LAND SUITABILITY CLASSIFICATION FOR MAIZE PRODUCTION IN BASAWA, SABON GARI LOCAL GOVERNMENT AREA OF KADUNA STATE, NIGERIA

BY

SHEHU Aminu Momodu

PI4SCGS8195

(M.Sc. REMOTE SENSING AND GIS)

DEPARTMENT OF GEOGRAPHY AND ENVIRONMENTAL MANAGEMENT,

FACULTY OF PHYSICAL SCIENCES,

AHMADU BELLO UNIVERSITY,

ZARIA, NIGERIA

SEPTEMBER, 2018

LAND SUITABILITY CLASSIFICATION FOR MAIZE PRODUCTION IN BASAWA, SABON GARI LOCAL GOVERNMENT AREA OF KADUNA STATE, NIGERIA

BY

SHEHU Aminu Momodu

PI4SCGS8195

(M.Sc. REMOTE SENSING AND GIS)

A DISSERTATION SUBMITTED TO THE SCHOOL OF POSTGRADUATE STUDIES AHMADU BELLO UNIVERSITY, ZARIA IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF MASTER DEGREE IN REMOTE SENSING AND GEOGRAPHIC INFORMATION SYSTEM

DEPARTMENT OF GEOGRAPHY AND ENVIRONMENTAL MANAGEMENT,

FACULTY OF PHYSICAL SCIENCES,

AHMADU BELLO UNIVERSITY,

ZARIA, NIGERIA

SEPTEMBER, 2018

DECLARATION

I declare that this dissertation titled **"Land Suitability Classification for Maize Production in Basawa, Sabon Gari Local Government Area, Kaduna State, Nigeria"** was written by me and is a product of my research work in the Department of Geography under the supervision of Dr. B. Abdulkarim and Dr. A.K. Usman. This dissertation has not been presented in the Department of Geography Ahmadu Bello University Zaria or anywhere for a degree. Allquotations and sources of information were acknowledged and referenced.

Shehu Aminu Momodu ……………………………….. ……………………

(Signature) **(Date)**

CERTIFICATION

This dissertation titled **"Land Suitability Classification for Maize Production in Basawa, Sabon GariLocal Government Area, Kaduna State, Nigeria",**by **Shehu Aminu Momodu** meets the regulations governing the award of the degree of Masters of Science (Remote Sensing and GIS) of Ahmadu Bello University, Zaria, and is approved for its contribution to knowledge and literary presentation.

…………………………………   **……………………**   **…………………..**

Dr. B. Abdulkarim   (Signature)   Date

Chairman, Supervisory Committee

…………………………………...   **……………………….**   **…...………………**

Dr. A.K. Usman   (Signature)   Date

Member, Supervisory Committee

………………………………..   **……………………….**   **…………………….**

Dr. A.K. Usman   (Signature)   Date

Head of Department, Geography

…………………………………   **…………………………**   **…………………….**

Prof. S.Z. Abubakar   (Signature)   Date

Dean, Postgraduate School

DEDICATION

To my Parents, Alhaji Shehu .H. Usman and Hajia Rabi Yunusa, that has been there for me all my life and to my sibilings, and to Almighty Allah for all his care, mercy and love.

ACKNOWLEGEMENTS

All thanks goes to Almighty Allah (SWT) who gave me the opportunity, wisdom, knowledge and health to undertake this work.

I wish to acknowledge my supervisors Dr. B. Abdulkarim and Dr. A.K. Usman. They have really tried for me despite all the tight schedules. I equally acknowledge the contribution of my teachers and colleagues at Ahmadu Bello University, Zaria whom supported in the data collection and analysis which includes Mr. Abdulfatai Bello, Mr Paul Jobin, Mr Richard Thlakma, Mallam Ilu Isa, Mallam Hassan Muazu, Mallam Ibrahim Jimon and Mr. .O. Stephen whom contributed a lot towards the conclusion of this Thesis especially the data collection and analysis. And to my lecturers at Ahmadu Bello University Zaria particularly; Prof. E.O Iguisi, Prof. I.J Musa, Mallam .I. Garba, Mallam I. Mukhtar, Dr. R.O Yusuf, Dr. Muhammad Isma‟il (MI), Dr. B. Akpu and the Department’s PG coordinator, Dr. Shehu Abbas for their mentorship.

I am indebted to my parents, Alhaji Shehu .H. Usman and Hajia Rabi Yunusa Shehu for their care, love and encouragement throughout my study years; God has seen your labour of love and He only will eternally reward you with Al-Janna Firdausi.

I am especially thankful to my family at large; Mrs. SefiaYahaya, Mrs. Bilikisu Andrew, Mrs. Mariam Shehu, Miss Aishatu Shehu and Miss Nefisatu Shehu and to my Nieces and Nephew; Master Idris Obeni Andrew, Miss Mariam Obeni Andrew, Miss ZanaibObeni Andrew and Miss ZanaibYahaha, who together have made life more beautiful in different ways by their love, attention, understanding and most importantly by their prayers. Your very many names are inscribed in my heart because you all are so dear to me.

Lastly, I am grateful to my friends who have shaped or touched my life in one way or the other; Anna Sylvester, Tina Aba Lucy, Patience Obaje, Wale Onifade, DanganaThimothy, Austin Ologun, Achimugu Solomon, Ibrahim Musa, Chenemi Musa, Austin Wamuo, Udogu Charles, Albert Joesph, Satmak Johnson, Abu Audu, Mustapha Seidu,Baffa Adamu, ChimaOnichakwe, Judith John, Ayuba Jemima Jemcy, Patience Odekina, Jane Nnagbo. I love you all!

ABSTRACT

This study assessed land suitability for maize production in Basawa area of Sabon Gari Local Government Area of Kaduna State. Satellite Imageries, Global Positioning System (GPS), Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) DEM were used to generate data on the elevation, slope, aspect, drainage and soil texture of the study area. Multi Criteria Evaluation (MCE) was used for land evaluation and eighty (80) soil samples from a grid map of the area at a depth of 0 – 30cm to analyze the soil pH, magnesium, Nitrogen, Cations Exchange Capacity, Sodium, Organic matter, Calcium, Phosphorus and Potassium levels. Land characteristics map combined with the soil physicochemical parameters were subsequently integrated in Arc GIS 10.3 to generate the land suitability map for the selected crop. Analytical Hierarchy Process (AHP) was used in analyzing the weighting criteria for suitability class. The pH of the soil ranges from (4.12), low Sodium (0.3586mol kg^{-1}) and low Phosphorous (9.38mg kg^{-1}), Nitrogen (0.617g kg^{-1}) and Organic matter (1.04%). Other characteristics of the soil were medium concentration of Magnesium (0.86mol kg^{-1}), Potassium (0.17mg kg^{-1}) and Calcium (4.1286mol kg^{-1}) and Cations Exchange Capacity (6.41cmol(+) kg^{-1}). Suitability analysis revealed that only 4411.67sq.m^2 (8.91%) of the land is highly suitable for the growth of maize. While 26069.38sq.m^2 (52.65%) is moderately suitable, 14151.99sq.m^2 (28.58%) and 4878.75sq.m^2 (9.86%) of the land were found to be marginally and not suitable respectively. The study recommends the need for effective land management techniques by the Kaduna State Ministry of Agriculture to increase the nutrient level and balance the physiochemical concentration of the soil elements to attain a higher suitability level for the growth of maize.

TABLE OF CONTENTS

CHAPTER THREE: STUDY AREA AND METHODOLOGY

LIST OF TABLES

LIST OF FIGURES

Figure Page

LIST OF APPENDICES

CHAPTER ONE: INTRODUCTION

1.1 BACKGROUND TO THE STUDY

Land is the solid surface of the Earth that is not permanently covered by water. The vast majority of human activities throughout history have occurred in land areas that support agriculture, habitat, and various natural resources (Michael and Chris, 2013). Land suitability is the fitness of a given type of land for a defined use (Food and Agriculture Organization (FAO, 1976).

Land suitability evaluation is a classification of land in terms of their suitability for a specific land use (FAO, 1976). Suitability is a function of crop requirements and land characteristics. Suitability is a measure of how well the qualities of land unit match the requirements of a particular form of land use (FAO, 1976). The objective of land suitability evaluation is the prediction of inherent capacity of the land units without deterioration or to minimize socioeconomic and environmental costs. Physical land evaluation is a prerequisite for land-use planning, because it guides decisions on optimal use of land resources. In multi-criteria decision making, this is utilized for determination of optimum land use type for an area (Elaalem, Comber and Fisher, 2001; De La Rosa, 2000; Van Ranst, Tang, Groenemans, and Sinthurahat, 1996).

The FAO approach to land suitability evaluation classifies land according to a range from highly suitable to not suitable (FAO, 1976). This procedure starts by identifying relevant landuse types. The land use requirements are then matched with defined land conditions. The land conditions are described as dynamic regimes or land qualities, which are estimated from measured or estimated attributes, known as land characteristics (Melitz, 1986). FAO guidelines for land evaluation are widely accepted (FAO, 1983). The quality of land suitability assessment, and hence the reliability of landuse decisions, depend largely on the quality of the soil information used to derive them (Mermut and Eswaran, 2001).

The present shortage of good land for food production which are caused by competing demand for other landuse such as industrialization, housing, grazing, fuel wood, cash crop and degradation caused by unsuitable land use practices calls for a reliable land evaluation (FAO, 1985; Raji, 1999). Land suitability analysis for crop is a prerequisite to achieve optimum utilization of the available land resources for sustainable agricultural production. Land evaluation is a tool for land use planning for sustainable agriculture (Perveen, Nagasawa, Uddin, and Delowar, 2012). Soil characterization and land evaluation for various land use is one of the strategies for achieving food security as well as sustainable environment (Esu, 2004). The starting point toward sustainable management is adequate information on land resources and their suitability are not in proper form in spite of several spots studied in Nigeria (Ogunkunle, 2004).

The productivity of soils in Nigerian Savanna region is decreasing due to their fragile nature. These lands have been utilized intensively for all purposes at the expense of their suitability resulting in degradation and altering the natural ecological conservatory balances (Ande, 2011). Maize production required certain climatic conditions, terrain and other soil properties to be in place. Maize is grown under divergent physical condition. Maize is one of the most widely cultivated crops and grown in both tropical and warm temperate latitude. Maize is grown in climates ranging from temperate to tropical during the period when mean daily temperatures are above 15^0C and frost-free. Maize is grown mostly in regions having rainfall between 60cm to

110cm. The best suitable soil for Maize is deep, rich soils of the sub-tropics, where there is abundant nitrogen (Martin and Leonard, 1967).

Maize is one of the important grains in Nigeria. It is a multipurpose crop in which every part of it has great economic value. The grain, leaves, stalk, tassel and cob can all be used to produce a large variety of food products. Studies by Badu-Apraku *et al.*,(2012) on maize production in different parts of Nigeria has shown an increasing importance of the crop amidst growing utilization by food processing industries and livestock feed mills. In Basawa, Sabon Gari Local Government Area of Kaduna state in Nigeria, the demand for maize is increasing on a daily basis, because it is a major staple food for human and animals. But despite the economic importance of maize, it has not been produced in such quantity that could meet food and industrial needs of the country, and this could be attributed to low productivity due to lack of improved technologies for maize production (Osundare, 2013). One of the major limitations to maize production in Nigeria is the declining soil fertility which is exacerbated by continuous cultivation, high cost and sometimes unavailability of fertilizer (Ismalia, Gana and Dogora, 2010).

Badu-Apraku, Menkir, Fakorede, and Ellis-Jones (2012) stressed that after the introduction of maize to Africa in the sixteenth century, the crop rapidly gained popularity as a major food crop as well as a trade commodity in most of West and Central Africa. Today, maize is widely grown in this agro ecological sub region. It is a highly suitable crop, especially well adapted to the Savanna zones. Maize, as a major source of calories is not only for humans but also for animals in Nigeria as well as other parts of the world. This has resulted in more land being opened up for large scale production (Udoh and Ogunkunle, 2012).

In view of the demand for maize, Nigeria and international bodies such as Food and Agriculture Organization (FAO) have developed interest in promoting maize production for households' food security and poverty alleviation. In Basawa, Sabon Gari area of Kaduna State, agricultural activity especially maize production is the main means of livelihood.

Observations have shown a decline in both quantity and quality of production in the study area. There has been 30% decline in the cultivation of maize production in Basawa, Sabon Gari Local Government area of Kaduna state(Food and Agriculture Organization Statistics (FAOSTAT, 2000). This has become a discourse among the inhabitants. One of the strategies to achieve food security with sustainable environment is to study soil resources in details through soil characterization and land evaluation for various land utilization(Esu, 2004).

However, with the introduction of Remote Sensing and Geographic Information System (GIS), data can now be accessed for effective and efficient studies with regards to maize production in Basawa area of Sabon Gari L.G.A. Remote Sensing is the science and art of acquiring information about an object, area, or phenomenon through an analysis of the data acquired by a device which is not in contact with the object, area or phenomenon under investigation (Anji, 2008). This technique has increasingly become important in providing reliable and timely information on land issues like suitability analysis; such information is difficult to acquire through conventional ground surveys. GIS is defined as computer systems capable of assembling, storing, manipulating, and displaying geographically referenced information (United State Geological Survey (USGS, 1998). In the context of land suitability analysis, GIS offers a flexible and powerful tool as it can combine large volumes of different kinds of data into new datasets and display these new datasets in the form of informative and accessible thematic maps (Foote and Lynch, 1996; Marble *et al*., 1984). Different GIS software is capable of incorporating and manipulating a spatial data which will be used for decision making particularly the agricultural sector.

1.2 STATEMENT OF THE RESEARCH PROBLEM

Improving yield and efficiency in resource use is vital to ensuring adequate food security and environmental sustainability. The slight increase in maize production in Nigeria has been attributed to increase in hectares devoted to its cultivation and not optimum yield of each farmland. Also, recent report of FAOSTAT (2012) has shown that the cultivation of areas used for maize production (Kaduna state) have declined by about 20 % from the periods of 1991 to 2000 and 2001 to 2010. In addition, the potential yield of maize crop using the improved seedling in Nigeria is not enough compared to that of the developed countries (Oyekale, 2008). Improper land-use results to land degradation and decline in agricultural productivity. However, in practice, particularly in Nigeria, the use to which land is put is not often related to the land potential capacity for its use type (Senjobi, 2007). Land have been utilized intensively for all purposes at the expense of its suitability capacity thereby resulting in land degradation and altering the natural ecological conservatory balances in the landscape (Ogunkunle, 2004).

Nigeria, having the largest population in Africa characterized by rapid population growth, a high degree of dependence on agriculture at the household level and large area of low potential (sub humid and sub arid) rainfed farm land, is experiencing predominantly a nutrient depletion scenarios (Mortimore and Harris, 2003). Among many factors limiting agricultural development in Nigeria is the lack of sufficient information on soils and their characteristics (Adamu, 2012).

Nigeria's immense agricultural potential is a great asset for the nation and Africa, with promises for food security when fully harnessed (Akinwunmi, 2014). Only 40% of Nigeria's 84 million hectares of arable land is presently cultivated (Akinwunmi, 2014). To increase productivity of agriculture in Kaduna State and Nigeria in general, there is a need for suitability assessment of land which will assist in identifying key soil properties for optimum yield of maize production.

Njar, Iwara, Egbe, Offiong and Essoka (2012) assessed the suitability of two prominent land parcels for maize production in Obiaruku community of Delta state and found that the well-drained soil was classified as highly suitable for maize production due to its high level of essential nutrient; whereas soil of the riverine area were classified as moderately suitable for maize production due to its medium level of nutrient. Also, Ofor, Ibeawuchi and Oparaeke (2009) carried out a study on crop protection, problem and control measure in production of maize and Guinea corn in Northern-Guinea Savannah of Nigeria. The study revealed that maize has a high demand for nutrients compared to cereals like rice, millet and wheat. Maize requires both the major nutrients (N, P and K) and the secondary nutrients (S, Mg, Ca, B, Fe, Cl, Cu etc.) in adequate amount to ensure good root establishment, vigorous and healthy growth and increased yields.

Esu (2004) studied soil in detail through processes of soil characteristics and land evaluation for various land utilization type is one of the strategies for achieving food security as well as sustainable environment. However, despite the important of land evaluation on sustainable management of land and for enhanced crop production, specific soil suitability studies; such as suitability assessment for maize production have not been properly documented (Aondoakaa and Agbakwuru, 2012; Njar, et al., 2012).

Hussaini (2011) studied the land suitability for some selected crops in Institute for Agricultural Research (IAR) farm, Zaria, Kaduna State, Nigeria. The researcher made used of FAO land suitability evaluation criteria to evaluate the selected crops by delineating three soil mapping units. The result showed that two of the soil units were moderately suitable (S2) for cotton and maize but highly suitable for sorghum while the third soil unit was marginally suitable (S3) for cowpea and not suitable (N1) for cotton and maize.

Suitability evaluation needs a specification of the respective crop requirements and calibrating them with the terrain and soil parameters. According to Dent and Young (1981), optimal crop growth and productivity is based; amongst other factors on soil conditions, soil organic matter content expressed by the organic carbon content, soil depth are amongst the main factors that influence crop adaptability to a given land area. It is also obvious that most studies on land evaluation were carried out on a national or regional scale, neglecting the local scale, and most study use the qualitative land evaluation. This study will use both qualitative and quantitative methods of land evaluation. It is in the context of this neglect that this study becomes imperative.

Sabon Gari local government area is one of the fast growing town in Kaduna state has been affected by the fact that so many agricultural types are being developed to meet various growing food demand as a result of the growing population. But maize which is an important food crop appears to lagging behind. Records gotten from the Secretariat of Sabon Gari local government area shows that there is complains from the farmers that the production is low.In this regard, Basawa area of Sabon Gari local government area is used as a case study in this researchwork to find out if the study area is suitable for maize production, the quantity produced, how sufficient is it for the inhabitants and the scale of production. Therefore, information is needed on physical and chemical properties of the land to ascertain its suitability for maize production. The need for such information constitutes the problem ofthe research interest.This is the gap the study intends to fill. This study therefore intends to address the following research questions.

i. What are the physical characteristics of the terrain that affect the suitability of the land for maize production in the study area?
ii. What are the physiochemical parameters of the soil that affect the suitability of the land for maize production in the study area?
iii. What is the spatial variation in soil suitability for maize production in the study area?
iv. What is the extent of land suitable for maize production in the study area?

1.3 AIM AND OBJECTIVES

The aim of the study is to evaluate land suitability for maize production in Basawa, Sabon Gari Local Government Area of Kaduna State. The aim was achieved through the following specific objectives:

i. identify and map the physical characteristics of the terrain in the study area.
ii. determine the physiochemical parameters affecting land suitability for maize production in the study area.
iii. classify the suitability levels of the soil for maize production in the study area.
iv. map out suitable areas for maize production in the study area.

1.4 SCOPE OF THE STUDY

The spatial scope of the research covered farm land located in Bassawa, Sabon Gari Local Government Area in Kaduna state with an area of 49511.79sq.m^2 of land. The study analyzed land suitability for maize (*Zeamays*). For the purpose of this study, the following factors was used for suitability analysis, which include the land characteristics and physical properties; Elevation, Aspect, Drainage, Soil Texture and Slope map and the chemical properties include;

pH, Nitrogen (N), Phosphorus (P), Potassium (K), Organic matter (OM), Calcium (Ca), Magnesium (Mg), Sodium (Na), Cations Exchange Capacity (CEC) and derived from ASTER DEM was used for the analysis. The temporal scope is 2006 to 2015.

1.5 JUSTIFICATION OF THE STUDY

Inventory of land resource is a prerequisite for proper utilization and sustainable management of the natural resource base of any country. Accurate inventories become imperative for the assessment of available natural resources of a country (FAO). There is urgent need to optimize land use in the most practicable and logical ways to continue sustainable production while conserving fragile ecosystems. The study provides information on Agricultural land, help in maintaining the promotion of compatible land uses and management practices in the area. In recent years, thematic mapping has undergone some changes due to advances in geographic information science and remote sensing, especially in the soil studies. The study also demonstrates the potentials of using Remote Sensing and GIS in land suitability mapping at larger scale (local level) which can be applied to the medium and even the smaller scales (state and the country at large), it also provided a guide for the quantitative assessment of land for agriculture and have address the practical survey problem (especially the traditional survey method, planners) that has been used for decades in the hope that this will enable a more consistent approach to land suitability evaluation. With the help of the research work, it will enable the farmers to have more knowledge on area in which is the best site for crop planting and it will help in harvesting more products in order to address the situation of low productivity in the country.

CHAPTER TWO

CONCEPTUAL FRAMEWORK AND LITERATURE REVIEW

2.1 CONCEPTUAL FRAME WORK

2.1.1 Land Suitability

It is useful for the purpose of this study to define what “Land suitability” means. A definition of this concept proposed by the Food and Agriculture Organization of the United Nations (FAO) is that land suitability is the fitness of a given type of land for a defined use. The land may be considered in its present condition or after improvements. The process of land suitability classification is the appraisal and grouping of specific areas of land in terms of their suitability for defined uses. Land suitability analysis is a prerequisite to achieve optimum utilization of the available land resources for sustainable agricultural production. One of the most important and urgent problems in the study area is to improve agricultural land management and cropping patterns to increase the agricultural production with efficient use of land resources (Pareta and Jain, 2010). In general, a land area can be classified as “Suitable” or “Not Suitable” for a certain use. Suitable areas can be portioned in classes, which reflect the degree of suitability. The number of classes can vary, but it should be kept to the minimum necessary and should never exceed the number of five (Tinguely, 2012).

In these schemes, four categories are recognized. The highest category is the order that reflects; in broad features, whether a soil is suitable or not for a given use. Two orders are recognized:

S = Suitable. Land in which benefits exceed the costs and sustained use does not incapacitate the soil over a sufficiently long period of time.

N = Not suitable: Land can be classified as not suitable for a certain use for diverse reasons. The use proposed may be deemed technically impractical, as in irrigation of abrupt rocky terrain, or that it causes serious environmental degradation, for example, cultivation on steep slopes. Frequently, however, the reason is economic, in that the profit expected does not justify the cost required.

The second category is the class that reflects degrees of suitability with in the order. These are numbered consecutively in Arabic numerals.

For the order S, three to five classes are normally considered. For example, the three classes are:

S1 = Highly suitable: without limitations for sustained use or minor limitations that do not affect productivity nor appreciably increase costs.

S2 = Moderately suitable: moderately serious limitations that reduce profits or involve risks of degradation in sustained use of the soil.

S3 = Marginally suitable: the limitations for sustained use are serious and the balance between costs and benefits make the use only marginally justifiable. Its use is normally justified on other purpose than economic grounds.

In the order N, three classes are also recognized:

N1 = Not currently suitable: land with limitations that could be eliminated by technical means or investment, but that these changes are at present unfeasible.

N2 = Permanently unsuitable: serious limitations of generally physical nature, which are assumed to be beyond solving over long term.

X = Land for conservation: unsuitable for exploitation, being lands of special protection, due to their conservation, wildlife, of special scientific, ecological or social interest (example, parks, reserves or recreational zones).

Limits between the orders (S and N) and between the different classes (S1, S2, S3 and N1, N2) are established by the presence of limiting factors. One limiting factor is a characteristic of soil that hampers its use, reduces productivity, increases costs and implies degradation risk, or all of the above. This limiting factor is used to define the third category of the system, which is the subclass. In the symbol of each subclass, the number of limitations involved should be kept to the minimum of one letter or rarely two. Limitations proposed include: t, slope; e, erosion risk; p, depth; s, salinity; d, drainage; c, bioclimatic deficiency; r, rockiness; i, flood risk.

Finally, the fourth category is the unit that establishes the differences within the subclasses as a function of the desired use. All of the units within a subclass (S2rA, S2rM ...) have the same degree of suitability at the subclass level (S2) and analogous characteristics of limitation at the subclass level (r). The units differ from each other in their characteristics of production or in secondary aspects of their management demands. Their examination enables a detailed interpretation at the planning level of exploitation. The units are distinguished by upper-case letters that are placed at the end. There is no limit at all for the number of units examined within a subclass. These defined are: A, intensification in the agricultural use without need of great improvements; M intensification in the agricultural use with need of major improvements (irrigation, etc.); P, use for pasture for livestock; F, forestation. In some cases, the designation "conditionally suitable" can be added so long as certain conditions are satisfied

2.1.2 Remote Sensing and Geographic Information System on Land Suitability in Agriculture

The use of Geospatial technologies in the management of agricultural resources is increasing rapidly due to improvement in space-borne remote sensing satellites in terms of spatial, spectral, temporal and radiometric resolutions. The use of GIS and Remote Sensing in land evaluation has attracted the attention of several scholars (Rossiter, 1994; Patil*et al*., 2005; Salam and Rahman, 2007; ESRI, 2009). It is stated in literature that almost all land evaluation projects present results as maps. The location and other spatial characteristics of evaluation units are often important land characteristics in the evaluation itself (Rossiter, 1994).

The Geographic Information System (GIS) is a technique of utilitarian value with regards to agricultural land evaluation. GIS is defined as “an assemblage of computer equipment and a set of computer programs for the entry and editing, storage, query and retrieval, transformation, analysis, and display and printing of spatial data” (Rossiter, 1994). This shows that GIS has vast capabilities to work comprehensively on spatial data for several purposes including land evaluation for agriculture.

The importance of using GIS for development studies such as land use evaluation for agriculture cannot be over emphasized. GIS has been extensively used in other sectors of national development but the use of such technology to support decisions for sustainable agricultural development in rural settings is quite limited. The use of these technologies is, therefore, encouraged towards improvements in the standards and quality of rural life (Petja *et al*., 2014).

2.1.3 General Characteristics of Savannah Soils

The savannah soils are generally divided into Sahel, Sudan, Guinea and Derived Savannah zones based on moisture and vegetation (Aduayi, Chude, Adebusuyi and Olayiwola, 2002).

The soils are mostly associated with upper to middle slope positions which are well drained. They are widely used for crop production because they are mostly well drained unlike the wetland soils which are partially or completely water logged, though they are low in fertility

(Jone and Wild, 1975; Mokwunye and Batiano, 2002). Most of the soils are under continuous cultivation, so they rapidly lose their fertility due to rapid decline in organic matter, leaching of basic cations and high rate of acidification (Jone and Wild, 1975; Ogunwole, 2008).

The soils are deep to very deep; petroplinthites (hardened laterites) are major constraints to depth which are constraints to plant and roots development as reported by (Yaro, Kparmwang, Raji and Chude, 2006). The texture of the soils ranges from sandy loam to sandy clay loam (Oyinlola and Chude, 2010; Shobayo, 2010), while Odunze and Kureh, (2009) reported loam texture at the surface horizons, and clay loam and clay in the subsoil horizons. Generally, soils of the savannah area are reported to have high sand content at surface, as the soils are formed on aeolian sand cover (Sombroek and Zonneveld, 1971). Silt content of the soils was observed to slightly increase with increasing depth in soil profiles. Morbeg and Esu (1991) and Kparmwang (1993) in their studies of soils in the Savannah region of Northern Nigeria mentioned the influence of Harmattan dust in contributing silt to soil. The higher clay content in the subsurface horizons of many soils maybe attributed to illuviation and pedoturbation processes (Sharu, Yakubu and Tsafe, 2013). The surface of most savannah soil are reported to have high bulk density followed by a decrease in the sub soils and further rose in the lowest horizons (Zafari, 1993; Raji 1995; Maniyunda, 1999). The high bulk density is attributed to compaction caused by grazing animals and tillage operation (Shobayo, 2010; Sharu*et al.*, 2013). Root growth could also be inhibited due to high bulk

2.1.4 Maize (Zea *Mays)*

Maize (Zea *mays*) is one of the most important cereals of the world. It is called queen of cereals. It requires rainfall of 760-1520 mm per annum, although it is possible to obtain good yield with

460-760 mm of rainfall, if it is evenly distributed during the growing season. Maize crop requires warmth all through its active life period and practically no maize grows where the growing season temperature is <19^0C. Maize produces good results with mean temperature of 24^0C and a night temperature above 15^0C (Martin and Leonard, 1967). Maize can be grown on a wide range of soils, but performs best on well-drained, well-aerated, deep, loam and silt loam containing adequate organic matter and well supplied with available nutrients. Although it grows on a wide range of soils, it does not yield well on poor sandy soils, except with heavy application of fertilizer on heavy clay soils. Deep cultivation and ridging is necessary to improve drainage. Maize is suited for off-season cropping in swamps provided drainage is adequate (though planting in swamps is not always recommended for environmental reasons). Maize is very sensitive to stagnant water, particularly during its early stages of growth. Proper drainage is a must for the success of crop especially during raining season, as it does not tolerate water logging. Maize can be grown successfully on soils with a pH of 5.0-7.0 but a moderately acidic to neutral environment (5.5 – 7.5) is optimum (Naidu, Ramamurthy, Challa, Rajendra and Krishnan, 2006).

2.1.5 Multi Criteria evaluation (MCE) and Analytical Hierarchy Process (AHP)

This approach helps in the Decision Making, however Multi-criteria decision making (MCDM) is primarily concerned with how to combine the information from several criteria to form a single index of evaluation (Chen, Yu and Khan, 2012).

Criterion weights are the weights assigned to the objective and attribute maps (Meng *et al*. 2011). Deriving weights for the selected map criteria (land characteristics map layers) is a fundamental requirement for applying the AHP method (Malczewski 1999, 2004). The determination of the particular criterion weight is therefore a crucial step in Multi-Criteria

Decision Method(MCDM). As previously mentioned, the AHP is considered to be an adequate mathematical method for this step when analyzing complex decisional problems (Saaty 1977, 1980, Malczewski 2004). It derives the weights by comparing the relative importance of the criteria in a pairwise manner. Through a pairwise comparison matrix, the AHP calculates the weighting for each criterion (wi) by taking the Eigenvector corresponding to the largest Eigenvalue of the matrix, and then normalizing the sum of the components to unity.

2.2 THEORETICAL FRAMEWORK

2.2.1 Fuzzy Model

It is well known fact that many elements of land plot properties (soil, fertility of soil, microclimate, etc.) have uncertainties. Uncertainty is inherent in decision-making processes, which involves data and model uncertainty. These range from measurement errors, to inherent variability, to instability, to conceptual ambiguity, to over-abstraction, or to simple ignorance of important factors (Tinguely, 2012).

An underlying philosophy of the fuzzy sets theory is to provide a strict mathematical framework, where the imprecise conceptual phenomena in decision making may be precisely and rigorously studied, in particular for knowledge management (Tinguely, 2012). The fuzzy sets theory includes fuzzy mathematics, fuzzy measures, fuzzy integrals, etc. Fuzzy logic is a minor aspect of the whole field of fuzzy mathematics. In classical sets theory, the membership of a set is defined as true or false, 1 or 0. Membership of a fuzzy set, however, is expressed on a continuous scale from 1 (full membership) to 0 (full non-membership).

In the GIS context, in decision making regarding land allocation, suitability is considered a fuzzy theory expressed as fuzzy set membership (Burrough*et al*. 1992, Hall *et al*. 1992). There are a variety of reasons why the application of fuzzy set membership in criteria standardization is highly appealing. First, it provides a very strong logic for the process of standardization. The process of criteria standardization can be seen as one of recasting values into a statement of set membership, the degree of membership in the final decision set. Compared with linear scaling, standardization using fuzzy set membership represents a specific relation between the criterion and decision set. This clearly opens the way for a broader family of set membership functions than that of linear rescaling. Second, the logic of fuzzy sets bridges a major gap between Boolean assessment and continuous scaling in weighted linear combination. Boolean overlay is a classical set problem and assumes a crisp boundary and certainty. By considering the process of criteria evaluation as one of fuzzy sets, the continuity and uncertainty in the relation between criteria and decision set are recognized. When set membership values are reduced to 0 and 1 (i.e. certainty), the set becomes crisp (a special case of fuzzy set) and the results will be identical to those of Boolean overlay (Jiang and Eastman 2000).

2.3 LITERATURE REVIEW

Oluwatosin (2005) assessed suitability of some land in Northwestern Nigeria for rainfed crop production using a qualitative physical land evaluation method. The study revealed that all the soils were currently not suitable (N1) for cereals but were marginally suitable (S3) for grain legumes. Potentially all the soils were moderately suitable (S2), while those on the plain were highly suitable (S1) for grain legumes. Soils on plains were potentially more suitable than soil of the upland and valley bottom. The major limitations were nutrient availability (F) which cut across all the soil while erosion hazard and drainage were major limitation in the upland and valley bottom respectively. For sustainable crop production, the use of high fertility management practice was recommended to make the land highly suitable for both cereals and legumes.

Hussaini (2011) evaluated suitability of Institute for Agricultural Research (IAR) farm, Zaria for some selected crops. The study shows that the soils were shallow to very deep, well to poorly drain and were medium textured soils with blocky structure dominating the soil and increasing clay with depth were observed in the subsoils. The pH was low to medium, high exchangeable bases and high base saturation characterized the soils. The soils were reported to have low organic carbon, total nitrogen and available phosphorus which were general characteristic of savanna soils (Jones and Wild, 1975). Three soil units were delineated and classified as *TypicHaplustalf, Lithic Ustipsamment*and *TypicEndoaqualfs/ Endoaquepts*. Two of the soil units were moderately suitable (S2) for cotton and maize and highly suitable for sorghum while the third soil unit was marginally suitable (S3) for cowpea and not suitable (N1) for cotton and maize. Constraints to agricultural productivity in the farm were low organic matter, total nitrogen, available phosphorus and poor drainage. Thus for optimal agricultural productivity, they recommended standard rates of N and P from inorganic fertilizers, incorporation of crop residue and application of organic manure to invariably increase productivity of the soils.

In addition, Lawal *et al*., (2012) evaluated suitability of soils of lower river Oshin flood plains in Kwara State, Nigeria for rainfed arable crops, using the FAO land suitability evaluation method. They reported that there are three soils units in the study area. The soils were generally sandy loam in texture and had moderate bulk density which could favour good agricultural production. All the soils were reported to have medium to high organic carbon, available phosphorus and CEC. All the soil units were moderately suitable (S2) for maize production. The major limitation was drainage. For sustainable yield of maize in the area, adequate drainage need to be constructed to conduct excess water out of the field as maize is not tolerant to water logging.

For rice production, the area were marginally suitable (S3) with topography, soil texture and soil fertility being the major limitations. For sustainable production of rice, application of organic and inorganic fertilizer was recommended.

Sharu*et al.*,(2013) conducted a semi-detailed soil survey of Dingyadi District in Sokoto, Nigeria in order to characterize and classify the soils. Result of the survey revealed that three soil units were identified on the basis of land forms and surface texture. The soils were deep to shallow, well to imperfectly drain and the texture varied from loam, sandy loam and sandy clay loam. The soils were relatively high in bulk density and low porosity. The dominant exchangeable bases were calcium and magnesium with the soils having high base saturation. The soils were neutral to slightly alkaline in reaction. Organic matter, available P, total N and CEC contents of the soils were generally low and the soils were classified as *TypicEndoaqualfs (Haplic Luvisols), TypicHaplustepts (Argic Lixisols)* and *Lithic Ustorthents (RupticCambisols*) respectively based on USDA and correlate with WRB system of Classification. Owing to fact that this current study area is an agrarian community outskirt of Zaria town and not much study has been done on soils of the area, characterization and classification will help reveal information that could be useful in the management and use of the soils for sustainable agricultural production.

Elaalem (2012) compared two approaches to land suitability evaluations, Fuzzy MCDA and Boolean, to model the opportunities for maize production in the north-western region of Jeffara Plain, Libya. In this study a number of soil and landscape and climate criteria were identified and their weights specified as a result of discussions with local experts. The Fuzzy MCDA approach was found to be better than the Boolean approach. Boolean logic indicted that the study area has only four suitability classes (highly suitable, moderately suitable, marginally suitable and currently not suitable). In contrast, the results obtained by adopting the Fuzzy MCDA approach showed that the area of study has a greater degree of subdivision in land suitability classes for maize. The richer overall picture provides an alternative type of land suitability evaluation to Boolean approaches and allows subtle variations in land suitability to be explored.

A fuzzy membership functions (FMFs) was developed by Inakwu, Odeh and Crawford (2010) to determine soil suitability for multiple crops; determine the diversity of multiple suitability at each location using the Shannon‟s Index and equitability equation; and determine the overall versatility at the farm scale, and establish a new versatility equation by combining the previous versatility methodology with a diversity index. To understand the overall versatility of the study area suitability analysis was carried out for each of the several crops- canola, barley, field pea, Lucerne and wheat. The multiple suitability analysis demonstrated subtle differences in the trend or patterns of the individual crop mapped. The development of the improved versatility map, incorporating Shannon‟s index, yielded important information for management decisions. The results indicate that the Northern and Southern paddocks of the study area exhibited higher versatility than the rest of the farm and would be highly suited for multiple crop rotations.

Mokarram, Rangzan, Moezzi and Baninemehc (2012) combined fuzzy and Analytical Hierarchy Process (AHP) in preparing land suitability evaluation maps for Wheat using Fuzzy classification in Shavur area, Khuzestan province. The results are compared to a Crisp classification using the standard FAO framework (parametric) for land evaluation which includes non-physical parameters as well. In the study, eight soil parameters, such as soil Texture, Wetness (ground water depth and hydromorphy), Cation Exchange Capacity (CEC) and Exchangeable Sodium Percentage (ESP), Gypsum (%), $CaCO_3$ (%), Topography, Soil depth and pH values were taken into consideration. AHP was used in analyzing the weight and the result classified 26% of the area as moderately suitable, 25% as marginally suitable and 49% as unsuitable. The results with the Fuzzy theory showed that 31% of the study area as highly suitable for growing wheat 29 % as moderately suitable, 19% as marginally suitable and 21% as unsuitable. This study was limited to non-physical parameters targeting a single crop.

Mustafa, *et al.,*(2000) used Multi Criteria decision Making (MCDM) and remote sensing in analyzing land suitability for different crops and for generating cropping pattern for the summer and winter seasons in Kheragarah*tehsil* of Agra. Different soil chemical parameters and physical parameters were evaluated for different crops. Results indicated that about 55 % of the land is highly suitable (S1) for sugarcane while 60%, 54% and 48 % of the area are moderately suitable (S2) for cultivating pearl millet, mustard and rice respectively. 50 % of the area is found to be marginally suitable (S3) for growing maize. This study concentrated on cereals.

Elaalem (2013) used both the Parametric and Fuzzy MCE approach for land suitability for the cultivation of Olive. Different factors were used in the study, these factors are: Soil (i.e. available water holding capacity; soil depth; infiltration rate; soil texture; soil salinity; soil reaction), climate, and erosion hazard and slope steepness which were all weighted. Factors affecting land suitability model for olive in north-west of Jeffara Plain region, Libya were defined based on previous studies for the study area and discussion with local experts (Sys, Van Ranst, Debaveye and Beernaert, 1993) The results of Fuzzy MCE showed that the majority of the study area is highly suitable for olive production, while the results obtained from the use the parametric method showed that most of the study area is moderately suitable for olive production. The Fuzzy MCE approach was found to be better than the parametric approach. The Fuzzy MCE approaches accommodate the continuous nature of many soil properties and produce more intuitive distributions of land suitabilities value for olive.

Al-Mashreki*et al.*,(2011) presents a spatial modeling procedure for land suitability evaluation of rainfed sorghum crop using available biophysical information. Moreover, this study was undertaken to develop a physical land suitability method using GIS and remote sensing technologies in arid and semiarid ecosystems such as that of Ibb Governorate at Highland region of the southwestern Yemen. It aimed to provide a simple example of how GIS and remote sensing technologies can be applied to detect the types of potential land suitability of agriculture in the study area. In addition, it intended to design an information system for land resource assessment. Accordingly, this study reveals that the nearly 5 % of the study area is highly suitable, 25 % is moderately suitable, 31 % marginally suitable, 24 currently unsuitable as well as 15 % permanently not suitable for the production of sorghum.

Behnam, Dorri, Jaime and da Silva (2014) used different raster layers in analyzing the suitability for assessment of land suitability and the possibility and performance of a canola (Brassica napus L.) soybean (Glycine max L.) rotation in four basins of Golestan province, Iran, including climatic (precipitation, temperature), topographic (aspects and slope) and soil-related (texture, pH, EC) layers, were provided by interpolation, surface analysis and other related techniques in GIS. Overlaid layers were used to judge the capacity of agricultural lands to rotate a canola–soybean system in the study area, which included four important basins. Based on defined scenarios and pre-determined ecological requirements of the two studied crops, five suitability classes were detected and mapped. The results reveals that just 11.82% of total lands are very suitable to rotate soybean after canola while most agricultural lands in the study area fell into the moderate and low suitability classes. The consistency of results adopted from final overlaid maps with real statistics in the study region show that GIS as a systemic approach can play a vital role in saving time and reducing.

Al-Mashreki (2011) determined the variation in the output caused by different input weights for four criteria namely climate, soil, slope, and erosion. So that sixteen weighting schemes were constructed, associated with the criterion map layers and run using the model's implementation in ArcGIS. The weighting schemes were applied for the selected crop (maize). The model finds the best path given the weights placed. By varying the weight, several different paths can be found. The results revealed that the slope is a very highly sensitive element in the suitability classification for sorghum crop, whereas the soil is a highly sensitive, the climate and erosion are moderately sensitive. This implies that each factor has to be given suitable weighting reflecting its importance for the suitability of sorghum in the study area.

Teshome*et al.,*(2013) used the Physical land suitability in Abobo area, western Ethiopia, following the FAO methodology for the determination of length of growing period and maximum limitation method for suitability classification. The result of the study revealed that the climate of the study area is moderately suitable (S2) for the considered varieties of cotton, maize and sorghum, whereas it is marginally suitable (S3) for upland rice. Considering soil and landscape suitability, the most limiting factors were soil depth, wetness, and soil fertility, mostly nitrogen. Based on the FAO model, the potential yields of cotton, maize, upland rice and sorghum were 2,645, 6,409, 4,774 and 4,194 kg ha-1, respectively. However, yield reductions of 7.32 to 12.09% and 6.01 to 11.16% were observed in simulated rain fed yield for maize and upland rice, respectively, as compared with their corresponding potential yields. The differences might mainly be induced due to water limitation, soils and landscape attributes, which suggests use of supplementary irrigation and soil management for optimum and sustainable production. All the limitations, except soil depth, can be improved so as to attain the potential suitability through improving and sustaining soil OM and practicing integrated soil fertility management.

Kihoro, Njoroge and Hunja (2013) in Kirinyaga, Embu and Mberee counties in Kenya, biophysical variables of soil, climate and topography were considered for suitability analysis to develop a suitability map for rice crop based on physical and climatic factors of production using a Multi-Criteria Evaluation (MCE) and GIS approach. All data were stored in ArcGIS 9.3 environment and the factor maps were generated. For MCE, Pairwise Comparison Matrix was applied and the suitable areas for rice crop were generated and graduated. The current land cover map of the area was developed from a scanned survey map of the rice growing areas. According to the present land cover map, the rice cultivated area was 13,369 ha. Finally, different layers were analysed like the land cover map with the suitability map to identify variances between the present and potential land use. The crop-land evaluation results of the present study showed that, 75% of total area currently being used was under highly suitable areas and 25% was under moderately suitable areas. The results showed that the potential area for rice growing is 86,364 ha and out of this only 12% is under rice cultivation. This research provided information at local level that could be used by farmers to select cropping patterns and suitability.

Earlier studies on land evaluation underscore its importance in assessing the potentials of land for a specific purpose as well as understanding its optimal requirement. For example, Gbadegesin (1984) examined soils classification of the central savanna zone for maize cultivation. The soil requirements for maize cultivation were collated and the soil conditions in the respective areas were marched with soil requirement for maize production used a classification technique was used which rates the soil of each area on different classes that are suitable for maize production. In the study, soil was the main focus and classes were established on the ratings accorded to each area. Ogunwale*et al.,* (2009) evaluated the suitability of University of Ilorin farmland in the Southern Guinea Savanna ecological zone of Nigeria for cowpea. Five soil series were mapped out and were subjected to morphological, physical and chemical analysis. Their suitability classification shows that Bolorunduro series (unit), which covers about 32%, is the most suitable for cowpea cultivation. They also found out that the topography is not a constraint to the production of cowpea in Ilorin and environ. In another study, Ljusa and Pajovic (2002) investigated the land suitability for rain- fed agriculture in the province of Larache, Morocco. The study area was characterized by crops which were separated into three groups as food crops (maize, sugarcane, chickpea, potato, tomato, green, pepper, onion, sunflower and wheat), fodder crops (barley, sorghum and alfalfa) and tree crops (citrus and olives), all with different agricultural management. They found out that crops like chickpea, tomato, green pepper, onion, sorghum and alfalfa belong to the group of crops which are not recommended for rain- fed agriculture.

Francesco (2003) carried out land evaluation of Thies Region, Senegal, for maize. The evaluation showed that the northern part of the region contained suitable lands for maize while in northwest part along the shoreline, the crop-lands were unsuitable, which was due to the domination of sandy soils. Otomi (2010) evaluated land use along the course of River Ethiope in Abraka, Delta State. The study emphasized the suitability of the farmlands across the bank of the river for some crops like maize, okra and other vegetable crops. She maintained that the suitability of the lands for those crops was due to the availability of water in the soil. Agbogidi*et* *al.,* (2007) in a study carried out at the Research farm of the Delta State University, Asaba campus and the Delta State College of Agriculture Research Farm, Ozoro. The study demonstrated that soil contamination with crude oil has a highly significant effect of reducing some mineral element composition of maize. Their result shows that the suitability of the soil for maize production is minimized as a result of the contamination. They also maintained that their result could provide a basis for future work by plant breeders who are searching for means of boosting maize production in the oil producing areas of the Niger Delta region.

Dunshan*et al.,* (2006) studied land suitability for agricultural crops in Danling County- Sichuan province, China. Several crops were analyzed; in particular, the suitability for rice was compared to the one for other summer crops like sweet potato and maize. A comparison between wheat and rape (*Brassica napus*) was carried out since these are the more common crops to be rotated with rice. Al-Areba*et al.,* (2007) evaluated land suitability for key agricultural crops in Essaouira Province, Morocco. The principal crops cultivated in the area were barley, maize, onion, and wheat which are the main source of subsistence for the families in Essaouira. They also recommended results and solutions to the local stakeholders for an increase in yield. Suitability maps were produced for each specific crop. In general, the evaluation class for the crops suitability ranges from moderately suitable to permanently not suitable. This is due to the different condition that the crops require for their developments in the local area in question. Barley and wheat were the most important crops for the economy and subsistence of the families in the region since most families earned their livelihoods from the cultivation of these crops.

Nurmiaty and Sumbangan (2013) employed land evaluation method in geographic information system (GIS) based on the FAO Framework for Land Evaluation. Land availability was assessed from overlaying information on land use (obtained from available land use map and SPOT XS image interpretation) and suitability classes based on the FAO Framework, as well as administration boundary map. The results indicated that the S1 (highly suitable) class comprises a total area of approximately 34,468 ha, or about 24% from the total area. The limiting factors for S2 (moderately suitable) and S3 (marginally suitable) classes are slope and nutrient availability, but with the advanced management efforts (moderately input) such sub-classes can actually promote S3 class to S2 level. It was also found that from a total of 144,085 ha of the study area, potential maize development area (for intensification) covers approximately 24,716 ha (or 35.6%). Tanralili, Bantimurung, and Simbang sub-districts cover the largest suitable area, where no significant limiting factors exist. Surprisingly, potential development area for maize in Camba, Mallawa, and Tompobulu sub-districts denotes minus values. This implies the facts that maize cultivation is still practiced on the land that is ecologically not suitable, where steep slope is the dominant limiting factor.

Pareta and Jain (2010) applied the Multi-Criteria Evaluation (MCE), Pairwise Comparison Matrix known as Analytical Hierarchy Process (AHP) for suitable areas for crop land using QuickBird (60 cm) of 16 April, 2010, and IRS-P6, Resourcesat-1 LISS-IV Mx (5.8m) 26 September, 2009 satellite image was classified using ERDAS Imagine 9.3 by means of supervised classification. The results showed that agricultural practiced, which prevailed in the study area didn’t match with the potential suitability in the marginally suitable area. Thus, the average yield of the study area was substantially affected because of a significant proportion of crop land was under marginally suitable areas. The study concluded that it provided information at local level that could be used by farmers to select crop land, cropping patterns and suitability.

Fasina *et al.,*(2007) focuses on the some selected Cocoa soils of Ekiti State. Soils of were characterized, classified and evaluated for Cocoa production. The study revealed four major soil units located at four different sites (Aisegba, Ayedun, Ise and Ikoro). All the soils are well drained but concretional and gravelly in nature. Soil texture consists of sandy loam surface and clay loam/silt loam and clay in the subsurface. The soils are moderately acidic in reaction (6.16) and have low amounts of organic carbon (0.21-1.52%). The effective cation exchange capacities and percentage base saturations are low ranging from 0.70-1.51 meq/ 100 g of soil and 42.86-83.33%, respectively. The Aisegba and Ikoro soils classify as TupicPIinthudult (EutricPlinthosol-Ondo series) while Ayedun soils classify as TypicUdipsamment (Cambic Arenosol-Makun series and Ise soil was classified as AcrudoxicPlinthicKandiudult (EutricPlinthosol-Fagboseries). The major limitations of the soils are the gravelly Concretional nature of the soils, poor soil fertility and low rainfall distribution. On the basis of these limitations, all the soils have been classified as S3 (marginally suitable) for cocoa production.

A suitability analysis was carried out by Adesemuyi (2014) for Maize in Akure a humid zone of Southwestern Nigeria to evaluate the soil for a long term production of maize and to have a detailed soil data base for effective land use planning. Critical nutrient requirements for maize were collected from past research work and compared with data obtained from field survey. The suitability assessment result showed that although certain qualities or characteristics such as mean annual temperature, relative humidity, topography, and base saturation were optimum for maize cultivation, there was no highly suitable (S1) land for maize cultivation in the area. Some sections in area were moderately suitable (S2). While other sections were marginally suitable (S3), the sections occupying the depressions were currently non-suitable (N1) for maize production. In order to raise the productivity level of the land to optimum performance for maize production, the management techniques should enhance the nutrient and moisture holding capacity of the soil. Such techniques should include; continuous application of organic fertilizers/materials to the soil, improved efficiency of use of mineral fertilizers and use of low levels of chemical inputs, putting up appropriate drainage facilities in place to take care of the poorly drained area of the land while provision of irrigation facilities would make dry season.

A typical problem is faced in Nigeria, where agricultural lands are largely underutilized and mostly suffering from degradation leading to an unmitigated food security problem. Currently, food production growth rate in Nigeria remains unable to feed its fast growing population. This is largely attributed to the farm management practices on agricultural lands employed in crop production. A step in the right direction is to provide a central repository of data and knowledge where decision support on the best crop production practices to provide optimum yield in quality and quantity is made available in a view easily interpreted by the chief implementers, which in this case are the local farmers. This can be accomplished in part by building a system to provide soil suitability decision support.

The increasing world population, coupled with the growing pressure on the land resources, necessitates the application of technologies such as GIS to help in identifying the most suitable areas for a sustainable agricultural production for food supply according to the environmental potential. Selecting the best location for agricultural production is a complex process involving not only technical requirement, but also physical, economic, social, and environmental requirements that may result in conflicting objectives. Such complexities necessitate the simultaneous use of several decision support tools such as Geographic Information Systems

(GIS) and Multi Criteria Decision Analysis (MCDA) using analytical hierarchy process (AHP). In this paper a model was developed to determine the suitability of the area for agricultural production using soils, slope, water bodies and geological maps of the area to support decisions making for sustainable agricultural production. This integration could benefit farmers and decision makers in agriculture planning. The central theme of this paper is to explain the process of developing a prototype GIS application to provide a system for supporting location decisions with respect to the implementation of agricultural planning. GIS was used based on a set of criteria derived from the spatial and environment aspect.

CHAPTER THREE

STUDY AREA AND METHODOLOGY

3.1 STUDY AREA

3.1.1 Size and Location

The study area is located between Latitude 11^{o} $10^{'}15^{''}$Nand between 11^{o} 16’20$^{''}$N, and longitudes 7^{o} 39’37$^{''}$E and 7^{o}42’45$^{''}$E. The area lies within Sabon Gari Local Government Area, Nigeria with a land area of approximately 600 square kilometers. It is bounded in the North by Ikara Local Government, to Makarfi Local Government in the North-West, Giwa Local Government to the West and Zaria Local Government to the South. Sabon-Gari LGA comprises several sub-settlement, namely, Samaru, Hayin-Dogo, Bomo, Dogarawa, Zango, Palladan, Hanwa, Chikaji, Muchia, Government Reserve Area and Sabon-Gari as shown in Figure(3.1).

3.1.2 Weather and Climate

Basawa is located at a height of about 669m above sea level in the centre of Northern Nigeria. The climate of the study area is characterized by the occurrence of distinct wet and dry seasons (Owonubi *et al*, 1991). It belongs to the dry subhumid tropics with a severe deficit in rainfall from October to May and surplus from June to September (Table 3.1). This implies that water is not available all year round for crop production. The area experiences a tropical continentality and is well pronounced in the dry season particularly in the month of December and January. It has a mean annual rainfall of about 954.21mm. The mean annual rainfall attains it highest value in August and drops rapidly to its lowest in March (Table 3.1).

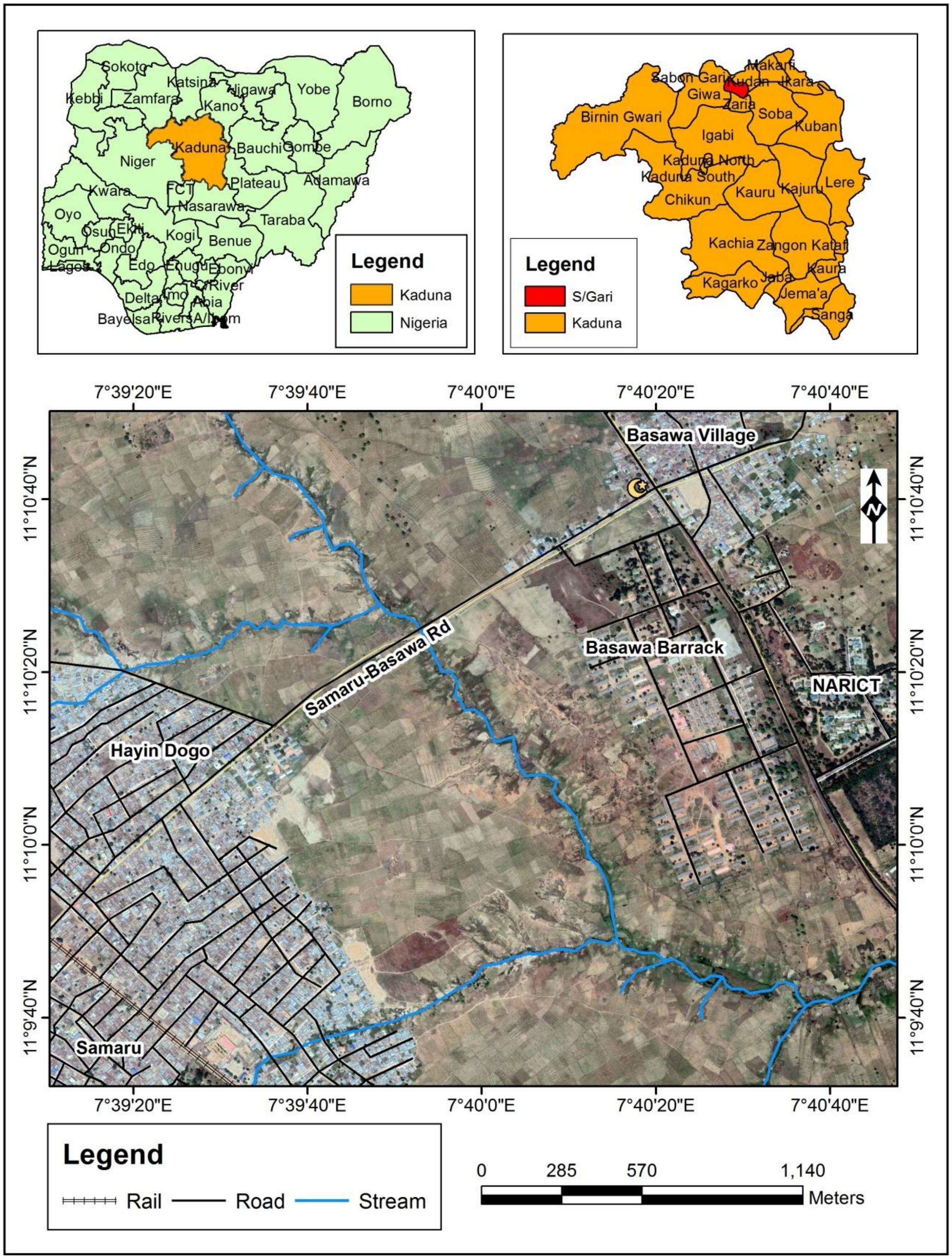

Figure 3.1: Study Area
Source: Adopted from Google Earth (2016)

Availability of water, radiation, together with temperature determines crop species, type of cultivars and management methods that are suitable for cereal crop production in any area (Ogunwole *et al.*, 2004). As a result of the high solar radiation in the savanna, temperatures in the study area are generally uniformly high with a slight drop in December and January (Table 3.2).

3.1.3 Soils

The soils in the study area have been classified according to Hoores classification scheme for Africa as tropical ferruginous soil. They are zonal soils developed under climatic regimes with seasonal rainfall of 500-1200mm and cover nearly half of Northern Nigeria (Oguntoyinbo, 1983). The soil material consists of several feet of deposited silt sand overlaying sedimentary decomposed rock. The soil is poorly drained because of the high percentage of fine textured materials in the upper layers, which results in water logging especially during the rainy season and tends to dry out and cracks during dry season. Alluvial soil is formed along riversides (i.e., fadama). It is made up of several feet of grey white loamy coarse sand with layers of grey heavy mottles occurring at varying depths within the profile. The alluvial soils are usually under intense cultivation of sugarcane and vegetables year-in year-out and as a result in farmers resort to using fertilizers to improve soil fertility (Oguntoyinbo, 1983).

3.1.4 Vegetation

The description of the natural vegetation of the study area is given by Ramsay and de Leeuw (1966) and Keay (1989). The area falls into the Northern Guinea Savanna zone (Keay, 1959). The Northern Guinea Savanna zone comprises of open subhumid broad-leaved savanna woodland with a well-developed short to medium grass layer. In the study area, the cultivated portions are made up of shrubs, few trees, herbs and grasses. The shrubs and trees include

Isoberlinadoka(Craib and Stapf), *Guiarasenegalensis, Combretumglutinosum, and Terminchiaavicennoides.*

The ground layer is made up of the following major grasses, *Pennisetumpedicallatum* (Linn.), *Andopogonpseudapricus*(Hack), *Andropogongayanus*(Hack). The herbs and grasses are made up the common weeds of the arable parts of the area. The uncultivated areas usually carry a vegetation of open shrub woodland in varying stage of re-growth.

3.1.5 Geology

The geology of Basawa area has been studied by Olowu (1967); McCurry (1970); Wright and McCurry (1970); Tokarski (1972); Karofi (1972) and Akpoborie (1972). The Zaria area is underlain by metamorphic and igneous rocks termed "the Basement Complex" because of their intricate pattern.

The Basement Complex rocks in the Samaru –Zaria area has been highly weathered, and has been generally referred to as weathered mantle (du Preez, 1956; Olowu, 1967; Wright and McCurry, 1970). It may be for this reason that many authors report of the area as being underlain by undifferentiated "Basement Complex" (Geological Survey of Nigeria, 1974; Bennet *et al.*, 1977). This weathered material is marked by a network of superficial harmattan deposits where deposition has been influenced by landforms as well as alternating dry and wet seasons. Three groups of Basement Complex rocks were recognized in Zaria area. The first group is a complex, including Pre-Cambrian gneisses of variable composition and migmatite which is medium to coarse grained and moderate to weakly foliated. These types of rocks predominate the low lying surface or plain.

Table 3.1: Monthly and annual mean rainfall (mm) in year intervals over period 2006 – 2015

Periods	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total of annual mean
2006-2007	0.00	0.00	1.70	60.50	405.70	346.60	460.80	564.30	306.90	36.80	0.00	0.00	181.94
2008-2009	0.00	0.00	0.00	157.70	180.30	201.20	514.80	798.70	424.50	240.70	0.00	0.00	209.83
2010-2011	0.00	0.00	0.00	66.30	216.20	320.80	438.80	587.80	325.00	136.30	0.00	0.00	174.30
2012-2013	0.00	0.00	0.00	81.10	329.90	287.70	480.20	589.70	503.30	90.20	0.00	0.00	196.84
2014-2015	0.40	0.00	90.90	141.70	217.30	185.50	396.80	674.30	524.30	64.40	0.00	0.00	191.30
Mean Monthly Rainfall (2006 - 2015)	**0.08**	**0.00**	**18.52**	**101.46**	**269.88**	**268.36**	**458.28**	**642.96**	**416.80**	**113.68**	**0.00**	**0.00**	**954.21**

Source: Institute for Agricultural Research, Meteorological Unit, ABU, Zaria.

Table 3.2: Monthly mean Temperature (^{0}C) in year intervals over period 2006 – 2015

Months	Temp. (^{0}C) Max	Min	Range
January	32.80	15.81	16.99
February	33.10	18.10	15.00
March	39.16	23.50	15.66
April	35.50	23.42	12.08
May	36.11	25.82	10.29
June	31.84	23.00	08.84
July	32.34	23.10	09.24
August	31.15	24.20	06.95
September	29.00	22.13	06.87
October	39.11	22.30	16.81
November	34.13	17.21	16.92
December	32.13	17.01	15.12
Mean	**33.86**	**21.30**	

Source: Institute for Agricultural Research, Meteorological Unit, ABU, Zaria.

A second group consists of low grade metamorphic rocks derived from early Paleozoic to Cambrian sediment. These include schist, quartzite, and psammitic rocks. These rocks are interbedded into the synclinal belts of the gneisses and migmatite. These rocks form a narrow belt of parallel ridges, low rounded hills and valley bottomlands, which trend roughly north-south across the headstream of the Tubo to the west of Zaria.

The third group consists of intrusive rocks of late Paleozoic to Cambrian age, whichwere intruded into the gneisses and migmatites. These rocks are generally referred to as 'Older Granites. They are mainly porphyritic biotite granite, and hornblende granites with large feldspar phenocryst. These rocks are more resistant to weathering and form inselbergs. Other rocks in the group are granodiorites and aplites. In Bassawa area, the 'Older Granites' cover a very small area, with their largest outcrops forming the Kufena Inselbergs.

3.1.6 Relief and Drainage

Drainage and relief of the study area lies within the Kaduna Plains which forms a vast gently undulating topography with very long slopes, except at its junction with the East- West watershed near Funtua and the Southern Nupe plains. These parts are markedly dissected. The dissection of the East-West watershed is believed to be due to uplift along the axis of the watershed, with subsequent rejuvenation of rivers south of it as supported by the development of terraces, gully erosion and increased number of stream tributaries (McCurry, 1973). The study area can be described as having a medium textured dendritic drainage pattern. There are mesas, few in number, generally unconspicuous and located on interfluves within Basawa, Zaria.

The Basawa area of the Kaduna plain is drained by three major river catchment systems; the southward flowing Galma and seasonal Tubo rivers drain the Kaduna plain and empty into River Kaduna, which is a tributary of the Niger; the northwestern part is drained by the Sokoto/Rima and Gagare river system; while River Kano and Chalawa drain north eastwards to the inland basin of lake Chad. The study area is drained by the tributaries of the Shika River, which in turn is of the tributary of the Galma River.

3.1.7 Landuse

The most prominent landuse practice in the study area is agricultural land use i.e. cultivation, animal husbandry, Subsistence and commercial agriculture is mostly practiced in the outlying districts of the study area.Dugje, Kamara and. Ajeigbe (2009) found out that majority of the farmers in Basawa planted millet, cowpeas, sorghum and maize. The Maize cultivation was ranked highest in the area. This is because the economic base of virtually all rural and semi urban settlement in Northern Nigeria is agriculture and it is subsistent. The use of land for agricultural activities is influenced by several factors such as land per resident ratio and location of soil quality. As the land per resident ratio increase (population density increases) the percentage of land in fallow decreases due to increase in farming intensities. The increase in intensity in land use as population density increase creates problem in maintenance of soil fertility.

3.2 METHODOLOGY

3.2.1 Reconnaissance Survey

A reconnaissance survey and field observation of the study area was carried out on 23th August, 2016, in order to have adequate knowledge of the study area. It also helped the researcher gain insight on nature of soil and topography in the study area. The researcher also observed that the area contain some few landuse type, such as few buildings close to the farm, rocky areas and a plain surface.

3.2.2 Materials

The materials used for the study include:

- Satellite imagery (QuickBird imagery of 2014 with spatial resolution of 1m);
- Global positioning system (GPS);
- ASTER DEM of the study area;
- Rainfall record.
- Temperature record.
- Soil texture map.
- Literature materials.

3.2.3 Sources of Data

Satellite imagery (QuickBird imagery of 2014 with spatial resolution of 1m) was obtained from National Space Research and Development Agency (NASRDA).Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) DEM of 30m resolution was obtained from United States Geological Survey (USGS) Website. This was used in generating the Slope map, Elevation map, Aspect map of the study area.

Rainfall and Temperature record was sourced from Institute of Agriculture Research (IAR) Zaria, Kaduna State. This was used to generate rainfall distribution pattern in the study area.

The soil textural map were scanned and imported into Arc GIS10.3, then geo-referenced by using four (4) Ground Control Points (GCP) that were read fromUniversal Transverse Mercator (UTM). For registration process (image geo-referencing), some modifications were made during the geo-referencing for the selected control points in order to minimize the error during digitization. The map was projected to WGS 1984 using Minna datum, UTM zone 32.

3.2.4 Detailed Field Work

3.2.4.1 Field Survey and Data Collection

Grid cells were prepared on the base map for sampling. Eighty (80) soil samples were collected at an interval of 100m in the field (Fig. 3.2) using the USDA Soil Survey Manual (Soil Survey Staff, 1981). In order to reduce cost, four (4) soil samples was bulk to give sub- samples which give a total of twenty (20) soil samples from the eighty (80) soil samples that was collected from the field and were taken to the laboratory for analysis. At each soil site, a GPS (Global Position System, Garmin 76 model) reading was used in taking the coordinates (Appendices 11). The field equipmentthat was used in collecting the soil samples includesthe soil auger and measuring tape.

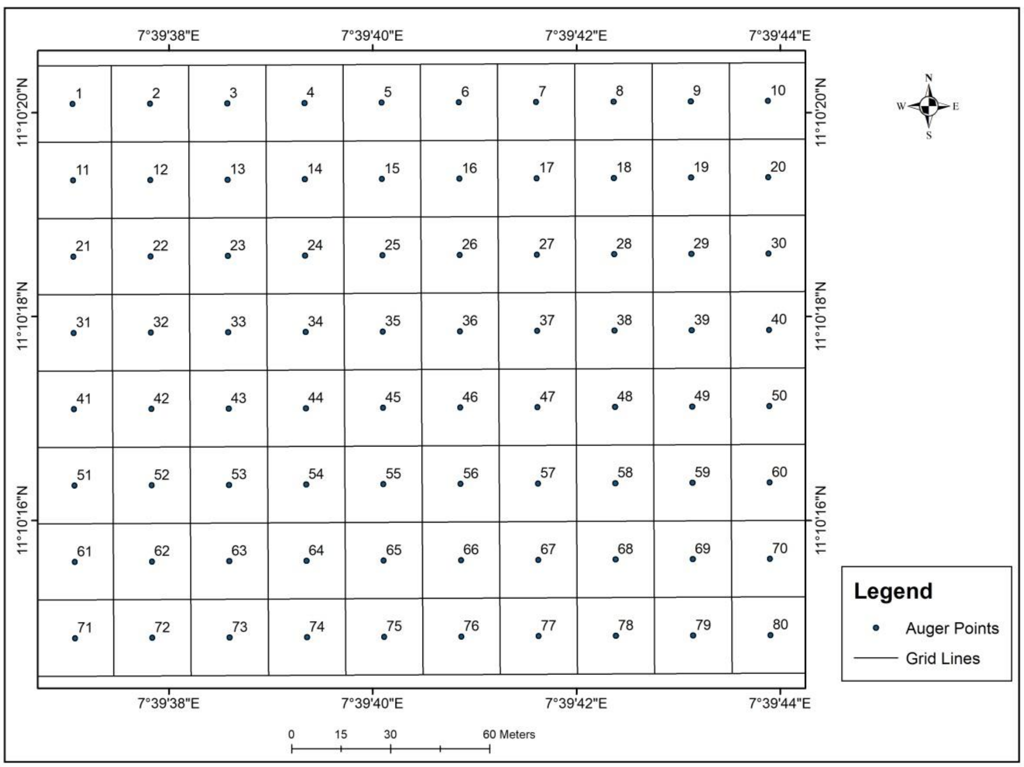

Figure 3.2: Soil Sampling Points
Source: Author's Analysis, 2017

3.2.5 Data Processing

3.2.5.1 Laboratory Analysis

Soil samples collected from the study area was taken to the Standard laboratory (IAR), air dried and gently crushed with porcelain pestle and mortar; and then passed through a 2mm sieve to remove coarse fragments. The fine earth samples (<2mm soil portion) collected was analysed. Particle size distribution was determined using hydrometer method (Gee and Bauder, 1986). Sand, silt and clay were determined using standard methods. The dispersed samples were shaken on a reciprocating shaker after which particle size distribution was determined with the aid of Bouyoucous hydrometer at progressive time intervals. The textural classes determined with the aid of USDA textural triangle.

The soil pH was determined both in water and 0.01M $CaCl_2$ solution, using a soil to solution ratio of 1:2.5 (IITA, 1979). On equilibration, pH was read with a glass electrode on a Pye-Unicam model 290mk pH meter. Delta pH (dpH) values were determined. The Walkley – Black (1934) wet digestion method was used to determine the organic carbon content of the soil samples. Total nitrogen was determined using the micro – kjedhal method. Soil available phosphorus was determined using the Bray I method calorimetrically. Electrical Conductivity of the saturated paste extract of 1:2.5 soils to water ratio as determined using a rheostat, Wheatstone bridge model at 25^0C (Bower and Wilcox, 1965). Exchangeable Ca, Mg, Na and K were extracted with 1M ammonium acetate (1M NH_4OAc) solution buffered at pH 7.0 as described by (Anderson and Ingram, 1998). Potassium and Salinity in the extract was read on a GallenKamp flame Analyzer. The extracts were diluted two times with the addition of 2ml of 6.5% lanthanuv cm cehloride solution to prevent ionic interference before Ca and Mg were read. The Ca and Mg were read on a pye unicam model SP 192 atomic absorption spectrophotometer (AAS) at 423 and 285nm wavelength respectively. The sum of Ca, Mg, Na, and K gave total exchangeable bases. The soils were leached with 1M KCl solution. Exchangeable acidity (Al+H) in the 1M KCl extract was determined by titration with 0.1M sodium hydroxide solution as described by (Anderson and Ingram, 1998). Cation Exchange Capacity (CEC) of the soil was determine with 1M NH_4OAc (1M ammonium acetate), buffered at pH 7.0 (Chapman 1965, Rhoades, 1982). The excess acetate was removed by repeated washing with alcohol. The absorbed ammonium ions were displace with 10% sodium chloride (pH 2.5) and determined by the Kjeldahl procedure (Soil Survey Staff, 1972).

3.2.5.2 Generation of Elevation

The Digital Elevation Model (DEM) of the area was extracted from Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER). This was done by converting raster DEM into points using the conversion tool in ArcGIS 10.3. The converted point was interpolated using Kriging interpolation technique. And a new raster surface was created showing the difference in height over the study area and then served as the elevation map.

3.2.5.3 Generation of Slopeand Aspect

The slope of an area shows the changes in topography of the area while the aspect shows the direction of slope. Slope and Aspect of the area was automatically generated from ASTER-DEM of Basawa. In the GIS environment, the ASTER-DEM was subjected to spatial analysis using the 3D spatial analyst tool in ArcGIS 10.3 environment to generate the slope and aspect option in raster format.

3.2.5.4 Generation of Drainage Map

The Digital Elevation Model (DEM) combined with high spatial resolution QuickBird imagery was used as guide for extracting information about drainage of the area. First edition was scanned and imported into ArcGIS 10.3 environment where it was geo-reference based on the map projection UTM Zone 32 North and datum WGS 1984. Basawa town was clipped from the map and its drainage digitized. This was done by creating a line feature in ArcCatalog and the editing tool was used to extract the drainage network of the study area.

3.2.5.3 Generation of Soil Textural Map

The soil textural map of Nigeria was scanned and imported into ArcGIS 10.3 environment where it was geo-referenced using UTM Zone 32 North with datum WGS 1984. The soil texture map was captured by digitizing the existing soil map of the area.

3.2.6 Distribution of physical and chemical parameters in the study area

The laboratory results were entered into the Microsoft Excel with their respective coordinates (Latitude and Longitude) were transformed and imported into ArcGIS 10.3 environment in order to analyze the spatial distribution of the selected Physiochemical parameters (pH, N, Ca, Na, Mg, CEC, OM, K and P) in the study area. Different thematic maps (layers) were generated for each of the Physiochemical parameters using Inverse Distance Weighted (IDW) interpolation in the ArcGIS 10.3 environment. The IDW interprets spatial autocorrelation in a literal fashion. A surface created with IDW will not exceed the known value range or pass through any of the sample points. IDW is a good interpolator for phenomena whose distribution is strongly correlated with distance. One potential advantage of IDW is that it gives you explicit control over the influence of distance, an advantage over Spline or Kriging methods (Mustafa *et al*, 2011). Each physiochemical parameter were reclassified and converted into raster format.

3.2.7 Steps used in deriving criterion weights using AHP

The relationship between the five thematic layers and their attributes were derived using analytic hierarchy process (AHP). The methodology for deriving the weights of the thematic layers and their corresponding attributes using AHP were performed by ranking the relative importance of criteria (Table 3.3). The procedure involved the following steps:

Table3.3: Explanation of the intensity scale

Scale	Degree of Preference
1	Equal importance
3	Moderate importance of one factor over another
5	Strong importance
7	Very strong importance
9	Extreme importance
2,4,6,8	Intermediate values

Sources: Saaty and Vargas (1991).

Step 1: To classify the different level of suitability followed by the determination of criteria for the evaluation.

Step 2: Generation of pair-wise comparison matrices (PWCM): The relative importance of criteria with each factors was considered base on their importance for production of maize, the values of importance are taken from Saaty's 1-9 scale mentioned above. For the physiochemical parameters N, P, K and OM was rated 1 which is Equal importance, while CEC, Mg, Ca, Na and pH was rated 1/3 which is less important. Other criterion used in this study includes Elevation, Slope, Aspect and other physical parameters i.e. soil Texture, drainage etc. was weigh.

Step 3: The rating of the suitability classes of sub criteria were used in land suitability analysis, a map represents each evaluation criteria with ordinal values (S1, S2, S3 and N1) indicating the degree of suitability with respect to a sub criterion, based on Maize requirement (see Table 3.4) (Sehgal, 1999).

Table 3.4 Factor Suitability Rating for Maize

Land Characteristic / diagnostic factor	Highly suitable (S1)	Moderately Suitable (S2)	Marginal Suitable (S3)	Not Suitable (N)
Climate				
Rainfall (mm)	>800	700 – 800	600 – 700	<600
Temperature (0C)	24 – 30	20 - 24, 30 – 32	15 - 20, 32 – 35	<15, >35
Land/soil physical property				
Slope (%)	0 – 2	4 – 8	8 – 16	<16
Soil Texture	CL,L	SL, LS	LCS	CS
Drainage	Well	Moderately Well	Imperfect	Poor, very poor
Nutrient availability (top soil)				
pH	6 - 6.5	5.5 - 6.0, 6.5- 7	5.0 - 5.5,7.0-8.2	< 5.0 - >8.2
N (g kg^{-1})	>0.8-0.4	0.4-0.2	< 0.2	Any
P (mg kg^{-1})	> 40	10-40	3-10	< 3
Ca(mol kg^{-1})	>0.5	0.40-0.5	0.2-0.34	<0.2
Na(mol kg^{-1})	>0.5	0.40-0.5	0.2-0.34	<0.2
Mg(mol kg^{-1})	>0.5	0.40-0.5	0.2-0.34	<0.2
OM (%)	>1	0.5-1	<0.5	
K(mg kg^{-1})	>0.3-0.5	0.2	0.1-0.2	<0.1
CEC (cmol (+) kg^{-1})	>25	13 - 25	6 – 12	<6

Adopted from FAO (1983), Sys *et al*.., (1993)
Key: CL=clay loam, L=loam, SL=sandy loam, LS= loam sand, LCS=loam clay sand, CS=clay sand

Step 4: Ranking: Finally, weighting of the physiochemical is combined with the weighting of the physical characteristics to form an overall rating of the suitability. The attributes with the highest weighting is ranked as the best choice.

It should be noted that for preventing bias through criteria weighting the Consistency Ratio (CR) was used. As a rule of thumb, a CR value of 10% (0.1) or less is considered as acceptable according to Mustafa *et al,* (2011)

CI = (λ - n) / (n – 1).......... (1)

CR = CI / RI..................... (2)

Where: λ: The average of consistency vector

CI: Consistency Index

CR: Consistency Ratio

RI: Random Index

n:The numbers of criteria or sub-criteria in each pairwise comparison matrix.

The final suitability classes were analysed using Weighted Sum Overlay in the ArcGIS 10.3 environment by combining all raster layers to produce the final suitability map (Table 4.11 and 4.12).

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1 PHYSICAL CHARACTERISTICS OF THE TERRAIN IN THE STUDY AREA

The result of physical characteristics of the terrain was generated from Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) digital elevation model and is presented in Figure 4.1 to Figure 4.5 respectively.

4.1.1 Digital Elevation Model (DEM)

The DEM of the study area generated from Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) DEM extract of the study area as shown in Figure (4.1).

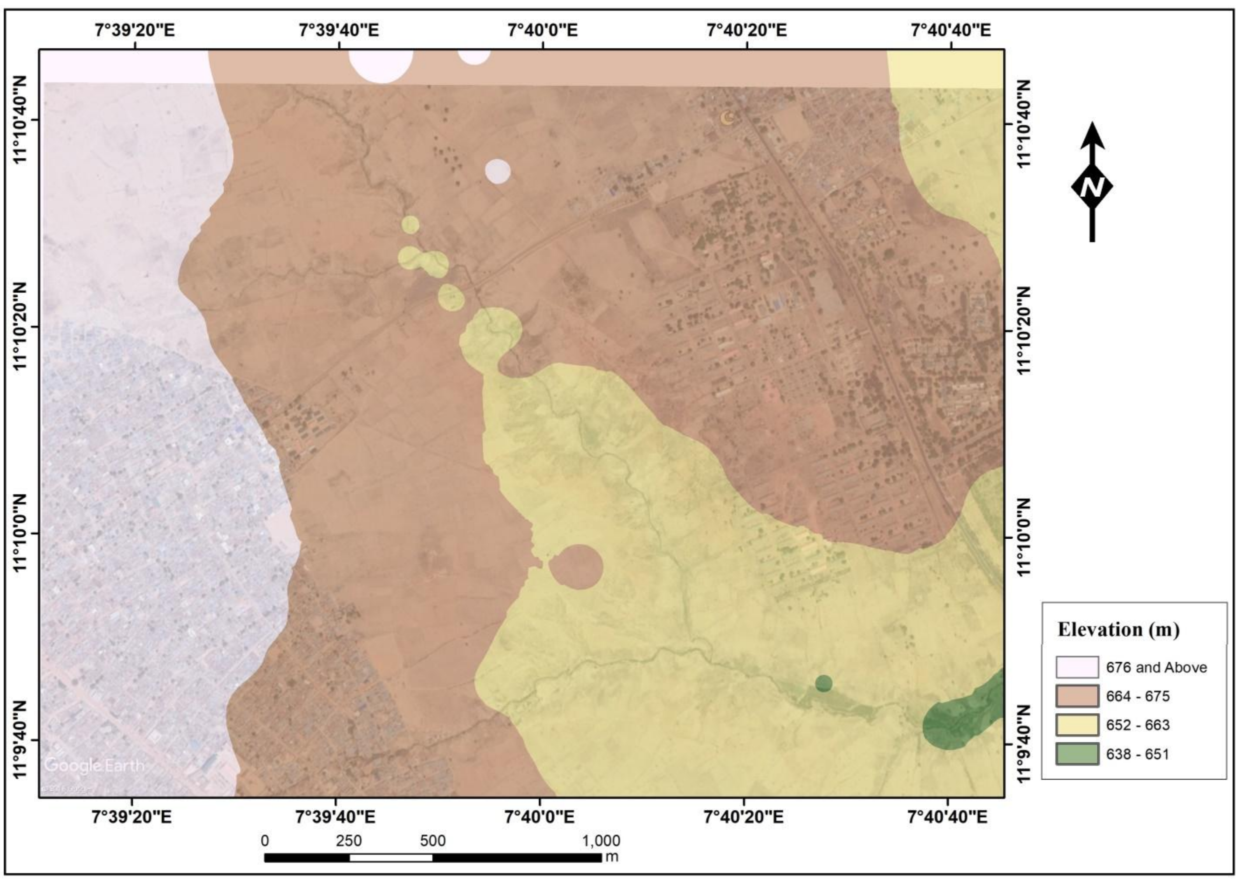

Figure 4.1: Digital Elevation Model of the Study Area
Source: Author Analysis 2017

The results of the analysis from the DEM in Figure 4.1 showed that the difference between minimum and maximum elevation of the study area is 8.0m. It can be seen that the highest elevation represented in white ranges between 676 and above sea level and the lower elevation with green color ranges between 638 to 651m above sea level located towards northern part of the study area. The generated DEM was used to analyze the terrain and then used to mark out drainage patterns of the study area. A satellite imagery of the study area was used to extract the existing drainage in the locality by digitizing these drainage channels and other planimetric features. In marking out the drainage pattern, topographic attributes such as slope and aspectwere considered.

4.1.2 SLOPE

The slope of the study area was generated from Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) DEM of the study area using the spatial analyst tool in ArcGIS 10.3 as shown in Figure (4.2).The extraction of slope map was performed using Digital Elevation Model (DEM). The slope was classified into five different classes ranging from flat to undulating terrain. The classes of slope of the area showed that the area is relatively flat because the dominant surface is from 0 – 0.85 followed by 0.86 – 1.70, 1.71– 2.85 and highest slope was found to be between 2.86 and above. The northern part of the area is an indication of hilly areas which is not suitable for cultivation of maize. Slope is important in soil formation and management because it influences the rate of soil formation, runoff, soil drainage, erosion, use of machinery and choice of crops (Sys et al., 1993).

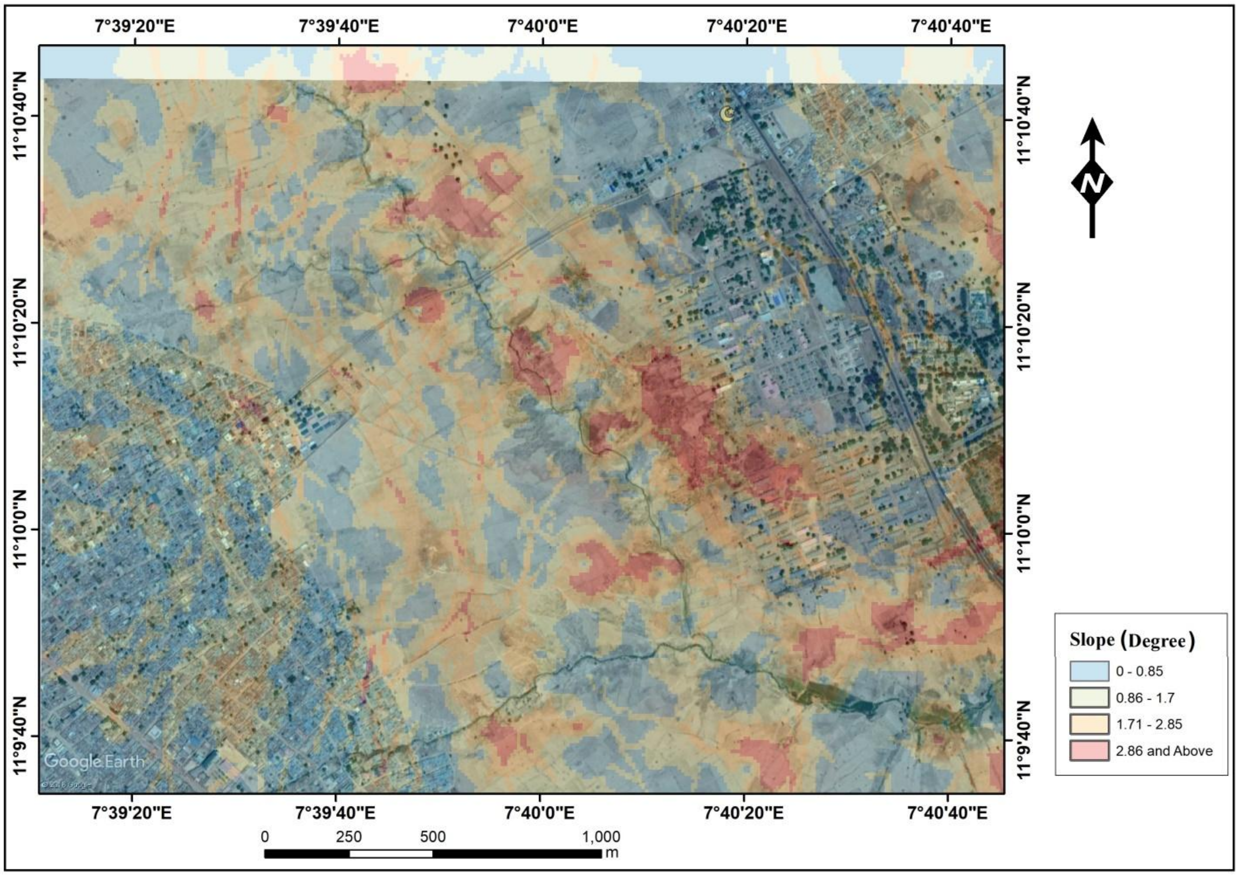

Figure 4.2: Slope Matrix of the Study Area
Source: Author Analysis 2017

4.1.3 ASPECT

Aspect generally refers to the horizontal direction to which a mountain slope faces. In the northern hemisphere north facing slopes receive very little heat from the sun in mid-winter. Conversely, south facing slopes receive much more heat. Therefore, south facing slopes tend to be warmer than the northern sides. In low land areas people prefer planting their crops on the sunny faced slopes. Thus, southern facing slopes have higher intensity of importance. East facing slopes are mostly sunny in the morning when temperatures are colder while west facing slopes receives sun rays in the afternoon. Consequently, east facing slopes are colder than west facing slopes which to some extent determine the choice of location of planting.

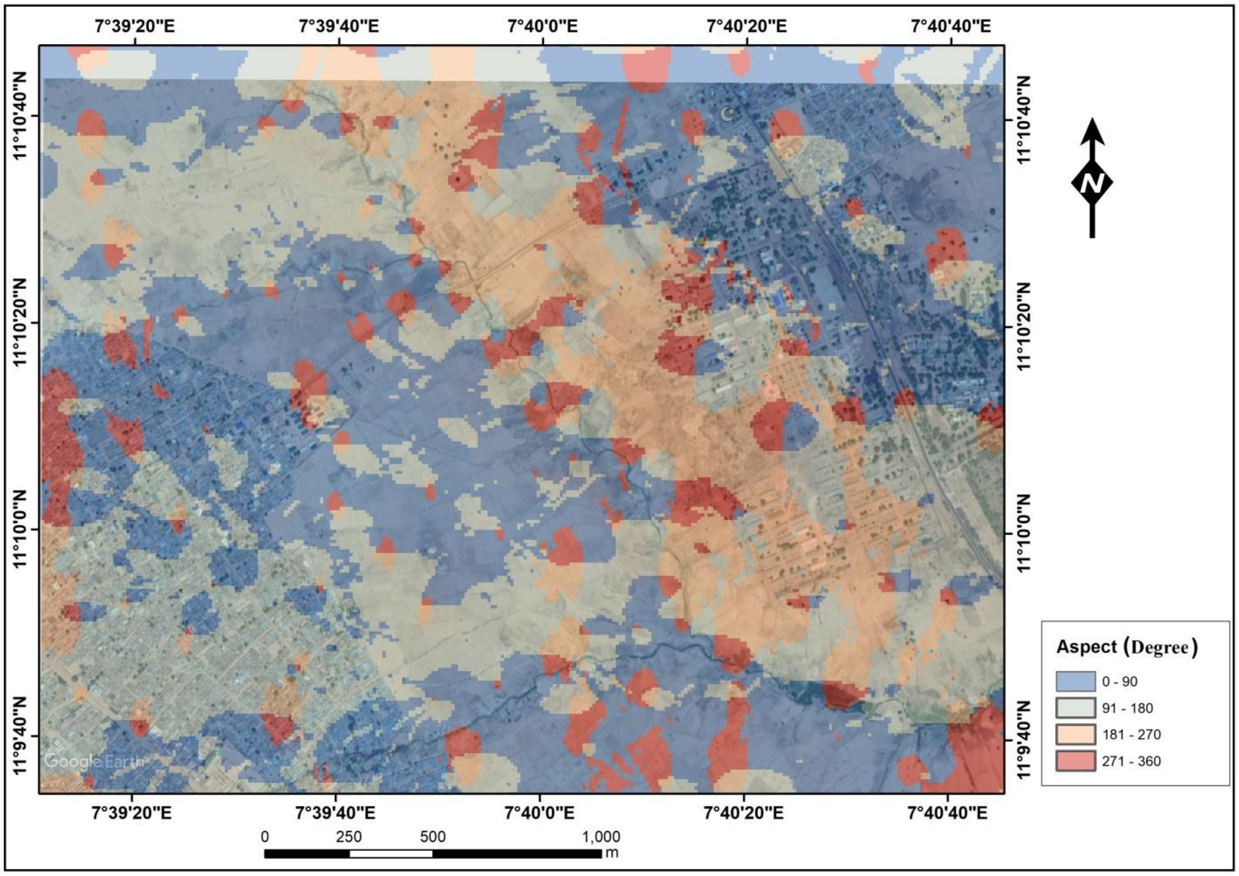

Figure 4.3: Aspect of the Study Area
Source: Author Analysis 2017

4.1.4 DRAINAGE PATTERN

Drainage pattern is formed by a streams, rivers and lakes in a particular drainage basin. The drainage pattern of the study area was generated from Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) DEM of the study area using the spatial analyst tool in ArcGIS 10.3 as shown in Figure (4.4).

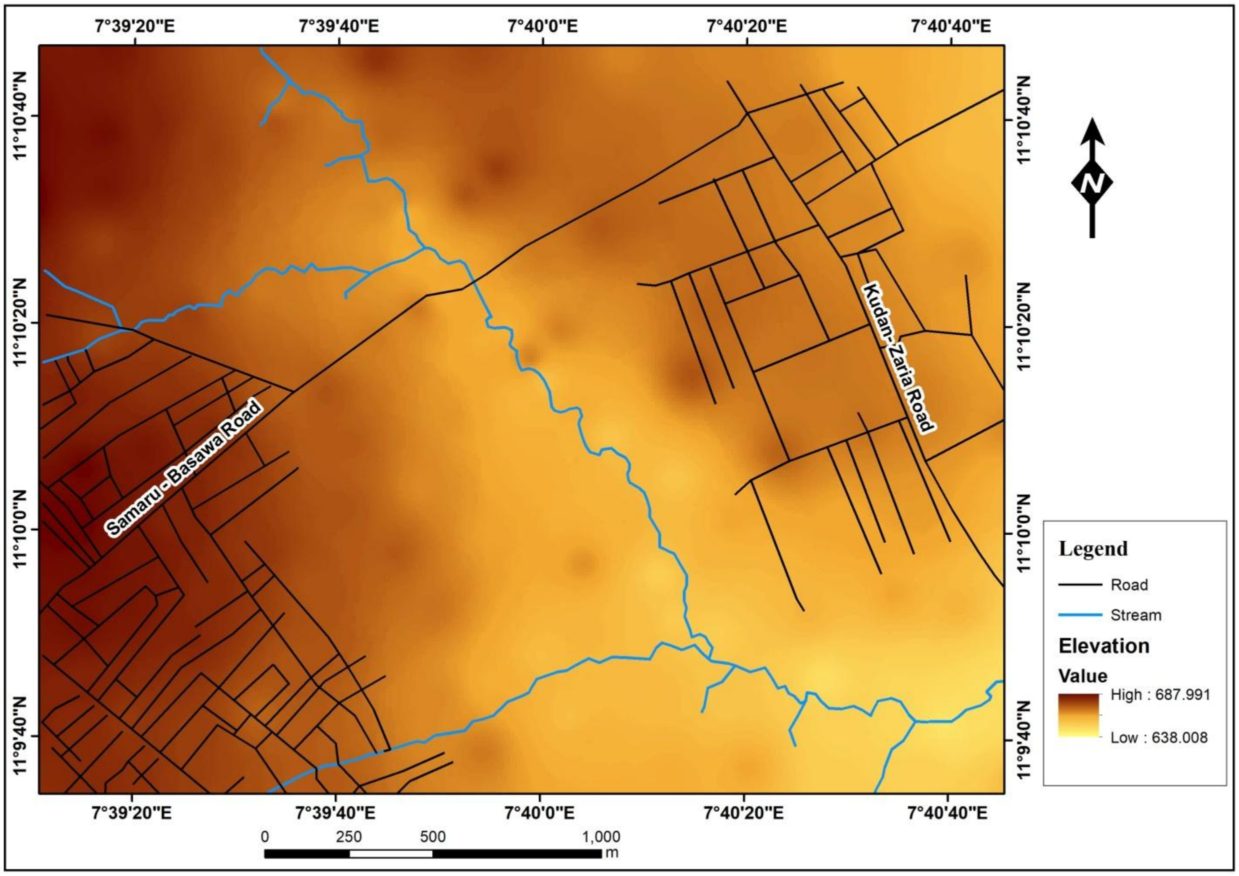

Figure 4.4: Drainage Pattern of the Study Area
Source: Author Analysis 2017

From the drainage pattern map extracted from the Digital Elevation Model (DEM), the area appears to have a dendritic drainage pattern. A dendritic drainage patternis the most common form and looks like the branching pattern of tree roots. It develops in regions underlain by homogeneous material. That is, the subsurface geology has a similar resistance to weathering so there is no apparent control over the direction the tributaries take. Tributaries are joining larger streams at acute angle (less than 90 degrees). This is true as seen in the drainage lines as they flow into the stream in the locality.The Soil of the study area is well-drained and got its source from River Galma, which move eastward toward the study area. The well-drained soil according to Sys et al (1993) is having a coarse texture soil with available water capacity which is highly suitable for the production of maize.

4.1.5 SOIL TEXTURE

Soil texture is one of the determinants of the potentiality of a soil to hold nutrients and most of the physical characteristics of the soil depend upon texture class because is the relative proportions of the various size groups of individual soil grains in a mass of soil. Texture is an important factor to consider when rating soil for its suitability. Root penetration, nutrition absorption, water holding capacity, water infiltration and percolation are affected by soil texture type (Sys *et al*., 1991). Loamy and sandy loam is much more preferred soil texture for arable crop. Soils of the study area ranged from loamy sand to sandy loam. Texture was not a limitation to the production of maize in the study area. Application of sufficient quantity of organic matter and incorporation of plant residues would be required for sustainable crop production (Omar, 2011).From the laboratory analysis, it was revealed that sand constitutes the highest soil particles in the study area followed by silt and then clay, with Loamy Sand and Sandy Loam as the general textural class. The findings of Malgwi *et al.* (2000) and Voncir *et al*. (2008) shows that sorting of soil materials by biological activities, clay eluviation or surface erosion or combination of these pedological processes are the result of the dominance of sand in the Northern Nigerian soils. Also, lower clay content of the surface soil is a characteristic that has been observed for most soils on Basement complex in Nigeria (Esu, 1987).

4.2 CHEMICAL AFFECTING LAND SUITABILITY FOR MAIZE PRODUCTION

The physiochemical parameters of land suitability for maize (Zea Mays) that were analysed for this study are; pH, Nitrogen (N), Phosphorus (P), Potassium (K), Organic matter (OM), Calcium (Ca), Magnesium (Mg), Sodium (Na) and Cations Exchange Capacity (CEC). The results were presented in Figure 4.6 to Figure 4.14. However, Appendix (1) shows the result of the laboratory analysis for the 20 selected soil samples in the study area. Also, the Concentration of Measure Parameters and their Evaluations in the Study Area is shown in Table 4.1 guided by FAO records.

Table 4.1: Concentration of Measure Parameters and there Evaluations in the Study Area

Parameters	**Measure (Average)**	**Evaluation**
pH	4.12	Extremely acidic
N	0.617 (g kg^{-1})	Low
P	9.38 (mg kg^{-1})	Low
K	0.17 (mg kg^{-1})	Medium
Mg	0.86 (mol kg^{-1})	Medium
CEC	6.41 (cmol(+) kg^{-1})	Medium
Na	0.35 (mol kg^{-1})	Low
OM	1.04 (%)	Low
Ca	4.12 (mol kg^{-1})	Medium

Source: Author analysis (2017)

The distribution of the soil parameters would help in the identification of their concentration. Inverse Distance Weighted (IDW) model was used for the analysis. The distribution of the parameters using different ranges values or ratings from lower values to the higher values as showed in Fig 4.6 to 4.14

4.2.1 pH map

The result of pH obtained from laboratory analysis is presented in Figure 4.6.

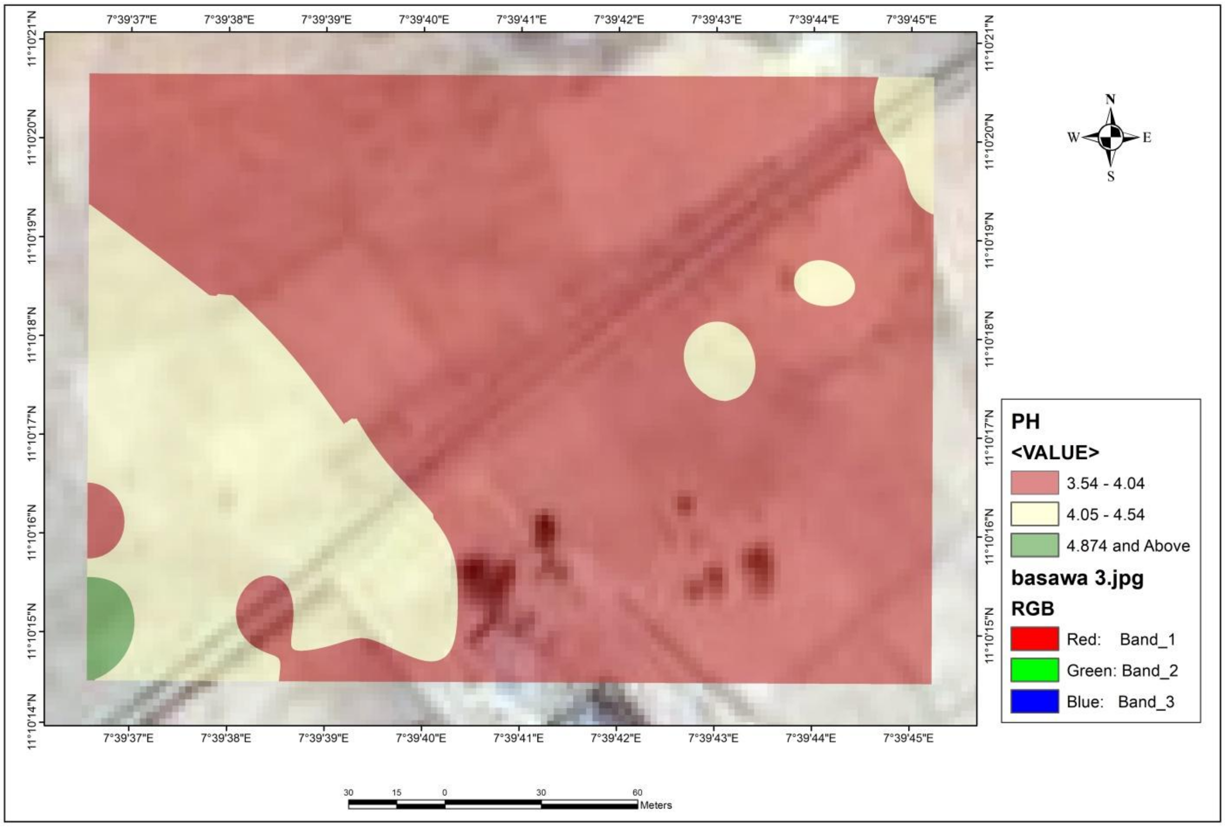

Figure 4.5: pH values of the Soil Samples Analysis
Source: Author Analysis 2017

The result of the Soil pH ranges from 5.04 to 3.54, with mean value of 4.12. The pH of the soil varies from extremely acidic to strongly acidic (Malgwi, 2007). The pH value will not be favorable to the plant because it is below pH of 6-7 which was reported to be the requirement for most crops. Similar result had been reported by Audu, Abdullahi, Noma, and Abdulaziz (2009); Lawal *et al.* (2012). These values are within the pH requirement for most arable crops for nutrient up take (Brady and Weil, 1999).

4.2.2 Organic matter (OM) map

The laboratory analysis result of organic matter is presented in Figure 4.6. Organic matter is one of the most important aggregate stabilizing agents in the soil. Organic matter is central to the maintenance of soil fertility: mineralization of N, P and S, the soil's ability to hold nutrients cations, structural stability and water holding capacity are all affected by OM content. Nutrients can be easily supplied where fertilizers are available. The very high OM decomposition rates in the warmer climates make it difficult to maintain high carbon levels in cultivated soils (GAISER 1993 cited in FAO (1983).

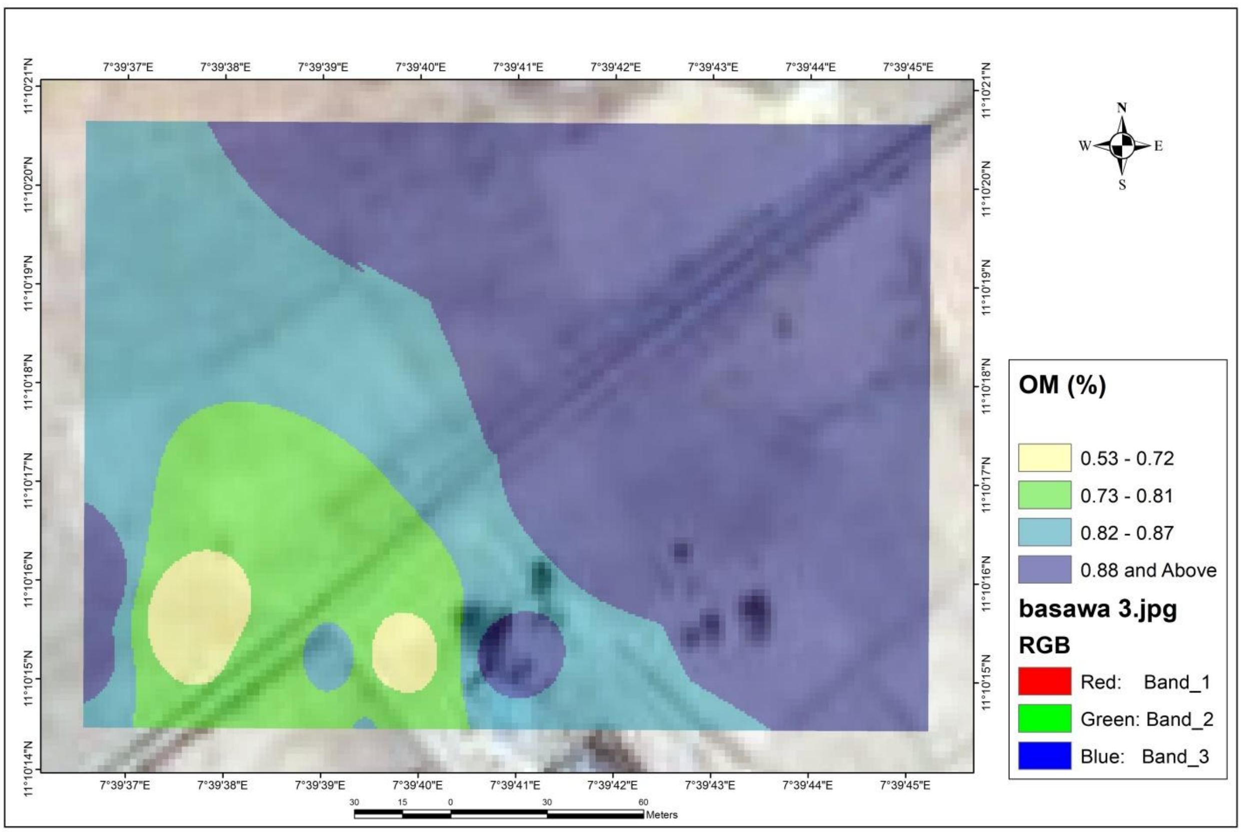

Figure 4.6: Organic matter Soil Samples Analysis
Source: Author Analysis 2017

The result in Figure 4.6 and the data in Table 4.1 revealed that the average measured of organic matter is 1.04(%). Organic matter contents for all the soils were rated low. Organic matter was generally very low in the study area which may be partly due to effect of land use activities and high temperature which favours rapid mineralization of organic matter (Fasina, 1999). Furthermore, low organic matter content of the soils was attributed to continuous cultivation and addition of organic residues which determines organic matter content in soils is low and their loss through mineralization is high (Binns, Machonachie and Tanko, 2003).

4.2.3 Sodium (Na) map

The result of sodium obtained from laboratory analysis is presented in Figure 4.7.

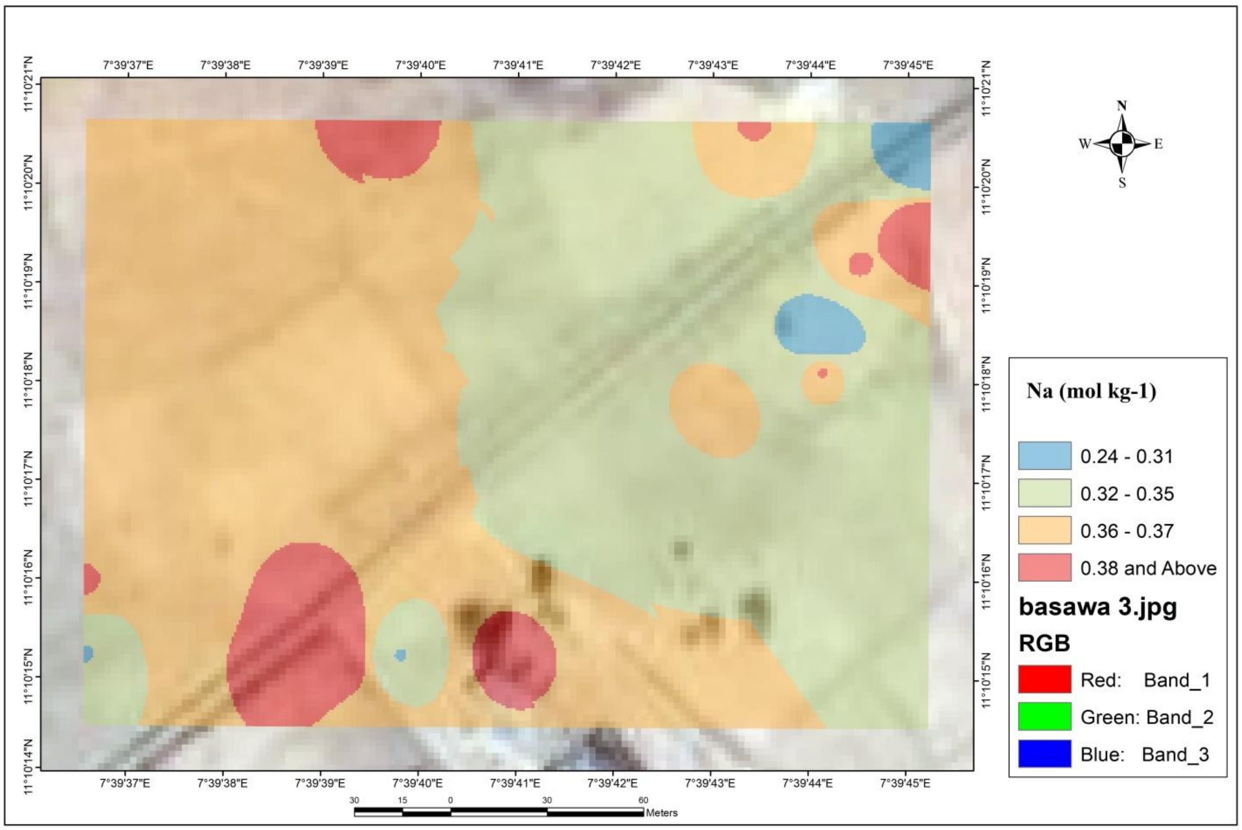

Figure 4.7: Sodium Soil Samples Analysis
Source: Author Analysis 2017

The result in Figure 4.7 revealed that sodium was evenly distributed in the study area which is as the result of different crop planted in the study area which required different fertilizer. The data in Table 4.1 revealed the average concentration of sodium is 0.35 (mol kg^{-1}) in the study area which indicates high evaluation for maize cultivation as supported by FAO (1998). The values of

Na content were irregularly distributed within the soils. Generally, the higher value of Na could destroy soil structure. Similar to the report of Malgwi, (2001) in Kano and Babalola *et al.*, (2011) in Kogi and Ekiti who reported higher Na and attributed it to the nature of parent material in the location and low quality of irrigation water.

4.2.4 Calcium (Ca) map

The laboratory analysis of result of calcium is presented in Figure 4.8.

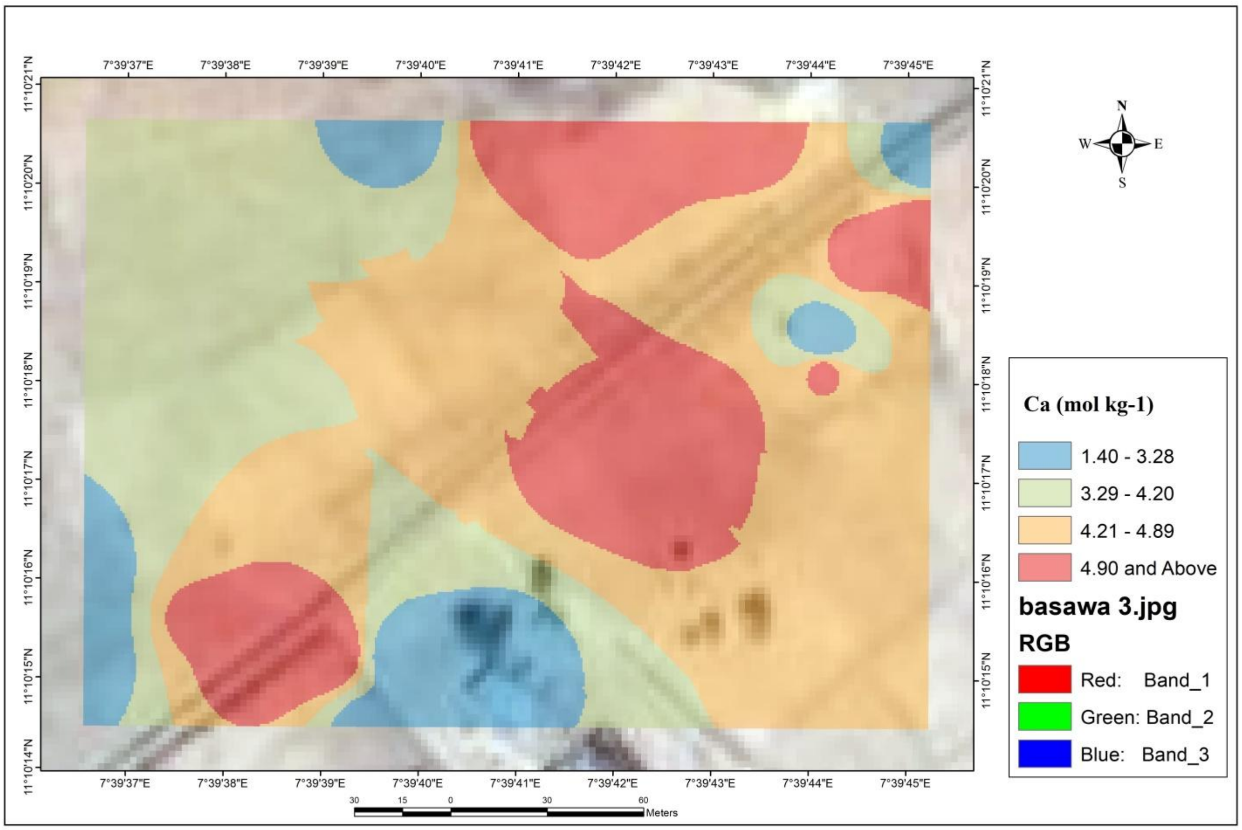

Figure 4.8: Calcium Soil Samples Analysis
Source: Author Analysis 2017

The result in Figure 4.8 revealed that all the plots in the study area have mixed concentrations of Calcium. The data in Table 4.1 revealed that the average concentration is about 4.21 (mol kg^{-1}) which is medium for maize production as pointed out by FAO (1983). Similar result was reported by several researchers (Yaro, 2005; Hussaini, 2011; Singh *et al.*, 2013). The predominance of Ca was partly due to exchange sites having high affinity for Ca (Esu, 1982) and also due to calcium bearing parent material (Nahusenay*et al.*, 2014).

4.2.5 Magnesium (Mg) map

The obtained laboratory result of magnesium is presented in Figure 4.9.

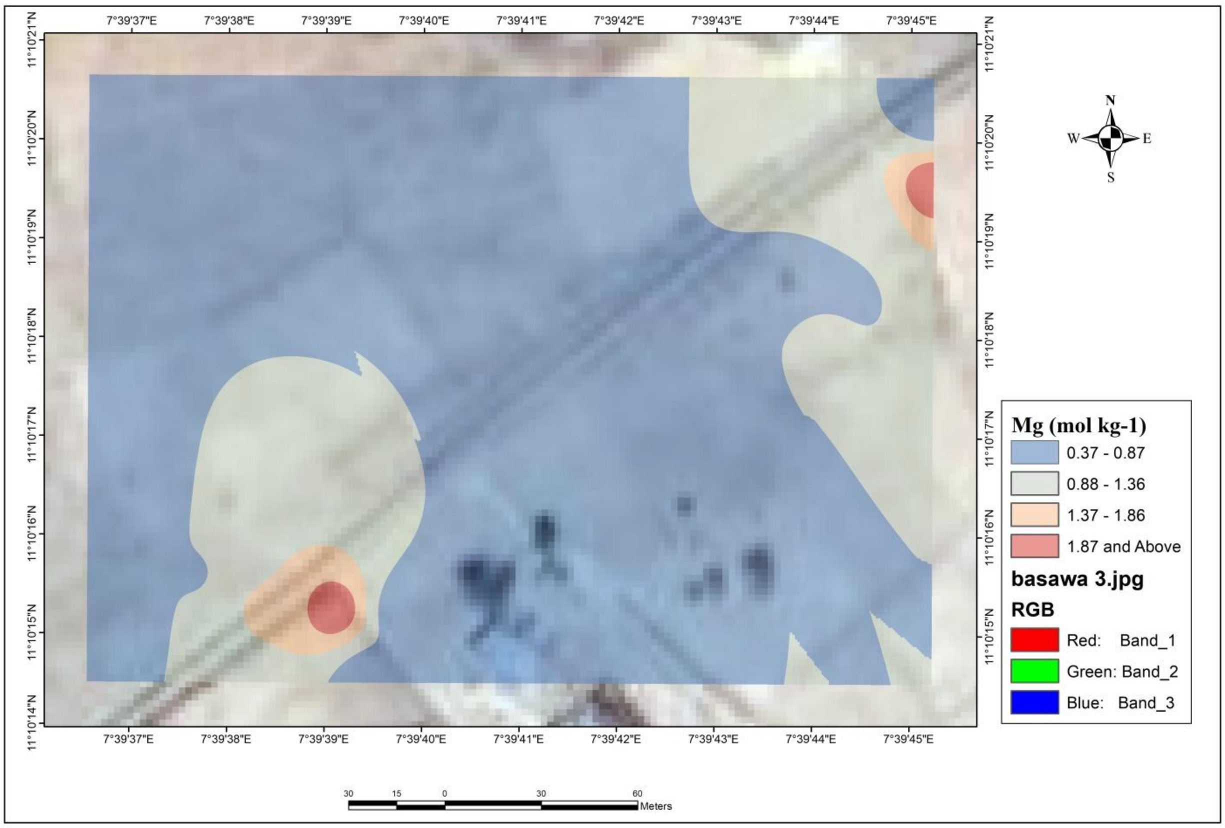

Figure 4.9: Magnesium Soil Samples Analysis
Source: Author Analysis 2017

The result in Figure 4.9 and the data in 4.1 revealed that the average concentration of magnesium is 0.86 (mol kg^{-1}) which indicates medium concentration of Magnesium in the study area. Similar result was reported by Odunze and Kureh (2009) on soils of Zaria.Magnesium (Mg) is one of the exchangeable bases that are needed in the soil for plant development.

4.2.6 Nitrogen (N) map

The result of Nitrogen obtained for laboratory analysis is presented in Figure 4.10. Nitrogen in ammonia form and high levels of Magnesium, Calcium and Sulphur can negatively interfere with Potassium uptake (McCants and Woltz, 1967).

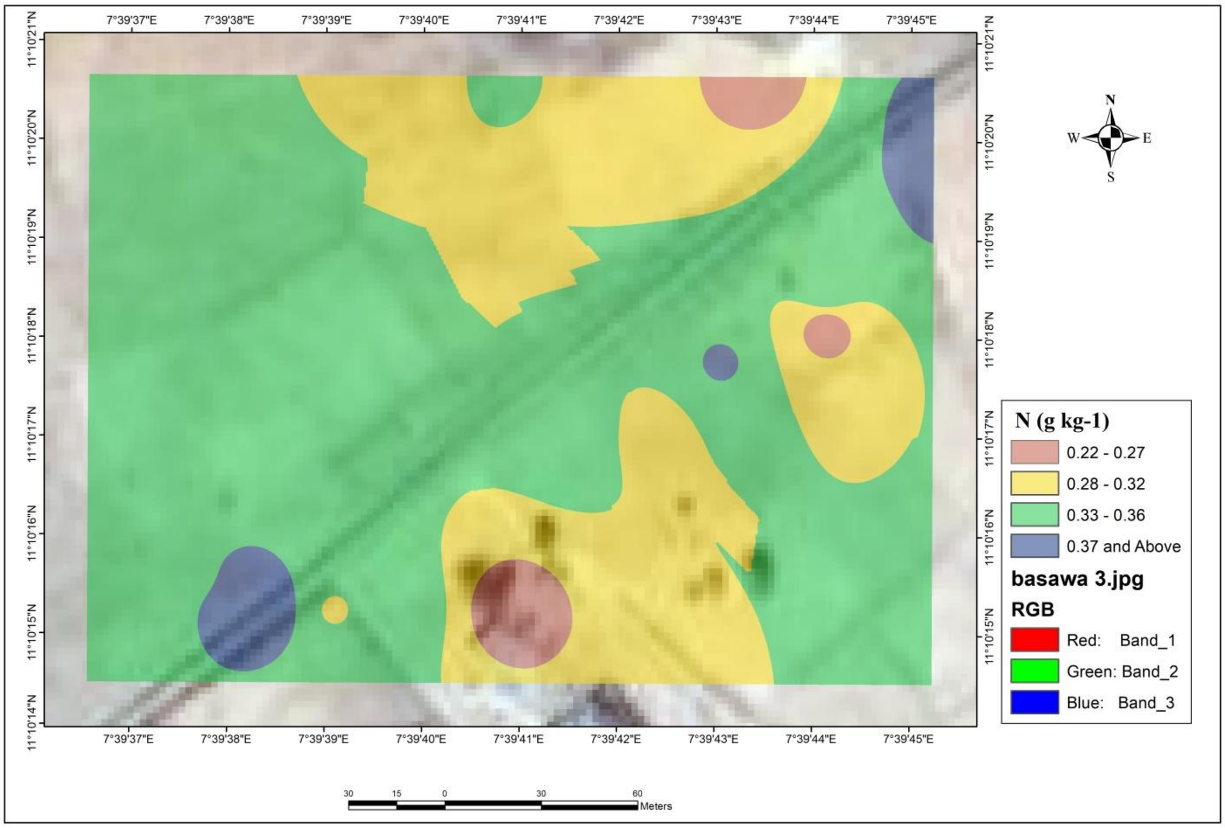

Figure 4.10: Nitrogen Soil Samples Analysis
Source: Author Analysis 2017

The result of nitrogen concentration in the study area as shown in Figure 4.10 revealed that all the plots showed almost similar amount of nitrogen in the study area. The data in table 4.1 showed that the average concentration of nitrogen in the study area is about 0.617(g kg^{-1}) which is low (Malgwi 2007). Nitrogen is mobile in soils, as a result its losses through various mechanism like NH_3 volatilization, succeeding denitrification, chemical and microbial fixation, leaching and runoff results in residual/available N becomes poor in soils (Awanish, Mishra, Srivastav and Rakesh, 2014). Similar results of low N values were reported by Hussaini (2011); Maniyunda (2014) in Zaria, and Sharu*et al.*, (2013) in Sokoto State. Nitrogen values of the soils changed irregularly with depth which could be attributed to influence of continuous cultivation, a common practice that is accompanied by crop residue removal (Noma *et al.*, 2011).

4.2.7 Potassium (K) map

The result of potassium obtained for laboratory analysis is presented in Figure 4.11.

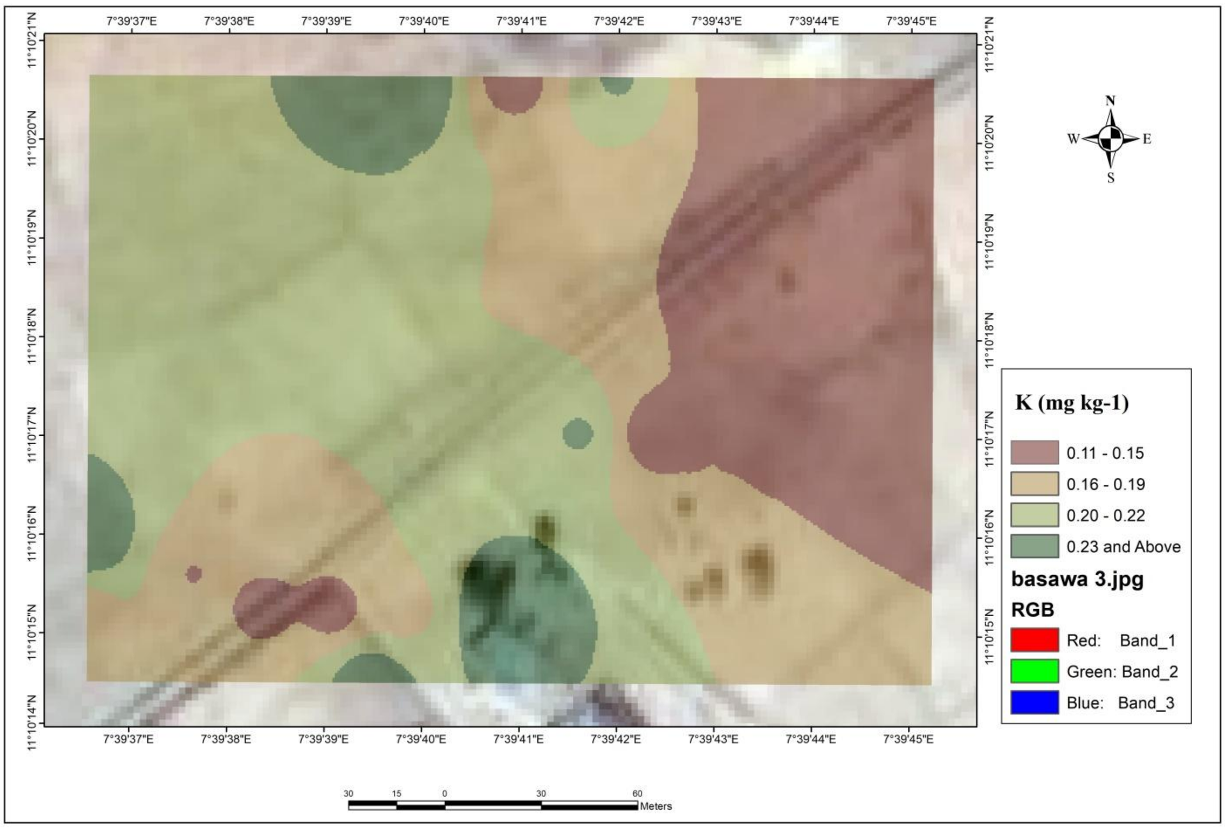

Figure 4.11: Potassium Soil Samples Analysis
Source: Author Analysis 2017

The result in Figure 4.11 revealed that the large concentration of potassium falls between 0.16 to 0.19(mg kg^{-1}) and 0.20 to 0.22(mg kg^{-1}) respectively. The data in table 4.1 showed that the average concentration of potassium is about 0.17(mg kg^{-1}) which happened to be medium to maize cultivation based on FAO (1998). This is similar to the findings of Hussaini (2011) and

Maniyunda and Gwari (2014). These show that the study area has a potential for maize production with other factors been equal. However, the high potassium content in the cured leaves, which varies between 1.5 and 8%, is considered a parameter of good quality and is universally applied to maize in all production areas (McCants and Woltz, 1967).

4.2.8 Phosphorus (P) map

The obtained laboratory result of Phosphorus is presented in Figure 4.12. Phosphorus, although taken up in lower amounts than nitrogen but it must be readily available during the whole crop cycle and particularly in the early growth of plants. Any deficiency in the first part of the cropping cycle limits leaf expansion and leads to an unusual dark coloration, formation of necrotic patches on the lower leaves, and stunted and delayed maize growth and ripening (Papenfus and Quin, 1984).

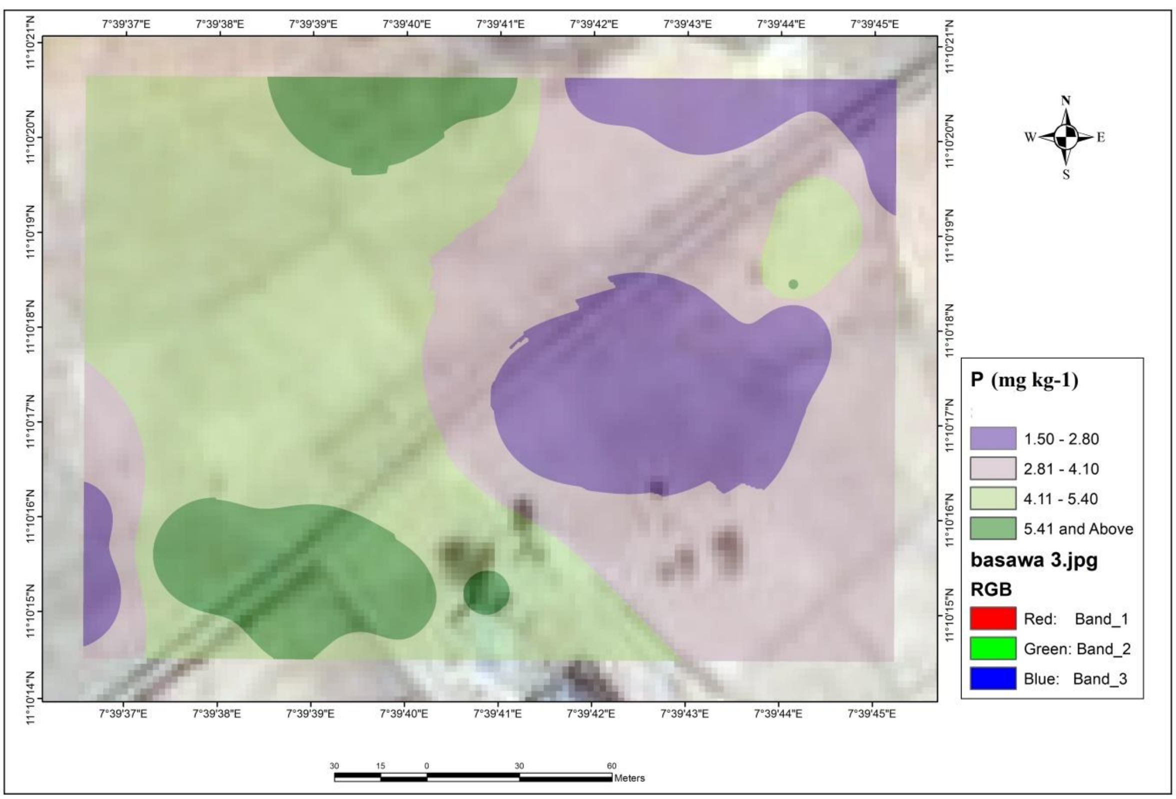

Figure 4.12: Phosphorus Soil Samples Analysis
Source: Author Analysis 2017

The concentration of phosphorus is about 9.38(mg kg^{-1}) as showed in table 4.1 revealed a low evaluation for maize cultivation in the study area. It was observed that phosphorus content decreased with depth and appreciable quantities were found only at the top soils. However, the irregular pattern in accumulation of phosphorus at the surface; a pronounced occurrence in the savanna was attributed to decrease in the return of P to soil surface as the vegetation becomes sparser (Mosugu, 1989; Raji *et al*., 1996). The values were lower than those reported by Ogban *et al.*, (1999) for soils of the South-Eastern Nigeria, and might be due to enhanced recycling in the more luxurious forest vegetation. Low results will lead in a decline in the yield and quality of the cured leaves. Later in the cycle, the root growth and consequential exploration of a greater soil volume excludes any deficiency phenomena.

4.2.9 Cations Exchange Capacity (CEC) map

The laboratory analysis for CEC in the study area is presented in Figure 4.13 and the average measured of CEC based on FAO (1998) as shown in Table 4.1 revealed that the average measured of CEC was 6.41(cmol(+) kg^{-1}) which are found to be medium (Malgwi, 2007) standard for maize cultivation.

The CEC measurements are commonly made as part of the overall assessment of the potential fertility of a soil (London1991).CEC were rated medium based on the findings of Adepetu, Aduagi, and Alofa (1979) who reported CEC values of < 6, 6 - 12 and > 12 cmol(+)kg-1 as low, medium and high respectively.

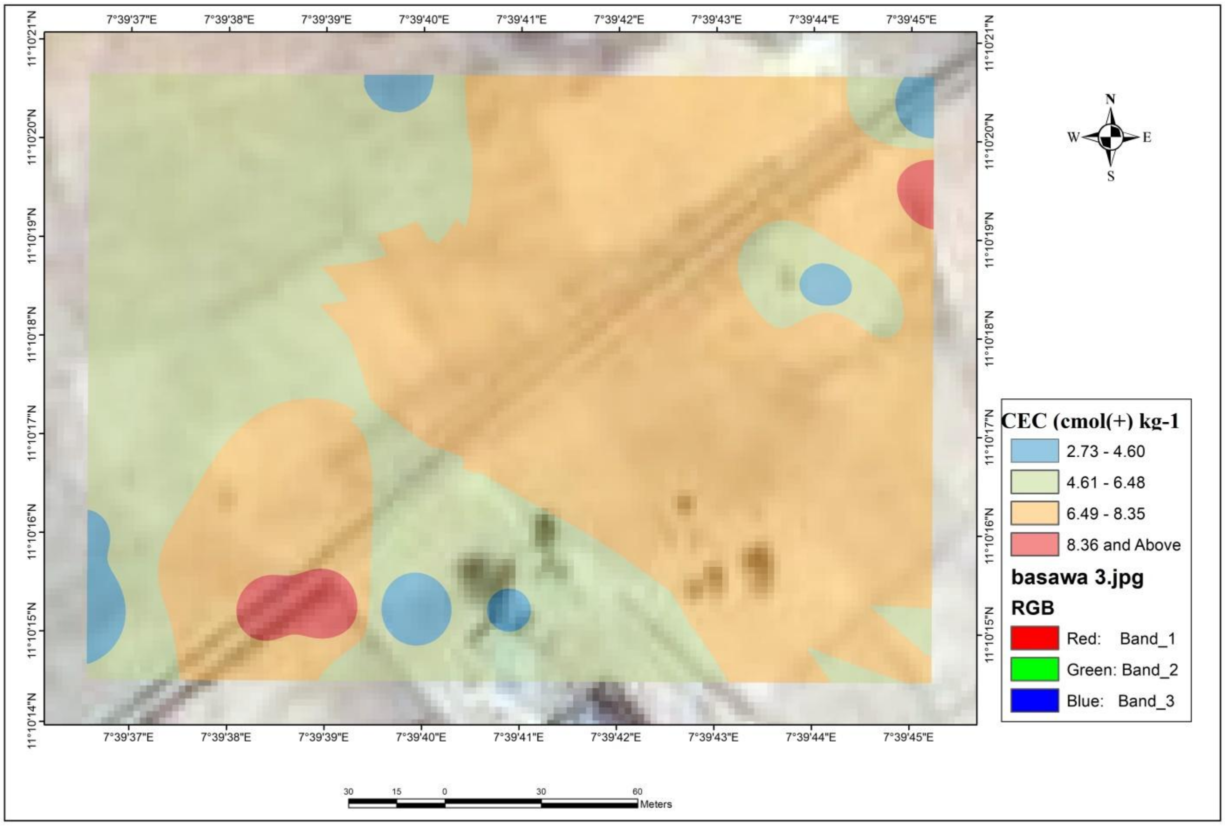

Figure 4.13: CEC Soil Samples Analysis
Source: Author Analysis 2017

4.3 SUITABILITY LEVELS OF THE SOIL FOR MAIZE PRODUCTION

The suitability for each physiochemical parameter was generated individually and rank in Table 4.2 to 4.10.

4.3.1pH

The data in Table 4.2 revealed that the soil pH value ranging from 4.55 and 5.04 is ranked the moderately suitable in terms of suitability for maize production while pH value ranging from 3.54 and 4.04 is not suitable or have the least suitability. Sys *et al*., (1993) reported pH values of 6, 6.5 are highly suitable for the optimum yield of maize (Table 3.4). The Soil of the area was moderately to non-suitable in term of Soil pH. At very low pH, solubility of Al, Mn and Zn increase, and can become toxic to sensitive plants. At high pH values, the solubility of Mn, and to a lesser extent Zn and Cu, can become so low that maize are unable to obtain adequate supplies from the soil. This may be attributed to the influence of organic matter through biogenetic cycling of bases, a process which reduces acidification of soils (Jones and Wild, 1975; Mosugu, 1989; Maniyunda, 1999; Shobayo, 2010).

Table 4.2: Suitability of pH in the Study Area

Range of pH Concentration	Rank	Level of Suitability
4.55 – 5.04	1	Moderately Suitable
4.05 – 4.54	2	Marginally Suitable
3.54 – 4.04	3	Not Suitable

Source: Author's Analysis, 2017

4.3.2 Organic matter (OM)

The data in Table 4.3 revealed that the concentration of Organic Matter value ranging from 0.88 and above(%) is ranked the highest in terms of suitability for maize production while OM value ranging from 0.53 to 0.72(%) is not suitable or have the least suitability. Sys et al., (1993) suggested OM values of > 1 are highly suitable for the optimum yield of maize (Table 3.4). The low organic matter content recorded on the average for the soils cannot sustain crop production on a long term basis under continuous crop production. Therefore, organic matter has to be substantially increased through effective crop residue management, increased use of leguminous plant as well as the use of nitrogenous and phosphate fertilizers. Maniyunda (1999); Odunze (2006); Shobayo (2010) and Maniyunda and Gwari (2014) also reported low organic matter for soils in the Northern Guinea savanna.

Table 4.3: Suitability of Organic Matter (OM) in the Study Area

Range of OM Concentration (%)	Rank	Level of Suitability
0.88 and above	1	Highly Suitable
0.82 – 0.87	2	Moderately Suitable
0.73 – 0.81	3	Marginally Suitable
0.53 – 0.72	4	Not Suitable

Source: Author's Analysis, 2017

4.3.3 Sodium (Na)

The data in Table 4.4 revealed that Sodium (Na) value ranging from 0.38 and above (mol kg^{-1}) is ranked the highest in terms of suitability for maize production while Na value ranging from 0.24 to 0.31 (mol kg^{-1}) may not be suitable or have the least suitability. Sys et al., (1993) suggested Na values of >0.5 are highly suitable for the optimum yield of maize (Table 3.4). This result is different from the results of other researchers within the study area due to the high content of sodium in the soils of the present study but was similar to the finding of Malgwi (2001) on salt affected soils in Kano. These show that Basawa soils are now affected by salt accumulation. Therefore, good soil management practices have to be put in place to reduce its side effect on crop

Table 4.4: Suitability of Sodium (Na) in the Study Area

Range of Na Concentration (mol kg^{-1})	Rank	Level of Suitability
0.38 and above	1	Highly Suitable
0.36 – 0.37	2	Moderately Suitable
0.32 – 0.35	3	Marginally Suitable
0.24 – 0.31	4	Not Suitable

Source: Author's Analysis, 2017

4.3.4 Calcium (Ca)

The data in Table 4.5 revealed that Calcium (Ca) value ranging from 4.90 and above (mol kg^{-1}) is ranked the highest interms of suitability for maize production while Ca value ranging from 1.40 to 3.28 (mol kg^{-1}) may not be suitable or have the least suitability. Sys et al., (1993) suggested Ca values of >0.5 are highly suitable for the optimum yield of maize (Table 3.4). Calcium (Ca) in the study area being >0.5 (mol kg^{-1}),it is suitable for maize production and deficiency syndrome will not be observed in the study area, these implies that Ca is well supplied for maize growth and development.

Table 4.5: Suitability of Calcium (Ca) in the Study Area

Range of Ca Concentration (mol kg^{-1})	Rank	Level of Suitability
4.90 and above	1	Highly Suitable
4.21 – 4.89	2	Moderately Suitable
3.29 – 4.20	3	Marginally Suitable
1.40 – 3.28	4	Not Suitable

Source: Author's Analysis, 2017

4.3.5 Magnesium (Mg)

The data in Table 4.6 revealed that Magnesium (Mg) value ranging from 1.87 and above (mol kg^{-1}) is ranked the highest in terms of suitability for maize production while Mg value ranging from 0.37 to 0.87 (mol kg^{-1}) may not be suitable or have the least suitability. Sys et al., (1993) reported Mg values of >0.5 for the optimum yield of maize (Table 3.4). The level of Magnesium is generally medium in the study area. For sustainable maize production, fertilizer containing sufficient amount of Mg could be applied to the area with low amount.

Table 4.6: Suitability of Magnesium (Mg) in the Study Area

Range of Mg Concentration (mol kg^{-1})	Rank	Level of Suitability
1.87 and above	1	Highly Suitable
1.37 – 1.86	2	Moderately Suitable
0.88 – 1.36	3	Marginally Suitable
0.37 – 0.87	4	Not Suitable

Source: Author's Analysis, 2017

4.3.6 Nitrogen (N)

The data in Table 4.7 revealed that Nitrogen (N) value ranging from 5.40 and above(g kg^{-1}) is ranked the highest in terms of suitability for maize production while N value ranging from 1.50 to 2.79(g kg^{-1}) may not be suitable or have the least suitability. FAO (1983) suggested N values of > 0.8-0.4(g kg^{-1}) are highly suitable for the optimum yield of maize (Table 3.4). Also, research by McCants and Woltz, (1967) show that the amount of fertilization depends only partly on the soil content and on the amount actually absorbed by the plant because of its recognized beneficial effects on the quality of the leaves such as greater burning capacity, elasticity and intensity of color. The content of Nitrogen is low in the study area been less than the critical value > 0.8-0.4(g kg^{-1}). These will affect crop production because maize requires a lot of Nitrogen for its growth, for sustainable maize production, addition of Nitrogen fertilization will be required.

Table 4.7: Suitability of Nitrogen (N) in the Study Area

Range of N Concentration (g kg^{-1})	Rank	Level of Suitability
0.36 and above	1	Highly Suitable
0.31 – 0.35	2	Moderately Suitable
0.26 – 0.30	3	Marginally Suitable
0.22 – 0.25	4	Not Suitable

Source: Author's Analysis, 2017

4.3.7 Potassium (K)

The data in Table 4.8 revealed that Potassium (K) value ranging from 0.22 and above is ranked the highest in terms of suitability for maize production while K value ranging from 0.11 to 0.14 may not be suitable or have the least suitability. FAO (1983) suggested that K values of >0.3-0.5 are highly suitable for the optimum yield of maize (Table 3.4).

Table 4.8: Suitability of Potassium (K) in the Study Area

Range of K Concentration (mg kg^{-1})	Rank	Level of Suitability
0.37 and above	1	Highly Suitable
0.33 – 0.36	2	Moderately Suitable
0.28 – 0.32	3	Marginally Suitable
0.22 – 0.27	4	Not Suitable

Source: Author's Analysis, 2017

4.3.8 Phosphorous (P)

The data in Table 4.9 revealed that Phosphorous (P) value ranging from 5.40 and above(mg kg^{-1}) is ranked the highest in terms of suitability for maize production while P value ranging from 1.50 to 2.79(mg kg^{-1}) may not be suitable or have the least suitability. FAO (1983) suggested P values of >40 are highly suitable for the optimum yield of maize (Table 3.4). The supply of phosphorus distributed before transplanting, preferably banded not too deeply as supported by McCants and

Woltz (1967) at ridge formation. It is worth considering that the repeated and excessive applications of this element in traditional cultivation areas, with limited uptake and reduced or no losses through leaching, have led to a general phosphorus increase in the soil content, which usually contains more than sufficient amounts (McCants and Woltz, 1967). Nevertheless, phosphorus fertilization shows a positive effect on the crop because phosphorus absorption is strongly limited by low soil temperatures and a non-neutral pH.

Table 4.9: Suitability of Phosphorous (P) in the Study Area

Range of P Concentration (mg kg^{-1})	Rank	Level of Suitability
5.40 and above	1	Highly Suitable
4.10 – 5.39	2	Moderately Suitable
2.80 – 4.09	3	Marginally Suitable
1.50 – 2.79	4	Not Suitable

Source: Author's Analysis, 2017

4.3.9 Cations exchange capacity (CEC)

The data in Table 4.10 revealed that Cations Exchange Capacity (CEC) value ranging from 8.36 and above(cmol(+) kg^{-1}) is ranked the highest in terms of suitability for maize production while CEC value ranging from 2.73 to 4.60(cmol(+) kg^{-1}) is not be suitable or have the least suitability. FAO (1983) reported that CEC values of >25 are highly suitable for the optimum yield of maize (Table 3.4). The CEC affects the way a soil should be managed for maize cultivation. For example, a soil with a low CEC (less than 5 meq/100g) generally has a low clay and organic matter content, has a low water holding capacity, requires more frequent lime and fertilizer additions, and is subject to leaching and such soils will have lower yield potential than soils with higher CEC under the same level of management, but high productivity can be maintained by intensive management (Steven, 1998).

Table 4.10: Suitability of Cations Exchange Capacity (CEC) in the Study Area

Range of CEC Concentration (cmol(+) kg^{-1})	Rank	Level of Suitability
8.36 and above	1	Highly Suitable
6.49 – 8.35	2	Moderately Suitable
4.61 – 6.48	3	Marginally Suitable
2.73 – 4.60	4	Not Suitable

Source: Author's Analysis, 2017

4.4SUITABLE AREAS FOR MAIZE PRODUCTION

The pairwise comparison matrix (PWCM) was carried out for rating and weighing of the different criteria. The fundamental scales given by Satty for comparing the two criteria was used. The quantitative value from 1-9 scales was given (Satty and Vargas, 2001), considering the comparative importance of two criteria. Based on experts` opinion, the overall rating for the comparison was generated on Table 4.11 and 4.12, which derived the weights with an acceptable consistency ratio. This was used to generate a soil suitability map which was then used in combination with other land attributes to generate the suitable map for maize production.

Table 4.11: Pairwise Comparison for the Criteria

	N	P	K	CEC	Mg	Ca	Na	pH	OM	Weight
N	1									23%
P	1	1								18%
K	1	1	1							14%
CEC	1/3	1/3	1/3	1						11%
Mg	1/3	1/3	1/3	1/3	1					9%
Ca	1/3	1/3	1/3	1/3	1/3	1				7%
Na	1/3	1/3	1/3	1/3	1/3	1/3	1			5%
pH	1/3	1/3	1/3	1/3	1/3	1/3	1/3	1		4%
OM	1	1	1	1	1	1	1	1	1	10%

Source: Author Analysis 2017

Table 4.12: Terrain Characteristics of the Study Area

Terrain Elements	Weights
Elevation	40%
Slope	26%
Aspect	17%
Soil Texture	11%
Drainage	07%

Source: Author Analysis 2017

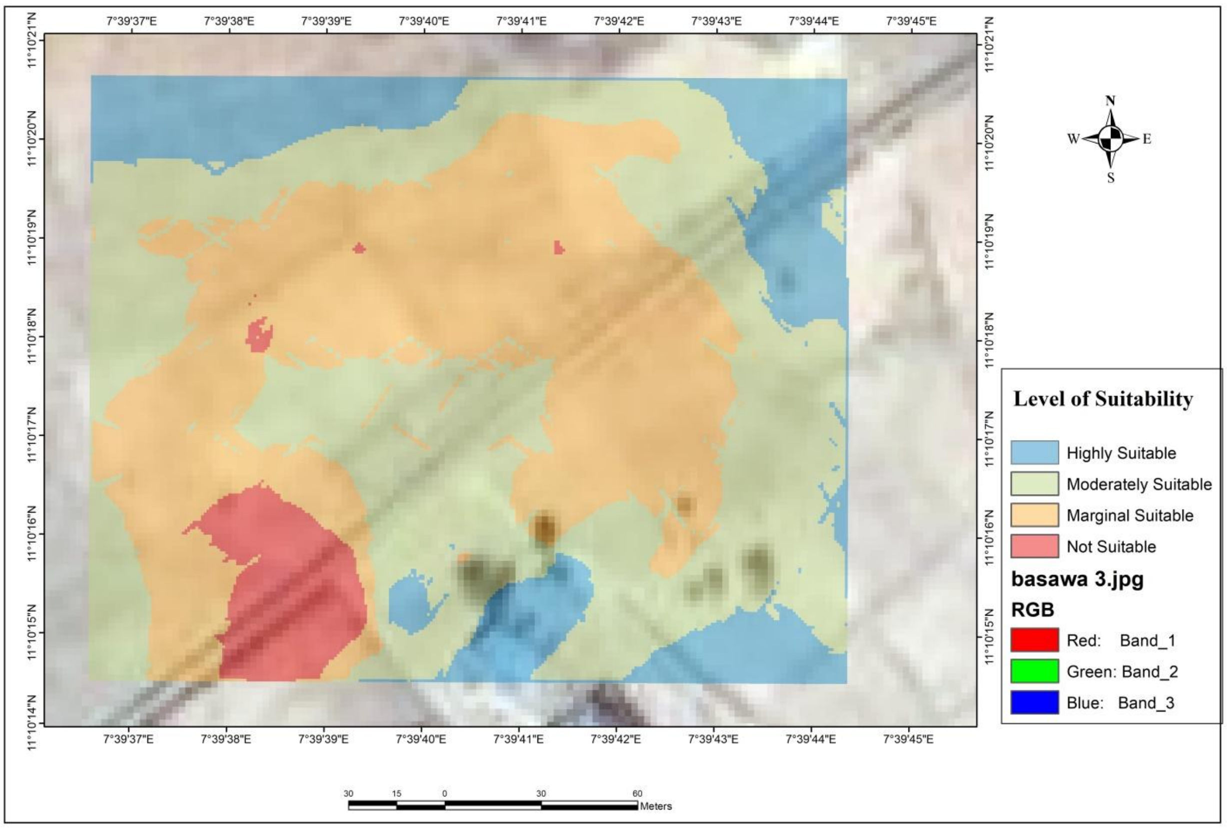

Figure 4.14: Suitability Areas for Maize Production in Basawa
Source: Author Analysis 2017

Table 4.13: Area Coverage Maize Suitability in the Study Area

Level of Suitability	Area Extent ($Sq.m^2$)	% of Area
Highly Suitable	4411.67	8.91
Moderately Suitable	26069.38	52.65
Marginally Suitable	14151.99	28.58
Not Suitable	4878.75	9.86
Total	**49511.79**	**100**

Source: Author Analysis 2017

The result of the analysis in figure 4.14 and Table 4.13 revealed that the highly suitable area that meet up with all the requirement is within (S1)8.91% (4411.67$Sq.m^2$). This area possesses the qualities that is requires (most suitable) to cultivate maize. According to NEDECO (1974) is Hydromorphic in nature, it mostly consist of silt and some combination of loamy soils, clayey and sand that developed within the terraces which is good for cereal crops. Even though, the area is a very small portion within the land, in this case the area is having minor limitations that will not significantly reduce production and will not raise input above an acceptable.

Moderately suitable (S2), having an area with 52.65% (26069.38$Sq.m^2$), this area is falling within the irrigated field in the study area which is affected by salinity, poorly drained and low nutrients. However, the land is having limitations which, in aggregate are severe for sustained application of given use and will so reduce productivity or benefit or increase required input, that this expenditure will be only moderately justified.

Marginally suitable **(**S3**),** having an area with 28.58% (14151.99$Sq.m^2$), this area is affected by severely erosion, shallow soils, very low organic matter and slopping topography. It is dominated by an undifferentiated texture there by making the soil to be sandy. However, the land having limitations which may be surmountable in time, but which cannot be corrected with existing knowledge at currently acceptable cost; the limitation are too severe as to preclude successful sustained use of the land is the given manner.

The area not suitable (N) for maize cultivation having an area with 9.86% (4878.75Sq.m^2), this area is generally affected by badland topography, rock outcrop, complex texture and very poor nutrient others include built-up areas and water bodies which are generally not for cultivation. Land having limitations which appear as severe as to preclude any possibilities of successful sustained use of the land to the given manner. Tinguely (2012) explained that a reason why an area is classified as non-suitable is because of technical considerations (such as slope and soil fertility, etc.). This findings is similar to the research conducted by Mustafa, *et al* (2000) unlike the result of suitability analysis was carried out by Adesemuyi (2014) for Maize in Akure a humid zone of Southwestern Nigeria which found that there was no highly suitable land for maize cultivation in the area. The results revealed that the slope is a very highly sensitive element in the suitability classification for maize crop, followed soil is a highly sensitive; the rainfall is moderately sensitive as in the findings by Al-Mashreki (2011). This implies that each factor has to be given suitable weighting reflecting its importance for the suitability of maize in the study area.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 SUMMARY OF FINDINGS

This research aimed to assess land suitability for Maize Production in Basawa area of Sabon-Gari Local Government Area of Kaduna State with the aid of mapping the suitable area for production of maize Using Geospatial Techniques. The study integrated satellite imagery, ASTER DEM, field work and laboratory physico-chemical analysis of twenty (20) auger points. The suitable site for maize production was determined by overlaying the thematic map for the soil properties, slope, aspect and elevation.

From the land use of the area, it shows that cultivated land dominated the area and the land is well drained. The terrain is relatively flat unless to some extend the northern part of the area which is an indication of hilly areas.

The spatial distribution of the physico-chemical parameters shows that the area is extremely acidic with pH < 4 and Organic matter (OM) and Phosphorous (P) was low (1.04% and 9.38 mgkg^{-1}). The distribution of Nitrogen (N) and Sodium (Na) from their mean shows low(0.617 gkg^{-1}and 0.35 mol kg^{-1}) respectively. Potassium (K), Magnesium (Mg) and Cations exchange capacity (CEC) are within the medium threshold (0.17 mg kg^{-1}, 0.86 mol kg^{-1}, 6.41 cmol (+) kg^{-1}) while calcium (Ca) is medium (4.12 mol kg^{-1}) and the whole area is affected with salinity.

The suitability for maize production from the parameters shows that soil drainage and slope are within acceptable suitable range while those falling within moderate to marginal are K, Mg, CEC and Ca. while P, N and Om was low when comparing with maize requirement.

The final analysis shows that the study area was moderately to marginally suitable as results of low outputs recorded by most of the farmers; which was mainly attributed to inadequate fertilizer since a small percentage of the farmer who used adequate fertilizer recorded high outputs

5.2 CONCLUSION

The need to generate adequate information for optimal and sustainable exploitation of the land for agricultural purposes of Basawa, Sabon-Gari, L.G.A. is imperative. The study uses M.C.E, satellite imageries, Digital Elevation Model (DEM) and soil physical and chemical properties to determine areas suitable for maize production.Loamy Sand and Sandy Loam as the textural class. The soils are well drained, relatively flat, very few rock outcrops, the soil of the area is affected with salinity and some of the essential elements needed in the soils like Nitrogen, Phosphorous and most micronutrients are lacking in the soils. The pH of the area is generally acidic and hence toxic to must crops,From results of the analysis, it can be concluded that highly suitable areas was found to constitute about 8.91% from the total area, while the moderately suitable areas was for found to be 52.65%, 28.58% marginally and 9.86% not suitable classes.

5.3 RECOMMENDATIONS

i There is the need for land optimum performance for maize production In order to raise the productivity level of the study area.

ii There is need for management techniques in the study area in order to enhance the nutrient and moisture holding capacity of the soil. The techniques should include continuous application of organic fertilizers/materials to the soil, use of low levels of chemical inputs and improved efficiency of use of mineral fertilizers.

iii The land is tested for other crops and the crop that best fit the land.

REFERENCES

Adamu, G.K. (2012). An Assessment of the Surface Characteristics and potentials of Fadama Soils in the Reaches of Two Major Streams in Kano State, Nigeria. Unpublished Ph.D. Thesis Submitted to the Department of Geography Bayero University, Kano.

Adesemuyi, E.A (2014). Suitability assessment of soils for maize (Zea mays) production in a humid tropical area of south-western Nigeria. *International Journal of Advanced Research* Vol. 2, Issue 2, 538-546.

Adepetu, J.A., Aduagi, E.A. and Alofa, C.A. (1979). A preliminary of fertility status of some soils in Ondo state under traditional cultivation. *Ife Journal of Agriculture* 134:149.

Aduayi, E.A., Chude, V.O., Adebusuyi, B.A. and Olayiwola, S.O. (2002).Fertilizer Use and Management Practice for Crops in Nigeria.*Journal of Agricultural Resources*, 8:101-133.

Agbogidi, O. M., Eruotor, P.G., Akparobi, S.O. and Nnaji, G.U. (2007). Evaluation of Crude Oil Contaminated Soil on the Mineral Nutrient Element of Maize. *Journal of Agronomy,* 6(1):188-193.

Akinwunmi A. (2014).*Food Security through Agricultural Transformation Agenda*. Leadership News Paper.www.Leadership.ng.Retrieved May, 29 2014.

Al-Areba, A.A., Salami, A.A., Ouafae, .A.,Rigobert, .B., Laura, .D., and Gebremeskel, .G., (2007). Land evaluation in essaouira province Morocco. Proceedings of the 27th Professional Course on Geomatics and Natural Resources Evaluation, November 6, 2006-June 22, 2007, Foreign Affairs, IstitutoAgronomico Per L'oltremare, pp: 1-213.

Al-Mashreki, M. H., Juhari M., Abd Rahim S., Md. Desa K., Lihan T. and Haiden R. (2011). GIS-Based Sensitivity Analysis of Multi-Criteria Weights For Land Suitability Evaluation of Sorghum Crop in the Ibb Governorate, Republic of Yemen.*J. Basic. Appl. Sci. Res.*, 1(9)1102-1111

Ande, O.T. (2011), “Soil suitability evaluation and management for cassava production in the Derived Savanna area of Southwestern Nigeria”, *International Journal of Soil Science*. 6, (2): 142-149.

Anderson, J. S. and Ingram, J.I.S. (1998).Tropical Soil Biology and Fertlity.A Handbook of Methods.2nd Edition. Information Press, U.K. Pp. 221.

Anji, R. M. (2008). *Textbook of Remote Sensing and Geographic Information System, B.S.* publication, Hyderabad.

Aondoakaa, S.C. And Agbakwuru, P.C. (2012). An assessment of land suitability for rice cultivation in Dobi, Gwagwalada area council, FCT Nigeria. *Ethiopian Journal of Environmental Studies and Management* Vol. 5 no.4 (Suppl.1).

Akpoborie, I.A. (1972). Hydrogeological control of the structures along Samara Creek. Unpublished Reports.36p. Ahmadu Bello University, Zaria, Nigeria.

Audu, M.A., Abdullahi A., Noma S.S. and Abdulaziz S. (2009). Salinity and Sodicity Status of Worno Irrigation project area, Sokoto, Northwest Nigeria. In Fasina A.S., Ayodele, O.J., Salami, A.E; Ojeniyi, S.O. (eds) *Management of Nigerian Soil Resource for enhanced Agricultural Productivity.* Proceeding of the 33rd Annual conference of the Soil Science Society of Nigeria (SSSN*)* 60 -65 pp.

Awanish K., Mishra,V. N., Srivastav, L. K. and Rakesh B. (2014) Evaluations of soil Fertility Status of Available Major Nutrients (N,P & K) and MicroNutrients (Fe, Mn, Cu & Zn) in Vertisol of Kabeerdham District of Chhattisgarh, India.*International Journal of Interdisciplinary and Multidisciplinary Studies (IJIMS)*, Vol 1, No.10, 72-79. Retrieved from http://www.ijims.comISSN: 2348 – 0343.

Babalola TS, Oso T, Fasina AS and Godonu K (2011) Land evaluation studies of two wetland soils in Nigeria. *International Research Journal of Agricultural Science and Soil Science* Vol. 1(6) pp. 193-204.

Badu-Apraku, A., Menkir, M.A.B, Fakorede, S. and Ellis-Jones, J. (2012). Building partnerships and encouraging innovation for sustainable maize production: the West and Central Africa Collaborative Maize Research Network, achievements and impact. IITA Ibadan, Nigeria.82 pp.

Behnam K. Mohammad A. D and Jaime A. T da Silva (2014). Assessment of land suitability and the possibility and performance of a canola (*Brassica napus*L.) – soybean (*Glycine max* L.) rotation in four basins of Golestan province, Iran. Egyptian Journal of *Remote sensing and Space science* DOI: 10.1016/j.ejrs.2013.12.001.

Benneth, J.G., Hatcheon, A.A., Kerr, W.B., Mansfield, J.E., and Racklam, L.J. (1977). Environmental Aspects of the Plains.Vol 1.Landforms and Soils. Land Resources Report 19. Land Resources Division Tolworth Tower, Surbitol Survey, England, 277 pp.

Binns J. A., Machonachie, R. A. and Tanko A. I. (2003).*Water, Land and Health in Urban and Peri-urban Food Production*: The case Kano, Nigeria, Retrieved fromwww.cityfarmer.org.

Bower, C.A. and Wilcox, L.V. (1965). Soluble salts by electrical conductivity. In Black, C.A. (Editor-in Chief) Methods of Soil Analysis Part 2. Chemical and Microbiological Properties, pp. 936-940. American Society of Agronomy, Inc., Published Madison, Wisconsin, USA.

Brady. N.C. and Weil R.R. (1999).*The Nature and Properties of Soils*.12th ed. Prentice Hall, upper Saddle River, New York. 881pp.

Burrough, P. A., Macmillan, R. A., and Van, D. W., (1992). Fuzzy classification methods for determining suitability from soil profile observation and topography. *Journal of soil science,* 43, 193-210.

Chapman, H.D. (1965). Cation-exchange capacity. In: C.A Black (ed). Methods of soil analysis-Chemical and microbiology properties. Agronomy 9:891-901.

Chen Y., Yu J. and Khan S. (2012) spatial sensitivity analysis of multi-criteria weights in GIS based land suitability evaluation. *Environmental Modelling & Software* Vol.25, 1582- 1591.

De La Rosa, D., (2000). Micro LEIS Conceptual Framework: *Instituto de RecursosNaturalesyAgrobiologia*,CSIC, Sevilla, Spain, 267: 212.

Dent, D. & Young, A. (1981).*Soil Survey and Land Evaluation*. UK: George Alien and Unwin Ltd.

Dugje, I.Y., Kamara, A.Y. and. Ajeigbe, H. (2009). Biophysical Characterisation of Crop Fields in Sudan Savanna Zone of North Western Nigeria: Kano-Katsina-Maradi Pilot Learning Site Sudan Savanna Agro-Ecological Zone Innovation Platform. Sub Saharan Challenge Programme for Integrated Agricultural Research for Development. *International Institute of Tropical Agriculture* (IITA, *Research to Nourish Africa*).

Dunshan, C., Claudia, D.B., Sara, D.S., Hui, D., Maddalena, D.L.L., Weidong, L. and Hailong, M.A. (2006). Land Evaluation in Danling Country, Sichuan Province, China. *Proceedings of 26th Course professional Master Geomatics and Natural Resource Evaluation, Nov. 7, 2005- June 23, 2006.*

duPreez, J.W. (1956). Origin and distribution of Nigeria laterites.*Proc. 3rd Inter. W. Africa Conf*. 1949. Pp 223-234.

Elaalem E, A. Comber, and P. Fisher, (2001).“A Comparison of Fuzzy AHP and Ideal Point Methods for Evaluating Land Suitability”, *Transactions in GIS*, 15: 329- 346.

Elaalem M. (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.

Elaalem M. (2013). A Comparison of Parametric and Fuzzy Multi-Criteria Methods for Evaluating Land Suitability for Olive in Jeffara Plain of Libya.*www.sciencedirect.com* APCBEE Procedia 5 405 – 409.

ESRI (Economic and Social Research Institute) 2009: GIS best practice: GIS for agriculture. New York: ESRI.

Esu, I.E. (1982).*Evaluation of Soils for Irrigation in the Kaduna Area of Nigeria*. An unpublishedPh.D. Thesis submitted to Soil Science Department, Ahmadu Bello University, Zaria.

Esu, I.E. (1987). Fertility status and management of some upland basement complex soils in Nigeria. Tropical Savanna region.*Nigerian Journal of Soil Science* 7:155-183.

Esu, I.E. (2004). Soil characterization and mapping for food security and sustainable environment in Nigeria", *Proceedings of the 29th Annual Conference of the Soil Science Society of Nigeria*, Dec. 6 – 10, University of Agriculture Abeokuta, Nigeria, pp. 20-24.

Fasina, A.S. (1999). Characteristics, classification and management of soils of Lagos State.*in*: Babalola, O., Omoti, U. and Isenmila, A.E. (eds), *Management of the soil resources of Nigeria for sustainable agricultural production in the 21st century*, pp. 33 - 38. Proc. of the 25th Annual Conference of Soil Science Society of Nigeria, held at Precious Palm Royal Hotel, Benin city, Edo State, Nigeria. 21st – 29th Nov. 1999.

Fasina A.S and Adeyanju A (2007). Comparison of three Land Evaluation Systems in Evaluating the Predictive Value of some selected soils in Ado-Ekiti, Southwest Nigeria. *Journal of Soil Science* 17:113-119.

Fasina A.S, Omotosho S.O, Shittu O.S, Adenikinju A.P (2007): Properties, Classification and Suitability Evaluation of some Selected Cocoa Soils of Southwestern Nigeria. Am. – Eurasian J. Agric. Environ. Sci. 2 (3): 311 – 317.

Food and Agriculture Organization(1976).*A framework for land evaluation*, 1th ed., Food and Agricultural Organization of the United Nations., Rome, FAO, 1-187.

FAO (1983). Guidelines: *Land evaluation for rainfed agriculture*. Soils Bulletin 52. FAO, Rome, 237 pp.

FAO (1985). Guidelines: *Land evaluation for irrigated agriculture*, Soil Bulletin, No. 55. Food and Agriculture Organization. Rome. Italy, pp. 229.

FAO (1998).Topsoil Characterization for Sustainable Land Management:*Land and Water Development Division Soil Resources*, Management and Conservation Service. P30

FAOSTAT (Food and Agriculture Organization/Statistics (2000) Trade data base, Production data base http://faostat.fao.org. Accessed 01/02/2013.

FAOSTAT (Food and Agriculture Organization/Statistics (2012) Trade data base, Production data base http://faostat.fao.org. Accessed 01/02/2013.

Foote K., and Lynch, M. (1996).*Geographic Information Systems as an Integrating Technology*: Context, Concepts and Definition University of Texas, Austin, Texas, USA.

Francesco, A. (2003) Land Evaluation in the Province of Thesis, Senegal. *Proceedings of 23rdCourse Professional Master Geometrics and Natural Resources Evaluation, Nov. 8, 2002.*

Garcia, O. A. (2003). *Physical Properties of Magnesium Affected In Colombia*. Lecture given at College of Soil Physics Treste.LNS0418016, 6pp.

Gbadegesin, A. S. (1984) *Soil Classification for Maize Production in the Savanna Belt of Oyo State.* Unpublished Ph. D. Thesis, University of Ibadan.

Gee G. W. and J. W. Bauder. (1986): Particle size analysis. In Methods of soil analysis, Part 1st.Vol. 9. (Ed. A. Klute) pp. 91–100.*American Society of Agronomy*: Madison, WI.

Gosden, P.N. (1978). Land Resources of Central Nigeria, Present Farming System. Vol.1. Introduction and description of the farming systems. Land Resource Report 17, Land Resources Division, Tolworth Tower, Surbiton, Surrey, England. 115 pp.

Hall. G. B., Wang. F. and Subaryono (1992)) Comparison of Boolean and Fuzzy classification method in Land Suitability analysis by using Geographic Information System. *Environment and Planning*, 24, 497-516.

Hussaini, G.M. (2011). Land Suitability Evaluation for Some Selected Land Use Type in the Institute for Agricultural Research Farm, Zaria, Nigeria. Unpublished M.Sc. Thesis. Department of Soil Science, ABU, Zaria.

Inakwu O.A. Odeh and Mark C. (2010) Soil suitability and crop versatility assessment using fuzzy analysis at a farfv m scale. World Congress of Soil Science, Soil Solutions for a Changing World 1 - 6 August, Brisbane, Australia.19th Symposium http://www.iuss.org.

IITA.(1979). *Selected methods for soil and plant analysis*. International Institute of Tropical Agriculture.Manual series No. 1 pp 70.

Ismalia, N.M. Gana, K.T. and Dogora D. (2010).Cereals production in Nigeria.Problems, Constraints and Opportunities for betterment.*African Journal of Agricultural Research* 2010, 5, 12, 1341-1350. Ministry of Agriculture, Nigeria, 2012.

Jiang H. and Eastman J. R. (2000) Application of fuzzy measures in multi-criteria evaluation in GIS *int. j. geographical information science*, vol. 14, (2) 173 – 184.

Jones, M.J. and Wild, A. (1975).*Soils of West Africa Savanna soils*. Commonwealth Agricultural Bureaux, pp. 241.

Keay, R.W.J. (1959).*An Outline of Nigerian Vegetation*.3rd ed. London. 45pp.

Keay R.W. J. (1989). *Trees of Nigeria.*Oxford Sci. Pub.476 pp.

Kihoro, J., Njoroge, J.B., and Hunja, M. (2013). Investigating the impact of rice blast disease on the livelihood of the local farmers in greater Mwea region of Kenya. SpringerPlus. 2[1]:308.

Kparmwang, T. (1993).*Characterization and Classification of Basaltic Soils in the Northern Guinea Savanna Zone of Nigigeria*.UnpublishedPh.D Thesis. Department of Soil Science, ABU, Zaria. pp. 176.

Lawal, B.A., Ojanuga A.G., Noma, S.S., Adeboye, M.K.A., Dikko, A.U and Singh, A. (2012). Suitability Evaluation of Soils of Lower River Oshin Flood plain, Kwara State, Nigeria for Rain-Fed Arable Crop Cultivation. *Nigerian Journal of Soil and Environmental Research.*Vol. 10:71 – 78.

Ljusa, M. and Pajovic, I. (2002). Land Evaluation in the Province of Larache Morocco. *Proceedings of 22nd Course Professional Master Geometrics and Natural Resources Evaluation*.

London J. R. (1988). Toward a standard field assessment of soil texture for mineral soils. Soil survey and land Evaluation 8 (3) 161-165.

London J.R. (1991).Booker Tropical Soils Manual.John Willey and Sons Inc. New York.

Malczewski, J. (1999). GIS and Multicritera decision analysis. Wiley & Sons Inc., New York, USA.

Malczewski, J., (2004). GIS-based land-use suitability analysis: a critical overview. *Progress in Planning* 62 (1), 365.

Malgwi, W.B., Ojanuga, A.G., Chude, V.O., Kparmwang, T. and Raji, B.A (2000). Morphological and Physical Properties of Some Soil at Samaru, Zaria, Nigeria.Nigerian Journal of Soil Research 1:58 – 64.

Malgwi, W.B. (2001). *Characterization of salt affected soils in some selected location in the North Western Zone of Nigeria*. An unpublished PhD Thesis submitted to Soil Science Department, Ahmadu Bello University, Zaria.

Malgwi W.B. (2007). *Soil Survey: Soil Analytical Data Interpretation for Land Management*. Paper presented at Training Workshop in Soil Survey and Land Evaluation Methodology for Federal Department of Agriculture and Land Resource Staff in Kaduna.

Maniyunda, L.M. (1999). *Pedogenesis on Loess and Basement Complex rocks in a subhumid environment of Nigeria and the suitability of the lands for rainfed cultivation.* Unpublished M.Sc. Thesis. Department of Soil Science, ABU, Zaria. pp. 49-67.

Maniyunda, L.M., Raji, B.A., Odunze, A.C. and Malgwi, W.B. (2014). Morphological and Physical Properties of Soils on Basement Complex in Northern Guinea Savanna of Nigeria. Nigerian Journal of Soil Science 24 (1): 36-50.

Maniyunda, L.M. and Gwari M.G. (2014). Soils Development on a Top sequence on Loessial Deposit in Northern Guinea Savanna, Nigeria. *Journal of Agricultural and Biological Science.*VOL. 9(3) ISSN 1990-614. Retrieved fromwww.arpnjournals.com.

Marble, D.H., Calkins, H.W. and Pequet, D.J. (1984).Basic Readings in Geographic Information Systems SPAD System Limited, Williamsville, NY.

Martin, J.H. and Leonard, W.H., (1967). Principle of Field Crop Production. The McMillan and Co., New York.

McCants, C. B. and WOLTZ, W. G. (1967).Growth and mineral nutrition of tobacco.Adv. Agron. 19:2ll-265.

McCurry, P. (1970). The Geology of Degree Sheet 21 (Zaria).Unpublished M.Sc Thesis.Dept. of Geology, ABU, Zaria, Nigeria. 136pp.

McCurry, P. (1973). Geological elements of terraces near Ahmadu Bello University – a comment. *Savanna* 2:2-83.

Melitz, P.J. (1986). The Sufficiency Concept in Land Evaluation.*Soil Survey. Land Eval.*, 6(1): 9-19.

Meng Y, Malczewski J. and Boroushaki S. (2011). A GIS-Based Multicritera Decision Analysis Approach for Mapping Accessibility Patterns of Housing Development Sites: A Case Study in Canmore, Alberta *Journal of Geographic Information System*, 3, 50-61

Mermut, A. R. and Eswaran, H. (2001).Some Major Developments in Soil Science since the Mid-1960s.*Geoderma*, 100: 403-426.

Micheal, A and Chris, P. (2013).A Dictionary of Environment and Conservation, p. 239, ISBN 0199641668.

Mokarram, M., Rangzan, K. Moezzi, A. and Baninemehc J. (2012). Land suitability evaluation for wheat cultivation by fuzzy theory approaches as compared with parametric method. The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Vol. 38, Part II.

Mokwunye, A.U. and Batiano, B. (2002).Meeting the Phosphorus Need of Soils and Crops of West Africa. The Role Of Indigenous Phosphate Rocks, in. *Integrated Plant Nutrient Management in Sub-Sahara Africa*.Pp209-224.

Moberg, J.P. and Esu, I.E. (1991). Characteristic and Composition of Some Savanna Soils in Nigeria. *Geoderman*48:113-129.

Mortimore, M. and Harris F. (2003) Do small farmers" achieve contradict the nutrient depletion cenarios for Africa? *Land use policy* 22: 43-56.

Mosugu, M.E. (1989). A Bio-clinosequence study of upland soils developed on older granites in Nigeria. M.Sc Thesis, ABU, Zaria (Unpub, pp 132).

Mustafa A.A, Man Singh, R. N Sahoo, Nayan Ahmed, Manoj Khanna, A. Sarangi and Mishra A. K. (2000) Land Suitability Analysis for Different Crops: A Multi Criteria Decision Making Approach using Remote Sensing and GIS. *Researcher*, 2011; 3 (12) http://www.sciencepub.net/researcher.

Mustafa A.A, Man Singh, R. N Sahoo, Nayan Ahmed, Manoj Khanna, A. Sarangi and A. K. Mishra (2011) Land Suitability Analysis for Different Crops: A Multi Criteria Decision Making Approach using Remote Sensing and GIS. *Researcher*, 2011; 3 (12) http://www.sciencepub.net/researcher.

Nahusenya, A., Kibebew, K., Heluf, G. and Abayneh, E. (2014) Characterization and classification of soil along the toposequence at the WadlaDelanta Massif, North Central Highlands of Ethiopia. *Journal of Ecology and the Natural Environment*. Vol. 6(9):304-320.

Naidu, L.G.K., Ramamurthy, V., Challa, O., Rajendra, H. and Krishnan, P. (2006). Manual Soil-Site Suitability Criteria for Major Crops. National Bureau of Soil Survey and Land Use Planning (ICAR) No.129, NBSS & LUP, Nagpur, pp 1-8.

NEDECO, (Netherlands Dev. Company) (1974). Kano River Irrigation Project (KRIP) Main Report. Part VIII. Ministry of Agriculture and Natural Resources, Kano, Nigeria.

Njar, G.N., Iwara, A.I., Egbe, M., Offiong, R.A. and Essoka, P.A. (2012). An Evaluation of Soil Suitability for Maize Production in Obiaruku Community in Nigeria.*British Journal of Advance Academic Research*, 1(1): 16-27.

Noma, S.S., Tanko, I.I, Yakubu, M. Dikko, A.U., Abdullahi.A.A and Audu, M. (2011).Variability in the physico-chemical properties of the soils of Dundaye District, Sokoto State, Nigeria.In Hassan, W.A. Kyiogom, U.B. Tukur, H.M. Ipinjolu, J.K. Maigandi, S.A. Singh, A., Ibrahim, N.D., Dikko, A.U., Bashir, Y.A. and Muhammad, N. (Eds). Mobilizing Agricultural Research Towards Attaining Food Security And Industrial Growth in Nigeria. *Proceedings of the 45th annual conferences of the Agricultural*

Society of Nigeria held at the Faculty of Agriculture, UsmanuDanfodiyo University Sokoto, Nigeria, 24th to 28th Oct.

Nurmiaty and Sumbangan B. (2013) Spatial Based Assessment of Land Suitability and Availability for Maize (*Zea mays* L.)Development in Maros Region, South Sulawesi, Indonesia.*Open Journal of Soil Science*, Vol. 3, 244-251.

Odunze, A.C. (2006). Soil properties and management strategies for some sub humid savanna zoneAlfisols in Kaduna State, Nigeria. *Samaru Journal of Agricultural Resource*. 22:3-14.

Odunze A.C. and Kureh, I. (2009).Land Use limitations and management option for a Savanna Zone Alfisol.*Journal of Agriculture and Environment for International Development*.103 (4): 321-335.

Ofor, M.O Ibeawuchi, I.I and Oparaeke A.M. (2009).Crop Protection Problems in Production of Maize and Guinea Corn in Northern Guinea Savanna of Nigeria and Control Measures.*Nature and Science*; 7(11):80-82.

Ogban, P.I., Akwue, I.P. and Maduako, O. (1999).Properties and Management of Catenary Soils on coastal plain sands in South-Eastern Nigeria.*In:* Babalola, O., Omoti, U. and Isenmila, A.E. (eds), *Management Of The Soil Resources Of Nigeria For Sustainable Agricultural Production in the 21st century*, pp. 45-61.Proceeding of the 25th Annual Conference of Soil Science Society of Nigeria, held at Precious Palm Royal Hotel, Benin city, Edo State, Nigeria. 21st – 29th Nov. 1999.

Oguntoyinbo, J. (1983). Geography of Nigerian Development.Heinemann.

Ogunkunle, A.O. (2004). Soil survey and sustainable land management. Proceedings of the 29th Annual Conference of the Soil Science Society of Nigeria, 2004, Dec. 6-10. University of Agriculture, Abeokuta, Nigeria, pp: 12-16.

Ogunwale J. A. Olaniyan J. O and. Aduloju M.O (2009) Suitability evaluation of the University of Ilorin farmland for cowpea.*Crop Res.* 37 (1, 2 & 3): 34-39.

Ogunwole, J.O., Bello, A.L. and Owonubi, J.J. (2004). Environmental characterization of cereals producing areas of Nigeria. In: Idem, N.U.A. and Showemimo, F.A. (eds.). Cereal crops of Nigeria. *Principles of Production and Utilization*, pp. 16- 37.xxii, 337. Ade Commercial Press, Zaria.

Ogunwole, J.A. (2008). Soil Aggregate Characteristic and Organic Carbon after 45 Annual Application of Manual and Organic Fertilizer.*Biology, Agriculture and Horticulture*, Vol. 25:223-233

Olaleye, A.O., Ogunkunle, A.O., Sahrawt, K.L and Singh, B.N. (2002). "Characterization of some benchmark wetland soil in Nigeria for Rice Cultivation". Communication in Soil Science and Plant Annual (USA). 32(1&2), 189-208.

Olowu, J. (1967). Preliminary Investigation of the groundwater conditions in Zaria. Sheet 1462 SW Report 1462, Geological Survey of Nigeria, Zaria Nigeria.

Oluwatosin, G.A. (2005) Land Suitability Assessment in Continental Grits of Northwestern Nigeria for Rainfed Crop Production. *West African Journal of Applied Ecology*, 7: 53 – 67.

Omar, G. (2011). Assessment of the Fertility Status of some Irrigated Fluvisols in Northern Guinea Savannah of Nigeria.*Savannah Journal of Agriculture*, 6(1):19-31.

Osundare, F.O. (2013). Socio-economic study of maize farmers under different production technologies in southwestern Nigeria", 2013.

Otomi, E. L. (2010) *Land Use along the Course of River Ethiope in Abraka, Delta State.*Unpublished M.Sc. Thesis, Delta State University, Abraka.

Owonubi, J.J., Abdulmumin, S., Malgwi, W.B. and Muazu, S. (1991). Review of soil water balance studies in the Sudano-Sahelian Zone. Proceedings of the Niamey workshop. IAHS Publ. No. 199. M.V.K. Sivakumar, J.S. Wallace, C. Renard and C. Giroux (eds.). 18-23 Feb. ICRISAT, Niamey, Niger.

Oyekale, A.S. (2008). Land degradation, soil conservation practices and poverty incidences in southwestern Nigeria".*Agricultural Journal*, 3(6):482-487.

Oyinlola, E.Y. and Chude, V.O. (2010). Status of Available Micronutrients of The Basement Complex Rock – Derived Alfisols In Northern Nigeria Savanna. *Tropical and Subtropical Agroecosystems*, 12: 229 – 237.

Papenfus, H.D., and Quin, F.M., (1984). Tobacco.In the physiology of tropical field crops. Edited by Goldsworthy, P.R., and Fisher, N.M., Wiley, J. $ Sons.,Chichester, U,K,. pp.607-636.

Pareta K and Jain C. K. (2010). Land Suitability Analysis for Agricultural Crops using Multi-Criteria Decision Making and GIS Approach (2010) http://agropedia.iitk.ac.in/sites/default/files/Land%20Suitability%20Analysis%20for%20Agricultural%20Crops.pdf.

Patil, V.C., Ajit, M., Shashidhara, G.B. and Shanwad, U.K. (2005).*Remote Sensing, Geographical Information System and Precision Farming in India: Opportunities and Challenges.* Department of Agronomy, University of Agricultural Sciences, Dharwad, India.

Perveen, F., Nagasawa, R., Uddin, I. and Delowar H.K.M. (2012), “Crop – land suitability analysis using a multicriteria evaluation and GIS approach”, available at: http://www.digitalearthisde.org/cms/upload/Paper%20and%20Abstract/Perveen.pdf (accessed 12/12/2015).

Petja BM, Nesamvuni E & Nkoana A 2014: Using geospatial information technology for rural agricultural development planning in the Nebo Plateau, South Africa. *Journal of Agricultural Science*, 6(4), 10-18.

Raji, B.A., Esu, I.E., Chude, V.O., Owonubi, J.J. and Kparmwang, T. (1996). Profiles, Classification and Management Implication of Soils of Illela Sand Dunes, NW Nigeria.*Journal of Science Food Agriculture,* 71:425-432.

Raji, B.A. (1995). *Pedogenesis of ancient dune soils in the Sokoto sedimentary basin, NW Nigeria*. Unpublished Ph.D. Thesis. Dept. of Soil Science, ABU, Zaria.

Raji, A.O. (1999): Discrete Element Modeling of the Deformation of Bulk Agriculture Particulates. Unpublished Ph.D Thesis, University of Newcastle-upon-Tyne.

Ramsay, D.M. and de Leeuw, P.N. (1966).Analysis of Nigeria Savanna IV. Ordination of vegetation development on different parent materials. *J. Ecol*. 53:661-677.

Rhoades, J.D. (1982).). Cation-exchange capacity. In: A.L. page (ed). Methods of soil analysis. Part 2: Chemical and microbiology properties (2nd ed.) Agronomy 9:149-157.

Rossiter, D.G., (1994). Land Evaluation, Cornell University, College of Agriculture and Life Sciences, Department of Soil, Crop and Atmospheric Sciences.

Saaty, T.L., (1977). A scaling method for priorities in hierarchical structures.*Journal of Mathematical Psychology* 15, 231 281.

Saaty, T.L. (1980). The analytic hierarchy process: McGraw Hill International., New York.

Saaty, T.L., and Vargas, L.G. (1991) Prediction, Projection and Forecasting. Dordrecht, Kluwer Academic.

Satty, T.L.and. Vargas, L.G., (2001) “Models, methods, concepts and applications of analytical hierarchy process”. *International Series inOperations Research and Management Sciences*.Boston/ Dodrecht/ London, Kluwer Academic Publishers.

Salam, M.A & Rahman H (2007).*Application of Geospatial Technology for Land Evaluation andSuitability Analysis for Aman Rice Crops in Bangladesh*. Bangladesh Space Research and Remote Sensing Organization (SPARRSO) Agargaon, Sher-e-Bangla Nagar, Dhaka-1207, Bangladesh.

Sehgal, J. (1999). Pedology: Concept and Applications. Kalyanipublishers.Lodhiana, India.

Senjobi, B.A. (2007) Comparative assessment of the effect of landuse and landtype on soil degradation and productivity in Ogun State, Nigeria", 2007. Unpublished Ph.D Thesis submitted to the Department of Agronomy, University of Ibadan, Nigeria.

Sharu, M., Yakubu, M. and Tsafe, A.I. (2013). Characterization and Classification of Soils on an Agricultural landscape in Dingyadi District, Sokoto State, Nigeria. *Nigerian Journal of Basic and Applied Sciences*, 21 (2), 137 -147.

Shobayo, A.B. (2010). *A Lithosequence Of Soils Developed On Basement Complex Rocks Of Zaria, The Northern Guinea Savanna, Nigeria*. Unpublished M.Sc., Thesis. Department of Soil Science, ABU, Zaria.

Singh, B. T., Nandini D. K., Bijen K. Y., Bishworjit N., Nongdren K. S. L. and Herojit S. A., (2013).Characterization, and Evaluation for Crop Suitability in Lateritic Soils. *African Journal of Agricultural Research* vol. 8(37) pp 4628-4636. doi:10.5897/AJAR12013.7309. Retrieve from http://www.academicjournals.org/AJAR.

Soil Survey Staff.(1972). Soil Taxonomy.U.S. Dept. Agric. Handbook 436. U.S. Govt. Printing Office, Washington D.C.

Soil Survey Staff.(1981). Keys to Soil Taxonomy, 8th edition.USDA Natural Resource Conservation Service, U.S. Government Printing Office, Washington DC.

Sombroek, W.G. and Zonneveld, I.S. (1971).*Ancient Dune fields and Fluviatile Deposits in Rima-Sokoto River Basin NW. Nigeria.*Soil Survey Paper No. 5. Soil Survey Inst. Wageningen, The Netherlands, pp. 109.

Steven, C., (1998).Managers/Management of soil erosion. In: Management Practices for Maintaining soil Productivity in the douglas-firregion (Ed) Sam D. Angima and Thomas A. Terry. In Best.Oregon State University.Extension service.

Sys C, Vanranst E. and Debvay J. (1991).*Land Evaluation*. Part: III. General Administration for Development Cooperation Agriculture, Brussels, Belgium. pp: 199.

Sys, C., Van Ranst, E., Debaveye, J. and Beernaert, F. (1993).*Land evaluation, Part 3: Crop requirements.*Agricultural Publications 7.General Administration for Development Cooperation, Brussels.

Teshome Y., Kibret T, Gebrekidan H and Beyene S. (2013) Physical Land Suitability Evaluation for Rainfed Production of Cotton, Maize, Upland Rice and Sorghum in Abobo Area, western Ethiopia *American Journal of Research Communication* 1(10): 296-318www.usa-journals.com ISSN: 2325-4076.

Tokarski, A. (1972). Heterogeneous terrace arrangement West of ABU, Zaria.Occassional paper, No. 2. Dept. Geol., ABU, Zaria.26pp 1 Map.

Tinguely U. (2012). Suitability Mapping for *Jatropha curcas* Production in Kenya - A Spatial Modelling Approach. An M.Sc Theses submitted to Institute of Geography, Department of Integrative Geography Faculty of Natural Sciences University of Bern, Switzerland.

Udoh, B. T. and Ogunkunle, A. O. (2012). Land suitability evaluation for maize (Zea mays) cultivated in a humid tropical area of South-eastern Nigeria. Niger. *J. Soil Sci.* 22(1): 1-10.

United States Geological Survey (1998). GIS.https://www.usgs.gov/research/gis/title.html.Retrieved on 14th January, 2016.

Van Ranst E., Tang, H., Groenemans, S. and Sinthurahat, S. (1996), "Application of fuzzy logic to land suitability for rubber production in peninsular Thailand". *Geoderma*, 1: 1-19.

Voncir, N., Mustapha, S. Tenebe, V.A, Kumo, A.L and Kushwaha, S. (2008). Content and profile distribution of extract Zinc (Zn) and some physiological properties of soil along a toposequence at Bauchi, Northern Guinea Savannah of Nigeria International Journal of soil science 3:62-68.Walkley, A. & Black, I. A. (1934) An Examination of the Degtjareff Method for Determining Soil Organic Matter and a Proposed Modification to the Chromic Acid Titration Method. *Soil Science,* 37, 29-38.

Walkley, A. and Black, A. (1934). An examination of Degtjareff Method of Determining Soil Organic Matter and a proposed modification of the chromic acid titration method. Soil Science 37: 29-38.

Wright, J.B. and McCurry, P (1970).Geology of Zaria. In: Mortimore, M.J. (ed), Zaria and its Regions.*Occasional Paper* 4, Department of Geography, A.B.U., Zaria.

Yaro, D.T. (2005). *The Position of Plinthite in a Landscape and its Effects on Soil Properties.* Unpublished Ph.D Thesis.Department of Soil Science, ABU, Zaria, Nigeria.

Yaro, D.T., Kparmwang, T., Raji, B.A. and Chude, V.O. (2006). The extent and properties of plinthite in a landscape at Zaria, Nigeria, *International Journal of Soil Science*, 1(3), pp. 171-183.York. 603 pp.

Zarafi, G.S. (1993). *Morphological, physicochemical and mineralogical properties of hydromophic soils in the Zaria region*. Unpublished M.Sc. Thesis. Department of Soil Science, ABU, Zaria. pp 8-24.

APPENDICE 1: Result of Laboratory Analysis of Soil Samples

S/NO	Clay (%)	Silt (%)	Sand (%)	PH	OM (%)	Ca (mol kg^{-1})	Mg (mol kg^{-1})	K (mg kg^{-1})	Na (mol kg^{-1})	CEC (cmol (+) kg^{-1})	N (g kg^{-1})	P(mg kg^{-1})
1	8	24	68	3.95	0.534	2.1	0.47	0.28	0.37	4.42	0.35	3.34
2	8	24	68	4.36	0.741	5.3	0.84	0.15	0.36	7.25	0.21	4.36
3	8	28	64	4.13	0.862	6.5	1.44	0.14	0.37	9.05	0.14	5.41
4	8	26	66	4.31	0.862	6.9	2.36	0.13	0.43	10.22	0.42	8.31
5	8	24	68	3.87	0.780	2.2	0.38	0.27	0.35	4.70	1.22	7.32
6	6	38	56	4.54	0.690	1.8	0.42	0.17	0.31	3.10	1.17	5.35
7	8	24	68	3.97	1.431	2.1	0.48	0.29	0.38	4.45	0.53	9.22
8	8	22	70	3.70	0.914	5.3	0.64	0.23	0.32	7.49	0.12	8.35
9	6	22	72	3.99	1.621	5.8	0.78	0.13	0.34	7.85	0.37	11.29
10	8	24	68	4.36	0.861	5.3	0.84	0.15	0.36	7.25	1.36	10.37
11	8	26	66	3.54	0.742	5.4	1.06	0.11	0.37	7.94	1.42	11.23
12	8	16	76	4.57	1.700	1.4	0.37	0.12	0.24	2.73	0.59	9.36
13	8	26	66	3.54	0.924	5.4	1.06	0.11	0.37	7.94	0.45	10.34
14	8	16	66	4.31	1.863	6.9	2.36	0.13	0.43	10.22	1.22	9.41
15	8	26	76	4.57	0.874	1.4	0.37	0.12	0.24	2.73	0.22	12.38
16	8	24	66	4.54	0.741	5.4	1.06	0.11	0.37	7.94	1.34	10.22
17	8	22	70	3.70	0.534	5.3	0.64	0.23	0.32	7.49	0.37	12.29
18	6	24	72	3.99	1.321	5.8	0.78	0.13	0.34	7.85	0.11	15.32
19	8	24	68	3.97	1.401	2.1	0.48	0.29	0.38	4.05	0.42	13.31
20	6	38	56	5.54	1.433	1.8	0.42	0.12	0.31	3.50	0.31	10.34

APPENDICE 11: Coordinates of Location

Location	Latitude	Longitude
Point 1	11.17225	7.6602
Point 6	11.17225	7.6617
Point 10	11.17226	7.6621
Point 13	11.17204	7.6607
Point 18	11.17205	7.6617
Point 21	11.17183	7.6602
Point 25	11.17162	7.6607
Point 30	11.17184	7.6621
Point 33	11.17162	7.6607
Point 37	11.17163	7.6615
Point 41	11.17141	7.6602
Point 45	11.17142	7.6611
Point 50	11.17142	7.6621
Point 54	11.17121	7.6609
Point 57	11.17121	7.6615
Point 61	11.171	7.6602
Point 66	11.171	7.6613
Point 70	11.17101	7.6621
Point 74	11.17079	7.6609
Point 78	11.1708	7.6617

APPENDICE 111

RATING FOR SOIL DATA INTERPRETATION

1. Soil Reaction

Extremely acid	< 4.5
Very strongly acid	4.5 - 5.0
Strongly acid	5.1 - 5.5
Moderately acid	5.6 - 6.0
Slightly acid	6.1 - 6.5
Neutral	6.6 - 7.3
Slightly alkaline	7.4 - 7.8
Moderately alkaline	7.9 - 8.4
Strongly alkaline	8.5 - 9.0
Very strongly alkaline	> 9.0

2. Organic Matter (gkg-1)

Low	< 10
Medium	10 – 15
High	> 15

3. Nitrogen (gkg-1)

Low	< 1.5
Medium	1.5 – 2.0
High	> 2.0

4. Phosphorus (mgkg-1)

Low	0 – 10
Medium	10 – 20
High	> 20

5. Exchangeable Cation [cmol(+)kg-1]	Ca	Mg	K	Na
Low	0 – 2	0 – 0.3	0 – 0.15	0 – 0.1
Medium	2 – 5	0.3 – 1.0	0.15 - 0.30	0.1 – 0.3
High	> 5	> 1.0	> 0.30	

6. Cation Exchange Capacity [cmol(+)kg-1]	**NH4OAc**	**ECEC**
Low	< 6	< 4
Medium	6 – 12	4 – 10
High	> 12	> 10

Source: Malgwi (2007) Soil survey manual.