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Land Suitability Analysis for Cassava *(Manihot SPP.)* Cultivation in Southern Part of Adamawa State, Nigeria

Kefas, J [α] & Zemba, A. A.[σ]

Abstract- The study assessed the physical land suitability for cassava cultivation in southern part of Adamawa State using Multi-criteria evaluation and GIS technique. Within the study area, the production of cassava is mainly for food and there are only little opportunities for its commercial development. This therefore makes it necessary to carry out land suitability analysis in order to provide information on the study area that would guide in sustaining long term production of cassava. The environmental variables examined were Mean Annual rainfall, Mean Temperature, Length of rainfall, Relief and Soil which were obtained from the Upper Benue River Development Authority (UBRDA), Yola. The primary data were sourced by means of field survey to obtain the coordinates of the current cassava growing areas for mapping. The five factor maps were reclassified based on environmental requirement of cassava crop in the IDRISI Taiga environment and different weights were assigned to each factor to represent their relative importance using the pair-wise comparison Matrix. Descriptive statistics in form of simple percentage and charts were used to present the result which reveals explicitly on a single map; the areas that are suitable (65.92%) and those that are not suitable (34.08%) for cassava cultivation. Similarly, the current cassava growing areas were mapped and the areas identified are Dissol, Mbulo, Maitani, Farang, Timdore and Wadore which fell within the suitable category. The study has therefore recommended that institutions of learning and agencies in the state should encourage the use of GIS in their various research works because it is accurate and time saving as it is evident in this study. Cassava production should also be encouraged among farmers so as to utilize the proportion of land area found to be suitable for cassava production in Southern Adamawa State.

Keywords: land suitability, cassava cultivation, multi-criteria evaluation, pair-wise comparison matrix, idrisi taiga.

I. Introduction

Crop-land suitability analysis is a prerequisite to achieving optimum utilization of the available land resources for sustainable agricultural production. One of the most burning needs in both developed and developing nations is to improve agricultural land management and to impart suitable cropping patterns in order to increase agricultural production with efficient use of land resources (Perveen *et al*., 2007). Hence comprehensive, reliable and timely information on agricultural resources is necessary for Nigeria where agricultural potential of the land resources is being pressurized by high population growth and environmental hazard like drought and soil erosion.

On the other hand, Nigeria has been faced with food supply deficiency which has almost become an intractable problem in the past decades (Mathias, 2014). This situation is highly pronounced in urban areas due to high population density with agricultural land being frequently in short supply and more mouths to feed. In order to meet the increasing demand for food, the farming community has to increase production so as to meet the growing demand of the growing population (Venkatesan *et al,* 2010).

However, Nigerian soils have a substantial agricultural potential but a fundamental constraint to its development is the unreliable method of data acquisition and management on agricultural land (Joshua *et al,* 2013). The consequence is poor knowledge and unreliable data for agricultural planning. In addition, the use of land is not only determined by the user but also the land suitability which is governed by different land attributes such as the soil types, underlying geology, topography and hydrology (FAO, 1993). These attributes can limit the extent of land available for various purposes. To get the maximum benefit out of the land, its proper use within the context of suitability is inevitable. In Nigeria however, the productivity of soil is decreasing because lands have been utilized for all purposes at the expense of their suitability thereby resulting in land degradation (Senjobi, 2007).

In view of the above, the importance of cassava (*Manihot spp.*) in mitigating hunger and providing food security is timely and cannot be over emphasized. Its food security features have attracted interest for some time and being known to be common within the tropical environment, cassava has the potential to combat hunger and address food security issues (Harvest Plus, 2012). Hence, the suitable areas for agricultural use are determined by an evaluation of the climate, soil, topography as well as understanding of local biophysical restraints. But where many variables of this nature are involved, Geographic Information System (GIS) technology offers a dynamic tool for

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multidimensional process of land use evaluation with a powerful tool for geo-environmental analysis (Pereira & Duckstein, 1993; Perveen *et al*, 2007). It allows the user to integrate database generated from various sources and analyze them efficiently in a spatio-temporal domain by overlaying different map layers.

Within the study area the demand for cassava-related products are on the increase but its production is basically for food. Hence, more areas of cassava cultivation need to be discovered so as to attract investors in the commercialization of cassava in this region. Thus, in mapping out the distribution of major food crops in Adamawa state; Sajo & Kadams (1999) posited that "the southern agricultural zone of Adamawa state receives annual rainfall of 1400mm; and is therefore important for root and tuber crops". Land suitability is however not determined by single environmental factor, but the collection and analysis of information which may have significant influence on the use that can be made of the soil (Joshua et al, 2013). Moreover, the study of how the combination of these environmental factors affect the cultivation of cassava has never been delved into within the study area. This therefore makes it necessary to carry out land suitability analysis in order to unravel its suitability and capability for sustaining long term production of cassava in southern part of Adamawa State.

II. The Study Area and Methodology

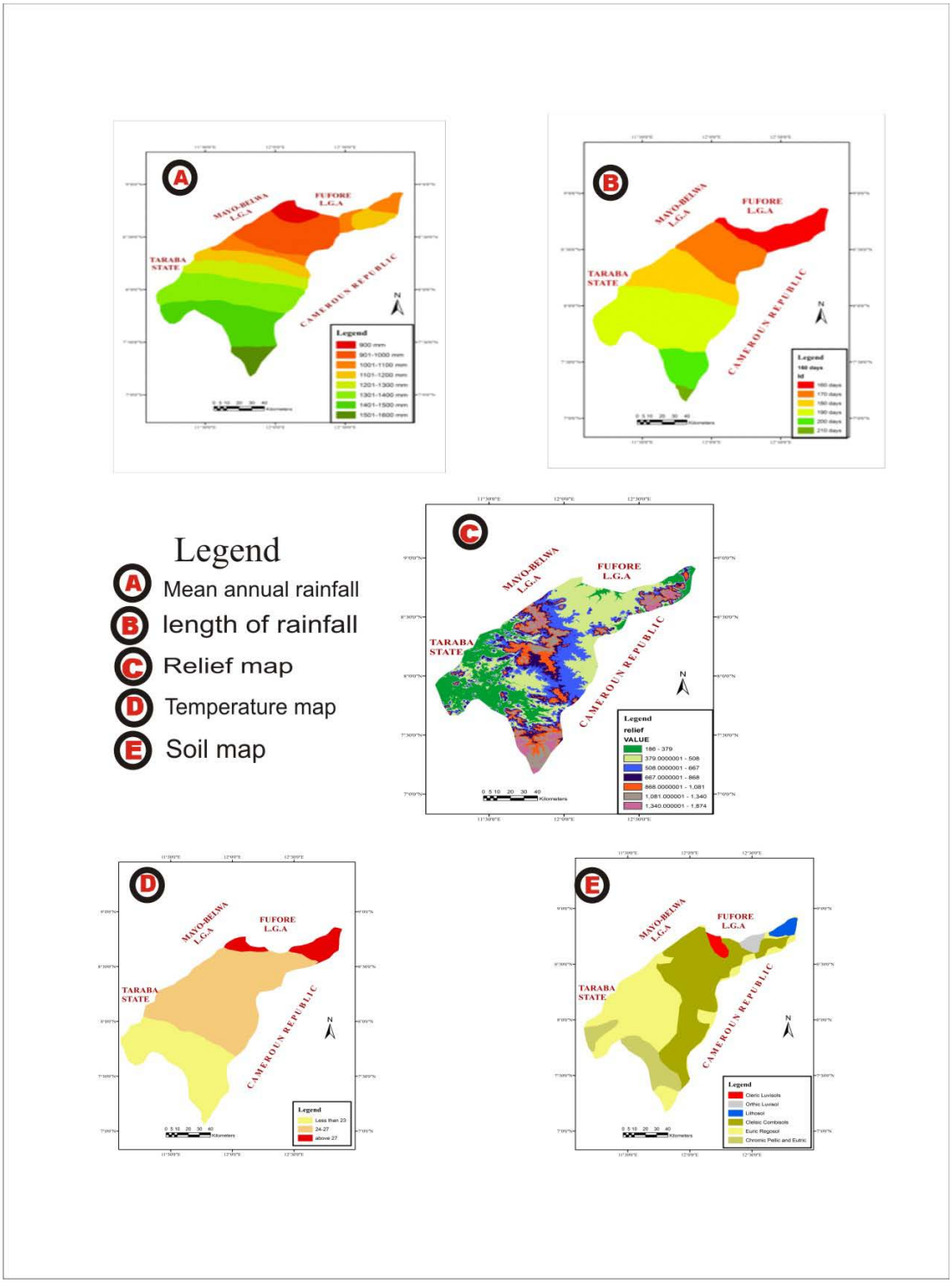
a) *The Study Area*

The study area is located between Latitude 7̊0 ' to 9˚0' N and Longitude 11˚0' to 13˚ 0' E. It has a total landmass of 10602.95 km^2 with a population of 507047 people (projected from 2006 Census to 2015). It comprises of Jada, Ganye and Toungo Local Government Areas of Adamawa State. It is bounded by Mayo-Belwa and Fufore Local Government Areas to the North, the Cameroon Republic to the eastern side and Taraba state borders the area to the South and West as shown in Figure 1.

The movement of the Inter Tropical Discontinuity (ITD) and altitude are the basic elements controlling rainfall distribution in the study area. Rainfall decreases form the south (1600mm) towards the north (900mm) within the study area. The mean onset date for rainfall within the study area is 10th April while the cessation date is 6th November. The temperature is high throughout the year because of the incoming radiation with a sharp drop at the onset of rains due to the effect of cloudiness. The maximum temperature usually occurs in April to about 38˚C while the minimum temperature can be as low as 18˚C between December and January (Adebayo, 1999).

Geologically, the study area falls within the eastern extension of the Nigerian Precambrian rocks. It has several high-level plateau surfaces which are part of discontinued mountain ranges. The most striking landform feature in the area is the mountain ranges, which in most cases appear as grouped hills and generally, trending from north to south particularly along the eastern border lands of Nigeria with Cameroon. The most popular of these ranges is the

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Source: Adapted from the Upper Benue River Development Authority, Yola (2014)

Figure 1: The Study Area and its Environmental Characteristics

Alantika and the Mangia hills south-west of Jada (Tukur, 1999). The soil is derived from a soil survey of a former Gongola state under different map units, ranging from units 201-242. The soils include luvisols, lithosols, combisols and vertisols. These soils have different characteristics ranging from high base saturation, deep and well drained, high organic matter content, low to moderate saturation, poorly drained and dark colored among others (Ray, 1999).

b) Data Types and Sources

The physical parameters (factors) directly related to cassava crop production were considered for analysis. These factors include relief, soil, annual rainfall,

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length of rainy days and temperature of the study area. Both primary and secondary data were considered for the study. Primary data were collected from the field by means of physical observation and picking of geographic coordinates of the current areas of cassava cultivation using the Global Positioning System (GPS) as presented in Table 1. The secondary data which is basically concerned with the five factor maps were generated from thematic map of Adamawa State which was obtained from the Upper Benue River Development Authority, Yola (2014).

c) Equipment and Materials

The hardware component consists of Garmin 12 GPS receiver (hand held) which was used to obtain the geographic coordinates of cassava cultivation sites. Pavilion 15 HP Laptop Computer, HP 4400 Series Scanner, DeskJet 2510 Series Printer and a Photocopier were used in carrying out the analysis. The software consists of IDRISI Taiga and ARC GIS 10.0. The IDRISI Taiga was used for overlay operations and calculations of areas while the ARC GIS 10.0 was used for geo-referencing and digitization of maps.

Table 1: Current Cassava Cultivation Sites

Location	Coordinate	Site
Lat. / long.	08˚07'51.7"N, 12˚01'29.3"E	Maitani
Lat. / long.	08˚32'21.9"N, 11˚59'08.6"E	Timdore
Lat. / long.	08˚37'36.8"N, 12˚01'17.2"E	Mbulo
Lat. / long.	08˚44'22.1"N, 12˚02'26.0"E	Farang
Lat. / long.	08˚19'19.1"N, 12˚03'24.4"E	Dissol
Lat. / long.	08˚25'53.7"N, 12˚06'25.3"E	Wadore

Source: Reconnaissance and Field Data Acquisition, (2015)

d) Data Processing

The five parameters (annual rainfall, annual rainfall length, air temperature, soil and relief maps) were geo-referenced by transforming their LATLON to Universal Transverse Mercator (UTM) coordinate System in the ArcGIS 10.0. The 'X' and 'Y' minimum and maximum values of the coordinates were used to create map boundary. The LATLON of the tie-points were inserted one after the other to ensure the true coordinates of these points. After geo-referencing, the maps were re-sampled in order to take their exact cell size as well as to enable the overlay process. The re-sampled maps were later digitized and saved as project map which were being imported to Idrisi Taiga for overlay analysis.

e) Method of Data Analysis

The map algebra (overlay) method of analysis using GIS was employed for data analysis. This method combines information from one GIS layer with another to derive an attribute for both of the layers. This overlay or spatial join can integrate data of different types such as soils, vegetation, land ownership, jurisdictions and other data available for analysis (Samuel, 2014). Hence, the suitability criteria for cassava production were defined on the basis of literature reviews and experts knowledge as presented in Table 2.

f) Assigning Criteria Weights for Cassava Suitability

Different weights were assigned to each factor to represent their relative importance using the pair-wise comparison analysis developed by Saaty (1980). The purpose of the criteria weighting was to express the importance of each criterion relative to other criteria in determining the suitability for cassava growing sites. The more important criterion had the greater weight in the overall evaluation as presented in Table 3. Finally the weighted criteria were processed to generate the composite suitability map. This method of analysis was selected because it allows

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Table 2: Criteria Definition of Environmental Factors for Cassava Cultivation

Factors	Criteria
Rainfall length	≥107 rainy days
Annual rainfall	1000-2000mm
Temperature	≤27˚C
Relief	150-1000m.
Soil	Light sandy loams

Source: USDA (1997), NRCS Plants Database 2008; Adjei, 2012

Table 3: Weighting Criteria by Pair-wise Comparison

Criteria	Temperature	Rainfall length	Soil	Annual rainfall	Relief
Temperature	1	5	5	7	3
Annual rainfall	1/5	1	1	5	1/3
Rainfall length	1/5	1	1	5	3
Relief	1/7	1/5	1/5	1	1/3
Soil	1/3	3	1/3	3	1

Source: Adapted from Saaty, (1990)

the decision makers to assign different levels of importance to the different factors involved in land suitability (Qiu *et al*, 2013).

After applying the AHP generated weights in the data, the additional subroutine (overlay modules) of IDRISI Taiga using image calculator was used for the analysis. The process involves the summation of a continuous multiplication of each criterion by its weight (Temperature × 0.480) + (Rainfall Length × 0.194) + (Soil × 0.156) + (Annual rainfall × 0.124) + (Relief × 0.042). This process was carried out in order to produce a fuzzy suitability map which was later reclassified to produce the cassava suitability map.

g) Mapping Cassava Suitable Areas

The suitable site for cassava cultivation on the composite map is concerned with areas that met the five (5) criteria for cassava suitability evaluation. Any area that fails to meet one of the five criteria was considered not suitable for cassava cultivation (fuzzy concept). Thus, two classes of suitability for cassava cultivation were derived from the algebra. This was revealed explicitly on a single map, the areas that can support the production of cassava and those that are not suitable for cassava cultivation.

h) Mapping of Current Areas of Cassava Cultivation

The processes of mapping out current areas producing cassava in the study area were carried out in ArcGIS environment by inserting the coordinates of the identified cassava production areas on a geo-referenced and digitized map of the study area. This process explicitly shows the distribution of the current cassava production areas on the map of the study location.

III. Results and Discussion

To assess whether or not the five variables are suitable for cassava cultivation, the land suitability order by FAO 1983 was adopted which indicate in simplest form whether land is suitable (S) or not suitable (NS) for the specified use. Hence, the overall suitable area for cassava cultivation covers 6989.46 km^2 (65.92%), whereas about 3613.49 km^2 (34.08%) of the study area falls within the unsuitable area as presented in Figure 2.

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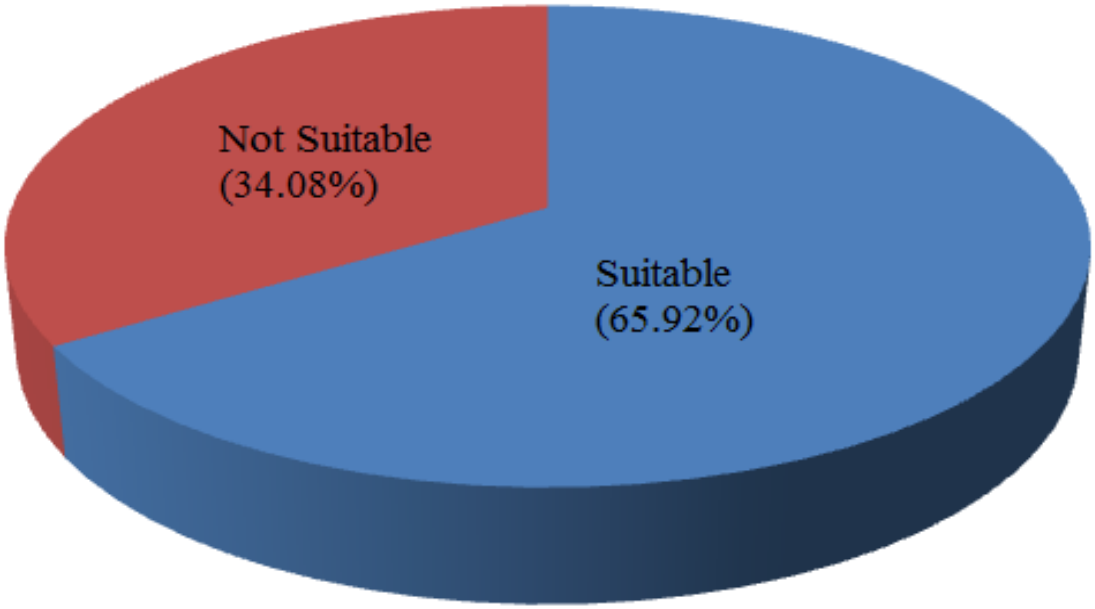


Figure 2: Suitability Status of Land for Cassava Cultivation in Southern Part of Adamawa State

a) Suitable Area (S)

The "suitable area" which is mostly in the central part although, cutting across the three Local Governments of the study location covers the largest portion of the map with a total area of 6989.46 km^2 (65.92%). This area has satisfied the requirements of the five variables used in the analysis and one of the reasons for such is attributed to the good soils of the region which is mostly loamy sands. These soils are well drained, moist and fertile with light to medium textures such as sandy loam, silt loam and clay loam (Ray, 1999). Such fertile soils tend to have a deep horizon that is friable enough to allow the development of the tubers (Cassava Production Guidelines, 2010). The Mean Rainfall of more than 1500 mm with up to 200 days of rainfall is another factor that supports the growth of cassava at all levels within the study location. The rainfall amount and duration is sufficient enough to give support during the critical period in cassava growth which is between 30 to 150 days after planting (Cassava Production Guidelines, 2010).

The Mean Temperature of the study area within the Suitable (S) category has a considerable effect on cassava production. According to Alves *et al* (2000), the highest root production for cassava crop can be expected in the tropics where temperature average 25-27˚C which corresponds with the condition obtainable in most part of the study location.

b) Not Suitable Area (NS)

The unsuitable area includes places in the western/eastern border, the extreme south and the north-eastern part, with some traces in the central part of the study area. In this part of the study location Relief, Temperature and Mean Annual Rainfall are responsible for the unsuitable category as they tend not meet the environmental requirements for cassava production hence, fell outside the suitability range for cassava cultivation.

Firstly, the striking landform features of the Atlantika, Verre and Shebshi Mountain ranges which are evident within the unsuitable area can inhibit the growth of cassava especially at the root development stage. This corresponds with recommendations of the Guidelines for Cassava Assembler Programme of the SMFI (2012) that cassava does not perform well with elevation exceeding 1000 meters above sea level. The Atlantika Mountain (1000-1400m) East of Ganye and Jada forms a natural boundary between Nigeria and Cameroun, the Shebshi mountain range (highest elevation 2,042m.) is South of Ganye and the Verre hills are found East of Jada (Tukur, 1999). Soils on these platform can pose a limiting factor that can lead to scanty growth potential (Ray, 1999); of cassava crop.

Mean Annual Rainfall is another factor responsible for the unsuitable nature of land for cassava production. This is because the northern part of the study area with less than 1000 mm of rainfall has fallen out of suitability range for cassava production. This assessment is imperative because cassava responds to water deficiency at different levels of development-morphological, physiological, cellular and metabolic (Augusto, 2002). For instance, cassava responds to water deficiency by rapidly reducing its evaporating leaf area and partially closing the stomata (Vincent, 2009). The reduction in storage root yield depends on the duration of the water deficit and is determined by the sensitivity of a particular growth stage to water stress.

The temperature condition in some part of the study area is above 27˚C which is beyond the suitability

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range of temperature for cassava production. This will have negative effects on cassava growth because temperature affects sprouting, leaf formation, leaf size and storage root formation.

c) Current Cassava Growing Areas (Mapped)

The areas currently under cassava cultivation are depicted in Figure 3. The essence is to determine whether or not they match with the suitable growing areas as revealed by this study. Thus, the areas identified as the current cassava cultivation areas at the time of investigation include Maitani, Dissol, Timdore, Wadore, Mbulo and Farang. The study therefore reveals that all the six areas identified fell within the suitable area of cassava cultivation. Thus, the study has corresponded with the postulations of Sajo and Kadams (1999) that "the southern agricultural zone of Adamawa state receives an annual rainfall of 1400mm is therefore important for root and tuber crops".

d) Decision Making Guide for Current and Potential Farmers of Cassava

Beside the general suitability evaluation, individual criterion for securing agricultural land use plays an important role. This is because calculation of relative weights of factors for the production of cassava was based on the expert opinion and local knowledge obtained from field surveying. It was found that the highest weights were assigned to temperature and length of rainfall. Soil and annual rainfall were also found effective while relief was identified as the least important factor to be considered in cassava crop suitability.

Temperature is the most important because sprouting of the stem cutting in cassava often has a temperature range within which it germinates, and they will not do so above or below such range (George and Rice, 2000). At low temperatures 16°C sprouting of the stem cutting is

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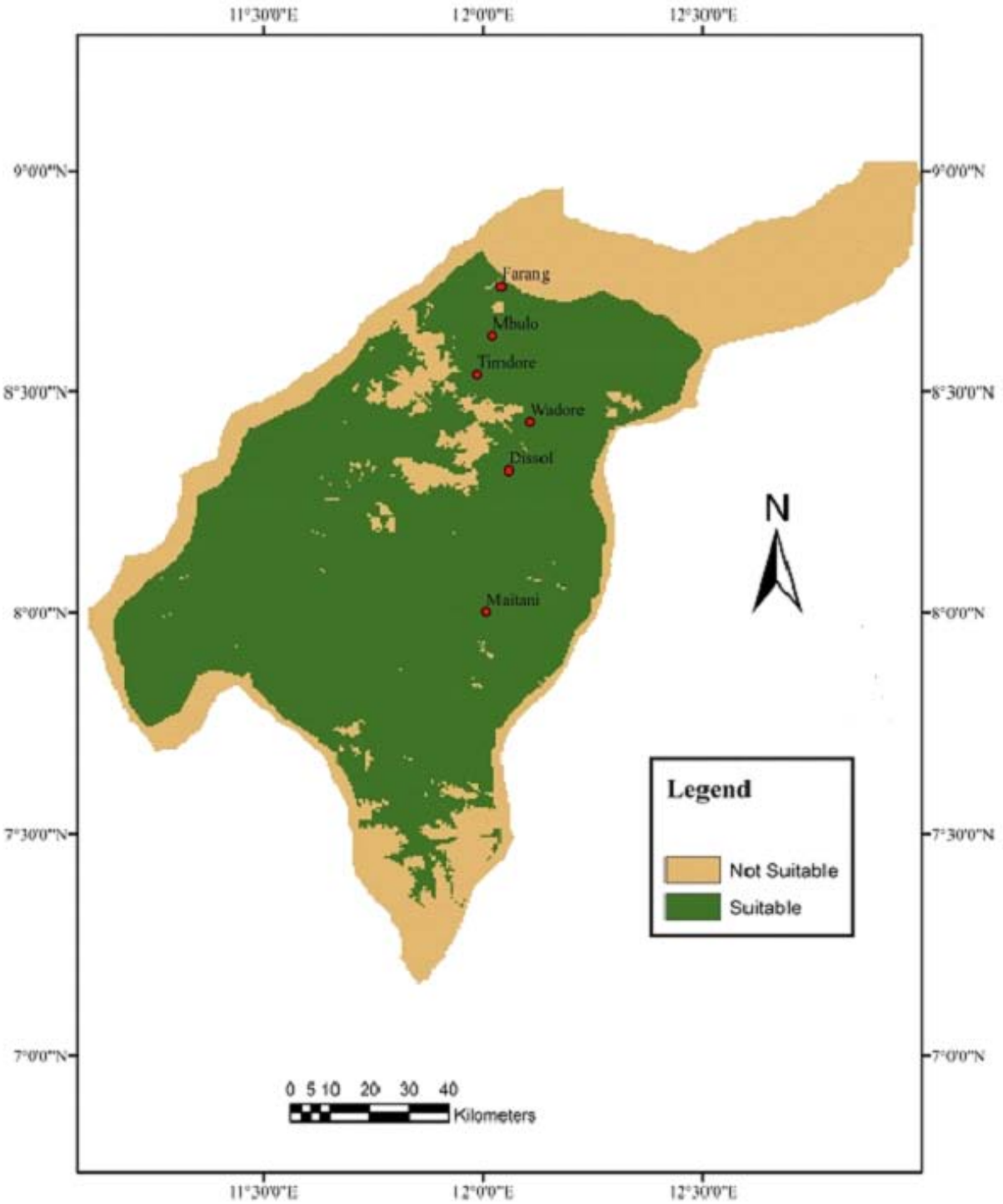


Figure 3: Areas Currently under Cultivation of Cassava in Southern part of Adamawa State

Source: Derived from Overlay Analysis of the Idrisi Taiga

delayed and the rate of leaf production is decreased. Sprouting is hastened when the temperature increases up to 30°C but is inhibited with temperatures greater than 37°C (Augusto, 2002).

After germination, rapid growth of cassava results in a high demand for light and moisture especially during the first critical stage. Matured seed need to take in significant amount of water before growth can resume. In addition, exposure to prolonged length of rainfall is required to shorten the length of dormancy in cassava growth and development.

The not suitable category includes mountainous areas of the region at high degree of physical limitation which could not be easily overcome. It is therefore not

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economical to put such land under production. Such a qualitative evaluation is to help decision makers (local farmers and agricultural development institutes) to select the most appropriate site for cassava cultivation.

Comparison of the present land use for cassava cultivation with the analysed suitability classes was conducted to examine the degree of mismatch. It was noted that the "suitable class" has no constraint as all the identified areas of current cassava cultivation fell within the said category.

IV. Conclusions

In this study, Multi Criteria Evaluation with GIS technique was applied to identify suitable areas for cassava cultivation in Southern Adamawa state. The result obtained from the study indicates that GIS technique could provide a superior guide map for decision makers which could be used to consider crop substitution in order to achieve better agricultural production. The study clearly brought out areas suitable for cassava cultivation which was derived from the five criteria maps. These maps were analysed within the context of GIS after a pair-wise comparison of each factor relative to the other. Many inputs into the GIS based land suitability evaluation are the maps of the criteria (mean annual rainfall map, annual rainfall length map, air temperature map, soil map, and relief map) which represent the complex information in a simple, classified map.

V. Recommendations

Based on the findings of this study, the following recommendations are made:

i. Potential cassava farmers should allocate their resources in ensuring that the 65.92% of the total landmass suitable for cassava production is well utilized whereas, the "not suitable" category for the said crop should be allocated to other crops.
ii. Agricultural Development Agencies should provide loans for potential cassava farmers so as to encourage abundant supply of cassava.
iii. The institutions of learning and agencies in the state should encourage the use of GIS in conducting researches because it is accurate and time saving as it is evident in this research.
iv. Resource planners and decision makers should rely on this assessment so as to avoid the complex problem that involves subjective assessments with multiple criteria.

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