SOIL SUITABILITY ASSESSMENT FOR OIL PALM AND PLANTAIN PRODUCTION IN KHANA AREA OF RIVERS STATE, SOUTHERN NIGERIA.

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ABSTRACT
A semi- detailed soil survey of the soils of Khana Local Government Area(LGA), Rivers State was carried out to assess the suitability of the soils for oil palm and plantain production using the nonparametric method. The soils were well -drained with soil textures ranging from loamy sand to sandy loam at surface horizons and sandy clay loam at subsurface horizons. The soils were strongly acid to moderately acid (pH 4.31 – 6.16), and of low total nitrogen (0.23 – 1.39 g/kg). Available P was low to high (1.84 – 57.47 mg/kg), and soils were low in effective cation exchange capacity (3.439 – 6.265cmol/kg), low to high base saturation (21.22 – 61.62 %.), low exchangeable bases (0.02 - 1.61cmol/kg),. The four soil types (Inceptisols, Entisols, Ultisols and Alfisols)identified in the study area were moderately suitable (S2) for oil palm production, but marginally suitable (S3) for plantain cultivation due to excessive rainfall.. Pedons 1, 2, 3, 5,6 and 7 covering 40,482 hectares representing 81.96% were moderately suitable (S2) for oil palm production and Pedon 4 and 8 covering 8950 hectares representing 17.84% were marginally suitable (S3) for oil palm cultivation. All mapping units in the study area were marginally suitable (S3) for plantain cultivation due to excessive rainfall experience in the area. Appropriate timing, as regards to plantingseason is suggested to reduce the effect of excessive rainfall, thus, improving the productive status of the soils for plantain cultivation on sustainable basis.
Keywords: Soil suitability assessment, oil palm, plantain, Khana Rivers State

INTRODUCTION

If agricultural production must become attractive to farmers, it must become a profitable venture and the first step is the ability to guide the farmers on the kind of land utilization that the soils in a area can support on a continuous and sustainable basis (Umweni and Ogunkule 2014). Land evaluation provides key information on the ability of land for sustainable agricultural crop cultivation and soil management. It is on record that in Nigeria, most of the arable lands are put into use without proper land evaluation assessment, and some times, available land evaluation results are not properly utilized. According to Amara *et al*. (2016), land suitability evaluation of soils is the rating of soils based on their inherent characteristics for optimum returns per unit area of land. Soil suitability evaluation process, provides information on the use of land and guide the farmers on how to maximize land use potential for sustainable agricultural crop production. The study of soil – site suitability evaluation help to predict crop performance of an area of land. FAO (1976) also described soil suitability evaluation as the rating of soils for optimum crop production using the available limited land resources. It is also the systematic process of identifying and measuring land qualities as assessing them for alternative kind of use of the land resources (Abagyeh *et al.*, 2016) Soil suitability evaluation on the other hand, is the process of estimating the potential of land for alternative kind of utilization (Peter et al, 2020). Soil suitability evaluation is also the process of matching land quality and soil morphological, physical and chemical properties as a criteria for proper and utilization for sustainable production of common community crops. Land evaluation provides information on the potentials and constraints of land for define land use, in terms of crop performance as affected by soil inherent characteristics and the physical environment (Abagyeh, 2016). Again, apart from assessing optimum performance and maximum production of crop, soil suitability evaluation. Dent and Young (1981) described soil suitability evaluation as a process of evaluating individual crop requirement based on the physical growth environment and soil properties. Finally, in a situation where over Ninety percent (90%) of the Khana LGA populations are crop farmers and shifting cultivation is becoming a thing of the past, soil suitability information relevant to sustainable crop production in the area is imperative.

MATERIALS AND METHODS

Study Location:

This research was conducted on 49,631.54 hectares in Khana Local Government Area of Rivers State. It is lies between latitude 4.67172N and longitude 7.34398E. According to Ayolagha, and Peter, 2013), Khana LGA has monthly minimum and maximum temperature that varies between 25^{0c} and 28^{0c}. The mean annual rainfall distribution ranged over 2500 mm/annum; while the relative humidity also varies between 81-87% depending on the season of the year. The soils of Khana local government area are derived from geologic materials developed from coastal plain sands underlying alluvium. The climax of the vegetation has been greatly altered by the effect of land degradation caused by crude oil pollution, unrestrained forest exploitation and incessant land cultivation.

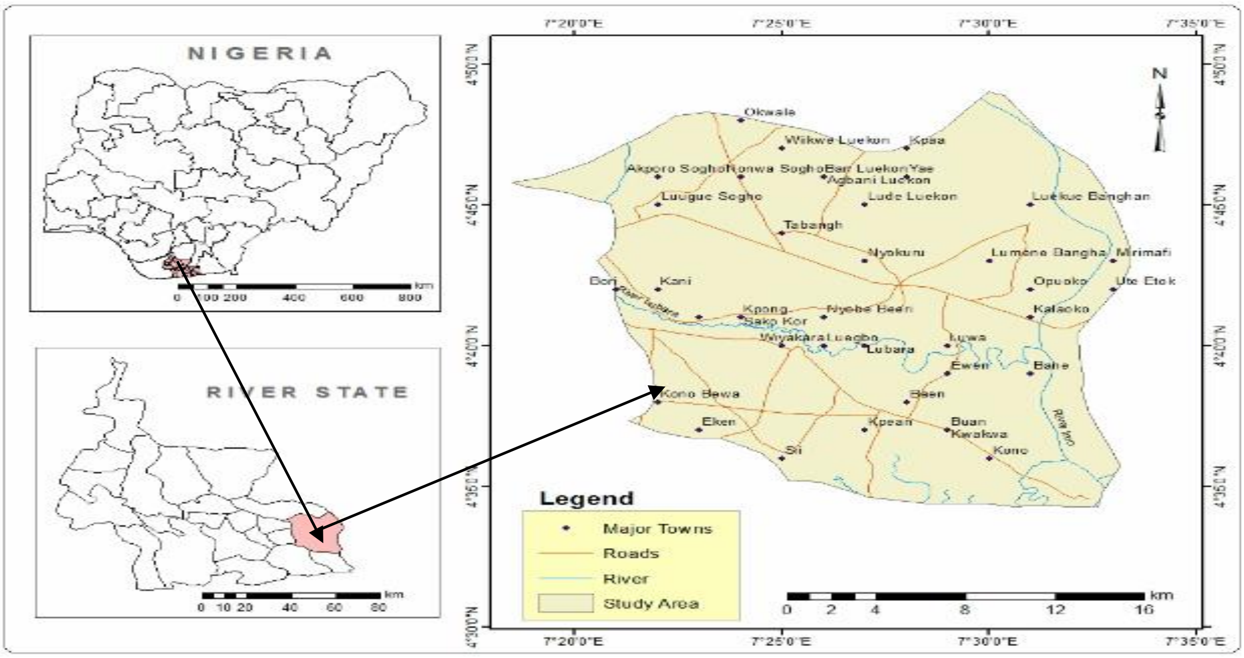


Fig. 1 Map of Khana Local Government Area

Field Work

A semi detailed survey study was carried out on 49,631.54 hectares of land in Khana Local Government Area of Rivers State,Nigeria. A political map of Khana showing different boundaries, road networks and settlements in the area was used as established map for the study after geo-referencing and digitization the study area was gridded using (1000 m x 500) using the rigid grid method and eight mapping units were identified. One modal soil profile pit (2m x 2m x 2m) each was dug on each mapping unit identified and described using FAO guidelines (1990). Soil samples were collected from each identified horizon of these profiles and were subjected to laboratory analyses using standard procedures most appropriate.

Laboratory analysis

Particle size distribution of soils in the study area were determined using the Bouyoucos (1951). Soil organic carbon was determined using Walkley and Black wet oxidation method of 1934. Soil total nitrogen was determined by the Micro- kjeldah method. Soil available phosphorus was determined by Bray and Kurtz No 2 (1945) method as described by Jou (1979) and Loganathan (1984).). Exchangeable cations such as potassium (K) and sodium (Na) were determined using 1 N NH_4OAc in pH 7.0.; while calcium and magnesium were also determined using atomic adsorption spectrometer. Soil effective cation exchange capacity (ECEC). Were determined by the summation of exchangeable acidity and soil percent base saturation was calculated to be the sum of total exchangeable bases all divided by Cation exchange capacity (CEC) X 100

Land Suitability Evaluation Procedure (LSE)

The nonparametric method of land suitability evaluation system (FAO, 1976) was used for the study. Each of the pedons were placed in their respective suitability classes by matching them with the already established land qualities requirements for the two crops of interest. The potentials and limitations of five land qualities/characteristics (climate, topography, wetness, soil physical properties and soil fertility) in determining the suitability of the soils identified in the study site for the cultivation of selected community crops was evaluated using Sys (1985), Sys *et al* (1991), Naidu *et al* . (1994), Mohekar, (1997), Djanudin *et al*. (2003), Senjobi and Ogunkule, (2010) and Adesemuyi (2014). Land suitability classes were obtained by matching some of the land qualities with the land use requirements for each community crop produced in the study area. Aggregate suitability class of each pedon, was obtained in line with the law of minimum which states that "performance is always determined by the least favourable characteristic or plant nutrients in the lowest supply" (FAO, 1984). Land suitability classifications of the selected community crops were expressed in land suitability maps

Table 1. Land requirements for the production of Oil Palm (*Elaeis guineensis*)

Land requirement/ Land characteristics	Land Suitability Class (s)					
	S1	S2	S2	S3	40	N2
Climate (c)						
Annual rainfall (mm)	>2000	1700 -2000	1450 - 1700	1300 – 1450	1300 – 1250	<1250
Length of dry season (M)	<1	1 – 2	2 - 3	3 – 4	3 – 4	>4
Mean annual temp (^{0}c)	>25	22 – 25	20 - 22	18 - 20	16 – 18	<16
Relative humidity (%)	>75	70 – 75	65 - 70	62 - 65	60 – 62	<60
Topography (t)						
Slope (%)	0 - 4	4 – 8	8 - 16	16 - 30	>30	>30
Wetness (w)						
Flooding	Fo	Fo	F1	F2	F2	F3
Drainage	Well drainage	Mod.drained	Mod.drained	Poor aeric	Poorly drained	Very poorly drained
Soil physical properties						
Texture	CL,SCL,L	CL, SCL, L	SCL	SCL, Lfs	Any	C, Cs, Any
Soil depth (cm)	>125	>100	>75	>60	<55	<50
Fertility (f)						
CEC (cmol/kg^{-1} clay)	>16	Any	<10	<10	<5	<5
Base saturation	>35	30 - 20	20 - 15	15 - 10	<10	<10
Organic matter (%)	>1.5	0.8 – 1.5	<0.8	<0.5	<0.3	<0.2

Modified from: Sye *et al.*, (1991). Symbols used for soil texture, structure and flooding are defined as follows: Cs: structure clay; Cm: massive clay; SiCs: silty clay, blocky clay; SiCL: silty clay loam; CL: clay loam; Si: silt; SiL: silty loam; SC: sandy clay; L: loam; SCL: sandy clay loam; Lfs: loamy fine stand; LS: loam sand; Lcs: loam coarse sand; Fs: fine sand; S: sand; CS: coarse sand. F0 = No flooding, F1 =1 – 2 flooding months in > 10 years, F2 = not more than 2 – 3 months in 5 years out of 10 years, F3 = 2 months almost every year, F4 = 2 – 3 months every year

Table 2. Land requirements for the production of Plantain (*Musa paradisiaca*)

Land requirement/ Land characteristics	S1	S2	S3	N1
Climate (c)				
Annual rainfall (mm)	1250-1750	1750-2000 1000-1250	1200-2500 750-1000	>2500 <750
Length of dry Season (m)	<2	2-3	3 -4	>4
Mean Annual temp (^{o}c)	20 – 23	23 – 30 18 – 20	30 – 40 15 – 18	>40 <15
Topography (t)				
Slope (%)	<8	8 – 16	16 – 13	>30
Erosion hazard (eh)	Very low	Low - moderate	Severe	Very severe
Wetness (W)				
Flooding	F0	F1	F2	>F2
Drainage (surface)	Good - moderate	Moderate - poor	Poor – moderate rapid	Very poor rapid
Soil Physical Characteristics				
Texture (surface)	Fine - medium	Medium – slightly coarse	Coarse	Very coarse
Surface stoniness	<5	5 – 15	15 – 40	40 – 45
Rockout Crops (%)	<5	5 – 18	15 – 25	25 – 30
Soil depth (cm)	>100	75 – 100	50 – 75	50 – 45
Coarse Materials (%)	<15	15 – 35	35 – 55	>55
Fertility (f)				
CEC (mol-Kg^{-1}) clay	>16	Any	8 – 12	5 – 8
Base Saturation (%)	>35	20 – 25	15- 20	10 – 15
pH (H_20)	5 – 6	4.5 5.6	<42 - >7.5	<4
Organic carbon (%) 0-15cm	>1.2	0.8 – 1.2	0.5 – 0.8	0.8 – 0.5
Alkalinity (ESP)	15	15 – 20	20 – 25	>25

Djaenudin *et al.*, (2003) Modified from *Sye et al .(*1991

RESULTS AND DISCUSSION

Soil Properties

The soils of the study area were very deep soils except pedon 4 with a depth of <55cm. They were also well drained except pedon 4 that was imperfectly drained. Soil colour ranged from dark brown (7.5YR5/3) moist to dark yellowish brown (10YR4/4) moist. The dark colouration a surface horizon is an evidence that organic matter are presence at surface soil horizon confirming the observation of Plaster (1992) and Brady and Weil (2002); while the dark yellowish brown colour without mottles indicated the drainage condition of the soils that qualify it as well drained soils. The soil textural class varied between sandy loam and sandy clay loam confirming the report by Peter *et al*. (2020) that absence of mottles in soils shows well drained condition of such soils. Soil structure ranged from granular to sub-angular blocky. The soils were non sticky at epipedons to slightly sticky at endopedons. Sand-sized fractions dominated other particle sizes in all pedons and horizons varying from 691.2 g/kg 8636 g/kg. This was followed by clay ranging from 59.9 to 248.6g/kg; while silt was the least of the particle size fractions ranging from 23.6 to 154 g/kg. The pattern of distribution of this three particle size fraction might be attributed to the parent materials from which the soils were formed (coastal plain sand and alluvium). This supports the finding of Akpan-Idiok (2012) that parent materials strongly determine the pattern of particle size distribution. It was also observed that sand particle fractions decreased down the profile; while clay and silt increased down the depth of the profile; which could be attributed to pedogenic processes of illuviation and eluviation that occurs in the soils. Bulk density decreased from 2.89 to 1,33 mg/m^2. Soil reaction (pH) ranged from strongly acid to slightly acid (4.31 – 6.16) in epipedons and endopedons. Organic carbon values were very low soils (1.50 – 14.15 g/kg.)while total nitrogen contents of the soils were low (0.23 – 1.39 g/kg). Available phosphorus was very low high (1.84 – 57.47 mg/kg) in the soils. Exchangeable bases of Ca, Mg, K and Na were all low across the eight pedon ranging from 0.10 – 1.61cmol/kg, 0.02 – 0.95cmol/kg, 0116 – 0.30cmol/kg and 0.128 – 0.607cmol/kg. ECEC was also low and varied 3.439 – 6.265cmol/kg. Percentage base saturation was low to high 21.22 – 61.62 %. The low nutrient status of soils of the study area could be attributed to high level of leaching experienced in the study area to high due to high rainfal

Table 3: Morphological and Physical characteristics of Soils of the Study Area

Pedon Design	Horizon depth	Colour (moist)	TC	Structure	Consistence	Drainage	Boundary	Roots	Sand ←	Silt g/kg	Clay →	BD g/cm³	TP %
PEDON 1													
A	0-18	7.5YR 3/3 (DB)	SL	G	Friable	WD	Clear Smooth	M2 rts	792.4	40	167.4	1.4842	44.2
AB1	18-40	10 Y4/3 (DGB)	SL	G	Friable	WD	Diffuse	CI rts	772.4	50	177.6	1.623	38.98
AB2	40-73	10YR 5/2 (GB)	SL	G	Friable	WD	Diffuse	FI rts	762.6	70	167.4	1.841	30.79
BW1	73-102	10YR 4/4 (DYB)	SL	C	Loose	WD	Diffuse	VFI rts	706.5	120	174.5	1.334	49.84
BW2	102-131	10 YR 5/4 (YB)	LS	SBK	Firm	PD	Clear Smooth	VF1Yts	772.6	90	137.4	1.7492	32.72
PEDON 2													
A	0-12	10YR 4/1 (DG)	LS	G	Friable	WD	Abrupt Wavy	M2 rts	833.6	103.6	62.8	1.478	44.44
AB1	12-26	7.5YR3/2(VDG)	LS	G	Friable	WD	Clear Smooth	F2 rts	863.6	53.6	82.8	1.346	49.4
AB2	26-40	2.5YR 5/2 (G)	LS	C	Loose	WD	Clear Smooth	Vflrt's	833.6	73.6	92.8	1.566	41.33
BW1	40-99	10 YR ¾ (LB)	LS	SBK	Loose	WD	Abrupt Wavy	Vflrts	833.6	43.6	122.8	1.512	43.16
BW2	99-200	10 YR ¾ (YB)	LS	SBK	Loose	WD	Abrupt Wavy	vf2 rts	843.6	23.6	132.8	1.731	34.94
PEDON 3													
A	0-23	7.5YR 4/1 (DB)	LS	SBK	Firm	WD	Clear Smooth	M2 rts	802.4	50	147.6	1.5080	42.8
AB	23-60	7.5YR 4/4 (B)	SL	SBK	Firm	WD	Clear Smooth	f2 rts	782.5	60	157.5	1.7320	36.2
B	60-78	7.5YR5/8 (DYB)	SL	SBK	Firm	WD	Clear Smooth	f2 rts	762.4	50	187.6	1.8701	34.26
Bt	78-145	10 YR 6/8 (PY)	SCL	SBK	Firm	WD	Clear Smooth	vf1 rts	722.4	70	207.6	1.7492	37.32
Bt2	145-200	10 YR 7/8 (YB)	SCL	SBK	Firm	WD	Clear Smooth	vf1 rts	712.6	60	227.4	2.8920	30.20
PEDON 4													
A	0-23	7.5YR5/3(DB)	LS	G	Loose	PD	Clear Smooth	M1rtC	802.4	60.2	137.4	1.4892	46.24
Abw	23-50	7.5 YR 4/3 (B)	LS	G	Loose	PD	Clear Smooth	M1rts	792.4	60.2	147.4	2.3050	31.80

Texture:LS:=loamy sand, SL=sandy soil,SCL=sandy clay loam

Structure:C=crumb,G=granular,SBK=sub-angular blocky
Drainage:WD=well-drained,PD=poorly drained
Roots:M-medium,C=coarse,Vf=very fine,f= fine, rts=roots
BD=bulk density
TP=total porosity

Table 3 continues: Morphological and Physical characteristics of Soils of the Study Area

Pedon Design	Horizon depth	Colour (moist)	TC	Structure	Consistence	Drainage	Boundary	Roots	Sand ←	Silt g/kg	Clay →	BD g/cm^3	TP %
PEDON 5													
A	0-13	7.5YR 3/2 (DB)	LS	Crumby	Firm	WD	CS	M2rts	802	140.1	57.9	1.6501	40.32
AB	13-46	7.5YR3/4 (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	7.5YR 4/1 (DG)	LS	SBK	Friable	WD	CS	M2 rts	781.6	154	64.4	1.4401	50.20
AB	26-52	7.5YR3/1(VDG)	LS	SBK	Friable	WD	CS	C1 2 rts	760	140	100	1.4926	47.28
B	52-114	7.5YR4/4 (DYB)	SCL	SBK	Firm	WD	CS	C2 rts	720.4	140	139.6	1.6012	41.16
Bt	114-200	7.5YR 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	10YR 5/4 (DYB)	SL	SBK	Firm	WD	CS	f2 rts	801.6	101.4	97	1.8624	35.27
B	35-78	10YR 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	10YR 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	10YR 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	10YR5/6 (PYB)	SL	SBK	Firm	WD	CS	vf1 rts	813.6	63.6	122.8	1.683	36.71

Key: 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

Table 4. Chemical properties of soils of the study area

	Horizon Depth (cm)	pH (H_2O)	OC	OM g/kg^{-1}	TN	Av. P mg/Kg^{-1}	Ca^{2+}	Mg^{2+} cmol/kg^{-1}	K^+	Na^+	Ca:Mg	$EA1^{3+}$	EH^+	TEA cmol/kg^{-1}	ECEC	C:N	BS %
PEDON 1 OxyaquicDystrudept/ StagnicEndogleyicCambisol (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
	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
BW_2	102-131	5.55	4.16	7.17	0.40	18.23	0.80	0.46	0.164	0.150	2:1	0.75	0.75	1.55	3.124	10.4:1	56.335
PEDON 2 TypicUdipsamment/Haplic, HypoferralicArenosol (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
BW_2	99-200	5.6	1.40	2.41	0.23	5.94	0.25	0.07	0.276	0.494	4:1	0.800	0.440	1.24	2.33	6.09:1	47.03
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	27.4:1	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

OC=organic carbon, OM=organic matter, TN= total nitrogen, Av.P= available phosphorus, EAl= exchangeable Aluminium, EH= exchangeable hydrogen, TEA= total exchangeable acidity, CEC= cation exchange capacity, BS= base saturation, C:N= carbon-nitrogen ratio, Ca:Mg= calcium-magnesium ratio

Table 4. Continues: Chemical properties of soils of the study area

	Horizon	pH	OC	OM	TN	Av. 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 6 TypicKandiudults/HaplicVeticAcrisol (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 OxyaquicKandiudalf/GleyicVeticLixisol (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 FluventicDystudept/HaplicFluvicCambisol (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

OC=organic carbon, OM=organic matter, TN= total nitrogen, Av.P= available phosphorus, EAl= exchangeable Aluminium, EH= exchangeable hydrogen, TEA= total exchangeable acidity, CEC= cation exchange capacity, BS= base saturation, C:N= carbon-nitrogen ratio, Ca:Mg= calcium-magnesium ratio

Land Suitability evaluation for oil palm production

Suitability classification of pedon 1 – 8 for oil palm production in the study area revealed that Pedon 1 and 5 are moderately suitable (S2) for oil palm production with limitations in climate, wetness, soil physical properties and fertility. These two pedons cover land area of 10,700 hectares that represent 21.55 % of the land size in the study area. Pedon 2, 3, 6, 7 and 8 were also moderately suitable (S2) for oil palm production but with defects in climate,soil physical propertiesand fertility. These covers land area of 29,982 hectares which represent 60.41 % of total land site in the study area. Pedon 4 was permanently not suitable (N) for oil palm production due to limitation in soil physical properties. Pedon (4) cover an area of 7,700 hectares representing 15.52 % of the total land area. Pedon 8 was marginally suitable (S3) for oil palm production but with defect in fertility. It covers land area of 1,250 hectares representing 2.32 % of the total land area in the study area. In terms of specific severity in fertility defect, CEC was low in all the 8 pedons; while organic carbon was low in pedons 1, 2, 3, 4, 5, 6, and 7 but very low in pedon 8 and while pH was low in pedon 6. Pedon 4 had specific severe limitation in term soil depth due to low water table in the area.

Land suitability evaluation for plantain production

Land suitability classes of all the pedons for plantain production in the study area indicated that Pedon 4 is also marginally suitable for plantain production with limitation in climate and wetness. This pedon (4) cover 7,700 hectares of land representing 15.52 % of the total land in the area Pedons 1, 2, 3, 5, 6, 7 and 8 are marginally suitable for plantain production with limitation climate only. The seven pedons cover an area of 41,032 hectares of land representing 84.48 % of the total land size of the study area. Topography, Soil characteristics and Fertility status of the soil in the study area were all at optimal level of suitability for plantain production in the study area

Table 8: Summary Table for Suitability Evaluation for Oil palm (*Elaeisguinesis)* Cultivation in Pedons 1-8

Land Requirements/Land Suitability	Pedons and their Suitability Class (s)							
	P1	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**
Climate (c)								
Average rainfall (mm)	2000 – 2500 (S1)	2000 – 2500 (S1)	2000 – 2500 (S1)	2000 – 2500 (S1)	2000 – 2500 (S1)	2000 – 2500 (S1)	2000 – 2500 (S1)	2000 – 2500 (S1)
Length of dry Season (months)	<2months (S2)	<2 months (S2)	<2 months (S2)	<2 months (S1)	<2 months (S2)	<2 months (S2)	<2 (S2)	<2 (S2)
Mean Annual temp (ºC)	25 – 28 (S1)	25 – 28 (S1)	25 – 28 (S1)	25 – 28 (S1)	25 – 28 (S1)	25 – 28 (S1)	25 – 28 (S1)	25 – 28 (S1)
Relative humidity (%)	.>80 (S1)	>80 (S1)	>80 (S1)	>80	>80 (S1)	>80 (S1)	>80 (S1)	>80 (S1)
Topography (t)								
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)
Wetness (W)								
Flooding	Moderate (S2)	F0 (S1)	F0 (S1)	F2 S3)	F1 (S2)	F0 (S1)	F0 (S1)	F0 (S1)
Drainage (surface)	Moderate drained (S2)	WD (S1)	WD (S1)	PD (S3)	PD (S2)	WD (S1)	WD (S1)	WD (S1)
Soil Physical Characteristics (s)								
Texture (surface)	SL (S2)	LS (S2)	SL (S2)	LS (S2)	LS (S2)	LS (S2)	SL (S2)	LS (S2)
Soil depth (cm)	131 (S1)	200 (S1)	200 (S1)	50 (N1)	120 (S1)	200 (S1)	200 (S1)	200 (S1)
Fertility (f)								
CEC (cmolkg^{-1}) clay	3 – 6 (S2)	2 – 3.4 (S2)	5 – 6.3 (S2)	3.7– 3.9 (S2)	3.05– 6.5 (S2)	3 – 4.02 (S2)	4 – 5 (S2)	2 – 3.4 (S2)
Base Saturation (%)	35 – 56.4 (S1)	38 – 54 (S1)	34.3– 50.4(S1)	34.1 – 45 (S1)	24. 8 – 55 (S1)	29 – 33 (S1)	30.4 – 62 (S1)	38 – 57.3 (S1)
pH (H_20)	5 .5 – 6.13 (S1)	5 .60 – 6.16 (S1)	5.14– 6.11(S1)	5.43– 6.08(S1)	4.5 – 5.7 (S1)	4.3 – 4.8 (S2)	4.7 – 5.9 (S1)	5 .67 – 5.83 (S1)
Organic carbon (%) 0-15cm	1.42 (S1)	1.06 (S2)	1.06 (S2)	1.08 (S2)	1.11 (S2)	1.11 (S1)	1.06 (S1)	0.35 (S3)
Aggregate Suitability Class	S2 (c, w, s, f)	S2 (c, s, f)	S2 (c, s, f)	N1 (s)	S2 (c, w, s, f)	S2 (c, s, f)	S2 (c, s, f)	S3 (f)
Size (Hectare)	4750	1400	19882	7700	5950	5350	3350	1250
% Coverage	9.57	2.82	40.06	15.52	11.98	10.78	6.75	2.52

Source: Djaenudin*et al.*, (2003) Modified from *Sys et al., (*1991).

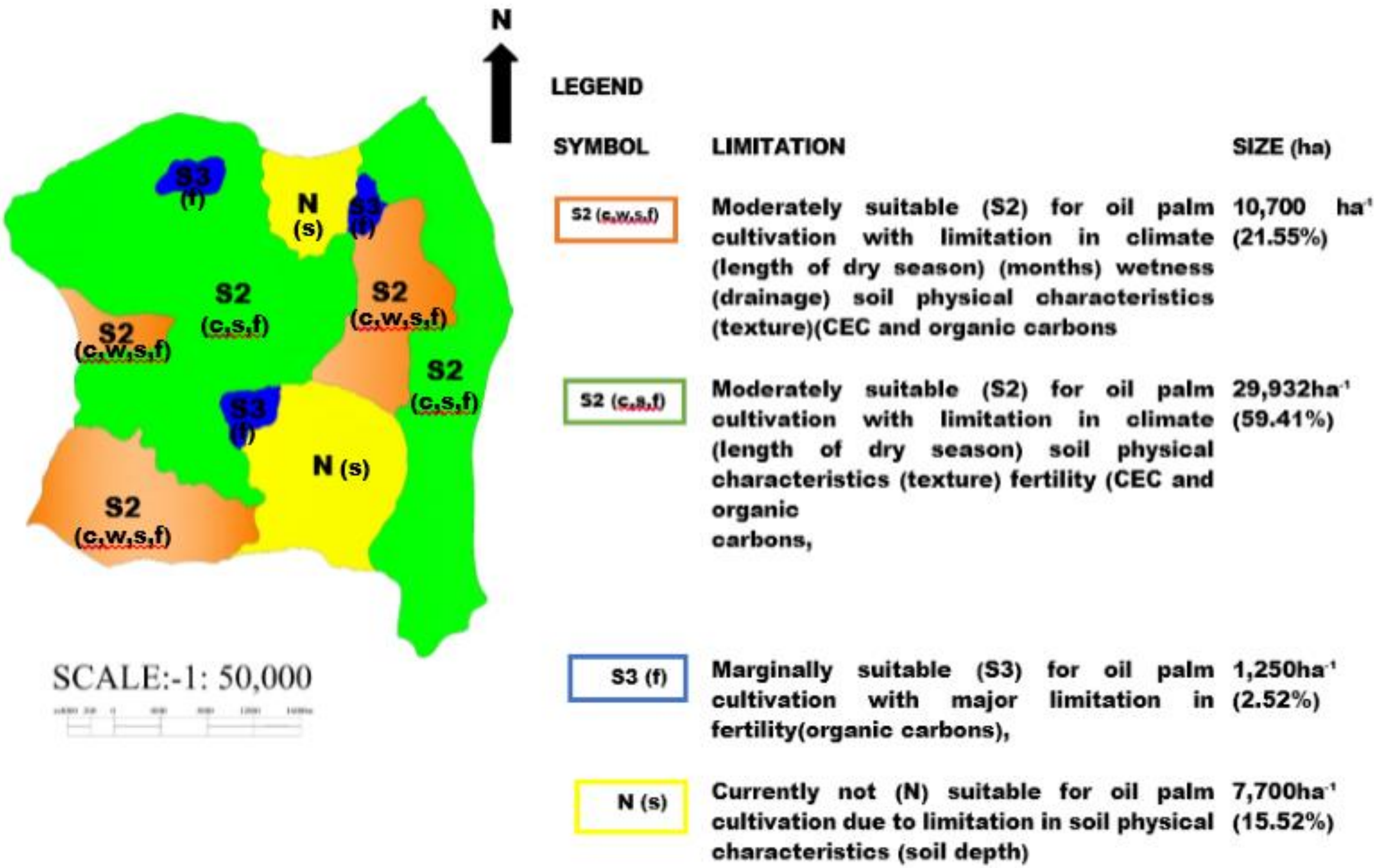
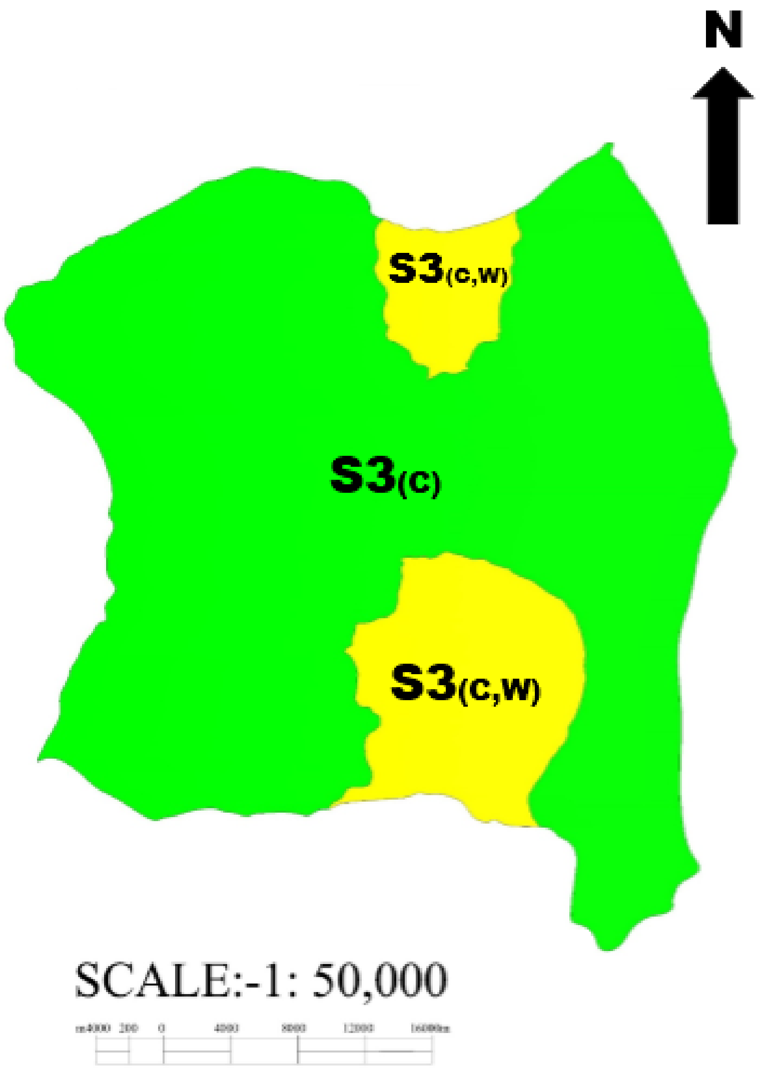


Fig. 10: Land Suitability Map for Oil palm in Khana LGA

Table 10: Summary Table for Suitability Evaluation for Plantain (*Musa spp*) cultivation in Pedons 1-8

Land Requirements/Land Suitability	Pedons and their Suitability Class (s)							
	P1	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**
Climate (c)								
Annual rainfall (mm)	2000 – 2500 (S3)	2000 – 2500 (S3)	2000 – 2500 (S3)	2000 – 2500 (S3)	2000 – 2500 (S3)	2000 – 2500 (S3)	2000 – 2500 (S3)	2000 – 2500 (S3)
Length of dry Season (months)	<2 months (S1)	<2 months (S1)	<2 months (S1)	<2 months (S1)	<2 months (S1)	<2 months (S1)	<2 months (S1)	<2 months (S1)
Mean Annual temp (°C)	25 – 28 (S2)	25 – 28 (S2)	25 – 28 (S2)	25 – 28 (S2)	25 – 28 (S2)	25 – 28 (S2)	25 – 28 (S2)	25 – 28 (S2)
Topography (t)								
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)								
Flooding	F1 (S2)	F0 (S1)	F0 (S1)	F2 (S3)	F1 (S2)	F0 (S1)	F0 (S1)	F0 (S1)
Drainage (surface)	MD (S2)	WD (S1)	WD (S1)	PD (S3)	PD (S2)	WD (S1)	WD (S1)	WD (S1)
Soil Physical Characteristics (s)								
Texture (surface)	LS (S2)	LS (S2)	SL (S2)	LS (S2)	LS (S2)	LS (S2)	SL (S2)	LS (S2)
Surface stoniness vol.(%)0 -10cm	NIL (S1)	NIL (S1)	NIL (S1)	NIL (S1)	NIL (S1)	NIL (S1)	NIL (S1)	NIL (S1)
Rock outcrops (%)	NIL(S1)	NIL(S1)	NIL(S1)	NIL(S1)	NIL(S1)	NIL(S1)	NIL(S1)	NIL(S1)
Soil depth (cm)	131 (S1)	200 (S1)	200 (S1)	50 (N1)	120 (S1)	200 (S1)	200 (S1)	200 (S1)
Coarse Materials (%)	NIL (S1)	NIL (S1)	NIL (S1)	NIL (S1)	NIL (S1)	NIL (S1)	NIL (S1)	NIL (S1)
Fertility (f)								
CEC (mol-Kg^{-1}) clay	2.68– 5.65 (S2)	2.01– 3.41(S2)	4.5 – 6.3 (S2)	3.7– 3.9 (S2)	3.05 – 6.5 (S2)	2.76 – 4.1(S2)	3.6 – 5.4 (S2)	1.76 – 3.44 (S2)
Base Saturation (%)	34.9 – 56.34 (S1)	38 – 54.1 (S1)	21.2 – 47 (S1)	34 – 45 (S1)	24.84 – 55.23 (S1)	28.81 – 32.5 (S1)	34 – 4.99 (S1)	37.9 – 57.3 (S1)
pH (H_20)	5 .5 – 6.13 (S1)	5 .60 – 6.16 (S1)	5.14 – 6.11 (S1)	5.43 – 6.08 (S1)	4.50 – 5.71 (S2)	4.31 – 4.81 (S2)	4.70-5.90 (S1)	5.8 – 5.83 (S1)
Organic carbon (%) 0-15cm	1.42 (S1)	1.06 (S1)	1.02 (S1)	1.1 (S1)	1.11 (S1)	1.11 (S1)	1.001 (S1)	0.4 (N1)
Alkalinity (Esp)	0.04 (S1)	0.2 (S1)	0.04 (S1)	0.05 (S1)	0.04 (S1)	0.055 (1)	0.009 (S1)	0.2 (S1)
Aggregate Suitability class	S3 (c)	S3 (c)	S3 (c)	S3 (c, w)	S3 (c)	S3 (c)	S3 (c)	S3 (c)
Size (Hectare)	4750	1400	6832	5850	4950	5350	3350	650
% coverage	9.57	2.82	13.77	11.79	9.97	10.78	6.75	1.31

Source: Djaenudin et al., (2003) Modified from Sys et al., (1991)



LEGEND

SYMBOL	LIMITATION	SIZE (ha)
S3 (c,w)	Marginally suitable (S3) for plantain cultivation with limitation in climate (rainfall), wetness (flooding)	$7700ha^{-1}$ (15.52%).
S3 (c)	Marginally suitable (S3) for plantain cultivation with major limitation in climate (rainfall)	$41,932ha^{-1}$ (84.4%).

Fig. 12. Land Suitability Map for Plantain in Khana LGA.

CONCLUSION

None of the pedons (mapping units) was highly suitable (S1) for oil palm and plantain production in the study area. Pedon 1, 2 3 3 5 6 and 7 were moderately suitable for the cultivation of oil palm with limitations in climate, wetness, soil physical characteristics and fertility, while pedon 4 was permanently not suitable for oil palm cultivation due to defects in soil depth to water table and pedon 8 was marginally suitable for oil palm cultivation with constraint in fertility. Pedon 1, 2, 3, 5, 6, 7 and 8 were marginally suitable for plantain cultivation with major limitation in climate (rainfall); while pedon 4 was also marginally suitable for plantain cultivation but with limitations in both climate (high rainfall) and wetness of the soils (depth to water table). Therefore, we recommend that the major constraints/ defects militating against profitable oil palm and plantain production in the study area should be managed through an integrated management system approach that will identify mitigation measures for the improvement of the productive capacities of the soils of the LGA. While for the purposes of specificity and economic suitability, oil palm (40,782 hectares) cultivation is recommended for profitable and sustainable agriculture in the study area.

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