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Land Suitability Assessment for Sustainable Vegetables Production in Kumbotso Local Government Area of Kano State, Nigeria

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Abstract

The study was carried out in an irrigation site of Kumbotso Local Government Area of Kano State, with the aim to assess the suitability of soils for vegetables production (Tomato, Onion and Cabbage). Three soil units were identified, and three profiles were sunk in each of the unit. The profiles were described according USDA soil survey manual, and soil samples were collected from pedogenic horizons. The soil samples were analyzed for various physical and chemical properties following the standard procedures. The soil fertility of the areas was low and bulk density ranges from moderate to high which may affect onion production. All the soil units are suitable for production of tomato and cabbage crops, except soil units 4, 5 and 6 which are not suitable for any crop across all the methods, while simple limitation and Khiddir methods classified all the soil units as not suitable for onion production. The suitability of soils for vegetable production increases from SLM to Rabia squire root method, with Khiddir showing poor performance. Rabia method performed better than any method followed by Khiddir and SLM for tomato and cabbage production, additionally, in terms of onion evaluation, Rabia method is also the best followed by Storie, and SML. The major advantage of employing various suitability evaluation methods may assist farmers to make wide range of choices with respect of crops to be grown in the land.

Keywords:

Suitability classes Pedogenic horizon Simple Limitation Method Rabia Square-root Method Khiddir method

JEL Classification:

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1. Introduction

Agriculture is one of the paramount sectors in Nigeria's economy contributing to over 20% of gross domestic product (GDP) and with over 70% of the population engaged in farming (World Bank, 2016). Despite such engagement,

the country still faced huge food security challenges with average food deficit of 42 kcal per capita per day between 2014 and 2016 (FAOSTAT, 2017). Agricultural productions in Nigeria is predominantly characterized by poor inputs and managements, carried out under rain fed or irrigation systems, with very low outputs, which were mostly determined by biophysical and environmental factors.

Vegetable production is widely increasing throughout the world which may exert pressure on available resources considering the rapid growth of the world population. This may in its turn be a limiting factor to arable lands around the world, and the need for effective and efficient application of land resources was strongly needed, especially through land evaluation. FAO (1993) emphasized that sustainable agriculture would only be achieved if lands are categorized and utilized based upon their different uses. Land evaluation assesses the performance of land based on more or less systematic analyses of the physical and chemical conditions. Land evaluation is a tool or a technique to compare the various use potentials and benefits that can be obtained from the specific land that support various crop productions. The meaning of land evaluation in its simplest form was to selects the best lands for specific purpose.

Tomato, onion, and cabbage are important vegetable crops used in many households every day in Nigeria, and their nutritional benefits cannot be overemphasis. There is urgent need to boost and sustain the production of these crops through detailed assessment of their production sites. Therefore, the study was aimed to assess the suitability of various soils for vegetable production using different methods.

Materials and Methods

The study was carried out within the irrigation site of the floodplains of the confluence between River Challawa and River Kano in the southern part of Kano City in Kumbotso Local Government Area of Kano State. It was located between latitude 11.84925° and 11.866868°, and longitude 008.502147° and 008.523708°, with average elevation of 436m. Three soil sectors were identified, and three soil units were further identified in each sector, one profile was sunk in each unit, described and sampled according to USDA soil survey manual (Soil Survey Staff, 1981). Standard laboratory procedures were followed to analyze the soil samples, most of the properties analyzed directly influenced the performance of vegetable crops. Particle size distribution was done using the Bouyoucos (1953) Hydrometer Method (Gee and Or, 2002) while Bulk density was determined using the core sampler method (Campbell and Henshall, 1991). Soil pH was determined in glass electrode using 1:2.5 soils: water ratio (IITA, 1982), Electrical conductivity (EC) was read in EC meter using Bower and Wilcox (1965) method, Organic carbon was determined using Walkey and Black (1934) wet oxidation method (Nelson and Summer, 1982), Cation exchange capacity was determined with 1M ammonium acetate (NH4OAc) buffered at pH 7.0 (Chapman, 1965; Rhodes, 1982). Total nitrogen content of the soil was determined using the Macro-Kjeldhal Method. Exchangeable sodium percentage (ESP) was calculated after analyzing sodium concentration and cations exchange capacity of the soil using the relation:

$$\% ESP = \frac{Exc.Na^+}{CEC} x \ 100$$

Soil suitability evaluation procedure

The suitability assessment methods considered in this study were simple limitation (SLM) and parametric methods (PR). In SLM procedure, the crops requirement tables were made (Table 1 and 2), and matched with the present land characteristic (Table 3 and 4). Depending on the extent of their matches, the final suitability class was assigned as suitable (S1), moderately suitable (S2), marginally suitable (S3) and not suitable (N). The overall suitability class was determined by the most limiting factor among the various matching, except Rabia method where most maximum factor was considered. methods Parametric (PM) consists of numerical rating of different limitation levels of land and climatic characteristics according to numerical scale between the maximum value normalized as 100% and the minimum value of 0. The classes were designated as 100 - 75, 74-50, 49 - 25 and 24 - 0 which were equivalent to qualitative class S1, S2, S3 and N respectively. Lastly, the climatic as well as the land indices were calculated from these individual rating, as shown in the following procedures;

1. The Storie method (Storie, 1978):

$$I = A x \frac{B}{100} x \frac{C}{100} x \frac{DC}{100}$$
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where I is the specified index and A, B, C etc. are different ratings given for each property.

2. Square Root Method (Khiddir, 1986):

$$I = A_{min} \ x \ \sqrt{\frac{B}{100}} \ x \ \frac{C}{100} \ x \ \frac{D}{100} \ 2$$

3. Rabia and Terribile (2013):

$$I = A_{max} \ x \ \sqrt{\frac{B}{100}} \ x \ \frac{C}{100} \ x \ \frac{D}{100} \qquad 3$$

where A and Amin are the minimum rating class, A_{max} is the maximum rating value, and B, C, D etc. are the remaining ratings (%) other than minimum and maximum in each factor.

2. Results and Discussions

The result of soil analyses was presented in Tables 3 and 4. The soil texture in all the soil units were sandy loam and loam, except soil unit 9 where loamy sand was observed, and all the soil textures were within the textural classes required for optimum vegetable production. Brady and Weil (2010) linked soil texture to nature of parent materials from which the soils were derived, and the rate and nature of weathering processes. Bulk density has very significant role in onion production, and therefore varied across the locations (1.32 -1.62 gcm⁻³), and the topography was level $(0 - 1)^{-3}$ 2 %) to slightly sloppy (2 - 4%), which may affect the infiltration rate of the soils and water retention. The soil pH were slightly acidic to neutral in reaction (6.6-7.0) in all the soil units, and salinity (EC 0.05-2.05 dSm⁻¹) and sodicity (ESP 0.59-1.56%) were absent in all the soils units (Table 3). The fertility of the soil was rated low (Chude, et al., 2011) with the evidence of low organic carbon (0.55-0.99%), total nitrogen (0.01-0.02%) and CEC (<15 $cmol(+)kg^{-1}$).

		Suitability Rating						
Land Quality/soil site characteristics		Unit	S1	S2	S3	Ν		
			75-100	50-74	25-49	<25		
	Mean temperature	с	25 - 28	29 – 32,	33 – 36,	<15,		
Climatic (c)	In growing season			20 - 24	15 - 19	>36		
	Total rainfall	mm	600 - 750	500-600,	450-500,	<450,		
				750-100	>1000	>1000		
Topography (t)	Slope	%	1-3	3-5	5-10	>10		
Wetness (w)	Soil drainage	-	Well	Moderate	Imperfect	Poor		
			drained					
Soil physical	Texture	-	sl, l, cl, scl	sicl, sic,	С	ls, s		
				sc,c				
Properties (s)	Soil depth	cm	>75	50 - 75	25 - 50	<25		
Fertility	pH	1:2.5	6.0 - 7.0	5.0 – 5.9,	<5,>8.5			
				7.1 - 8.5				
	CEC	cmol(+)kg ⁻¹	>15	10-15	10-5	<5		
Soil toxicity (n)	Salinity (EC)	dSm ⁻¹	<4	4 - 8	8-16	>16		
	Sodicity (ESP)	%	<15	15-20	19 - 25	>25		
Source: Modified from NBSS&LUP 1994								

rce: Modified from NBSS&LUP, 1994

			Suitability Rating						
Land Quality/so	il site	Unit	S1	S2	S3	Ν			
characteristics			75-100	50-74	25-49	<25			
	Mean temperature	с	14-19	20 - 25,	26 – 30,	>30			
Climatic (c)	In growing season		500 600	20 - 24	15 -19	>36			
		111111	300-000	430-300, 600 -700	/00-800	<430, >800			
Topography (t)	Slope	%	1-3	3-5	5-10	>10			
Wetness (w)	Soil drainage	Class	Well drained	Moderate	Imperfect	Poor			
Soil physical	Texture	Class	sl, l, cl	sicl,sic, sc,c	c	ls, s			
Properties (s)	Soil depth Bulk density	cm gcm ⁻³	>75 1.3-1.4	50 - 75 1.1-1.2, 1.5 -1.6	25 - 50 1.6 - 1.7	<25 <1, >1.7			
Fertility	рН	1:2.5	5.8 - 6.5	5.4 - 5.7, 6.6 - 7.5	5- 5.4 -, 7.5-8.0	<5,>8			
	Organic Carbon	%	>1.5	1.5 - 1	0.5 - 1	< 0.5			
	Nitrogen	%	>2	1.5 - 2	1.0 - 1.4	<1			
	CEC	cmol(+)kg ⁻¹	>15	10-15	10-5	<5			
Soil toxicity (n)	Salinity (EC)	dSm ⁻¹	1.2 - 3	1.0 - 1.2, 3.1-4	>4				
	Sodicity (ESP)	%	<15	15-20	19 - 25	>25			

 Table 2: Land suitability criteria (crop requirement) for Onion production

The low CEC observed might be attributed to the low clay and organic matter content. The finding was in agreement of the results obtained by Havlin et al. (2005) and Yakubu et al. (2011) who attributed strong relationship between CEC with clay, sand and organic materials.

The criteria summarized by Sys *et al.* (1991) and FAO (1993) were used for identifying vegetable crops requirement (Tables 1 and 2) and the value of each soil property was matched with present land characteristics (Table 3 and 4). Simple Limitation Method (SLM) and Parametric Methods (Storie and Square Root methods (Khiddir and Rabia)) were used for assessing

the suitability of the soils to onion, tomato and cabbage crops productions.

In the Simple limitation method, the overall suitability of particular class was controlled by the most limiting factor as shown in Tables 5 and 6 for tomato, cabbage and onion. The soil units 1, 2, 3, 7, and 8 were placed into marginally suitable class (S3) with climate and fertility as the major limitations. Soil units 4, 5, 6 and 9 were considered not suitable for either tomato or cabbage production, with pronounced limitations related to climate, shallow water table and fertility, with some soil physical restrictions Table 5).

Source: Modified from NBSS&LUP, 1994.

Land Characteristics	Sector One			Sector Two			Sector Three		
	Unit 1	Unit 2	Unit 3	Unit 4	Unit 5	Unit 6	Unit 7	Unit 8	Unit 9
Temperature °C	26 - 30	26 - 30	26 - 30	26 - 30	26 - 30	26 - 30	26-30	26 - 30	26 - 30
Rainfall mm/annum	800	800	800	800	800	800	800	800	800
Topography	2 - 4	2 - 4	2 - 4	0 - 2	0 - 2	0 - 2	0 - 2	0 - 2	0 - 2
Drainage	WD	WD	WD	PD	PD	PD	WD	WD	WD
Texture	Sandy Loam	Sandy Loam	Sandy Loam	Loam	Sandy Loam	Sandy Loam	Sandy Loam	Loam	Loamy sand
Depth (cm)	207	207	200	75	95	85	217	210	200
pН	7.0	7.1	7.0	6.6	7.7	7.4	7.3	7.2	7.1
CEC (cmolkg ⁻¹	5.2	6.0	6.1	6.5	5.9	5.9	6.1	6.2	6.1
Salinity(EC) dSm ⁻¹	0.28	0.5	0.05	2.05	0.62	0.64	0.42	0.71	0.33
Sodicity (ESP) %	1.56	1.35	0.85	0.98	0.98	0.59	0.95	0.79	1.19

Table 3: land Characteristics use for suitability rating of the site for Tomato and Cabbage productions

Note: WD=well drain, PD=poorly drain, CEC=cation exchange capacity, EC=electrical conductivity, ESP= exchangeable sodium percentage.

Land Characteristics	Sector One			Sector T	Sector Two			Sector Three		
	Unit 1	Unit 2	Unit 3	Unit 4	Unit 5	Unit 6	Unit 7	Unit 8	Unit 9	
Temperature °C	26 - 30	26 - 30	26 - 30	26 - 30	26 - 30	26 - 30	26 - 30	26 - 30	26 - 30	
Rainfall mm/annum	800	800	800	800	800	800	800	800	800	
Topography (t)	2 - 4	2 - 4	2 - 4	0 - 2	0 - 2	0 - 2	0 - 2	0 - 2	0 - 2	
Drainage (w)	WD	WD	WD	PD	PD	PD	WD	WD	WD	
lexture	Sandy Loam	Sandy Loam	Sandy Loam	Loam	Sandy Loam	Sandy Loam	Sandy Loam	Loam	Loam y sand	
Depth (cm)	207	207	200	75	95	85	217	210	200	
Bulk density (gcm ⁻³)	1.60	1.55	1.6	1.32	1.50	1.33	1.51	1.41	1.62	
pН	7.0	7.1	7.0	6.6	7.7	7.4	7.3	7.2	7.1	
Organic carbon (%)	0.89	0.65	0.9	0.58	0.86	0.99	0.77	0.82	0.55	
Nitrogen (%)	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.02	
CEC (cmolkg ⁻¹)	5.2	6.0	6.1	6.5	5.9	5.9	6.1	6.2	6.1	
Salinity(EC) dSm ⁻¹	0.28	0.5	0.05	2.05	0.62	0.64	0.42	0.71	0.33	
Sodicity (ESP) %	1.56	1.35	0.85	0.98	0.98	0.59	0.95	0.79	1.19	

Table 4: Land Characteristics use for suitability rating of the site for Onion production

Note: WD=well drain, PD=poorly drain, EC=electrical conductivity, ESP= exchangeable sodium percentage

Land Characteristics	Sector One			Sector Two			Sector Three		
	Unit 1	Unit 2	Unit 3	Unit 4	Unit 5	Unit 6	Unit 7	Unit 8	Unit 9
Temperature °C	S 3	S 3	S 3						
Rainfall mm/annum	S 3	S 3	S 3						
Topography	S2	S2	S2	S 1	S 1	S 1	S 1	S 1	S 1
Drainage	S 1	S 1	S 1	Ν	Ν	Ν	S 1	S 1	S 1
Texture	S 1	S 1	Ν						
Depth (cm)	S 1	S 1	S 1	S2	S 1	S 1	S 1	S 1	S 1
рН	S2	S2	S2	S2	S 3	S2	S2	S2	S2
CEC (cmolkg ⁻¹	S 3	S 3	S 3						
Salinity(EC) dSm ⁻¹	S 1	S 1	S 1	S 3	S 1	S 1	S 1	S 1	S 1
Sodicity (ESP) %	S 1	S 1	S 1						
Overall suitability	S3cf	S3cf	S3cf	Ncwf	Ncwf	Ncwf	S3cf	S3cf	Ncsf

Table 5: Soil suitability rating for Tomato and Cabbage Using SLM

Note: WD=well drain, PD=poorly drain, CEC=cation exchange capacity, EC=electrical conductivity, ESP= exchangeable sodium percentage

Land Characteristics	Sector One Sector Two		Sector 7	Sector Three					
	Unit 1	Unit 2	Unit 3	Unit 4	Unit 5	Unit 6	Unit 7	Unit 8	Unit 9
Temperature °C	S 3	S3	S 3	S 3	S 3	S 3	S 3	S 3	S 3
Rainfall mm/annum	S 3	S 3	S 3	S 3	S 3	S 3	S 3	S 3	S 3
Topography	S2	S2	S2	S 1	S 1	S 1	S 1	S 1	S 1
Drainage	S 1	S 1	S 1	Ν	Ν	Ν	S 1	S 1	S 1
Texture	S 1	S 1	S 1	S 1	S 1	S 1	S 1	S 1	Ν
Depth (cm)	S 1	S 1	S 1	S2	S 1				
Bulk density	S2	S2	S2	S 1	S2	S 1	S2	S 1	S 3
рН	S2	S2	S2	S2	S 3	S2	S2	S2	S2
Organic Carbon	S 3	S 3	S 3	S 3	S 3	S 3	S 3	S 3	S 3
Nitrogen	Ν	Ν	Ν	Ν	Ν	Ν	Ν	Ν	Ν
CEC (cmolkg ⁻¹	S 3	S 3	S 3	S 3	S 3	S 3	S 3	S 3	S 3
Salinity(EC) dSm ⁻¹	S 1	S 1	S 1	S 3	S 1				
Sodicity (ESP) %	S 1	S 1	S 1	S 1	S 1	S 1	S 1	S 1	S 1
Overall suitability classes	Ncf	Ncf	Ncf	Ncwf	Ncwf	Ncwf	Ncf	Ncf	Ncsf

Table 6: Soil suitability rating for Onion production Using SLM

Note: WD=well drain, PD=poorly drain, CEC=cation exchange capacity, EC=electrical conductivity, ESP= exchangeable sodium percentage

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The result of land suitability assessment for simple limitation in tomato and cabbage production was presented in Table 5, and it was revealed that soil units 1, 2, 3, 7 and 8 are marginally suitable (S3) for tomato and cabbage crop production, climate and fertility are the major constrain for optimum production. Soil units 4, 5, 6 and 9 were not suitable (N) for the production of tomato and cabbage and the mains limiting factors observed in these units were climate, fertility, wetness and soil texture.

Based on the matching of present soils characteristic (Table 3) with the crops requirements (Table 2) in simple limitation methods, the results revealed that all the soil units were not suitable (N) for onion production (Table 6), due prevalence of limitations in climate, fertility, wetness and soil texture, and some of these limitations are very difficult to control (temperature and soil texture). Although, climatic condition was marginally favorable for production of onion, and other conditions like soil depth, electrical conductivity and exchangeable sodium

percentage were highly favorable, hence crop yield are directly influence by the most limiting factor which affect the growing conditions of the environment.

Three parametric methods were used for assessing the suitability of the soils for the growth of vegetables (Table 7). According to Storie index method, all the soil units were ranged from highly suitable (S1) to marginally suitable (S3) except two soils units that were not suitable (Unit 4 and 5) for tomato and cabbage production (Table 7), while most of the soil units can support vegetable onion crop production, except soil unit 4, 5 and 9 which were not suitable. Soil units 7 and 8 were highly suitable for tomato and cabbage crops production, while units 1, 2, 3 (S2) and 6 and 9 (S3) were placed in moderately and marginally suitable classes respectively. Similarly, for onion production, the soils were classified as highly suitable (unit 9), moderately suitable (unit 7), marginally suitable (units 1, 2, 3 and 6) and not suitable (units 4, 5 and 9) as shown in table 7.

 Table 7:Qualitative land suitability classes of study area for tomato, cabbage, and onion

Soil	Tomato a	Onion						
Units	SLM	Storie	Khiddir	Rabia	SLM	Storie	Khiddir	Rabia
1	S3cf	S2	Ν	S2	Ncf	S 3	Ν	S2
2	S3cf	S2	S 3	S 1	Ncf	S 3	Ν	S2
3	S3cf	S2	Ν	S 1	Ncf	S 3	Ν	S2
4	Ncwf	Ν	Ν	S 3	Ncwf	Ν	Ν	S 3
5	Ncwf	Ν	Ν	S 3	Ncwf	Ν	Ν	S 3
6	Ncwf	S3	Ν	S2	Ncwf	S 3	Ν	S2
7	S3cf	S1	S 3	S 1	Ncf	S 2	Ν	S2
8	S3cf	S 1	S 3	S 1	Ncf	S 1	Ν	S 1
9	Ncsf	S 3	Ν	S 3	Ncsf	Ν	Ν	S 3

All the soil units were classified as marginally suitable and not suitable for production of tomato and cabbage as demonstrated by Khiddir method, while all the soil units were not suitable for onion production in same approach. With respect to Rabia method, the soil units (soil units 2, 3, 7, and 8) were considered highly suitable for tomato and cabbage, and S3 appeared three times (soil units4, 5 and 9, while S2 appeared only twice in soil unit 1 and 6. Furthermore, for onion

production Rabia method classified most of the soils as moderately suitable (soil units 1, 2, 3, 6 and 7), while all the other were classified highly suitable (unit 8) and marginally suitable (soil units 4, 5 and 9).

Comparing the methods, potentials suitability classes of the soils increase from simple limitation to Rabia square root methods, with poor performance observed in Khiddir method. Simple limitation, Storie index and Khiddir square root method had place soil units 4, 5 and 6 into unsuitable classes (N) for tomato and cabbage production because of the effect of minimum limiting rating factors. This problem was overcomed with the introduction of Rabia method which uses maximum rating factor in determining the final suitability class, where all the not suitable units were improved to moderately and marginally suitable classes with the same limitations.

3. Conclusion

The soil fertility of the areas was low and bulk density ranges from moderate to high which may affect onion production as it required low bulk density for proper rooting systems. The distribution of various suitability classes varies with respect to crops, soil units and methods. This study revealed that not all the soils are highly suitable for vegetable crop production, even the same soil unit support different crops. Most of the soil units were suitable for production of tomato and cabbage crops, and based on simple limitation and Khiddir methods all the soil units were classified as not suitable for onion production. Employing various evaluation methods may assist farmers to make various choices of crops to be grown. The suitability of soils for vegetable production increases from SLM to Rabia squire root method. with Khiddir showing poor performance. Based on the performance, Rabia method performed best followed by Khiddir and SLM for tomato and cabbage production, while in terms of onion evaluation, Rabia is also the best followed by Storie, and SML and Khiddir performed poorly. The major advantage of employing various suitability evaluation methods may assist farmers to make wide choices of crops to be grown in the land.

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