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CONTENTS

Unrevealing the role of epistasis through Triple Test Cross in Indian mustard **330**
NARENDER SINGH, USHA PANT, NEHA DAHIYA, SHARAD PANDEY, A. K. PANDEY and SAMEER CHATURVEDI

Testing of InfoCrop model to optimize farm resources for mustard crop under *tarai* region of Uttarakhand **335**
MANISHA TAMTA, RAVI KIRAN, ANIL SHUKLA, A. S. NAIN and RAJEEV RANJAN

In vitro **evaluation of endophytes and consortium for their plant growth promoting activities on rice seeds** **342**
DAS, J., DEVI, R.K.T. and BARUAH, J.J.

Effect of subsurface placement of vermicompost manure on growth and yield of wheat (*Triticum aestivum* L. Var. UP 2526) **348**
ABHISHEK KUMAR and JAYANT SINGH

Assessment of different nutrient management approaches for grain yield, gluten content and net income of common bread wheat (*Triticum aestivum* l.) in Western Himalayan region of Uttarakhand **359**
BHAWANA RANA and HIMANSHU VERMA

Suitability assessment of land resources forc assava(*Manihot esculentus* L.) and yam (*Dioscorea spp L.*) cultivation in Khana LGA, Rivers State, Southern Nigeria **367**
PETER, K.D., UMWENI, A.S. and BAKARE, A.O.

Biophysical and biochemical characters conferring resistance against pod borers in pigeonpea **375**
PARUL DOBHAL, R. P. MAURYA, PARUL SUYAL and S.K. VERMA

Population dynamics of major insect pest fauna and their natural enemies in Soybean **385**
SUDHA MATHPAL, NEETA GAUR, RASHMI JOSHI and KAMAL KISHOR

Fumigant toxicity of some essential oils and their combinations against *Rhyzopertha dominica* (Fabricius) and *Sitophilus oryzae* (Linnaeus) **389**
NIDHI TEWARI and S. N. TIWARI

Long term efficacy of some essential oils against *Rhyzopertha dominica* (Fabricius) and *Sitophilus oryzae* (Linnaeus) **400**
NIDHI TEWARI and S. N. TIWARI

Management strategies under chemicals, liquid organic amendments and plant extracts against black scurf of potato caused by *Rhizoctonia solani* Kühn in *tarai* regions of Uttarakhand **408**
SURAJ ADHIKARI, SHAILBALA SHARMA, R. P. SINGH, SUNITA T. PANDEY and VIVEK SINGH

Effective management strategies against ginger rhizome rot caused by *Fusarium solani* by the application of chemicals, bioagents and Herbal *Kunapajala* in mid hills of Uttarakhand **417**
SONAM BHATT, LAXMI RAWAT and T. S. BISHT

Distribution and morphological characterisation of isolates of *Fusarium moniliforme* fsp. *subglutinans* causing Pokkah Boeng disease of sugarcane in different sugarcane growing areas of Udham Singh Nagar district of Uttarakhand 429
HINA KAUSAR, BHAGYASHREE BHATT and GEETA SHARMA

Biointensive management of *Meloidogyne enterolobii* in tomato under glasshouse conditions 435
SHUBHAM KUMAR, ROOPALI SHARMA, SATYA KUMAR and BHUPESH CHANDRA KABDWAL

Effect of pre-harvest application of eco-friendly chemicals and fruit bagging on yield and fruit quality of mango 447
KIRAN KOTHIYAL, A. K. SINGH, K. P. SINGH and PRATIBHA

A valid and reliable nutrition knowledge questionnaire: an aid to assess the nutrition friendliness of schools of Dehradun, Uttarakhand 452
EKTA BELWAL, ARCHANA KUSHWAHA, SARITA SRIVASTAVA, C.S. CHOPRA and ANIL KUMAR SHUKLA

Potential of common leaves of India as a source of Leaf Protein Concentrate 460
RUSHDA ANAM MALIK, SHAYANI BOSE, ANURADHA DUTTA, DEEPA JOSHI, NIVEDITA, N.C. SHAHI, RAMAN MANOHARLALand G.V.S. SAIPRASAD

Job strain and muscle fatigue in small scale unorganized agri enterprises 466
DEEPA VINAY, SEEMA KWATRA, SUNEETA SHARMA and KANCHAN SHILLA

Drudgery reduction of farm women involved in weeding of soybean crop 475
SHALINI CHAKRABORTY

Childhood obesity and its association with hypertension among school-going children of Dehradun, Uttarakhand 482
EKTA BELWAL, K. UMA DEVI and APARNA KUNA

Spring water and it's quality assessment for drinking purpose: A review 489
SURABHI CHAND, H.J. PRASAD and JYOTHI PRASAD

Spatial distribution of water quality for Indo-Gangetic alluvial plain using Q-GIS 497
SONALI KUMARA, VINOD KUMAR and ARVIND SINGH TOMAR

Application of geospatial techniques in morphometric analysis of sub-watersheds of Nanak Sagar Catchment 505
AISHWARYA AWARI, DHEERAJ KUMAR, PANKAJ KUMAR, R. P. SINGH and YOGENDRA KUMAR

Evaluation of selected carbon sources in biofloc production and carps growth performance 516
HAZIQ QAYOOM LONE, ASHUTOSH MISHRA, HEMA TEWARI, R.N. RAM and N.N. PANDEY

Calcium phosphate nanoparticles: a potential vaccine adjuvant 523
YASHPAL SINGH and MUMTESH KUMAR SAXENA

Factors affecting some economic traits in Sahiwal Cattle 528
DEVESH SINGH, C. B. SINGH, SHIVE KUMAR, B.N. SHAHI, BALVIR SINGH KHADDA, S. B. BHARDWAJ and SHIWANSHU TIWARI

The effect of probiotics and growth stimulants on growth performance of Murrah Buffalo 532
SAMEER PANDEY, RAJ KUMAR, D.S. SAHU, SHIWANSHU TIWARI, PAWAN KUMAR, ATUL SHARMAand KARTIK TOMAR

Suitability assessment of land resources for cassava (*Manihot esculentus* L.) and yam (*Dioscorea spp L.*) cultivation in Khana LGA, Rivers State, Southern Nigeria

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ABSTRACT: This study was conducted in Khana Local Government Area of Rivers State, Southern Nigeria to investigate the suitability of agricultural land resources at semi detailed soil survey level using the nonparametric approach. Eight soil mapping units were established and suitable guidelines specific for each pedons were followed in establishing the suitability of the land for cassava and yam cultivation. The data from the eight pedons covering 49,631.54 hectares area were used for the assessment. The results showed that 40,681.54 hectares representing 81.97%of the total land in Khana LGA were moderately suitable (S2) for cassava production; while 8,950 hectares representing 18.04 % of the total land area were also marginally suitable (S3) for cassava production. An area of 30,582 hectares representing 61.82% were moderately (S2) suitable for yam production and 4,750 hectares representing 8.57 % were marginally suitable (S3); while 12,450 hectares representing 25.08% were currently not suitable (N) for yam production. Furthermore, the study showed that cassava and yam can adapt to similar environment in terms of climate, soil physical characteristics and fertility. Thus, land suitability map produced from this study would guide the choice of site to increase and sustain cassava and yam production in Khana.

Key words: Cassava and yam cultivation, land resources, Khana, suitability assessment, rivers State

Suitability assessment of land resources for the cultivation of certain community crops is a key to sustainable crop production visa'vis land use planning and policy making for agricultural crop production (Peter and Umweni, 2020a). Suitability assessment of land resource studies are aimed at categorizing better and poor qualities of agricultural land and suggest the best management practice to ameliorate some of the inherent land quality features as well as sustaining the better land qualities (Peter *et al.,* 2019). This study aimed at increasing the production of cassava and yam in the region to enhance national food security, rural empowerment and standard of living. Cassava and yam are some of the arable crops produced by small farmers in Khana Local Government Area for decades (Peter *et al*., 2019). These crops are important for both human as food, animal feed and raw materials for industries. According to Raji (2016), cassava play a very vital role as cash crop earner for growers and low food cost for both urban and rural dwellers as well as house hold food security and it is cultivated in all parts of Nigeria where rainfall is above 1000mm per annum, and cassava account for 70% of total tuber crops cultivated in Africa. Yam is a staple food crop of Nigeria which grows mainly on well drained soils (Peter and Aaron, 2019). Yam is mainly used for human food either boiled, roasted, baked, fried, pounded or in so many processed forms (Raji, 2016). Cassava and yam peels are also used to feed livestock such as goat, sheep, cattle and pig and also as organic source of fertilizers (Peter and Onweremadu, 2015). Irrespective of the economic contribution of these two community crops in Khana and huge production and the distributions of cassava and yam in neighbouring local governments and state, suitability assessment studies of the land resources in the area have not been conducted (Peter *et al.,* 2019). Thus, this study is intended to fill the gap in information in Khana Local Government Area of Rivers State for sustainable cassava and yam production. This will enable cassava and yam farmers in the area to make adequate land use initiative to improve and maintain high yields of their crops on sustainable basis and improve their standard of living.

MATERIALS AND METHODS

Study area

Khana local government is one of the four local governments that made up of Ogoni kingdom. It lies between 4.67172N and longitude 7.34398E (Peter and Umweni,2020). It covers 49,631.54 hectares of land located in the southern part of Nigeria. The area experiences early rain from February to December with little dry season from December to late February with a distribution that ranged between 2000 - 2500mm/annum in a bimodal form with two peaks in June and September and a period of low precipitation popularly known as August break (Oyegun and Olosunorisa, 2002, and Raji, 2016). Mean temperature of the area varies annually and seasonally between 25 and 28°C; and relative humidity also varies between 81-87% depending on the season of the year (Ayolagha and Peter, 2013, Peter and Anthony, 2017 and Peter and Umweni, 2020). The vegetation of Khana is the tropical rainforest dominated by tropical forest trees species such as *Delinox regia, Chrotariaexelsa, Mahogany, Iroko, Ciebapetandra* among others and some area are devoted to secondary vegetation and fallow with grasses such as Guinea grass (*Panicum maximum*) and Elephant grass (*Penisetum purpureum*) (Peter and Umweni, 2020). Anthropogenic activities such deforestation, crude oil pollution, bush burning and continuous croppinghave altered the natural vegetation in the area (Peter *et al.,* 2019). The major type of land use in the area, is the small-scale agriculture with community grown crops like cassava, yam, maize fluted pumpkin, cocoyam, okro etc. According to Peter and Umweni, (2020), four soil orders, largely Inceptisols/Cambisols, Entisols/ Arenosols, Ultisols/Acrisols and Alfisol/Lixisol are commonly identified in Khana. The soils are well drained coastal plain sand underlying alluviumof marine deltaic deposits commonly called Ogoni sands (Esu, 2010, Peter and Ayolagha, 2013, Peter and Onweremadu 2015, Peter and Anthony, 2017 and Peter and Umweni, 2020).

Field studies

A semi detailed soil survey was carried out on the 49.631.54 hectares of land in Khana. The entire land area of Khana LGA was gridded using 1000 m x 500 m grid (50ha per auger boring points) at semi detailed level of soil survey. A total of nine hundred and nine three (993) auger sampling points were identified. Eight mapping units were also identified and delineated at semi detailed level. One soil profile pit each of 2mx 2m x 2m was examined in each of the mapping unit and was described using FAO guidelines (1990)

Laboratory studies

Soil samples collected from each pedon was air-dried and crushed to pass through a 2mm sieve and analysis was carried out using standard laboratory procedures in the Soil Science Laboratory, Federal University Technology, Owerri, Imo State. Particle size analysis was determined by the hydrometer method (Juo,1979). Soil textural classes were determined using textural triangle (Soil Survey Staff, 2003). Bulk density was determined by core method as described by Blake and Hartge (1986). Soil Reaction (pH) was determined in H_2O and I N KCl solution. Organic carbon was determined by dichromate wet oxidation method of Walkey and Black (1934) as described in methods of soil analysis (Juo, 1979). Available Phosphorus (P) was determined by Bray and Kurtz No 2 (1945) method as described by Juo (1979) and Loganathan *et al.* (1984). Total nitrogen was determined by the Macro Kjedahl digestion method as described by Juo (1979) and Loganathan *et al*. (1984). Basic cations (Ca, Mg,

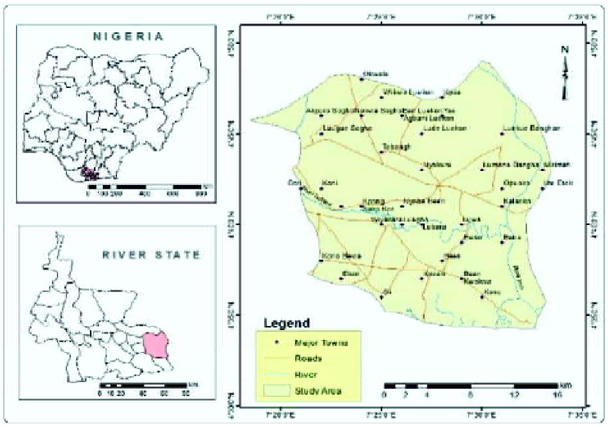

Fig. 1: Map of Khana Local Government Area (Project Site) Sources: Government of Rivers State, Office of Surveyor General (2014)

Table 1: Land requirements for the cultivation of Cassava *(Manihot sp. L.)* production

Land use requirement	S_1	S_12	S_2	S_3	N_1	N_2
Climate (c)						
Annual rainfall (mm)	1400-1800	1000-1400 1800-2400	750-600 >2400	600-500	550-500	<500
Length of growing season (months)	3-4	4-5 1-3	5-6 <1			
Mean temperature (°C)	26-20	26-30 20-18	>30 18-16	16-14	14-12	<12
Topography (t)						
Slope (%)	0-4	4-8	8-16	16-30	30-50	>50
Wetness (w)						
Drainage	Good	Good	moderate	Somewhat poorly drained	Poor drainage	Poor, very poor, not drainable
Soil physical characteristics (s) Texture	L,SCL	SC,SiCi,SiCL, CL, SCL, SC	Cs, Lfs, LS, LSC Fs	Cs,S,CS	SC,Cm	Cm,Si
Soil depth (cm)	>125	>100	>75	>55	>50	>50
Fertility (f)						
CEC (cmol/kg)	>16	Any	<10	<10	<5	<5
Base saturation (%)	35	35-20	20-15	15-10	<10	<10
Organic matter (g/kg O.C0-15cm	>15	8-15	<8	<5	<3	<2

Symbols used for soil texture and structure are defined as follows; Sc: structure clay, Cm: massive clay, SiCi: Silty 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 sand, LS: loam sand, LSC: loamy coarse sand, Fs: fine sand, S: sand, CS: coarse sand. Source: Senjobi and Ogunkunle, (2010).

Table 2: Land requirements for the Cultivation of Yam (*Dioscorea sp.* L.)

Land requirement/ Land characteristics	Land Suitability Class (s)			
	S1	S2	S3	N1
Climate (c)				
Annual rainfall (mm)	>2000	1300 – 1999	1000 – 1299	600 – 500
Moisture Availability (m)	≥5	4	3	<3
Length of growing season (Days	≥200	130 – 200	100 - 150	<100
Mean temperature (°C)	21- 28	25 – 30	30 – 35	>35
Topography (t)				
Slope (%)	0 – 4	4 – 8	8 – 16	16 – 30
Wetness (w)				
Flood hazard	F0	F1	F2	>F2
Drainage	Well drained	Moderate	Moderate	Poorly drain
Soil physical characteristics (s)				
Texture (surface)	LS, SCL	SC, SiC&SiCL	Cs, Lfs, LS, LSC & Fs	Cs, S & CS
Soil depth (cm)	Deep (>200)	>100	>75	>55
Fertility (f)				
Total N g/kg^{-1}	>1.5	<1.2	0.6	<0.6
pH (H_2O)	>5 – 6.5	4.5 – 5	4. 44	<4.0
ECEC (cmol/kg	>12	Any	8 – 5	<5
Base saturation (%)	>60	>40 – 60	20 -39	<20
Exchangeable K (cmol/kg	>2.0	1.5	1.0	<1.0
Organic matter (g/kg O.C	>15	8 – 15	<8	<5

Symbols used for soil texture and structure are defined as follows; Sc: structure clay, Cm: massive clay, SiCi: 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 sand, LS: loam sand, LSC: loamy coarse sand, Fs: fine sand, S: sand, CS: coarse sand. Source: Eze (2014) Modified from Sye*et al.* (1985)

K and Na) were determined by extracting soil with neutral ammonium acetate (I M NH_4OAc) buffered at pH 7.0. Exchangeable cations: Ca, Mg, K and Na were leached from the soil with NH_4OAc solution. Sodium and K were determined with a flame photometry. Soil CEC was determined as the sum of total exchangeable bases plus exchangeable acidity. Base Saturation was calculated using total exchangeable bases divided by CEC and multiplies by 100.

Land suitability evaluation

The suitability of soils was assessed for cassava and yam using non-parametric method of land suitability evaluation system (FAO, 1976). Each pedon was placed in their respective suitability classes by matching them with the already established land qualities requirements for the two crops of interest. According to Peter *et al.* (2019) and Peter and Umweni, (2020), the potentials and limitations were identified in Khana for the cultivation of cassava and yam using five land qualities/characteristics (climate, topography, wetness, soil physical properties and soil fertility) for determining the suitability of the soils. This was done using Senjobi and Ogunkunle, (2010) suitability guidelines for cassava and using Eze (2014) modified from Sys (1985) suitability guidelines for yam. Land suitability classes were obtained by matching some of the land qualities with the land use requirements for the two crops of interest produced in the study area. Aggregate suitability classes of each pedon for both cassava and yam, were 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 relevant land suitability maps.

Data Analysis

Spearman rho ranking correlations were used to compare the effective guidelines for the different crops

RESULTS AND DISCUSSION

Land suitability classification for cassava

The results of land suitability classes of the various pedons in the study area for cassava cultivation showed that Pedons 1 and 5 were moderately suitable (S2) for cassava cultivation with reasonable defects in climate, wetness and fertility (Table 3). This contradicts the finding of Raji (2016) who reported that the soils of Kwara were marginally suitable for cassava cultivation due to limitations in soil physical properties and fertility. The total land coverage for both pedons (1 and 5) is 10,700 hectares, that is, 21.55% of the study area. Pedons 2, 3, 6, and 7 were also moderately suitable (S2) for cassava cultivation with moderate constraints in climate and soil fertility. These four pedons covered a land area of 29,982 hectares and represented 60.41% of the total study area. Pedon 4 was marginally suitable (S3) for cassava cultivation with major defects in soil wetness and Pedon 4 covered an area of 7700 hectares representing 15.52 % of the study area. Pedon 8 was marginally suitable (S3) for cassava cultivation with

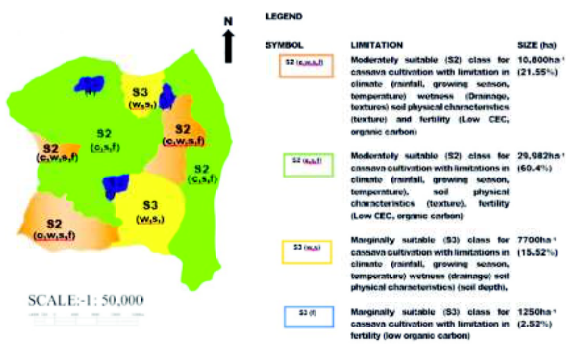

Fig. 2. Land Suitability Map for Cassava in Khana LGA

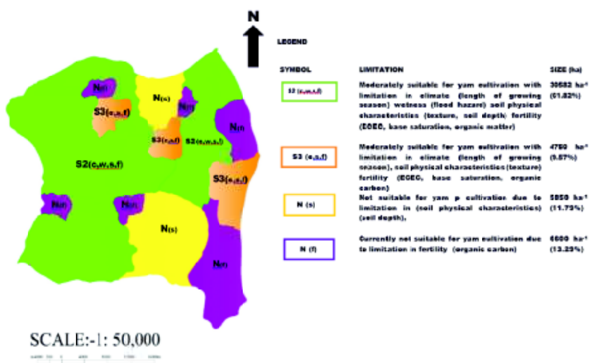

Fig. 3 Land Suitability Map for yam in Khana LGA

Table 3: Summary Table for Suitability Evaluation for Cassava (*Manihot sp. L.*) Cultivation for Pedons 1 - 8.

Land Requirements/Land Suitability	Pedons and their Suitability Class (s)							
	P1	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**
Climate (e)								
Annual rainfall (mm)	2000-2500 (S2)	2000-2500 (S2)	2000-2500 (S2)	2000-2500 (S2)	2000-2500 (S2)	2000-2500 (S2)	2000-2500 (S2)	2000-2500 (S2)
Length of growing Season	5 months (S2)	5 months (S2)	5 months (S2)	5 months (S2)	5 months (S2)	5 months (S2)	5 months (S2)	5 months (S2)
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)
Wetness (W)								
Drainage (surface)	MD (S2)	WD (S1)	PD (S1)	MD (S3)	MD (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)	SL (S2)
Soil depth (cm)	131 (S1)	200 (S1)	200 (S1)	50 (S3)	120 (S2)	200 (S1)	200 (S1)	200 (S1)
Fertility (f)								
CEC (mol-Kg^{-1}) clay	2.68–5.7 (S2)	2.01–3.41 (S2)	4.52– 6.3 (S2)	3.75–3. 92 (S2)	3.05–6.5 (S2)	2.04–3.72 (S2)	3.64–5.0 (S2)	1.76 –3.34 (S2)
Base Saturation (%)	34.9–56.34 (S1)	37.91–50.4 (S1)	21.22–47 (S1)	34.06–44.95(S1)	24.84–55.23 (S1)	59.35–90 (S1)	30.37–61.62 (S1)	37.9–57.3 (S1)
Organic carbon (g/kg^{-1}) 0-15cm	1.48 (S2)	1.06 (S2)	1.02 (S2)	1.08(S2)	1.11 (S2)	0.82 (S2)	1.001(S2)	0.35 (S3)
Aggregate Suitability Class	S2 (c, w, s, f)	S2 (c, s , f)	S2 (c, s, f)	S3 (w , 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: Senjobi and Ogunkunle, (2010)

- Pedons 1, 2, 3, 5, 6, 7 (40,682 ha) were moderately suitable (S2) for cassava cultivation with limitations in climate (rainfall, length of growing season and mean annual temperature), soil physical properties (texture) and fertility (low CEC and organic carbon).
- Pedon 4 (7700 ha) was marginally suitable (S3) for cassava cultivation with limitations in wetness (drainage) and soils physical characteristic (eg depth to water table).
- Pedon 8 (1250 ha) was also marginally suitable (S3) for cassava cultivation but with constrain in fertility (low organic carbon).

major limitations in soil fertility. This is in tandem with the report of Raji (2016), and these soils would become moderately suitable, if the fertility problems were addressed through fertilizer applications. Marginal suitability (S3) of pedon 8 for cassava cultivation due to defects in fertility was also in line with the findings of Kintche *et al.*(2017), who reported that most cassava yield loss to farmers was mainly as a result of poor soil fertility leading to poor growth and development. This is also in tandem with the observations of Ande (2011) who reported that CEC and organic carbon markedly influenced almost all soils properties, especially when their levels are beyond critical limit for crop growth. Pedon 4 had specific limitations of soil depth and surface drainage. This is similar to the findings of Ande (2011) regarding the soil suitability evaluation and management for Cassava cultivation in the Derived Savanna Area of Southwestern Nigeria.

Land Suitability Classification for Yam

The results of suitability rating or classes for the cultivation of yam across the eight pedons in the area showed that Pedons 1, 3 and 5 were moderately suitable (S2) for yam cultivation in the study area with limitations in climate, wetness, soil physical characteristics and fertility (Table 4). Similar observations were reported by other workers (Asadu and Ezike, 2017 and Ali *et al.,* 2017) that low fertility status of soils especially, nitrogen, magnesium and calcium, affects the leaf and tendril growth and tuber formation in yam and yam tuber yield correlated to the

Table 4: Summary Table for Suitability Evaluation for Yam (*Dioscorea sp. L.*) cultivation in Pedons 1-8

Land Requirements/Land Suitability	P1	P2	P3	P4	P5	P6	P7	P8
Climate (c)								
Annual 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)
Moisture Availability (m)	8 Months (S1)	8 Months (S1)	8Months (S1)	8 Months (S1)	8 Months (S1)	8 Months (S1)	8 Months (S1)	8 Months (S1)
Length of growing season (Days)	180 (S2)	180 (S2)	180 (S2)	180 (S2)	180 (S2)	180 (S2)	180 (S2)	180 (S2)
Mean temperature (°C)	22–28 (S1)	22–28 (S1)	22–28 (S1)	22 - 28 (S1)	22–28 (S1)	22–28 (S1)	22–28 (S1)	22–28 (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)								
Flood hazard	F1 (S2)	F0 (S1)	F1 (S1)	F2 (S3)	F1 (S2)	F0 (S1)	F0 (S1)	F0 (S1)
Drainage	M (S2)	WD (S1)	WD (S2)	P-M (S3)	PM (S2)	WD (S1)	WD (S1)	WD (S1)
Soil physical characteristics (s)								
Texture (surface)	SL (S1)	SL (S2)	SL (S2)	LS (S2)	LS (S1)	SL (S2)	SL (S2)	SL (S1)
Soil depth (cm)	131 (S2)	200 (S1)	200 (S2)	50 (N1)	120 (S2)	200 (S1)	200 (S1)	200 (S1)
Fertility (f)								
Total N g/kg	1.39 (S2)	1.09 (S2)	0.90(S2)	1.07 (S2)	0.41 (S2)	0.45 (N1)	1.12 (S2)	0.70 (S2)
pH (H_2O)	>5.5–6.13 (S1)	5.60–6.16 (S1)	5.14–6.11 (S1)	5.43–6.08 (S1)	4.50–5.71 (S1)	4.31–4.81 (S3)	4.70–5.90 (S1)	5.67–5.83 (S1)
CEC (cmol	2.68–5.65 (S2)	2.01–3.41(S2) (S2)	4.52–6.27 (S2)	3.75–3.92 (S2)	3.05–6.49 (S2)	2.76–4.02 (S3)	3.64–4.99 (S2)	1.758–3.439 (S2)
Base saturation (%)	34.87–56.36 (S2)	37.91–54.1 (S1)	21.22–47 (S2)	34.06–44.96 (S3)	24.84–55.23 (S2)	34.87–56.36 (S2)	30.37–61.62 (S2)	37.85–57.26 (S2)
Organic carbon (g/kg)	1.48 (S2)	1.06 (S2)	1.02 S2	1.083 S2	0.82 (S2)	1.11 S2	1.001 (S2)	0.35 (N1)
Aggregate Suitability class	S2 (c, w, s, f)	S2 (c, s, f)	S2 (c, w, s, f)	N1 (s)	S2 (c, w, s, f)	N1 (f)	S2 (c, s, f)	N1 (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: Eze (2014) Modified from Sys (1985)

•Pedons 1, 3, and 5 (30582) were moderately suitable (S2) for yam cultivation but with limitations in climate (length of growing season), wetness (flood hazard and drainage), soil physical properties (soil texture and depth) and fertility (low total nitrogen, base saturation, ECEC and organic carbon).

•Pedons 2 and 7 (4750 ha) were also moderately suitable for yam cultivation but with defects in climate length of growing season), soil physical properties (soil texture) and fertility (low nitrogen, ECEC and organic carbon).

•Pedon 4 (7700 ha) was not suitable (N) for yam cultivation due to defect in soil physical characteristics (soil depth to water table).

•Pedon 6 and 8 (6600 ha) were current not suitable (N) for yam cultivation due to limitation in fertility (low nitrogen and organic matter).

maximum leaf index and there was a need to improve some cultural practices to conserve the fertility status of soils. The three pedons (1, 3 and 5) covered a land area of 30,000 hectares and, represented 61.62 % of the total land in the study area. Pedons 2 and 7 were also moderately suitable (S3) for yam cultivation in the study area with limitations in climate, soil physical properties and fertility and, covered 4,750 hectares, representing 9.57 % of the total land in the study area. Pedon 4 was permanently not suitable (N) for yam cultivation with severe defects in soil depth. It covered an area of 7,700 hectares, (13.52 % of the land). Pedons 6 and 8 were currently not suitable (N) for the cultivation of yamdue to severe defects in fertility and, covered 6,600 hectares of land (13.29 % of the total land). As regards the specific fertility limitations, total nitrogen was moderate in all the eight pedons. Total N and Organic carbon were very low in pedons 6 and 8. However, this limitation can be corrected by the application of organic and inorganic manures to the soils in the study area, thereby changing them to become moderately suitable (S2). This is also in line with the findings of Raji (2016) who reported that the soils with low fertility status can be easily corrected by addition of organic or inorganic amendments at recommended rates.

CONCLUSION

It is concluded that 75% of the total land sites in KhanaLGA were moderately suitable (S2) for cassava and yam production which cover 40,681.54 hectares (81.97% of the total land) in Khana LGA, while 8,950 hectares representing 18.04 % of the total land area were also marginally suitable (S3) for cassava production. Again, 30,582 hectares (61.82%) were moderately (S2) suitable for yam production and 4,750 hectares (8.57 %) were marginally suitable (S3); while 12,450 hectares (25.08%) were currently not suitable (N) for yam production. The land suitability map produced from this study should be employed as a basis for land site selection for cassava and yam production for increasing the output for cassava and yam in Khana Local Government Area of Rivers State.

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