Nigerian Journal of Soil Science

Journal homepage:www.soilsjournalnigeria.com

Soil suitability evaluation for maize in Lere local government area of Kaduna State Nigeria

Magaji M. J.[*1], Samndi A. M.[1] Ado A. A.[1], Buji I. B.[2], and Abubakar M. A.[3]

[1]Department of Soil Science, Faculty of Agriculture, Bayero University Kano, Nigeria,
[2]Department of Soil Science, Faculty of Agriculture, University of Maiduguri,
[3]Department of Agronomy, Faculty of Agriculture, Nasarawa State University, Keffi

ARTICLE INFO

Article history:
Received August 17, 2021
Received in revised form August 20, 2021
Accepted September 18, 2021
Available online November 28, 2021

Keywords:
Land Evaluation,
Suitability Evaluation,
Parametric
Non-Parametric

Corresponding Author's E-mail Address:
mjmagaji.ssc@buk.edu.ng +2348069033203

https://doi.org/10.36265njss.2022.320104
ISSN– Online **2736-1411**
Print **2736-142X**

ABSTRACT

The soils of Lere (Saminaka) in Kaduna state, Northern Guinea Savanna climatic zone was evaluated for suitability of maize (*Zea mays*) cultivation, employing various methods. Data were obtained through field study and laboratory analyses. Three soil Units were delineated, and one profile was sunk in each of the soil units. The profiles were described according to USDA soil survey manual, and soil samples were collected from each pedogenetic horizon, stored in nylon bag properly levelled. The soil samples were processed and analyzed using standard laboratory procedures. The soil Units were designated as SM1, SM2, and SM3. The textural class of the surface soils are sandy loam to loam. The result shows that soils pH is strongly to moderately acidic (5.5 – 5.8); soil fertility was generally low with evidence of low organic carbon (0.59 – 0.66%), total nitrogen (0.35 – 0.70%) and CEC (4.1 – 5.3 cmolkg^{-1}), while potassium (0.12 – 0.31 cmolkg^{-1}) and phosphorus (12.6 – 25.3 mg kg^{-1}). The results also showed that climate, topography (slope), soil depth, and texture and fertility are optimum for maize production, with drainage and base saturation as the major limiting factors, with the aggregate of not-suitable (Nfw) in all the soil units based simple limitation method. By employing other methods (Storie and Khiddir square root), the same results were obtained, with little improvement in the Square root method (Rabiah) as the classes change from N or N_1 to S_3. Incorporating soils with organic materials and encouraging subsurface drainage will improve maize production.

1.0 Introduction

Soil suitability assessment refers to the investigation of a particular part of land's appropriateness to a specific type of land use. This assessment involves considering many factors that directly or indirectly control the ability of soils to host the land use under investigation. An ecosystem needs an estimation of quantity and quality of its resources, and the suitability of these resources for a specific range of land uses to assure its future productivity and biodiversity's sustainability (Kilic *et al.* 2005). In general, soil suitability analysis can answer the following two fundamental questions "which" and "where"; which land use is to apply under certain conditions and where is the best site to apply such land use. Land suitability assessment methods can be divided into non - parametric (simple limitation regarding number and intensity) and parametric approach (Storie index and square root) (Sys *et al.*,1991).

Maize (*Zea mays* L.) is a sturdy, annual plant originated from North America belonging to the grass family Poaceae, and sub-family Maydeae. It is a versatile crop growing in all sorts of altitudinal and land fertility conditions. It is an important cereal crop having global importance (Atnafua and Roa, 2013). Maize can be grown in a range of climatic conditions from arid regions with 250mm/annum of rainfall to highly humid areas with rainfall of about 5000mm (Dowswell *et al.,* 1996). The crop is now being grown in all the agro-ecological zones of Nigeria, unlike in previous years, where the bulk of maize grain was produced in the southwest zone of the country (Iken and Amusa, 2004).

Despite the various uses of maize in Nigeria, maize production has been dramatically constrained by several factors which may include: use of low yielding local varieties, low soil fertility; variable nature of soils in the savanna regions, low organic matter contents (< 0.5%) and diversity of the climate in the area. In some places, soil water availability is very critical, and in some others, water logging is common-place (e.g. Fadama). Erosion due to the wind and running water usually create problems (Ofor *et al.* 2009), in most of the surface soils. Most of the soils in the savannah region have not been evaluated concerning various crops production, which may affect the overall outputs. Blind fertilizer application is one of the major problems in most soils in the region, as soil varied even within a single meter and may require variable doses of inputs and management across the entire area.

Considering the rapid growth of the world populations, which is, in turn, a limiting factor to the arable lands around the world, the dire need for effective and efficient assessment of the croplands has been felt more than ever. Knowledge of soil suitability evaluation is required in Nigeria. Performing land suitability evaluation and generating maps of land suitability for different land use types will facilitate sustainable agriculture (Vargahan *et al.* 2011). Sustainable agriculture will be achieved if lands are categorized and utilized based on their different uses. Therefore, the objectives of this research were to determined the present soil condition of the study area and evaluate their suitability for maize production.

2.0. Materials and Methods

2.1. Study Area

The study was conducted in Lere Local Government which fall within Northern Guinea Savannah in Kaduna State, and lies between latitude 10˚23'7.15" N and longitude 8˚34'24.51" E) with an elevation of 751.99m above sea level, The area is characterized by an average annual rainfall of 1100mm per annum spread from late April or early May to late October (wet season). The mean ambient temperature varies from 27 - 35˚ C depending on the season. In contrast, the average humidity during the wet season is 72% with about 21% during the period of dry, cool weather from November to January known as the 'Harmattan' (Ajala *et al.* 2007). Soils of the savanna region are generally alkaline, but in some cases, soils with low pH values have been reported (UAC, 1989). The Primary source of livelihood in the area is farming, engaging about 70 percent of the rural population. Farming is traditional with an emphasis on the cultivation of crops which include maize, millet, groundnut, cowpea et cetera, and keeping of livestock.

2.2. Field study and sample preparation

Three soil units were selected, and one standard profile was excavated in each of the soil units. The profiles were described according to the USDA Soil Survey manual, and soil samples were evenly collected from each genetic horizon of the profile. The soils were packed in a nylon bag and adequately labelled. The samples were air-dried and sieved through 2 mm sieve for laboratory analysis. Standard laboratory analysis was followed to determine soil parameters that directly or indirectly influence maize growth and development. Soil properties considered are particle size distribution, soil pH, electrical conductivity, organic carbon, total nitrogen, available phosphorus, exchangeable bases (Ca, Mg, Na, and K), cation exchange capacity, base saturation, and exchangeable sodium percentage.

2.3. Soil Evaluation Methods

The Food and Agricultural Organization states that land suitability is a function of crop requirement and land characteristics and it is a measure of how well the qualities of the land unit matches the requirements of a particular form of land use. In soil evaluation, the specific crop requirements will be calibrated with the terrain and soil parameters (Dent and Young, 1981) so that the identified limiting factors could be managed to suit crop requirements and improve productivity. Land evaluation thus enables management guidelines to promote more sustainable use of the soil and environmental resources (Maniyunda et al., 2007).

Three evaluation procedures were considered in this study, namely; simple limitation, storie index and square roots methods (Khiddir 1986 and Rabia 2013).

2.4. Non-Parametric Method (Simple Limitation)

Using the simple limitation method soil units were placed in suitability classes by matching their characteristics with the established requirements for maize (Table 2). The final (aggregate) suitability class indicates the most limiting characteristics of the unit (FAO, 1976 and Sys *et al.* 1991). It involves categorizing the soil into four classes; highly suitable (S1), moderately suitable (S2), marginally suitable (S3) and not suitable (N). If the soil characteristics fulfil all the crop requirements, the land is classified as S1. If one or more characteristics do not meet the crop requirements, the land can be classified as S2, S3 or N. With some improvement in the limiting factors, and the class may change to the next immediate class for example for S3 to S2.

2.5. Parametric Method

The process involves assigning values to each of the soil quality attributes ranging from 100 to 0 with decreasing potentials (Table 1). The quality that strongly influences a giving land uses has the highest value, and low values were assigned to poor soil quality. The techniques recognized three suitability classes (S1, S2 and S3) with decreasing potentials and two non-suitable classes (N1 and N2). Assigning quantitative values to each is mostly governed by Sys *et al.* (1991) report. Sometimes adjustment may be made concerning the width of each class; wider width is usually employed to the quality that strongly affects a given use. The three methods explained by Sys *et al.* (1991) are the Storie method, the square root method (Khiddir 1986) and the maximum limitation method (Rabia and Terribile, 2013).

Storie Index

$$I = A\,X\,\frac{B}{100}\,X\,\frac{C}{100}\,X\ldots\ldots$$

where *I* is suitability index, A is the rating value for depth parameter and *B*, *C*, *D* are the rating values for other parameters.

Square Root Method

Using the Square Root method, equation based on Khiddir, (1986) and (Rabia and Terribile, 2013);

$$I = Rmin\,X\,\sqrt{\frac{A}{100}}X\,\sqrt{\frac{B}{100}}X\,\sqrt{\frac{C}{100}}X\ldots$$

Where *Rmin* is the minimum rating criterion and A, B, and C are characteristic other than the minimum.

$$Si = Wmax\sqrt{\frac{A}{100}} \times \sqrt{\frac{B}{100}} \times \sqrt{\frac{C}{100}} \times \ldots$$

Wmax is the maximum rating criterion and A, B, and C are characteristic other than the maximum.

Table 1; Qualitative land suitability classes for the different land indices

Land Index	Definitions	Symbols
75 – 100	Highly suitable	S1
50 – 75	Moderately suitable	S2
25 – 50	Marginally suitable	S3
12.5 - 25	Currently not suitable	N1
0 -12.5	Permanently not suitable	N2

Source: Sys et al. (1991) Albaji, et al. (2009)

Table 2: Soil suitability criteria (crop requirement Maize)

Land Quality/soil site characteristics		Units	Suitability Rating				
			S_1 - N_2	S_2	S_3	N_1	
			75 - 100	50 - 75	25 - 50	12.5 - 25	0 - 12.5
Climatic (c)	Mean annual temperature	°C	22-26	18-16 26-30	30-36 15 -16	36-40 10-15	>40 <10
	Total rainfall	mm	850-1250	600 -750 1250-1600	300-600 1600-1800	250-300, 1800-2000	<250 >2000
Topography (t)	Slope	%	0-4	4-8	8-16	16-30	>30
Wetness (w)	Soil drainage	Class	Well-drained	Moderate	Imperfect	Poor	Very poorly
Soil physical	Texture	Class	scl, l, cl	sicl,sic, sc,c	sl,	ls	s
Properties (s)	Soil depth	cm	>120	75-120	40-75	30-40	<30
Fertility (f)	pH	1:2.5	5.5 – 6.5	6.5 – 7.5 6.6 – 7.5	5- 5.4, 7.5-8.0	4.5-5, 8-8.5	<4 >8.5
	Organic Carbon	%	>2	0.8-2	0.5 – 0.8	0.3-0.5	<0.3
	Nitrogen	%	>0.15	0.08-0.15	0.04-0.08	0.02-0.04	<0.02
	Available P	$mgkg^{-1}$	>22	7-22	3-7	2-3	<2
	CEC	$cmol(+)kg^{-1}$	>24	16-24	10-16	7-10	<7
	Base Saturation	%	>50	35-50	20-35	15-20	<15
	Exchangeable K	$cmol(+)kg^{-1}$	>0.5	0.3-0.5	0.2-0.3	0.1-0.2	<0.1

KEY, sc (sandy clay), scl (sandy clay loam), cl (clay loam), l (loam), sl (sandy loam), ls (loamy sand) sicl (silty clay loam), sic (silty clay), c (clay), s (sand), P (phosphorus), K (potassium) and CEC (cation exchange capacity).
Source: Modified from FAO (1983) and Adesemuyi, et al., (2014)

3.0. Results and Discussions

The factor rating of land use requirements for maize (Tables 2) was matched with the properties of the studied soils (Table 3). The ultimate evaluation of the qualitative land suitability for different typical land uses using simple limitation, and parametric methods are given in Tables 4 and 5.
Based on simple limitation, results showed that there was no limitation in rainfall and topography in all the soil units and were designated as S1 (Table 4). Drainage is the major problem for maize production in Saminaka Unit 2 and 3 (SMK 2 and 3) and was represented as N1. The primary fertility constraints were only observed in SMK 1 and 3, as exchangeable potassium (N1) and nitrogen (N1). None of the soil units was free from all limitations, and therefore the aggregate suitability classification was N1. Hence all the soils were not suitable for maize production.

Table 3: Soil Characteristics of the study sites

Land Quality/soil site characteristics		Unit	SMK 1	SMK 2	SMK 3
Climatic (c)	Mean annual temperature	°C	31	31	31
	Total rainfall	mm	1100	1100	1100
Topography (t)	Slope	%	0-2	0-2	0-2
Wetness (w)	Soil drainage	Class	Moderate	Poorly	poorly
Soil physical	Texture	Class	sl	sl	l
Properties (s)	Soil depth	cm	103	128	134
Fertility (f)	pH	1:2.5	5.7	5.8	5.5
	Organic Carbon	%	0.62	0.66	0.60
	Nitrogen	%	0.071	0.071	0.035
	Available P	$mgkg^{-1}$	11.78	25.25	12.60
	$CEC_{(clay)}$	$cmol(+)kg^{-1}$	18.9	15.2	20.3
	Base Saturation	%	50.9	83.5	65.5
	Exchangeable K	$cmol(+)kg^{-1}$	0.12	0.31	0.18

KEY: l (loam), sl (sandy loam), P (phosphorus), K (potassium) and CEC (cation exchange capacity).

KEY: l (loam), sl (sandy loam), P (phosphorus), K (potassium) and CEC (cation exchange capacity).

Table 4: Soil Suitability Classification Based on Simple Limitation Method

Land Quality/soil site characteristics		Unit	SMK 1	SMK 2	SMK 3
Climatic (c)	Mean annual temperature	°C	S3	S3	S3
	Total rainfall	mm	S1	S1	S1
Topography (t)	Slope	%	S1	S1	S1
Wetness (w)	Soil drainage	Class	S2	N1	N1
Soil physical	Texture	Class	S3	S3	S1
Properties (s)	Soil depth	cm	S2	S1	S1
Fertility (f)	pH	1:2.5	S1	S1	S1
	Organic Carbon	%	S3	S3	S3
	Nitrogen	%	S3	S3	N1
	Available P	$mgkg^{-1}$	S3	S1	S3
	$CEC_{(clay)}$	$cmol(+)kg^{-1}$	S2	S3	S2
	Base Saturation	%	S1	S1	S1
	Exchangeable K	$cmol(+)kg^{-1}$	N1	S3	S3
Aggregate Suitability Class			N1f	N1w	N1fw

The results of two parametric approaches were presented in Table 5 and were slightly different. However, they did not correlate with one another, and the results show a trend of increasing hierarchy of suitability from Storie index to the square root methods. The process involved numerical ranking from 100 to 0 (table 1). The upper limit of each class was used to represent the whole class.

The results showed an improving trend from simple limitation through storie index to square root method. The extreme performance of the square root method, especially Rabia method, was observed in this study. Ashraf, (2010) reported that the outcome of different land suitability methods was usually correlated to each other (square root parametric method commonly gives higher results than the storie index and simple limitation methods.

In a study carried out by (Vargahan *et al.*, 2011) to compare four land suitability methods (simple limitation, limitation regarding number and intensity, Storie and Square root) and revealed that the square root parametric method was mainly better and more commonly used method in qualitative evaluation. The study also recommended that utilizing the outcome of this method in quantitative evaluation gives more realistic results.

The results of the non-parametric evaluation showed a close relation between Simple Limitation method and storie index because of the strong influence of limiting factors in the approach, which subsequently determined the soil index. Storie index and simple limitation always gave a lower suitability index when compared with the parametric approach. By comparing different methods of land evaluation, it could be perceived that the results of parametric methods, in particular, the Square Root method gave far more consistent results.

Table 5: Comparison of Soil Suitability Procedures

Soil	Simple Limitation	Storie Index	Square Root	
Units			Khiddir	Rabia
SMK 1	N1f	11 = N2	12 = N2	28 = S3
SMK 2	N1w	20 = N1	11 = N2	26 =S3
SMK 3	N1fw	16 = N1	10 = N2	17 = N1

4.0. Conclusion

Different methods of suitability evaluation could be used to classify soils for given crop productions. Though based on the results obtained in all the procedures, none of the soil was suitable for maize production. However, the Rabia method classified SMK 1 and 3 as marginally suitable. The limitations observed were not beyond control, with some improvement in fertility and drainage; the sites may support maize production.

5.0. Recommendation

Square root method should be used for land suitability evaluation, and the result of soil various soil suitability methods should be compared with the yield to choose the best among them. There is a need to employ other procedures for soil suitability studies to improve the quality of our land.

References

Adesemuyi, E. A. (2014). Suitability assessment of soils for maize (Zea mays) production in a humid tropical area of south-western Nigeria. *International Journal of Advanced Research*, Volume 2, Issue 2, 538-546

Ajala, M. K., Nwagu, B. I. and Otchere, E. O. (2007). “Socio-Economics Free-Range Poultry Production among Agropastoral Women in Giwa Local Government Area of Kaduna State, Nigeria” *Nigerian Veterinary Journal.* Vol. 23(3):11-18.

Albaji, M., Naseri, A. A., Papan, P. and Boroomand, S. N. (2009). Qualitative Evaluation of Land Suitability for Principal Crops in the West Shoush Plain, Southwest Iran, *Bulgarian Journal of Agricultural Science, 15 (No 2), 135-145 Agricultural Academy.*

Ashraf, S. (2010). “Land Suitability Analysis for Wheat Using Multicriteria Evaluation and GIS Method,” *Research Journal of Biological Sciences*, vol. 5, 601-605.

Atnafua Bekele, Tnaro Nageshwar Roa. (2013). Heterosis Study for Grain Yield, Protein and Oil Improvement in Selected Genotypes of Maize (*Zea mays* L). *Journal of Plant Sciences*. Vol 1, (4) 57-63. Doi: 10.11648/j.jps.20130104.12.

Dent, D. Young, A. (1981). Soil Survey and Land Evaluation. George Alien and Unwin Ltd., London, UK.

Dowswell, C. R., Paliwal, R. L., and Cantrell, R. P.

(1996). Maize in the Third World, Westview Press. 268 pp.

FAO (1976). Framework for Land Evaluation. FAO Soils Bull. 32: FAO, Rome, 87pp.

FAO (1983). Guidelines: Land evaluation for rainfed agriculture. FAO Soils Bulletin, No 52, FAO, Rome.

Iken, J. E. and Amusa, N. A. (2004). "Maize research and production in Nigeria" *African Journal of Biotechnology.* Vol. 3 (6), 302-307.

Khiddir, S. M. (1986). A statistical approach in the use of parametric systems applied to the FAO framework for land evaluation. Ph.D., State University of Ghent, Belgium, 141 pp.

Kilic, S., Evrendilek, F., Senol, S. and Gelik, I. (2005). "Developing a suitability index for land use and agricultural land covers: A case study in Turkey," *Environ. Mon and Assess* vol. 102, pp. 323–335.

Maniyunda, L. M., Malgwi, W. B. and Yaro, D. T. (2007), "Evaluation of the suitability of Galma River basin for irrigated agriculture", Proceedings of the 31st Annual Conference of Soil Science Society of Nigeria. 13th – 17th Nov. 2006, ABU Zaria Nigeria, pp. 23-28.

Ofor, M. O., Ibeawuchi, I. I. and Oparaeke, A. M. (2009). "Crop Protection Problems in Production of Maize and Guinea Corn", *Nature and Science*, ISSN: 1545-0740. Volume 7 - Number 11 (Cumulated No. 32), 8-14.

Rabia, A. H. and Terribile, F. (2013). "Introducing a New Parametric Concept for Land Suitability Assessment," *International Journal of Environmental Science and Development,* vol. 4, No. 1,

Sys[a], I, Van Ranset, E. and Debaveye, J. (1991). Land Evaluation, Part I, Principle in Land Evaluation and Crop Production Calculation, International Training Center for Post Graduate Soil Scientists, Ghent University, Ghent., Belgium.

Sys[b], I., Van Ranst, E. and Debaveye, J. (1991). "Land evaluation, part I. Principles in land evaluation and crop production calculations," *General administration for development cooperation*, Brussels, pp. 40-80.

Vargahan, B. Shahbazi, F. and Hajrasouli, M. (2011). "Quantitative And Qualitative Land Suitability Evaluation For Maize Cultivation In Ghobadlou Region, Iran," *Ozean Journal Of Applied Sciences,* vol. 4, no. 1, Issn 1943-2429.