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Land Suitability Analysis Of Bambara Nut (Vigna Subterranean) In Sokoto State, Nigeria

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Abstract: ***Land suitability assessment is a prerequisite to achieving optimum utilization of the available land resource. Knowledge on suitable sites that have the best combination of factors for Bambara nut cultivation is lacking. This study assessed suitable sites for Bambara nut cultivation in Sokoto State using Spatial Multi Criteria Assessment (SMCA). It also identified the factors responsible for Bambara nut cultivation, as well as generating suitability classes for Bambara nut cultivation in Sokoto State. These were with a view to determining other areas suitable for cultivation in Nigeria apart from the Southern states in the country. Secondary data used include, Climatic data, Soil data, Geology, Landsat 8 images, Slope, Shuttle Radar Topographic Mission (SRTM) data and administrative maps of the study area. The data were processed, classified and weighted overlay on Arc GIS Software. The processed data collected were finally subjected to SMCA within Arc GIS environment. The result of the MCE-GIS analysis shows that two of the land types are suitable for Bambara nut cultivation in the study area. The area of the suitable lands is 18870.7 hectares and that of highly suitable land is 208.28 hectares. The land accounted for 57.71% of the total area of the study. Sandy soil was found to have the highest impact in determining location suitable for Bambara nut cultivation in the area. It accounted for over 50 percent of soil in the area. The study concluded that large scale Bambara nut cultivation in the study area is highly encouraged and that farmers are to be encouraged to embark on commercial farming of the crop.***

Keywords: ***Bambara Nut, Land Suitability Assessment, Spatial Multi Criteria Assessment***

I. INTRODUCTION

Bambara groundnut *(Vigna subterranean)* a self-pollinating annual legume, is one of the most favored legumes by resource-limited farmers living in rural areas (Azam-Ali *et al.*, 2001). It is grown widely in Eastern African and mostly grown in the drier parts of sub-Saharan Africa (Suhairi, 2016). It has the agronomic characteristic of high tolerance to drought; ability to yield on lands that are not fertile enough for cultivation of many other crops; and good nutritional characteristics, as well as primarily grown for human consumption as a cheap source of plant protein (Mohammed *et al*., 2016). It is a valuable contributor to a balanced diet that can help to alleviate food insecurity, contribute to reduced protein malnutrition, which is common in rural communities in Africa (Ouedraogo *et al.*, 2008; Shegro *et al*., 2013). Despite its high nutritive value and many uses, the crop is under-utilized; landraces are unimproved due to neglect of the crop by scientists (Berchie *et al*., 2010).

The rate at which the World's population is presently increasing in relation to agricultural growth indicates that not only should the production of main crops be increased, but

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that other crops that had been neglected should be given attention, among the latter group of crops is the Bambara groundnut which flourished in Africa before the introduction of the peanut (Aviara *et al.*, 2013). If self-sufficiency in agricultural production is to be achieved in developing countries, land evaluation techniques will be required to develop models for predicting the land's suitability for different types of agriculture (Attual and Fisher, 2014). Identification of suitable areas for growing Bambara is important because as a nitrogen-fixing legume, it contributes to the maintenance of soil fertility. Bambara nut is considered to have an advantage over most crops due to its adaptation to poor soils and tolerance. Major challenge that is limiting the full utilization of this crop is limited knowledge on where it is suitable to grow based on soil and climate conditions (Suhairi *et al*., 2018). The crop is popular in Africa because of its resistance to drought and pests, and its ability to produce reasonable yields when grown on poor soils (Dimakatso, 2006). It is used for both human and animal consumption.

Sokoto State, a semi-arid region of Nigeria, is a major area where drought has adversely affected agricultural productivity (Adegboyeba *et al.*, 2016). Rainfall is very erratic and unpredictable with irregular onsets and cessations which adversely affect the duration of cropping seasons (Godwin, 2015) and desertification (Odjugo and Ikhuoria, 2003). Hence, the general dryness of the region only allows for few crops to be grown (Barau and Oladiji, 2017). Amadou *et al*., (2001) opined that despite the advantage of Bambara groundnut of being adaptable to extreme climate condition, the crop remained underutilized. Most research did not focus on mapping the suitability of this crop in northern Nigeria. This research intends to bridge the information gap by integrating soil properties with climatic data using geospatial techniques, in determining land suitability for optimum yield of Bambara nut.

The aim of this study is to assess land suitable for growing Bambara groundnut in Sokoto State. The objectives include identifying the places of Bambara nut cultivation, examining the factors contributing to the optimum growth of crop and identifying suitable site for its cultivation.

II. THE STUDY AREA

Sokoto State in Northern Nigeria was used for the study. The State is located on latitude 4^0E to 7^0E and 11.30^0'N to 15^0N. It is one of the States in the country that share boundary with the Sahara Desert. It is a Sahelian state surrounded by sandy savannah (Alatise and Ikumawoyi, 2007). It is bordered in the North by Niger Republic, Zamfara State to the East and Kebbi State to the South and West. The State has a population of 3,696,999 as per the 2006 census (NPC). Over 80% of the inhabitants are involved in farming. Crops such as millet, guinea corn, rice, sweet potatoes, cassava, groundnuts, and beans are produced for subsistence. Furthermore, cash crops that include wheat, cotton and vegetables are produced by the farmers.

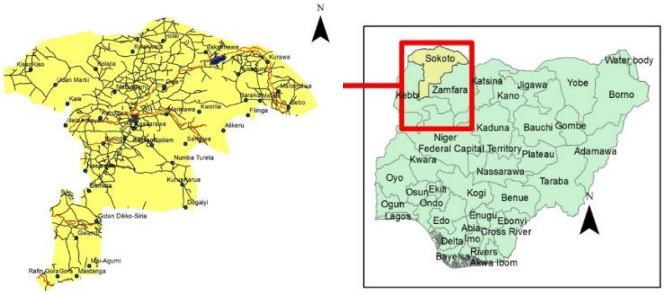

Figure 1: Sokoto State

III. MATERIALS AND METHODS

Reconnaissance survey was initially carried out to identify available farms in the area and other features. Some assessments that include types of economic activities and agricultural practices were assessed during this survey. Global Positioning System (GPS) hand-held receiver was used to obtain coordinates of farms in the area. It was also used to collect ground control points, which were used in geo-referencing base map. Satellite images of Landsat 8; an American Earth Observation satellite captured in 2019 was used to determine the land use pattern of the area. This imagery was downloaded from USGS earth explorer and Google.

Other data used include soil map from FDALR 1990. This provides the geo-referenced information on soil such as site characteristics and the soil physical properties. Digital Elevation Model (DEM) with 30m resolution, extracted from Space Shuttle Radar Mission (STRM), was also downloaded from USGS earth explorer, and used to generate slope of the area. Geological map: a special-purpose map displaying geological features was also assessed. It revealed rocks units/ geological strata indicating where they are exposed at the surface. Climate data which is a time series of measurements of sufficient length determining climatic factors and their variability was also used. The climate dataset was obtained from CHIRPS which provide the average monthly climate interpolated by the weather stations data. Administrative map of study area containing graphically recorded information on the administrative settings of the area.

The consideration is mainly on requirement for the cultivation of Bambara nut, which is determined by climatic requirements, topography landscape and soil factor, PH factor etc. Climate factor; Bambara groundnut is resistant to drought (Temegne, 2011; Tsoata, 2015; Tsoata, 2016.). According to FAO (2007), the required minimum annual rainfall for optimal performance is about 300 mm and the optimum is between 750 and 1,400 mm. However, the rainfall should not exceed 3,000 mm. Furthermore, annual rainfall ranging from 500 to 1,200 mm is required during the growing season (Anonymous, 2016). Even though the groundnut can tolerate heavy rainfall, too much of it at harvest period may cause yield losses. The optimum temperature required for the crop is between 19°C and 30°C. Temperatures below 16 °C and above 38°C are not suitable for Bambara groundnut production (Massawe, 2003).

Soil factor: Sandy soils are the best for the production of Bambara groundnut (FAO 2007). However, it can grow on

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sandy-to-sandy loam and well-drained soil, which make it easier to harvest (Temegne et al., 2018). These soils prevent clogging. Light textured soils are recommended. The optimal depth of the soil is between 50 and 100 cm. Soil pH required is between 5 and 6.5 and should not be less than 4.3 or greater (Anonymous, 2015). Bambara groundnut commonly does well even on low–fertility soils than most crops (Borgot, 1992). The cultivation of Bambara groundnut is of particular importance in semi – arid areas. In such regions, the crop has been found to thrive and produce yield under adverse conditions, such as limited water supply and low soil fertility.

Slope factor: The slop information was obtained from Digital Elevation Model (DEM). Nigeria administrative map was also added. Sokoto State shape file was over laid on the imported data and the study area was clipped out to extract the relevant portion of the SRTM Imagery. The coordinate of the clipped image was re-projected to WGS 1984, UTM Zone 31S, the spatial extension analysis ArcGIS software was used for these processes. The software packages used for the study include SPSS software, ArcGIS version 10.4.1, Erdas Imagine 2014. Microsoft Excel was used for the creation of tables, charts, and storage of the data from the field work which was later imported into the ArcGIS environment.

The required scenes of the study area were downloaded from earth explorer. The composite of scenes was generated using standard false colour composite with red for near infrared, green for red and blue for green. Then mosaicking was done after the layer stacking, the image was geo-referenced to assign the appropriate reference information to make the image compatible. Images obtained for this study were classified using supervised classification method. Supervised classification was used because it requires the use of training pixels which help to identify and verify important data points on the map and thereby reproduce the real ground situation. After the physical mapping of some accessible farmland in the study area, the coordinate gotten was used to trained satellite data. The combined process of visual interpretation of tone, pattern, shape, size and texture of the imageries and digital image processing was used to identify homogenous groups of pixels, which represent various land used to interest, and eight classes of land cover were classified; and these are built-up, arable land, irrigated cultivation, grass bare land, B/nut farm, shrub land, forest, and water body.

A. ANALYTICAL HIERARCHY PROCESS

The Bambara nut land suitability assessment was conducted using analytical hierarchy process (AHP); a multi criteria decision analysis (MCDA). The process involves the integration of several criteria into a single index of evaluation for the alternative sites, in hierarchical order. Several parameters that include Temperature, Rainfall, Soil texture, Soil pH, Slope, Relative humidity, and Land Uses were assessed and weighted to delineate the potential area for growing the Bambara nut.

The purpose of weighing was to determine the importance of each factor relative to other factors that affect the crop yield and growth rates. Each of the criteria maps was integrated into the suitability classes based on the crop requirement. Determination of criterion weight using AHP involved assigning a value to the criterion based on their importance. This process usually requires expert opinion to make the decision in assigning the importance on each criterion. Five scale of comparative importance was used for pairwise comparison matrix of the AHP (Table 1). The pairwise comparison matrix of the AHP was conducted. Within the comparison matrix, a bigger value implies that one of the criteria is more important that the other. The weight for individual criterion was computed.

Strength of importance	Numeric representation	Description
Equal importance	1	Two factors contribute equally to the issue been considered
Moderate importance	3	One factor is slightly favoured over another
Strong importance	5	One factor is strongly favoured over another
Very strong importance	7	One factor is favoured over another at very strongly order
Extreme importance	9	One Factor is favoured over another at highest possible order

Source: Saaty and Vargas (2013)

Table 1: Scale of Comparative Importance

B. LAND USES AND OTHER LOCATIONAL DATA

The area was classified into eight land use types namely: built-up, Bambara farmland, irrigated cultivation, water body, and shrubs, Arable land, Grass bare land and forest.

The locational data obtained from the field were entered into the Microsoft Excel and saved in workbook file format. It was subsequently imported into Arc-map software where the coordinates of the farms were overlaid on the shapefile of the boundary, road network, river, drainages, and other classified features to show the spatial distribution. The weighted factor maps were overlaid using weighted overlay extension of spatial analyst tool. This was done to show distinctive land features, spatial distribution of existing farms as well as the proposed sites for cultivation of Bambara nut. The weight for individual criterion computed (Table 2).

Factors	Temperature	Rainfall	Soil texture	Soil pH	Slope	Humidity	Land Use	Total
Weight	20	15	15	10	10	10	20	100

Table 2: Weight for each factor

IV. ANALYSIS

The land use pattern of the study area is shown in figure 2. Analysis from the map in figure 2, represented in pie chart (Figure 3), shows that arable land has the highest portion. This reveals that the study area has an active agricultural site. Determination of this area is giving an insight into the extent of agricultural practices in the area.

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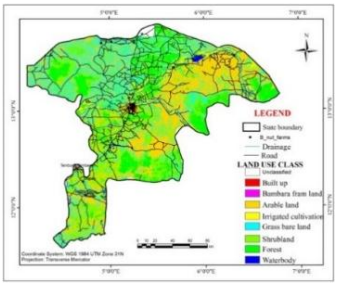

Figure 2: Land use map

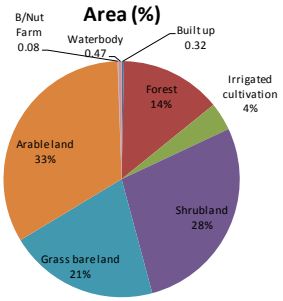

Figure 3: Land use portion

A. CLASSIFICATION OF SOIL IN SOKOTO STATE

It was discovered from the soil map that the area is composed of three types of soils namely, loamy sand, sand sandy, sand to loamy, with the loamy sand as the dominant soil type. Next to loamy soil in size is the sand sandy which is considered highly suitable. The least soil type in the study area is sand clay loam (Figure 4). The suitability of the area based on the soil texture in shown in Figure 5.

B. SLOPE AND RAINFALL ANALYSIS

Four classes ranging from the lowest to the highest were revealed by the slope map generated using STRM data and DEM module. As described by the FAO, the most suitable slope for Bambara nut cultivation belongs to the first class, which is from 0 -10, highly suitable is between 1.10 and 2.60 and from 2.70 to 4.70 is moderately suitable. Bambara nut grows well on a flat land. As shown in figure 6.

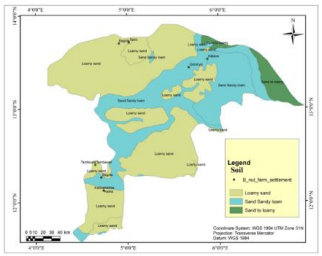

Figure 4: Soil Map

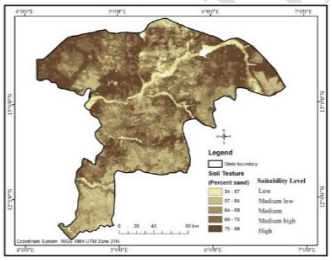

Figure 5: Suitability based on texture

Rainfall distribution in the study area is between 500mm to 700mm as shown in the figure 7. The dominant distribution of rainfall in the area is between 850 - 890mm. The most suitable rainfall for Bambara nut cultivation is between 300 – 400 mm of the classes of rainfall.

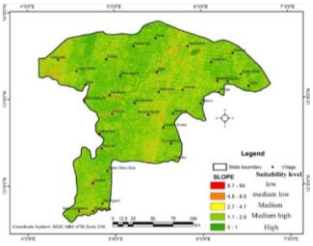

Figure 6: Slope analysis

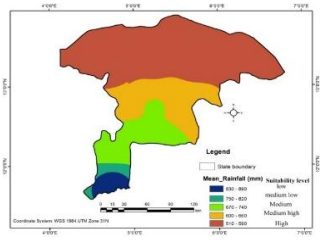

Figure 7: Rainfall distribution

C. TEMPERATURE

The average temperature of the study as shown in figure 8 is always around 30^0C, and from literature review, the most suitable temperature for Bambara nut cultivation ranges from 29^0C-30^0C. Hence, the average temperature in the area is suitable for cultivation of Bambara nut.

D. LAND SUITABILITY FOR BAMBARA NUT CULTIVATION

The evaluation results of the land suitability for Bambara nut in the study area suggest that the distribution of land suitability for the crop ranges from highly suitable, moderately suitable, and non-suitable. The highly suitable part accounted for seven percent (7%) while the moderately suitable accounted for eighty percent (85%) and eight percent (8%) area are classified as non-suitable respectively as shown in figures 9 and 10.

V. DISCUSSION

The findings of this study have indicated that soil has the highest impact in determining suitable location for Bambara nut cultivation among the factors considered. This pertinent in the study area because the dominant soil type in the area is sandy to loam soil, which is concurrent with the provision by the FAO (2007) for the soil requirement of Bambara nut cultivation. This soil type accounted for over fifty percent (50%) of soil in the study area. Hence, about fifty seven percent (57%) of the area is classified as medium suitability, while the area with high suitability is less than one percent (1%). The major areas that are predominantly averagely suitable are found in Goronyo LGA of the State. Moderately suitable areas are found in Kebbi, while those that are highly suitable are in Tambuwal LGA.

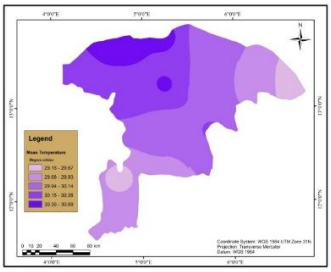

Figure 8: Temperature distribution

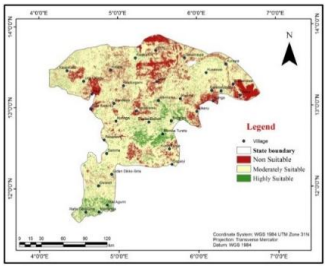

Figure 9: Suitability Map

S/n	Suitability class	Area (ha)	Area (%)
1	Highly Suitability	2189.655	7.637795
2	Moderately Suitable	24289.37	84.72439
3	Non-Suitable	2189.655	7.637795
4	Non-Classified	-	-
Total		28668.67509	100.00

Table 3: Suitability table

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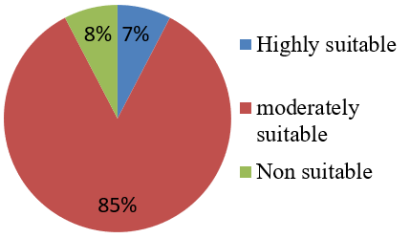

Figure 10: Bambara Nut Suitability Area

The results also revealed that slope also impacted location of areas suitable for Bambara nut cultivation. The slope of the area fit perfectly with the requirement for Bambara nut cultivation ranging from 0.1- 4. The nut cultivation does well in a flat plain because runoff are of low intensity and soil nutrients are preserved. The slope also suitable for mechanized farming of the crop. This implies that cultivating Bambara nut on a large scale in the study area is recommended. Practicing it will increase the production of the crop in the region.

Land use was one of the requirements that was considered. It was discovered that forest, shrub and arable covered over sixty five percent (65%) of the areas and were situated within the highly suitable and medium suitable areas. The findings have indicated that two of the land types are suitable for Bambara nut cultivation. These two (2) classes of lands accounted for 57.71% of the total area. They include the highly suitable lands, which covers 2189.655 hectares and the moderately suitable covering 208.28 hectares.

VI. CONCLUSION

In this study, spatial factors necessary for Bambara nut cultivation were identified in Sokoto State. The findings revealed that most of the areas i.e., about 85% are moderately suitable. Only few areas, which are about 7% of the entire area is unsuitable for the cultivation of the nut. The areas found to be highly suitable is 8%. This indicates that this crop, which is an indigenous and resilient crop from Africa has the potential to grow in Sokoto State, a place that is climatically affected by drought. Thus, farming the nut in the State will improve their agricultural productivity. The simple practical land suitability assessment carried out in this study provides the useful decision-making approach for farmers and decision makers in carrying out suitability assessment for a specific crop, especially underutilized crops with little information, at any location, to improve food production. Since the crop can grow in a harsh environments and poor soil where many other crops could fail, encouraging its cultivation by the government will significantly improve revenue for the State as well as income to the farmers.