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Evaluation of Land Suitability for RICE (*Oryza sativa* L.) and Cassava (*Manihot esculenta* Crantz) Production on Selected Soils across Niger State, Nigeria

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ABSTRACT

Soil survey was carried out within five Local Government Areas in Niger State namely: Kontagora, Wushishi, Bida, Katcha and Lapai in Sub-Humid Niger Trough Agroecological zone of Nigeria. The soils were developed from alluvial deposits, Cretaceous Nupe Sandstone and undifferentiated basement complex rocks as the parent materials. The soils were surveyed at detailed scale (1:4,000) to assess their suitability, identify limitations and suggest sustainable management options for rice and cassava production. Alfisols constituted 61 % of the soil units, while Entisols covered 39 % of the soil units studied across Niger State. The parametric evaluation indicated the soil salinity was highly suitable, while chemical fertility was the most critical factor for both rice and cassava production across the entire study areas in the State. The land suitability evaluation showed that about 39 % and 50 % of land units were highly suitable (S1) for rice and cassava production, respectively under potential evaluation, and none under actual evaluation. Rice and cassava had 44.44 % and 50 % of the land units as moderately and marginally suitable, respectively under actual evaluation. Only land units NG 4 and NG 3 were not suitable for rice and cassava cultivation respectively under actual condition. Management practices suggested for upgrading the suitability of the land units for rice and cassava cultivation includes: application of inorganic fertilizers, organic matter, and animal manure for nutrient availability and retention, while construction of drainage structure and ridges were suggested to improve drainage condition of the soil

Key words: Parametric evaluation, Cassava, Rice, Detailed survey, Suitability.

INTRODUCTION

Agriculture is a major source of livelihood in Nigeria and contributes to accelerating economic growth of most developing countries through the provision of food for man and raw materials to manufacturing industries (Sajjad *et al*., 2014). Agriculture and its allied sectors contribute greatly to the Gross Domestic Product of developing countries like Nigeria. However, Nigerian soils have a substantial agricultural potential but fundamental constraints to its development are the unreliable method of data acquisition and management on agricultural land (Joshua et al, 2013; Wang et al., 2017) with resultant poor farm management practices, low yield and an unnecessary high cost of production (Aderonke and Gbadegesin, 2013; Fatihu *et al.*, 2020; Fatihu *et al.*, 2021a). The consequences are poor knowledge and unreliable data for agricultural planning. In addition, the use of land is not only determined by the user but also the land suitability, which is governed by different land attributes such as the soil types, underlying geology, topography and hydrology (FAO, 1993). These attributes can limit the extent of land availability for various purposes. To get the maximum benefit out of a land, its proper use within the context of suitability is inevitable. However, the productivity of soil is decreasing in Nigeria, because lands have been utilized for all purposes at the expense of their suitability, thereby resulting in land degradation (Senjobi, 2007; Fatihu *et al*., 2021b; Ya'u *et al*., 2021). Land evaluation using a scientific procedure is essential to assess the potentials and constraints of a given land for agricultural purposes (Rossiter, 1996; Amirshenava and Osanloo, 2021). Knowledge of soil limitations arising from land evaluation reports aims at ameliorating such limitations before, or during cropping period (Lin *et al*., 2005). Land suitability analysis identifies possible suitable land uses for each location and suggests management practices required to further improve the condition of the land for sustainable use (Wang *et al*., 2017).

The basic features of land evaluation are the comparison of the requirement of land use types with the characteristics of available land resources. This is done through interpretation of surveys and studies of soils, crops, climates and land forms, as well as socioeconomic attributes (Dent and Young 1987). To increase food production and provide food security, there is need to understand the interaction of soil, water, climate, crops, animals and people. This will aid in land use planning for improved productivity and commercialization of crops and livestock systems (Olowojoba *et al*., 2016). Hence, land evaluation presents information and recommendations for planners and decision makers to decide which crops to grow in a particular place, and the limitation of land use. The main product of land evaluation investigation is a land classification that indicates the suitability of different types of land for specific land uses, mostly described on maps with accompanying reports from FAO (2006; 1993).

Rice solves food problem of many densely populated countries, Nigeria inclusive (Ujoh *et al.*, 2019). Nigeria can borrow a leaf from other densely populated nations and having similar security problems in Africa, by instituting the rice culture through identifying a suitable environment for sustaining it (Idoga, 2005). Idoga (2005) identified constraints caused by increasingly declining rainfall in upland rainfed rice producing area, the need for emphases on shifting to lowland rice production. The characteristics of these lowland soils and indeed their suitability for rainfed rice production are however not well known leading to crop failures due to drying in shallow swamps with poor water retention in Benue State certain areas (BNARDA, 1993: Idoga, 2005). Hence a proper inventory of soils is a basic tool for decision-making on the development of these soils for any agricultural use and in particular for rice cultivation.

Cassava is principally grown for its starch containing tuberous roots, which are the major source of dietary energy for more than 500 million people in Africa (FAO, 2003). Nigeria ranks as the largest producer of cassava worldwide, with over 35 million tons of fresh roots from 3.1 million ha of land (FAO, 2003). The production of cassava in Nigeria accounts for 70 % of the total production of tuber crops in Africa. Cassava has played significant role as cash crop earner for growers, low-cost food sources ensuring food security to many households, and contribute greatly as raw material and constituents of animal feed for industries. Hence, its production is considered as a viable sector of agriculture that has potential of increasing income and generating employment opportunity to many Nigerians (Ehirim *et al*., 2006). The Nigerian government has initiated cassava production and exportation to move Nigeria economy away from total dependence on oil sector.

Nigerian land masses are facing competitive uses that very often lead to their misuse and degradation, making them vulnerable to farming risk and low output, hence may fall short of its demand and hinders meaningful national development (Ehirim *et al*., 2006). It is therefore pertinent to have a good understanding of the alternative uses of the lands maximing their potential of agricultural uses. Land use also ought not to be based primarily on the needs and demands of the users, but rather on the understanding of the suitability of such a land for the intended use to achieve environmental sustainability (FAO, 1983).

The need to provide more information on the quality of our soil resources is more essential now than before, principally because of the new urge to open up more land for commercial agriculture as part of diversifying the economy of the nation. Therefore, the objective of this study is to establish baseline soil quality information by characterizing selected soils in Niger State, Nigeria, assess their suitability for rice and cassava production and suggest management options for their use.

MATERIALS AND METHODS

Description of the Study Areas

The study was conducted within five Local Government Areas (LGAs) namely: Kontagora, Wushishi, Bida, Katcha and Lapai across Niger State, situated within the Sub-Humid Niger Trough Agroecological zone of Nigeria (Ojanuga, 2006), characterised by Northern and Southern Guinea Savanna. The study areas covered between Latitude 08° 33.460' and 10° 26.388' N and longitude 005° 20.230' and 006° 27.456' E. The soils within Wushishi, Bida, Katcha and Lapai LGAs were formed from alluvial deposits and Cretaceous Nupe Sandstone (feldspar sandstone and siltstone) and Kontagora site located in northern part of the state is underlain by undifferentiated basement complex rocks as the parent materials (Ojanuga, 2006). Geomorphology of the study areas showed topography that it is generally nearly flat to flat plains with gentle undulating plains in Kontagora area. The areas generally were within relatively low relief, and the elevation above sea levels increased from south to northern part of the state.

The long time mean annual rainfall was recorded as 1015 mm/annum for Kontagora Local Government Area (LGA), 1079.7 mm/annum for Wushishi LGA and 1240 mm/annum for Bida, Katcha and Lapai LGAs. The rainy season normally starts around March/April and ends in October. The rainfall pattern is uni-modal tending towards bi-modal in the southern part of the state. The period of the rainy season increases southward and varied between 120 – 240 days. The mean daily sunshine hours on monthly basis ranged between 6 hours in the month of August and 11 hours November to March. The mean daily temperature varied between 27°C and 34.3°C.

The dominant land uses include rice, cassava, melon (egusi), sesame and sugarcane, while sorghum, yam, millet and cowpea production are at subsistence level.

Field Studies

The study was conducted in areas covering between 10 and 40 ha within the five LGAs in Niger State. The areas were surveyed at detailed level using rigid grid method at a scale of 1:2,000. Traverses were made at 100 m interval and auger observations were taken along each transect with the aid of base map and hand-held GPS Garmin *Etrex 10* model and final soil map was produced at a scale of 1:4,000. Observations were made on the physiographic information and soil descriptions were done following field guidelines for soil survey (Soil Science Division Staff, 2017; FAO, 2006). Auger points with similar soils properties were delineated and eighteen soil mapping units were identified within the entire study areas across Niger State. Thirty six soil profile pits were dug across the study areas with two representatives in each unit. Soil samples were collected within genetic horizons for laboratory analyses. Morphological properties such as colour, texture, structure, consistence, clay films, concretions, boundary, pores and roots occurrence were described in the field according to the USDA Soil Survey Manual (Soil Science Division Staff, 2017).

Laboratory Analyses

Particle size distribution of the less than 2 mm soil samples was carried out using hydrometer method described by IITA (1979). Soil pH was determined in a 1:1 soil/water ratio and the saturation extract was also used to obtain electrical conductivity (Udo *et al*., 2009). Exchangeable bases (Ca, Mg, K and Na) were extracted using ammonium acetate (NH_4OAc) saturation method and determined using atomic absorption spectrophotometer, while exchange acidity was obtained by titration method described by Thomas (1982).

Cation exchange capacity (CEC) was determined by neutral (pH 7.0) NH_4OAc saturation method (Rhoades, 1982). Base saturation percentage was calculated as the proportion of exchangeable bases to CEC. Organic carbon was determined by Walkley-Black dichromate wet oxidation method (Nelson and Sommers, 1982), total nitrogen (TN) was by micro-Kjeldahl technique as described by Bremner and Mulvaney (1982) and available phosphorus (AP) by method described in IITA (1979) laboratory manual.

Soil Classification

The soils were classified according to USDA Soil Taxonomy (Soil Survey Staff, 2022) and World Reference Base for Soil Resource 2014 (IUSS Working Group WRB (2022).

Land Suitability Evaluation

Square root multiplication approach (Equation 1) of the parametric method was adopted to assess suitability of the soils for rice and cassava production. Suitability classification was arrived at by matching the land qualities with requirements for rice and cassava production (Table 1 and Table 2 respectively) (Naidu *et al*., 2006; Sys *et al*., 1993). To obtain crop suitability rating, index of productivity in Table 3 (FAO, 1983) was used to classify the overall score obtained from the quality assessment.

$$IP = A\left(\sqrt[2]{\frac{B}{100} x \frac{C}{100} x \frac{D}{100} x \frac{E}{100} x \frac{F}{100} x \frac{G}{100}}\right) \text{ --------------- equation 1}$$

IP = Crop Suitability Index (Index of Productivity)

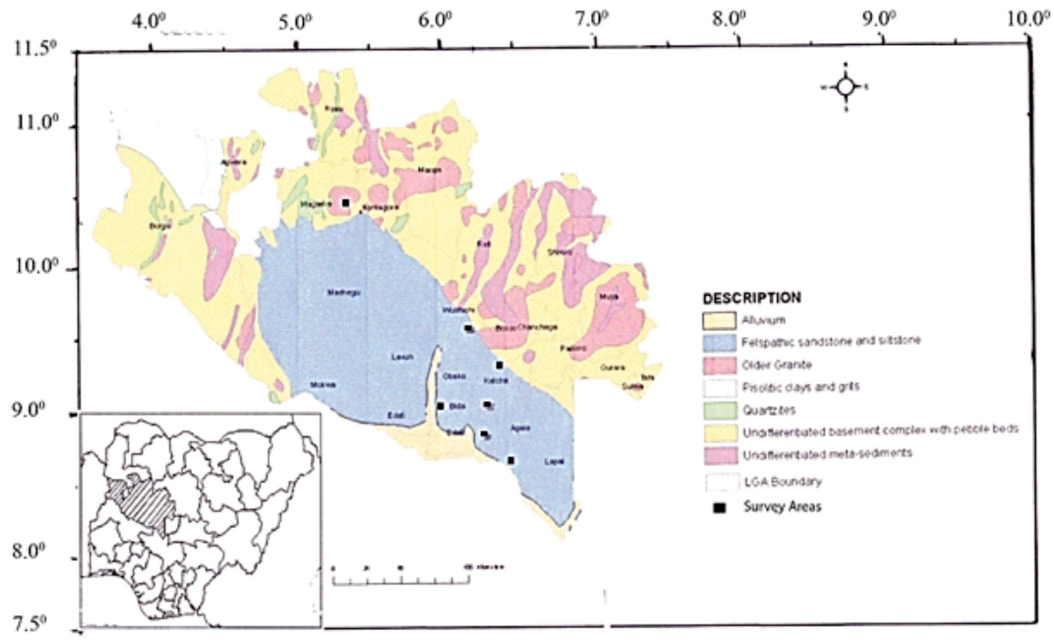

Figure 1. Geological map of Niger State showing soil survey areas

A = Climate (c)
B = Erosion hazard (e)
C = Wetness (w)
D = Rooting condition (r)
E = Soil physical characteristics (s)
F = Chemical fertility (f)
G = Salinity hazard (n)

A, B, C, D, E, F and G = lowest characteristic rating for their respective land qualities groups.

The land evaluation was carried out for both actual and potential rice and cassava cultivation, in which chemical fertility properties such as soil pH, CEC and available phosphorus which are easily altered by management practice are not considered in calculating index of productivity for potential land use. In calculating index of productivity for current rice and cassava cultivation, all characteristics are grouped to form land qualities.

RESULTS AND DISCUSSION

Land Qualities

The soils of the study areas within five LGAs across Niger State were delineated into eighteen mapping units (NG 1 to NG 18). Most critical characteristics representing land qualities considered to significantly influence crop suitability within the study area are presented in Table 4. Mean annual rainfall and mean daily temperature (27 – 34.3 ^{o}C) across the study areas were considered as optimum climate for crops production. Most of the soils were mostly on level to nearly level slope (0 – 2 %), except for soils of units NG 3 and NG 10 at Kontagora and Katcha LGAs situated on moderate slope (4 – 7 %) respectively exposing the units to erosion hazard when cleared for cultivation. Soil units developed on alluvial deposits situated within floodplains and lower slope positions were mostly poorly to very poorly drained with few moderately to imperfectly drained (Table 4). Soil units NG 1, NG 4, NG 9 and NG 14 were well drained and sited within crest to middle slope positions. The soils were mostly very deep (>150 cm), with units NG 8, NG 10, NG 11, NG 12, NG 13, NG 17 and NG 18 varying between deep and very deep, and soil depths were restricted by water table or parent rocks. Soils within units NG 3 and NG 4 were shallow to moderately deep (Table 4; Soil Science Division Staff, 2017) due to undifferentiated basement complex rock and parent material encountered restricting root penetration.

Soil texture varied widely across the study areas within Niger State, consisting of coarse (loamy sand), medium (sandy loam, sandy clay loam, loam) and fine (clay) materials. Soil reaction (pH) ranged from 5.30 (strongly acid) to 8.42 (strongly alkaline). The soils were generally non-saline as electrical conductivity values were far below 4.00 d Sm^{-1} critical level (Soil Science Division Staff, 2017). Cation exchange capacity varied between 3.2 and 8.7 and was rated as low to medium for savanna soils (Kparmwang *et al*., 2001). The content of available phosphorus varied widely across the soils with values between 0.54 and 80.3 mg kg^{-1} and rated as low to high (Kparmwang et al., 2001). Chemical fertility was the most

Table 1. Factor Ratings of Land Use Requirements for Rice Suitability

Factor	Land qualities/ Characteristics	Unit	S1 (100)	S2 (85)	S3 (60)	N (40)
A	**Climate (c)**					
	Annual rainfall	mm	>1250	1000-1250	850- 1000	<850
	Mean Temperature	^{o}C	29-32	21-29	18-21	<18
B	**Erosion hazard (e)**					
	Slope	%	0 - 2	2 – 4	4 - 7	7 – 12
C	**Wetness (w)**					
	Drainage	--	imperfectly, moderately	well, poorly	v. poorly	excessively
D	**Rooting Condition (r)**					
	Effective soil depth	cm	>100	75 - 100	50 - 75	< 50
E	**Soil Physical Characteristics (s)**					
	Soil texture	-	SL, SCL, L, CL	SiL, SC	SiC, LS	S, C
F	**Chemical fertility (f)**					
	soil pH	-	5.5 – 7.0	4.5 – 5.4, 7.0 – 8.5	4.0 - 4.5, 8.5 – 9.0	<4.0, >9.0
	CEC	cmol(+)/kg	>18.0	12.0 -18.0	6.0 – 12.0	>6.0
	Avail. P	mg/kg	> 15.0	10.0 – 15.0	5.0 – 10.0	< 5.0
G	**Salinity Hazard (n)**					
	Electrical Conductivity	dS/m	< 3	4 - 8	8 - 12	12 - 16

SL: sandy loam, LS: loamy sand, SCL: sandy clay loam, L: loam, C: clay, gSL: gravelly sandy loam, CL: clay loam, SiL: silt loam, SC: sandy clay, SiC: silty clay, S: sand, C: clay.

Table 2. Factor Ratings of Land Use Requirements for Cassava Suitability

Factor	Land qualities/ Characteristics	Unit	S1 (100)	S2 (85)	S3 (60)	N (40)
A	**Climate (c)**					
	Annual rainfall	mm	1100 - 1500	900-1100, 1500- 2500	500- 900, 2500-4000	<850, >4000
	Mean Temperature	ºC	24 - 30	18-24	12 - 18	<12
B	**Erosion hazard (e)**					
	Slope	%	0 - 5	5 – 12	12 - 20	> 20
C	**Wetness (w)**					
	Drainage	--	well,	imperfectly, moderately	poorly	v. poorly, excessively
D	**Rooting Condition (r)**					
	Effective soil depth	cm	>100	75 – 100	50 - 75	< 50
E	**Soil Physical Characteristics (s)**					
	Soil texture	-	L, SL, SiL, CL	LS, SCL, SiCL, SC	S, SiC, C	cS, cC, G
F	**Chemical fertility (f)**					
	soil pH	-	5.5 – 7.0	4.5 – 5.4, 7.0 – 8.5	4.0 - 4.5, 8.5 – 9.0	<4.0, >9.0
	CEC	cmol(+)/kg	>18.0	12.0 -18.0	6.0 – 12.0	>6.0
	Avail. P	mg/kg	> 15.0	10.0 – 15.0	5.0 – 10.0	< 5.0
G	**Salinity Hazard (n)**					
	Electrical Conductivity	dS/m	< 3	4 - 8	8 - 12	12 - 16

SL: sandy loam, LS: loamy sand, SCL: sandy clay loam, L: loam, C: clay, gSL: gravelly sandy loam, CL: clay loam, SiL: silt loam, SC: sandy clay, SiC: silty clay, S: sand, C: clay, cS: coarse sand, cC: cracking clay, G: gravels.

Table 3. Suitability index for the Crop Suitability Classes

Class	Suitability Index	Definition
S1	>75	Highly suitable
S2	50 – 74	Moderately suitable
S3	25 – 49	Marginally suitable
N1	15 – 24	Currently not suitable
N2	<15	Permanently not suitable

critical land quality either as CEC or available phosphorus that significantly influenced (lowered) crop suitability. Most of the land qualities assessed virtually limit suitability of the crops within the study area except salinity hazard (electrical conductivity) that was very low, hence was not a potential salt hazard to crop production within Niger State at present.

Soil Classification

The soil developed on recent alluvial deposits situated within floodplains and lower slope positions constituted 38.89 % of the soil units studied. These soils were classified as Entisols at Order level (Soil Survey Staff, 2022), Fluvaquents at the Great group level as were mostly poorly to very poorly drained indicating redoximorphic features. At the Sub-group level, the soils were classified as Vertic Fluvaquents (Table 5) as were characterized by cracks at some period of the year. The classification correlated with Glyic Fluvisols or Haplic Fluvisols in WRB Soil Resource 2014 classification (IUSS Working Group WRB, 2022). Soil units between crest and lower slope positions were mostly well drained, with few that were moderately to imperfectly drained. These soils had argillic subsoil horizons and ochric surface horizons with base saturation exceeding 35 %. Therefore, fit more into the order Alfisols at Order level of USDA Soil Taxonomy (Soil Survey Staff, 2022). Soils of mapping units NG 3, NG 6, NG 12, NG 15 and NG 16 were characterised by aquic moisture regime, therefore, classified as Aqualfs at the Suborder level, and Endoaqualfs at the Great group level (Table 5). The soils of BKG I were classified as Typic Endoaqualfs at Subgroup, whereas NG 15 fitted into Arenic Endoaqualfs at Subgroup level and was due to loamy sand texture

Table 4: Summary of Land Qualities (Characteristics) of the Study area

Soil Mapping Unit	Climate (c)		Erosion Hazard (e)	Wetness (w)	Rooting condition (r)	Soil Physical (s)	Chemical fertility (f)			Salinity Hazard (n)
	Rainfall	Temp.	Slope	Drainage	Effect. Soil Depth	Texture	Soil pH	CEC	Avail. P	Elect. Cond
	(mm)	(ºC)	(%)	-	(cm)	-	-	cmol/kg	mg/kg	dS/m
Kontagora LGA										
NG 1	1015	27 - 33	0 - 2	wd*	180	SL, LS/ SCL	5.85 – 6.16	3.8 – 4.6	0.54-7.54	0.010 – 0.014
NG 2	1015	27 - 33	0 - 2	vpd	160 – 162	L, C	5.78 – 6.28	6.9 – 8.6	0.54-2.69	0.006 – 0.008
NG 3	1015	27 - 33	4 - 7	pd	30 – 89	SCL, SL	6.00 – 6.96	5.6 – 7.8	3.23-4.85	0.008 – 0.011
NG 4	1015	27 - 33	0 - 2	wd	48 – 80	SL/gSL	6.05 – 6.23	3.8 – 5.8	5.93	0.008 – 0.010
Wushishi LGA										
NG 5	1079.7	30.4–34.3	0 – 2	pd – vpd	155– 174	SL/ SCL	5.55 – 5.87	6.4 – 7.2	12.4-80.3	0.0075 – 0.008
NG 6	1079.7	30.4– 34.3	0 - 2	impd	175 – 180	SCL, L	5.59 – 5.73	4.9 – 6.0	0.54-3.77	0.0085 – 0.009
Bida LGA										
NG 7	1122	29 -33	0 – 2	pd	110**	L - CL	5.5 – 6.7	3.4 – 4.7	3.5-5.78	0.021 – 0.032
NG 8	1122	29 -33	0 - 2	pd	103 -174	CL - C	5.7 – 6.3	7.2 – 8.3	5.6-13.5	0.017 – 0.047

*wd: well drained, pd: poorly drained, vpd: very poorly drained, impd: imperfectly drained, ** encountered water table, SL: sandy loam, LS: loamy sand, SCL: sandy clay loam, L: loam, C: clay, gSL: gravelly sandy loam, CL: clay loam.

Table 4 continued. Summary of Land Qualities (Characteristics) of the Study area

Soil Mapping Unit	Climate (c)		Erosion Hazard (e)	Wetness (w)	Rooting condition (r)	Soil Physical (s)	Chemical fertility (f)			Salinity Hazard (n)
	Rainfall	Temp.	Slope	Drainage	Effectv. Soil Depth	Texture	Soil pH	CEC	Avail. P	Elect. Cond
	(mm)	(ºC)	(%)	-	(cm)	-	-	cmol/kg	mg/kg	dS/m
Katcha LGA										
NG 9	1122	29 -33	1 - 2	wd*	200	SL, LS	6.53 – 6.84	7.4 – 7.8	44.3-54.41	0.06 – 0.44
NG 10	1122	29 -33	4 - 7	pd	80 – 130	LS/ gSCL	6.40 – 6.42	4.9 – 7.6	11.85-14.5	0.32 – 0.44
NG 11	1122	29 -33	0 - 2	vpd	120 **	SL	6.22 – 8.42	4.2 – 4.9	2.16-2.69	0.011 – 0.019
NG 12	1122	29 -33	0 - 2	wd	100 **	SL, LS	6.05 – 6.24	4.2 – 5.8	10.24-15.6	0.023 – 0.18
NG 13	1122	29 -33	0 – 2	pd	120 – 150	SL, CL	6.00 – 6.40	5.4 – 6.2	2.63-3.83	0.010 – 0.015
NG 14	1122	29 -33	0 - 2	wd	183 – 220	LS	6.38 –6.41	4.9 – 5.4	8.62-15.09	0.008
NG 15	1122	29 -33	1 – 2	md	177- 184	LS/ SL	6.30 – 6.55	3.2 – 4.5	14.55-39.3	0.008
NG 16	1122	29 -33	0 - 2	vpd	200	SL - LS	6.09 – 6.33	5.3 – 6.6	9.69-15.1	0.008– 0.009
Lapai LGA										
NG 17	1122	29 -33	1– 2	md	120 – 156	SC – SCL	5.3 – 5.8	4.9 – 8.7	7.73-7.88	0.022 – 0.042
NG 18	1122	29 -33	0 - 2	md	103 – 160	CL	5.5 – 5.6	6.8 – 7.4	4.55-5.08	0.033 – 0.045

*wd: well drained, pd: poorly drained, vpd: very poorly drained, impd: imperfectly drained, ** encountered water table, SL: sandy loam, LS: loamy sand, SCL: sandy clay loam, L: loam, C: clay, gSL: gravelly sandy loam, CL: clay loam.

within the upper < 50 to 100 cm surface horizons. Typic Endoaqualfs were noted by Maniyunda et al. (2015) in Floodplain soils of Northern Guinea Savanna zone. Soils of units NG 4 and NG 10 were characterized by plinthite and were classified as Typic Plinthustalfs and Typic Plinthaqualfs respectively. Sixty one percent of the soil mapping units studied constituted Alfisols, and correlated with Luvisols and Lixisols (Table 5) of the WRB Soil Resource 2014 (IUSS Working Group WRB, 2022).

Land Suitability Evaluation for Rice Cultivation

All the land units were critically influenced by chemical fertility as either marginally suitable (S3) or not suitable (N). Other land qualities that limits the suitability of land for rice production includes soils physical characteristics (s), wetness (w), erosion hazard (e) and rooting condition (r). Land qualities that were rated as highly suitable for rice for most of the study area include salinity hazard (n), erosion hazard (e) and rooting condition (r). The climate of the entire study areas moderately suitable for rice production (Table 6).

The parametric evaluation of the land suitability for rice indicated 38.89 % land units (NG 1, NG 6, NG 7, NG 8, NG 13, NG 17 and NG 18) were highly suitable (potentially) and none was highly suitable under actual (current) evaluation. Up to 44.44 % of the land units were moderately suitable with respect to both actual and potential suitability (Table 6). Fifty percent of the land units were marginally suitable (S3) under actual evaluation, while 16.67 % under potential suitability evaluation. Chemical fertility (f) was the most critical factor evaluated to limits rice cultivation in the study areas. The results corroborate the findings of Udoh et al. (2011), which reported that suitability of alluvial soils in Southeastern Nigeria varied between S3 and N1 classes for rice cultivation. Similarly, Olaleye et al. (2002) and Olowolafe and Patrick (2001) also observed that soil chemical fertility to be among notable critical factors limiting wetland rice cultivation in Nigeria. Therefore, cultivation of rice would require soil management through application of organic matter and NPK fertilizers to upgrade the soil chemical fertility. Only soil unit NG 4 at Kontagora LGA was evaluated as permanently not suitable for rice production. To upgrade S3 and S2 land units to higher classes for rice production, fertilizer application, organic matter sourced from crop residue and farmyard manure will be required to improve nutrient availability and retention, increase CEC, water retention and aggregate stability (Odunze, 2017; Abagyeh *et al*., 2016). There will also be need to construct drainage structures, ridges and incorporate organic matter to improve drainage condition (Odunze, 2017) for rice production.

Land Suitability Evaluation for Cassava Cultivation

Salinity hazard was the only land quality rated as highly suitable for cassava across the entire study areas, while other soil qualities varied in their rating of suitability with chemical fertility been the most critical and varied between S3 and N (Table 7). Fatihu *et al.* (2020) evaluated chemical land quality and rated it as S3.

Table 5. Soil classification of the Study Areas

Soil Mapping Unit	USDA Soil Taxonomy	WRB 2014 (FAO UNESCO)
Kontagora LGA		
NG 1	Typic Kanhaplustalfs	Haplic Lixisols (Loamic)
NG 2	Vertic Fluvaquents	Gleyic Fluvisols (Loamic)
NG 3	Typic Endoaqualfs	Leptic Lixisols (Loamic)
NG 4	Typic Plinthustalfs	Ferric Lixisols (Loamic)
Wushishi LGA		
NG 5	Vertic Fluvaquents	Gleyic Fluvisols (Loamic)
NG 6	Vertic Endoaqualfs	Eutric Gleysols (Loamic)
Bida LGA		
NG 7	Vertic Albaqualfs	Gleyic Lixisols (Oxyaquic)
NG 8	Vertic Fluvaquents	Gleyic Fluvisols (Clayic)
Katcha LGA		
NG 9	Typic Hapludalfs	Haplic Luvisols (Loamic)
NG 10	Typic Plinthaqualfs	Ferric Luvisols (Loamic)
NG 11	Vertic Fluvaquents	Gleyic Fluvisols (Loamic)
NG 12	Typic Endoaqualfs	Gleyic Lixisols (Loamic)
NG 13	Vertic Fluvaquents	Gleyic Fluvisols (Loamic)
NG 14	Arenic Hapludalfs	Haplic Luvisols (Loamic)
NG 15	Arenic Endoaqualfs	Gleyic Luvisols (Loamic)
NG 16	Typic Endoaqualfs	Gleyic Luvisols (Loamic)
Lapai LGA		
NG 17	Vertic Fluvaquents	Haplic Fluvisols (Eutric)
NG 18	Vertic Fluvaquents	Haplic Fluvisols (Eutric)

Table 6. Suitability Index and Sub-classes (Actual and Potential) for Rice

Soil Mapping Unit	Land Qualities (%)							Actual Suitability		Potential Suitability	
	Climate (c) A	Erosion Hazard (e) B	Wetness (w) C	Rooting Condition (r) D	Soil Physical Character. (s) E	Chemical fertility (f) F	Salinity Hazard (n) G	Suitability Index	Suitability Classes	Suitability Index	Suitability Classes
Kontagora LGA											
NG 1	85	100	85	100	100	60	100	60.35	S2fw	78.37	S1
NG 2	85	100	60	100	100	40	100	41.64	S3fw	65.84	S2w
NG 3	85	60	100	40	100	40	100	32.26	S3fr	41.64	S3re
NG 4	85	100	85	40	60	40	100	10.40	N2	38.39	S3srw
Wushishi LGA											
NG 5	85	100	60	100	100	60	100	51.00	S2fw	65.84	S2w
NG 6	85	100	100	100	100	40	100	53.76	S2f	85.00	S1
Bida LGA											
NG 7	85	100	85	100	100	40	100	49.56	S3fw	78.37	S1
NG 8	85	100	85	100	100	60	100	60.35	S2fw	78.37	S1
Katcha LGA											
NG 9	85	100	85	100	85	60	100	55.96	S2fsw	72.25	S2sw
NG 10	85	60	100	85	40	60	100	29.74	S3fres	38.39	S3sre
NG 11	85	100	60	100	100	40	100	41.64	S3fw	65.84	S2w
NG 12	85	100	85	100	85	40	100	45.70	S3fsw	72.25	S2sw
NG 13	85	100	100	100	100	40	100	53.76	S2f	85.00	S1
NG 14	85	100	85	100	60	40	100	38.39	S3fsw	60.70	S2sw
NG 15	85	100	100	100	60	40	100	41.64	S3fs	65.84	S2s
NG 16	85	100	60	100	60	60	100	39.51	S3fsw	51.00	S2sw
Lapai LGA											
NG 17	85	100	100	100	85	60	100	60.35	S2fsw	78.37	S1
NG 18	85	100	100	100	100	40	100	53.76	S2f	85.00	S1

Table 7. Suitability Index and Sub-classes (Actual and Potential) for Cassava.

Soil Mapping Unit	Land Quality (%)							Actual Suitability		Potential Suitability	
	Climate (c) A	Erosion Hazard (e) B	Wetness (w) C	Rooting Condition (r) D	Soil Physical Characterist. (s) E	Chemical fertility (f) F	Salinity Hazard (n) G	Suitability Index	Suitability Classes	Suitability Index	Suitability Classes
Kontagora LGA											
NG 1	85	100	100	100	85	60	100	60.70	S2csf	78.37	S1
NG 2	85	100	40	100	85	40	100	31.35	S3csfw	49.56	S3csw
NG 3	85	85	60	40	60	40	100	18.81	N1	29.74	S3cre
NG 4	85	100	100	40	85	40	100	31.35	S3crsf	49.56	S3csr
Wushishi LGA											
NG 5	85	100	40	100	85	60	100	38.39	S3cwf	49.56	S3cws
NG 6	85	100	85	100	85	40	100	45.70	S3cwsf	72.25	S2cws
Bida LGA											
NG 7	100	100	60	100	100	40	100	48.99	S3fw	77.46	S1
NG 8	100	100	60	100	60	60	100	46.48	S3fsw	60.00	S2ws
Katcha LGA											
NG 9	100	100	100	100	85	60	100	71.41	S2fs	92.20	S1
NG 10	100	85	60	85	60	60	100	39.51	S3wfres	51.00	S2wers
NG 11	100	100	40	100	100	40	100	40.00	S3fw	63.25	S2w
NG 12	100	100	100	100	85	40	100	58.31	S2fsw	92.20	S1
NG 13	100	100	60	100	100	40	100	48.99	S2fw	77.46	S1
NG 14	100	100	100	100	85	40	100	58.31	S2f	92.20	S1
NG 15	100	100	85	100	85	40	100	53.76	S2fsw	85.00	S1
NG 16	100	100	40	100	85	60	100	45.17	S3fsw	58.31	S3sw
Lapai LGA											
NG 17	100	100	85	100	85	60	100	65.84	S2fsw	85.00	S1
NG 18	100	100	85	100	100	40	100	58.31	S2fw	92.20	S1

Parametric evaluation of land suitability for cassava showed that none of the soils were classified as S1 based on actual suitability, while 50 % were highly suitable based on potential evaluation.

Sien *et al.* (2017) evaluation of land suitability also rated most of the land (75 %) as S1. Actual suitability evaluation indicated 44.44 % were S2, while under potential evaluation only 22.22 % falls within the same class. Fifty percent of the land units were marginally suitable under actual evaluation, while 27.78 % under potential evaluation. The most critical land quality limiting suitability of the soils for cassava below S1 was chemical fertility, and this was in line with previous study by Raji (2016) and Ahukaemere et al. (2016). Only land unit NG 3 at Kontagora LGA was evaluated as not suitable for cassava production under actual evaluation and none under potential evaluation. To upgrade the suitability of land units for cassava production, organic matter and manure would be required to enrich the soil fertility, construction of drainage structure, ridges and incorporation of organic matter as management practices are expected to improve drainage condition of the soils (Odunze, 2017; Abagyeh et al., 2016). Irrigation will also be required to supplement rainfall in Wushishi and Kontagora LGAs for optimal cassava production, especially during the dry season.

CONCLUSION

Alfisols constituted 61 % of the soil units, while Entisols covered 39 % of the soil units in the study area. Soil salinity was the only soil quality highly suitable, while chemical fertility was the most critical limiting soil quality for both rice and cassava production across the entire study area as shown by the parametric evaluation. The land suitability evaluation showed that about 39 % and 50 % of land units were highly suitable (S1) for rice and cassava respectively under potential evaluation and none under actual evaluation. Rice and cassava had 44.44 % and 50 % of the land units as moderately and marginally suitable respectively under actual evaluation. Only land units NG 4 and NG 3 were not suitable for rice and cassava cultivation under actual condition respectively. Some of the management practices suggested for upgrading suitability of the land units for rice and cassava cultivation includes: fertilizer, organic matter and manure application for nutrient availability and retention, while construction of drainage structure and ridges with incorporation of organic matter was suggested to improve drainage condition of the soils.

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