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Evaluation of land suitability for citrus cultivation in Khana Local Government Area of Rivers State, Southern Nigeria

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Abstract

Soils of Khana Local Government Area of Rivers State, Southern Nigeria were evaluated using semi detailed soil survey for citrus cultivation. The purpose of this research was to evaluate the suitability of soils of the study area for the cultivation of citrus. The total land area covers 49,631.54 ha and was delineated into eight mapping units based on the soil types. One pedon each was dug in each mapping unit and described using the FAO system. The nonparametric method of soil suitability evaluation was used. Four soil orders, majorly Inceptisols/Cambisols, Entosols/Arenosols, Ultisols/Acrisols, and Alfisols/Lixisols, were identified in the area. The results showed that land requirements/characteristics such as climate (mean annual rainfall), wetness (depth to water table) and fertility made the land marginally suitable (S3) to not suitable (N) for citrus cultivation across the eight pedons. The three limitations for citrus cultivation in the area are climate (annual rainfall), wetness (depth to the water table) and fertility (low status of NPK and pH). The land is potentially suitable for citrus cultivation but currently marginally and not suitable due to these three limitations.

INTRODUCTION

Land suitability evaluation is best described as the process of estimating the agricultural land potential for diverse kinds of utilization on a sustainable basis (Peter and Umweni, 2020a). According to Bintang and Tampubolon (2018), land suitability assessment is done by matching land qualities and characteristics to the criteria of the land suitability classes. Land suitability evaluation is also the assessment of agricultural land resources aiming to optimize land productive potentials, adding that land evaluation provides key information on the ability of land for sustainable crop production and soil management (Chukwu et al., 2014; Peter and Umweni, 2020a). It is also the interpretation of soil survey data in order that every hectare of land could be used in accordance with its capability, suitability and limitations (Food and Agriculture Organization, 2006). Soil suitability assessment involves a scientific procedure, which is essential to assess the potential and constraints of a given land for agricultural purposes (Rossiter, 1996). Therefore, to maintain sustainable agriculture, land use planning should be undertaken by investigating the soil through land suitability evaluation studies at both local and regional levels (Sereke, 2002; Essoka and Essoka 2013; Douglas and Peter, 2016; and Peter and Umweni, 2020a). Again, knowledge of the potentials and limitations of agricultural land resources in Khana Local Government Area, will enable crop farmers in the area to make adequate land use initiative to improve and maintain high yield of citrus crops on a sustainable basis and, at the same time, improve their standard of living (Peter and Umweni,

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2020b). This requires a proper organization of land and soil data in such a way that they could be interpreted and applied for sustainable agricultural production. Citrus are predominantly produced on large scale within the Middle belt in Nigeria and have enormous market value with very high sales, especially within the dry season. Citrus is an important crop due to its nutritional and medicinal values. There are different citrus cultivars cultivated in Nigeria, such as sweet orange (*Citrus sinesis* Osbeck), lime (*Citrus aurantifolia* Swingle), tangerine or tangor (*Citrus nobilis*) and (*Citrus reticulate*, Blanco). Therefore, this study aimed to evaluate the suitability of agricultural land resources for citrus cultivation in Khana Local Government Area of Rivers State, Southern Nigeria on a sustainable basis.

MATERIALS AND METHODS

The study was carried out in Khana Local Government Area of Rivers State, Southern Nigeria within the Tropical Rainforest zone. It is located between latitude 4.67172N and longitude 7.34398E (Figure 1) (Peter and Umweni, 2020b). The study location covers 49,631.54 ha of land with a rainfall pattern that is in a bimodal form that usually start effectively from late February to October with a period of low precipitation in August commonly called August break (Peter and Ayolagha, 2012). The period of effective low precipitation occured mainly from late November to early March. Sometimes, it is accompanied by serious dry cold wind commonly called harmathan wind. The average rainfall of the study location was between 2000 mm to 2500 mm with monthly temperature range of 26 °C to 35 °C and relative humidity varying from 81 % to 87 % depending on the season (rainy season and dry season) (Peter and Umweni, 2020b).

Field work

The entire land of Khana LGA was identified and delineated into eight mapping units based on vegetation, topography, soil types, drainage condition, textures and structures. One soil profile pit of 2 m × 2 m × 2 m was dug in each representative soil mapping unit. Each of the soil profile was described in line with soil procedure as recommended by Food and Agriculture Organization (1988). Soil samples were collected from identifiable horizons in each of the profile pit for physical and chemical analysis. Undisturbed core samples were collected from each identified profile pit horizon for bulk density determinations. The coordinates of all profile pits were collected using a hand-held geographical positioning system (GPS). Soil color notation in the field was described using the Munsell color chart (1992).

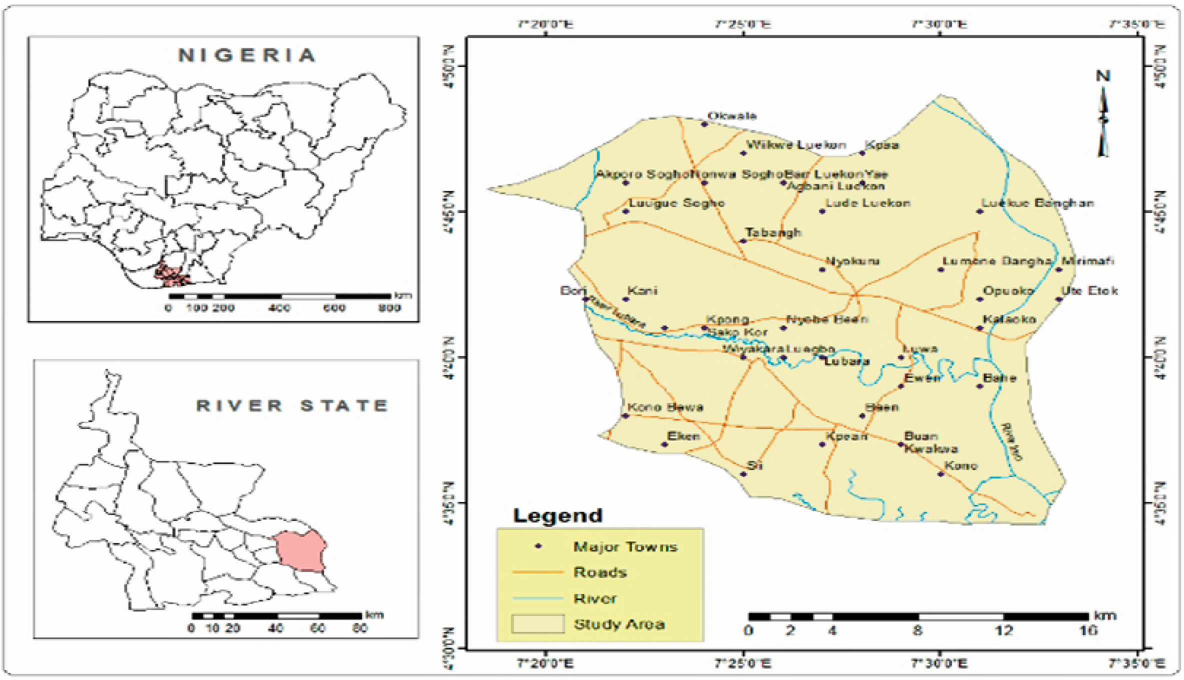

Figure 1. Map of Khana Local Government Area (Project Site). Sources: Government of Rivers State, Office of Surveyor General (2014)

Laboratory analysis

Soil samples collected were analyzed using routine soil analysis procedures most appropriate at the Soil Science Laboratory, Federal University Technology, Owerri - Imo State, to determine the physical and chemical characteristics of the soils. Soils collected were air-dried, crushed gently and sieved with a 2 mm mesh sieve. Soil particle size distributions were determined using the hydrometer method of Bouyoucus (1962) and Blake (1965), bulk density was determined by oven drying the undisturbed soil samples collected using a cylindrical core samplers, and bulk density was calculated as the weight of the soils divided by the volume of soil sample. Soil reaction (pH) was determined using the glass electrode pH meter (Mclean 1965). Organic carbon was determined using the dichromate wet oxidation method (Walkey and Black, 1934). Organic matter was obtained by multiplying the percentage of organic matter by 1.72. Total nitrogen was determined by the macro-Kjeldahl digestion methods by Jackson (1973) as described by Bremner and Mulvaney (1982). Available phosphorus was determined by Bray and Kurtz No 2 method (1945). Exchangeable cations were determined by extracting them with neutral ammonium acetate

Table 1. Soil-site suitability criteria for citrus production

Soil-site characteristics		Unit	Rating			
			Highly suitable (S1)	Moderately suitable (S2)	Marginally suitable (S3)	Not suitable (N)
Climate regime	Mean temperature in growing season	°C	28–30	31–35 24–27	36–40 20–23	> 40 < 20
	Total rainfall	mm	1,200–1,800	1,000–1,200	800–1,000	< 800
Land uality	Land characteristics					
Moisture availability	Length of rowing period	Days	240–265	180–240	150–180	< 150
Oxygen availability to roots	Soil drainage	Class	Well drained	Moderately to imperfectly	Poorly	Very poorly
	Depth of water table	cm	> 250	250–300 250–150	75–150	< 75
Nutrient availability	Texture	Class	Scl, 1, siel, cl, s.	Sc, sc, c	C (> 70%)	S, Is
	Ph	1:25	6.5–7.5	5.5–6.4 7.6–8.0	4.0–5.4 8.1–8.5	< 4.0 > 8.5
	$CaCO_3$ in root zone	%	Non cal	Up to 5	5–10	> 10
	Available nutrient and status (NPK & Zn)	Rating class	High	Medium	Low	
Rooting conditions	Effective soil depth	cm	> 150	100–150	50–100	< 50
	Presence of gravel in subsoil	%	Non gravelly	15–35	35–55	< 100
	Occurrence of hard pans in sub soil	cm	> 200	200–150	100–150	< 100
Soil toxicity	Salinity (EC saturation extract)	$dS.m^{-1}$	Non saline	Upto 1.0	1.0–2.5	> 2.5
	Sodicity (ESP)	%	Non sodic	5–10	10–15	> 15
Erosion hazard	Slope	%	< 3	3–5	5–10	

Remark: Irrigation sources are mandatory for successful crop; Source: Mohekar (1997).

(IM NH_4OAc) buffered at pH 7.0. Exchangeable cations (Ca, Mg, K and Na) were leached from the soil with NH_4OAc solution. Na and K were determined with flame photometry; while Ca and Mg were determined by the EDTA titration method of Heald (1965). Base saturation was calculated as the sum of exchangeable bases divided by ECEC multiplied by 100.

Soil classification

Based on the results of the laboratory analysis and field morphological characteristics, the eight pedons were classified according to soil taxonomy United States Department of Agriculture (2014) and correlated with the World Reference Base for Soil Resources (2014).

Land suitability evaluation procedure

Soil characteristics of each soil mapping unit were matched with the requirement of the land qualities (climate, topography, wetness, soil physical characteristics, and fertility) to a suitability class assigned to it, following the guidelines provided by Mohekar (1997), (Table 1 and Table 2). The final suitability class of each mapping unit is the class indicated by the characteristics with the lowest ranking, which is in line with the "Law of Minimum" (Food and Agriculture Organization, 1984). The suitability classes of each mapping unit were ranked, and the rankings were compared using Spearman's ranking correlation coefficient.

RESULTS AND DISCUSSION

Physical and chemical characteristics of the soils

Table 3 showed the selected physical and chemical characteristics of soils in the study area. Sand size particle dominated other soil particles in all the eight Pedons. Sand particles varied from (705.5 to 792.4) $g.kg^{-1}$ in Pedon 1, (833.6 to 863.6) $g.kg^{-1}$ in Pedon 2, (712.6 to 802.4) $g.kg^{-1}$ in Pedon 3, (792.4 to 802.4) $g.kg^{-1}$ in Pedon 4, (702.2 to 802) $g.kg^{-1}$ in pedon 5, (760 to 781.6) $g.kg^{-1}$ in Pedon 6, (691.2 to 812.4) $g.kg^{-1}$ in Pedon 7 and (813.6 to 853.6) $g.kg^{-1}$ in Pedon 8, accordingly. The high-level sand in surface horizons is also in line with the report of Akamigbo and Asadu (1983), who reported that sand particles were observed more in surface level as a result of the

Table 2. Factor rating of land quality for the Thanh Tra'' Pomelo (Citrus)

Land quality	Diagnostic factor	Unit	Factor rating			
			S1	S2	S3	N
Temperature	Mean temperature in growing season	°C	5–30	30–33 25–18	30–35 18–13	> 15 < 13
Water availability	Average annual rainfall (R)	mm	1,500–2,000	2,000–2,500	2,500–3,000 1,100–1,200	> 1,000 < 1,100
Fertility availability	Organic carbon (C)	%	> 25	1.0–2.5	< 1.0	-
	Total nitrogen (N))	%	> 0.2	0.1–0.2	< 0.1	-
	Available phosphorus (P_2O)	ppm	> 15	6–15	< 6	-
	Available potassium (K_2O)	mg	> 15	10–15	< 10	-
	Soil reaction (pH)	-	5.5–6.5	6.5–7.5 5.0–5.5	7.5–8.5 4.0–5.0	> 8.4 < 4.0
Rooting condition	Soil depth (D)	cm	> 100	70–100	50–70	< 50
Erosion hazard	Slope gradient (SL)	degree	0–30	3–80	8–150	> 150
Water and nutrition retention	Soil texture (T)	-	L, LS	SL, SiL	Si, CL	S, C

Remarks: L= Loam, LS= Loam sand; Si= Silt. SiL= Silt loam; S= Sand, SL = Sand loam, C = Clay, CL = Clay loam SI = Highly suitable, S2= Moderately suitable, S3= Marginally suitable, N= Not suitable

Table 3. Morphological and physical characteristics of soils of the study area

Pedon design	Horizon depth	Color (moist)	TC	Structure	Consistence	Drainage	Boundary	Roots	Sand ←	Silt g.kg^{-1}	Clay →	BD g.cm^{-3}	TP %
PEDON 1													
A	0–18	7.5 YR 3/3 (DB)	SL	G	Friable	WD	CS	M2 rts	792.4	40	167.4	1.4842	44.2
AB1	18–40	10 Y 4/3 (DGB)	SL	G	Friable	WD	Diffused	CI rts	772.4	50	177.6	1.623	38.98
AB2	40–73	10 YR 5/2 (GB)	SL	G	Friable	WD	Diffused	FI rts	762.6	70	167.4	1.841	30.79
BW1	73–102	10 YR 4/4 (DYB)	SL	Crumb	Loose	WD	Diffused	VFI rts	706.5	120	174.5	1.334	49.84
BW2	102–131	10 YR 5/4 (YB)	LS	SAB	Firm	PD	CS	VF1Yts	772.6	90	137.4	1.7492	32.72
PEDON 2													
A	0–12	10 YR 4/1 (DG)	LS	F G	Friable	WD	AW	M2 rts	833.6	103.6	62.8	1.478	44.44
AB1	12–26	7.5 YR3/2(VDG)	LS	G	Friable	WD	CS	F2 rts	863.6	53.6	82.8	1.346	49.4
AB2	26–40	2.5 YR 5/2 (G)	LS	Crumby	Loose	WD	CS	Vfl rt's	833.6	73.6	92.8	1.566	41.33
BW1	40–99	10 YR ¾ (LB)	LS	SAB	Loose	WD	AW	Vfl rts	833.6	43.6	122.8	1.512	43.16
BW2	99–200	10 YR ¾ (YB)	LS	SAB	Loose	WD	AW	vf2 rts	843.6	23.6	132.8	1.731	34.94
PEDON 3													
A	0–23	7.5 YR 4/1 (DB)	LS	SBK	Firm	WD	CS	M2 rts	802.4	50	147.6	1.5080	42.8
AB	23–60	7.5 YR 4/4 (B)	SL	SBK	Firm	WD	CS	f2 rts	782.5	60	157.5	1.7320	36.2
B	60–78	7.5 YR 5/8 (DYB)	SL	SBK	Firm	WD	CS	f2 rts	762.4	50	187.6	1.8701	34.26
Bt	78–145	10 YR 6/8 (PY)	SCL	SBK	Firm	WD	CS	vf1 rts	722.4	70	207.6	1.7492	37.32
Bt2	145–200	10 YR 7/8 (YB)	SCL	SBK	Firm	WD	CS	vf1 rts	712.6	60	227.4	2.8920	30.20
PEDON 4													
A	0–23	7.5 YR 5/3(DB)	LS	FG	Loose	PD	CS	M1rtC	802.4	60.2	137.4	1.4892	46.24
Abw	23–50	7.5 YR 4/3 (B)	LS	FG	Loose	PD	CS	M1rts	792.4	60.2	147.4	2.3050	31.80
PEDON 5													
A	0–13	7.5 YR 3/2 (DB)	LS	Crumby	Firm	WD	CS	M2rts	802	140.1	57.9	1.6501	40.32
AB	13–46	7.5 YR 3/4 (DB)	SL	SBK	Firm	WD	CS	f2 rts	762.2	150	87.8	1.7440	36.30
AW1	46–71	7.5 YR 4/6 (SB)	SL	SBK	Firm	PD	CS	vf1 rts	722.4	120.2	157.4	1.7459	37.24
BW2	71–120	7.5 YR 6/4 (LB)	SL	SBK	Firm	PD	CS	vf1 rts	702.2	100.2	197.6	1.8016	34.62
PEDON 6													
A	0–26	7.5 YR 4/1 (DG)	LS	SBK	Friable	WD	CS	M2 rts	781.6	154	64.4	1.4401	50.20
AB	26–52	7.5 YR 3/1(VDG)	LS	SBK	Friable	WD	CS	C12 rts	760	140	100	1.4926	47.28
B	52–114	7.5 YR 4/4 (DYB)	SCL	SBK	Firm	WD	CS	C2 rts	720.4	140	139.6	1.6012	41.16
Bt	114–200	7.5 YR 6/4 (LYB)	SCL	SBK	Firm	WD	CS	vf2 rts	702.4	91.2	206.4	1.7309	36.1
PEDON 7													
A	0–17	10 YR 4/1 (DG)	SL	Crumby	Loose	WD	CS	M2 rts	812.4	110	77.6	1.6081	24.44
AB	17–35	10 YR 5/4 (DYB)	SL	SBK	Firm	WD	CS	f2 rts	801.6	101.4	97	1.8624	35.27
B	35–78	10 YR 4/6 (PYB)	SL	SBK	Firm	WD	CS	vf1 rts	760	140	100	2.3152	30.64
Bt	78–200	10 YR 6/4 (LYB)	SCL	SBK	Firm	WD	CS	vf1 rts	691.2	60.2	248.6	1.5022	43.76
PEDON 8													
A	0–22	10 YR 2/2 (VDB)	LS	Granular	Friable	WD	CS	M2 rts	853.6	53.6	92.8	1.537	42.22
Ah	22–36	10 YR 4/3 (B)	LS	Granular	Friable	WD	CS	1 rts C	823.6	53.6	112.8	1.568	41.05
AB	36–50	10 YR 6/3 (LYB)	SL	Crumby	Loose	WD	CS	vf2 rts	823.6	43.6	132.8	1.581	40.56
B	50–109	10 YR 5/3 (LB)	SL	SBK	Firm	WD	CS	vf1 rts	813.6	63.6	122.8	1.663	37.48
BW	109–200	10 YR 5/6 (PYB)	SL	SBK	Firm	WD	CS	vf1 rts	813.6	63.6	122.8	1.683	36.71

Remarks: DB= Dark brown, DGB= Dark gray brown, GB= Gray brown, DYB= Dark yellowish brown, YB= Yellowish brown, SL= Sandy loam, LS= Loamy sand, G= Granular, SAB Sub-angular blocky, WD= Well drained, PD= Poorly drained, CS= Clear smooth, M= Many, I= Fine, 2= Medium, F= Few, C= Common, VF= Very few, rts= roots. TC= Textural class, BD= Bulk density and TP= Total porosity.

eluviation and illuviation processes in soils. The high sand fraction in surface horizon was also influenced by the parent material from which the soils are formed (Akpan-Idiok (2012); Peter and Umweni, 2020b). There were some degrees of variability in silt contents in all the eight pedons. It varied from (40 to 120) g.kg^{-1} in Pedon 1, (23.6 to 103.6) g.kg^{-1} in Pedon 2, (50 to 70) g.kg^{-1} in Pedon 3, 60.2 g.kg^{-1} in Pedon 4, (100.2–140.1) g.kg^{-1} in Pedon 5, (702.4 to 781.6) g.kg^{-1} in Pedon 6, (60.2–10) g.kg^{-1} in Pedon 7 and (53.6 to 63.6) g.kg^{-1} in Pedon 8. Clay content of soils in the study area also varied between (137.4 to 177.6) g.kg^{-1} in Pedon 1, (62.8 to 132.8) g.kg^{-1} in Pedon 2, (147.6 to 227.4) g.kg^{-1} in Pedon 3, (137.4 to 147.4) g.kg^{-1} in Pedon 4, (57.9 to 197.6) g.kg^{-1} in Pedon 5, (64.4 to 206.4) g.kg^{-1} in Pedon 6, (77.6 to 248.6) g.kg^{-1} in Pedon 7 and (92.8 to 132.8) g.kg^{-1} in Pedon 8 accordingly (Peter and Umweni, 2020b). Soil reactions (pH) in water, as shown in Table 4, varied from acidic (4.31) to slightly acidic (6.16). Soil pH increased from 5.43 to 6.13 in pedon 1 and increased from 5.6 to 6.16 in pedon 2. It also increased from 5.4 to 6.11 in pedon 3. It was also observed that soil pH increased from 5.43 to 6.08 in pedon 4 and increased from 4.50 to 5.71 in pedon 5. In pedon 6, there was an increase from 4.31 to 4.81, and in pedon 7, there was a decrease from 5.9 to 4.7 and an increase from 5.59 to 5.83 in pedon 8. There was a decrease in soil pH down the profile depth, which is in line with the finding of Peter and Umweni (2020b). Soil organic carbon was generally low in all pedons (1.40 to 14.15 g.kg^{-1}). This is also in line with the findings of Thurow

Table 4. Chemical characteristics of soils of the study area

	Horizon	pH	OC	OM	TN	Alv. P	Ca^{2+}	Mg^{2+}	K^{+}	Na^{+}	Ca:Mg	$EA1^{3+}$	EH^{+}	TEA	ECEC	C:N	BS
	Depth (cm)	(H_2O)	←	g.kg⁻¹ →		mg.kg⁻¹	←	cmol.kg⁻¹	→			←	cmol.kg⁻¹		→		%
PEDON 1 Oxyaquic Dystrudept/ Stagnic Endogleyic Cambisol (Oxyaquic, Hyperdystric)																	
A	0–18	5.66	14.15	24.59	1.39	10.88	0.78	0.40	0.200	0.183	2:1	1.76	1.04	2.80	4.483	10:01	34.865
AB_1	18–40	5.43	11.11	19.15	1.08	15.63	1.0	0.81	0.189	0.162	1:1	1.84	1.65	3.49	5.651	10:01	38.039
AB_2	40–73	6.08	12.08	20.83	1.04	9.27	1.0	0.82	0.177	0.135	1:1	1.15	1.03	2.18	4.312	12:01	49.44
BW_1	73–102	6.13	5.13	9.75	0.54	12.43	0.60	0.41	0.170	0.140	2:1	0.84	0.52	1.36	2.68	10.43:1	49.254
PEDON 2 Typic Udipsamment/Haplic, Hypoferralic Arenosol (Hyperdystric)																	
A	0–12	6.16	10.57	18.23	1.09	6.23	0.63	0.23	0.301	0.607	2:1	1.14	0.496	1.64	3.408	9.70:1	51.86
AB	12–26	5.94	8.28	14.27	0.89	4.76	0.37	0.12	0.254	0.47	3:1	0.624	0.432	1.056	2.280	9.30:1	54.1
B	26–40	5.96	4.39	7.57	0.39	2.94	0.19	0.05	0.277	0.411	4:1	0.720	0.432	1.152	2.06	19.4:1	46.65
BW_1	40–99	6.05	3.09	5.33	0.36	9.17	0.10	0.02	0.276	0.366	5:1	0.768	0.480	1.248	2.01	8.58:1	37.91
PEDON 3 Oxyaquic Dystrudept/Plinthic Endogleyic Cambisol (Oxyaquic, dystric)																	
A	0–23	6.08	10.06	17.34	0.90	39.08	1.50	0.95	0.198	0.220	1.58:1	1.76	1.48	3.24	6.108	10.59:1	46.955
AB	23–60	5.14	8.15	14.05	0.63	26.19	0.10	0.40	0.180	0.202	2.25:1	1.44	1.40	2.84	4.522	12.93:1	34.104
B	60–78	6.11	6.26	10.79	0.59	14.23	1.00	0.36	0.161	0.190	2.78:1	1.32	1.05	2.37	4.081	10.61:1	41.926
Bt_2	78–145	5.28	4.18	7.21	0.42	12.64	1.10	0.56	0.142	0.183	1.96:1	2.16	2.12	4.28	6.265	9.95:1	47.647
Bt_3	145–200	5.97	2.13	3.67	0.30	13.22	0.50	0.31	0.135	0.170	1.61:1	2.11	2.03	4.14	5.255	7.1:1	21.218
PEDON 4 Aquic Udipsamment/Haplic Endostagnic Arenosol (Greyic, Hyperdystric)																	
A	0–23	5.43	10.83	18.67	1.07	20.11	1.1	0.17	0.21	0.238	1.13:1	1.01	0.95	1.96	3.678	10.12:1	34.059
Abw	23–50	6.08	10.17	17.53	0.98	6.44	0.80	0.72	0.116	0.128	1.11:1	1.12	1.04	2.16	3.924	10.38.1	44.954
PEDON 5 Typic Dystrudept/Haplic Ferralic Cambisol (Chromic, Hyperdystric)																	
A	0–13	5.71	11.1	19.14	0.41	24.19	0.10	0.38	0.181	0.186	1.58:1	1.30	0.90	2.20	3.047	27.1	24.839
AB	13–46	5.12	12.0	20.69	0.37	22.80	0.50	0.24	0.169	0.174	2.08:1	1.41	2.12	3.53	4.613	327.4:1	28.750
BW1	46–71	4.92	8.0	13.79	0.30	21.69	1.61	0.44	0.160	0.186	3.41:1	1.31	2.06	3.57	5.766	27:1	53.228
BW2	71–120	4.50	6.21	10.70	0.24	9.33	1.40	0.40	0.149	0.174	3.51:1	1.9	2.12	4.02	6.484	26.1	55.228
PEDON 6 Typic Kandiudults/Haplic Vetic Acrisol (Hyperdystric)																	
A	0–26	4.81	11.1	19.14	0.45	23.9	0.90	0.66	0.170	0.220	1.36:1	1.60	1.12	2.72	3.86	2.6:1	32.397
AB	26–52	4.62	9.11	15.71	0.31	13.14	0.60	0.48	0.170	0.208	1.25:1	1.09	1.47	2.56	4.018	29.4:1	29.889
B	52–114	4.5	3.0	5.17	0.23	14.00	0.50	0.46	0.167	0.196	1.08:1	1.10	1.08	2.18	3.503	13.4:1	32.490
Bt	114–200	4.31	4.10	7.07	0.26	14.00	0.50	0.67	0.168	0.169	1.1	0.60	0.67	1.27	2.775	16:1	28.809
PEDON 7 Oxyaquic Kandiudalf/Gleyic Vetic Lixisol (Arenic, Oxyaquic)																	
A	0–17	5.9	10.01	17.26	1.12	30.88	0.90	0.66	0.196	0.194	1.36:1	1.84	1.12	3.04	4.99	8.93:1	48.653
AB	17–35	5.7	8.06	13.99	0.86	13.09	0.92	0.44	0.161	0.182	2.09:1	1.16	1.00	2.16	3.863	9.4:1	30.367
B	35–78	4.90	6.11	10.88	0.71	10.16	1.10	0.83	0.160	0.180	1.33:1	0.96	1.14	2.1	4.37	8.9:1	54.035
Bt	78–200	4.70	4.18	7.21	0.49	9.59	1.00	0.48	0.145	0.146	2.08:1	0.84	1.03	1.89	3.641	8.53:1	61.621
PEDON 8 Fluventic Dystudept/Haplic Fluvic Cambisol (Chromic dystric)																	
A	0–22	5.83	3.49	6.02	0.70	7.78	0.21	0.08	0.258	0.385	2.68:1	0.912	0.496	1.408	2.341	5.06:1	37.85
Ah	22–36	5.69	2.59	4.47	0.33	57.47	0.43	0.18	0.250	0.426	2.39:1	0.592	0.368	0.96	2.246	7.85:1	57.26
AB	36–50	5.59	3.69	6.36	0.47	10.85	0.32	0.09	0.283	0.418	3.56:1	0.592	0.336	0.928	2.039	4.16:1	54.49
B	50–109	5.72	3.19	5.50	0.67	1.82	0.34	0.10	0.278	0.416	3.4:1	0.448	0.176	0.624	1.758	4.76:1	54.51
BW	109–200	5.67	1.50	2.58	0.26	51.17	0.32	0.10	0.263	0.382	2.7:1	1.088	0.328	1.416	3.439	5.77:1	41.94

and Smith (1998); Essoka and Essoka (2014); and Peter and Umweni, (2020). Total nitrogen levels ranged from very low (0.24 g.kg^{-1}) in pedon 5 to low (1.39 g.kg^{-1}) in pedon 1. Total N decreased down the depth the profile across the pedons. The low level of total N in the soils in the study area was as a result of excessive soil planted to leaching due to intensive rainfall experienced in the area, supported by the findings of Udo and Ogunwale (1986) & Peter and Umweni (2020a). Available phosphorus also varied from 1.82 m.kg^{-1} (very low) to 57.47 m.kg^{-1}. There was no decrease in the available P content down the profile depths, but there were differences in the level of available P nonlinear to soil depths in all pedons.

Soil classification

Four soil orders, majorly Inceptisols/Cambisols, Entosols/Arenosols, Ultisols/Acrisols, and Alfisols/Lixisols, were identified. According to Peter and Umweni (2020b), they were further classified as Oxyaquic Dystrudept/Stagnic Endogleyic Cambisol in pedon 1, Typic Udipsamment/Haplic Hypoferralic Arenosol in pedon 2, Oxyaquic Dystrudept/Plinthic Endogleyic Cambisol in pedon 3, Aquic Udipsamment/Haplic Endostagnic Arenosol in pedon 4, Typic Dystrudept/Haplic Ferralic Cambisol in pedon 5, Typic Kandiudults/Haplic Vetic Acrisol (Hyperdystric) in pedon 6, Oxyaquic Kandiudalf/Gleyic Vetic Lixisol (Arenic, Oxyaquic) in pedon 7, and Fluventic Dystudept/Haplic Fluvic Cambisol (Chromic dystric) in pedon 8.

Land suitability of the study area for citrus cultivation

The suitability classification of each pedon in the study area for citrus cultivation showed that Pedons 1 and 5 were currently marginally (S3) suitable for citrus cultivation in the study area due to limitations in climate (rainfall), wetness and fertility (Table 5). This is in line with the findings of Ikhe et al. (2017), who reported that excess rain caused citrus to be waterlogged, which eventually caused molding,

Table 5. Summary of Suitability Evaluation for Citrus cultivation in Pedons 1–8

Land requirements/Land suitability	Pedons and their suitability class (s)							
	P1	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**
Climate								
Total rainfall (mm	2,000–2,500 (S3)	2,000–25,00 (S3)	2,000–2,500 (S3)	2,000–2,500 (S3)	2,000–2,500 (S3)	2,000–2,500 (S3)	2,000–2,500 (S3)	2,000–2,500 (S3)
Length of growing period (day)	180 days (S1)	180 days (S1)	180 days (S1)	180 days (S1)	180 days (S1)	180 days (S1)	180 days (S1)	180 days (S1)
Mean temperature in growing season (°C)	25–28 (S1)	25–28 (S1)	25–28 (S1)	25–28 (S1)	25–28 (S1)	25–28 (S1)	25–28 (S1)	25–28 (S1)
Topography								
Slope (%)	0–4 (S1)	0–4 (S1)	0–4 (S1)	0–4 (S1)	0–4 (S1)	0–4 (S1)	0–4 (S1)	0–4 (S1)
Erosion hazard (eh)	Very low (S1)	Very low (S1)	Very low (S1)	Very low (S1)	Very low (S1)	Very low (S1)	Very low (S1)	Very low (S1)
Wetness (W)								
Depth of water table (cm)	131 (S3)	> 200 (S1)	>200 (S1)	50 (N)	120 (S3)	200 (S1)	200 (S1)	200 (S1)
Soil drainage (surface)	MD (S2)	WD (S1)	WD (S1)	MD (S2)	MD (S2)	WD (S1)	WD (S1)	WD (S1)
Soil Physical Characteristic (s)								
Texture	LS (S1)	LS (S1)	SL (S1)	SL (S1)	SL (S1)	LS (S1)	SL (S1)	LS (S1)
Effective Soil depth	131 (S2)	200 (S1)	200 (S1)	50 (S3)	120 (S2)	200 (S1)	200 (S1)	200 (S1)
Presence of gravel in subsoil	Nil (S1)	Nil (S1)	Nil (S1)	Nil (S1)	Nil (S1)	Nil (S1)	Nil (S1)	Nil (S1)
Occurrence of Hard Pan in Subsoil	Nil (S1)	NIL (S1)	NIL (S1)	NIL (S1)	NIL (S1)	NIL (S1)	NIL (S1)	NIL (S1)
Fertility								
pH	5.43–6.13 (S2)	5.60–6.16 (S2)	5.14–6.11 (S2)	5.43–6.06 (S2)	4.50–5.71 (S3)	4.31–4.81 (S3)	4.70–5.70 (S3)	5.67–5.83 (S2)
Availability of nutrient and status (NPK)	Very low (S3)	Very low (S3)	Very low (S3)	Very low (S3)	Very low (S3)	Very low (S3)	Very low (S3)	Very low (S3)
Sodicity (Esp)	0.038 (S1)	0.2 (S1)	0.036 (S1)	0.05 (S1)	0.036 (S1)	0.06 (S1)	0.01 (S1)	0.2 (S1)
Aggregate Suitability Class	(S3) (c, w, f)	S3 (c, f)	S3 (c, f)	N (w)	S3 (c, w, f)	S3 (c, f)	S3 (c, f)	S3 (c, f)
Size (Hectare)	4,750	1,400	19,882	7,700	5,950	5,350	3,350	1,250
% Coverage	9.57	2.82	40.06	15.52	11.98	10.78	6.75	2.52

Remarks: Pedons 1 and 5 (10,700 ha) were marginally suitable (S3) for citrus cultivation with defects in climate (rainfall), wetness (depth to water table) and fertility (Low N, P and K status) in the soils; Pedons 2, 3, 6, 7, and 8 (31,232 ha) were also marginally suitable (S3) for citrus cultivation but with limitations in both climate and fertility; Pedon 4 (7,700) was not suitable (N) for citrus cultivation due to limitation in wetness (soil depth to water table); Source : Mohekar (1997).

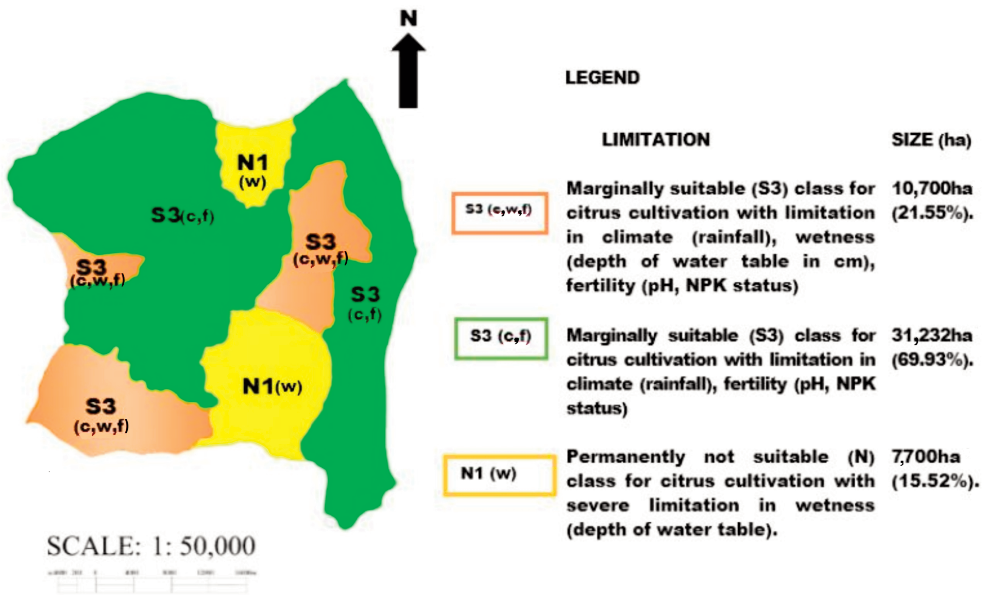

Figure 2. Land Suitability Map for Citrus in Khana Local Government Area.

adding that under such condition, citrus takes in more water and becomes more diluted. Both pedons (1 and 5) cover an area of land of 10,700 ha, representing 21.55 % of the study area. Pedons 2, 3, 6, 7 and 8 were also marginally (S3) suitable with limitations in climate and soil fertility. The main climatic factor affecting citrus production in the area was rainfall. This is synonymous with the finding of Ali et al. (2017), reporting that rainfall affected the growth and development of citrus in the humid tropical region. They added that excessive rain could lead to the excessive drop of flowers, resulting in fruitless conditions. Pedons 2, 3, 6, 7, and 8 cover a land area of 31,232 ha, representing 62.93 %, of the study area while pedon 4 was permanently not suitable (N) to citrus cultivation due to severity in wetness (depth to the water table) (Figure 2). This confirmed the report of Ridolfi (2006), that tree crops were stressed when the depth to the water table was shallow, leading to poor growth and dead of plants due water logging conditions. Pedon 4 covers a land area of 7,700 ha, representing 15.52 % of the study area. The specific fertility limitation was nutrient availability and status, especially NPK, which was very low in all pedons (1–8), while for pedon 4, it was the soil depth to the water table.

CONCLUSIONS

The land resource (soil) of Khana LGA is marginally suitable (S3), and some were currently not suitable (N) for citrus cultivation due to certain limitations. These limitations ranged from climate (rainfall) to wetness and fertility. A total of 41,931.54 of land representing 84.49 % of the study area were marginally suitable (S3) for citrus cultivation due to constraints in climate (rainfall), wetness and fertility, while 7,700 ha representing 15.51 % of the study area were permanently not (N) suitable for citrus cultivation due to severity in wetness (depth to the water table). However, some of these limitations can be improved through appropriate management practices in the study area for sustainable citrus cultivation.

REFERENCES

Akamigbo, F.O.R. and Asadu, C.L.A. (1983). Influence of parent materials on the soils of Southestern Nigeria. *East African Agricultural and Forestry Journal*, 48(4), pp. 81–91.

Akpan-Idiok, A.U. (2012). Physicochemical properties, degradation rate and vulnerability potentials of soils formed on coastal plain sands in Southeast, Nigeria. *International Journal of Agriculture Research*, 7(7), pp. 358–366.

Ali, H., Lai, M.I., Nawaz, M.Z., Sharif, M., and Saleem, B.A. (2017). Symptom based automated detection of citrus diseases using color histogram and textural descriptors. *Computers and Electronic in Agriculture*, 138, pp. 92–104

Bintang, Supriadi, and Tampulobon, E. (2018). Evaluation of land suitability for shallot (*A. asculonicum* L.) and orange (*Orange* sp.) at Harian District Samosir Regency. *IOP Conference Series: Earth and Environmental Science*, 122(1), pp. 012035

Blake, G.R. (1965). Particle density. In: C.A. Blake, ed., *Method of Soil Analysis Part 1*. Madison, Wisconsin, USA: American Society of Agronomy, pp. 371–373.

Bouyocus, G.H. (1962). Hygrometer method improved for making particle size analysis of soil. *Agronomy Journal*, 54(5), pp. 464–465.

Bray, R.H. and Kurtz, L.T. (1945). Determination of total and available form of phosphorus in soils. *Soil science*, 59(1), pp. 39–45.

Bremner, J.M, and Mulvaney, C.S. (1982). Nitrogen-total. In: Page, A.L., Miller, R.H., and Keeney, D.R. eds., *Methods of Soil Analysis. Chemical and Microbiological Properties*. Madison, Wisconsin, USA : American Society of Agronomy, Soil Science Society of America, pp. 595–624.

Chukwu, G.O., Nwosu, P.O., and Onyekwere, I.N. (2014). Suitability evaluation of land resources zones of Nigeria for cocoyam production. *US Open Soil Science Journal*, 1(1), pp. 1–8.

Douglas, K. and Peter, K.D. (2016). Assessment of selected soil quality indicators in Obio/Akpor Local Government Area of Rivers State, Southeastern Nigeria. *IIARD International Journal of Geography and Environmental Management*, 2(8), pp. 10–21.

Essoka A.N. and Essoka, P.A. (2014). Characterization and classification of Obudu Mountain steep hillside soils. *Nigerian Journal of Soil Science*, 24, pp. 1–12.

Essoka, A. N. and Essoka, P.A. (2013). Classification of the Obudu Plateau (Crest) and Sub Plateau soils of Cross Rivers State, Nigeria. *Proceeding of the 37th Annual Conference of Soil Science Society of Nigeria, Makurdi,* 23(1), pp. 32–40.

Food and Agriculture Organization. (1984). *Land evaluation for forestry. FAO Forestry Paper 48.* Rome: Food and Agriculture Organization, pp. 123.

Food and Agriculture Organization. (1988). *FAO-UNESCO Soil map of the world. The legend world soil resources. Report 60.* Rome: Food and Agriculture Organization, pp. 72–74

Food and Agriculture Organization. (2006). *FAO/UNESCO Soil map of the world, revised legend. World resources report 60.* Rome: Food and Agriculture Organization, pp. 138

Government of Rivers State, Office of the Surveyor General (2014). Administrative Map of Khana Local Government Area showing settlements, boundaries, road networks and rivers, pp. 1

Heald, W. R. (1965). Calcium and magnesium. In:

A.G. Norman, ed., *Methods of Soil Analysis Part 2 Chemical and Microbiological Properties*. Madison Wisconsin, USA: American Society of Agronomy, pp. 999–1010.

Ikhe, U.D., Gabhane, V.V., Sonune, B.A., and Damre, P.R. (2017). Assessment of yield and quality of grapes on different soils in Buldana District of Maharashtra. *The Bioscan*, 12(1), pp. 385–393.

Jackson, M.L. (1973). *Soil chemical analysis*, 2nd ed. New Delhi, India: Prentice Hall pub. Pvt Ltd., pp. 97

Mclean, E.O. (1965). Aluminium. In: C.A. Black, ed., *Methods of Soil Analysis No.9 Part 2.* Madison Wisconsin, USA: American Society of Agronomy, pp. 978–998.

Mohekar, D.S. (1997). *Characterization of some orange growing soils of Nagpur district and their suitability evaluation*. Thesis. Dr. Punjabrao Deshmukh Krishi Vidyapeeth, Akola.

Munsell colour. (1992). *Munsell colour chart, Munsell colour Baltimore, M.D USA. Status of human induced soil degradation*. Wageningen: ISRIC., pp. 21

Peter, K. D. and Umweni, A.S. (2020a). Morphological and physical properties of development form coastal plain sands and alluvium in Khana Local Government Area of Rivers State Southern Nigeria. *African Journal of Suistainable Agricultural Development*, 1(1), pp. 1–19.

Peter, K. D. and Umweni, A.S. (2020b). Characterization and classification of soils developed from coastal plain sands and alluvium in Khana Local Government Area of Rivers State, Southern Nigeria. *Direct Research Journal of Agriculture and Food Science*, 8(7), pp. 246–256.

Peter, K.D. and Ayolagha, G.A. (2012). Effect of remediation on growth parameters, grain and dry matter yield of soybean (*Glycine max*) in crude oil polluted soil in Ogoniland, Southeastern Nigeria. *Asian Journal of Crop Science*, 4(3), pp. 113–121.

Ridolfi, L., D'Odorico, P., and Laio, F. (2006). Effect of vegetation–water table feedback on the stability and resilience of plant ecosystem. *Water Resource Research*, 42(1),pp. 1–5

Rossiter, D.G. (1996). A theoretical frame work for land evaluation. *Geoderma*, 72(3-4), pp. 165–190.

Sereke, F. (2002). *Land evaluation for sustainable highland agriculture in N W-Thailand (Pang Ma Pha) with special respect to soil and water resources*. Diploma Thesis. Su Hgart Institute for Soil Science, University of Hohenheim.

Thurow, T.L. and Smith, J.E. (1998). Assessment of soil and water conservation methods applied to the cultivation of steep lands of southern Honduras. *Texas A&M University, Technical Bulletin* No.98–2.

Udo, E.J. and Ogunwale, J.O. (1986). *Laboratory manual for the analysis of soil, plant and water samples.* 2nd ed., Ibadan: Department of Agronomy, University of Ibadan, pp. 183

United States Department of Agriculture. (2014). *Keys to soil taxonomy*. 12th ed., USA, Washington DC: United States Department of Agriculture, Natural Resources Conservation Service.

Walkley, A. and Black, I.A. (1934). An examination of the Degtjareff method of determining soil organic matter, and a proposed modification of the chromic acid titration method. *Soil science*, 37(1), pp. 29–38.

World Reference Base for Soil Resources. (2014). *International soil classification System for naming soils and creating legends for soil maps, world soil reports no. 106.* Rome: Food and Agriculture Organization, pp. 13–22