SUITABILTY EVALUATION OF SOILS OF RIVER CHANCHAGA FLOODPLAIN FOR RICE PRODUCTION IN NIGER STATE, NIGERIA

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ABSTRACT

This study assessed the suitability of floodplain soils along the River Chanchaga in Niger State, Nigeria, for sustainable rice production. Three physiographic units (upper, middle, and lower slopes) were identified within the upstream floodplain, with three profile pits dug and sampled at each location according to FAO guidelines. Standard laboratory procedures determined soil properties. Qualitative land suitability evaluation, comparing soil characteristics with rice requirements, indicated the soils were currently unsuitable (N) for rice cultivation, primarily due to limitations in chemical properties. Upstream soils exhibited sandy loam, sandy clay, and clay loam textures, with a dominance of sand (402-842 g kg⁻¹). Soil pH ranged from slightly acidic to neutral (5.5-6.8), while organic carbon was high across all sites. Nitrogen and phosphorus distribution varied with depth. Calcium was the dominant exchangeable base, while potassium was moderate (<0.30 cmol kg⁻¹). Cation exchange capacity (CEC) and percentage base saturation (BS) were moderate to high (63.4-88.5%). Quantitative land suitability evaluation using the Storie method also classified the upstream area as unsuitable (N), although the Rabia equation indicated moderately suitable (S2). This comprehensive analysis highlights the need for soil improvement strategies to enhance the suitability of these floodplain soils for rice production.

Keywords: Floodplain soils, qualitative and quantitative, Physical and chemical properties

INTRODUCTION

Worldwide, floodplain "Fadama in Hausa" soils are useful for agricultural production as they constitute a huge reserve of available nutrients for utilization by crop plants (Sheriff, *et al.,* 2008). Floodplains soils refer to soils of wetland or the seasonally flooded or floodable plains along rivers and / or depressions on adjacent low terraces (Ibrahim and Omotosho, 2012). They are found scattered in all parts of tropical regions but more important in areas with low precipitation, the attention of both farmers and government to the exploitation of floodplain, which is believed to have more agricultural potentials than the upland soils (Samuel *et al*., 2023).The process of land suitability classification involves the assessment and categorization of specific areas of land in terms of their suitability for defined uses (Sathiyamurthi *et al*., 2024). Floodplains in Nigeria are now becoming the "food basket" because they serve as the main source for growing crops for man and food supply to livestock all year round. With the exponential increase in human population, there is pressing need to boost food production by utilizing all available land resources. The data that was generated from this study would equip floodplain users, with necessary information that would be essential for the management of the floodplain soils for maximum and sustainable agricultural production that could guarantee national food security. However, despite the importance of land evaluation on sustainable management of land and for enhanced crop production, specific soil suitability studies; such as suitability assessment for rice production have not been properly documented; and available ones show locations and ecological bias. Given the importance of soils to the past and present societies, there is need to investigate the soils of River Chanchaga floodplains soils at upstream for the purpose of tapping its potentials for rice production. Unfortunately, much has not been done to highlight the inherent potentials of this natural asset. This study is intended to evaluate potentials of the floodplain soil for rice production. The result of this resource will guide all stakeholders to determine effective management strategies for sustainable use of the floodplain for rice production.

MATERIALS AND METHODS

Study Site

The study was conducted on the floodplain of the River Chanchaga (upstream), the upstream falls under Paikoro Local Government Area on latitude 09° 31.59′ N and longitude 06° 34.51′ E (Fig.3.1), with average elevation between 184.8 m to 206.5 m above sea level. The selection was also attributed to differences in the geology and vast land mass of floodplain which was used for rice productions at the site. The study area lies within the tropical hinterland climatic region designated as sub- humid, with mean annual rainfall ranged between 1,200 within May to October peaking in August and dry season of about five (5) months within November to March, with a dry season of about five months Maximum mean temperature range is between 28 and 33°C with relative humidity of over 80 % in the morning and falls to between 40 and 70 % in the afternoon (Ojanuga, 2006). The vegetation of Niger State as Adeboye *et al*. (2011) characterized is southern Guinea Savanna with various plant species such as *Andropogon gayanus, Daniellia oliverii, Vitellaria paradoxa (*Shea butter trees*) Isoberlina species, Hyperti spp* (Weed grass) and *Azadirachta Indica* (Neem tree) which are among the commonest trees, shrubs and grasses. Geology of the area is underlain predominant by igneous and metamorphic rocks of the pre- Cambrian Basement Complex while granites, gneisses, quartzites, and schist are the dominantly rock types. The landscape consists dominantly of undulating terrain with occasional isolated granite and gneiss hills, and a steeply rising quartzitic rigdes. Lawal *et al.* (2012) observed quartz to be prominent mineral constituents of the soils around Minna.

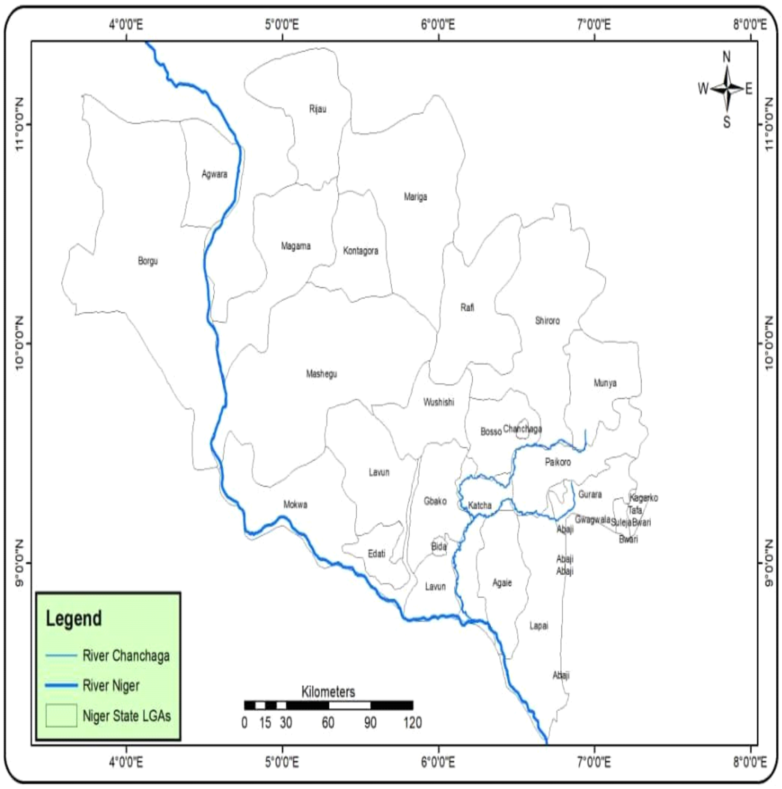

Figure 1: Niger State Map Showing the Study Area

Field work

Soil sample units were identified, mapped and delineated for suitable rice production by using baseline contour map. The ground control points were measured across the extent of the study area using hand held Global-positioning system (GPSMAP 76) receivers. Soil survey instrument used includes Soil description sheets, Munsell Soil Colour chart (2009), machete, shovel, spade, soil auger, mallet, digger, plastic bowl, buckets and field book with biro, pencil, ruler and a digital camera. Profile pits were dug to specification of 2m by 2m by 1.5m and described according to guidelines for soil profile description. The genetic horizons were identified on the basis of the observed differences in some morphological characteristics of the soils which include colour, texture, structure, depth of horizons, and topography which was used to establish the soil boundaries Soil samples were analyzed for some physical and chemical properties following the procedures.

Land Suitability Evaluation for Rice Production. Simple limitation method

Land suitability evaluation for rice was carried out using the revised FAO s Framework for Land Evaluation (FAO, 2015) and Sys *et al.* (1991, 1993). Soils of the site evaluated were placed in the suitability classes, using the qualitative methods by matching their characteristics with the requirement of rice. The major factors to be evaluated were soil characteristics (soil depth, texture, drainage, pH, organic carbon, available P, CEC, and base saturation). The overall suitability class for each identified soil was determined by using the limitation methods (most undesirable characteristics or quality of the land).

Parametric method

The parametric land evaluation consists of numerical rating of different levels of land characteristics and qualities according to a numerical rating between a minimum to maximum value (Sys *et al*., 1991; O'geen *et al*., 2008). The land characteristics and qualities used for the parametric land method were climate (annual rainfall and temperature), wetness (drainage), topography (slope), soil physical characteristics (texture, depth), nutrient availability (pH, N, P, K), and nutrient retention capacity (Organic carbon, CEC).The methods used in calculating soil/ land indices were:

I- Storie index

IP = A X B/100 X C/100 X ……..F/100 (3.1)

Where I is the index (%) of suitability, A = index of the most limiting factor, B, C are indexes of other rating besides the minimum rating.

ii- Rabia equation

Where I is the index (%) of suitability, Rmax = maximum rating and A, B, C…. other rating besides the maximum rating.

RESULTS AND DISCUSSION

Morphology and physical and chemical properties of the study area

The texture of the studied soils by feel method is generally sandy clay loam and sandy loam at the surface over clay loam at subsurface horizon, the presence of poor drainage as indicated by presence of mottles at the surface. The surface is moderate crumb to moderately sub- angular blocky at the subsurface.

The result on table 1 depicts the physical properties of the soil of the study sites upstream.

Soil texture and particle size distribution of the soils

The soil texture ranged from sandy loam over loam at all the slope level of upstream while the Particle size distribution, Table 2 showed that for the three (3) slopes: upper, middle and lower slope of upstream soil indicates that the sand ranged from 402 to 822 g kg^{-1}. The high sand fraction is a feature of most savanna soils due to illuviation and elluviation processes as well as the effect of erosion and lessivage. Soils with high sand content are vulnerable to erosion because they are easily detached by heavy rainfall or running water (Usman, 2021). The siltcontent ranged from 133 to 393 g kg^{-1} . Silt fraction was irregular with depth due to the rate of materials brought by the flood. Clay content of the soil ranged from 45 to 205 g kg^{-1} .

Effective soil depth

Horizon differentiation reveals much about soil formation and its processes. In upper slope of upstream, it is Ap (0-25 cm) horizon overlaying Btgl horizon. The Btg1 horizon was not very thick (25-52 cm), likewise Btg2, (52-100 cm) and Btg3 (100-140 cm). The BC was so thick extending from 140-200 cm, in the middle slope, Ap (0-19 cm) horizon overlaid Btg1 (21-41cm) over Btg2 (41-83 cm) and Btg3 (90-130 cm) at >130 cm there was water logged at the and B2 (53-100 cm) horizon over BC (100 - 174 cm) horizon which was thick, water logged at >174 cm. At the lower slope, Ap (0-29 cm) horizon overlaid Btg1 (29-51 cm), Btg2 (51-87 cm), and Btg3 (87-126 cm) horizons, there was no much variations in the horizon but BC (126 - 200 cm) horizon, was very thick.

Table 1: Particle Size Distribution of Upstream Soils

Horizon	Soil Depth (cm)	Sand g kg^{-1}	Silt	Clay	Silt/Clay ratio	Textural Class
			UPPER SLOPE			
Ap	0 – 25	712	213	75	3.08	Sandy Loam
Btg1	25 – 52	532	343	125	2.74	Sandy Loam
Btg2	52 – 100	492	323	185	1.75	Loam
Btg3	100 – 140	562	303	135	2.24	Sandy Loam
BC	140 – 200	632	253	115	2.20	Sandy Loam
			MIDDLE SLOPE			
Ap	0 – 21	632	293	75	3.90	Sandy Loam
Btg1	21 – 41	662	193	145	1.33	Sandy Loam
Btg2	41 – 83	752	153	95	1.61	Sandy Loam
Btg3	83 – 125	682	183	135	1.36	Sandy Loam
BC	125 – 200	402	393	205	1.92	Loam
			LOWER SLOPE			
Ap	0 – 19	822	133	45	2.96	Loamy Sand
Btg1	19 – 52	632	283	85	3.32	Sandy Loam
Btg2	52 – 90	612	243	145	1.67	Sandy Loam
Btg3	90 – 130	582	323	95	3.40	Sandy Loam

Chemical properties of the soils

The results of the chemical properties of the Soils are shown in table 2 and their interpretation was based on the concept of Esu (1991), Chude *et al.,* (2011) and Lawal *et al.,* (2012). The soil reaction (pH) falls within the range of 5.5 to 6.8 described as strongly to neutral acidic, which is considered highly suitable for rice production. Organic carbon (OC) content ranged from 2.7 to 8.1 g kg^{-1} rated high. Total nitrogen (TN) content ranged from 0.04 to 0.25 g kg^{-1} rated low to high, Available phosphorus ranged from 1 to 3 mg kg^{-1} rating low, the low value agrees with the view of Usman *et al.,* (2020) that the total quantity of phosphorus in most native soils is low, with most of it present in the form quite unavailable to plants. For Exchangeable bases (Ca, Mg, K and Na) all rated moderate to high. The exchangeable acidity (EA) ranged from 0.04 to 0.07 cmol kg^{-1} at the upper slope, at the middle slope EA ranged 0.04 to 0.08 cmol kg^{-1} and at the lower slope it ranged from 0.02 to 0.04 cmol kg^{-1}. Cation exchange capacity (CEC) ranged from 6.5 to 13.0 cmol kg^{-1} rated low to moderate. The percentage base saturation (BS) ranged from 63.4to 88.5% all rated moderate to high. The distribution of base saturation is irregular in all the slope levels, this could be attributed to the plant litter decomposition process which incorporated cations from te litter into the soil surface and also the contribution by harmattan dust known to contain high fraction of cations especially Ca (Ali *et al.,*2022)

Table 2 Chemical Properties of Upstream Soils of River Chanchaga Floodplain

Horizon	Soil Depth (cm)	pH	EC µS/cm	TN (gkg)	TOC (g kg^{-1})	Avail. P (mg kg^{-1})	Exch. Bases Ca	Mg	K	Na	Exch. Acid	CEC	BS %
							(cmol kg^{-1})						
UPPER SLOPE													
Ap	0 – 25	6.1	0.07	0.15	8.1	1	4.00	2.20	0.21	0.28	0.07	9.3	71.9
Btg1	25 – 52	6.1	0.07	0.12	7.3	2	3.40	2.00	0.22	0.27	0.05	8.8	66.9
Btg2	52 – 100	6.2	0.12	0.10	3.9	1	5.00	2.40	0.29	0.20	0.04	8.9	88.5
Btg3	100 – 140	6.2	1.25	0.16	2.7	1	4.70	2.10	0.28	0.16	0.05	9.4	77.0
BC	140 – 200	5.5	0.15	0.06	4.2	3	3.90	2.30	0.24	0.15	0.07	9.3	70.8
MIDDLE SLOPE													
Ap	0 – 21	6.3	0.04	0.07	2.7	1	4.96	0.16	0.23	0.20	0.04	6.5	85.0
Btg1	21 – 41	6.8	0.04	0.04	3.7	2	3.52	1.12	0.19	0.28	0.05	7.0	73.0
Btg2	41 – 83	6.7	0.06	0.08	4.2	1	2.56	1.12	0.20	0.33	0.08	6.7	63.4
Btg3	83 –125	6.6	0.04	0.08	4.8	3	3.00	1.80	0.21	1.19	0.04	9.4	65.9
BC	125–200	6.8	0.32	0.18	4.2	7	4.40	2.70	0.30	1.41	0.07	10.8	81.6
LOWER SLOPE													
Ap	0 – 19	6.5	0.09	0.25	3.6	9	3.36	2.64	0.19	0.30	0.03	7.4	88.0
Btg1	19 – 52	6.7	0.06	0.22	3.4	5	4.80	2.20	0.22	0.29	0.04	9.4	79.8
Btg2	52 – 90	6.6	0.27	0.20	5.0	1	4.00	2.60	0.27	0.43	0.02	10.1	72.2
Btg3	90 –130	6.5	0.23	0.13	5.9	2	5.20	3.60	0.29	0.49	0.03	13.0	73.7

Table 4: Factor Rating of Land use requirement for rice production

LAND QUALITY	UNITS	HIGHLY SUITABLE (S1)	MODERATELY SUITABLE (S2)	MARGINALLY SUITABLE (S3)	NOT SUITABLE (N)
Rainfall (mm)	mm	>1200	1000- 1200	850- 1000	<850
Temperature	oC	29- 32	21- 29	18-21	<18
Texture		SL,SCL,L,CL	SiL, SC	SiC, LS	S,C
Effective depth	cm	>100	75- 100	50- 75	<50
Soil reaction		5.5- 7.0	4.5-5.4 7.0-8.5	4.0- 4.5 8.5-9.0	<4.0,>9.0
Organic carbon		2.0- 4.0	1.0- 2.0	0.5- 1.0	<0.5
Total Nitrogen	g/kg	>2	1-2	0.5- 1	<0.5
Available phosphorus	mg/ kg	>15.0	10.0- 15.0	5.0- 10.0	<5.0
Potassium	g/kg	>0.2	0.1- 0.2	<0.1	<0.1
CEC	cmol/ kg	>18.0	12- 18.0	6.0- 12.0	<6.0
Base saturation	%	>75	50- 75	30- 50	<30
ESP	%	<15	15- 40	40- 50	>50
EC	dS/m	<3	4- 8	8- 12	12- 16
Slope	%	0- 2	2- 4	4-7	7- 12
Drainage		Imperfectly/ moderately	Well, poorly	Very poorly	Excessively

SL= Sandy Loam; SCL= Sandy Clay Loam; L= Loamy; CL= Clay Loam; SiL= Silty Loam; SC= Sandy Clay; SiC= Silty Clay; LS= Loamy Sand; S= Sandy; C= Clay

Table 5: Suitability evaluation of Upstream for rice using simple limitation

Parameters	Upper Slope		Middle Slope		Lower slope	
	Actual	Potential	Actual	Potential	Actual	Potential
Rainfall	100	100	100	100	100	100
Temperature	100	100	100	100	100	100
Slope	85	85	85	85	85	85
Drainage	100	100	100	100	100	100
Texture	60	60	60	60	60	60
Soil depth	100	100	100	100	100	100
TN	40	100	40	100	40	100
Available P	40	100	40	100	40	100
K	60	100	60	100	60	100
Org. carbon	100	100	100	100	100	100
CEC	85	85	85	85	85	85
BS	85	85	100	100	100	100
ESP	100	100	100	100	100	100
EC	100	100	100	100	100	100
Suitability index	1.41	18.84	0.99	26.0	0.52	51.0
Suitability Class	N1f	S3s	N1f	S3s	N1f	S3s

N1f= N1= currently not suitable, f= fertility; S3= marginally suitable, s= soil physical characteristics

Land suitability evaluation for rice production

At the upstream, the climatic parameters evaluated were annual rainfall and average temperature which were rated highly suitable S1 (100) in all the sites. The average temperature (34°C) was highly suitable S1 (100) at the upper, middle and lower slope. Topographic parameter (slope percent) was (0-2%) was highly suitable S1 (100). Soil physical parameters evaluated were soil texture and depth, the depth of the upstream sites was highly suitable S1 (100) at all levels while the texture was rated moderately suitable S3 (60) at the upper and middle slope and the lower slope rated not suitable (N). Fertility parameters evaluated for rice production were soil pH, organic carbon, total Nitrogen, available phosphorus, exchangeable potassium, CEC and base saturation. Soil pH was rated moderately suitable S2 (85) at the upper, middle and lower slope. Organic carbon was highly suitable S1 (100) at the upper slope, and not suitable at the middle and lower slope. Total nitrogen was rated currently not suitably (N1) at the upper, middle and lower slope of the upstream. Available phosphorus at the upper, middle and lower slope rated currently not suitable, potassium as rated moderately suitable S3 (60) at the upper and middle, but not suitable at the lower slope. CEC was rated moderately suitable (S2) at the upper slope, but marginally suitable S3 (60) at the middle and lower slope. Base saturation was rated moderately suitable S2 (85) at the upper, middle and lower slope. The salinity and sodicity that is the exchangeable sodium percentage and Electrical conductivity was all rated highly suitable at the upper, middle and lower level.

Land evaluation using Storie Index approach

Results obtained from the evaluation of suitability classification for the study sites for rice production are shown on Tables 4. The result showed that the soils of upstream was not suitable for rice production (N2f) at the upper, middle and lower slopes in its present status as a result of limitations of nutrient availability (fertility).

Table 6: Suitability evaluation of upstream for rice production using Storie index

Parameters	Upper Slope		Middle Slope		Lower slope	
	Actual	Potential	Actual	Potential	Actual	Potential
Rainfall	100	100	100	100	100	100
Temperature	100	100	100	100	100	100
Slope	85	85	85	85	85	85
Drainage	100	100	100	100	100	100
Texture	60	60	60	60	60	60
Soil depth	100	100	100	100	100	100
TN	40	100	40	100	40	100
Available P	40	100	40	100	40	100
K	60	100	60	100	60	100
Org. carbon	100	100	100	100	100	100
CEC	85	85	85	85	85	85
BS	85	85	100	100	100	100
ESP	100	100	100	100	100	100
EC	100	100	100	100	100	100
Suitability index	4.16	14.74	4.90	20.40	4.90	20.40
Suitability Class	N1f	S3s	N1f	S3s	N1f	S3s

N1f= N1= currently not suitable, fertility; S3= marginally suitable, s= soil physical characteristics

Land suitability evaluation using Rabia equation approach

Rabia equations apply the maximum rating to evaluate the equation. Results derived from the evaluation are shown in table 4. The results stated that upstream soils were currently not suitable (N1sf) at the upper, middle, and lower slope for rice production as a result of limitations of nutrient availability, and soil texture. Moreover, at the upstream after amending the fertility limitations, it became moderately suitable (S2n) at the upper, middle and lower slope.

Table 7: Suitability evaluation of upstream for rice production using Rabia

Parameters	Upper Slope		Middle Slope		Lower slope	
	Actual	Potential	Actual	Potential	Actual	Potential
Rainfall	100	100	100	100	100	100
Temperature	100	100	100	100	100	100
Slope	85	85	85	85	85	85
Drainage	100	100	100	100	100	100
Texture	60	60	60	60	60	60
Soil depth	100	100	100	100	100	100
Available P	40	100	40	100	40	100
K	60	100	60	100	60	100
Org. carbon	40	100	40	100	40	100
CEC	85	85	85	85	85	85
BS	85	85	100	100	100	100
ESP	100	100	100	100	100	100
EC	100	100	100	100	100	100
Suitability index	11.90	60.70	18.81	60.70	18.81	60.70
Suitability Class	N1sf	S2s	N1sf	S2s	N1sf	S2s

N1f= N1= currently not suitable, fertility; S3= marginally suitable, s= soil physical characteristics

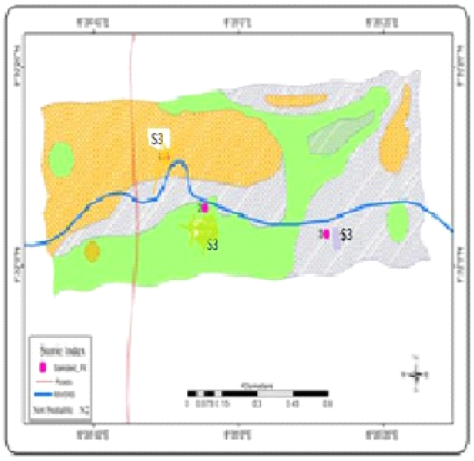

Figure 3: Suitability Map Using Storie index

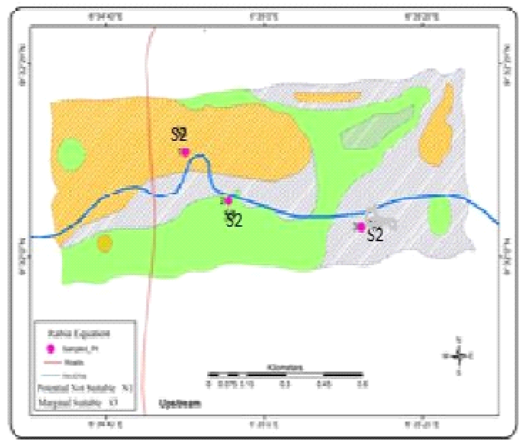

Figure 4: Suitability Map Using Rabia Equation

CONCLUSION AND RECOMMENDATIONS

The objective of this research was to evaluate the suitability of the floodplain soils of river Chanchaga (upstream) for rice production with the aim of instituting best management practices for increased rice production. From the research findings, the suitability rating of floodplain soils indicated not suitable (N) under Storie index but showed moderately suitable (S2) under Rabia equation method after amending the fertility limitations. Management practices such as Fertilizer application, organic matter incorporation are hereby recommended for increased rice production in the study area.

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