcel of land covering about 18,500 hectares at Dangerri (Near Lokoja) in Kotton-Karfe Local Government Area, Kogi State from November 2013 to April 2014. The specific study area is located within latitudes 7°52'02.51"N -7°58'01.28"N and longitudes 6°48'11.15"E-6°56'57.96"E. The land area lies on the banks of River Niger and River Benue. The study area as shown in Fig. 1, lies within the Zone F (Sub-Humid Niger-Benue Trough) (Ojanuga, 2006) with mean annual rainfall of 1120 mm at Lokoja (NiMet, 2015). A distinct dry season of about 5months duration occurs from November to March while the rains occur substantially from April to October. Mean annual temperature ranges from 25 °C–29 °C. The study area was very close to the confluence of Rivers Niger and Benue near Lokoja. Therefore drainage conditions of the soils are influenced by the proximity to the rivers which characteristically overflow their banks yearly at the peak of raining seasons. Geologically, the area is an extension of the Middle Niger Basin and primarily characterised by an overlay of laterite capped Nupe sandstones (Ojanuga, 2006). Parent material of the soils is sandstone materials in the uplands and alluvial deposits of the rivers Niger and Benue.

Field Survey

A rigid grid method of soil survey was adopted for the land resource survey. Transects were laid out 500 m apart and auger observations were taken at 500 m interval along transects. Examination points were pre-determined in a GIS environment and the co-ordinates were pre-loaded into a Global Positioning System (GPS) devise with which the points were located on the field. Soil morphological properties such as texture, colour, consistency, mottles, etc. were examined at 0–15 cm, 15–30 cm, 30–60 cm, 60–90 cm and 90-120 cm depths at each examination point. Similar (points) sites having same morphological characteristics were grouped together to form mapping units. These were further examined with modal soil profiles measuring 200 × 150 cm dug up to 180 cm depth where possible. A total number of eight soil mapping units were identified and eight soil profiles were described and sampled according to standard (FAO) guidelines. In addition, composite soil samples from 0–30 cm depth from the examination points were also collected randomly and bulked for fertility studies therefore; a total of about 180 soil samples were collected for laboratory analysis.

Laboratory Analysis

Soil samples collected from the field were air dried, crushed and passed through 2 mm sieve for physical and chemical analysis while a part of each sample was passed through 0.5 mm mesh sieve to achieve maximum surface area for organic carbon determination (Udoh and Ogunwale, 1986). The soils were analysed for particle size using the modified hydrometer method. The pH and electrical conductivity were determined potentiometrically using a glass electrode pH meter, total nitrogen was determined using the micro-Kjeldahl method, available *P* was determined colourimetrically, exchangeable bases and exchangeable acidity were extracted with neutral normal acetic acid.

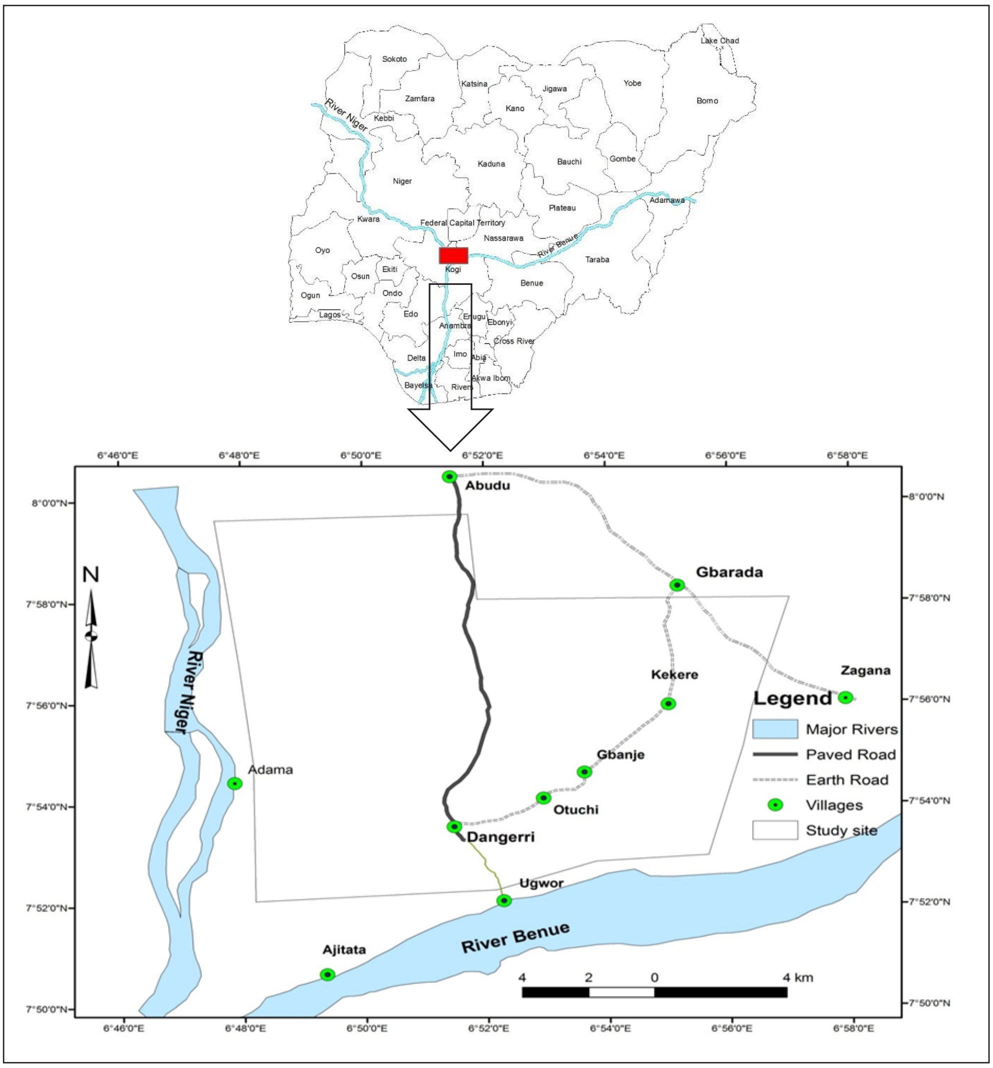

Figure 1. Location of the Dangerri Study Area.

Table 1. Land quality and factor rating for sugarcane.

Land use requirement			Factor Rating and Score			
Land Quality	**Diagnostic Factor**	**Unit**	**S1 (100)**	**S2 (80)**	**S3 (60)**	**N (40)**
Water Availability (c)	Annual Rainfall	mm	>1600	1,100–1,600	800–1,100	<800
Nutrient Available (f)	N	%	>0.2	0.1–0.2	<0.1	
	P	mg/kg	>25	6–25	<6	
	K	Cmol/kg	>60	30–60	<30	
	pH	–	6.1–7.3	7.4–7.8	7.9–8.4	>8.4
				5.1–6.0	4.0–5.0	<4.0
	B/Sat	%	>80/50–80	35–50	<35	
Texture	Particle size class	class	C,L,SCL, SiL,Si,CL,L	SiCL,SL	SiC,LS	C (% clay $\geq$ 65) G,SC,S,AC
Rooting Conditions (s)	Soil Depth	cm	>100	50–100	25–50	<25
Topography (t)	Slope	%	0–2	2–5	5–12	>12
Wetness (w)	Drainage		WD	MWD	FWD	PD

Source: (Sys et al. 1993); (Charuppat, 2002)
Legend: C = Clay, CL = Clay loam, S = Sand, SCL = Sandy clay loam, SL = Sandy loam, SiL = Silty loam, Si = Silt, L = loam, LS = Loamy sand, SiCL = Silty clay loam, SiC = Silty clay, G = Gravel soil, SC = Slop complex, S = Sand, AC = Alluvial complex
FWD = Fairly well drained, WD = Well drained, MWD = Moderately well drained, PD = Poorly drained;
Suitability Evaluation: S1 = Highly Suitable, S2 = Moderately Suitable, S3 = Marginally Suitable, N = Unsuitable/Not Suitable

The exchangeable bases were determined using Atomic Absorption Spectrometry whereas exchangeable bases were determined titrometrically. All parameters were determined by standard procedures as contained in IITA (1982).

Soil Classification

The soil types on the study site were identified, characterised and classified using the internationally accepted USDA Soil Taxonomy (Soil Survey Staff, 2014) and the classifications were correlated with World Reference Base (WRB) system (FAO/ISSS, 2006).

Suitability Evaluation

The suitability evaluation according to the modified FAO framework (FAO, 2007) was adopted for land rating using modified suitability criteria for sugarcane from Sys et al. (1993) and Charuppat (2002) (Table 1). In the non-parametric approach, land requirements are simply matched with the land qualities and characteristics to place soil units or pedons in classes designated as S1 (highly suitable), S2 (moderately suitable), S3 (marginally suitable), and N (not suitable) according to the suitability indices indicated in Table 2.

For parametric evaluation, each limiting characteristics was rated by scoring using the criteria presented in Table 1. The index of suitability (actual and potential) was calculated using the equation:

$$IP = A \times \sqrt{\frac{B}{100} \times \frac{C}{100} \times \ldots \frac{F}{100}}$$

Where IP = Index of Productivity, A = overall fertility limitation and B, C …F is the lowest characteristics ratings of each land quality group.

Five land quality groups climate (c), topography (t), soil physical properties (s), wetness (w), and fertility (f) were used in this method of evaluation. Only one member in each group was used for calculation purpose because there are usually strong correlations among members of the same group (e.g. texture and structure). For actual suitability index, all the lowest characteristics ratings for each land qualities group were substituted into the index of suitability equation above. However, in the case of potential suitability index, it is assumed that the corrective limitation observed will no longer have such constraints.

The overall suitability index (SI) calculated for each pedon is assigned to suitability class as shown in Table 2.

RESULTS

Nine soil mapping units were discovered in the surveyed area and the Soil Map of Dangerri Study Area is presented as Fig. 2. The taxonomic classification of the different soil mapping units identified are denoted with alphabets A, B, C, D, E, F, G, H, I, and their area coverage is as shown in Table 3. The matching of the land qualities of the various mapping units with suitability evaluation for Non-Parametric Suitability Evaluation (actual and potential) and Parametric Suitability Evaluation (actual and potential) for sugarcane in the Dangerri study area are presented in Tables 4 and 5, respectively.

The Suitability map of the Dangerri study area is given in Figures 3, 4, 5, and 6, which present the Non-Parametric (actual) Suitability map, Parametric (actual) Suitability map, Non-Parametric (potential) Suitability map, and Parametric (potential) Suitability map of the Dangerri study area, respectively. Table 6 shows the summary of the Non-Parametric suitability classification and land area of the Dangerri study area which shows that a greater proportion (49.48%) of the soils are marginally suitable for sugarcane cultivation following the current status of the soil. If some land developments are made, the potential marginally suitable area will be 44.91% while the potential moderately suitable increased from 4.95% to 9.52%. Table 7 shows the summary of the Parametric suitability classification and land area of the Dangerri study area and this reveals that carrying out some land development measures on the soil will make the soil have a potential highly suitable area of about 4.57%, and a potential moderately suitable area increases from 9.52% to 41.87% thereby giving a potential marginally suitable area of 16.52% from the actual marginally suitable area of 44.91%, and further improve currently not suitable area potentially from 23.55% to 15.02%. Table 8 gives the ranking of the various mapping units by the suitability classification for sugarcane in the Dangerri study area, while Table 9 presents the Spearman's rank correlation coefficient among land suitability evaluation procedures used for both actual and potential evaluation. This table shows that there is a perfect positive and significant correlation in the ranking of the mapping units by the evaluation procedures used.

DISCUSSION

The soils of the study area were classified as Fluvaquentic Eutrudept, Fluventic Eutrudept, Kanhaplic haplaustalf, Lithic haplustept, Typic Kanhaplaustalf, Rhodic haplaustalf, Arenic haplaustalf, Aquic Dystrudept, and Fluventic Dystrudept in the USDA soil classification system. This classification is in line with that of Olaleye (1998) who reported that the major wetland soils in Nigeria belong to Alfisols, Inceptisols, Entisols, Histosols and Vertisols soil orders.

In terms of colour, the soils of the study area are characterised by dark brown to yellowish brown, very dark greyish brown to greyish brown and brownish yellow colour. The soils are very acidic to slightly acidic soils with pH range of 4.25–5.9. This characterisation

Table 2. Rating of limiting factors and suitability index of land quality for parametric suitability evaluation

Suitability Class	Suitability Index (SI)	Designation
Highly Suitable	>75	S1
Moderately Suitable	50-75	S2
Marginally Suitable	25-50	S3
Marginally Not Suitable	10-25	N1
Permanently Not Suitable	<10	N2

Source: Sys et al. (1991)

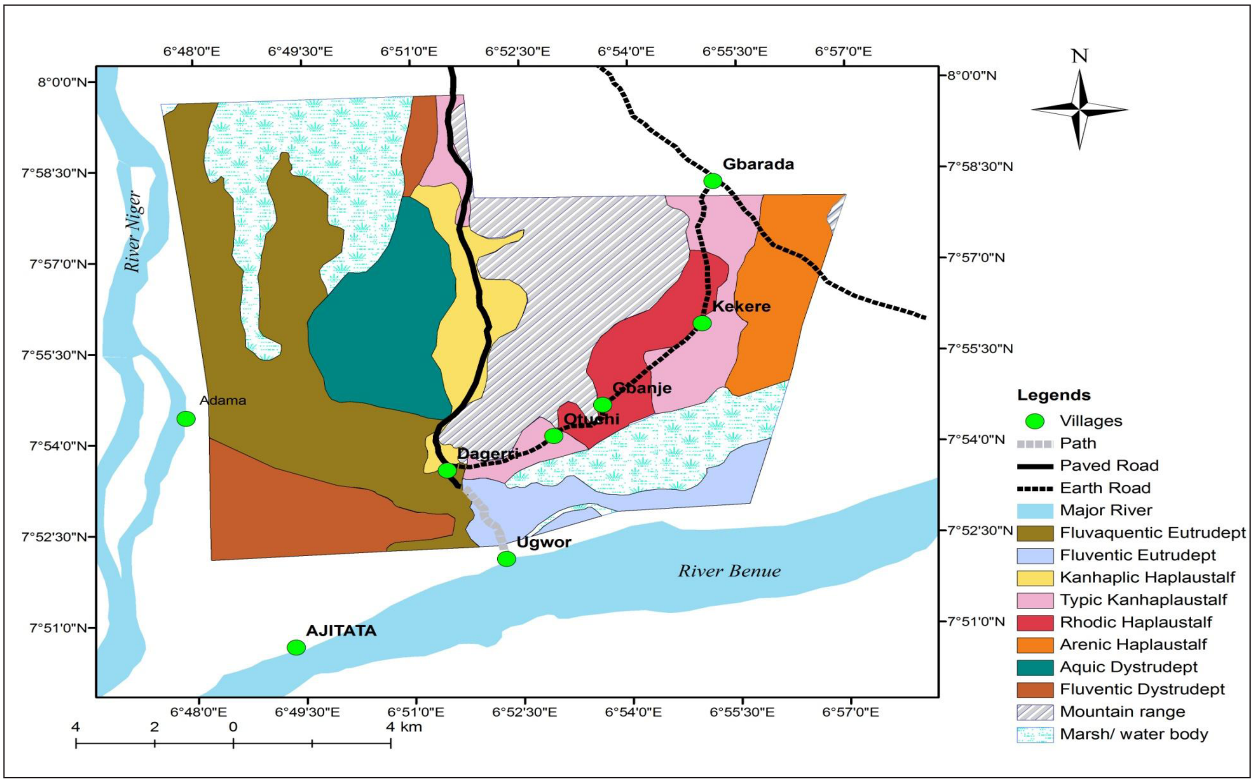

Figure 2. Soil Map of the Study Area at Dangerri, Central Nigeria.

Table 3. The taxonomic classification and coverage areas of each mapping unit of soils of Dangerri study site

Mapping Unit	Soil name		Area Coverage	
	USDA Soil Taxonomy (2010)	WRB (2006)	(ha)	(%)
A	Fluvaquentic Eutrudept	Gleyic Fluvisol (Eutric)	3629.83	19.36
B	Fluventic Eutrudept	Haplic Fluvisol (Eutric)	855.95	4.57
C	Kanhaplic Haplaustalf	Haplic Lixisol (ruptic)	928.15	4.95
D	Lithic Haplustept	Leptic Cambisol (ruptic)	2816.74	15.02
E	Typic Kanhaplaustalf	Haplic Lixisol (Eutric)	1357.83	7.24
F	Rhodic Haplaustalf	Nitic Lixisol (Rhodic)	885.89	4.72
G	Arenic Haplaustalf	Vetic Lixisol (Arenic)	1050.75	5.60
H	Aquic Dystrudept	Stagnic Fluvisol (oxyaquic, Dystric)	1600.00	8.53
I	Fluventic Dystrudept	Haplic Fluvisol (Dystric)	1498.66	7.99
Marsh/water	Nil	Nil	4126.06	22.02
Total			**18749.86**	**100**

Table 4. Non-Parametric suitability classification for sugarcane at Dangerri study area

Land Quality	Mapping Units								
	A	B	C	D	E	F	G	H	I
Climatic factor (c)									
Annual Rainfall (mm)	1120 (S2)	1120 (S2)	1120 (S2)	1120 (S2)	1120 (S2)	1120 (S2)	1120 (S2)	1120 (S2)	1120 (S2)
Soil Characteristics (s)									
Effective soil depth (cm)	180 (S1)	160 (S1)	180 (S1)	–	180 (S1)	170 (S1)	180 (S1)	101 (S1)	160 (S1)
Texture	C, CL (S1)	CL, C (S1)	SL (S2)	SL (S2)	LS (S3)	LS (S3)	LS (S3)	SCL, C (S1)	CL (S1)
Topography (t)	MS	MS	MS	–	MS	MS	US	LWS	LWS
Slope (%)	0–2 (S1)	0–2 (S1)	0–5 (S2)	(N)	4–7 (S3)	5–7 (S3)	3–5 (S3)	3–5 (S1)	0–2 (S2)
Fertility (f)									
pH	4.8 (S3)	4.9 (S3)	5.4 (S2)	5.9 (S2)	4.9 (S3)	5.5 (S2)	5.2 (S2)	3.75 (N)	4.25 (S3)
B/Sat (%)	91.46 (S1)	98.17 (S1)	97.75 (S1)	98.22 (S1)	92.28 (S1)	90.83 (S1)	91.44 (S1)	18.28 (S3)	61.91 (S1)
Avail P (μ/g)	2.51 (S3)	5.34 (S3)	24.34 (S2)	30.60 (S1)	18.93 (S2)	22.24 (S2)	5.36 (S3)	2.13 (S3)	1.83 (S3)
Tot N (g/kg)	0.12 (S2)	0.13 (S2)	0.13 (S2)	0.22 (S1)	0.14 (S2)	0.06 (S3)	0.11 (S3)	0.20 (S2)	0.21 (S1)
K (cmol/kg)	86.02 (S1)	58.65 (S2)	62.56 (S1)	109.48 (S1)	15.64 (S3)	23.46 (S3)	31.23 (S2)	27.37 (S3)	58.65 (S2)
Wetness (w)									
Drainage	FWD (S3)	WD (S1)	WD (S1)	–	WD (S1)	WD (S1)	WD (S1)	PD (N)	FWD (S3)
Actual	S3fw	S3f	S2stf	Nstw	S3stf	S3stf	S3stf	Nfw	S3fw
Potential	S3w	S2c	S2t	Nstw	S3t	S3t	S3t	Nw	S3w

Legend: C = Clay, CL = Clay loam, SL = Sandy loam, LS = Loamy sand, SCL = Sandy clay loam; MS = Middle Slope, US = Upper slope, LWS = Lower slope; FWD = Fairly well drained, WD = Well Drained, PD = poorly drained; Suitability Evaluation: S1 = Highly Suitable, S2 = Moderately Suitable, S3 = Marginally Suitable, N = Unsuitable/Not Suitable

Table 5. Parametric suitability classification for sugarcane at Dangerri study area

Land Quality	Mapping Units								
	A	B	C	D	E	F	G	H	I
Climatic factor (c)									
Annual Rainfall (mm)	(S2) 80	(S2) 80	(S2) 80	(S2) 80	(S2) 80	(S2) 80	(S2) 80	(S2) 80	(S2) 80
Soil Characteristics (s)									
Effective soil depth (cm)	(S1) 100	(S1) 100	(S1) 100	-	(S1) 100	(S1) 100	(S1) 100	(S1) 100	(S1) 100
Texture	(S1) 100	(S1) 100	(S2) 80	(S2) 80	(S3) 60	(S3) 60	(S3) 60	(S1) 100	(S1) 100
Topography (t)				-					
Slope (%)	(S1) 100	(S1) 100	(S2) 80	(N) 20	(S3) 60	(S3) 60	(S3) 60	(S1) 100	(S2) 80
Fertility (f)									
pH	(S3) 60	(S3) 60	(S2) 80	(S2) 80	(S3) 60	(S2) 80	(S2)80	(N) 40	(S3) 60
B/Sat (%)	(S1) 100	(S1) 100	(S1) 100	(S1) 100	(S1) 100	(S1) 100	(S1) 100	(S3) 60	(S1) 100
Avail P (Mg/Kg)	(S3) 60	(S3) 60	(S2) 80	(S1) 100	(S2) 80	(S2) 80	(S3) 60	(S3) 60	(S3) 60
Tot N (g/kg)	(S2) 80	(S2) 80	(S2) 80	(S1) 100	(S2) 80	(S3) 60	(S3) 60	(S2) 80	(S1) 100
K (cmol/kg)	(S1) 100	(S2) 80	(S1) 100	(S1) 100	(S3) 60	(S3) 60	(S2) 80	(S3) 60	(S2) 80
Wetness (w)				-					
Drainage	(S3) 60	(S1) 100	(S1) 100	-	(S1) 100	(S1) 100	(S1) 100	(N) 40	(S3) 60
Actual	S3 (41.58)	S2 (53.64)	S2 (57.28)	N2 (7.16)	S3 (32.22)	S3 (32.22)	S3 (32.22)	N1 (22.64)	S3 (37.20)
Potential	S2 (53.64)	S1 (80.00)	S2 (71.52)	N2 (8.00)	S2 (53.64)	S2 (53.64)	S2 (53.64)	S3 (35.76)	S3 (48.00)

Suitability Evaluation: S1 = Highly Suitable, S2 = Moderately Suitable, S3 = Marginally Suitable, N = Not Suitable

Table 6. Summary of the Non-Parametric Suitability Classification for Sugarcane in the Dangerri Study Area

Land Suitability Class	Actual		Potential	
	Area (ha)	Area (%)	Area (ha)	Area (%)
Moderately Suitable (S2)	928.15	4.95	1784.10	9.52
Marginally Suitable (S3)	9278.91	49.48	8422.96	44.91
Not Suitable (N)	4416.74	23.55	4416.74	23.55
Marshy Area	4126.06	22.02	4126.06	22.02
Total	18749.86	100.00	18749.86	100.00

Table 7. Summary of the Parametric Suitability Classification for Sugarcane in the Dangerri Study Area

Land Suitability Class	Actual		Potential	
	Area (ha)	Area (%)	Area (ha)	Area (%)
Highly Suitable (S1)	-	-	855.95	4.57
Moderately Suitable (S2)	1784.10	9.52	7852.45	41.87
Marginally Suitable (S3)	8422.96	44.91	3098.66	16.52
Not Suitable (N)	4416.74	23.55	2816.74	15.02
Marshy Area	4126.06	22.02	4126.06	22.02
Total	18749.86	100.00	18749.86	100.00

Table 8. Ranking of Mapping Units by the Suitability Classification for Sugarcane in the Dangerri Study Area

Mapping Units	Non-Parametric		Parametric	
	Actual	Potential	Actual	Potential
A	3	3	3	3
B	2	1	2	1
C	1	2	1	2
D	9	9	9	9
E	5	5	5	4
F	6	6	6	5
G	7	7	7	6
H	8	8	8	8
I	4	4	4	7

Table 9. Spearman's rank correlation coefficient among land suitability evaluation procedures (actual & potential)

	NPa	NPp	Pa	Pp
NPa	1.000	.983**	1.000**	.883**
NPp		1.000	.983**	.900**
Pa			1.000	.883**
Pp				1.000

** Correlation significant at 0.01 levels.
Legend: NPa = Non-Parametric (actual); NPp = Non-Parametric (potential); Pa = Parametric (actual); Pp = Parametric (potential).

agrees with Ogbaji (2010) and Ukabiala (2012) who reported that the river Benue floodplain soils are characterised by dark greyish brown, greyish brown, yellow surface overlying pinkish, grey olive yellow subsurface; medium or strong medium/coarse sub-angular blocky structure with very sticky consistence in the subsurface and strongly acid to slightly acid/neutral when dried. It was also observed that the limiting factors for sugarcane cultivation in the study area are available P, exchangeable K, total N, pH, wetness (prolonged water logging conditions), soil texture, topography, and climate which is a common limitation to all the mapping units. This observation is also in line with Isitekhale et al. (2014) who reported available P, exchangeable K, and total N as the limiting factors for sugarcane in lowland soils of Anegbette, Edo State.

By Non-Parametric (actual) evaluation, mapping unit C is moderately suitable (S2) for sugarcane cultivation with soil characteristics (s), topography (t) and fertility (f) identified as the limitations apart from climate which is the only constraint common to the entire mapping units. If some of the identified constraints in mapping unit C are ameliorated, the potential suitability evaluation for this mapping unit remains (S2) with topography (t) left as the only limitations which may not be easily ameliorated. The S2 class covers about 4.95% of the total land area of the Dangerri study site.

Mapping units A, B, E, F G and I, have a common suitability class which is marginally suitable (S3) for sugarcane cultivation. Mapping units A and I are (S3) with fertility (f) and wetness (w) being the common constraints. The potential suitability evaluation of both mapping units therefore remains (S3) with wetness (w) as the only limitation; Mapping unit B is (S3) with fertility being the only limitation, the potential suitability evaluation becomes moderately suitable (S2) with climate being the only constraint; Mapping units E, F, and G are marginally suitable (S3) with soil characteristics (s), topography (t) and fertility (f) being the major constraints identified. If the possible

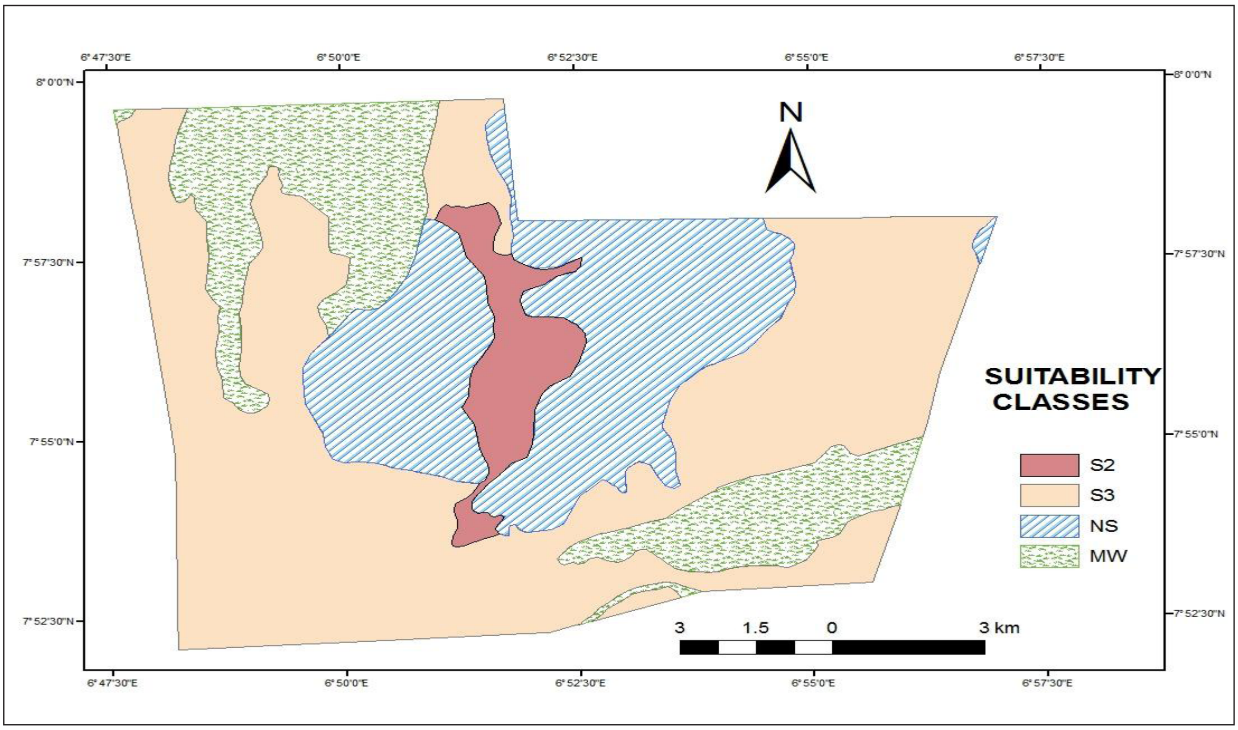

Figure 3. Non-Parametric (actual) Suitability Map of the Dangerri study area
Legend: S2 = Moderately Suitable; S3 = Marginally Suitable; NS = Not Suitable; MW = Marshy/Water

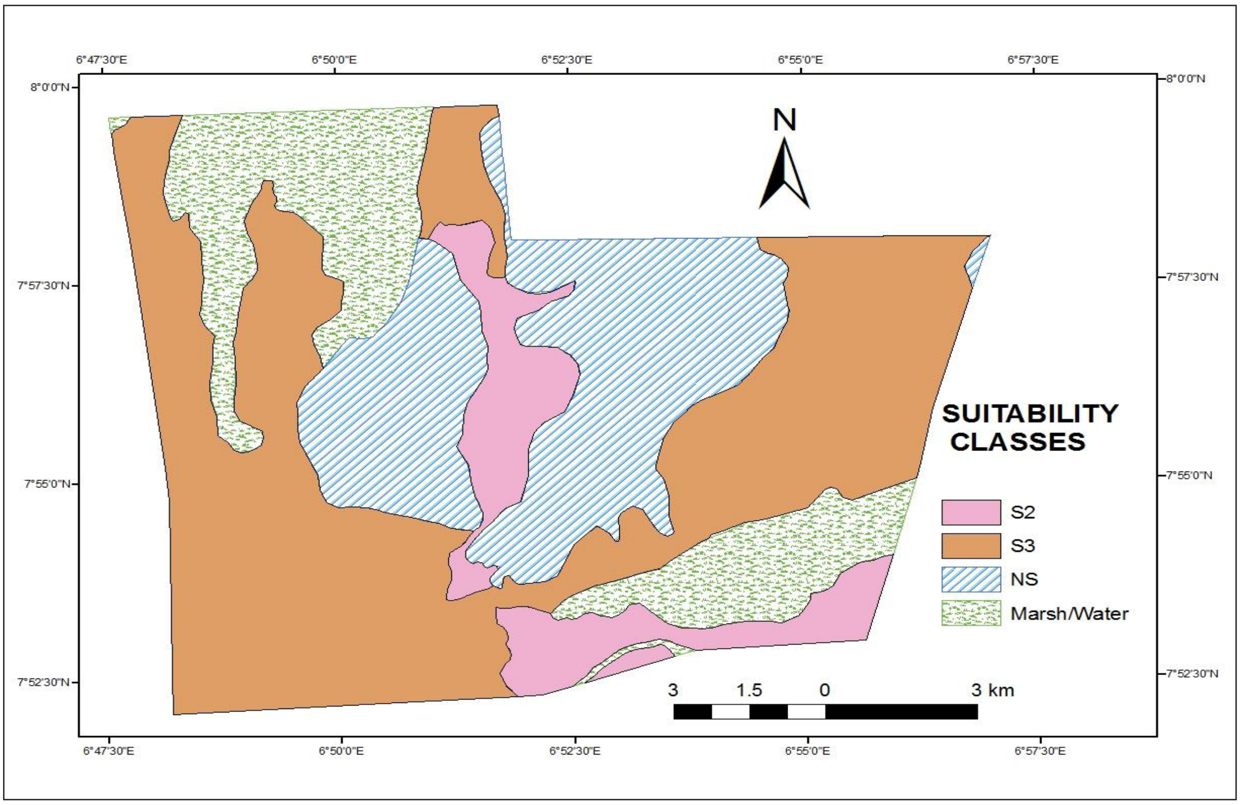

Figure 4. Parametric (actual) Suitability Map of the Dangerri study area
Legend: S2 = Moderately Suitable; S3 = Marginally Suitable; NS = Not Suitable; MW = Marshy/Water

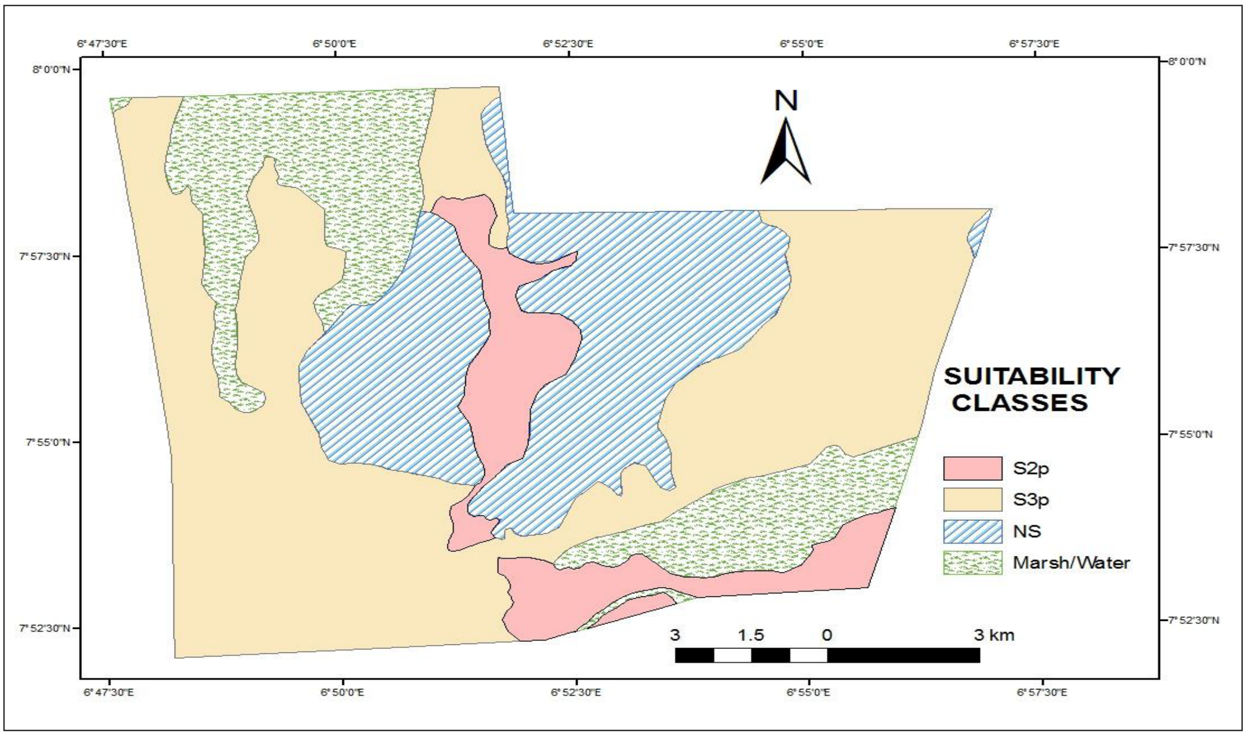

Figure 5. Non-Parametric (potential) Suitability map of the Dangerri study area
Legend: S2 = Moderately Suitable; S3 = Marginally Suitable; NS = Not Suitable; MW = Marshy/Water

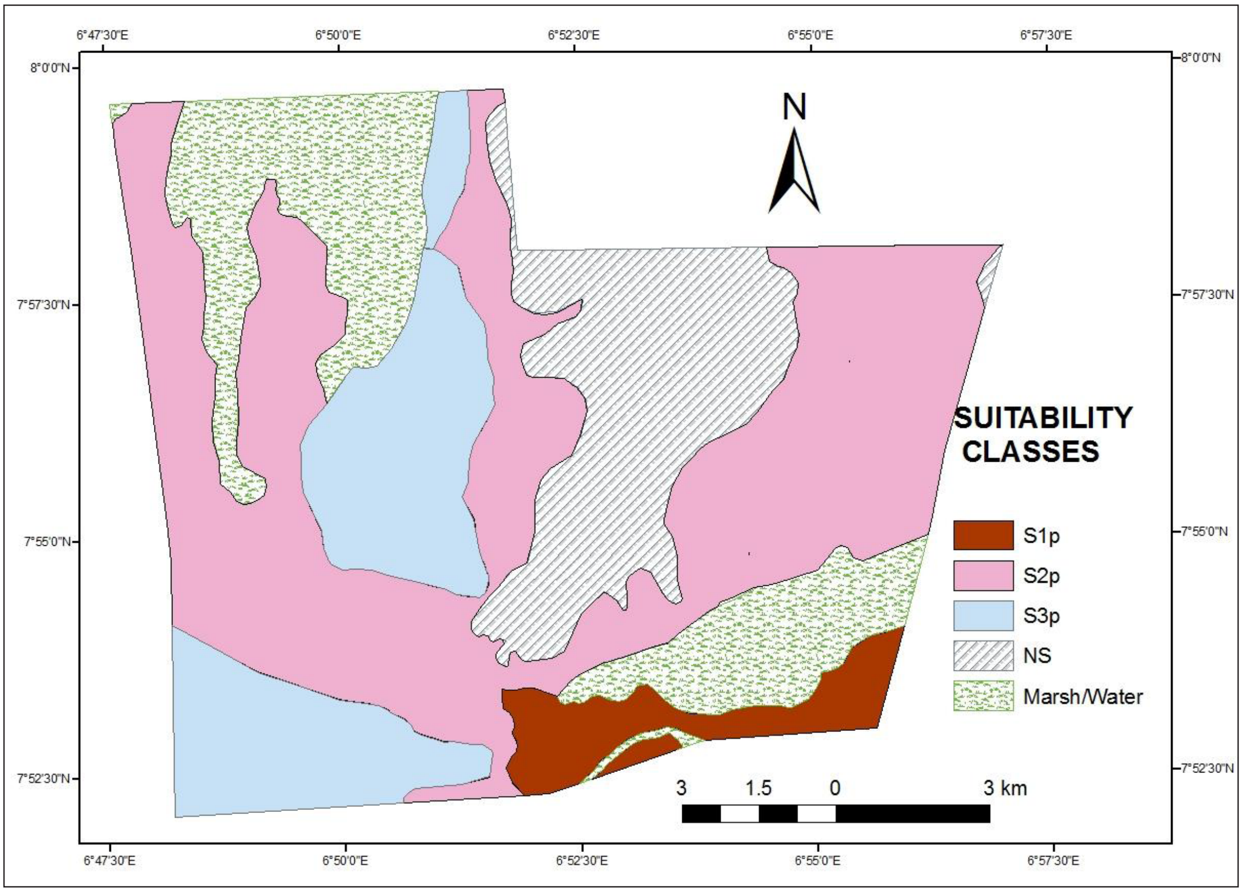

Figure 6. Parametric (potential) Suitability map of the Dangerri study area
Legend: S1 = Highly Suitable; S2 = Moderately Suitable; S3 = Marginally Suitable; NS = Not Suitable; MW = Marshy/Water

constraints are eliminated, the potential suitability evaluation of these mapping units remains marginally suitable (S3) with topography (t) as the only limitations which are somewhat difficult to correct due to its cost implication. The (S3) class covers about 49.48% of the total land area of the Dangerri study site.

Mapping units D and H are permanently not suitable (N2) and currently not suitable (N1) for sugarcane cultivation, respectively, owing to the following limitations: soil characteristics (s), topography (t), and wetness (w) for mapping unit D, while mapping unit H have fertility (f) and wetness (w) as its limitations. The potential suitability evaluation of mapping unit D remains permanently not suitable (N2) because this particular mapping unit is a mountainous area and therefore would be difficult to correct any constraints or limitations on this mapping unit. So also for mapping unit H, the potential suitability evaluation remains marginally not suitable (N1) with wetness (w) being the only constraint after fertility constraints has been ameliorated. The (N) class covers about 23.55% of the total land area of the Dangerri study site.

In the case of Parametric suitability evaluation (actual and potential) for sugarcane, Actual suitability evaluation for mapping units A, E, F, G, and I are marginally suitable (S3) with Suitability Index of 41.58 (S3), 32.22 (S3), 32.22 (S3), 32.22 (S3), and 37.20 (S3), respectively, and a corresponding potential suitability index (SIp) of 53.64 (S2), 53.64 (S2), 53.64 (S2), 53.64 (S2), and 48.00 (S30), respectively. Mapping units B and C are moderately suitable (S2) with an actual suitability index of 53.64 (S2) and 57.28 (S2), respectively, and a corresponding potential suitability index (SIp) of 80.00 (S1) and 71.52 (S2), respectively. Mapping unit H is marginally not suitable (N1) with an actual suitability index value of 22.64 (N1), and a corresponding potential suitability index (SIp) of 35.76 (S3). Mapping unit D is permanently not suitable (N2) with an actual suitability index of 7.16 (N2) and a corresponding potential suitability index (SIp) value of 8.00 (N2).

CONCLUSIONS

About 4126.06 ha (22.02%) of the soil is marshy. The soils of the study area are classified as Inceptisols and Alfisols in the USDA soil classification system. A total of about 55.47% of the soils are classified as Inceptisols because the soils are formed from the alluvial deposition of materials transported by the rivers with insufficient time for profile development before another cycle of deposition. The soils are very acidic to slightly acidic. Suitable land area by Non-Parametric approach covers a total land mass of about 10,207.06 ha (54.43%) of which 928.15 ha (4.59%) is moderately suitable and 9278.91 ha (49.48%) is marginally suitable, whereas 4416.74 ha (23.55%) is not suitable (N) for sugarcane cultivation in the area. However, if some ameliorations are made on the land, the region has a potentially suitable area of about 10,207.06 ha (54.43%) of which, 1784.10 ha (9.52%) is moderately suitable and 8422.96 ha (44.91%) is marginally suitable, whereas 4,416.74 ha (23.55%) is not suitable (N) for sugarcane cultivation in the area.

Suitable land area by parametric approach covers a total land mass of about 10,207.06 ha (54.43%) of which 1784.10 ha (9.52%) is moderately suitable and 8422.96 ha (44.91%) is marginally suitable, whereas 4,416.74 ha (23.55%) is not suitable (N) for sugarcane cultivation in the area; however, if some of the limitations are taken care of, the suitability rating increases with a potentially suitable area of about 11807.06 ha (62.96%) of which 855.95 ha (4.57%) is highly suitable, 7852.45 ha (41.87%) is moderately suitable and 3098.66 ha (16.52%) is marginally suitable, and 2816.74 ha (15.02%) is not suitable (N) for sugarcane cultivation in the area.

The major limiting factors for sugarcane cultivation in the study area are available P, exchangeable K, total N, pH, wetness (drainage), soil texture, topography, and climate which is a common limitation to all the mapping units. However, following the suitability classes of the various mapping units of the Dangerri study area, most of the soils are marginally suitable for sugarcane cultivation unless serious land development measures such as flood control, drainage and liming are effected.

RECOMMENDATIONS

1) Soil management practices and corrective measures which are cost effective like application of organic manures, compound fertilizers and liming should be applied to the soils of the study area to supply deficient nutrients and correct soil acidity.
2) Physical land development like drainage, flood control, and sub-soiling could be done in the area to mitigate some of the limitations in the area.
3) Acid tolerant crops, fruits and vegetables like low land rice, radishes, sweet potatoes, peppers, potatoes, beans, cabbage, carrots, cucumbers, onions, squash, sweet corn, tomatoes, other than sugarcane could be considered as alternative to sugarcane following the current status of the soils of the study area.
4) Further studies should be carried out in this area to ascertain the effects and the cost/ benefits of the various soil management practices to be employed for successful sugarcane cultivation in the area.

ACKNOWLEDGEMENTS

The funding of this work by National Sugar Development Council (NSDC) in collaboration with En-Science Nigeria Ltd; the supports of the Executive Secretary of NSDC as well as Dr. F. O. Uzu and Mr. A. Aligbe in the execution of this work are gratefully acknowledged.

REFERENCES

Allen C. J., Mackay M. M., Aylward J. H., Campbell J. A. (1997): New technologies for sugar milling and by-product modification. In: Keating BA and Wilson JR (Eds): Intensive Sugarcane Production: Meeting the Challenges Beyond 2000. CAB International, Wallingford, UK, 1997, pp. 267–286.

Akamigbo F. O. R. (2009): Characterization and land use management of floodplain soils of central Cross River state, Nigeria. Global Journal of Agricultural Science 8: 1596–2903.

Charuppat T. (2002): Land use change detection, land evaluation and land use planning in Lam PhraPhloeng watershed. Doctor of Science Thesis in Soil Science, Graduate School, Khon Kaen University [ISBN 974-328-118-5].

FAO (1976): A Framework for Land Evaluation. Soil Resources Management and Conservation Service Land and Water Development Division.FAORome. FAO Soil Bulletin 32 (72).

FAO (1976): Framework for land evaluation. Soil salt marsh vegetation. In: Vegetation Reimold, FAO. Rome. R. Journal bulletin 32: 19.

Fasina A. S. (2005): Properties and classification of some selected Wetland soils in Ado Ekiti, Southwest Nigeria.Applied Tropical Agriculture 10: 76–82.

Fasina A. S., Adeyanju A. (2007): Comparison of three Land Evaluation Systems in Evaluating the Predictive Value of some selected soils in Ado-Ekiti, Southwest Nigeria. Journal of Soil Science 17: 113–119.

Gopinathan M. C. (2010): Research and Technology Transfer Strategies for the next decade - an Indian Example. Proceedings of the International Society of Sugar Cane Technologists, 27: 1.

International Institute for Tropical Agriculture (1978): Automated and semi-automated methods for plant and soil analysis, IITA Manual Series No 7 Ibadan, Nigeria, 33 p.

Isitekhale H. H. E., Aboh S. I., Ekhomen F. E. (2014): Soil suitability evaluation for rice and saugarcane in lowland soils of Anegbette, Edo State, Nigeria. The International Journal of Engineering and Science 3: 54–62.

Leopold L. B., Wolman M. G., Miller J. P. (1964): Fluvial Processes in Geomorphology. San Francisco, California: Dover Publications, Inc. New York, NY. ISBN 0486685888

National Sugar Development Council, NSDC (2003): Information Brochure towards Self Sufficiency in Sugar, Abuja, 26 p.

Nigerian Meteorological Services (NiMet) (2015): First quarter weather bulletin for 2015. nimet.gov.ng › publication › first-quarter-weather-bulletin-2015

Ogbaji P.O. (2010): Characterization and irrigation suitability classification of Onwu river floodplain soils in Cross River State, Nigeria. M.Sc. Thesis, University of Calabar, Calabar, Nigeria.

Ojanuga A. G. (2006): Agro-ecological Zones of Nigeria Manual (F. Berding and V. O. Chude, Eds). NSPFS/ FAO/FMA and RD, Abuja, Nigeria. 128 p.).

Olivério J.L., Ferreira F.M. (2010): Cogeneration – a new source of income for sugar and ethanol mills or bioelectricity—a new business. Proceedings of the International Society of Sugar Cane Technologist 27: 1–13.

Olivério J.L., Ribeiro J.B. (2006): Cogeneration in Brazilian Sugar and bioethanol Mills: Past, present and challenges. International Sugar Journal 108: 391–401.

Okusami T. A. (1985): Properties of some hydromorphic soils in West Africa, pp. 59–65. The wetlands and Rice in sub-Saharan Africa.International Institute of Tropical Agriculture, Ibadan, Nigeria.

Olaleye A. O. (1998): Characterization, Evaluation, Nutrient dynamics and Rice Yields of Selected Wetland soils in Nigeria. PhD Thesis, the Department of Agronomy, University of Ibadan, 202 p.

Onyekwere I. N., Akpanidio, A. U., Amalu U. C., Asawalam D. O., Eze P. C. (2001): Constraints and opportunities in agricultural utilization of some wetland soils in AkwaIbom State. Proceedings of 27th Annual Conference of Soil Science Society of Nigeria, pp. 139–146.

Rogers R. D., Spear, S. K., Swatloski, R. P., Reichert, W. M., Godshall, M. A., Johnson, T. P., Moens L. (2001): Non-sugar products from sugarcane for the new millennium: Green Pathways to a carbohydrate economy? Proceedings of the International Sugar Cane Industry Technologists 60: 291–301.

Schmudde T. H. (1968): "Floodplain" in R.W. Fairbridge. The Encyclopedia of Geomorphology (New York: Reinhold), pp. 359–362

Soil Survey Staff (2010): Key to Soil Taxonomy.11th Edition. USDA Natural Resources Conservation Services, Washington D. C., 338 p.

Sys C., Van Ranst E., Debaveye J. (1991): Land evaluation, part I. Principles in land evaluation and crop production calculations. General Administration for Development Cooperation, Brussels, pp. 40–80.

Sys C., Van Ranst E., Debaveye J. (1993): Land evaluation. Part 3: Crop requirements. Agricultural Publications 7, 3. General Administration of Development Cooperation of Belgium, Brussels, 199 p.

Udoh J. E., Ogunwale L. M. (1986): Laboratory manual for analysis of soil, plant and water samples. University of Ibadan Press, pp. 151–162.

Ukabiala M. E. (2012): Characterization and classification of river Benue floodplain soils in Bassa

Local Government Area of Kogi State, Nigeria. M.Sc. Thesis, Kogi State University, Anyigba.

United Nations Population Division (1996): World Population Prospects: The 1996 Revision. Volume II: The Sex and Age distribution of the World Population. Catalogue of Population Division Publications, Database, and Software.

Uzu F. O., Orimoloye J. R., Ugwa I. K. (2003): Characteristics and Agricultural Potentials of Soils of the Floodplain of North Western Nigeria. (NRCRI Umudike, Abia State Oct. 4-9th 2003) Proceedings of the 29th annual conference of the Soil Science Society of Nigeria, pp. 325–326.

Van K. H., Breman H. (1990): Agricultural development in the West African Sahelian region: A cure against land hunger. Agricultural Ecosystem and Environment 32:177–197.

Received May 17, 2018
Accepted after revisions: June 4, 2020