APPLICATION OF GEOGRAPHIC INFORMATION SYSTEM IN SITE SELECTION FOR THE PRODUCTION OF IRISH POTATOES IN ADAMAWA STATE OF NIGERIA

Samuel Hyellamada Jerry
GDSS Digil,
Email: Samjerry455@gmail.com,

Dr. Bulus Luka Gadiga
Geography Department, Adamawa State University, Mubi.PMB 25 Mubi Adamawa State Nigeria
Email: bulgami@gmail.com

Dr Alfred D. Mshelia
Geography Department, Adamawa State University, Mubi.PMB 25 Mubi Adamawa State Nigeria
Email: alfredmshelia@yahoo.com

Abstract
The application of Geographic Information System in site selection for Irish Potatoes production in Adamawa State, North-Eastern Nigeria has been carried out in this study. The study area has a landmass of approximately 38,890.02 sq km. Assessment of the land in terms of the suitability is based on Boolean logic and the method described in FAO guideline 2008. A land unit resulting from the overlay process of the maps layers has unique information of land qualities (Suitable and Unsuitable) on which the suitability is based. Identified map layers used include Soil, Relief, Rainfall length, Mean annual rainfall and Temperature of the study area. These thematic land qualities with their associated attribute data were encoded in GIS database. Overlay operation was performed on those layers as the suitability model assigned. Models of overlay were applied to the overlay process and suitability classes formulated. Results indicate that the Most suitable, Suitable and marginally suitable areas for Irish Potatoes cover about 4.30%, 41.09%, and 45.66% of the total land area respectively. In conclusion, the land suitability map for Irish Potatoes established using GIS can enhance the planning alternatives within the study area (Adamawa State) with meaningful strategy in terms of location. Relevant recommendations have been provided.

KEYWORDS: Overlay, Suitable, Unsuitable, Geographic Information System, Irish Potatoes

1.0 Introduction

Irish potatoes (*Solanum tuberosum L.*) is the world's fourth largest food crop after wheat, rice and maize (Raemaekers, 2001). World production reached a record of 320 million tons in 2007 and production in the developing countries has almost doubled since 1991, with a corresponding increase in consumption (Sofyan et al, 2007). Potato is an important source of food, employment and income in developing countries (FAO, 2008). The potato's high energy content and ease of production have also made it an important component of urban agriculture which provides jobs and food security to some 800 million people globally

(Sofyan et al, 2007). Hundreds of millions of people in the developing countries including Nigeria are facing food crisis as the cost of their staple foods continues to rise. Rice prices have almost doubled during the year 2008, as wheat prices are climbing rapidly while maize prices are skyrocketing. But On the contrary, the price of potato has remained stable. The potential of the potatoes is yet to be fully realized and has never been more evident until the recent rising prices of rice, wheat and maize ((FAO, 2008). Potatoes have the potential to relieve the pressure of increasing cereal prices on the poorest people and contribute significantly to food security. Potatoes are grown and eaten locally, with little significant international trade compared to cereals, so they are particularly valuable as food in the developing countries. Potatoes mature in 3-4 months and can yield about 40 tons/ha and hence ideally suited to places where land is limited and labour is abundant (FAO, 2008).

Land Suitability is the degree of appropriateness of land for a certain use. Land Suitability could be assessed for present condition (Actual Land Suitability) or after improvement (Potential Land Suitability). Actual Land suitability is based on current soil and land Conditions. The information is based on physical environment data generated from soil or land resources surveys. The information is based on soil characteristics and climate data related to growth requirements of crops being evaluated. Potential Land Suitability is the suitability that could be reached after the land is improved. The land to be evaluated can be natural (conversion) forest, abandoned or unproductive lands, or land currently used for agriculture, at a sub-optimal level of management in such a way that the productivity can be improved by changing to more suitable crops (Sofyan, et al, 2007).

Geographic information systems have been widely used to support real world decision-making processes that involve finding regions capable of supporting certain land uses. For example, identifying an area capable of supporting a certain agricultural crop or locating a site ‘suitable for a landfill are tasks often tackled with the assistance of GIS tools. Spatial decision-making processes like these require the assessment of alternative sites based on criteria that are defined by a variety of environmental and/or socioeconomic factors. The process of assessing these factors involves comparing the actual conditions of the alternative sites with desirable characteristics, and is usually referred to as capability/suitability evaluation (Stoms et al. 2002).The diversity of the types of land-use suitability studies can be attributed to the different ways the term land use is defined by various applications and the context of its use. For example, it is likely that the urban planners and the agricultural experts would have different perception of the term.

About 870 million people in the world are estimated to have been undernourished (in terms of dietary energy supply) in the period 2010–12 (FAO, 2012). This figure represents 12.5 percent of the global population, or one in eight people. The vast majority of these, 870 million, live in developing countries, where the prevalence of undernourishment is now estimated at 14.9 percent of the population (FAO, 2012). The International Food Policy Research Institute reported that without new investment in food production, estimated food-deficit countries' import needs would rise from the current 95 billion kilogram a year to 229 billion by the year 2020, quadrupling in Asia and rising 150 percent in sub-Saharan Africa as a result of continued poor food production (FAO, 2008). Climatic change is also expected to aggravate the rising food shortage as well as the ever-increasing population, and lack of adequate data on sites suitability of crops in a given region (Madefa, 2012). It is therefore of paramount importance to map out climatic site that are suitable for the cultivation of Irish potatoes in order to encourage the production of more crops to fight the menace of hunger and future food crisis. This study therefore, used GIS techniques to map out areas that are suitable for the production of Irish potatoes in Adamawa State.

Irish potato is one of Nigerian staple foods. It requires low temperature for its growth and hence is chiefly grown around Jos Plateau State and other areas in Benue and Kaduna States (Mih, et al 1993). It is a very rich source of starch and has a high calorific value. This crop is not a common tuber crop cultivated in

Adamawa State because the climatic requirement does not favour the growth of such crop in the State. However, Irish Potato is being cultivated in few area of the State namely Ganbe Village in Mayo-belwa and Kwaja village in Mubi South Local Government Area (Madefa, 2012). This study therefore assesses the suitability of areas in the state where the production of Irish potatoes is possible in terms of climatic variables using geoinformation technologies.

1.1 Climatic and Topographic Requirements for the Cultivation of Irish Potatoes.

Potatoes (Irish) requires an Annual rainfall of equal or greater than 1000mm, Rainfall length of 90-170 days, Temperature of equal or less than 27^0C and Soil type that is Loamy in nature and a relief of 1000-2300m above sea level and also a relatively low terrain of less than 200m above sea level with low temperature and adequate water supply are require for its production (Raemaekers, 2001; Babaji, et al, 2007; Rosie, and Micheal, 2008; and Punjab, 2010; Jane, and Nyamongo, 2009).

2.0 The Study Area

Adamawa state is located in the North – Eastern part of Nigeria. It lies between latitude 7^0N and 11^0N and longitude 11^0E and 14^0E. It share boundary with Taraba state in the South – Eastern part, Gombe State in the North – Western part and Borno in the North. The State has international boundary with the Republic of Cameroon along the Eastern side (Figure 1). Adamawa State is divided into twenty – one Local Government Areas with a total land area of 38,890.02 sq km (Adebayo, 1999).

3.0 MATERIALS AND METHODS

Depending on the availability of software, digital hardware, level of sophistication and knowledge, time as well as the objectives of the research, the use of Geographic Information System (GIS) techniques for the suitability study varies in approach and methodology. For the purpose of this research, software packages and hardware materials for Remote Sensing and GIS techniques was applied to generate a precise and reliable result. The acquisition of the relevant data (annual rainfall, length of rainfall, temperature, relief and soil map of the study area) identification and definition of site as well as the digital mapping and analysis of the data was carried out.

3.1 Factors and Constraints used in Site Suitability

A factor is a criterion that enhances or detracts from the suitability of a specific alternative for the activity under consideration. It is therefore most commonly measured on a continues scale. For example, a forestry company may determine that the steeper the slope, the more costly it is to transport wood (Eastman, 2009) and also temperature, rainfall are another examples of a factor.

The factors that were used for this study are; annual rainfall, length of rainfall, temperature, relief and soil map of Adamawa State. These factors were chosen because they are the major environmental factors that affect or determine the production of a crop (Irish Potatoes) Raemaeker (2001), Madefa (2012).

A constraint serves to limit the alternatives under consideration. A good example of constraint would be the exclusion from development of areas designated as wildlife reserves. Another might be the stipulation that no development may proceed on slopes exceeding a 30% gradient. In many cases, constraints will be expressed in the form of a Boolean (logical) map: areas excluded from consideration being coded with a "0" and those open for consideration being coded with "1". However, in some instances, the constraint will be expressed as some characteristic that the decision set must possess. For example, we might require that the total area of lands selected for development be no less than 5000 hectares, or that the decision set consist of

a single contiguous area. Constraints such as these are often called goals or targets (Eastman, 2009). The ultimate meaning of constraints is to limit the alternatives under consideration.

3.2 GIS operations for land-use suitability modeling

The distinguishing feature of GIS is its capability to perform an integrated analysis of spatial and attributes data. GIS can be used not only for automatically producing maps, but it is unique in its capacity for integration and spatial analysis of multisource datasets such as data on land use, population, topography, hydrology, climate, vegetation, transportation network, public infrastructure, etc. The data are manipulated and analyzed to obtain information useful for a particular application such as land-use suitability analysis. The aim of a GIS analysis is to help a user to answer questions concerned with geographical patterns and processes.There is an enormously wide range of analytical operations available to the GIS users and a number of classifications of those operations have been suggested (Goodchild, 1987; Tomlin, 1990; Burrough, 1992). From the land-use suitability analysis perspective it is useful to make distinction between two broad categories of GIS operations: basic (or fundamental) and advanced operations. This distinction is based on the extent to which these operations can be used in a variety of spatial analyses including land-use suitability analysis. The operations considered to be useful for a wide range of applications are referred to as fundamental ones. They are more generic than the advanced functions in the sense that they are available in a wide variety of GIS systems for different data structures.

The fundamental operations include: measurement, (re)classification, scalar and overlay operations, neighborhood operations, and connectivity operations. Many popular GIS systems, such as ArcGIS (Booth and Mitchell, 1999), Idrisi (Eastman, 1997), have the capability to perform most, if not all, of the basic operations. The basic operations can be considered as the spatial data handling ‘primitives’ or ‘building blocks’ for advance analysis (Berry, 1993). They are invariably low level geometric operations and could be thought of as tools that build relationships among and between spatial objects. To be useful for spatial decision making and planning, GIS should also provide the capabilities of data manipulation and analysis.

3.3 Data Analysis.

Two GIS packages were used for the data analysis. These are: ArcGIS 9.3; was used for georeferencing, and digitizing maps, and IDRISI Taiga was used for all analysis. Other supporting non – GIS packages were also used which are; Microsoft word 2007 and Corel draw I2. A map algebera (Overlay) method of analysis using GIS was employed for this research work, this method was undertaken over others GIS analysis because of the Overlay analysis integrates spatial data with attribute data (Attributes are information about each map feature). Overlay analysis does this by combining information from one GIS layer with another GIS layer to derive or infer an attribute for one of the layers. At its simplest, overlay analysis can be a visual operation, but analytical operations require one or more data layers to be joined physically. This overlay, or spatial join, can integrate data of different types, such as soils, vegetation, land ownership, jurisdictions, etc. with assessor's parcels and also the type of data available of for the research.

3.4 Map Algebra.

Definition of Suitability and Unsuitability Criteria

The research defined criteria for the Land Suitability Analysis based on the FAO (1976) Mukhtar (2012) and Boolean Logic Theory of suitability guidelines and modified criteria

According to available datasets. The criteria for suitability for Irish potatoes production are shown in Table 1. Was adopted in this research.

According to these criteria, values for layers are quantitatively scored according to suitability. For example, areas that meet the condition were assigned 1, and 0 to area that did not meet the conditions as shown in table 1, an overlaid subroutine of IDIRIS 32 was used for map algebra as shown in figure 2.

4.0 RESULTS AND DISCUSSIONS

4.1 Introduction

This section deals with the task of analyzing and presentation of data generated from the overlay processes. The information obtained from the overlay are presented in form of maps, chart, and tables for better understanding of the processes involved in this study.

4.2 Assessing the Suitability of the Climatic variable of Adamawa State for the Production of Irish Potatoes

The climatic and topographic variables used in assessing the suitability of Adamawa state for the cultivation of Irish Potatoes are mean annual rainfall map, rainfall length map, temperature map, soil map and relief map of the study area (table 2, figure 3, 4, 5, 6 and 7) which after reclassification based on the suitability criteria in table 2, the suitability of the mean annual rainfall, annual rainfall length and temperature were shown as constrain of respective factors (figure 8,9,10, 11 and 12).

The processes involved mapping out site that are suitable for Irish Potatoes production in the State, these was carried out in the IDRISI Taiga environment. The physo-climatic map of Irish Potatoes (the five maps overlaid) was used for the mapping process. The query module-tool in IDRISI environment was used to identify areas with the same colours representing a certain number of criteria met by a given area.

The areas identified on the overlain map (Figure 14) for the four level of suitability for Irish Potato production were automatically calculated with the aid of area sub-routine in Idrisi modules in square kilometer. To get the percentage equivalent of each level of suitability the area were converted manually using a scientific calculator. The results obtained are shown in Table 4 and figure 14.

The various data used in this study was analyzed for assessment purpose. The analysis reveals that, the greater percentage of the state covering a total area of 37,217.75 km² (95.7%) is suitable for Irish Potatoes production but is only 1,672.27 km² part of the state is considered to be most suitable for the production of the crop. The other 35,545.48 km² is been considered as suitable and moderately suitable with relatively high cost of production in relation to the most suitable area. Adamawa State can be considered as suitable for the cultivation the Irish Potatoes.

Conclusion

It has been confirmed in the course of this research that, even though the primary economic activates of the people of Adamawa State is agriculture, but only few engaged themselves in the production of Irish Potatoes (Madefa, 2012). This study also shows that

i. Adamawa State is endowed with vast land for the cultivation of Irish Potatoes, which the research revealed that more than half or nearly all the part of the state total landmass is considered to be suitable for the production of the crop. Yet this massive land mass was underutilized for Irish Potato production. Most Local Government Areas in the state have a share of the total land that is suitable for the production of the crop.

Putting an instrument to empirical test will prove its reliability in terms of efficiency. The assessment of the potentiality of GIS for site suitability selection for the cultivation of Irish Potatoes in this research work has proven its reliability. With reliability data input, this instrument has demonstrated its reliability on the search for site suitability for not only crops, but for all spatial correlated assessment making process.

Following the findings in the research work, it can be concluded that Adamawa State would be a good place to invest in the cultivation of Irish Potatoes. Irish Potatoes suitable land is underutilized for probably lack of awareness on sites suitable, it cultivation and its importance in tackling the problem of food shortages.

LIST IF FIGURES AND TABLE

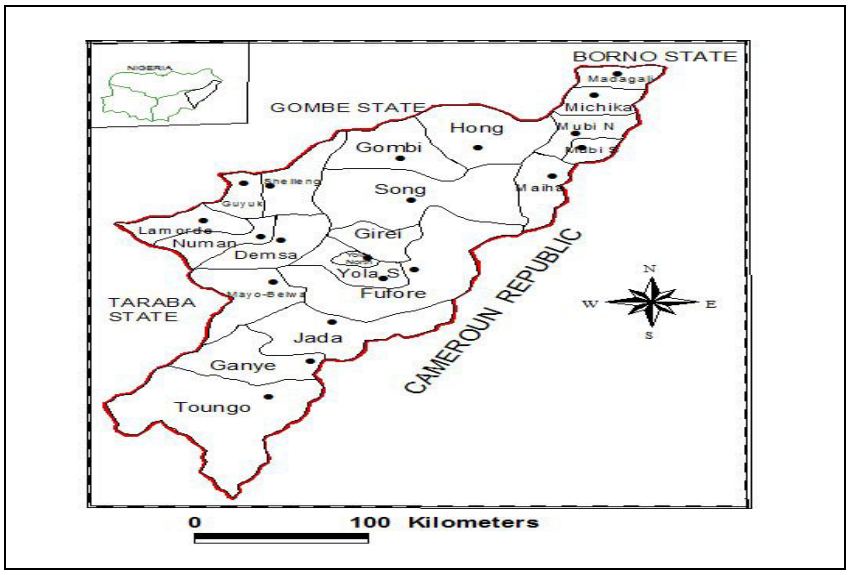

Figure 1: The Study Area

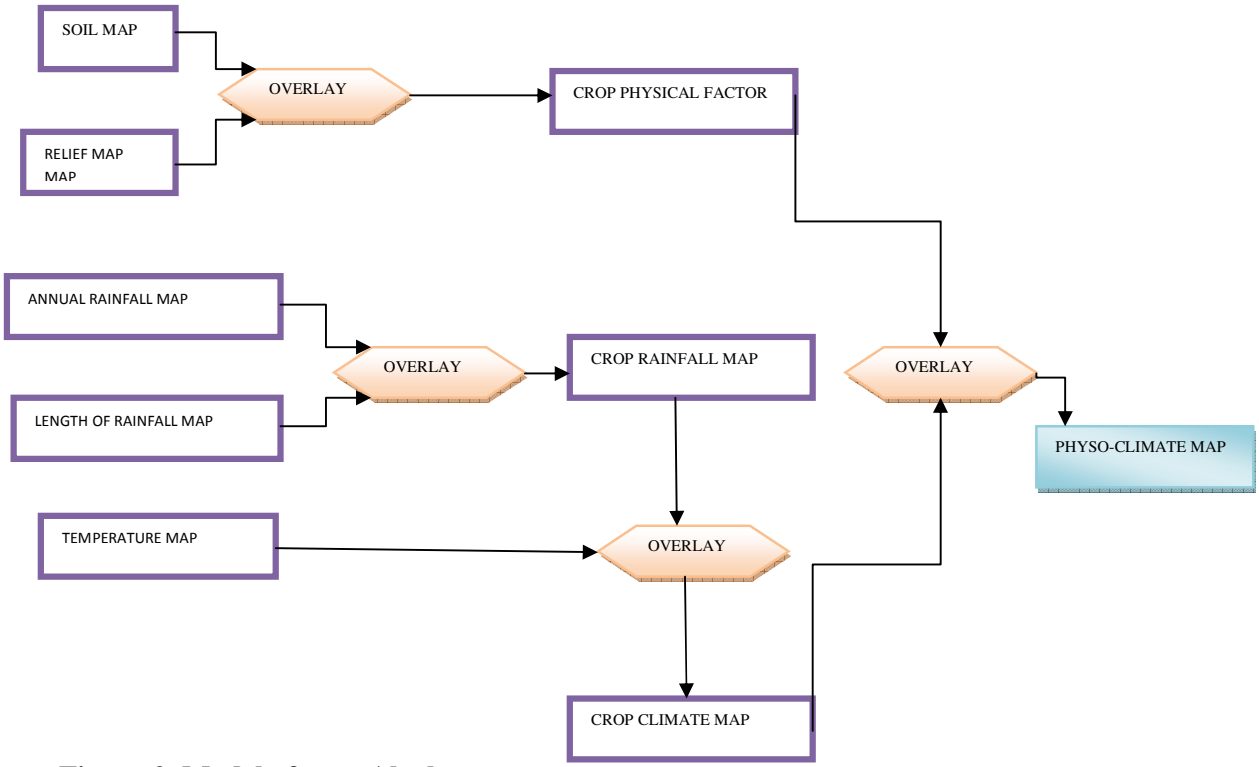

Figure 2. Model of map Algebra

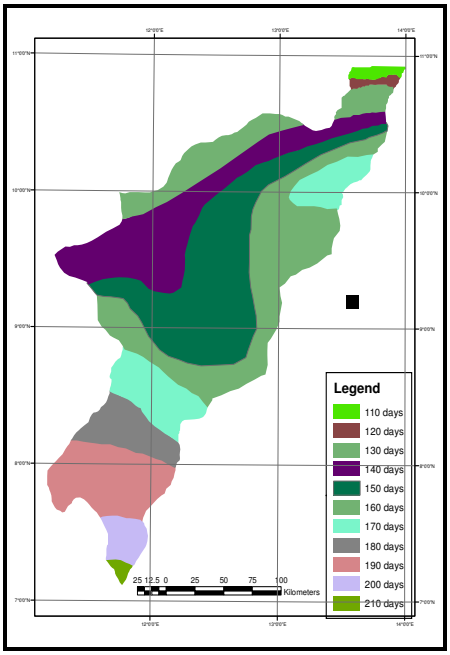

Figure 3: Rainfall Length of Adamawa State

Source: Modify from Adebayo 1999

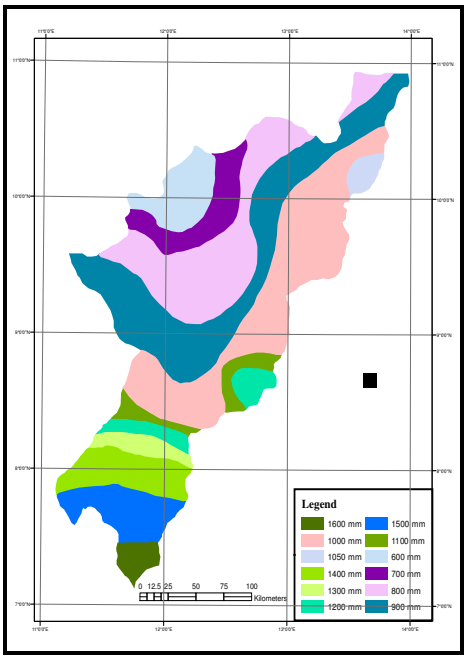

Figure 4: Mean Annual Rainfall of Adamawa State

Source: Modify from Adebayo

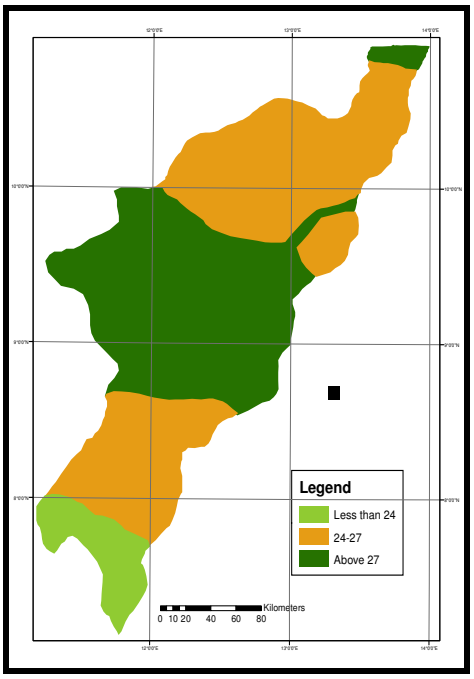

Figure 5: Mean annual temperature of Adamawa State

Source: Modify from Adebayo 1999

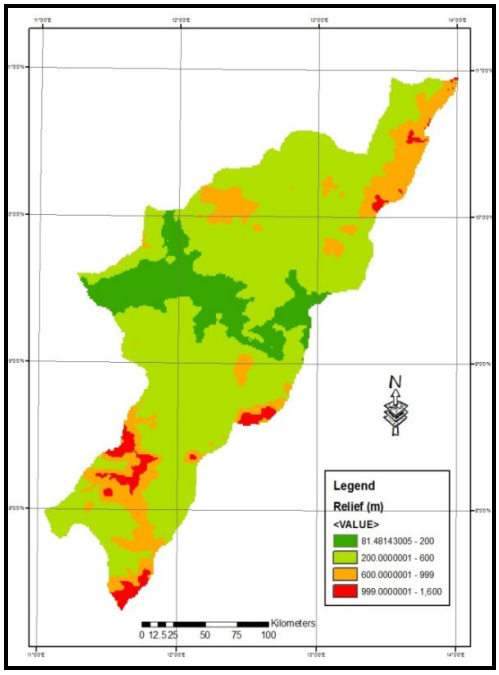

Figure 6: Relief of Adamawa State

Source: Modify from Adebayo 1999

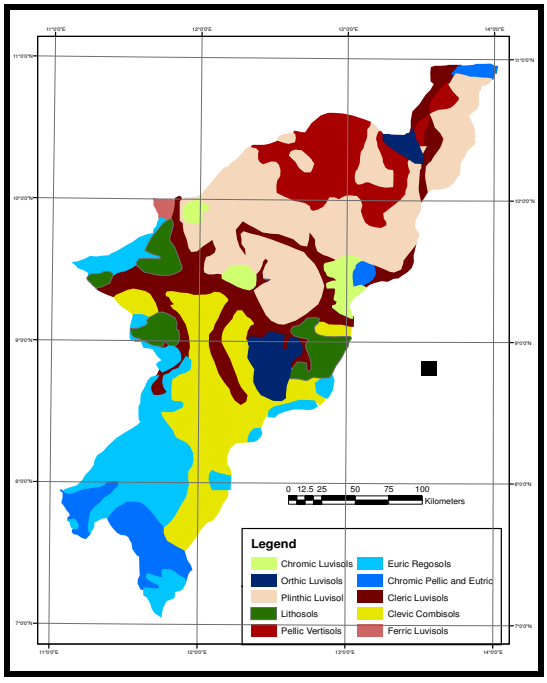

Figure 7: Soil of Adamawa State

Source: Modify from Adebayo 1999

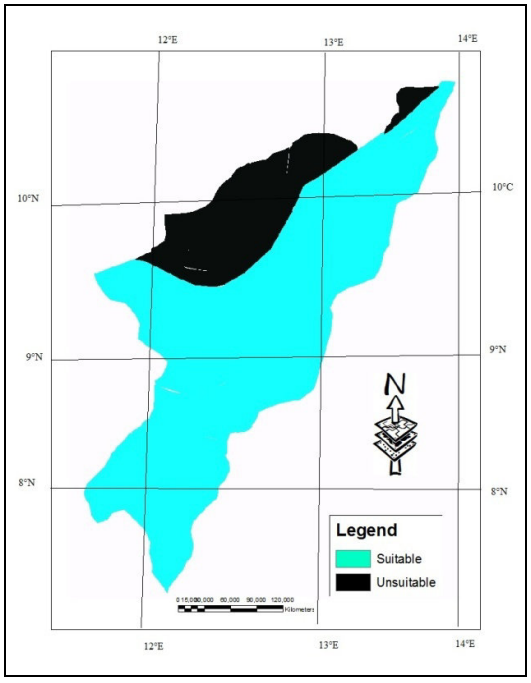

Figure 8. Constrain of annual rainfalls lenght for Irish Potatoes

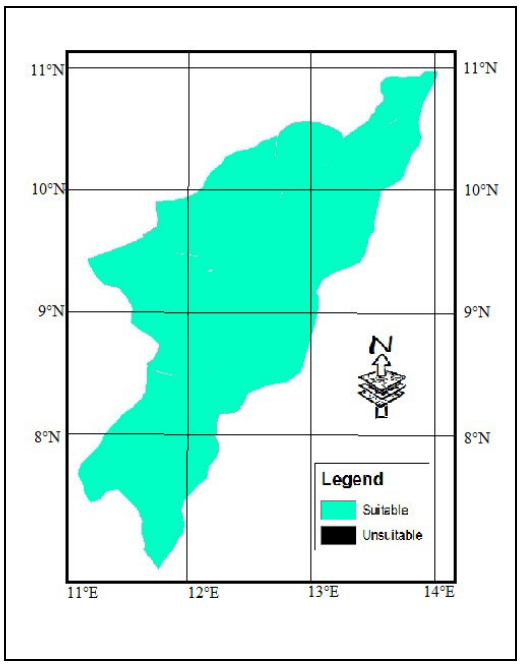

Figure 9. Constrain of Mean annual rainfalls for Irish Potatoes

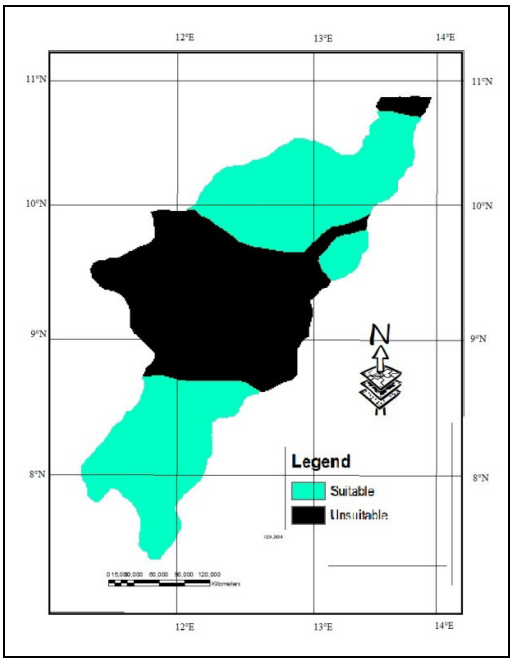

Figure 10. Constrain of mean annual temperature of Irish Potato

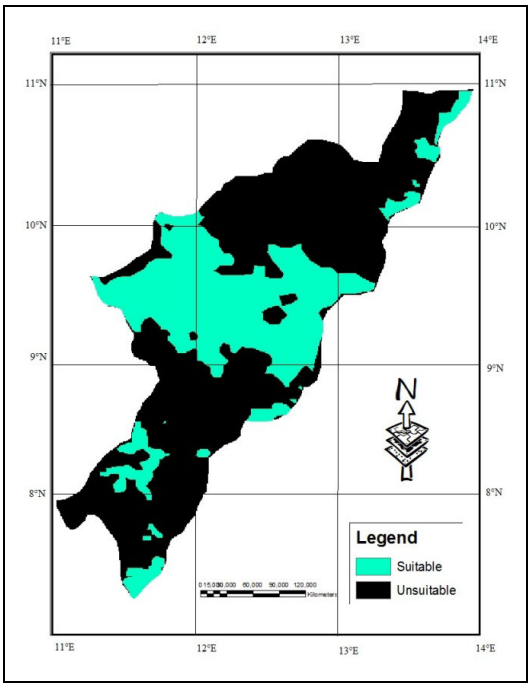

Figure 11. Constrain of Relief Irish Potatoes

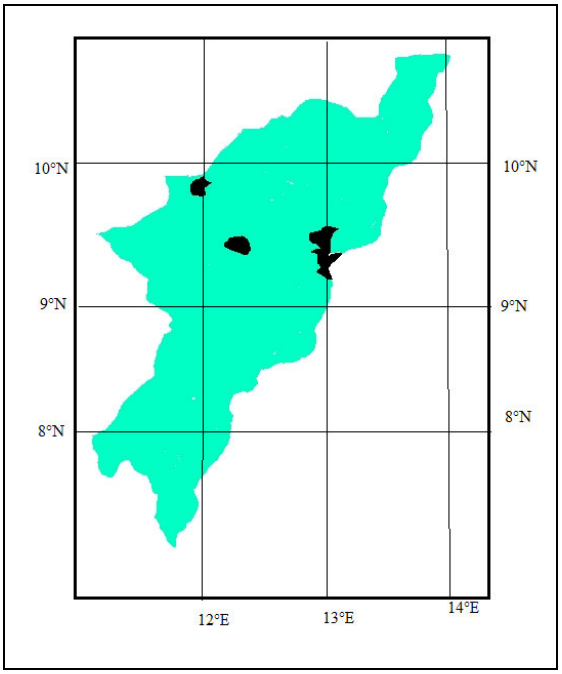

Figure 12. Constrain of Soil for Irish Potatoes

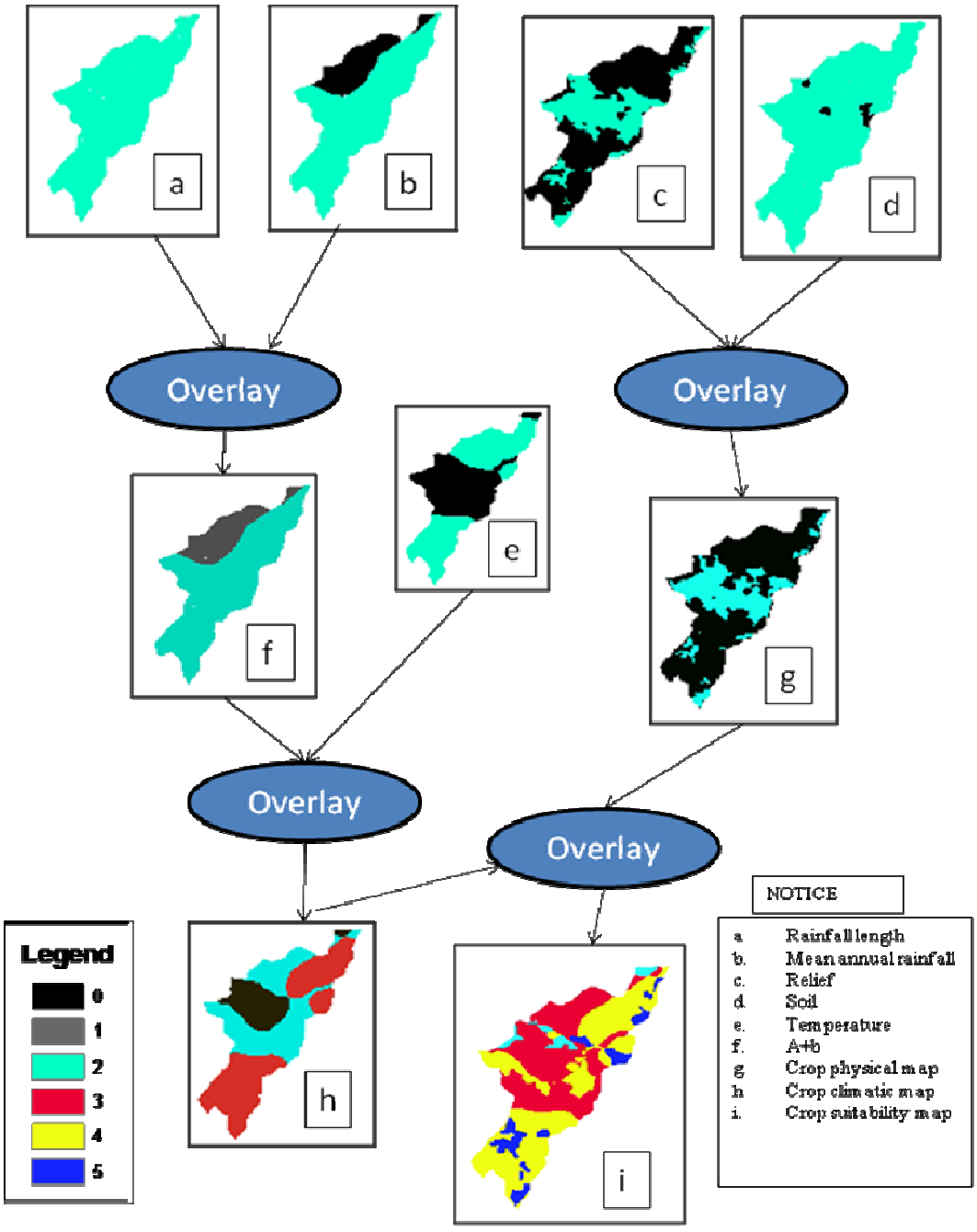

Figure 13. Model showing Map Overlay for Analysis

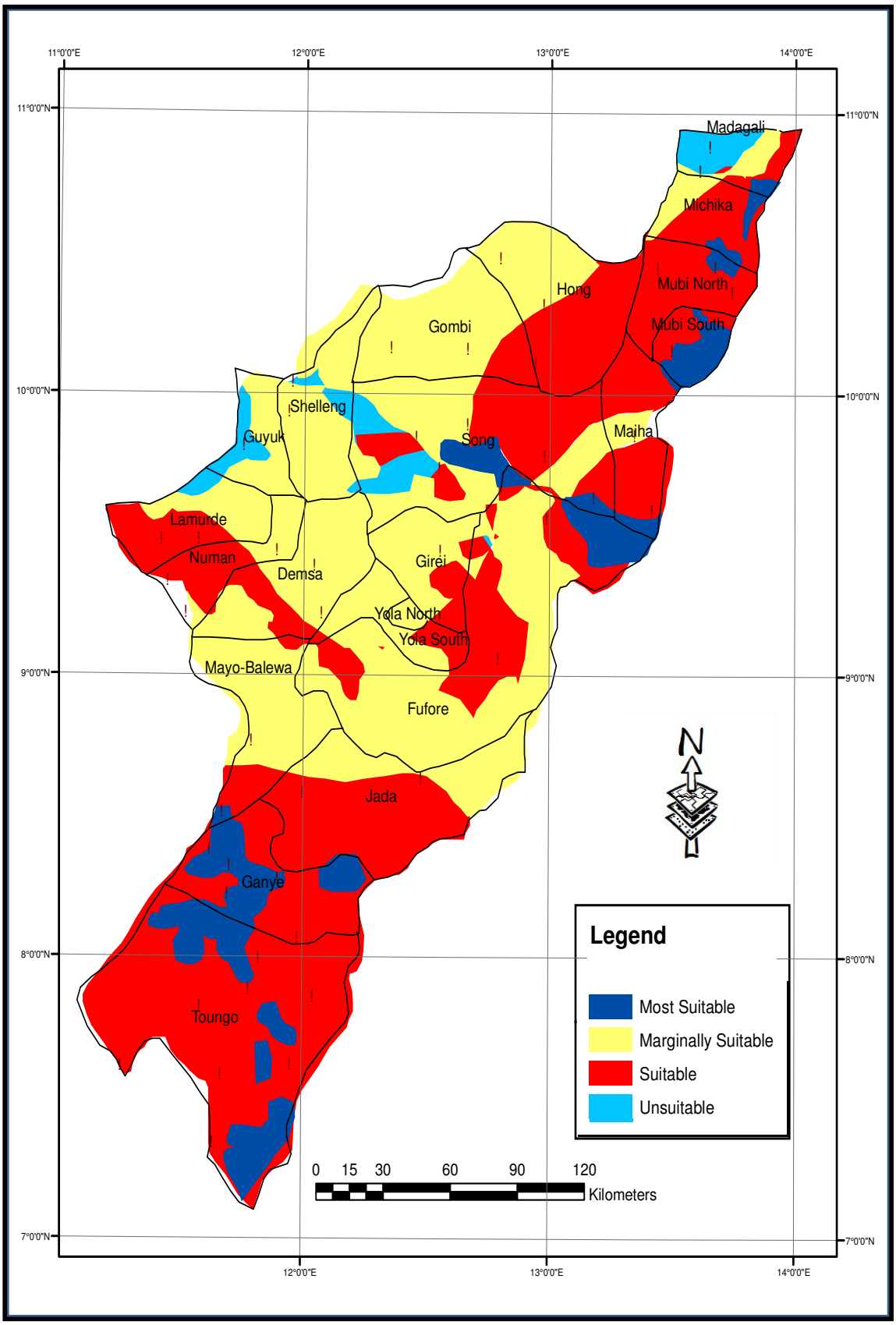

Figure 14. Suitability areas of Irish Potatoes in Adamawa State using sub-division of FAO guideline

Table 1: Criteria Defination

	Criteria	Constrain	
		Suitable	unsuitable
Rainfall length	**≥ 90 Days**	**1**	**0**
Annual rainfall	**1000-2500**	**1**	**0**
Temperature	**≤ 27°C**	**1**	**0**
Soil	**Loamy**	**1**	**0**
Relief	**≤200m and ≥ 1000m**	**1**	**0**

Table 2; Suitability of the Climatic/Topographic variable of Adamawa State

s/n	Requirement	Suitability Condition	Adamawa Condition	Remark
1	Rainfall Length	Equal or greater than 90days	110-210days	Suitable (100%) Figure 3
2	Annual rainfall	1000-2500mm	600-1600mm	Suitable (71.3%) Figure 4
3	Temperature	Equal or less than 27°c	Zone1 24-27°c Zone2 greater than 27°c Zone3 less than 24°c	Suitable (54.19%) Figure 5
4	soil	Loamy soil (Friable loam, Sandy loam, Clay loam, Red loam and lateritic loam)	Mostly loamy soil	Suitable (96.99%) Figure 6
5	Relief	Equal or greater than 1000m and can still strive on low altitude of less than 200m above sea level	Highland ≥1000m Upland 201-999m Lowland ≤200m	Suitable (36%) Figure 7

Table 3. Suitability areas of Irish Potatoes in Adamawa State using sub-division

Category of Suitability	Area Covered (km^2)	Percentage (%)
Most Suitable Area	1,672.27	4.30
Suitable Area	15,979.91	41.09
Marginally Suitable Area	17,757.18	45.66
Unsuitable Area	3,480.66	8.95
Total	38,890.02	100

REFERENCE

Adebayo, A.A. (1999). Introduction. In Adebayo A. A. and Tukur A.L.(Ed), *Adamawa in Map*. Yola: Paracalate.

Babaji B. A., Amans E. B., A. M. Falaki, U. F. Chiezey, Mahmud, M.,. (2007). *Contributions Of Shoot N, P And K To Tuber Yield.* Journal of Agricultural and Biological Science , 4-5.

Berry, J.K., (1993). *Cartographic modeling: the analytical capabilities of GIS*. In: Goodchild, M., Parks, B., Steyaert, L. (Eds.), Environmental modeling with GIS, Oxford University Press, Oxford, pp. 58–74.

Booth, B., Mitchell, A., (1999). *Getting Started with ArcGISe, ESRI,* Redlands, CA.

Burrough, P.A., (1992). *Development of intelligent geographical information systems*. International Journal of Geographical Information Systems 6 (1), 1–11.

CIP. (1982). World potato facts. International Potato Center (CIP), Lima, Peru. , 54.

Eastman, J.R., (1997). *Idrisi for Windows, Version 2.0: Tutorial Exercises,* Graduate School of Geography—Clark University, Worcester, MA

Eastman, J. R. (2009). IDRISI Taiga, Guide to GIS and Image Processing. USA: Clark Labs, Clark University.

FAO, F. a. (1976). A Framework of Land Evaluation, Rome.

FAO. (2008). International Year of the Potato. Retrieved 06 2012, from Agricultural Organization of the United Nations.: http://ww.potato2008.org

FAO, WFP and IFAD. (2012). The State of Food Insecuirity in the World. Rome: FAO.

Goodchild, M.F., (1987). *A spatial analytical perspective on geographical information systems*. International Journal of Geographical Information Systems 1 (4), 327–334.

Mukhtar Elaalem (2012) *Land Suitability Evaluation for Sorghum Based on Boolean and Fuzzy-Multi-Criteria Decision Analysis Methods.* International Journal of Environmental Science and Development, Vol. 3, No. 4, August 2012

Madefa, L. (2012, July). Irish Potato and Soya bean Cultivation in Adamawa State. (S. H. J., Interviewer) Yola: A A D P.

Mih, A.M., H.W. Rossel, and G.l. Atiri. (1993). Incidence and distribution of potato viruses in Plateau State, Nigeria. African Crop Science Journal 1 , 131–138.

Punjab, N. B. (2010). Punjab National Bank. Retrieved June 20, 2012, from www.Pubkrishi.com: http://www.pubkrishi.com

Raemaekers, H. (2001). Crop production in Tropical Africa. Belgium: Geokint graphics nv.

Rosie, B. L and Micheal N. D. (2008). Potatoes. west Lafayette: Department of Horticulture.

Sofyan R,Wahyunto,Fahmuddin A and Hapid H. (2007). *GUIDLINES TO LAND SUITABILITY EVALUATION*, with a Case Map of Aceh Barat District. Indonesia: Indonesian Soil Research Institute and World Agroforestry Centre.

Stoms, D. M., McDonald, J. M., & Davis, F. W. (2002). *Fuzzy assessment of land suitability for scientific research reserves.* Environmental Management, 29(4), 545–558.

Tomlin, C.D., (1990). *Geographical Information Systems and Cartographic Modeling,* Prentice-Hall, Englewood Cliffs, NJ.