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Land suitability mapping for groundnut production in southern region of Borno state, Nigeria

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Abstract

Groundnut (*Arachis hypogea*) is a leguminous oilseed crop cultivated in the semi-arid and subtropical region of the world. In West Africa, groundnut plays an important role. This includes food production for household consumption, cash crops, sources of employment, and incomes for smallholders in rural households. In Nigeria, it was among the major sources of income before the oil boom. Some of the activities surrounding its production are the development of commerce, employment, and foreign exchange. This study aims to identify the most suitable sites for groundnut production in the Southern Borno Region, Nigeria with the objectives to identify areas of groundnut cultivation within the southern Borno region and to conduct a suitability analysis for groundnut production within the study area. Primary and secondary data and questionnaires were used in this study. Climatic data such as Temperature, Rainfall, Precipitation, Wind speed, Relative Humidity, Soil, and Topographic data were also used. The parameters were overlaid using the weighted overlaid operation in ArcGIS 10.3 and ranked from the most suitable to the least suitable for wheat production within the study region. The result of the study revealed that groundnut is cultivated in all parts of Southern Borno Region. It revealed that areas around Askira/Uba, Chibok and Damboa are the most suitable site for groundnut cultivation. This study demonstrates the capabilities of Remote Sensing and GIS Systems for multi-criteria analysis in Land Suitability Mapping. It is recommended that farmers around Askira/Uba, Chibok and Damboa be encouraged to cultivate more groundnuts.

Keywords: Groundnut-production; Multi-criteria; Land suitability; Parameters; Climatic; Overlay

1. Introduction

Groundnut (*Arachis hypogea*) is a leguminous oilseed crop cultivated in the semi-arid and subtropical regions of the world. It is grown in nearly 100 countries with a production of 41.3 metric tons as of 2012. China, India, Nigeria, USA, and Myanmar are the leading groundnut producing countries in the world. According to [1], 50% of groundnut produced globally is used for oil extraction globally while 37% and 12% are being used for confectionary and seeds respectively.

In West Africa, groundnut plays an important role. This includes food production for household consumption, cash crops, sources of employment, and incomes for smallholders in rural households. In Nigeria, it was among the major sources of income before the oil boom. Some of the activities surrounding its production are the development of

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commerce, employment, and foreign exchange. With the global decrease in the price of oil at the international market and the global clamor for a change in energy sources, the need to return to agriculture has now become necessary.

Globally, technological advancement has been made in food and crop production to boost production. Among this advancement is the understanding of human and natural systems as they affect crop production. The human system could include traditional and cultural practices, while the natural system could be climatic parameters such as rainfall, precipitation, temperature, topography, and other factors which could be related to the soil and geology of a given area. The understanding of the role of these factors is becoming is cornerstone to boosting agricultural production. This can be made possible with the application of Remote Sensing and Geographic Information System GIS.

Remote Sensing can simply be defined as the science and art of acquiring information from an object without making physical contact. Through Remote Sensing, information such as rainfall, temperature, topography, and precipitation among other climatic parameters can be recorded. GIS on the other hand is a computer-aided program that can receive data, store it, process it, and develop it into information that can be used for policies. The application of remote sensing and GIS can be used for the integration of the human and natural systems to understand the role played by each as it relates to crop production. This is what this study tends to do. This study therefore tends to focus on the natural system/parameters to identify the most suitable sites for groundnut production in the southern part of Borno State, Nigeria.

Farming have been the major source of Nigeria's economy before the discovery of oil. However, with the present decline in the price of oil globally and increasing population, the need for a more sustainable means of livelihood and source of income to boost the economy has become necessary. There is a global campaign for Nigeria to go back to Agriculture which has been the major backbone of the economy before the oil boom. In other to do that effectively, the knowledge of what will flourish where and when has become necessary.

Groundnut (*Arachis hypogea*) is a leguminous oilseed crop cultivated in the semi-arid and subtropical regions of the world. It is grown in nearly 100 countries on six continents between 40 N and S of the equator on nearly 24.6 m ha, with a production of 41.3 million tons and productivity of 1676 kg ha. Among the major countries that produce groundnut in large quantities are China, India, Nigeria, USA, and Myanmar. Going by the continental production, Asia, produced 11.6 m ha (47.15%), and Africa, with 11.7m ha (47.56%), holds the maximum global area under groundnut, [1].

Groundnut has a wide range of uses. According to [1], 50% of groundnut is used for oil extraction globally, 37% for confectionary use, and 12% for seed purposes. In West Africa, groundnut plays an important role in food production. It is also used for household consumption and as a cash crop, source of employment, and income for smallholders in rural households.

Nigeria is the highest groundnut producer in Africa. It was the number 1 source of income before the discovery of crude oil, the groundnut production, marketing, and trade served as major sources of employment, income, and foreign exchange before Nigeria became independent. However, the discovery of oil led to the neglect of the Agricultural sector of which groundnut production is one of it. With the global fall in the price of oil and a global clamor for other sources of energy, the need to go back to Agriculture has now become necessary.

Groundnut is one of the Agricultural commodities with a high market value globally. The need for boost its production will lead to increasing foreign exchange for the country. Borno State is generally known for the production of groundnut. However, since groundnut is not the only crop that is been cultivated in the region, the need to identify the most suitable areas where groundnut cultivation has become necessary. This will the farmers to prioritize their production and also give room for the cultivation of other crops. Quite some studies have been carried out on groundnut production however, such studies on the southern Region of Borno State despite being the major area for groundnut production are scanty in Literature. Among some earlier studies carried out on groundnut production is that of [2] and [3]. The studies conclude that a multi-criteria analysis of soil, topography, and climatic parameters could be used to identify the most suitable site for groundnut production. However, none of these studies focus on the southern Region of Borno State hence the study.

This study aims to identify the most suitable sites for groundnut production in the Southern Borno Region, Nigeria with a specific objective of the identifying area of groundnut cultivation within southern Borno region and conducting a suitability analysis for groundnut production within the study area.

Suitability analysis in Agriculture is a very important parameter that will ensure optimum input and optimum production. Due to the global glamour for Nigerians to go back to Agriculture, the need to identify suitable areas for crop production is now timely. This will aid a boost in production which in the long run will boost the fragile economy. Southern Region of Borno State is known for groundnut production. A study like this will provide information for local farmers and investors in the Agricultural sector on the viability of groundnut production within the region.

This study was carried out in Southern Borno which is made up of nine (9) LGAs namely; Askira/Uba, Bayo, Biu, Chibok, Damboa, Gwoza, Hawul, Kwaya Kusar, and Shani, (see Fig. 1). The area is habited by Marghi, Bura, Babur, Gwoza speaking tribes. Most of the region is dominated by farming activities.

The Region is located between latitude 100 00-110 30N longitude 110 36-130 58 E. It shares boundaries with Kaga, Konduga, and Bama to the north, part of Cameroun and Adamawa State to the east and south respectively, and Gombe State to the west.

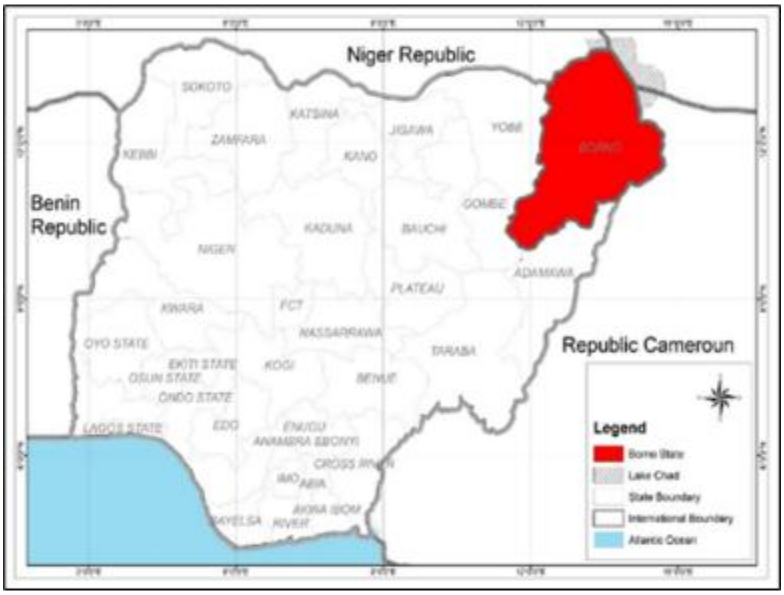


Figure 1 Study area map

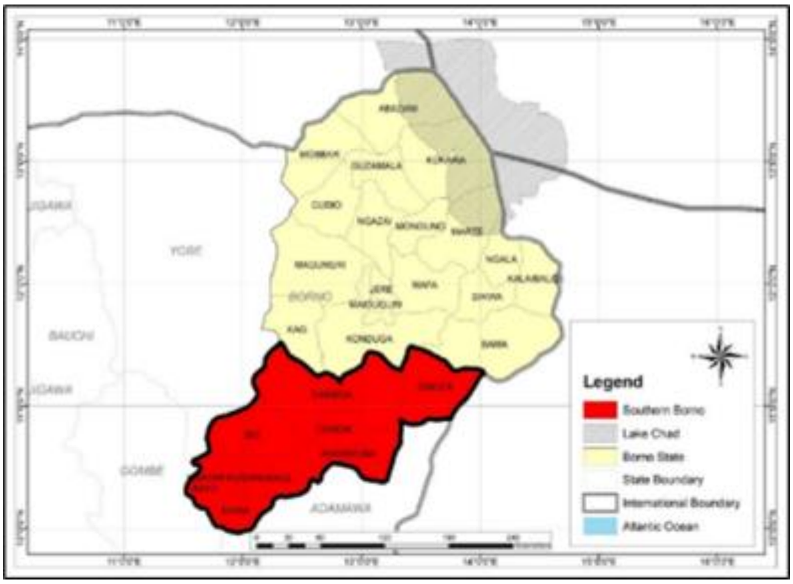


Figure 2 Southern Borno Region

2. Materials and method

This research includes the integration of geospatial and non-spatial data, as well as on-screen digitization of obtained data, to conduct a spatial distribution analysis of agricultural land suitability of wheat production in the Southern Borno region. Data used in the study were both primary and secondary.

2.1. Primary Data

The primary data used for this study is elicited from interviews. The study adopted a snowball method in the identification of respondents for the interview. The first is the identification of a groundnut retailer from the groundnut market in Maiduguri the capital of Borno State. The retailer helps us identify a wholesaler. The farmers were identified through the retailer. Information on areas of groundnut production was obtained from the farmer.

2.2. Secondary Data

The study used Remote Sensing for climatic parameters. They include rainfall, temperature, wind speed, and relative humidity. Other secondary data used are soil and topographic information.

2.3. Land Suitability

Land suitability mapping was developed using an innovative approach that integrates soil and climatic data for land suitability assessment. Suitability maps for each land use were developed to show the suitability classes and display the spatial representation of soils suitable for agriculture. This enables the classification of the land between the most suitable and the least suitable using a wide range of criteria. Land suitability mapping is usually done in Agriculture to determine areas where crop yield will be very high.

In Land suitability mapping, a wide range of parameters are usually assembled based on the favorability of the crop in question. It can then be weighted and overlaid to identify where parameters are most favorable. This procedure is very effective with the use of a Geographic Information System (GIS). This is because of its ability to integrate multiple data with uniform geographic coordination. The GIS can also analyze areas with high and low potential based on data input. This method is more reboot than an ordinary statistical package because of its ability to handle spatial display.

2.4. Parameters for Groundnut Production

The parameters for groundnut cultivation are multi-criterial. They include Soil, Topography, and climatic parameters.

2.4.1. Slope

Slope is defined as the measure of the rate of change of elevation of horizontal surface which explains the rise or fall of landforms and percentage of steepness. In this research, the moderate degree of slope is more suitable than the higher degree of slope. The slope was generated using the Shuttle Radar Topography Mission (SRTM) elevation dataset. The slope raster was reclassified into 3 categories namely; marginally, moderately, and highly suitable.

2.4.2. Temperature

Climate change has a direct impact on increasing temperature and alters the pattern of agricultural practices especially groundnut production [4]. It is a known fact, however, that temperature may be regarded as a decisive factor in the growth and development of groundnut plants. Peak temperatures inhibit the growth of groundnut. The temperature raster was reclassified into 3 categories namely; marginally, moderately, and highly suitable.

2.4.3. Rainfall

Rainfall is the most significant climatic factor affecting groundnut production. Low rainfall and prolonged dry spells during the crop growth period were reported to be the main reasons for low average yields in most of the regions of Asia and Africa, for example in India [5], [6] and several parts of Africa [7]. Persistent droughts and insufficient rainfall represent one of the greatest constraints on groundnut crop production.

2.4.4. Relative Humidity (Moisture Level)

The importance of moisture distribution to groundnut yield is well appreciated. Not only yield but also other yield attributes, growth, and development are affected by soil moisture deficit or water stress. Moisture stress also affects physiological characteristics like photosynthesis, stomatal conductance, leaf water potential, radiation and water use efficiencies, and partitioning of dry matter. [8], observed large reductions in photosynthesis and stomatal conductance as the relative water content of groundnut leaves decreased from 80 to 75% (due to moisture stress). [9], reported that leaf water potential, transpiration rate, and photosynthesis rate decreased progressively with increasing duration of water stress. [10], reported that water deficit decreased leaf area index, relative water content, and transpiration at about 3 weeks after the occurrence of water deficit at the soil level. [11], observed that the fraction of photosynthetically active radiation intercepted and harvest index was reduced under water stress.

2.4.5. Wind Speed

High wind speeds have a negative influence on groundnut production. Groundnut plants exposed to gusty winds have a chance of being blown away by winds thereby causing poor yields.

Table 1 Data Used for the study

S/No	Data	Source	File Format	Resolution	Year
1	Elevation	http://srtm.csi.cgiar.org/	Raster	90 m	2018
2	Soil type	FAO	Raster		
3	Temperature	NASA	NETCDF	0.5×0.5 degree	2020
4	Rainfall	NASA	NETCDF	0.5×0.5 degree	2020
5	Relative Humidity	NASA	NETCDF	0.5×0.5 degree	2020
6	Wind Speed	NASA	NETCDF	0.5×0.5 degree	2020
7	Landuse/Landcover	MODIS Land Cover product	Raster	500 m	2020

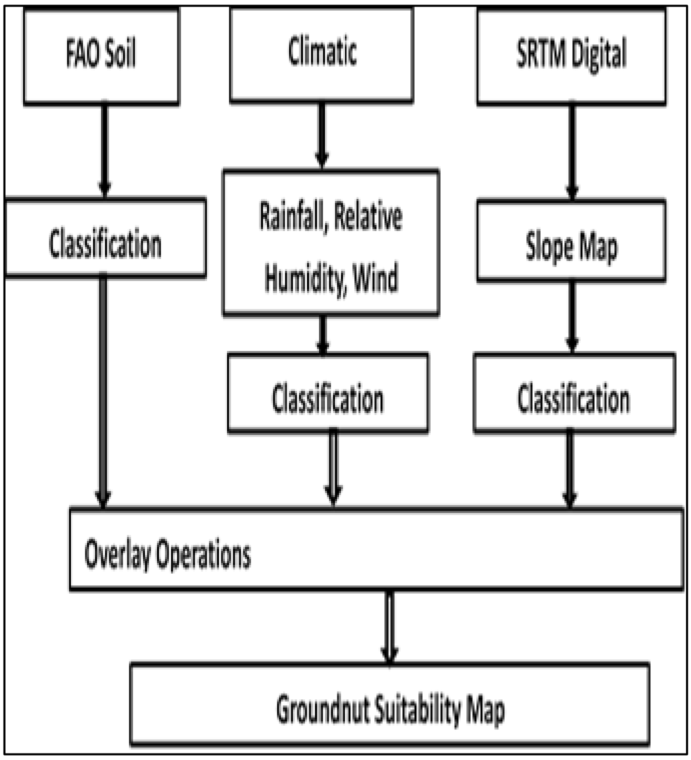


Figure 3 Methodology Workflow

Table 2 Data Analysis by Objectives

	Objectives	Data	Analysis	Expected results
Obj. One	identify the area of groundnut cultivation within southern Borno	Interview		Areas of groundnut Production
Obj. Two	conduct a suitability analysis for groundnut production within the study area;	Slope, Temperature, soil, rainfall, Humidity, wind, and slope	Classification, weighted overlay	The Most suitable site for groundnut production

3. Results and discussion

This chapter presents the results and the various analyses carried out according to the methodology clearly stated in Chapter three. It is also focused on the analysis of both the soil characteristics and climatic parameters for suitability analysis for groundnut production in Southern Borno with a clear focus on the aim and specific objectives. Land suitability for groundnut production is influenced by soil and climatic factors. The criteria for selecting suitable sites for groundnut production have been identified based on the kinds of literature reviewed.

3.1. Important Criteria for GIS Analysis

All the criteria for the suitability analysis for groundnut production in Southern Borno were acquired using remote sensing and geospatial approach to unveil the suitable sites that groundnut production will thrive within the study area. The layers deployed for the suitability analysis are as follows: Landuse/landcover, soil, temperature, rainfall, relative humidity, wind speed, and slope.

3.2. Landuse/Landcover, Soil and Climatic layers (Criteria)

The Landuse/Landcover map (See Figure 4) revealed that the study area was dominated by cropland, grassland, and tree cover compared to urban settlement, water body and wetland.

Figure 5 depicts the soil texture characteristics within the study area. It was observed that the study area is dominated by clay, sandy clay-loam, sandy loam, silt, silt loam and silty clay with high concentration of clay soil type. Groundnut plants are perfectly grown in well-drained sandy loam or sandy clay loam soil for better performance.

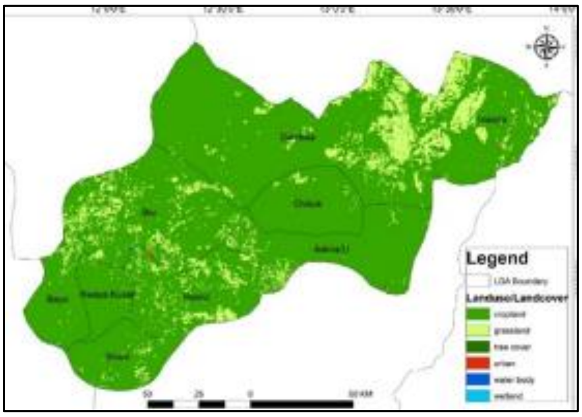


Figure 4 Landuse/Landcover Map of the study area

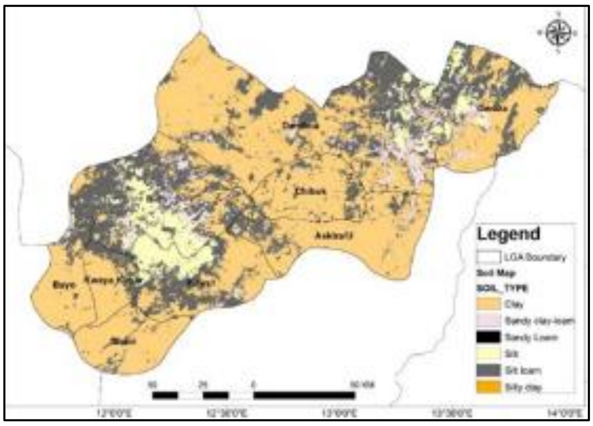
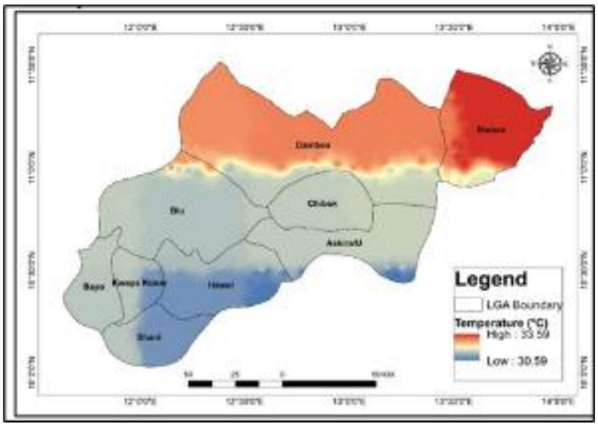


Figure 5 Soil Map of the study area



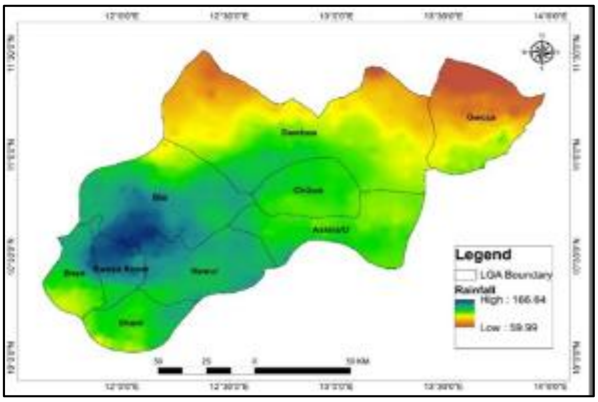
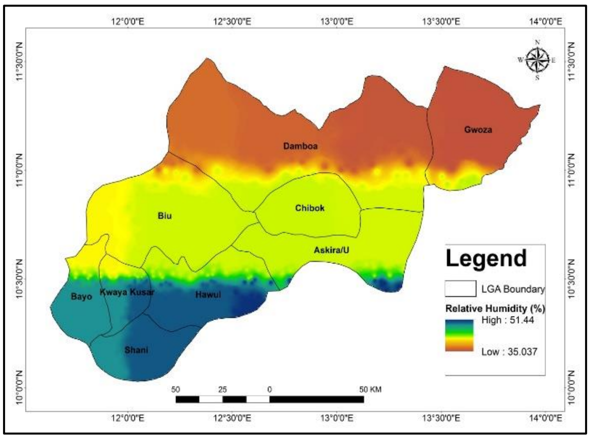


Figure 6 Temperature Map of the study area

Figure 7 Rainfall Map of the study area

The temperature map is shown in Figure 6 with a temperature range between 30.59°C and 33.59°C. The result further shows that the average temperature within the study area is 32.02°C. It was observed that the northern part of the study area including Damboa and Gwoza is hotter than the southern part of the study area. Optimum temperature is essential for good germination of groundnut plants.



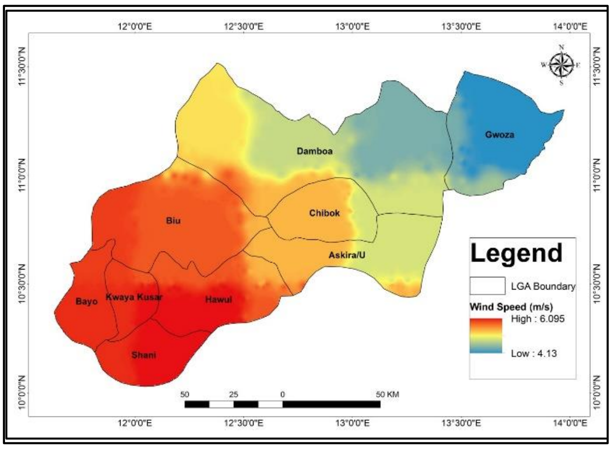


Figure 8 Relative Humidity Map of the study area

Figure 9 Wind Speed Map of the study area

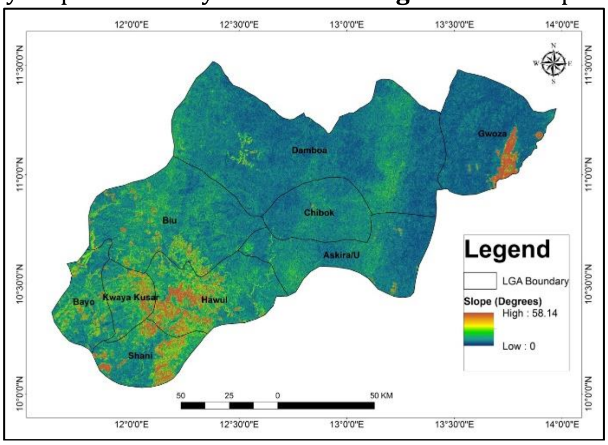


Figure 10 Slope Map of the study area

Figure 7 depicts the rainfall distribution within the study area with rainfall range between 59.99 mm and 166.64 mm with average value of 125.82 mm. Moisture level within the study area varies with peak levels witnessed at the southern part while the Northern part is characterized by low values depicting dryness. Other important criteria employed are Relative Humidity, wind speed and slope (See Figure 8, 9 and 10). Steep slopes allow rapid runoff, erosion of top soil profiles and mineral deposition in lower profiles.

3.3. Land Suitability Analysis based of Identified Criteria

Areas around Gwoza, Hawul and Shani were discovered to be moderately suitable based on the topography while the other areas were found to be highly suitable. The result of the temperature shows that Shani, Bayo and Biu areas were Highly suitable while Damboa and Gwoza were marginally suitable.

Result for the soil analysis indicate that areas around Gwazo and Biu were considered suitable based of soil type. Areas around Damboa, Gwoza is recorded marginal while Bayo, Hawul and Kwaya-Kusar is recorded highly suitable. The result of the of the wind speed reveals that area around Gwoza is regards as suitable while Biu, Hawul and Shani axes were found to be marginally suitable (See Table 3 and 4).

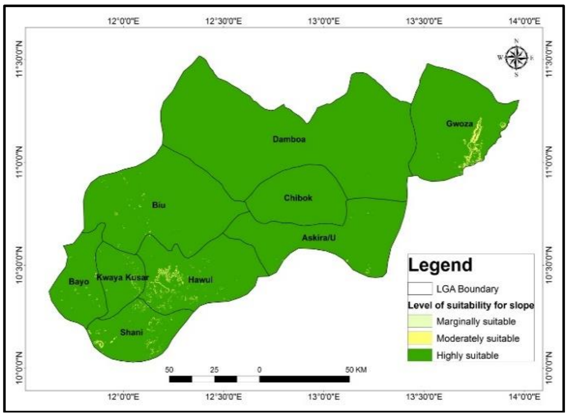


Figure 11 Reclassified slope map of the study area

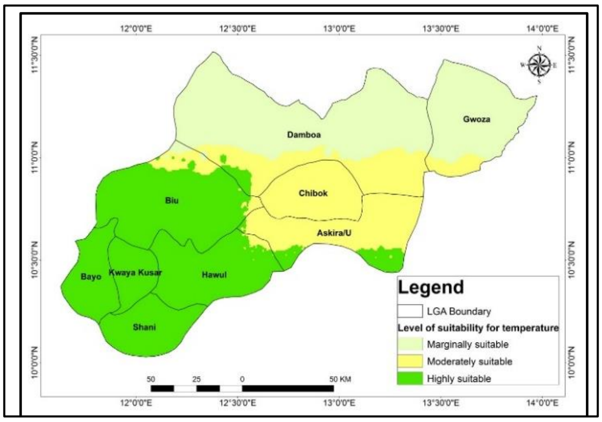


Figure 12 Reclassified temperature map of the study area

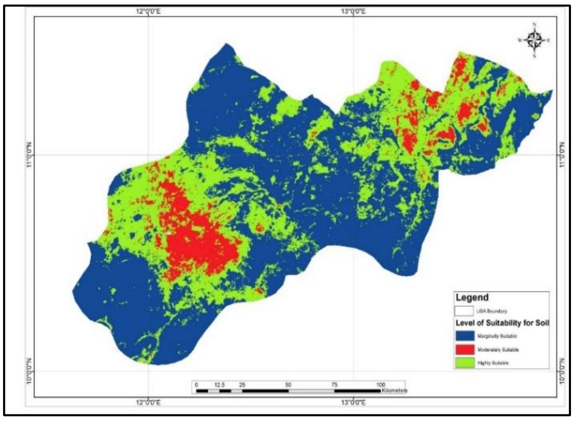


Figure 13 Leve of sitability for soil map

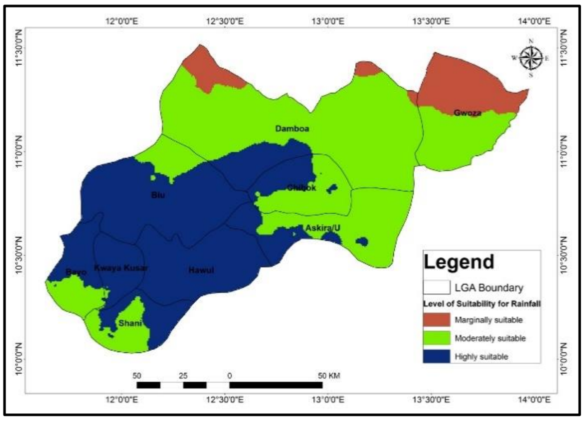


Figure 12 Reclassified rainfall map of the study area

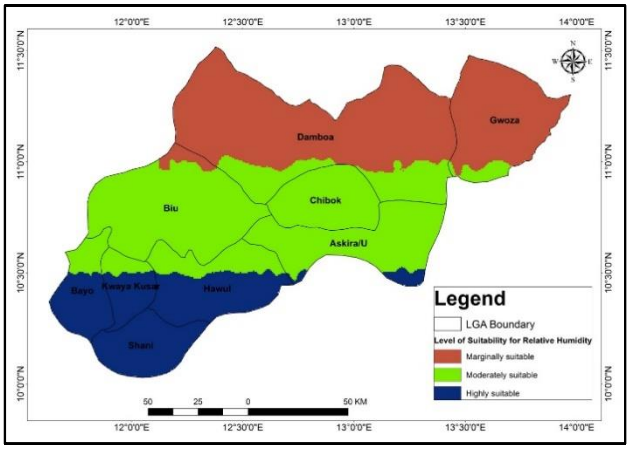


Figure 15 Reclassified rainfall map of the study area

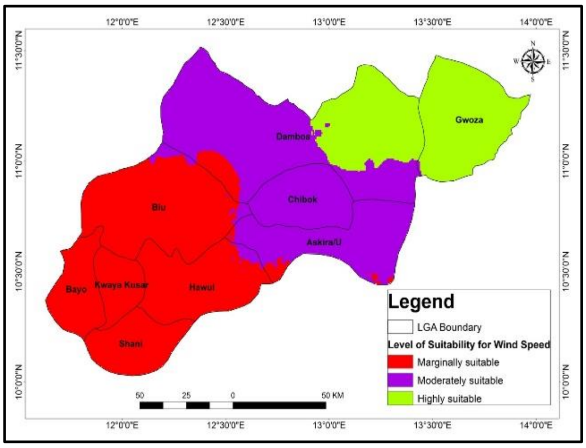


Figure 16 Reclassified wind speed map of the study area

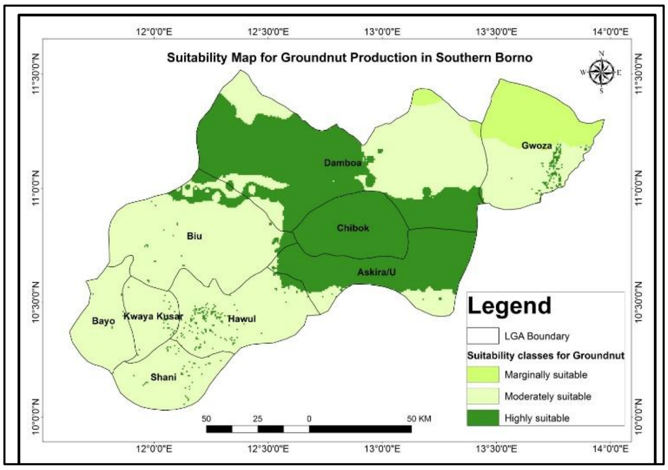


Figure 17 Suitability Map for groundnut production in Southern Borno

3.4. Pairwise Comparison Matrix (PWCM)

The pairwise comparison matrix (PWCM) was performed for rating and weighting of the different criteria. The fundamental scales provided by [12] for the comparisons of two criteria were employed. The quantitative value from 1 to 9 scales was given by [12] considering the comparative significance of two criteria. The preference matrix of criteria was presented in Table 3 where values were set between equal (1) to strong (9) preference. However, the overall rating based on experts' opinions for the comparison was generated and presented in Table 3. This was utilized to generate a suitability map for groundnut production in Southern Borno.

Table 3 Pairwise Comparison Preference Matrix for the criteria

	Soil	**Slope**	**Wind speed**	**Relative Humidity**	**Temperature**	**Precipitation**
Soil	1	0.2	1	1	0.11	0.11
Slope	5	1	0.5	0.5	0.2	0.2
Wind speed	1	2	1	0.5	0.2	0.2
Relative Humidity	1	2	2	1	0.2	0.2
Temperature	9	5	5	5	1	0.2
Precipitation	9	5	5	5	5	1

Table 4 Overall weights for land characteristics and climatic parameters

Criteria	Weights
Soil	4.124
Slope	7.302
Wind speed	6.429
Relative Humidity	7.949
Temperature	26.549
Precipitation	47.647

3.5. Suitability Evaluation for Groundnut Production in Southern Borno

Based on the weights generated in Table 3 above, the suitability map for groundnut production was generated (See Figure 17). Suitability evaluation for the study area revealed that 35.12% was highly suitable, 58.36% of the area was moderately suitable and 6.51% was marginally suitable for groundnut production.

4. Conclusion

This study is a suitability mapping for groundnut production in southern region Borno state to identify a suitable site for groundnut production. literature on land suitability mapping for groundnut production was reviewed. The study analyzes several criteria including soil, rainfall, temperature, relative humidity, slope, and wind speed of the study area and their suitability level to identify the suitable area for groundnut production in the study area. Findings from the interview revealed that groundnut is been cultivated in all areas with the Southern Region of Borno State, Askira/Uba, Chibok, and Damboa were discovered to be the most suitable sites for groundnut production within the study area, and areas around Gwaza were considered as marginally suitable

The specific objectives were to identify areas of groundnut cultivation and the most suitable site for groundnut cultivation in the study area. A multi-criteria decision-making method, (FOA) was used. The criteria were assigned a weight based on their importance in determining the suitable site for groundnut production. The result of the first objective shows that the study area is a suitable area for groundnut cultivation. The second objective to conduct a suitable analysis for groundnut production was achieved by performing, Shuttle Radar Topographic Mapping (SRTM) and option of all the criteria along with the weighted overlay to identify the most suitable area for groundnut cultivation within the study area. A GIS weighted overlay Technique has the potential and capability to integrate spatial and attribute data for producing a land suitability classification map for the southern Borno region, the data shows in the study area is moderately suitable land, (S2) are dominants followed by highly suitable in (S3) and marginally suitable in (S1). This study information about the land suitability of groundnut in the study area and hence offers farmers alternative land uses to reduce the risk of crop failure.

Recommendation

It is recommended that farmers around Askira/Uba, Chibok, and Damboa be encouraged to cultivate more groundnuts while farmers in the other areas should concentrate on the cultivation of other crops. Studies on the suitability analysis of other crops should also be encouraged in other to encourage precision Agriculture.

Compliance with ethical standards

Acknowledgments

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Disclosure of conflict of interest

No conflict of interest is to be disclosed.

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