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A GIS-based land suitability assessment of wheat production in Kano using selected physical parameters

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Abstract

Wheat is the second largest contributor to Nigeria's food import bill and puts pressure on the foreign reserve of the nation. Land suitability assessment is a prerequisite to achieving optimum utilization of the available land resources. Lack of knowledge on best combination of factors that suit production of wheat has contributed to the low produce. The study aims to assess land suitability of wheat production in kano using selected physical materials with the objectives to map out existing locations for wheat production in kano state, determine other areas that may be suitable for wheat production. The study utilized Landsat 8; Shuttle Radar Topography Mission (SRTM) Multi-criteria Evaluator (MCE) integrated with GIS. Spatial factors for wheat cultivation such as soil texture, soil type, soil slope, rainfall range, geology map, elevation, land use land cover and their attribute were identified and were processed into spatial data. The factors were weighed according to their relevance. Land suitability model was constructed in ArcGIS software and spatial data were imported into (SRTM) and link to the land suitability model constructed. The spatial data integrated were computed and final visualization of land suitability map was produced and using ArcGIS 10.3 to identify potential areas. The result obtained showed that 16% were unsuitable, 19% were moderately suitable, 25% were highly suitably and then 40% were most suitable in the study area. Based on this finding, it is recommended that wheat cultivation should be practiced in a large scale in Kano state.

Keywords; Land suitability; Production; Topography; Model; Visualization; Wheat

1. Introduction

Globally, agriculture has demonstrated the ability to boost food supply more quickly than population expansion, a trend that can be anticipated going forward [1]. Concern over food security is on the rise throughout Africa, particularly in sub-Saharan Africa. It is anticipated that food security in sub-Saharan Africa would deteriorate, notwithstanding the generally positive image of the world's food supply and/or demand [2].

Due to the fact that more than $2 billion is spent yearly on the importation of more than five million metric tons of wheat, wheat is the second largest contributor to Nigeria's food import bill and puts pressure on the foreign reserve of the nation [3]. Over the past few years, flour millers have imported an average of 4.7 million tons of wheat annually [4]. Nigeria produced around 200,000 metric tons of wheat domestically in 2020 [5], less than anticipated mostly because of unfavorable weather and a lackluster selection of seed types.

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The majority of wheat produced in Nigeria is cultivated on a modest scale by small-scale farmers in the country's northern regions. Following the large-scale irrigation dam building in the 1970s, wheat production started on a comparatively commercial scale, even though farmers were not well-versed in better wheat production techniques [6]. A significant amount of wheat was imported into the nation as a result of the expanding local demand for wheat goods brought on by the population's shifting tastes in wheat products. Because baked goods made from wheat products are inexpensive and easy, more Nigerian households than ever before turn to these meals to satisfy their nutritional demands [7]. Important dietary staples made from wheat flour include semolina, bread, noodles, and pasta, among others. These foods constitute a regular feature of meals in the majority of rural and urban households in the nation. Bread, cookies, cakes, biscuits, spaghetti, and several noodle varieties are all made using wheat. It is also used in Nigeria to make regional dishes including Danwake, Taliya, Gurasa, Tuwo, Alkaki, Fura, Algaragis, and Alkubus.

Because of its inherent properties, wheat was previously referred to be a crop par excellence [8]. It is a highly valuable source of carbohydrates for human diets and has good baking characteristics. Wheat has the ability to be kept for an extended amount of time in the shape of bread, cakes, or biscuits, or it can be stored as a coarse grain. This feature makes wheat a convenient food source, particularly for urbanites. More significantly, wheat has a protein concentration of almost 44%, which is higher than the combined protein amounts of meat, milk, and eggs.

These and other factors explain why wheat is a powerful diplomatic tool on a global scale and why emerging nations are currently working so hard to produce enough of it on their own. In the past, wheat was mostly used by the nobility in northern Nigeria to make celebratory delicacies such curasa, taliya, tsats-tsafa, alkaki, and dubulam. But before its importation was outlawed in 1986, wheat consumption had spread throughout all societal classes, even the rural ones. When bread became the cheapest meal accessible in 1960, its consumption skyrocketed. During the colonial era, bread was considered a luxury item and was consumed in limited amounts. The consumption of wheat bread increased rapidly, and this growth was matched by the phenomenal rise in bakeries and confectioneries as well as the number of flour mills, which increased from one in 1960 to twenty-two in 1986 [9]. Nigeria had to boost its wheat imports from 0.26 million metric tonnes in 1970 to around 1.5 million metric tonnes in 1986 in order to fuel such mills.

1.1. Relief and drainage

The area’s highest elevation is in a village called Husure at eastern part of the area, about 564M above the sea level and minimum elevation of 488M down south of the area and with an average height of 526M above the sea level. Drainage in the area is largely influenced by the relief; low land areas have the rivers and streams. River Challawa is the only big river with tributaries, Magaga, Takwami, Guzu-guzu, Kutumbulu, Iyaka and some lakes. The area has a drainage density of 1.46km2 as calculated by [10]. The general pattern of drainage in the area is dendrite mostly running in the north south direction. The study area and part of the metropolis is drained by two major river systems - the Jakara and the Kano Rivers. Kano metropolis is divided in to two hydro-geological watersheds, to the west-south of divide is zone of high surface water discharge and retention which coincides with the zone of basement complex structure.

1.2. Statement of Problems

Kano state is an area where population growth constrains land resource, farmers lack basic scientific information about the land use requirement and potential. Most wheat is imported today, and as such, the country is in dire need to accelerate local production. Production constraints are manifold and vary from crop to crop between regions. Burgeoning population viz-à-viz increasing demand for food; growing competition for cultivable land, irrigation water and energy; intensive cropping especially in the Indo-Gangetic plains, which are fertile plains in the northern region of the Indian subcontinent, resulting in irrational use of resources; pest-environment interaction; reduction of natural resource base; declining total factor productivity, which translates to how much output can be produced from a certain amount of inputs,; and yield plateau are the prominent challenges put forth against crop production. Wheat production not only faces the above routine challenges, but the intensity gets magnified in the context of climate change owing to its vulnerability.

1.3. Justification of study

Land suitability is essential for land use planning and development, there is dearth of information about land suitability mapping for wheat cultivation in Kano state. Hence the study will integrate the technology of remote sensing and GIS to identify suitable areas in Kano state. The findings of this study will be used by farmers, stakeholders and policy makers for sustainable and smart use of land.

The study aims to assess land suitability of wheat production in kano using selected physical materials with the objectives to map out existing locations for wheat production in kano state, determine other areas that may be suitable for wheat production.

1.4. Study Area

The Kano Region, which has a land area of around 20, 760 square kilometers and is situated at 481 meters (or roughly 1580 feet) above sea level, is made up of over 92, 250, 81 hectares of forested vegetation and grazing pasture in addition to 1, 754, 200 hectares of agricultural land. The Kano Region is surrounded by the Niger Republic to the north, Jigawa and Bauchi State to the east, Katsina State to the west, and Kaduna State to the south-west. The area is in Nigeria's Sudano-Sahelian zone and is roughly situated between longitudes 8° 45 E and 12° 05 E and latitudes 10° 30 N and 13° 02 N.

1.4.1. Climate of the Area

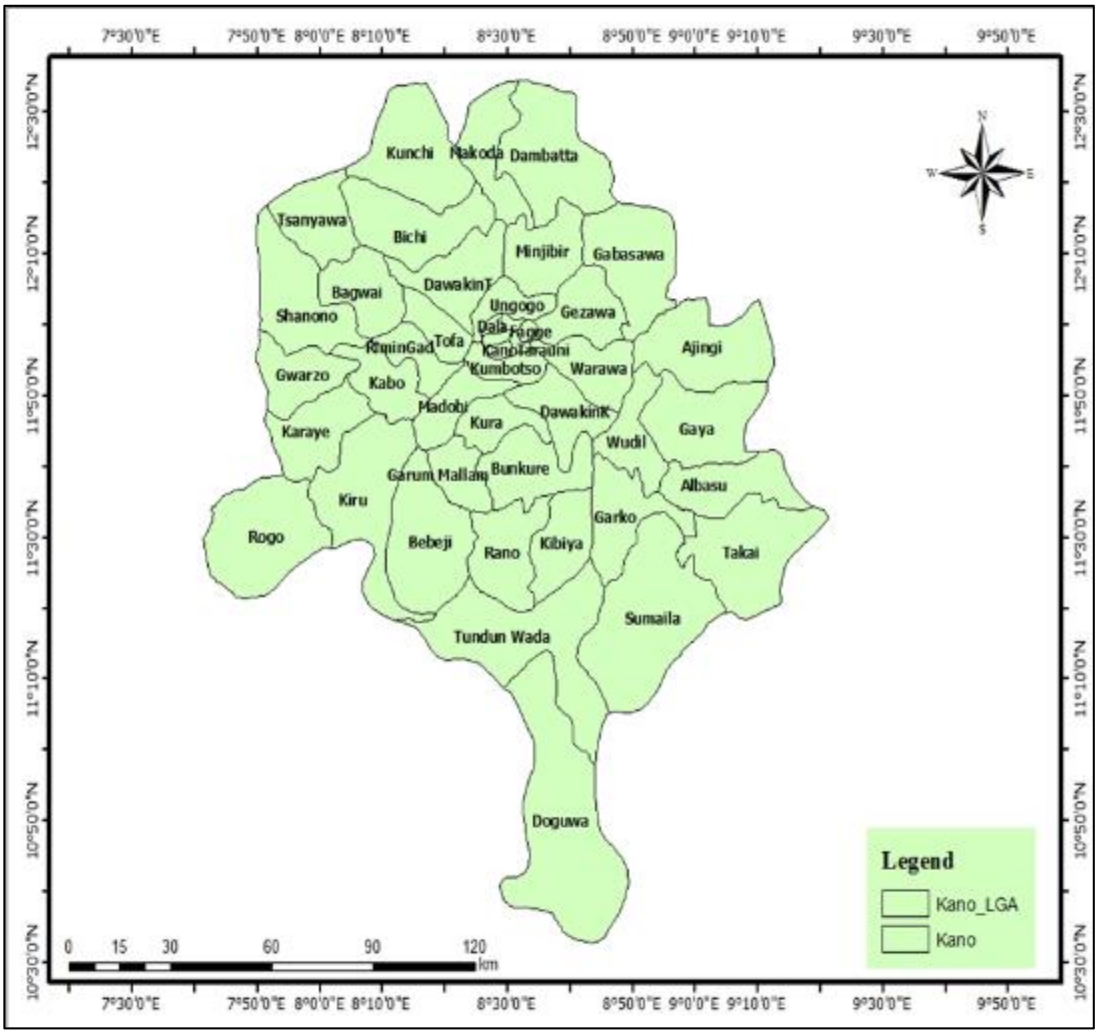

Figure 1 Map of Study Area

Although there are indications of historical climatic shifts, the Kano region currently has a tropical wet and dry climate, designated as Aw in Koppen's classification. Overall, Kano's climate is similar to that of the West African savannah. Throughout the year, the area has relatively high temperatures. Seasonal variations are seen in Kano, with a progressive increase from January to April, when the maximum temperature can reach 43°C [11]. Based on the element of temperature, there are three primary seasons. a dry and chilly season: The period is November through February. In this period, the monthly average temperature ranges from 21 to 23°C, with daily variations of 12 to 14°C. Right now, the winds from Hamattan are predominant. A hot and dry season that lasts from March to mid-May follows the time. During this time, the daily temperature ranges up to 20°C, with a mean monthly temperature exceeding 300°C. The warm wet season that follows with mean monthly temperatures of around 26°C and a diurnal range of roughly 10°C, peaking at 13°C in September [12].

The Kano metropolis and its northern and southern boundaries according to continentality and latitudinal variables. In the southern Kano region (which includes parts of the local governments of Doguwa and Tudun-Wada), the yearly rainfall may reach around 1000 mm. In contrast, the annual value obtained in the northernmost region is less than 800 mm, particularly in the area of the desert. [13] claim that there is variability in the yearly rainfall figures from year to year. For example, the years 1999, 2004, 2010, and 2012 saw above-average yearly temperatures and rainfall.

The main tribes are hausa and Fulani who are mainly farmers, traders, and minor crate men The state has 44 local government areas. Kano state is one of the fastest growing towns in the African Savannah region. In the 2006 census, the state's population was 2,826,307. Kano state experience rapid population growth rate, the population of Kano as at (year 2000) is 1.6million [14]. However, the population data shows that in 2003 the population raised to 2.3 million (approximately) and 2.8million. Kano city has for centuries been the most important commercial and industrial nerve centre of Northern Nigeria, attracting millions from all parts of the country and beyond. Immigration and natural growth rate of 3% is expected to continue to increase the population. With a population presently estimated at 3.5 million [15]. Kano state is among the fastest growing cities in Nigeria. With a population density of about 1000 inhabitants per km^2 within the Kano closed-settled zone compared to the national average of 267 inhabitants per km^2. It is also one of the most crowded cities, the city also has a large migrant worker population which has been increasing at the rate of 30 to 40 per cent per annum [16]. Kano is the second largest industrial and commercial centre in Nigeria after Lagos.

Table 1 Countries Estimated Wheat Production (Metric Tons)

Country	**Estimated wheat production (metric tonnes)**
NIGERIA	420,000
ARGENTINA	14,560,000
AUSTRALIA	20,376,000
BRAZIL	5,962,604
CANADA	25,860,400
FRANCE	39,704,764
GERMANY	25,427,000
INDIA	72,060,000
IRAN, ISLAMIC REP OF	14,000,000
ITALY	8,628,758
KAZAKHSTAN	9,942,300
PAKISTAN	19,767,000
RUSSIAN FEDERATION	45,412,712
UKRAINE	17,517,700
UNITED STATE OF AMERICA	58,737,800

Source: FAO stat (2020) world production of wheat 627,130,584.

2. Materials and method

2.1. Data Collection and Source

The data collection used in this study were primary and secondary. Primary data used include GPS coordinate's while the secondary data used include; Landsat-8 (2019) with the resolution of 22M Acquired in earth explorer soil map (from food and agricultural organization) climate data (Giovanni) SRTM DEM (30m resolution) from USGS archive choice of software. The software used for the study includes ArcGIS 10.3 and ERDAS IMAGINE 9.2. ERDAS used for raster image data processing and ArcGIS 10.3 was used for vector analysis. The images were downloaded (in zipped format) then extracted using WinRAR software; (extracted images were processed after wards to ArcGIS10.3)

2.2. Image classification

ERDAS IMAGINE 9.2 was used to stack the image and then resized the images were classified using supervised classification method training pixels have to be selected in a sample set. The combined process of visual interpretation of tone, pattern, size, texture and shape of the imageries and digital image processing was also used to identify homogeneous groups of pixels, which represent various land used to power, and six classes of land land cover were classified; and these are cropland, grassland, tree cover, wetland urban and also water body. This process was achieved after the download of different scenes of Kano state from satellite, it was layer stacked, composite using band (RGB 5,4,3) red for near infrared, green for red and blue for green and also mosaicing was done too after layer stacking, the image was also Geo-referenced to appoint the right reference information in order to make the image compatible. Supervised classification was employed to classify features of interest on ERDAS IMAGINE 9.2 respectively into urban, grassland, cropland, water body, tree cover and wet land. Supervised classification was used because it requires the use of data identified. Other spatial data were considered like Rainfall, Temperature, which was overlaid in the study area to produce spatial factor map.

2.3. Method of Data Analysis

Weight the spatial factors in MCD which is the spatial factors identified in the objective one includes soil types, cultivated area, tree cover, wetland, grassland water body, slope, and urban. The purpose of weighing was to determine the importance of each factor relative to other factors that affect crop growth and yield rates. The spatial data in this study was divided into constraints and a factor database. The criterion weight was calculated by giving a value to each criterion based on its importance using analytical hierarchy process (AHP) methodologies. This approach generally involves the input of an expert. Table 3.1 shows that one criterion is more important than the other based on the comparison matrix.

2.4. Data preparation

This study made use of freely available global datasets from a variety of databases. Geo-referenced soil data from the Soil Grids database was used in this investigation [17]. On a worldwide scale, it provides Geo-referenced information on soil, including site features, chemical and physical soil qualities, and soil categorization. ISRIC's globe soil grids are a product of ISRIC. The data on land usage was compiled by the system is described as an automated soil mapping method based on global soil profile and environmental covariate data with a spatial resolution of 250 m and a precision of 0.0083 decimal degrees. The CHIRPS climate dataset comprises the average of monthly climate interpolated with a 1 km precision from meteorological station data. The information on land use was gathered

The CHIRPS climate data set contains the average of monthly climate interpolated from weather station data with a 1 km precision. Landsat 8 data on land use was downloaded (OLI). The planned land use necessitates the fulfillment of a land use requirement. The focus of this research is on the requirements for growing Wheat grain, which are determined by climatic conditions. Topography landscape and soil factor. Table 3.1 below present the description of the data used in this analysis Geological map: A geological map is a special-purpose map made to show geological features. Rocks units or geological strata to indicate where they are exposed at the surface.

2.5. Soil Map

It is a geographical map which shows diversity of soil types or soil properties like soil pH, textures, organic matter, depths of horizons etc. in the area of interest. It is typically the end result of a soil survey inventory. Landsat 8 which is an American Earth Observation satellite; Climate data which is a time series of measurements of sufficient length, consistency and continuity to determine climate variability and change; Administrative map of Kano State that contains graphically recorded information pertaining to administrative matters of Kano State; SRTM: the shuttle Radar Topography Mission is an international research effort that obtained digital elevation models on a near-globe scale from 56 to 60 N, to generate the most complete high-resolution digital topographic database of earth prior to the release of the ASTER DEM in 2009 were use in this study.

Table 2 Data types and sources

S/N	Data type	Resolution	Sources	Relevance
1	Sat Image	22M	sentinel	Classification of land use of the study are
2	Soil map	100M	FAO	To clip the study area soil map
3	Climate data	200M	Giovanni	To get the rainfall, temperature, Ph of study area
4	Geology map	___	Nigerian geological survey	To clip the study area map
5	Administrative map of kano state	___	Surveyor General	To generate the shape file of study area
6	SRTM-DEM	30m	USGS	To generate the slope of the study area

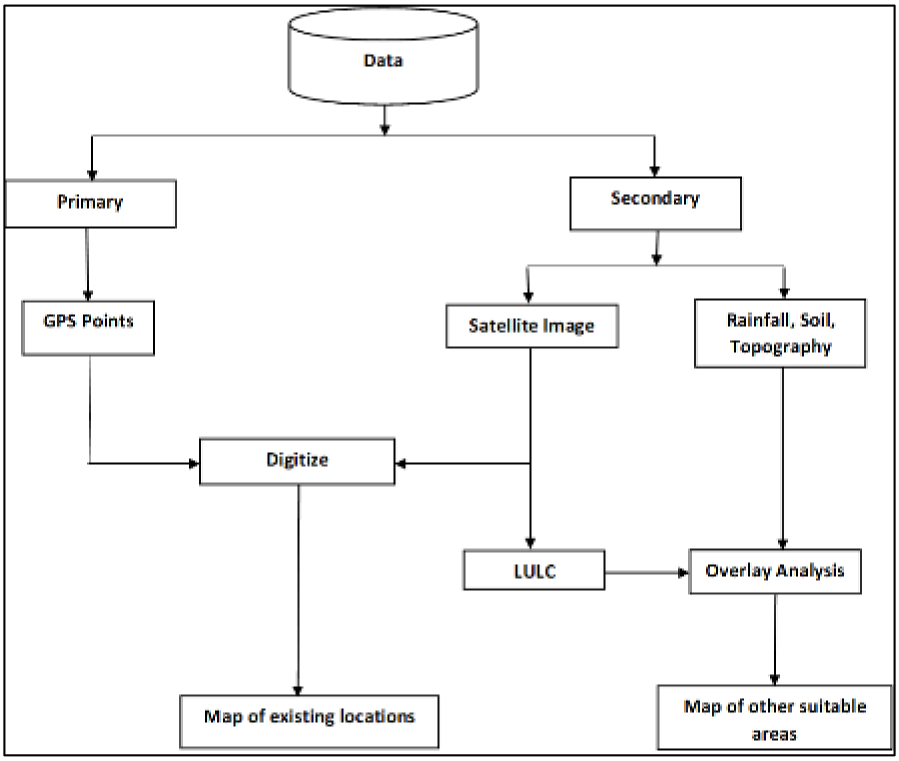

Figure 2 Methodology Workflow Adopted for the Study

2.6. Soil factor

Clay loam soils are the best for the production of wheat [18], however, it can be grown on a clay loam or loam texture, good structure and moderate water holding capacity are ideal for wheat cultivation. Caution should be taken to avoid very porous and excessively drained soil. Soil should be neutral in its reaction. The optimal depth of the soil is between 1 and 3 [19].

2.7. Slope factor

The slope information was obtained from Digital elevation model (DEM) using GIS software package ArcGIS 10.3. The source of DEM was SRTM which was 30m spatial resolution. Nigeria administrative map was added, in the SRTM, data was exported to ArcGIS for further analysis. Kano state shape file was over laid in the imported data and the study area was clipped out to extract the relevant portion of the SRTM IMAGERY that falls within the boundary of the study area.

The coordinate of the clip image was re projected to WGS 1984, UTM Zone 31S, the spatial extension analysis ArcGIS 10.3 software was used to generate slope DEM.

2.8. Climate factor

Annual rainfall of 254 mm (10 inches) is usually considered the minimum, and the soil should be adequately fertile. Barley and rye can be grown in soil less fertile than that required for wheat. Soils with a good humus content (partially decayed organic matter) and chemical fertilizers generally are necessary during growing season is around 15.5°C. The weather should be warm and moist during the early stage of growth and sunny and dry in the later stages. The average temperature of the hottest month should not exceed 20°C. A frost-free period of 100 days is usually required but some fast-ripening varieties may mature only in 90 days. The amount of rainfall required for wheat cultivation varies between 30 cm and 100 cm. The major wheat lands of the temperate regions have an annual rainfall of 38 cm to 80 cm. The spring wheat region of Canadian Prairies only receives around 46 cm of rainfall, but it comes in the early summers when the wheat is growing. Wheat is also grown in areas having lesser amount of rainfall, i.e., 25 cm. This has been done by adopting dry farming method. Also, where irrigation facilities are available, wheat is cultivated in dry lands too.

Table 3 Pairwise Matrix

	SOIL	RAINFALL	GEOLOGY	ELEVATION	SLOPE
SOIL	1	0.5	0.333333333	0.333333333	0.25
RAINFALL	2	1	0.333333333	0.333333333	0.25
GEOLOGY	3	3	1	0.333333333	0.25
ELEVATION	3	3	5	1	0.25
SLOPE	4	4	2	2	1
TOTAL	13	11.5	8.666666667	4	2

Table 4 Normalization

	Soil	Rainfall	Geology	Elevation	Slope	Sum	Weight	CR
SOIL	0.0769	0.0435	0.0385	0.0833	0.125	0.3672	0.0734	0.9547
RAINFALL	0.1538	0.0870	0.0385	0.0833	0.125	0.4876	0.0975	1.1215
GEOLOGY	0.2308	0.2609	0.1154	0.0833	0.125	0.8154	0.1631	1.4133
ELEVATION	0.2308	0.2609	0.5769	0.25	0.125	1.4436	0.2887	1.1548
SLOPE	0.3077	0.3478	0.2308	0.5	0.5	1.8863	0.3773	0.7545
TOTAL	1	1	1	1	1	5		5.3988

3. Result and discussion

3.1. Classification of Wheat requirements

Wheat is an important source of carbohydrate Hey SJ (2015), it is the leading source of vegetable protein in human food globally, with the content of about 13%.

3.2. The slope Map of the study area

Optimum slope requirement ranges from 0.4 south, southeast and no direction, to 4.8 east and northeast suitable. The slope map of the study area was generated using STRM data and DEM module in ArcGIS 10.3. The slope map shows seven classes ranging from the lowest (33.36-67.52) to the highest (0.1-059). The most suitable for wheat is the first-class as represented in figure 4.

3.3. Elevation Map of the study area

Elevation map ranges from 224-1,213 in the study area the suitability range for wheat cultivation falls within 1-2000 any value from 2000-3000 is less suitable as shown in figure 5.

3.4. Classification of soil in Study area

The soil map of Kano state was digitized and their classification shows that the soils were made up of five types namely silt clay, silt loamy silt, sandy clay-loam and clay. Silt loam accounts for the dominant soil type which is highly suitable. Next to silt clay in size is silt loam which appears to be high followed by silt which is moderate and then sandy clay-loam which appear to be low then clay is the least soil type in the study area as represented in figure 6.

3.5. Land use/ land cover of the Study Area

In terms of land use, the study is classified into six land use type based on FAO scheme namely, wheat cropland appears to be the highest, high grass land, moderately distributed tree cover, wetland, urban and then water body which is the least (irrigation cultivation) as seen in figure 7.

3.6. Geology Map of the study Area

Geology classification of the study area, shows the basement complex (the assemblage of metamorphic and igneous rock) underlying stratified rocks in the study area with the average thickness 14.33m and an average resistivity value of s178Ωm, Chad formation which low and then young granite as the lowest respectively as shown in figure 8.

3.7. Rainfall

Rainfall distribution in the study area is between 16.2cm to 37.8cm as shown in figure 9. The dominant distributed rainfall in the study area is 37.8cm which is the most suitable rainfall for wheat cultivation, the classes of the rainfall were included in MCE analysis for the determination of the suitable location in the study area.

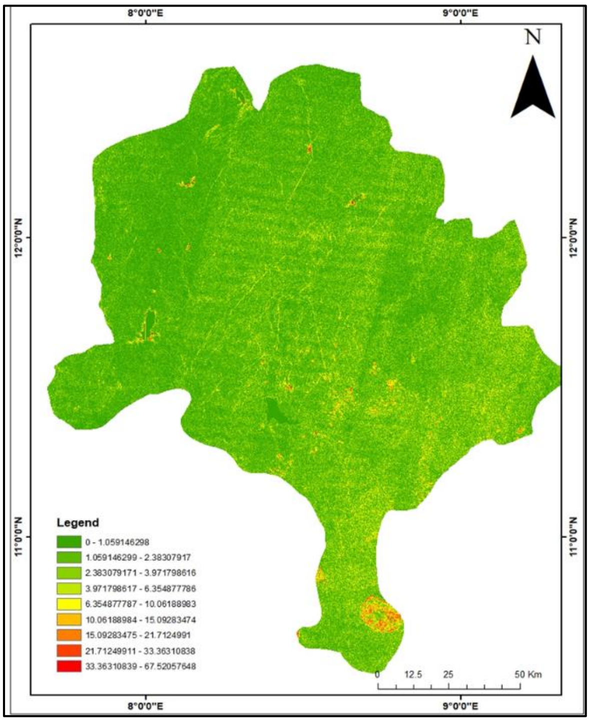

Figure 3 The Slope map of the study area

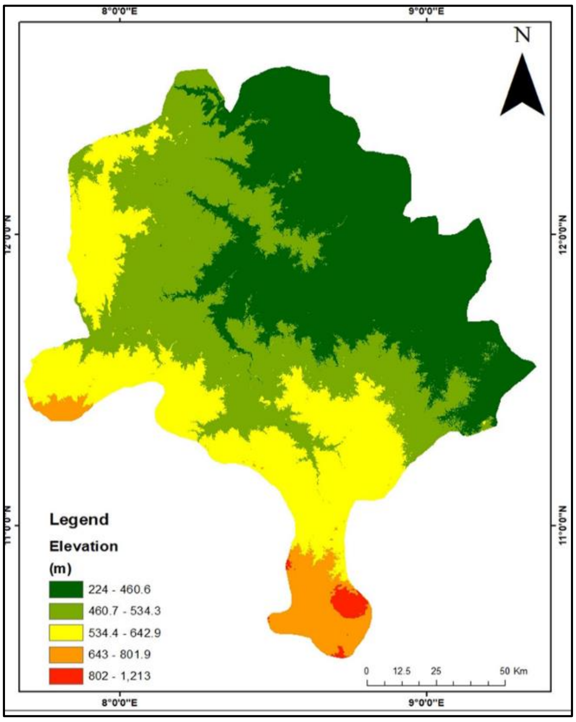

Figure 4 Elevation map of the study area

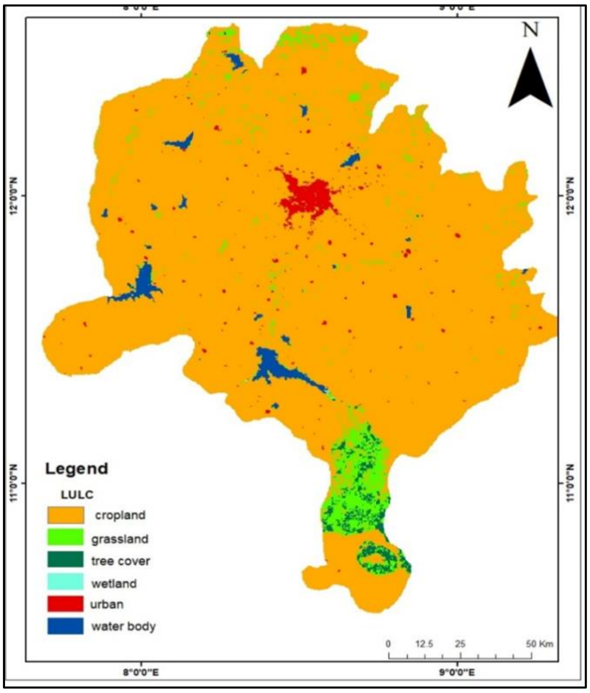

Figure 5 The land use of the study area

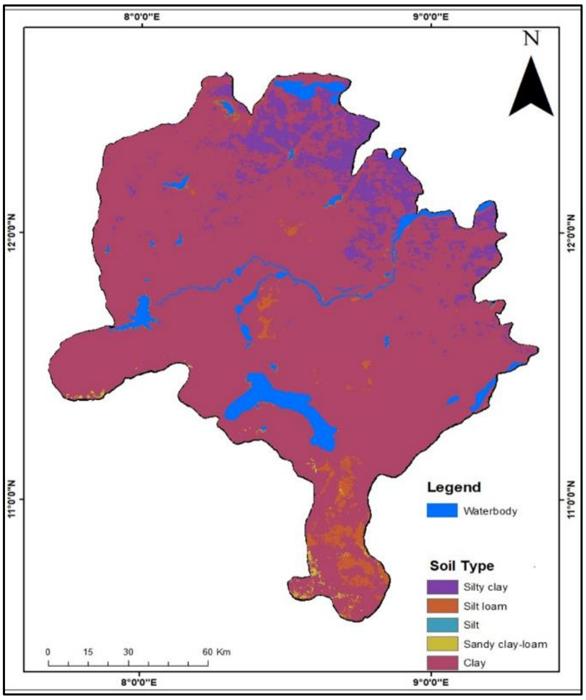

Figure 6 Soil map of the study area

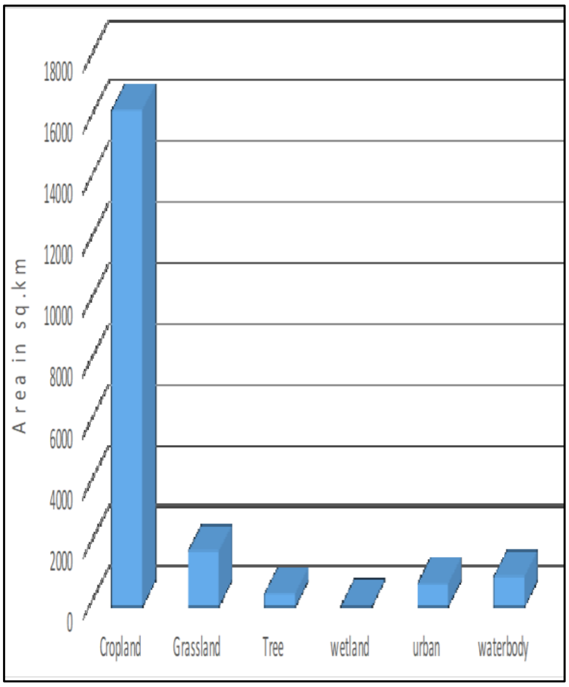

Figure 7 Bar chat for suitability

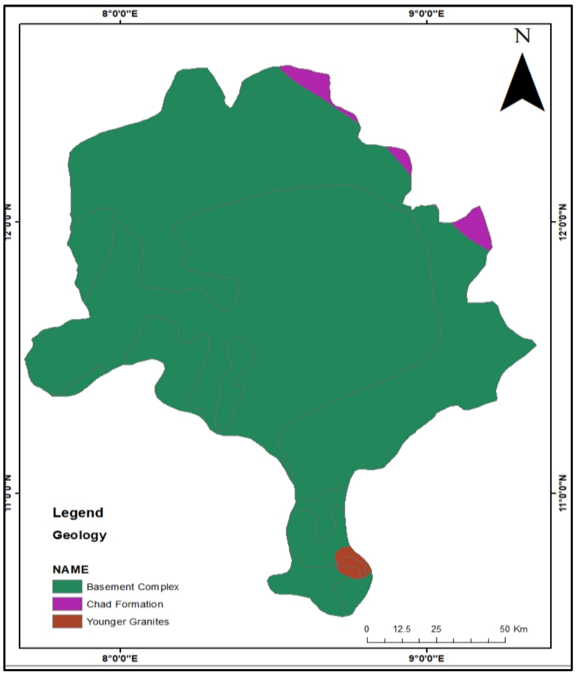

Figure 8 Geology map of the study area

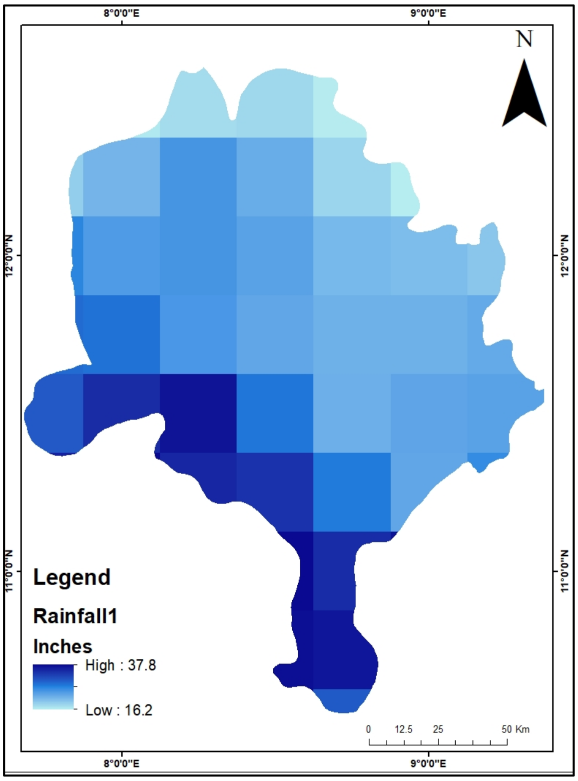

Figure 9 Rainfall map of the study area

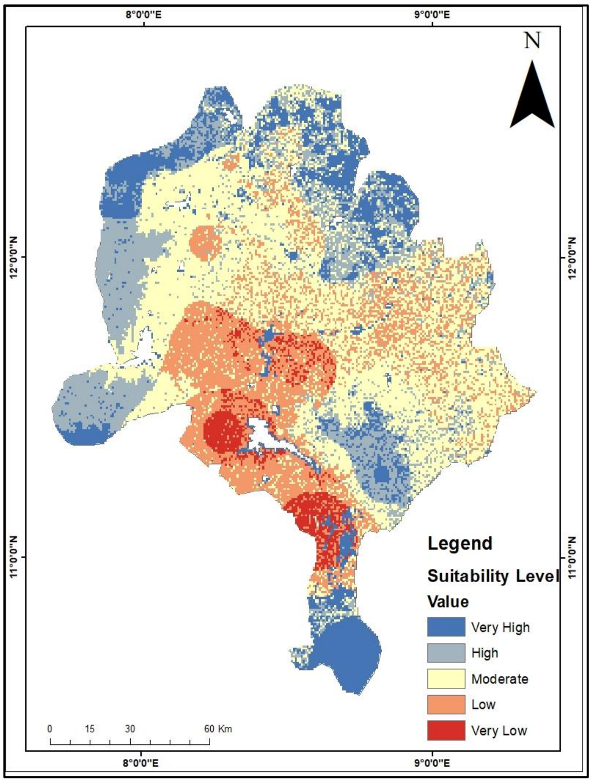

Figure 10 The suitability leval value

Table 4 Suitability class

S/N	Suitability class	Area (ha)	Area (%)
1	Very low	49961.1	2.6293862
2	Low	246759.68	12.986633
3	Moderate	361375.9	19.018732
4	High	771158	40.585019
5	Very high	470850.4	27.78023

3.8. Land Suitability for wheat cultivation

The results of the land suitable for wheat in the study area suggest that the distribution of land suitability for wheat ranges from very high suitable, high, moderate, low to very low suitable in Kano State as represented in figure 10 and the area distribution is shown in table 4.

3.9. Discussion

The results also shows that slope also impacted location of areas suitable for wheat cultivation. The slope of the area fit perfectly with the requirement for wheat cultivation ranging from 0-1.0591. Wheat cultivation does well in a flat plain because runoff are of low intensity and soil nutrient are preserve. It also encourages mechanized farming of the crop if available. The implication of this, for the purpose of Wheat production in the country, is that there is high possibility of cultivating Wheat on a large scale in the study area, which if practiced will increase the production of the crop in the region. Land use was one of the requirements that was considered, it was discovered that Cropland 89 percent, Grass land 5.6 percent, percent accounted for 94.6 percent of the study areas were encompass within the high suitability and medium suitability in the suitability map. The result of the MCE- GIS analysis demonstrates that three of the land types are suitable for Wheat cultivation in the study area. The area of the highly suitable lands is 470850.4 hectares, and that of the high suitability is 771158 hectares and moderately suitable is 361375.9 hectares. The three types of lands accounted for 84.5 of the total area of the study area.

4. Conclusion and recommendation

Land suitability assessment is a prerequisite to achieving optimum utilization of the available land resource. Lack of knowledge on best combination of factors that suit production of wheat cultivation using multi-criteria evaluator (MCE) integrated with GIS. The study was carried out in Kano State Nigeria. Spatial factors for wheat cultivation such as, soil type, PH climate and their attributes were identified in the study area using expert opinion of crop specialist. The identified factors were processed into spatial data. The factors were weighed according to relevance the factors. Land suitability map was generated and linked the data so as the spatial data will be computed to identify land suitable areas for cultivation of wheat. The land suitability map was computed and final visualization of land suitability map was produced and send to ArcGISB10.3 to identify potential areas. In this study, MCE-GIS method was undertaken to study the suitability of wheat. From the results it was found that the total land under the study area. In this study, spatial factors necessary for wheat production were identified in the study area. The maps that emerged from the totality of the findings shows the suitability analysis of the areas to be 25% very high suitable, 40% highly suitable, 17% moderately suitable and 16% are not suitable for wheat cultivation. Since wheat grain that is an indigenous and resilient crop from Africa which has the potential to grow in Kano State that is affected by drought and other natural climatic events therefore government should support farmers in farming the grain in the state to improve their agricultural productivity in order to bridge the gap.

Compliance with ethical standards

Acknowledgments

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Disclosure of conflict of interest

No conflict of interest is to be discloseds

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