Sub–Theme: Application of remote sensing and GIS in food and drought risk management

The use of GIS and remote sensing in Land Suitability Classification for Groundnut Production in Katsina State, Northwest, Nigeria.

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Abstract

Land suitability is a function of crop requirement and soil characteristics. It is a prerequisite for sustainable agricultural practices. This paper briefly presents the land suitability for Groundnut production. The analysis of the data collected for both climatic elements such as rainfall and temperature, physical and chemical characteristics of soil was obtained through the use of descriptive statistics using SAS of 9.4 version software. The distribution map of each of the soil properties was generated in ArcGIS. The suitability for Groundnut cultivation in Katsina shows that rainfall, elevation, temperature, drainage, erosion, soil depth, pH, OC, OM, and Phosphorus are found within the acceptable suitable class, while those found below average are CEC, TN, EC and ESP. Land suitability class S1 (highly suitable) covers 1328.40 ha which is about 21.19% of the study area; land suitability S2 (moderately suitable) covers 1098 ha, representing 17.53% of the total study area, while land suitability class S3 covers 1767 ha occupies about 28.19% of total area. Furthermore, the N1 (potentially not suitable) class occupies about 851.33ha which take the portion of 13.58%, while the last suitability class N2 (potentially and actually not suitable) is covering about 1223.08 ha which is about 19.51%, and these are areas that scored below average of Groundnut requirement. This land (N2) is affected generally by poor scenery, rock outcrop, complex texture as well as infertile soil.

Keywords: Remote sensing, Land suitability, Spatial variability, Sustainable Agriculture, GIS

Introduction

Land is one of the most important natural resources, and maintaining it in good health, is very much needed for meeting out the increasing demand for food, fibre, fodder and fuel (Fadlalla & Elsheikh, 2016). The coupling of soil characterization, soil classification and soil mapping provides a powerful information for land users in field of agricultural sustainability (Sharu, M. B., Yakubu, M., Noma, S. S., & Tsafe, A. I, 2013). It assumes greater significance in present situation wherein the scope for further extension of cultivation is very limited (Tesfay, Biedemariam, & Hagazi, 2017a). It is necessary to select the judicious crops for cultivation according to the soil suitability, so that maximum profit may be achieved while maintaining the ecological sustainability (Öztürk, 2017). The crop land use planning involves making knowledgeable decisions about land use and the environment. Soil information is a vital component in the planning process, reflecting directly upon land-use suitability (Coleman & Galbraith 2000). The Land suitability is the process way or manner of assessing the suitability or ability of a given type of land facet for specific use (Bhandari, S., Jhadav, S. T., & Kumar, S, 2013). Land suitability classification process is the evaluation and grouping of specific areas of land in terms of their suitability for defined agricultural use (Bock *et al.*, 2018). Land suitability analysis is a prerequisite for sustainable agricultural practices. It involves evaluation of the factors like climate, elevation, as well as soil etc. Land suitability is a function of crop requirements and soil characteristics (Ahmed, 2015). Matching the land characteristics with the crop requirements provides suitability (Mathewos, M., Dananto, M., Erkossa, T., & Mulugeta, G. 2018). So, "suitability is a measure of how well the qualities of a land unit match the requirements of a particular form of land use" (FAO, 1976). Land suitability classification aims at evaluating and classifying land units on the basis of specific land and soil features and their limitations (Raju, 2015). Soil-site suitability studies provide information on the choice of crops to be grown on best suited soil units for maximizing the crop production per unit of land, labour and inputs (Zhang *et al*., 2015). The land suitability for a defined use and the impact of that use on the environment is determined by land conditions and land qualities (Tesfay, Biedemariam, & Hagazi, 2017b). The sustainable land use depends on soil resilience that is the balance between soil restorative and soil degradation processes (Kahsay, Haile, Gebresamuel, Mohammed, & Moral, 2018). Ecologically every factor of environment exerts directly or indirectly a specific effect on growth and development of the plants. However, it varies from habitat to habitat and determines the suitability of a plant to any particular environment (Ismail, 1991). Land management practices, which made up of unreasonable land use, has caused deterioration of soil quality, which may in turn resulting in soil structure degradation and organic matter loss which affect water, air and nutrient fluxes as well as plant growth (Hassan, P., Jusop, S., Ismail, R., Aris, A. Z., & Panhwar, Q. A. 2016). For planning and effective utilization of soil resources, the information relating to the soil-site characteristics for cultivation of crops is necessary (Leakey, *et al* 2006). In order to follow the principles of sustainable agriculture one has to grow the crops where they suit best and for which first and the foremost requirement is to carry out land suitability analysis (Ahamed *et al*. 2000). The natural resources like soil and water and associated climatic features deeply influence the cropping pattern and crop productivity in specified areas (Perveen, Nagasawa, Uddin, & Delowar, 2005). Each plant species requires definite soil and site conditions for its optimum growth. Since the availability of both water and plant nutrients is largely controlled by the physico-chemical properties and micro environment of the soils, therefore, the success and failure of cropping any plant species, in a particular area, is largely determined by these factors (Nanganoa et al., 2019)

Objectives

The main objective of the study was to carried out the land suitability analysis for Groundnut in Katsina district based on FAO framework of land suitability classification using GIS and remote sensing.

Study area

Agriculturally, is found in the Sudan Savannah Zone of Nigeria, located on latitude 12° 27′ 16.00″ N to 12°59′ 26.95″N and longitude on 7″12′6.20″ E to 7°12′6.37″E. It falls in the Sudan Savannah zone, a climatic belt characterized by long dry seasons and short rainy season. Katsina central senatorial zone as the name implied, is a political entity located in the central part of Katsina state and the extremely north - western part of the state. It comprises of eleven local Government areas of Katsina, Kaita, Kurfi, Jibia, Batagarawa, Rimi, Batsari, Dutsin-ma, Safana, Danmusa, and Charanchi with land coverage of about 6, 269ha. It is relatively bounded by Funtua senatorial zone of the state to the South, Zamfara state to the west, Niger republic to the North, Kano and Jigawa states to the East. The zone has a total population of about 2, 667,000 in 2018 as projected from 2006 census figure based on growth rate of 3 %.

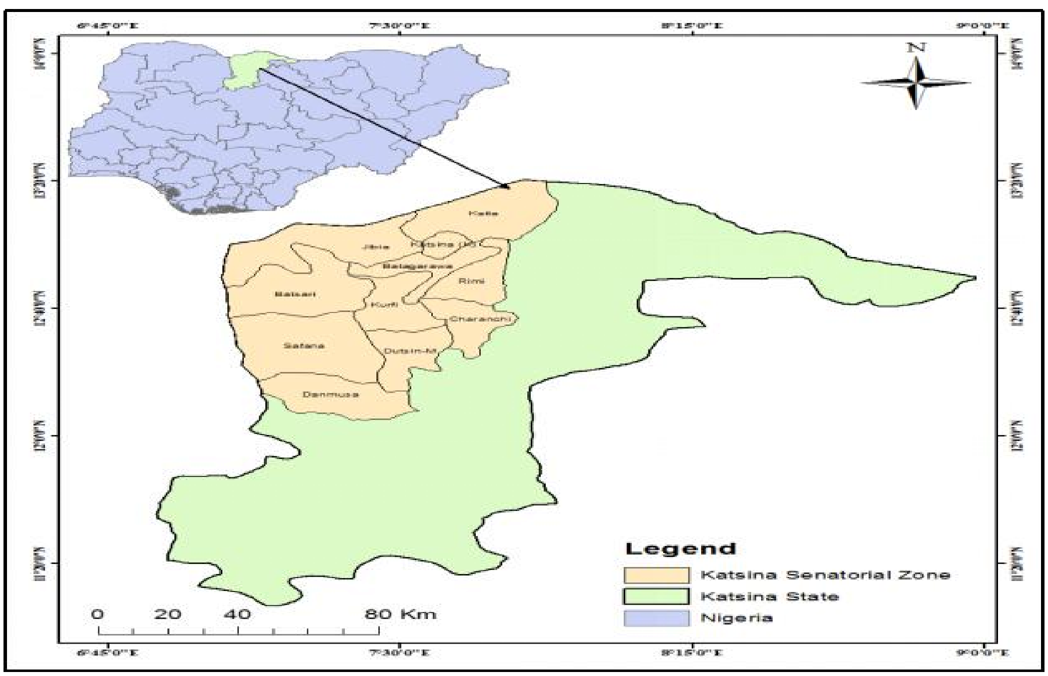
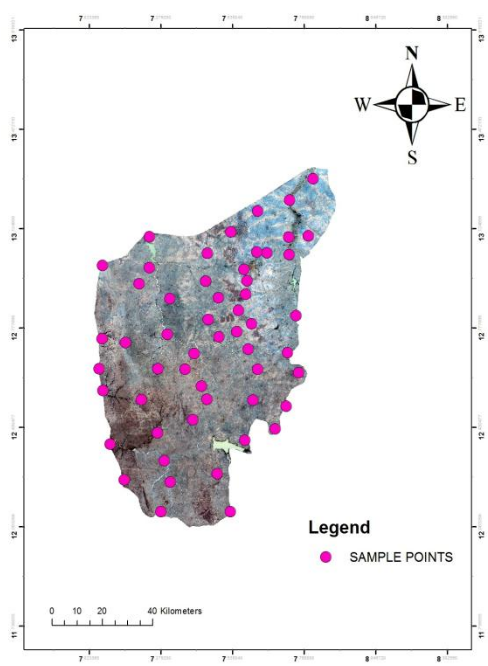


Figure 1 Map of study area

Materials and method

For the suitability analysis 55 samples of soil (surface soil samples) were collected at the depth of 0-30cm in which it airs dried, gently crushed, and sieve through 2mm for routine analysis (Yusuf, 2011). The coordinates of each soil sample were taken for geospatial distribution analysis. The analysis of the data collected for both climatic elements such as rainfall and temperature, soil physical characteristics and chemical characteristics of soil was obtained through the use of descriptive statistics using SAS of 9.4 version software. The distribution map of each of the soil properties was generated in ArcGIS environment of 10.3 version using inverse distance weighted (IDW) techniques

The land qualities and characteristics used for suitability evaluation in this study were climate, topography and soil characteristics. In accordance with FAO (Jafazadeh, 2008). which consists of matching land characteristics against crop requirements and assigning a suitability rate for each land characteristic, land suitability evaluation for the major crops produced in the study area was carried out. Groundnut is among the most preference cash crop in the study area. The selection of this crop was made based on its dominance (area coverage), preference and economic importance in the area. Climatic and land parameters were assigned to each factor affecting the suitability for Groundnut. Land suitability requirement of Groundnut were established using FAO (Kalogirou, 2002; Aaharaf 2011; Sharififar 2012).



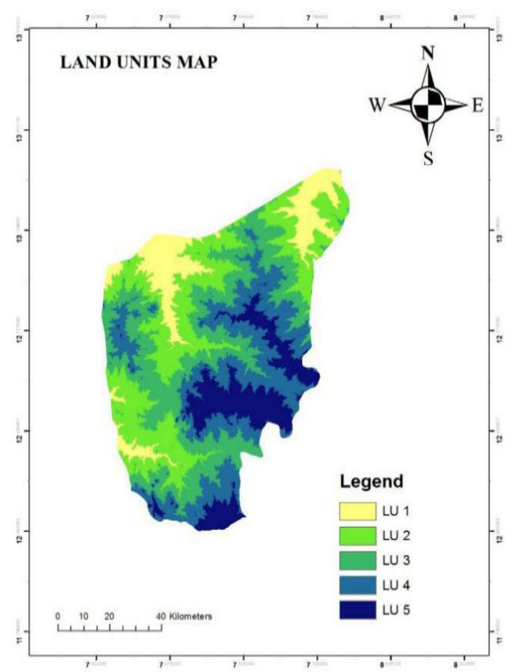


Figure 2 Map of sample points **Figure 3** Land units

At the reconnaissance survey, the analysis of the land units was executed in order to determine land suitability classification. The land suitability classification was falls in to five classes that indicate the degree of suitability. These classes are S1 (highly suitable), S2 (marginally suitable), S3 (moderately suitable), N1 (not suitable but, could be suitable under certain management practice), N2 (not suitable even under management practice). Based on the available data at reconnaissance level, climate, and land characteristics that were used as diagnostic criteria to determine land suitability classification made on the basis of land evaluation. For the evaluation of land resources by climate and land characteristics, the element of climate, land and soil properties under investigation are presented in (table 1)

Table 1 Climate and land characteristics as parameters for land suitability

Land characteristic	symbol
Rainfall	c
Temperature	,,
Slope/Elevation	s
Texture	t
Soil depth	,,
CEC	f
pH	,,
OC	,,
OM	,,
TN	,,
P	,,
EC	,,
ESP	,,

Where c = climate limitation, s = slope limitation, t = soil limitation, and f = fertility limitation.

Source Field work (2019).

The evaluation was done base on the parametric approach to defined the degree in limitation of diagnostic criteria and the subsequent process of obtaining the land suitability rating percent by dividing value of parameter over higher range of parameter (Udo *et al* 2012). Algebraically the formula to obtained land suitability can be express as

$$Si = \frac{value\ of\ parameter}{high\ range\ of\ parameter} * 100$$ …………………equation 3

Where Si = suitability index

In the process of obtaining the suitability index the parametric approach by the division process (mean of parameter over high range of suitability classification) multiply by percentage was used to define the level of limitation expressed as percentage (Udo *et al* 2012). The evaluation of these was done based on a relative limitation scale, rating and land suitability classes (table 1) and the evaluation of the properties for land suitability classification is presented in a scheme of which the frame is given (table 2).

Table 2 Limitation category, rating and suitability classes

Limitation	Rating	Land suitability class
Highly suitable	100-85	S1

Moderately suitable	85-60	S2
Marginally suitable	60-40	S3
Actually not suitable But potentially suitable	40-25	NI
Actually and potentially unsuitable	25-0	N2

Source Sys (1993).

The land units were evaluated according to the criteria of (table 2). The following definition of suitability classification for each land unit in (table 3) can be applied in order to obtained the land suitability classes.

Table 3 Framework of a land suitability table

Parameters	**Range in the degree of limitation**					
	0	**1**	**2**	**3**	**4**	**5**
	S1	**S1**	**S2**	**S3**	**N1**	**N2**
	100	**95**	**85**	**60**	**45**	**25**
PPT						
Temp.						
Slope						
Soil depth						
CEC						
pH						
OC						
OM						
TN						
P						
EC						
ESP						
Texture						

Source Sys (1993).

The land suitability classification of Groundnut and the approach toward determining the land indices was acquired from rating of land properties of the combination of land suitability requirement for the crop (table 5) and framework of FAO land suitability (table 4).

Table 4 Suitability classes for land index

Limitation	**Rating**	**Land suitability class**
0 : No	100-85	S1

1 : Slight	85-60	S2
2 : Moderate	60-40	S3
3 : Severe	40-25	NI
4 : Very severe	25-0	N2

Source Sys (1993).

Results and discussion

According to Sys (1993) the determination land suitability classification based on FAO framework of land suitability classification (1976), involves the compare of land characteristics with crop requirements. The climate and soil requirement of Groundnut are shown in (table 6). Equally important the range of climate and soil requirements of Groundnut production is also reveals in the same table. Therefore, the potentialities of climatic characteristics and soil for Groundnut cultivation in the study area is in table 5 and table 6 respectively for comparing the individual scores of parameters for determination of soil requirement. However, the climate elements in the study area are at optimum level as it matched with the millet requirements.

Table 5 Groundnut Suitability Rating and Matching Requirements

Parameter	Groundnut rating req.	LU 1	LU 2	LU 3	LU 4	LU 5
Rainfall (mm)	200-1900	678.92	604.07	605.04	704.34	702.43
Temp. (°C)	10-34	26.79	26.78	26.69	26.71	26.66
Elevation (m)	400-558.5	434.95	469.3	514.95	530.5	558.5
Soil depth (cm)	25-100	25.35	24.96	17.5	21.4	22.3
CEC (cmol/kg)	1.6-16	6.11	5.8	7	5.85	7.17
Ph (Ph/m)	5.4-8.2	6.8	6.5	6.7	6.3	6.4
OC (%)	0.4-2.5	2.22	1.67	1.91	1.94	2.09
OM (%)	0.5-5.0	3.45	2.96	3.28	3.35	3.62
TN (%)	0.05-0.5	0.1	0.1	0.14	0.14	0.13
P (%)	0.5-30	6.04	4.4	8.48	10.23	6.02
EC (mS/m)	0-12	0.03	0.03	0.04	0.04	0.04
ESP (%)	0-20	1.53	1.83	1.06	1.26	1.42

Table 6 Suitability scores and classification for Groundnut

Parameter	LU 1	LU 2	LU 3	LU 4	LU 5
Rainfall (mm)	N1(36)	N1(32)	N1(32)	N1(37)	N1(37)
Temp. (°C)	S2(79)	S2(79)	S2(79)	S2(79)	S2(78)
Elevation (m)	S2 (78)	S2 (84)	S1 (92)	S1 (94)	S1 (100)
Soil depth (cm)	N2(25)	N2(25)	N2(18)	N2(21)	N2(22)

CEC (cmol/kg)	N1(38)	N1(36)	S3(44)	N1(37)	S3(49)
Ph (Ph/m)	S2(83)	S2(79)	S2(82)	S2(77)	S2(78)
OC (%)	S1(89)	S2(67)	S2(76)	S2(78)	S2(84)
OM (%)	S2(69)	S3(59)	S2(66)	S2(67)	S2(72)
TN (%)	N2 (20)	N2 (20)	N1 (28)	N1 (28)	N1 (26)
P (%)	N2 (20)	N2 (15)	N1 (28)	N1 (34)	N2 (20)
EC (mS/m)	N2(0.3)	N2(0.3)	N2(0.4)	N2(0.4)	N2(0.4)
ESP (%)	N2(8)	N2(9)	N2(5)	N2(6)	N2(7)

Source: Sys (1993)

Table 7. Suitability rating of Beans on climate and soil properties

Parameter	LU 1	LU 2	LU 3	LU 4	LU 5
Rainfall (mm)	NS	NS	NS	NS	NS
Temp. (^{o}C)	S	S	S	S	S
Elevation (m)	S	S	VS	VS	VS
Soil depth (cm)	VNS	VNS	VNS	VNS	VNS
CEC (cmol/kg)	NS	NS	LS	NS	LS
Ph (Ph/m)	VS	VS	VS	VS	VS
OC (%)	VS	S	S	S	S
OM (%)	S	LS	S	S	S
TN (%)	VNS	VNS	NS	NS	NS
P (%)	VNS	VNS	NS	NS	VNS
EC (mS/m)	VNS	VNS	VNS	VNS	VNS
ESP (%)	VNS	VNS	VNS	VNS	VNS

Source: Udo et at (2012). Where VS= very suitable, S= suitable, LS= low suitable, NS= not suitable, VNS= very not suitable.

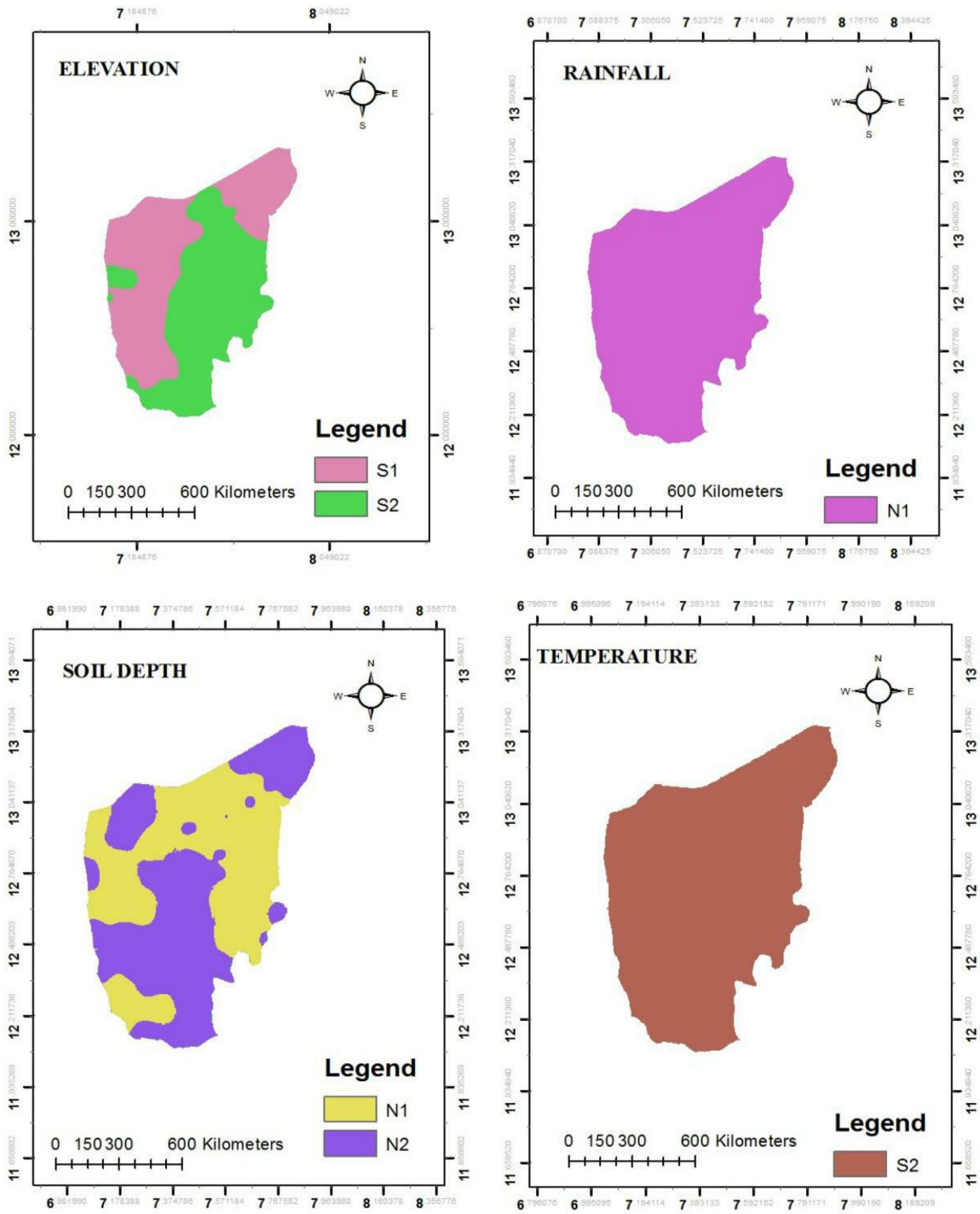


Figure: 4. Suitability of physical properties for groundnut production

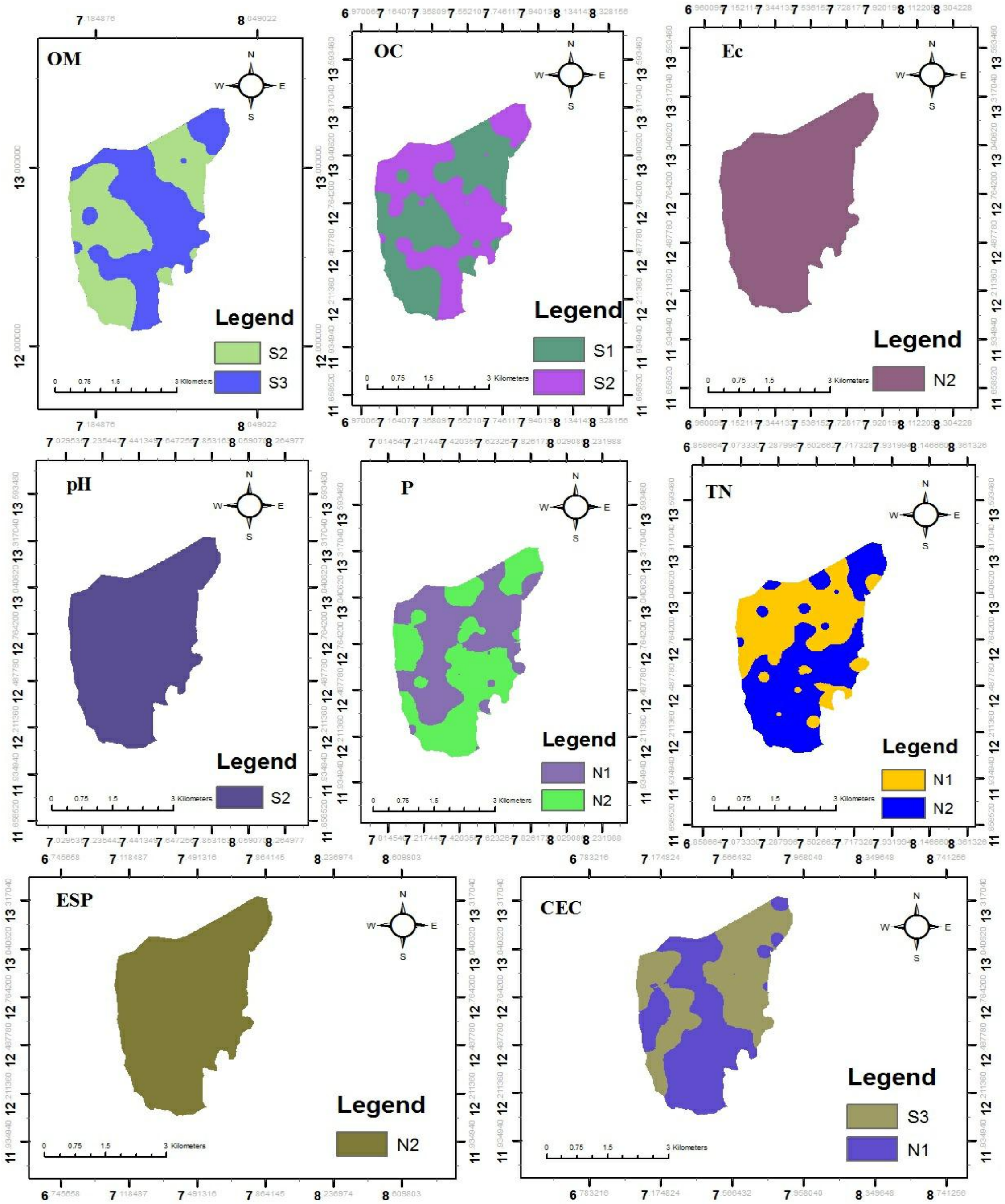


Figure: 5. Suitability of chemical properties for groundnut production

Table 8a. Suitability classes for Groundnut properties'

	RAINFALL		TEMP.		ELEVATION		SOIL DEPTH		CEC		OC	
SUITABILITY CLASS	Area (ha)	(%)	Area (ha)	(%)	Area (ha)	(%)	Area (ha)	(%)	Area (ha)	(%)	Area (ha)	(%)
S1					2215.46	35.34	3318.81	52.94			4261.04	67.97
S2			6269	100	4047.27	64.56	2950.19	47.06			2007.96	32.03
S3									3484.94	55.59		
N1	6269	100							2784.06	44.41		
N2												
TOTAL AREA	6269	100	6269	100	6269	100	6269	100	6269	100	6269	100

Table 8b. Suitability classes for Groundnut properties'

	OM		pH		TN		P		ESP		EC	
SUITABILITY CLASS	Area (ha)	(%)	Area (ha)	%	Area (ha)	(%)	Area (ha)	(%)	Area (ha)	%	Area (ha)	%
S1												
S2	3980.82	63.5	6269	100								
S3	2288.18	36.5										
N1					2130.83	33.99	2934.52	46.81				
N2					4138.17	66.01	3334.48	53.19	6269	100	6269	100
TOTAL AREA	6269	100	6269	100	6269	100	6269	100	6269	100	6269	100

6.7 Combined thematic maps for Groundnut suitability

The pairwise matrix comparison for all the factors under analysis of beans cultivation were overlay weighted of the alternatives, from which the final rate were calculated the final suitability map for beans production. Model builder showed in figure 6.19 were used in the combining of the thematic layers produced in figure 6.17 and 6.18 from the AHP analysis performed in the weighted overlay processes.

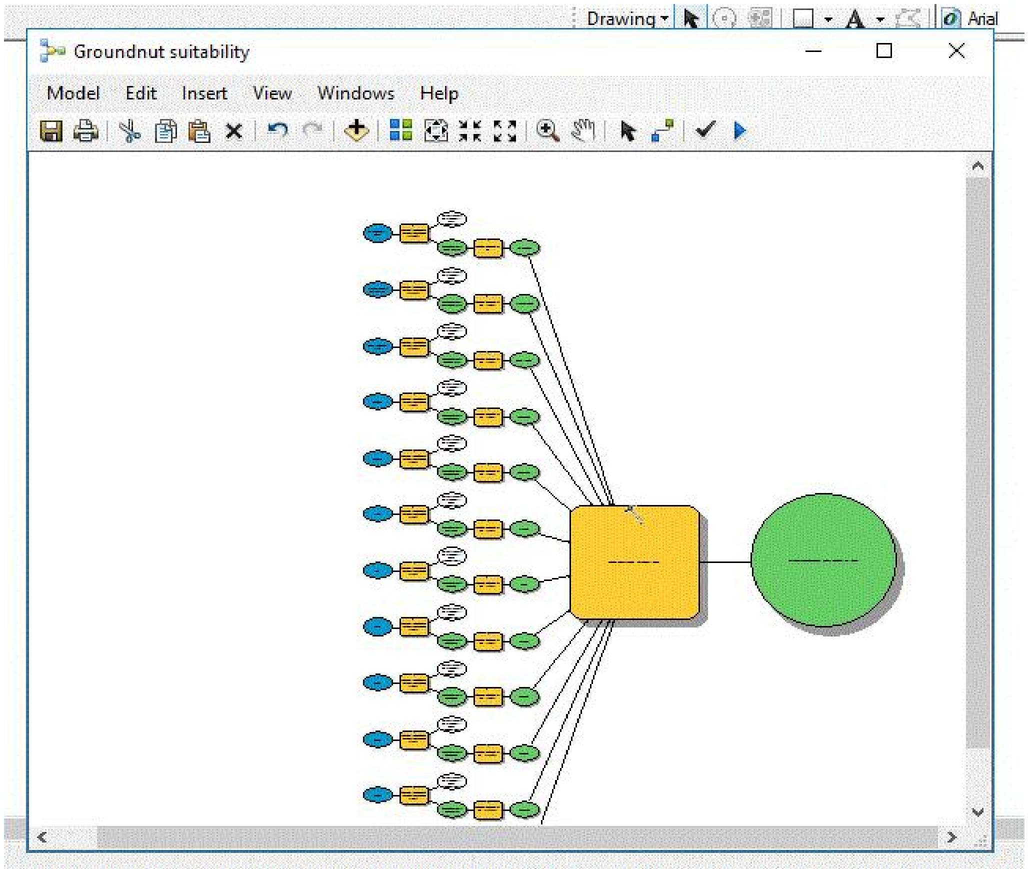


Figure: 6. Model builder for Groundnut Suitability

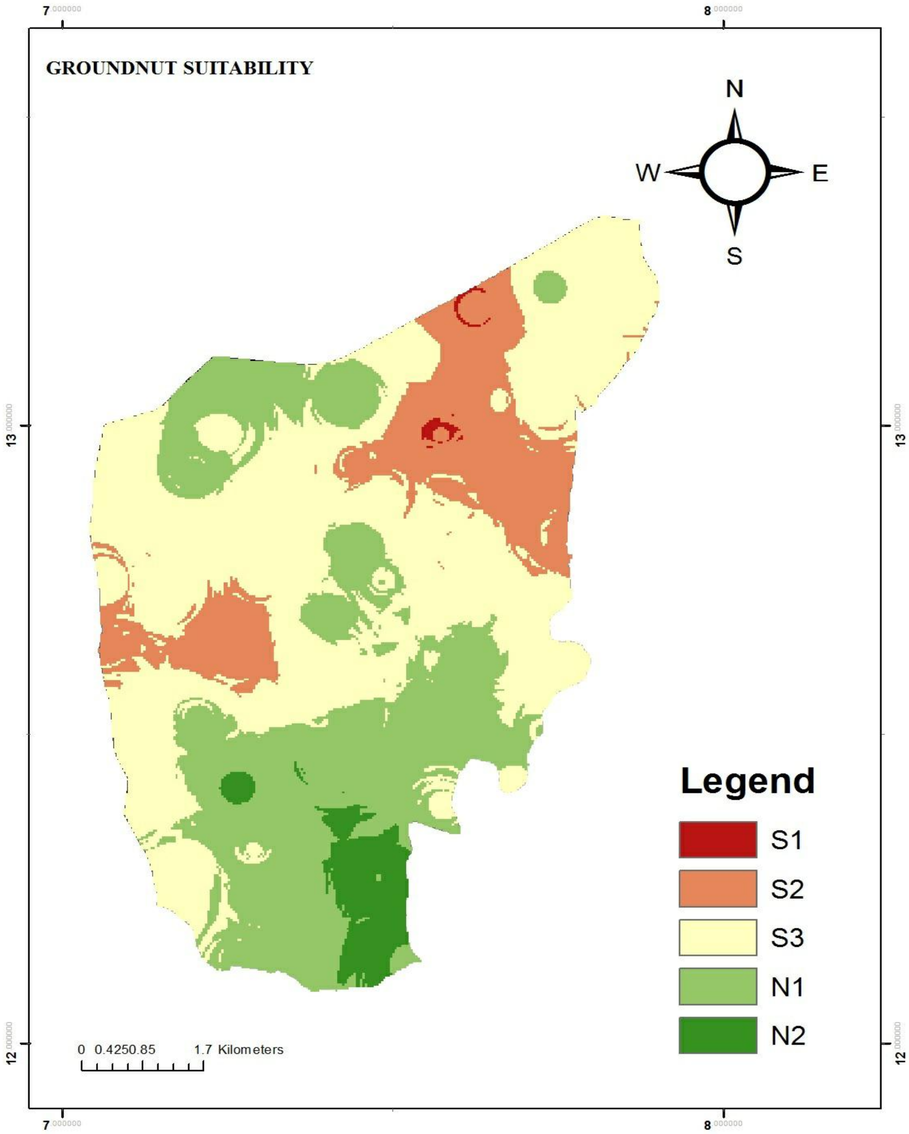


Figure 7. The map of land suitability for groundnut

Table 9. Groundnut suitability classes

Suitability classes	Area in ha	% of area covered
S1	21.31	0.34
S2	1873.80	29.89
S3	3066.17	48.91
N1	903.36	14.41
N2	404.35	16.45

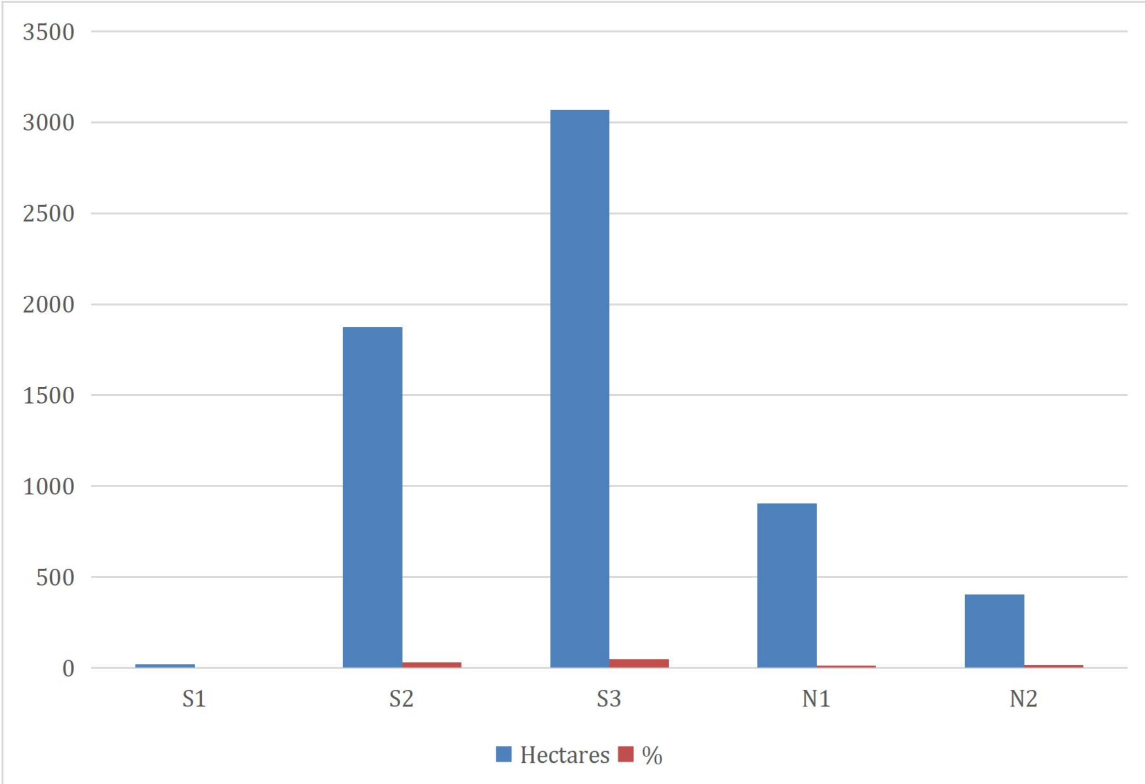


Figure 8. Distribution graph for groundnut suitability

The soil suitability classification for Groundnut in Katsina north are shown in figure 4. The table 5 and figure 7 reveal the distribution of soil suitability classification for groundnut. It was found that soil suitability classification for S1 (highly suitable) covers only 0.34% (21.31ha). The soil suitability class S2 (moderately suitable) cover 29.89% (1873.80ha) spreading all over the study area. While the soil suitability class S3 (marginally suitable) cover 48.91% (3066.17ha) almost half of the study area and found in all the land units. The presence of Groundnut above the average requirement is found in this class which spread in areas of Danmusa, Safana, Batsari, Charanchi, and Kaita respectively. The soil suitability class of N1 (potentially not suitable) cover 14.41% (903.36ha) this is noticed in Zobe, Tudu, Tashr ice, Kurfi, Jibia, and Dankaba. But the soil suitability class for N2 (potentially and actually not suitable) covers 16.45% (404.35ha) of the study area that restricted to only land unit 5 in areas of Danmusa and Maidabino.

Recommendation and future research studies

Competing needs must be considered when planning for long-term land use development. Different users will have different goals; for example, some will want to promote rain-fed agricultural or irrigation, while others will want to promote forestry or watershed protection. As a result, determining the extent to which planning meets or should satisfy the requirement is a difficult task. As also experienced during the research, land capability classification is not likely to work effectively unless it gives local farmers some overall benefits. The land capability classification is not an end on itself.

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