An application of GIS and remote sensing for land use evaluation and suitability mapping for yam, cassava, and rice in the Lower River Benue Basin, Nigeria

by

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submitted in accordance with the requirements
for the degree of

DOCTOR OF PHILOSOPHY

in the subject

ENVIRONMENTAL MANAGEMENT

at the

UNIVERSITY OF SOUTH AFRICA

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APRIL 2016

DECLARATION

Student number: 51223759

I declare that **An application of GIS and remote sensing for land use evaluation and suitability mapping for yam, cassava, and rice in the Lower River Benue Basin, Nigeria** is my own work and that all the sources that I have used or quoted have been indicated and acknowledged by means of complete references.

_________________________ **_4/4/2016**___________________

SIGNATURE DATE

DEDICATION

I dedicate this research work to my children Jeffrey, Vania, Zilla and David.

ACKNOWLEDGEMENTS

I would like to express my sincere gratitude to the following individuals and organisations for their assistance and support towards the completion of this study:

- Firstly, I am most grateful to Almighty God for his gift of life and knowledge.
- I wish to recognise Dr B.M. Petja my supervisor, for nurturing me from the beginning of this study to completion. His wealth of experience is immensely reflected in this study. I remain forever grateful.
- I also owe a lot of thanks to my parents Prof. and late Mrs. Clement Abah for their love and understanding from the beginning of this study to the end.
- Special thanks to my wife Ann Abah and my children Jeffrey, Vania, Zilla and David for their love, patience, and encouragement throughout the duration of this study.
- I am grateful to my siblings John, Emmanuel, Angela, and Charles for their support.
- I recognise the support of Prof. John Idoko, Martha Van Wyk (UNISA), Biodun Alabi (NACA), Olarenwaju Temitope Christiana, Ibelema Jaja, Engr. Addi Shuaib (NIHSA), Maimuna Borno (NIMET), Dr. Sabastine Wakdok (NACA), Mr. Henry Umaru (NACA), Mr. Adejoh M. Agude (Office of the Surveyor General), and George Songu (iLEAD).
- Finally, I remain grateful to all those from the communities I visited and those too numerous to mention who, in one way or another, contributed to this study.

ABSTRACT

Agricultural production has contributed over time to food security and rural economic development in developing countries particularly supporting the countryside. Evidence show that crop yields are declining in the Lower River Benue Basin of Nigeria. This study conducted a land use evaluation and suitability mapping for production of yam, cassava and also assessed the possible socioeconomic impediments that may hinder or enhance sustainable agricultural development in the Lower River Benue Basin. The study adopted physical assessments and socioeconomic approach coupled with mapping which incorporated processing of satellite imagery. Statistical methods were used to measure the status, trends, level of dispersion, and relationships between the variables of physical and socioeconomic parameters. Modelling techniques for determining potential impacts assessment, agricultural suitability index, adaptive capacity index, finally producing suitability maps. Geo-informatics processes were used to produce a digital elevation model, land use and land cover map, and normalised difference vegetation index map. The results were thematic maps, weighted percentages of attribute data, and suitability maps produced through weighted overlay. An intensive analysis of climatological data depicted a progressive intensity of rainfall, and a decreasing trend in the number of rain days; a gradual temperature rise; and high relative humidity during the planting season which is about 168 days. Laboratory analysis show that soils in the study area require fertility enhancement with inorganic fertilisers to encourage better crop yield. Results show that the Lower River Benue Basin is suitable for yam, cassava, and rice cultivation as classified on maps of suitable areas. Rice had the highest suitability percentages (38.30%). The study area was found to be moderately suitable for each of the crops examined by more than 40% for each crop. Cassava had the least suitability percentages (34.47%). Evidence suggests that agricultural development in the Lower River Benue Basin is under threat from potential impacts of climate variability and change, population growth, and infectious diseases. The agricultural suitability index of the study area regards the study area as suitable (70.5%) and the adaptive capacity index of the study area was moderate (50.83%), but it was found that serious attention need to be given to farm technology and infrastructure. Mitigation strategies and recommendations which are beneficial to the sustainable development of agriculture have been provided in line with the established characteristics of the Lower River Benue Basin.

KEYWORDS

Geo-informatics; agricultural development; socioeconomics; agricultural suitability mapping; River Benue Basin; agricultural suitability index; adaptive capacity index

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AAS	: Atomic Absorption Spectrophotometry
AEZ	: Agro-Ecological Zoning
AIDS	: Acquired Immunodeficiency Syndrome
ARCN	: Agricultural Research Council of Nigeria
ASI	: Agricultural Suitability Index
ASTER	: Advanced Spaceborne Thermal Emission and Reflection Radiometer
ATA	: Agricultural Transformation Agenda
DEM	: Digital Elevation Model
DFID	: United Kingdom Department for International Development
EDTA	: Complexometric titration technique
ESP	: Exchangeable sodium percentage
ESRI	: Environmental Systems Research Institute
FAO	: Food and Agricultural Organisation
FGD	: Focus group discussion
FGN	: Federal Government of Nigeria

FMARD	: Federal Ministry of Agriculture and Rural Development
FMOH	: Federal Ministry of Health
FPDD	: Fertilizer Procurement and Distribution Division
FSW	: Female sex workers
GDP	: Gross Domestic Product
GeoSFM	: Geospatial Stream Flow Model
GIS	: Geographic Information System
GLCF	: Global land cover facility
GPS	: Global Positioning System
HCl	: Hydrogen Chloride
HIV	: Human Immunodeficiency Virus
HNO_3	: Nitric acid
IITA	: International Institute of Tropical Agriculture
ILO	: International Labour Organisation
ILWIS	: Land and Water Information System software
IPCC	: Intergovernmental Panel on Climate Change
ISO	: International Standard Organisation
LGA	: Local Government Area
MSM	: Men who have sex with men
NACA	: National Agency for the Control of AIDS, Nigeria
NBS	: National Bureau of Statistics
NDVI	: Normalised Difference Vegetative Index
NIFA	: National Institute of Food and Agriculture
NIHSA	: Nigerian Hydrological Services Agency
NIMET	: Nigerian Meteorological Agency
NIWA	: Nigeria Inland Waterways Authority
NOA/IOM	: National Academy of Science/Institute of Medicine
NPC	: National Population Commission

OSGF	: Office of the Surveyor General for the Federation
RI	: Reoccurrence Interval
SAI	: Standardised Anomaly Index
SAR	: Sodium Adsorption Ratio
SPSS	: Statistical Package for Social Sciences
SRP	: Seasonal Rainfall Prediction Report
SWAT	: Soil and Water Assessment Tool
UNEP	: United Nations Environmental Programme
UNISA	: University of South Africa
USDA	: United States Department of Agriculture

CHAPTER ONE

INTRODUCTION

1.0 Introduction

Around ten to twelve thousand years ago, the human race began to domesticate plants and animals for food (Rosenberg, 2012). Before this first agricultural revolution, people mostly relied on hunting and gathering to obtain food supplies. Even though there are still groups of hunters and gatherers in the world today, most societies have switched to agriculture (Rosenberg, 2012). Rosenberg (2012) stipulated that the beginning of agriculture did not just occur in one place but appeared almost simultaneously around the world, possibly through trial and error with different plants and animals or by long term experimentation. Mabuza *et al*. (2008) defined agriculture as the cultivation of land, raising and rearing of animals for the purpose of production of food for man, animals and industries. Agriculture involves and comprises crop production, livestock and forestry, fishery, processing and marketing of agricultural production.

According to Rosenberg (2012), farming in the twentieth century became highly technological in more developed nations while less developed nations continued with practices which are similar to those developed after the first agricultural revolution, thousands of years ago. About 45% of the world's population rely on agriculture for their livelihood. The global population involved in agriculture ranges from about 2% in the United States to about 80% in some parts of Asia and Africa. There are two types of agriculture, subsistence and commercial. The majority of the world’s population is involved in agricultural practice and subsistence agriculture to tend to their need for food (Aliber and Hart, 2009). Subsistence agriculture could potentially contribute to household food security and livelihoods with well-developed support systems, hence the need for technological advancement in agriculture (Aliber and Hart, 2009).

Okuneye and Adebayo (2002) described agricultural development in Nigeria as slow in spite of the various agricultural policies over the years. Deliberate actions by the Government of Nigeria towards stimulating development in the agricultural sector can be traced back to the 1970s. The near eclipse of the sector in the era of the oil boom (1972–1975) and inconsistent government policies (Okuneye and Adebayo, 2002; Adebayo *et al*., 2009) have been cited as the main challenges to food security in Nigeria. In order to empower people with adequate food security, which is the goal of agricultural systems, efforts should be put into identifying, implementing, and promoting policy programs and investments both at private and public-sector levels. These, according to Adebayo *et al*. (2009), prompted the Government of Nigeria to put in place several such programs and policies over the years. These according to Adebayo *et al*. (2009), include cooperative schemes, farm settlement scheme, integrated agricultural development programmes (1970s), Operation Feed the Nation (1977), rural banking scheme (1977), land use decree (1978), green revolution programme (1980), directorate of foods, roads and rural infrastructure (1986), better life programme (1987), national directorate of employment (1986), Nigeria Agricultural Cooperative Bank, Nigeria Agricultural Land Development Agency (1991), Family Support Programme (1994), family economic advancement programme (1997), People’s Bank of Nigeria (1989), national fadama development programmes (1999), root and tuber expansion programme (2000), the Presidential Initiatives (2001), national economic empowerment and development strategy (2004), the seven point agenda (2007), and the agricultural transformation agenda (2011).

There are two key sustainable development plans of the present Government of Nigeria. The Vision 20:20:20 agenda (NPC, 2009) which seeks to put Nigeria among the first twenty developed nations by the year 2020 and the Transformation Agenda (NPC, 2011) which has short term sector specific strategic goals towards attaining Vision 20:20:20. These plans show signs of promise with well-articulated sustainability plans. However, they may require legislative backing to outlive the present government. Notwithstanding, the need for effective agricultural land use planning cannot be overemphasised. Hence, this study used agricultural land use evaluation and suitability mapping to derive areas of suitability for yam, cassava, and rice to enhance agricultural planning in the Lower River Benue Basin.

1.1 Statement of the problem

The sustainability of agricultural production systems has become a major concern of agricultural researchers and policy makers in both developed and developing countries (Rossiter, 1995; Medugu, 2006; IITA, 2008; Alademerin and Adedeji, 2010). In order to achieve an effective sustainable plan for the development of agriculture, it is important to determine the potential that exists through land evaluation and land use planning. Land evaluation is the assessment of land suitability when used for a specified purpose, involving the execution and interpretation of surveys and studies of landforms, soils, vegetation, climate and other aspects of land in order to identify and make a comparison of promising kinds of land use in terms applicable to the objectives of the evaluation (FAO, 1976).

Land evaluation has received the attention of several scholars in Nigeria (Mbajiorgu and Anyadika, 1997; Akinbol *et al.*, 2008; Babalola *et al.*, 2011). However, very few land evaluation studies have been carried out in the Lower River Benue Basin (Uchua and Nduke, 2011; Uchua *et al.*, 2012). These studies (Uchua and Nduke, 2011; Uchua *et al.*, 2012) utilised GIS and Remote Sensing in mapping agricultural systems associated aspects in the Lower River Benue Basin.

Contemporary factors such as climate variability, population growth, HIV and AIDS and related diseases, rural-urban migration, and availability of hybrid species influence agriculture's contributions to economic growth in Nigeria (Anthony, 2010). These factors have not received adequate attention in land evaluation studies in Nigeria. This is a gap in such research.

Most of the agricultural produce in Nigeria comes from available wetlands (Babalola *et al*., 2011). The Lower River Benue Basin is regarded as the food basket of Nigeria because of its importance in the production of staple foods for the country. Thus, its sustainability is essential to the socioeconomic development of the country (Uchua and Nduke, 2011; Abah, 2012). In recent years, a gradual reduction of agricultural produce has been observed through the reduction in supply chain to some processing plants in Benue (Shabu *et al*., 2011). The recession of the Lower River Benue has led to some adverse ecological changes and decline of agricultural production in the face of rapid population growth in the area (Uchua *et al*., 2012). The rate of rural-urban migration in communities located in the Lower River Benue Basin is significant enough to affect agricultural production. Internal migration in Nigeria is induced by scarcity of land, impoverished soil, declining crop yields, poor harvests and soil erosion, among others (Anyanwu, 1991). Migration is also known to increase the rate of HIV transmission and may limit access to treatment and care (Habib and Jumare, 2008). The rate of HIV prevalence in the Lower River Benue Basin was 12.7% in 2010, which was the highest in Nigeria (FMOH, 2010). It is therefore important for land evaluation studies in the Lower River Benue Basin to assess these challenges adequately alongside other socioeconomic and biophysical characteristics. This would provide policy makers with more far-reaching recommendations to plan the sustainable development of agriculture in the Lower River Benue Basin.

This study was a land use evaluation of the Lower River Benue Basin based on climatic, terrain, and socioeconomic characteristics and suitability mapping for rice, yam, and cassava. The findings present the holistic agricultural potential of the basin and specific details for enhancing yam, cassava and rice cultivation to guide policy makers in strategic planning for sustainable agricultural development. The findings of this study have far reaching implications for adaptation to climate variability and forecasting the trends of yam, cassava, and rice production in the Lower River Benue Basin.

This study aims to fill gaps in land evaluation of the Lower River Benue Basin by demonstrating the importance of assessing socioeconomic attributes alongside biophysical attributes as advised by the FAO, and also in addition, issues on climate variability, population growth and HIV and AIDS in modelling for land evaluation and crop suitability mapping for agricultural purposes.

1.2 Rationale for the study

There is currently limited literature on land use planning for crop cultivation in the Lower River Benue Basin for strategic planning towards sustainable agricultural development. Available literature contains inadequate information on the use of GIS and Remote Sensing in land evaluation specifically for crop farming. This study, therefore, contributes contemporary information on the suitability of the biophysical and socioeconomic characteristics of Lower River Benue Basin for the cultivation of yam, cassava, and rice.

The study utilised various methods including geospatial techniques and the Food and Agricultural Organisation (FAO) framework as a guide. The findings in this study could be invaluable to policy makers, agricultural planners, farmers, and communities in the Lower River

Benue Basin. The study contributes contemporary information of relevance towards the planning of sustainable agricultural programmes and specifically for improvements in the cultivation of rice, yam and cassava in the Lower River Benue Basin.

The integration of biophysical and socioeconomic data in planning sustainable agricultural programmes brings into light the anthropogenic issues which affect the sustainability of agricultural development. The use of socioeconomic data alongside biophysical data revealed development gaps which are critical for the optimal use of the environment while minimising the potential threats to livelihoods and sustainable development of agriculture.

1.3 Aim and objectives of the study

The study aimed at determining the suitability of rice, yam and cassava as arable crops in the Lower River Benue Basin. This will help relevant policy makers to plan for the sustainable development of agriculture in the Lower River Benue Basin. In realising the above aim, the study had the following specific objectives:

1. To characterise trends of climatic variability and assess its impact on the changing patterns for crop production in the Lower River Benue Basin.
2. To integrate land use, climate, hydrological and soils data for developing and mapping crop suitability potential for yam, cassava, and rice in the Lower River Benue Basin.
3. To determine the influence of biophysical and socioeconomic factors on agricultural production in the Lower River Benue Basin and assess their role as possible impediments in light of the changing climate.

4. To identify impact mitigating strategies for socioeconomic adaptation to stress factors (climate variability, rural-urban migration, population growth, and HIV and AIDS) that may hinder agricultural development in the Lower River Benue Basin.

1.3.1 Study hypotheses

Achieving the objectives of the study required the use of various research methods which sought to address the following hypotheses:

I. Climatic factors in the Lower River Benue Basin are suitable for the cultivation of rice, cassava, and yam.

II. Soils in the Lower River Benue Basin are suitable for the cultivation of rice, cassava, and yam.

III. Remote sensing and GIS tools can be used to improve the outcome of crop suitability mapping.

IV. Socioeconomic parameters can enhance outcomes of land use evaluation for agriculture.

V. Climate variability, population growth, and HIV and AIDS can negatively impact agricultural development in the Lower River Benue Basin.

1.4 Study area

1.4.1 Geographical location

The area of study is located in the West African country of Nigeria. It is located in the North Central region of Nigeria between Latitudes 7^o 13’N and 8^o00’N and Longitudes 8^o00’E and 9^o00’E (Figure 1.1) with a basin area of about 77, 379.32km^2 and a population figure of 1, 356, 225 people (FGN, 2007). Most parts of the Lower River Benue Basin fall within the boundaries of Benue State. There are thirteen Local Government Areas (Makurdi, Gboko, Tarka, Gwer west, Gwer east, Guma, Buruku, Otukpo, Agatu, Ushongo, Ohimini, Obi, and Konshisha) covered either in whole or in part by the study area (Figure 1.1). Some aspects of this study dealt with Makurdi, Gboko and Tarka in more detail.

1.4.2 Climate and vegetation

According to Ayoade (2004) and Climate-data (2015), the climate of Makurdi and Katsina Ala and Otukpo, which are located within the Lower River Benue Basin, (Figure 1.1) are the tropical wet and dry type, Koppen's Aw classification, with double maxima. The rainy season usually lasts from April to October with an average annual rainfall of 1,332mm (Makurdi), 1,547mm (Katsina Ala), and 1496mm (Otukpo). The rainfall and temperature charts for Makurdi, Katsina Ala and Otukpo are presented in Figures 1.2 to 1.4. The mean annual temperatures range from 27.2°C (Makurdi), 26.9°C (Katsina Ala), and 26.5°C (Otukpo). The average annual humidity of 59.6% and mean monthly sunshine of about 7 hours. The areas have five months of dry season (November – March) and consists of guinea savannah vegetation type with scattered woodland, shrubs and grassland. Precipitation is usually lowest in December, with an average of 0 mm (Makurdi), 5 mm (Katsina Ala), and 6mm (Otukpo). Most precipitation falls in September, with an average of 249 mm (Makurdi), 277mm (Katsina Ala), and 277mm (Otukpo). At an average temperature of 30.0°C (Makurdi), 29.3°C (Katsina Ala) and 28.7°C (Otukpo), March is the hottest month of the year. Temperatures are lowest in July with an average of 25.8°C (Makurdi) and 25.4°C (Katsina Ala). Temperatures are lowest in August in Otukpo with an average of 24.8°C.

1.4.3 Geology and drainage

In terms of geology, the study area is a sedimentary basin that is made up of alluvium, shale, sandstones, siltstones and coastal sand plains, as well as ferruginous soils which can be subdivided on the basis of texture of the surface horizon into hydromorphics, lithosols and laterites (Kogbe, 1989). The land is generally low lying (averaging 100m-250m) and gently undulating (Kogbe, 1989). River Benue is the dominant geographical feature in the state. River Benue rises from the Adamawa Plateau of Central Cameroon, then flows west across Central Nigeria, and joins River Niger as the main drainage feature in the area. It is one of the few large rivers in Nigeria. The Katsina-Ala is the largest tributary of the River Benue, while smaller rivers include Mkomon, Amile, Kpa, Okpokwu, Duru, Loko Konshisha, Ombi Mu, Be, Apa Ogede and Aya. The flood plains of the River Benue are characterised by extensive swamps and ponds which have potential for dry season irrigated farming. Though Benue State has high drainage density, many of the streams are seasonal.

1.4.4 People and economy

The Lower River Benue Basin is described as the Nigeria's "food basket" state because of its rich and diverse agricultural produce which include yam, rice, beans, cassava, potatoes, maize, fruit trees, soya beans, sorghum, millet and cocoyam. It is occupied mainly by the Tiv, Idoma, Etulo, and Jukum ethnic groups. The people of the Lower River Benue Basin are mostly agrarian peasants who engage predominantly in subsistence crop farming. There are, however, a few who practice fishing and livestock farming. Very few industries exist (plastic, soya bean oil, agro allied mill, and brewery) but there is an abundance of small and medium scale enterprises mostly associated with agricultural processing, food, and local textile.

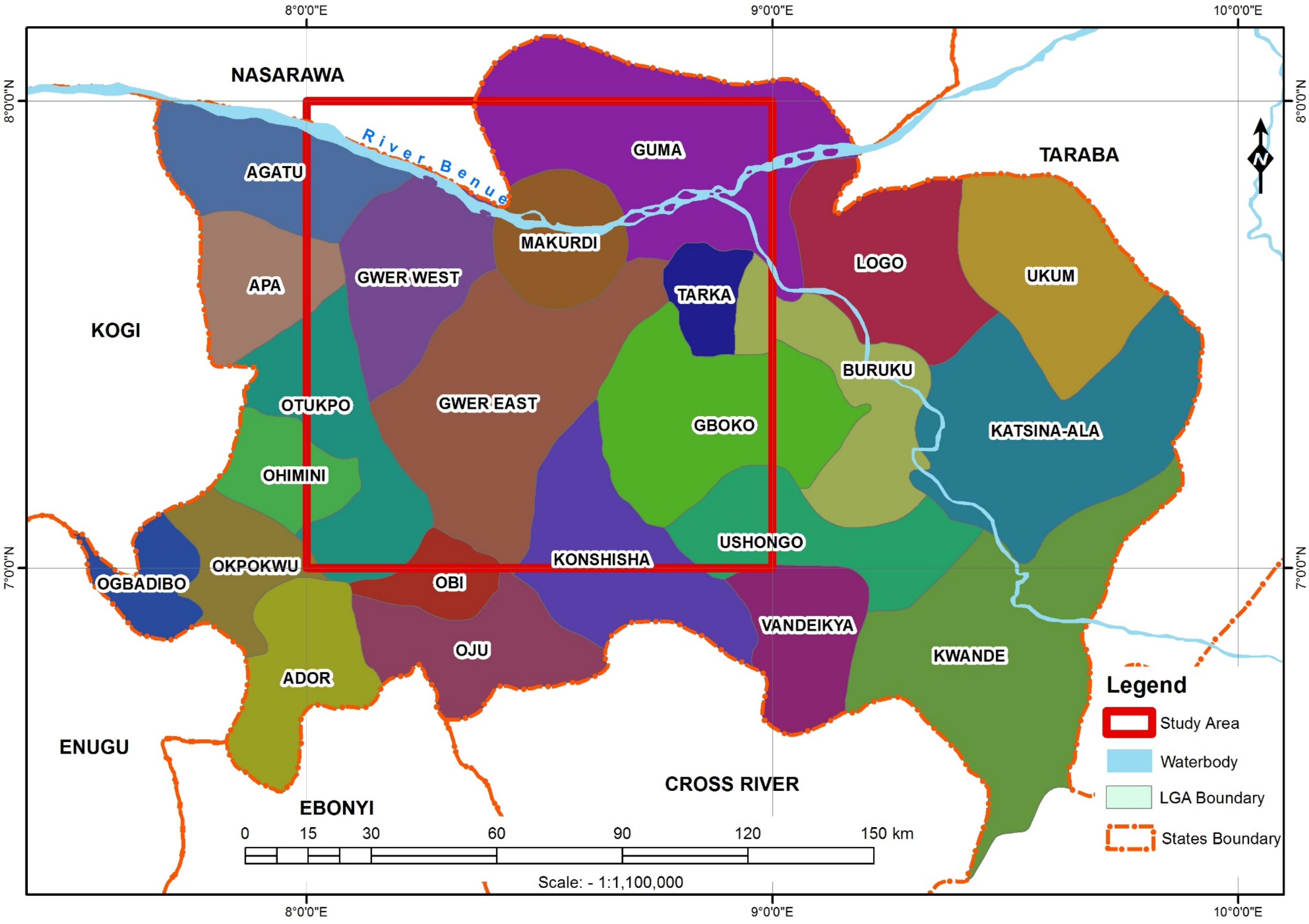

Figure 1.1: Map of study area within the Lower River Benue Basin

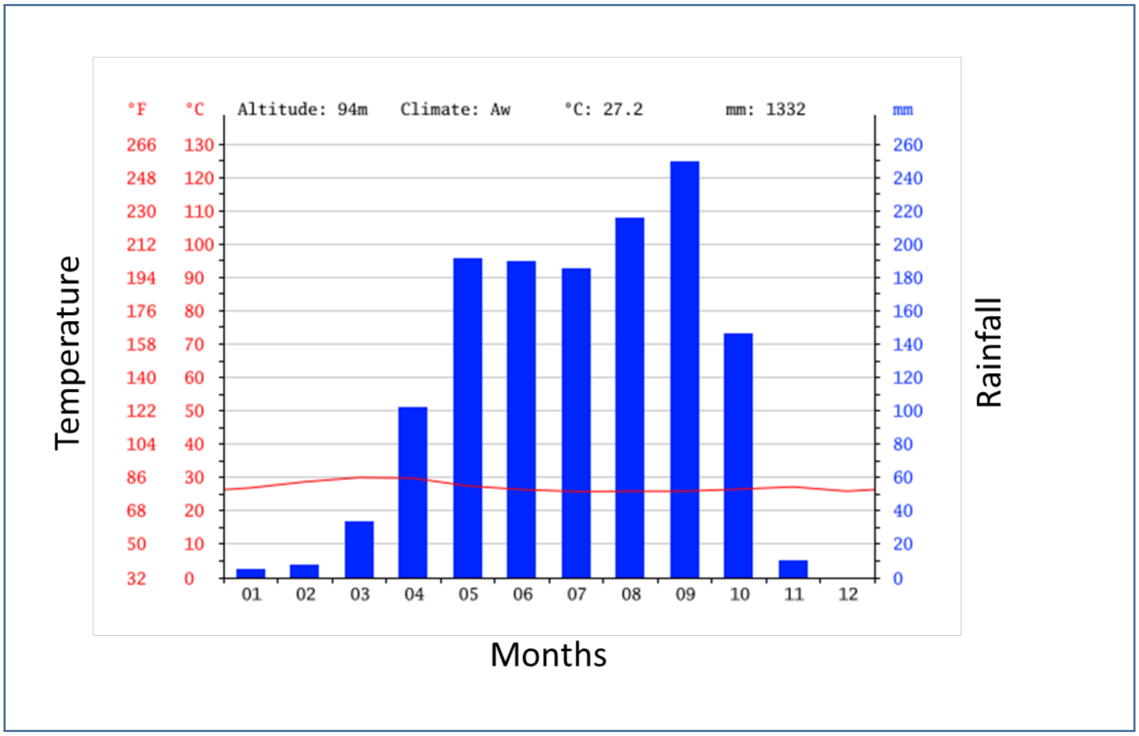

Figure 1.2: Monthly rainfall and temperature in Makurdi in 2015 (Source: Climate-data, 2015)

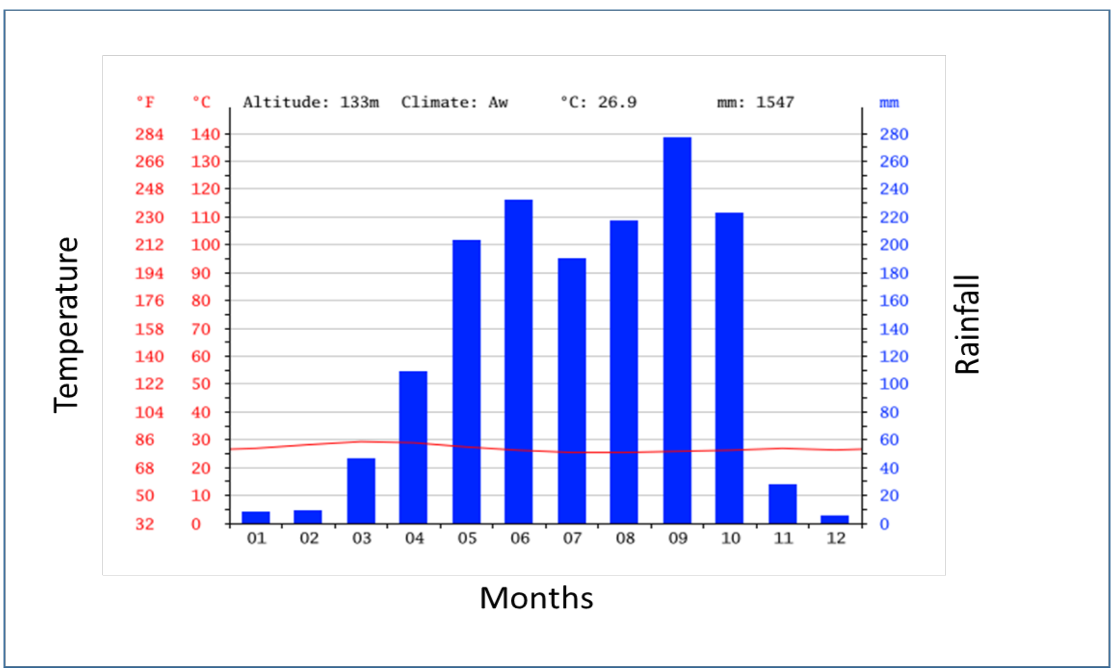

Figure 1.3: Monthly rainfall and temperature in Katsina Ala in 2015 (Source: Climate-data, 2015)

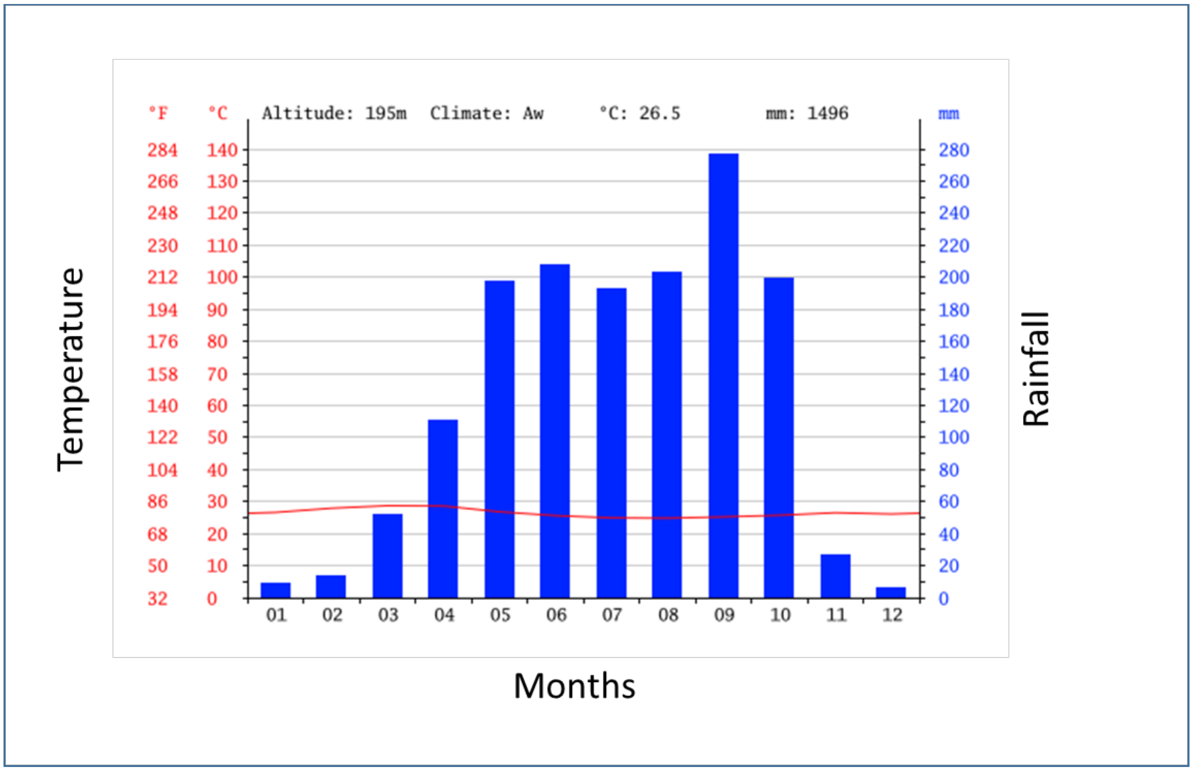

Figure 1.4: Monthly rainfall and temperature in Otukpo in 2015 (Source: Climate-data, 2015)

1.5 Agriculture in Nigeria

Nigeria is the most populous country in Africa, with an estimated population of 162,470,737 inhabitants (World Bank, 2013a). Nigeria's population is divided among 478 different ethnic groups, some numbering fewer than 10,000 people. Of the different ethnic groups, ten (Hausa, Fulani, Yoruba, Ibo, Kanuri, Tiv, Edo, Nupe, Ibibio and Ijaw) account for nearly 80% of the population. Twenty-five percent of the population is in the former Western Region (12% area coverage), 21% in the former Eastern Region (9% area coverage), and 53% in the former Northern Region (79% area coverage).

Prior to the attainment of independence, agriculture was the most important sector of the Nigerian economy, and accounted for more than 50% of GDP and more than 75% of export earnings. Nigerian agricultural holdings are small and scattered, and farming is carried out with simple tools. These small farms produce about 80% of the total food. About 30.7 million hectares (76 million acres), or 33% of Nigeria's land area, are under cultivation (Nations Encyclopaedia, 2013).

According to Federal Ministry of Agriculture and Rural Development - FMARD (2010), crop farming is the dominant agricultural activity in Nigeria: the crop sub-sector contributes about 85% to the agricultural gross domestic product (GDP), whereas livestock contributes about 10%, fisheries about 4%, and forestry about 1%. Root crops (in particular, cassava and yam) dominate in tonnage, though cereals (maize, guinea corn, rice, and millet) are becoming important domestic food items. Root crops account for 9% of GDP, whereas cereals account for 8%.

Nigeria moved from a position of self-sufficiency in basic foodstuffs to one of heavy dependence on imports. Under-investment, a steady drift away from the land to urban areas (cities), increased consumer preference for imported foodstuffs (particularly rice and wheat) and outdated farming techniques continued to keep the level of food production well behind the rate of population growth (Aregheore, 2005).

Ragasa *et al*. (2010) elaborated on the views of Aregheore (2005) stating that Nigeria's agricultural development progressed through three phases namely, pre-1970, 1971–1985, and from 1986 to date. In the pre-1970 phase, private operators dominated production activities in the agriculture sector. The 1971–1985 periods saw a pronounced decline in the share of agriculture value-added in GDP, in part because of the rising dominance of the oil sector, but also because of the extreme uncertainty in policy direction brought about by increased government intervention in the sector.

Presently, there is an Agricultural Research Council of Nigeria (ARCN) in the Federal Ministry of Agriculture and Rural Development (FMARD). There are also fifteen agricultural research institutes under the aegis of the ARCN. The most recent policy of Government on sustainable agriculture is the Agricultural Transformation Agenda (ATA). The ATA focuses on agriculture as a business as opposed to a developmental project which has been the case in the past. The ATA will help achieve the transformation of the agricultural sector to create jobs, wealth and ensure food security; develop value chains where Nigeria has comparative advantage; and it has a sharp focus on youth and women (FMARD, 2010).

According to Okojie (2007), the ATA is especially crucial for the development of women because women make important contributions in the agricultural sector. However, they lack access to land for farming, and they have limited access to agricultural inputs, such as improved seedlings, agricultural extension services, credit, and improved technology. Most of their farming and processing activities are performed using manual labour. This makes farming and food processing very arduous contributing to low output and high wastage.

The International Institute of Tropical Agriculture (IITA, 2008) emphasised that attaining sustainable agricultural systems would require the commitment of policy makers in Nigeria. Policy makers in Nigeria must appreciate the need for a sustainable policy to guarantee the implementation of sustainable agriculture. Medugu (2006) re-echoed the burden of agricultural resources in Nigeria which are located mostly in rural areas and most of them are under the influence of the rural population. Therefore, monitoring the interaction of rural exploitation and production activities in rural areas is important in national development efforts for sustainable agriculture (Medugu 2006).

IITA (2008) explained that the implementation of sustainable agriculture in Nigeria should consider the sustainable livelihoods framework which places emphasis on increasing livelihood assets and improving the capabilities of the rural poor. According to IITA (2008), this approach could lead to improvement in sustainable production through the transfer of agricultural technologies and management practices, improved access to input and commodity markets, and contribute to an enabling policy environment.

As stated by the Agricultural Research Council of Nigeria (ACRN, 2010), a total of 205 agricultural technologies have been produced mostly by agricultural research institutes (Table 1.1). However, proper records are not available to show that the ACRN or the institutes actually monitor the adoption or impact of these technologies. Ragasa *et al*. (2010) stated that 40% of individual researchers did not have any knowledge about the adoption or impact of new varieties or breeds that they have produced, and 20% did not have information about the adoption or use of new management practices or technologies developed.

1.5.1 Crop farming in Nigeria

According to the World Bank (2013b), there are several types of crop farming depending on the type of crops and region. Crop farming is either rain-fed or irrigated. Rain-fed agriculture is predominant in Nigeria while large-scale irrigation projects are few and generally restricted in scope (Rilwani and Gbakeji, 2009). The latest crop production index for Nigeria shows agricultural production for each year relative to the base period 2004-2006. It includes all crops except fodder crops. Regional and income group aggregates for the FAO's production indexes are calculated from the underlying values in US dollars, normalised to the base period 2004-2006 (World Bank, 2011). Figure 1.5 shows the crop production index for Nigeria from 1961 to 2010. The trend shows a decline from 2006.

Table 1.1: Number of technologies produced by research institutes in Nigeria (1997–2008)

S/N	Organisation	Biological Technologies	Mechanical Technologies	Chemical Technologies	Management Technologies
1	Cocoa Research Institute of Nigeria (CRIN)	2	0	0	11
2	Institute for Agricultural Research (IAR)	5	30	0	7
3	Institute of Agricultural Research and Training (IAR&T)	4	1	2	4
4	Lake Chad Research Institute (LCRI)	9	0	0	0
5	National Agricultural Extension and Research Liaison Services (NAERLS)	0	0	0	0
6	National Animal Production Research Institute (NAPRI)	6	4	0	13
7	National Cereals Research Institute (NCRI)	4	0	0	6
8	National Institute for Freshwater Fisheries (NIFFR)	4	4	0	2
9	National Institute for Oil Palm Research (NIFOR)	3	6	5	5
10	National Institute for Horticultural Research (NIHORT)	4	0	1	0
11	Nigerian Institute of Oceanography and Marine Research (NIOMR)	0	0	0	4
12	National Root Crops Research Institute (NRCRI)	9	4	3	7
13	National Stored Products Research Institute (NSPRI)	0	2	0	5
14	National Veterinary Research Institute (NVRI)	4	1	3	0
15	Rubber Research Institute of Nigeria (RRIN)	4	4	5	8
	Total	**58**	**56**	**19**	**72**

Source: ARCN (2010).

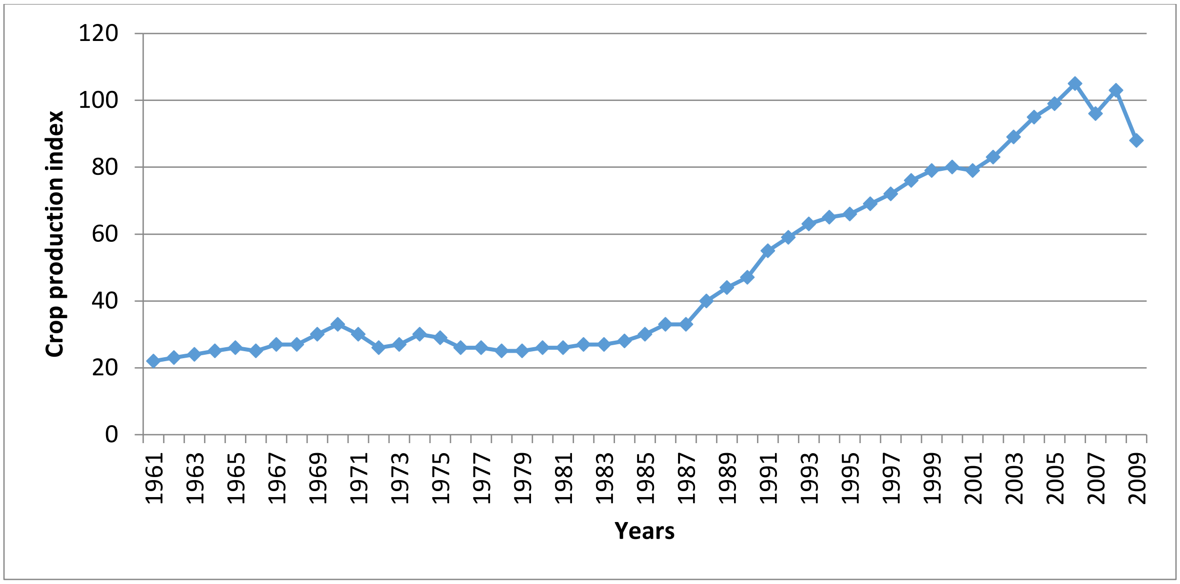

Figure 1.5: Crop production index for Nigeria, 1961 – 2010 (Source: World Bank, 2011)

The contribution of agriculture to National Gross Domestic Product (GDP) has been hovering around 40-41% annually since 2003 (Azih, 2011). The largest sub-sector contribution to this national output is from the crops sub-sector which annually ranged between 36% (2003, 2004 and 2005) and 37% (2006 and 2007) (Azih, 2011). The livestock sub-sector contribution to GDP is almost constant at 2.6% while that of fishing is at 1.37%. The agricultural sector GDP growth rate is the highest contributor to non-oil GDP growth rate. After an initial dip from 6.64% in 2003 to 6.50% in 2004, the growth rate appreciated per annum from 2004 (7.06%) to 7.43% in 2007 (Azih, 2011). With increases in crop yield owing to renewed government commitment and funding support, agriculture has become an important contributor to the Nigerian economy in the past decade despite the predominance of the oil sector (Oji-Okoro, 2011). This is reflected in the status of Nigeria in the world ranking of crop production by the FAO. Nigeria ranks high in the production of several crops and is the highest producer of cassava and yam in the world (FAO, 2013). Figure 1.6 provides information on the production output of various crops in Nigeria in 2011. Comparing Figure 1.6 with Figure 1.7, there was a rapid increase in the production of several crops in Nigeria.

As Olajide *et al.* (2012) put it, though crop production is on the rise in Nigeria, only less than 50% of Nigeria's cultivable agricultural land is under cultivation. Crop production in Nigeria is dominated by smallholder and traditional farmers who use rudimentary production techniques with resultant low yields. According to Olajide *et al.* (2012), these farmers are constrained by many problems including those of poor access to modern inputs and credit, poor infrastructure, inadequate access to markets, land and environmental degradation, and inadequate research and extension services. This suggests a lot is still needed to ensure Nigeria is headed towards sustainable agriculture. It also suggests that there are huge investment opportunities in the agricultural sector in Nigeria. Land evaluation is, therefore, a useful planning method to optimise the opportunities in the agricultural sector in Nigeria.

1.5.2 Governance of agriculture in the Lower River Benue Basin

Information presented in this section was obtained from the Benue State Ministry of Agriculture and Natural Resources (Benue State Government, 2013). The governance of agriculture in Benue State follows the three tier system of governance practiced in Nigeria. National policies developed at the Federal level are implemented at subnational levels by the Benue State Ministry of Agriculture and Natural Resources and the Departments of Agriculture in the 23 LGAs of Benue State. Figure 1.8 shows the relationship between the various governance structures for agriculture in Benue state.

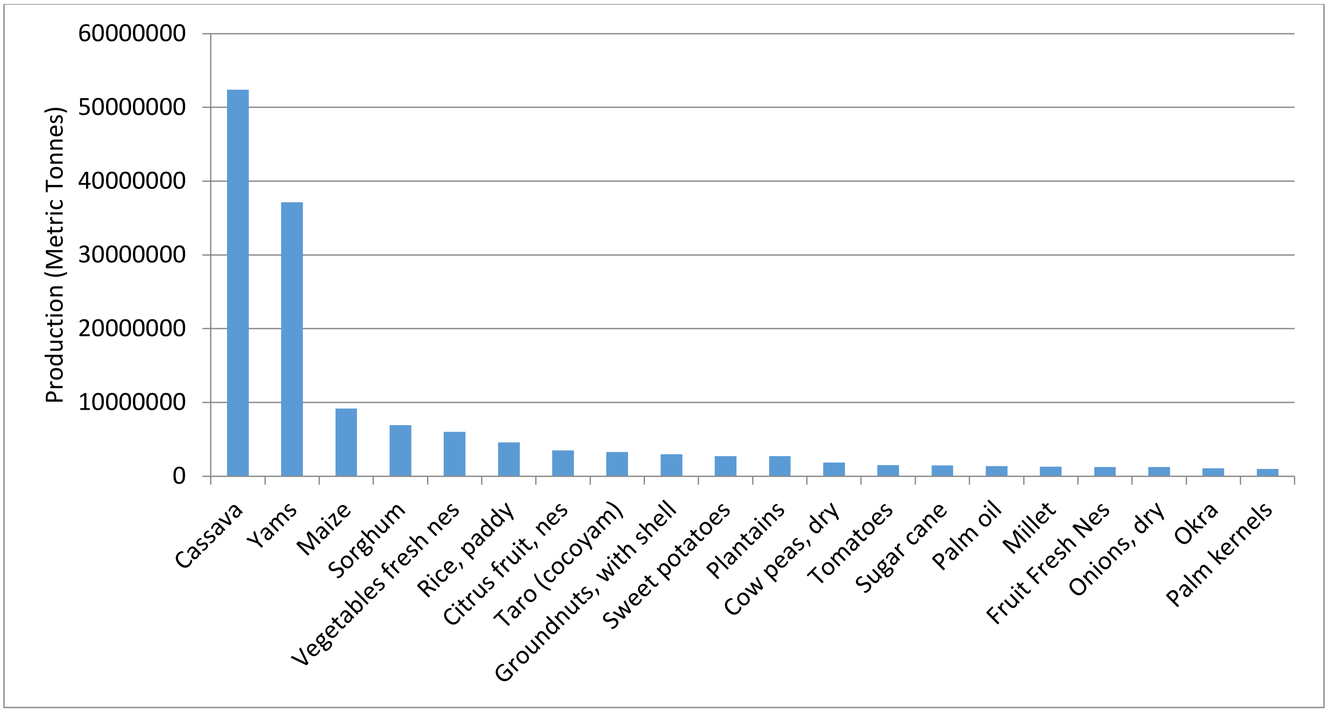

Figure 1.6: Crop production in Nigeria in 2011 (Source: FAO, 2013)

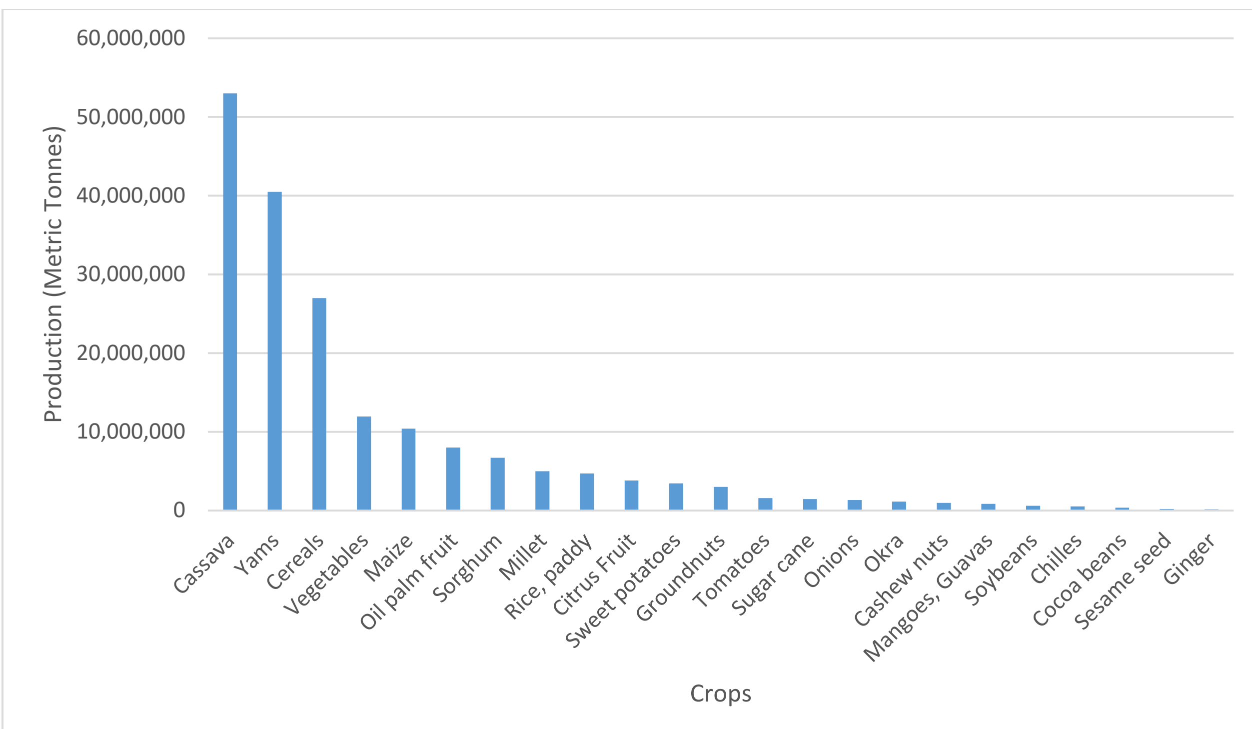

Figure 1.7: Crop production in Nigeria in 2013 (Source: FAO, 2015)

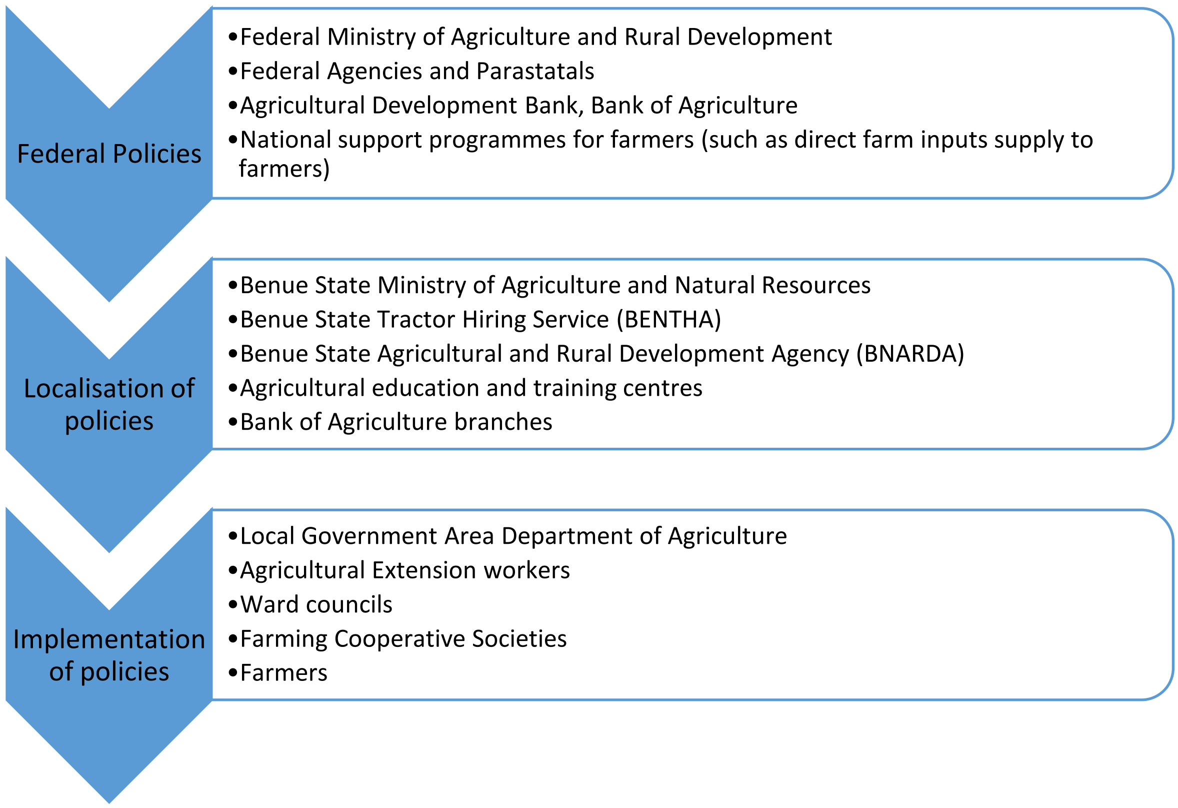

Figure 1.8: Governance structure for agriculture in the Lower River Benue Basin

Benue State Ministry of Agriculture and Natural Resources (Benue State Government, 2013) is responsible for the design of policies and programmes to promote agricultural development and monitor implementation. The following specific policy objectives guide the mission of the ministry:

- Attainment of self-sufficiency in the basic food products for enhanced food security.
- Increase production of agricultural raw materials to meet the growing demand in the agro-allied industries.

- Increase production of exportable products in order to attract foreign exchange earnings for the State.
- Modernisation of agricultural production, processing, storage and distribution through the infusion of improved technological packages and management so that agriculture can be more expensive to the demands of other sectors of the economy.
- Create more agricultural and rural employment opportunities and to improve the living standards of farmers and rural dwellers through enhanced income.
- Protection and improvement of agricultural land resources and protection of the environment through appropriate farming techniques for a sustainable agricultural environment.
- Establishment of appropriate support institutions and operation of administrative organs to facilitate the integrated development and realisation of the State's agricultural potentials.
- Train and enlighten agricultural human resource stock to transform agriculture into a thriving business.

The ministry strives to achieve these objectives through six directorates namely; Directorate of administration and supplies; Directorate of finance and accounts; Directorate of agriculture; Directorate of engineering services; Directorate of livestock services; and Directorate of fisheries (Benue State Government, 2013).

1.5.3 Agricultural development projects in Benue State

In order to encourage the development of agriculture in Benue State, the State Government has implemented several intervention policies to support farmers and farming activities. Some of these interventions include the establishment of the Benue State Tractor Hiring Agency, Agricultural Development Corporation, Taraku Mills Nigeria Limited, Benue State Agricultural and Rural Development Authority, Benue State Accelerated Food Production Programme, establishment of Swine Integrated Farm Project, Cassava Processing Factory, Benue State Fertiliser Blending and Mixing Plant, Livestock Investigation and Breeding Centre, and yearly supply of farm inputs (fertilisers, knap sack sprayers, water pumps, herbicides) at subsidised rates. The most recent intervention, according to the Benue State Ministry of Agriculture and Natural Resources, was the procurement of one hundred and forty eight (148) units of 75 Horse power tractors that were sold to farmers at 30% subsidy. The repayment schedule for the tractors was spread over three years to enhance affordability and repayment by farmers (Benue State Government, 2013).

1.5.4 Crop and livestock farming in Benue State

According to the Benue State Ministry of Agriculture and Natural Resources (Benue State Government, 2013), about 80% of the population of Benue state depends on agriculture for their sustenance and livelihood. Major crops grown in Benue state are cassava, rice, soybeans, sesame, citrus, mangoes and yam. Animals reared in the state include pigs, goats, poultry birds, and cattle. The River Benue and Katsina Ala and their tributaries provide huge opportunities for irrigation farming and fish farming in the Lower River Benue Basin.

1.5.5 The vision of Benue State Government for agriculture (2021-2031)

According to the Benue State Ministry of Agriculture and Natural Resources (Benue State Government, 2013), the Government of Benue State envisions that between 10 to 20 years, agriculture would become well-coordinated and driven through private sector efforts. Government would mainly play regulatory roles and provide supportive services. The visions of the Benue State Government for agriculture (Benue State Government, 2013) can be summarised as follows:

- A fully mechanised sector with appropriate farm machineries
- Single interest rate credit facilities available to farmers on a promptly basis
- An improved agriculture extension worker to farmers' ratio of 1:350.
- Improved technical capacity for agricultural extension workers in Benue State
- A transformed agricultural sector that will attract young school leavers
- Adequate availability of farm inputs (improved seeds, cuttings, breeds of animals and birds, fertilisers, herbicides, mobile threshers, harvesters, processing machines, and animal drugs).
- Availability of functional agro-processing factories for the use of farm produce
- Establishment of produce marketing board for stabilisation of agricultural produce prices
- A functional buffer stock programme to mop farmers' excess produce during harvest at economic prices to ensure food security during scarcity.
- All year round agriculture through irrigation farming in most of the Fadama areas in the state.
- Existence of private owned foundation stock centres for day old chicks, African swine fever-free weaned pigs, genetically improved goats, sheep, chicken, and upgraded disease resistant yearling bulls.
- Privately owned animals and chicken feed factories
- Existence of functional fish hatchery farm for the production of fish fingerlings to increased homestead fish production in the state.

- An increased number of organised farmers' cooperative societies that can support themselves for profitable agricultural businesses
- Exportation of agricultural produce from Benue State to developed countries
- Existence of foreign investors and foreign managed private farms in the state

1.5.6 Drainage basins in Nigeria

Nigeria is endowed with numerous rivers and streams. The biggest water bodies are the rivers Niger and Benue. Most of the major floods which occur annually in Nigeria occur within the floodplains of the rivers Niger and Benue and their numerous tributaries. Water bodies in Nigeria are categorised into eight contiguous hydrological areas which serve as units for scientific assessment and management of water resources of the country. Each of these hydrological areas is supervised by River Basin Authorities. These River Basin Authorities interface with the Nigerian Hydrological Services Agency (NIHSA) and the Nigeria Inland Waterways Authority (NIWA) with regards to the measurement of parameters, water transportation, flood management, dam management, and agricultural development amongst other relevant issues. The Lower Benue River Basin Authority oversees the management of the Lower River Benue Basin (NIHSA, 2014).

1.5.7 Lower River Benue Basin Development Authority

The Lower Benue River Basin Development Authority was established by Decree No. 25 of 1976 along with 11 other River Basins Development Authorities. The main objectives were to among other things enhance sustainable agriculture by optimising the land and water resources potential of the country within their areas of operation. The scope of operations covers a wide range of multi-purpose uses including crop farming, irrigation, livestock, forestry and fisheries along with the development of water resources, boreholes and dams. Other objectives include the provision of access to safe and sufficient water resources in a sustainable manner to meet the agricultural and socio-economic development needs in the basin, in such a way it contributes to public health, poverty eradication, and enhanced food security while at the same time maintaining the integrity of freshwater ecosystem of the basin. In addition, the Lower River Benue Basin Development Authority is responsible for planning, conserving, developing, managing and delivering both surface and underground water resources and allied services to all Nigerians in the catchment area (Uchua, 2011).

CHAPTER TWO

REVIEW OF LITERATURE

2.0 Introduction

This chapter presents materials from scholarly literature on the various issues within the scope of this study**.** Issues such as the theoretical framework for land evaluation, history and definitions of agriculture, geospatial based techniques for land evaluation, and sustainable agriculture have been explained, citing relevant literature.

2.1 Theoretical framework for agricultural land use evaluation

The Food and Agricultural Organisation (FAO) land evaluation approach was first presented at an expert meeting in Wageningen, Netherlands in October 1972 where it was extensively discussed and further refined. The modern era of land evaluation began with the publication of the United Nations Food and Agricultural Organisation (FAO) “Framework for Land Evaluation” in FAO Soils Bulletin 32 (1976) and subsequent guidelines for land evaluation of general kinds of land use (FAO, 1983; 1984; 1985; 1991; 1995). The FAO framework is not a formal methodology but a collection of concepts, principles, and procedures on the basis of which local, regional and national evaluation systems can be developed (Verheye *et al*., 2008).

The FAO framework for land evaluation (FAO, 1976) has provided guidance for land suitability assessment in countries where data scarcity often constrains modelling. Several programming techniques are available to match the results of land evaluation with the available means of governments, land users and other stakeholders, to achieve optimal land use (Beek *et al.*, 1997).

Land evaluation is often carried out in response to the recognition of a need for changes in the way in which land is currently being used. It is, therefore, not an end in itself. The information and recommendations from land evaluation represent a part of the multiple inputs into the land use planning process, which often follows land evaluation (Rossiter, 1995).

According to Rossiter (1995), early methods for land evaluation compared land in physical terms, by describing relatively permanent impediments to unrestricted land use. These physical land classifications usually have an implicit economic basis. Physical attributes of land, as quantified by natural resource scientists, affect its economic value and these effects can be quantified in economic terms by the land evaluator. Although this quantification may be difficult, it is necessary for land evaluations to be useful to decision makers who base their decisions on economics. These views by Rossiter (1995) are an integral part of the FAO land evaluation framework of 1976. Riveira and Maseda (2006) posited that the simplicity of the pre-FAO methods meant that they are easily and broadly applied in real planning situations. However, weak points are the lack of consideration of socioeconomic factors and their applicability to a single global use. Socioeconomic factors are nowadays the main determinants of land suitability hence the FAO framework stands as one of the most adequate evaluation methods (Riveira and Maseda, 2006). Verheye (1985) stated that after the introduction of the FAO (1976) framework, more attention has been paid to climatic factors and the role of socioeconomics in land evaluation for agricultural purposes. The FAO framework definitely has become the main point of reference for land evaluation (George, 1997) because, the principles of the FAO (1976) Framework specify that land should be assessed with respect to its suitability for a range of alternate land uses based on several criteria which include:

- The requirements of specific land uses
- A comparative multi-disciplinary analysis of inputs versus benefits
- The physical, economic and social context, and
- Potential environmental impacts and land-use sustainability.

The FAO framework has provided a basis for the development of various land evaluation techniques such as the Automated Land Evaluation System (Rossiter and Van Wambeke, 1991); the Quantified Land Evaluation which depends intrinsically on mathematics and computation (Beek *et al*., 1987; Wagenet and Bouma, 1993); the Economic Land Evaluation (Rossiter, 1995; Johnson and Cramb, 1996); and the Agro-Ecological Zoning (AEZ) (FAO, 1996). Another post-FAO system is the Fertility Capability Classification (Sanchez *et al*., 2003) which groups soils according to the problems they pose for agricultural management.

Beyond the FAO (1976) framework, the inclusion of climatic and socioeconomic data in land evaluation for agriculture has become popular. Yialouris *et al*. (1997) carried out a suitability evaluation for 5 crops and selection of optimum crops using the FAO framework and GIS. The study by Yialouris *et al*. (1997) utilised maps of soil, various land uses and climatic information. Bacic *et al*. (2003) studied land evaluation information by land use planners and decision-makers in Santa Catarina, Brazil. Bacic *et al*. (2003), as part of the study conclusion, stated that land evaluation methods should involve knowledge on physical, environmental, socio-cultural, and economic context of the area. According to Beek *et al*. (1997), land evaluation for agriculture assesses relevant land use type and its associated crop and management requirements. In this case, biophysical and socioeconomic parameters form the major inputs for a land evaluation process whereby biophysical analysis precedes socioeconomic analysis (which is preferred by most physical scientists) or a simultaneous process that attempts to integrate both biophysical and socio-economic data during analyses (favoured by social scientists, especially at the farm level) (Beek *et al*., 1997).

2.2 Sustainable agriculture

Sustainable agriculture is driven through science based approaches. Science based agriculture has led to an improvement in agricultural processes and yields in the twenty first century. As Dreyfus (1987) puts it, stable agriculture based on a tradition which is transmitted through generations has been gradually replaced by the image of an ultra-modern enterprise, whose rapid evolution is propelled by the progress of science and technology. Francis (1988) defined sustainable agriculture as “a management strategy whose goal is to reduce input costs, minimise environmental damage, and provide production and profit over time.”

Harwood (1990; p12) stated three principles that are behind sustainable agriculture, which are "the interrelatedness of all parts of a farming system, including the farmer and his family; the importance of the many biological balances in the system; the need to maximise use of material and practices that disrupt those relationships.”

According to Allen *et al*. (1991), sustainable agriculture tries to focus on the environmental conservation which is to be achieved through changing farm production practices without reducing farmers' profits. An expanded concept of sustainable agriculture, is defined by Allen *et al*. (1991) as “a sustainable food and agriculture system is one which is environmentally sound, economically viable, socially responsible, non-exploitative, and which serves as the foundation for future generations. It must be approached through an interdisciplinary focus which addresses the many interrelated parts of the entire food and agriculture system, at local, regional, national, and international levels. Essential to this perspective is recognition of the whole-systems nature of agriculture; the idea that sustainability must be extended not only through time, but throughout the globe as well, valuing the welfare of not only future generations, but of all people now living and of all species of the biosphere."

The United Nations Environment Programme (UNEP, 1992) provoked global political respectability on the concept of sustainable development. Since land is a finite resource (UNEP, 1992), the assumption that suitable lands for expansion could always be found when needed is false. It is, therefore, not surprising that the efficient use of agricultural lands is becoming a matter of life or death for the increasing population of mankind (Smyth and Dumanski, 1993). Around the world today, there is clear evidence of impending land shortage for various purposes and especially for agriculture. For this reason, the United Nations (2012) has continued to advocate for the sustainable use of earthly resources to ensure the livelihood of future generations.

The National Institute of Food and Agriculture (NIFA, 2009) of the United States Department of Agriculture presented the legal definition of sustainable agriculture as addressed by the United States Congress in the 1990 (Food, Agriculture, Conservation, and Trade Act of 1990, Public Law 101-624, Title XVI, Subtitle A, Section 1603). According to NIFA (2009), the term "sustainable agriculture" is defined as "an integrated system of plant and animal production practices having a site-specific application that will over the long-term: satisfy human food and fibre needs; enhance environmental quality and the natural resource base upon which the agriculture economy depends; make the most efficient use of non-renewable resources and on-farm resources and integrate, where appropriate, natural biological cycles and controls; sustain the economic viability of farm operations; and enhance the quality of life for farmers and society as a whole."

Douthwaite and Ortiz (2001) support the opinion that science plays a crucial role in helping humanity avoid the impending catastrophe of food insecurity which is partly of its own making. Sustainable agriculture demands more prudent use of land resources which underscores the importance of land evaluation in order to derive maximum benefits with minimum degradation (Dorronsoro, 2002). If sustainable agriculture is science based, the body of evidence-based knowledge should be passed directly on to farmers in the form of improved seeds and cropping systems, fertilisers, plant growth regulators, pesticides, tillage and spray and improved post-harvest equipment (Protacio, 2009). Planning for sustainable agriculture in Nigeria requires a good knowledge of the agricultural sector and current agricultural practices. These are examined in the next section.

2.3 Land evaluation for agriculture

Demand for land for agricultural purposes is increasing globally, implying a limitation in land resources. This has necessitated a yearning for decisions leading to the most beneficial use of limited land resources. Evidence based decisions made for optimal benefits of land resources have considerable implications for conserving land resources for the future. The function of land evaluation in this regard is to bring about an understanding of the relationships between the condition of the land and the uses to which it is put into, and to present planners with comparisons and promising alternative options (Njar *et al*., 2012). The information and recommendations from land evaluation are important for land use planning processes which often follows land evaluation (George, 1997).

Land use evaluation determines land use options which are important for land use planning. Van Diepen *et al*. (1991) described land use planning as "the allocation of land to various categories of use according to criteria formulated during the land evaluation process." In determining land use options it is important to consider management related attributes (George, 1997). This is because management related attributes which include inputs and socioeconomic settings influence production levels. The management related attributes define land utilisation types. A land utilisation type has been defined as "a use of land defined in terms of a product, or products, the inputs and operations required to produce these products, and the socioeconomic setting in which production is carried out" (FAO, 1996).

There are basic requirements that allow for the efficient and sustainable functioning of each land utilisation types. The major requirements for rain-fed crop production land utilisation type border on crop physiology, technology of management systems, and avoidance of land degradation (George, 1997).

Several methods used for land evaluation for agriculture and other purposes have been developed by various scholars as highlighted in the theoretical framework. Riveira and Maseda (2006) reviewed rural land use planning models. The models reviewed include Expert Systems (Zhu *et al*., 1996; Yialouris *et al*., 1997; Jun, 2000); mathematical models (Weerakon, 2002; Oliveira *et al*., 2003); and spatial simulation models (Parker *et al*., 2003; Barredo *et al*., 2004). Riveira and Maseda (2006) recommended that the framework for land use planning and land evaluation should not be confined to assessing the physical characteristics alone, but should consist of the analysis of physical suitability, economic viability, social consequences, and potential environmental impacts. In addition, socioeconomic factors are nowadays the main determinants of land suitability hence the FAO framework stands as one of the most adequate evaluation methods.

The FAO framework provides a flexible system in which various assessment methods can be integrated. It allows for a multi-criteria evaluation and integration with spatial technology such as Geographic Information Systems (GIS) in mapping optimum land uses. Ashraf (2010) stated that the multi-criteria evaluation approach within GIS context involves land suitability evaluation based on the FAO framework by overlapping maps with GIS techniques for land suitability classification. GIS and remote sensing play a vital role in linkage and analysis of data in land evaluation, in particular for detection (direct/indirect), extrapolation, interpretation and monitoring (Godert *et al*., 2001).

2.3.1 Application of GIS and Remote Sensing in land evaluation for 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 a Geographic Information System (GIS) for development studies such as land use evaluation for agriculture cannot be overemphasised. 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).

The aim of development is centred on enriching quality of life in all segments of the population particularly the rural population. Achieving integrated development of a nation is difficult without proper scientific planning. Integrated development improves the status of a nation not just in economic terms but in all aspects of life and activity which are subject to manipulation and controlled change including agricultural land use patterns (Ghosh and Ghosh, 2013).

Agricultural land use patterns are highly dynamic features of a cultural landscape and factors responsible for land use change are similarly evolutionary. Ortserga (2012) noted that change in agricultural land use is a multi-faceted phenomenon which can be adequately assessed by multi-factor model approach. Ortserga (2012) stated further that social and economic factors, some of which are improved standard of living, economic reorientation, technology, population, liberalised access to personal income and social responsibility are the most prominent factors that influence land use change in rural areas. Therefore, planning for rural agricultural land use development must be broad-based to cover all issues relating to land use and not just a single factor. This suggests that planning for a sustainable shift in agricultural land use in rural areas can be sufficiently achieved through a multi-factor integrated approach.

Riveira and Maseda (2006) revealed that there is a shortage of models focused on rural land use and that designing a rural land use planning model should involve the integration of different computer tools. This can be achieved in a GIS environment. According to Kumara (2008), the principle applications of GIS in rural development are land and resource mapping, integration of local and scientific spatial knowledge, community-based natural resource management, area planning, environmental management, and management of pests and natural hazards. The integration of local knowledge into GIS makes analysis more participatory and enhances ownership and utilisation of information.

Enete and Amusa (2010) revealed that farmers in Nigeria have been slow in changing their farming practices such as bush burning, deforestation, rain-fed agriculture and land tenure systems, and they lack the requisite education, information and training necessary to adapt to climate change. Enete and Amusa (2010) suggested that planning for rural agricultural development should adequately cover irrigation, drainage, weather forecasting, agricultural technological infrastructure, training in agriculture, capacity building for farmers, drought resistant and short duration high yielding crops development, integration of indigenous and modern knowledge on climate change adaptation, strengthening of the extension services, and encouragement of formation of farmer groups. In order to holistically assess these various aspects which are not exhaustive, an integrated approach utilising a computer based tool such as GIS could be effective. Enete and Amusa (2010) stressed that GIS has robust analytical and manipulative capabilities which can enable modelling for rural agricultural enhancement. This study will incorporate a broader range of quantified data on socioeconomic aspects, local knowledge on farm management, and climatic data to improve the outcome of modelling for agricultural land use evaluation. This would also include the use of GIS and Remote Sensing for crop suitability mapping.

2.3.2 Case studies in the use of GIS and Remote Sensing in land evaluation for agriculture

Scholars have used various methods to integrate spatial and land characteristics in land evaluation studies for agriculture. GIS and remote sensing provide a platform which allows for manipulation of data using fuzzy logic (Baja *et al*., 2001; Joss *et al*., 2008). Therefore GIS and remote sensing have become modern tools which can aid in bottom-up planning for a variety of problems confronting rural dwellers (Rasmussen *et al.*, 1999; Twumasi *et al*. 2003, 2012, Twumasi, 2005). Hunduma (2012) used GIS and remote sensing for fertiliser suitability mapping for wheat at Lume micro watershed, Central Ethiopia. Analysis in Hunduma (2012) involved satellite imagery digital processing, thematic map production on physical themes, and weighted overlay analysis in GIS. The findings of Hunduma (2012) were recommended for use in Ethiopia by development agents to guide farmers on fertiliser application rates. Figure 2.1 summarises the methodology used by Hunduma (2012).

In a similar study, Ashraf (2010) conducted land suitability analysis for wheat in Iran using multi-criteria evaluation and GIS. The methodology used for the physical land suitability analysis was a multi-criteria evaluation based on FAO land evaluation framework. The methodology consisted of matching soil/land qualities against wheat needs and assigning a suitability rating to each land characteristic in order to develop a set of themes for evaluation and ultimately to produce a suitability map. The study by Ashraf (2010) was a biophysical evaluation that provided information at local level that could be used by farmers to select their cropping patterns. Figure 2.2 summarises the methodology used in Ashraf (2010).

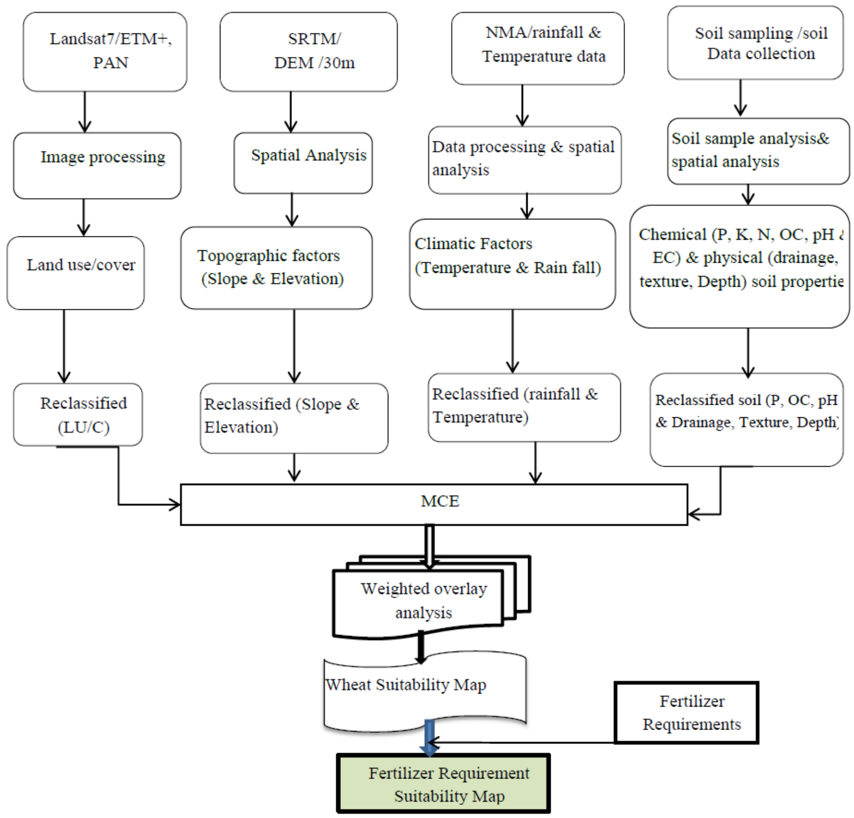

Figure 2.1: GIS methodology used by Hunduma (2012) for fertiliser suitability mapping in Lemu, Ethiopia

GIS provides an opportunity for an integrated assessment of the resource development potential within a given time and scale. This contributes in ensuring that development tallies with environmental sustainability in the pursuit of sustained economic outputs (Petja *et al.*, 2009). According to Lingjun *et al.* (2008), GIS and remote sensing has allowed for a transition from qualitative to quantitative assessment of land suitability based on relevant natural, economic, social and technical data.

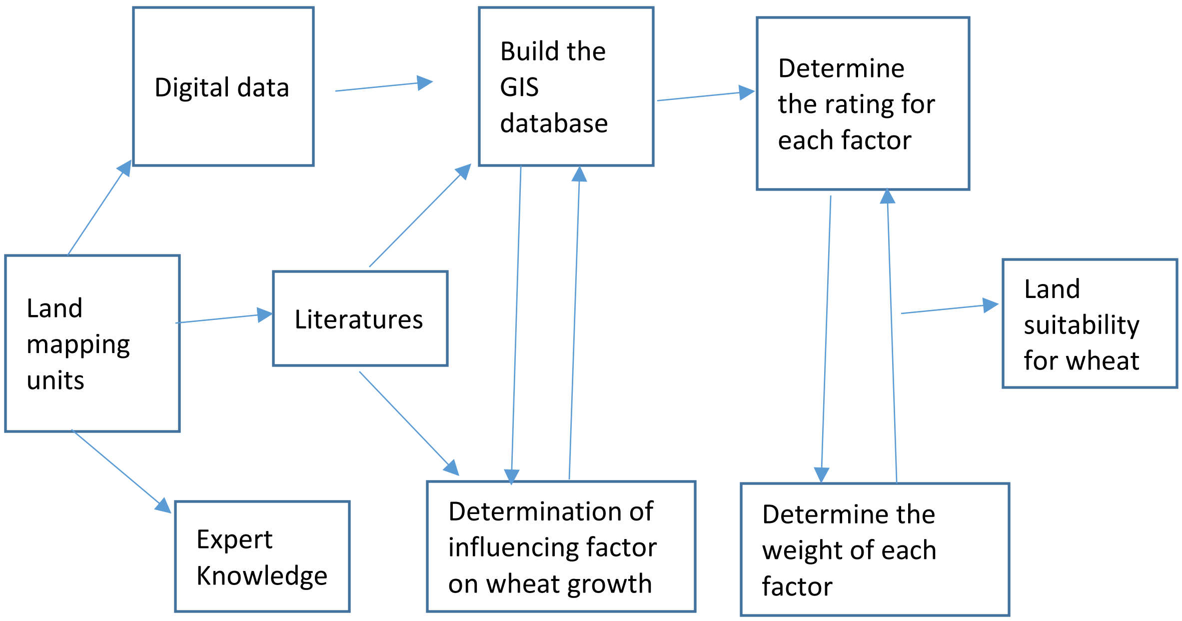

Figure 2.2: GIS methodology used in Ashraf (2010) for wheat suitability mapping in Iran

In a large study by Stickler *et al*. (2007), the biophysical potential for three major crops (soybean, sugar cane, oil palm) in the tropics was mapped globally. Stickler *et al*. (2007) identified growth requirements for these crops and used the data to develop spatially-explicit variables and identified regions where these crops can be profitably grown. As part of the method used by Stickler *et al*. (2007), impeding socioeconomic factors were identified and included in the analysis model.

Son *et al*. (2008) conducted an integrated land use planning for sustainable agriculture and natural resources management in the Vietnamese Mekong delta. The study by Son *et al*. (2008) investigated the productive systems of agriculture and the land use decision making issues which were socioeconomic in nature that bothered households. Son *et al*. (2008) utilised spatial and socioeconomic data obtained through household survey and qualitative methods. Son *et al*. (2008) found that, even though existing production systems had not matched land requirements for large areas, socioeconomic factors ensured partial effective management of land resources.

Heumann *et al*. (2013) embarked on land suitability modelling using a geographic socio-environmental niche-based approach in north-eastern Thailand. The study by Heumann *et al*. (2013) tried to understand the land suitability for crops and utilised data on the built environment, natural abiotic conditions, and household social factors which were responsible or externally influenced the human modification of the niche.

A study by Yen *et al*. (2013) assessed constraints on agricultural production in the northern uplands of Vietnam. Yen *et al*. (2013) adapted the FAO framework to determine land suitability for eight crops including maize, irrigated rice, rain-fed rice, vegetables, groundnut, sweet potato, soybean and cassava. The study by Yen *et al*. (2013) assessed both biophysical and socioeconomic constraints. In order to analyse biophysical constraints, Yen *et al*. (2013) analysed data on soil, rainfall, temperature, satellite images, land use maps, and digital elevation model. Yen *et al*. (2013) analysed socioeconomic constraints by collecting data through household survey. The household survey involved face-to-face interviews conducted in individual households listed by the village chief based on levels of agricultural investments. Yen *et al*. (2013) found that the land in the area could support more than one crop type based on rainfall, availability of capital, farm labour, and harvest value. Yen *et al*. (2003) used the suitability information to educate farmers in the region about how to make informed land use decisions.

Chen and Lu (2014) assessed the effects of land use, topography and socioeconomic factors on river water quality in a mountainous watershed with intensive agricultural production in East China. Chen and Lu (2014) stated that a good understanding of both anthropogenic activities and natural factors was necessary in the study of land resources. Chen and Lu (2014) analysed data using statistical methods such as Variance, Pearson correlations, Principal component analysis, Redundancy analysis, and Multiple regression analysis in an integrated GIS model which assessed the spatial-temporal variations and influence of watershed land use, topography and socio-economic factors in the study area. Chen and Lu (2014) stated as part of the study conclusion, that anthropogenic activities and natural factors enhance the understanding of factors which affected the land use and resources within the watershed. These studies have demonstrated that the assessment of socioeconomic factors provide evidence beyond mapping about anthropogenic contributions which can be enhanced to optimise the agricultural potential and quality of environmental conditions.

2.3.3 GIS and land evaluation for agriculture in Nigeria

Despite the utilitarian value of GIS and remote sensing in land evaluation for sustainable agriculture which has been emphasised, the practice is still relatively an emerging technique in Nigeria. Rilwani and Gbakeji (2009) examined the challenges and prospects of geoinformatics in agricultural development in Nigeria. A critical analysis of the prevailing situation in Nigeria revealed the shortcomings of the current methods of data collection, analysis and management. The challenges of agricultural development highlighted in Rilwani and Gbakeji (2009) include technological development, inconsistency and inept implementation of government policies, low level of investment, small land assets, diversity of cultivation systems and market imperfection. The study emphasised the need to adopt geoinformatic methods to improve agricultural productivity to meet the nutritional need of the teeming Nigerian masses as well as for export income.

The study by Rilwani and Ikuoria (2006) showed that there are numerous crop-yield prediction models that relate crop yields to a single set of factors. These models have been inadequately applied, largely because they are specifically located. Most of the models are mostly based on the assessment of biophysical properties of land potential, and other important factors of crop production such as socioeconomic factors and climate are held constant. There is, therefore, a need to utilise comprehensive land evaluation methods for crop farming in Nigeria in line with the new concept of precision farming.

Nuga (2001) reviewed the application of GIS for sustainable land resource management in Nigeria. According to Nuga (2001), the current methods of land evaluation for agriculture in Nigeria suffer from a number of inherent deficiencies that limit their usefulness as a tool for effective land use planning. The need for the integration of GIS with processes of land evaluation, for improved quality of land decisions and sustainable land use and management was emphasised. Uchua *et al*. (2012) mapped and analysed agricultural systems in the lower river Benue basin in Nigeria using various GIS software to identify relationships between variables responsible for agricultural systems in the lower river Benue basin. Uchua *et al*. (2012) analysed the locational characteristics of various agricultural systems such as upland cereal, tuber-based, plantation or tree crop, and agroforestry. Uchua *et al*. (2012) acknowledged the recession of the Lower River Benue which has led to some adverse ecological changes and the decline of agricultural production in the face of rapid population growth in the area.

2.4 Climate change and agriculture

Climate is the primary determinant of agricultural productivity. Given the fundamental role of agriculture in human welfare, concerns have been expressed about the potential effects of climate change on agricultural productivity (Adams *et al*., 1998; Tiwari, 2000). The

Intergovernmental Panel on Climate Change (IPCC) (2007) defined climate change as “a change in the state of the climate that can be identified by using statistical tests and other methods to detect changes in the mean and/or the variability of its properties, and that persists for an extended period typically decades or longer.” The global warming trend has continued beyond four decades without reversal (IPCC, 2007) and there are heightened concerns that the current warming of the earth’s climate is being influenced by anthropogenic factors with evidence from increases in global average air and ocean temperatures (Odjugo, 2011). According to Odjugo (2011), climate change is caused by two basic factors namely natural processes (biogeographical) and human activities (anthropogenic). In 2005, agriculture contributed an estimated 10-12% of global greenhouse gas emissions (IPCC, 2007). Agriculture influences the storage of carbon in the soils and some agricultural practices have led to the direct release of greenhouse gases, specifically methane and nitrogen emissions.

Agriculture can be affected by climate change and could suffer important adverse impacts (Mendelsohn, 2000). Though there will be gains in some crops in some regions of the world, the overall impacts of climate change on agriculture are expected to be negative and pose threats to global food security (Nelson *et al*., 2009). Iglesias *et al*. (2009a) provided a summary of key factors with high impact ratings that are expected to be modified with climate change. These include changes in sea level, carbon-dioxide concentration and soil erosion which has major consequences for agricultural productivity and is directly affected by climate conditions.

Climate change will have a global effect on agriculture. In the United States (U.S.), agriculture produces approximately 300 billion dollars a year in commodities. Around the mid-century, temperature increase is expected to exceed 1°C to 3°C and precipitation extremes will intensify, and the yields of major U.S. crops and farm returns are projected to decline (Walthall *et* *al*., 2012). Iglesias *et al*. (2009b) pointed out climate change as one of the serious challenges agriculture will face in the coming decades. Iglesias *et al*. (2009b) further stated that an improved understanding of the climate-agriculture-societal response interactions is highly relevant to development policies.

In Nigeria, agriculture is the main source of food (Manyong *et al*., 2005) and the source of raw materials used in the processing industries as well as a source of foreign exchange earnings for the country (Mohammed-Lawal and Atte, 2006). Agriculture in Nigeria is mostly rain-fed (Rilwani and Gbakeji, 2009; Ayinde *et al*., 2011) and any change in climate is bound to impact its productivity in particular and other socioeconomic activities in the country.

Odjugo (2011) assessed climate change and global warming in Nigeria over two climatic periods 1901-1938 and 1971-2008. Odjugo (2011) found that temperature in Nigeria increased by 1.78^{o}C between the two climatic periods. This was above the global temperature average rise of 0.74^{o}C for 100 years (IPCC, 2007). Rainfall decreased by 91 millimetres in Nigeria between the two climatic periods with major shifts in double and single rainfall peaks. The study also highlighted an increase in rainfall in the coastal areas.

Another study by Olusina and Odumade (2012) looked at future weather, temperature and rainfall conditions in Nigeria for the next 50 years (2000-2050). Olusina and Odumade (2012) found that climatic variability is likely to increase and intensify leading to more droughts, floods and storms. Ayinde *et al*. (2011) assessed the effect of climate change on agricultural productivity in Nigeria using climatic data from 1975 – 2005. Ayinde *et al*. (2011) found that there was rainfall variability (inter-annual) and unreliability. There were sharp reductions in annual temperature with unsteady trends and variations. There is evidence of climate change in Nigeria as intense rainfall has increased due to a reduction in the onset and cessation periods of rainfall, and an increase in drought in the northern parts due to desertification (Anuforom, 2013). The current evidence presented suggests that Nigeria, like most parts of the world, is experiencing the basic features of climate change. This is why adaptation to climate change is important.

2.4.1 Adaptation to climate change

According to the International Panel on Climate Change (IPCC, 2007), conscious efforts towards adaptation to climate change have become necessary, even as various countries of the world have begun to put in place mitigation measures. This will ensure long term mechanisms to deal with impacts of climate change.

Even though the threat of climate change has a global coverage, countries less responsible for climate change are significantly more vulnerable (Bondeau *et al*., 2007). This has necessitated a clamour for developed countries to assist developing countries that are “particularly vulnerable” to climate change in meeting costs of adaptation to its adverse effects (IPCC, 2007). The simple reasons for this is the perception that the countries that are least responsible for climate change are said to have the highest social vulnerability indices. These poor social vulnerability indices cover issues such as human health, and food security which are critical to survival. Agriculture is adjudged as one of the most vulnerable economic activities to be affected by climate change especially in developing countries (Füssel, 2009).

Adaptation to climate change has received attention from several scholars (Adger *et al*., 2004; Dessai *et al*., 2003; Kelly and Adger, 2000; Smit *et al*., 2000; Tubiello *et al*., 2000). According to Smith and Wandel (2006), adaptation could refer to a process of achieving a set of actions or outcomes in a system (household, community, group, sector, region, country) so as to equip the system to cope better with, manage or adjust to some changing condition, stress, hazard, risk or opportunity. The parameters considered for planning adaptation strategies can vary in scale from the organism or individual to the population of a single species or an entire ecosystem (Krimbas, 2004).

Adaptation potential is assessed through indicators of adaptive capacity which allows for the determination of the robustness of response strategies over time, and to better understand the underlying processes (Adger *et al*., 2004). According to Smit *et al.* (2001), adaptive capacity indicators can be derived from six determinants which include economic resources; technology; infrastructure; information, skills and management; institutions and networks; and equity. Other methods with social, institutional, economic and environmental variables have been proposed by Folke *et al*. (2003), and Wall and Marzall (2004).

Adger *et al*. (2004) advised against aggregating indices of adaptation across scales because they differ at various scales. According to Adger *et al*. (2004), the occurrence of adaptation is not instantaneous but requires time for adaptive capacity to translate to adaptation. Adaptive capacity, therefore, represents potential to realise actual adaptation, and as such, a high degree of adaptive capacity only reduces a system’s vulnerability to future hazards.

It has been noted that capacity to adapt to climate change is insufficient in certain societies such as subsistence farming communities. Adaptive capacity is easily influenced by economic and natural resources, social networks, entitlements, institutions and governance, human resources, and technology. Therefore, as stated by Adger *et al*. (2007), adaptation to climate change and risk of exposure to climate risk can be exacerbated through multiple stresses related to HIV and AIDS, land degradation, trends in economic globalisation and violent conflict.

2.5 Effects of population growth, increased income, and HIV and AIDS on agriculture

In addition to climate change, other challenges facing sustainable agriculture are associated with population and income growth. A total of 870 million people, mostly in developing countries, remain chronically undernourished and there are serious concerns about the implications of growing populations on global food security (FAO, 2009; FAO, 2012). The growth in world population and the displacement of populations increases the demand of agricultural land for housing. According to the United Kingdom Department for International Development (DFID, 2004), agriculture has performed remarkably well over the last 50 years, by keeping pace with rapid population growth and delivering food at progressively lower prices. This success has been at the expense of the natural resource base, through overuse of natural resources as inputs or through their use as a sink for pollution. This supports an earlier assertion by Shrestha and Rayappa (1990) that agricultural development and population growth are related.

Wilkes *et al*. (2013) suggested that increasing income levels in developing countries will heighten demand for food and land use change in the near future. This is because the majority of the sustainability plans are being developed in upper-middle or high-income countries and sustainability plans are receiving inadequate attention in developing countries. According to Wilkes *et al*. (2013), national communications from many developing countries indicate the greater policy priority given to economic growth and poverty alleviation. Even though economic growth is important, it should be pursued with a sustainability development plan to ensure a holistic maturation of a nation. As Iglesias *et al*. (2009b) noted, economic development drives technological change, population defines demand and consumption, and land use change is influenced by policy.

Sustainable agriculture is also threatened by HIV and AIDS, and other related diseases such as Tuberculosis and Malaria. According to the United Nations (2004), the majority of the population in the countries most affected by HIV and AIDS live in rural areas. In many African countries, farming and other rural occupations provide a livelihood for more than 70% of the population. Hence, it is to be expected that the HIV and AIDS epidemic will adversely affect the agriculture sector in those countries, especially in countries that rely heavily on manpower for production.

HIV and AIDS undermines agricultural systems and affects the nutritional situation and food security of rural families. The FAO (2002) estimated that in the 25 most-affected African countries AIDS has killed seven million agricultural workers since 1985. It is forecast that 16 million people will die of AIDS between 2002 and 2022. Given the fact that HIV and AIDS is concentrated among the age group of 15 - 49 years old, who are most able bodied, then agriculture suffers most in terms of production and market for the accruing products (FAO, 2002).

2.6 Summary

This study has reviewed several literature on land use evaluation for agriculture, crop suitability mapping, and the influence of stress factors such as climate change, population growth and HIV and AIDS on sustainable agricultural development. This study, therefore, adopted the FAO (1976) approach for land use evaluation for agriculture based on the key principles presented by George (1997) such as requirements for land uses; physical, economic and social aspects; and potential environmental impacts and sustainability. This study utilised the concept of Agro-Ecological Zoning (FAO, 1996) which was a further development of the FAO framework. The concept of assessing climatic and socioeconomic data alongside other biophysical data in land evaluation as stated in literature (Verheye, 1985; Beek *et al*., 1997; Bacic *et al*., 2003) was instrumental to this study. Examples of literature (Ashraf, 2010; Chen and Lu, 2014; Heumann *et al*., 2013; Petja *et al*., 2014; Riveira and Maseda, 2006; Son *et al*., 2008; Stickler *et al*., 2007; Yen *et al*., 2013) which had adapted methods using electronic techniques such index modelling, GIS, and Remote Sensing for land evaluation for agriculture and suitability mapping were helpful to this study. The main aspects this study assessed in land evaluation for agriculture and suitability mapping included climatic factors, soil, drainage, land use, elevation, and socioeconomics. The impact of stress factors such as climate change, population growth and HIV and AIDS on sustainable agricultural development as explained in the literature were also assessed for the study area. The research design and methods used to achieve the study objectives are presented in the next chapter.

CHAPTER THREE

RESEARCH DESIGN AND METHODOLOGY

3.0 Introduction

The chapter deals with the design and methodology that was used for this study. The research methodology consisted of a desktop study and actual fieldwork survey for investigation and data collection. Prior to the commencement of baseline ecological data gathering in the field, consultation visits were carried out to the traditional rulers in the study area.

The Local Government Areas (L.G.As) selected for data gathering and socioeconomic survey were Makurdi, Tarka and Gboko (Figure 1.1) based on criteria of centrality, population size, road access, farming population, availability of farming cooperative societies, preponderance of rice, yam, and cassava farmers, and proximity to the River Benue and River Katsina Ala. Secondary data from academic journal articles on other areas of the Lower River Benue Basin were sourced to compare and support field data results.

The fieldwork surveys involved stratified sampling and field observation through rapid appraisal. The details of materials and methodology adopted for data collection, analyses and production of necessary maps are provided in this chapter.

3.1 Research proposal and ethics approval

A research proposal to carry out this study was prepared and submitted to the College of Agricultural and Environmental Sciences of the University of South Africa. Upon approval, an ethics application form for this research was submitted to the Ethics Review Committee of the

College of Agricultural and Environmental Sciences for consideration and approval. After the ethics application review meeting, ethics approval was given for the duration of the research with reference number 2014/CAES/059. The research proposal and ethics approval letters are attached in Appendix 1.

3.2 Consultations with traditional leaders and relevant authorities

Consultations for this research began with the traditional leaders within the study area. Meetings were held with the traditional leaders of two of the three Local Government Areas which formed a major part of the study area within the Lower River Benue Basin (Makurdi, Tarka, and Gboko). The traditional leaders consulted for this research are the Ter Makurdi II Chairman, Makurdi Local Government Traditional Council, and Ter Mbakor, Tarka Local Government Traditional Council. After careful consideration of the purpose and importance of the study, letters of approval were obtained from the traditional rulers (Appendix 2). The traditional leaders also sent prior messages to other traditional heads within their influence of authority.

In other to obtain the approval of the government environmental agency in charge of the study area, the Benue State Environmental Sanitation Agency was approached. Approval for this research by the Agency was conveyed in a letter attached in Appendix 3. Other government institutions consulted for information to aid data analyses included Lower Benue River Basin Authority, Benue State Ministry of Lands and Survey, Benue State Ministry of Agriculture, Benue State Library, National Hydrological Service Agency, Nigerian Inland Waterways Authority, Nigerian Geological Survey Agency, and the Nigerian Meteorological Agency.

3.3 Types of data sets

The study utilised both primary and secondary data. Primary data comprised biophysical and socioeconomic data collected from the field through sampling, rapid appraisal and observation. Secondary data included satellite imagery, collateral maps on topography, permissible limits for soil data, relevant literature from academic journals, hydrologic and climatic data.

3.4 Collection of biophysical data and analysis methods

3.4.1 Soil data

The essence of soil analysis in this study was to ground truth soil results for remote sensing analysis carried out on satellite imagery of the study area. The soil results also supported the process of drawing up conclusions and recommendations for this study. Soil samples were collected through stratified random sampling from cassava, rice and yam farms in Makurdi, Tarka, and Gboko. These farms belonged to farmers who are members of farming cooperative societies in Makurdi, Tarka and Gboko L.G.As within the study area. This was to ensure the findings of the study have a targeted effect on these cooperative societies.

A total of 36 soil samples were collected from the selected farms in Makurdi (12 samples), Tarka (12 samples), and Gboko (12 samples). In each of the Local Government Areas, 2 samples each were taken in large rice, cassava, and yams farms which were triangulated with consideration for areas of similar topography, management history and crop performance. In each farm, sample points were at least 250 metres apart. The depth of sampling was from 0-30 centimetres (cm) since it was for agricultural land evaluation purposes. At each sampling point, surface (0 – 15cm) and subsurface (15 – 30cm) soil samples were collected. Secondary data of soils from Otukpo, Ohimini, Katsina Ala, Gboko (Benue Cement Company area), and Bassa (Kogi State) from journal publications was used to support the results of samples collected and analysed. A handheld Global Positioning System (GPS) device, Garmin 12 XL series with accuracy of between 15 to 20 metres, was used to document the coordinates of all sampling points.

The soil samples were collected using a standard metal soil auger and were stored in foil papers and black polythene bags and labelled appropriately. The samples were transported to the Soil Science Laboratory in the Federal University of Calabar, Cross River State, for further physical and chemical analyses. The laboratory agreement letter is attached in Appendix 4.

3.4.1.1 Soil laboratory analyses

Physical and chemical analyses were carried out on the soil samples to determine available attributes across several parameters. Table 3.1 presents the list of parameters the soil samples were analysed for.

Table 3.1: Soil sample analyses parameters

S/N	Type of Analysis	Parameters
1	Physical	Sand, Silt, Clay, Textural Class, Silt/Clay ratio
2	Chemical	PH, Organic Carbon (C), Total Nitrogen (N), Available Phosphorus (P), Exchangeable bases [Calcium (Ca), Magnesium (Mg), Potassium (K), and Sodium (Na)], Exchange acidity, effective cation exchange capacity (ECEC), and base saturation.
3	Fertility indices	Calcium/Magnesium ratio, Magnesium/Potassium ratio, and Carbon/Nitrogen ratio
4	Micronutrients	Iron (Fe), Manganese (Mn), Nickel (Ni), Vanadium (V), Cobalt (Co), and Molybdenum (Mo).

3.4.1.1.1 Physical tests

Soil samples were air-dried and ground with a wooden roller before sieving with a 2mm mesh. The particle size distribution of the soils was determined using the Bouyoucos hydrometer method (Gee and Bauder, 1986). Sodium hexa-metaphosphate was used as a dispersant after which the textural classes was determined using the soil texture triangle (Figure 3.1) developed by the United Stated Department of Agriculture (USDA, 1996).

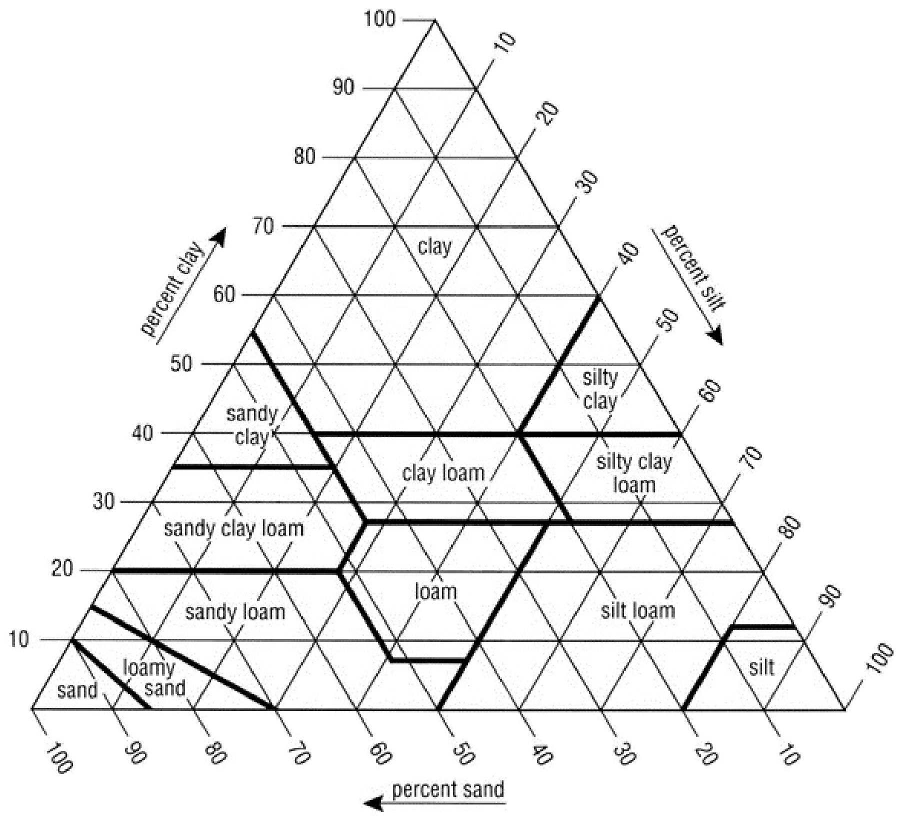

Figure 3.1: USDA soil texture triangle (Source: USDA, 1996)

3.4.1.1.2 Chemical tests

The pH of soil was measured using the soil/water ratio of 1:2 method of the International Institute of Tropical Agriculture (IITA, 1979). Soil organic carbon was determined using the method of Walkley and Black (1934). Total nitrogen was determined by the micro-Kjeldahl digestion method (Jackson, 1962) while available phosphorus was determined using the Bray and Kurtz (1945) No. 1 method. Exchangeable bases (Ca, Mg K and Na) were extracted from ammonium acetate buffered at pH 7 (neutral IM NH4OAc, pH 7.0), flame photometry, and versenate EDTA titration method as prescribed in Jackson (1962) and IITA (1979). The effective cation exchange capacity (CEC) was determined through the summation of exchangeable bases. Micronutrients in the soils (Fe, Mn, Ni, V, Co, and Mo) were extracted by digesting the samples with a mixture of concentrated nitric acid (HNO_3) and hydrogen chloride (HCI) and their concentrations determined by Atomic Absorption Spectrophotometry (AAS) method - Buck Scientific 200A flame atomisation prescribed by Barnhisel and Bertsch (1982).

Quality assurance was guaranteed by laboratory officers through double determinations and use of blanks for correction of background. The unit of measurement for exchangeable elements was centimoles of positive charge per kilogram ($cmolkg^{-1}$) while other elements such as phosphorus and micronutrient were measured at milligrams per kilogram ($mgkg^{-1}$).

3.4.1.2 Soil nutrient index analysis

In order to analyse the soil fertility status of soils in Makurdi, Tarka and Gboko, different indices like soil reaction index, and nutrient index with respect to organic carbon, available phosphorus and available potassium were calculated based on the specific rating chart. The specific rating chart is presented in Tables 3.2 and 3.3. The rating charts were used to rate the soil analysis results and nutrient index respectively. This procedure was used elsewhere in Verma *et al.* (2005) and Ravikumar and Somashekar (2013). After soil nutrient values were rated using the soils rating chart, the nutrient index for soils in Makurdi, Tarka, and Gboko were calculated using Equation 1 (Verma *et al*., 2005; Ravikumar and Somashekar, 2013).

$$NI = \frac{(1\ X\ nsrl)+(2\ X\ nsrm)+(3\ X\ nsrh)}{Tns} \qquad \text{Equation 1}$$

Where *NI* = nutrient index, *nsrl* = number of samples rated low, *nsrm* = number of samples rated medium, *nsrh* = number of samples rated high, and *Tns* = total number of samples. The results of the calculated nutrient index were thereafter classified using Table 3.3 which classified soils low, medium or high according to the nutrient index values.

Table 3.2: Rating chart for analysed soil nutrient values

Parameter	Category ratings		
Soil pH	**Acidity**	**Neutral**	**Alkaline**
Range	Below 6.0	6.0-8.0	Above 8.0
Soil reaction index	I	II	III
Organic Carbon (C)	**Low**	**Medium**	**High**
Range (%)	Below 0.5	0.5-0.75	Above 0.75
Nutrient index	I	II	III
Available Phosphorus (P)	**Low**	**Medium**	**High**
Range ($mgkg^{-1}$)	Below 2.2	2.2-5.4	Above 5.4
Nutrient index	I	II	III
Potassium (K)	**Low**	**Medium**	**High**
Range ($cmolkg^{-1}$)	0.1	0.1-0.2	Above 0.2
Nutrient index	I	II	III

Source: Ravikumar & Somashekar (2013)

Table 3.3: Nutrient index categories

Nutrient index	**Range**	**Categories (C, P, K)**
I	Below 1.67	Low
II	1.67-2.33	Medium
III	Above 2.33	High

Source: Ravikumar & Somashekar (2013)

3.4.1.3 Soil irrigation quality

The soil irrigation quality for the analysed soils sampled was assessed by calculating the exchangeable sodium percentage (ESP) which identifies the degree to which the adsorption and exchange complex of soil is saturated with sodium. The ESP was calculated using Equation 2 (Ravikumar and Somashekar 2013):

$$ESP = Exchangeable\ \frac{Na}{Ca+Mg+K+Na} X\ 100 \qquad \text{Equation 2}$$

The sodium adsorption ratio (SAR) of the soils was calculated to assess whether the parameter posed a hazard to irrigation in soils of the area. This is because *SAR* of water is directly related to the adsorption of sodium by soil and is a valuable criterion for determining the suitability of irrigable soils. Equation 3 was used to calculate *SAR* (Prasanth *et al*., 2012; Ravikumar and Somashekar, 2013).

$$SAR = Exchangeable\ \frac{Na}{\sqrt{\frac{(\frac{Ca}{Mg})}{2}}} \qquad \text{Equation 3}$$

3.4.2 Climatic analysis

Climate is influenced by geographic location and elevation. Temperature, soil temperature, rainfall, humidity, sunshine, are important climatic factors that influence land use and agricultural production Ayoade (2004), Cicek and Turkogu (2005), Tyubee (2006), and Adamgbe and Ujoh (2012). The Nigerian Meteorological Agency Abuja (NIMET) was approached to obtain 40 years (1973-2013) data on climatic factors mentioned above for Makurdi meteorological station. However, available data obtained from NIMET included rainfall (1973-2013), minimum and maximum temperature (1973-2014), solar radiation (1973-2014), and relative humidity (1974-

2008). Data on sunshine hours and soil temperature for the period was not readily available (Appendix 5).

Climatic data (rainfall, temperature, humidity, and solar radiation) was analysed for trends, variations, possible future scenarios and suitability for crop production. Signature anomalies which may suggest climatic variability were of particular interest and as such the standardised anomaly index and the reoccurrence interval was used as elsewhere in Ologunorisa and Tor (2006). Variability was calculated using the standardised anomaly index (SAI) which is presented as Equation 4.

$$SAI = \frac{X-(\bar{X})}{SD} \qquad \text{Equation 4}$$

Where *X* is the annual total or average, and $(\bar{X})$ is the mean of sum of annual totals for years investigated. *SD* is the standard deviation of the variables.

The onset and cessation of rainfall was calculated using a threshold of 51mm following the method described in Adamgbe and Ujoh (2012). This is because NIMET uses the Seasonal Rainfall Prediction software which was beyond the scope of this study. The reoccurrence interval *(RI)* of extreme rainfall events was calculated using the annual series analyses method of the Gumbel extreme value distribution (Equation 5).

$$RI = \frac{N+1}{M} \qquad \text{Equation 5}$$

Where *RI* is the return period in years, *N* is total number of extreme events, and *M* is the rank of individual extreme event.

The various atmospheric vapour calculations were carried out using the methods described in FAO (1998). The saturation vapour pressure was calculated using Equation 6.

$$e^o(T) = 0.6108exp[17.27T/T + 237.3] \qquad \text{Equation 6}$$

Where *e°(T)* is saturation vapour pressure at the air temperature measured in kilo Pascal (kPa), *T* is for both minimum and maximum air temperature *[°C]*, and *exp[..]* is 2.7183 (base of natural logarithm) raised to the power [..].

The mean saturation vapour pressure was calculated with *e°(Tmin)* and *e°(Tmax)* using Equation 7.

$$Es = e°(Tmax) + e°(Tmin)/2 \qquad \text{Equation 7}$$

Where *Es* is the mean saturation, and *e°(T)* values from Equation 6.

In order to arrive at the actual vapour pressure for the period 1973-2013, Equation 8 was used.

$$Ea = \frac{RHmean}{100xEs} \qquad \text{Equation 8}$$

Where *Ea* is the actual vapour pressure, *RHmean* is the mean daily relative humidity, and *Es* is the value of mean saturation vapour pressure.

The vapour pressure deficit was calculated using Equation 9.

$$Vapour\ pressure\ deficit = Es - Ea \qquad \text{Equation 9}$$

Where *Es* is the mean saturation and *Ea* is the actual vapour pressure.

Analysis was conducted using Microsoft Excel and Statistical Package for Social Sciences (SPSS version 17) software environment.

3.4.3 Drainage analysis

The River Benue is the main water body in the Lower River Benue Basin. There are several tributaries that discharge into the river Benue. The biggest is River Kastina Ala. The River Benue and its tributaries play a significant role in the distribution of nutrients in the floodplains of the Lower River Benue Basin. The physiography of the Lower River Benue Basin was determined from satellite imagery of the area and a topographic map. This helped in identifying the sources of surface-water.

Data on drainage discharge and water levels was collected over a period of more than fifty years (1955-2012) from three hydrological stations (Umaisha, Makurdi, and Katsina Ala) operated by the Nigerian Hydrological Services Agency (NIHSA). The River Benue discharge rate was analysed from hydrologic data. The hydrological parameters of particular interest were discharge rate and rating curve, water level, availability for irrigation, volumes of water and amounts of water for storage, flood peaks, and damming potentials.

3.5 Socioeconomic survey

3.5.1 Scope of socioeconomic survey

In carrying out people-oriented research particularly with reference to livelihoods, participatory methodologies have been advocated (FAO, 1985; Burdge, 2004). These include consultations with key stakeholders, Focus Group Discussion sessions and participant observation. The socioeconomic survey was conducted in Makurdi, Tarka and Gboko LGAs to add information to this study in line with provisions in literature (Chen and Lu, 2014; Heumann *et al*., 2013; Son *et al*., 2008; Stickler *et al*., 2007; Yen *et al*., 2013).

3.5.2 Focus Group Discussions (FGDs)

During consultations, the details of membership composition and areas of focus of farming cooperative societies from the three L.G.As were obtained. The list of farming cooperatives was trimmed to fifteen (five with large membership from each of the three L.G.As). Letters were written to the cooperatives and upon approval, Focus Group Discussion (FGD) sessions were held in each L.G.A with the farming cooperative societies. The sample of the letter sent to the cooperatives is attached in Appendix 6. Most of the farming cooperative societies had mixed membership while five had female only membership (Appendix 7).

In the FGD approach, relevant issues and questions on socio-economic elements were raised and answers solicited from the participants according to their role in the communities, cooperative societies, and agricultural experiences. Essentially, the socio-economic issues raised included their way of life (socio-cultural), economy (main occupations and sources of income), agricultural experience, and available social infrastructures amongst other issues. Participants also had the opportunity to ask questions which bothered them about the study. At the end of each session of the FGD, rapid appraisal visits was undertaken to sight and verify some of the claims made by the cooperative society members. Some of the FGD attendance sheets are attached in Appendix 8.

3.5.3 Questionnaire administration

The questionnaires were administered randomly to available members of farming cooperative societies that offered to fill them in Makurdi, Tarka, and Gboko during Focused Group Discussion meetings. The benefits, objectives and importance of the study were made clear at the gathering. After the signing of consent forms by the randomly selected members that volunteered, questionnaires with both structured and semi-structured questions were administered to capture socioeconomic data. A total of 300 questionnaires were administered in Makurdi, Tarka and Gboko. However, only 281 were recovered as some members who opted to fill the questionnaires at home failed to return them. A sample of the consent form and actual questionnaire administered to each respondent are attached in (Appendices 9 and 10).

3.5.4 Key informant interviews

Key informant interviews were conducted with the traditional rulers in Makurdi and Tarka. In particular, interviews were conducted with Ter Markurdi II and Ter Mbakor and Chairman of Tarka Council of Traditional Rulers for information concerning agricultural practices and government support. In addition to these, interviews were also conducted with influential figures recommended by the cooperative societies. One of such figures was the Executive Director of the Initiative for Leadership and Entrepreneurial Development (iLEAD) who was consulted for information on the Benue State Government and various International Partners providing training on sustainable and mechanised agriculture to farming cooperative societies in Benue State. Staff of the Benue State Ministry of Water Resources, and staff of the Benue State Ministry of Agriculture and Natural Resources were interviewed. Women and youth leaders were also interviewed for information concerning women and youth involvement in agricultural practices.

3.5.5 Secondary data sources

Socio-economic data were obtained on population structure, composition, and other attributes from national census archives, Benue State Government Agencies and data from published sources. These information proved useful in the expanded scope of land evaluation for agriculture used in this study by providing additional information for analysis.

3.5.6 Data analysis and presentation of results

The total number of questionnaires collected from the field was 281. The data from the questionnaires were transferred into a replicated online questionnaire database designed on Survey Monkey. Survey Monkey is a free online platform for academic and research surveys for digital data entry, electronic storage, and preliminary analysis. After data from all questionnaires were captured, the database was exported to Microsoft Excel and Statistical Package for Social Sciences (SPSS version 17). Before data was used in the SPSS environment, all the data was weighted and scored numerically given that some data variables were not numerical. All data variables were thereafter labelled appropriately before analysis. The electronic entry and transfer of data had an error margin of ±3 values. Data analysis including descriptive statistics such as summary tables, crosstab comparative analysis, and univariate summary statistics in tabular and graphical forms, and correlation analyses were performed in the Microsoft Excel and SPSS software environment, except for exponential population growth and dependency ratios which were calculated using equations 10, 11, 12, and 13.

Population exponential growth, $Pn = Po * (1 + r)n$ Equation 10

Where P_o is the base population, *r* is the growth rate of the population (2.8% FGN, 2007), n is time lapse in years, and *1* is a constant.

Overall dependency ratio is given by the Equation (World Bank, 2007):

$$\frac{No.of\ persons\ under\ 15\ or\ over\ 60}{No.of\ persons\ between\ 15{-}59\ years\ old}\ x\ 100$$ Equation 11

Or Old dependency ratio + young dependency ratio.

The young dependency ratio is given by the Equation:

$$\frac{No.of\ persons\ under\ 15\ years}{No.of\ persons\ between\ 15{-}59\ years\ old}\ x\ 100$$ Equation 12

The old dependency ratio is given by the Equation:

$$\frac{No.of\ persons\ over\ 60\ years}{No.of\ persons\ between\ 15{-}59\ years\ old}\ x\ 100 \qquad \text{Equation 13}$$

3.6 Methodology for Remote Sensing and GIS analyses

This section deals with the methodology used for Remote Sensing and GIS analyses. The methodology involved both desktop study and field survey investigation.

3.6.1 Data types

To achieve the objectives earlier stated, the data required for this research was include information on**:**

1. Satellite Imagery of the Study Area (Landsat)
2. Topographic map of the study area
3. Digital Elevation Model (DEM)
4. Soil sample data
5. Climatic data (Rainfall and Temperature)
6. Drainage map
7. Socioeconomic data
8. Information on crop (yam, cassava, rice) requirements

3.6.2 Sources of spatial data

3.6.2.1 Satellite imagery (Landsat 7)

Landsat sensors record reflected and emitted energy from Earth in various wavelengths of the electromagnetic spectrum. Landsat 7 records blue, green, and red light in the visible spectrum as well as near-infrared, mid-infrared, and thermal-infrared light. Landsat records this information digitally and it is downlinked to ground stations, processed, and stored in a data archives.

The Landsat Satellite imagery was obtained from Global Land Cover Facility (GLCF) through the earth explorer platform. Landsat 7 ETM+ data was obtained for the study area for the year 2015, which had ortho-rectified the systematic radiometric, atmospheric and geometrical distortions of the imagery to a quality level of 1G before delivery (USGS, 2015). According to the USGS (2015), the use of LPGS ensures systematic radiometric and geometric accuracy of imagery. The geometric accuracy of the systematically corrected products through LPGS is usually within 250 meters (1 sigma). The Landsat scenes covered a region of approximately 182 km x 185 km and had a spatial resolution of 30 metres. Each Landsat scene was identified by a Path and Row number. The Landsat scenes covering the study area were Path 187 and 188 of Row 055.

Table 3.4: Landsat imagery details

Parameters	**Details**
Upper left X	440385
Upper left Y	903915
Lower right X	681015
Lower right Y	695985
West longitude	8° 27' 31.6682" E
North latitude	8° 10' 37.5059" N
East longitude	10° 38' 35.1730" E
South latitude	6° 17' 38.3162" N
Projection description	UTM Zone 32 / WGS84/metres
Projection datum	WGS84
Projection units	Metres
EPSG_code	32632
Covered area	50034 sq km
Num columns	8021
Num rows	6931
Num bands	1
Pixel width	30metres
Pixel height	30metres
Bit depth	8
Sample type	Unsigned 8-bit Integer
GT_citation	UTM Zone 32 N with WGS84
Photometric	Greyscale (Min is Black)

Parameters	Details
Row per strip	1
Compression	None
Pixel scale	(30, 30, 1)
Tiepoints	(0.00, 0.00, 0.00) --> (440400.000, 903900.000, 0.000)
Model type	Projection Coordinate System
Raster type	Pixel is Point

3.6.2.2 Topographic map of the study area

The Topographic maps of the study area was obtained from the Office of the Surveyor General of the Federation, Nigeria in Abuja. The topographic map sheets was at a scale of 1:50,000 for more details to be captured. Information such as settlements, rivers, contours, spot heights etc. was extracted to form part of the data used during the remote sensing and GIS analysis. Sixteen (16) Topographic map sheets covered the entire study area at the desired scale. Each map sheet covered an area of 27km by 27km per quadrant. The information of the Topographic map sheets are presented in Table 3.5.

Table 3.5: Topographic map sheet details

Sheet Name	Sheet numbers	Quadrants
Agana	250	NE, NW, SE and SW
Makurdi	251	NE, NW, SE and SW
Otukpo	270	NE, NW, SE and SW
Gboko	271	NE, NW, SE and SW

3.6.2.3 Digital Elevation Model (DEM)

The NASA Shuttle Radar Topographic Mission (SRTM) has provided digital elevation data (DEMs) for over 80% of the globe. This data was downloaded from the National Map

Seamless Data Distribution System, or the USGS ftp site. The elevation details was obtained from the SRTM using the Global Mapper 15 software and compared with the contour extracted from the topographic map using the ArcMap 10.3 software, to have a full understanding of the topography. The digital elevation model of the study area is provided in Figure 3.2.

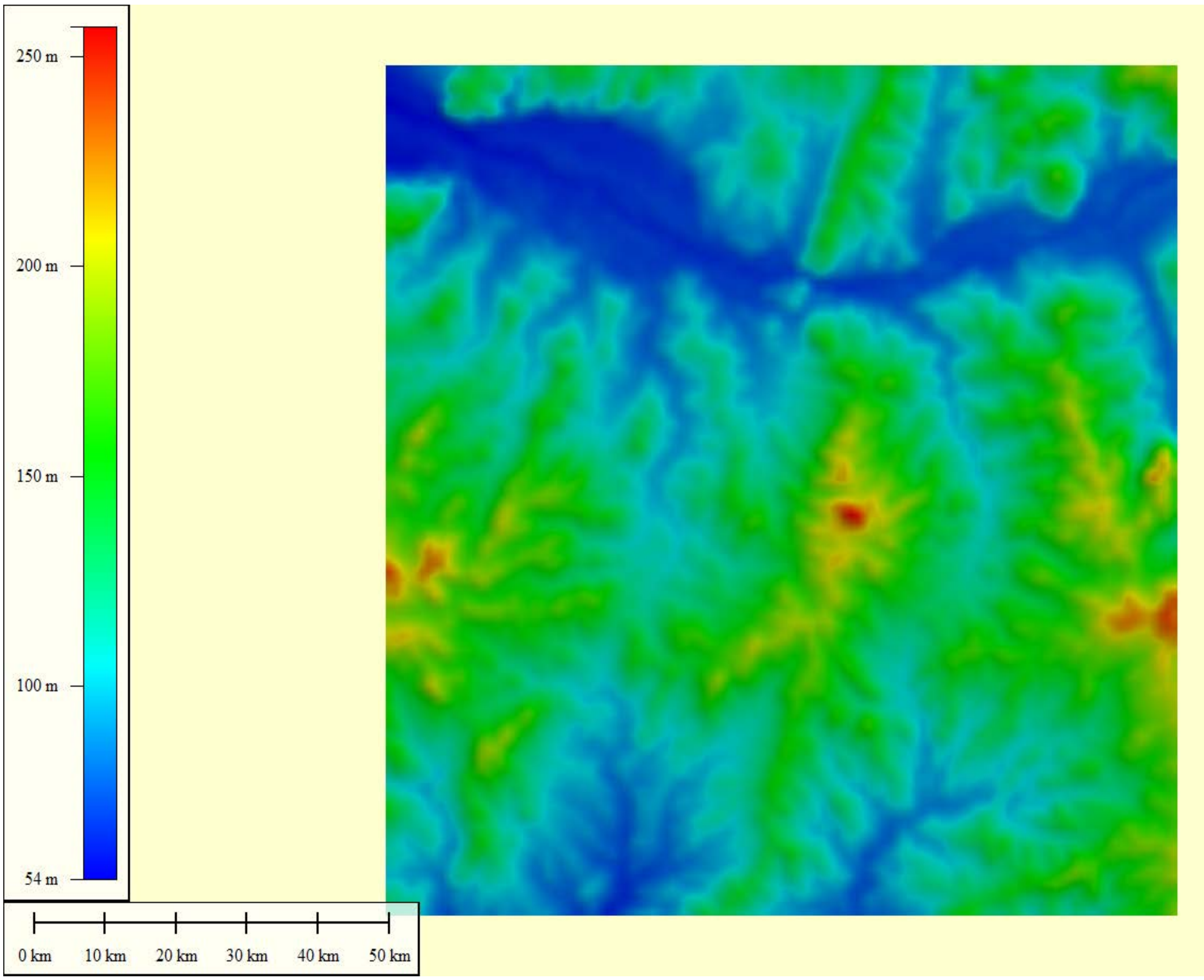

Figure 3.2: Digital Elevation Model of the study area from SRTM

3.6.2.4 Other maps produced

Maps were derived for themes such as climate, drainage, soil and population. The climatic maps were for rainfall and temperature from data collected from secondary sources. The physiography of the Lower River Benue Basin was determined from satellite imagery of the area and topographic map. The soil map was extracted from the FAO (2014) digital soil map of the world. The population density map was produced from National Census figures for the Local Government Areas that fall under the study area. These maps are presented in Chapter four except the population density map which is presented in Chapter five.

3.6.3 Image analysis

The remote sensing analyses for the research included Land use land cover analysis and NDVI. These two (2) analyses were achieved using a combination of software (Idrisi 17.0 Selva edition and ArcMap 10.3) and geoprocessing operations. The spatial analyses were done in Idrisi while the cartographic finishing was achieved using the ArcMap 10.3 software.

3.6.3.1 Land Use classification

Classification involved labelling the pixels belonging to particular spectral classes using the spectral data available. The supervised method of classification was used which gave rise to the training sets provided in Table 3.6. A classification scheme was developed for the study area based on the prior knowledge of the study area.

The Landsat imagery was first mosaicked using the geo-reference properties of both imagery and a feathering of two (2) was applied to reduce the edging. The various bands from 1 – 4 was independently mosaicked. After which, a subset of the study area was made from the two

(2) scenes of Landsat imagery downloaded. This subset was done using the Idrisi 17 Selva edition software.

Table 3.6: Classification domains for Land Use Land Cover mapping

Code	Classification domains
1	Bare land
2	Built – up area
3	Scattered vegetation
4	Waterbody
5	Wetland
6	Rock outcrop

From empirical analysis and Principal Component Analysis, it has been proven that the bands that carry the greatest information about natural environment are the visible (Red, Blue and Green) wavelength bands. Using the Idrisi Selva software a true colour composite was made in Red, Green and Blue (RGB) representing Bands 3, 2 and 1 respectively.

Based on the colour composite created (Figure 3.3), the following steps were taken to classify the image used for generating the land use land cover map for this study.

1. The training sites representing the various cover types were identified and carefully studied for digitising.
2. Polygons were digitised around the training sites identified and unique identifiers were assigned. This was done obeying the rule of thumb stipulating that the number of pixels in each training set (all the training sites for a single cover class) should not be less than 10 x the number of bands (70 pixels for Landsat with three (3) bands).
3. The pixels within each site was analysed and spectral signatures were created using SIGCOMP

4. Though the pixels were adequately covered for each cover, Maximum Likelihood Classification was chosen. The algorithm used by the classifier (Maximum Likelihood) is based on two principles;
    - The cells in each class sample in the multidimensional space being normally distributed
    - Bayes' theorem of decision making

The tool considered both the variance and covariance of the class signatures as it assigned each cell to one of the classes represented in the signature file. With the assumption that the distribution of a class sample was normal, classes were characterised by the mean vector and the covariance matrix. Given these two characteristics for each cell value, the statistical probability was computed for each class to determine the membership of the cells to the class. When the default EQUAL option for a priori probability weighting was specified, each cell was assigned to the class to which it had the highest probability of being a member.

3.6.3.2 Normalised difference vegetation index (NDVI)

The NDVI was expressed as the difference between the near infrared and red bands normalised by the sum of those bands. This is the most commonly used vegetation index in literature as it retains the ability to minimise topographic effects while producing a linear measurement. The NDVI was calculated using the empirical format by Rouse *et al*. (1973) (Equation 14).

$$NDVI = \frac{NIR - RED}{NIR + RED} \qquad \text{Equation 14}$$

Where NIR is near infrared band of TM (Band 4), and RED refers to Red band of TM (Band 3). The measurement scale had the desirable property of ranging from -1 to 1 with 0 representing the approximate value of no vegetation. Thus negative values represented non-vegetated surfaces.

Idrisi offers 19 vegetation Index models grouped into slope based and distance based models. Since it was apparent that soil influence was mostly visible in all the indexes, the research carefully studied and chose the model that best reduced the influence of soil considering the fact that the Landsat image are acquired in November when the biomass was less and the soil influence may be significant.

3.6.4 Spatial analysis and mapping

Operations such as vector to raster conversion, reclassification, weighted overlay etc. were performed at this stage using the ArcMap 10.3 software and its geoprocessing tools in ArcToolbox. A "Weighted Overlay Operation" was adopted using GIS techniques for identification of areas of the various crop suitability depending on a number of thematic layers and based on the principle of Multi-Criteria Evaluation used in various literature presented in Chapter two.

3.6.4.1 Thematic layers for ArcMap analysis

The ArcMap 10.3 software was used to create the various thematic maps from available data. The maps (rainfall, drainage, temperature, DEM, Land use land cover and soil) were converted from vector format to raster format using the conversion tools in ArcToolbox for use in the GIS weighted overlay operation.

3.6.4.2 Thematic map reclassification

Using the spatial analyst tools in ArcToolbox, the various raster maps were reclassified. A scale of 1 to 5 was adopted to indicate the level of importance. Value 5 represented extreme importance while value 1 represented not important. The scaling of the criteria was done in line with the level of contribution of the factors to the growth of rice, yam, and cassava from literature and conditions obtainable in the study area (Table 3.7).

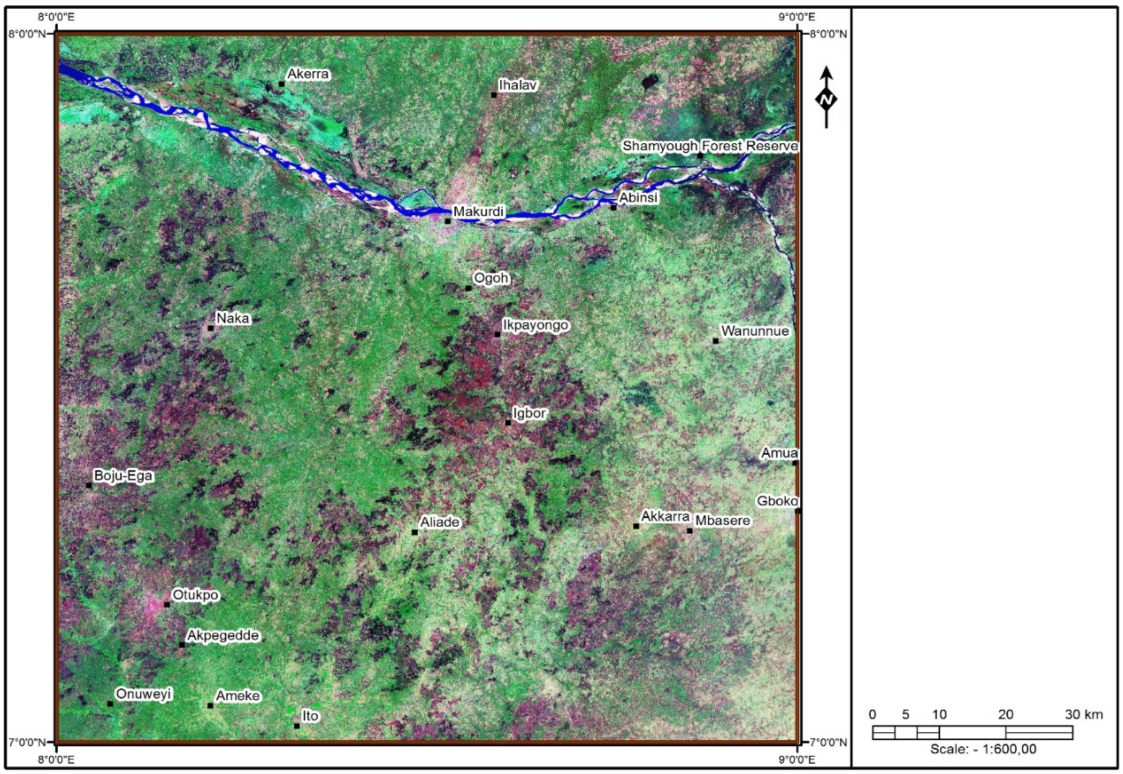

Figure 3.3: Landsat imagery composite (Bands 3, 2, 1)

Table 3.7: Scale of importance table

Scale of importance	**Description**
1	Non Importance
2	Less Importance
3	Moderate Importance
4	Strong Importance
5	Extreme Importance

3.6.4.3 Crop requirements for weighting

Suitable parameters for cassava cultivation in savannah regions are documented in Titus et al. (2011) and Ande (2011). Cassava can grow on a wide variety of soils with a wide pH range but preferably 5.5–6.5, with moderate amounts of phosphorus and organic carbon. It requires a temperature range of between 25^{o}C and 29^{o}C, and with a rainfall range of 500 to 1500 mm. Cassava can grow on level to moderate slope and does not require much water for growth.

Suitable conditions for rice cultivation in southern guinea savannah is presented in Aondoakaa and Agbakwuru (2012). Rice requires a temperature range of 20^{o}C to 27^{o}C and a rainfall range of 1150mm to 3000mm. Rice varieties cultivated in the Lower River Benue Basin require wetland soils which loamy to clay loam. Rice tolerates acidic soil pH and requires moderate to high amounts of phosphorus.

Growth requirements for yam cultivation are discussed in Kutugi (2002) and Eruola *et al*. (2012). The conditions for yam cultivation are similar to that of cassava except that yam does not tolerate water stress.

Given these requirements for the growth of rice, yam and cassava from literature, Table 3.7 was used to rank the range requirements of extreme importance for each crop within the biophysical results obtained in this study. Following the results of the ranking, the requirements of extreme importance for each crop have been presented in Table 3.8.

3.6.4.4 Parameter weighting

All the parameters were compared against each other in a pair – wise comparison matrix which was a measure of the relationship between the parameters in order to rule out bias. Subsequently, a numerical value expressing the level of importance of one parameter against another was assigned. Each raster was assigned a percentage of influence according to its importance derived for each crop. Therefore, the weights used for the overlay were relative percentages vertically compared for each parameter, and the sum of the percentage weights of influence added up to 100% for each crop (Table 3.9). The process of arriving at the weights for this study is prevalent in literature (Ashraf, 2010; Hunduma, 2012; Petja *et al.*, 2014).

Table 3.8: Requirements of extreme importance for cultivation of rice, yam, and cassava

Parameters	**Rice**	**Yam**	**Cassava**
Rainfall (mm)	>1500	1000-1250	750-1000
Temperature (^{o}C)	23-26	26-29	26-29
Soil classes	Clay loam	loamy sand	loamy sand
Soil pH	5.0-5.5	6.0-6.5	5.5-6.0
Soil organic carbon	1.5<2.0	2.0>	2.0>
Soil Phosphorus (mgkg^{-1})	5-10	10-15	10-15
Soil Potassium (cmolkg^{-1})	0.8-1.0	0.5-0.7	0.5-0.7
Land Cover classes	Wetland	Scattered vegetation	Scattered vegetation
DEM (metres)	0-100	100-200	100-200

3.6.4.5 Crop suitability mapping

After the preparation of all the thematic layers, reclassification as well as preparation of the table of weights, the weighted overlay operation was performed on the ArcMap 10.3 software. The crop suitability maps were created through the weighted overlay geoprocessing tool in ArcMap 10.3 ArcToolbox by using the weights assigned to each of the parameters (climate, soil, land cover, and DEM). Using five classes, the various layers were classified from very high suitability to very low suitability. Suitability maps were created for rice, yam, and cassava. These maps were compared with the prevailing cultivation situation of these crops and the socioeconomic attributes of farmers in the Lower River Benue Basin. This was done to highlight the constraints other than biophysical issues which may serve as impediments to the development of agriculture in the region. Figure 3.4 illustrates the mapping process utilised in this study and the results are presented in chapter four.

Table 3.9: Weighted index of parameters

Parameters	Weights (%) Rice	Yam	Cassava
Rainfall	23.08	33.33	23.08
Temperature	10.25	15.00	10.38
Humidity	5.14	10.00	5.00
Soil class	12.82	4.45	7.69
pH	10.26	1.11	1.54
Organic carbon	5.13	5.56	4.62
Phosphorus	7.69	3.33	6.15
Potassium	2.56	2.22	3.08
Land cover	7.69	8.33	7.69
DEM (slope)	15.38	16.67	30.77
Total	**100%**	**100%**	**100%**

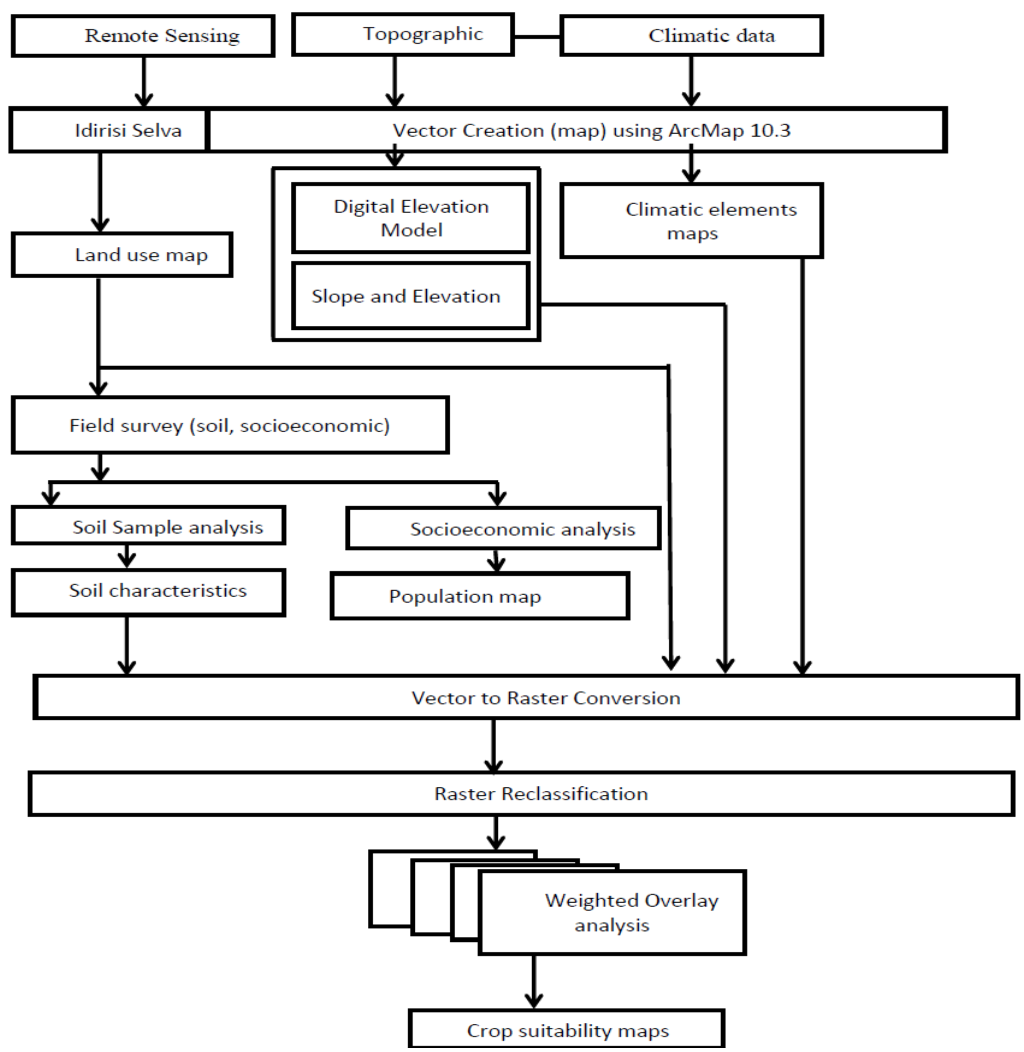

Figure 3.4: Summary of GIS analysis process

3.7 Methodology for potential impact assessment

This section dealt with the assessment of potential impacts (climatic variability, rural-urban migration, population growth, and HIV/AIDS) to sustainable agriculture in the Lower River Benue Basin, using the following literature:

- International Standard Organisation (ISO) 14001-impact identification and impact evaluation methodology (2004).
- Iglesias *et al*. (2009a), and Várallyay (2010).
- The issues raised concerning emerging climatic and soil fertility changes during Focus Group Discussions.
- Review of land evaluation, suitability maps, and socioeconomic survey results.

The steps taken for the impact assessment process included:

- Establishing the basis for the impact assessment
- Development of Interaction Matrix
- Identification of Impacts
- Classification of impacts and
- Evaluation of impact significance

3.7.1 Establishing the basis for the impact assessment

The data collected on climate, soil, drainage, and socioeconomics were used to draw up a comprehensive list of the likely environmental sensitivities to climate change related physical dynamics, and population dynamics with a view to determining how these sensitivities would impact on agricultural production which is the mainstay of people in the Lower River Benue Basin.

3.7.2 Environmental sensitivities interaction matrix

The interactions between environmental sensitivities and agricultural production were assessed in a matrix. Based on the nature of these interactions, it was possible to determine the probability of occurrence, and the effect of the interaction was adjudged to be positive or negative. The positive interactions were represented by (+) sign while the negative interactions were represented by (–) sign in the matrix table. Interactions that were both positive and negative are represented by (+/-) sign.

3.7.3 Evaluation of impacts

The evaluation of significance of the impacts was based on an internationally accepted standard method (ISO 14001) using the background and full understanding brought about by the processes in sections 3.7.1 and 3.7.2.

The identified impacts were then qualified and quantified. The Impact qualification classified the impacts as adverse (-) or/and beneficial (+); short term (S) or long term (L); and reversible (R) or irreversible (I). Adverse impacts are those which impact negatively on the environment and wellbeing of people while beneficial impacts are those which enhance agricultural production and social environments. Short term means a period of time less than 10 years while any period greater than 10 years is considered long term. An impact is reversible when the impact can be reverted to previous conditions or controlled without further consequences to agricultural production. Impacts are irreversible if the impact remains permanent or cannot be reverted in a reasonable period of time.

The impact quantification involved the use of a set of criteria and weighting scale to evaluate the significance of the impacts. These were the probability of occurrence of impacts from the sensitivity matrix (P); Public interest and perception of perceived impact of emerging environmental changes on agricultural production (I), and Interaction effect of impacts from sensitivity matrix (E).

The quantification scale of 1, 3, and 5 was used. This is a modification of the arbitrary scale proposed by Vesilind *et al.* (1994). The ratings are as described and were adapted from ISO 14001(2004) – Environmental Management System Approach. The criteria and ratings used were:

1. Probability of Impact occurrence (P) - What is the probability of impact occurring from study findings?
   - 1 = Low probability (rare)
   - 3 = Medium probability (likely)
   - 5 = High probability (very likely)

2. Public interest/perception (I) - What is public perception and interest rating of the impacts based on the perceived effect on agriculture from socioeconomic survey findings?
   - 1 = Low interest/perception (Rural-urban migration)
   - 3 = Intermediate interest/perception (Population growth, HIV/AIDS)
   - 5 = High interest/perception (Climate change)

3. Interaction effect of impacts (E) - What is the interaction effect of the impacts from the sensitivity rating matrix?
   - 1 = Low (+)
   - 3 = Medium (+/-)
   - 5 = High (-)

For this study, the probability (P), the public interest and perception (I) and interaction effect (E) were judged to be important indicators of the impacts hence the significant impacts were rated based on the sum of P+I+E. The maximum possible rating score from this sum was 15.

Impacts whose sum of P+I+E was less than 5 were rated as low. These impacts were adjudged not to require mitigation but should be monitored. Those whose sum of P+I+E was between 5 and 10 were rated as having medium significance while those whose sum of P+I+E was between 10 and 15 were adjudged as having high significance. Impacts with medium and high significant values require mitigation through community efforts and special assistance from policy makers. Recommendations were made for these impacts. Impacts with low significance should be mitigated through appropriate standard agricultural practises.

3.8 Agricultural suitability index (ASI) modelling

The study attempted to categorise the overall agricultural suitability of study area by developing an agricultural suitability index (ASI) model. The ASI model comprised significant parameters from climate, soil, drainage, socioeconomics and potential impacts. The ASI model exists as a Microsoft Excel based electronic tool and has three basic features including a checklist with options to guide the ranking of parameter indicators, and a rating score pivot table which feeds results into an interactive pivot dashboard. The checklist with the list of parameters and indicator options is provided in Appendix 11. The checklist options were rated in four categories (10, 20, 30 and 40) in order of importance to agricultural suitability based on limits and thresholds drawn from literature and result attributes of this study. The model was adapted from the FAO principles for agricultural ecological zoning (FAO, 1996) attempted elsewhere (Kilic *et al*., 2005). The checklist parameters were used to assess the findings from the study, and the focus of the overall agricultural suitability index was crop farming. The total cumulative rating score was used to calculate the agricultural suitability index of the study area with Equation 15:

$$\textit{Agricultural suitability index } (ASI) = \left(\frac{T}{2000}\right)100 \qquad \text{Equation 15}$$

Where T is the total cumulative rating score, 2000 is the maximum score achievable, and multiplied by 100.

The agricultural suitability index was classified into four classes of potential crop yield namely not suitable (<25%), marginally suitable (25-50%), suitable (50-75%), and highly suitable (75-100%). The ASI model provided additional analyses to arrive at the agricultural suitability status of the study area.

3.9 Climate change adaptive capacity index modelling

The methodology for adaptive capacity analysis was adapted from Smit *et al.* (2001), Smit and Pilifosova (2003), and the processes followed in Swanson et al. (2007). Smit *et al*. (2001) provided six determinants of adaptive capacity related to climate change. Each of these determinants have rationales which provide guidance for the development of indicators to measure degree of vulnerability (Table 3.10). These determinants and rationale were used to identify indicators that suit the agricultural focus of this study.

After the modification of the determinants to suit the purpose of this study, four features relating to agricultural adaptive capacity were identified for each determinant framework from the socioeconomic survey result summaries. These features were used in identifying indicators that were measureable using percentages (Table 3.11).

The indicator percentages were grouped in brackets based on intervals of five from 0-5% to 95-100%, and ranked in ascending order from 0-20 for ‘higher is better indicators’, and in descending order from 20-0 for ‘lower is better indicators’. The total possible score for each indicator was 20 and the total possible score for each determinant was 80. The determinant percentage score (DPS) was arrived at using Equation 16:

$$DPS = (Total\ indicator\ ranking\ scores/80)\ x\ 100 \qquad \text{Equation 16}$$

The adaptive capacity index (ACI) for the study area was therefore calculated by computing the percentages for each determinant and the cumulative percentage of determinants (Equation 17).

$$ACI = (Total\ determinants\ scores/600)\ x\ 100 \qquad \text{Equation 17}$$

Five category classes were used to measure the adaptive capacity index of the study area. The category classes used were 0% - 20% (Very low); 20% - 40% (Low); 40% - 60% (Moderate); 60% - 80% (High); and 80% - 100% (Very high). The results of biophysical analyses are presented in next chapter.

Table 3.10: Adaptive capacity determinants

Determinants	**Rationales**
Economic resource base	Adaptive capacity is enhanced by greater economic resources
	Adaption options are limited by inadequate financial resources
Technological advancement	The range of adaptation options is limited by inadequate technology
	Technologically challenged regions are less likely to develop and/or implement technological adaptations
Availability of information and skills	Limited access to information, skilled and trained personnel reduces adaptive capacity
	Greater access to information increases likelihood of timely and appropriate adaptation
Available infrastructure	Adaptive capacity is enhanced by greater variety of infrastructure
	Spatial attributes and quality of infrastructure also affect adaptive capacity
Institutional capacity	Social institutional strengthening helps to reduce impacts of climate related risks
	Policies and regulations influence adaptive capacity
Equity	The equitable distribution of resources enhances adaptive capacity
	Availability of and level of entitlement to resources are important to adaptive capacity

Source: Smit *et al*. (2001)

Table 3.11: The features and indicators used to calculate adaptive capacity index

Determinants	Features	Indicators
Agricultural economic base	Monthly income	Percentage of population earning high (above 1 dollar a day X 30 days) a month. Higher is better.
	Farm expenditure	Percentage of population spending above series average on farming. Higher is better.
	Crop yield	Percentage of population recording high crop yields. Higher is better.
	Agricultural diversity	Percentage difference between agricultural types. Lower is better.
Farm Technology	Irrigation	Percentage of population engaged in irrigation farming. Higher is better.
	Mechanisation	Percentage of population engaged in mechanised farming. Higher is better.
	Processing equipment	Percentage of population utilising modern processing equipment. Higher is better.
	Storage facilities	Percentage of population utilising appropriate storage facilities. Higher is better.
Farm management	Farm ownership	Percentage of population that own their own farmlands. Higher is better.
	Farm inputs	Percentage of population that have access to fertilisers. Higher is better
	Farm labour	Percentage of population heavily dependent on farm labour. Lower is better.
	Farming season	Percentage of population that have good knowledge on farming season. Higher is better.
Infrastructure	Dependence on agriculture	Percentage of population dependent on agriculture. Lower is better.
	Water sources	Percentage of population that have access to portable water. Higher is better.
	Housing type	Percentage of population that have access to modern housing (zinc roof and brick walls). Higher is better.
	Roads	Percentage of population that have access to tarred roads. Higher is better.
Networking	Cooperative membership	Percentage of farmers that belong to farming cooperative societies. Higher is better.
	Mobile communication	Percentage of population that have access to mobile telecommunication services. Higher is better.
	Agricultural extension	Percentage of population that have regular contact with agricultural extension workers. Higher is better.

Determinants	Features	Indicators
	Markets	Percentage of population that have close proximity (<5km) to markets. Higher is better.
Equity	Access to electricity	Percentage of population with access to electricity supply. Higher is better.
	Access to hospitals	Percentage of population with access to government hospitals. Higher is better.
	Access to schools	Percentage of population with access to government schools. Higher is better.
	Access to police	Percentage of population with access to police stations. Higher is better.

CHAPTER FOUR

BIOPHYSICAL ANALYSIS, LAND EVALUATION AND CROP SUITABILTY ASSESSMENT

4.0 Introduction

This chapter presents results and discussion of physical analyses carried out on climatic, drainage, and soil data. In addition, the chapter presents the results and discussion of Remote Sensing and GIS analyses carried out on thematic maps of the study area. The results of analyses were discussed alongside relevant secondary data.

4.1 Climatic characteristics of the Lower River Benue Basin

The results of analyses carried out on data of climatic parameters such as rainfall, temperature, relative humidity, and solar radiation is presented in this section.

4.1.1 Rainfall

The descriptive statistics and quantile-quantile plots of rainfall data from 1973-2013 is presented in Appendix 12.

4.1.1.1 Rainfall daily averages

The daily rainfall average calculated for the period 1973-2013 was 133.8mm and the median was 108.7mm. The highest daily rainfall recorded for the period was 149mm which was recorded on the 3rd of August 2000. The daily averages of rainfall for the period 1973-2013 is presented in Figure 4.1. The earliest rain recorded in the period was on January 1st 1985 when 18.6mm of rainfall was recorded, and on the 2nd of January 2008 when 3mm of rainfall was recorded. Daily rainfall began to increase significantly in the month of April and continued to increase and peaked in the months of August and September for the period 1973-2013.

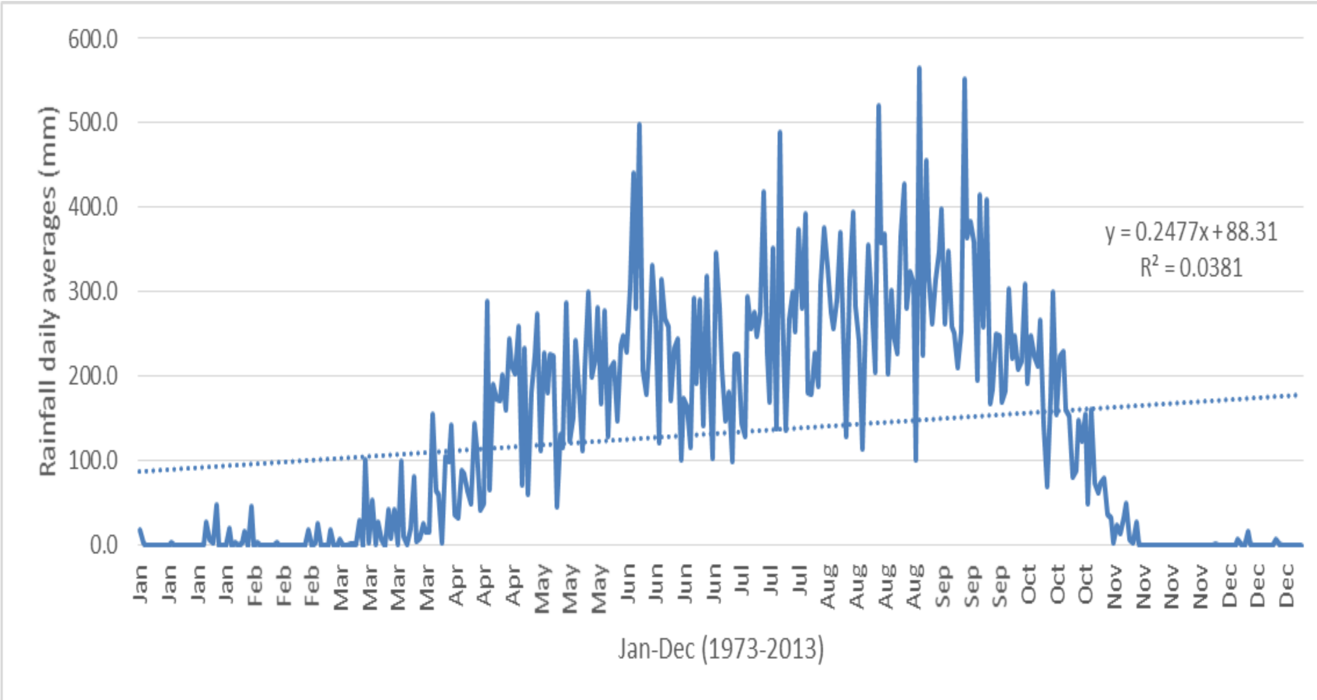

Figure 4.1: Daily rainfall averages of Makurdi, 1973 – 2013

4.1.1.2 Rainfall monthly totals

The monthly total rainfall for the period (1973-2013) is presented in Figure 4.2. August had the highest amount of 9220.7mm for the period and was followed by September with 9021.7mm. The lowest month was December with a monthly total of 37.6mm for the period. The months of April to October all recorded monthly totals above 3000mm, and more than 50% of the rainfall amount recorded was in four months (June-September).

4.1.1.3 Annual rainfall totals

The annual average rainfall amount recorded for the period 1973-2013 was 1194.1mm, and the median was 1207.9mm. The year with the highest amount of rainfall was 1999 (1617.1mm). Other years with high amounts of rainfall were 1984 (1572mm), 1998 (1537.6mm), 1975 (1508.6mm), 2012 (1466.7mm), 1980 (1425.5mm), and 2009 (1407.5mm). The year with the lowest amount of rainfall was 2003 (761.5mm). The annual rainfall totals for Makurdi is presented in Figure 4.3. The trend showed a linear regression of y=-0.0624x+1195.4.

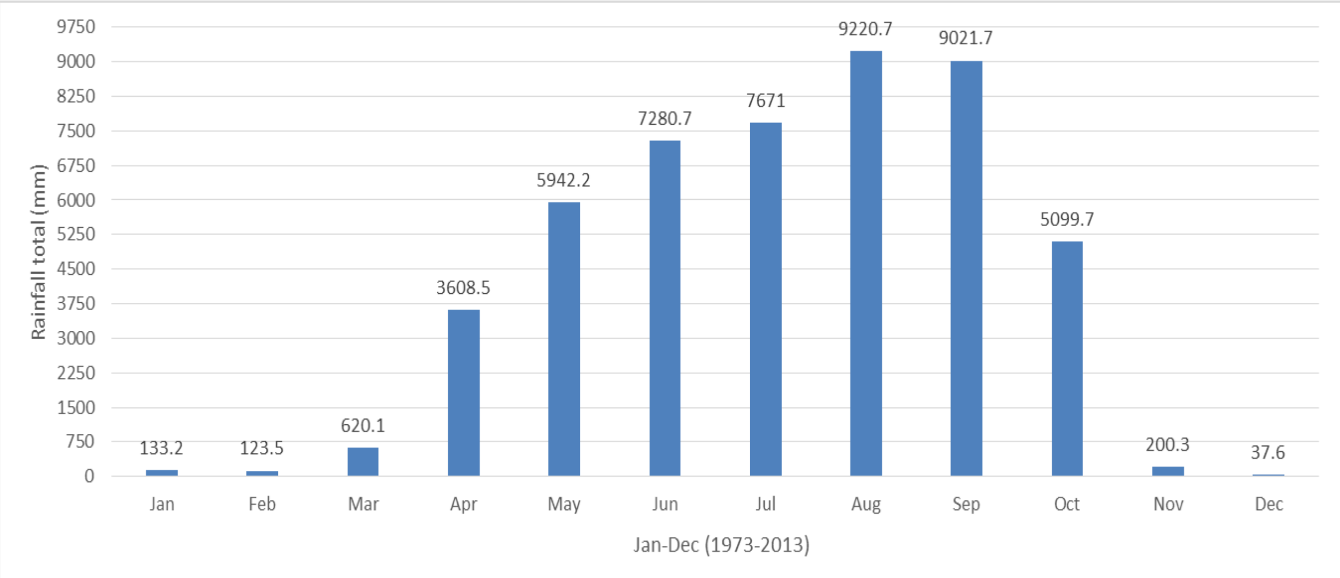

Figure 4.2: Cumulative monthly rainfall totals for Makurdi, 1973 – 2013

4.1.1.4 Rainfall onset and cessation

The average months of onset and cessation for rainfall duration for the period (1973-2013) was put at April and October. This means that sustained rainfall was available for rain-fed agriculture between the months of April to October 1973-2013. However, variations were observed annually with regards to onset and cessation of rainfall. It was observed that onset of rainfall began in March in 1980, 1984, and 1985. Onset of rainfall began in April for most of the remaining years. Rainfall cessation began in October in 1973, 1983, 1985, 2001, and 2003. Cessation of rainfall began in November for the remaining years. Even though rainfall onset began in April for most of the years assessed, the threshold was either reached or surpassed late in April. This suggests that rain-fed agricultural activities should now be delayed till the penultimate or ultimate week of April each year. Adamgbe and Ujoh (2012) extensively looked at climatic variations and crop yield in Benue for 25 years (1986 – 2010). Adamgbe and Ujoh (2012) as part of their finding revealed that climatic parameters including rainfall and temperature accounted for a 48% of the variance in rice yield, 71% of variance in cassava yield, and 78% of the variance in yam yield. Therefore, interpretation of annual weather variability is important to crop cultivation. The Nigerian Meteorological Agency seasonal rainfall prediction report (SRP) for 2016 (NIMET, 2016), showed that the 2016 rainfall onset began later in Makurdi than other areas of Benue (Table 4.1).

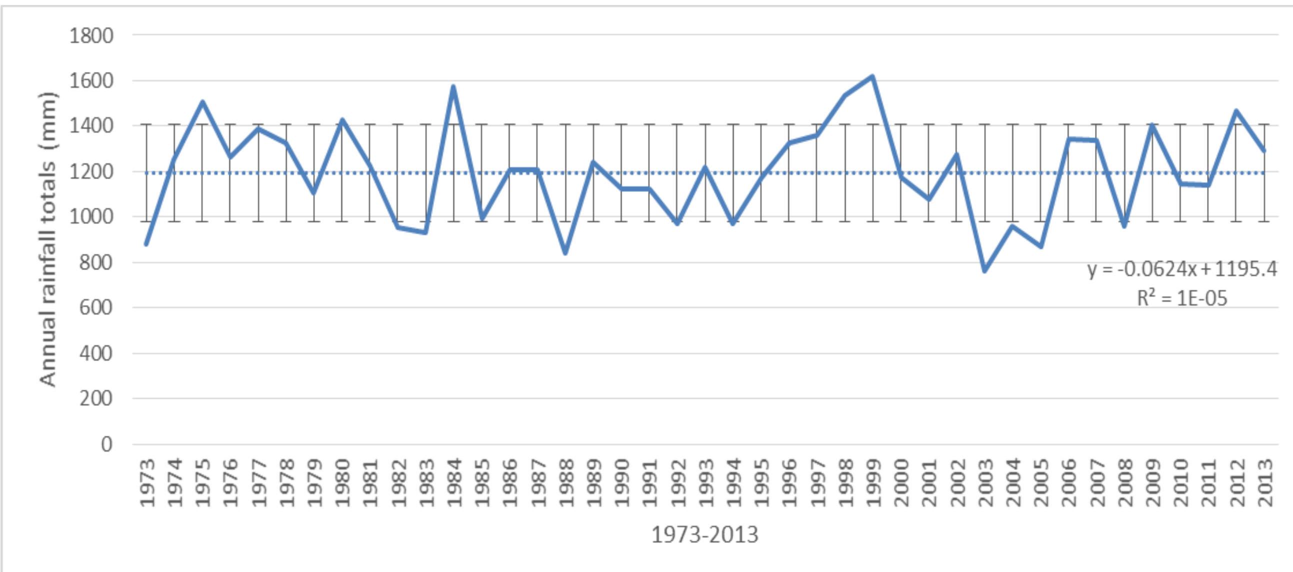

Figure 4.3: Annual rainfall totals for Makurdi, 1973 – 2013

4.1.1.5 Annual rainfall duration and intensity

The average number of rain days for the period (1973-2013) was 85.7 days. The map of rainfall intensity is provided in Figure 4.4 while the total number of annual rain days for the period 1973-2013 is presented in Figure 4.5. The year with the highest number of rain days was 1977 (159 days). Other years with high number of rain days were 1978 (156 days), and 1975 (121 days).

The year with the lowest number of rain days was 1983 (56 days). Figure 4.4 showed the spread of rainfall intensity in the study area with the southern parts around Gboko and Otukpo having more rainfall. The linear forecast presented in Figure 4.5 suggests that the number of total annual rain days is decreasing with the exception of 1977 and 1978 where there were spikes.

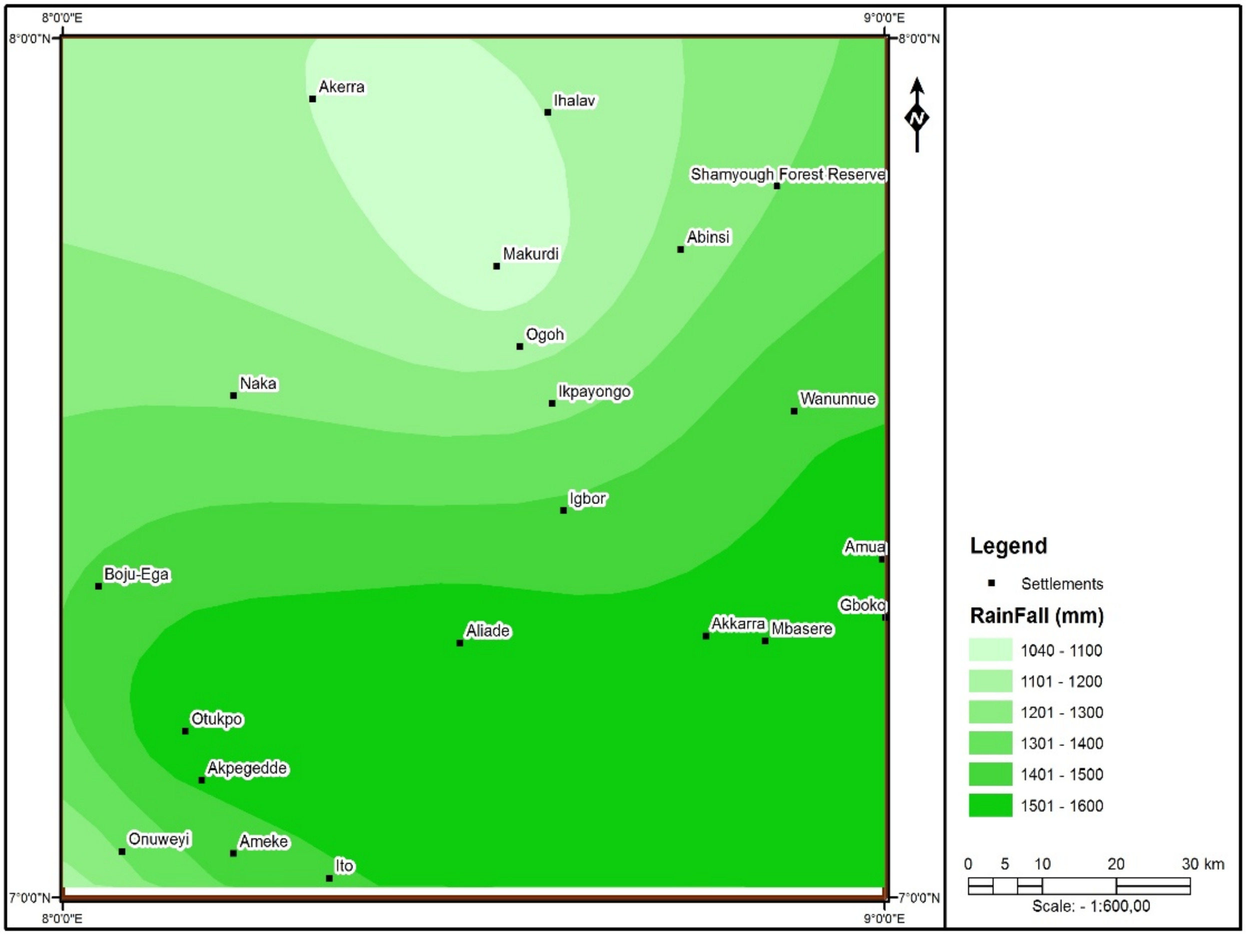

Figure 4.4: Rainfall intensity map of the study area

The relationship between total number of rain days and annual rainfall totals is presented in Figure 4.6, which showed that the year 1977 which had the highest number of rain days had produced an annual rainfall total of 1387.1mm. The year 1978 which had a total number of 156 rain days produced an annual rainfall total of 1326.2mm, and 56 rain days in 1983 produced an annual total of 930.3mm.

Table 4.1: The 2016 rainfall prediction for Benue State

Location	Longitude	Latitude	Onset date	End date	Rain days	Amount (mm)
Gboko	09.00	07.32	Apr 10	Nov 26	231	1486
Makurdi	08.54	07.73	May 1	Nov 20	203	1059
Otukpo	08.14	7.20	Apr 9	Nov 28	234	1524
Aliade	08.48	7.30	Apr 10	Nov 27	232	1493
Wanunne	08.89	07.57	Apr 13	Nov 24	226	1411
Katsina Ala	09.28	07.16	Apr 8	Nov 28	235	1537

Source: NIMET (2016)

A disturbing trend of increasing rainfall intensity can be observed in Figure 4.6. Although the total number of annual rain days seems to be decreasing, the annual rainfall totals is not decreasing. There are several years in which less than a hundred days of rainfall produced annual rainfall totals over 1200mm which is above the annual average of 1194.1mm calculated for the period 1973-2013. Notable among these years was 1999 which produced the highest annual rainfall total of 1617.1mm in 95 rain days. The year 1984 recorded an annual rainfall total of 1572mm in 79 days. Similarly, the year 1998 recorded annual rainfall totals of 1537.6mm in 76 days. The year 2012 which was most recently notable for rainfall intensity and severe flooding, recorded a total of 1407mm of rain in 89 days. The daily average of rainfall for 1998, 1999, 2000, 2009, and 2012 are presented in Figures 4.7 – 4.11.

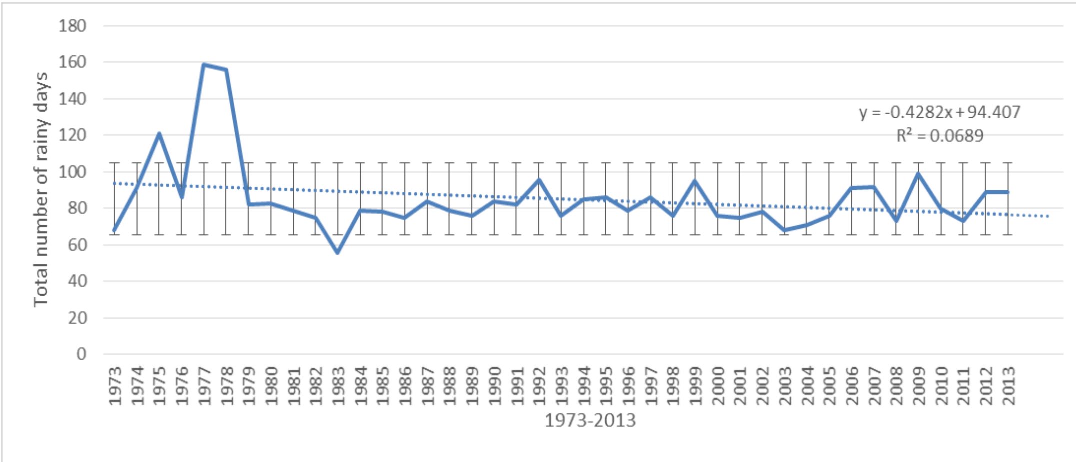

Figure 4.5: Total number of rain days in Makurdi, 1973 – 2013

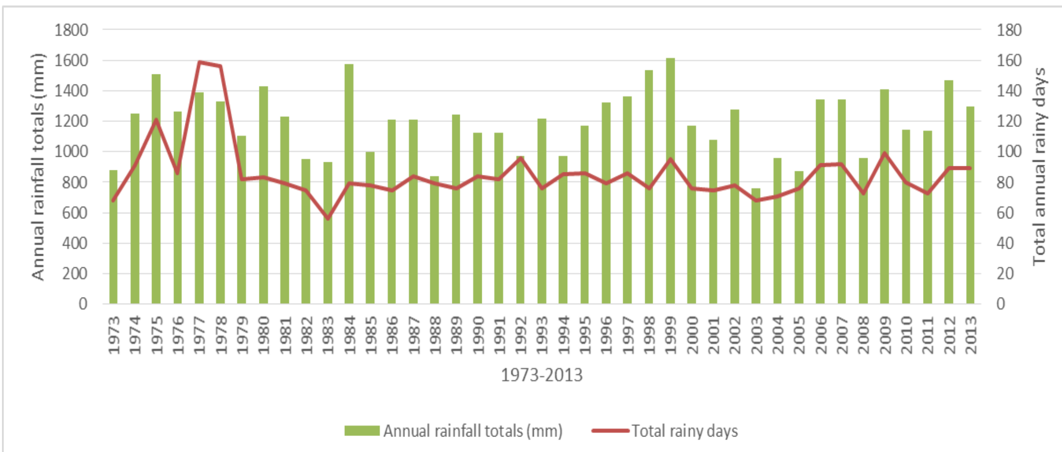

Figure 4.6: Annual rainfall totals and total number of rain days in Makurdi, 1973 – 2013

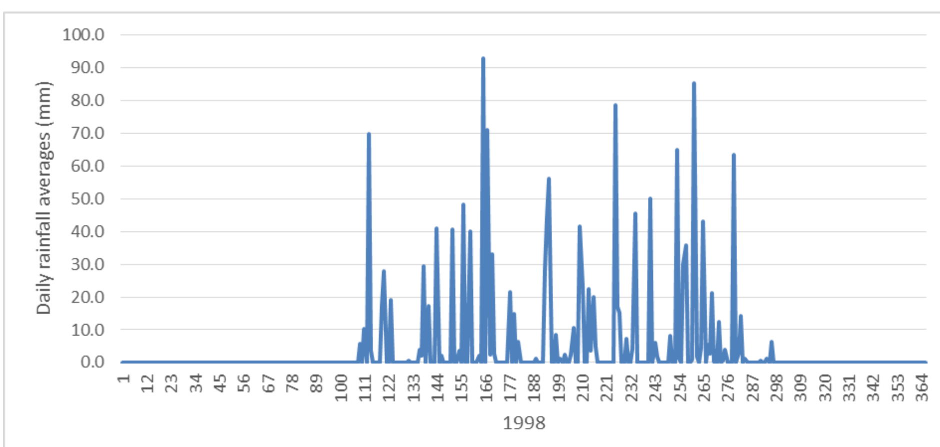

Figure 4.7: Daily rainfall averages of Makurdi in 1998

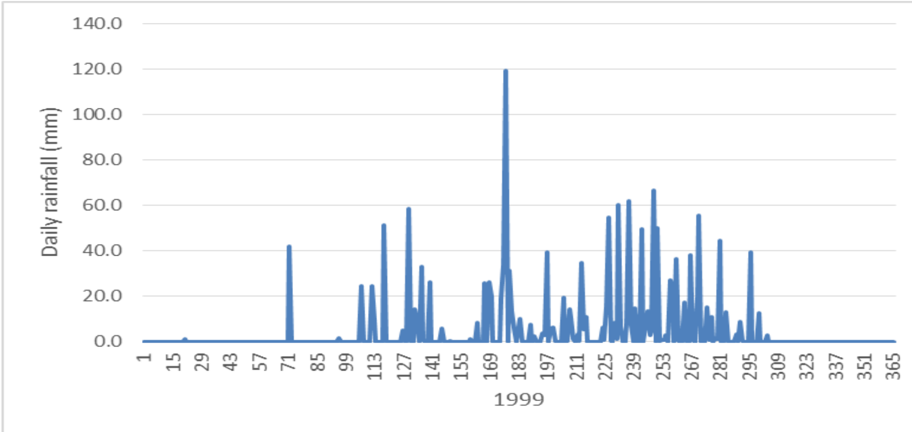

Figure 4.8: Daily rainfall averages for Makurdi in 1999

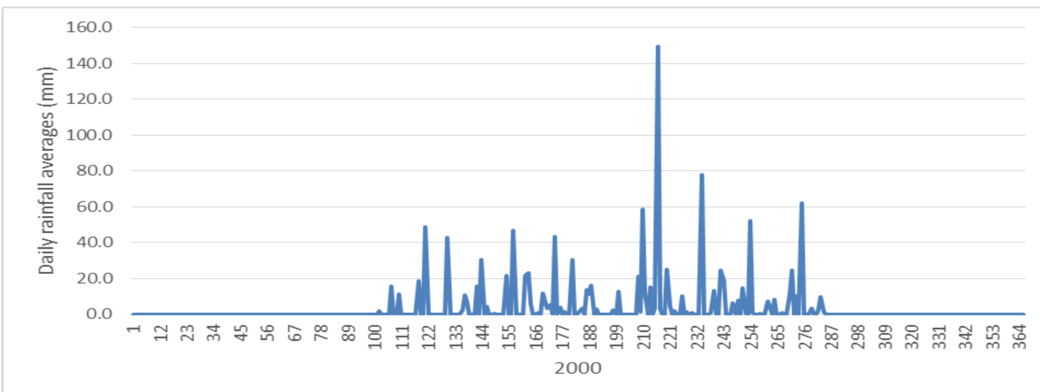

Figure 4.9: Daily rainfall averages for Makurdi in 2000

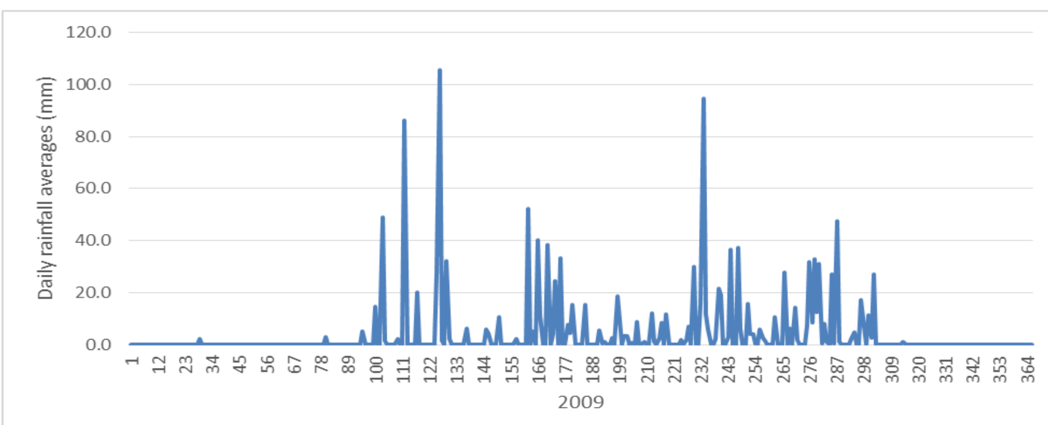

Figure 4.10: Daily rainfall averages for Makurdi in 2009

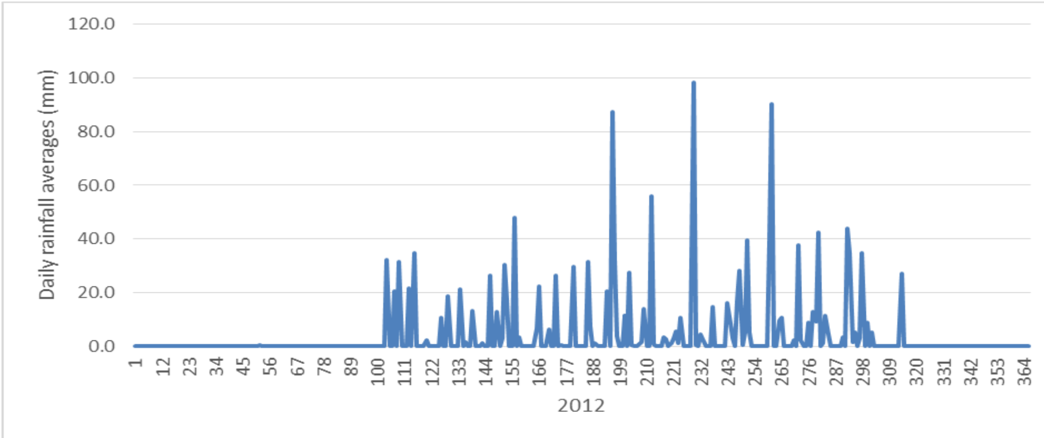

Figure 4.11: Daily rainfall averages for Makurdi in 2012

4.1.1.6 Heavy and extreme rainfall events

This study utilised daily rainfall averages of >40mm during a 24 hours period as heavy rainfall (rainstorms) as stated in FAO (1998). The number of heavy rainfall events in the period is presented in Figure 4.12. The year with the highest number of days of heavy rainfall was 1998. Other years with more than 10 days of heavy rainfall were 1984, 1999, and 2006.

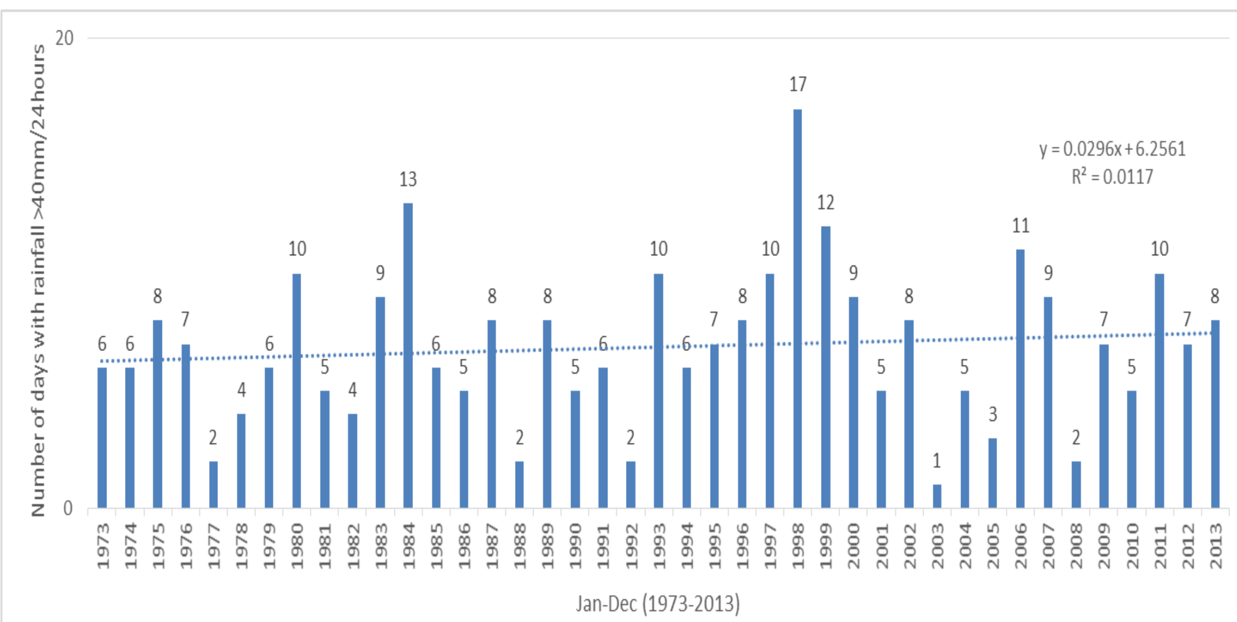

Figure 4.12: Number of heavy rainfall days in Makurdi, 1973 – 2013

Extreme daily rainfall causes flooding. The highest daily amounts of rainfall for the each year (Julian day) was adopted as extreme daily rainfall (Table 4.2). The reoccurrence interval showed that the extreme rainfall event ranked number one (149mm) may occur again in 42 years as shown by the outlier in Table 4.2. The second ranked event of 125.3mm may occur in 21 years. Extreme daily rainfall events below 100mm have shorter intervals between 1-5 years and are likely to occur more often as shown in the probability scatter diagram in Figure 4.13. Extreme daily rainfall events cause flooding in Makurdi annually and this is well documented in the media and several literature (Ologunorisa and Tor, 2006; Ocheri and Okele 2012; Abah, 2012; Shabu and Tyonum, 2013).

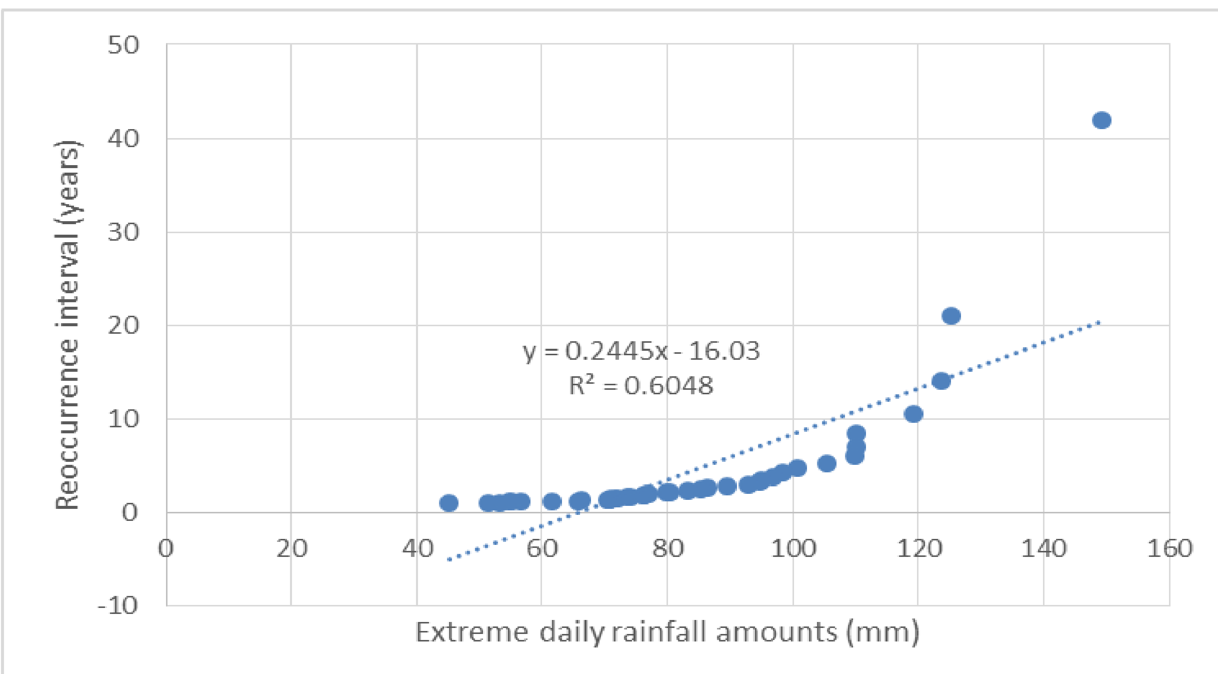

Figure 4.13: Extreme rainfall events and reoccurrence intervals in Makurdi

Table 4.2: Extreme daily rainfall events and reoccurrence intervals (1973-2013)

Date	Amount (mm)	Rank	Reoccurrence interval (years)
Aug 3, 2000	149.30	1	42
Jun 30, 1986	125.30	2	21
Jul 20, 1981	123.70	3	14
Jun 25, 1999	119.30	4	10.5
Sep 2, 1973	110.20	5	8.4
Sep 2, 1975	110.20	6	7
Jul 28, 1974	110.00	7	6
May 5, 2009	105.40	8	5.25
Sep 6, 1990	100.70	9	4.67
Aug 16, 2012	98.40	10	4.2
Aug 11, 2002	96.80	11	3.82
Aug 4, 1984	95.00	12	3.5
Jul 24, 2006	94.70	13	3.23
Jun 13, 1998	92.90	14	3
Sep 7, 1997	89.50	15	2.8
Aug 29, 1996	86.30	16	2.63
Aug 22, 1987	85.30	17	2.47
Sep 18, 1989	83.30	18	2.33
Jul 10, 1993	80.30	19	2.21
Sep 18, 2011	79.80	20	2.1
Sep 21, 2013	77.10	21	2
Jul 15, 1985	76.80	22	1.91
Aug 13, 2007	76.30	23	1.83
Jul 16, 1980	76.20	24	1.75
Jun 5, 1983	74.00	25	1.68
Sep 5, 2010	73.50	26	1.62
Aug 20, 1979	71.90	27	1.56
Jul 15, 1982	71.70	28	1.5
Oct 17, 1976	71.10	29	1.45
Aug 13, 1995	70.60	30	1.4
Jun10, 2005	70.60	31	1.35
Sep 11, 1992	70.50	32	1.31
May 14, 2008	66.40	33	1.27
Aug 30, 2004	65.80	34	1.24
Aug 22, 1994	61.70	35	1.2
Aug 27, 1991	56.60	36	1.17
Sep 2, 1977	55.10	37	1.14
Jun 7, 2003	54.70	38	1.11
Oct 17, 1978	53.30	39	1.08
Aug 2, 2001	51.30	40	1.05
Oct 27, 1988	45.20	41	1.02

4.1.1.7 Rainfall variability

Rainfall fluctuation was assessed in five year brackets. There were two consecutive periods of deviation from the annual mean (1983-1992, and 2003-2007). The standardised rainfall anomaly index (SAI) for the period 1973-2013 is presented in Figure 4.14. There were slightly more wet years (22) than drier ones (19). The year brackets of 1982-1995 and 2000-2011 witnessed more negative deviations. The period 1975-1978 and 1996-1999 were the most consistent wet periods. The standardised rainfall index revealed that rainfall for the period 1973-2013 witnessed very high variation and inconsistency. Even though Makurdi experiences spells of high rainfall intensity, the progressive consistency of rainfall in Makurdi is decreasing.

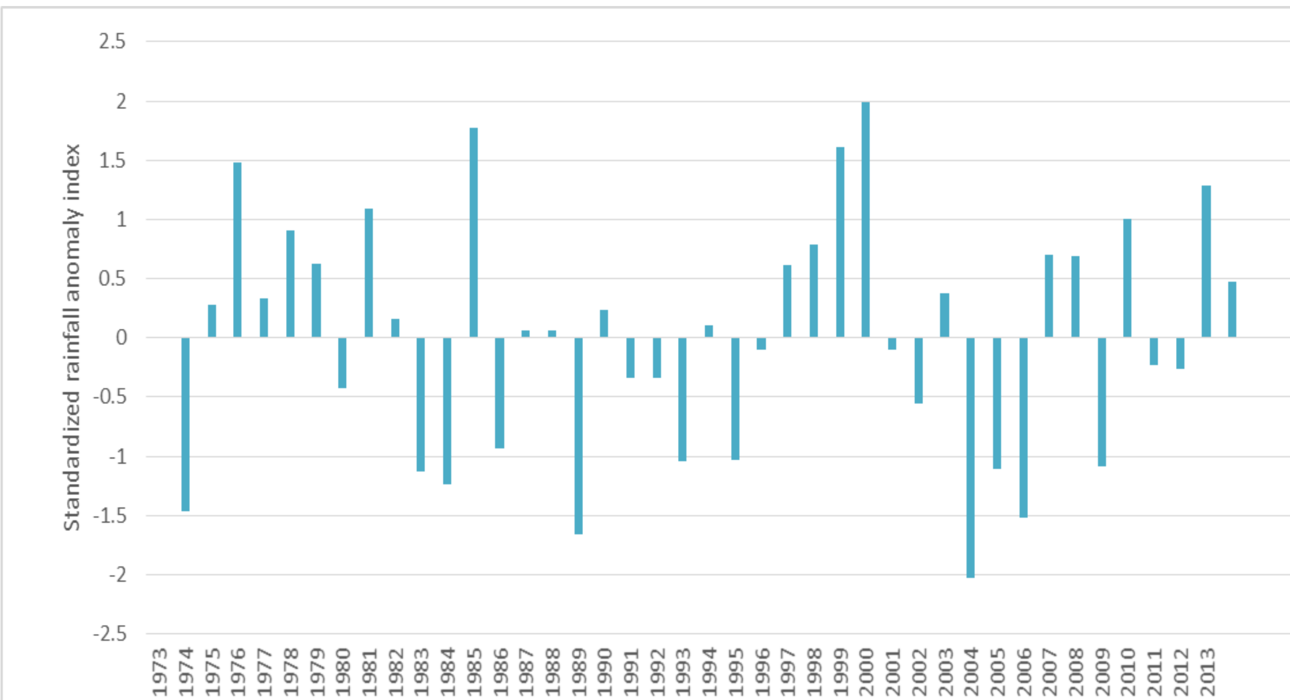

Figure 4.14: Standardised rainfall anomaly index for Makurdi, 1973 – 2013

4.1.2 Temperature

The descriptive statistics and quantile-quantile plots of the maximum and minimum temperature for Makurdi (1973-2014) is in Appendices 13 and 14.

4.1.2.1 Annual average temperature

The average annual temperature calculated for the period January 1973 to December 2014 was 27.84ºC. The highest annual temperature averages were recorded in 2005 (28.6ºC), 1998 (28.55ºC), 2010 (28.5ºC), and 2003 (28.43ºC). The lowest temperature values were recorded in 2012 (26.8ºC) and 1974 (27.2ºC). Annual temperature averages for the period are presented in Figure 4.15. A map showing the average temperature spread in the study are is presented in Figure 4.16. The map (Figure 4.16) showed higher temperature values in areas with lesser rainfall such as Makurdi.

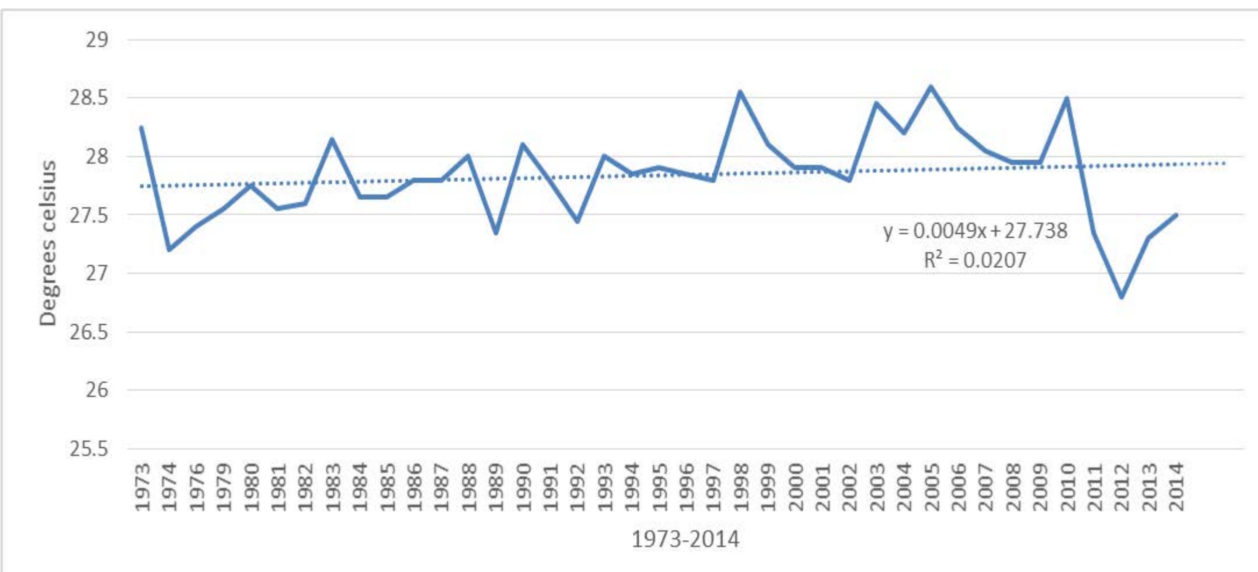

Figure 4.15: Annual temperature averages for Makurdi, 1973 – 2014

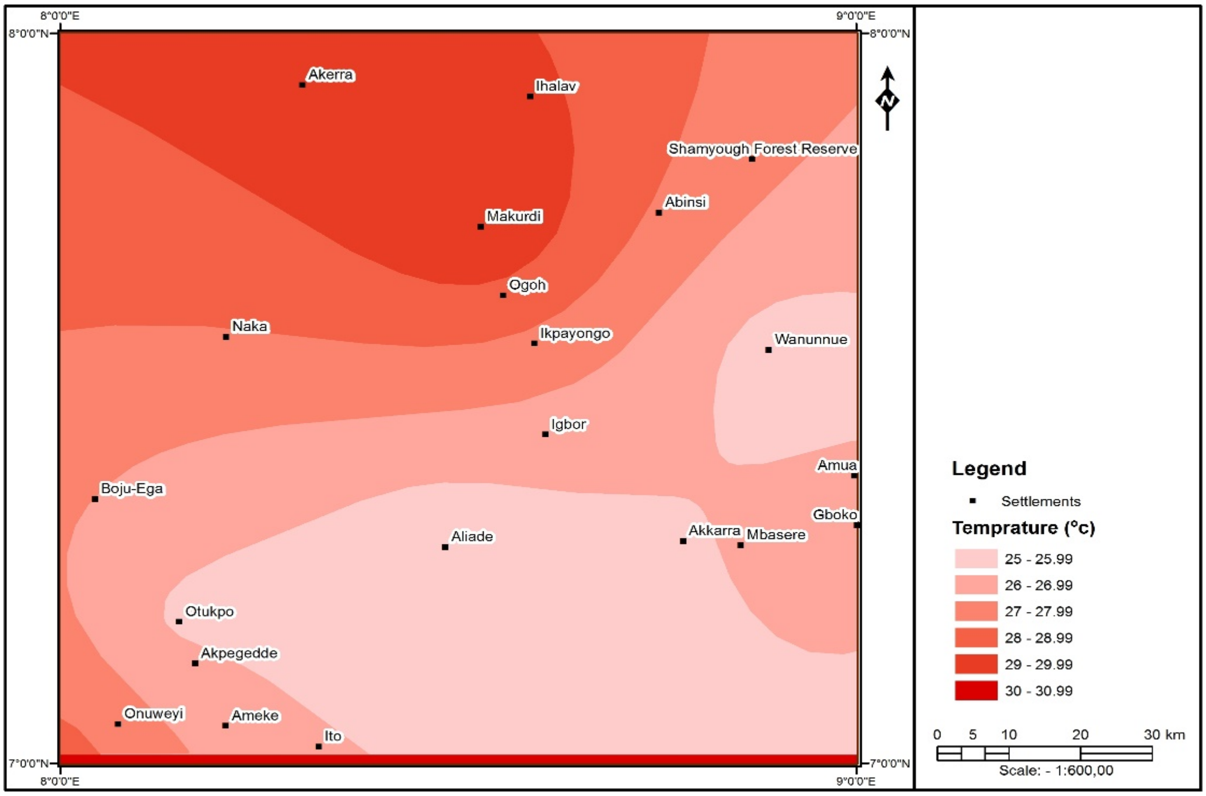

Figure 4.16: Temperature map of the study area

4.1.2.2 Maximum and minimum temperature

The average maximum and minimum daily temperatures for the period 1973-2014 is presented in Figure 4.17. Figure 4.17 showed that temperature is highest between the first 20 to 110 days of the year. Figure 4.18 showed that temperature drops and stabilises in the months with high rainfall (July, August, and September), and rises around the onset period of rainfall.

The highest maximum temperature for the period 1973-2014 was recorded on February 5 1998 (42^{o}C). A total of 186 days recorded maximum temperatures above 39^{o}C between 1973 and 2014 and were classified high discomfort days. All the high discomfort days with extreme maximum temperature (>39^{o}C) fell between the months of February and April. Most of the other days of the year between 1973 and 2014 had maximum temperature between 30^{o}C -39^{o}C. This means that atmospheric temperature in Makurdi causes some form of discomfort to humans and livestock for most parts of the year annually.

The annual average maximum temperature from 1973-2014 is presented in Figure 4.19. The years with the highest maximum temperature were 1998, 1973, 2003, 2005, and 2010.

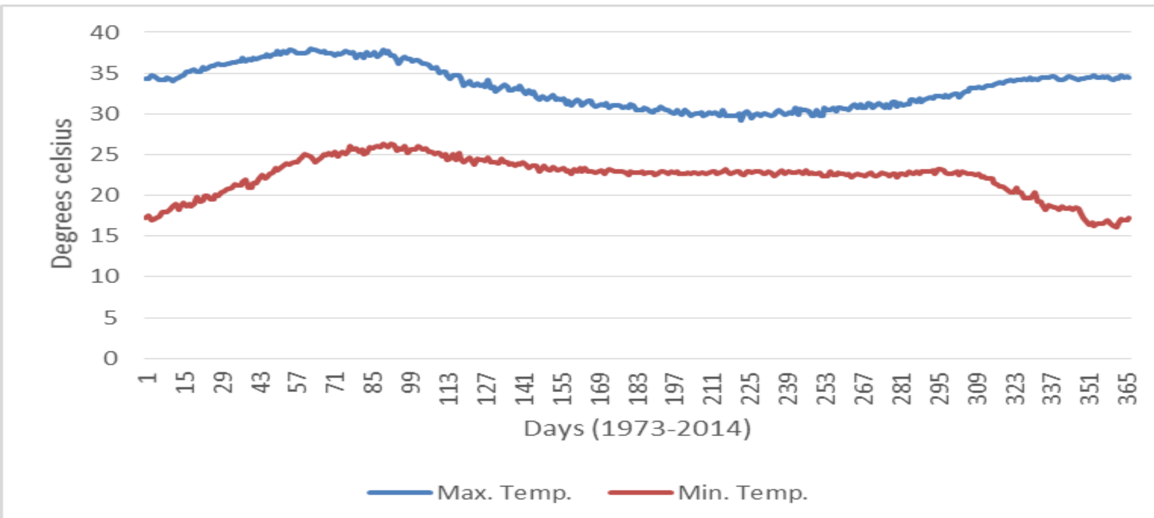

Figure 4.17: Daily temperature averages for Makurdi, 1973 – 2014

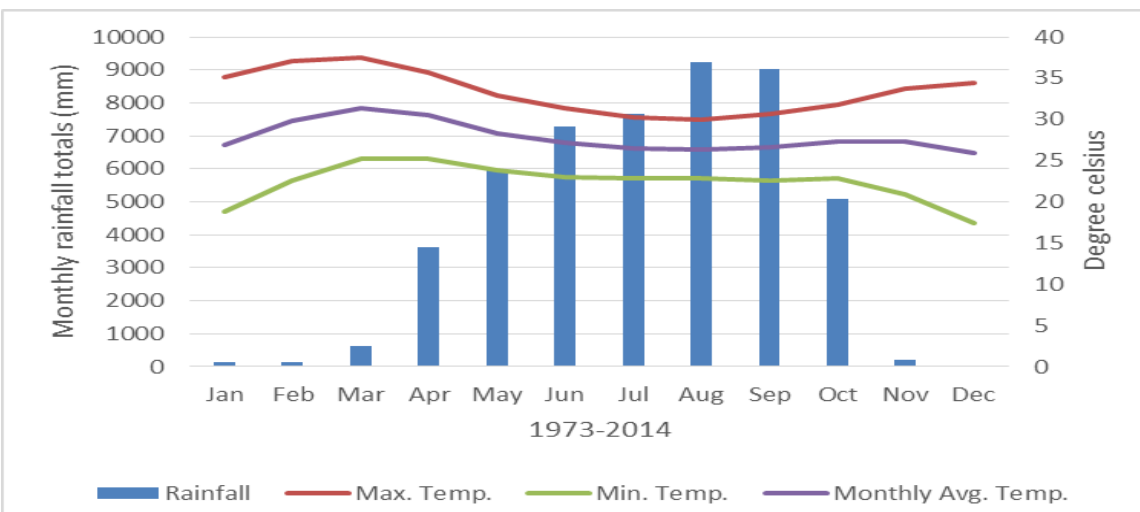

Figure 4.18: Monthly rainfall and temperature relations in Makurdi, 1973 – 2014

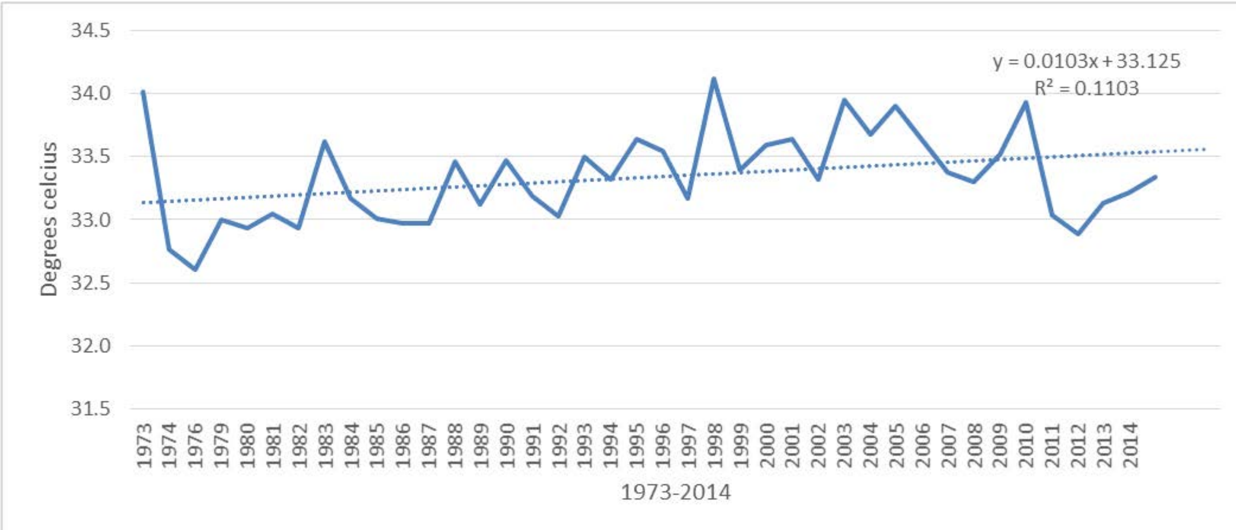

Figure 4.19: Annual average maximum temperature for Makurdi, 1973 – 2014

The lowest minimum temperature (10^{o}C) was recorded on February 2 1973. Minimum temperature below 12^{o}C for the period 1973-2014 was recorded in 22 days between the months of December and February. The year with the highest frequency of minimum temperature lower than 12^{o}C was 2012 which recorded 9 days of minimum temperature between 10.8^{o}C-11.8^{o}C on January13, and December 21-31. The year 2011 recorded 4 days of minimum temperature between 11^{o}C and 11.8^{o}C in December (2-9). The annual average minimum temperature from 1973 – 2014 is presented in Figure 4.20.

4.1.2.3 Temperature variation

The result of the standardised temperature anomaly index (SAI) for the period 1973-2014 revealed several departures from the reference annual mean (Figure 4.21). There were 20 years with positive anomalies indicating warmer temperature than the reference mean. Negative anomalies were observed in 19 years indicating cooler temperature than the reference mean. A string of negative anomalies occurred between 1974 and 1992, and a string of positive anomalies occurred between 1998 and 2010. The coolest year was 2012 and the warmest was 2005. These two temperature extremes occurred in the last 10 years. The near equal number of positive and negative temperature variations are similar to that of rainfall observed for the same period.

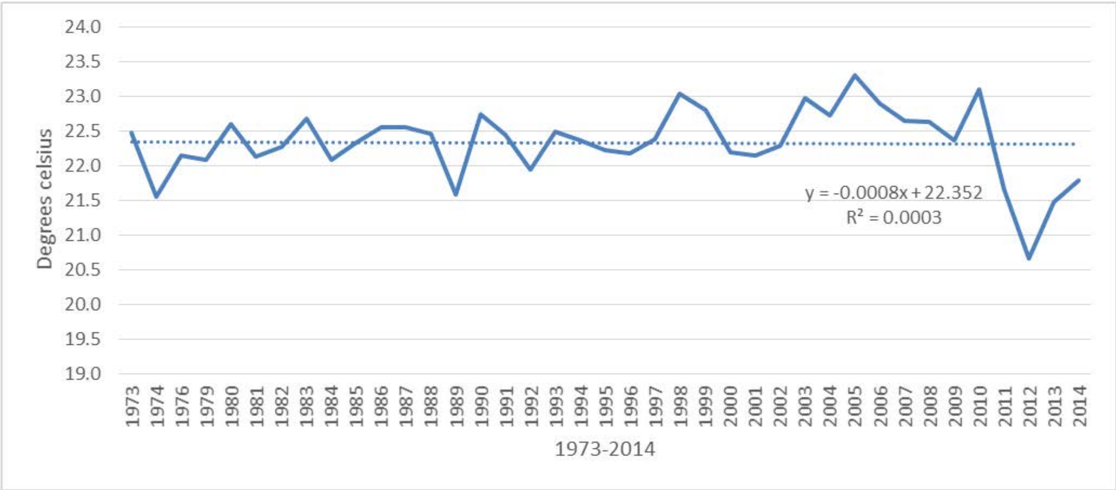

Figure 4.20: Annual average minimum temperature for Makurdi, 1973 – 2014

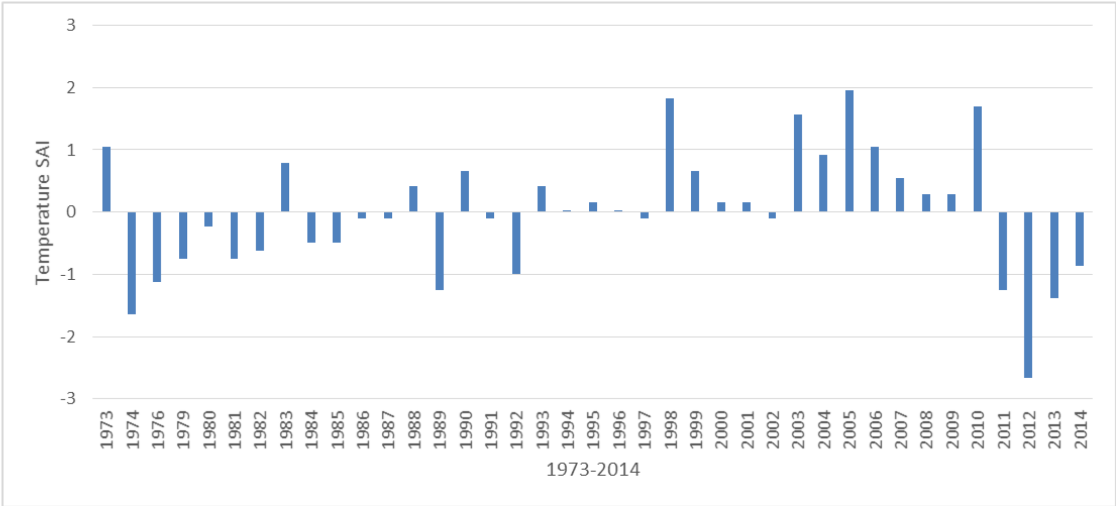

Figure 4.21: Standardised temperature anomaly index for Makurdi, 1973 – 2014

4.1.3 Relative humidity

The descriptive statistics and quantile-quantile plots of relative humidity data for Makurdi (1973-2014) is presented in Appendix 15.

4.1.3.1 Relative humidity averages

Relative humidity in Makurdi is quite high annually with an annual average of 67.8% calculated for the period 1974-2008. The most extreme value (99.5%) was recorded on August 13 in 1997 (Figure 4.22). Relative humidity values between 96.5% and 99.5% were recorded severally in 1974, 1975, 1979, 1981, 1983, 1988, 1993, 1995, 1997, 2006, and 2007. The daily relative humidity averages from 1974-2008 is presented in Figure 4.23.

The year with the highest humidity average was 1975 (73.7%). The year 2008 (72.6%) and 2007 (72%) had high humidity averages. The lowest humidity average was recorded in 1977 (59%). The humidity average for most of the years between 1974 and 2008 was between 60% and 70% (Figure 4.24). The relative humidity median between 1974 and 2008 ranged from 61.5% to 76.5%.

Figure 4.25 showed that relative humidity and temperature in Makurdi have an inverse relationship, and the months between February and April are periods of potential heat stress. The period between day 113 and day 305 are consistent with the peak of the wet season while the drop in both humidity and temperature from day 321 and between day 1 and day 65 suggest drier periods.

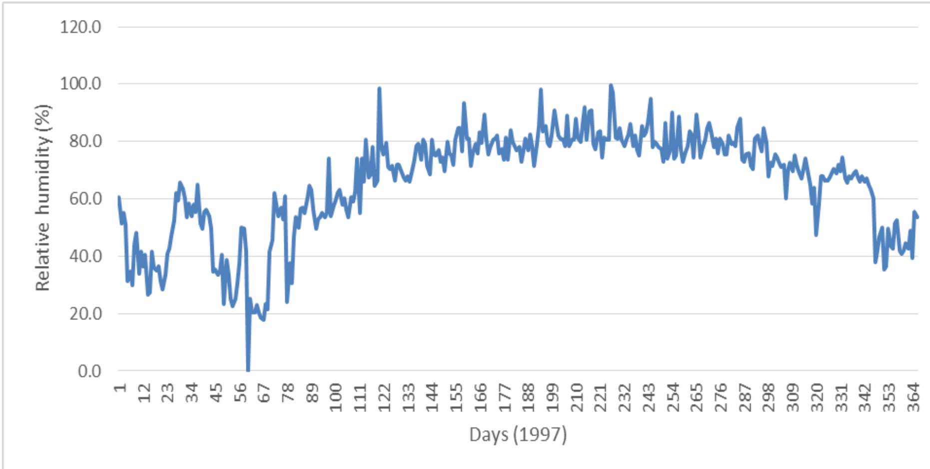

Figure 4.22: Daily relative humidity averages for Makurdi, 1997

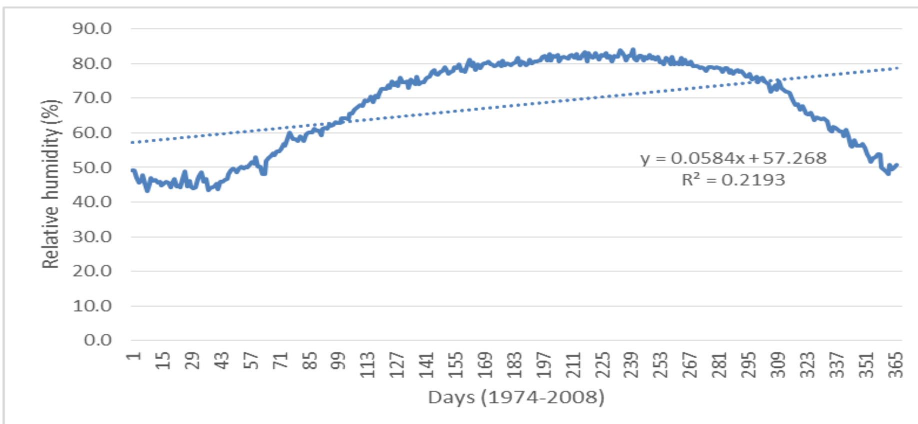

Figure 4.23: Daily relative humidity averages for Makurdi, 1974 – 2008

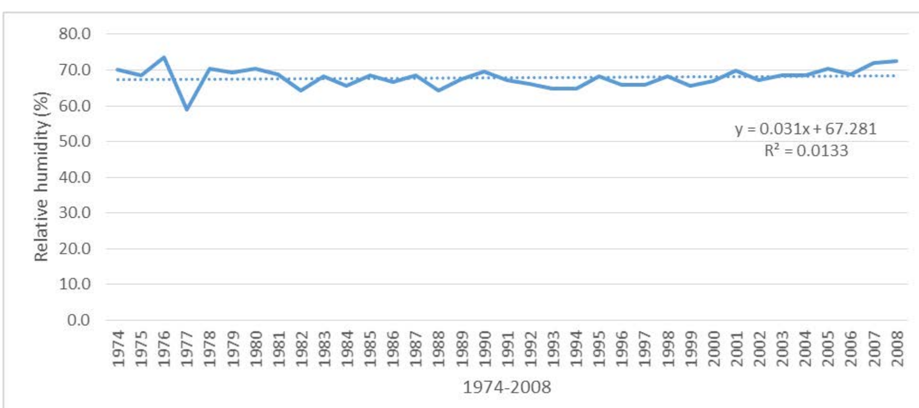

Figure 4.24: Annual relative humidity averages for Makurdi, 1974 – 2008

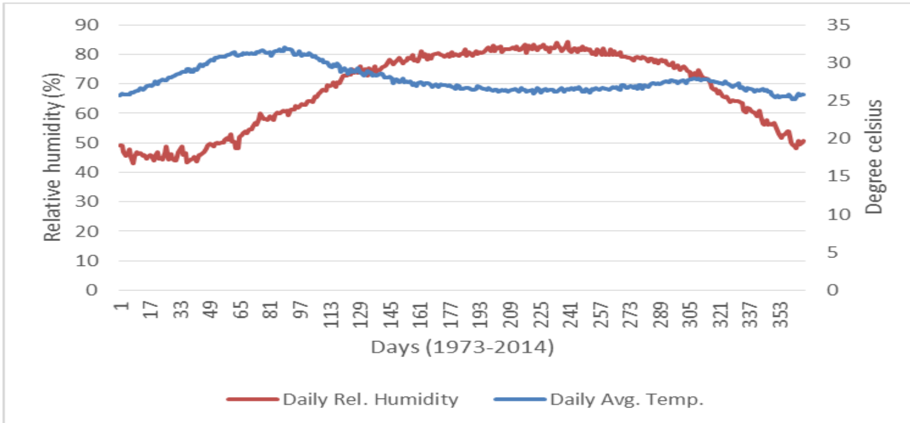

Figure 4.25: Daily relative humidity and temperature averages for Makurdi, 1973 – 2014

4.1.3.2 Relative humidity variation

The largest positive deviation of relative humidity from the reference annual mean was in 1976 and the largest negative deviation was a year later in 1977. Even though the highest relative humidity percentage was recorded in 1997 as earlier established, it had a negative deviation from the reference mean.

A five year moving average was put through the relative humidity anomaly series. The trend showed that relative humidity between 1974 and 2008 mostly had a negative deviation and this was continuous between 1984 and 2004 (Figure 4.26).

4.1.3.3 Atmospheric vapour deficit

The mean saturation vapour pressure (Es) calculated from daily maximum and minimum temperature series (1973-2013) was 3.9 kPa (Table 4.3) and the average actual vapour pressure (Ea) calculated was 2.7 kPa. The vapour pressure deficit (VPD) for the period calculated is presented in Figure 4.27. The average vapour pressure deficit was 1.3 kPa. The first quarter of the year had the highest vapour pressure deficit while the lowest vapour pressure deficit was experienced during the peak of the wet season in the third quarter. It is generally noted in literature that the ideal vapour pressure deficit for most crops is between 0.8 kPa to 1 kPa. The ideal period for rain-fed crop cultivation in the study area is between day 141 and day 309 (about 168 days annually between penultimate week of May and first week of November). Low VPD can cause plants to have mineral deficiencies, guttation, disease, and soft growth, while high VPD can cause wilting, leaf roll, and stunted growth.

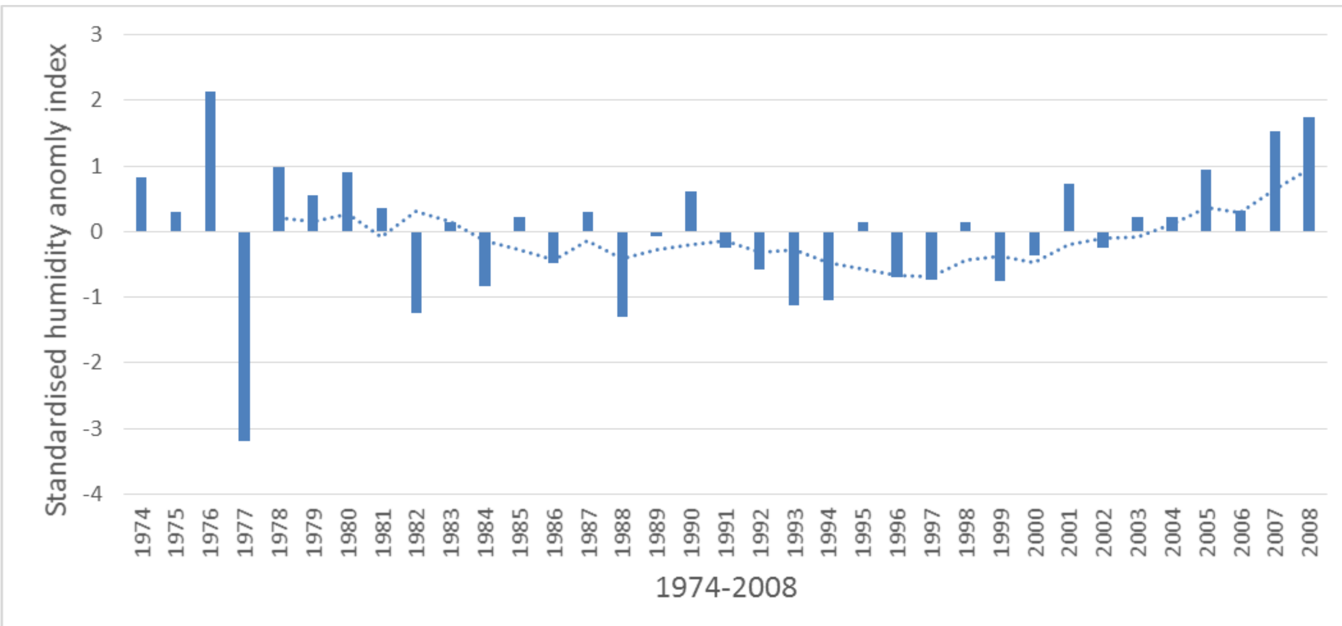

Figure 4.26: Relative humidity variation in Makurdi, 1974 – 2008

Table 4.3: Descriptive statistics of atmospheric vapour data of Makurdi (1973-2013)

	N	Range	Min	Max	Mean	Std. Dev.	Variance	Skewness
e° (Tmax)	366	2.57	4.05	6.62	5.1739	.75049	.563	.364
e° (Tmin)	366	1.61	1.83	3.44	2.7227	.36810	.135	-.589
Es	366	1.61	3.40	5.01	3.9483	.43603	.190	.972
Ea	366	1.50	1.60	3.11	2.6510	.41283	.170	-1.119
Vapour deficit	366	1.94	.55	2.50	1.2973	.61985	.384	.493

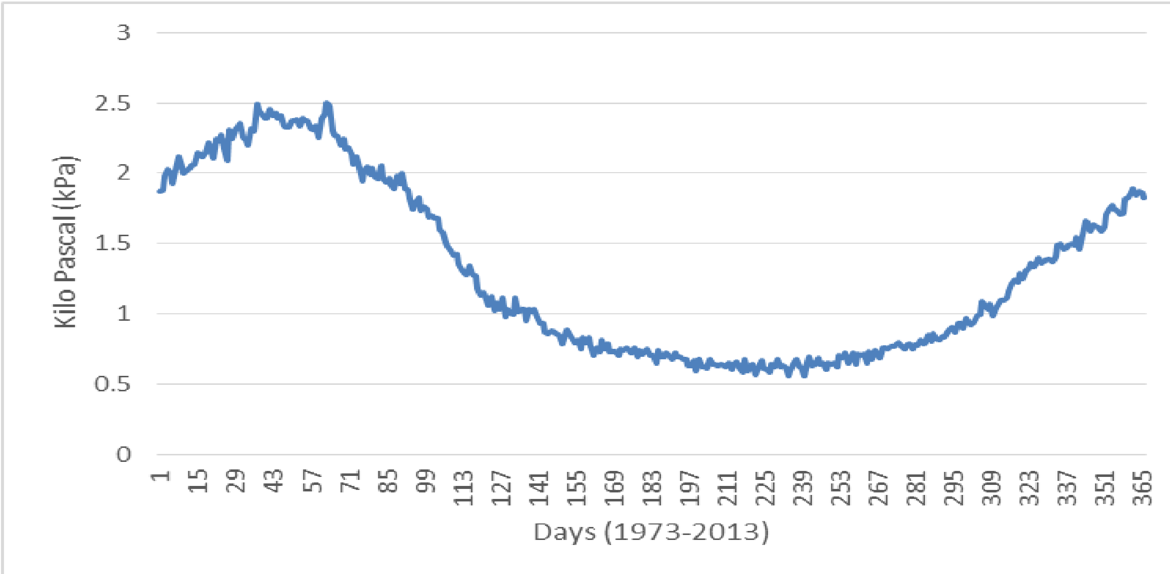

Figure 4.27: Atmospheric vapour pressure deficit in Makurdi, 1973 – 2013

4.1.4 Solar radiation

The data on solar radiation obtained for Makurdi was daily average solar radiation. The descriptive statistics is presented in Appendix 16. The average daily and annual solar radiation obtained was 20.1 MJ m^{-2} day^{-1}. The lowest was 5.7 MJ m^{-2} day^{-1} and was recorded in July 1985 and 1987. The peak of the rain season usually received the least solar radiation which is a function of cloud cover (Figure 4.28).

The daily equivalent evaporation was calculated by multiplying the daily solar radiation with a constant of 0.408 as stated in FAO (1998). The daily equivalent evaporation for Makurdi is presented in Figure 4.29. The annual total evaporation in Makurdi is 3006.8 mm day^{-1} with a daily average of 8.2 mm day^{-1}. Figure 4.29 showed that daily evaporation values in Makurdi corresponded to the daily solar radiation in Makurdi.

The year 2012 received the highest average solar radiation (21.4 MJ m^{-2} day^{-1}) and the lowest average of 19.5 MJ m^{-2} day^{-1} was recorded in 1980 and 1987. In total, nine years (1973, 1974, 1989, 1995, 2000, 2001, 2011, 2013, and 2014) had solar radiation averages above 20.3 MJ m^{-2} day^{-1} (Figure 4.30). Solar radiation in Makurdi has been extensively analysed and described as suitable for solar energy applications including farming (Isikwue *et al*., 2014).

Solar radiation has an immense influence on evaporation and transpiration. Table 4.4 showed the evaporation and transpiration parameters of crops and soil types of interest to this study. The evaporation and transpiration coefficients for rice (which is a cereal) were higher than that of cassava (which is a root crop), even though cassava has a longer growth duration and exposure to solar radiation. These coefficients are the integrated effects of both transpiration and evaporation over time. Table 4.4 also showed that the readily evaporable water for sandy loam and loam soils were greater than that of sand and loamy sand soils. The total evaporable water at soil depth of 10-15 metres was similarly greater in sandy loam and loam soils.

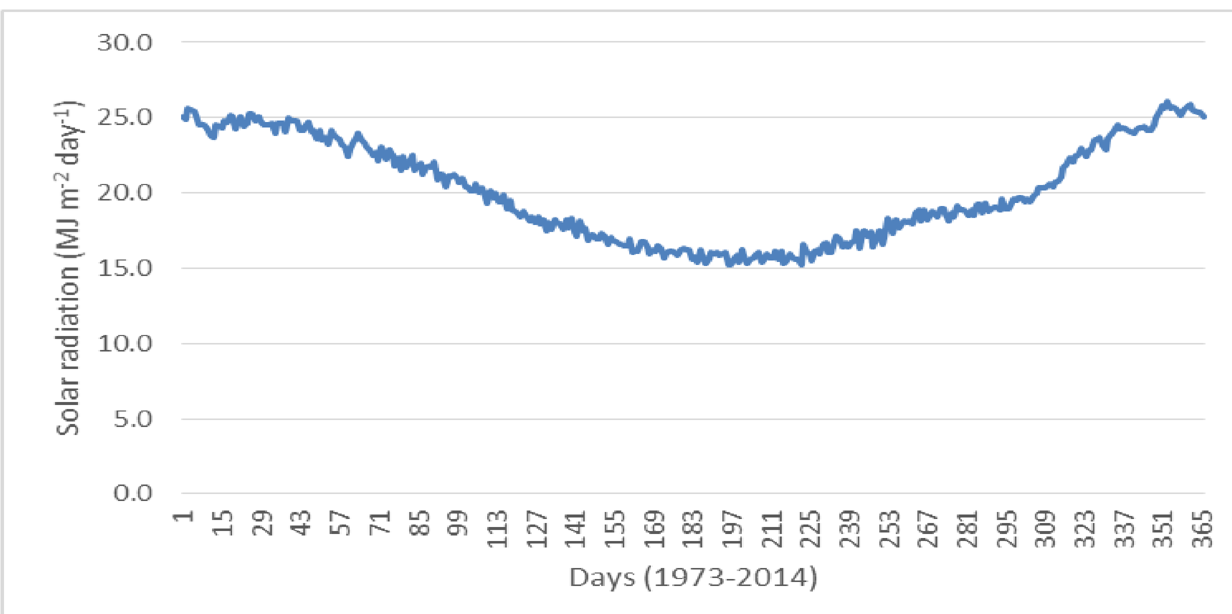

Figure 4.28: Daily solar radiation averages for Makurdi, 1973 – 2014

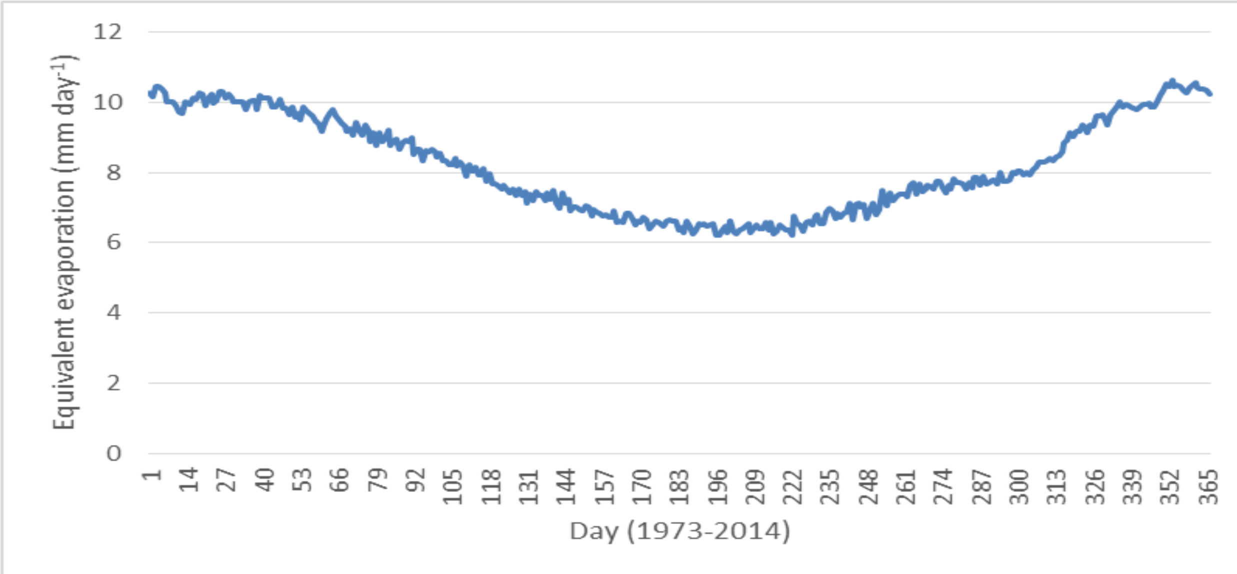

Figure 4.29: Daily evaporation amounts in Makurdi, 1973 – 2014

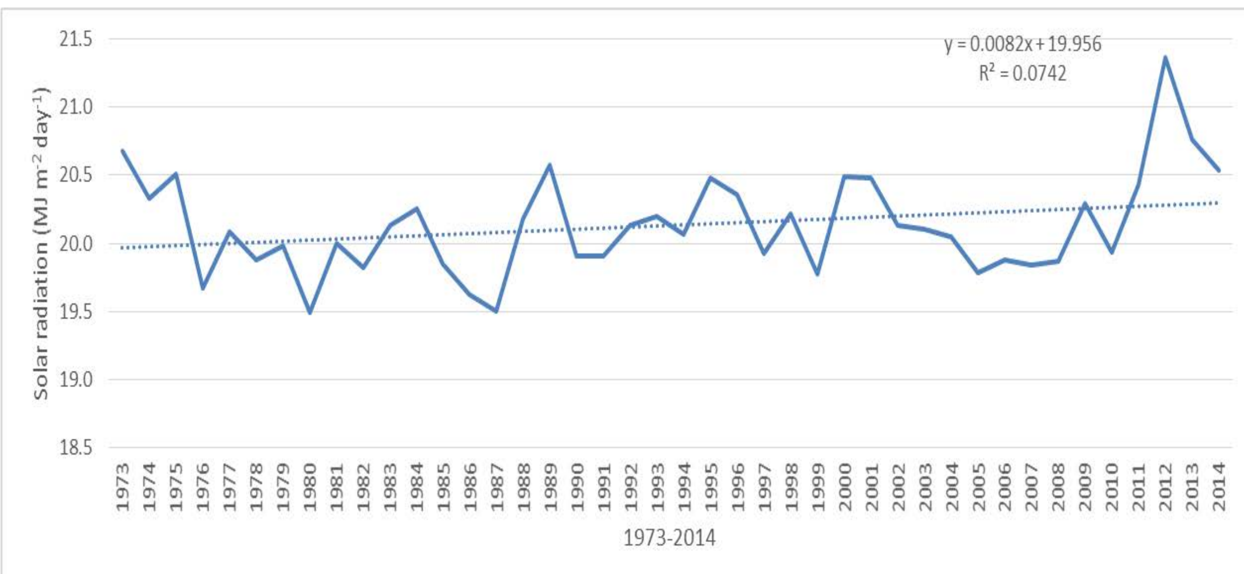

Figure 4.30: Annual solar radiation averages for Makurdi, 1973 – 2014

Table 4.4: Evaporation and transpiration characteristics of crops and soils of interest

Crop	Crop evaporation coefficient (Growth stage)			Duration of growth (days)	Maximum crop height (m)
	Initial stage	Mid stage	End stage		
Cassava	0.3	0.80^3	0.30	210	1-1.2
Rice	1.05	1.20	0.90-0.60	180	1

Soil	Water content at field capacity	Water content at wilting point	Evapotranspiration parameters (mm)	
	m^3/m^3	m^3/m^3	Readily evaporable water (mm)	Total evaporable water (mm) (soil depth, 10-15 m)
Sand	0.07 - 0.17	0.02 - 0.07	2 - 7	6 - 12
*Loamy sand	0.11 - 0.19	0.03 - 0.10	4 - 8	9 - 14
*Sandy loam	0.18 - 0.28	0.06 - 0.16	6 - 10	15 - 20
Loam	0.20 - 0.30	0.07 - 0.17	8 - 10	16 - 22

Source: Food and Agriculture Organisation (FAO, 1998)
*Shaded soil types are found in the study area

4.2. Drainage characteristics of Lower River Benue Basin

4.2.1 The River Benue

The River Benue meets with the River Niger about 483km from the coast at a confluence point in Lokoja. The width of the River Benue varies from about 488 to 976m. It is navigable during the wet season from May to September for a length of more than 965 km (Uchua and Ndukwe, 2011). The River Benue is about 1,440km long with a surface area of 129,000 hectares. The floodplain of the River Benue is about 181,000 hectares making it an important economic resource for the region (Ita *et al.*, 1985). Table 4.5 provides more information on the River Benue. The physiography of the Lower River Benue Basin which was determined from satellite imagery of the area and topographic map showed the major stream systems (Figure 4.31).

4.2.2 Discharge rate

The Instantaneous daily discharge data (1955 to 2014) was collected from three hydrological stations in the Lower River Benue Basin that were readily available. The stations are Umaisha (1980-2014), Makurdi (1955-2014), and river Katsina Ala (1955-2012). The Umaisha hydrological station is located close to the confluence of the River Benue and River Niger, while the others are located in Makurdi and Katsina Ala L.G.As. Although the entire data collected was for the period of January 1955 to May 2014, a few omissions exist due to faulty measuring equipment and the more recently commissioned Umaisha hydrological station.

Table 4.5: Attributes of the River Benue Basin

Geographical attributes	Data
Source	Adamawa mountains, Cameroon
Total length	1,440km
Catchment area	64,000km^2
Water area	Bankfull (In Nigeria): 1,290 km^2; flooded: 3,100 km^2 (Floodplain: 1 810 km^2)
Major tributaries	Mayo-Kebbi (Cameroon), Faro, Gongola, and Katsina Ala (Nigeria)
Volume of Discharge at Mouth	1 920 m^3/s (mean max.) 32 m^3/s (mean min.)

Source: Food and Agriculture Organisation (Source: FAO, 1990).

The average discharge at Umaisha from January 1980 to May 2014 was 4,919.47 cubic metres per second (m^3/s). The maximum discharge for the period was 19,120 m^3/s which was recorded on the 15/10/2012. The line chart in Figure 4.32 showed the discharge amounts at Umaisha from 01/01/1980 to 31/05/2014. The linear forecast trend line showed the trend of discharge is gradually rising.

Average discharge at Makurdi hydrological station was 3,468.24 m^3/s. The peak flow discharge of 16,400 m^3/s was recorded in three days 19th, 29th, and 30th in the month of September 2012 while the peak flow of 2011 was 9,436 m^3/s. The average flow derived for Makurdi which was 3,468.24 m^3/s was surpassed in June. One of the worst flooding events in Nigeria occurred in 2012 as intensive rainfall and river overflow caused extensive flooding in the flood plains of the River Benue and River Niger. The flooding of 2012 was escalated by the discharge of floodwaters from the Lagdo dam in Cameroon into the River Benue. Figure 4.33 showed the instantaneous daily discharge of the River Benue for the 2012.

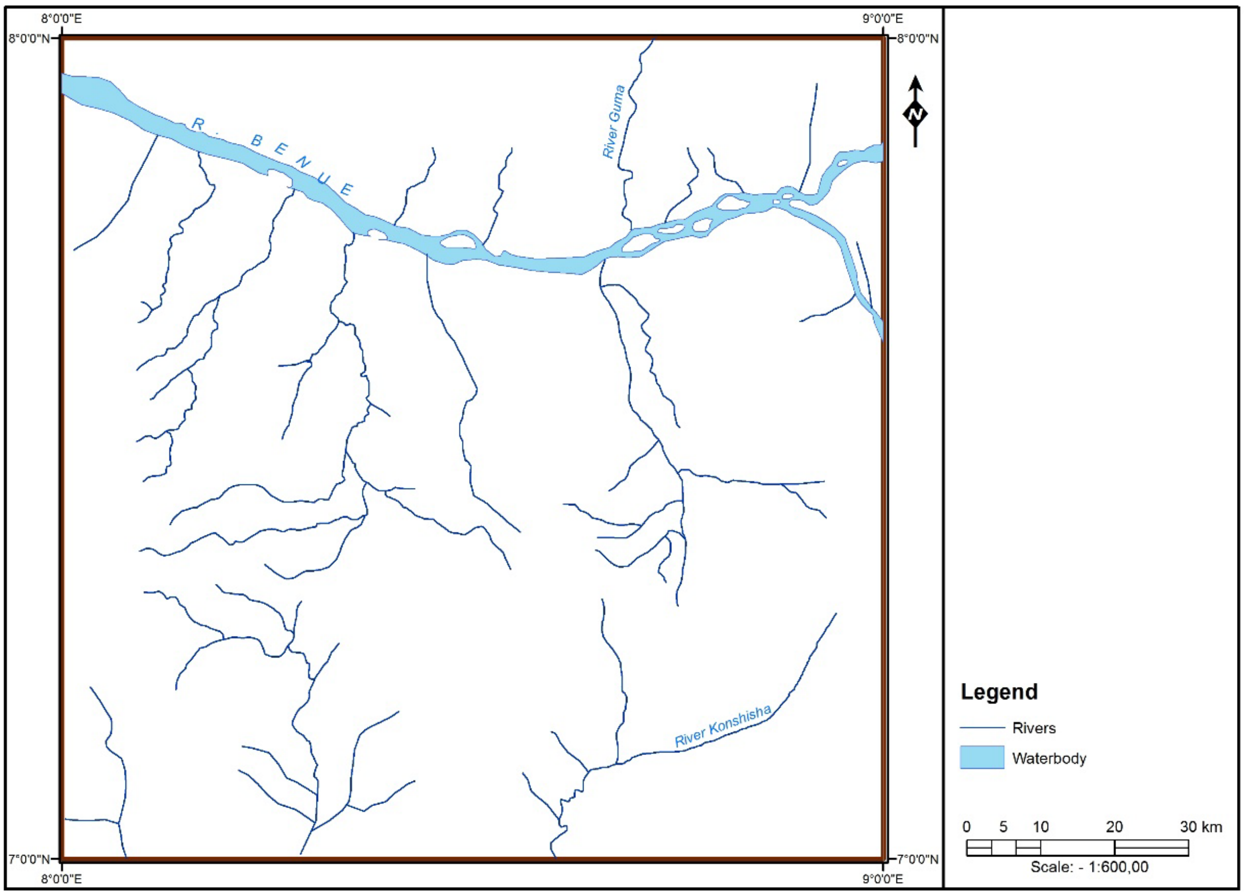

Figure 4.31: Drainage map of the study area

The lowest discharge rate in the River Benue was recorded in 1983 while the highest discharge rate occurred in 2012. The total flow in 2012 was not equalled between 1961 and 2011 (50 years). The second highest discharge rate of 15,975 m^3/s was recorded in September 1969. There was high inflow during the month of June before the arrival of peak flow periods of July and September from Upper Benue Basin. The high inflow in July, August and September 2012 led to River Benue overflowing its banks and submerging land areas and settlement in Upper and Lower Benue Basins. In addition, there was a high discharge into River Benue from Lagdo Reservoir in Cameroun in July and subsequent months. Thus, high flow in River Benue is due to both inflow from Lagdo dam in Cameroun and inflows from the Upper and Lower Benue Basins. Figure 4.34 showed the discharge amounts at Makurdi hydrological station from 01/01/1955 to 31/05/2014. The linear forecast trend showed a gradual rise over the years. The impact of rainfall on annual discharge on the River Benue in Makurdi is presented in Figure 4.35. The year with the highest annual total discharge rate was 1998.

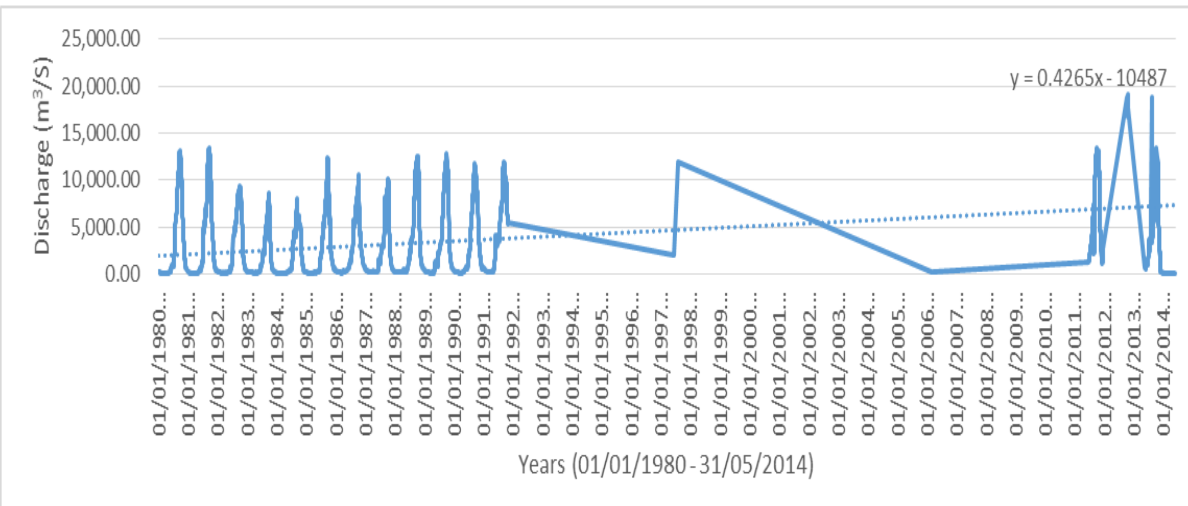

Figure 4.32: Daily flow hydrograph of the River Benue at Umaisha station, 1980-2014

At River Katsina Ala hydrological station, the average discharge from January 1955 to May 2014 was 933.12m^3/s. The maximum discharge for the period was 4,401 m^3/s which was recorded on the 20/10/1977. Figure 4.36 showed the discharge amounts at River Katsina Ala from 01/01/1955 to 01/10/2012. The linear forecast trend in Figure 4.36 showed a gradual rise in discharge. The monthly average discharge for the period 1980 – 2014 for Umaisha hydrological station (Figure 4.37) reveals that the River Benue recorded the highest discharge amounts in the months of September (10,556.95 m^3/s) and October (11,651.88 m^3/s). The months of July to November recorded significant discharge amounts from 1980– 2014 at Umaisha. The monthly average discharge for Makurdi was quite similar to Umaisha. In addition to the high discharge amount in September (10,390.17 m^3/s) and October (10,370 m^3/s), amounts over 2000 m^3/s was recorded between July and November (Figure 4.38). However, unlike Umaisha, the highest monthly average discharge amount in Makurdi was September.

Figure 4.33: Daily streamflow hydrograph of River Benue at Makurdi in 2012

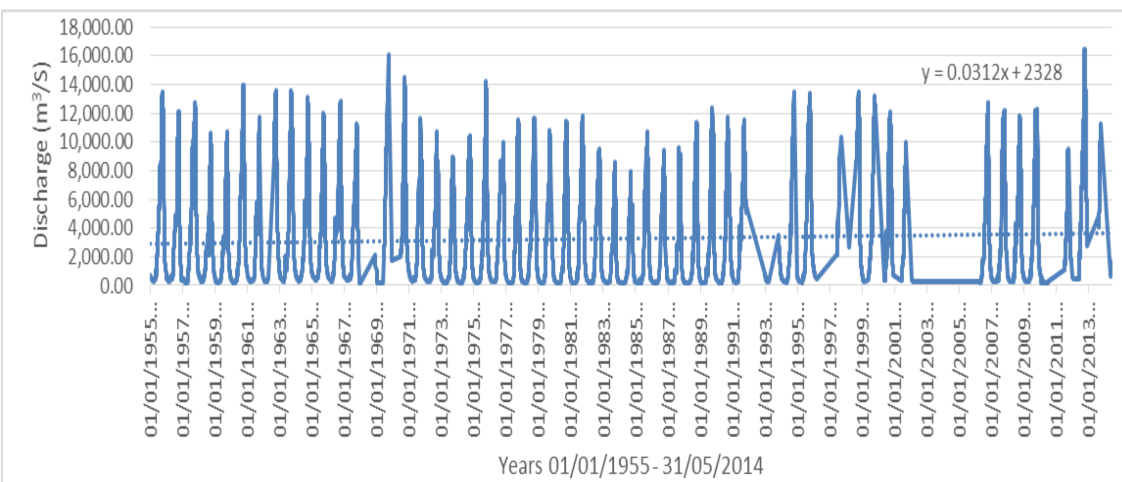

Figure 4.34: Daily flow hydrograph of River Benue at Makurdi station, 1955-2014

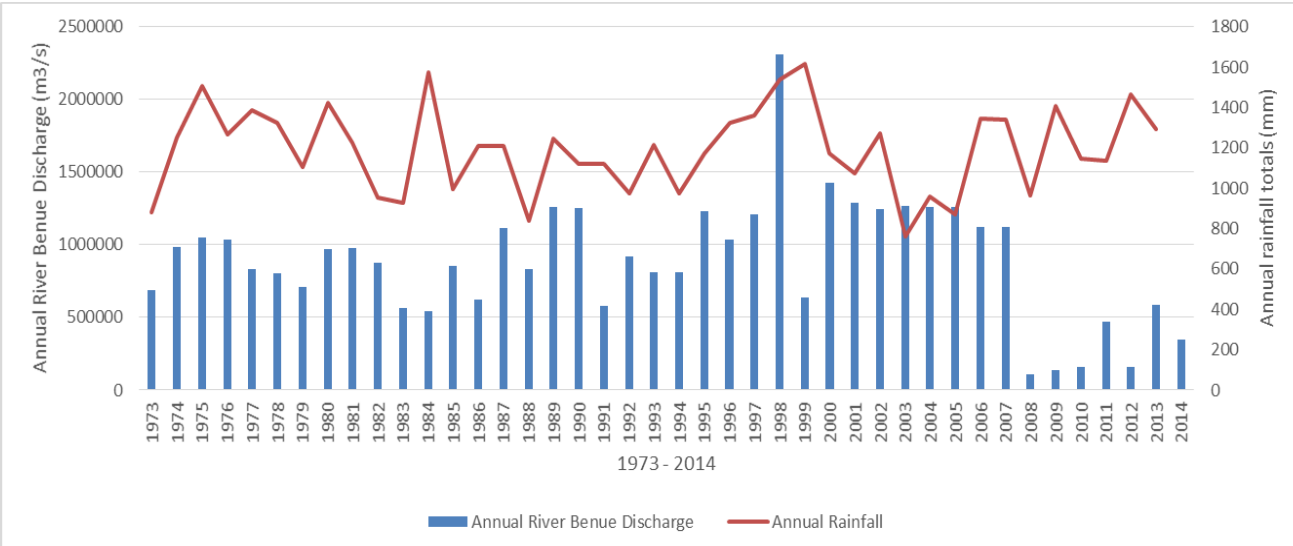

Figure 4.35: Graph showing annual discharge of River Benue and annual rainfall at Makurdi

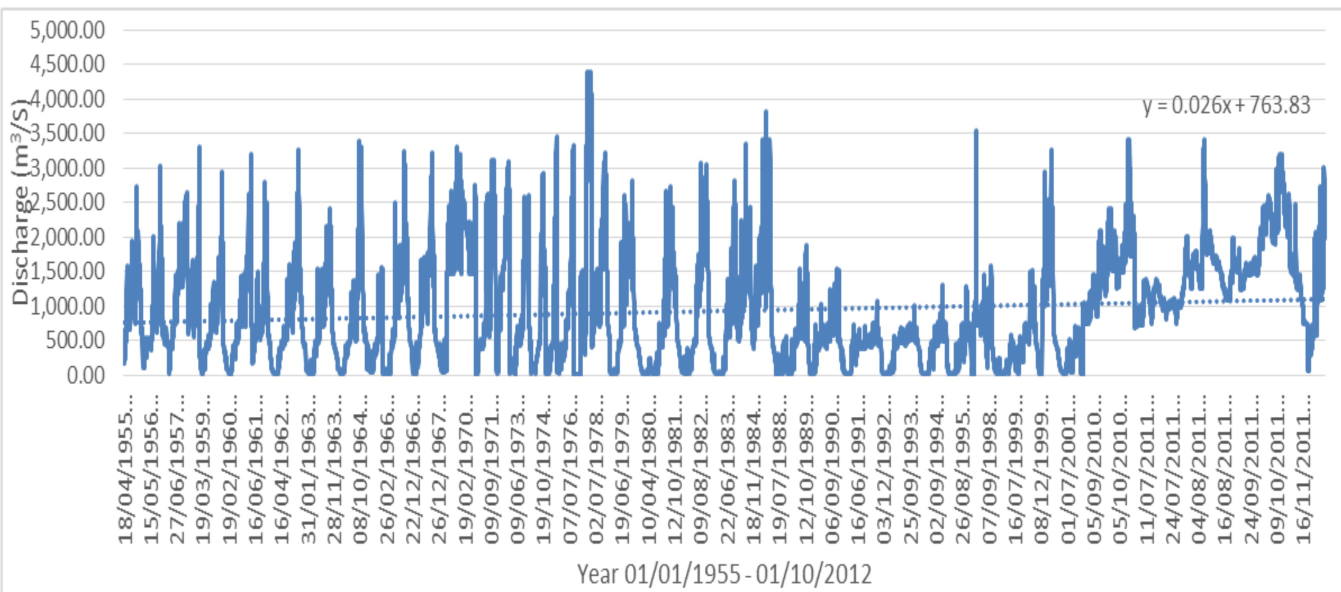

Figure 4.36: Daily flow hydrograph of the River Katsina Ala, 1955-2012

The monthly average discharge for Katsina Ala hydrological station (Figure 4.39) is not entirely similar to that of Makurdi and Umaisha. The station did not record any discharge amount over 2000 m^3/s in any month of year from 1955-2012. The months of September (1518.76 m^3/s)

and October (1781.85 m^3/s) recorded the highest monthly average discharge amounts. The lower amounts from Katsina Ala are understandable because it is a smaller river and a tributary of River Benue.

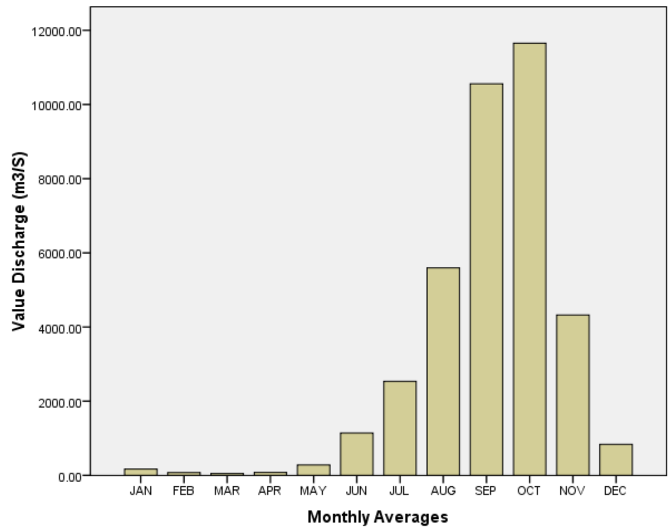

Figure 4.37: The monthly average discharge for Umaisha, 1980-2014

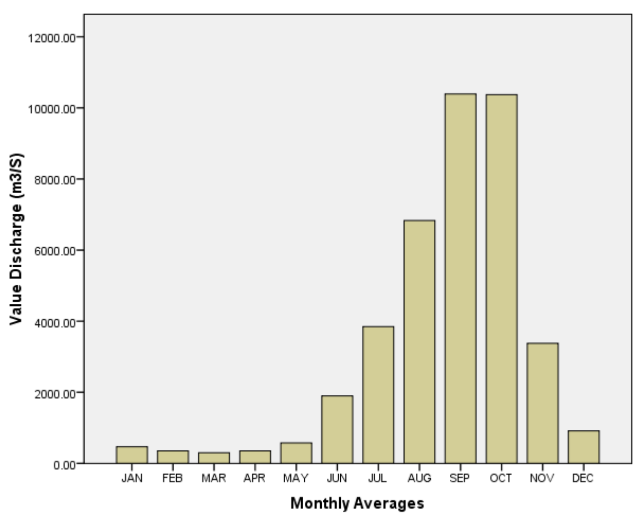

Figure 4.38: The monthly average discharge for Makurdi, 1955-2014

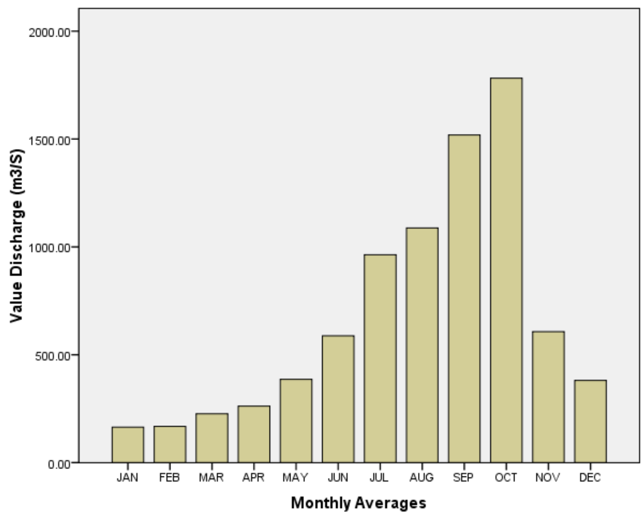

Figure 4.39: The monthly average discharge for Katsina Ala, 1955-2012

All the monthly averages of the three hydrological stations where correlated to test if a significant relationship existed between them. The result is presented in Table 4.6. The monthly discharge averages for Umaisha, Makurdi and Katsina Ala correlated positively with significant values ($p < 0.01$).

Table 4.6: Pearson's product correlation of monthly discharge averages for Umaisha, Makurdi, and Katsina Ala

Parameters		Umaisha Discharge (m^3/s)	Makurdi Discharge (m^3/s)	Katsina Ala Discharge (m^3/s)
Umaisha Discharge (m^3/s)	Pearson Correlation	1	.985**	.958**
	Sig. (2-tailed)		.000	.000
	N	12	12	12
Makurdi Discharge (m^3/s)	Pearson Correlation	.985**	1	.979**
	Sig. (2-tailed)	.000		.000
	N	12	12	12
Katsina Ala Discharge (m^3/s)	Pearson Correlation	.958**	.979**	1
	Sig. (2-tailed)	.000	.000	
	N	12	12	12

**. Correlation is significant at the 0.01 level (2-tailed).

4.2.3 Constant-step rating curve

The rating curve for the Umaisha, Makurdi, and Katsina Ala were produced (Figures 4.40 to 4.42). The rating curves for Umaisha and Makurdi showed a smooth stream flow with Umaisha surpassing the average discharge at 661cm (Figure 4.40). Makurdi surpassed the average stream flow of the station at 654 cm (Figure 4.41). River Katsina Ala rating curve showed a rough stream flow. The River Katsina Ala has several rapids and this may have reflected in the rating curve of the hydrological station. The stream flow of River Katsina Ala surpassed average discharge rate at 297cm (Figure 4.42).

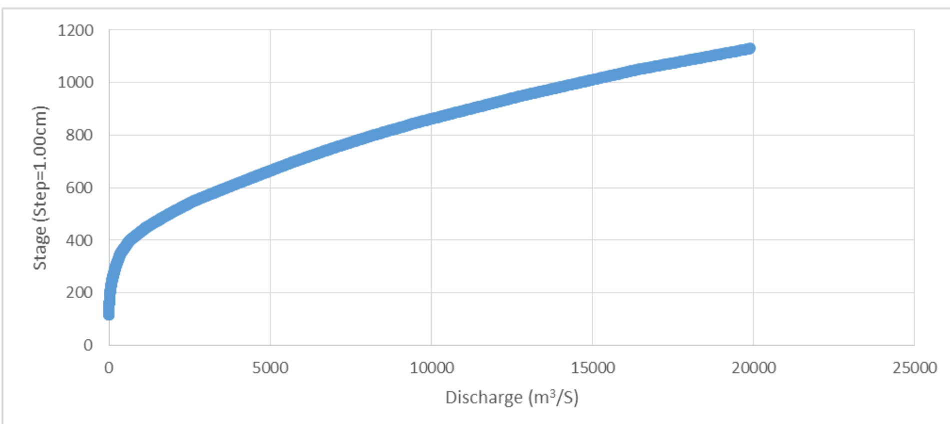

Figure 4.40: Stream flow rating curve for Umaisha hydrological station

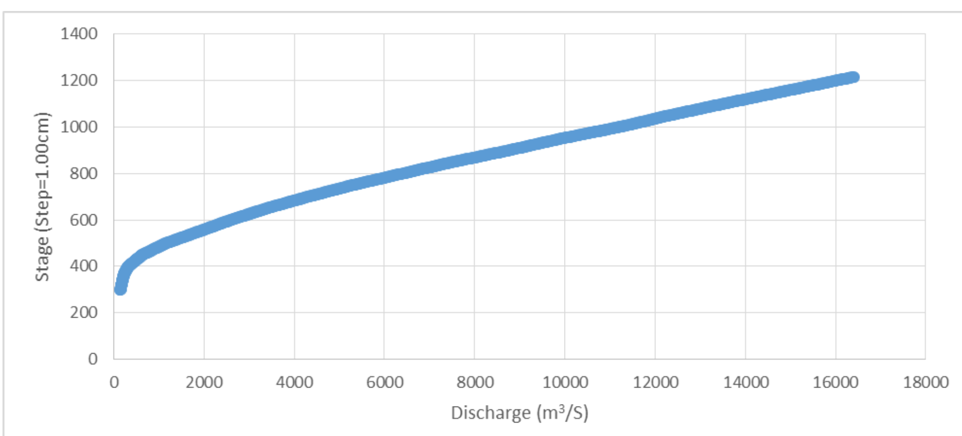

Figure 4.41: Stream flow rating curve for Makurdi hydrological station

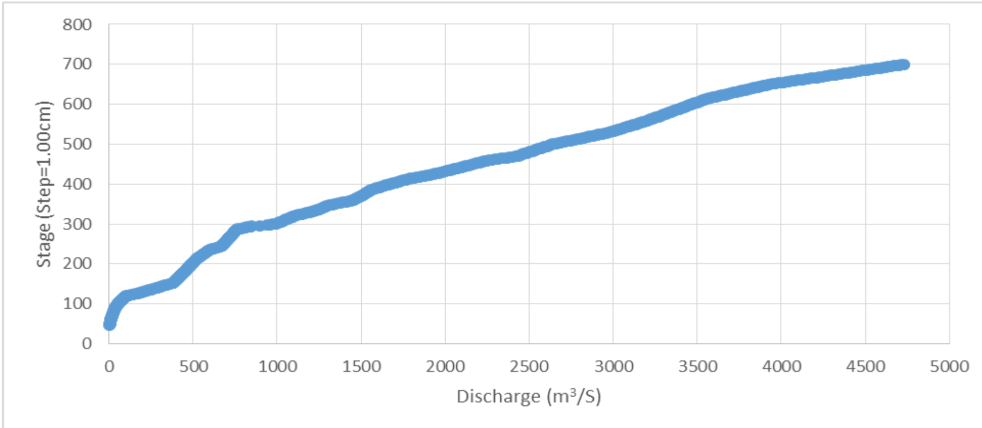

Figure 4.42: Stream flow rating curve for Katsina Ala hydrological station

4.2.4 Water levels

The instantaneous water level of the River Benue at Umaisha hydrological station had an average of 1,201.97cm. The maximum water level was 6,997.55cm which was recorded on the 1st of September 2013 is the highest for the years analysed (Figure 4.43). The linear trend suggests a gradual rise.

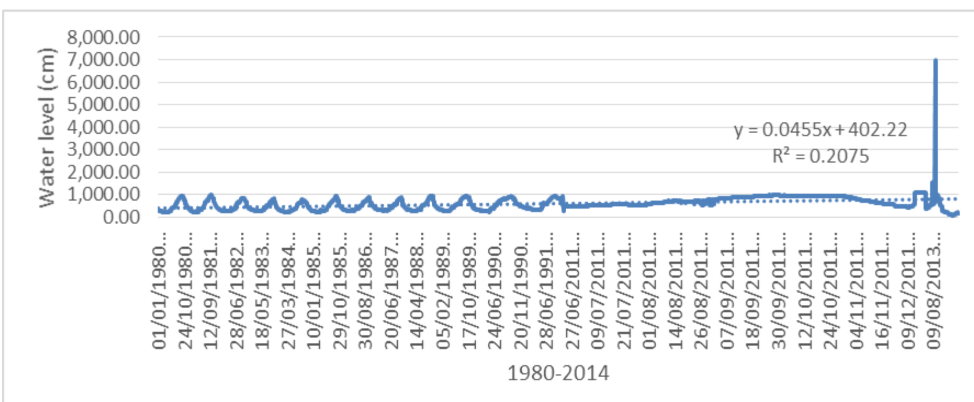

Figure 4.43: Instantaneous water level at Umaisha hydrological station, 1980 – 2014

The water levels of the River Benue at Makurdi from 1955 to 2014 had an average of 1,215cm and a maximum of 1,258cm recorded on the 24th and 25th September 2012 which is the period of the highest discharge recorded for the station (Figure 4.44). The lowest water level was

247cm recorded in February 1961 and April 1969. The highest water level of River Katsina Ala which coincides with the date with the highest discharge rate was 679cm recorded in October 1977 (Figure 4.45). The average water level obtained was 454.88cm and the lowest water level recorded in March 1990 was -86cm.

4.2.5 River Benue flooding

The Nigeria Hydrological Services Agency (NIHSA), in accordance with its statutory mandate to issue flood forecasts, monitors the trend of floods in Nigeria annually. NIHSA releases an annual flood outlook report which provides information to prepare Nigerians living in flood risk areas to be at alert in the event of floods which could damage property and human life.

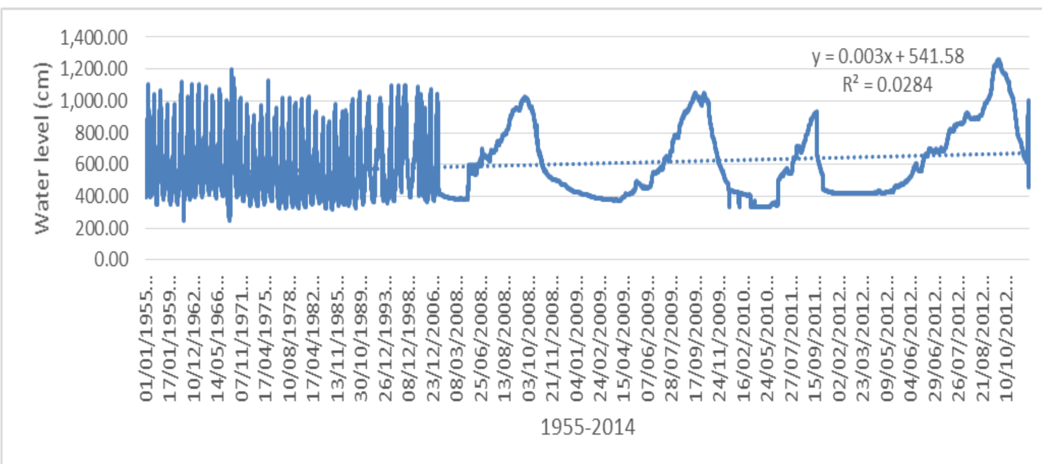

Figure 4.44: Instantaneous water level at Makurdi hydrological station, 1995 – 2014

The annual flood outlook report is prepared using Geospatial Stream Flow Model (GeoSFM) and Soil and Water Assessment Tool (SWAT) modelling software. The report categorises risk areas according to high, medium and low risk areas. This is done for all L.G.As in Nigeria. With this prior notice, steps are taken by people in high and medium risk areas to prevent damage to property and life. Some of these measures include.

- Maintenance of hydraulic structures such as dams, reservoirs and water-related infrastructure across the country;
- Clearing of water channels and on all avenues for river run-offs in all L.G.As
- Re-dredging and construction of drainages
- Temporary relocation of people living along the water-ways and those that are having socio-economic activities on the flood plains

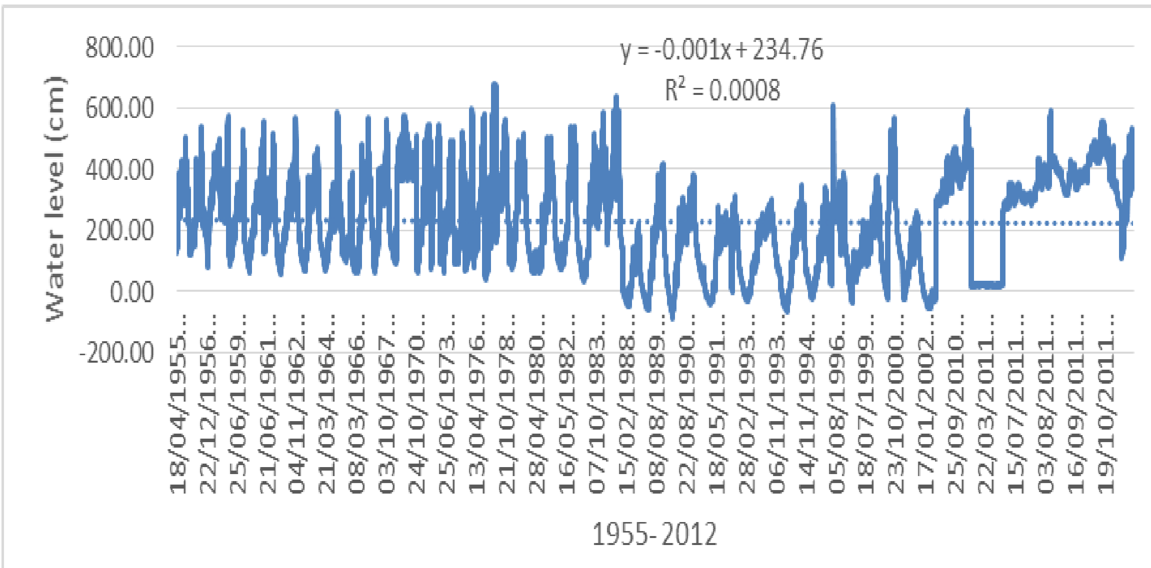

Figure 4.45: Instantaneous water levels at River Katsina Ala hydrological station, 1955 – 2012

The 2014 flood prediction was done by analysing simulated flow data for hydrological stations around the country. The 2012 Julian day for the River Benue at Ibi hydrological station Taraba State had a discharge of 16,910.63 m^3/s (Figure 4.46). This further attests to the unprecedented floods of the River Benue in 2012. The 2013 Julian day discharge was 10,752.78 m^3/s. These data contributed to the simulation of flows for the 2014 prediction. The predicted Julian day for 2014 for Ibi station was 10,466.76 m^3/s.

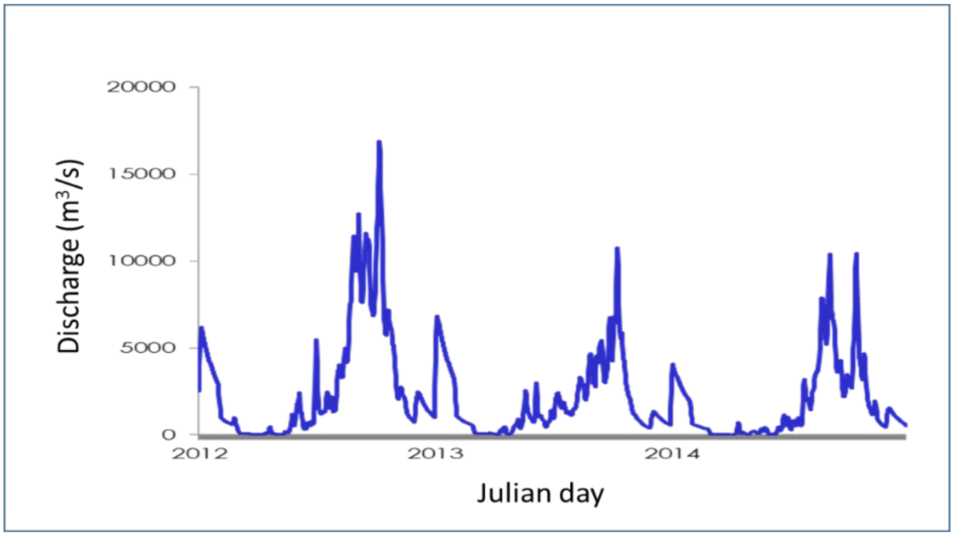

Figure 4.46: Flow simulation (2014) for River Benue at Ibi Taraba State (Source: NIHSA, 2014)

The flow simulation for River Katsina Ala hydrological station for 2014 produced a Julian discharge of 1,368.78 m^3/s. The Julian day for 2013 (1,801.86 m^3/s) was higher than that of 2012 (1,515.46 m^3/s) for Katsina Ala station (Figure 4.47).

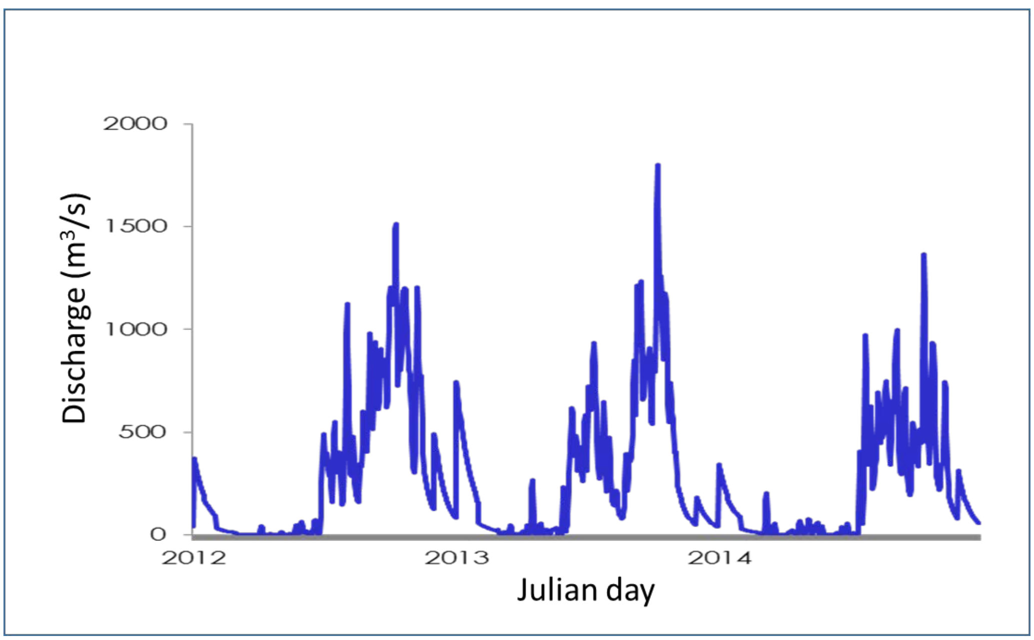

Figure 4.47: Flow simulation (2014) for River Katsina Ala (Source: NIHSA, 2014)

The 2012 Julian day discharge rate for Makurdi was 26, 088.72 m^3/s. This was not reflected earlier in the daily stream flow hydrograph for Makurdi as it was obtained from another report and no date was given for the Julian day by NIHSA (2014). The Julian day for 2013 for Makurdi hydrological station was 16,435.65 m^3/s while the 2014 prediction put the Julian discharge at 15,732.45 m^3/s (Figure 4.48).

In 2013, the annual flood outlook (NIHSA, 2014) listed Agatu, Makurdi, Buruku, and Guma as flood risk L.G.As (Figure 1.1). Among these L.G.As mentioned, flooding occurred in Agatu, Makurdi, Buruku, Guma, and Logo. Logo was not in the list of flood risk areas mentioned but witnessed some flooding.

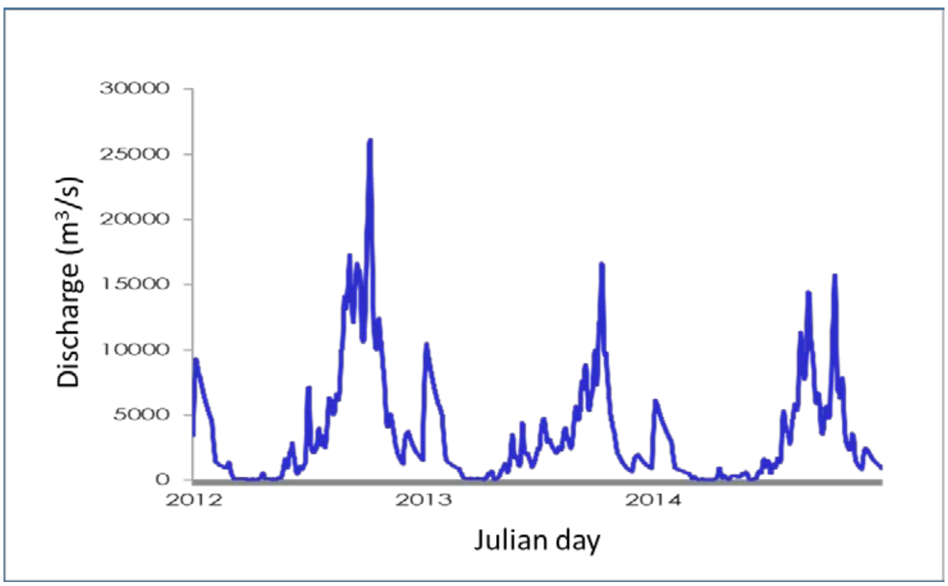

Figure 4.48: Flow simulation (2014) for River Benue at Makurdi (Source: NIHSA, 2014)

The 2014 annual flood outlook report (NIHSA, 2014), listed some L.G.As in Benue State as high risk and moderate risk areas that would witness flooding in 2014. The listed high risk L.G.As were Agatu, Buruku, Kwande, Guma, and Makurdi. The moderate risk L.G.As were Gwer west, Guma, Katsina Ala, Logo, Kwande, and Ushongo. Flooding was experienced in 7 LGAs between 2013 and 2014.

The drainage data presented provides evidence that the Lower River Benue Basin has abundant fresh water supplies during the wet and dry season that can be harnessed sustainably for rain-fed and irrigation farming and other agricultural activities. However, issues of flooding and drainage variation are concerns that can affect agricultural activities within the Lower River Benue Basin.

4.3: Properties of soil in the Lower River Benue Basin

4.3.1: Physical properties

The location and physical properties of the soils in the Lower River Benue Basin collected at surface (0-15cm) and subsurface (15-30cm) levels are summarised in Tables 4.7 to 4.9. The detailed results of soil analyses is provided in Appendix 17. The soil texture of the soil samples from farms in Makurdi (Cassava=C1, C2; Rice=R1, R2; Yam=Y1, Y2) were mostly sandy loam, and loamy sand. The texture of soil samples from Tarka (Cassava=C1, C2; Rice=R1, R2; Yam=Y1, Y2) were mostly sandy loam. Soil texture of samples from Gboko (Cassava=C1, C2; Rice=R1, R2; Yam=Y1, Y2) were mostly sandy loam.

Soils in Makurdi were mostly loamy sand. Loamy sand soils have low water holding capacity, good drainage and aeration. Soils from Tarka, and Gboko were mostly sandy loam. Soils with sandy loam texture are moderately drained and moderately aerated. Sandy loam soils have capacity to retain nutrients moderately. Loamy sand and sandy loam soils appear moderately suitable for irrigation, but may be drought prone (Utsev *et al.* 2014).

The range and mean of physical properties of soils collected from cassava, rice and yam farms are presented in Table 4.10 to 4.12. The sand fraction of soils collected from cassava farms ranged from 68-87% with a mean of 73.42% for surface soils, and 62-77% and a mean of 72.18% for subsurface soils. The percentage of sand in soil samples from rice farms ranged from 54-74% and a mean of 60.59% in surface soils, and a range of 52-72% and a mean of 64.52% in subsurface soils. The percentage of sand in soils collected from yam farms ranged from 57-84% with a mean of 70.25% for surface soils, and a range of 60-82% with a range of 69%.

Table 4.7: Location and physical properties of soils samples from farms in Makurdi

Farm site	Crop	Depth (cm)	GPS coordinates		Particle size distribution (%)			Textural class (USDA)	Silt/Clay ratio
			Northings	Eastings	Sand	Silt	Clay		
MKD C1	Cassava	0-15	7.835757	8.5862	87.00	8.00	5.00	Ls	1.60
		15-30			77.00	13.00	10.00	Sl	1.30
MKD C2	Cassava	0-15	7.835332	8.5861	85.00	7.00	8.00	Ls	0.88
		15-30			74.00	15.00	11.00	Sl	1.36
MKD R1	Rice	0-15	7.69826	8.53779	74.00	22.00	4.00	Ls	5.50
		15-30			72.00	24.00	4.00	Sl	6.00
MKD R2	Rice	0-15	7.698551	8.53746	72.00	20.00	8.00	Sl	2.50
		15-30			70.00	21.00	9.00	Sl	2.33
MKD Y1	Yam	0-15	7.8367	8.5874	84.00	13.00	3.00	Ls	4.33
		15-30			82.00	15.00	3.00	Ls	5.00
MKD Y2	Yam	0-15	7.838	8.58759	82.00	11.00	7.00	Ls	1.57
		15-30			80.00	12.00	8.00	Ls	1.50

MKD = Makurdi farm sites; Ls = Loamy sand; Sl = Sandy loam

Table 4.8: Location and physical properties of soils samples collected from farms in Tarka

Farm sites	Crop	Depth (cm)	GPS coordinates		Particle size distribution (%)			Textural class (USDA)	Silt/Clay ratio
			Northings	Eastings	Sand	Silt	Clay		
TRK C1	Cassava	0-15	7.66213	8.83203	68.00	29.00	3.00	Sl	9.67
		15-30			68.00	28.00	4.00	Sl	7.00
TRKC2	Cassava	0-15	7.66526	8.83358	68.00	22.00	10.00	Sl	2.20
		15-30			62.00	24.00	14.00	Sl	1.71
TRKR1	Rice	0-15	7.66737	8.83908	54.00	41.00	5.00	Sl	8.20
		15-30			54.00	40.00	6.00	Sl	6.67
TRKR2	Rice	0-15	7.66613	8.83974	56.00	38.00	6.00	Sl	6.33
		15-30			52.00	41.00	7.00	L	5.86
TRKY1	Yam	0-15	7.661	8.8379	57.00	39.00	4.00	Sl	9.75
		15-30			75.00	12.00	13.00	Sl	0.92
TRKY2	Yam	0-15	7.66016	8.84212	68.00	26.00	6.00	Sl	4.33
		15-30			62.00	28.00	10.00	Sl	2.80

TRK = Tarka farm site; Sl = Sandy loam; L = loam;

Table 4.9: Location and physical properties of soils samples collected from farms in Gboko

Farm site	Crop	Depth (cm)	GPS coordinates		Particle size distribution (%)			Textural class (USDA)	Silt / Clay Ratio
			Northings	Eastings	Sand	Silt	Clay		
GBKC1	Cassava	0-15	7.31069	8.98387	76.00	22.00	2.00	Ls	11.00
		15-30			72.00	22.00	6.00	Sl	3.67
GBKC2	Cassava	0-15	7.31024	8.98401	74.00	20.00	6.00	Sl	3.33
		15-30			70.00	21.00	9.00	Sl	2.33
GBKR1	Rice	0-15	7.31195	8.98329	71.00	24.00	5.00	Sl	4.80
		15-30			69.00	26.00	5.00	Sl	5.20
GBKR2	Rice	0-15	7.31195	8.98246	71.00	20.00	9.00	Sl	2.22
		15-30			68.00	22.00	10.00	Sl	2.20
GBKY1	Yam	0-15	7.30274	8.98333	67.00	30.00	3.00	Sl	10.00
		15-30			61.00	28.00	6.00	Sl	4.67
GBKY2	Yam	0-15	7.303465	8.98358	65.00	28.00	7.00	Sl	4.00
		15-30			60.00	20.00	20.00	Sl	1.00

GBK = Gboko farm site; Ls = Loamy sand, Sl = Sandy loam

Table 4.10: Physical properties of soils samples collected from cassava farms

Parameters	Surface soil		Subsurface soil	
	Range	**Mean**	**Range**	**Mean**
Sand (%)	68.00-87.00	73.42	62.00-77.00	72.18
Silt (%)	8.00-29.00	19.25	13.00-28.00	20.27
Clay (%)	2.00-10.00	7.33	4.00-14.00	7.55

Table 4.11: Physical properties of soils samples collected from rice farms

Parameters	Surface soil		Subsurface soil	
	Range	**Mean**	**Range**	**Mean**
Sand (%)	54.00-74.00	60.59	52.00-72.00	64.52
Silt (%)	20.00-41.00	26.23	21.00-41.00	28.77
Clay (%)	4.00-9.00	6.04	4.00-10.00	6.71

Table 4.12: Physical properties of soils samples collected from yam farms

Parameters	Surface soil		Subsurface soil	
	Range	**Mean**	**Range**	**Mean**
Sand (%)	57.00-84.00	70.25	60.00-82.00	69
Silt (%)	11.00-39.00	21.83	12.00-28.00	22.64
Clay (%)	3.00-7.00	7.5	3.00-20.00	7.91

4.3.2 Chemical properties of soil samples

The chemical properties of soil samples were summarised according to crop farms (cassava, rice, and yam). The results of micronutrient analysis summarised in the same way. The comprehensive result tables of chemical properties of soil samples are available in Appendix 17.

4.3.2.1 Chemical properties of soils from cassava farms

The chemical properties of soil samples collected from cassava farms are summarised with maximum permissible limits and presented in Table 4.13. The pH of soils collected from cassava farms were slightly acidic and ranged from 5.1-6.1 with a mean of 5.7 for surface soils, and a range of 5.2-6.1 with a mean of 5.7 for subsurface soils. The pH of soils collected from cassava farms were slightly acidic as a result of leaching of appreciable quantities of exchangeable base forming cations such a calcium, magnesium, potassium and sodium from the surface layers of the soils and high buffering capacity. This was observed elsewhere in the Lower River Benue Basin (Akpan-Idiok *et al.*, 2013; Utsev *et al.*, 2014). Literature has stated that cassava tolerates soils within a wide pH range (4.0-8.0) but the best pH range for growing cassava is 5.5–6.5 (Titus et al., 2011). The pH of these soils is, therefore, suitable for cassava cultivation.

The organic carbon content of samples from cassava farms ranged from 0.44-1.04% with a mean of 0.7% for surface soils, and a range of 0.46-0.93% with a mean of 0.72% for subsurface soils. The percentage of organic carbon were moderate but did not meet the acceptable limit of 2% (Table 4.13). The total percentage nitrogen ranged from 0.03-0.09% with a mean of 0.05% for surface soils, and a range of 0.03-0.08% with a mean of 0.05% for subsurface soils. The organic carbon content and total nitrogen were quite low. This has been attributed elsewhere (Apkan-Idiok *et al.*, 2013) to poor vegetative growth, fast rate of decomposition, and the high temperature of the ecological zone. However, the low content of nitrogen in the study area could be attributed to burning of bush and plant residue during the farming season, leaching and the high rate of organic matter decomposition by micro-organisms, as well as, rapid mineralisation and adsorption of nitrogen due to continuous farming. The low levels of organic carbon and total nitrogen cannot sustain intensive cropping, and the application of fertilisers is necessary (Abua and Edet, 2013).

Available phosphorus in the soil samples from cassava farms ranged from 1.62-42.37 $mgkg^{-1}$ with a mean of 8.48 $mgkg^{-1}$ for surface soils, while subsurface soils had a range of 1.00-13.50 $mgkg^{-1}$ with a mean of 5.66 $mgkg^{-1}$. Available phosphorus levels below 20 $mgkg^{-1}$ (Holland *et al*., 1989) are a limitation to successful crop production and therefore such soils should be enhanced with fertilisers. The low content of available phosphorus can be explained by the high phosphorus adsorption capacity of the soils, and the slight acidity of the soils prevalent in floodplain soils.

The levels of exchangeable bases (Ca, Mg, K, and Na) were moderate with mean values of 3.3 $cmolkg^{-1}$, 2 $cmolkg^{-1}$, 0.09 $cmolkg^{-1}$, 0.06 $cmolkg^{-1}$ for surface soils, and 3.28 $cmolkg^{-1}$, 1.96 $cmolkg^{-1}$, 0.09 $cmolkg^{-1}$, 0.06 $cmolkg^{-1}$ for subsurface soils respectively. Calcium and Magnesium were the dominant cations, while Potassium and sodium had low concentrations (Table 4.13). This was also reflected in the moderate levels of the effective cation exchange capacity (ECEC) which ranged from 4.78-7.13 $cmolkg^{-1}$ with a mean value of 6.3 $cmolkg^{-1}$ for surface soils, and a range of 5.83-7.96 $cmolkg^{-1}$ with a mean value of 6.23 $cmolkg^{-1}$ for subsurface soils. Exchangeable acidity ($Al3^{+}$ and H^{+}) of soils from cassava farms were well below the permissible limit of 4.1$cmolkg^{-1}$. Exchangeable acidity ranged from 0.6-0.96 $cmolkg^{-1}$ with a mean of 0.77 $cmolkg^{-1}$ for surface soils, and a range of 0.86-1.06 $cmolkg^{-1}$ with a mean of 0.92 $cmolkg^{-1}$ for subsurface soils.

The base saturation percentage of the soils were high and ranged from 86-88% with a mean of 86.58% for surface soils, and a range of 85-88% with a mean value of 86.55% for subsurface soils. These base saturation results are above the recommendations in Holland *et al*. (1989) and indicate the presence of good amounts of soluble forms of basic cations in soil solution. This kind of situation enhances the availability fertilisers in soil for crop uptake. It is generally accepted in literature that soils with base saturation percentages over 50% are fertile soils. The fertility indices of soils from cassava farms as presented in Table 4.13 also supports this assertion. These soils require fertility enhancement with organic/inorganic fertilisers for optimal crop production.

Micronutrients in this study are metals that are required by the body in trace quantities and are essential for maintaining various body functions and metabolic activities. The micronutrients analysed in this study were iron (Fe), manganese (Mn), nickel (Ni), vanadium (V), cobalt (Co), and molybdenum (Mo). According to the National Academy of Science/Institute of Medicine (NAS/IOM, 2003), the biological functions of micronutrients in plants, animals and humans are still under research. The ranking of micronutrients in order of concentration is Fe>Ni>Mn>Mo>Co>V. The values of micronutrients (Fe, Mn, Ni, V, Co, Mo) analysed for soils from cassava farms were all below tolerable limits (Table 4.14).

4.3.2.2 Chemical properties of soils from rice farms

The chemical properties of soil samples collected from rice farms are summarised in Table 4.15. The pH of soils collected from rice farms were slightly acidic and ranged from 5.1-5.7 with a mean of 5.5 for surface soils, and a range of 5.3-5.9 with a mean of 5.5 for subsurface soils. The pH of soils collected from rice farms were slightly acidic as a result of similar circumstances explained for soils from cassava farms.

The organic carbon content of samples from rice farms ranged from 0.44-2.13% with a mean of 1.4% for surface soils, and a range of 0.50-1.85% with a mean of 1.48% for subsurface soils. The percentage of organic carbon was generally moderate and high in some locations (Table 4.15). The organic carbon content of soils from rice farms were a bit better than cassava farms. The total percentage nitrogen ranged from 0.03-0.18% with a mean of 0.1% for surface soils, and a range of 0.03-0.16% with a mean of 0.1% for subsurface soils. The percentage nitrogen were higher than percentages from cassava farms but below tolerable limits of 0.2%.

Table 4.13: Chemical properties of soils from cassava farms in Makurdi, Tarka, and Gboko

Parameters	Surface soil		Subsurface soil		Maximum permissible limits
	Range	Mean	Range	Mean	
pH	5.1-6.1	5.7	5.2-6.1	5.7	5.1-6.5
Organic Carbon (C) (%)	0.44-1.04	0.7	0.46-0.93	0.72	2.0 (%) ++
Total Nitrogen (N) (%)	0.03-0.09	0.05	0.03-0.08	0.05	0.2 (%) ++
Available Phosphorus (P) (mgkg^{-1})	1.62-42.37	8.48	1.00-13.50	5.66	20 (mgkg^{-1}) +++
Calcium (Ca) (cmolkg^{-1})	2.11-3.80	3.3	2.80-4.60	3.28	10-20 (cmolkg^{-1}) +++
Magnesium (Mg) (cmolkg^{-1})	1.36-2.40	2	1.80-2.26	1.96	3-8 (cmolkg^{-1})
Potassium (K) (cmolkg^{-1})	0.06-0.10	0.09	0.05-0.14	0.09	0.6-1.2 (cmolkg^{-1}) +++
Sodium (Na) (cmolkg^{-1})	0.05-0.07	0.06	0.04-0.09	0.06	0.7-1.2 (cmolkg^{-1}) +++
Exchange Acidity (cmolkg^{-1})	0.6-0.96	0.77	0.86-1.06	0.92	4.1 (cmolkg^{-1}) +++
ECEC (cmolkg^{-1})	4.78-7.13	6.3	5.83-7.96	6.23	10.00 (cmolkg^{-1}) +++
Base Saturation (%)	86.00-88.00	86.58	85.00-88.00	86.55	60-80 (%) +++
Fertility indices					
Calcium/Magnesium ratio	0.94-2.43	1.69	1.32-2.09	1.7	3:1-5:1
Magnesium/Potassium ratio	17.50-37.50	24.22	16.14-37.20	23.73	1:2
Carbon/Nitrogen ratio	11.0-16.0	14.33	12.0-17.0	14	25

++ FPDD (1990), +++ Holland *et al*. (1989)

Available phosphorus in the soil samples from cassava farms ranged from 0.05-20.75 mgkg^{-1} with a mean of 4.89 mgkg^{-1} for surface soils, while subsurface soils had a range of 0.62-2.43 mgkg^{-1} with a mean of 5.25 mgkg^{-1}. Available phosphorus levels below 20 mgkg^{-1} (Holland *et al*., 1989) are a limitation to successful crop production and therefore such soils should be enhanced with fertilisers. The content of available phosphorus in soils from cassava farms (8.48 mgkg^{-1}and 5.66 mgkg^{-1}) were higher than soils from rice farms.

The level of exchangeable bases (Ca, Mg, K, and Na) were moderate with mean values of 2.5 cmolkg^{-1}, 1.99 cmolkg^{-1}, 0.08 cmolkg^{-1}, 0.06 cmolkg^{-1} for surface soils, and 2.49 cmolkg^{-1}, 1.91 cmolkg^{-1}, 0.08 cmolkg^{-1}, 0.06 cmolkg^{-1} for subsurface soils respectively. Calcium and Magnesium were the dominant cations, and the results were similar to soils from cassava farms (Table 4.15).

Table 4.14: Micronutrients of soils from cassava farms in Makurdi, Tarka, and Gboko

Parameters	Surface Range	Mean	Subsurface Range	Mean	Maximum tolerable limits
Iron (Fe)	201.06-900.48	589.09	429.23-900.49	560.78	10,000-100,000 mgkg^{-1}*
Manganese (Mn)	10.10-26.13	21.13	13.24-40.10	21.8	200-2000 mgkg^{-1}**
Nickel (Ni)	29.21-56.20	40.32	20.06-54.60	39.91	10-1000 mgkg^{-1}**
Vanadium (V)	0.09-0.16	0.12	0.05-0.22	0.12	20-500 mgkg^{-1}**
Cobalt (Co)	0.38-0.73	0.61	0.43-0.78	0.6	1-70 mgkg^{-1}**
Molybdenum (Mo)	1.09-2.29	1.4	0.20-1.89	1.32	4 mgkg^{-1}

* Brady and Weil (1996), ** Bohn *et al*. (1985)

This was also reflected in the moderate levels of the effective cation exchange capacity (ECEC) which ranged from 4.06-6.69 cmolkg^{-1} with a mean value of 5.88 cmolkg^{-1} for surface soils, and a range of 5.06-8.24 cmolkg^{-1} with a mean value of 5.81 cmolkg^{-1} for subsurface soils. Exchangeable acidity (Al^{3+} and H^{+}) of soils from cassava farms were well below the permissible limit of 4.1cmolkg^{-1}. Exchangeable acidity ranged from 0.62-0.92 cmolkg^{-1} with a mean of 0.8 cmolkg^{-1} for surface soils, and a range of 0.95-3.4 cmolkg^{-1} with a mean of 1.45 cmolkg^{-1} for subsurface soils.

The base saturation percentage of the soils was high and ranged from 79-89% with a mean of 78.25% for surface soils, and a range of 47-88% with a mean value of 77.6% for subsurface soils. These base saturation results were generally high except in the subsurface soils in the rice farms sampled in Tarka (Appendix 17). The subsurface soils with base saturations below 50% are becoming more acidic and this may not be unconnected with the intensive use of fertilisers in soils with low sand fractions. As established earlier, the soils sampled from rice farms are fertile but require enhancements with organic/inorganic fertilisers. These soils require fertility enhancement with organic/inorganic fertilisers for optimal crop production. The ranking of micronutrients in order of concentration is Fe>Ni>Mn>Mo>Co>V. The micronutrients (Fe, Mn, Ni, V, Co, Mo) values for soils from rice farms were all below tolerable limits (Table 4.16).

Table 4.15: Chemical properties of soils from rice farms in Makurdi, Tarka, and Gboko

Parameters	Surface soil		Subsurface soil		Maximum permissible limits
	Range	Mean	Range	Mean	
pH	5.1-5.7	5.5	5.3-5.9	5.5	5.1-6.5
Organic Carbon (C) (%)	0.44-2.13	1.4	0.50-1.85	1.48	2.0 (%) ++
Total Nitrogen (N) (%)	0.03-0.18	0.1	0.03-0.16	0.1	0.2 (%) ++
Available Phosphorus (P) (mgkg^{-1})	0.05-20.75	4.89	0.62-2.43	5.25	20 (mgkg^{-1}) +++
Calcium (Ca) (cmolkg^{-1})	1.86-3.40	2.5	1.04-4.01	2.49	10-20 (cmolkg^{-1}) +++
Magnesium (Mg) (cmolkg^{-1})	1.08-3.00	1.99	1.20-3.14	1.91	3-8 (cmolkg^{-1})
Potassium (K) (cmolkg^{-1})	0.05-0.09	0.08	0.07-0.14	0.08	0.6-1.2 (cmolkg^{-1}) +++
Sodium (Na) (cmolkg^{-1})	0.04-0.07	0.06	0.06-0.07	0.06	0.7-1.2 (cmolkg^{-1}) +++
Exchange Acidity (cmolkg^{-1})	0.62-0.92	0.8	0.95-3.4	1.45	4.1 (cmolkg^{-1}) +++
ECEC (cmolkg^{-1})	4.06-6.69	5.88	5.06-8.24	5.81	10.00 (cmolkg^{-1}) +++
Base Saturation (%)	79.00-89.00	78.25	47.00-88.00	77.6	60-80 (%) +++
Fertility indices					
Calcium/Magnesium ratio	0.87-1.88	1.33	0.68-2.00	1.37	3:1-5:1
Magnesium/Potassium ratio	20.00-33.50	25.25	13.33-44.86	24.57	1:2
Carbon/Nitrogen ratio	11.0-25.0	16.08	12.0-24.0	16.17	25

++ FPDD (1990), +++ Holland *et al*. (1989)

4.3.2.3 Chemical properties of soils from yam farms

The chemical properties of soil samples collected from yam farms are summarised in Table 4.17. The pH of soils collected from yam farms was slightly acidic and ranged from 5.3-6.0 with a mean of 5.7 for surface soils, and a range of 5.2-6.5 with a mean of 5.7 for subsurface soils.

Table 4.16: Micronutrients of soils from rice farms in Makurdi, Tarka, and Gboko

Parameters	**Surface Range**	**Mean**	**Subsurface Range**	**Mean**	**Maximum permissible limits**
Iron (Fe)	201.61-675.36	495.88	371.45-934.13	479.56	10,000-100,000 $mgkg^{-1}$*
Manganese (Mn)	10.20-22.18	21.2	18.60-32.11	21.11	200-2000 $mgkg^{-1}$**
Nickel (Ni)	29.14-69.21	46.65	21.11-63.50	47.29	10-1000 $mgkg^{-1}$**
Vanadium (V)	0.02-0.12	0.07	0.00-0.14	0.07	20-500 $mgkg^{-1}$**
Cobalt (Co)	0.38-0.85	0.63	0.51-0.73	0.61	1-70 $mgkg^{-1}$**
Molybdenum (Mo)	1.01-2.64	1.67	1.01-2.64	1.68	4 $mgkg^{-1}$

* Brady and Weil (1996), ** Bohn *et al*. (1985)

The pH of soils collected from yam farms was slightly acidic as a result of similar circumstances explained for soils from cassava farms. The organic carbon content of samples from rice farms ranged from 0.58-1.39% with a mean of 0.82% for surface soils, and a range of 0.58-0.90% with a mean of 0.85% for subsurface soils. The percentage of organic carbon was moderate (Table 4.17). The organic carbon content of soils from yam farms was lower than soils from rice farms and similar to soils from cassava farms. The total percentage nitrogen ranged from 0.03-0.12% with a mean of 0.07% for surface soils, and a range of 0.04-0.08% with a mean of 0.07% for subsurface soils. The percentage nitrogen was below tolerable limits of 0.2%. Available phosphorus in the soil samples from cassava farms ranged from 0.87-32.50 $mgkg^{-1}$ with a mean of 9.93 $mgkg^{-1}$ for surface soils, while subsurface soils had a range of 0.62-23.75 $mgkg^{-1}$ with a mean of 10.67 mgkg^{-1}. Available phosphorus levels were above 20 mgkg^{-1} in yam farms sampled in Gboko (Appendix 17).

The level of exchangeable bases (Ca, Mg, K, and Na) was moderate with mean values of 3.78 cmolkg^{-1}, 2 cmolkg^{-1}, 0.09 cmolkg^{-1}, 0.06 cmolkg^{-1} for surface soils, and 3.8 cmolkg^{-1}, 1.98 cmolkg^{-1}, 0.09 cmolkg^{-1}, 0.06 cmolkg^{-1} for subsurface soils respectively. Calcium and Magnesium were the dominant cations, and the results were similar to soils from cassava and rice farms (Table 4.17). The effective cation exchange capacity (ECEC) ranged from 5.35-6.71 cmolkg^{-1} with a mean value of 6.71 cmolkg^{-1} for surface soils, and a range of 4.51-9.95 cmolkg^{-1} with a mean value of 6.75 cmolkg^{-1} for subsurface soils. Exchangeable acidity (Al^{3+} and H^{+}) of soils from cassava farms were well below the permissible limit of 4.1cmolkg^{-1}. Exchangeable acidity ranged from 0.36-1.16 cmolkg^{-1} with a mean of 0.79 cmolkg^{-1} for surface soils, and a range of 0.73-0.92 cmolkg^{-1} with a mean of 0.83 cmolkg^{-1} for subsurface soils. The exchange acidity levels were lower than the rice farms and similar to soils from cassava farms.

The base saturation percentage of the soils was high and ranged from 84-93% with a mean of 87.75% for surface soils, and a range of 82-92% with a mean value of 87.55% for subsurface soils. These base saturation results were generally high and soils are appreciably fertile. The soils sampled from yam farms are fertile but require enhancements with organic/inorganic fertilisers. The ranking of micronutrients in order of concentration Fe>Ni>Mn>Co>Mo>V. The micronutrients (Fe, Mn, Ni, V, Co, Mo) values for soils from yam farms were all below tolerable limits and most of the values were higher than soils from cassava and rice farms (Table 4.18).

4.3.2.4 Chemical properties of soils in Makurdi

The soils in Makurdi are slightly acidic and ranged from 5.5-6.5 with a mean of 5.9. The mean organic carbon percentage was 0.52%. The mean percentage of nitrogen was 0.03% while available phosphorus had a mean of 5.01 $mgkg^{-1}$. The exchangeable bases (Ca, Mg, K, and Na) had a mean of 2.7, 2.2, 0.09, and 0.06 ($cmolkg^{-1}$) respectively. Exchangeable acidity was 0.81 $cmolkg^{-1}$. The mean ECEC was 5.9 $cmolkg^{-1}$ and the mean base saturation was 86.08%. Table 4.19 presents chemical details of soils in Makurdi. According to George and Mallery (2010) Gaussian distribution with kurtosis between -2 and +2 suggest a normal univariate distribution.

Table 4.17: Chemical properties of soils from yam farms in Makurdi, Tarka, and Gboko

Parameters	**Surface soil**		**Subsurface soil**		**Maximum permissible limits**
	Range	**Mean**	**Range**	**Mean**	
pH	5.3-6.0	5.7	5.2-6.5	5.7	5.1-6.5
Organic Carbon (C) (%)	0.58-1.39	0.82	0.58-0.90	0.85	2.0 (%) ++
Total Nitrogen (N) (%)	0.03-0.12	0.07	0.04-0.08	0.07	0.2 (%) ++
Available Phosphorus (P) ($mgkg^{-1}$)	0.87-32.50	9.93	0.62-23.75	10.67	20 ($mgkg^{-1}$) +++
Calcium (Ca) ($cmolkg^{-1}$)	3.55-4.00	3.78	2.20-5.40	3.8	10-20 ($cmolkg^{-1}$) +++
Magnesium (Mg) ($cmolkg^{-1}$)	1.06-2.14	2	1.40-3.50	1.98	3-8 ($cmolkg^{-1}$)
Potassium (K) ($cmolkg^{-1}$)	0.07-0.15	0.09	0.06-0.10	0.09	0.6-1.2 ($cmolkg^{-1}$) +++
Sodium (Na) ($cmolkg^{-1}$)	0.05-0.07	0.06	0.04-0.07	0.06	0.7-1.2 ($cmolkg^{-1}$) +++
Exchange Acidity ($cmolkg^{-1}$)	0.36-1.16	0.79	0.73-0.92	0.83	4.1 ($cmolkg^{-1}$) +++
ECEC ($cmolkg^{-1}$)	5.35-6.71	6.71	4.51-9.95	6.75	10.00 ($cmolkg^{-1}$) +++
Base Saturation (%)	84.00-93.00	87.75	82.00-92.00	87.55	60-80 (%) +++
Fertility indices					
Calcium/Magnesium ratio	1.64-3.59	2.05	1.39-2.44	2.09	3:1-5:1
Magnesium/Potassium ratio	14.27-22.50	22.61	20.00-37.89	22.67	1:2
Carbon/Nitrogen ratio	8.00-21.00	13	10.00-15.00	12.82	25

++ FPDD (1990), +++ Holland *et al*. (1989)

Table 4.18: Micronutrients of soils from yam farms in Makurdi, Tarka, and Gboko

Parameters	Surface Range	Mean	Subsurface Range	Mean	Maximum permissible limits
Iron (Fe)	381.10-806.19	592.02	213.18-800.13	609.01	10,000-100,000 $mgkg^{-1}$*
Manganese (Mn)	20.14-26.21	25.28	26.20-31.26	25.37	200-2000 $mgkg^{-1}$**
Nickel (Ni)	50.16-66.28	52.17	39.28-60.26	52.3	10-1000 $mgkg^{-1}$**
Vanadium (V)	0.08-0.21	0.16	0.04-0.25	0.16	20-500 $mgkg^{-1}$**
Cobalt (Co)	0.06-9.44	1.97	0.33-0.88	1.34	1-70 $mgkg^{-1}$**
Molybdenum (Mo)	1.11-2.26	1.66	1.06-2.24	1.61	4mgkg-1

* Brady and Weil (1996), ** Bohn *et al*. (1985)

Table 4.19: Descriptive summary of chemical properties of soils in Makurdi

Parameters	Minimum	Maximum	Mean	Std. Deviation	Variance	Kurtosis	
						Statistic	Std. Error
pH	5.50	6.50	5.9083	.28110	.079	.647	1.232
C (%)	.44	.64	.5200	.06769	.005	-1.144	1.232
N (%)	.03	.04	.0342	.00515	.000	-2.263	1.232
P ($mgkg^{-1}$)	.50	42.37	5.0142	11.78925	138.986	11.867	1.232
Ca ($cmolkg^{-1}$)	1.86	3.60	2.7283	.62098	.386	-1.313	1.232
Mg ($cmolkg^{-1}$)	1.40	3.14	2.2408	.45821	.210	1.315	1.232
K ($cmolkg^{-1}$)	.06	.15	.0892	.02353	.001	3.629	1.232
Na ($cmolkg^{-1}$)	.04	.07	.0592	.01084	.000	-.238	1.232
Al3+ ($cmolkg^{-1}$)	.10	.40	.2033	.08083	.007	2.256	1.232
H+ ($cmolkg^{-1}$)	.42	.80	.6092	.11389	.013	-.607	1.232
ECEC ($cmolkg^{-1}$)	4.51	7.10	5.9025	.80093	.641	-.675	1.232
Base saturation (%)	82.00	91.00	86.0833	2.71221	7.356	.026	1.232

The descriptive statistical summary of micronutrients analysed from Makurdi soils is presented in Table 4.20. The iron content ranged from 213.18 – 900.48 ($mgkg^{-1}$) while the mean value for Mn, Ni, V, Co, and Mo were 20.8, 37.59, 0.08, 1.9, and 1.86 ($mgkg^{-1}$), respectively. All these values were below the permissible limits. The order of concentration was

Fe>Ni>Mn>Co>Mo>V. The values of the micronutrients were correlated using the Pearson's product moment correlation coefficient and Spearman's rank correlation coefficient to assess the level of relationship between the elements for comparison. The results of the Pearson's correlation showed that Mn and Fe had a strong negative relationship ($p<0.01$) suggesting they are from different parent material and both elements did not show significant relationship with other elements (Mustapha and Fagam, 2007). Mo and Ni showed a strong positive relationship ($p<0.01$) suggesting that they are from the same parent material (Mustapha and Fagam, 2007). The result also showed a partial positive relationship between Ni, V, and Co. Anthropogenic factors played a role in the introduction of the Fe and Mn to the soils. The trend was similar with the results of the Spearman's correlation coefficient. The correlation results are presented in Tables 4.21 and 4.22.

Table 4.20: Descriptive statistics of micronutrient values of soils in Makurdi

Parameters	Minimum	Maximum	Mean	Std. Deviation	Variance	Kurtosis	
						Statistic	Std. Error
Fe ($mgkg^{-1}$)	213.18	900.48	5.2311E2	208.43913	4.345E4	-.558	1.232
Mn ($mgkg^{-1}$)	10.10	30.14	20.7958	6.41965	41.212	-1.111	1.232
Ni ($mgkg^{-1}$)	20.06	50.60	37.5883	10.73025	115.138	-1.042	1.232
V ($mgkg^{-1}$)	.00	.16	.0833	.05245	.003	-.813	1.232
Co ($mgkg^{-1}$)	.33	9.44	1.8975	3.04281	9.259	3.434	1.232
Mo ($mgkg^{-1}$)	1.04	2.29	1.8608	.43257	.187	-.550	1.232

4.3.2.5 Chemical properties of soils in Tarka

The soils in Tarka are slightly acidic and ranged from 5.3-6.1 with a mean of 5.7. The mean organic carbon percentage was 1.13% which was higher than that of Makurdi. The organic carbon content was high in a few sites. The mean percentage of nitrogen was 0.08% while available phosphorus had a mean of 4.6 mgkg^{-1} which was lower than that of Makurdi. The exchangeable bases (Ca, Mg, K, and Na) had a mean of 2.9, 1.47, 0.07, and 0.06 (cmolkg^{-1}) respectively. Exchangeable acidity was 1.23 cmolkg^{-1}. The mean ECEC was 5.7 cmolkg^{-1} and the mean base saturation was 78.5%. Table 4.23 presents chemical details of soils in Tarka.

The iron content of soils in Tarka ranged from 201.61 – 934.13 (mgkg^{-1}) while the mean value for Mn, Ni, V, Co, and Mo were 26.49, 56.6, 0.14, 0.73, and 1.88 (mgkg^{-1}) respectively (Table 4.24). All these values were below the permissible limits. The ranking order of concentration was Fe>Ni>Mn>Mo>Co>V.

Table 4.21: Pearson's correlation results for micronutrient values in Makurdi

Parameters	Fe	Mn	Ni	V	Co	Mo
Fe	1	-.758**	-.335	.399	-.276	-.188
Mn		1	.232	-.422	.104	.098
Ni			1	.539	.554	.800**
V				1	.543	.376
Co					1	.310
Mo						1

**. Correlation was significant at 0.01 level (2-tailed).

Table 4.22: Spearman's correlation results for micronutrient values in Makurdi

Parameters	Fe	Mn	Ni	V	Co	Mo
Fe	1.000	-.741**	-.315	.460	.322	-.175
Mn		1.000	.217	-.456	-.322	.133
Ni			1.000	.558	.524	.699*
V				1.000	.779**	.347
Co					1.000	.203
Mo						1.000

**. Correlation was significant at 0.01 level (2-tailed).

*. Correlation was significant at 0.05 level (2-tailed).

The correlation results showed that Fe had a positive and significant correlation ($p<0.05$) with V and Co. This means Fe, V, and Co are most likely from the same parent material (Mustapha and Fagam, 2007). Ni and Mo also showed positive correlation with a significant level ($p<0.01$). Since Ni and Mo showed a strong negative correlation with V, Ni and Mo come from a different parent material (Mustapha and Fagam, 2007). A partial positive correlation exists between Fe and Mn. Spearman's correlation showed a similar trend but there was no strong negative or positive correlation between Fe and the other elements. The correlation results are presented in Tables 4.25 and 4.26.

4.3.2.6. Chemical properties of soils in Gboko

The soils in Gboko are more acidic than soils in Makurdi and Tarka ranging from 5.1-5.8 with a mean of 5.3. The mean organic carbon percentage was 1.3% which was higher than that of Tarka. The mean percentage of nitrogen was 0.1% while available phosphorus had a mean of 13.73 $mgkg^{-1}$ which was the highest. The exchangeable bases (Ca, Mg, K, and Na) had a mean of 3.9, 2.3, 0.1, and 0.07 ($cmolkg^{-1}$) respectively.

Exchangeable acidity was 0.86 $cmolkg^{-1}$. The mean ECEC was 7.3 $cmolkg^{-1}$ and the mean base saturation was 88%. Table 4.27 presents chemical details of soils in Gboko. The iron content of soils in Gboko ranged from 201.06 – 726.13 ($mgkg^{-1}$) while the mean value for Mn, Ni, V, Co, and Mo were 20.32, 45, 0.12, 0.58, and 1 ($mgkg^{-1}$) respectively (Table 4.28). All these values were below the permissible limits. The order of concentration ranking was Fe>Ni>Mn>Mo>Co>V.

The correlation results of soil micronutrients in Gboko showed that Fe and Mn had a strong positive relationship at a significant level ($p<0.01$). Mn and V had a strong positive relationship at a significant level ($p<0.01$). Mn and Co had a positive relationship ($p<0.05$). Vanadium and Cobalt correlated with a positive significance ($p<0.05$). These elements are most likely from the same parent material (Mustapha and Fagam, 2007). Though Fe showed a partial positive relationship with Ni, Ni and Mo did not correlate with any other element. However, the Spearman's coefficient showed that Ni and Mo had a positive and significant ($p<0.05$) relationship. Fe had a positive significant ($p<0.05$) relationship with Mn and Ni. The relationship between Mn and V was positive and significant ($p<0.01$). At a significant level of 5%, there was a positive relationship between Mn and Co. The correlation results are presented in Tables 4.29 and 4.30.

Table 4.23: Descriptive statistics of chemical properties of soils in Tarka

Parameters	Minimum	Maximum	Mean	Std. Deviation	Variance	Kurtosis	
						Statistic	Std. Error
pH	5.30	6.10	5.6500	.30896	.095	-1.474	1.232
C (%)	.54	2.05	1.1275	.57089	.326	-1.278	1.232
N (%)	.04	.18	.0817	.04324	.002	1.534	1.232
P ($mgkg^{-1}$)	.87	20.75	4.5558	7.45281	55.544	2.585	1.232
Ca ($cmolkg^{-1}$)	1.04	3.86	2.8517	.91714	.841	-.656	1.232
Mg ($cmolkg^{-1}$)	1.08	1.86	1.4733	.27988	.078	-1.552	1.232
K ($cmolkg^{-1}$)	.05	.09	.0708	.01379	.000	-1.003	1.232
Na ($cmolkg^{-1}$)	.04	.07	.0550	.01168	.000	-1.428	1.232
Al3+ ($cmolkg^{-1}$)	.00	1.92	.3758	.59220	.351	4.183	1.232
H+ ($cmolkg^{-1}$)	.50	1.48	.8542	.33288	.111	-.363	1.232
ECEC ($cmolkg^{-1}$)	4.06	6.71	5.6808	.93675	.877	-.920	1.232
Base saturation (%)	47.00	88.00	78.5000	14.78021	218.455	2.182	1.232

Table 4.24: Descriptive statistics for micronutrient values for soils in Tarka

Parameters	Minimum	Maximum	Mean	Std. Deviation	Variance	Kurtosis	
						Statistic	Std. Error
Fe ($mgkg^{-1}$)	201.61	934.13	6.8263E2	252.84096	6.393E4	.469	1.232
Mn ($mgkg^{-1}$)	18.58	40.10	26.4933	6.73141	45.312	-.031	1.232
Ni ($mgkg^{-1}$)	41.29	69.21	56.6058	7.84033	61.471	-.079	1.232
V ($mgkg^{-1}$)	.08	.24	.1442	.04542	.002	.332	1.232
Co ($mgkg^{-1}$)	.50	.88	.7308	.11098	.012	.196	1.232
Mo ($mgkg^{-1}$)	1.43	2.64	1.8825	.41805	.175	-.148	1.232

Table 4.25: Pearson's correlation results for micronutrients in soils from Tarka

Parameters	Fe	Mn	Ni	V	Co	Mo
Fe	1	.530	-.452	.610*	.612*	-.288
Mn		1	-.372	.430	.170	-.448
Ni			1	-.820**	-.611*	.731**
V				1	.802**	-.577*
Co					1	-.313
Mo						1

*. Correlation was significant at 0.05 level (2-tailed).
**. Correlation was significant at 0.01 level (2-tailed).

Table 4.26: Spearman's correlation coefficient for micronutrients values in Tarka

Parameters	Fe	Mn	Ni	V	Co	Mo
Fe	1.000	.510	-.105	.421	.406	.095
Mn		1.000	-.371	.551	.235	-.519
Ni			1.000	-.802**	-.599*	.758**
V				1.000	.860**	-.603*
Co					1.000	-.318
Mo						1.000

**. Correlation was significant at 0.01 level (2-tailed).

*. Correlation was significant at 0.05 level (2-tailed).

Table 4.27: Descriptive statistics of chemical properties of soils in Gboko

Parameters	Minimum	Maximum	Mean	Std. Deviation	Variance	Kurtosis	
						Statistic	Std. Error
pH	5.10	5.80	5.3083	.18809	.035	3.876	1.232
C (%)	.68	2.13	1.2725	.49393	.244	-.685	1.232
N (%)	.06	.18	.0983	.03810	.001	.820	1.232
P ($mgkg^{-1}$)	1.08	32.50	13.7308	11.05358	122.182	-.969	1.232
Ca ($cmolkg^{-1}$)	2.68	5.40	3.9967	.77787	.605	.022	1.232
Mg ($cmolkg^{-1}$)	1.06	3.50	2.2742	.72055	.519	-.049	1.232
K ($cmolkg^{-1}$)	.06	.14	.0967	.02425	.001	.290	1.232
Na ($cmolkg^{-1}$)	.05	.09	.0675	.01055	.000	.888	1.232
Al3+ ($cmolkg^{-1}$)	.00	.26	.1242	.09811	.010	-1.614	1.232
H+ ($cmolkg^{-1}$)	.24	1.00	.7425	.20877	.044	2.235	1.232
ECEC ($cmolkg^{-1}$)	5.35	9.95	7.3025	1.44385	2.085	-.464	1.232
Base saturation (%)	84.00	93.00	88.0000	2.79610	7.818	-.594	1.232

Table 4.28: Descriptive statistics of micronutrient values in soils from Gboko

Parameters	Minimum	Maximum	Mean	Std. Deviation	Variance	Kurtosis	
						Statistic	Std. Error
Fe ($mgkg^{-1}$)	201.06	726.13	4.7125E2	176.58466	3.118E4	-1.279	1.232
Mn ($mgkg^{-1}$)	10.20	31.26	20.3217	7.08566	50.207	-1.189	1.232
Ni ($mgkg^{-1}$)	21.26	66.28	44.9458	12.87064	165.653	-.210	1.232
V ($mgkg^{-1}$)	.02	.25	.1233	.07832	.006	-1.334	1.232
Co ($mgkg^{-1}$)	.38	.82	.5767	.13694	.019	-.732	1.232
Mo ($mgkg^{-1}$)	.20	1.26	.9950	.27268	.074	7.589	1.232

Table 4.29: Pearson's correlation results for micronutrients values in soils from Gboko

Parameters	Fe	Mn	Ni	V	Co	Mo
Fe	1	.761**	.553	.540	.523	-.006
Mn		1	.216	.918**	.675*	-.075
Ni			1	.146	.467	.420
V				1	.620*	.003
Co					1	.265
Mo						1

**. Correlation is significant at 0.01 level (2-tailed).

*. Correlation is significant at 0.05 level (2-tailed).

Table 4.30: Spearman's correlation results for micronutrient values in soils from Gboko

Parameters	Fe	Mn	Ni	V	Co	Mo
Fe	1.000	.673*	.650*	.411	.497	.291
Mn		1.000	.154	.888**	.649*	-.030
Ni			1.000	.004	.476	.632*
V				1.000	.436	.137
Co					1.000	.093
Mo						1.000

*. Correlation is significant at 0.05 level (2-tailed).

**. Correlation is significant at 0.01 level (2-tailed).

4.3.3 Properties of soils from other parts of the Lower River Benue Basin

The results of soil samples from cassava farms in Otukpo, Ohimini, and Katsina Ala LGAs within the Lower River Benue Basin are provided in Table 4.31. The results show that cation exchange capacities of the soils are moderate but the organic matter content was high and comparable to some sites in Tarka and Gboko. The soils pH results are comparable to sample results from Makurdi and Tarka but less acidic than samples results from Gboko. Soils from Otukpo had loamy texture, and soils from Ohimini had sandy-silt-clay textures. The soils from

Katsina Ala were clay loam. These properties demonstrate good potential for retaining nutrients elements and trace metals within the top soil layer. However, soil toxicity may occur in such soils when unacceptable limits of trace elements accumulate in the top layer of soils over time. Crops may absorb high amounts which may be transferred into the human food chain.

Table 4.31: Properties of soils from Otukpo, Ohimini and Katsina Ala LGAs

Parameters	Otukpo LGA Mean	Ohimini LGA Mean	Katsina Ala LGA Mean
pH	6.0	6.3	6.2
Organic Carbon (C) (%)	2.10	2.60	3.48
ECEC (cmolkg^{-1})	7.66	8.20	8.15
Sand (%)	33.40	30.70	36.20
Silt (%)	49.70	52.10	46.44
Clay (%)	16.90	17.20	17.36
Textural class	Loam	Sandy-silt-clay	Clay loam

Source: Abah *et al*. (2013)

Another study conducted in Bassa, Kogi State, within the flood plain of the Lower River Benue Basin showed results relatively similar to the results from Makurdi, Tarka, and Gboko (Table 4.32). The texture of the soils were loamy, clayey, and sandy. The results showed that the soils were acidic (pH, 5.5-6.5) and contained high organic carbon in some sites (0.1-14.3%). The phosphorus levels ranged from 0-8 mgkg^{-1}. The exchangeable bases had moderate to high values with calcium and magnesium having the highest values. This was observed in other sites sampled in this study. The ECEC (6.54-22.20 cmolkg^{-1}) and base saturation (90-99%) also had high values which support good conditions for crop cultivation. However, just as in the case with soils sampled from Makurdi, Tarka, and Gboko, these soils require fertility enhancement.

Odoh *et al*. (2014) presented the properties of soils around Benue cement company Gboko, Benue state (Table 4.33). The soil results revealed the textural attributes of the soils. The sand fraction ranged from 70.70-74.70%, silt ranged from 10.70-17.70%, and clay ranged from 10.20-

16.60%. The chemical properties show that pH had a range of 6.60-7.50. Others were organic carbon (2.86-3.21), ECEC (13.80-19.80), total nitrogen (0.05-0.09%), available phosphorus (43.54-78.00 mgkg^{-1}), Ca (4.23-8.25 cmolkg^{-1}), Mg (2.25-4.55 cmolkg^{-1}), K (0.18-0.37 cmolkg^{-1}), Na (0.33-0.67 cmolkg^{-1}), exchangeable acidity (0.77-1.55 cmolkg^{-1}) and base saturation (78.55-89.75%). Unlike the soils samples analysed in this study, these soils were less acidic and had much higher phosphorus levels. Other results were relatively comparable to soils results for Gboko. According to Odoh *et al*. (2014), these soil results from around the Benue cement company were found to be higher than soil samples from the control site. This means cement dust and other industrial waste materials may have accumulated and contributed significantly to the results presented in Table 4.33. Odoh *et al*. (2014) stated that the soil results with higher nutrient availability were capable of supporting crops grown in the area, such as yam, maize, cassava and groundnut.

4.3.4 Soil nutrient index

The range of soil pH, C, P, K, exchangeable sodium percentage (ESP), and sodium adsorption ratio (SAR) for soils in Makurdi, Tarka, and Gboko are presented in Table 4.34. The soils in Gboko were slightly more acidic than soils in other areas sampled. The soils in Gboko contained more percentage of organic carbon than soils in Tarka and Makurdi. The situation was similar for phosphorus and potassium.

The soil samples nutrient values were rated using the soil nutrient rating chart presented in chapter 3 (Verma *et al.*, 2005; Ravikumar and Somashekar, 2013). The results are presented in Table 4.35. Most of the soil samples (75%) were categorised as acidic with a soil reaction index of I (pH below 6.0) while 25% percent were categorised as having a soil reaction index of II (pH 6.0-8.0).

Table 4.32: Properties of soils in Bassa, Kogi state.

Parameter	Site 1 & 2 (Loamy)		Site 3,4, & 5 (Clayey)		Site 6 & 7 (Sandy)	
	Surface mean	Subsurface mean	Surface mean	Subsurface mean	Surface mean	Subsurface mean
pH	6.2	6.2	5.5	5.6	6.3	6.5
C (%)	9.3	4.7	14.3	2.60	0.30	0.1
N (%)	0.8	0.40	4.50	0.9	0.1	0.1
P ($mgkg^{-1}$)	8	8	3	0	6	5
Ca ($cmolkg^{-1}$)	13.5	11.3	14.5	13.1	6.0	5.2
Mg ($cmolkg^{-1}$)	2.0	2.8	5.1	5.4	0.9	1.0
K ($cmolkg^{-1}$)	0.15	0.13	0.15	0.1	0.1	0.09
Na ($cmolkg^{-1}$)	0.15	0.13	0.12	0.1	0.06	0.07
EA ($cmolkg^{-1}$)	0.20	0.29	0.5	0.78	0.24	0.18
ECEC ($cmolkg^{-1}$)	15.96	13.47	22.20	21.54	7.30	6.54
BS (%)	99	13.47	90	81.1	97	97

Source: Akpan-Idiok *et al*. (2013)

Table 4.33: Properties of soils sampled around Benue Cement Company in Gboko LGA

Parameters	Range	Mean	SD
pH	6.60 -7.50	7.10	0.27
Organic Carbon (C) (%)	2.86 – 3.21	2.99	0.10
Total Nitrogen (N) (%)	0.05-0.09	0.07	0.01
Available Phosphorus (P) ($mgkg^{-1}$)	43.54-78.00	55.52	9.31
Calcium (Ca) ($cmolkg^{-1}$)	4.23-8.25	6.52	1.35
Magnesium (Mg) ($cmolkg^{-1}$)	2.25-4.55	3.25	0.71
Potassium (K) ($cmolkg^{-1}$)	0.18-0.37	0.26	0.06
Sodium (Na) ($cmolkg^{-1}$)	0.36-0.57	0.46	0.05
Exchange Acidity ($cmolkg^{-1}$)	0.77-1.55	1.05	0.21
ECEC ($cmolkg^{-1}$)	13.8-19.8	16.20	1.57
Base Saturation (%)	78.55-89.75	83.98	4.21
Sand (%)	70.7 -74.7	72.11	1.27
Silt (%)	10.7-17.7	14.46	1.93
Clay (%)	10.2-16.6	13.43	1.67

Source: Odoh *et al*. (2014)

Table 4.34: Summary of soil nutrient parameters for Makurdi, Tarka, and Gboko

Location	pH		C (%)		P ($mgkg^{-1}$)		K ($cmolkg^{-1}$)		ESP	SAR
	Range	M	Range	M	Range	M	Range	M		
Makurdi	5.5-6.5	5.9	0.44-0.64	0.52	0.50-42.37	5.01	0.06-0.15	0.09	0.78-1.34	0.05-0.12
Tarka	5.3-6.1	5.7	0.54-2.05	1.13	0.87-20.75	4.56	0.05-0.09	0.07	0.91-2.52	0.04-0.09
Gboko	5.1-58	5.3	0.68-2.13	1.27	1.08-32.50	13.73	0.06-0.14	0.1	0.70-1.45	0.04-0.09

M=mean

Based on the soil rating chart, most of the soils sampled had medium to high percentages of organic carbon. Only 13.9% of the samples had percentages categorised as low. Most of the soils sampled had low amounts of phosphorus (50%) and low amounts of potassium (86.11%). A good percentage (36.11%) of the samples had high content of available phosphorus.

Soils from other parts of the Lower River Benue Basin were assessed using the nutrient rating chart. The results from Otukpo showed the pH values had a soil reaction index of I, and that of Ohimini and Katsina Ala had soil reaction index of II. The pH soil reaction of index for soils in Bassa ranged from I to III, while that of Benue Cement Company area was index II. The nutrient index for organic carbon was Otukpo (III), Ohimini (III), and Katsina Ala (III). The organic carbon nutrient index for Bassa ranged from I-III, while Benue Cement Company Gboko was (III).

The phosphorus nutrient index for Bassa ranged from I-III, and that of Benue cement company Gboko was III. The potassium nutrient index for Bassa ranged from I-II only, and the results from Benue Cement Company Gboko ranged from I-III.

Following from the soil nutrient values calculated using the nutrient index formula, soils in the Lower River Benue Basin were generally classified as HML based on organic carbon, available phosphorus and potassium concentrations. Soils in Makurdi were classified as LLL based on nutrient index values, while soils in Tarka were classified as HLL. Soils in Gboko were classified as HHL. Even though variations may exist as evident from the classifications of Makurdi, Tarka and Gboko, Table 4.36 showed the soil nutrient values and the general soil nutrient classification for the Lower River Benue Basin.

Table 4.35: Rating of soil nutrient values using the soil nutrient rating chart

Parameters	**Categories and No. of soil samples**		
Soil pH	**Acidic**	**Neutral**	**Alkaline**
Range	**Below 6.0**	**6.0-8.0**	**Above 8.0**
Soil reaction index	I	II	III
Makurdi	7	5	0
Tarka	8	4	0
Gboko	12	0	0
Total	27	9	0
Percentage	75%	25%	
Organic Carbon (C)	**Low**	**Medium**	**High**
Range (%)	**Below 0.5**	**0.5-0.75**	**Above 0.75**
Nutrient index	I	II	III
Makurdi	5	7	0
Tarka	0	4	8
Gboko	0	0	12
Total	5	11	20
Percentage	13.9%	30.55%	55.55%
Available Phosphorus (P)	**Low**	**Medium**	**High**
Range (mg/kg)	**Below 2.2**	**2.2-5.4**	**Above 5.4**
Nutrient index	I	II	III
Makurdi	8	3	1
Tarka	8	2	2
Gboko	2	0	10
Total	18	5	13
Percentage	50%	13.89%	36.11
Potassium (K)	**Low**	**Medium**	**High**
Range (cmolkg-1)	**Below 0.1**	**0.1-0.2**	**Above 0.2**
Nutrient index	I	II	III
Makurdi	10	2	0
Tarka	12	0	0
Gboko	9	3	0
Total	31	5	0
Percentage	86.11%	13.89%	

The classification order of soil nutrients was Gboko (HHL)>Tarka (HLL)>Makurdi (LLL). These infer that organic carbon and phosphorus increased a bit with movement away from the River Benue. All the soils assessed had various degrees of fertility and were suitable for cultivation of crops such as yams, cassava, and rice. However, these soils require fertility management practices with the use of organic fertilisers and inorganic fertilisers to balance the composition of soil nutrients such as organic carbon, phosphorus, potassium, and nitrogen. The results of soil properties for this study are consistent with the map of soil type extracted from the FAO (2014) digital soil map of the world (Figure 4.49). The predominant soil types presented in Figure 4.49 are Ferric Acrisol and Distric Nitosol which can support the cultivation of rice, cassava, and yam.

Table 4.36: Nutrient index values of soils sampled in the Lower River Benue Basin

Parameter	**Nutrient index values**	**Remark**
Organic carbon (C)	2.42	H
Available phosphorus (P)	1.86	M
Potassium (K)	1.13	L
Location	**Nutrient index values**	**Remark**
Makurdi (C,P,K)	1.58, 1.42, 1.17	L, L, L
Tarka (C,P,K)	2.7, 1.5, 1.0	H, L, L
Gboko (C,P,K)	3.0, 2.7, 1.25	H, H, L

H = High; M= Medium; L= Low

The soil properties were found to be suitable for cultivation of crops including roots and tuber crops. However, a study by Sumithra *et al*. (2013) stated that cultivation of tuber crops in flood plains and sloping lands have potential for nutrient loss. The textural class of soils observed possess low potassium reserves and low ion exchange capacity, which determine the quantity of ions that soils can retain against leaching (Edem, 2007). An increase in organic matter content of the soils during cultivation usually improves the nutrients retention capacity of such soils.

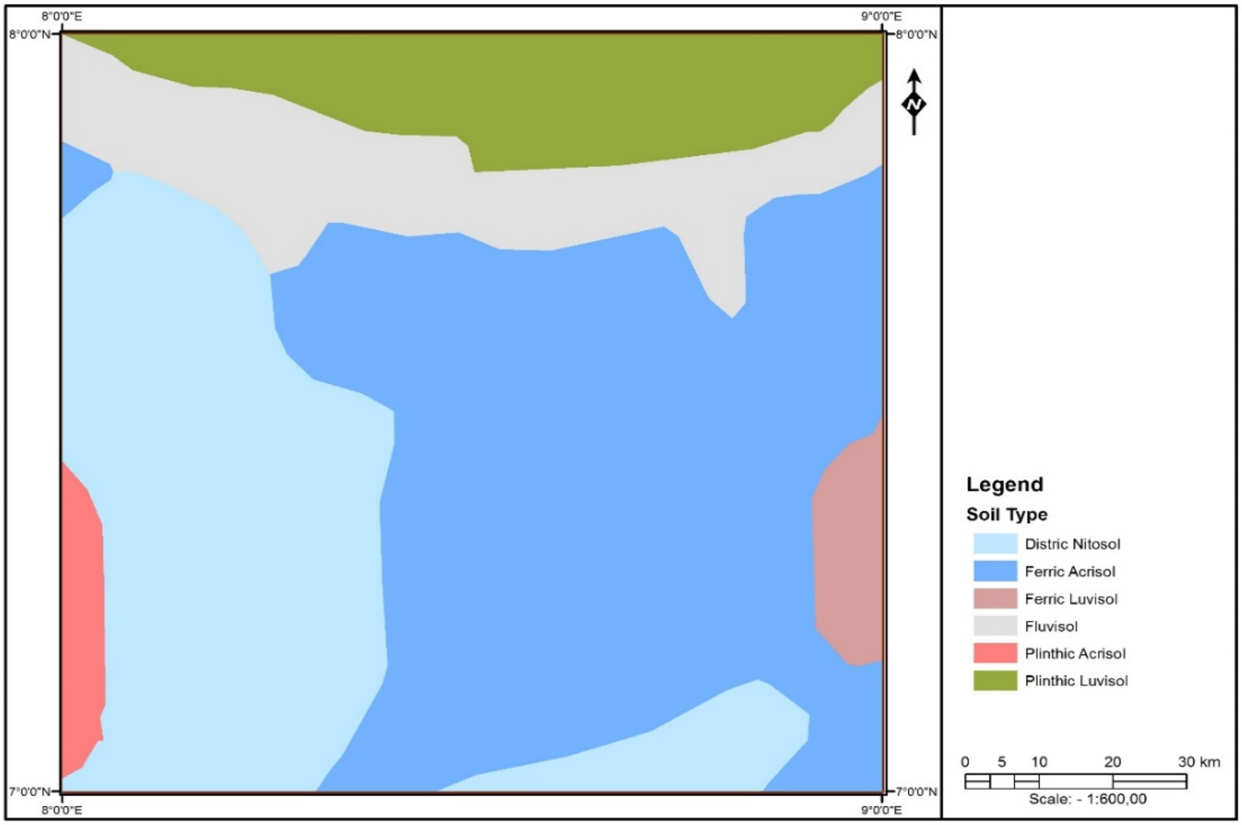

Figure 4.49: Soil classification map of the study area (Data: FAO (2014)

The chemical properties were below permissible limits and showed no indication of contamination. The micro-nutrients were below permissible limits and some of them had positive significant relationships suggesting common parent material. Parent material is found to have a profound influence on distribution of micro-nutrients (Mustapha and Fagam, 2007) and accounts primarily for the spatial occurrence pattern in the study area. According to Noe and Hupp (2007), the distribution mechanism of particulate nutrients in river basins are a function of flood hydrology during overbank flooding events. Nutrient processing in river basins are functions of climate, seasonality, geomorphology, and surface-subsurface hydrologic exchange (Noe and Hupp, 2007).

These mechanisms account for the order of spatial occurrence of nutrients analysed for the study area using the soil nutrient index.

Evidence of anthropogenic impact on soil nutrients in the study area was not significant probably due to the predominance of traditional farming methods and inconsistent use of fertilisers and herbicides. However, recent studies have shown that ineffective addition of soil enhancement nutrients in developing settings have begun to alter nutrient cycling and affect human health (Brevik and Sauer, 2015). Therefore, it is necessary to monitor the application of inorganic fertilisers in the study area due to the weak availability of nutrients observed. The use of inorganic fertilisers may enhance soil fertility. However, the excessive use of inorganic fertilisers and herbicides have negative implications for soil quality in the long term and this should be discouraged.

In order to increase output while maintaining the soil in good conditions, farmers in the area should consider the cultivation of improved crop varieties, shifting cultivation, cover cropping, rotation cropping, soil treatment with organic fertilisers and conservation practices. Mixed cropping with leguminous crops enhances soil conditions when roots and tuber crops are cultivated.

There are studies that show that farmers, especially in sub-Saharan Africa, practise intensive farming on small farms with low use of external inputs (Funes-Monzote, 2008). These methods cannot be transferred to vast commercial scales due to costs associated with transportation, labour, and soils depleted of nutrients. Soils with inadequate nutrients such as the results provided in this paper have given rise to the intensive use of external inputs in intensive farming (Vanlauwe *et al.*, 2010). According to Vanlauwe *et al*. (2010), the promotion of effective farm management practises should be done through farmer education and capacity building on integrated soil fertility management through intense interaction between farmers and extension services.

4.3.5 Irrigation quality

Exchangeable sodium percentage (ESP) is the parameter which measures the adsorption and exchange capacity of soil and determines whether soil is saturated with sodium. ESP levels are contributory determinants of soil pH, as high pH levels increase the alkalinity of soil. Therefore it is important to ensure soil has acceptable sodium adsorption and exchange limits where irrigation farming is considered. The range of exchangeable sodium percentage for soils in the Lower River Benue Basin were 0.78-1.34 (Makurdi), 0.91-2.52 (Tarka), and 0.70-1.45 (Gboko). The exchangeable sodium percentage for soils from Bassa ranged from 0.57 to 0.99 while those from the Benue Cement Company area had ESP of 4.39. Though all these ESP values fall into the excellent category, the ESP for the Benue Cement Company area was the highest. Table 4.37 showed the ESP classification of soils in Makurdi, Tarka, and Gboko according to Wilcox (1955) and Prasanth *et al*. (2012). As shown in Table 4.37, these soils fall under the excellent category, which is a good indication of fertile soils and good irrigation quality.

Sodium adsorption ratio (SAR) measures the suitability of land for irrigation purposes because sodium concentration can reduce soil permeability and cause soil structure (Todd, 1980). The extent to which sodium is adsorbed by the soils is important because irrigation water with high values of SAR may become a hazard to crops in soils with already high SAR values. Irrigation waters with high SAR values will affect the levels of calcium and magnesium in the soil. This results in weakening the ability of the soil to maintain stable aggregates and eventually loss of soil structure. Reduced infiltration and permeability of the soil to water limits successful crop production. Table 4.38 details the SAR status of soils analysed according to Todd (1980). The SAR range for soils in Makurdi, Tarka, Gboko, Bassa, and the Benue Cement Company area Gboko all fall within the excellent category. These results further attests to the very good quality of these soils for irrigation farming.

The values for sodium provided imply that the soils in the study area have good potential for irrigation farming with the use of stream and groundwater during the dry season. Irrigation farming can enhance productivity and improve the quality of the soils. The areas most suitable for the cultivation for rice, cassava and yam are mentioned in the next section.

Table 4.37: ESP levels for soils in the Lower River Benue Basin

Categories	ESP (%)	Makurdi	Tarka	Gboko	Bassa	BCC*
Excellent	<20	0.78-1.34	0.91-2.52	0.70-1.45	0.57-0.99	4.39
Good	20-40					
Permissible	40-60					
Doubtful	60-80					
Unsuitable	>80					

*****Benue Cement Company area Gboko.

Table 4.38: Sodium adsorption ratio of soils in the Lower River Benue Basin

Categories	SAR	Makurdi	Tarka	Gboko	Bassa	BCC*
Excellent	<10	0.05-0.12	0.04-0.09	0.04-0.09	0.03-0.07	0.16
Good	10-18					
Doubtful	18-26					
Unsuitable	>26					

*Benue Cement Company area Gboko.

4.4 Results of Remote Sensing and GIS analyses

The results of remote sensing and GIS overlay analyses is presented in this section. Generated maps such as land use and land cover, slope gradient, drainage, and crop suitability maps have been presented.

4.4.1 Land use and land cover (LULC) of study area

The study area had a predominance of scattered cultivation (Figure 4.50) which supported the finding that the study area has a preponderance of agrarian peasants. Scattered cultivation covered a total area of 4,691.18km^2 which made up 38.28% of the total study area which affirmed the field findings.

The Built-up area accounted for 2,343.14km^2 (19.12%) of the total area under study. Wetland and Waterbody (including rivers) covered a total area of 1,645.84km^2 (13.43%) and 1,523.29km^2 (12.43%) respectively. Bareland surfaces covered an area of 1,388.48km^2 (11.33%) while Rock outcrops accounted for the least area occupying 662.99km^2 representing 5.41% of the total area under investigation (Table 4.39). The generated land use and land cover map is presented in Figure 4.51.

Table 4.39: Land use and land cover classes of the study area

LULC Classes	Area (km^2)	Percentages %
Bareland	1,388.48	11.33
Built-up Area	2,343.14	19.12
Rock Outcrop	662.99	5.41
Scattered Cultivation	4,691.18	38.28
Waterbody	1,523.29	12.43
Wetland	1,645.84	13.43
Total	**12254.92**	**100%**

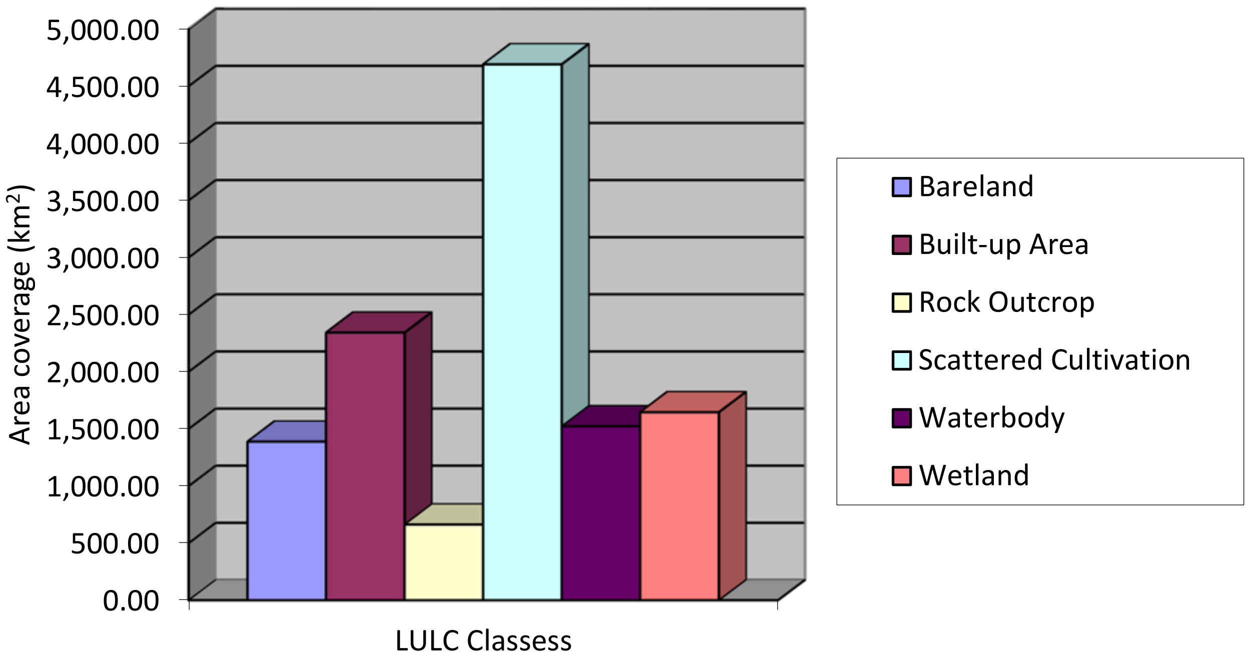

Figure 4.50: Land use and land cover extent of study area

4.4.2 Crop suitability mapping results

4.4.2.1 Normalised difference vegetation index (NDVI)

The NDVI results showed that the study area is appreciably vegetated which buttressed the finding from the Land Use Land Cover. The NDVI analysis showed values ranging from -1 to +1 (Figure 4.52). After the reclassification operation (Table 4.40), areas without vegetation were found to occupy a total area of 601.72km^2 which represented 4.91% of the study area. Sparsely vegetated areas covered 8,312.51km^2 (67.83%) which was the highest vegetal cover class. This was followed by 27.26% (3,340.69km^2) which was covered by high vegetation. The result of the NDVI showed the general vegetation condition of the study area (Figures 4.53 and 4.54). These results further attest to the general suitability and potential of the study area for crop cultivation.

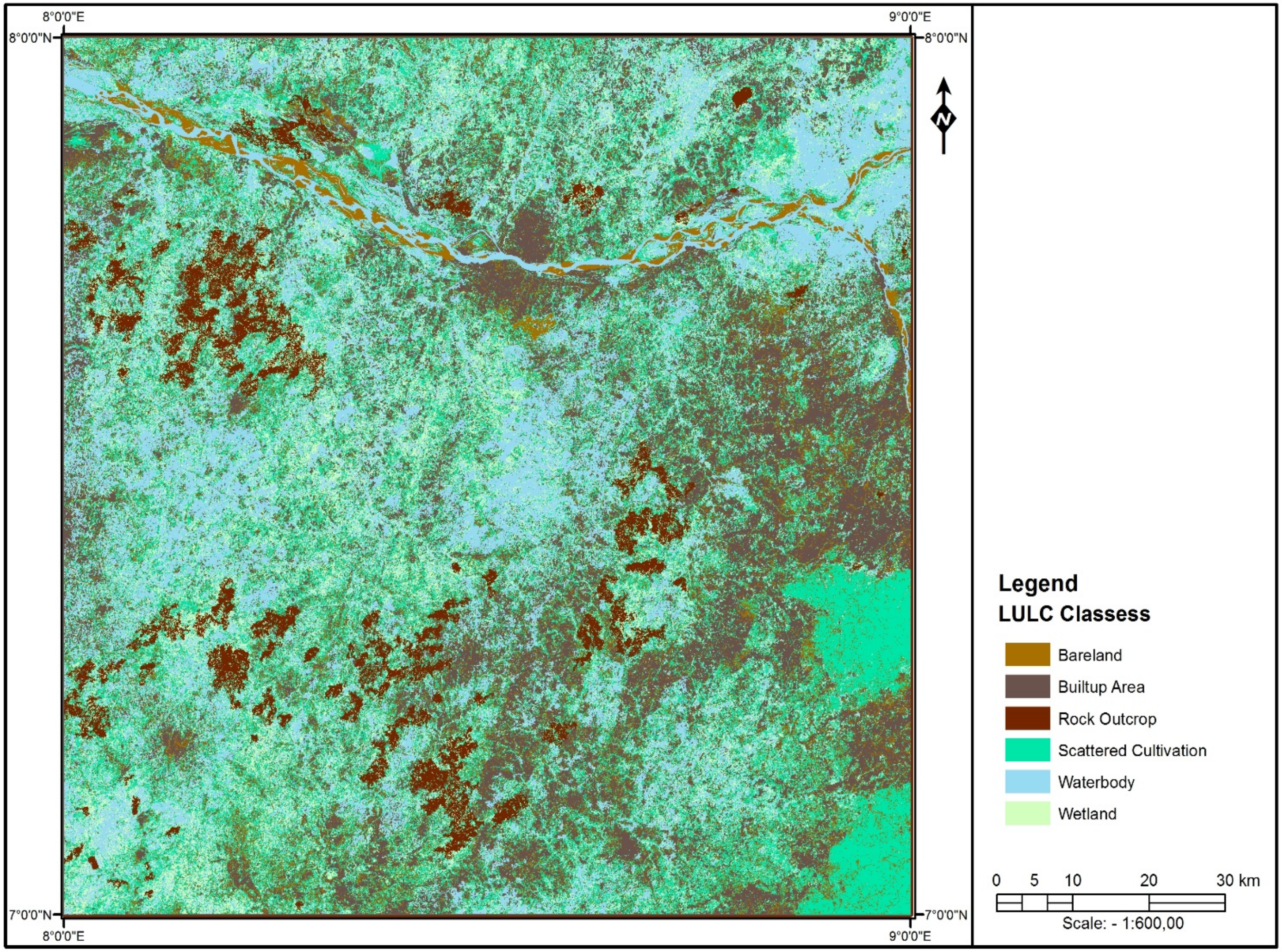

Figure 4.51: Land use and land cover map of study area

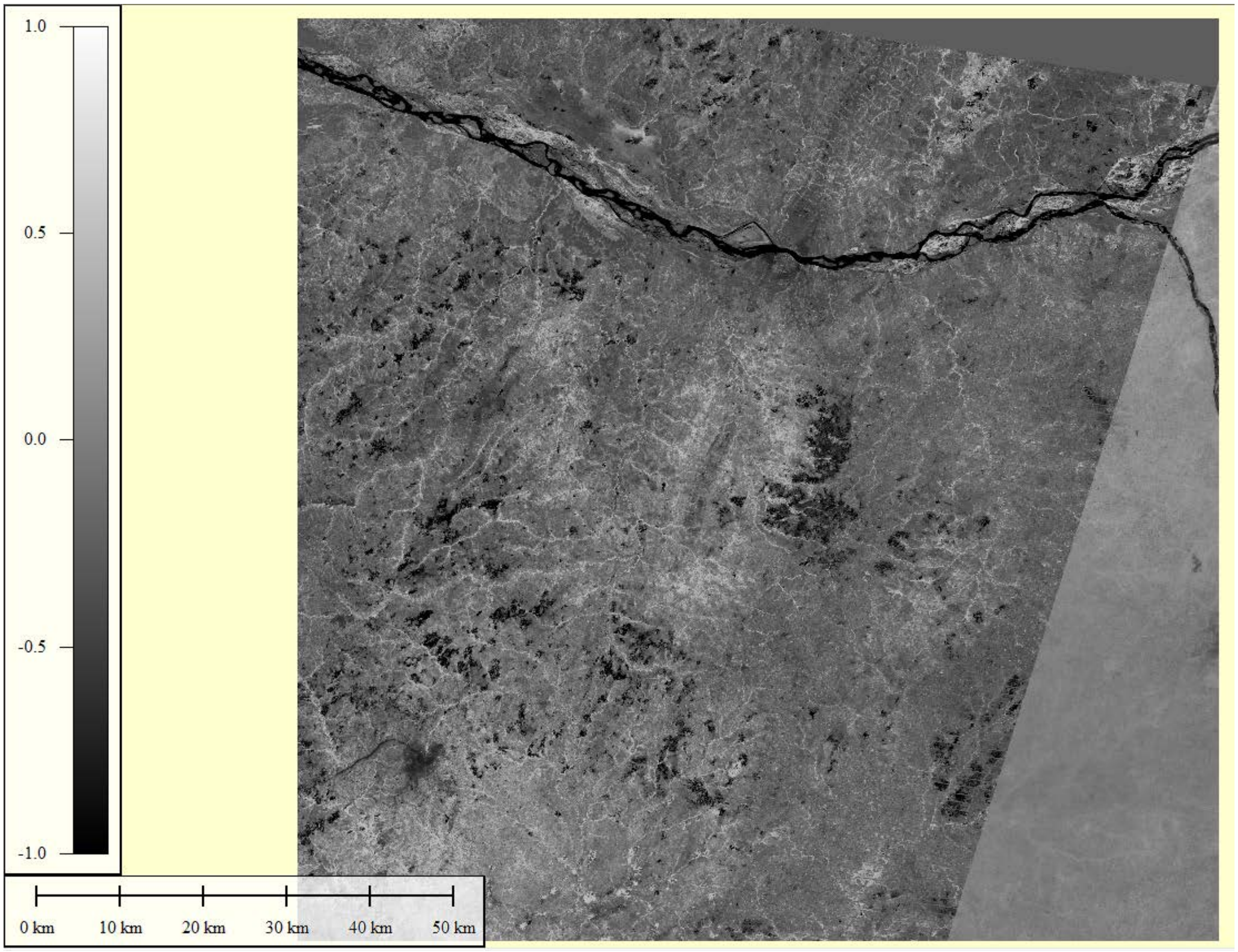

Figure 4.52: NDVI result of the study area

Table 4.40: Vegetation classes of the study area

Vegetation Class	Area (km^2)	Percentages %
No Vegetation	601.72	4.91
Sparse Vegetation	8312.51	67.83
High Vegetation	3340.69	27.26
Total	**12254.92**	**100%**

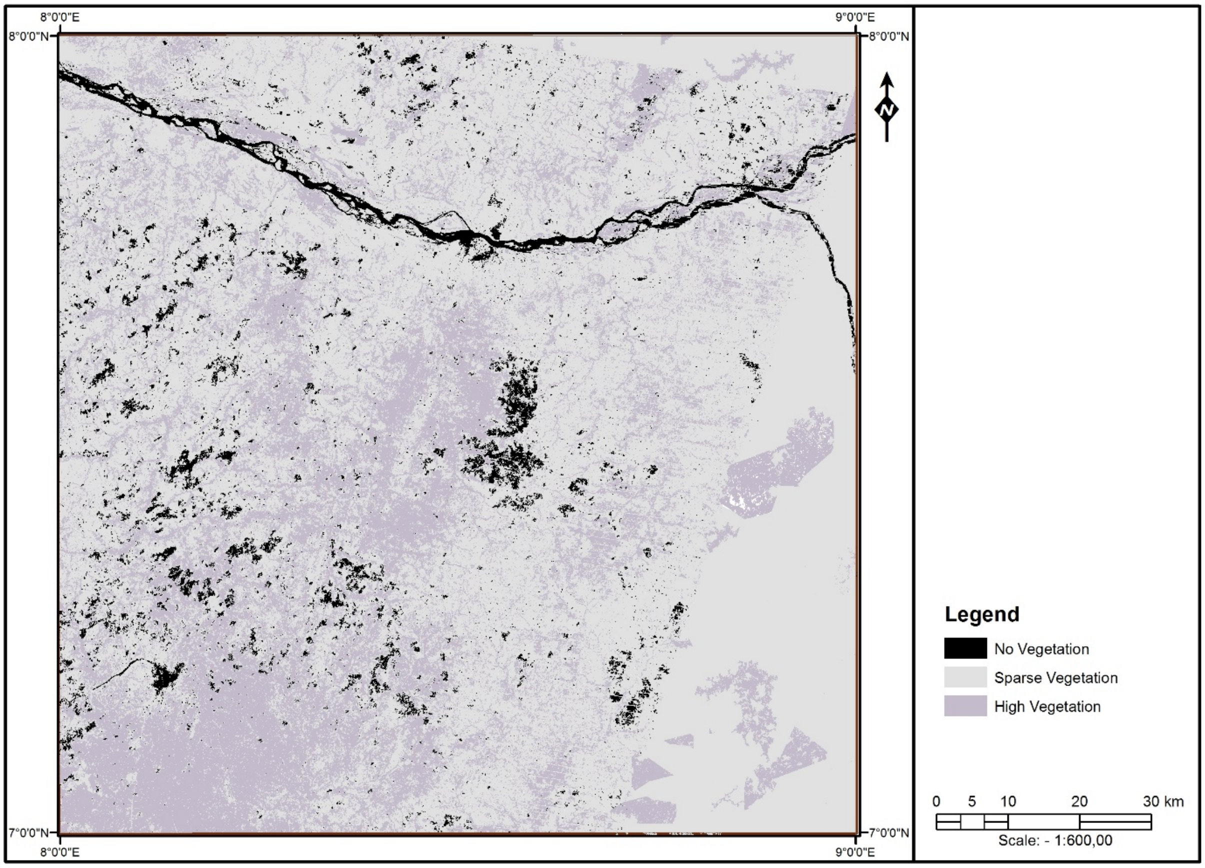

Figure 4.53: NDVI reclassification of the study area

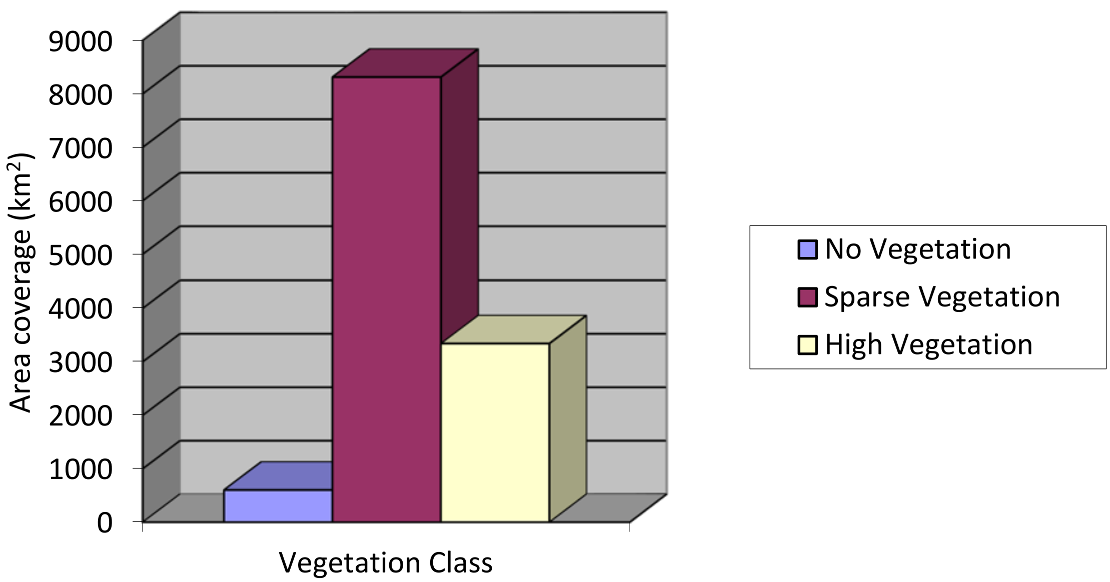

Figure 4.54: Graphical representation of NDVI reclassification (km^2)

4.4.2.2 Rice suitability classes

The total area of 4,193.65km^2 representing 34.22% of area under investigation was found to be highly suitable for rice cultivation (Table 4.41). Most of the other parts of the study area are moderately suitable for rice cultivation 45.46% (5,570.51km^2). Very high suitable areas covered only 500.00 km^2 (4.08%). The suitability map is presented as Figure 4.55.

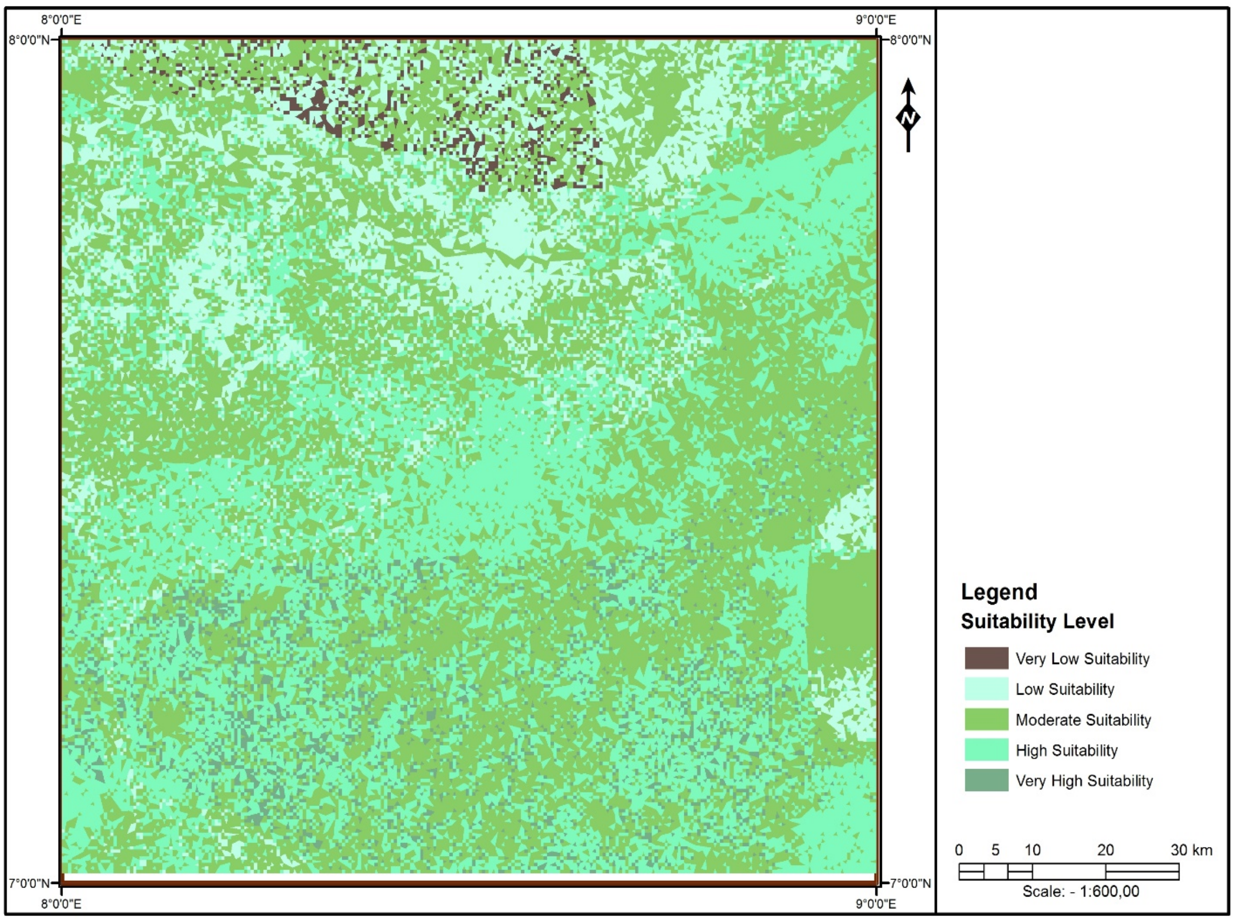

Figure 4.55: Rice suitability map of the study area

Table 4.41: Suitability classes for rice in the study area

Suitability classes	Area (km^2)	Percentages %
Very low suitability	153.25	1.25
Low suitability	1,837.52	14.99
Moderate suitability	5,570.51	45.46
High suitability	4,193.65	34.22
Very high suitability	500.00	4.08
Total	**12254.92**	**100%**

4.4.2.3 Cassava suitability classes

Cassava suitability classes showed that moderate suitability covered the largest part of the study area occupying 5,904.52km^2 (48.18%). It was closely followed by areas of low suitability covering an area of 4,127.49km^2 representing 33.68% of the total area. Highly suitable areas occupied 2,093.13km^2 (17.08%) of the total area under investigation. The least area was occupied by the very low suitability class covering 96.90km^2 (0.79%) of the study area (Table 4.42). Cassava is a crop that can survive on many soil types and usually copes with adverse weather conditions. It is therefore not surprising that given these fringe suitability classes (moderate and low), cassava seems to be a thriving crop in Benue state (Figure 4.56).

Table 4.42: Suitability classes for cassava in the study area

Suitability classes	Area (km^2)	Percentages %
Very low suitability	96.90	0.79
Low suitability	4,127.49	33.68
Moderate suitability	5,904.52	48.18
High suitability	2,093.13	17.08
Very high suitability	32.89	0.27
Total	**12254.92**	**100%**

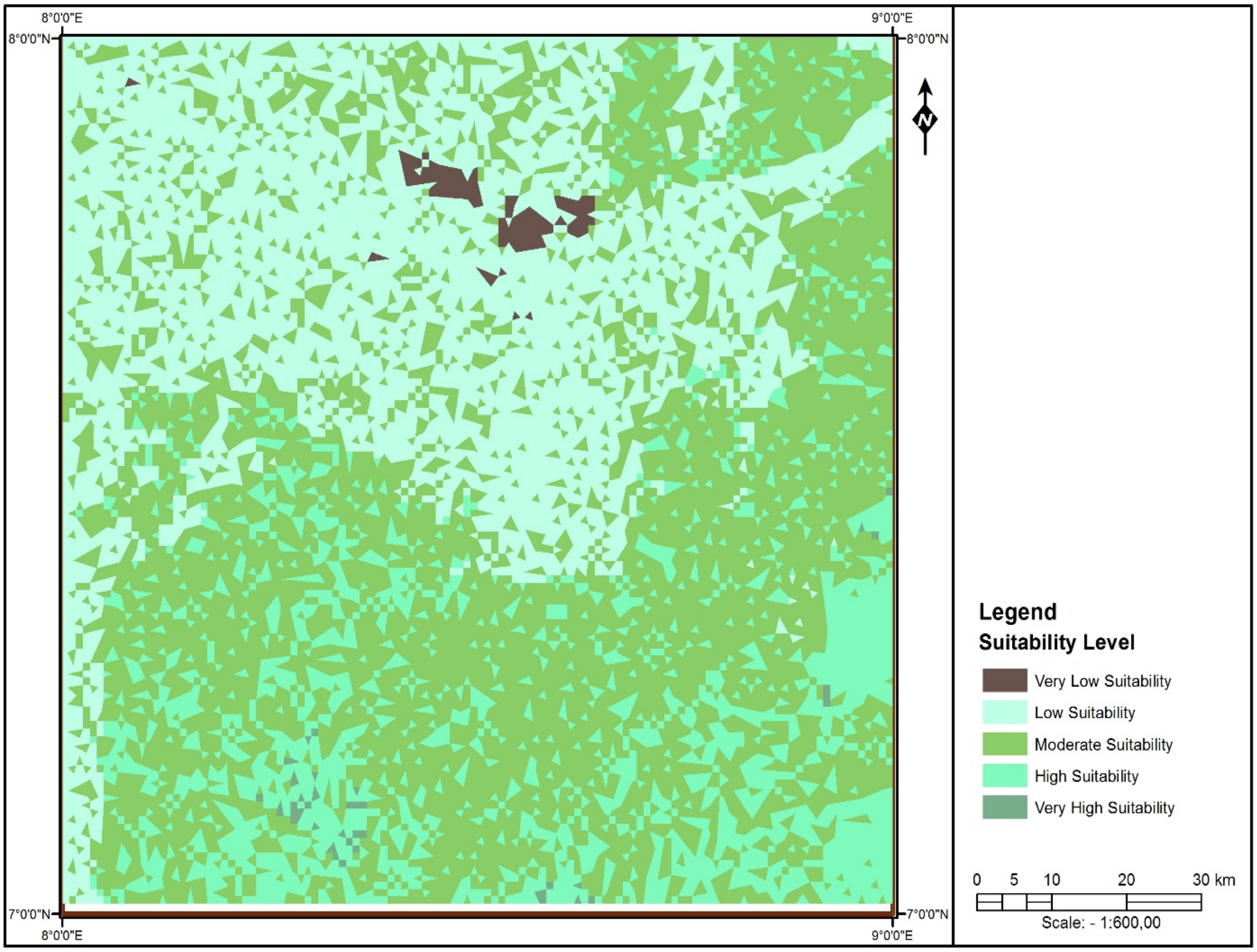

Figure 4.56: Cassava suitability map of the study area

4.4.2.4 Yam suitability classes

Moderately suitable areas for yam cultivation made up 48.85% (5,986.41km^2) of the study area and spread across the entire area under investigation (Table 4.43). The closest to moderately suitability was low suitability covering 29.57% (3,623.86km^2) of the study area. The areas marked as very low suitability for yam cultivation was 598.54km^2 representing 4.88% of the total study area (Figure 4.57).

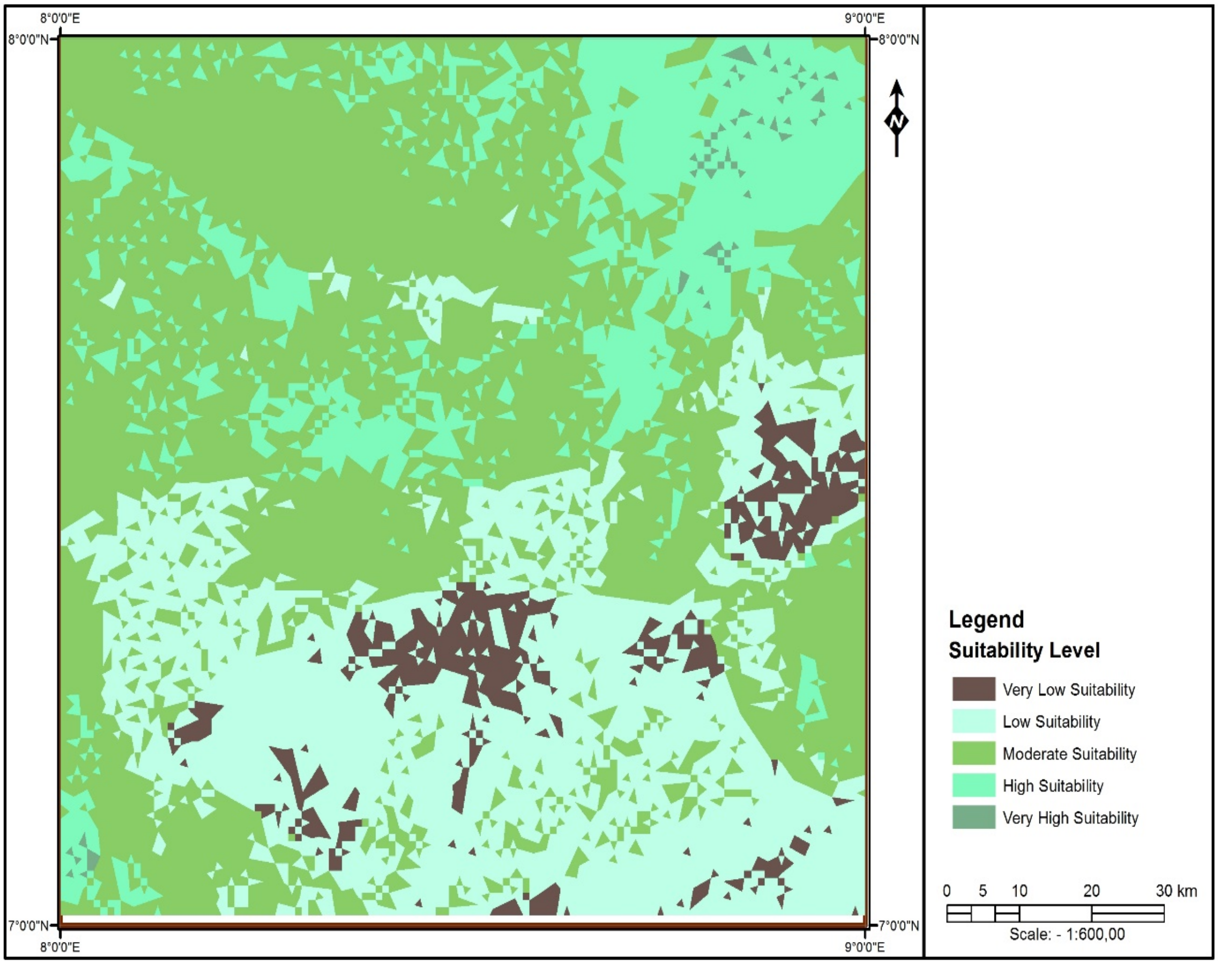

Figure 4.57: Yam suitability map of the study area

Table 4.43: Suitability classes for yam in the study area.

Suitability classes	Area (km^2)	Percentages %
Very low suitability	598.54	4.88
Low suitability	3,623.86	29.57
Moderate suitability	5,986.41	48.85
High suitability	1,994.80	16.28
Very high suitability	51.31	0.42
Total	**12254.92**	**100%**

4.4.3 Suitable areas for cultivation of rice, yam, and cassava in the study area

The Lower River Benue Basin is known for high amounts of agricultural produce especially cereals, roots and tubers, and legumes. It is therefore not surprising that most parts of study area was found to be moderately suitable for the cultivation of rice, yam, and cassava. Notwithstanding, the suitability maps indicated that areas highly suitable and very highly suitable for these crops are not as predominant except for rice which had an appreciable percentage area marked as highly suitable.

The suitability map for rice showed a high variation. The areas found to be highly suitable and very highly suitable for rice cultivation (Figure 4.55) fall under four Local Government Areas (L.G.As) including Gboko, Konshisha, Gwer east, and Otukpo (Figure 1.1). The streams in these areas are not tributaries of the River Benue but actually flow southwards from the River Benue (Figure 4.31). These areas experience the highest rainfall amounts (Figure 4.4) and the least temperature (Figure 4.16). The areas marked as very highly suitable, highly suitable and moderately suitable for rice cultivation fall under the soil type Ferric Acrisol and Distric Notosol soil types (Figure 4.49). One of the LGAs (Otukpo) used to have the largest rice mill in Nigeria but was neglected by Government and succumbed to issues of illegal levies within the premises and obscure activities of middlemen. The areas marked high and very high suitability for rice cultivation have the highest concentration of built up areas (Figure 4.51). Out of the three LGAs where soil samples were taken from for this study, Gboko was the most suitable for rice production in the order Gboko>Tarka>Makrudi (Figures 1.1 and 4.55).

The suitability map for cassava showed that cassava is more successfully cultivated in areas of moderate elevation (Figures 3.2 and 4.56). The areas of very high suitability fell within the southern fringes of Gwer east LGA. Areas marked as highly suitable and moderately suitable which were predominant fell under Gboko, Gwer east, Tarka, Konshisha, and Otukpo (Figure 1.1). Most parts of Benue however are known to produce large amounts of cassava annually. The rainfall and temperature of the cassava suitability areas were similar to that of rice suitability. The areas of very low suitability were areas around Makurdi. The order of suitability for cassava cultivation in the three LGAs where soil samples were taken for this study was Gboko>Tarka>Makurdi (Figures 1.1 and 4.56). Makurdi had the highest portion of very low suitable areas for cassava cultivation.

The suitability map for yam (Figure 4.57) was quite different from that of rice and cassava. The areas marked for having very low suitability and low suitability were within Gboko, Konshisha, Ushongo and parts of Gwer east which were quite suitable for rice cultivation in Figure 4.55. This may be a function of the relief system of highlands and floodplains in the area. The very highly suitable and highly suitable areas for yam production fell within Guma, Tarka, Gwer west, and the southern part of Otukpo (Figures 1.1 and 4.57). The preferred areas for yam suitability appeared more in areas of lesser rainfall, higher temperature and moderate relief in contrast to that of rice. The order of suitability for yam cultivation in the three LGAs where soil samples were taken from was Tarka>Makurdi>Gboko (Figures 1.1 and 4.57).

Overall, rice had the highest suitability percentages for both the very highly suitable and the highly suitable classes (Figure 4.58). This is an indication that more areas within the study area are better suited for rice cultivation than for yam and cassava. However, Figure 4.58 showed that the study area is moderately suitable for either of the crops examined with an average of more than 40% for each crop. Cassava had the least suitability for the combined low suitability classes (34.47%), and was followed by yam (34.45%).

Generally, the areas of suitability for these crops potentially provides a good population of farmers given that the major occupation in Benue State is crop farming. However, the predominant mode of farming is a mix of traditional and semi-traditional which limits optimal cultivation and yields.

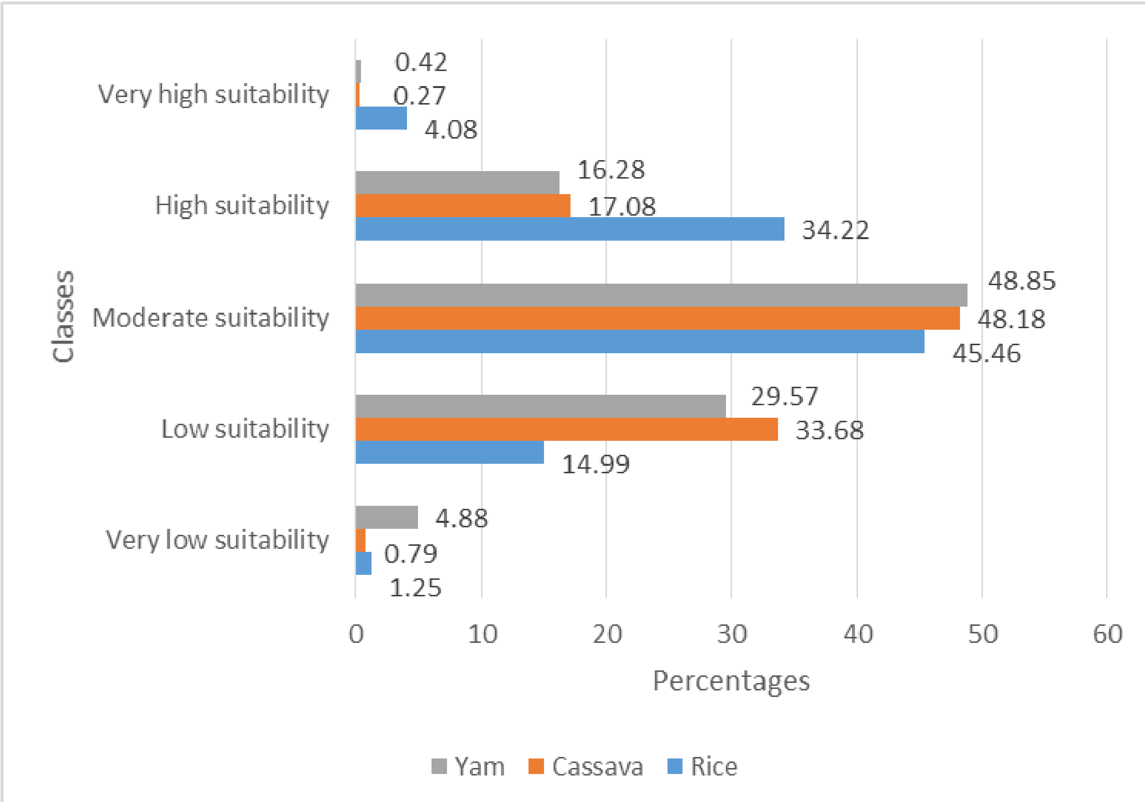

Figure 4.58: Suitability classes for rice, yam, and cassava in the study area

There are several varieties of rice, cassava, and yam that are cultivated in the Lower River Benue Basin. Information gathered from field interviews is presented in Table 4.44. The popular crop varieties were ranked in order of cultivation preference from 1 to 8 in five selected L.G.As. The most cultivated variety of cassava was TMS 98/0581. The most cultivated rice variety was FARO 52 (WITA 150), and the most cultivated variety of yam was *Gbangu* (white guinea yam). The cultivation of the first five varieties of rice, cassava, and yam should be encouraged in the

Lower River Benue Basin since they seem to yield better. The socioeconomic attributes of the study area are explored in greater detail in chapter five.

Table 4.44: Most popular varieties of rice, cassava, and yam cultivated in Benue State

L.G.A/ Crop	Ranking of crop varieties							
Gboko	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Cassava	TMS 98/ 0581	TME 419	NR 8082	98/0505	TMS 30572	TMS 01/1368	TMS 01/1371	
Rice	FARO 46 (ITA 150)	FARO 55 (NERICA 1)	FARO 44 (SIPI)	FARO 52 (WITA 4)				
Yam	*Gbangu* (White Guinea Yam)	*Danancha* (Greater Yam)	*Pepa* (Winged Yam)	*Hebamkwase* (Water yam)	*Amula* (Guyana Arrow root)	*Faketsa* (Yellow Yam)	*Ameh* (Purple Yam)	*Ogoja* (Rotundat a Yam)
Makurdi								
Cassava	TMS 98/ 0581	TME 419	NR 8082	98/0505	TMS 30572	TMS 01/1368	TMS 01/1371	
Rice	FARO 52 (WITA 4)	FARO 44 (SIPI)	FARO 46 (ITA 150)	FARO 55 (NERICA 1)				
Yam	*Gbangu*	*Danancha*	*Pepa*	*Hebamkwase*	*Amula*	*Faketsa*	*Ameh*	*Ogoja*
Tarka								
Cassava	TMS 98/ 0581	TME 419	NR 8082	98/0505	TMS 30572	TMS 01/1368	TMS 01/1371	
Rice	FARO 52 (WITA 4)	FARO 44 (SIPI)	FARO 46 (ITA 150)	FARO 55 (NERICA 1)				
Yam	*Gbangu*	*Danancha*	*Pepa*	*Hebamkwase*	*Amula*	*Faketsa*	*Ameh*	*Ogoja*
Otukpo								
Cassava	TMS 98/ 0581	TME 419	NR 8082	98/0505	TMS 30572	TMS 01/1368	TMS 01/1371	
Rice	FARO 52 (WITA 4)	FARO 44 (SIPI)	FARO 46 (ITA 150)	FARO 55 (NERICA 1)				
Yam	*Ameh*	*Gbangu*	*Pepa*	*Hebamkwase*	*Amula*	*Faketsa*	*Danancha*	*Ogoja*
Gwer west								
Cassava	TMS 98/ 0581	TME 419	NR 8082	98/0505	TMS 30572	TMS 01/1368	TMS 01/1371	
Rice	FARO 52 (WITA 4)	FARO 44 (SIPI)	FARO 46 (ITA 150)	FARO 55 (NERICA 1)				
Yam	*Gbangu*	*Danancha*	*Pepa*	*Hebamkwase*	*Amula*	*Faketsa*	*Ameh*	*Ogoja*

CHAPTER FIVE

SOCIOECONOMIC SURVEY OF FARMERS AND POTENTIAL IMPACTS ON AGRICULTURAL PRODUCTION IN THE LOWER RIVER BENUE BASIN

5.0 Introduction

This chapter presents the results of socioeconomic survey in Makurdi, Tarka, and Gboko Local Government Areas (L.G.A) of Benue state located in the Lower River Benue Basin. The results were supported with relevant secondary data. The total number of respondents were 281 from Makurdi, Tarka and Gboko Local Government Areas (L.G.A) of Benue State. Over 200 respondents answered most of the questions in the questionnaire (Figure 5.1). The results showed that the predominant sources of income of the people are agrarian based. There exists a number of farmers' cooperative societies which enhanced data collection. These cooperatives have potential to enhance information sharing and access to benefits from Government. It was observed that farmers in the region were confronted by several environmental problems, and as largely indicated in the questionnaire results, irregular wet seasons and staggering crop yields.

The results of the potential impact assessment conducted for this study and the results obtained from the agricultural suitability index and climate change adaptive capacity index models developed for this study are also presented in this chapter.

5.1. Population size and growth

Benue State had a total population of 2,753,007 persons according to the 1991 national census count (NPC, 1991), distributed across 23 L.G.As. Males made up 1,368, 965 and females made up 1,384,112. The 2006 national census put the population of the state at 4,219,244, with males making up 2,164,058 (51.29%) and females making up 2,055,186 (48.71%) (FGN, 2007). Females were more than males according to the 1991 census but the situation changed as reflected in the 2006 census. Benue State is the 7^{th} most populous state in Nigeria. The population of Makurdi, Tarka, and Gboko Local Government Areas (LGAs) selected for this study is presented in Table 5.1.

As shown in Table 5.1, all the LGAs have a combined population of more than 700,000. The large population sizes of Makurdi and Gboko contribute to high population densities in Benue State. Another feature of the figures in Table 5.1 is the fact that in all the LGAs, population of males outnumber that of the females. Based on the 2006 population census, the population of the thirteen LGAs in the study area were projected to 2026 using a national growth rate of 2.8% (FGN, 2007). The mathematical population projection method (the exponential growth model presented in chapter 3, equation 10) was used in the estimation of population. As observable in Table 5.2 the population of the study area will have doubled by 2016 and tripled to 6,920,319 persons by the year 2026. Figure 5.2 showed that the densely populated areas are Gboko, Makurdi, and Otukpo. Density was low around Tarka, and Gwer west.

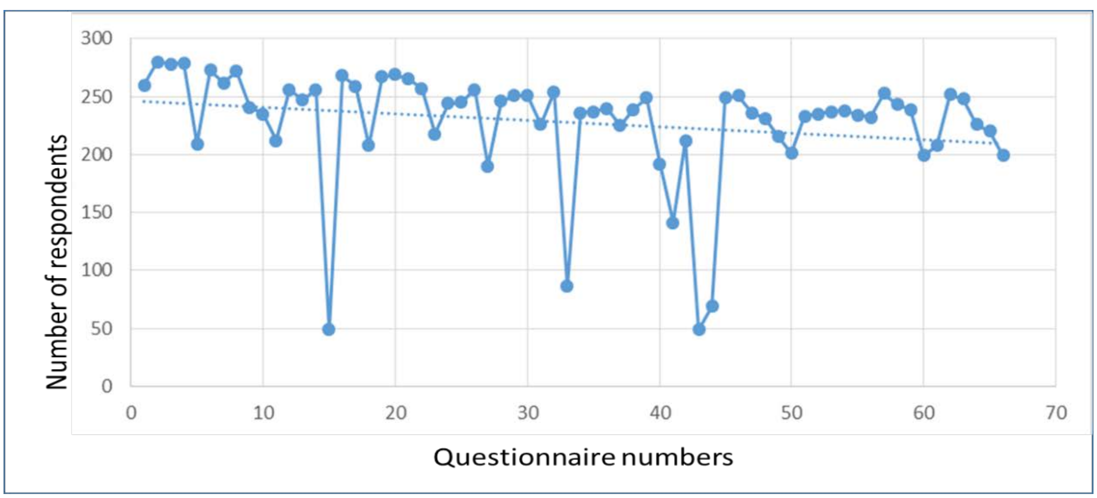

Figure 5.1: Number of respondents for each question of the questionnaire

Table 5.1. Population of Makurdi, Tarka, and Gboko LGAs in 2006

LGA	Males	Females	Total
Makurdi	157295	140103	297398
Tarka	42206	37288	79494
Gboko	198320	160616	358936
Total	**397821**	**338007**	**735828**

Source: Federal Government of Nigeria (2007)

Table 5.2: Population of study area in the period 2006-2026

Community	2006**	*2011	*2016	*2021	*2026
Makurdi	297398	388414	507285	662534	865297
Tarka	79494	103822	135596	177094	231291
Gboko	358936	468785	612252	799627	1044345
Gwer west	122145	159526	208348	272110	355387
Gwer east	163647	213729	279139	364567	476139
Guma	191599	250236	326818	426838	557468
Buruku	203721	266068	347496	453844	592738
Otukpo	261666	341747	446336	582932	761333
Agatu	115523	150878	197053	257359	336121
Ushongo	188341	245981	321261	419580	547989
Ohimini	71482	93358	121929	159245	207980
Obi	98855	129109	168622	220227	287625
Konshisha	225672	294737	384939	502745	656606
Total	**2378479**	**3106390**	**4057074**	**5298702**	**6920319**

**Census figures (FGN, 2007), * Projections.

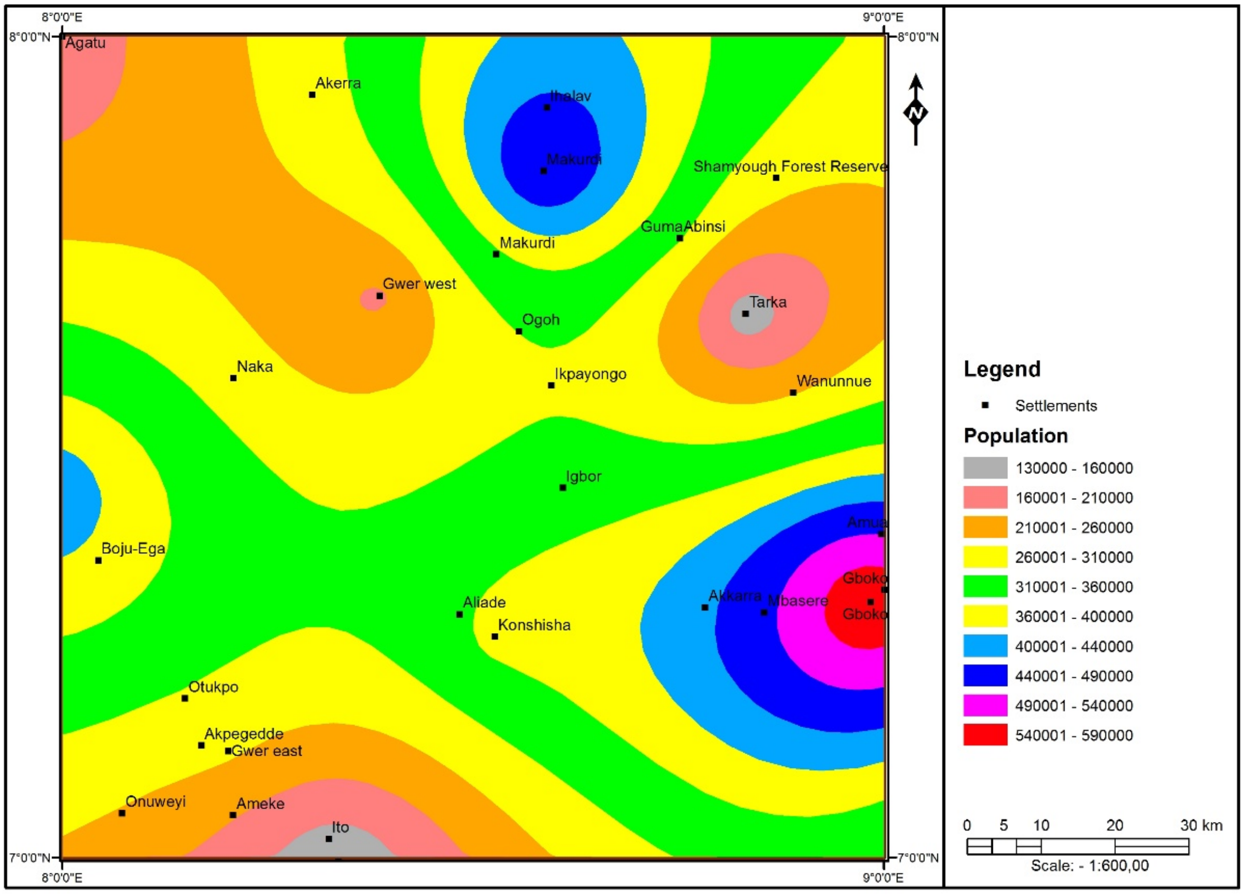

Figure 5.2: Population density map of the study area

5.2 Demographic structure

5.2.1 Ethnography and religion

Generally, residents of Makurdi, Tarka, and Gboko are characteristically homogeneous in ethnology. All the communities speak the Tiv language but with variant of similar dialects in very few cases. Consequently, Tiv is the medium of communication except in rare cases where Pidgin English or English language is used to communicate with strangers from other tribes. It must be noted that only a minority of the residents, especially the ones inhabiting the rural communities are not versed in this art of communication in a foreign language. A high number of settlers from other tribes reside in the L.G.A headquarters of Makurdi and Gboko.

The major religion of the people is Christianity (>90%), a considerable percentage of Islamic settlers exist in the study area (<10%). A high number of migrating nomadic Fulani herdsmen traverse through the state annually in search of green pasture for cattle. Very fatal clashes between Fulani herdsmen and farmers in Benue are an annual occurrence. The year 2014 recorded some of the worst clashes between the herdsmen and farming communities as widely reported in various media resulting in a high number of deaths and internally displaced persons. The African Traditional Religion (ATR) also exist and is practiced by some traditional rulers and their subjects. Rarely does one find any person within these communities not professing any of the above three religions.

The majority of respondents (94.44%) were of Tiv ethnicity, other ethnic groups indicated include Idoma, Igede, Yoruba, and Hausa. A total of 107 respondents (38.08%) indicated they were from Tarka LGA. Other LGAs with large respondents include Gboko (28.83%) and Makurdi (16.37%). Many other L.G.As in Benue state were also indicated by respondents. This does not represent the number of respondents resident in these three L.G.As. It was observed that most respondents indicated their L.G.A of origin rather than the L.G.A in which they were resident.

5.2.2 Sex and age of respondents

Table 5.3 and Table 5.4 presents the percentage of sex and age brackets of respondents. Out of the total respondents, 55.3% were males and 44.7% were females. The age structure revealed that the age brackets 20-29 years (27.10%), 30-39 years (26.34%), and 40-49 years (23.66%) formed the bulk of respondents. It was observed from field work that these age groups and a sizeable percentage of the age bracket of 50-59 years constitute the more active and productive farming population in the Lower River Benue Basin.

Table 5.3: Sex structure of respondents

Sex	No. of respondents	Percentage (%)
Female	122	44.7
Male	151	55.3
Total	**273**	**100%**
Skipped question	**8**	

Table 5.4: Age structure of respondents

Age structure	No. of respondents	Percentage (%)
10-19	10	3.82
20-29	71	27.10
30-39	69	26.34
40-49	62	23.66
50-59	33	12.60
60-69	15	5.73
70+	2	0.76
Total	**262**	**100%**
Skipped question	**19**	

In terms of the age-sex structure and distribution of respondents, the population is rather loaded from the lower age-cohorts of 20-49 years (Figure 5.3). The age-sex pyramid generally presents a young and growing population as was corroborated by the field work, and with the attendant heavy burden on the adult population. The structure suggests a high dependency ratio, and a huge number of underemployed youths as was witnessed during the field studies together with multiplier effects. Invariably, developmental policies and programmes need to be mainly tailored to accommodate the multi-faceted requirement of the adolescents and youth.

The observed trend from the age and sex pyramid of the respondents mirrors the age and sex trend of the overall households. Table 5.5 shows the dependency ratio for the entire household population of respondents. As shown on Table 5.5, the economically dependent percentage of the population such as children who are too young, and individuals that are too old, weighs heavily on the percentage working to earn active income. The importance of this ratio is a consequence of the fact that as it increases, there would be further increased strain on the productive part of the population to support the economically dependent.

Table 5.5: Dependency ratio of household age and sex structure of respondents

Dependency ratio	Male (%)	Female (%)	Total (%)
Young	78.04	82.75	84.34
Old	3.6	4.84	4.19
Overall	81.65	87.6	88.53

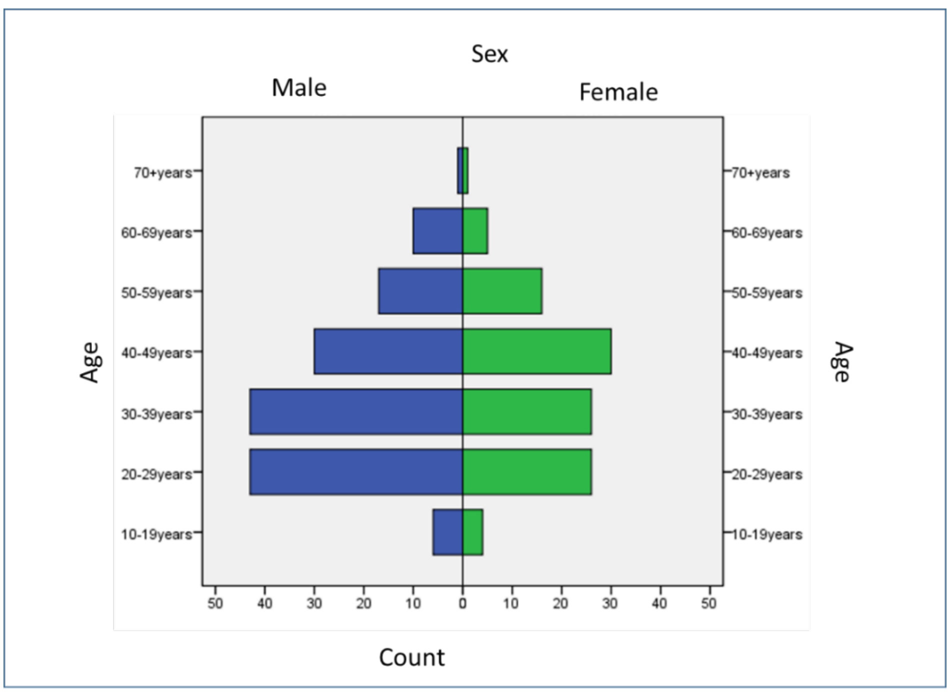

Figure 5.3: Pyramid showing age-sex structure cohorts of respondents

The results show that females are more dependent than the males. These high ratios may not be unconnected with the high dependency on agriculture for sustenance, large family sizes, and the consequent over-exploitation of land without replenishment.

5.2.3 Marital status, household size, and position of respondents

None of the respondents indicated they were cohabiting with a partner as presented in Table 5.6. However, 15.44% indicated that they were single. Majority of the respondents are married (78.31%) and 5.51% are widowed. Table 5.7 which shows the sex marital structure of respondents reveal that more males were married and single than females. Table 5.7 also show that more females were widowed. The average household size obtained was 13 persons. According to the National Bureau of Statistics (NBS, 2013), the national average household size for the north central region of Nigeria is 6 persons. The household comprise of the household head which could be either a man or woman who lives alone or is widowed. Others include a wife or wives, children, and relatives. Large families provide labour for farm activities, and as observed in rural areas, extended families live in separate homesteads in relatively close proximity to each other.

Table 5.6: Marital status of respondents

Marital Status	Frequency	Percentage (%)
Single	42	15.44
Married	213	78.31
Divorced/Separated	2	0.74
Widowed	15	5.51
Cohabiting	0	0.00
Total	**272**	**100%**
Skipped question	**9**	

The household position of the respondents revealed that household heads make up the majority of respondents with 43.7% (Table 5.8). As observed from field survey, household heads in the study area are responsible for taking major decisions concerning livelihood. In the absence of the household head, the most senior adult male household member takes over decision making. Where there are no adult males, the wife makes the livelihood decisions. Only wives made up 21.9% of female respondents (Table 5.8) and 11.7% of respondents indicated that they were the first child. A combined percentage of 14.6% were wives from a polygamous home.

Table 5.7: Sex structure of respondents' marital status

Marital Status	Male	Percentage	Female	Percentage
Single	34	22.97	7	5.83
Married	110	74.32	100	83.33
Divorced/Separated	1	0.68	1	0.83
Widowed	3	2.03	12	10.00
Cohabiting	0	0.00	0	0.00
Total	**148**	**100%**	**120**	**100%**
Skipped question	**3**		**2**	

Table 5.8: Position of respondents in households

Position	No. of respondents	Percentage
Household Head	108	43.7%
Only wife	54	21.9%
First wife	25	10.1%
Second wife	11	4.5%
First child	29	11.7%
Relation	17	6.9%
Guardian	3	1.2%
Total	**247**	**100**
Skipped questions	**34**	

5.2.4 Level of education

There are three universities in Benue State which serve as the focal institutions for university education for most of the residents in the Lower River Benue Basin. They are the Federal University of Agriculture North Bank Makurdi; The Benue State University Wurukum

Makurdi; and the University of Mkar, located near Gboko. Apart from these universities, there exist a number of other tertiary institutions. There are Polytechnics in Gboko, Ugbokolo, and Otukpo; Colleges of Education in Oju and Katsina Ala; College of Agriculture in Yandev; School of nursing in Makurdi and Mkar; and College of arts and professional studies in Makurdi. A major seminary (St. Thomas Aquinas) belonging to the Catholic Church is also located in Makurdi. A good number of government secondary and primary schools exists in every L.G.A of Benue state. However, they are not sufficient, and majority are in need of refurbishment. Gaps created in secondary and primary education have been exploited by private schools.

The level of education of residents in the Lower River Benue Basin influences the capacity of communities to improve farming practices and engage efficiently in other land use activities. Majority of the respondents have attained at least one form of formal education. Table 5.9 presents the educational levels of the respondents. The level of education with the highest percentage was secondary education (41.02%). Tertiary education was the next predominant educational level with a percentage of 35.16%.

Table 5.9: Highest education level of respondents

Level of Education	No. of respondents	Percentage (%)
Primary School	43	16.80
Secondary School	105	41.02
Vocational/Technical	12	4.69
Tertiary School	90	35.16
No formal education	6	2.34
Total	**256**	**100%**
Skipped question	**25**	

The number of children in school as indicated by respondents is quite high. Table 5.10 revealed that most of the children are in primary and secondary school. Very few children had no recognised form of education. The indications by respondents does not suggest any bias in the education of both sexes of children.

Table 5.10: Education status of respondents' children

Educational level	**Male Freq.**	**Male (%)**	**Female Freq.**	**Female (%)**	**Freq. Total**	**Percentage Total**
Primary School	112	49.34	115	50.66	227	44.60
Secondary School	97	54.80	80	45.20	177	34.77
Vocational/Technical	17	54.84	14	45.16	31	6.09
Tertiary School	39	58.21	28	41.79	67	13.16
Any other	3	42.86	4	57.14	7	1.38
Total	**268**		**241**		**509**	**100%**

5.2.5 Number of years respondents had lived in the communities

Economic reasons and education have been mentioned as the highest reasons for internal migration in Nigeria (Oyeniyi, 2013). Oyeniyi (2013) found that other reasons cited for internal migration for which Benue state is mentioned include sex trade, unskilled labour, trafficking of children from disadvantaged rural homes to work in urban areas, and conflict and flood displacement.

Most of the respondents were born into the communities (41.80%) or have spent more than twenty years in the communities where they reside (21.10%). These data suggests migration among respondents is low. Other respondents indicated they have lived in the communities for less than 20 years. This information is presented in Table 5.11. Those who indicated they were not native of the communities they reside in claimed various reasons for settling such as marriage, business, farming, and soil fertility.

Table 5.11: Number of years respondents had lived in communities

Number of Years	No. of respondents	Percentage
0-5	21	8.2
6-10	25	9.8
11-15	20	7.8
16-20	29	11.3
Above 20	54	21.1
Since birth	107	41.8
Total	**256**	**100%**
Skipped question	**25**	

5.2.6 Occupation of respondents

As mentioned in section 5.0, majority of the respondents and indeed residents in Makurdi, Tarka and Gboko practice farming as their source of livelihood. The results of respondents that indicated their occupation is presented in Table 5.12. The results revealed that 74.60% of respondents indicated farming as either a first or second occupation. More than 50% indicated farming as a first occupation. Business and Civil Servants followed at a distant 13.80% and 13.10% respectively. Very few of the respondents indicated fishing as an occupation. Out of the total number of female respondents, 70% indicated farming as their main occupation. The percentage of men engaged in farming as indicated by respondents is 75%. Married men who indicated farming as their main occupation was 57% while 60% of married female respondents indicated farming as their main occupation. Only very few single male and female respondents indicated farming as their main occupation. The average household size of respondents that indicated farming as their main occupation was 14 persons. This is consistent with field observation findings that farmers in the Lower River Benue Basin mostly have large families.

Table 5.12: Occupational types as indicated by respondents

Occupation	First Occupation Frequency	Second Occupation Frequency	Total Frequency	Total Frequency Percentage
Farming	193	7	200	74.60%
Fishing	2	8	10	3.70%
Technician/ Artisan	7	13	20	7.50%
Trading	9	17	26	9.70%
Business/ Contractor	14	23	37	13.80%
Civil servant	16	19	35	13.10%
Retired	3	8	11	4.10%
Student/Apprentice	19	6	25	9.30%
Unemployed	6	8	14	5.20%
Others (specify)	7		7	2.60%
No. of respondents				**268**
Skipped question				**13**

5.2.7 Income levels of respondents

The income levels of the respondents are presented in Table 5.13. Most of the respondents (70.27%) earn 30,000 Naira and below monthly. The highest income level category was between 1,000 – 10,000 Naira with a percentage of 30.89%. Less than 7% of respondents indicated that they earn above 80,000 Naira every month. The analysed income category with the highest percentage for male respondents was 1,000 - 10,000 with percentage of 29.1% and most male respondents (70.3%) indicated they earned 30,000 Naira and below which is consistent with Table 5.13. Most female respondents (70.20%) earned 30,000 Naira and below like their male counterparts (Table 5.14). Analyses revealed that even though income for married respondents were consistent with Table 5.13, most married respondents (29.50%) earned between 1,000 and 10,000 Naira (Table 5.15). Full time farmers constituted 62% of respondents that indicated income levels of 30,000 Naira and below. The majority of respondents who are farmers indicated they were crop farmers and this was distantly followed by livestock farmers. Fish farmers and food processors made up the remaining percentages. This indicates that even though agriculture is the predominant occupation in the Lower River Benue Basin, agricultural earnings are quite low.

Table 5.13: Income levels of respondents

Income levels (Naira)	No. of respondents	Percentage
Less than 1,000	22	8.49
1,000-10,000	80	30.89
11,000-20,000	43	16.60
21,000-30,000	37	14.29
31,000-40,000	18	6.95
41,000-50,000	11	4.25
51,000-60,000	16	6.18
61,000-70,000	7	2.70
71,000-80,000	7	2.70
Above 80,000	18	6.95
Total	**259**	**100%**
Skipped question	**22**	

Table 5.14: Cross-tabulation of sex and income categories of respondents

Income categories		Sex		
		Male	**Female**	**Total**
Please estimate your level of income in a typical month (Naira)	Less than 1000	9.5%	7.5%	8.6%
	1000-10,000	29.1%	31.8%	30.2%
	11,000-20,000	16.2%	17.8%	16.9%
	21,000-30,000	15.5%	13.1%	14.5%
	31,000-40,000	8.1%	5.6%	7.1%
	41,000-50,000	4.1%	4.7%	4.3%
	51,000-60,000	6.8%	5.6%	6.3%
	61,000-70,000	2.0%	3.7%	2.7%
	71,000-80,000	1.4%	3.7%	2.4%
	Above 80,000	7.4%	6.5%	7.1%
Total		100.0%	100.0%	100.0%

Table 5.15: Cross-tabulation of marital status and income levels of respondents

Income levels		Marital Status				
		Single	Married	Divorced/ separated	widowed	Total
Please estimate your level of income in a typical month (Naira)	Less than 1000	32.5%	4.5%			8.6%
	1000-10,000	32.5%	29.5%	50.0%	30.8%	30.2%
	11,000-20,000	12.5%	16.0%	50.0%	38.5%	16.9%
	21,000-30,000	10.0%	16.0%			14.1%
	31,000-40,000	2.5%	7.5%		15.4%	7.1%
	41,000-50,000		5.5%			4.3%
	51,000-60,000		8.0%			6.3%
	61,000-70,000		3.0%		7.7%	2.7%
	71,000-80,000	2.5%	3.0%			2.7%
	Above 80,000	7.5%	7.0%		7.7%	7.1%
Total		100.0%	100.0%	100.0%	100.0%	100.0%

5.2.8 Housing

From field observations, houses in the Lower River Benue Basin are made up of modern and traditional materials. In the urban areas, houses are mostly made up of zinc roofing sheets and cement or burnt mud bricks. These houses are usually plastered with cement. In the rural areas houses may be built with zinc roofing sheets or thatch roof, but with either cement, burnt bricks, or mud bricks. Families usually live together in the same compound and as members begin to marry, they move out to establish their own compounds.

According to respondents, 45.7% of them live in zinc roofed houses with cement blocks (Table 5.16). Another high percentage (20.2%) live in thatched roofed and mud walled houses. Those that live in zinc roofed and mud wall houses made up 12%, while those that live in houses made of only thatch were 11.6%. Table 5.16 presents the housing types of respondents.

5.2.9 Sources of domestic water supply

Water in desirable quantity and quality is of immense importance to any population. Where availability is inadequate, the population suffers greatly and is at risk of waterborne diseases. Accessibility to water is another important factor in determining the availability of water for a population. Where a population has to trek several kilometres in search of water; wait for the wet season; or spend a lot of money daily to buy water, it becomes too costly and would impact on the standard of living of the population. The Benue State Water Board has a pipe water network in Makurdi and a water board in Otukpo but functionality was inadequate and the facilities were undergoing rehabilitation at the time of the study. Portable tap water supply is presently non-existent in the communities. The communities mostly buy sachet water for drinking (a bag of 20 sachets cost between 100-150 Naira) and rely on bore holes, hand dug wells, streams, rain water. Most of the respondents (61.71%) indicated hand dug wells as the main source of water supply (Table 5.17). This percentage was followed by those who indicated bore holes (26.77%) as the main source of water supply. Sources of domestic water supply as indicated by respondents is presented in Table 5.18. Most of the respondents across the housing types utilise hand dug wells (Table 5.18).

Table 5.16: Housing types of respondents

Housing Types	No. of respondents	Percentage
Thatched all through	31	11.61
Thatched roof/wooden wall	4	1.5
Thatched roof/mud wall	54	20.2
Planks/wooden/zinc roof	14	5.24
Zinc roof/wooden wall	10	3.75
Zinc roof/mud wall	32	12
Zinc roof/cement block	122	45.7
Others (specify)	0	11.61
Total	**267**	**100%**
Skipped question	**14**	

Table 5.17: Sources of domestic water supply as indicated by respondents

Water sources	No. of respondents	Percentage
Rain water	13	4.83
River/Stream	17	6.32
Hand-dug well	166	61.71
Bore-hole	72	26.77
Others	1	0.37
Total	**269**	**100%**
Skipped question	**12**	

Table 5.18: Cross-tabulation of housing types and sources of domestic water of respondents

Housing types	Source of domestic water supply					
	Rain water	River/stream	Hand-dug well	Bore-hole	Others	Total
Thatched all through			80.6%	19.4%		100.0%
Thatched roof/wooden wall		25.0%	75.0%			100.0%
Thatched roof/mud wall	3.7%	13.0%	66.7%	14.8%	1.9%	100.0%
Planks/wooden/zinc roof	7.7%		76.9%	15.4%		100.0%
Zinc roof/wooden wall	10.0%		60.0%	30.0%		100.0%
Zinc roof/mud wall	3.1%	12.5%	50.0%	34.4%		100.0%
Zinc roof/block	5.0%	4.1%	57.0%	33.9%		100.0%
Total	4.2%	6.4%	62.3%	26.8%	.4%	100.0%

5.2.10 Methods of domestic refuse and sewage disposal

Refuse generated from households are predominantly organic, agricultural, polythene and packaged or manufactured food items. Household refuse is often disposed in open spaces and in the bush. The methods of domestic refuse disposal by respondents revealed that open dumping in various forms was the only way refuse was disposed (Table 5.19). Those who dump refuse at the backyard accounted for 47.17%. This was followed by those who burnt refuse after dumping (33.96%). Table 5.19 shows the methods of refuse disposal by respondents.

Sewage disposal as indicated by respondents is quite varied (Table 5.20). Most of the respondents claimed to dispose sewage within their homes using water systems (30.74%). Those that use pit latrines made up 28.4%. Respondents who indicated shared toilets and disposal in community bushes also had high percentages. Table 5.20 shows the various sewage disposal methods by respondents.

Table 5.19: Methods of refuse disposal by respondents in the Lower River Benue Basin

Disposal methods	No of respondents	Percentage
Backyard of house	125	47.17
River/Stream	6	2.26
Community refuse pit	36	13.6
Burning after gathering	90	33.96
Dumping in the farm	8	3.01
Total	**265**	**100%**
Skipped question	**16**	

Table 5.20: Methods of sewage disposal as indicated by respondents

Methods of disposal	No. of respondents	Percentage
Dumping in stream	5	1.9%
Pit latrine	73	28.4%
Water system in the house	79	30.7%
Community bush	47	18.3%
Shared toilet in compound	53	20.6%
Total	**257**	**100%**
Skipped question	**24**	

5.3 Farm management practices

5.3.1 Important months of the year for respondents

According to respondents, the second quarter (April, May, and June) is the most important quarter with regards to farming (Table 5.21). April and May were the most indicated months. These months coincide with the onset of rainfall and the planting season. Other important quarters with regards to farming were the third (July, August, and September) and fourth (October, November, and December) quarters. Several plants are maintained and harvested in these quarters. As for fishing, the most important quarter indicated was the fourth quarter and then followed by the third quarter. Fishing activities are also high in January. During these months, some water bodies in the Lower River Benue Basin usually have high volumes. The fourth quarter was indicated as the most important with regards to festivals. December was the most indicated month for festivals. Many end of year parties and the Christmas holidays are usually in December. The fourth quarter was also mentioned as the most important quarter for market boom (Table 5.21).

Table 5.21: Months of the year that are important to respondents with regards to farming

Activities	**Percentage Frequency**				
	Quarter 1	**Quarter 2**	**Quarter 3**	**Quarter 4**	
	Jan, Feb, Mar	**Apr, May, Jun**	**Jul, Aug, Sep**	**Oct, Nov, Dec**	**Total**
Farming	11.4	59.07	16.06	13.47	100%
Fishing	21	8	33	38	100%
Trading	16	20	12	52	100%
Festival	4.17	0	41.67	54.16	100%
Market boom	19	14	11	56	100%
No. of Respondents					**218**
Skipped question					**63**

5.3.2 Environmental resources and problems

Arable land and streams are some of the most important environmental resources in the Lower River Benue Basin. Other resources include forest resources, ancestral sites, and animals. With regards to importance of these resources, respondents indicated forest resources as the most important (40.6%). Other important resources include river and stream water (35.2%), animals (19.3%), ancestral sites (4.1%), and others (0.8%) mentioned dams. Arable land was not one of the options since its importance as a resource was evidently obvious.

Some environmental problems faced by communities in the Lower River Benue Basin include low soil fertility, pest attacks and invasion, erosion, flooding, low crop yield, food scarcity and health problems (Table 5.22). Respondents were asked to indicate prevalence and severity of these problems in their various communities. Soil erosion, flooding, and low yield were rated as severe, while pest attacks was the most severe environmental problem indicated by respondents. Food scarcity is not a severe problem in the Lower River Benue Basin as overwhelmingly indicated by respondents. However, the low crop yield indicated as severe may be progressive because the frequency ratings for severity levels of soil infertility were quite close. Table 5.22 reveals respondents' views on the prevalence and severity of environmental problems.

When asked if they had personally experienced any of these environmental problems in the last five years, 73.4% indicated in the affirmative and 26.6% indicated otherwise. The main issues mentioned fall into the following categories in descending order of frequency; financial losses, soil infertility and low yield issues, flooding and erosion, lack of access to farm inputs, and armed conflicts.

Table 5.22: Environmental problems in the study area and severity levels

Environmental problems	Not severe	Severe	Very severe	Rating Average	Total Frequency
Soil Infertility	**75**	67	60	2.93	202
Pest attack/ Invasion	51	59	**80**	3.15	190
Erosion	46	**109**	48	3.01	203
Flooding	77	**79**	33	2.77	189
Low yield	68	**97**	24	2.77	189
Food scarcity	**130**	37	18	2.39	185
Health problems	50	**69**	67	3.09	186
No. of respondents					**245**
Skipped question					**36**

Shaded portions are highest severity level as indicated by respondents

5.3.3 Major farm products and cultivation methods

The Lower River Benue Basin is known for the production of a varied number of agricultural produce such as grain crops, roots and tuber crops, legumes, fruits and livestock. The most extensively cultivated crop in Benue state between 2009 and 2012 was cassava (Table 5.23). Yam, groundnut, rice and maize were also extensively cultivated during the same period. Ginger was the least cultivated crop between 2009 and 2012. Although Benue State has immense irrigation farming potential, this did not reflect in the area cultivated for tomatoes which is an important irrigable crop.

Table 5.23: Cultivated area of major crops in Benue State (2009-2012)

Crops	Area cultivated ('000Hectares)			
	2009	2010	2011	2012
Maize	108.99	114.98	104.15	123.65
Millet	43.03	42.68	42.60	46.80
Sorghum	112.26	113.44	110.17	130.47
Rice	144.42	155.48	137.49	182.90
Cassava	276.03	281.50	267.63	294.65
Yam	226.76	228.14	225.97	289.49
Ginger	1.24	1.30	0.63	0.75
Melon	37.63	89.10	29.16	31.60
Tomatoes	13.35	16.30	6.93	7.95
Sesame seed	46.55	45.38	41.28	41.28
Groundnut	206.38	207.46	199.04	201.04
Soybeans	90.84	93.62	86.13	100.13
Citrus	101.25	152.12	69.52	70.57
Mangoes	97.94	106.38	35.10	45.10

Source: Benue State Ministry of Agriculture (2013)

The output yield for cultivated crops in Benue State between 2009 and 2012 is presented in Table 5.24. The crops with the highest output between 2009 and 2012 were citrus and mangoes. Benue State produces high quantities of citrus and mango fruits annually. In 2011, 'Teragro', the agro-business subsidiary of Transnational Corporation Nigeria signed an agreement with the Benue State government and took over the management of the Benue State Fruit Concentrate Company (Benfruit). The drop in output for citrus and mango in 2012 (Table 5.24) could be due to inconclusive data compilation at the Ministry rather than a sharp drop in actual output. This is because this trend is not observed in most of the other crops. The drop in output for ginger, melon and tomatoes may be due to the severe flooding events of 2011 and 2012 in Benue State. Although Benue State experienced one of the worst episode of flooding in decades in 2012, there is not much information to suggest that flooding or other adverse weather events affected the production of citrus and mangoes. Cassava, yam, groundnut and rice experienced consistently high outputs between 2009 and 2012. The ratio of output and hectares cultivated for each crop from 2009 – 2012 is presented in Table 5.25.

Table 5.24: Production output of major crops in Benue State (2009-2012)

Crops	Output ('000Metric Tons)			
	2009	2010	2011	2012
Maize	148.61	175.94	139.56	162.53
Millet	65.40	66.15	65.18	69.05
Sorghum	192.46	199.65	191.70	198.60
Rice	289.66	327.27	227.73	397.79
Cassava	3,643.66	3,721.62	3,559.48	3,597.28
Yam	2,902.80	2,954.41	2,874.34	2,994.30
Ginger	3.12	5.69	0.27	0.97
Melon	41.65	44.32	29.16	38.36
Tomatoes	52.29	66.36	18.85	19.86
Sesame seed	47.95	55.52	40.45	41.45
Groundnut	371.82	414.59	358.27	365.45
Soybeans	181.68	196.60	169.68	108.67
Citrus	32,187	31,953.4	1,067.13	1,102.35
Mangoes	11,135	12,678.4	986.35	832.30

Source: Benue State Ministry of Agriculture (2013)

The output data for major crops produced in Benue State was correlated with area cultivated to test the strength of relationship (Table 5.26). The Pearson correlation revealed a positive result ($p<0.05$) which suggests that a positively significant relationship exist between area cultivated and output.

This means that the bigger the size of the area cultivated, the higher the output of crops. These results do not suggest intensive cropping is widely practiced in Benue State as crop output depends on the size of farm cultivated. Consequently, huge gaps exist in the Lower River Benue Basin with regards to intensive cropping, mechanised agriculture, and sustainable agricultural practices. Benue State is endowed with a good number of livestock farmers. The kinds of livestock animals commonly reared in the state and their population is presented in Table 5.27. The population of pigs, goats, and chickens suggest that they are livestock animals of high significance in Benue State.

Table 5.25: Mean yield ratio for major crops in Benue State (2009-2012)

Crops	**Mean yield (MT/Ha)**			
	2009	**2010**	**2011**	**2012**
Maize	1.36	1.49	1.34	1.32
Millet	1.52	1.55	1.53	1.48
Sorghum	1.75	1.74	1.73	1.52
Rice	2.01	2.21	2.02	2.17
Cassava	13.20	13.21	13.30	12.20
Yam	12.80	12.95	12.72	10.34
Ginger	2.52	4.38	0.43	1.29
Melon	1.11	1.17	1.00	1.21
Tomatoes	3.92	4.45	2.72	2.72
Sesame seed	1.03	1.22	0.98	2.49
Groundnut	1.80	2.05	1.80	1.82
Soybeans	2.00	2.20	1.97	1.00
Citrus	318	210	15.35	15.62
Mangoes	113	119	16.20	18.45

Source: Benue State Ministry of Agriculture (2013)

Table 5.26: Correlation values for area cultivated and output

Parameters		**Crop Output**
Area Cultivated	Pearson Correlation	.653*
	Sig. (2-tailed)	.011
	Sum of Squares and Cross-products	572035.672
	Covariance	44002.744
	N	14

*Correlation is significant at the 0.05 level (2-tailed).

The crops indicated by surveyed respondents were grain crops, legumes, roots and tubers, vegetables, and fruits (Figure 5.4). Grain crops indicated included rice, maize, guinea corn, and millet. Rice had the highest frequency of 20.44% and was followed by maize with 8.64%. Beans, soybeans, groundnuts and sesame seeds were among crops indicated. Beans had a frequency of 14.54% and soybeans had a frequency of 12.35%.

Table 5.27: Livestock population in Benue State in 2012

Livestock	**Population**
Pigs	1,910,939
Goats	4,187,482
Sheep	1,512,977
Rabbits	61,261
Cats	397,586
Dogs	548,452
Cattle	107,538
Chicken	14,098,234
Duck	1,118,380
Guinea fowl	243,066
Pigeon	605,375
Turkey	20,781

Source: Benue State Ministry of Agriculture (2013)

The roots and tuber crops mentioned by respondents include yam, cassava, sweet potatoes, and cocoyam. Yam had the highest frequency of all the crops mentioned (25.24%) and cassava also had quite a high frequency (18.79%). Other crops mentioned were pepper, okra, vegetables (leaves), tomatoes, oranges and mangoes. Pepper was the most indicated vegetable. Only one respondent indicated a 'yam-only' farm. All others indicated they practiced mixed farming. Figure 5.4 shows the various crops cultivated by respondents. Even though a good number of agricultural cooperative societies now exist in communities within the Lower River Benue Basin, the benefits of such associations is still limited. This is because most of the respondents still use purely traditional farming methods. Table 5.28 summarises the various farming methods as indicated by respondents.

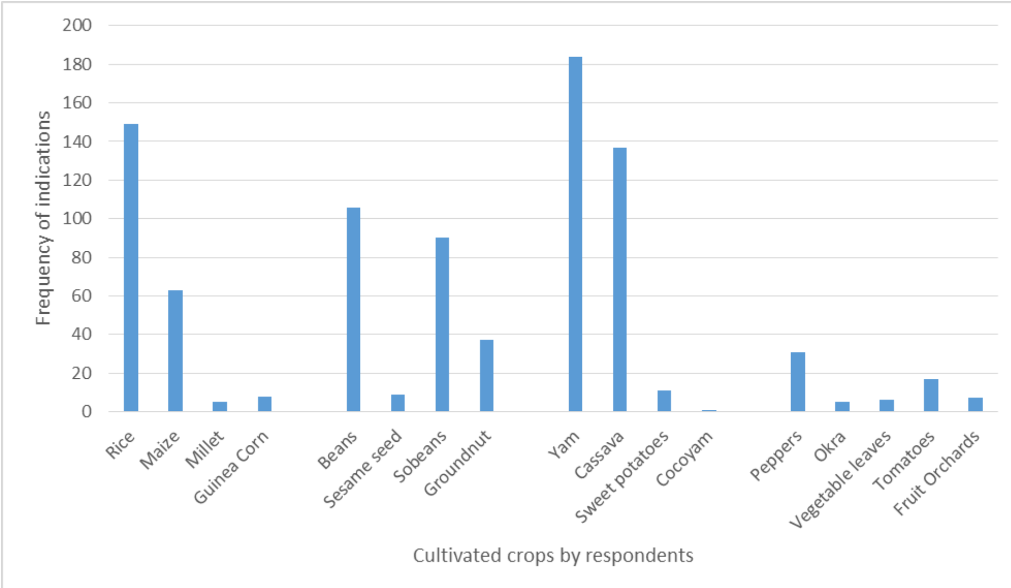

Figure 5.4: Cultivated crops indicated by respondents

Table 5.28: Farming methods indicated by respondents

Farming methods	No. of respondents	Percentage
Purely traditional	208	82.9%
Semi mechanised	41	16.3%
Mechanised	2	0.8%
Total	**251**	**100%**
Skipped question	**30**	

5.3.4 Annual farming season

The farming season for various crops vary annually and is mostly a function of the onset and offset of rainfall. Irrigation farming is, however, practised during the dry season. The month of April was the most indicated as the start month, while November and December were the most indicated end months. It is safe to say that the farming season for most crops occur between the months of April and November/December. The farming season start and end months indicated by respondents is provided in Table 5.29.

Table 5.29: Farming season start and end months indicated by respondents

Start months	Freq.	Percentage	End months	Freq.	Percentage
January	4	1.54	July	19	7.34
February	6	2.31	August	16	6.18
March	27	10.38	September	15	5.79
April	164	63.08	October	19	7.34
May	21	8.08	November	85	32.82
June	30	11.54	December	94	36.29
July	8	3.07	January	11	4.25
Total	**260**	**100%**	**Total**	**259**	**100%**
No. of respondents	**251**				
Skipped question	**30**				

5.3.5 Fertiliser utilisation and irrigation farming

Inorganic fertilisers are artificial nutrients added to soil to aid the proper growth of crops. According to the National Bureau of Statistics (NBS, 2013), 24.9% of farmers in the north central region of Nigeria had access and used fertilisers in 2013. The most popular fertiliser type indicated by respondents was the NPK which is nitrogen, phosphorus and potassium based (52.7%), followed by Urea based fertilisers (35.4%), and then single super phosphate (SSP, 11.9%). The use of manure or compost was not reported or observed. The number of bags used ranged from 1 – 25bags. Table 5.30 shows the number of bags used annually by respondents.

Table 5.30: Number of fertiliser bags utilised by respondents annually

Number of bags	No. of respondents	Percentage
1-5	109	54.5
6-10	51	25.5
11-15	23	11.5
16-20	10	5
Above 20	7	3.5
Total	**200**	**100%**
Skipped question	**81**	

The percentage of respondents who claimed irrigation is practiced in their communities are few (30.7%) as against those who claimed irrigation is not practised in their communities (69.3%). The predominant source of water for irrigation as indicated was river/stream (56%), which was followed by hand dug wells (22%). Dams and boreholes made up 11% and 4%. As observed from the field and respondents' views, the crops cultivated through irrigation farming include tomatoes, pepper, okra, vegetable leaves, rice, beans, and maize. A huge gap still exists in irrigation farming which has the potential to maximise farm output and income annually.

Dam (2012) conducted a socioeconomic survey among 160 dry season vegetable farmers in Benue State, and found that farm sizes were predominantly less than a hectare (61.9%). According to Dam (2012), the popular vegetables grown were spinach, tomatoes and okra. Lack of capital, storage facilities, pests and diseases, and farm inputs were the major issues affecting dry season farming practices in Benue State. Strengthening agricultural extension services, support with modern farming techniques and the promotion of irrigation farming among indigenous farmers were recommended by Dam (2012).

5.3.6 Farm size and output

The predominant farm size were between 1-5 hectares (37.5%). Other significant sizes include those between 5-7 hectares (21.3%) and 7-10 hectares. Table 5.31 gives details of farm sizes indicated by respondents.

Table 5.31: Farm sizes of respondents

Farm size in hectares (Ha)	No. of respondents	Percentage
Less than 1 hectare	22	9.2
1-5	90	37.5
5-7	51	21.3
7-10	40	16.7
10-15	18	7.5
15-20	12	5.0
Above 20 hectares	7	2.9
Total	**240**	**100%**
Skipped question	**41**	

Table 5.32 shows annual spending on farms by respondents. Most respondents claimed they spend above 30,000 Naira on their farms annually. More than half of the respondents (58%) spend more than 20, 000 Naira annually on their farms. Another 33.9% indicated they spend below 15,000 Naira annually. Most respondents involved in farming rice (62.3%), yam (64.3%), and cassava (64.8%) spend more than 20, 000 Naira annually on their farms.

Information obtained about value of farm output from respondents suggests most of the respondents were barely breaking even or making profit from harvest sales. The percentage of respondents that sold between 10-30% of farm output was 34%. Most respondents (56.8%)

indicated that they sold between 40-70% of farm output. Another 9.2% indicated that they sold between 80-100% of output.

Table 5.32: Annual farm spending by respondents

Farm spending (Naira)	**No. of respondents**	**Percentage**	**Percentage rice farmers**	**Percentage yam farmers**	**Percentage cassava farmers**
1,000-5,000	17	7.2	5.8	6	5.74
5,000-10,000	29	12.3	13.04	8.3	9.84
10,000-15,000	34	14.4	13.04	13.1	13.93
15,000-20,000	19	8.1	5.8	8.3	5.74
20,000-25,000	27	11.4	15.22	11.9	9.84
25,000-30,000	52	22.0	22.46	21.4	25.41
Above 30,000	58	24.6	24.64	31	29.5
Total	**236**	**100%**	**100%**	**100%**	**100%**
Skipped question	**45**				

Considering that 58% of respondents spend more than 20,000 Naira annually on their farms, it is worrisome that just a little above that percentage (73%) realise harvest output with approximate values above 30,000 Naira. This could means the cost of farm management is quite high or the produce are not priced adequately and the profit margin would be low. Details on the approximate value of harvest by respondents are provided in Table 5.33.

Table 5.33: Approximate value of farm harvest by respondents

Harvest value (Naira)	No. of respondents	Percentage	Percentage rice farmers	Percentage yam farmers	Percentage cassava farmers
Less than 10,000	21	8.9	10.07	9.36	6.5
10,000-30,000	43	18.1	18.71	14.04	18.7
30,000-50,000	50	21.1	16.55	16.37	17.07
50,000-70,000	36	15.2	15.11	18.71	17.9
70,000-100,000	44	18.6	19.42	21.64	20.32
Above 100,000	43	18.1	20.14	19.88	19.51
Total	**237**	**100%**	**100%**	**100%**	**100%**
Skipped question	**44**				

The majority of the respondents (76.2%) had disposed of their harvest for lack of storage facilities in the past, while 23.8% had never disposed their harvest for lack of storage facilities. The inadequacy of storage facilities also affected the percentage and quality of harvest available for sale.

The size of farm lands indicated by residents and the approximate values of harvest were correlated to test the relationship between them (Table 5.34 and Table 5.35). The correlation values obtained (Pearson, $p<0.01$; Spearman, $p<0.01$) suggested that a significant positive relationship exists between size of farmlands and values of annual harvest of respondents. The correlation results showed that farm harvest quantity is dependent on the size of farmland. If intensive or mechanised farming was common, harvest variation would be observable since harvest would not necessarily depend on size of farmland.

Table 5.34: Pearson's correlation values for farm size and value of harvest

Parameters		**Please state the size of your farm (s) in hectares**	**What is the approximate value of your harvest annually?**
Please state the size of your farm (s) in hectares	Pearson Correlation	1	.617**
	Sig. (2-tailed)		.000
	N	35	31
What is the approximate value of your harvest annually?	Pearson Correlation	.617**	1
	Sig. (2-tailed)	.000	
	N	31	237

**. Correlation is significant at the 0.01 level (2-tailed).

Table 5.35: Spearman's correlation values for farm size and value of harvest

Parameters		Please state the size of your farm (s) in hectares	What is the approximate value of your harvest annually?
Please state the size of your farm (s) in hectares	Correlation Coefficient	1.000	.574**
	Sig. (2-tailed)	.	.001
	N	35	31
What is the approximate value of your harvest annually?	Correlation Coefficient	.574**	1.000
	Sig. (2-tailed)	.001	.
	N	31	237

**. Correlation is significant at the 0.01 level (2-tailed).

5.3.7 Ownership of farmlands

The Lower River Benue Basin is occupied by communities which are mostly of Tiv ethnicity. Therefore, ownership of land(s) for farming or other purposes is deeply related to the traditional rites regarding Tiv land ownership. Land ownership is transferred by patrilineal inheritance in Tiv tradition. Land is mainly a property of families. These families are usually extended families and the eldest in the family reserves the right to allocate, sell, or rent out portions of land with the agreement of the rest of the family, and with the consent of the traditional chief. This is evident in the indications of respondents as well. Most respondents (57%) claimed that their farmlands were owned by their families. This suggests that they were only given permission to farm on these lands. Another 19.3% claimed they rented their farmlands while only 5.6% actually purchased their farmlands. The pattern was similar for respondents who indicated they cultivated rice, yam, and cassava. The very low number of cooperative farmlands was notable since 249 out of 281 respondents belonged to farming cooperative societies. Though the Benue State Government is responsible for all land in the state, there is little evidence of functional farms being run by the state government.

Table 5.36 provides details of farm ownership by respondents from the Lower River Benue Basin, while Figure 5.5 shows farm ownership types by male and female respondents. Male respondents dominated the various ownership types. The highest representation of females occurred under family land and inherited land. Even though all these lands may not necessarily belong to the women, given the cultural preference for land ownership among the Tivs, it is however a good indication that women also own land in the Lower River Benue Basin.

Table 5.36: Farm ownership types indicated by respondents

Farm ownership type	No. of respondents	Percentage	Percentage of rice farmers	Percentage of yam farmers	Percentage of cassava farmers
Purchased	14	5.6	5	6.85	7.03
Rented	48	19.3	16.43	18.88	17.97
Leased	3	1.2	0.71	0.57	1.56
Shared farming	2	0.8	0.71	1.14	1.56
community farm	5	2.0	2.85	2.85	2.34
Cooperative farm	1	0.4	0	0.57	0
Inherited	34	13.7	15	14.28	17.2
Family land	142	57.0	59.3	54.86	52.34
Total	**249**	**100%**	**100%**	**100%**	**100%**
Skipped question	**32**				

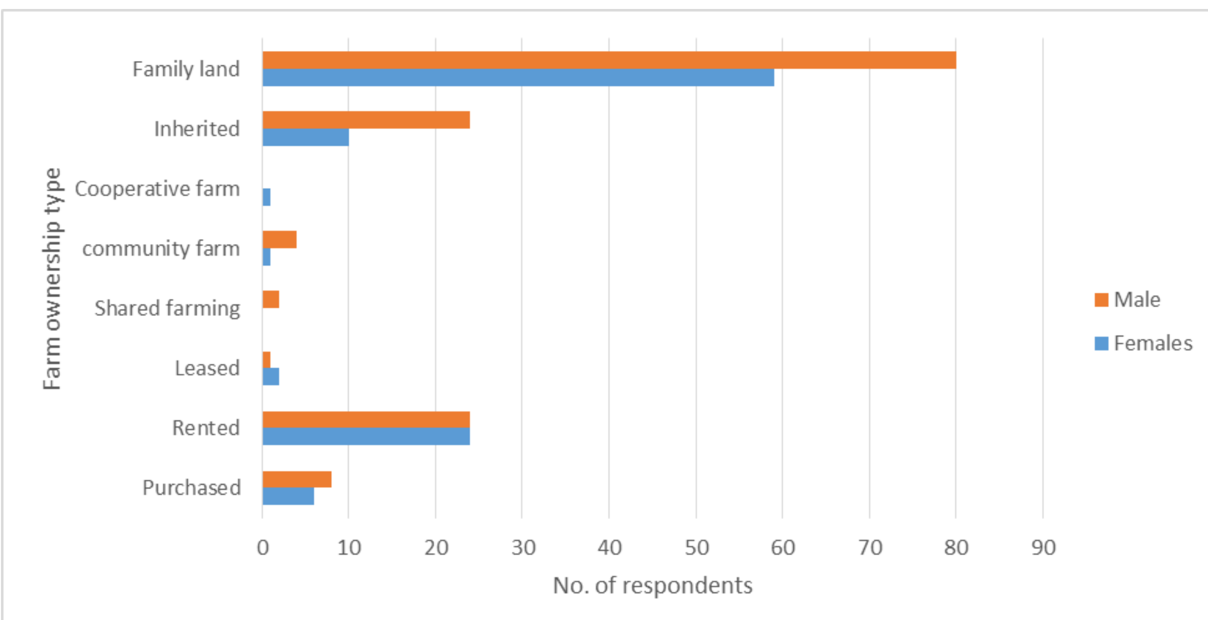

Figure 5.5: Farm ownership types by male and female respondents

5.3.8 Ownership of land and farms by women

Ownership of family or inherited land is usually associated with eldest male figures in families. However, where there are no male figures or the male figures are very young, it is not unusual to see women own land. Farming is a popular occupation for both men and women in the Lower River Benue Basin. The competing needs for land within families and communities make some women to purchase their own land or rent land for farming. Female only farming cooperatives also exist in communities in the Lower River Benue Basin. A good number of respondents (65.5%) answered affirmatively that women can own land and another 34.5% answered otherwise. As regards whether women can own their own farms, 92.8% of respondents indicated yes. Only 7.2% indicated otherwise. Affirmative answers were high from both sexes, but Figure 5.6 suggests respondents were clearly more agreeable to women owning farms than land.

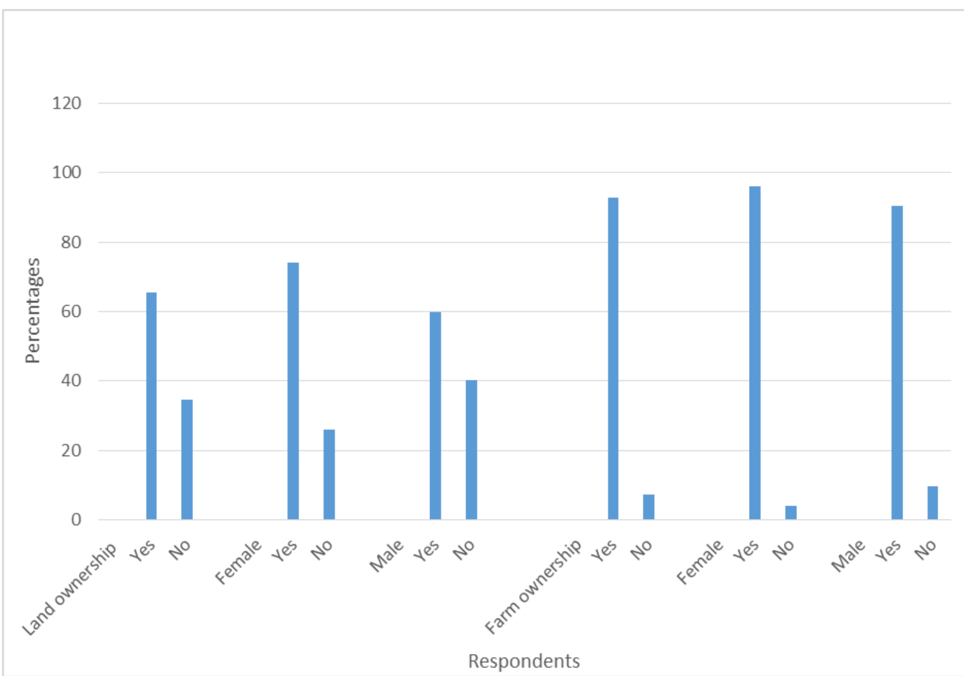

Figure 5.6: Respondent views on ownership of land and farms by women

A graph produced using data from FAO (2015) on the growth of the Nigerian population involved in agriculture is presented in Figure 5.7. Figure 5.7 projects that women will account for a considerable growth in the Nigerian population involved in agriculture in the near future while the population of men may drop.

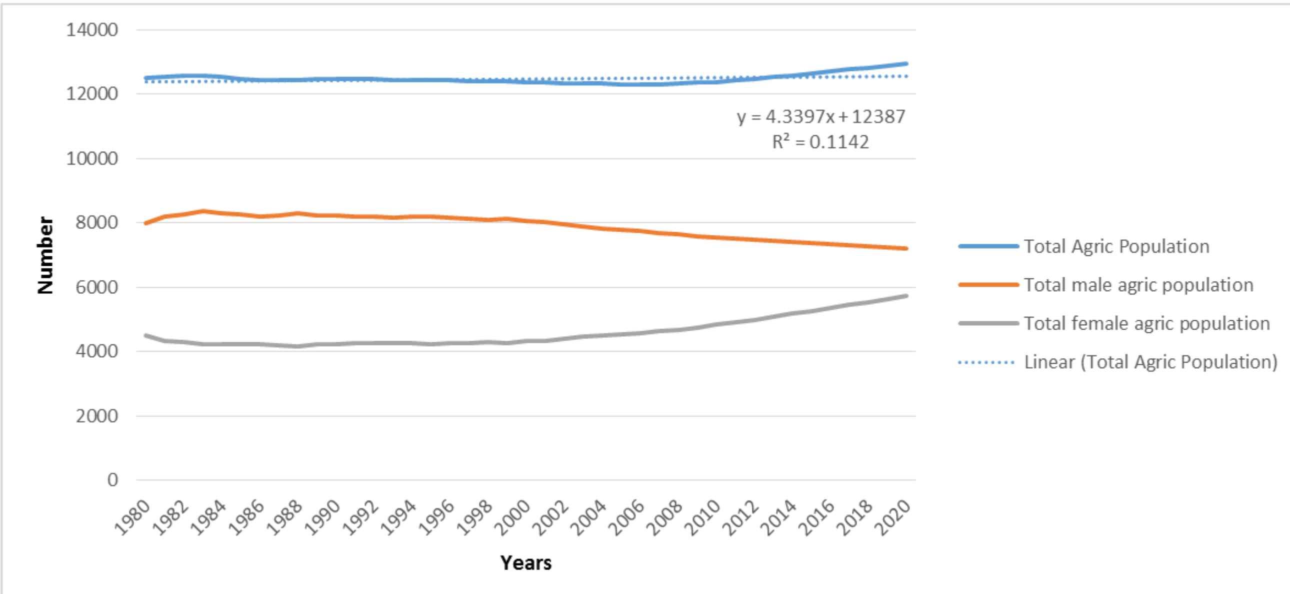

Figure 5.7: Population of Nigerians involved in agriculture from 1980-2020 (Data: FAO, 2015)

Obiora (2014) conducted a study on 120 women farmers in Benue State to assess the impact of the 2012 floods on these women farmers. According to Obiora (2014), these women lost houses and storage facilities (60.0%), farmland (60.0%), and human lives (10.0%). In order to survive the losses from the floods, 35.0% of the respondents resorted to begging alms. Another 30.0% migrated to neighbouring communities and 70% had no survival strategies and resigned to fate. Though the number of women farmers may be increasing, they remain quite vulnerable and require a lot of support.

5.3.9 Source of funding for farm operations

Respondents mostly sourced funding from relations (58.3%). But community cooperatives had started having a growing influence on funding for farm operations (22.9%). Borrowing from community cooperatives was not as challenging as regular banks because they have very flexible payback mechanisms and very low interest rates. Table 5.37 show information on sources of funding for farm operations as indicated by respondents.

Table 5.37: Sources of funding for farm operations as indicated by respondents

Funding sources	No. of respondents	Percentage
Commercial Bank	7	3.6
Community Bank	19	9.9
Microfinance Bank	10	5.2
Community Cooperatives	44	22.9
Relations	112	58.3
Total	**192**	**100%**
Skipped question	**89**	

Most respondents (63.22%) indicated that they borrowed between 1,000 Naira and 50,000 Naira while 25.28% borrowed between 50,000 Naira and 100,000 Naira. The remaining 11.5% indicated figures over 100,000 Naira. More than 90% indicated one year and under as the duration of the loans collected. This suggests these loans are usually collected for the farming season and paid after harvest sales. Interest rates indicated were quite low as more than 70% of respondents indicated between 5-10% interest rates. This may be because most loans are borrowed from relatives and community cooperatives, as presented in Table 5.37. Other respondents indicated interest rates between 10-30%. More than 200 respondents skipped the question on interest rates and it could mean a good number of respondents were not charged any interest on loans.

Farm inputs in some communities are loanable. Inputs such as seeds, seedlings, fertilisers, and some farming tools are sometimes loaned to farmers who pay after the farming season. The act of loaning farm inputs is, however, not popular as 82.5% of respondents indicated that they had never collected farm inputs on loan. Another 17.5% indicated they had collected farm inputs on loan. Most of the respondents who collected inputs on loan indicated fertilisers, herbicides and pesticides, while others indicated soybeans seeds, maize seeds, and rice seedlings.

5.3.10 Distance of farms from households

Most of the farms of respondents were within five kilometres from their households (Table 5.38). Out of this majority, 13% had farms which were less than one kilometre from their households. Only 25% travel beyond 5 kilometres to carry out agricultural activities. The details of farm distance from households of respondents is provided in Table 5.38.

Table 5.38: Farm distance from households of respondents

Distance in kilometres (km)	No. of respondents	Percentage
0 – 5	177	75
5 – 10	16	6.78
10 – 15	26	11.01
15 – 30	7	2.97
Above 30	10	4.24
Total	**236**	**100%**
Skipped question	**45**	

The distance of farms from households is crucial in explaining the difficulties farmers face in processing and transporting harvest to storages. Even though 87% of respondents had farms that were at least more than 10 kilometres from their households, Table 5.39 shows that 55.8% of respondents processed harvest after transporting it home. Another 34.2% indicated that they processed harvest in the farm with hired labour before transporting it to storages. The rest utilised community and commercial milling centres which would involve transporting the harvest to these centres. The high percentages of respondents processing harvest at home and in the farm with hired labour suggests that harvest is processed mainly through traditional labour intensive methods. The pattern was similar for rice, yam and cassava farmers. Since technology exists today for the mechanised processing of rice and cassava, it is worrisome that most of these farmers still utilised traditional methods. Table 5.40 shows that most of the farmers for each category of processing had farms that were 10 kilometres or less from their households.

Table 5.39: Where harvest is processed before storage as indicated by respondents

Harvest processing venue	No. of respondents	Percentage	Rice farmers percentage	Yam farmers percentage	Cassava farmers percentage
Commercial mill	12	5.2	5.07	6.06	5.9
In farm with hired labour	79	34.2	35.51	38.18	39.5
Community milling centres	11	4.8	4.35	5.46	7.6
At home	129	55.8	55.07	50.3	47
Total	**231**	**100%**	**100%**	**100%**	**100%**
Skipped question	**50**				

Table 5.40: Cross-tabulation of farm sizes and harvest processing centres

Farm distance	Where do you process your harvest before storage?				Total
	Commercial mill	In the farm with hired labour	Community milling centres	At home	
1-5km	60.0%	50.0%	25.0%	54.0%	51.1%
6-10km	40.0%	32.1%	50.0%	28.2%	31.1%
11-15km		12.8%	25.0%	12.9%	13.2%
>15km		5.1%		4.8%	4.6%
Total	100.0%	100.0%	100.0%	100.0%	100.0%

5.3.11 Crop yield

Even though purely traditional methods of farming are employed by the majority of farmers in the Lower River Benue Basin, respondents seemed to be sustaining increasing crop yield. The majority of the respondents claimed their crop yield was increasing. However, a high number of respondents also indicated that their crop yield was decreasing. Respondents claimed the increase and decrease were between 10-60%. Reasons for the decrease according to respondents included soil infertility, lack of funds, lack of farm inputs especially fertiliser and pesticides, disease and pest infestation, floods, erosion, and drought. Lack of fertilisers was the most indicated reason. Earlier studies had alluded to decreasing agricultural produce in the study area (Shabu *et al.*, 2011; Uchua *et al.*, 2012). Figure 5.8 presents the crop yield trend of respondents. More than 60% of the respondents who cultivated rice, yam, and cassava indicated increasing yields. Respondents indicated that the increasing trends were due to more availability of fertilisers, improved seedling, and expansion of area cultivated. The gulf between increasing and decreasing yields for rice was quite close (Figure 5.9).

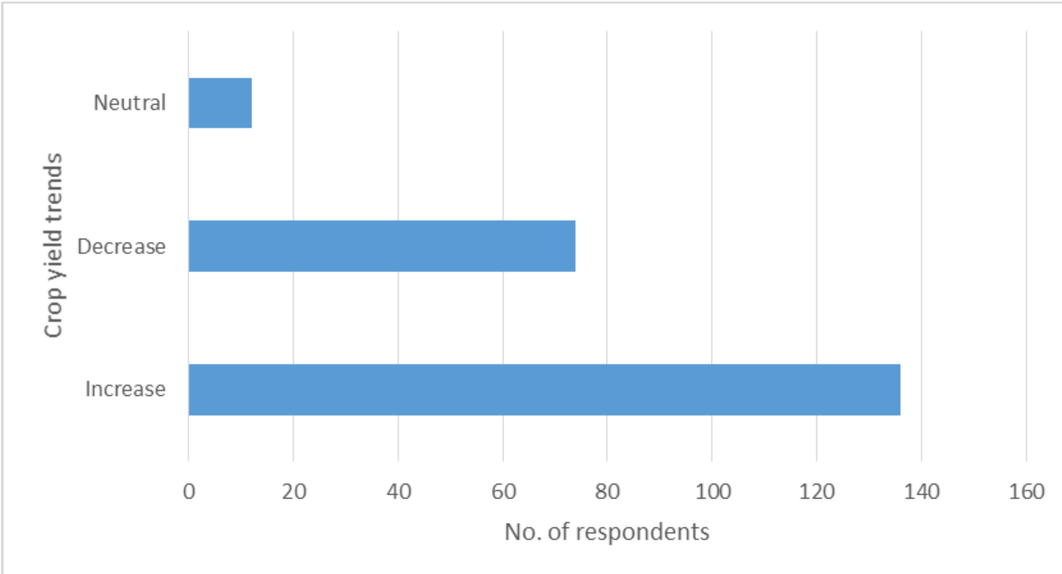

Figure 5.8: Status of crop yield of respondents

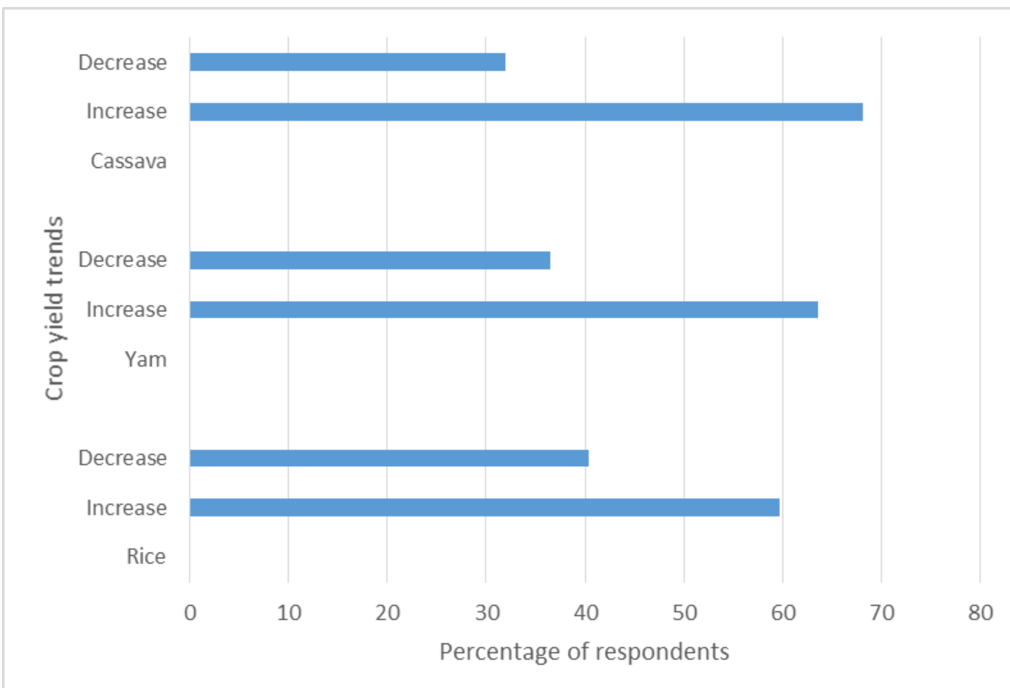

Figure 5.9: Crop yield status of rice, yam, and cassava farmers

5.3.12 Farm labour requirements

Farm labour is crucial to a successful farming season especially when traditional methods are predominant. Traditional methods of farming are labour intensive. The labour required is usually semi-skilled and experienced labour sourced mostly from extended families and friends. The average number of hours spent on farming annually by family labour and hired labour in the north central region of Nigeria are 82.9 and 15 respectively (NBS, 2013).

Going by the indications of respondents, it is clear that family labour is less available or is transforming into hired labour. This is because 50.2% of respondents indicated hired labour over family labour (30%). Table 5.41 provides details of the type of farm labour used by respondents.

Table 5.41: Farm labour type used by respondents

Farm labour type	No. of respondents	Percentage
Family labour	70	30
Hired labour	117	50.2
Labour rotation agreements (help me, I help you)	46	19.8
Total	**233**	**100%**
Skipped question	**48**	

April is the month when farm labour is mostly required. The month of April is when most farmers clear their farm lands and plant cereal crops such as maize, millet, and guinea corn. The month of April had the highest frequency of respondents. The months of June, July, and August are also important months as some more crops like rice and yam are planted during the month of June. Weeding activities and the application of herbicides and fertilisers are usually carried out during these months. The frequency of responses for November and December can be attributed to harvest of tuber crops and irrigation farming. Figure 5.10 provides details of the monthly farm labour requirements of respondents. The Chi-square test for farm labour requirements and total household size showed that a significant relationship existed between the two variables (Table 5.42).

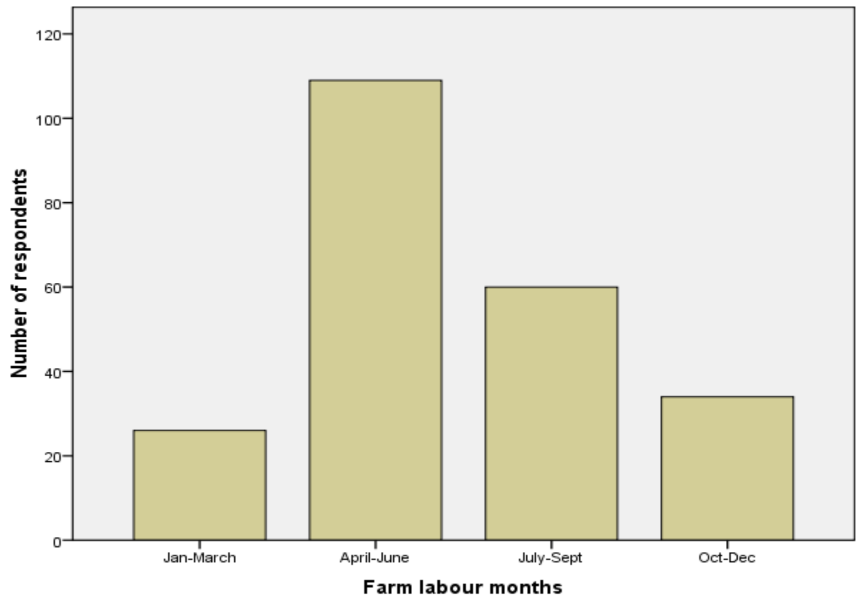

Figure 5.10: Monthly farm labour requirements by respondents

Table 5.42: Chi-square values for household size and farm labour requirements

Parameters	Value	Degrees of freedom (df)	Asymptotic Significance (2-sided)
Pearson Chi-Square	75.386[a]	36	.000
Likelihood ratio	73.914	36	.000
Linear-by-linear association	12.411	1	.000
Number of valid cases	196		

5.4 Available infrastructure

5.4.1 Markets

Most of the respondents sold their harvest in the market directly without using middlemen (Figure 5.11). Middlemen usually buy harvest from the homes and farms of farmers at very low prices before the harvest reaches the market. Middlemen activities are usually blamed for poor turnovers from harvest sales and high market prices of agricultural produce. Middlemen are mostly responsible for the intercommunity and interstate trade of agricultural produce. Some farmers, however, find this mode of sales convenient and transfer the burden of conveying produce to the market to the middlemen. A small number of respondents claimed not to sell their harvest. Figure 5.11 shows the frequency of respondents as regards the use of middlemen.

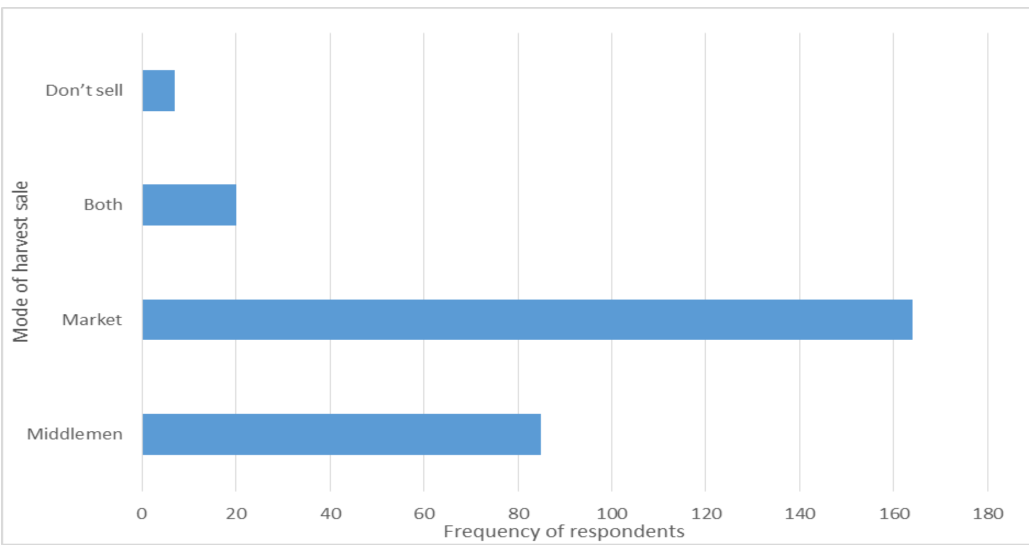

Figure 5.11: Mode of harvest sales by respondents

The distance of markets from farms and households also influence the decision whether farmers should sell to middlemen or not. The farther the market is from the farm or household, the easier it becomes to make the decision to sell to middlemen and avoid transportation costs, levies and other associated costs. Most of the respondents (70.26%) claimed they have markets within a kilometre and under five kilometres to their farms or households. The remaining percentage have markets that are beyond five kilometres. Table 5.43 provides these details.

5.4.2 Community visits by agricultural extension workers

Agricultural extension workers are government officers who work with rural communities and families to improve farming methods and output. They are the first line of liaison between the government and rural farmers. Respondents were asked if they had been visited by an agricultural extension worker in their communities, and if yes, when? Figure 5.12 shows the percentage of responses. Most of the respondents (84.19%) had never been visited by an agricultural extension worker in their communities. Inadequate agricultural extension services has been a major challenge to agricultural development in Nigeria for years, and Benue State is yet to meet her agricultural extension service per farmer ratio (Daudu *et al*. 2009). Respondents who claimed they had been visited by an agricultural extension worker before were asked to state year of visiting. Most indications were of recent visits as recently as in 2014. The gradual increase in visits may be due to the increased commitment of Government of Nigeria which is focused on reaching rural farmers directly in their communities with information, farm inputs, and modern machinery. This agenda has also promoted the establishment of farming cooperative societies to strengthen communal access to loans and other government services.

Table 5.43: Market distances from farms/households of respondents

Distance in kilometres (km)	No. of respondents	Percentage
<1km	15	6.47
1-5km	148	63.79
5-10km	44	18.96
10-20km	18	7.76
30-50km	7	3.02
Total	**232**	**100%**
Skipped question	**49**	

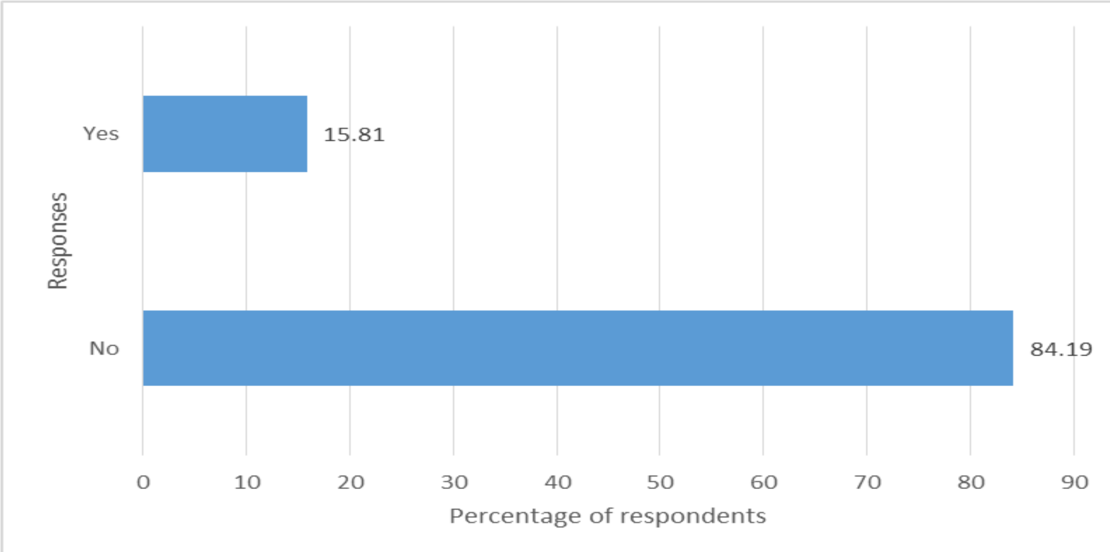

Figure 5.12: Percentage of respondents who had been visited by an agricultural extension worker

5.4.3 Community milling and storage facilities

Milling and storage facilities are grossly inadequate in the communities in the Lower River Benue Basin. Designated rice mills exist in Makurdi, Gboko and Tarka L.G.As but relevant milling machines were inadequate and mostly privately owned. Most farmers resorted to self-help. Milling of grain crops is mostly done traditionally and local mud barns are used for the storage of harvest in rural areas. There are grain storage facilities (Silos) established by the State Government in Makurdi, Katsina Ala, and Gboko for the preservation of excess cereal and leguminous crops after each farming season. This stored grain is usually disposed of during times of shortages. However, these silos are not readily accessed by farmers based on interviews conducted. In the semi urban and urban areas, personal stores within households are mostly used for the storage of harvest. Respondents (74.67%) indicated the lack of milling and storage facilities in their communities (Figure 5.13). Respondents that indicated milling and storage facilities exist in the communities mentioned rice mills (Makurdi, Gboko, and Tarka), tomatoes processing factory (Tarka), cultivating machine (Tarka), groundnut shelling machine (Tarka), harvesting machine (Tarka), spray machines (Tarka), soymilk factory (Tarka), warehouse (Makurdi). These facilities indicated by respondents were privately owned facilities. Lack of adequate milling and storage facilities in the Lower River Benue Basin has been blamed for a lot wastage of agricultural produce over the years.

5.4.4 Available amenities

Availability of electricity in communities can boost local industries and post-harvest agricultural activities. Inadequate electricity is a challenge in the Lower River Benue Basin and indeed many parts of Nigeria as the Government of Nigeria strives to improve power infrastructure. The NBS (2013) provided data on power blackouts in the north central region of Nigeria. According to the NBS (2013), respondents from the survey indicated that 3.3% never experienced blackouts; 63.5% experienced blackout every day; 26.6% experienced blackouts several times a week; 6.4% experienced blackouts several times a month; and 0.2% experienced blackouts several times a year. Over 50% of respondents in this study claimed to have electricity supply.

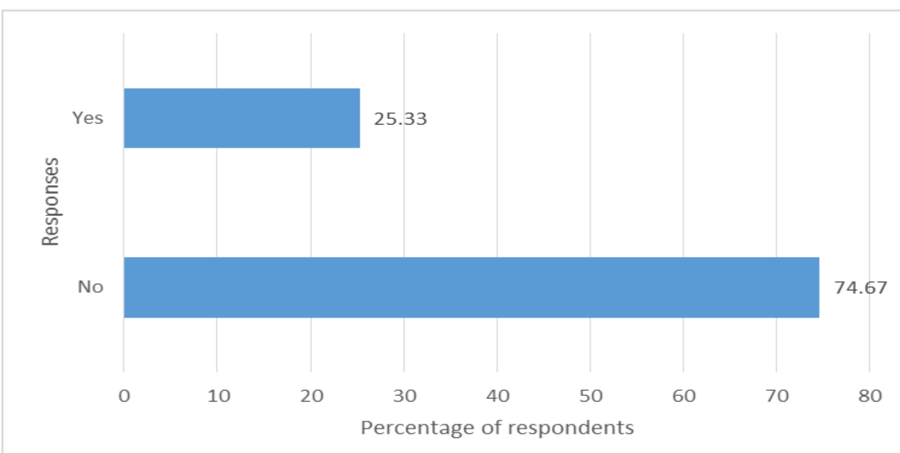

Figure 5.13: Responses on availability of community milling and storage facilities

Piped water is grossly inadequate as only 23.3% indicated availability in their communities. Piped water here may refer to community borehole projects by government. The most available facilities were the Global Satellite Mobile communication networks (86.2%) and markets (72.7%). Government schools (66.8%), radio signals (60.1%), and hospitals (56.9%) were also appreciably indicated. Banks were the least available. Only about half of the respondents (50.6%) had police stations in the communities. The inadequate level of community policing has given rise to several vigilante groups in many communities in the Lower River Benue Basin. Wide spread conflict between nomadic Fulani herdsmen and local farmers is quite common in the Lower River Benue Basin. These conflict give rise to a huge number of internally displaced persons annually, resulting to loss of livelihoods and agricultural produce. Motorcycles are the most predominant form of transportation in the communities. Vehicles such as cars, buses, and trucks are also available in some communities (Figure 5.14). The inadequate availability of proper means of transportation increases the cost of transporting agricultural produce. Table 5.44 shows the list of available amenities as indicated by respondents.

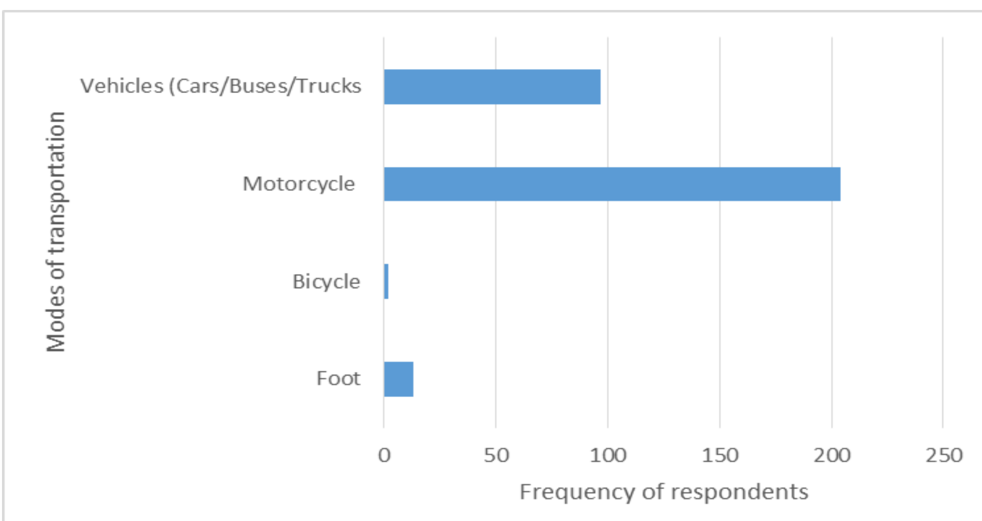

Figure 5.14: Modes of transportation by respondents

5.4.5 Farmers cooperative societies

A total of 249 respondents (88.61%) belonged to purely farming cooperative societies (Figure 5.15). Another 11.39% belonged to other cooperatives or skipped the question. These farming cooperative societies are strongly encouraged by government. Farmers can leverage on them to access relevant agricultural services from government and other organisations. Farming cooperative societies provide avenues for information sharing and mentoring to improve agricultural practices. Shared assets become available for farmers to enhance farming operations through cooperative societies.

Table 5.44: Available amenities in the communities of respondents

Amenities	Frequency of respondents	Percentage
Electricity	133	52.6%
Pipe borne water	59	23.3%
Tarred roads	73	28.9%
Television service	110	43.5%
Radio signals	152	60.1%
GSM networks	218	86.2%
Banks	47	18.6%
Markets	184	72.7%
Hospitals (Government)	144	56.9%
Schools (Government)	169	66.8%
Police station	128	50.6%
No. of respondents	**253**	
Skipped question	**28**	

It seems the benefits of belonging to farming cooperative societies had not yet been experienced by a lot of members. This is because 67.34% of respondents who belonged to farming cooperative societies claimed that they had not benefited anything from these cooperatives. These cooperative societies have in-house rules which are applied in selecting individual beneficiaries. In most cases, the level of commitment of a member is measured by meeting attendance, and payment of dues or other obligations.

Beneficiaries are usually selected on a first come, first serve basis. Other criteria may apply across the various cooperatives. Respondents that claimed they have benefited made up 32.66%, and they were mostly from Tarka and Makurdi L.G.As in that order. Items indicated by beneficiaries were categorised into loans, information, and farm inputs (fertilisers, soybean seeds, and cassava stems).

The Government of Nigeria operated an electronic wallet (e-wallet) system at the time of this study, which had started in 2013. The e-wallet system was operated through mobile telephone communication and information was sent through short message services (SMS) to registered farmers. Through the e-wallet, registered farmers are informed directly through SMS when the government has provided farm inputs to cooperative societies. Farmers who receive messages simply approach the cooperatives they belong to and collect their allocations free of charge. However, complains are rife that farms inputs arrive well after they are needed and sometimes, cooperative societies charge farmers sundry costs before collection to raise revenue. Continuous monitoring of the e-wallet system may ensure members of cooperative societies begin to benefit more from the association.

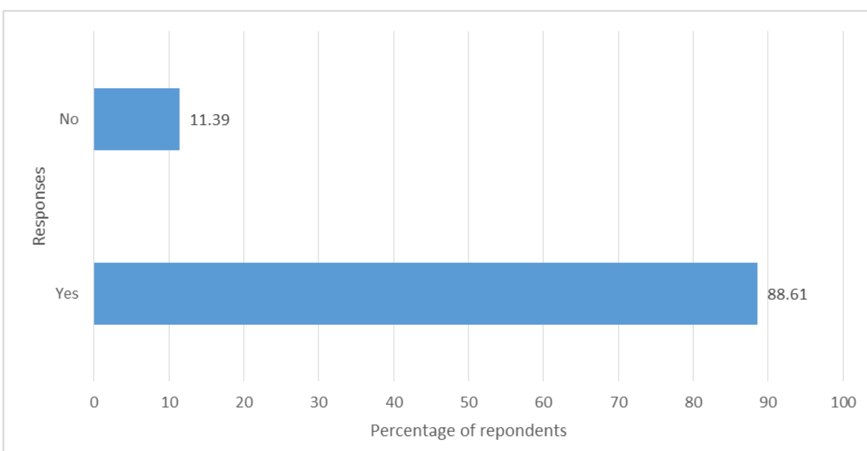

Figure 5.15: Percentage of respondents that belonged to farming cooperative societies

5.4.6 Alternative cropping

Alternative cropping in this case are crops that farmers would be willing to cultivate if new evidence is presented to support the need to change such as better yield potential, higher market value, soil and weather suitability requirements, and cheaper cost of cultivation. Respondents (72.6%) were open to try the cultivation of different crops other than the ones they were used to cultivating if recommended based on evidence. With the current focus of government on high yield crops with export value such as rice and cassava, it would not be out of place for farmers to consider the cultivation of crops with the potential to earn them more income. Irrigation farming provides respondents with the potential for additional earnings through the dry season. Figure 5.16 shows the frequency of respondents concerning alternative cropping. Cassava was clearly the preferred alternate crop of respondents. The reason is probably the growing interest on cassava as a crop with high industrial and export value. Beans, soybeans, and rice are also important options indicated by respondents. Beans and soybeans are popular crops used in mixed cropping in the Lower River Benue Basin. It is important to note that out of the three most cultivated crops earlier indicated by respondents which were yam, rice, and cassava, only cassava has been indicated as a predominant alternative. The cultivation of cassava has been promoted by the government for many years. There is a policy to use cassava to experiment with the manufacture of biofuel, and to substitute at least 20% percent of wheat flour with cassava flour in the production of bread. To this end, the government claims it has assisted several farmers with cassava multiplication technology, and cassava flour processing equipment through the Federal Ministry of Agriculture and Rural Development. None of the respondents, however, was yet to be a beneficiary. Irrigated crops like perishable vegetables had low frequencies. However, rice and maize which are also cultivated through irrigation farming had high frequencies. Reasons respondents indicated for choosing these crops included availability, income, yield potential, marketability, and high demand.

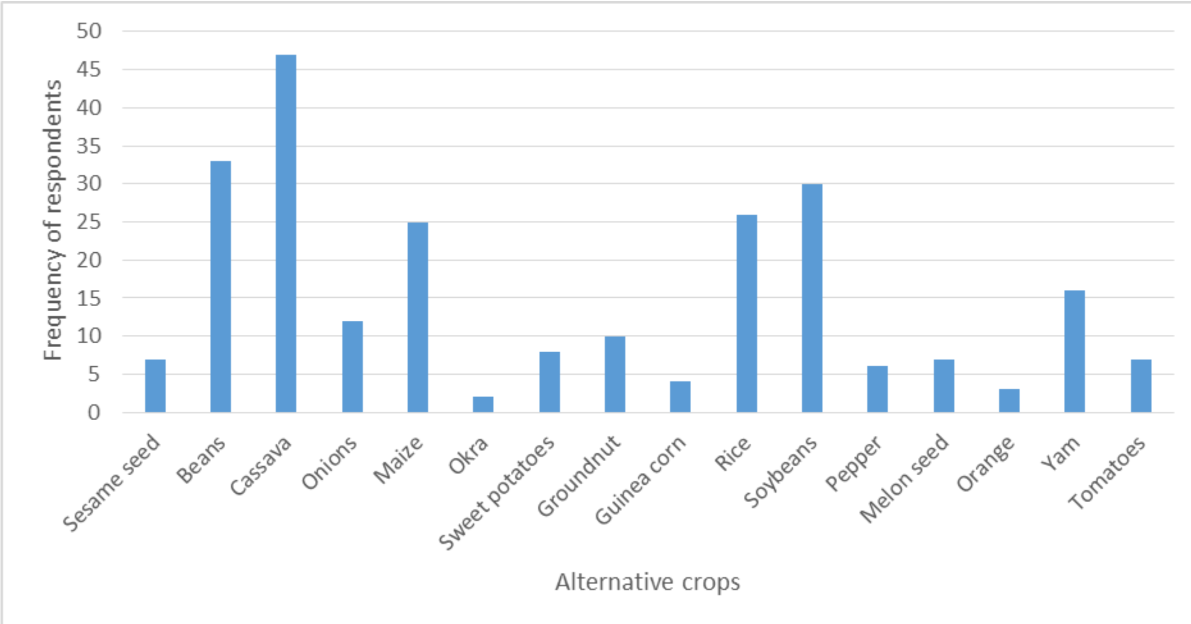

Figure 5.16: Frequency of preferred alternative crops indicated by respondents

5.5 Knowledge of HIV and AIDS and climate change

5.5.1 HIV and AIDS in Benue State

Benue State has a high burden of HIV and AIDS with a progressive rise from 8.5% (2003) to 12.7% (2010) (FMOH, 2010). This made it important to find out how respondents perceived HIV and AIDS. A total of 213 respondents (84.5%) knew what HIV is as against 15.5% who didn't know HIV. If 15.5% is added to the 10.3% who abstained from answering the question, it becomes a significant percentage to worry about in the fight against HIV. In 2010, Wannune the headquarters of Tarka L.G.A was the site with the highest HIV prevalence of 21.3% in the country (Table 5.45).

In 2013, an epidemiologic appraisal of HIV was conducted in Nigeria by the National Agency for the Control of AIDS (NACA, 2013). Benue State was one of the states selected for the study based on the high HIV prevalence rate of the state. According to NACA (2013), the study was conducted in 10 L.G.As of the state utilising various methodology and interviewed 1,844 key informants.

Female sex workers (FSWs) and men having sex with men (MSM) were at the core of the concentrated epidemics identified by the study as a huge risk to the spread of HIV in the state. The study by NACA (2013) discovered that 855 female sex workers (FSWs) hot spots existed with a population of about 10,034 female sex workers (Table 5.46). The total number of men having sex with men identified at hot spots in the state was 1,018 (Table 5.46). Table 5.46 shows that Makurdi and Otukpo had the highest population of FSWs and the state had a density of 18 FSWs per 1000 adult men across the whole State. Makurdi and Gboko had the highest number of MSM identified at hot spots in the state.

Table 5.45: HIV prevalence in Benue State sampled sites in 2010

Sites	Site status	Prevalence (%)
Ihugh	Urban	18.0
Makurdi	Urban	10.3
Otukpo	Urban	9.1
Okpoga	Rural	5.3
Wannune	Rural	21.3

Source: Federal Ministry of Health (2010)

The study found that on the average, approximately 40 patrons visited hot spots on a typical day for casual partners, and 62% of these hot spot patrons came from a zone classified as zone 2 which comprised of Gboko, Gwer east, Makurdi and Tarka (Figure 5.17). It would not be out of place to state here that the farming population in these mentioned Local Government Areas may form part of the patrons. The epidemic appraisals by NACA (2013) assessed 78 villages in the 10 L.G.As selected for the study. Of these, 100% reported having people living with HIV. About 90% of these villages had FSWs resident in the village.

As part of the study (NACA, 2013), polling booth surveys were conducted among 3,727 men and women (married and unmarried) from villages across the selected L.G.As of Benue. The study found that 38% of both married and unmarried men had ever visited a female sex worker, and 18% of both categories visited a female sex worker in the last six months. Transactional sex was reported by unmarried women (45%) and married women (30%) within the last six months of the study.

Table 5.46: Population size and density of Female Sex Workers (FSWs) in Benue state Nigeria.

L.G.As	No. of FSWs	FSWs per 1000 Adult Men	No. of MSM at Hot Spots
Kwande	554	9	51
Okpokwu	430	10	127
Gboko	1229	14	255
Gwer-east	873	21	70
Katsina Ala	760	13	0
Takar	376	19	45
Ukum	895	16	10
Makurdi	1962	26	228
Otukpo	1715	26	175
Vandekya	1240	21	58
Total	**10,034**	**17.6**	**1018**

Source: NACA (2013)

NACA (2013) observed that multiple sexual partners were high across the sampled L.G.As among unmarried and married adults and recommended intensive HIV prevention efforts in rural populations in Benue state. These findings have huge implications for farming populations which exist mostly in rural areas in Benue state. The percentage of respondents in this study who claimed to know about HIV is presented in Figure 5.18. HIV and AIDS is a health challenge capable of affecting the productivity of farmers and the livelihood of affected families in any community.

The stigma and discrimination associated with HIV can lead to denial preventing infected farmers from seeking treatment. HIV stigma and discrimination can make affected famers abandon their communities for new ones or even abandon farming completely. HIV stigma and discrimination can affect the level of patronage for an affected farmer’s goods. Even though a HIV AND AIDS anti-stigmatisation and discrimination Bill was signed into law by the President of Nigeria in January 2015, it is assumed that HIV stigma and discrimination is still an issue in rural communities. A total of 57.7% of respondents claimed they don’t know any farmer who has HIV or has died from AIDS. However, another 42.3% claimed that they know farmers who have HIV or have died from AIDS. As indicated by respondents in Table 5.47, HIV poses a significant health challenge to farmers in the Lower River Benue Basin. The responses on how respondents prevent themselves from HIV was revealing. Even though most of the responses demonstrated basic knowledge of HIV prevention, they were poorly conveyed by most respondents.

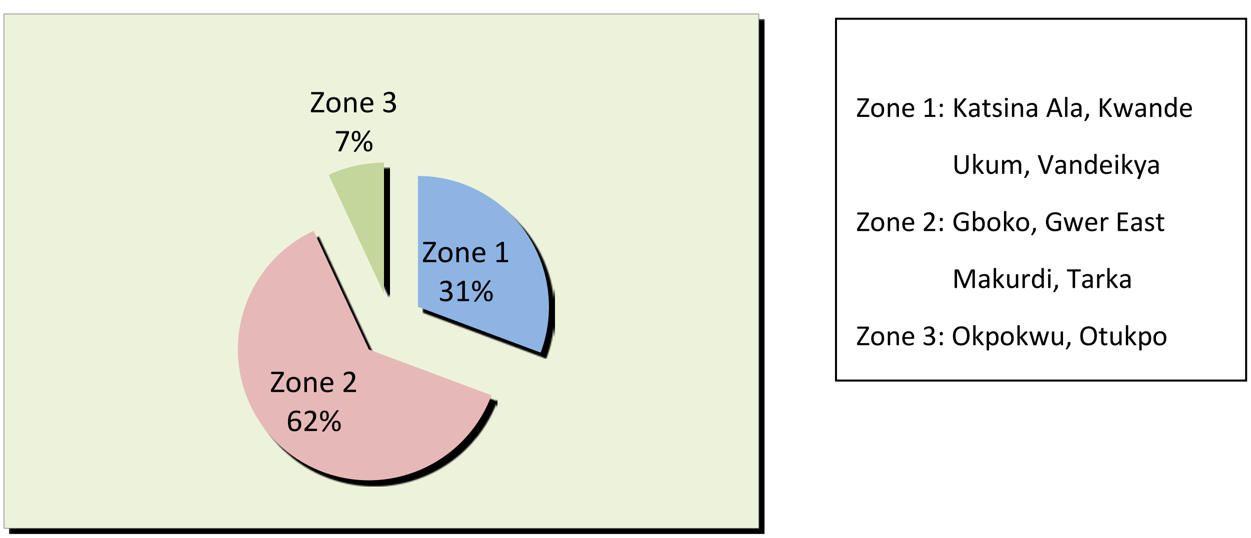

Figure 5.17: Distribution of patrons visiting casual partners in Benue state (Source: NACA, 2013).

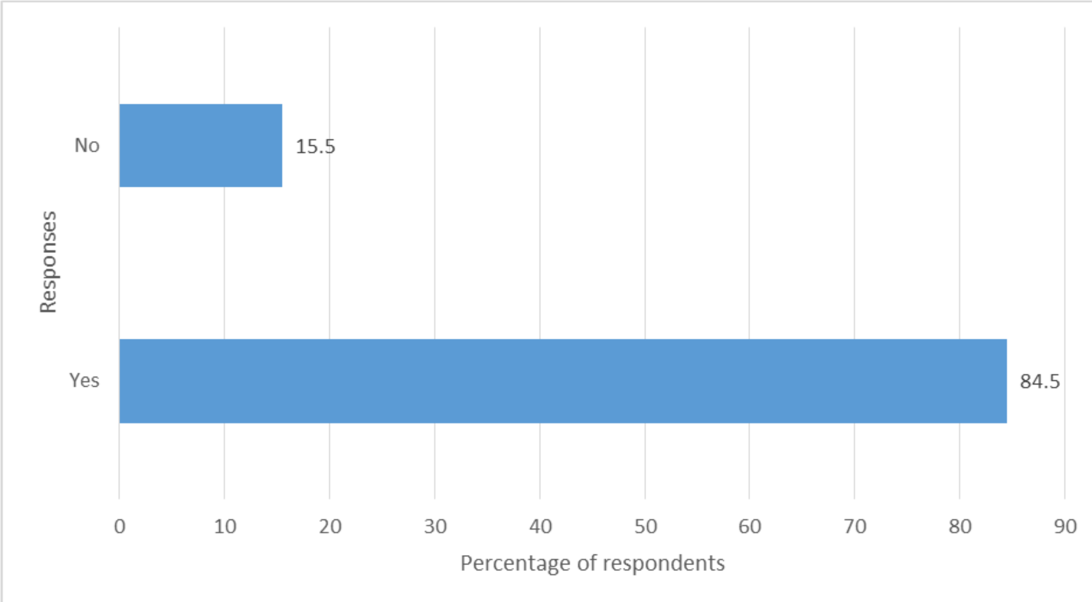

Figure 5.18: Percentage of respondents on knowledge of HIV

Table 5.47: Knowledge of farmers affected by HIV and AIDS (infected or died) by respondents

Responses	No. of respondents	Percentage
Yes	105	42.3
No	143	57.7
Total	**248**	**100%**
Skipped question	**33**	

5.5.2 Climate change

The phenomenon of climate change is gradually affecting communities especially within the tropical region. Evidence shows that climatic elements such as temperature and rainfall intensity are gradually on the increase. Incidences of flooding, erosion and droughts are becoming more frequent. Agricultural activities are the first line livelihood activities that face the greatest threat. In the Lower River Benue Basin, agriculture plays a major role in the upkeep of communities. It is, therefore, important for communities to be aware of the impending threat of climate change and continue to adjust their cultivation habits in line with noticeable changes in climatic elements and results from soil output due to infertility, and erosion. It was heart-warming to note that 70.9% of respondents had at least heard about climate change. Figure 5.19 presents the percentage of respondents who had heard about climate change.

Respondents were asked if they have noticed any variability in the weather in the last ten years. The result is presented in Figure 5.20. The most occurring variability observed by respondents was irregular rainfall. Respondents indicated that rainfall duration had become shorter. Drought was used to describe the increased number of dry days noticed by some respondents. Even though the duration of the wet season had become shorter, the intensity of rainfall increased as indicated by some respondents. Respondents also claimed the intensity of heat had increased. Overall, irregular onset and cessation of rainfall, shorter wet season, increased rainfall intensity, increased heat intensity, drought and flooding were the summaries of weather variability noticed by respondents.

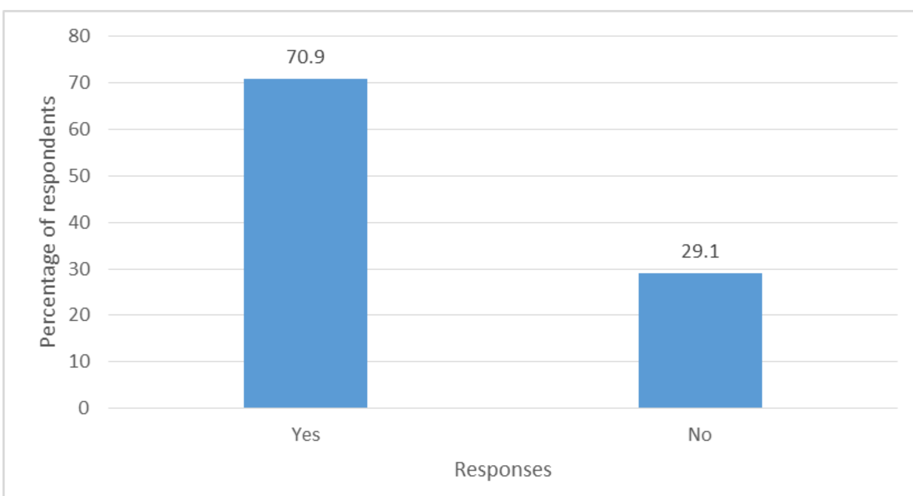

Figure 5.19: Percentage of respondents that had heard about climate change

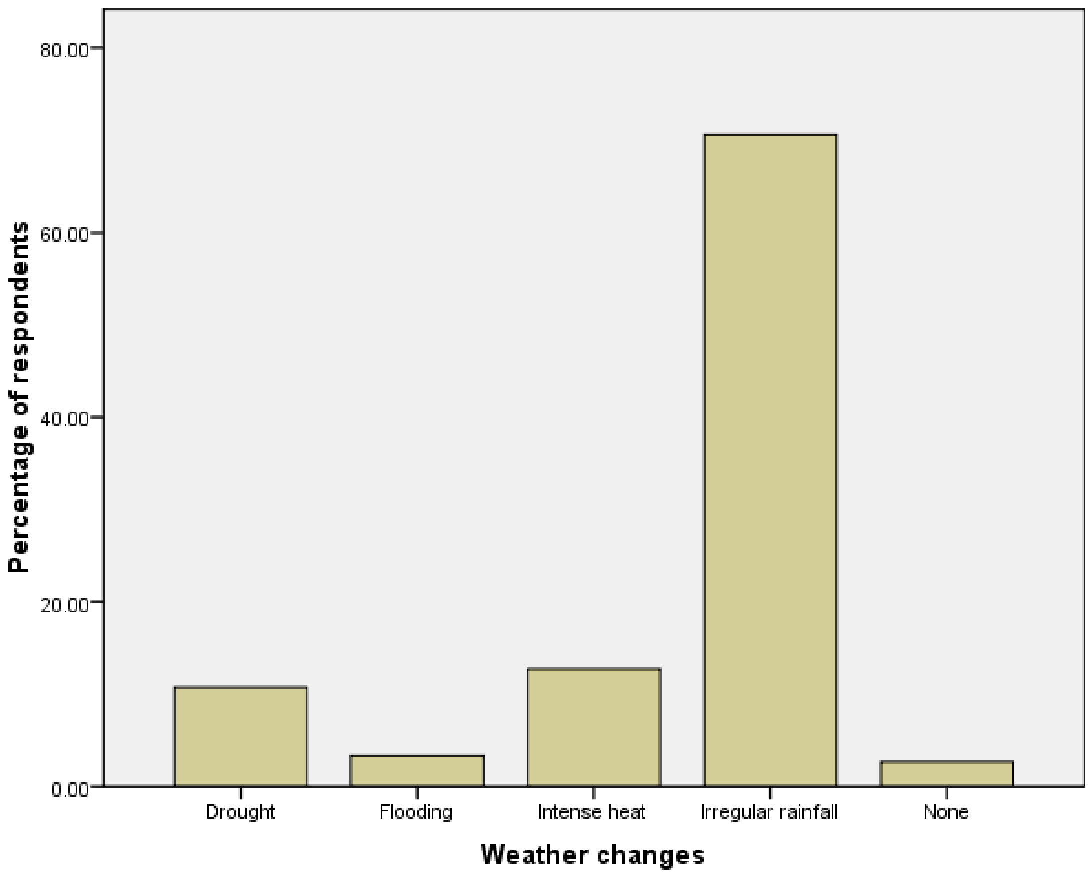

Figure 5.20: Weather variability observed by respondents in the preceding 10 years

5.6 Results of analysis of socioeconomic factors

Principal component analysis was carried on socioeconomic variables using the correlation procedure to identify relevant socioeconomic factors and explore component relationships between them. The sum of the squared component loadings and the amount of variance accounted for by all the components is presented in Table 5.48.

The variance in the total collection of variables which are explained by the components is presented in Table 5.49. As shown in Table 5.49, 73.93% of the variance was explained by the 3 extracted components.

Table 5.48: Presentation of variable communalities

Variables	Initial	Extraction
Age	1.000	.740
Household size	1.000	.790
Education	1.000	.858
Position in Household	1.000	.828
Years in settlement/community	1.000	.758
Income (Naira)	1.000	.742
House type	1.000	.395
Harvest monetary value	1.000	.771
Farm size	1.000	.869
Farm distance from house	1.000	.642

Extraction method: Principal component analysis.

Table 5.49: Total variance explained by components

	Initial eigenvalues			Extraction sums of squared loadings			Rotation sums of squared loadings		
Comp.	Total	% Variance	% Cumulative	Total	% Variance	% Cumulative	Total	% Variance	% Cumulative
1	3.757	37.567	37.567	3.757	37.567	37.567	2.992	29.920	29.920
2	2.205	22.049	59.616	2.205	22.049	59.616	2.236	22.356	52.277
3	1.432	14.318	73.934	1.432	14.318	73.934	2.166	21.657	73.934
4	.852	8.515	82.449						
5	.730	7.300	89.748						
6	.409	4.087	93.835						
7	.286	2.860	96.695						
8	.198	1.982	98.676						
9	.125	1.248	99.924						
10	.008	.076	100.000						

Extraction method: Principal component analysis.

Table 5.50 presents the results of each variable's loading on the three components extracted. For this study, positive correlation values above 0.5 and negative values farthest from 0 are significant.

Table 5.50: Component matrix values of variables

Variables	Component		
	1	2	3
Education	**.843**	-.263	.280
Harvest monetary value	**.838**	.155	.214
Income (Naira)	**.751**	-.160	.391
Age	**.746**	-.225	**-.364**
Years in settlement/community	.249	**.753**	**-.360**
Household size	**.556**	**.646**	-.254
Position in Household	**-.511**	**.636**	.403
Farm size	**.541**	**.616**	.445
House type	-.297	**.516**	-.202
Farm distance from house	-.460		**.654**

Extraction method: Principal component analysis.

The first principal component is positively correlated with six of the variables. There was higher influence in the component with increasing levels of education, harvest value, income, age, household size, and farm size. These six criteria vary together in component 1. An increase in one most likely prompts an increase in the others. The strongest variable in this component is education, which suggests that component 1 is primarily a measure of economic activity which can be affected by position in household and farm distance. Communities with high number of educated people are most likely to have good harvest values, higher income, productive age structure, and appreciable farm size. The household position of individuals may however affect these observation negatively.

Component 2 shows a positive correlation with five variables. These variables are aligned and increase together. The variable with the highest value is years in the settlement/community. The high value for housing type suggests a lack of quality housing type. Even though, the number of years spent in the community influences household size, position in the household, and farm size, it does not improve the quality of housing. Component 2 is a measure of socioeconomic activity.

The third component increased with farm distance from households and the figures showed that this is negatively increasing age and years in settlement/community. Farther farms in communities may be owned by younger and newer settlers. The third component is a function of the nature of agricultural activity in households.

These variables were rotated using the Viramax with Kaiser Normalisation (Table 5.51) to test for significantly different iterations. The rotation similarly converged in six iterations. The results showed that component 1 was primarily increasing with education, and influenced the increase of income, harvest value and farm size. Component 2 primarily increased with number of years in settlement/community. This variable influenced the increase of household size and farm size. The increasing trend in component 3 was orchestrated by position in household. The individual's position in the household increases favourably with farm distance from house but was negatively affected by age.

Table 5.51: Rotated component matrix values of variables

Variables	**Principal component**		
	1	**2**	**3**
Education	**.860**	-.102	-.327
Harvest monetary value	**.802**	.297	-.198
Income (Naira)	**.845**	0	-.154
Age	.411	.116	**-.746**
Years in settlement/community?	0	**.867**	0
Household size	.286	**.818**	-.200
Position in Household	-.212	.307	**.830**
Farm size	**.674**	**.559**	.320
House type	-.378	.453	.217
Farm distance from house	0	-.296	**.744**

Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalisation.

5.7 Potential impacts of climate change and population dynamics on agricultural development in the Lower River Benue Basin

This section identifies and describes the potential impacts of climate change and population dynamics on agricultural production with a view to proffer mitigating strategies for sustainable agricultural growth. The likelihood and magnitudes of these impacts were predicted and their significance evaluated with information from the environmental sensitivities matrix (Appendix 18).

5.7.1 Climate and related physical factors

According to Várallyay (2010), Climate change may impact the agro-ecological potential and biomass production of various natural and agro-ecosystems of soil. The localised potential impacts on agricultural production in the Lower River Benue Basin are as follows:

5.7.1.1 Atmospheric carbon dioxides and oxides

The increase in carbon dioxide and oxides are imminent with the increasing temperature observed. These would result in faster growth of cultivated plants and weed (medium, **+/-)**; modification of soil carbon and nitrogen ratio (medium, -); aggressive competition of weed with cultivated crops (medium, -); change agricultural ecological systems (high, **+/-)**; and potential modification of the nitrogen cycle (medium, -); and decreased crop yield (medium, -).

5.7.1.2 Rainfall intensity

The increasing trend of intensifying rainfall over a relatively shorter duration and with irregular onset and cessation periods will adversely affect agricultural production. This has the potential to intensify the hydrological cycle (high, +/-); increase seasonal variation of rainfall (high, -); change the rate of erosion and accretion patterns of soil particles (medium, -); increase occurrence of storm floods (medium, -); increase marshy and waterlogged areas (medium, +/-); and increase pest attacks on cultivated crops (medium, -).

5.7.1.3 Frequency of floods and droughts

The spatial-temporal variation of weather elements may increase the frequency of floods and droughts. When this happens, it is anticipated that flood and drought risk areas would increase (high, -); occurrence of floods and drought would increase (high, -); crop failure rate would be high (-); crop yield would likely decrease (low, -); and competition for water may be prevalent (low, -).

5.7.1.4 Temperature intensity and variation

An increasing trend of temperature will have negative consequences for agricultural production. Temperature and humidity values in the Lower River Benue Basin are amongst the highest values in Nigeria (Tyubee and Anyadike, 2012) reaching extreme condition around the planting season of March and April. Associated potential impacts with these scenarios include modification of crop suitability and production which would be highly negative with significant effects on the farming livelihoods; increase in weeds, pests, and diseases (medium, -); changes in crop water requirements (medium, -); and changes in daytime and night time temperature (medium, -).

5.7.1.5 Heat stress

An increase in heat stress would increase heat waves (high, -) causing discomfort for manual farm labour (high, -). Increased pest activity (medium, -), and damage to crop flowering and grain formation processes may occur (high, -).

5.7.1.6 Surface water trends

Increased surface water volumes and sediment flow (high, +) would be a resultant effect of higher water tables and increased rainfall. However, increased river flooding may occur (high, +/-). Higher water levels and discharge rate (+), and increased salinity (low, -).

5.7.1.7 Soil quality/fertility

The trend of soil fertility is expected to decrease further when climatic conditions become adverse. Increased soil erosion by water and wind (medium, -). The combined influence of rainfall intensity and variation, low relief of the area, and depleting secondary vegetation would accelerate erosion processes. Increased soil acidification (high, -) due to reduced infiltration and leaching, and reduced decomposition rate of vegetation litter may occur. Soil salinisation/alkalisation (medium, -) in some areas is likely due to imbalances in rainfall rate, infiltration and leaching or accumulation of carbonates. Other impacts would include increased waterlogged soils (medium, +/-), deficient soil moisture regimes (medium, -), soil structure destruction (medium, -), alteration of soil nutrient regime (high, -), and soil toxicity (low, -).

5.7.2 Population and related dynamics

Using the knowledge of the socioeconomic survey findings, a list of the likely impacts on agricultural production by aspects of population was developed.

5.7.2.1 Population growth

It is expected that the rate of the population of the Lower River Benue Basin will continue to increase exponentially at a rate of 2.83%. With this rate of growth, the population of the study area would be 6,920,319 by the year 2026. Population growth adds to the pressure on available land for agriculture and may probably lead to changes in land use patterns (high, +/-). Availability of agricultural land may become less available as other land uses may take up more land (high, -).

Increased cropping (high, +/-) and intensified irrigation farming (medium, +/-) may occur. There would be increased demand for agricultural produce (high, -) and food shortages (medium, -). Population growth would lead to increased market competition (high, +), increased deforestation (high, -), increased armed conflict (high, -), and increased pressure on social amenities (high, -).

5.7.2.2 Rural-urban migration

Population growth may result in other associated issues such as increased rural-urban migration. As already established, increased pressure on agricultural land, market competition, conflict, flooding, drought, and pressure on amenities, to mention a few, may push out more people into neighbouring towns and states. This could result in agricultural occupational loss (medium, -), localised loss of farmers' population (low, -), decrease in farm labour (low, -), decrease in agricultural productivity (low, -), and increase in rural poverty (medium, -).

5.7.2.3 Household income

An increase or decrease in the general trend of household income may affect the livelihood standards of the population. The need to seek more income generating activities or to experience urban lifestyle activities can lead to migration (medium, -). The general increase household incomes can lead to a higher cost of living and inflation (high, -). Income levels can lead to limited access to farm inputs (medium, -), and less capital to farm (medium, -). Reduced income levels can limit household access to social services (medium, -).

5.7.2.4 Infectious diseases and HIV and AIDS

Climate change and population growth could lead to the proliferation of infectious diseases including HIV and AIDS through migration of disease vectors into new climatic zones, and increased risk of infectious diseases due to a higher rate of human interaction. If this scenario occurs, it will lead to decreased agricultural productivity due to loss of man hours during sick periods, or as in the case of HIV and AIDS, it may result in loss of farming seasons due to prolonged infectious illnesses (low, -). In order to avoid stigma and discrimination, migration may become an option for affected people (low,-). Loss of farmers due to death from disease may deprive households of mentoring and experience in agricultural practices (low, -). Households and communities where infectious diseases are prevalent would have an increased dependence burden (medium, -). Ultimately, the threat of agricultural occupational loss is present in communities where infectious diseases are prevalent (low, -).

5.8 Potential impact evaluation

The qualitative and quantitative evaluation of potential impacts is presented in Appendix 19. The ranking summary is presented in Table 5.52. Most of the impacts were ranked high from the quantification of probability, public perception, and environmental interaction effect. As Table 5.52 shows, agriculture in the Lower River Benue Basin is significantly threatened with adverse changes in climate and population dynamics. Some impacts of population and related dynamics were ranked medium. It is, therefore, necessary to proffer mitigation strategies that may assist farmers to prepare and cope with impacts ranked medium and high. The overall agricultural suitability index of the study area and the adaptive capacity index gives a good assessment of the current suitability for agricultural production and resilience to climate change. These are presented in the next sections.

Table 5.52: Percentage ranking of potential impacts on agricultural development in the Lower River Benue Basin

Environmental issues and impacts	Percentage of ranking 0-5 (Low)	5-10 (Medium)	10-15 (High)
Climate and related physical dynamics			
Increase in atmospheric dioxides and oxides			11.11%
Increased rainfall intensity			12.96%
Increased frequency of floods and droughts			9.26%
Increased temperature intensity and variation			7.41%
Increased heat stress			7.41%
Increased surface water trends			11.11%
Decreased soil quality/fertility			14.81%
Population and related dynamics			
Increased population growth		18.18%	14.81%
Increased rural-urban migration		45.45%	
Increased or decreased household income			9.26%
Infectious diseases and HIV and AIDS		36.36%	1.85%

5.9 Agricultural suitability index (ASI) of the study area

The agricultural suitability index (ASI) value of 70.5% calculated for the study area compared favourably with the level of vegetative cover of the study area presented in Figure 4.53. The results of the rating score table used to arrive at the agricultural suitability index value is in Appendix 20.

The ASI value of 70.5% fell into the suitability category. The parameter with the highest percentage was drainage (83.33% - highly suitable) and was followed by soil (77.78% - highly suitable). The lowest percentage recorded was for potential impacts (25% - marginally suitable), which was primarily a function of the ranking of identified impacts (Figure 5.21). This means that the future development of agricultural production in the study area is susceptible to several threats if measures are not taken to prevent or mitigate the environmental consequences of a changing climate and the effects of unwholesome farm practises. The agricultural suitability index model developed for this study provided an appreciable picture of the agricultural potential of the study area. The model allowed for the inclusion of parameters beyond the physical attributes of the study area which are relevant to the development of agriculture. The ASI emphasised an integration of both socio-economic and physical factors in order to arrive at decision making that will encourage sustainable agriculture. The parameters of this tool are adaptable and it would be interesting to see results from other scenarios.

Several quality gaps revealed by the rating score table (Appendix 20) would need to be bridged if the study area is to achieve its full agricultural potential and be classified as highly suitable. Strategies and recommendations to contribute towards this realisation are provided in Chapter 6.

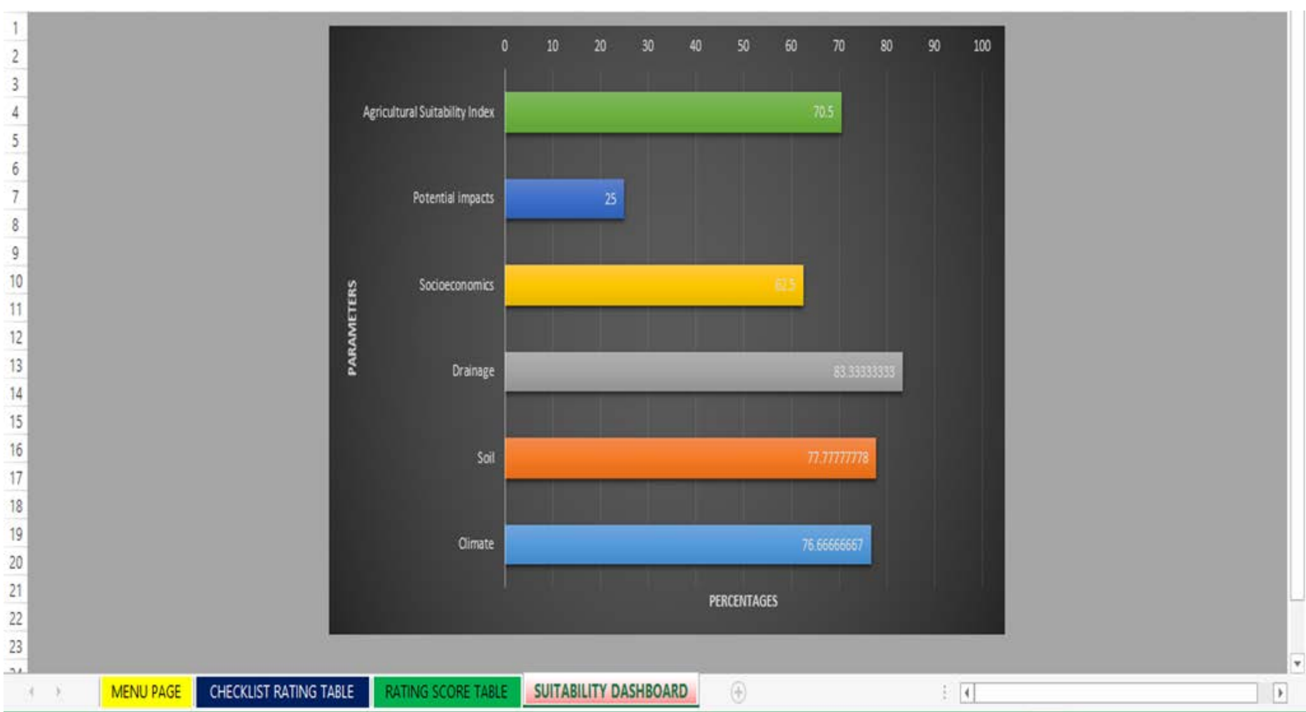

Figure 5.21: The agricultural suitability index dashboard produced for the study area

5.10 Adaptive capacity index of the study area

The adaptive capacity index calculated for the study area was 50.83% (Table 5.53). The index score falls into the moderate adaptive capacity category. The most vulnerable determinant was farm technology with the lowest percentage of 18.75% (very low). The least vulnerable determinant was networking with an appreciable percentage of 68.75% (high). Other determinants such as equity, farm management, and agricultural economic base had a percentage score of about 60% (moderate). The infrastructure determinant had a low percentage score of 36.25% (low). Figure 5.22 presents the determinant scores alongside the adaptive capacity index of the study area calculated for this study.

The moderate adaptive capacity suggests that farmers in the study area are already striving very hard to cope with whatever climatic variabilities they have observed. However, this adaptive capacity category does not place farmers in the study area in a strong position especially with a lean moderate score of 50.83%. Other multiple stresses related to HIV and AIDS, land degradation, trends in economic globalisation and violent conflicts can adversely affect the adaptive capacity of farmers in the study area.

There is a need to begin to look at critical gaps exposed through this adaptive capacity analysis process with a view to finding home grown solutions that will strengthen the adaptive capacity of farmers in the Lower River Benue Basin to impacts of climatic variability. Recommendations towards this realisation are provided in Chapter 6.

Table 5.53: The determinant scores and adaptive capacity index of the study area

Determinants	Indicators	Indicator (%) & ranking scores	Determinant score (%)	Adaptive capacity index (%)
Agricultural economic base	Percentage of population earning high (above 1 dollar a day X 30 days) in a month. Higher is better.	60.62 (13)	61.25	**50.83**
	Percentage of population spending above series average on farming. Higher is better.	66.10 (14)		
	Percentage of population recording high crop yields. Higher is better.	59 (12)		
	Percentage difference between agricultural types. Lower is better.	52 (10)		
Farm technology	Percentage of population engaged in irrigation farming. Higher is better.	30.7 (7)	18.75	
	Percentage of population engaged in mechanised farming. Higher is better.	0.8 (1)		
	Percentage of population utilising modern processing equipment. Higher is better.	10 (2)		
	Percentage of population utilising appropriate storage facilities. Higher is better.	23.8 (5)		
Farm management	Percentage of population that own their own farmlands. Higher is better.	5.6 (2)	60	
	Percentage of population that have access to fertilisers. Higher is better	82.5 (17)		
	Percentage of population heavily dependent on farm labour. Lower is better.	49.8 (11)		
	Percentage of population that have good knowledge on farming season. Higher is better.	90 (18)		

Determinants	Indicators	Indicator (%) & ranking scores	Determinant score (%)	Adaptive capacity index (%)
Infrastructure	Percentage of population dependent on agriculture. Lower is better.	78.3 (5)	36.25	
	Percentage of population that have access to portable water. Higher is better.	27.14 (6)		
	Percentage of population that have access to modern housing (zinc roof and brick walls). Higher is better.	57.7 (12)		
	Percentage of population that have access to tarred roads. Higher is better.	28.9 (6)		
Networking	Percentage of farmers that belong to farming cooperative societies. Higher is better.	88.61 (18)	68.75	
	Percentage of population that have access to mobile telecommunication services. Higher is better.	86.2 (18)		
	Percentage of population that have regular contact with agricultural extension workers. Higher is better.	15.81 (4)		
	Percentage of population that have close proximity (<5km) to markets. Higher is better.	70.26 (15)		
Equity	Percentage of population with access to electricity supply. Higher is better.	52.6 (11)	60	
	Percentage of population with access to government hospitals. Higher is better.	56.9 (12)		
	Percentage of population with access to government schools. Higher is better.	66.8 (14)		
	Percentage of population with access to police stations. Higher is better.	50.6 (11)		

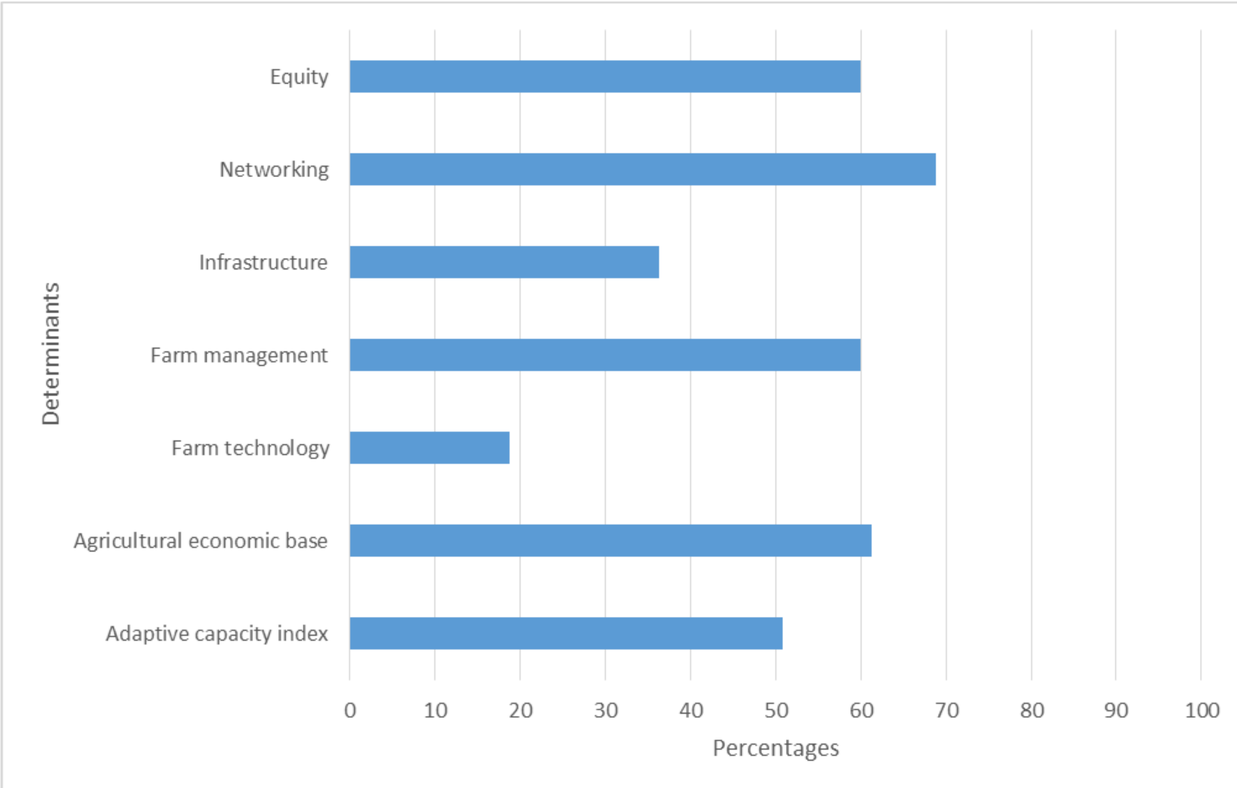

Figure 5.22: Determinant scores and adaptive capacity index of the study area

CHAPTER SIX

CONCLUSION

6.0 Introduction

This chapter summarises the study's findings and highlights the implications of these findings on the future of agricultural development in the Lower River Benue Basin. The chapter also proposes the mitigation strategies for the potential impacts that threaten the sustainable development of agriculture in the study area. Other issues such as the recommendations to the government, limitations of the study, contributions to knowledge and areas of further research are also presented.

6.1 Conclusions

The study has dealt with land use evaluation and suitability mapping for rice, cassava, and yam in the Lower River Benue Basin. The study utilised various methods including an assessment of climate, soil, crop cultivation, and socioeconomic variables to address the study hypotheses towards achieving the study objectives. Modern analytical mapping technology was used to arrive at concrete findings aimed at the improvement of agricultural activities in the Lower River Benue Basin.

The study observed a trend of late rainfall onset and early rainfall cessation. Rainfall intensity seems to be increasing with a gradual reduction in the number of rainy days. The number of rainstorms is increasing, and the reoccurrence interval for most extreme rainfall events put between 1 to 5 years. The study highlighted the effect of climatic variation on yield variance for rice, cassava, and yam production. Analyses revealed that rainfall between 1973 and 2013 in the study area had a high variation.

The daily maximum temperature and annual temperature averages for the study area is gradually rising leading to increased heat stress. The vapour pressure deficit results suggested that the days between the penultimate week of May and first week of November (about 168 days) are optimal for rain-fed crop cultivation in the study area. Solar radiation and evaporation values were found to be adequately suitable for agricultural purposes.

High drainage discharge from the River Benue was observed. The River Benue occasionally overflows during peak periods causing flooding which affects crop cultivation. Even though rainfall intensity contributes to the River Benue overflow, the greatest influence is the release of excess dam water from the Lagdo dam in Cameroon. Agricultural activities around the banks of the River Benue in the wet season may be counterproductive. The rating curve of the River Katsina Ala suggests it has rapids which point to good damming potentials. Constructing a good dam on the River Katsina Ala may be favourable to agricultural development and other benefits for the local population. Even though the climatic factors were found to be favourable for crop production as stated in the hypothesis, the study observed variations which could progressively affect crop production in the near future.

The soils in the study area were mostly sandy loam and loamy sand with some clay content in certain parts. These soils are good enough to support crop cultivation especially rice, cassava, and yam as assumed in the hypothesis. Physical and chemical analyses showed that the soils had a local structure and spatial dependencies, and were moderately fertile but required effective application of inorganic and organic fertilisers annually for enhanced crop growth. The soil nutrient index showed that soil fertility indices increased away from the River Benue. The suitability maps showed that the order of crop suitability for areas where soil samples were taken from for this study was Gboko>Tarka>Makurdi for rice, Gboko>Tarka>Makurdi for cassava, and Tarka>Makurdi>Gboko for yam.

The main occupational activities in the study area were agricultural based. Farming cooperatives were actively increasing but were yet to meaningfully impact on the agricultural development of members. Very little communal and cooperative owned agricultural facilities were observed. The preponderance of agricultural activities had very little effect on the income of the population which was generally quite low and was largely a function of the traditional methods employed by farmers. The socioeconomic findings from principal component analysis showed that communities with high economic and socioeconomic status based on the level of education, harvest value, income, age, household size, and farm size will have the highest potential to achieve adequate agricultural development and growth targets. Effective agricultural extension services were inadequate and are required throughout the Lower River Benue Basin to enhance agricultural practises. Above all, adequate support from Government at all levels to purchase excess produce, provide silo services, farming equipment, and credit facilities would build the capacity of the agricultural value chain of the study area.

Agriculture in the Lower River Benue Basin faces several challenges which threaten the future of agricultural development in the basin. Some of these challenges have been identified and categorised into environmental, climatic variability, infectious diseases, population growth, and migration. These challenges were largely driven by climatic and population dynamics within the region. As a result, a detailed potential impact assessment was carried out to highlight possible threats to agricultural production and on the socioeconomic status of communities in the Lower River Benue Basin. Most of the threats identified were ranked high after analysis. Mitigation strategies that would be useful in averting some of these potential impacts, and help to cope with those that actually occur, have been proffered. Awareness and sensitisation campaigns should begin today to equip every farmer in the Lower River Benue with the necessary information and tools to embrace sustainable agricultural practises and sustainable livelihood activities.

Agricultural development has the highest potential for revenue generation in the Lower River Benue Basin, and as such, should be given priority status by relevant government authorities. In order to draw focus to the need for the improvement of crop cultivation in the study area, suitability maps have been produced to highlight areas suitable for crop cultivation and especially the cultivation of rice, cassava, and yam. The results of the suitability maps attest to the effectiveness of GIS and remote sensing in suitability mapping and has therefore confirmed the assumptions in the hypothesis. In addition, the agricultural suitability index value of 70.5% obtained from agricultural suitability index modelling for the study area fell into the suitable category. The inclusion of socioeconomic parameters enhanced land evaluation and agricultural suitability index results as stated in the hypothesis.

The adaptive capacity index modelling for the study area returned a value of 50.83% (moderate adaptive capacity). This revealed the need to work urgently to optimise the quality of adaptation determinants such as farm technology and infrastructure, while working to improve on the other determinants in view of the progressive trend of climatic variation in the study area.

It is expected that with strategic dissemination of the findings of this study, the stakeholders would be constructively engaged to steer implementation of policies and agricultural activities in a sustainable and more profitable direction. All stakeholders should realise that if no determined and diligent steps are taken, agricultural development in the Lower River Benue Basin will progressively deteriorate.

6.2 Proposed mitigation strategies for potential impacts

The detailed mitigating strategies proffered for potential impacts are presented in Appendix 21. The mitigation strategies proffered were at community level and recommendations to the Benue State Government. The strategies were developed after a careful review of relevant literature on the subject (Olesen, 2009; Paustian *et al.*, 2006; Petroni, 2009; Wassie and Boke, 2009; Abu *et al.*, 2011). Given the high and medium quantification ranking for most of the potential impacts identified, mitigating strategies will immensely assist farmers in the Lower River Benue Basin to cope with adverse climatic variability as they occur, and control population and related dynamics at the household and community level. Policy makers should be aware that funding and material support is critical in the execution of mitigation strategies such as the ones proffered. Policy makers therefore have an overarching role related to efficient implementation of specific policies for the sustainable development of agriculture in the Lower River Benue Basin.

6.2.1 Summarised mitigating strategies for climate variability

1. In order to mitigate atmospheric carbon dioxides and oxides, planting of trees in communities and on non-agricultural lands is expedient in order to increase soil carbon and reduces atmospheric carbon dioxide.
2. Farmers should break farming seasons by planting crops which produce before flood months and consider irrigation farming during the dry season.
3. Rain-fed crop cultivation should concentrate between the months of May and October annually.
4. Extreme temperatures can harm crop production but impact may be reduced by modifying the microclimate.

5. Farmers should water farms in the morning in times of heat stress by installing sprinklers, with a water hose, or by manual watering.
6. Farmers should avoid farmlands close to river banks and areas of river flooding during the wet season.
7. The efficient use of NPK fertilisers can enhance balanced fertilisation in the study area. The use of organic manure and composting should be encouraged in between and pre-farming seasons as they improve both physical and chemical properties of soil.

6.2.2 Summarised mitigation for population related dynamics

1. Cooperative societies should introduce information sharing and briefings on the benefits of family planning and challenges of large households during meetings. Cooperatives should encourage farmers to visit family planning centres.

2. Farmers should discourage their children from migrating for reasons other than gainful employment and marriage. Farmers should support the education of their children as much as possible.

3. Cooperative societies should educate members on the importance of savings and financial prudence. Farmers should monitor spending to avoid wastages.

4. Cooperative societies should discuss the prevention of infectious diseases and HIV and AIDS in meetings frequently. Partnership with civil society organisations working on public health can avail farmers with necessary prevention tools and information.

6.2.3 Recommendations to Benue State Government

1. **Building capacity of communities to cope with adverse weather conditions and climate variability**

    - The Benue State Government (BSG) should put in place mechanisms for the periodic and effective monitoring of micro weather elements, soil quality, and crop yield.
    - Without proper funding, farmers may not effectively embrace good management farm practices. The BSG should make available credit facilities at flexible rates for farming cooperative societies.
    - The BSG should maintain a state wide register of farming cooperative societies and document challenges faced by farmers annually and be responsive to requests from them.
    - The BSG should adequately provide farmers with relevant information regarding the weather and flood warnings to enable farmers plan appropriately.
    - The BSG should control corruption and ensure all agricultural policies are implemented efficiently, especially policies on access to mechanised farming equipment.
    - The BSG should adequately catalogue crops produced in every area of the state and support farmers with necessary farm inputs, especially improved crop varieties with better yield.
    - The BSG should ensure state owned silos programs are operational and professionally managed.
    - The BSG should organise workshops to educate farmers on good farm practices and how to access agricultural related services from government.

- The BSG should provide equipment and resources which will assist farmers engage in irrigation farming. If possible, a standard dam should be constructed on River Katsina Ala.
- Agricultural extension workers should be monitored to ensure diligence.
- The BSG should encourage and support farmers to focus on the cultivation of yam, rice, and cassava, and mixed farming with leguminous crops as suggested in the suitability maps produced.

2. Curbing population and related dynamics

- The BSG should improve the infrastructure in rural areas to close the urban-rural divide in terms of quality of life.
- The BSG should provide improved primary health care and family planning services at community level.
- The BSG should create enabling environment for the private sector to establish agricultural processing centres.
- The BSG should support the establishment of agricultural microfinance banks and subsidise cost of farm inputs.
- The BSG should support the State Agency for the Control of HIV/AIDS to implement HIV programs effectively.
- The BSG should provide free HIV testing at community level.
- The BSG should provide support to families affected and burdened with HIV/AIDS and other infectious diseases.
- Agricultural extension workers should be trained on HIV education as part of job description.

6.3 Limitations of the study

The researcher pursued the achievement of the aim and objectives of this study through scientifically established methodologies. However, the researcher faced the following limitations.

1. Incomplete drainage discharge data on the River Benue affected exhaustive comparative analysis with rainfall data from the study area.
2. The study was carried out with private funds, and as such, chemical and micronutrient analyses of soil samples was limited. Future studies of this nature should consider pursuing scholarships to adequately cover a lot more parameters for soil analyses.
3. Secondary data on local level information had to be sourced directly through many physical visits to state government offices and communities as many Benue state government offices do not have active websites or online data repositories.

6.4 Contributions to knowledge by the study and areas of further research

The study has provided important information on land evaluation and suitability mapping for rice, cassava, and yam. Specifically, the study has made some significant contributions. The study has demonstrated the efficacy of remote sensing and GIS techniques in mapping suitable areas for crop cultivation in the Lower River Benue Basin. These techniques are an improvement to the conventional methods which is mostly based on soil analysis. The use of remote sensing and GIS techniques allowed for the inclusion of other attributes specific to the study area which enhanced the accuracy and presentation of suitability maps. The suitability maps for the cultivation of rice, cassava, and yam, and highlighted very clearly, areas most suitable for the cultivation of these crops.

The study presented the soil nutrient index of the study area alongside useful information on the irrigation potential of soils in the area. The study provided vital information on the vapour pressure deficit and the varieties of rice, cassava, and yam which should be promoted for cultivation in the study area. The study used impact assessment modelling to identify potential impacts that threaten agricultural development in the study area including information on climate variability, population growth and HIV/AIDS, and has proffered mitigation strategies which will sustain the development of agriculture in the Lower River Benue Basin.

In order to further assess the agricultural suitability status of the study area, the study developed a Microsoft Excel based electronic tool called the agricultural suitability index (ASI) model. This tool provided further analyses which produced results that compared favourably with the map results of GIS analyses. The adaptive capacity index of farmers in the study area was calculated by adapting established scholarly methodology. This revealed critical gaps which should be bridged if farmers in the study area are to sufficiently adapt to impacts of climate change.

Similar studies in the literature (Patil *et al*., 2005; Salam and Rahman, 2007; Ashraf, 2010; Hunduma, 2012; Uchua *et al*., 2012; Petja *et al.*, 2014) were based on physical data for assessing agricultural and economic potentials. This study, however, extensively assessed socioeconomic factors that largely serves as impediments for agricultural growth despite the physical suitability of the environment, based on the concepts and examples provided in literature (Bacic *et al*., 2003; Beek *et al*., 1997; Chen and Lu, 2014; Heumann *et al*., 2013; Son *et al*., 2008; Verheye, 1985; Yen *et al*., 2013). The assessment of socioeconomic factors provided evidence of anthropogenic contributions which can be enhanced to optimise the agricultural potential and quality of environmental conditions in the study area. Several issues which had to do with cultivation methods, farm practises, resources management, yield optimisation and farm inputs application were brought to the fore and contributed immensely in arriving at the findings presented in this study. In addition, the analysis of emerging stress issues such as climate variability, population growth, and HIV/AIDS provided a balanced and holistic view of the immediate and futuristic interrelationship between biophysical factors, socioeconomic factors and sustainable agricultural development in the study area. Above all, the utilitarian value of GIS and remote sensing enabled modelling with multiple rural level biophysical data and socioeconomic attributes which justified the FAO framework usually preferred in countries where scarcity of data can constrain land suitability assessments.

Drawing from the methodological approach of this study, the current and future agricultural potentials of the study area has been examined from the physical, economic and social dimensions of the environment. It is, therefore, clear that the consideration of socioeconomic data adds value to the process of agricultural land evaluation, and the completeness of agricultural suitability. In general, the methodological steps and the collective findings of this study presents important information on the Lower River Benue Basin which would be beneficial to the scientific community and future research in the study area and beyond. Areas of further research should focus on the use of remote sensing and GIS to project trends of climatic variation and crop yield, the performance of various crop varieties under current and future scenarios of physical and socioeconomic conditions, and the long term effects of nutrient enhancing inorganic fertilisers on soils in the study area.

The findings of this study, which would be widely disseminated, would be useful to relevant policy makers, active players in government and local communities as a quality reference material in designing, planning, coordinating and implementing sustainable agricultural development activities that would be owned by farming cooperatives and local communities. This study has, therefore, achieved its objectives.

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APPENDIX 1: PROPOSAL AND ETHICS COMMITTEE APPROVAL LETTERS

UNISA university of south africa

A I R M A I L

ABAH R C MR
NATIONAL AGENCY FOR THE
CONTROL OF AIDS PLOT 823
RALPH SHODEINDE STREET
CENTRAL AREA, ABUJA
NIGERIA

STUDENT NUMBER : 5122-375-9
ENQUIRIES : mandd@unisa.ac.za

FAX : (012) 429-4150

2014-02-20

Dear Student

I have pleasure in informing you that your research proposal has been approved. Please register and pay online for the research component of the degree for the 2014 academic year. Registration for 2014 commenced on 26 November 2013 and closes on 15 March 2014. Please refer to the Unisa website: www.unisa.ac.za/studentfunding if you are interested in applying for a postgraduate bursary. The closing date for the bursaries is 14 February 2014.

Yours faithfully

for Registrar

1

UNIVERSITEIT VAN SUID-AFRIKA
PRETORIA
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UNISA university of south africa

2014-04-11

Ref. Nr.: 2014/CAES/059

To:
Student: RC Abah
Supervisor: Dr BM Petja
Department of Environmental Sciences
College of Agriculture and Environmental Sciences

Student nr: 51223759

Dear Dr Petja and Mr Abah

Request for Ethical approval for the following research project:

An application of GIS and remote sensing techniques in land use evaluation and suitability mapping for yam, cassava and rice in the Lower River Benue Basin, Nigeria

The application for ethical clearance in respect of the above mentioned research has been reviewed by the Research Ethics Review Committee of the College of Agriculture and Environmental Sciences, Unisa. Ethics clearance for the above mentioned project (Ref. Nr.: 2014/CAES/059) **is given** after careful consideration of all documentation submitted to the CAES Ethics committee. Approval is given for the duration of the research project.

Please be advised that should any part of the research methodology change in any way as outlined in the Ethics application (Ref. Nr.: 2014/CAES/059), it is the responsibility of the researcher to inform the CAES Ethics committee. In this instance a memo should be submitted to the Ethics Committee in which the changes are identified and fully explained.

The Ethics Committee wishes you all the best with this research undertaking.

Kind regards,

Prof E Kempen,
CAES Ethics Review Committee Chair

Prof MJ Linington
Executive Dean: College of Agriculture and Environmental Sciences

University of South Africa
Preller Street, Muckleneuk Ridge, City of Tshwane
PO Box 392 UNISA 0003 South Africa
Telephone: +27 12 429 3111 Facsimile: +27 429 12 429 4150
www.unisa.ac.za

APPENDIX 2: LETTERS FROM TRADITIONAL RULERS

TER-MAKURDI PALACE

CHAIRMAN, MAKURDI LOCAL GOVT. TRADITIONAL COUNCIL

P.O. Box 966, Makurdi
Benue State.
e-Mail: suleabenga@yahoo.com

All Correspondence to be Addressed to
His Royal Highness Ter Makurdi II

Ref. No:

Date: 3rd April, 2014.

Roland Clement Abah,
National Agency for the Control of AIDS,
Plot 823 Ralph Shodeinde Street,
Central Area,
Abuja.

<u>RE: Application for Permission to Collect Soil Samples for Research Work</u>

The title of the letter refers.

We received your application for permission for the collection of Soil Samples from selected farms in our communities for your PhD Research Work titled *"An Application of GIS and Remote Sensing Techniques in Land Use Evaluation and Suitability Mapping for Yam, Rice and Cassava in the Lower River Benue Basin in Nigeria."*

We have studied your research proposal and here by grant you permission to meet with owners of selected farms to obtain the soil samples. We hope the output of the research would be circulated to us.

Thank You

HRH Dr. J.D. Sule Abenga JP
Ter Makurdi II
07036004621

HRH CHIEF DR. J. D, SULE ABENGA JP
TER MAKURDI II

TARKA LOCAL GOVERNMENT TRADITIONAL COUNCIL

Ref No: TLG/TC/PUB/VOL1/22

Office of His Royal Highness the Ter Mbakor
Tarka Local Government Traditional Council
Wannune, Benue State.

Ref No:.. **Date:** 09-04-14

Roland Clement Abah,
National Agency for the Control of AIDS,
Plot 823 Ralph Shodeinde Street,
Central Area,
Abuja.

RE: Application for Permission to Collect Soil Samples for Research Work

The title of the letter refers.

We received your application for permission for the collection of Soil Samples from selected farms in our communities for your PhD Research Work titled *"An Application of GIS and Remote Sensing Techniques in Land Use Evaluation and Suitability Mapping for Yam, Rice and Cassava in the Lower River Benue Basin in Nigeria."*

We have studied your research proposal and here by grant you permission to meet with owners of selected farms to obtain the soil samples. We hope the output of the research would be circulated to us.

Thank You

TARKA LG TRADITIONAL COUNCIL
SIGN
WANNUNE

Indyer Akume
Ter Mbakor
08084

APPENDIX 3: APPROVAL BY BENUE ENVIRONMENTAL SANITATION AGENCY

BENUE STATE ENVIRONMENTAL SANITATION AUTHORITY

In replying please quote the date and number of this letter

BENUE STATE ENVIRONMENTAL SANITATION AUTHORITY — CLEANLINESS IS NEXT TO GODLINESS

P.M.B. 102155
Makurdi
Benue State
08076091500

Ref:..

Date: 28th Jan., 2014

The Chairman,
The Ethics Committee,
College of Agriculture
And Environmental Science,
UNISA.

A LETTER OF CONSENT IN FAVOUR OF MR. ABAH ROLAND

We have received a proposal from Mr. **Abah Roland Clement** who intends to pursue a project in Lower River Benue Basin titled; "APPLICATION ON GIS IN LAND EVALUATION" in your Prestigious College, UNISA.

I hereby write to give my consent for him to do so, I declare also that, this study will not have any negative impact on our Environment, please.

Thank you.

MR. EDIGA AKPA
General Manager

Babatunde Oyefeso, DNMC
1st Floor, Phase 1, Rivers House
Plot 83, Ralph Shodeinde Street
CBD, Abuja
+234 802 302 5288
Notary Public of Nigeria
17/2/14

Student No: 51223759

APPENDIX 4: ACCEPTANCE LETTER FROM LABORATORY

DEPARTMENT OF SOIL SCIENCE
UNIVERSITY OF CALABAR
P.M.B. 1115, CALABAR - NIGERIA

Vice - Chancellor
Professor James Epoke
B.Sc.(Nig), M.Sc.(London),
Ph.D.(Lagos)
Tel. 087-232790, 235547
email: vcunical@yahoo.com

Head of Department
Dr. Nkereuwem M. John
B.Agric (Unical); M.Sc & Ph.D. (Ibadan)
Phone: 08061163822
Email: dmmjohn@yahoo.com

FACULTY OF AGRICULTURE
Telephone: Calabar 224748-50
Telegrams: UNICAL

OUR REF: UC/FAG/SS/AD.18

DATE: February 7th, 2014

The Chairman
Ethics Committee
College of Agriculture and Environmental Sciences (CAES)
University of South Africa UNISA
Preller Street
City of Tshwane
SA

Sir,

CAPABILITY AND CAPACITY TO HANDLE SOIL ANALYSES IN OUR LABORATORY

We write to express our capacity to handle all aspects of soil analyses at the instance of your Ph.D student, Roland Clement Abah. Consequently, we have a well equipped laboratory to handle all Soil and Plant Analyses.

We want to thank you for this rare opportunity to serve in this capacity.

Yours faithfully,

Dr. N. M. John
Ag. Head of Department

Babatunde Oyefeso, ChMC
1st Floor, Phase 1, Rivers House
Plot 83, Ralph Shodeinde Street
CBD, Abuja
+234 802 302 5288
Notary Public of Nigeria
17/2/14

Student NO: 51223759

APPENDIX 5: LETTER FROM NIGERIAN METEOROLOGICAL AGENCY

NiMet
Nigerian Meteorological Agency

NIGERIAN METEOROLOGICAL AGENCY

National Weather Forecasting and Climate Research Centre
Bill Clinton Drive, Nnamdi Azikwe International Airport, Abuja, FCT, Nigeria

ISO 9001 2008
AEROMET

Abah Roland Clement
Plot 823 Ralph Shodeinde Street,
Central Area,
Abuja

02/07/2015

FORWARDING OF CLIMATE DATA OF MAKURDI

In further reference to your letter of 09/03/2015 requesting for meteorological data for Makurdi, Benue State, please find attached the requested data.

2. The data comprises monthly maximum and minimum temperature, relative humidity, rainfall and solar radiation for the forty years period.

3. Thank you sir and please accept the best consideration of the DG/ CEO.

Maimuna U. Borno

For Director General

E-mail: info@nimet.gov.ng Website: www.nimet.gov.ng Phone, 092910424 092910425 P.M.B 615 Garki- Abuja

APPENDIX 6: LETTER TO FARMING COOPERATIVE SOCIETIES

Roland Clement Abah
College of Agric and Environmental Science
University of South Africa, UNISA
2nd July, 2014

To ....

....

....

....

Dear Sir/Madam,

TITLE OF RESEARCH PROJECT: An application of GIS and Remote Sensing Techniques in Land Use Evaluation and Suitability Mapping for Yam, Cassava, and Rice in the Lower River Benue Basin, Nigeria.

The aim of this study is to use GIS and remote sensing techniques to evaluate agricultural land use in the lower river Benue basin based on climatic, terrain, and socioeconomic characteristics. The agricultural products which this study will focus on are yam, cassava, and rice. The study will attempt to establish the biophysical and socioeconomic characteristics of the lower river Benue basin; the influence of climate on crop farming in the lower river Benue basin; the trend of yam, cassava, and rice produce in the lower river Benue basin; map existing agricultural land use of the lower river Benue basin using GIS and remote sensing; generate an agricultural suitability map for the cultivation of yam, cassava, and rice in the lower river Benue basin using GIS and remote sensing; improve GIS models to support sustainable agricultural development within a rural setting; and identify impact mitigating strategies for socioeconomic adaptation to climate change, rural-urban migration, population growth, and HIV/AIDS in the lower river Benue basin. This will help relevant policy makers to plan for the sustainable development of agriculture in the lower river Benue basin.

It is in this light that I request for a suitable date to have a focused group discussion with your organisation and administer some questionnaires to your members. I would be very grateful if this request is granted at the shortest possible time to enable proceed with my research.

Thank you and please be assured of my very high regards.

Roland Clement Abah

APPENDIX 7: LIST OF SELECTED FARMING COOPERATIVES IN MAKURDI, TARKA AND GBOKO L.G.As

S/N	NAME	REGISTRATION NUMBER
1	Mbachaver Ikyondo Fadama III Community Cooperative Society	18913
2	Kungwa Wives Multi-Purpose Cooperative Society (Women focused)	19060
3	Uchi Mbakor MCS	19506
4	Dooshima U Kasev Mbachaverkyondo MCS (Women focused)	19174
5	Wannune Community of Handcraft Workers Cooperative	18765
6	Paddy Rice Dealers (PRIDAN) Cooperative Society	19519
7	Ipav Sisters MCS Ltd (Women focused)	19549
8	Great Progressive MCS Ltd	19548
9	United Farmers Cooperative Society Ltd	19559
10	Mar Shangev-Tiev MCS Ltd	19582
11	Mbazun Farmers Cooperative Society Ltd	19528
12	Achusa Concerned Citizen MCS Ltd	19541
13	Royal Farmers Cooperative Society	19596
14	Medissa Multi-Purpose Cooperative Ltd (Women focused)	19544
15	Zenico Multi-Purpose Cooperative Ltd (Women focused)	19543

APPENDIX 8 FDG SAMPLE ATTENDANCE SHEETS

ACTIVITY TITLE: FADAMA III COOPERATIVE

ATTENDANCE SHEET DATE: 17/07/14

S/N	NAME	SEX	CONTACT PHONE NUMBER	SIGN
1	PETER Ayomgeka	Male	08100257204	[illegible]
2	IGBA IGYOOR	M	07066743125	[illegible]
3	PETER KEGH	M	07066135915	[illegible]
4	TERFA-Akpoaha	M	08134381317	[illegible]
5	ORSEE KURA	M	08166961419	[illegible]
6	Aondoylia Tyongi	M	07036278193	A.T
7	AGBUKU TERDUE	M	08145537904	[illegible]
8	AKAA IPAN	M	07032947720	[illegible]
9	TERFA Hembaor	M	08084446170	[illegible]
10	Kuhwayah MICHAEL	M	08169956362	[illegible]
11	ABA IORTIM	M	08135408215	ABA
12	JOSEPH GBER	M	08063822000	[illegible]
13	KATSINA AONDOVER	M	08060507820	[illegible]
14	JOSEPH ATYEM JOCKER	M	08065027795	[illegible]
15	TERYIMA MASE	M	08135610395	[illegible]
16	SHAMGA TERSOO	M	08160281717	[illegible]
17	MSUGHTER AOR	M	08171104054	[illegible]
18	Jimima Hiua	M	08165323802	[illegible]
19	MYBESENTERWASE	F	07059672148	AAF
20	YOUGHUL SUGHIER	M	08105534545	[illegible]
21	AONDAFA MBALAM	F		[illegible]
22	Elizabeth Tyotule	F	07063156616	[illegible]

17/7/14

PAGE ①

ACTIVITY TITLE: DOOSHIMA U KASEV MBA CHAVER IKYONOU

ATTENDANCE SHEET DATE: 18-7-2014

S/N	NAME	SEX	CONTACT PHONE NUMBER	SIGN
1	UDDON CECILIA	F	07056581908	[signature]
2	TSENONGU DORCAS	F	08073575697	[signature]
3	ASHE IBEE	F	08069545132	[signature]
4	Mbawuese Amber	F	08056214367	[signature]
5	Juliana Akuaku	F	08152531037	AK.
6	Esther Nyinongu	F		[signature]
7	KUYISA NDYER	F	08131682709	K.N
8	CILANA ANELEM	F	08187383904	[signature]
9	CHIV NGOUNDU	F	07061096571	[signature]
10	CHAROLINE TYOBAN	F	08059475211	[signature]
11	MBASE ITYOUGH	F	081466212132	M.A
12	NGIAHIUN IORYAASA	F		[signature]
13	VERONICA TSEEN	F	08167609336	V.T
14	MKAANEM NGOUNDU	F	08138551863	[signature]
15	YEMENA TYO	F		Y.T.
16	VICTORIA TSEEN	F	07057448085	TV
17	TYO MBALOFE	F		[signature]
18	HANNA TSAR	F	08168886821	[signature]
19	NDUAR MCHIHI	F		NM.
20	MBASEN ~~AZEEZE~~	F	08096217912 ~~08069346343~~	MA.
21	MBAMEEN AKI	F		[signature]
22	KWAGHKUMA AKAAKOHOL	F		KA

[signature]
18/7/14

APPENDIX 9: SAMPLE OF SIGNED CONSENT FORM

CONSENT

I, the undersigned, ...MBAYASE ADAGHER.................. (full name) have read the above information relating to the project and have also heard the verbal version, and declare that I understand it. I have been afforded the opportunity to discuss relevant aspects of the project with the project leader, and hereby declare that I agree voluntarily to participate in the project.

I indemnify the university and any employee or student of the university against any liability that I may incur during the course of the project.

I further undertake to make no claim against the university in respect of damages to my person or reputation that may be incurred as a result of the project/trial or through the fault of other participants, unless resulting from negligence on the part of the university, its employees or students.

I have received a signed copy of this consent form.

Signature of participant: ....

Signed at .IKYONDU............. on ..18: 7 · 2014...

WITNESSES

1 ...MKPERAI CHILEKOMBU..................

2 Member Kpepii.............................

RESEARCHER

.... / 18/7/14 ....

Consent Form, College of Agriculture and Environmental Sciences, Unisa   Page 3

APPENDIX 10: SOCIOECONOMIC SURVEY QUESTIONNAIRE

SOCIOECONOMIC SURVEY QUESTIONNAIRE

This socioeconomic survey is for research purposes only. The researcher is undertaking a Doctor of Philosophy degree in Environmental Management and solicits your cooperation to establish the socioeconomic situation of certain agricultural interests in your community. Your name and other personal attributes are not required at all. All information volunteered will be treated with confidentiality and stored appropriately.

Settlement/Community………………

L.G.A…………………………………

State…………………………………..

Ethnic Group…………………………

Section A: Respondent's Profile

1. Sex
   - 1.1. Male
   - 1.2. Female

2. Age
   - 2.1 10-19 years
   - 2.2 20-29 years
   - 2.3 30-39 years
   - 2.4 40-49 years
   - 2.5 50-59 years
   - 2.6 60-69 years
   - 2.7 70+ years

3. Marital Status
   - 3.1 Single
   - 3.2 Married
   - 3.3 Divorced/Separated
   - 3.4 Widowed
   - 3.5 Cohabiting

4. Total size of household:………..

5. Age and Sex structure of household members

Age	Male	Female	Total
0-4 years			
5-12			
13-25			
26-40			
41-59			
Above 60			

6. How many of your children presently attend the following categories of schools?

School	Boys	Girls	Total
Primary			
Secondary	`		
Vocational/ Technical			
Tertiary			
Any other			

7. Respondent's highest level of education
   - 7.1 Primary school
   - 7.2 Secondary school
   - 7.3 Vocational/Technical school
   - 7.4 Tertiary school
   - 7.5 No Formal Education

8. Position in Household
   - 8.1 Household Head
   - 8.2 Only Wife
   - 8.3 First Wife
   - 8.4 Second Wife
   - 8.5 First Child
   - 8.6 Relation
   - 8.7 Guardian

9. How long have you lived in the settlement/community?
   - 9.1 0-5 years
   - 9.2 6-10 years
   - 9.3 11-15 years
   - 9.4 16-20 years
   - 9.5 Above 20 years
   - 9.6 Since birth

10. If non-native, please state why you settled in the community

    …………………………………………..

11. Occupation (if more than one, tick as 1st, 2nd, etc.)

    - 11.1Farming
    - 11.2Fishing
    - 11.3Technician/Artisan
    - 11.4Trading
    - 11.5Business/Contractor
    - 11.6Civil Servant
    - 11.7Retired
    - 11.8Student/Apprentice
    - 11.9Unemployed
    - 11.10Others (specify):………

12. Please estimate your level of income in a typical month (Naira)
    - 12.1 Less than 1, 000
    - 12.2 1,000-10,000
    - 12.3 11,000-20,000
    - 12.4 21,000-30,000
    - 12.5 31,000-40,000
    - 12.6 41,000-50,000
    - 12.7 51,000-60,000
    - 12.8 61,000-70,000
    - 12.9 71,000-80,000
    - 12.10 Above 80,000

13. If you are engaged in farming please can you estimate how much you realize?

Occupation	Amount Earned in a Month	Amount Earned in a Year
Crop Farming		
Fishing/Fish pond		
Food processing		
Livestock		

14. What type of house do you own/live in?

14.1 Thatched all through

14.2 Thatched roof/wooden wall

14.3 Thatched roof/mud wall

14.4 Planks/wooden/zinc roof

14.5 Zinc roof/wooden wall

14.6 Zinc roof/mud wall

14.7 Zinc roof/block

14.8 Others (specify)
……………………………

15. Source of domestic water supply

15.1 Rain water

15.2 River/Stream

15.3 Hand-dug well

15.4 Bore-hole

15.5 Others (specify)………………

16. Where do you dispose of your domestic refuse/garbage?

16.1 Backyard of house

16.2 River/Stream

16.3 Community refuse pit

16.4 Burning after gathering

16.5 Dumping in the farm

16.6 Others (specify)……………

17. Where do you dispose of your sewage/faeces?

17.1 Dumping in stream

17.2 Pit latrine

17.3 Water system in the house

17.4 Community bush

17.5 Shared toilet in compound

17.5 Others (specify) ..……………..

Section B: Farm Management

18. What month of the year is important to you and your community for:
18.1Farming ……………..
18.2Fishing ………………
18.3Trading ………………
18.4Festivals ……………..
18.5Market boom……………

19. What environmental resources are important in your community

19.1 Forest resources

19.2 River/Stream water

19.3 Ancestral sites

19.4 Animals

19.5 Others (please specify)……….

20. Please indicate the environmental problems which your community/settlement experiences

Environmental. Problem	Not Sever	Sever	Very Sever
Soil Infertility			
Pest attack/Invasion			
Erosion			
Flooding			
Low yield			
Food scarcity			
Health problems			

21. Has your economic activity (ies) been affected in any way in the past five years or so?
21.1 Yes
21.2 No

22. If yes, in what specific way have you been affected?
………………………………………
………………………………………
………………………………………

23. Please name the major crops cultivated in your community
…………………………………………………
…………………………………………………
…………………………………………………
………

24. What cultivation method is mostly used?

24.1 Purely Traditional
24.2 Semi Mechanized
24.3 Mechanized

25. Please indicate the start and end months for planting and harvesting in your community

Start………………………………

End……………………………….

26. What kind of fertilizer do you use and how many bags in one growing season
Type………………………………

No of Bags/Quantity……………..

27. Do farmers in your community practice irrigation farming?
27.1 Yes

27.2 No

28. If yes, please state the source of water and major crops

…………………………………….

…………………………………….

29. Estimate how much you spend on all inputs in managing your farm in a year (Naira)

29.1 1,000-5,000
29.2 5,000-10,000
29.3 10,000-15,000
29.4 15,000-20,000
29.5 20,000-25,000
29.6 25,000-30,000
29.7 Above 30,000? State estimate.

30. What is the approximate value of your harvest annually?

30.1 Less than 10,000

30.2 10,000-30,000

30.3 30,000-50,000

30.4 50,000-70,000

30.5 70,000-100,000

30.6 Above 100,000? State estimate

31. Please state the size of your farm (s) in hectares

31.1 Less than 1 hectare
31.2 1-5
31.3 5-7
31.4 7-10
31.5 10-15
31.6 15-20
31.7 Above 20 hectares

32. What percentage of your harvest do you sell for cash or barter?

…………………………………………

33. Have you ever disposed your harvest for lack of storage facilities?

33.1 Yes

33.2 No

34. How did you get your farmland?

34.1 Purchased

34.2 Rented

34.3 Leased

34.4 Shared farming

34.5 community farm

34.6 Cooperative farm

34.7 Inherited

34.8 Family land

35. Where do you obtain loans for personal or farming use from?

35.1 Commercial Bank

35.2 Community Bank

35.3 Microfinance Bank

35.4 Community Cooperatives

35.5 Relations

36. What is the range and duration of loan amounts?

Range………………………………

Duration……………………………

37. Have you ever collected farm inputs on loan before?

37.1 Yes

37.2 No

38. If yes, what kind of farm inputs did you collect on loan?

………………………………………

39. What is the average interest rate of the loans you have collected?

………………………………………

40. Can a woman own land in your community (whether purchased or inherited)?

40.1 Yes

40.2 No

41. Can a woman own a farm in your community?

41.1 Yes

41.2 No

42. How far is your farm from your house (please indicate metres or kilometres)?

………………………………………….

43. Where do you process your harvest before storage?

43.1 Commercial mill

43.2 In the farm with hired labour

43.3 Community milling centres

43.4 At home

44. In your opinion, is your harvest increasing or decreasing and by what percentage?

………………………………………

45. What is the most important reason for the increase of decrease?

………………………………………

………………………………………

46. What kind of labour do you use on your farm?

46.1 Family labour

46.2 hired labour

46.3 Labour rotation agreements (help me, I help you)

47. At what time of the year do you require labour the most?

………………………………………

Section C: Infrastructure

48. Do you sell your harvest to middle men or in the market?

………………………………………

49. How far is the nearest market from your farm/house in metres or kilometres?

………………………………………

50. Have you ever met an Agric Extension Worker? If yes, please state when

………………………………………

51. Do you have milling and storage facilities in your community? If yes, please state what you have

………………………………………

52. Please tick what is available in your community

52.1 Electricity

52.2 Pipe borne water

52.3 Tarred Roads

52.4 Television service

52.5 Radio signals

52.6 GSM networks

52.7 Banks

52.8 Markets

52.9 Hospitals (Government)

52.10 Schools (Government)

52.11 Police Station

53. What is the most popular form of transportation in your community?

……………………………………

54. Do you belong to any cooperative or farming association? If yes, please state the name?

…………………………………………………
……………………………

55. Have you benefited anything from the cooperative? If yes please state

…………………………………………………
……………………………

56. What other crops can you cultivate apart from what you cultivate now?

……………………………………….

Why?…………………………………...

57. Do you know what HIV is?

57.1 Yes

57.2 No

58. Do you know any farmer that has HIV or has died from AIDS?

58.1 Yes

58.2 No

59. How do you prevent yourself from HIV?

…………………………………………………
……………………………

60. Have you ever heard of climate change?

60.1 Yes

60.2 No

61. What changes have you noticed about the weather during the planting season in the last ten years?

………………………………………..

………………………………………..

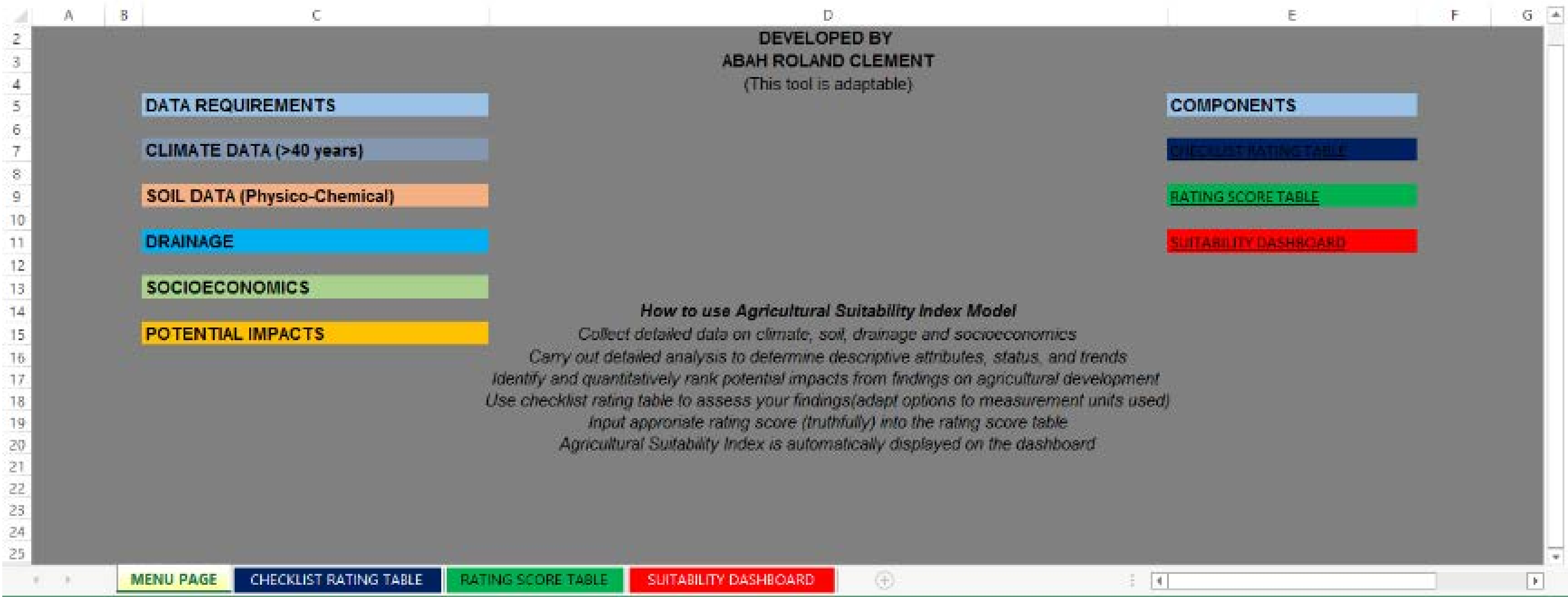
Thank you for your co-operation.

APPENDIX 11: AGRICULTURAL SUITABILITY INDEX MODEL (CHECKLIST & ELECTRONIC TOOL SAMPLE)

	Checklist rating			
Parameters	**10**	**20**	**30**	**40**
What was the average annual rainfall (mm)?	500-1000	>2000	1500-2000	1000-1500
Were there more values above average annual rainfall?		No		Yes
Was the trend of rainfall rising?		Yes	No	Stable
What was the highest daily rainfall recorded (mm)?		<100	>200	100-200
What was the series average for extreme rainfall reoccurrence intervals?	</=5yrs	5</=10yrs	10</=15yrs	10</>20yrs
Was the average annual temperature between 18 to 26 Degrees Celsius?	>26	<18		Yes
Were there more values above average annual temperature?		Yes	No	Stable (+/-2)
What was the trend of temperature in the area?	Rising		Declining	Stable
What was the average annual relative humidity?	80-90%	70-80%	50-60%	60-70%
Were there more values above average annual relative humidity?		Yes	No	Stable (+/-2)
What was the trend of relative humidity?	Rising		Declining	Stable
What was the average annual solar radiation (MJ m-2 day-1)?	10-15	15-20	20-25	25-30
Were there more values above average sunshine hours/solar radiation?		Yes	No	Stable (+/-2)
What was the trend of sunshine hours/solar radiation?		Rising	Declining	Stable
How many days had vapour pressure deficit between 0.55kPa to 0.1kPa	<50	50-100	100-200	>200
What was the most predominant soil type?	Clay	Clay loam	Loam	Loamy sand/Sandy loam
What was the range of soil pH?	<6	>8		6-8.
What was the average value of organic carbon for the series (%)?	<0.5		0.5-0.75	>0.75
What was the average value of Nitrogen for the series (%)?	>0.2			<0.2
What was the average value of Phosphorus for the series (mgkg-1)?		<2.2	2.2-5.4	>5.4
What was the average value of Potassium for the series (cmolkg-1)?	<0.1	0.1-0.2		>0.2
What was the average value of soil Base saturation for the series (%)?	<60	60-70	70-80	>80
What was the range of soil Sodium Absorption Ratio?	>26	18-26	10-18.	<10
What was the range of Exchangeable Sodium Percentage (%)?	>80	50-80	20-50	<20
How many all year round streams are in the area?	<3	3-5.	5-10.	>10

	Checklist rating			
Parameters	**10**	**20**	**30**	**40**
Was there any river with an average discharge of at least 1000 m3/s?	NO			YES
Is the area a coastal area?	YES			NO
What is the nature of surface water found in the area?	Salty/Polluted	Brackish	Marshy/Swamp	Freshwater
What is the average relief of the area?	0-50	50-100	100-150	>150
How often is the area flooded?	Annual	Biannually	Occasionally	Rarely
What is the population density?	Very high	high	low	moderate
What is the predominant level of education?	Informal	Primary	Secondary	Tertiary
What was the predominant refuse disposal type?	Open dump	Gathering and burning	Dumping in pit	Central collection
What was the predominant farming method?	Very local	Traditional	Semi industrial	Industrial
Categorise agricultural yield capacity of population	Very low	Low	High	Very high
Categorise availability of agricultural storage facilities (%)	<20	20-50	50-75	75-100
Categorise annual farm season comfort	Very tedious	tedious	normal	above normal
What was the level of migration?	Very high	high	low	very low
Categorise availability of government schools (%)	<20	20-50	50-75	75-100
Categorise availability of government hospitals (%)	<20	20-50	50-75	75-100
Categorise availability of Police stations (%)	<20	20-50	50-75	75-100
Categorise availability of communication facilities (GSM) (%)	<20	20-50	50-75	75-100
Categorise availability of access roads (%)	<20	20-50	50-75	75-100
Categorise availability of markets within 5 kilometres of household (%)	<20	20-50	50-75	75-100
Categorise the prevalence of armed conflict in the area	Quite high	high	low	rare
What is the current HIV prevalence rate of the state (%)?	>5	5-3.	3-1.	<1
What is the HIV literacy of the population (%)?	<20	20-50	50-75	75-100
Are there adequate HIV services according to respondents?	Very inadequate	Below average	Average	Sufficient
Most of the potential impacts identified were?	Negative	Positive/Negative		Positive
Most of the potential impacts identified were rated?	High	Medium		Low

	Checklist rating			
Parameters	**10**	**20**	**30**	**40**
Agricultural suitability index (%) = (Total score (T)/2000)X100 where T is total cumulative rating score; 2000 is the maximum score possible; and multiplied by 100%	**<25% (Not suitable)**	**25-50% (marginally suitable)**	**50-75% (Suitable)**	**75-100% (Highly suitable)**



(The electronic tool is in the attached CD)

PARAMETERS
Agricultural Suitability Index
Potential Impacts
Socioeconomics
Drainage
Soil
Climate
0
10
20
30
40
50
60
70
80
90
100
PERCENTAGES
MENU PAGE
CHECKLIST RATING TABLE
RATING SCORE TABLE
SUITABILITY DASHBOARD

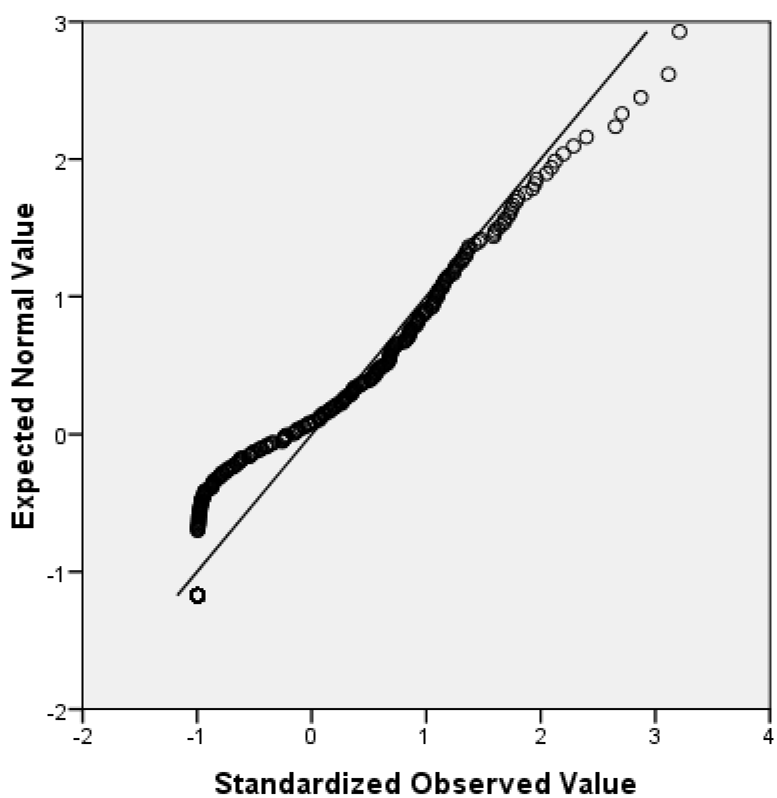
APPENDIX 12: RAINFALL DATA DESCRIPTIVE STATISTICS (1973-2013)

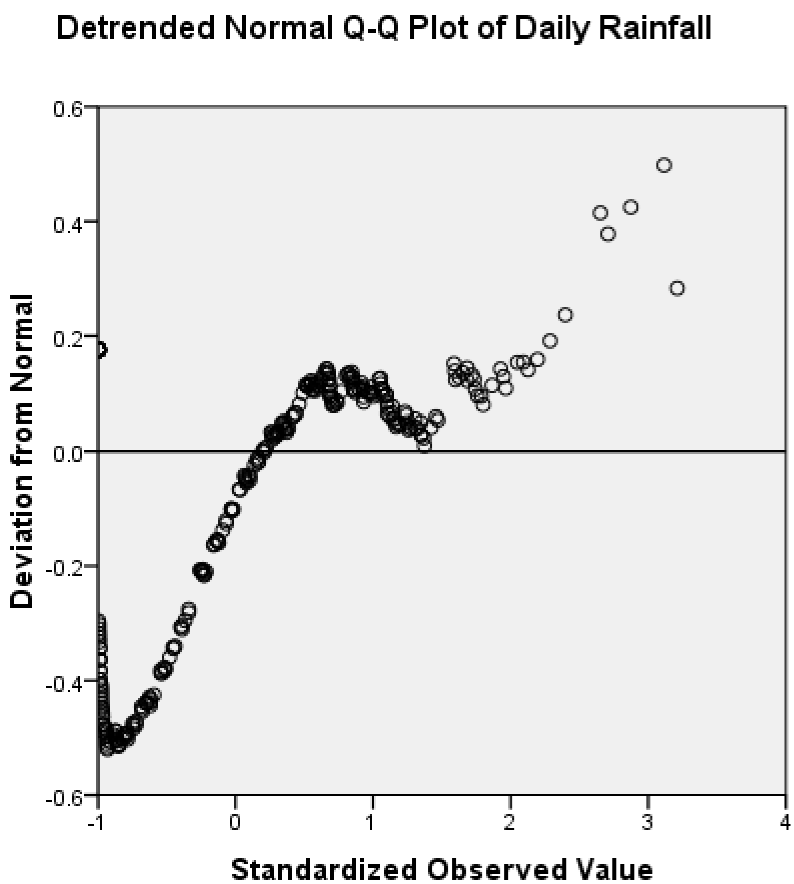
Years	Maximum	Mean		Std. Deviation	Variance	Skewness	
	Statistic	Statistic	Std. Error	Statistic	Statistic	Statistic	Std. Error
1973	110.20	2.4173	.49914	9.53611	90.937	6.927	.128
1974	110.00	3.4318	.55884	10.67654	113.989	5.393	.128
1975	110.20	4.1395	.58811	11.23580	126.243	5.028	.128
1976	71.10	3.4577	.51298	9.81383	96.311	3.691	.128
1977	55.10	3.8071	.39675	7.57988	57.455	2.894	.128
1978	53.30	3.6378	.41711	7.96888	63.503	3.099	.128
1979	71.90	3.0255	.49875	9.52867	90.795	4.391	.128
1980	76.20	3.8948	.58248	11.14356	124.179	3.499	.128
1981	123.70	3.3619	.57341	10.95489	120.010	6.299	.128
1982	71.70	2.6110	.42830	8.18269	66.956	4.700	.128
1983	74.00	2.5488	.49654	9.48629	89.990	4.679	.128
1984	95.00	4.2951	.68856	13.17290	173.525	4.116	.128
1985	76.80	2.7266	.47532	9.08100	82.465	5.055	.128
1986	125.30	3.3088	.55376	10.57950	111.926	5.906	.128
1987	85.30	3.3093	.54747	10.45933	109.397	4.552	.128
1988	45.20	2.2948	.36698	7.02076	49.291	3.834	.128
1989	83.30	3.4090	.55775	10.65576	113.545	4.199	.128
1990	100.70	3.0710	.51687	9.87480	97.512	5.134	.128
1991	56.60	3.0753	.45191	8.63372	74.541	3.605	.128
1992	70.50	2.6577	.40291	7.70819	59.416	4.385	.128
1993	80.30	3.3345	.55871	10.67406	113.936	4.289	.128
1994	61.70	2.6663	.43207	8.25467	68.140	4.197	.128
1995	70.60	3.2112	.51312	9.80320	96.103	4.221	.128
1996	86.30	3.6172	.55521	10.62178	112.822	4.142	.128
1997	89.50	3.7296	.59148	11.30030	127.697	4.506	.128
1998	92.90	4.2126	.70101	13.39275	179.366	4.036	.128
1999	119.30	4.4304	.67125	12.82420	164.460	4.286	.128
2000	149.30	3.2060	.62778	12.01007	144.242	7.073	.128
2001	51.30	2.9479	.44278	8.45938	71.561	3.375	.128
2002	96.80	3.4882	.54200	10.35485	107.223	4.378	.128
2003	54.70	2.0863	.32634	6.23471	38.872	4.138	.128

APPENDIX 12: RAINFALL DATA DESCRIPTIVE STATISTICS (1973-2013)

Years	Maximum	Mean		Std. Deviation	Variance	Skewness	
	Statistic	Statistic	Std. Error	Statistic	Statistic	Statistic	Std. Error
2004	65.80	2.6164	.44517	8.51662	72.533	4.265	.128
2005	70.60	2.3871	.39082	7.46660	55.750	4.724	.128
2006	94.70	3.6795	.58237	11.12614	123.791	4.601	.128
2007	76.30	3.6710	.54380	10.38924	107.936	3.750	.128
2008	66.40	2.6279	.41178	7.87772	62.059	4.342	.128
2009	105.40	3.8562	.61710	11.78969	138.997	5.087	.128
2010	73.50	3.1400	.49872	9.52804	90.784	4.172	.128
2011	79.80	3.1178	.51924	9.92014	98.409	4.223	.128
2012	98.40	4.0074	.62611	11.97821	143.477	4.541	.128
2013	77.10	3.5485	.53516	10.22419	104.534	4.019	.128

Normal Q-Q Plot of Daily Rainfall



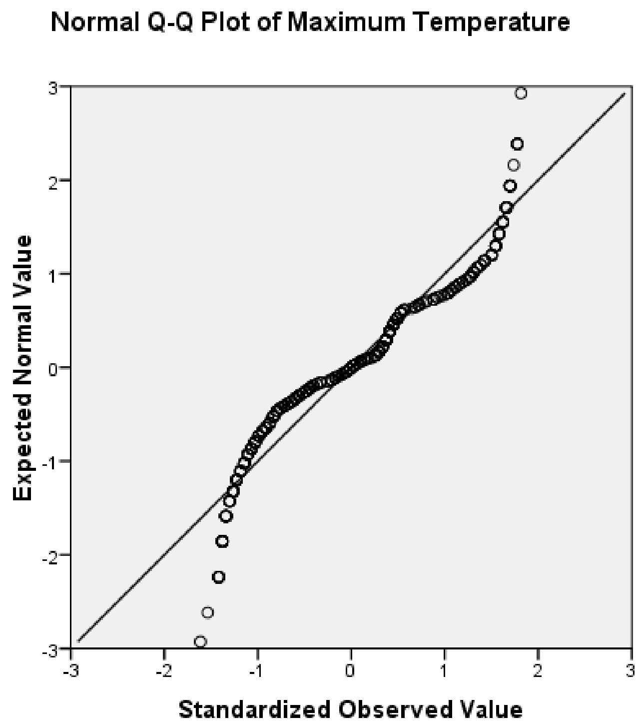

Detrended Normal Q-Q Plot of Daily Rainfall
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
Deviation from Normal
-1
0
1
2
3
4
Standardized Observed Value

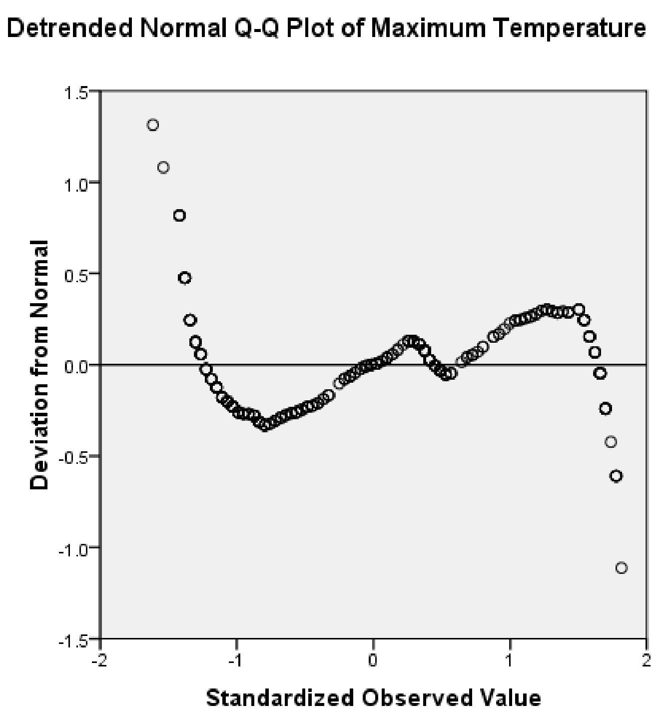
APPENDIX 13: DESCRIPTIVE STATISTICS OF MAXIMUM TEMPERATURE FOR MAKURDI (1973-2014)

	N	Range	Minimum	Maximum	Mean	Std. Deviation	Variance	Skewness	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error
1973	365	16.00	25.00	41.00	34.0110	3.05173	9.313	.002	.128
1974	365	15.00	25.00	40.00	32.7671	2.80757	7.882	.243	.128
1976	366	15.00	24.00	39.00	32.6093	2.84154	8.074	-.049	.128
1979	365	14.00	25.00	39.00	32.9973	2.85405	8.146	.110	.128
1980	366	14.00	25.00	39.00	32.9298	3.06527	9.396	.075	.128
1981	365	15.00	25.00	40.00	33.0493	3.10844	9.662	-.069	.128
1982	365	14.00	25.00	39.00	32.9315	2.95817	8.751	.010	.128
1983	365	15.00	26.00	41.00	33.6192	3.55029	12.605	.259	.128
1984	366	15.00	25.00	40.00	33.1667	2.85870	8.172	.249	.128
1985	365	18.00	23.00	41.00	33.0110	2.80793	7.884	-.081	.128
1986	365	14.00	26.00	40.00	32.9671	2.86203	8.191	.152	.128
1987	365	14.00	26.00	40.00	32.9699	2.85678	8.161	.161	.128
1988	366	16.00	25.00	41.00	33.4645	3.19890	10.233	-.020	.128
1989	365	16.00	25.00	41.00	33.1205	3.06374	9.387	.137	.128
1990	365	16.00	25.00	41.00	33.4740	3.37207	11.371	.135	.128
1991	365	15.00	25.00	40.00	33.1890	2.87369	8.258	.251	.128
1992	366	16.00	25.00	41.00	33.0301	3.00259	9.016	.184	.128
1993	365	14.00	25.00	39.00	33.4981	2.95529	8.734	-.116	.128
1994	365	17.00	23.00	40.00	33.3233	3.10788	9.659	.053	.128
1995	365	15.00	25.00	40.00	33.6411	3.13084	9.802	-.070	.128
1996	366	16.00	24.00	40.00	33.5437	3.26408	10.654	-.157	.128

APPENDIX 13: DESCRIPTIVE STATISTICS OF MAXIMUM TEMPERATURE FOR MAKURDI (1973-2014)

	N	Range	Minimum	Maximum	Mean	Std. Deviation	Variance	Skewness	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error
1997	365	15.00	24.00	39.00	33.1671	2.71281	7.359	-.211	.128
1998	365	18.00	24.00	42.00	34.1178	3.41616	11.670	.132	.128
1999	365	14.00	25.00	39.00	33.3945	3.05768	9.349	-.099	.128
2000	366	16.00	25.00	41.00	33.5874	3.16431	10.013	-.034	.128
2001	365	15.00	25.00	40.00	33.6411	3.27494	10.725	-.250	.128
2002	365	16.00	24.00	40.00	33.3178	2.97477	8.849	-.071	.128
2003	365	14.00	26.00	40.00	33.9479	3.09481	9.578	-.041	.128
2004	366	16.00	25.00	41.00	33.6803	3.22388	10.393	.053	.128
2005	365	15.00	26.00	41.00	33.9041	3.26135	10.636	.050	.128
2006	365	15.00	26.00	41.00	33.6384	3.01838	9.111	-.036	.128
2007	365	16.00	24.00	40.00	33.3753	3.13242	9.812	.174	.128
2008	366	15.40	25.00	40.40	33.3019	2.83315	8.027	.011	.128
2009	365	15.00	26.00	41.00	33.5205	2.99409	8.965	.080	.128
2010	365	14.70	26.50	41.20	33.9249	3.42413	11.725	.160	.128
2011	365	15.00	24.30	39.30	33.0384	2.98867	8.932	-.208	.128
2012	366	15.90	24.40	40.30	32.8847	3.06828	9.414	.081	.128
2013	365	15.10	24.50	39.60	33.1307	3.03248	9.196	-.023	.128
2014	365	13.60	25.60	39.20	33.2156	2.83546	8.040	-.096	.128


Normal Q-Q Plot of Maximum Temperature
Expected Normal Value
Standardized Observed Value
3
2
1
0
-1
-2
-3


Detrended Normal Q-Q Plot of Maximum Temperature
Deviation from Normal
Standardized Observed Value
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
-2
-1
0
1
2

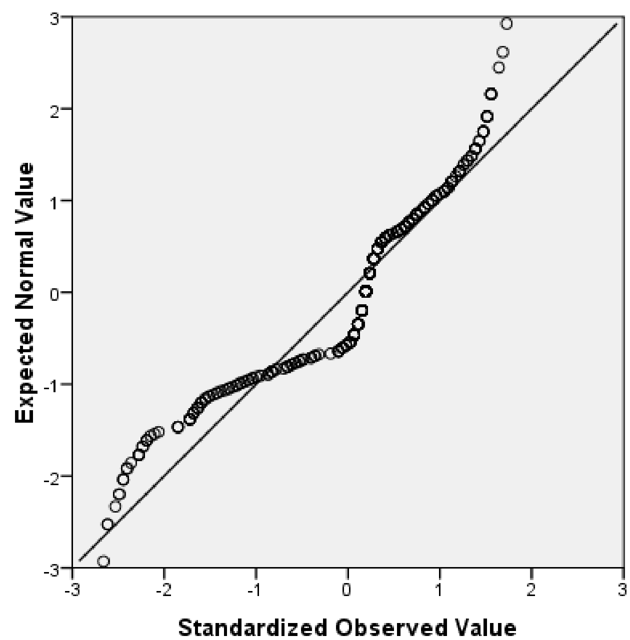
APENDIX 14: DESCRIPTIVE STATISTICS OF MINIMUM TEMPERATURE FOR MAKURDI (1973-2014)

	N	Range	Minimum	Maximum	Mean	Std. Deviation	Variance	Skewness	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error
1973	365	18.00	10.00	28.00	22.4822	3.16624	10.025	-1.098	.128
1974	365	16.00	11.00	27.00	21.5562	3.27667	10.737	-.993	.128
1976	366	14.00	13.00	27.00	22.1530	2.63768	6.957	-1.167	.128
1979	365	17.00	12.00	29.00	22.0926	3.55449	12.634	-1.087	.128
1980	366	15.00	14.00	29.00	22.5978	2.99000	8.940	-.821	.128
1981	365	18.00	13.00	31.00	22.1370	3.58306	12.838	-.645	.128
1982	365	16.00	12.00	28.00	22.2712	3.08940	9.544	-.780	.128
1983	365	16.00	13.00	29.00	22.6822	3.00692	9.042	-.489	.128
1984	366	17.00	11.00	28.00	22.0820	3.28448	10.788	-.860	.128
1985	365	16.00	12.00	28.00	22.3397	2.70626	7.324	-.842	.128
1986	365	16.00	11.00	27.00	22.5534	3.15889	9.979	-1.002	.128
1987	365	18.00	11.00	29.00	22.5507	3.58963	12.885	-.908	.128
1988	366	17.00	12.00	29.00	22.4617	2.94468	8.671	-.413	.128
1989	365	16.00	12.00	28.00	21.5890	3.57508	12.781	-.717	.128
1990	365	15.00	14.00	29.00	22.7452	2.36812	5.608	-.555	.128
1991	365	16.00	12.00	28.00	22.4493	3.08680	9.528	-.893	.128
1992	366	16.00	12.00	28.00	21.9481	3.44746	11.885	-.846	.128
1993	365	13.00	14.00	27.00	22.4932	2.96372	8.784	-.777	.128
1994	365	15.00	13.00	28.00	22.3616	3.33161	11.100	-.928	.128
1995	365	15.00	14.00	29.00	22.2219	3.45100	11.909	-.673	.128

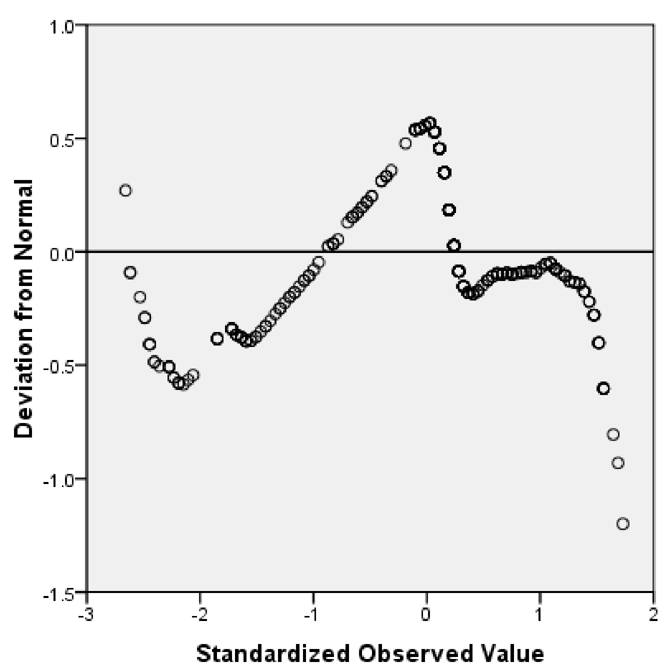
APENDIX 14: DESCRIPTIVE STATISTICS OF MINIMUM TEMPERATURE FOR MAKURDI (1973-2014)

	N	Range	Minimum	Maximum	Mean	Std. Deviation	Variance	Skewness	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error
1996	366	17.00	11.00	28.00	22.1776	3.63071	13.182	-.944	.128
1997	365	15.00	13.00	28.00	22.3890	2.89408	8.376	-1.103	.128
1998	365	15.00	14.00	29.00	23.0493	3.04504	9.272	-.787	.128
1999	365	16.00	12.00	28.00	22.8137	3.00518	9.031	-1.155	.128
2000	366	15.00	13.00	28.00	22.1995	2.99060	8.944	-.560	.128
2001	365	15.00	13.00	28.00	22.1534	3.39093	11.498	-.705	.128
2002	365	16.00	12.00	28.00	22.2877	3.29118	10.832	-.683	.128
2003	365	19.00	10.00	29.00	22.9808	3.34585	11.195	-1.082	.128
2004	366	15.00	14.00	29.00	22.7350	2.94483	8.672	-.869	.128
2005	365	14.00	15.00	29.00	23.3123	3.14677	9.902	-.681	.128
2006	365	17.00	12.00	29.00	22.8959	3.60328	12.984	-1.057	.128
2007	365	17.00	12.00	29.00	22.6521	3.03134	9.189	-.855	.128
2008	366	16.20	12.00	28.20	22.6388	2.72089	7.403	-.746	.128
2009	365	16.00	11.00	27.00	22.3699	3.18697	10.157	-1.169	.128
2010	365	16.60	12.40	29.00	23.0981	3.57608	12.788	-1.143	.128
2011	365	16.60	11.40	28.00	21.6668	3.72861	13.903	-.922	.128
2012	366	15.00	10.80	25.80	20.6642	2.91165	8.478	-1.142	.128
2013	365	12.50	13.00	25.50	21.4748	2.64471	6.994	-1.197	.128
2014	365	16.40	12.80	29.20	21.7945	2.75966	7.616	-1.046	.128

Normal Q-Q Plot of Minimum Temperature



Detrended Normal Q-Q Plot of Minimum Temperature



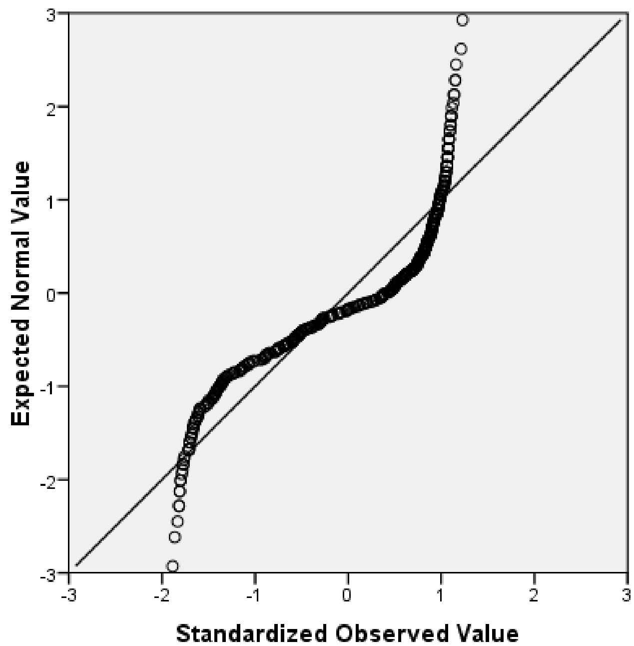
APPENDIX 15: DESCRIPTIVE STAT. OF RELATIVE HUMIDITY IN MAKURDI (1974-2008)

	N	Range	Minimum	Maximum	Mean	Std. Deviation	Variance	Skewness	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error
1974	365	73.50	23.00	96.50	70.0671	15.51697	240.776	-.887	.128
1975	288	75.00	22.00	97.00	68.6198	17.28856	298.894	-.903	.144
1976	366	69.50	26.00	95.50	73.7158	10.68919	114.259	-1.172	.128
1977	123	63.50	25.50	89.00	59.0244	12.65718	160.204	-.641	.218
1978	365	69.00	26.50	95.50	70.4986	13.43337	180.455	-.612	.128
1979	365	77.50	19.50	97.00	69.3000	16.05514	257.768	-.915	.128
1980	366	67.00	29.00	96.00	70.3497	14.69356	215.901	-.674	.128
1981	365	80.00	18.00	98.00	68.8425	16.97220	288.055	-.959	.128
1982	365	83.00	13.50	96.50	64.3795	21.04464	442.877	-.851	.128
1983	365	86.00	11.50	97.50	68.1616	17.23612	297.084	-1.017	.128
1984	366	76.00	19.50	95.50	65.4863	17.13407	293.577	-.949	.128
1985	365	70.00	26.00	96.00	68.4370	13.97383	195.268	-.870	.128
1986	365	76.50	18.50	95.00	66.5425	14.46639	209.276	-.524	.128
1987	365	72.50	23.00	95.50	68.6205	15.80254	249.720	-.696	.128
1988	366	79.00	18.50	97.50	64.1831	18.62972	347.066	-.540	.128
1989	365	80.00	16.50	96.50	67.5740	17.45146	304.554	-1.190	.128
1990	365	71.50	25.00	96.50	69.4959	14.21419	202.043	-.888	.128
1991	365	79.50	15.00	94.50	67.1452	16.98050	288.337	-1.012	.128
1992	366	75.50	19.00	94.50	66.2090	16.50739	272.494	-.965	.128
1993	365	83.50	15.00	98.50	64.7329	17.08847	292.016	-.769	.128
1994	365	78.00	17.50	95.50	64.9137	16.98092	288.352	-.801	.128

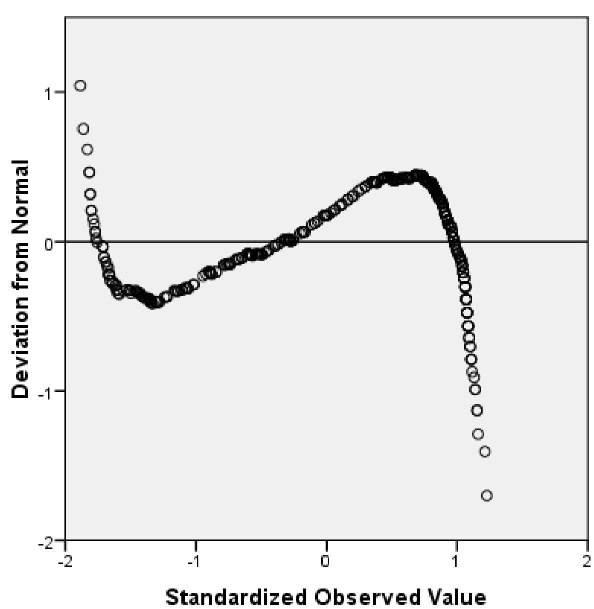
APPENDIX 15: DESCRIPTIVE STAT. OF RELATIVE HUMIDITY IN MAKURDI (1974-2008)

	N	Range	Minimum	Maximum	Mean	Std. Deviation	Variance	Skewness	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error
1995	365	78.00	20.00	98.00	68.2110	13.53732	183.259	-.522	.128
1996	366	81.00	15.00	96.00	65.9454	18.29869	334.842	-1.107	.128
1997	365	81.50	18.00	99.50	65.7863	17.79275	316.582	-.817	.128
1998	365	75.50	20.00	95.50	68.2192	14.17008	200.791	-.915	.128
1999	365	77.50	17.50	95.00	65.7123	17.76114	315.458	-.889	.128
2000	366	74.50	18.00	92.50	66.8333	15.60320	243.460	-.963	.128
2001	365	66.50	28.00	94.50	69.7904	14.31799	205.005	-.789	.128
2002	365	78.50	17.00	95.50	67.0951	15.79976	249.633	-.895	.128
2003	365	74.40	19.30	93.70	68.4019	17.08973	292.059	-1.160	.128
2004	366	81.00	14.70	95.70	68.4205	15.33012	235.012	-1.136	.128
2005	365	71.00	23.30	94.30	70.3962	13.42991	180.362	-.626	.128
2006	365	75.00	22.00	97.00	68.6671	17.65896	311.839	-.946	.128
2007	306	75.00	22.00	97.00	72.0114	14.69691	215.999	-1.545	.139
2008	334	69.60	23.70	93.30	72.5853	12.96283	168.035	-1.040	.133

Normal Q-Q Plot of Relative humidity



Detrended Normal Q-Q Plot of Relative humidity



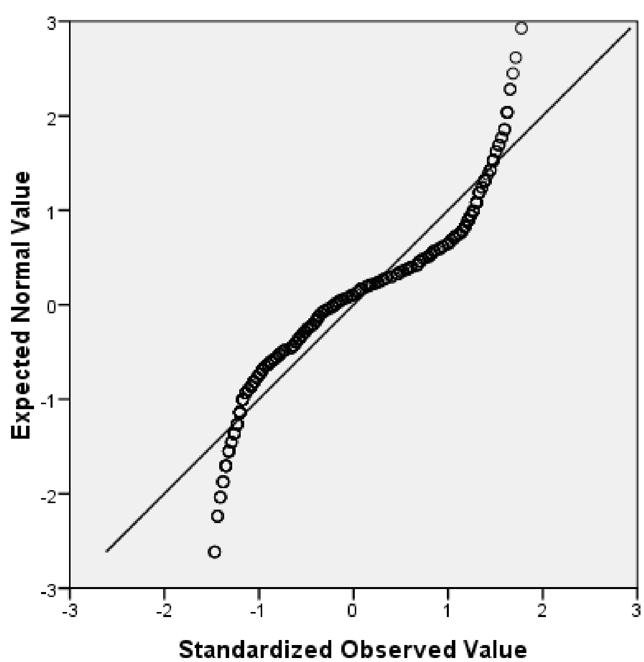
Appendix 16: Descriptive Statistics of Solar Radiation for Makurdi (1973-2014)

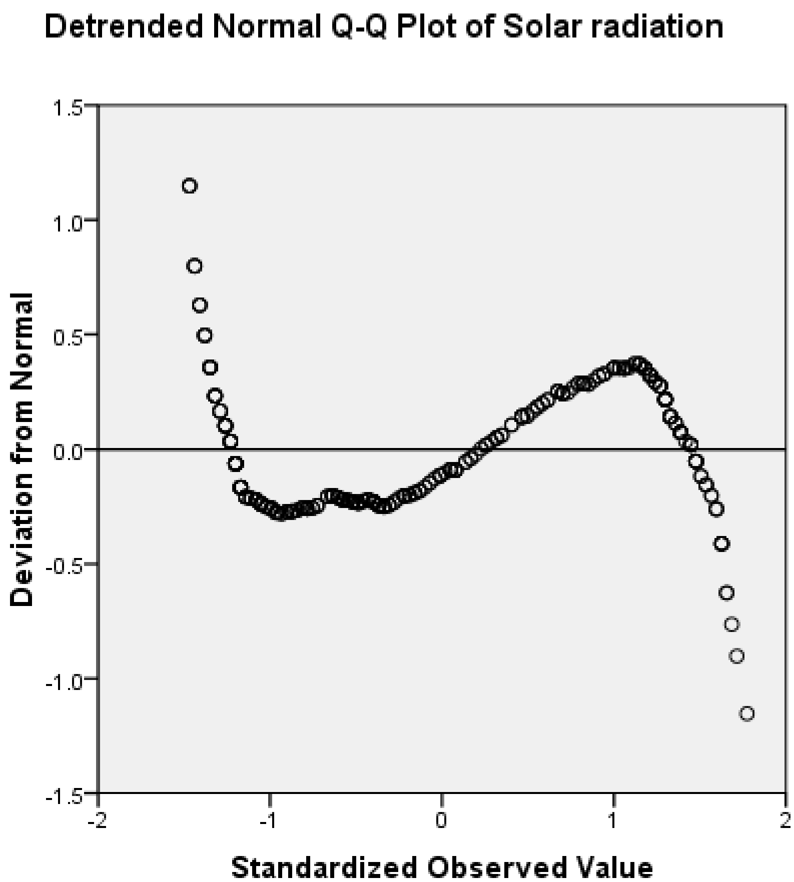
	N	Range	Minimum	Maximum	Mean	Std. Deviation	Variance	Skewness
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic
1973	365	21.00	9.90	30.90	20.6808	3.88448	15.089	.303
1974	365	21.60	8.20	29.80	20.3277	4.06220	16.501	.366
1975	365	17.60	12.30	29.90	20.5252	3.62561	13.145	.275
1976	366	24.70	6.00	30.70	19.6697	3.71418	13.795	.216
1977	366	16.50	11.80	28.30	20.1038	3.38382	11.450	.188
1978	366	20.60	8.90	29.50	19.8850	3.48093	12.117	.215
1979	365	22.70	8.10	30.80	19.9838	4.33376	18.781	.510
1980	366	22.80	6.20	29.00	19.4981	4.04991	16.402	.310
1981	365	21.20	8.10	29.30	19.9989	4.33008	18.750	.146
1982	365	19.40	9.90	29.30	19.8238	4.03920	16.315	.344
1983	365	19.80	10.00	29.80	20.1315	4.04427	16.356	.077
1984	366	18.90	12.40	31.30	20.2560	3.78579	14.332	.590
1985	365	24.90	5.70	30.60	19.8479	4.00805	16.064	.456
1986	365	18.00	11.50	29.50	19.6268	3.70265	13.710	.356
1987	365	23.40	5.80	29.20	19.5005	4.39706	19.334	.157
1988	366	24.70	6.20	30.90	20.1790	3.82285	14.614	.122
1989	365	22.20	8.50	30.70	20.5773	4.43872	19.702	.145
1990	365	23.60	6.20	29.80	19.9058	4.21749	17.787	.340
1991	365	23.30	6.40	29.70	19.9079	3.96411	15.714	.297
1992	366	22.20	8.60	30.80	20.1372	4.53202	20.539	.395
1993	365	22.30	8.30	30.60	20.2014	3.78867	14.354	.254
1994	365	21.30	8.10	29.40	20.0641	4.25220	18.081	.083
1995	365	24.40	5.80	30.20	20.4781	4.36490	19.052	.067
1996	366	26.10	5.70	31.80	20.3623	4.51715	20.405	.136
1997	365	23.90	6.30	30.20	19.9277	4.19238	17.576	.309
1998	365	23.10	8.10	31.20	20.2175	4.12829	17.043	.155
1999	365	20.90	8.40	29.30	19.7767	3.71716	13.817	.229
2000	366	23.00	8.10	31.10	20.4893	4.28574	18.368	.265
2001	365	24.40	5.80	30.20	20.4841	4.65038	21.626	-.005
2002	365	20.80	8.50	29.30	20.1345	4.17730	17.450	.207

Appendix 16: Descriptive Statistics of Solar Radiation for Makurdi (1973-2014)

	N	Range	Minimum	Maximum	Mean	Std. Deviation	Variance	Skewness
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic
2003	365	23.20	8.10	31.30	20.1047	4.06703	16.541	.357
2004	366	23.50	5.70	29.20	20.0492	4.30399	18.524	-.046
2005	365	19.50	8.90	28.40	19.7847	3.90131	15.220	.019
2006	365	24.10	5.70	29.80	19.8767	3.93666	15.497	.417
2007	365	24.40	6.10	30.50	19.8378	4.33947	18.831	.241
2008	366	24.00	5.80	29.80	19.8669	3.81504	14.555	.072
2009	365	21.80	8.10	29.90	20.2910	3.71205	13.779	.425
2010	365	21.00	9.00	30.00	19.9310	4.24564	18.025	.368
2011	365	21.80	8.50	30.30	20.4359	4.11004	16.892	.302
2012	366	21.20	8.80	30.00	21.3596	3.46041	11.974	.141
2013	365	19.60	10.20	29.80	20.7649	3.91996	15.366	.024
2014	365	23.60	6.40	30.00	20.5375	3.87417	15.009	.227

Normal Q-Q Plot of Solar radiation





Detrended Normal Q-Q Plot of Solar radiation
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
Deviation from Normal
-2
-1
0
1
2
Standardized Observed Value

APPENDIX 17: DETAILED SOIL RESULTS

APPENDIX 17.1: PHYSICAL CHARACTERISTICS OF SOIL SAMPLED WITHIN THREE ARABLE FARMLAND SITES IN MAKURDI, BENUE STATE-NIGERIA

			GPS COORDINATES		PARTICLE SIZE DISTRIBUTION (%)			TEXTUAL	
FARM SITE	CROP	DEPTH	NORTHINGS	EASTINGS	SAND	SILT	CLAY	CLASS (USDA)	SILT/CLAY RATIO
MKD C1	CASSAVA	0-15	7.835757	8.5862	87.00	8.00	5.00	Ls	1.60
		15-30			77.00	13.00	10.00	Sl	1.30
MKD C2	CASSAVA	0-15	7.835332	8.5861	85.00	7.00	8.00	Ls	0.88
		15-30			74.00	15.00	11.00	Sl	1.36
MKD R1	RICE	0-15	7.69826	8.53779	74.00	22.00	4.00	Ls	5.50
		15-30			72.00	24.00	4.00	Sl	6.00
MKD R2	RICE	0-15	7.698551	8.53746	72.00	20.00	8.00	Sl	2.50
		15-30			70.00	21.00	9.00	Sl	2.33
MKD Y1	YAM	0-15	7.8367	8.5874	84.00	13.00	3.00	Ls	4.33
		15-30			82.00	15.00	3.00	Ls	5.00
MKD Y2	YAM	0-15	7.838	8.58759	82.00	11.00	7.00	Ls	1.57
		15-30			80.00	12.00	8.00	Ls	1.50

MKD = Makurdi Farm sites; GPS = Global Positioning System; USDA = United States Department of Agriculture; C1,2 = Cassava;R1,2 = Rice; Y1,2 Ls = Loamy sand; Sl = sandy loam

APPENDIX 17.2: CHEMICAL CHARACTERISTICS OF SOILS SAMPLED WITHIN THREE ARABLE FARMLAND SITES IN MAKURDI; BENUE STATE - NIGERIA.

					Total		Exchangeable bases				Exchange Acidity (cmolkg-1)			Base	Fertility indices		
Farm site	Crop	Depth (cm)	pH (H20)	Organic C (%)	N (%)	Avail P (Mg/kg)	Ca	Mg	K	Na	AL3+	H+	ECEC (cmolkg-1)	saturation (%)	Ca: Mg	Mg: K	C: N
MKD C1	CASSAVA	0-15	5.8	0.44	0.03	42.37	3.60	2.40	0.08	0.06	0.16	0.80	7.10	87.00	1.50	30.00	15
		15-30	6.0	0.46	0.03	1.87	2.80	2.00	0.09	0.06	0.24	0.64	5.83	85.00	1.40	22.22	15
MKD C2	CASSAVA	0-15	5.6	0.48	0.03	2.61	2.11	2.25	0.06	0.06	0.10	0.50	5.08	88.00	0.94	37.50	16
		15-30	5.8	0.52	0.04	2.01	2.82	2.14	0.11	0.04	0.20	0.66	5.97	86.00	1.32	19.45	13
MKD R1	RICE	0-15	5.5	0.44	0.03	0.50	2.60	3.00	0.09	0.07	0.40	0.52	6.69	86.00	0.87	33.33	15
		15-30	5.8	0.50	0.04	0.62	2.40	2.00	0.08	0.06	0.20	0.76	5.50	82.00	1.20	25.00	13
MKD R2	RICE	0-15	5.7	0.46	0.03	1.62	1.86	2.01	0.08	0.06	0.12	0.60	4.73	85.00	0.93	25.13	15
		15-30	5.9	0.54	0.03	1.08	2.12	3.14	0.07	0.07	0.26	0.69	6.35	85.00	0.68	44.86	18
MKD Y1	YAM	0-15	6.0	0.58	0.04	1.75	3.60	2.20	0.10	0.07	0.16	0.48	6.27	90.00	1.64	22.00	15
		15-30	6.3	0.58	0.04	0.62	2.20	1.40	0.07	0.04	0.20	0.60	4.51	82.00	1.57	20.00	15
MKD Y2	YAM	0-15	6.0	0.64	0.03	2.62	3.55	2.14	0.15	0.07	0.14	0.42	6.47	91.00	1.66	14.27	21
		15-30	6.5	0.60	0.04	2.50	3.08	2.21	0.09	0.05	0.26	0.64	6.33	86.00	1.39	24.56	15

APPENDIX 17.3: MICRONUTRIENT (MgKg-1) STATUS OF SOILS SAMPLED WITHIN THREE ARABLE FARMLAND SITES IN MAKURDI; BENUE STATE - NIGERIA.

Farm site	Crop	Depth (cm)	Fe	Mn	Ni	V	Co	Mo
MKD C1	CASSAVA	0-15	900.48	13.72	44.80	0.16	0.73	2.29
		15-30	495.26	15.86	42.80	0.08	0.69	1.89
MKD C2	CASSAVA	0-15	816.21	10.10	29.21	0.10	0.64	2.11
		15-30	618.10	13.24	20.06	0.05	0.55	1.04
MKD R1	RICE	0-15	675.36	22.18	39.60	0.12	0.85	1.65
		15-30	371.45	25.38	35.40	0.00	0.67	2.15
MKD R2	RICE	0-15	601.17	20.04	29.14	0.09	0.70	1.40
		15-30	524.10	28.16	21.11	0.01	0.51	1.21
MKD Y1	YAM	0-15	388.22	24.28	50.60	0.16	9.44	2.26
		15-30	292.66	30.14	48.90	0.04	0.45	2.24
MKD Y2	YAM	0-15	381.10	20.19	50.16	0.12	7.21	2.01
		15-30	213.18	26.26	39.28	0.07	0.33	2.08

APPENDIX 17.4: PHYSICAL CHARACTERISTICS OF SOIL SAMPLED WITHIN THREE ARABLE FARMLAND SITES IN TARKA, BENUE STATE-NIGERIA

FARM SITE	CROP	DEPTH	GPS COORDINATES NORTHINGS	GPS COORDINATES EASTINGS	PARTICLE SIZE DISTRIBUTION (%) SAND	SILT	CLAY	TEXTURAL CLASS (USDA)	SILT/CLAY RATIO
TRK C1	CASSAVA	0-15	7.66213	8.83203	68.00	29.00	3.00	sl	9.67
		15-30			68.00	28.00	4.00	sl	7.00
TRKC2	CASSAVA	0-15	7.66526	8.83358	68.00	22.00	10.00	sl	2.20
		15-30			62.00	24.00	14.00	sl	1.71
TRKR1	RICE	0-15	7.66737	8.83908	54.00	41.00	5.00	sl	8.20
		15-30			54.00	40.00	6.00	sl	6.67
TRKR2	RICE	0-15	7.66613	8.83974	56.00	38.00	6.00	sl	6.33
		15-30			52.00	41.00	7.00	l	5.86
TRKY1	YAM	0-15	7.661	8.8379	57.00	39.00	4.00	sl	9.75
		15-30			75.00	12.00	13.00	sl	0.92
TRKY2	YAM	0-15	7.66016	8.84212	68.00	26.00	6.00	sl	4.33
		15-30			62.00	28.00	10.00	sl	2.80

TRKC1 = Tarka cassava farm sites1; TRKC2 = Tarka cassava farm site 2; TRKR1 = Tarka rice farm site 1; TRKR2 = Tarka rice farm site 2; TRKY1 = Tarka yam farm site 1; TRKY2 = Tarka yam farm site 2; Sl = sandy loam; L = loam; GPS = Global Positioning System

APPENDIX 17.5: CHEMICAL CHARACTERISTICS OF SOILS SAMPLED WITHIN THREE ARABLE FARMLAND SITES IN TARKA; BENUE STATE - NIGERIA.

Farm site	Crop	Depth (cm)	pH (H20)	Organic C (%)	Total N (%)	Avail P (Mg/kg)	Exchangeable bases Ca	Mg	K	Na	Exchange Acidity (cmolkg-1) AL3+	H+	ECEC (cmolkg-1)	Base saturation (%)	Fertility indices Ca: Mg	Mg: K	C: N
TRKC1	Cassava	0-15	6.1	0.68	0.05	1.62	3.40	1.40	0.08	0.06	0.16	0.52	5.62	88.00	2.43	17.50	14
		15-30	6.0	0.54	0.04	1.00	3.20	1.80	0.07	0.04	0.24	0.68	6.03	85.00	1.78	25.71	14
TRKC2	Cassava	0-15	6.0	0.70	0.05	1.86	2.68	1.36	0.07	0.05	0.12	0.50	4.78	87.00	1.97	19.43	14
		15-30	6.1	0.66	0.04	1.01	3.40	1.86	0.05	0.04	0.22	0.64	6.21	86.00	1.83	37.20	17
TRKR1	Rice	0-15	5.4	2.05	0.18	20.75	2.00	1.20	0.06	0.04	0.16	0.74	4.20	79.00	1.67	20.00	11
		15-30	5.5	1.77	0.15	2.25	1.800	1.20	0.09	0.06	1.92	1.48	6.55	48.00	1.50	13.33	12
TRKR2	Rice	0-15	5.5	2.01	0.08	20.18	2.03	1.08	0.05	0.05	0.15	0.70	4.06	79.00	1.88	21.60	25
		15-30	5.3	1.68	0.07	2.43	1.04	1.21	0.07	0.06	1.28	1.40	5.06	47.00	0.86	17.29	24
TRKY1	Yam	0-15	5.3	0.86	0.07	0.87	3.60	1.80	0.08	0.07	0.00	1.16	6.71	85.00	2.00	22.50	12
		15-30	5.5	0.90	0.08	0.87	3.60	1.80	0.09	0.07	0.16	0.76	6.48	86.00	2.00	20.00	11
TRKY2	Yam	0-15	5.5	0.81	0.10	0.89	3.86	1.49	0.08	0.05	0.01	1.03	6.52	84.00	2.59	18.63	8
		15-30	5.6	0.87	0.07	0.94	3.61	1.48	0.06	0.07	0.09	0.64	5.95	88.00	2.44	24.67	12

APPENDIX 17.6: MICRONUTRIENT (MgKg-1) STATUS OF SOILS SAMPLED WITHIN THREE ARABLE FARMLAND SITES IN TARKA; BENUE STATE - NIGERIA.

Farm site	**Crop**	**Depth (cm)**	**Fe**	**Mn**	**Ni**	**V**	**Co**	**Mo**
TRK C1	CASSAVA	0-15	585.31	20.58	56.20	0.12	0.69	1.65
		15-30	900.49	36.22	54.60	0.16	0.71	1.49
TRKC2	CASSAVA	0-15	560.20	26.13	53.10	0.10	0.61	1.60
		15-30	726.21	40.10	50.26	0.18	0.78	1.43
TRKR1	RICE	0-15	202.61	18.58	66.20	0.08	0.68	2.64
		15-30	911.74	26.32	63.50	0.12	0.73	2.64
TRKR2	RICE	0-15	201.61	21.06	69.21	0.09	0.50	2.10
		15-30	934.13	32.11	60.14	0.14	0.68	2.17
TRKY1	YAM	0-15	821.69	22.36	61.50	0.16	0.85	1.84
		15-30	800.13	28.10	52.16	0.18	0.88	1.60
TRKY2	YAM	0-15	806.19	20.16	51.11	0.16	0.80	1.80
		15-30	741.26	26.20	41.29	0.24	0.86	1.63

APPENDIX 17.7: PHYSICAL CHARACTERISTICS OF SOIL SAMPLED WITHIN THREE ARABLE FARMLAND SITES IN GBOKO, BENUE STATE-NIGERIA

			GPS COORDINATES		PARTICLE SIZE DISTRIBUTION (%)			TEXTURAL	
FARM SITE	CROP	DEPTH (CM)	NORTHINGS	EASTINGS	SAND	SILT	CLAY	CLASS (USDA)	SILT / CLAY RATIO
GBKC1	CASSAVA	0-15	7.31069	8.98387	76.00	22.00	2.00	Ls	11.00
		15-30			72.00	22.00	6.00	Sl	3.67
GBKC2	CASSAVA	0-15	7.31024	8.98401	74.00	20.00	6.00	Sl	3.33
		15-30			70.00	21.00	9.00	Sl	2.33
GBKR1	RICE	0-15	7.31195	8.98329	71.00	24.00	5.00	Sl	4.80
		15-30			69.00	26.00	5.00	Sl	5.20
GBKR2	RICE	0-15	7.31195	8.98246	71.00	20.00	9.00	Sl	2.22
		15-30			68.00	22.00	10.00	Sl	2.20
GBKY1	YAM	0-15	7.30274	8.98333	67.00	30.00	3.00	Sl	10.00
		15-30			61.00	28.00	6.00	Sl	4.67
GBKY2	YAM	0-15	7.303465	8.98358	65.00	28.00	7.00	Sl	4.00
		15-30			60.00	20.00	20.00	Sl	1.00

GBK = Gboko farm site Sl = Sandy loam soil Ls = Loamy sand soil

APPENDIX 17.8: CHEMICAL CHARACTERISTICS OF SOILS SAMPLED WITHIN THREE ARABLE FARMLAND SITES IN GBOKO; BENUE STATE - NIGERIA.

Farm site	Crop	Depth (cm)	pH (H20)	Organic C (%)	Total N (%)	Avail P (Mg/kg)	Exchangeable bases				Exchange Acidity (cmolkg-1)			Base saturation (%)	Fertility indices		
							Ca	Mg	K	Na	AL3+	H+	ECEC		Ca : Mg	Mg : K	C : N
GBKC1	CASSAVA	0-15	5.3	1.00	0.09	10.50	3.80	2.20	0.10	0.07	0.18	0.78	7.13	86.00	1.73	22.00	11
		15-30	5.2	0.93	0.08	13.50	4.60	2.20	0.11	0.08	0.24	0.72	7.96	88.00	2.09	20.00	12
GBKC2	CASSAVA	0-15	5.1	1.04	0.07	10.20	3.01	2.11	0.09	0.07	0.19	0.63	6.10	87.00	1.43	23.44	15
		15-30	5.4	0.93	0.06	13.26	4.18	2.26	0.14	0.09	0.26	0.80	7.73	86.00	1.85	16.14	16
GBKR1	RICE	0-15	5.2	2.13	0.18	3.50	3.40	2.00	0.08	0.06	0.00	0.80	6.34	87.00	1.70	25.00	12
		15-30	5.4	1.85	0.16	1.50	4.00	2.00	0.09	0.07	0.20	1.00	7.36	84.00	2.00	22.22	12
GBKR2	RICE	0-15	5.1	2.06	0.09	3.12	2.68	2.01	0.06	0.07	0.10	0.52	5.44	89.00	1.33	33.50	23
		15-30	5.3	1.29	0.10	1.08	4.01	3.04	0.14	0.06	0.18	0.81	8.24	88.00	1.32	21.71	13
GBKY1	YAM	0-15	5.3	1.39	0.12	32.50	4.00	1.50	0.09	0.06	0.00	1.00	6.65	85.00	2.67	16.67	12
		15-30	5.8	0.76	0.06	23.75	5.40	3.50	0.10	0.07	0.00	0.88	9.95	91.00	1.54	35.00	13
GBKY2	YAM	0-15	5.4	1.21	0.10	30.60	3.81	1.06	0.07	0.05	0.12	0.24	5.35	93.00	3.59	15.14	12
		15-30	5.2	0.68	0.07	21.26	5.07	3.41	0.09	0.06	0.02	0.73	9.38	92.00	1.49	37.89	10

APPENDIX 17.9: MICRONUTRIENT (MgKg-1) STATUS OF SOILS SAMPLED WITHIN THREE ARABLE FARMLAND SITES IN GBOKO; BENUE STATE - NIGERIA.

Farm Site	**Crop**	**Depth (cm)**	**Fe**	**Mn**	**Ni**	**V**	**Co**	**Mo**
GBKC1	CASSAVA	0-15	316.21	16.15	41.20	0.10	0.38	1.21
		15-30	520.30	21.25	38.10	0.12	0.43	0.20
GBKC2	CASSAVA	0-15	201.06	12.06	32.22	0.09	0.50	1.09
		15-30	429.23	28.10	21.26	0.22	0.63	0.82
GBKR1	RICE	0-15	279.26	11.11	52.10	0.04	0.64	1.04
		15-30	461.20	20.68	40.93	0.08	0.69	1.01
GBKR2	RICE	0-15	266.22	10.20	38.22	0.02	0.38	1.01
		15-30	521.69	18.60	44.29	0.06	0.51	1.06
GBKY1	YAM	0-15	629.19	26.21	66.28	0.21	0.68	1.26
		15-30	603.26	31.26	60.26	0.25	0.82	1.07
GBKY2	YAM	0-15	726.13	20.14	60.28	0.08	0.60	1.11
		15-30	701.28	28.10	44.21	0.21	0.66	1.06

APPENDIX 18: ENVIRONMENTAL SENSITIVITIES MATRIX FOR IMPACT ASSESSMENT

Environmental Issues	**Observable trends**	**Potential impacts on agricultural production**	**Probability of occurrence**	**Interaction effect**
Climate and Related Physical Factors				
Atmospheric Carbon dioxide and oxides	Increase	Increased crop/weed production	Medium	+/-
		Potential modification of carbon/nitrogen ratio	Medium	-
		Aggressive competition of weeds with crops	Medium	-
		Change in agricultural ecological processes	High	+/-
		Modification in nitrogen cycle	Medium	-
		Decreased crop yield	Medium	-
Rainfall intensity	Increase	Intensified hydrological cycle	High	+/-
		Increased seasonal variation of rainfall	High	-
		Change in erosion and accretion patterns	Medium	-
		Increased occurrence of storm floods	Medium	-
		Damage to cultivated crops	Medium	-
		Increase in marshy and waterlogged areas	Medium	+/-
		Increased pest attacks on crops	Medium	-
Frequency of floods and droughts	Increase	Increase in flood and drought risk areas	High	-

		Increase in flood and drought occurrence	High	-
		Failure of cultivated crops	Medium	-
		Decreased crop yield	Low	-
		Increased competition for water	Low	-
Temperature intensity and variation	Increase	Crop suitability and productivity modification	High	-
		Increase in weeds, crop pest and diseases	Medium	-
		Changes in crop water requirements	Medium	-
		Change in daytime and night time temperature	Medium	-
Heat stress	Increase	Increase in heat waves	High	-
		Increased discomfort for manual farm labour	High	-
		Increased pest activity	Medium	-
		Damage to flower and grain formation	High	-
Surface water trends	Increase	Increase in water volumes and sediment flow	High	+
		Increased river flooding	High	+/-
		Higher water levels and discharge rates	High	+
		Increased water salinity	Low	-
		Loss of agricultural lands	Medium	-
		Reduced irrigation activities at river banks	Medium	-
Soil quality/fertility	Decrease	Increased soil erosion by water and wind	Medium	-

		Soil acidification	High	-
		Soil salinization/alkalisation	Medium	-
		Increase in water logged soils	Medium	+/-
		Deficient soil moisture regimes	Medium	-
		Soil structure destruction	Medium	-
		Alteration of soil nutrient regime	High	-
		Soil toxicity	Low	-
Population and related dynamics				
Population growth	Increase	Change in land use patterns	High	+/-
		Decreased availability of agricultural land	High	-
		Over cropping	High	+/-
		Irrigation intensity	Medium	+/-
		Increased demand for agricultural produce	High	-
		Food shortages	Medium	-
		Increased market competition	High	+
		Increased deforestation	High	-
		Increase in armed conflicts	High	-
		Increased pressure on social amenities	High	-
Rural-urban migration	Increase	Agricultural occupational loss	Medium	-
		Localised loss of farmers	Low	-

		Decrease in farm labour	Low	-
		Decrease in agricultural productivity	Low	-
		Increase in rural poverty	Medium	-
Household income	Increase/Decrease	Increase in migration	Medium	-
		Higher cost of living/Inflation	High	-
		Limited access to farm inputs	Medium	-
		Limited access to farm capital	Medium	-
		Limited access to social services (health, education, communication, electricity, portable water	Medium	-
Infectious diseases and HIV and AIDS	Increase	Decreased agricultural productivity	Low	-
		Increase in migration	Low	-
		Agricultural brain drain	Low	-
		Increased dependence burden	Medium	-
		Agricultural occupational loss	Low	-

APPENDIX 19: IMPACT EVALUATION

Environmental Issue	Description of impacts	Impact qualification						Impact quantification				
		Adverse	Beneficial	Short term <10 years	Long term >10 years	Reversible	Irreversible	P	I	E	P+I+E	Overall Ranking
Climate and related physical dynamics												
Increase in atmospheric dioxides and oxides	Increased crop/weed production	-	+		L	R		3	5	3	11	High
	Potential modification carbon/nitrogen ratio	-			L	R		3	5	5	13	High
	Aggressive competition of weeds with crops	-			L	R		3	5	5	13	High
	Change in agricultural ecological processes	-	+		L		I	5	5	3	13	High
	Modification in nitrogen cycle	-			L		I	3	5	5	13	High
	Decreased crop yield	-		S		R		3	5	5	13	High
Increased rainfall intensity	Intensified hydrological cycle	-	+		L		I	5	5	3	13	High
	Increased seasonal variation of rainfall	-			L		I	5	5	5	15	High
	Change in erosion and accretion patterns	-			L		I	3	5	5	13	High
	Increased occurrence of storm floods	-			L		I	3	5	5	13	High
	Damage to cultivated crops	-		S			I	3	5	5	13	High
	Increase in marshy and waterlogged areas	-	+		L	R		3	5	3	11	High

Environmental Issue	**Description of impacts**	**Impact qualification**						**Impact quantification**				
		Adverse	Beneficial	Short term <10 years	Long term >10 years	Reversible	Irreversible	P	I	E	P+I+E	Overall Ranking
	Increased pest attacks on crops	-		S		R		3	5	5	13	High
Increased frequency of floods and droughts	Increase in flood and drought risk areas	-			L		I	5	5	5	15	High
	Increase in flood and drought occurrence	-			L		I	5	5	5	15	High
	Failure of cultivated crops	-		S		R		3	5	5	13	High
	Decreased crop yield	-		S		R		1	5	5	11	High
	Increased competition for water	-		S		R		1	5	5	11	High
Increased temperature intensity and variation	Crop suitability and productivity modification	-			L		I	5	5	5	15	High
	Increase in weeds, crop pest and diseases	-			L		I	3	5	5	13	High
	Changes in crop water requirements	-			L		I	3	5	5	13	High
	Change in daytime and night time temperature	-			L		I	3	5	5	13	High
Increased heat stress	Increase in heat waves	-			L		I	5	5	5	15	High
	Increased discomfort for manual farm labour	-			L		I	5	5	5	15	High
	Increased pest activity	-			L		I	3	5	5	13	High
	Damage to flower and grain formation	-			L	R		5	5	5	15	High

Environmental Issue	Description of impacts	Impact qualification						Impact quantification				
		Adverse	Beneficial	Short term <10 years	Long term >10 years	Reversible	Irreversible	P	I	E	P+I+E	Overall Ranking
Increased surface water trends	Increase in water volumes and sediment flow		+		L		I	5	5	1	11	High
	Increased river flooding	-	+		L		I	5	5	3	13	High
	Higher water levels and discharge rates		+		L		I	5	5	1	11	High
	Increased water salinity	-			L		I	1	5	5	11	High
	Loss of agricultural lands	-			L		I	3	5	5	13	High
	Reduced irrigation activities at river banks	-			L		I	3	5	5	13	High
Decreased soil quality/fertility	Increased soil erosion by water and wind	-			L		I	3	5	5	13	High
	Soil acidification	-			L		I	5	5	5	15	High
	Soil salinization/alkalisation	-			L		I	3	5	5	13	High
	Increase in water logged soils	-	+		L		I	3	5	3	11	High
	Deficient soil moisture regimes	-			L		I	3	5	5	13	High
	Soil structure destruction	-			L		I	3	5	5	13	High
	Alteration of soil nutrient regime	-			L		I	5	5	5	15	High

Environmental Issue	Description of impacts	Impact qualification						Impact quantification				
		Adverse	Beneficial	Short term <10 years	Long term >10 years	Reversible	Irreversible	P	I	E	P+I+E	Overall Ranking
	Soil toxicity	-			L		I	1	5	5	11	High
Population and related dynamics												
Increased population growth	Change in land use patterns	-	+		L		I	5	3	3	11	High
	Decreased availability of agricultural land	-			L		I	5	3	5	13	High
	Over cropping	-	+		L	R		5	3	3	11	High
	Irrigation intensity	-	+		L	R		3	3	3	9	Medium
	Increased demand for agricultural produce	-			L		I	5	3	5	13	High
	Food shortages	-		S		R		3	3	5	11	High
	Increased market competition		+		L		I	5	3	1	9	Medium
	Increased deforestation	-			L		I	5	3	5	13	High
	Increase in armed conflicts	-		S		R		5	3	5	13	High
	Increased pressure on social amenities	-			L		I	5	3	5	13	High
Increased rural-urban migration	Agricultural occupational loss	-			L	R		3	1	5	9	Medium
	Localised loss of farmers	-		S		R		1	1	5	7	Medium

Environmental Issue	**Description of impacts**	**Impact qualification**						**Impact quantification**				
		Adverse	Beneficial	Short term <10 years	Long term >10 years	Reversible	Irreversible	P	I	E	P+I+E	Overall Ranking
	Decrease in farm labour	-		S		R		1	1	5	7	Medium
	Decrease in agricultural productivity	-		S		R		1	1	5	7	Medium
	Increase in rural poverty	-			L	R		3	1	5	9	Medium
Increased or decreased household income	Increase in migration	-			L	R		3	5	5	13	High
	Higher cost of living/Inflation	-			L	R		5	5	5	15	High
	Limited access to farm inputs	-		S		R		3	5	5	13	High
	Limited access to farm capital	-		S		R		3	5	5	13	High
	Limited access to social services (health, education, communication, electricity, portable water	-		S		R		3	5	5	13	High
Infectious diseases and HIV and AIDS	Decreased agricultural productivity	-		S		R		1	3	5	9	Medium
	Increase in migration	-			L	R		1	3	5	9	Medium
	Agricultural brain drain	-		S		R		1	3	5	9	Medium
	Increased dependence burden	-			L	R		3	3	5	11	High
	Agricultural occupational loss	-			L	R		1	3	5	9	Medium

APPENDIX 20: AGRICULTURAL SUITABILITY INDEX OF THE STUDY AREA BASED ON FINDINGS

Parameters	Rating scores
What was the average annual rainfall (mm)?	40
Were there more values above average annual rainfall?	40
Was the trend of rainfall rising?	20
What was the highest daily rainfall recorded (mm)?	40
What was the average of the series for extreme rainfall reoccurrence intervals?	10
Was the average annual temperature between 18 to 26 Degrees Celsius?	40
Were there more values above average annual temperature?	40
What was the trend of temperature in the area?	40
What was the average annual relative humidity?	40
Were there more values above average annual relative humidity?	20
What was the trend of relative humidity?	30
What was the average annual sunshine hours/solar radiation (MJ m-2 day-1)?	30
Were there more values above average sunshine hours/solar radiation?	20
What was the trend of sunshine hours/solar radiation?	20
How many days had vapour pressure deficit between 0.55kPa to 0.1kPa	30
What was the most predominant soil type?	40
What was the range of soil pH?	10
What was the average value of organic carbon for the series (%)?	10
What was the average value of Nitrogen for the series (%)?	40
What was the average value of Phosphorus for the series (mgkg-1)?	40
What was the average value of Potassium for the series (cmolkg-1)?	20
What was the average value of soil Base saturation for the series (%)?	40
What was the range of soil Sodium Absorption Ratio?	40
What was the range of Exchangeable Sodium Percentage (%)?	40
How many all year round streams are in the area?	40
Was there at least one river with an average discharge of at least 1000 m3/s?	40
Is the area a coastal area?	40

Parameters	**Rating scores**
What is the nature of surface water found in the area?	40
What is the average relief of the area?	30
How often is the area flooded?	10
What is the population density?	40
What is the predominant level of education?	20
What was the predominant refuse disposal type?	10
What was the predominant farming method?	20
Categorise yield capacity of population	30
Categorise availability of agricultural storage facilities (%)	20
Categorise annual farm season comfort	20
What was the level of migration?	30
Categorise availability of government schools (%)	30
Categorise availability of government hospitals (%)	30
Categorise availability of Police stations (%)	30
Categorise availability of communication facilities (GSM) (%)	40
Categorise availability of access roads (%)	20
Categorise availability of markets within 5 kilometres of household (%)	30
Categorise the prevalence of armed conflict in the area	10
What is the current HIV prevalence rate of the state (%)?	10
What is the HIV literacy of the population (%)?	40
Are there adequate HIV services according to respondents?	20
Most of the potential impacts identified were?	10
Most of the potential impacts identified were rated?	10
Total value obtained (T)	**1410**
(T/2000)x100 = Agricultural suitability index	**70.50%**

APPENDIX 21: PROPOSED MITIGATION STRATEGIES FOR POTENTIAL IMPACTS

Environmental Issue	Description of impacts	Impact ranking	Simple community level mitigating strategies for potential impacts
Climate and related physical dynamics			
Increase in atmospheric dioxides and oxides	Increased crop/weed production	High	In order to increase soil carbon and reduces atmospheric carbon dioxide, cooperatives should encourage farmers to embark on massive planting of trees in communities and on non-agricultural lands. Farmers can also plant all year round shrubs around the boundaries of farm lands. Good agricultural practises: • Efficient use of chemicals (fertilisers, pesticides, herbicides) • Crop rotation and mixed cropping with leguminous and cover crops • Mono-cropping of leguminous crops with irrigation in between planting seasons • Mulching • Avoid bush burning and deep tilling of soil • Tilling on existing weeds before planting • Increase use of composting and organic manure • Adjust farming season annually • Organise information sharing meeting around important farming periods • Monitor colour, growth and produce of plants annually
	Potential modification carbon/nitrogen ratio	High	
	Aggressive competition of weeds with crops	High	
	Change in agricultural ecological processes	High	
	Modification in nitrogen cycle	High	
	Decreased crop yield	High	
	Intensified hydrological cycle	High	

Environmental Issue	Description of impacts	Impact ranking	Simple community level mitigating strategies for potential impacts
Increased rainfall intensity	Increased seasonal variation of rainfall	High	In order to maximise the influence of rainfall, cooperatives should encourage farmers identify months with most frequent rainfall intensity. This information will assist in increasing the resilience of the production systems and adjusting to crops that produce before these months. Farmers should also consider irrigation farming during the dry season where surface water shortages don’t exist. Create temporary drains around the farms during months of heavy rainfall. Avoid planting crops with heavy leaf cover or crops that can be inundated by storms waters during months of heavy rainfall. Improve retention capacity of soil by adding crop residues and manure to soils. Embrace alternate cropping, crop rotation, and add legumes to cereal based farms. Farmers should cultivate disease resistant crops and use pesticides efficiently. Farmers should cultivate more rice in areas experiencing increased waterlogging.
	Change in erosion and accretion patterns	High	
	Increased occurrence of storm floods	High	
	Damage to cultivated crops	High	
	Increase in marshy and waterlogged areas	High	
	Increased pest attacks on crops	High	
Increased frequency of floods and droughts	Increase in flood and drought risk areas	High	Farmers should break farming season by planting crops which produce before flood months.
	Increase in flood and drought occurrence	High	

Environmental Issue	Description of impacts	Impact ranking	Simple community level mitigating strategies for potential impacts
	Failure of cultivated crops	High	Farmers should consider irrigation farming during the dry season where surface water shortages don't exist. Where surface water shortages exist, groundwater can be used. Cooperatives can come together and construct earth dams on small surface water bodies increase water availability during the dry season. Farmers should plant crop varieties that produce within short periods.
	Decreased crop yield	High	
	Increased competition for water	High	
Increased temperature intensity and variation	Crop suitability and productivity modification	High	Extreme temperatures can harm crop production but impact may be reduced by modifying the microclimate. Farmers should begin to see tree planting in communities and around their farms as a necessary action against future extreme temperature. Cooperatives can work with communities to establish tree buffer zones where man-made forests can be planted. Trees should be planted as boundary marks between farmlands. Farmers should report new crop disease patterns observed to the Local Government Area agricultural department
	Increase in weeds, crop pest and diseases	High	
	Changes in crop water requirements	High	
	Change in daytime and night time temperature	High	
Increased heat stress	Increase in heat waves	High	

Environmental Issue	Description of impacts	Impact ranking	Simple community level mitigating strategies for potential impacts
	Increased discomfort for manual farm labour	High	Farmers should water farms in the morning in times of heat stress by installing sprinklers, with a water hose, or by manual watering. Farmers should plant pest resistant crop varieties. Crop rotation may reduce incidence of crop disease. Pesticides should be used efficiently. Farmers should avoid manual labour during hours of extreme heat. Farmers should apply a spread of mulch around the crops. This protects the soil from direct sun exposure and preserve moisture. In large farms, freshly cut weeds should be allowed to remain for some days before removal.
	Increased pest activity	High	
	Damage to flower and grain formation	High	
Increased surface water trends	Increase in water volumes and sediment flow	High	Farmers should avoid farmlands close to river banks and areas of river flooding during the wet season. Farmers can cultivate areas inundated by river flooding after flood waters have receded in the dry season. Such lands would have been enriched with minerals. Cultivation around river banks should be done during the dry season.
	Increased river flooding	High	
	Higher water levels and discharge rates	High	
	Increased water salinity	High	
	Loss of agricultural lands	High	
	Reduced irrigation activities at river banks	High	
Decreased soil quality/fertility	Increased soil erosion by water and wind	High	Intensive and continuous cultivation should be discouraged. Short fallow periods and land rotation should be allowed
	Soil acidification	High	

Environmental Issue	Description of impacts	Impact ranking	Simple community level mitigating strategies for potential impacts
	Soil salinization/alkalisation	High	after every few years. The erosion of top soil should however be monitored. The overuse of inorganic fertilisers can increase soil acidity and the aluminium content in soil. Inorganic fertilisers should be used efficiently. The efficient use of NPK fertilisers can enhance balanced fertilisation in the study area. The use of organic manure and composting should be encouraged in between and pre-farming seasons as they improve both physical and chemical properties of soil. Bush burning which is a common practice of farm preparation in the study area should be firmly discouraged to allow crop residue contribute to organic matter build up. Farmers should embrace and invest in labour saving farm management practices such as use of farm machinery for cultivation, weeding and harvesting. Zero tillage practices are beneficial in preserving organic carbon in soil. Diversion ditches and pre-ridging are beneficial in increasing soil organic matter. Diversion ditches control soil
	Increase in water logged soils	High	
	Deficient soil moisture regimes	High	
	Soil structure destruction	High	
	Alteration of soil nutrient regime	High	

Environmental Issue	Description of impacts	Impact ranking	Simple community level mitigating strategies for potential impacts
	Soil toxicity	High	water to prevent waterlogging, erosion and rapid leaching of nutrients. Pre-ridging promotes build-up of organic matter. Irrigation water should not be high in sodium as this would create salinity problems and cation imbalances. It is advisable to use fresh flow water from rivers and streams or groundwater. The use of water from stagnated lakes should be discouraged. Farmers in the study area should engage in the cultivation of crops that tolerate moderately acidic soils
Population and related dynamics			
Increased population growth	Change in land use patterns	High	Cooperative societies should introduce information sharing and briefings on the benefits of family planning and challenges of large households during meetings. Cooperatives should encourage members to visit family planning centres. Farmers should educate peers on the future implications of large population on agricultural production such as availability of land and food shortages. Cooperative societies should partner with civil society organisations within their communities to gain education on improving quality of life. Cooperatives should intensify
	Decreased availability of agricultural land	High	
	Over cropping	High	
	Irrigation intensity	Medium	
	Increased demand for agricultural produce	High	
	Food shortages	High	
	Increased market competition	Medium	
	Increased deforestation	High	

<table>
<tr><th>Environmental Issue</th><th>Description of impacts</th><th>Impact ranking</th><th>Simple community level mitigating strategies for potential impacts</th></tr>
<tr><td rowspan="2"></td><td>Increase in armed conflicts</td><td>High</td><td rowspan="2">advocacy to government to provide adequate security in communities against armed attacks.

Cooperatives should encourage the cultivation of yams, rice, cassava and leguminous crops as supported by the suitability maps produced.</td></tr>
<tr><td>Increased pressure on social amenities</td><td>High</td></tr>
<tr><td rowspan="5">Increased rural-urban migration</td><td>Agricultural occupational loss</td><td>Medium</td><td rowspan="5">Farmers should discourage their children from migrating to cities for reasons other than gainful employments and marriage.

Farmers should support the education of their children as much as possible.

Farmers should teach their children about the benefits of farming and encourage them to gain modern education on mechanised and commercial agriculture.

Cooperative societies can support the formation of youth farming clubs in their communities to develop their interest and skills in agriculture.</td></tr>
<tr><td>Localised loss of farmers</td><td>Medium</td></tr>
<tr><td>Decrease in farm labour</td><td>Medium</td></tr>
<tr><td>Decrease in agricultural productivity</td><td>Medium</td></tr>
<tr><td>Increase in rural poverty</td><td>Medium</td></tr>
<tr><td rowspan="4">Increased or decreased household income</td><td>Increase in migration</td><td>High</td><td rowspan="4">Cooperative societies should educate members on the importance of savings and financial prudence. Farmers should monitor spending to avoid wastages.</td></tr>
<tr><td>Higher cost of living/Inflation</td><td>High</td></tr>
<tr><td>Limited access to farm inputs</td><td>High</td></tr>
<tr><td>Limited access to farm capital</td><td>High</td></tr>
</table>

Environmental Issue	Description of impacts	Impact ranking	Simple community level mitigating strategies for potential impacts
	Limited access to social services (health, education, communication, electricity, portable water	High	Farmers should be discouraged in investing in non-profitable ventures such as holidaying in the cities, unnecessary marriages, and extra marital parenting. Cooperative societies should assist members with soft loans from levies collected and make efforts to collectively access agricultural loans and other benefits from government and private sector. Farmers should increase the quality of harvest through effective methods of farming and storage to gain more profit.
Infectious diseases and HIV and AIDS	Decreased agricultural productivity	Medium	Cooperative societies should discuss the prevention of infectious diseases and HIV and AIDS in meetings frequently. Partnership with civil society organisations working on public health can avail farmers with necessary prevention tools and information. Farmers should educate family members and peers on prevention of infectious diseases and HIV and AIDS. Famers should encourage family members to access counselling and testing services. Famers should abstain from behaviour that can put them at risk of infectious diseases.
	Increase in migration	Medium	
	Agricultural brain drain	Medium	
	Increased dependence burden	High	
	Agricultural occupational loss	Medium	

<u>Recommendations to Benue State Government</u>

1. **Building capacity of communities to cope with adverse weather conditions and climate variability**

    - The Benue State Government (BSG) should put in place mechanisms for the periodic and effective monitoring of micro weather elements, soil quality, and crop yield.
    - Without proper funding, farmers may not effectively embrace good management farm practices. The BSG should make available credit facilities at flexible rates for farming cooperative societies.
    - The BSG should maintain a state wide register of farming cooperative societies and document challenges faced by farmers annually and be responsive to requests from them.
    - The BSG should adequately provide farmers with relevant information regarding the weather and flood warnings to enable farmers plan appropriately.
    - The BSG should control corruption and ensure all agricultural policies are implemented efficiently, especially policies on access to mechanised farming equipment.
    - The BSG should adequately catalogue crops produced in every area of the state and support farmers with necessary farm inputs, especially improved crop varieties with better yield.
    - The BSG should ensure state owned silos programs are operational and professionally managed.

- The BSG should organise workshops to educate farmers on good farm practices and how to access agricultural related services from government.
- The BSG should provide equipment and resources which will assist farmers engage in irrigation farming. If possible, a standard dam should be constructed on River Katsina Ala
- Agricultural extension workers should be monitored to ensure diligence.
- The BSG should encourage and support farmers to focus on the cultivation of yam, rice, and cassava, and mixed farming with leguminous crops as suggested in the suitability maps produced.

2. Curbing population and related dynamics

- The BSG should improve the infrastructure in rural areas to close the urban-rural divide in terms of quality of life.
- The BSG should provide improved primary health care and family planning services at community level.
- The BSG should create enabling environment for the private sector to establish agricultural processing centres.
- The BSG should support the establishment of agricultural microfinance banks and subsidise cost of farm inputs.
- The BSG should support the State Agency for the Control of HIV and AIDS to implement HIV programs effectively.
- The BSG should provide free HIV testing at community level.
- The BSG should provide support to families affected and burdened with HIV and AIDS and other infectious diseases.
- Agricultural extension workers should be trained on HIV education as part of job description.