MAPPING AND ANALYSIS OF AGRICULTURAL SYSTEMS IN A PART OF THE LOWER RIVER BENUE BASIN, NIGERIA

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DECLARATION

I hereby declare that this work is the product of my own research efforts; undertaken under the supervision of Professor Emmanuel Adewale Olowolafe (PhD) and has not been presented elsewhere for the award of a degree or certificate. All sources have been duly distinguished and appropriately acknowledged.

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CERTIFICATION

This is to certify that this thesis has been examined and approved for the award of the degree of DOCTOR OF PHILISOPHY IN ENVIRONMENTAL RESOURCES PLANNING.

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DEDICATION

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Abstract

The present recession of the Lower River Benue has led to some adverse ecological changes and the decline of agricultural production in the face of rapid population growth in the area. The solution to the problem certainly requires a detailed agricultural land use analysis. The existing agricultural systems in the Lower River Benue Basin were identified and analyzed in order to determine their characteristics and spatial trends as a basis for conscious agricultural planning and intensification in the area. This was achieved through the integration of the conventional and space-based technologies. The methods adopted in the study included administration of 250 copies of a questionnaire on the farmers, rapid rural appraisal, field survey and field measurements as well as laboratory analysis of the satellite and collateral datasets using appropriate GIS software packages which include: ILWIS 3.3, ArcView 3.2, ArcGIS 9.1, Erdas Imagine 8.7 together with Microsoft Office packages for thesis preparation and presentation. Statistical techniques such as measures of central tendencies and correlations were employed to determine the level of dispersion and establish relationships between the variables of the prevailing agricultural systems and the farming community. The study identified and analyzed the spatial distribution of the following agricultural systems: irrigated, lowland rice-based, upland cereal and tuber-based, plantation or tree crop, agroforestry-based as well as fishing and livestock in the LRBB at varying scales with upland cereal and tuber based system dominating with an area coverage of 64.11%. It was found that 96.8% of the farmers practise mixed cropping together with crop rotation and mono cropping. Analysis of the socio-economic characteristics of farmers revealed that 56.8% constitute the active farming population with 12 persons per household; 73.2% attained at least secondary education, and 77.1% of the male respondents have a wife each. Assessment of each of the agricultural systems led to basin characterization and generation of physiographic units, slope pattern, Digital Elevation Models, 3D visualization, Normalized Difference Vegetation Index as well as land cover classification and mapping. It is concluded that adequate information on agricultural land use, using space-based techniques, permits conscious agricultural planning and intensification of production with the view of addressing issues of food security, unemployment and poverty reduction in the Lower River Benue Basin.

CHAPTER ONE
INTRODUCTION

1.1 BACKGROUND OF THE STUDY

Agriculture plays a dominant role in the economies of both developed and developing countries. Whether agriculture represents a substantial trading industry for an economically strong country or simply sustenance for a hungry, overpopulated one, it plays a significant role in almost every nation. The production of food is important to everyone and producing food in a cost-effective manner is the goal of every farmer as well as large-scale farm managers and regional agricultural institutions. A farmer needs to be informed to be efficient, and that includes having the knowledge and information products to forge a viable strategy for farming operations. This information will help the farmer to understand the health of his crop, extent of infestation or stress damage, or potential yield, soil conditions, water requirements, environmental problems as well as the need for the intensification of agricultural production and/or expansion of agricultural lands to support the growing food demands (Nathan, 2000).

Growth in farm income and household food security has lagged behind the expectations of the 1996 World Food Summit, which was committed to halving the number of the undernourished by 2015. Norman (1993) stated that increases in agricultural productivity required to boost farm income and food security depend ultimately on farm management decisions in relation to choices of enterprises, production technologies and agricultural inputs, among others.

According to Idachaba (1982), agriculture has changed dramatically around the world, especially since the end of World War II. Food and fiber productivity soared due to new technologies, mechanization, increased chemical use, specialization and government policies that favored maximizing production. These changes allowed many more farmers with increased labor demands to produce the majority of the food and fiber in Nigeria. Although these changes have had many positive effects and reduced many risks in farming, there have also been significant costs. Prominent among these are topsoil depletion, groundwater contamination, the decline of family farms, continued neglect of the living and working conditions for farm laborers, increasing costs of production, and the disintegration of economic and social conditions in rural communities.

Mabogunje (2003) reiterated that agriculture is the backbone of the Nigerian economy. It contributes about 30 percent of the GDP, employs about 68% of the labour force, and accounts for over 70% of the non-oil exports, and provides over 80% of the food requirements of the country. So, for a primarily agrarian country like Nigeria, accurate and timely information on the agricultural practices, types of crops grown and the number of hectares occupied, crop yield and crop growth conditions are essential for strengthening the country's food security and distribution system. Pre-harvest estimates of crop production are needed for guiding the decision makers in formulating optimal strategies for planning, distribution, price fixation, procurement, transportation and storage of essential agricultural products.

Obamiro (2008) stated that, with increasing population pressure in Nigeria and the concomitant need for increased agricultural production (food and fibre crops as well as livestock), there is a definite need for improved management of the nation’s agricultural resources. In order to accomplish this, it is necessary to first obtain reliable data on not only the types, but also the quality, quantity and location of these resources. Information on land use/land cover of the area therefore, will permit a better understanding of the land utilization aspects of cropping pattern, grazing lands, wastelands, surface water bodies, settlements and communication network, which are vital for development planning.

According to Floyd (1982) and Liman (1982), Nigeria has always been supported by international agencies in her determination to develop her agricultural sector. These agencies include the World Bank, Food and Agriculture Organization (FAO), UNDP, USAID and Japanese Government. In spite of massive government investment in the sector and related programmes over the years in the form of input subsidies to the River Basin Development Authorities, Agricultural Development Projects (ADPs), Green Revolution, Operation Feed the Nation (OFN), Directorate for Food Roads and Rural Infrastructure (DFFRI), National Agricultural Land Development Authority (NALDA), among others, the sector remains dominated by small-holder peasant farmers, who are dependent on nature and are barely exposed to modern technology. Small landholders in the agricultural sector produce about 90% of the output in the sector. Furthermore, the Nigeria Agricultural and Cooperative Bank (NACB), now known as the Nigerian Agricultural, Cooperative and Rural Development Bank (NACRDB), after merging with the defunct People's Bank and FEAP, has continued to serve as an on-lending financial institution to farmers nationwide.

Policies and priorities in the agricultural sector are set by the Federal Government of Nigeria (FGN) with advice from the National Council on Agriculture, which is made-up of federal and state government representatives. The FGN has been involved in large scale irrigation, rural infrastructure development, namely: roads, large grain storage schemes, agricultural research, education and extension services, and major investment programmes (Mabogunje, 2003). Recent global and regional advances in addressing issues of Millennium Development Goals (MDGs) and NEPAD (New Partnership for African Development), of which food security and poverty reduction are targeted, are receiving laudable attention in various countries including Nigeria.

Benue State which is situated within the Lower River Benue flood plain is often referred to as the *'food basket of the nation'* and it is also an important agricultural state in Nigeria. Thus, the mainstay of the economy of the area over the years has been agriculture. Similarly, the predominant agricultural activity in the state is rainfed agriculture and it is complimented by irrigation or fadama cultivation, which is usually practiced in the alluvial flood plains of the Rivers Benue, Katsina-Ala, Mu, Gwer and Guma. According to Idachaba (1982), agriculture in the state is highly extractive and it is carried out mostly with the use of hand tools using existing inputs under traditional form of land tenure system and mostly geared towards internal demands. Other land use types apart from agriculture that are found in the area at varying degrees include settlements, commercial features, communication routes, institutional features as well as recreational facilities.

Population growth is a major factor of pressure on natural resources and of environmental degradation. Correct diagnosis of problems related to the population/food nexus usually requires a local, sometimes even a household level of analysis, although action may require national and international support. The Lower River Benue Basin (LRBB) is important because of its rich agricultural potentials and it contains the representatives of all the landscape segments which include the alluvial plains, valley fills, buried pediments and pediments (Uchua, 2006). However, the increasing population in the area has necessitated the need for a state-of-the-art review and assessment of best practices for sustainable agricultural land use and effective management of natural resources in the wake of changing ecosystem of the River Benue basin. Such practices can be included in packages of policy measures to increase production, while ensuring sustainability and fostering accessibility of food supplies.

The outcome of the Nigerian Census exercise conducted in 2006 put the population of Benue State at about 4.2 million people whereas Makurdi and Guma Local Government Areas which account for the bulk of the flood plain under study have a population of 1,356,225 made up of 683,157 male and 673,068 female and a population density of 17 people per sq km (NPC Report, 2006).

Uchua (1993) noted that the effect of the steady rise in population density in the basin generally has necessitated the need for intensification of agricultural production and/or expansion of agricultural lands to support the growing food demands. The resultant effects of these are acute competition and land scarcity. Consequently, the communal ownership of land in the area is fast becoming weaker in importance whereas the individual ownership is becoming very much on the ascendancy. Much of the erstwhile communally held land is being allocated to individuals or sold to them for permanent or private use. This is because the population of the area is becoming more aware of the immense value of land following the expansion and intensification of agricultural land use activities. In specific terms, the commonest modes of land transfer in the area and elsewhere are inheritance, borrowing, purchasing, gift, leasehold and least frequently, compulsory acquisition by government through its power of statutory domain.

The utilization of land involves a complexity of interacting variables such as population, the land tenure system, the level of technology, the stage of a region's development and even the various propensities in the taste of the community in question. It is evident therefore that, land use is not static but it changes in accordance with the changes in all the above variables. This is to say that there is heterogeneity in the land use of any given area due primarily to the influence of certain factors operating naturally or caused by man. A good knowledge of land use of any given geographical region has to do with the human activities on land, the facilities placed on the land, the effects of such human activities on the environment and the actual people making use of the land under consideration (Shibasaki, 2002). All these could be ascertained using tools of land use analysis such as field surveys, aerial photographs, satellite imagery and topographical maps.

Watershed (or catchment) is referred to as a geographic area that drains to a common point, which makes it an attractive planning unit for technical efforts to conserve soil and maximize the utilization of surface and subsurface water for crop production. It is also regarded as an area that contains socio-economic, administrative and plot boundaries, lands that fall under different property regimes and farmers whose actions may affect each other’s interests. Socio-economic boundaries, however, normally do not match biophysical ones (Singh and Singh, 1997). It is important to plan the agricultural activities in the Lower River Benue Basin on priority basis for achieving fruitful results, which also facilitate the process of addressing the problem areas so as to arrive at possible suitable solutions. The resources-based approach is found to be realistic for watershed prioritization since it involves an integrated approach and the same has been followed in this study.

The watershed approach enables agricultural planners to internalize such externalities and other linkages among agricultural and related activities by accounting for all types of land uses in all locations and seasons. This system-based approach is what distinguishes watershed management from earlier plot-based approaches to soil and water management. This approach aims to optimize moisture retention and reduce soil erosion, thus maximizing crop productivity and minimizing land degradation. Improved moisture management increases the productivity of improved seeds and fertilizer application, so conservation and productivity-enhancing measures are complementary.

In watershed prioritization, conservation and management strategies are embarked upon and respective sub-watersheds are earmarked for particular land use based on their land capability classification as conservation measures in the upper watershed have a positive impact on productivity in the lower watershed. Cultivable areas are put under crops according to strict principles of suitability-based cultivation. Erosion-prone, less favorable lands are put under perennial vegetation. Reducing erosion in the upper reaches of the watershed also helps to reduce sedimentation in the lower reaches. For larger watersheds, where the detailed soil maps are not available and preparation is costly and time consuming, a method, which uses the layers derived from satellite data, is most convenient. Priority of watershed depends upon various parameters; hence it is imperative to prioritize the watersheds on the basis of conservation and developmental needs. The objectives of prioritizing watersheds include:

i. Identification of both viable and problem watersheds
ii. Rating of watersheds based on resources set up based on soil erodability, physiography and land use
iii. Listing settlements in priority watersheds for action plan

Furthermore, Chibber (1989) observed that as the scale of human activities expands, the capacity of ecosystems to regenerate the natural resource base becomes an increasingly binding constraint to further growth and development. With respect to agriculture, the combined effect of population growth in developing countries, of increases in per capital income and of changes in dietary patterns linked, among other things, to growing urbanization, will bring about substantial increases in demand for food and other agricultural products. Increased food demand will have to be met either through local food production or through increased export earnings, mainly agricultural for many developing countries. In either case, there will be context-specific constraints that are likely to entail, even in the presence of progress in land saving agricultural technology, further expansion into less and less productive land, growing water requirements, deforestation and additional exploitation of fisheries resources and further environmental degradation.

Agricultural land, in essence, is the land that is primarily used for production of food, fibre, animal rearing as well as other commercial and horticultural crops, that is, land under cultivation (irrigated and non-irrigated), fallow, plantations and grazing areas. The relief, soils, climate and vegetation have been particularly important in explaining the intensity of the agricultural occupation in the Makurdi area (Iorbee, 1992). An increasing awareness of the need for careful management of land use and land development has grown over the last decade in Nigeria, particularly, with respect to environmentally related sensitivity. Agriculture has especially received a considerable attention in this respect.

Uchua (2006) further stressed that there is the traditional practice of intensive mixed cropping in the area and the crops grown in the area include root crops such as yam, cassava, sweet potatoes and cocoyam; vegetables like spinach, tomatoes, pepper, onions and ginger; cereal/leguminous crops such as maize, millet, soya-beans, rice, sorghum as well as tree crops like mango, cashew, guava, orange, plantain, as well as sugarcane. Although commercial agriculture in the state is gradually rising, it is observed that there is concentration on the cultivation of food crops so as to adequately cater for the demands of the surging population.

Surma (1991) maintained that agricultural resources are among the most important renewable and dynamic resources. Comprehensive, reliable and timely information on agricultural resources is very much necessary for a country like Nigeria and in particular, Benue State which depends largely on agriculture. Agricultural surveys therefore need to be frequently conducted throughout the nation in order to gather information and associated statistics on cropland, rangeland, livestock and other related agricultural resources. This information is most important for the implementation of effective management decisions at local, state and national levels. In fact, agricultural survey is very essential for planning and allocation of the limited resources to different sectors of the economy.

According to Townsend (1999), increased land and labour productivity can be achieved in the short term through wider local application of existing technologies, and in the long term through development or adaptation of new technologies for identified agricultural production systems. To date, agricultural research in developing regions has been mostly concentrated on production in relatively high potential environments, and on traditional export and the main staple food commodities. There is need for a partial shift in emphasis for research strategies to include the development of technologies for indigenous food crops and non-traditional export commodities. Appropriate technologies may vary considerably for commercial farms and for small agricultural producers. Commercial farmers usually have fewer difficulties in adopting the required technology. Small farmers are constrained by factors such as lack of credit and risk considerations. The challenge is that of devising the policies and institutions needed for the creation, adaptation and dissemination of appropriate technologies for different categories of farmers.

Patel et al (2002) reiterated that space-based techniques have been and will continue to play a very important role in the improvement of the present systems of acquiring and generating agricultural information. When adequate information on the component parts of the agricultural system are available or can be collected, then regional or national economic concerns can be addressed through improved management programmes to ensure both the sustainable utilization of the available resources for food. Also appropriate high level decisions regarding food movements, pricing, imports and exports can be determined. The premier way of generating this information in a cost-effective and synoptic way is through the use of satellite remote sensing, GIS and other related methodologies.

1.2 STATEMENT OF THE RESEARCH PROBLEM

Factors influencing future trends in food security depend on both the supply of and demand for food. Among the major driving forces expected to influence future food production and consumption are population growth, environmental conditions, urbanization, and income growth, among others, and their impact varies from region to region. Buchanan and Pugh (1955) stated, over four decades ago, that agricultural practices are not static in any area for all times but must be seen to represent a state of equilibrium in a dynamic process of continued adjustments between man and the physical environment on which he lives. It is evident that the Lower River Benue Basin is already experiencing some adverse ecological changes occasioned by the receding trend of the River Benue with its attendant effects on livestock, irrigation agriculture, crop species and productivity (Idachaba, 1982 and Nyagba, 1991). In a related perspective, the issue of the decline in agricultural productivity as a result of increasing non-agrarian population is indeed worrisome more so that Benue State which is situated within the Lower River Benue Basin is acclaimed to be *the food basket of the nation (Nigeria).*

It is common knowledge in agricultural regions of the world that farming systems are associated with such concepts as labour supply, marketing, finances, natural resources, equipment, and natural hazards amongst others. The interactions between these variables offer greater management flexibility, provide for more environmentally and economically sound practices, and create safer and healthier conditions for the peasant farmers to operate and for improved raising of farm animals.

Taking cognizance of the receding nature of the River Benue and the ecological changes on its corridor, resulting in a decline of agricultural productivity especially in the face of rapid population growth in the area, it has become necessary to identify, map and analyse the agricultural systems that are predominant. To achieve this goal, satellite remote sensing and GIS technologies, complemented by existing conventional methods, have been employed for the analysis of agricultural systems in the Lower River Benue Basin (LRBB).

To address the main goal of this study, the following basic questions are to be considered:

i. What farming systems are operational in the Lower River Benue Basin?
ii. What are the factors influencing the choice of agricultural systems in the area?
iii. What are the land management techniques adopted by the farmers and other agro-allied institutions to improve the performance of agricultural systems in the area?
iv. What are the crops that are cultivated in the basin?
v. What are the constraints (institutional and environmental) to sustainable agricultural land use in the area?
vi. How can satellite remote sensing and GIS techniques be used in the analysis of agricultural systems in the LRBB for effective planning and enhanced decision making?

1.3 AIM AND OBJECTIVES OF THE STUDY

The main aim of this research is to identify, map and analyse the agricultural systems that are predominant in the Lower River Benue Basin using Satellite Remote Sensing, Geographic Information System and existing conventional methods.

The specific objectives of the study are as follows:

i. To identify the farming systems which are operational in the Lower River Benue Basin.
ii. To produce maps of the agricultural systems and other related attribute maps such as 3D visualization and DEM using space derived data and GIS techniques.

iii. To determine the factors influencing the choice of agricultural systems.

iv. To appraise the land management techniques adopted by the farmers and other agro-allied institutions to improve the performance of agricultural systems.

v. To identify the crops which are cultivated in the area.

vi. To identify the institutional and environmental constraints to sustainable agricultural land use in the LRBB.

1.4 THEORETICAL FRAMEWORK

The main driving forces that can lead to unsustainable agricultural systems have been summarized by IBSRAM (1997) as being: population growth and distribution; poverty and income disparity; inappropriate legal systems and institutions; environmental degradation, and climate change. The consequences for land use occurred from (a) the high demands for more food production, (b) the need to expand and intensify the use of arable land, (c) the need to prevent and reverse land degradation, and (d) the need to balance agricultural and non-agricultural land use. A number of solutions have been proposed, including using more productive and efficient land use systems, restorative and conserving land use systems, using more socially and culturally acceptable land use systems and applying adequate supportive policy and land use regulations.

A major issue in the study area is the receding nature of the River Benue as well as incessant floods which have resulted in a whole lot of problems in the LRBB including the ecological changes of its corridor, a decline in agricultural productivity particularly in the face of rapid population growth, topsoil depletion, groundwater contamination, the decline of family farmlands and increasing costs of production (Idachaba, 1982). Increases in agricultural productivity required to boost farm income and food security would therefore, depend ultimately on farm management decisions in relation to choices of enterprises, production technologies and agricultural inputs.

In the context of this study, sustainable agricultural system is regarded as "agricultural system that combines technology, policies and activities aimed at integrating socio-economic principles with environmental concerns". Five main pillars of sustainable agricultural system have been described, and these are, to maintain or enhance production, to reduce the level of production risk, to protect the potential of natural resources and prevent degradation of soil and water quality, to be economically viable, and to maintain social acceptability (IBSRAM, 1997). A framework for sustainable agricultural system is a long time endeavour requiring the identification of the characteristics of individual agricultural systems, general screening, diagnosis, monitoring, of signs and phases of environmental health care (Hannam, 1999). Hence, it follows that the first step in the journey to sustainability of any agricultural enterprise in an area is the identification and characterization of individual agricultural system. Consequently, it is this concept of agricultural sustainability that the present study is anchored upon.

Farming systems exhibit great diversity over the decades as confirmed by various researchers notably; Duckham and Masefield (1970), Grigg (1974), Kostrowicki (1974), Spedding (1979), Ruthenberg (1980) and FAO (1989). Such systems have been classified in various ways as reviewed by Fresco and Westphal (1988) and Beets (1990) who also presented an ecologically-based classification and typology of farming systems. In an attempt to analyse the agricultural systems in the study area, the classification of agricultural systems presented shall be distinct and specifically oriented to (i) the use of a farm management and farm-household perspective and (ii) the use of a framework for analysis, not only in the Lower River

Benue Basin but also in the other river basins in Nigeria targeted at improved agricultural productions as a way of tackling issues of food security and poverty reduction in the country.

While classifying farming systems by ensuring food security and poverty reduction, Dixon and Gulliver (2005) affirmed that differences in the farming system account for a major part of the variation in farm management decisions. They reiterated that an ideal framework would allow for the tremendous diversity of agricultural settings which could be simplified and codified, without eliminating important differences that need to be taken into account, and would be hierarchical in order to meet the different needs of decision makers at different levels to buttress the need for improved production as well as agricultural intensification.

Neither is it an exaggeration nor an overstatement to state that in the Lower River Benue Basin no previous studies have clearly mapped up or explicitly differentiated the various agricultural systems that are operational in the area. Not until such a classification is properly done to enable researchers, stakeholders and the general public know the particular agricultural systems that are actually affected by the problems of the area and not until then that appropriate solutions can be proffered or rendered. Consequently, there is the need for this study to identify and map the various agricultural systems in the LRBB in line with the definition and concepts which are postulated by Fresco and Westphal (1988), Beets (1990), Lal (1991a) and Dillon (1992). Not until then that we can analyse the prevailing agricultural systems in the Lower River Benue Basin using satellite remote sensing and Geographic Information System technologies.

1.5 SCOPE OF THE STUDY

The study is largely to apply modern research techniques of satellite remote sensing and Geographic Information Systems complemented by intensive field observations and measurements, administration of 250 questionnaires as well as detailed laboratory analysis of space-derived and collateral datasets. This formed the basis for the identification and analysis of the various agricultural systems in the area. Increased population in the area coupled with the changing ecosystem of the Rivers Benue and Katsina-Ala have resulted in a decline in agricultural production which has called for a holistic assessment of the existing farming systems so as to device ways of buttressing agricultural intensification and improved food production as variables needed to address issues of food security and sustainable socio-economic development in the basin.

1.6 JUSTIFICATION OF THE STUDY

The study area is situated within the alluvial basin of the Benue River that happens to be the major geographical feature of the area. Hence, the area has its uniqueness considering the peculiar nature of the environment and associated ecological features. Consequently, there are a number of agricultural activities taking place in the basin, which include livestock grazing, rainfed cultivation, irrigation as well as wetland and fadama agriculture. Applying remote sensing and GIS technologies for agricultural land use system analysis in the basin will be something new. Furthermore, the trend of literature search has shown that some researchers in related fields of study carried out in other regions have either used remote sensing or GIS separately. However, to integrate these technologies with conventional techniques in the Lower River Benue Basin for the analysis of agricultural systems is again something new.

Increased food production in third world countries is essential primarily to feed the rapidly growing population. Increasing environmental problems as well as intensification of agriculture have resulted in drastic changes in land use and Land cover and space-use patterns directly affecting denudation processes. Geomorphological hazards, particularly excessive overland flow, landslides, rill, gully and soil erosion, have become common problems. Sustained land management can only be achieved if these problems are identified, understood and solved. Population pressure calls for increased production of agricultural products. Land use information, in this regard, is urgent and important. Information on the current land use forms the starting point in land use planning and management in the LRBB.

Surma (1991) stated that there is need for building and sharing the agricultural land use knowledge base of an area at any given time. Over the years, many doomsayers have predicted that agricultural growth would fail to meet the food needs of growing populations, leading to starvation and death on a global scale. Those predictions were averted because of rapid progress in advancing and using knowledge. Even with such progress, poverty is widespread among so many people depending on agriculture in the developing countries; millions are hungry, and famines frequently occur in certain regions. Overcoming these challenges is made progressively more difficult by rapid population growth on the fixed natural resource base believed to be reaching its limits. Agricultural innovation, therefore, must clearly continue at an accelerated rate in order to respond to these challenges. Creating and using traditional and new knowledge for development is indeed essential. Knowledge, both indigenous and new has been pivotal to agricultural development. Such knowledge has historically supported food security objectives, but must now also contribute to poverty eradication and environmental sustainability as well. Attaining the potential contributions of agriculture to the Millennium Development Goals (MDG) will depend on continued creation and use of new, as well as existing, agricultural knowledge at an accelerated rate.

The desire to promote the applications of Remote Sensing and GIS technologies in natural resources inventory, environmental management and human activities targeted at enhanced decision making and overall national development cannot be over emphasised. It is in the light of this, amongst other factors, which the study aimed at agricultural land use system analysis using Satellite Remote Sensing and GIS technologies. The choice of an area in Benue State for this research is based largely on her emerging dominance in agricultural production and development in Nigeria. This study is, therefore, expected to help in formulating future strategies geared towards intensive utilisation of satellite technology to complement the conventional methods for sustainable agricultural development as a window for tackling issues of food security and poverty eradication.

1.7 THE STUDY AREA

1.7.1 Geographic Location and Extent

Specifically, part of the Lower River Benue Basin which occupies a significant portion of Benue State and chosen as the area of study is located between Latitudes 7^o 40'N and 7^o52'N, and Longitudes 8^o 25'E and 9^o 12'E with an area of about 77,379.32 sq km and extending from Gbajimba (Guma LGA) to Gbagi Ocholi (Gwer West LGA) (Figure 1). The state capital is situated 315km southeast of Abuja the Federal Capital Territory. The area has a population of 1,356,225 that is, 683,157 male and 673,068 female (NPC Census, 2006) and a population density of 17 persons per sq km. Federal University of Agriculture, Makurdi and Benue State University are the major tertiary institutions that are located in the Lower-Benue River flood plain.

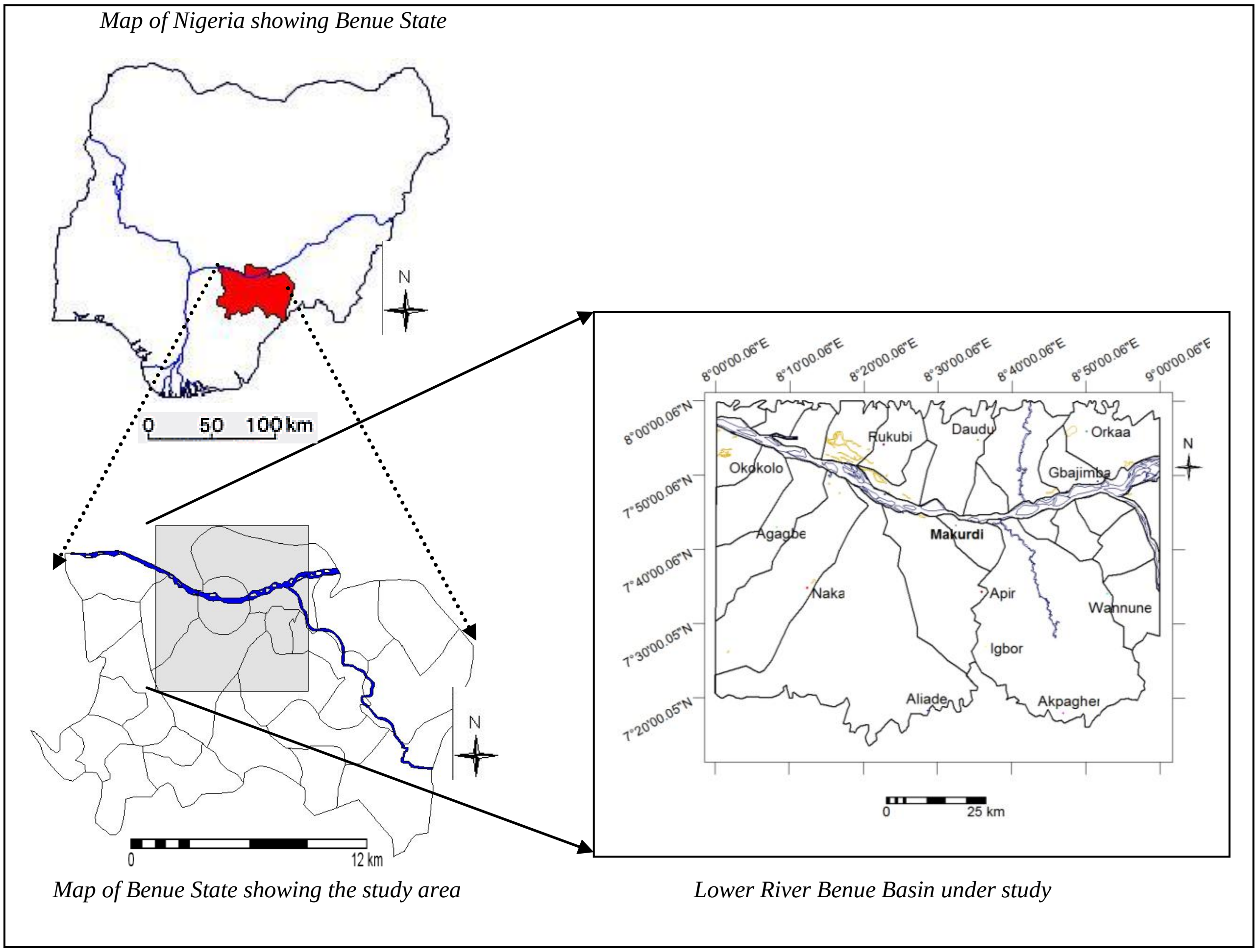


Figure 1. Location of the Study Area

1.7.2 <u>Geology</u>

According to Kogbe (1989), the Lower River Benue Basin lies within the Benue Valley and Trough. During the Tertiary and possibly the interglacial periods of the Quaternary Glaciation, the waters of the Atlantic Ocean transgressed the Benue and Niger Valleys, otherwise known as the Niger/Benue trough. As a result, marine sediments form the dominant surface geology of much of Benue State. These sediments have undergone varying degrees of metamorphism and are underlain at variable depth by Basement Complex rocks. In the southern areas such as Ado, Ogbadibo and Okpokwu, the meta-sediments may be more than 20m thick. Benue State geology can, therefore, be broad Meta-sediments occurring in most parts of the state and associated with the Benue trough.

Basement Complex rocks comprising ancient igneous and metamorphic rocks occur mainly in Kwande and the eastern part of Oju. The materials also outcrop in widely scattered locations as upland residuals, such as inselbergs, knolls and ruwares and underlie all of the meta-sediments. The basement rocks are dominated by porphyritic granites, migmatites, diorites, pegmatites and gneisses. In much of LRBB, both the tertiary sedimentary rocks and the basement complex have been deeply weathered to produce regolith and saprolite several metres deep. These rocks are rich in solid minerals, such as limestone, baryte, coal, gypsum, salt, shales, silica, sand and kaolin which are currently being mined.

The meta-sediments as contained in Figure 2 are dominantly sandstone, but also contain shale, siltstone, limestone and quartzite. On the flood plains of the Benue are Katsina Ala Rivers and other smaller rivers, alluvial deposits, comprising of assortment clays, sand, gravels and pebbles, overlie the meta-sediments and form the superficial geology. These rocks are rich in solid minerals, such as limestone, baryte, coal, gypsum, salt, shales, silica, sand and kaolin which are currently being mined.

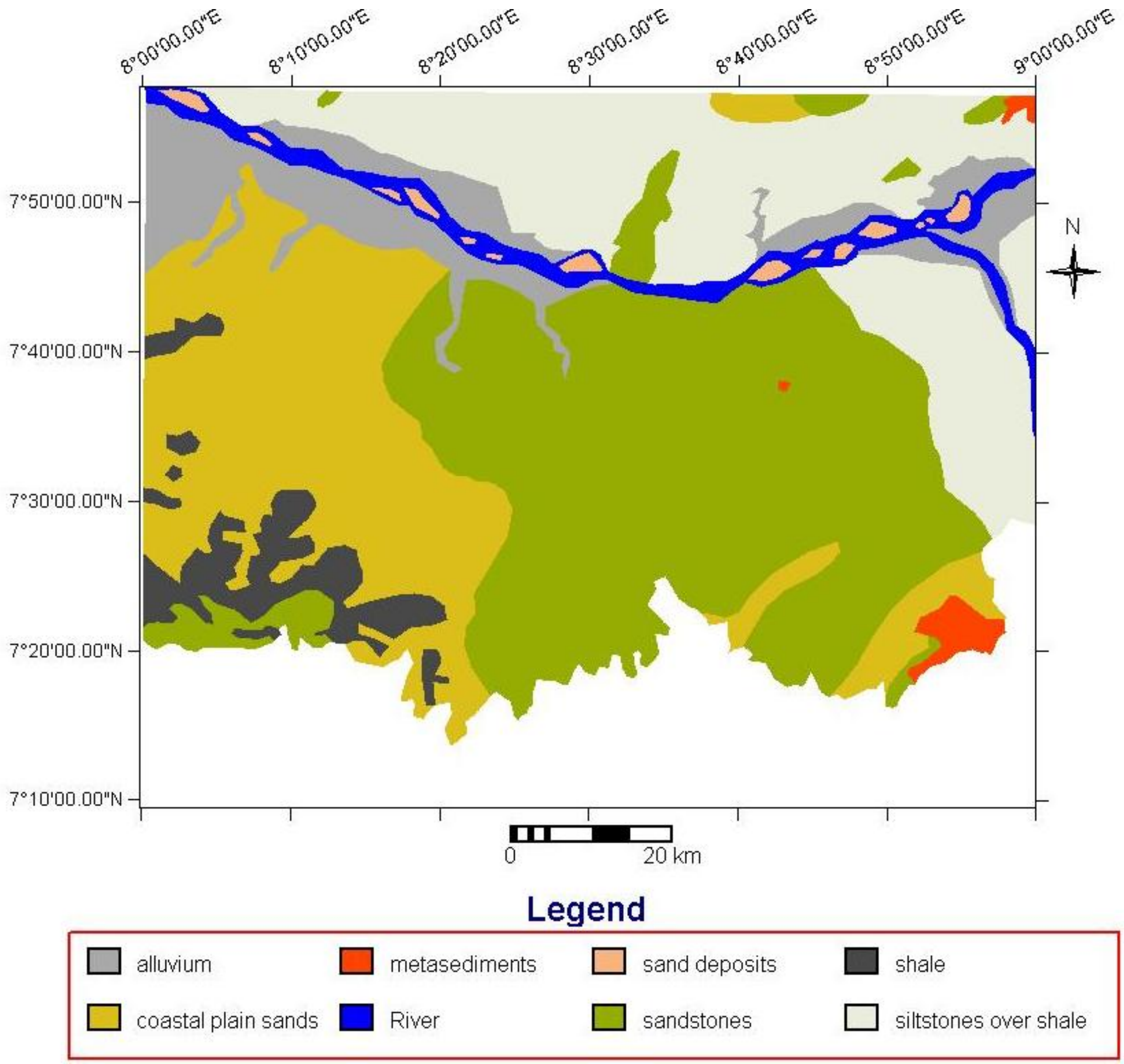


Figure 2. Geological Map of the Lower River Benue Basin (after, Kogbe, 1989)

1.7.3 **Relief, Drainage and Hydrology**

The land is generally low lying (averaging 100m-250m) and gently undulating with occasional inselbergs, knolls, laterite capped mesas and buttes. In some few locations such as Igbor, Mkar, Wannune and Adikpo, the terrain is characterised by steep slopes, deep incised valleys and generally rugged relief. Elsewhere, the topography is made up interfluves, broad open valleys and flood plains. The flood plains which are characterised by extensive swamps and ponds are good for dry season irrigated farming.

The drainage and hydrology of the area is part of the drainage system of the Benue River basin, which is influenced by climate, rock structure, topography and human activities in the area. Benue river is the main tributary of the River Niger. It rises from the Adamawa Plateau of Central Cameroon Mountains, flows west across central Nigeria, and joins the River Niger about 483km from the coast. Its width varies from about 488 to 976m, and its navigable length is more than 965 km during the wet season (May to September) and it is about 1,370km long, making it useful for transportation of freight and passengers, as well as for tourism, fishing and flood plain agriculture (Iorbee, 1992).

The two main rivers in the study area which are River Benue and River Katsina-Ala have numerous tributaries. Many other rivers and streams which do not drain into these two main rivers also exist. All these rivers and streams form extensive alluvial floodplains that are suitable for irrigated agriculture. Associated with these rivers and streams are numerous lagoons, lakes and ponds which are used extensively for fishing and dry season irrigated farming. The KatsinaAla River is the largest tributary, while the smaller rivers include Mkomon, Amile, Duru, Loko Konshisha, Kpa, Okpokwu, Mu, Be, Aya, Apa Ogede and Ombi. Though the area has high drainage density many of the streams are seasonal. Also, the permanent water table in many parts of the basin is very low, as a consequence of the thick overlying permeable meta-sediments and the great depth to which weathering has reached.

Some of the hydrological features of the area are that: runoff is common both on the land surface and river channels during the rainy season; the water in the channels of most of the tributary streams of the River Benue usually dry up during the dry season; and most of the rivers in the area overflow their banks especially at the peak of wet seasons thereby resulting in mild but sometimes devastating floods. The rivers, streams, dams and ponds in the area are used for a number of purposes such as industrial uses, domestic uses, irrigation, fishing, source of potable pipe-borne water, drinking water for livestock, recreational purposes among others. The drainage network and the sub-watersheds of the area are contained in Figure 3.

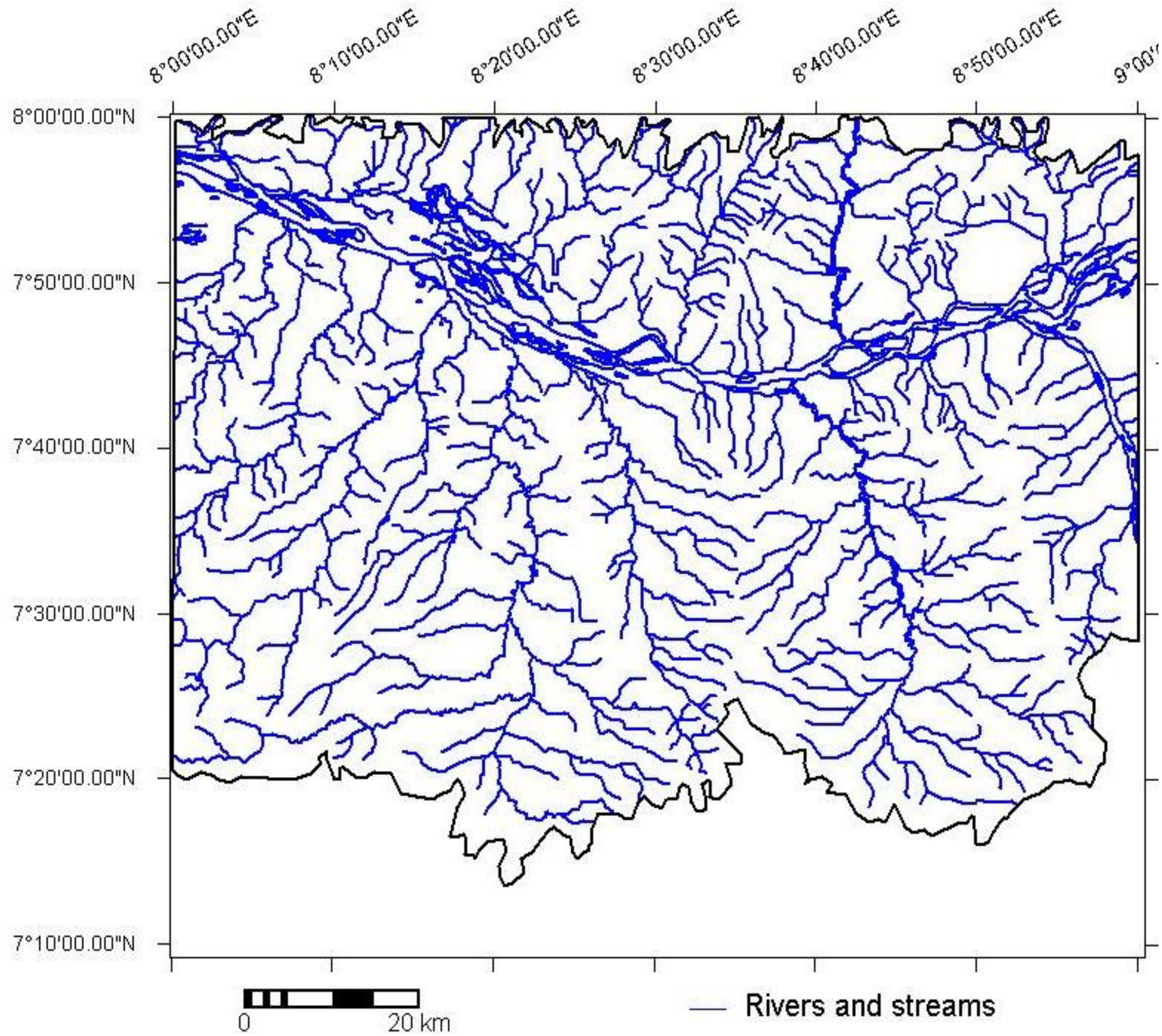


Figure 3. Drainage Density of the Lower River Benue Basin

Note: (Major Rivers and Streams)

1. Acha	2. Ahum	3. Akereku	4. Akpaku
5. Akponaja	6. Akwa	7. Ana	8. Fete
9. Gelaza	10. Guma	11. Gwer	12. Hawe
13. Inaji	14. Jado	15. Kereke	16. Kugwa
17. Mu	18. Ohina	19. Oku	20. Owopi
21. Peyer	22. Ube	23. Ukoghor	24. Uuma
25. Yugbu	26. Benue	27. Katsina-Ala	

1.7.4 <u>Climatic Characteristics of the Study Area</u>

Climate is the main determining factor for agricultural productivity in the Lower River Benue Basin, as indeed throughout the world. According to Ayoade (1983), the prevailing climate of the Central Nigeria where the study area is situated is the tropical wet and dry type, and could be coded using the Koppen's system of climatic classification of 1923 as *Aw* (tropical seasonally wet and dry). Furthermore, Thornthwaite represented the area as *B3* (Humid climate with seasonal distribution of moisture adequacy) and Miller's system as *A1* (hot climate with equatorial double maxima). For the purpose of this study, Koppen's system of climatic classification (*Aw*) was adopted.

The area generally experiences a typical tropical climate with two distinct seasons, the wet or rainy season and the dry season. The rainy season lasts from April to October with annual rainfall in the range of 850 -1200 mm. The dry season begins in November and ends in March. The main determinant of crop growth in the basin is rainfall. Even irrigated areas depend on rainfall to recharge the rivers such as Rivers Benue, Katsina-Ala, Mu, Gwer and Guma or groundwater reserves from which irrigation water is obtained. The duration of the rains greatly affects the level of water availability in the area and affects the spectral response of surface features especially vegetation and soils.

The mean monthly values of rainfall in the area range from 7.7mm to 227.5mm as contained in Table 1. This has resulted in three rainfall regimes in the area: the wet regime, the moderate regime and the dry regime. Days with at least 1.0mm of rainfall also range from an average of 0.2 to 13.3days per month. This to a larger extent has effect on the general agricultural land use situation of the area thereby encouraging irrigation cultivation along River Benue and other major rivers and streams.

According to Ayoade (1983), the temperature of the Benue trough is constantly high throughout the year and generally fluctuates between 23°C in the coldest month and 38°C in the warmest month. Actual measurements in the Lower River Benue Basin between 1998 and 2008 confirm that the temperature within the period ranged from 26.3°C in December and 31.8°C in March (Table 1). There is a slight cooling effect from the harmattan winds especially during the night in the months of November to February and it is associated with periodic dust haze resulting from the prevailing NE trade winds across the Sahara Desert . The hot and humid conditions in the area are responsible for the breeding of crop pests that destroy grain crops such as maize, sorghum and millet on the farms and during storage.

It is practically impossible to carry out agricultural activities without water availability. As such the farmers in the Lower River Benue flood plain rely heavily on the water from River Benue especially during dry season for irrigation farming as the area experiences drought mostly in the months of November to February and also having high temperature values. Although in the rainy season the farmers indulged in rainfed agriculture as the area experiences a mean annual rainfall of 1152.5mm.

This climatic trend to a greater extent affects the type of farming systems that are operational in any given season in the basin. Some crops like tomatoes cannot strive with high humidity as it may become vulnerable to diseases attack during the period. Table 2 shows that the mean daily sunshine duration ranges from 4.7hours to 8.0hours while the mean monthly humidity is highest in the month of September with 77.1%. However, every crop has levels of sunshine requirements as it helps in the process of photosynthesis and harvesting.

Table 1. Mean Monthly Temperature and Rainfall of the LRBB (1998 – 2008)

Month	**Mean Monthly Temperature (^oc)**			**Mean Monthly Rainfall (mm)**	**Average Days (with at least 1.0mm rainfall)**
	Maximum	**Minimum**	**Mean**		
January	35.3	19.1	27.2	0.00	0.0
February	37.2	22.7	29.9	0.00	0.0
March	37.9	25.7	31.8	21.4	1.7
April	35.9	25.6	30.7	78.0	5.6
May	33.5	24.5	29.0	140.8	8.9
June	31.3	23.2	27.2	216.8	10.3
July	30.4	23.1	26.7	145.7	12.9
August	30.0	23.1	26.5	227.5	13.3
September	31.0	22.7	26.8	220.6	13.3
October	32.3	22.9	27.6	94.0	7.8
November	34.3	21.0	27.6	7.70	0.5
December	35.0	17.7	26.3	0.00	0.2
Total				**1152.5**	**74.5**
Average	**33.6**	**22.6**	**28.1**	**96.0**	**6.2**

Source: Nigerian Meteorological Agency, Makurdi.

Note: The shaded portions indicate the months with highest values of temperature and rainfall and also show their relationship in the area.

Table 2. Mean Monthly Humidity and Mean Daily Sunshine of the LRBB (1998 – 2008)

Month	**Mean Monthly Humidity (%)**			**Mean Daily Sunshine Duration (Hours)**
	Morning 10am	**Afternoon 4pm**	**Mean**	
January	44.5	26.5	35.5	7.0
February	48.7	27.2	37.9	7.6
March	58.4	34.2	46.3	6.8
April	68.7	48.2	58.4	7.0
May	73.8	58.4	66.1	6.9
June	79.7	66.0	72.8	6.1
July	81.4	69.5	75.4	4.9
August	83.1	70.7	76.9	4.7
September	84.0	70.2	77.1	5.4
October	79.0	63.1	71.0	6.5
November	71.0	44.0	57.5	8.0
December	52.5	28.4	40.4	7.5
Total				**78.4**
Average	**68.7**	**50.5**	**59.6**	**6.5**

Source: Nigerian Meteorological Agency, Makurdi.

Note: The shaded portions indicate the months with highest values of R.H and Sunshine in the area

1.7.5 Soils

The Lower Benue flood plains under study is dominated by alluvial soils which are referred to as sediment made up of mud, silt, and sand, that is deposited on flood plains and deltas by rivers and streams during seasonal flooding (Nyagba, 1991). Alluvial soils are typically very rich and fertile thereby supporting the cultivation of lowland rice, vegetables and irrigated crops. The soil forming factors in the area such as climatic factors, density of vegetation, organic matter, parent materials and topography, are not different from the factors elsewhere.

According to Fagbami (1986), ferruginous soils which can be sub-divided on the basis of texture of the surface horizon into the hydromophics, the lithosols and laterites are by far the dominant soil group found in the tropical guinea savanna region of Benue State. The marked period of dry season prevents the development of thick forest; thus, grassland prevails. The vegetation dies back in the dry season and breaks down to provide a layer of humus at the surface. During this season capillary action brings materials towards the surface. However, in the wet season rapid leaching occurs, but Al and Fe remain in the upper layers to give the soil a bright red colour. The change between leaching and capillary action between the seasons leads to the development of a compact portion just below the surface, known as lateritic soils.

The dominant soil type in the portion of the Lower River Benue Basin is the ferralsols and hydromorphic soils. These are soils developed in alluvial deposits of river flood plains and consist of appreciable depth of various thin layers of sediments of differing texture. The soil parent materials are highly varied ranging from clays to loams, sand gravels or any combination of these following the pattern of sedimentation. In fact the basin of Rivers Benue, Katsina-Ala, Dura, Amile and several other rivers have thousands of areas of floodplains on which occur hydromorphic soils that are best suited for swamp rice, sugarcane, maize, and to some extent cassava. The soils of the LRBB are very fertile. Fertility management is principally through effective farming practices. With increasing human population, the fallow period has been drastically reduced, thus prompting the need for the use of inorganic and organic fertilizers (Fagbami, 1983).

1.7.6 Vegetation

The natural vegetation covering Lower River Benue Basin is the woodland and tall grass savanna type, precisely the guinea savanna (or parkland or savanna woodland) that is made up of pockets of forests, woodland, shrubs and scrubs as well as coarse grasses. Udo (1970) and Iloeje (1975) noted that the vegetation of the area was previously under forest cover. However, indiscriminate and persistent clearance of the vegetation for arable farming coupled with bush burning, hunting and grazing among other factors have greatly affected the original forests. The natural vegetation is now characterized by a mosaic of secondary forest and savanna with rolling hills which range between 150 - 300m above sea level, and the grassy open land induced by bush burning and clearing by farmers.

The scattered trees are mainly those of economic value and include locust bean, shear butter, mango, silk cotton, cashew, oil palm (Table 3). These trees produce valuable fruits, wood and fibre which can be utilized for small scale cottage industries. Generally, forest vegetation in the area can be grouped into: village forest; gallery forests; and forest reserves. In these forests, typical rain forest trees such as mahogany, Obeche, Iroko, occur and are used for timber.

The vegetation cover of the area, just like many other areas in the northern parts of Nigeria, changes annually between the rainy and dry seasons. In the wet season the grasses, shrubs and leaves of trees are found fresh and green but in the dry season, they wither and die off leaving behind dry grasses and some trees with stems and branches only to revive again with the advent of the next wet season. The trees adapt to drought conditions through long taproots, leathery leaves and succulent stems that help some trees to retain their greenness all the year round.

Table 3. Common Crops in the Lower River Benue Basin

S/N	English Name	*Scientific Name*	Local Name (Tiv)
1	Mango	*Mangitera indica*	Mangoro
2	Grape fruit	*Citrus paradisi*	Ifuku alum
3	Guava	*Psidium guajava*	Guava
4	Banana	*Musa paradisiaca*	Ayaba
5	Pineapple	*Ananas comosus*	Agede
6	Cashew	*Anacardium occidentale*	Shase
7	Coconut	*Cocos nucifera*	Ikyeve
8	Cassava	*Manihot esculenta*	Alogo
9	Sweet potato	*Ipomoea batatas*	Atsaka
10	Yam	*Pachyrrhivus erosus*	Iyough
11	Cotton	*Gossypium*	Mough
12	Ginger	*Zingiber officinale*	Seta
13	Maize	*Zea mays*	Ikureke
14	Bean	*Vigna phaseolus*	Alev
15	Sugarcane	*Saccharum officinarum*	Iyelegh
16	Peanut	*Arachis hypogea*	Igbough ahi
17	Tomato	*Lycopersicon esculentum*	Tematu
18	Onion	*Allium cepa*	Alabesa
19	Rice	*Poaceae gramineae*	Chinkafa

20	Millet	*Eleusine coracana*	Amine
21	Oil Palm	*Elaeis guineensis*	Ikye
21	Okra	*Hibiscus sabdariffa*	Atuul
22	Pepper	*Piper nigrum*	Mkem
23	Sorghum	*Sorghum bicolor*	Wua
24	Tobacco	*Nicotiana tabacum*	Taav
25	Orange	*Citrus sinensis*	Alum
26	Sorrel Plant	*Hibiscus Sabdariffa*	Ashwe

Source**:** Nyagba, (1991)

1.7.7 <u>The People and Economy</u>

The Lower River Benue Basin is inhabited predominantly by the Tiv people; although a good number of minority groups such as Idoma, Jukun, Fulani and Etilo also inhabit some parts the area. Consequently, the major language spoken in the area is Tiv language although English is also spoken in schools, offices and markets. In terms of religion, the inhabitants of the LRBB are predominantly Christians while a meager proportion constitutes the population of traditionalists and Muslims.

According to the 2006 the area has a population of 1,356,225 people comprising of 683,157 males and 673,068 females (NPC, 2006) with a population density of 17 persons per sq km in an area of 77379.32 sq km. The rich socio-cultural structure of the people include festivities; display of cultural heritage; age-group competition; cultural dance troupes; praise singing; marriage and funeral celebrations; inculcation of ancestral oral literature to the youths by the aged; expression in colourful cloths as well as numerous other social involvements. Indeed, cultural displays from Benue have won laurels at national and international cultural festivals.

Lower Benue River Basin has large expanse of fertile land with a good drainage system. The flood plains of the rivers which are characterized by extensive swamps and ponds provide opportunities for dry season irrigated agriculture and fish farming. The area is connected to other parts of Nigeria by road, rail, air and water (Rivers Benue and Katsina-Ala). It has abundant food and raw materials such as yam, cassava, sweet potato, sorghum, millet, soyabeans, beniseed, rice, maize, mangoes, palm oil, cashew, tomatoes, pepper, leafy vegetables, just to mention a few. These have earned Benue State which is situated in the area the position of the ‘Food Basket of the Nation’. Crops and economic trees that are found in the area are planted in orchards and dwelling compounds such as mango, guava, cashew, orange and pawpaw (Table 3). The plant species covering the area are put to various uses including medicinal, raw materials (paper production, roofing of buildings, furniture and construction) grazing, fuel and energy among many other uses.

Processing facilities include: Taraku Oil Mill, for soya-beans as well as maize processing and Agro-Millers in Makurdi for rice processing. There are other privately owned small-scale rice milling factories all over the area but are inadequate to handle the quantity of rice produced. A well developed industrial layout in Makurdi, the State capital, has also provided suitable sites for investors willing to establish agro-allied industries in the area.

Benue state is acclaimed the nation's "food basket" because of its rich and diverse agricultural resources; consequently agriculture is the main industry in the area with about 85% of the working population estimated to be wholly or partly employed in it. Given this fact, priority attention has always been given to agricultural and rural development as deliberate government strategy to improve the living standards of the people. The crops cultivated through rainfed and irrigation agricultural systems in the area are as highlighted in the Table 3.

Furthermore, the inhabitants as well as the pastoral nomads rear a variety of animals such as sheep, goats, guinea fowl, chicken and cattle for domestic consumption and commercial purposes. It was observed during fieldwork that apart from built-up areas, uncultivated rock outcrops and erosion surfaces; the land area is completely utilized all the year round for agricultural purposes. The settlement pattern of the area is generally the dispersed type except that the heart of Makurdi the Benue State capital is nucleated. Also, there are trade links between the people of the area with other surrounding and far away towns. This is facilitated by good access roads connecting the area with many other places.

It also boasts of one of the longest stretches of river systems in the country with great potential for a viable fishing industry, dry season farming through irrigation and for an inland water way development. According to Raw Materials Research and Development Council - RMRDC (2003), some of the mineral resources found in the area include bentonite, crude salt, petroleum, limestone, glass sand, barites, feldspar, marble, mica, silica quartz, lead, calcium, bauxites, magnetite, coal, zinc ore and so on. Apart from the farming population other people in the area are civil servants with the federal and state establishments, Makurdi, Gwer West and Guma LGA's, teachers in the schools, health workers with the clinics. Some people are traders or they combine trading with other activities; others are fishermen at the surrounding ponds, dams, rivers; while others indulge in crafts.

CHAPTER TWO
REVIEW OF RELEVANT LITERATURE

2.1 INTRODUCTION

This chapter amongst other things have characterized the various tropical agricultural systems and the factors influencing their nature and scope in the wake of global effort towards addressing the issues of food security and poverty reduction. The principles of agricultural systems analysis such as land, land use, land cover, river basin and sustainable agriculture are considered. River Basins Development in Nigeria, with particular emphasis on the Lower Benue River Basin Development Authority is also captured. Further attention has been given to the space-based technologies, that is, Remote Sensing and Geographic Information System as they are applicable to the mapping and analysis of agricultural systems.

2.2 AGRICULTURAL SYSTEMS IN THE TROPICS

An agricultural system otherwise known as farming system is an assemblage of components which are united by some form of interaction and interdependence and which operate within a prescribed boundary to achieve a specified agricultural objective on behalf of the beneficiaries of the system. Spedding (1979) opined that, farmers in the parts of Africa where population growth is near, or has exceeded, the carrying capacity of the land at current technological levels face a serious crisis. This crisis is the result of the breakdown of traditional farming systems. The consequences are environmental deterioration on a massive scale, widespread poverty, malnutrition, and famine. In some countries, the crisis is contributing to political instability and civil war. Ruthenberg (1980) traced the process of intensification of tropical farming systems, resulting from increasing population pressure on the land, as passing from shifting systems through fallow systems to permanent upland systems, sometimes with perennial crops and irrigation.

According to Obamiro et al (2003), agricultural system could also be regarded as a population of individual and homogeneous farm systems that have broadly similar resource bases, enterprise patterns, household livelihoods and constraints, and for which similar development strategies and interventions would be appropriate. The main emphasis in farming systems analysis is a holistic approach, whereby household structure, gender, social networks, local institutions, information, policies, markets and all other factors as they affect the livelihood of the various homogeneous groups are brought into play. The analysis could be static, dynamic and comparative depending on the objectives of the study. This study dwells largely on the static analysis which is the comparison of the farming systems at a point in time. For clarity purpose, the dynamic analysis is the analysis of the developments over time, in each of the identified homogeneous farming groups, while comparative analysis of the farming systems is the analysis of similarities and differences among the identified farming systems.

Norman, et al (1982) and Ker (1995) in their work on the farming system of the African savanna maintained that farming systems research relates to the whole farm rather than individual elements; it is driven as much by the overall welfare of farming households as by goals of yield and profitability. Farming systems are closely linked to livelihoods because agriculture remains the single most important component of most rural people's living and also plays an important role in the lives of many people in peri-urban areas. Farming systems involve a complex combination of inputs, managed by farming families but influenced by environmental, political, economic, institutional and social factors. Research and extension institutions are increasingly aware that a holistic approach, drawing on both local and external knowledge, is necessary if they are to be effective in addressing poverty and sustainability.

According to Beets (1990), tropical agricultural production systems show a tremendous variation throughout the tropics. They are hardly ever stable, but are constantly changing. Major factors that determine farmers' choice of production systems can be classified into three major classes of factors: the political and economical frame conditions, the household characteristics, and the natural resource base. Figures 4 and 5 depict the factors influencing farmers' choice of production systems, the relationship between farmers' choices and environmental effects as well as the reciprocal relationships between components of an agrarian system.

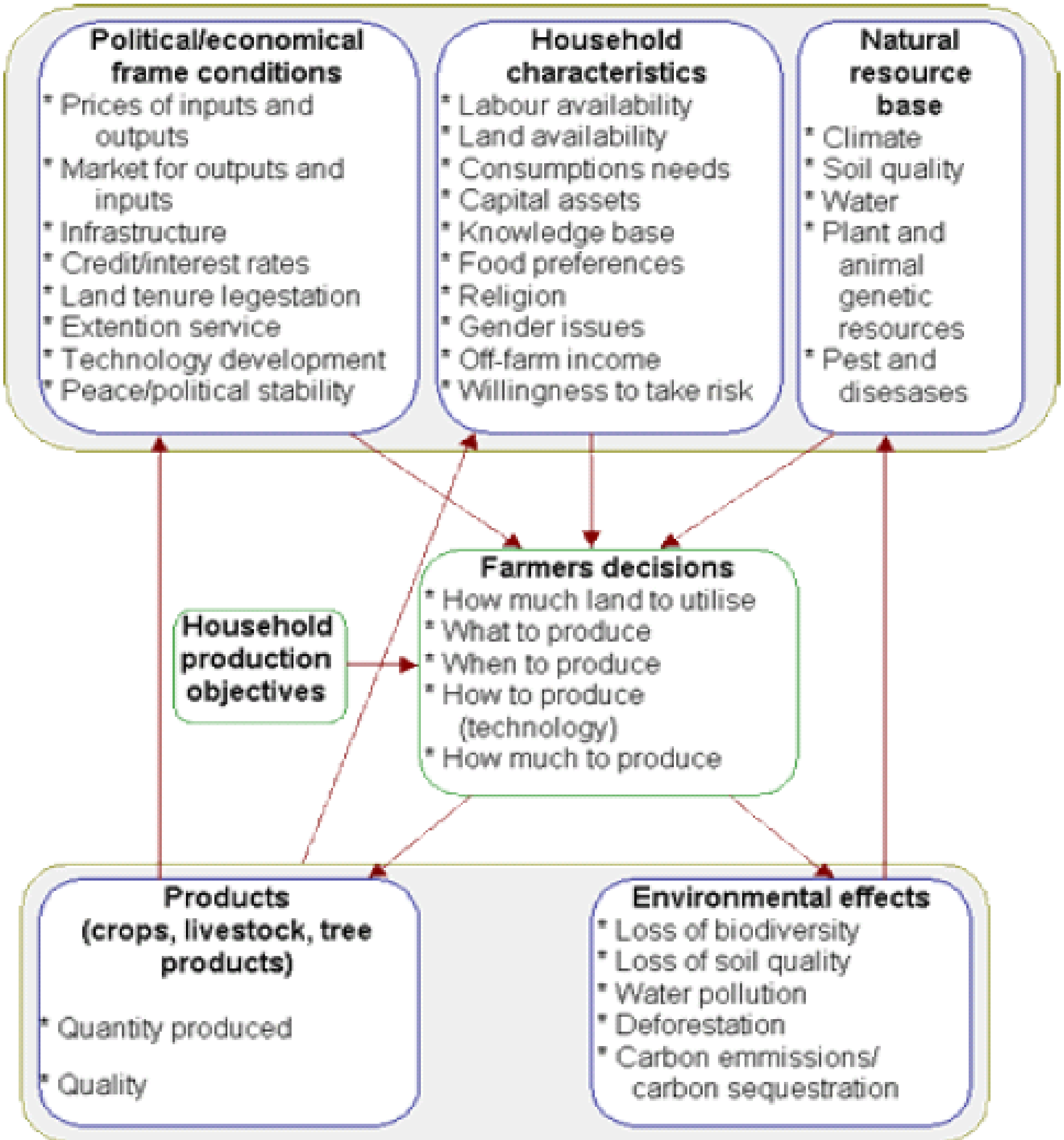


Figure 4. Farmers' Choice of Production Systems (after Beets, 1990)

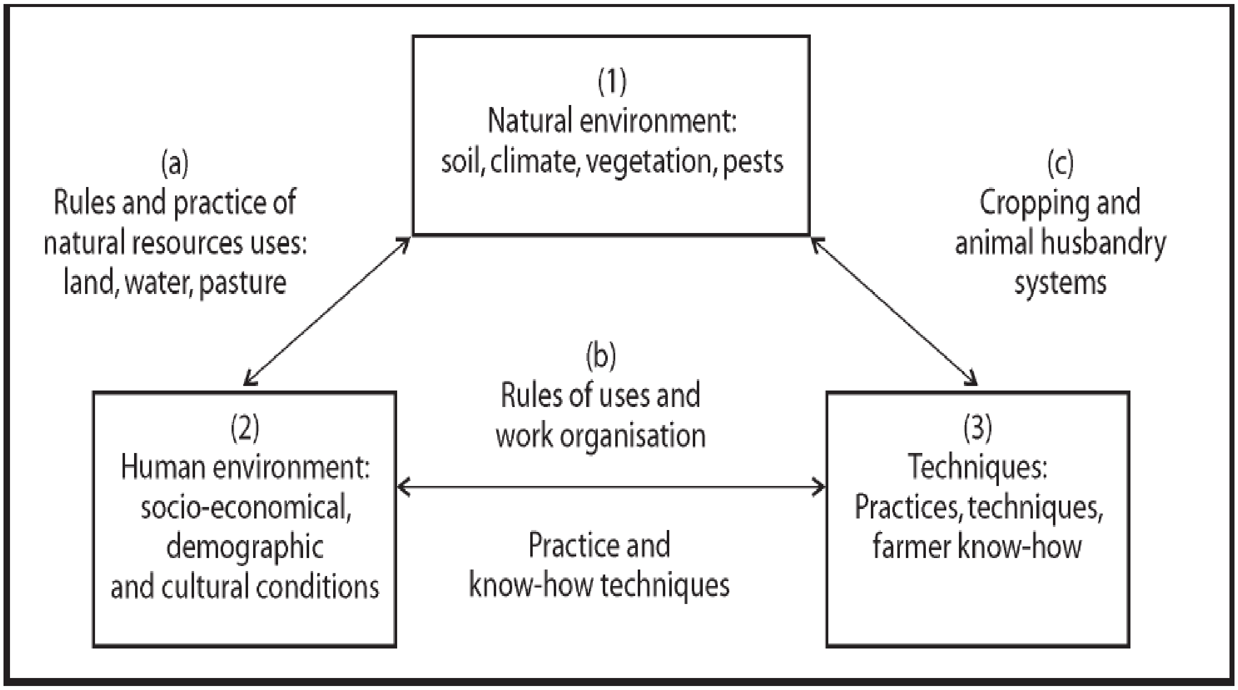


Figure 5. Reciprocal Relationships between Components of an Agrarian System (after Collinson, 1982)

The conditions of the political and economic frame are generally outside the control of farmers, and are determined by national and regional policies, international markets, and trade regulations. Important frame conditions are prices of inputs and outputs, markets, infrastructure, and land tenure systems. Farmers' decision making will also be influenced by the services of the extension service, and access to new technology through research. Political unrest and wars are other frame conditions that strongly influence farmers' decision making. The more farmers are integrated into markets, the more the political/economic frame conditions are important. Peasants are typically less integrated into the market than commercial farmers.

The second major class of factors which influence farmers' decision making is the household characteristics. Labour and land availability, consumption needs and food preferences, capital assets, knowledge base (literacy and traditional knowledge), religion, off-farm income, and willingness to take risk are all important factors which will influence household decision making. Poor families with few capital assets (animals and crops) will in general be less willing to take risk. Farmers with a good knowledge base can more easily take part in market activities, and can more effectively make use of extension services and new technologies.

The natural resource base is the third major class of factors which influence farmers' decision making. Some of these natural resources are outside the control of the farmer, such as climate and water for irrigation, whereas the farmer can to some extent control soil quality and farm genetic resources. Farmers need to consider the quality and quantity of these resources when decisions are made. The household production objectives, together with an assessment of the political and economical frame conditions, the household characteristics, and natural resource base, will form the basis for households' decision making. Households differ with regard to production objectives. Poor households will, in general, be more subsistence-oriented, while better-off households will be more cash and profit-oriented. The interest to maintain the farm resources will also differ between households. The key decisions households make with regard to agricultural production is on what to produce, how to produce, and how much to produce. Different households make different decisions due to variation in household characteristics such as labour availability, access to capital and off-farm income. The sum of decisions of all households will determine the amount of products offered on the market, and the relationship between supply and demand of products will, in a free market, determine the price of products.

The decisions farmers make with regard to what to produce and what type of technology to use have environmental consequences. The sum of all farmers' decisions will determine the quality of the future land resources. The choice of agricultural technology can, for example, determine the degree of soil erosion, water pollution, and carbon emission. There is a feedback mechanism between these processes and the quality of the natural resource base.

Tropical production systems will change over time due to changes in the political and economic frame conditions, household characteristics, and the natural resource base. Decision makers can influence the development of tropical production systems through price policies, interest rates, land tenure legislation, extension, and research. Farming systems have undergone major changes during the course of history. In pre-agricultural times, people obtained food through gathering, hunting, and fishing. Such production systems still exist in some parts of the tropics.

As population density increases, farmers take up agricultural activities. The first type of agriculture introduced is normally different forms of 'slash and burn' agriculture.

Farmers burn the vegetation and cultivate the land for some years. The effect of burning is to add plant nutrients, increase soil pH, and reduce weed infestation. However, yields will decline during the first years of cultivation due to increased weed infestation and loss of soil fertility. When the yield becomes too low, the land is returned to fallow for a period of time before it once again is cleared and burned. This type of agriculture is found under low population densities and is still practiced in parts of humid and sub-humid areas. There is generally a strong relationship between farming intensity, population growth, and agricultural mechanization. Fallow systems dominate when population density is low, whereas annual cultivation will only appear in more densely populated areas.

ICRISAT (1989) considered agricultural intensification as increased frequency of cultivation. Other features of agricultural intensification are transition from hand-hoe to the plough, an increase in investment for de-stumping, terracing, use of manure, and a change from general use rights to specific land rights. The following factors have been found to affect the shift from a fallow system to a more intensive system:

a) Availability of new land

b) Yield level under shifting cultivation as compared to under permanent agriculture

c) The cost of clearing new land

d) Access to mechanization

e) Access to markets

f) Prices (farmers may revert to shifting cultivation as a response to increase in fertilizer prices)

g) The cost of moving physical structures

The cost of moving to new land will typically be lower for smallholders and peasants than for large scale farmers. Large scale/mechanism farmers will clear the land completely for roots and stones, whereas small scale farmers normally do not destump the trees. Clearing the land of roots and stones will also make it easier to introduce animal traction for ploughing. Animal traction is for this reason seldom practiced in fallow systems. Moreover, large-scale farmers may have more easy access than peasants to purchased inputs useful for maintaining soil productivity. Fallow systems are therefore more attractive to smallholders and peasants than to larger-scale farmers.

Collinson (1982) stated that, an overview of tropical production systems shows that they can be classified into arid, semi-arid, sub-humid, humid and highland areas. This classification is based on length of available growing period and temperature during the growing season. There is general a strong relationship between agro-climatic conditions, population density, cropping system and livestock production.

Arid areas are characterized by low population density, and nomadic livestock systems are often practiced. A nomad is highly mobile, but does not necessarily return to the same base every year. A nomad does not normally grow crops. The semi-arid tropics is characterised by permanent agriculture and livestock production is often a mix of transhumance and sedentary livestock production. Cereal crops like pearl millet and sorghum and grain, legumes like cowpea and groundnut are dominating crops in semi-arid tropics. Soils are often poor in nitrogen and phosphorous. Farming in semi-arid areas is characterized by relatively low response to inputs, high erosion rates, and erratic rainfall which often causes extreme variation in yield.

Sub-humid areas including the Lower Benue River Basin have the best conditions for irrigation agriculture and high population density. Maize and rice are major crops in sub-humid areas. Livestock production is mainly sedentary. Different crops are often combined on the same piece of land in mixed cropping systems in the sub-humid and humid conditions. Major crops in the humid tropics are maize, tuber crops, rice, plantains, and tree crops such as oil palm. Livestock density is low in humid areas due to prevalence of livestock pests. Trypanosomasis, which is transmitted by the tsetse fly, is a major threat to livestock in the forest fallow and bush fallow systems. The reason is that the tsetse fly is shade-loving, and can only survive under forest bush cover. Pest and diseases often cause serious losses in humid areas. Storage of agricultural products is another serious problem in the humid tropics.

The foregoing literature shows that there is a tremendous variation in the type of agricultural production system practised in the tropics. It has been shown that farmers make their decision based on political and economic frame conditions, household characteristics, and the natural resource base. These factors, together with household production objectives, form the basis for household decision making. Households decide on what to produce, how to produce, and how much to produce. These choices will have environmental consequences, and will determine the quantities and quality of the products offered on the market.

According to Boserup (1965), each stage in the process of farming intensification required more labour to produce more quantity of output with a given level of technology, thus there was a direct incentive to practice extensive rather than intensive farming provided that sufficient land was available. She further added that only when land became limiting because of population pressure would farmers intensify their production, and even then they would continue to use techniques adapted to more extensive systems as long as possible, until forced by starvation to adopt more labour-intensive techniques such as manuring and soil conservation, and then, and only then, would they adopt or invent labour-saving technologies such as machination.

Although no two farms are exactly alike, it is obvious to anyone who has traveled in the countryside anywhere in the world that most farms in a particular area usually have many common features. Depending on the environment in that area, most of them grow the same crops, keep the same animals, and go about their farming in roughly similar ways. Therefore, they can be said to practice similar farming systems. Farmers have to adapt their farming to their natural environment — to succeed; they must work with nature and not against it. They must also adapt their systems to infrastructural factors, such as land-tenure arrangements, and the availability of inputs such as water, power, fertilizers, pesticides, labour, advice, and information. External economic factors such as location, availability of roads, communications, and markets for selling produce, prices, credit, produce subsidies, and other features affect the attractiveness and profitability of different farming systems. Internal factors such as farm size, the available labour force, resources that can be invested and fixed improvements are other obvious determinants. Finally, personal choice and preferences may influence the system (Ruthenberg, 1980).

The term *agricultural system* and *farming system* are often used interchangeably (MacDonald 1981, Lal, 1991a and Beets 1990). He added that, agricultural system is often used for broad, global systems whereas farming system is used for a more narrowly defined unit. The broadest classification of tropical agricultural systems can be in animal and crop-based systems. When those broadest agricultural systems are further divided it seems better to speak of farming systems as contained in Figures 6 and 7. For the purpose of this study, the classification of Tropical Agricultural Systems proffered by Beets (1990) was adopted.

The Guinea savannas where the study is based is less densely populated than areas nearer to the coast, still have land that is very lightly used, particularly at a distance from the roads. The more easily accessible land is largely used for annual crops, generally with low external inputs, and producing low yields. Crops include maize and sorghum; millets in the northern part; cotton, cassava, soybean and cowpea; yam near the southern border, and wetland rice in parts of the river plains and valley areas. Homesteads often have some vegetables and fruits. Cattle are held on many farms for draught or for milk but are less common near the southern border because of the tsetse threat. Small livestock is often held in the homesteads. Manure is used to maintain the productivity of the homestead garden, and some manure may be applied on the nearest fields as well. Part of the farms has draught power, mainly oxen, some of the largest farms have a tractor, but many farmers cultivate their land with the hoe, and therefore the extent of their cultivated land is severely limited. Generally the household consumes a large part of the farm produce; some is sold at harvest time.

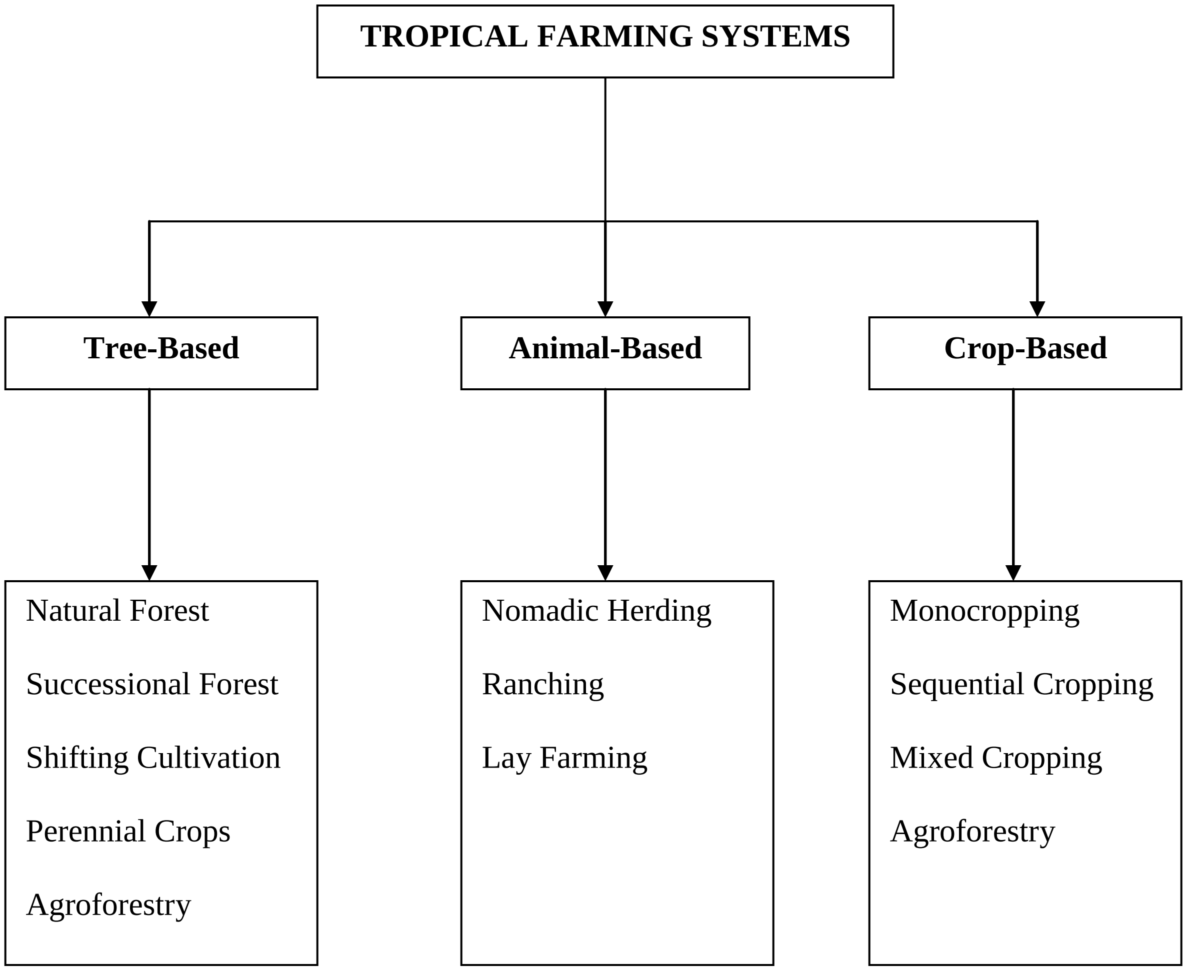


Figure 6. Principal Farming Systems of the Tropics (after Lal, 1991a)

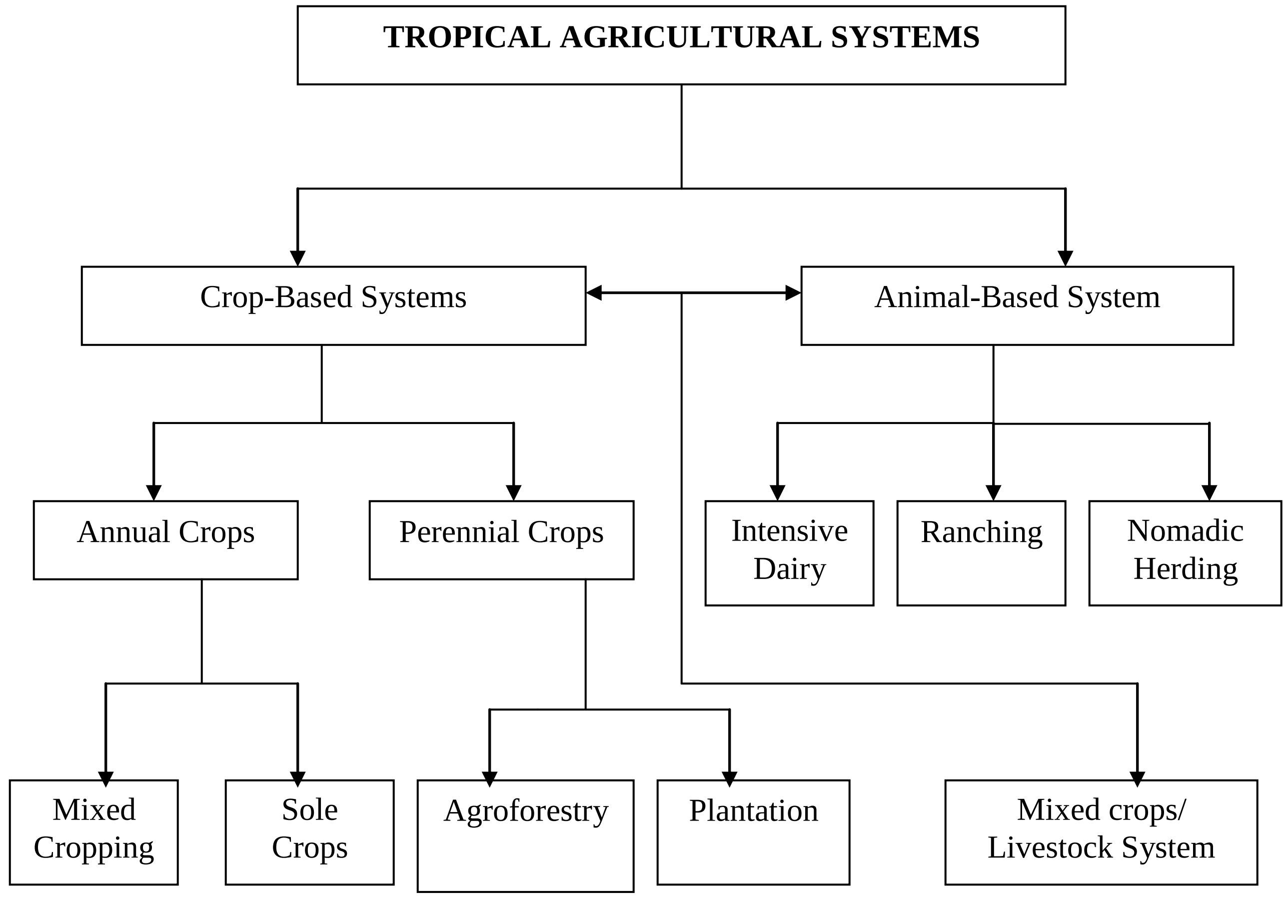


Figure 7: A Schematic Classification of Tropical Agricultural Systems (after Beets, 1990)

2.2.1 <u>Characterization and Mapping of Agricultural Production Systems</u>

Suggestions of relevant parameters for mapping agricultural production systems are provided from studies on land evaluation for agriculture - for which land utilization types are defined (FAO, 1996a) - and from studies on the mapping of farming systems at regional to global scales (Dixon and Gulliver, 2005).

a) natural resources base

b) dominant livelihood sources (land-use purpose and management)

c) products & services

d) land use management including processing & off-farm income

e) market orientation

f) capital intensity

g) labour intensity

h) power source

i) technology use and management

j) socio economic factors such as: farm size & scale and land tenure, income level, infrastructure, and population density

Since a major reason for mapping agricultural production systems is to support decision making in relation to land management interventions, it is pertinent that ‘core’ ‘characterization’ parameters should included as follows:

i. Current land use purposes (that is, the targeted agricultural goods and services – crops, livestock, aquaculture, forestry, and so on) and the associated management.

ii. The range of potential land uses given the existing resource base, and

iii. The prevailing socioeconomic conditions which exert the strongest influences on the choice of acceptable land-use and land-management options.

These considerations constitute the basis for the mapping of agricultural production systems, areas of similar resource base, similar land use purpose and management, as well as similar socio-economic setting.

2.2.2 Factors that influence the Nature and Scope of Farming Systems

Norman (1993) stated that there are basic factors that influence the nature and scope of farming systems; these include the exogenous factors and the endogenous factors (Table 4). The ***Exogenous factors*** (that is., the social environment) are largely out of the control of the individual farming family. These factors will influence what the farming family can do and can be divided into three broad groups:

a) Community structures, norms, and beliefs.

b) External institutions, which include extension, credit, and input distribution systems on the input side and markets on the output side.

c) Other influences, such as population density, location, and infrastructure.

The ***Endogenous factors***, on the other hand, are those that the individual farming household controls to some degree. These include the types of inputs, that is, land, labour, and capital. It is important to recognize that these resources and managerial ability vary among households and regions. The resources vary on the basis of quantity and quality, both of which influence the performance and the potential of the system. In addition, these inputs or resources may or may not be owned by the household. Access to one or more of these resources may be on another basis of which may limit or restrict the ease or intensity of use and thus, in turn, affect the goals and performance of the farm family. Nevertheless, it is the farming family that decides on the farming system that will emerge. However, this system will be influenced and sometimes constrained by the technical element and exogenous factors. The farming system is obviously complex, and the results can vary greatly because of differences in the 'total, environment. These facts help explain why some technology thought to be relevant often has not been adopted, or when it has, why the degree of adoption has varied widely. Not considering the human element in agricultural research has contributed to many so-called 'improved' technologies being irrelevant.

Three critical aspects of floodplain farming are inherent in the area which includes the following:

i. *Soil fertility problems* — Soil conservation and the maintenance or improvement of soil fertility are crucial to sustainable and productive tropical farming systems.

ii. *Risk and uncertainty* — Some of the risks facing farmers have to do with rainfall uncertainty. Farmers are compelled to cope with many other risks, including crop and animal diseases and pests, economic uncertainties and environmental hazards like floods, erosion and mudslides.

iii. *Labour productivity* — The marked seasonality of floodplain farming means that there are peak labour demands for fairly short periods, followed by longer periods with lower demands. Under these conditions, with a relatively inelastic labour supply, farmers find it difficult to increase their labour productivity.

Lal (1983) noted that agricultural types and systems depend heavily on the character of production, that is, whether crops are produced in subsistence or a market economy. One of the main features of subsistence farming is that the farmer has to produce in order to live. Consequently, he often resists changing production methods since, when the changes turn up to be unproductive, his livelihood and survival are threatened. The way farming is organized further depends on the level of technology and the land area available. At high levels of technology and land abundance, generally, a high level of mechanization, uniformity of land, soil fertility and genotype are needed. On the other hand, when land is scarce, cropping systems tend to be more intensive and less mechanized. Viewing farming as a 'system' means integrating the bio-physical dimensions - such as soil nutrients and water balances - with socio-economic aspects at the level of the farm, where most agricultural production and consumption decisions are made. The target of this study is to apply farming systems analysis on a river basin scale, thus allowing us to define broad regional systems, the current constraints on their development, and their potential.

According to Beets (1990), when the above factors are taken into consideration, the main determinants of agricultural types can be summarized as follows:

i. Land availability and population density

ii. Type of crop rotation and cropping pattern

iii. Water supply

iv. Type of implement used for cultivation and

v. Degree of commercialization

Table 4: Determinants of Farming Systems

NATURAL		SOCIO-ECONOMIC	
Physical	**Biological**	**Endogenous**	**Exogenous**
Climate	Crop	Family composition	Population
Topography	Livestock	Health and Nutrition	Tenure
Soils	Weeds	Education	Off-farm opportunities
Physical Structure	Pests	Food preferences	Social infrastructure
	Disease	Risk aversion	Credit
		Attitudes/goals	Markets
		Gender relations	Prices
			Technology
			Input supply
			Extension
			Savings opportunities

Source: Norman (1993)

2.2.3 Traditional Farming Systems

Lal (1974) stated that traditional farming systems have not changed much since the early 20th century. Shifting cultivation and bush fallow rotation are widely used in the tropics. These subsistence systems are diverse and based on low inputs. Several crops are grown simultaneously on the same piece of land. In some regions, especially on marginal or steep lands in densely populated regions, traditional "slash and burn" farming has been destructive and has caused severe soil and environmental degradation. In most of the lowland tropics with sparser population and relatively fertile soils, however, traditional systems have proved to be ecologically stable despite the minimal inputs of the shifting cultivators.

The degree of severity of soil erosion and water runoff under traditional farming systems depends on the soil, land-use intensity, relief and cultural practices adopted. Runoff and erosion are generally reduced if the fallow period is long enough to restore soil physical properties and increase the soil organic matter content. Traditionally, farmers abandon the land when crop yields are too low either because of prevalence of pests or because of deterioration in soil quality. The rate of decline in crop yield on soils under traditional farming depends on many factors – soil properties, crops grown, prevalent climate and soil management practices.

A study by FAO (2002) in East Africa indicates that on soils of high inherent fertility, it took 20 years of continuous cultivation to cause severe yield decline. On soils of low inherent fertility, however, yield declined under traditional farming in 1 to 2 years. There are urgent reasons to improve productivity even on soils where yield decline does not occur rapidly. The system is ecologically stable and works as long as the farmers are willing to remain at the subsistence level.

Farming systems of Sub-Saharan Africa, North Africa and the Middle East as well as the mode of distribution of some farming systems in Africa as compiled by FAO (2000) are contained in Table 5.

Table 5. Farming Systems of Sub-Saharan Africa, North Africa and the Middle East

Farming system	**Land area (% of region)**	**Agricultural population (% of region)**	**Principal livelihoods**
Region: Sub Sahara Africa			
Maize mixed	10	15	Maize, tobacco, cotton, cattle, goats, poultry, off-farm work
Cereal/root crop mixed	13	15	Maize, sorghum, millet, cassava, yams, legumes, cattle
Root crop	11	11	Yams, cassava, legumes, off-farm income
Agro-pastoral millet/sorghum	8	9	Sorghum, pearl millet, pulses. sesame, cattle, sheep, goats, poultry, off-farm work
Highland perennial	1	8	Banana, plantain, enset, coffee, cassava, sweet potato, beans, cereals, livestock, poultry, off-farm work
Forest based	11	7	Cassava, maize. beans, cocoyam
Highland temperate mixed	2	7	Wheat barley, peas, lentils, broad-beans, rape, potatoes, sheep, goats, cattle, poultry, off-farm work
Pastoral	14	7	Cattle, camels, sheep, goats, remittances
Tree crop	3	6	Cocoa, coffee, oil palm, rubber, yams, maize, off-farm work
Commercial –	5	4	Maize, pulses, sunflower, cattle, sheep,

largeholder and smallholder			goats, remittances
Coastal artisanal fishing	2	3	Marine fish, coconuts, cashew, banana, yams, fruit, goats, poultry, off-farm work
Irrigated	1	2	Rice, cotton, vegetables, rainfed crops, cattle, poultry
Rice/tree crop	1	2	Rice, banana, coffee, maize, cassava, legumes, livestock, off-farm work
Sparse agriculture (arid)	18	1	Irrigated maize, vegetables, date palms, cattle, off-farm work
Urban based	<1	3	Fruit, vegetables, dairy, cattle, goats, poultry, off-farm work
Region: North Africa/Middle East			
Highland mixed	7	30	Cereals, legumes, sheep, off-farm work
Rainfed mixed	2	18	Tree crops, cereals, legumes, off-farm work
Irrigated	2	17	Fruits, vegetables, cash crops
Dryland mixed	4	14	Cereals, sheep, off-farm work
Pastoral	23	9	Sheep, goats, barley, off-farm work
Urban based	<1	6	Horticulture, poultry, off-farm work
Sparse (arid)	62	5	Camels, sheep, off-farm work
Coastal artisanal fishing	1	1	Fishing, off-farm work

Source: FAO (2000)

2.2.4 <u>Crop Farming</u>

Webster and Wilson (1980) considered crop farming as extensive cultivation of plants to yield food, feed, or fibre; to provide medicinal or industrial ingredients; or to grow ornamental products. Crop farming developed in ancient times, as hunter-gatherers of the Stone Age turned to the cultivation of favoured species. Modern crops were gradually derived from their wild ancestors through continual selection for larger seed size, improved fruit, and other desirable traits.

Modern crops evolved around their ancient centers of origin. Wheat, barley, oats, millet, sugar beet, and most forage legumes and grasses were developed in the region encompassing the Middle East, North Africa, and southern Europe. Corn, potatoes, peanuts, sunflowers, and tobacco were cultivated in the Americas. Soya beans, onions, lettuce, and peas were first grown in China. Sugar cane and rice, most citrus fruits, and bananas came from southern Asia.

According to Beets (1982), crops spread widely even in the ancient world. Corn and potatoes were grown throughout North and South America long before the Europeans arrived; and early wheat and barley were distributed throughout the Near East well before the time of the pharaohs. Later, as sailing ships spanned the globe, favoured crops became distributed worldwide by colonists, who carried seeds from their homelands and added them to the crops of the new land. Between the 16th and 19th centuries, the opening up of vast new lands through conquests, as well as the need to provide slaves and other large concentrations of workers with a ready supply of cheap food, stimulated the movement and cultivation of crops on a worldwide scale. In the 20th century, the decline of suitable new croplands and the dramatic increase in world population gave a new focus and a sense of urgency to the exploration and development of food crops.

Modern crop farming varies widely in its scope, ranging from intensively managed small plots to commercial farms covering thousands of acres. Successful crop farmers must be expert at selecting the varieties of plants that are adapted to their soils and climate. They must be skilled in preparing soil and in planting, growing, protecting, harvesting, and storing crops. They must also be able to control weeds, insects, and diseases, and have marketing skills to enable them to gain reasonable returns from their crops.

A. <u>Grain crops</u>

The most important food-energy source for three-quarters of the world's population is grain. Most grains are members of the grass family, grown for their large edible seeds. Chief among these are wheat, rice, corn (maize), barley, oats, rye, sorghum, and millet. All are widely used as food for humans, both directly and in processed forms. Corn, barley, oats, and sorghum also serve as livestock and poultry feeds; stalks and straw from these crops are important sources of fodder. Grains are among the oldest crops, with their cultivation dating back about 10,000 years (Biggs and Gibbon, 1986).

Wheat, barley, oats, and rye are grown most commonly in areas with moderate to low annual rainfall (25 to 76 mm/10 to 30 in), where they are more productive than crops that require more water. Higher rainfall, irrigation, and fertilization, however, boost the yields of these cereal grains. Rice is primarily a tropical or subtropical cereal, although the Asian growers have developed short-season strains adapted to temperate areas.

Most rice is grown in water or in paddy fields with ample water supplies. Upland, or dry land, rice is grown in limited areas. Historically, sorghum has been a tropical grain, grown for food in Africa and Asia. In the past half century its use has spread so widely that it has become an important livestock feed in dry land areas such as the northern parts of Nigeria.

Grain crops are well adapted to mechanization. In some parts of the world most grain production is on large farms, where agricultural machinery performs the tilling, planting, and harvesting. This is less true in the tropics such as Nigeria and in locations where the terrain is too rough for machinery. In these areas grain is grown on small farms, and much of the planting, harvesting, and threshing continues to be done by hand or with primitive equipment. The development in the 1960s of improved grain-crop varieties with higher yields, stronger pest resistance, and greater response to fertilizers has improved productivity throughout much of the world. In many areas of the tropics, the new developments triggered the so-called green revolution, a dramatic increase in grain production. More work was needed, however, to adapt superior varieties to local conditions and to solve human problems associated with the distribution of their benefits.

B. Forage crops

Forage-crop farming is concerned with the production of food for the world's livestock industries. Forage crops are mowed, dried, and stored as hay; chopped and stored wet as silage; or fed directly to cattle as pasture or as freshly chopped forage. In tropical and subtropical regions, most livestock consume forages as pasture.

Forage-crop farmers normally grow one or more legumes in association with a grass. Bacteria in the root nodules of the legumes convert atmospheric nitrogen by a process called nitrogen fixation into forms available to these plants and enrich the soil for the grasses as well, thereby reducing the need for fertilizer and increasing the yields and the quality of the forage.

C. <u>Fruit crops</u>

The farming of fruit crops differs in some ways from other agricultural crops. While most other crops grow from seeds, fruit trees are propagated by grafting buds on to seedling rootstalks. Traditionally, fruit growers harvested apples and other fruit by hand. With the larger orchards, however, more and more fruit growers are using the same types of harvesting machinery that other crops require.

The temperate, subtropical, and tropical regions of the world all grow important fruit crops. Apples, pears, peaches, plums, nectarines, and cherries are the major temperate fruits. Oranges, lemons, limes, tangerines, olives, and figs are subtropical crops. The leading tropical fruits include bananas, avocados, mangoes, dates, pineapples, and papayas.

Grigg (1974) explained that nearly all commercial fruit trees are propagated vegetatively, that is, without the use of seeds. Growers take cuttings or buds from the varieties that have desirable fruit qualities and graft these onto seedling rootstocks of the strains selected for adaptation to local soil and climatic conditions and for resistance to root-destroying diseases and insects. In recent years, many fruit growers have shifted to the use of “dwarfing” rootstocks to reduce tree size. This procedure makes fruit harvesting easier and less costly, and it permits increased plant density and high yields per unit area of land.

Cultural practices differ for each fruit species, depending on the type of soil, climate, and fertilizer it needs. Close control of insects and diseases is essential in commercial plantings to produce high-quality fruit and profitable yields. Commercial growers began to rely heavily on chemical sprays in the 1960s, but after two decades of accelerating pest resistance and environmental damage, modern growers have shifted towards biological pest control and careful monitoring of pest populations, spraying chemicals only at those times when the controls would be most effective. Most fruit crops are harvested by hand, but commercial fruit growers in the developed countries use mechanization where practical in order to reduce labour and other costs.

D. Nuts crops

A wide variety of nut crops are grown in tropical and temperate climates. Coconuts and oil-palm nuts come from the tropics. Walnuts, pecans, almonds, chestnuts, and hazelnuts come from deciduous trees in temperate zones. Peanuts and coconuts are the most important nut crops and are common sources of food and edible oils. Palm nuts are an increasingly important source of edible and industrial oils. Most other nut species are grown primarily for food; notable exceptions include groundnuts, which are grown for industrial oils, and cola nuts, which produce caffeine, a stimulant.

Improved devices for harvesting, shelling, and drying have made it possible for commercial nut farming to evolve into a large industry. Cultural practices differ depending on the nature of the specific crop, its soil and climatic needs, and available labour. Insect and disease controls are particularly important in commercial plantings and must be carefully adapted to the individual pest and crop.

E. Vegetable farming

According to Spedding (1979), a wide variety of herbaceous plants are cultivated for their edible leaves, stems, roots, fruits, and seeds. Vegetables provide important minerals and vitamins in human nutrition and add variety and interest to meals. Vegetables are grown in environments ranging from city window boxes and home gardens to large commercial farms. More than 40 types are widely cultivated, including leafy salad crops (such as lettuce, spinach, cabbage), root crops (beets, carrots, potatoes, sweet potatoes), cole crops (cabbage, broccoli, cauliflower), and a variety of other types grown for their fruit or seed (peas, beans, sweet corn, squashes, melons, tomatoes).

Many vegetable species, through careful selection of varieties, can be grown in widely diverse environments. Growers must still be careful, however, to choose varieties adapted to their particular soils and climates. Most of the common vegetable species used for crop farming were developed in temperate regions, but some have been adapted to the tropics. Tropical vegetables include a variety of root crops (particularly yams and cassava); diverse melons, squashes, and beans; and many kinds of plants grown for their edible leaves and stems.

Most fresh vegetables were formerly grown close to population centers and were available only during or shortly after harvest. Canning was the major method of processing. The shift to marketing through chain-store supermarkets, and the development of large food-processing companies, concentrated purchasing power among comparatively few buyers requiring steady, year-round supplies of uniform-quality vegetables. At the same time, large-scale vegetable production became possible in areas far from major population centers because of rapidly expanding irrigation systems, improved insect sprays and weed control, and the development of sophisticated machinery for planting, spraying, harvesting, and grading.

Ozkan *et al* (1998) stated that vegetable farming, compared with other types, requires substantial skills and luck to be successful. Growers must be poised at producing high-quality, attractive vegetables that the public will want to buy. They must be knowledgeable about soil preparation, planting and growing crops, weed and pest control, and water management. They must harvest and handle their products carefully to maintain quality, and they must develop and follow well-planned sales strategies. Mistakes, oversights, poor weather, or bad luck can render a vegetable crop unsightly and unsaleable or reduce yields below profitable levels.

F. Non-food crops

Large areas of cropland in the world are given over to such important products as tobacco, rubber, cotton, industrial and medicinal supplies, and ornamental plants. Some crops (tobacco, cotton) are widely grown around the world; others (rubber, sisal, certain oilseeds) are grown in tropical or other areas especially suited to their needs. All species require careful management and good farming practices. Tobacco and cotton are particularly demanding crops. They can offer high potential returns to growers but are vulnerable to a wide range of insect and disease pests that growers must guard against through careful pest-management programmes.

G. Energy-producing crops

According to Chan (1985) energy-producing crops are receiving increased attention as supplies of fossil fuels dwindle. The conversion of plant material to usable energy depends either on direct burning of the material or on fermentation of plant sugars into alcohol. Wood, corncobs, straw, and other fibrous and woody products can be converted directly to energy by burning, but are difficult to gather, handle, and transport over long distances. Current attention is being devoted, therefore, to crops such as sugar cane and sugar beet that produce large quantities of sugars easily fermented into alcohol. Close behind in terms of potential are starch producers such as corn and potatoes. Available low-cost chemistry can convert these starches into sugars for making alcohol. Other possibilities exist wherever plant materials and crop wastes are produced, but technologies for breaking down cellulose and other plant fibres into sugars for fermentation are complicated and costly at present and need further development before they can become commercially feasible.

2.2.5 **Livestock Farming**

Seré and Steinfeld (1996) developed a global livestock production system classification scheme (Figure 8). In it, livestock systems fall into four categories: landless systems, livestock only and rangeland-based systems (areas with minimal cropping), mixed rainfed systems (mostly rainfed cropping combined with livestock) and mixed irrigated systems (a significant proportion of cropping uses irrigation and is interspersed with livestock). A method has been devised for mapping the classification, based on agro-climatology, land cover, and human population density. Information on livestock distribution is extremely useful in drawing policy makers' attention to areas of high density of particular livestock species that are therefore surmised to be at risk of environmental degradation and constitute areas of high animal and possibly human health risks and thus require attention.

One of the major limitations in livestock sector planning, policy development and analysis is the paucity of reliable and accessible information on the distribution, abundance and use of livestock. With the objective of redressing this shortfall, the United Nations Food and Agriculture Organisation's Livestock Production and Health Division (FAO-AGA) has developed a global livestock information system in which geo-referenced livestock data are collated, standardised and made freely available through FAO's website.

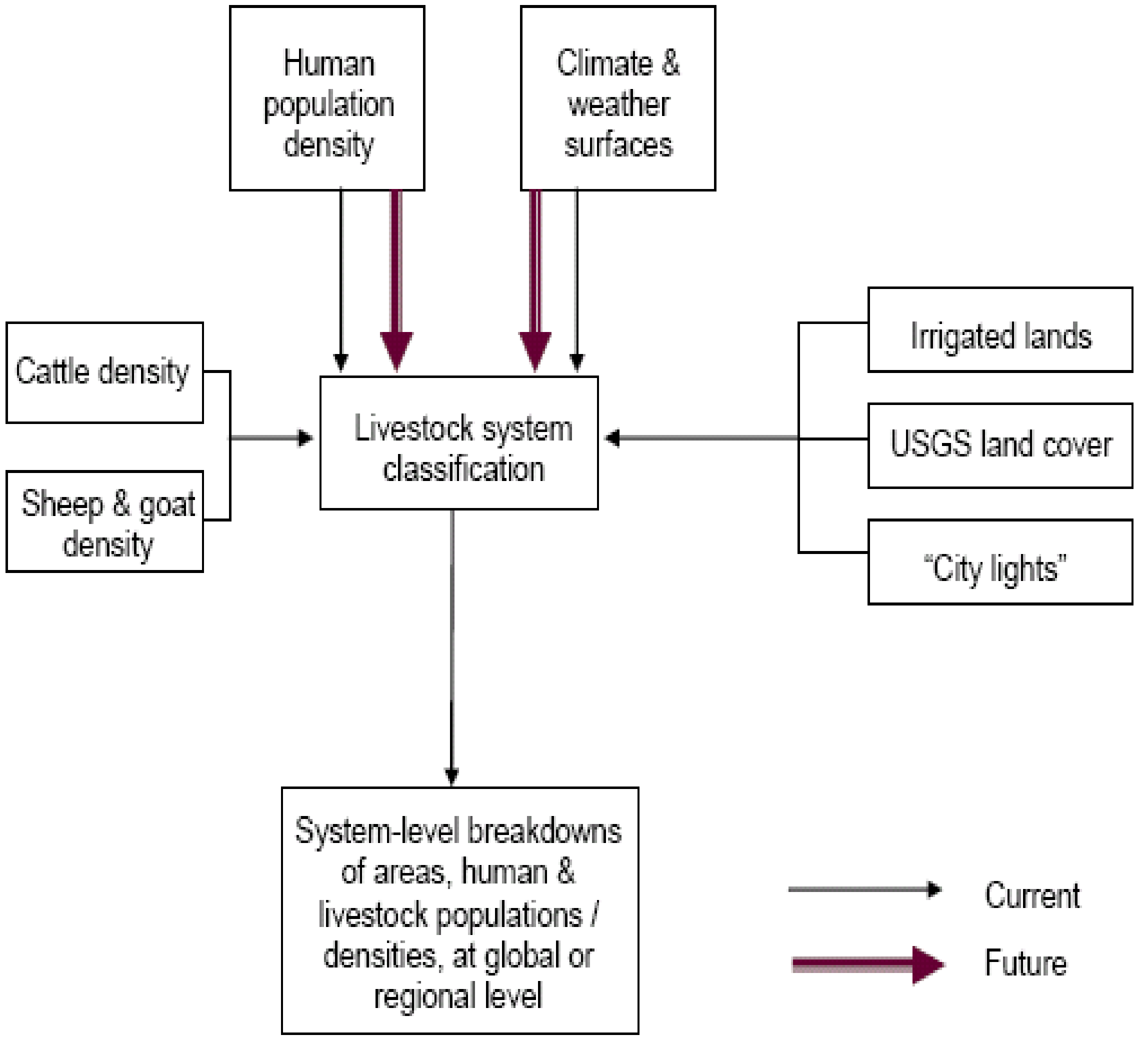


Figure 8. Livestock Production System (after Seré and Steinfeld, 1996)

2.3 THE CONCEPT OF FOOD SECURITY

Food security is not to be defined as being the same as food self-sufficiency or agricultural development, because these are narrower concepts than food security. Although food self-sufficiency might be a valid policy objective in some situations, the challenge to food-security researchers is to measure the real costs and reduction of risks associated with increasing the self-sufficiency index of a particular crop in a particular country. Similarly, agricultural development, if successful, could make a contribution to food supplies, and is essential for raising the average standard of living in the region, but should not be confused with food security (FAO, 2000).

Food security exists when "all people at all times have access to safe nutritious food to maintain a healthy and active life" (FAO, 1996b). The 1996 World Food Summit in Rome defined food security as a state when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life. The main goal of food security is for individuals to be able to obtain adequate food needed at all times, and to be able to utilize the food to meet the body’s needs. Food security is multifaceted. The World Bank (2001) identified three pillars underpinning food security; these are food availability, food accessibility, and food utilization. This infers from concept that food security is not just a production issue. Food availability for the farm household means ensuring sufficient food is available for them through own production. However, due to lack of adequate storage facilities and pressing needs, they mostly end up selling excess produce during the harvesting period, and sometimes rely on market purchases during the hungry season.

Food access means reducing poverty. Simply making food available is not enough; one must also be able to purchase it, especially the low-income households.

Pervasive poverty among the rural population in Nigeria is an indication of low agricultural productivity and relatively low incomes (Abdullahi, 1999). D'Silva and Bysouth (1992) regarded absolute poverty as lack of access to resources required for obtaining the minimum necessities essential for the maintenance of physical efficiency. This connotes that the poor farmers will have little access to food, either produced or purchased. Farm families with limited access to productive resources such as land, inputs and capital, required for attaining physical efficiency in food production could be food insecure, that is, resource poverty could lead to low productivity, food insufficiency, and lack of income to purchase the needed calories.

Food utilization means ensuring a good nutritional outcome, which is nutrition security. Having sufficient food will not ensure a good nutritional outcome if poor health results in frequent sickness. Building this pillar means investing in complementary resources such as nutrition education, health care, provision of safe water and better sanitation, instituting gender symmetry, and removal of child abuse practices (Doppler, 2002).

Availability	=	Sufficient food in the farm household
Accessibility	=	Affordability and good road networks to the markets for sales and purchase
Utilization	=	Good nutritional outcomes

2.3.1 Major Issues in Food Security

FAO (2002) stated that the rate of increase in undernourishment in Africa vastly exceeds that of other developing regions. Achieving food security is imperative, but how to do so is an elusive, complex problem. Part of the problem is the very low current and past levels of investment in productivity-increasing measures in African agriculture, which have meant high unit costs of production and progressive environmental degradation. The results are low incomes for farmers and other rural residents, reduced competitiveness, and increasing food insecurity and child malnutrition.

The near stagnant economies in parts of Africa are to a large extent a reflection of stagnant agriculture. Lower unit costs in production, resulting from productivity increases, would lead to lower consumer prices for food and higher farm incomes, which, in turn, would promote economic growth through lower wage costs, higher investments, and increasing consumer demand outside agriculture. Smallholder-led economic growth could lead to dramatic improvements in food security and nutrition. Science and technology can directly contribute to food security through improved crops and cropping practices, labour-saving technologies, better communications, and improved quality of food processing, packaging and marketing. Women and children must be major beneficiaries of any advances.

Smallholder farmers who are the major producers of food in Nigeria are noted to reside mainly in the rural areas, poorer and less food secure than the rest of the population. Dealing with food insecurity in Nigeria means tackling the problems faced by these rural farm families in their effort in making a livelihood. Problems faced by the farm families are diverse in nature. This is as a result of diversity in their accessibility to resources, their choice of activities, and the entire structure of their lives. Every farmer is unique; however, those who share similar conditions also often share common problems and priorities. Therefore, farming systems approach offers a framework for understanding the needs of families within a system and the relative importance of strategies for development and food security (FAO, 2001).

Omojola and Soneye (1993) did a similar study in Nigeria, using the discriminant analysis. His variables and analysis was based on food expenditure and socio-demographic variables. He found that % of total food expenditure going to livestock and fish products, total household income, family size and level of formal education of household head are the key discriminating variables between the food secure and insecure on the national level. In essence, food security is a multifaceted concept, which cannot be treated in isolation from other indexes of living standards. Therefore efforts geared towards achieving food security should also address other areas of human and infrastructure development.

Food Security, we all know, is much more than food quantity. The green revolution has not ended the recurring problems of starvation and malnutrition encountered in many parts of the world, and in particular sub-Saharan Africa. More often than not, the issue of food security, as emphasized by many researchers, is about access to existing food, and about the quality of this food. Access itself is more complex than the popular image of emergency work, moving food to an area where the population is in danger of starvation. Access to food needs to be continuous, adapted in quantity and quality to the needs and the traditions of the different members of a population.

Food Security can be a survival issue in extreme cases. In many more cases, it is an issue of development, and an issue of human right. What do we, researchers, have to offer? What do we do to improve food security? What could we do? In an attempt to address these questions, Abdullahi (1999) earlier suggested that we could:

a) Review the current state of the art with respect to research and development activities that affect food systems in sub-Saharan Africa;

b) Identify gaps in current food and health research strategies;

c) Recommend future research strategies;

d) Improve the links between researchers, in particular young scientists, in Africa.

From the various brain-storming sessions taking place in the world, researchers will be able to identify gaps, and they will be able to work towards recommending research strategies. Improving links between researchers is a direct objective of international cooperation between continents. Many questions are being asked by Food Security researchers, around the world. Questions are, after all, at the source of all research! But others -politicians, practitioners, donors and beneficiaries of our work- have questions for researchers, too. Are we listening to them? We would like to offer some of them here, in order to start another angle of thinking:

i. What problems have we solved, in recent decades?
ii. Which ones do we still need to work on?
iii. Why have we failed to solve some of the problems?
iv. What is the plan for the future?

Rukuni and Eicher (1987) made the important point that even if a country is self-sufficient in food, this does not imply that all (or even a large proportion) of its people may have access to sufficient food at all times. Urban or landless people may not have sufficient money to buy food, and the rural poor who have land may suffer from lack of food during times of drought or during the "hungry gap" before the harvest. Therefore, access to food is as important as food availability and research and policy action should be directed to both these aspects. They suggest six challenges for food-security researchers in Africa as follows:

i. Food and agricultural production;
ii. Marketing, rural infrastructure, and storage;
iii. Raising rural per-capita incomes and generating employment in rural areas;
iv. Food access and nutrition;

v. National food-security policy analysis; and

vi. Regional food-security policy analysis.

The United Nations Food and Agriculture Organization (FAO) has estimated that almost 200 million Africans were undernourished at the dawn of the millennium, compared with 133 million 20 years earlier (FAO, 2000). The rate of increase in undernourishment in Africa vastly exceeds that of other developing regions. Yet, West Africa has gone against the trend in the rest of Africa, with its numbers and the prevalence of undernourishment falling dramatically over the period, and this is reason for optimism that trends can be reversed in other parts of Africa (FAO, 2002). Countries that stand out are Benin, Ghana and Nigeria, but they were the only Sub-Saharan African countries that had consistent declines in both the numbers and the prevalence of undernourished people over the past 20 years.

About 33 percent of people in Sub-Saharan Africa are undernourished, compared to about 6 percent in North Africa and 15 percent in Asia (FAO, 2002). More than 60 percent of the undernourished are in Eastern Africa, with more than half of the populations in Congo Democratic Republic and Mozambique affected, while Angola, Cameroon, Ethiopia, Kenya, Tanzania, and Zambia show prevalence rates between 40 and 50 percent. Nigeria's prevalence rate is low, but its large population means that the country accounts for 22 percent of the food insecure in West and Central Africa.

Achieving food security in Africa is complex. Clearly increased food availability is a necessary component but not a sufficient one. Over the past 20 years, per capita crop and livestock production in Sub-Saharan Africa declined by about 0.2 percent per year (FAO, 2000). In the last 10 years there has been a reversal to an annual per capita increase of 0.3 percent. Hence, while recent production trends per capita have been encouraging, projected aggregate demand growth of 2.8 percent per year to 2015 is likely to exceed projected production growth of 2.6 percent per year over the same period. This will represent a challenge for Africa and implies major food imports in the absence of significant productivity growth.

Garret and Ruel (1999) maintained that African farming systems have usually provided the minimum level of subsistence food production needed for survival in most years. Until comparatively recently, in those areas where communication and transport facilities were virtually nonexistent, there was little advantage in producing a surplus for sale or exchange outside the community, because there were so many difficulties in transporting and marketing it; thus communities lived at a subsistence level. Some insurance against the risk of crop failure are provided by storing grain for a few years or by planting more cassava or tuber crops than will be needed immediately. Surplus grain could also be exchanged for livestock in good years, and the livestock could again be exchanged for grain if times became hard.

The world's population is becoming increasingly urbanised as a result of both natural increase and rural-urban migration. The percent of urban residents in sub-Saharan Africa is expected to rise from 30-47%. This rapid increase in urbanisation poses new and different challenges for food security in the region. The three fundamental components of food security availability, access and utilisation differ in urban and rural contexts and across urban socio-economic groups. A greater diversity of both local and imported food products are available in cities although, most of the food is not produced within city boundaries. Similarly, much of the available food is processed either locally or imported in a processed form. To cater to busy urban lifestyles, cities offer access to a wide variety of food prepared outside the home; including street food and food served in restaurants and kiosks (Lal, 1991a).

Access to food in urban areas is dependent on cash exchange, with few exceptions, where urban food production contributes directly to household intake. Reliance on purchased food is a leading factor in household food insecurity of poor urban populations, who lack a fixed income. Although a wider variety of food is available, the food consumed in urban areas is not necessarily of superior nutritional quality and food safety is a growing concern in many urban environments. The different influencing factors which impact food security in urban populations, particularly among the urban poor should be considered when designing policies and programmes to improve food security (FAO.1983).

2.3.2 Global Concern about Food Security

People's food and nutrition security needs vary over their life cycles, as do the implications for their physical and mental health and well-being. Food security today is less a problem of general food availability than of access. People must have access to food. Physiological utilization implies that in addition to food access, there are other factors to consider like safe drinking water, primary health care and environmental hygiene to minimize gastro-intestinal infections that can negate the benefits of a nutritious diet. Food security is distinguished from the three forms of hunger – transient, endemic and hidden – which are discussed later.

African farmers pursue a wide range of crop and livestock enterprises that vary both across and within the major agro-ecological zones. Food production and food security in Africa depend on many different systems, unlike other regions of the world where the contribution to food production and food security is based on a limited number of systems. For the foreseeable future in Africa a multitude of farming systems need to become more productive and to generate the desired productivity increase.

FAO (2000) maintained that with increasing urbanization in Africa there is a food and nutritional transition underway leading to problems of over-nutrition such as increased obesity, diabetes, hypertension and cardiovascular risks. This is fuelled by supermarkets, new food processing technologies, increased private foreign investment, television and media penetration, and the increasing opportunity costs of time. While this is likely to be a growing problem towards 2015, this report does not address it explicitly. It adopts a narrower definition of food security consistent with its brief to explore the scope for science and technology (S&T) to enhance agricultural productivity, which is much less likely to influence the nutritional transition.

According to the report of the World Bank (1986), achieving food security in its totality continues to be a challenge not only for the developing nations, but also for the developed world. The difference lies in the magnitude of the problem in terms of its severity and proportion of the population affected. In developed nations the problem is alleviated by providing targeted food security interventions, including food aid in the form of direct food relief, food stamps, or indirectly through subsidized food production. These efforts have significantly reduced food insecurity in these regions. Similar approaches are employed in developing countries but with less success. The discrepancy in the results may be due to insufficient resource base, shorter duration of intervention, or different systems most of which are inherently heterogeneous among other factors.

There are factors that influence the physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active healthy life. These factors include unstable social and political environments that preclude sustainable economic growth, war and civil strive, macroeconomic imbalances in trade, natural resource constraints, poor human resource base, gender inequality, inadequate education, poor health, natural disasters, such as floods and locust infestation, and the absence of good governance. All these factors contribute to either insufficient national food availability or insufficient access to food by households and individuals.

According to Maxwell *et al* (2000), the root cause of food insecurity in developing countries is the inability of people to gain access to food due to poverty. While the rest of the world has made significant progress towards poverty alleviation, Africa, in particular Sub-Saharan Africa continues to lag behind. Projections show that there will be an increase in this tendency unless preventive measures are taken. Many factors have contributed to this tendency including the high prevalence of HIV/AIDS; civil war, strive and poor governance; frequent drought and famine; and agricultural dependency on the climate and environment.

FAO (2000) maintained that, over seventy percent of the food insecure population in Africa lives in the rural areas. Ironically, smallholder farmers, the producers of over 90 percent of the continent's food supply, make up the majority (50 percent) of this population. The rest of the food insecure population consists of the landless poor in rural areas (30 percent) and the urban poor. Throughout the developing world, agriculture accounts for around 9 percent of the GDP and more than half of total employment. In countries where more than 34 percent of the population is undernourished, agriculture represents 30 percent of GDP and nearly 70 percent of the population relies on agriculture for their livelihood. This fact has in the past been used in support of the argument as to why developing countries should move away from agriculture and invest in technology. Because over 70 percent of the poor live in rural areas, where also the largest proportion of the food insecure live, it is evident that we cannot significantly and sustainably reduce food insecurity without transforming the living conditions in these areas. The key lies in increasing the agricultural profitability of smallholder farmers and creating rural off-farm employment opportunities. The objective of this paper is to highlight the challenges to food security in Africa while providing alternative solutions to the problem that would not only allow for poverty alleviation but also wealth creation. While the focus of this paper is in alleviating food insecurity in the rural areas, effort has been made to address the plight of the urban poor.

Food security has three aspects; food availability, food access and food adequacy. Food availability has to do with the supply of food. This should be sufficient in quantity and quality and also provide variety. Food access addresses the demand for the food. It is influenced by economic factors, physical infrastructure and consumer preferences. Hence food availability, though elemental in ensuring food security, does not guarantee it. For households and individuals within them to be food secure, food at their access must be adequate not only in quantity but also in quality. It should ensure an adequate consistent and dependable supply of energy and nutrients through sources that are affordable and socio-culturally acceptable to them at all times. Ultimately food security should translate to an active healthy life for every individual. For this to take place the nutritionally adequate diet should be biologically utilized so that adequate performance is maintained in growth, resistance or recovery from disease, pregnancy, lactation and or physical work. Hence adequate health and care must be provided in addition to adequate food.

Pinstrup-Aderesen (2002) stated that food insecurity has the potential to influence food intake and ultimately the health and nutritional status of households. In developing countries over 85 percent of the food consumed by poor households in rural setting is obtained from the farm. The importance of foods purchased from markets in meeting household food security depends on household food income and market price. The seasonality of foods available at the household level may highly influence food availability in places where little to no food preservation is practiced. This is the case with fruits and vegetables, which are highly perishable. Agricultural land use information is a crucial input in developing strategies and plans to tackle issues of interest to Nigeria, including: Food security & poverty; Land degradation; Climate change; Policy formulation; Land use planning; and Investments in sustainable agriculture.

Barry (2006) and Oxfam (2006) find that the food crisis in Africa is continuing to worsen. In the 1960s Oxfam provided part of the impetus to set up the United Nations Food and Agricultural Organisation's (FAO) Freedom from Hunger Campaign, aimed at reducing food insecurity. That campaign has failed miserably in Africa. Whilst the average "developing world" figure for under-nourishment is 17 percent, in sub-Saharan Africa the figure is 33 percent. For Central Africa it is 55 percent. On average the number of African food emergencies per year since the mid 1980s has tripled. They reiterated that the situation may not going improve and the commitment to halve hunger by 2015, as part of the Millennium Development Goals, will not be met by in Africa at current rates of progress. The central reason why the situation has not improved is the major powers' failure to respond speedily and appropriately to the emergency food situations. Since 1981 the number of those living on less than a $1 a day in sub-Saharan Africa has increased twofold to over 310 million people. A food crisis which emerged in the northeast of Kenya in 2005 particularly affected pastoralist peoples. While the country saw a 15 percent increase in the harvest yield and a 5 percent rise in GDP, the proportion of the population living on less than $1 a day had risen to 66 percent, up from 40 percent in 1990. According to the New Partnership for African Development (NEPAD), it would require an investment of $18 billion a year into the rural infrastructure to achieve the World Food Summit goal to cut hunger by 50 percent. Much of African agriculture remains rain-fed only, and those irrigation schemes that do exist are concentrated in large commercial agribusiness estates. According to the Oxfam report a temperature increase of 2.5 degrees centigrade by 2080 will put an estimated 60 million additional people in Africa at risk of hunger. A higher rise would put 80 million at risk. The major powers are encouraged to commit greater emergency assistance more rapidly, to purchase food locally, and to secure more long-term aid for agricultural investment as most of the promises made by Western governments failed to materialize.

2.4 PRINCIPLES OF AGRICULTURAL SYSTEM ANALYSIS

This segment is devoted largely to a vivid explanation of some important principles upon which the analysis of agricultural land use systems using the techniques of Remote Sensing and GIS, are based. Such concepts include the following; land, land resources, land use and land cover (land use system, land use system analysis, agricultural holdings, sustainable agricultural land use, land use planning and management), and flood plain agriculture. Furthermore, review of relevant literature on agricultural land use studies is carried out with the aim of highlighting the outcome of related studies conducted in Nigeria and other parts of the world using these technologies.

2.4.1 Land

Barlowe (1978) have identified several concepts of land, the principal ones being the physical concepts, legal concepts, abstract concept, socio-political concept, spiritual concept and economic concepts.

i. *The physical concept* sees land as the physical expression of the nation state, which includes the physical soil, natural resources like water, trees, animals, rocks, minerals, fixed structures and the space above the land.

ii. *The legal concept* is defined and determined by law. It sees land from the point of view of nature, quantum, duration, distribution, ownership rights and duties attached to land.

iii. *The abstract concept* is derived from the physical immobility of land. The static nature of land has considerable influence on how decisions are affected on the use of land.

iv. *The socio-political concept* regards land as a nation of people, that is, as town, or community within a socio-political framework.

v. *The spiritual concept* attaches religious or spiritual value to the land, and the rural dweller's life is not complete without these values. Because the livelihood depends largely on land, many rural dwellers in Nigeria believe that there is deity (god) in the land.

vi. *The economic concept* maintains that land is the major source of man's wealth, the natural resources of raw materials that are needed for the daily requirement of our food, fibre and energy. Given such wide-ranging connotation, it is not astonishing that land ownership, for the bulk of rurality is the primary determinant of degree of wealth, social status, access to power, and in many instances, even elemental survival. According to Igbozurike (1986), land being the essential fulcrum of rural existence, how the land is handled often has a very significant bearing on rural development.

Land is therefore variously defined in line with individual's predictions, orientation, occupation and ideology. Igbozurike (1986), Lanre (1991) and Ker (1995) stated that, land means many things to many people and the meaning whether ascribed or inherent, assumes greater profundity with the degree of rurality. Land therefore, is defined as including the sum total of the natural and man-made resources over which possession of the earth's surface gives control. This includes the entire earth's surface, water and ice as well as ground, in addition to building sites, farms, soil and forest, mineral deposits and water resources. It also involves such natural phenomena as access to sunlight, rain, wind and changing temperature and location with respect to markets and other areas. Moreover, it includes all the man-made improvements that are attached to the surface of the earth and cannot be easily separated from it (Barlowe, 1978).

FAO (1994: 30) further considered land as:

> "any delineable area of the earth's terrestrial surface, involving all attributes of the biosphere immediately above or below this surface, including those of the near-surface climate, the soil and terrain forms, the surface hydrology (including shallow lakes, rivers, marshes, and swamps), near-surface layers and associated ground water and geo-hydrological reserve, the plant and animal populations, the human settlement pattern and physical results of past and present human activity (terracing, water storage or drainage structures, roads and buildings)."

Geertman and Reitsema (1995) stated that the value of and man's goals are related so also man's wants and needs are directly or indirectly related to land. This is to say that land is the mixture of nature and man together with his institutions. Among the physical resources of the earth, land is the major resource. When you talk of land, it is described in terms of its area (size), the quality of the soil, and the physical features of the area (moisture, slope, precipitation, climate, drainage) among others. Land is described in this way because as human beings, we are concerned with the quality of activities that land can support as a resource either at present or in the future. It is for this singular reason that people often ask such questions as:

a) What land use is current?

b) What land use is possible?

c) What land use is best for that particular area?

Campbell (1987) stated that land is one vital natural resource to be utilized for living and working space, and to support the natural flora and fauna. Land is also an integral part of the environment, as the case with other resources such as waters and space. Therefore land resource management in Nigeria should be strategically oriented toward sustainable development. Land is a strategic ecosystem component for sustainable development. Its limited availability, however, substantially affects national development activities. Problems related to land conservation are mostly concerned with use, utilization, and tenure aspects.

Since land embraces a number of attributes, which are characterized by chains of phenomenal interrelationships and dependence, there are bound to be inevitable changes in the characteristics of land units both on temporal and spatial scale. Furthermore, since land includes past and present human activities on land, which include agricultural land use, it is necessary to very frequently assess and reassess the impact of land use practices on land by man. Despite a considerable achievement in technology both to improve on land management practices and information to assist in the planning and decision-making on land and land use, the net condition of land continues to degrade very rapidly due to rapid population increase and limited legal provision to prevent the environment from being damaged (Abdulkadir, 1993). Irrespective of the fact that the concept of land is being considered in different ways and various ramifications, it is indeed common knowledge to say that, land is the bedrock upon which bulk of human activities are concentrated. It therefore needs to be appraised and assessed at meaningful intervals so that information can be derived for further planning and development purposes.

Ideologies, both local and foreign, seem to have their roots on land. Capitalism thrives on the ownership of land and its usage. Marxism in spite of its economic and political issues in defense of the proletariat, and in the pursuit of classless society, admits of a large-scale ownership and usage of land. Ownership and utilization of land resources is everybody's business, and in a capitalist economy such as ours, land ownership and utilization is a legitimate business (Onabanjo 1983, in his occasional speeches as Ogun State Governor, Nigeria).

According to Deckshatulu and George (1993), land from time immemorial has been treated as a measure of wealth, status and power all over the world. In India, during the feudal rules people were awarded favours by the kings in form of titles of ownership for land holdings. Precisely because of this reason Land has also been the source of many bloody wars and disputes not only between the Nations, kings and families who wanted to establish there supremacy over each other but also between common people as this was the only source of their livelihood. It has been cause of family rifts turning brothers into enemies. It has also led to disputes running through generations unresolved, attributed to lack of proper land management systems, poor record keeping, negligence on part of those who were supposed to be responsible for Land Management and also an inefficient judiciary.

They further reiterated further that land has also served as a strong tool for manipulation and exploitation of the poor. It has also been a root cause of many a malpractice carried out by those who were rich and influential which results in an exorbitant loss of revenue to the government each year, year by year. People have shown irrigated areas as non-irrigated, fertile lands as barren, curtailed the crop yields by declaring lesser hectarage of cultivated land. There are numerous instances where these perjuries are performed in cognizance with the revenue collectors who form the lowest link in the chain of revenue officials and are primarily responsible for the accuracy in cadastral database.

2.4.2 Land Resources

Avery (1977), considered land resources to include surface, subsurface and super-surface features of the earth as these affects the activities and environment of mankind. These resources include soil, mineral water, climate and other features to the extent that they can be observed, classified and especially fixed. Detailed knowledge of land resources both in their natural aspects and as affected by humans is required to guide public and private decisions. It has been recognized that the physical and economic supply of land resources is decreasing- at least in relation to continued impact and demands., He added that the government unit or individual that have primary access to land information will also have an advantage in controlling land use too. This is because current land use pattern in an area constitutes a precise database for all comprehensive land information system.

In the light of the foregoing, land is indeed regarded as a resource only when its characteristics enable it to serve human needs hence a piece of land not useful to man is not considered in any way as a resource. Thus, we may want to know what a piece of land is devoted to, and in this regard, the agricultural land use study of the Lower River Benue Plains using the techniques of satellite Remote Sensing and GIS becomes essential.

2.4.3 Land Cover

Land cover is variously defined by ESA/ESRIN-FAO (1996) in the following ways:

a. The biophysical state of the earth's surface and its immediate subsurface
b. The make up of the land surface, whether it comprises arable land, trees, or buildings and so forth
c. The vegetation (natural and cultivated) or man-made constructions, which occurs on the earth's surface. Water, ice, bare rocks, sand and similar surfaces also count as land cover.

Land cover describes broadly the nature of the earth's surface in terms of water, natural vegetation, cultivation, artificial surfaces and so on. Land cover is determined by hydrology, climate substrate type and anthropogenic intervention and is obviously closely linked to land use, the more specific application to which the land is put, and thus to agricultural production systems (Di Gregorio, and Jansen, 1998).

Land use must not be confused with land cover. Land cover is an element of land, whereas land use is not. Land cover is further defined as: "The vegetation (natural or planted) or man-made constructions (buildings, and so on) which occur on the earth surface. Water, ice, bare rock, sand and similar surfaces also count as land cover." In the words of Campbell (1987), land cover can be regarded as the surface cover on the ground, whether vegetation, urban infrastructure, water, bare soil or other. Identifying, delineating and mapping land cover is important for global monitoring studies, resource management, and planning activities. Identification of land cover establishes the baseline from which monitoring activities (change detection) can be performed, and provides the ground cover information for baseline thematic maps.

The difference between land cover and land use will be illustrated by two examples. The land cover "forest" can be described by direct field observations such as vertical vegetation structure, vegetation height and density. Aspects of the land use of "forest" may be "rubber tapping", "bio-diversity conservation", "recreation", "timber production", or "shifting cultivation". Another example is grassland with grass as land cover: the land use may be "hay production", "grazing", "not used", or "recreation". These examples indicate that land cover may be determined by direct observation, whereas information on land use requires in principle an interview with the person who controls or carries out the land use. Remotely sensed data from aerial photographs or satellite images, can be correlated with land cover, and used for mapping land cover. Land use, in turn, may be related with actual land cover, so that land use may be mapped with land cover as an intermediate step. "Ground truthing" is required to provide evidence for the surveyed aspects and to describe the actual land uses (FAO, 1994).

The identification of land cover types depends on the ability to recognize particular features on satellite images by geo-referencing them in geographical co-ordinates. Previous studies on land use and land cover have shown that, land cover mapping is a more complex exercise, as it involves not only the identification of a particular feature, but also the current delineation of its boundaries. It also requires the ability to recognize and delineate a given class in the entire study area with the level of accuracy determined by the scale of the final output.

Land use and land cover data is one of the most important data layers in any Geographic Information System for agricultural resource management. The lack of recent, reliable and up-to-date data for preparation of land use and land cover maps has made satellite imagery, the only practical source for up-to-date data for such studies. Information on land use and land cover thus permits a better understanding of the land utilization aspects on cropping pattern, grazing lands, wastelands, surface water bodies, settlements and communication network, which are vital for development planning (Uchua, 1999).

2.4.4 Land Use Systems, Analysis and Planning

Human beings make use of the land they inhabit to a degree unmatched by any other species. Anyone who has flown in an aeroplane can attest to the extent to which people have modified the landscape below to suit their own purposes. The human imprint is most marked in the temperate and tropical zones, but even remote deserts, high mountains, and

Polar Regions bear evidence of the works of people. Land represents about 29 per cent of the Earth's surface. The uses to which this land is put known as land use morphology vary considerably from place to place. In the continental United States, for example, land is more or less equally divided amongst forest, pasture, crops, and built-up areas. By contrast, 75 per cent of the land in the Democratic Republic of the Congo is forested, and only about 10 per cent is devoted to crops and pasture.

Ahmed and Sanders (1998) regarded land use as the various ways by which man utilizes the land resources at a given time period. In other words it has to do with series of operations on land, carried out by humans, with the intention to obtain products and benefits through using land resources. Land use is therefore, the primary indicator of the extent and degree to which man has made an impression on the earth's surface. It reflects political, social and economic aspects of human culture and provides an index of the intensity of human life style.

Land use is characterised by the arrangements, activities and inputs people undertake in a certain land cover type to produce, change or maintain it (FAO, 2005). Knowledge of current land use (& land resources) is needed for formulating changes leading to sustainable use of the resources. Land use information provides answers to one or more of the following questions concerning the current use of the area:

i. *What*: the purpose of activities undertaken - the specific products and services, that are sought
ii. *Where:* the geographic location and extent of the spatial unit under consideration
iii. *When*: the temporal aspects of various activities undertaken - the sequence of carried out operations like planting, weeding,

iv. *How*: the technologies employed - technological inputs and materials such as fertilizer, irrigation, labour,

v. *How much*: quantitative measures - areas, products

vi. *Why*: the reasons underlying the current land use –land tenure, labour costs, market conditions.

According to Barlowe (1978), the activities of man on land take place within a threefold framework. These frameworks involve the impact that physical and biological factors, economic considerations, and institutional arrangements have on private and public decision relative to land use. Together, these three groups of factors set the limit as to what individuals, groups and governments can accomplish with any given level of technology in their development utilisation and conservation of land resources. This is to say that land use is the purpose the land serves, for example, recreation, wildlife habitat, or agriculture. Land use applications involve both baseline mapping and subsequent monitoring, since timely information is required to know what current quantity of land is in what type of use and to identify the land use changes from time to time. This knowledge will help develop strategies to balance conservation, conflicting uses, and developmental pressures. Issues driving land use studies include the removal or disturbance of productive land, urban encroachment, and depletion of forests.

Precise descriptions of land use are needed for sound analysis of land use performance, notably its feasibility, productivity, sustainability, and environmental impact. The performance of land use can only be determined if land use is described for a known location and a known period of time. This means that spatial and temporal boundaries of the land use must be defined. Actual land use must be described as part of a system. If land use pattern change is to be a possible option for meeting increasing needs for food production or to mitigate declining yields, a larger area must be brought into cultivation. This can be done by decreasing the ratio between fallow and cultivated land within a given village territory or by including new territory for cultivation. One obvious premise for this is that idle, uncultivated land must be available within an acceptable distance to the farmer. Whether this is the case is, however, influenced by social and cultural parameters which enable and constrain access to land.

Land is an element of land use systems and thus referred to as the compounded properties of climate, soil, terrain, flora and fauna (including crops, weeds, diseases, livestock, wildlife, and pests) and the results of past land use (notably infrastructure). Aspects of land are very important for precise analysis of the performance of a land use system. Databases containing land information, for example, on soil, land cover, or climate, may be linked with the Land Use Database in order to carry out land use systems analysis. Nonetheless, some aspects of land can be stored in The Land Use Database. It concerns notably infrastructure and selected observations. Infrastructure is defined as: "Permanent installations constructed to assist economic activity such as roads, irrigation or drainage works, buildings and communication systems." (FAO 1993)

Infrastructure present in or around a plot may be used in the context of a particular land use. In The Land Use Database, information on such infrastructure can be stored. A system is therefore, defined as: "A limited part of reality with well-defined boundaries that contains interrelated elements, where the elements within the boundaries have strong functional relations with each other, and limited weak or non-existent relations with elements in other systems" (De Wit, 1993). If this definition of a system is adopted, a land use system is thus, defined as: "A specific land use, practised during a known period on a known and contiguous area of land with identical characteristics." To study the performance of land use(s), a land use system must be the basic entity of description. Previous studies (Omojola and Soneye 1993, Usman 1991) have confirmed that a good knowledge of land use of any given geographical area has to do with the human activities on land, the facilities placed on land, the effects of such human activities on the environment, and the actual people making use of the land under consideration.

According to Saha and Pande (1990), the constraints imposed by geography, population density, climate, and other factors make usable land an especially precious commodity in some countries. In the low-lying Netherlands, strenuous efforts have been made to increase the amount of land available for economic use by reclaiming large areas from the sea. Similarly, in Japan, where most of the population is crowded onto the narrow coastal plains that lie between the mountainous interior and the sea, engineers create additional land by filling bays and harbours. In Bangladesh, devastating floods arrive with depressing regularity. They are the result of extensive deforestation in the mountains upstream, torrential monsoon rainfall, and occasional tidal waves in the Bay of Bengal. Combined with slowly rising sea levels, these forces threaten to reduce permanently the land area available for human habitation.

Information generation from remotely sensed data captured by various types of sensors flown aboard different platforms at varying heights above the terrain, and at different times of the day and the year, does not lead to a simple classification. To date the most successful attempt in developing a general-purpose classification scheme comparable with remote sensing data has been done by Anderson (2002). Many of the other classification schemes used with remotely sensed data are modification of the Anderson’s classification which suggest that classification system should recognize both activities (land use) and resources (land cover) of the area under study. Such a land use classification that utilizes satellite remote sensing data should meet the following criteria:

a) The minimum level of interpretation accuracy using remotely sensed data should be at least 95%
b) The accuracy of interpretation for the several categories should be equal
c) Repeatable results should be obtainable from one interpreter to another and from time of sensing to another
d) The classification system should be applicable over extensive areas
e) The categorization should permit land use to be inferred from the land cover types
f) The classification should be suitable for use with remotely sensed data obtainable at different times of the year
g) The categorization should be dividable into more detailed sub-categories that can be obtained from large imagery or ground surveys
h) Aggregation of categories should be possible
i) Comparison with future land use and land cover data should be possible,
j) Multiple uses of land should be recognized when possible.

In most countries, increasing pressure to use land for economic development is leading to conflict. Farmland, wetlands or other land close to cities are been sought by developers to convert into suburbs, motorways, or shopping centers. Conservationists may resist efforts to level natural forests and replace them with tree plantations, ranches, or farms. Developing countries in particular are frequently faced with a dilemma. Their need for money leads them to liquidate their forests and modify their savannahs to obtain timber, beef, tea, rubber, and other cash crops for export, yet they must conserve these same ecosystems to guarantee resources for the future.

A. Land use system

A land use system on the other hand, is defined as: "a specific land use practiced during a known period on a known and contiguous area of land with identical characteristics and associated with inputs, outputs and possibly land improvements" (FAO, 1984). To study the performance of land use(s), a land use system must be the basic entity of description. The spatial boundaries of a land use system confines a tract of land on which one specific use is practised. The temporal boundaries of a land use system are determined by changes in land use (De-Wit, 1993). The socio-economic component of a land use system includes the decision making process plus socio-economic circumstances that influence the holder's decision to reserve a plot for a specific land use. This includes political and institutional aspects. Circumstances that may be relevant are: labour availability, presence of a market, costs of inputs, and product prices. These circumstances determine if a certain land use system is feasible in economic terms, and therefore, when known to the holder, influence his decisions regarding land use.

Most of the population in the Lower Benue Basin depends on a mixed livelihood strategy, combining crop farming, livestock keeping, fishing and natural resource exploitation. This diversity of livelihood components, many of which depend on wetlands, is an effective strategy for spreading risk, and income and subsistence sources vary at different times, especially according to season. Almost all of the floodplain population in the area is involved in crop farming. Of the total area under arable agriculture about 10% is comprised of floodplain farming systems. The main growing season in the floodplain is between November and April, and produces maize, rice, sweet potatoes, sugar cane, fruit and vegetables. Floodplain farming systems are diverse, and include raised gardens, rain-fed village gardens, seepage gardens, drained seepage gardens, lagoon gardens and riverbank gardens

According to Fresco *et al* (1994), the concept of the land use system in sustainable land management embraces a set of components. Basically the system contains three parts, representing input, process and output. He added that the concept of the land use system can be broadly seen as follows:

The *Input*: concerns data collection, data processing, paradigm and strategic environment.

The *Process*: includes land allocation based on the spatial plan and five year development plan; implementing land allocation through the provision of permits for location, land use change and land use practices; and the monitoring and controlling of land use practices.

The *Output*: contains the objective of the land use system, namely a sustainable and optimum land use and the establishment of four orders of land management.

The goal of land use system for sustainable land management is to establish sustainable and optimum use of land for maximum prosperity of the people, both for the landowners and the community as a whole. To obtain this goal, land use management pursues what is called "four orders of land management", they are: legal order, administration order, use order, and order of maintenance and conservation of environment. Mwale (1995) reiterated that, through this strategy, land use management will establish a land use arrangement as follows:

(a) All types of land use are accommodated according to the plan, and there will be no conflicts among them. Besides, they must be in balance and in harmony both in terms of hectares and location.

(b) All types of land use must be discerned based on the technical criteria for maximizing benefit and minimizing externalities, and must avoid any activity hazardous to the environment or which diminishes the land's carrying capacity.

According to Stomph *et al* (1994), the type, timing and sequence of operations are very important for a thorough analysis of the performance, for example productivity and sustainability, of a land use system. Temporal aspects of land use must also be considered in the analysis of the temporal variation in labour demands, fertilizer requirements, cash flow, etc. Detailed descriptions of an operation includes amongst others the type and quantity of implements used, the type, quality and quantity of material inputs applied and labour inputs used, the main power source used, and details on products/benefits achieved.

In many developing countries, agro-ecological and socio-economic conditions differ considerably in both space and time. On top of this variable environment, farmers use a wide range of production systems, resulting in a large variation in productivity across and among agro-ecological zones, and among farm types. Additionally, the low availability of geo-referenced data and information, and the often poor relations between the civil society (farmers, extension services, and Non-Governmental Organizations (NGOs) and development projects), research institutes, and decision makers have considerably limited the targeting of technologies to the specific environments, and consequently the development of sustainable agricultural production systems for larger areas in these countries. Considering that in most countries the population growth rates exceed largely the annual growth rate of agricultural production, and soil mining is almost a rule, options for agricultural development based on sustainable production systems with increased yields are urgently needed. Research has yielded alternative technologies, but transfer to villages has often failed, due to a number of reasons. Among them are the non-adaptation of technology to farmer's ability, financial constraints, low availability of inputs, poor extension services, land tenure problems, and the non-compatibility with the extensive, individualists strategies of both crop and livestock farmers (FAO, 1995).

Van-Duivenbooden (1995) maintained that land use planning, being an integral part of farmer's practice ever since people started to cultivate crops, may provide a way to solve many of these problems. At present, land use planning means almost implicitly the development of sustainable production systems for a given region. Interactive Development Scenarios (IDS) models may be tools that outline options for development through identification of appropriate land use systems, i.e. the combination of specified land uses (or production systems) practised on a given land unit that can be geo-referenced. Figure 9 shows the schematic representation of a land use system.

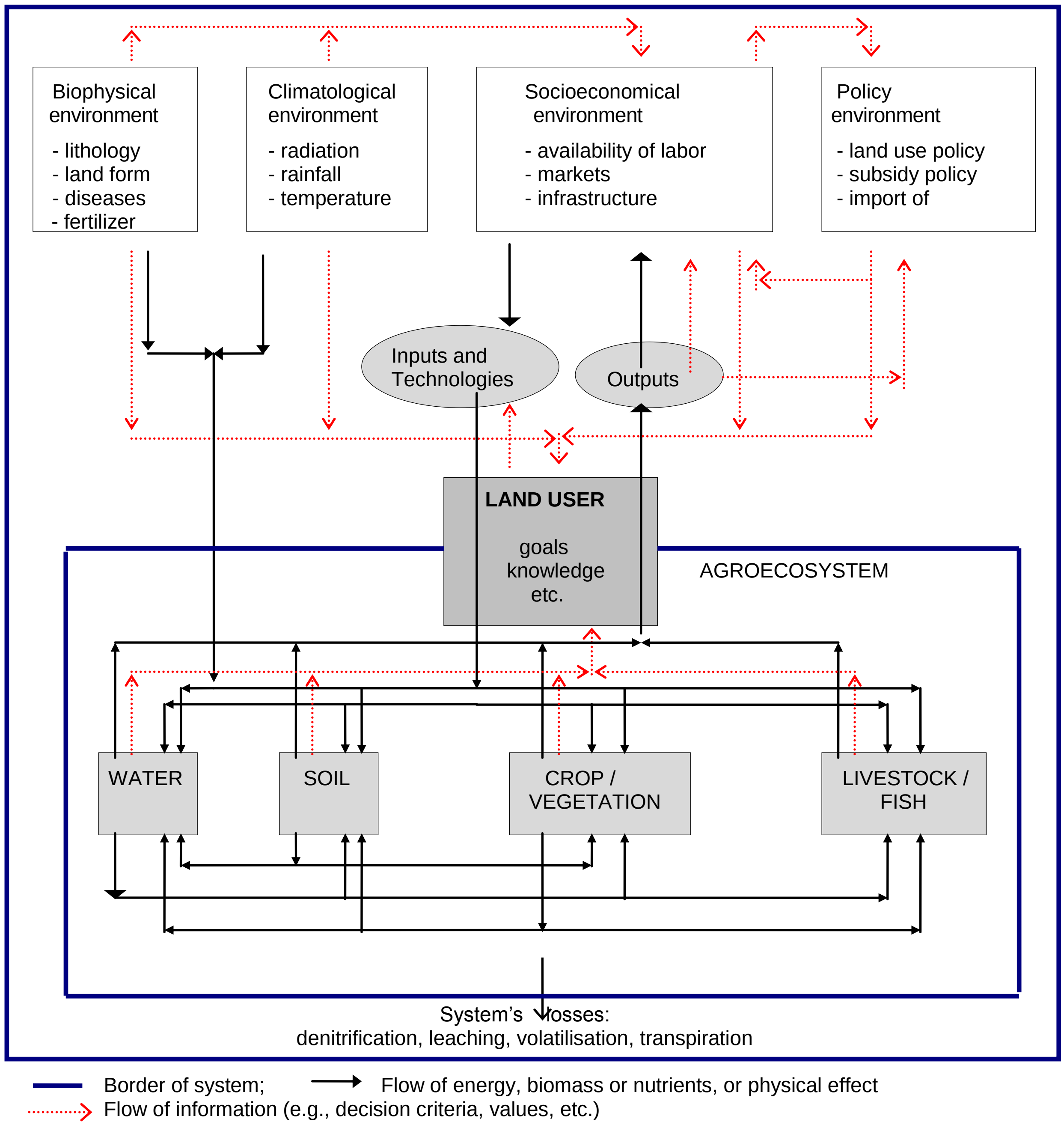


Figure 9. Schematic Representation of a Land Use System (after Van Duivenbooden, 1995)

To link various research disciplines, formulation of development scenarios of sustainable land use systems is considered an effective mechanism, because it requires the identification and quantification of inputs and outputs from the one and the other. The scenarios must be defined according to stakeholders (that is, for farmers, village heads, regional and national decision-makers) and for each scale (Van-Duivenbooden, 1995). Formulation of such development scenarios permits identification of technologies and interventions at different scales and moments, and of the priorities of agricultural research. This will lead to an improved impact of research.

B. Land use systems analysis

Based on the requirements described above and experiences in various projects on land use planning, "Land Use Systems Analysis (LUSA)" is introduced as an alternative methodology. It aims to cover the successful management of resources to satisfy changing human needs without degrading the environment or the natural resource base. Components and the functioning of land use systems are analysed in five steps, in an interdisciplinary way, to give quantified and clear alternative land use options on different scales (Table 6).

Table 6. The Steps in Land Use Systems Analysis

S/N	Action Steps	Answering
1	Definition and formulation of vision and common goals of farmers researchers and land use planners	"Where do we want to go?"
2	Characterization of the actual land use systems at different levels of scales	"Where are we; what do we know?"
3	Research restricted to the most important components and flows of land use systems	"What do we have to understand better?"
4	Analysis of development scenarios with simulation and optimization models linked to a GIS	"What can we logically expect?"
5	Testing of a new technologies and management practices by both farmers and scientists by putting them into practice	"Does it really work?"

Source: Van-Duivenbooden, (1995)

C. Land use planning and management

Planning generally involves study on how changes in one factor ought to be made so that the future society will achieve an improvement in human welfare without destruction or without deterioration of the environment. In effect, it is a form of control over society, which seeks to work towards some common goal, whether this is the elimination of bad structures or the protection of the countryside. Planning is therefore regarded as a very important process in moulding the themes, which form the core of human geography such as places, people and work. Planning process exists within a system consisting of a political organization with a political environment which in turn exerts influence on the organization (Herington, 1989).

Planning exists in many spheres of human activity. It might be nice to live in a world without planning but most people would find it very difficult if they did. In the various activities of human beings, it is generally suggested that some form of advance planning is necessary if we are to achieve our meaningful objectives. Planning therefore has to look to the future and be concerned with finding solutions to problems of the area under study.

Warner (1991) and Warren (1991) maintained that decisions on land use have always been part of the evolution of human society. In the past, land use changes often came about by gradual evolution, as the result of many separate decisions taken by individuals. In the more crowded and complex world of the present they are frequently brought about by the process of land use planning. Such planning takes place in all parts of the world, including both developing and developed countries. It may be concerned with putting environmental resources to new kinds of productive use. The need for land use planning is frequently brought about, however, by changing needs and pressures, involving competing uses for the same land.

Land use planning according to Van-Duivenbooden (1995) is the systematic assessment of land and water potential, alternative patterns of land use and other physical, social and economic conditions, for the purpose of selecting and adopting land use options which are most beneficial to land users without degrading the resources or the environment, together with the selection of measures most likely to encourage such land uses. Without any direction or guidelines, a community has no control over its future development. Lack of planning can result in conflicts between neighbouring land uses, uncontrolled and excessive exploitation of natural resources, inappropriate development, loss of rural character, destruction of habitat, and contamination of surface and ground water.

Why Plan? Land use planning helps the community residents to:

a) Promote acceptable land uses.

b) Manage renewable resources.

c) Protect land resources and features of special value.

d) Encourage appropriate community development.

The function of land use planning is to guide decisions on land use in such a way that the resources of the environment are put to the most beneficial use for man, whiles at the same time conserving those resources for the future. This planning must be based on an understanding both of the natural environment and of the kinds of land use envisaged. There have been many examples of damage to natural resources and of unsuccessful land use enterprises through failure to take account of the mutual relationships between land and the uses to which it is put. It is a function of land evaluation to bring about such understanding and to present planners with comparisons of the most promising kinds of land use.

Increasing population pressure and changing human needs play a critical role in the competition for different uses for the same tract of land. Optimal land use planning, is therefore, needed to assure not only the improvement of the social conditions of the present population, but also the conservation of the environment for future generations. Any successful development programme requires a comprehensive inventory of human, economic and physical resources, an appraisal of the present situation, and analysis of the cultural and physical problems in resource development, and an estimate of resource potentials in spatial terms. These are the basic elements of a land evaluation for regional land use planning. The results of land evaluation provide information on which decisions for future land use can be taken so that a permanent ecological balance might be achieved.

Herington (1989) maintained that the planning process of land use consists of data collection, data processing, and formulating the plan. The Reliable land data should be fresh, recent, accurate and appropriately detail in conformity with the objective. The unit planning area should also, hierarchically embraces the national, state and local levels. The land data has to include: present land use, land capability and other physical land characteristics, land status and social economic condition, and other supporting data. Prerequisites for land use and spatial planning include data collecting and data processing that produce a land data base in the form of geographic information system. Land data base covers present land use, land capability, other land physical characteristics, social economical data, land tenure, climate and other land related data for the land management. The paradigm for land use and spatial planning embraces state ideology, constitution, agrarian law, environmental law, other land related laws and the guidelines of the national development. Besides, the planning must consider the prevailing globalization, which influences almost every aspect of human and nation life. The globalization has resulted to a strategic environment which creates opportunities and constraints. The strategic environment must be seen from the scope of international, regional and national.

Pretty (1995) further explained that the land use planning may be concerned with putting environmental resources to new kinds of productive uses. Changing needs and pressure, involving competing uses for the same land frequently brings about, the need for land use planning however. The function of land use planning is to guide decisions on land use in such a way that the resources of the environment are put to the most beneficial use for man, whilst at the same time conserving those resources for the future.

Lanre (1991) maintained that comprehensive information on the spatial distribution of agricultural land use and the pattern of their change is a prerequisite for planning, utilization and management of the agricultural resources of the Lower Benue flood plain in particular and the country in general. Such information thus permits a better understanding of the land utilization aspects on cropping pattern, grazing lands, wastelands, surface water bodies, settlements and communication network, which are vital for the overall national development planning. He therefore, summed up land use planning as a defined use of land consisting of a set of technical specifications about the physical and socio-economic setting of the area and use under consideration.

Trotter (1991) stated that efficient utilization of land available for a variety of uses needs a variety of information pertaining to the Land, and the approach adopted or propagated by the use of Geographical Information System, which is one, the latest technological break through. However to enable an accurate GIS, the information has to be positionally accurate and a variety of related information therefore is built on the cartographic base maps, which have to be accurate, so that the GIS developed on it is also accurate, and the planning based on the results obtained through application of such GIS, becomes highly relevant. Thus the cartographic database created has to be highly accurate, in whatever scale it is made. It is not out of place to have a 3-D GIS that will provide height information in the form of contours or Digital Elevation Model (DEM), built, as close an interval as possible, appropriate to the topography of the area.

There is an increasing need to be able to precisely describe and classify land cover and land uses in order to define sustainable land use systems that are best suited for each place. Land needs to be better matched to its uses to increase production, while at the same time attempting to protect the environment, biodiversity, and global climate systems. It is therefore essential to have detailed and in-depth knowledge of potentials and limitations of the present uses. This information is required in many aspects of land use planning and policy development, as a prerequisite for monitoring, modeling and environmental change, and as a basis for land use statistics at all levels. A global agreement on the definition and classification of both land use and land cover does not exist. As a result, many classification systems and innumerable map legends exist, and maps and statistics from different countries, and in many cases even from the same country, are incompatible with each other. Technological advances, such as the vast amount of remote sensing data having become available from earth observation satellites, make it increasingly possible to map, evaluate and monitor land cover and land use over wide areas (FAO 1997).

According to Deckshatulu and George (1993), large volume of data is gathered whenever preparation of physical plan is taken up and a good number of maps and charts as a part of the exercise on plan formulation are also prepared. However, today no system has been built to compile this geographically referenced data in a systematic manner and store them for retrieval at a subsequent point of time. Planners and decision-makers at micro-level have to depend upon spatial and non-spatial data for optimal interpretation. Hence, the planners need to have at their disposal sophisticated data management systems to handle such spatially correlated data. The emergence of Remote Sensing and Geographic Information System as a powerful tool for spatial analysis and storage has in effect alleviated the problem by computerization of the spatial data. This new technology can reduce the time and cost to the planners in organizing the data in arriving at precise conclusion and decisions.

The information requirements for land use planning comprise reliable, up-to-date and comprehensive data on physical, ecological, and socio-economic resources. It is well established therefore that Remote Sensing has the potential to make the most significant contribution in the area of land use data collection, and more so in the agricultural land use. The latter is apparently the most important area of interest to all countries of the world, and especially in the developing countries like Nigeria, hence it is one of the major sectors of the economy.

Ogidan (2001) said that "as population expands all uses of land and soil become more competitive. Good agricultural land will be under increasing pressure from urban growth and expanding public facilities such as highways and airports. Much of this will be taken from our supply of irreplaceable, highly productive soils because the steep, rough areas are much less desirable for urban and public facility development. Most of the decisions will be irreversible, so the importance of sound land use planning is evident". In the case of rural land, the need to safeguard valuable agricultural lands is a major focus of land use planning.

According to Herington (1989), the requisite of land use planning is an inventory of the resources of the land area prerequisite for use, an exercise translating into maps and reports. What the ordinary farmer needs is the interpretation of soil maps, in the form of land capability of land suitability maps. But in a rural economy like Nigeria, most peasant Nigerian farmers may not even be able to use these maps, because they may not understand them. Land capability or suitability refers to the best or most economical use of a piece of land. Land use planning goes beyond this, to recommend the best land use after due economic, sociological and environmental impact considerations. The choice of crop in an agricultural development project must be acceptable to the people. The use recommended must be environment-friendly, for example it must be able to sustain the productive capacity of the land and discourage environmental degradation.

In a classical case, land use planning starts with knowing the available soil resources, the potentials of each and every one and identifying and defining relevant land utilization types, (for example, growth of maize, oil palm, rice or cassava). The plan for the use of the land would take all these into consideration such that the allocation of land to a defined land use would ensure the sustainability of the production and maximum conservation of the soil resources. The ultimate optimization of economic benefit to the users of the land is assumed to be guaranteed by the plans drawn up, and the maintenance recommended in the plan.

Land use planning therefore, is now a widely accepted way to handle complex problems of resource allocation and decision-making. It involves the use of collective intelligence and foresight to chart direction, order, harmony and progress in public activity relating to human environment and general welfare. In order to provide a more effective and meaningful direction for better planning and development, necessary support of the relevant research organizations becomes essential. Hence the need for a suitable information system is increasingly being felt in all planning and developmental activities, whether these are for agriculture and non-agricultural areas.

Planning exists in many spheres of human activity. It might be nice to live in a world without planning but most people would find it very difficult if they did. In the various activities of human beings, it is generally suggested that some form of advance planning is necessary if we are to achieve our meaningful objectives. Planning therefore has to look to the future and be concerned with finding solutions to problems of the area under study. Any aspect of land use planning, regardless of scale and purpose, requires some relevant data. Land use planning, which in turn can guarantee sustainable land management, is in its infancy in the Lower River Benue floodplain due to limitations of data availability and poor processing techniques. There is a dire need to manage land in order to ensure effective and economic use of available good lands, which are limited in relation to demands. Apart from managing virgin lands effectively there is a strong need to conserve the land for sustainable future use.

Usman (1991) and Uchua (1999) stated that accurate and current information on land use and land cover is essential for many planning activities. Remote Sensing methods are therefore becoming increasingly important for mapping land use and land cover due to the following reasons;

i. Images of large areas can be acquired rapidly.

ii. Images can be acquired with a spatial resolution that matches the degree of detail required for the survey.

iii. Remote Sensing images eliminate the problems of surface access that often hamper ground surveys

iv. Images provide a perspective that is lacking for ground surveys.

Nowadays the agro-economical policies keep changing. Farmers are more responsible for their own production system and production risks. The present and future production systems must be directed towards the development of a more sustainable agriculture. For subsistence farming a better adaptation to local climate and soil properties is needed. Knowledge about the functioning of the agricultural ecosystem and the interaction with the socio- economical and management factors has to be increased.

2.4.5 River Basin and Floodplain Agriculture

According to Adams (1995), a floodplain is the relatively flat area that borders a river which is periodically inundated with water during high flow periods. When excess runoff causes the stream discharge to increase beyond the capacity of the channel, water spills out onto the flood plain. Increasing the cross-sectional area of stream flow causes a decrease in stream velocity. The resulting decrease in velocity causes sediment to deposit as alluvium on the flood plain. These alluvial deposits are often rich in nutrients and thus naturally fertilize flood plain soils. The most economically important use of floodplains is agriculture. In many instances continuous cropping is possible in floodplain environments, without the fallowing which is so widely necessary in dry lands.

The high productivity of flood plain agriculture is matched by risk, because the extent and duration of flooding are to some degree unpredictable. The third main element of economic use of African flood plains is fish production. The life cycle of many fish species is linked to seasonal flood regimes. As the floods recede, fish of many species move back to the main river channel, and eventually to standing pools where they survive through the dry season. Farming in the tropics often includes flood plain cropping with periodic irrigation. A river's flood plain is the area on either side of the river over which it deposits soil when it floods. Farming is practiced along the flood plains of rivers such as the Nile in Egypt, Niger and Benue in Nigeria which also forms large waterways.

Most of the major African rivers including River Benue have been dammed, in order to control the so called 'wastage' of water in wetlands. Yet river control and transformation of flooding patterns have serious implications for flood plain ecology. Clearly, the impact of development projects has often a negative impact on flood plain environment, because knowledge on the part of engineers, economists and other planners about the ecology and human use of wetlands is limited. Traditionally, there is a symbiotic cycle: flooded clay basins are used by fishermen in the floods, then by agriculturalists that grow receding flood cereals, then finally by pastoralists in the dry season.

The Benue River shapes a corridor of productivity that has, for thousands of years, provided people with dynamic and rich livelihoods, and has made human survival possible even in times of desolate drought. People have always followed the rhythms of the rivers flow, which can sometimes vary dramatically from year to year. Within the harsh and frequently unpredictable sahelian climate, people wove their productive activities together in patterns that were compatible with the environment and mutually reinforcing. Flood plain pastures of thick grass supported livestock, wildlife and nurseries for fish. Harvested rice fields were grazed by livestock, which in turn fertilized the fields with their manure. Farming of millet, vegetables and rice; livestock herding; fishing, hunting and gathering of wild plants to use as food and medicine co-existed, waxing and waning in response to changes in climate and river flows.

The development of towns and agricultural enterprises on flood plains has highlighted the need for improved flood plain management practices. Effective floodplain management is necessary to reduce economic losses and minimize the potential loss of life from flooding. In 2000, the Agriculture and Resource Management Council of Australia and

New Zealand published *Floodplain Management in Australia - Best Practice Principles and Guidelines*. This document states that the principal aim of flood plain management "is to reduce the effect of flooding and flood liability on individual owners and occupiers of flood-prone property, and to reduce private and public losses resulting from floods."

2.4.6 Sustainable Agricultural Land Use

Thompson (2009) opined that agriculture has changed dramatically around the globe, especially since the end of World War II. Food and fibre productivity soared due to new technologies, mechanization, increased chemical use, specialization and government policies that favoured maximizing production. Although these changes have had many positive effects and reduced many risks in farming, there have also been significant costs. Prominent among these are topsoil depletion, groundwater contamination, the decline of family farms, continued neglect of the living and working conditions for farm labourers, increasing costs of production, and the disintegration of economic and social conditions in rural communities.

According to Wilson and Tyrchniewicz (1995), definitions of sustainable agriculture are generally concerned with the need for agricultural practices to be economically viable, to meet human needs for food, to be environmentally positive, and to be concerned with quality of life. Since these objectives can be achieved in a number of different ways, sustainable agriculture is not linked to any particular technological practice. Nor is sustainable agriculture the exclusive domain of organic farming. Rather, sustainable agriculture is thought of in terms of its adaptability and flexibility over time to respond to the demands for food and fiber (both high and low), its demands on natural resources for production, and its ability to protect the soil and the resources. This goal requires an efficient use of technology in a manner conducive to sustainability. Furthermore, because agriculture is affected by changes in market and resource decisions in other sectors and regions, it is important that these changes do not provide a rationale for depleting the agricultural resource base locally.

Das (1997) stated that sustainable agriculture, an aspect of the economic and social development that meets the needs of the present without compromising the ability of future generations to meet their own needs, an idea summed up in the term sustainable development. Two concepts are fundamental to the sustainable use and management of the earth's natural resources. First, the basic needs of humanity—for food, clothing, shelter, and jobs—must be met. This involves paying attention to the largely unmet needs of the world's poor, as a world in which poverty is endemic will always be prone to ecological and other catastrophes. Second, the limits to development are not absolute, but are imposed by present states of technology and social organization and by their impacts on environmental resources and on the biosphere's ability to absorb the effect of human activities. Both technology and social organization can be improved to make way for a new era of environmentally sensitive economic growth. This process of change is under way in the field of agricultural development, in which a transition towards sustainable agriculture is improving food production, particularly for the poor, as well as protecting the environment.

Sustainable agriculture as practiced all over the world is an integrated system of plant and animal production practices having a site-specific application that will, over the long term:

i. To satisfy human food and fibre needs

ii. To enhance environmental quality and the natural resource base upon which the agricultural economy depends

iii. To make the most efficient use of non-renewable resources and on-farm resources and integrate, where appropriate, natural biological cycles and controls

iv. To sustain the economic viability of farm operations

v. To enhance the quality of life for farmers and society as a whole.

Sustainable agricultural practice in any region is a system of food or fibre production which is poised to systematically pursue the following goals highlighted by Das (1997):

a) A more thorough incorporation of natural processes such as nutrient cycling, nitrogen fixation, and pest-predator relationships into agricultural production processes;

b) A reduction in the use of those off-farm, external, and non-renewable inputs with the greatest potential to damage the environment or harm the health of farmers and consumers, and a more targeted use of the remaining inputs used with a view to minimizing variable costs;

c) A more equitable access to productive resources and opportunities, and progress towards more socially just forms of agriculture;

d) A greater productive use of the biological and genetic potential of plant and animal species;

e) A greater productive use of local knowledge and practices, including innovative approaches not yet fully understood by scientists or widely adopted by farmers;

f) An increase in self-reliance amongst farmers and rural people;

g) An improvement in the match between cropping patterns and the productive potential and environmental constraints of climate and landscape to ensure long-term sustainability of current production levels;

h) Profitable and efficient production with an emphasis on integrated farm management and the conservation of soil, water, energy, and biological resources.

When these components come together, farming becomes integrated, with resources used more efficiently and effectively. Sustainable agriculture, therefore, strives for the integrated use of a wide range of pest, nutrient, soil, and water management technologies. It aims for an increased diversity of enterprises within farms combined with increased linkages and flows between them. By-products or wastes from one component or enterprise become inputs to another. As natural processes increasingly replace external inputs, so the impact on the environment is reduced. The basic challenges for sustainable agriculture in any area include the following;

i. Substantial reduction in input use and variable costs, in order to maintain profitability.

ii. To maintain yields at current levels while reducing environmental damage.

iii. To increase yields per hectare while not damaging natural resources.

According to Nicolas and Foskett (1999), sustainable land management means putting land under productive, effective, environmentally sound, uses so as to generate maximum benefits at the same time maintaining its fertility and natural balance. In many developing countries, including Nigeria, many problems are associated with the identification of sustainable land management practices. Among these problems are some implications of national policies such as: absence of clearly defined policies for land use, rapid population growth and the associated reduction of individual land holdings over time, inadequate professional assistance and extension programmes, seasonally changing political situations and lack of political stability, fragmentation of holdings, distribution of land for many uses, a variety of crops due to food security reasons, shortage of proper land management skills, lacking awareness of environmental and natural phenomena like droughts, erosion, floods, hurricanes and so on.

The natural resource base of suitable land, water, forests, and biodiversity largely determines the potential of agriculture. These resource endowments have a major influence on human activity in agriculture, and in turn, are affected by them. Historically, agriculture responded only to the need for food. Much later, it sought to respond to poverty-reduction mandates as well. Now it seeks to simultaneously help meet the triple objectives of poverty reduction, food security, and environmental sustainability. Agriculture can make significant contributions to attaining the millennium development goals. It is the sector from which most of the rural poor in developing countries derive their income, and both rural and urban people obtain most of their food, which is produced largely by women. As agriculture depends heavily on the natural resource base, it influences environmental sustainability. Agriculture is also closely linked to human health and education.

Most of the land suitable for agriculture is already in production. Therefore, meeting current and future food requirements will require rapid increases in productivity; otherwise, an undesirable expansion onto fragile and marginal lands will result. There is widespread concern that deforestation and land degradation are severely diminishing the potential of ecosystems. The main causes of these conditions go well beyond agriculture; however, agriculture does play a role: when policies are inappropriate, unsustainable agricultural practices are used and property rights are insecure.

Generally, sustainable development aims at maintaining equilibrium between the human needs and economic developments within the parameters of environmental conservation through efficient use of natural resources to ensure tradeoffs between desired productions-consumption levels (Das, 1997). The well known Brundtland Commission defined sustainability as a "Development that meets the needs of the present without compromising the ability of future generations to meet their own needs". In essence, sustainable development is a process of change in which the exploitation of resources, the direction of investments, the orientation of technological development and institutional changes, all are in harmony. Sustainable development of natural resources is based on maintaining the fragile balance between productivity functions and conservation practices through monitoring and identification of problem areas, agricultural practices, crop rotation, use of bio-fertilizers, energy efficient farming methods and reclamation of under-utilized lands. Sustainable development requires a holistic approach towards harnessing natural resources after taking into account the precarious environmental conditions.

According to Nicolas and Foskett (1999), for any sustainable agricultural land use development to be successful, many principles should be taken into account. These are comparative, competitive, dynamic, accommodative, sustainable and economic growth and equality. A planned development can only be successful if it is implemented through the arrangement of land use and land tenure as an integrated element of development based on policy at national and local levels and takes into account the existing local conditions. Likewise, sustainable development will only be possible with the establishment of orderly land utilization, maintenance and environment through land use planning so as to achieve optimal and effective results. Ogidan (2001) noted that, land use planning is therefore expected to abate land utilization that exceeds its carrying capacity, which might have resulted from differences in population, urbanization and economic growth between regions.

According to Hart and Sands (1992), biodiversity supports the production of an ecosystem's goods and services essential for life as well as for many cultural values.

Improving crops, livestock and feeds; increasing soil fertility; and controlling pests and diseases often depend on these resources; however, increasing population pressure, deforestation, and unsustainable agricultural practices are contributing to degradation of these "life insurance policies." This has therefore paved the way for a concept known as *Sustainable Livelihoods* which focuses on activities that promote sustainable human communities. The approach begins with peoples' assets and capabilities, and seeks to build on them. A livelihood is said to be sustainable if it can adapt to stresses and shocks, maintain and enhance its capabilities and assets, and at best, enhance opportunities for the next generation. This approach recognizes that the root of all human development and economic growth is livelihoods-not jobs per se, but the wide, infinitely diverse range of activities people engage in to make their living-together with assets or entitlements they own or can access. Hence, it integrates considerations of income generation; the production of sufficient, nutritious food; women's empowerment; and environmental management.

2.5 DYNAMICS OF THE RIVER BENUE ECOSYSTEM

JICA (1992) stated that all rivers consist of a flow both of water and of sediment materials derived from rock and organic matter that can vary in size from fine clay particles to huge boulders. The features produced by a particular river thus depend not only on the characteristics of the water flow, notably its volume (discharge), distribution over time, and energy, but also on the amount and size of the sediment load (sediment discharge). The third contributory factor is the geology of the basin, which helps condition the type and amount of sediment, and also affects the amount of work a river has to do and the features that result, because some rocks are more resistant than others.

The portion of River Benue selected for the study is at its maturity stage thus, Middle Course River processes such as lateral rather than vertical erosion and sediment transport dominates the portion. The majority of sediment is transported as suspended load, and the sediment becomes finer as the river approaches its confluence point. Coarser pebbles derived from upland erosion are largely deposited, and gravels and sands stored in alluvium become the dominant sediment type. The valley is wider than in the upper course, the sides are less steep, and the channel is bordered by a floodplain, that is, an area of low relief that is inundated by water when the river floods, and which is covered in alluvium. The river commonly adopts a sinuous (winding) course, sweeping across its floodplain in a series of long bends called meanders. The river also has a broad and flat floodplain that is covered with sand, gravel, and clay. The flood plains are formed as the river runned along the valley floods and spills out of its channel. The river then deposits the alluvial sediments as it flows over portions of the floodplain. A schematic model portraying the anatomy of the river at the maturity stage is as shown in Figure 10.

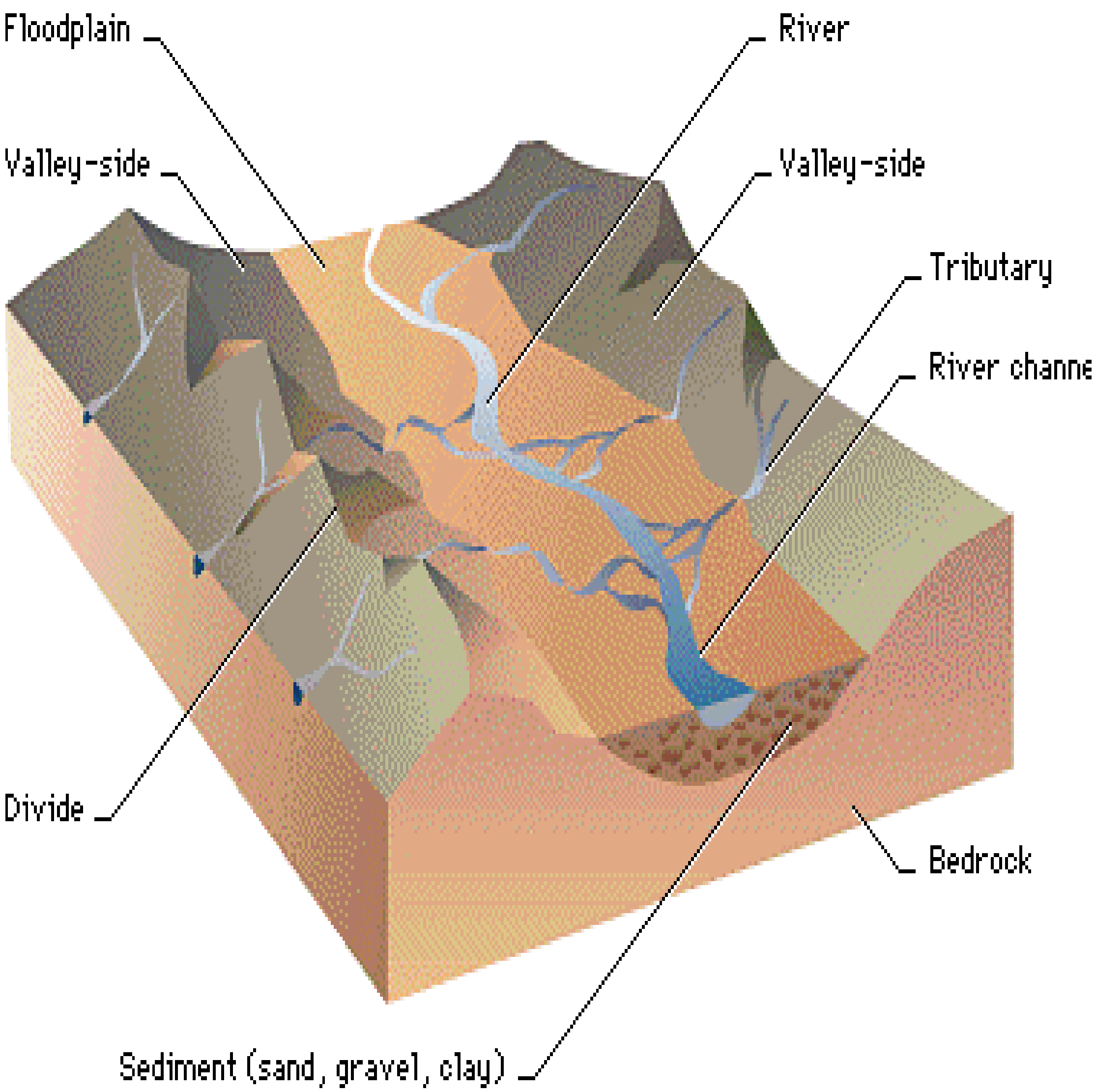


Figure 10. Schematic Model showing the Anatomy of a Floodplain (after JICA 1992)

Over the years the amount, variability, and reliability of water flow in the channel of River Benue have enormous significance for plants, animals, and people living along the course of the river. River Benue and its flood plains possess diverse and valuable ecosystem. Not only is the availability of fresh water in itself vital to sustaining life, but it also supports the growth of vegetation and abundant insect life that form the base of the food chain. In the river channel fish feed on the plants and insects and are themselves eaten by birds, amphibians, reptiles, and mammals. Away from the channel, wetlands maintained by seepage and occasionally flooded by the river support rich and diverse habitats that are important not only for resident species, but also for migrating birds and animals that use wetlands as staging posts while moving seasonally between different homes (domiciles).

River Benue ecosystem is one of the most important issue in this study as the prevailing situation is dependent entirely upon the changing regime of the river. Hence, great care has to be exercised when altering this regime through intensive human activities in and around the river. Conflict between natural and human exploitation of the river is, of course, nothing new. Historically, rivers, their flood plains, estuaries, and deltas have been central to human development involving agriculture, transport, industry, waste disposal, and settlement.

The inhabitants of the area are indeed attracted to the river largely as the result of reliable source of water supply and the rich agricultural soils lay down by fluvial deposition to support basin cultivation all the year round. For generations, people in the interior of Nigeria has been making their living working the fertile soils and fishing the waters of the River Benue. Unfortunately, recent diversions of water upstream as the result of series of dam construction, however, have altered the ecology of the river and are threatening the traditional way of life of the people.

2.6 RIVER BASINS DEVELOPMENT IN NIGERIA

River Basin Development Authority was established to be a body corporate with perpetual succession. The membership of each Authority consist of a Chairman and seven other persons to be appointed by the President, Commander-in-Chief of the Armed Forces, all of whom shall possess a detailed knowledge of the area of operation of the appropriate Authority. The functions of each Authority are as follows:

a. To undertake comprehensive development of both surface and underground water resources for multipurpose use with particular emphasis on the provision of irrigation infrastructure and the control of floods and erosion and for water-shed management;

b. To construct, operate and maintain dams, dykes, polders, wells, boreholes, irrigation and drainage systems, and other works necessary for the achievement of the Authority's functions and hand over all lands to be cultivated under the irrigation scheme to the farmers;

c. To supply water from the Authority’s completed storage schemes to all users for a fee to be determined by the Authority concerned, with the approval of the Minister;

d. To construct, operate and maintain infrastructural services such as roads and bridges linking project sites provided that such infrastructural services are included and form an integral part of the list of approved projects;

e. To Whom It May Concern: develop and keep up-to-date comprehensive water resources master plan, identifying all water resources requirements in the Authority's area of operation through adequate collection and collation of water resources, water use, socio-economic and environmental data of the River Basin.

2.6.1 **Names of Authority, Area of Operation and Headquarters**

i. Anambra-lmo River Basin Development Authority: The whole of Anambra and Imo States. Headquarter - **Owerri**.

ii. Benin-Owena River Basin Development Authority: The Whole if Edo and Ondo States excluding those parts of Edo State drained by the Benin, Escravos, Forcados and Ramos Rivers creek systems. Headquarter - **Benin**

iii. Chad Basin Development Authority: The whole of Borno State excluding those parts drained by the Jama'are and Misau Rivers systems but including those parts of old Gongola State drained by the Yedseram and Goma Rivers systems. Headquarter - **Maiduguri**

iv. Cross River Basin Development Authority: The whole of Cross River State. Headquarter - **Calabar**

v. Hadejia-Jama'are River Basin Development Authority: The whole of Kano State and those parts of Bauchi and Borno States drained by the Jama'are and Misau Rivers systems. Headquarter - **Kano**

vi. Lower Benue River Basin Development Authority: The whole of Benue and Plateau State. Headquarter - **Makurdi**

vii. Niger Delta Basin Development Authority: The whole of Rivers State and those parts of Bendel State drained by Benin, Escravos, Forcados and Ramos Rivers creek systems. Headquarter - **Port Harcourt**

viii. Niger River Basin Development Authority: The whole of Kwara and Niger States; the Federal Capital Territory; whole of Kaduna State excluding Katsina State. Headquarter - **Minna**

ix. Ogun-Oshun River Basin Development Authority: The whole of Oyo, Ogun and Lagos States. Headquarter - **Abeokuta**

x. Upper Benue River Basin Development Authority: Those parts of Bauchi State drained by the Gongola River system; the whole of Taraba State excluding those parts drained by the Yedseram River system Headquarter - **Yola**

xi. Sokoto-Rima River Basin Development Authority: The whole of Sokoto State and Katsina State. Headquarter - **Sokoto**

2.6.2 The Lower Benue River Basin Development Authority (LBRBDA)

The Lower Benue River Basin Development Authority was established in 1976 along with 11 other River Basins Development Authorities (RBDAs), vide Decree No. 25 of 1976. The main aim of the RBDAs were to among other things boost mechanized agriculture by optimizing the land and water resources potential of the country within their areas of operation for multi purpose uses ranging from irrigation, livestock, forestry and fisheries along with the development of water resources, boreholes and dams. The Authority's catchment area covers Benue, Plateau, Nasarawa States, and the eastern part of Kogi State. It covers altogether, 10 Senatorial Districts, 3 each in Benue, Plateau and Nasarawa States, and 1 from Kogi. The LBRBDA has 24 projects sited in 12 LGAs of the catchment states.

The LBRBDA is to provide sustainable access to safe and sufficient water resources to meet the agricultural and socio-economic development needs of people in her catchment area, and other various uses in ways that contribute to public health, poverty eradication, and enhanced food security while at the same time maintaining the integrity of freshwater ecosystem of her catchment area. The LBRBDA is also responsible for planning, conserving, developing, managing and delivering both surface and underground Water Resources and allied services to all Nigerians in the catchment States of Benue, Plateau, Nasarawa and Kogi (East of River Niger) for multipurpose uses.

2.7 REMOTE SENSING AND GIS APPLICATIONS IN AGRICULTURE

2.7.1 Satellite Remote Sensing Technology

The term Remote Sensing is broadly defined as "the art, science and technology of acquiring, recording and analysing the characteristics of earthly phenomena, area or objects using space-borne devices that are not in physical contact with the phenomena, area or object under investigation (Avery 1977, Lillesand and Keifer 2003). In other words, Remote Sensing is the science and art of acquiring information (spectral, spatial, and temporal) about material objects, area, or phenomenon, without coming into physical contact with the objects, or area, or phenomenon under investigation. Without direct contact, some means of transferring information through space must be utilized. In remote sensing, information transfer is accomplished by use of electromagnetic radiation (EMR). EMR is a form of energy that reveals its presence by the observable effects it produces when it strikes the matter.

Estes (1992) stated that in remote sensing the acquisition of data is dependent upon the sensor system used. Various remote sensing platforms (aircraft, satellite) are equipped with different sensor systems. A sensor is a device that receives electromagnetic radiation, converts it into a signal and presents it in a form suitable of obtaining information about the land or earth resource as used by an information gathering system. Sensors can be grouped, either on the basis of energy source and the spectral region being used.

According to Johannsen (2005) and Nathan (2000), remote sensing technology has seen many changes in the past three decades. The major changes are that from satellite altitudes we are or will be able to (a) image or see with more detail, a smaller piece of land, (b) define more precisely the specific colours or light responses reflecting off of the field and (c) obtain data on a regular interval of every other day or every 5-7 days. These changes make for real advances to agriculture as we need to be able to view those small areas in the field that are giving us problems, determine what the problem is within a field by interpreting remotely sensed data and receive data/information on a regular interval. It also has a unique capability of recording data in visible as well as invisible (that is, ultraviolet, reflected infrared, thermal infrared and microwave) parts of the electromagnetic spectrum. Therefore certain phenomenon, which cannot be seen by human eye, can be observed through remote sensing techniques i.e. the trees, which are affected by disease, or insect attack can be detected by remote sensing techniques better than human eyes could see.

Agarwal and Garg (2000) noted that detection, identification, measurement and monitoring of agricultural phenomena are predicated on the assumption that agricultural landscape features (for example crops, livestock, crop infestations and soil anomalies) have consistently identifiable signatures on the type of remote sensing data in use.

Some of the parameters which may cause these identifiable signatures include crop type, state of maturity, crop density, crop geometry, crop vigor, crop moisture, crop temperature, soil moisture, soil temperature. An image analysis can correlate a certain signature with one of these many characteristics. It is important to consider in this regard the significance of choosing the appropriate sensor system, as well as the scale and resolution requirements that will yield optimum benefits for objectives of agricultural survey.

Remote Sensing, which is not a solution in itself but only a means to an end, has become a powerful tool in both survey and evaluation of land resources, monitoring changes in the atmosphere and overall land utilization. The detection of land use changes both in the urban and rural areas can be done much faster with the aid of data gathered from Remote Sensing devices, which can be manipulated and subjected to digital analysis. The technique has created unprecedented opportunities for nations to undertake proper inventories and evaluation of their resources; make appropriate plan for their utilization as well as monitor both natural and human-induced changes in the environment.

According to Trotter (1991), satellite data have a number of advantages over conventional methods as they provide regular and repetitive coverage, thus the required information can often be simply extracted from them. The data are inherently in digital format and so can be used directly in digital cartographic production systems. Data costs are often much less and the cost of establishing ground control is much easier.

2.7.2 Electromagnetic Spectrum (EMS)

Lillesand and Kiefer (2003) stated that the basic principles of remote sensing with satellites and aircraft are similar to visual observations. Energy in the form of light waves travels from the Sun to Earth. Light waves travel similarly to waves traveling across a lake. The distance from the peak of one wave to the peak of the next wave is the wavelength. Energy from sunlight is called the illumination. The wavelengths used in most agricultural remote sensing applications cover only a small region of the electromagnetic spectrum. Wavelengths are measured in micrometers (μm) or nanometers (nm). 1 μm is about 0.00003937 inch and 1 μm equals 1000 nm. The visible region of the electromagnetic spectrum is from about 400 nm to about 700 nm. The green color associated with plant vigor has a wavelength that centers near 500 nm.

Electromagnetic energy is arranged in a continuum according to *wavelength*, *frequency* and *energy* called the Electromagnetic Spectrum (EMS). The EMS is divided into regions of the Electromagnetic energy ranging from the very short waves [x-rays & gamma rays], to the very long waves of the radio waves region (Kyllo, 2003). In remote sensing, the visible, infrared and microwave (radar) are the most useful regions as contained in Figure 11 and Table 7.

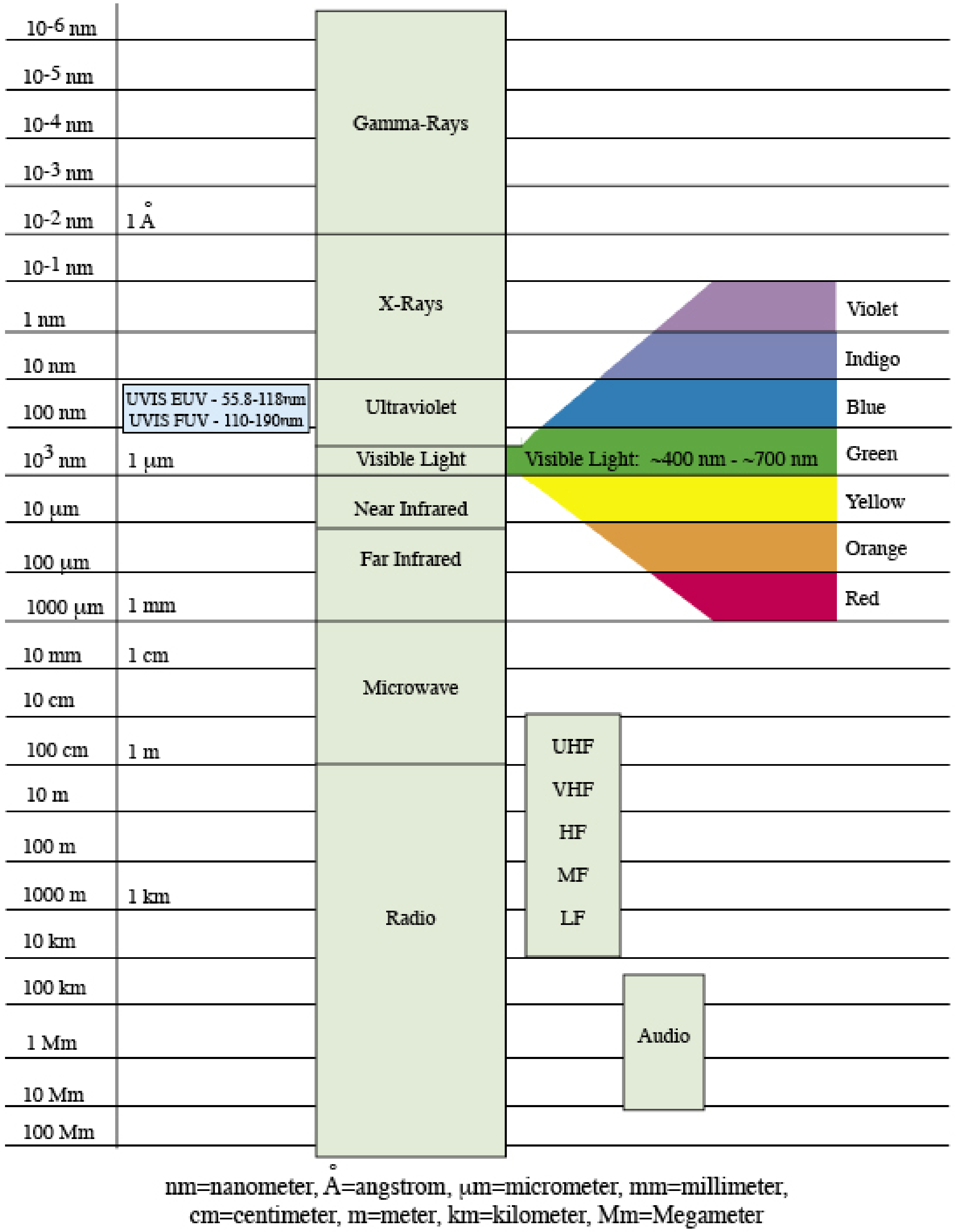


Figure 11. Electromagnetic Spectrum (after Kyllo, 2003)

Table 7: Major Regions of the EMS and their use.

Region Name	Wavelength	Remarks
Gamma Ray	< 0.03 nanometers	Entirely absorbed by the Earth's atmosphere and not available for remote sensing.
X-ray	0.03 to 30 nanometers	Entirely absorbed by the Earth's atmosphere and not available for remote sensing.
Ultraviolet	0.03 to 0.4 micrometers	Wavelengths from 0.03 to 0.3 micrometers absorbed by ozone in the Earth's atmosphere.
Photographic Ultraviolet	0.3 to 0.4 micrometers	Available for remote sensing the Earth. Can be imaged with photographic film.
Visible	0.4 to 0.7 micrometers	Available for remote sensing the Earth. Can be imaged with photographic film.
Infrared	0.7 to 100 micrometers	Available for remote sensing the Earth. Can be imaged with photographic film.
Reflected Infrared	0.7 to 3.0 micrometers	Available for remote sensing the Earth. Near Infrared 0.7 to 0.9 micrometers. Can be imaged with photographic film.
Thermal Infrared	3.0 to 14 micrometers	Available for remote sensing the Earth. This wavelength cannot be captured with photographic film. Instead, mechanical sensors are used to image this wavelength band.
Microwave or Radar	0.1 to 100 centimeters	Longer wavelengths of this band can pass through clouds, fog, and rain. Images using this band can be made with sensors that actively emit microwaves.
Radio wave	> 100 centimeters	Not normally used for remote sensing the Earth.

Source: Lillesand and Kiefer (2003)

2.7.3 Agricultural Remote Sensing

According to Kyllo (2003), agricultural remote sensing is commonly done in the *visible, near-infrared and thermal infrared* portions of the spectrum; however, new applications in the microwave area are being developed. An instrument called radiometer measures the amount of energy radiating from a surface in a particular portion of the spectrum. Radiometers can be hand-held for research purposes and monitoring of small field plots or placed on-board aircraft and satellites to survey entire fields, farms, or agricultural regions. The radiometer has special filters that can be designed so that only radiation from a specific part of the spectrum is measured. The apparent reflectance of crops is best used to learn about their properties. Reflectance is the ratio of the radiance from an object to the irradiance reaching the object.

Miller et al (2002) carried out a study using space derived data in Canada concluded that there are several areas of which the agricultural applications can benefit from the utilization of space-borne remote sensing data but the notable ones include the following;

i. Crop stress mitigation and site specific management which has to do with sustainability with precision agriculture,

ii. Crop productivity as well as yield prediction,

iii. Soil quality including soil erosion and soil nutrients, and

iv. Agro-environmental health.

A. Relevant resolutions in agricultural remote sensing

Kyllo (2003) reiterated that, there are several types of remote sensing systems used in agriculture but the most common is a passive system that senses the electromagnetic energy reflected from plants. The Sun is the most common source of energy for passive systems. Passive system sensors can be mounted on satellites, manned or unmanned aircraft, or directly on farm equipment. There are several factors to consider when choosing a remote sensing system for a particular application, including spatial resolution, spectral resolution, radiometric resolution, and temporal resolution.

i. <u>Spatial resolution</u>

Spatial resolution refers to the size of the smallest object that can be detected in an image. The basic unit in an image is called a pixel. One-meter spatial resolution means each pixel image represents an area of one square meter. The smaller an area represented by one pixel the higher the resolution of the image.

ii. <u>Spectral resolution</u>

Spectral resolution refers to the number of bands and the wavelength width of each band. A band is a narrow portion of the electromagnetic spectrum. Shorter wavelength widths can be distinguished in higher spectral resolution images. Multi-spectral imagery can measure several wavelength bands such as visible green or NIR. Landsat, Quickbird and Spot satellites use multi-spectral sensors. Hyper-spectral imagery measures energy in narrower and more numerous bands than multi-spectral imagery. The narrow bands of hyper-spectral imagery are more sensitive to variations in energy wavelengths and therefore have a greater potential to detect crop stress than multi-spectral imagery. Multi-spectral and hyper-spectral imagery are used together to provide a more complete picture of crop conditions.

iii. <u>Radiometric resolution</u>

Radiometric resolution refers to the sensitivity of a remote sensor to variations in the reflectance levels. The higher the radiometric resolution of a remote sensor, the more sensitive it is to detecting small differences reflectance values. Higher radiometric resolution allows a remote sensor to provide a more precise picture of a specific portion of the electromagnetic spectrum.

iv. Temporal resolution

Temporal resolution refers to how often a remote sensing platform can provide coverage of an area. Geo-stationary satellites can provide continuous sensing while normal orbiting satellites can only provide data each time they pass over an area. Remote sensing taken from cameras mounted on airplanes is often used to provide data for applications requiring more frequent sensing. Cloud cover can interfere with the data from a scheduled remotely sensed data system. Remote sensors located in fields or attached to agricultural equipment can provide the most frequent temporal resolution.

B. Wavelength regions for agricultural surveys

The knowledge of spectral signatures is essential for exploiting the potential of remote sensing techniques. This knowledge enables one to identify and classify the objects of agricultural resources. It is also required for interpretation of all remotely sensed data, especially in agricultural resource data whether the interpretation is carried out visually or using digital techniques. It also helps us in specifying requirements for any remote sensing mission for example, the optimal wave length bands to be used or which type of sensor will be best suited for a particular task (agricultural survey).

All objects of agricultural resource on the surface of the earth have characteristic spectral signatures. Balaselvakumar (2002) conducted an agricultural survey in India using satellite remote sensing and was able to highlight areas of agricultural phenomena and appropriate wavelengths employed as contained in Table 8.

Table 8. Agricultural Phenomena and Appropriate Wavelengths

S/No	Areas of Agricultural Phenomena	Wavelength employed
1	Plant diseases and insect infestation	0.4-0.9 mm and 6-10 mm
2	Natural vegetation, types of crop and fresh inventories	0.4-0.9 mm and 6-10 mm
3	Soil moisture content (radar)	04-0.8 mm and 3-100 mm
4	Study of arable and non-arable land	0.4-0.9 mm
5	Assessment of plant growth and crop yield forecasting	0.4-0.9 mm
6	Soil type and characteristics	0.4-1.0 mm
7	Flood control and water management	0.4-1.0 mm and 6-12mm
8	Surface water inventories, water quality	0.4-1.0 mm and 6-12 mm
9	Soil and rock type and conditions favourable for hidden mineral deposits	0.4-1.0 mm and 7-12 mm

Source: Balaselvakumar (2002)

Johannsen (2005) in his study on advances in remote sensing agriculture stated that, the remote sensing devices operate in the green, red and near infrared regions of the electromagnetic spectrum for agriculture and other allied phenomena. Agricultural resources can be obtained by measuring spectral, spatial and temporal variations of electromagnetic radiation emanating from points of interest and then analyzing these measurements to relate them to the specific classes of agricultural phenomena as shown above. He considered spectral variations are changes in the intensity of radiation at a given wavelength, that is, difference in colour. Spatial variations are changes in radiation from one location to another, that is, difference in shape and position. Temporal variations are changes in radiation from one time to another, that is, difference over time. One of the most successful applications of multi-spectral space imagery (sensor) is monitoring the state of the world's agricultural production. This application includes and differentiation of the agricultural phenomena.

C. Areas of remote sensing applications for agricultural surveys

Some specific applications of remote sensing techniques in agricultural surveys as highlighted by Jenabfer (2001) and contained in Table 9, are in the following areas: Detection, Identification, Measurement, and Monitoring of agricultural phenomena. But specifically the technology shall be helpful in the following ways;

i. To monitor cultivated areas: annual crops, vineyards and olive groves.
ii. To manage production: managing cropping patterns, inventorying crops, estimating yields and organizing harvesting, estimating irrigation requirements and assessing the impact of bad weather,
iii. To check and monitor agro-environmental measures and subsidies based on acreage,
iv. To manage farming practices at parcel level (precision farming).

Table 9. Specific Areas of Remote Sensing Applications in Agriculture

S/N	Applicable to Crop Survey	Application to Range Survey	Application to Livestock Survey
1	Crop identification	Delineation of forest types	Cattle population
2	Crop acreage	Condition of range	Sheep population
3	Crop vigour	Carrying capacity	Pig population
4	Crop density	Forage	Poultry population
5	Crop maturity	Time of seasonal change	Age and sex distribution
6	Growth rates	Location of water	Distribution of animals
7	Yield forecasting	Water quality	Animal behaviour
8	Actual yield	Soil fertility	Disease identification
9	Soil fertility	Soil moisture	Types of farm building
10	Effects of fertilizer	Insect infestation	
11	Soil toxicity	Wildlife inventory	
12	Soil moisture		
13	Water quality		
14	Irrigation requirement		
15	Disease infestation		
16	Insect infestation		
17	Water availability		
18	Location of Canals		

Source**:** Jenabfer (2001)

D. Importance of remote sensing in agricultural surveys

Jenabfer (2001) reiterated that, remote sensing is nothing but a means to get the reliable information about an object without being in physical contact with the object. It is on the observation of an object by a device separated from it by some distance utilizing the characteristics response of different objects to emissions in the electromagnetic energy is measured in a number of spectral bands for the purpose of identification of the object. With the primary aim of improving the present means of generating agricultural data, a number of specific advantages may result from the use of remote sensing techniques.

i. **Vantage point -** Because the agricultural landscape depends upon the sun as a source of energy, it is exposed to the aerial view and, consequently, is ideally suited or remote sensing techniques.

ii. **Coverage -** With the use of high-altitude sensor platforms, it is now possible to have a better synoptic view that gives room for the mapping of extensive areas on a single image. The advent of high-flying aircraft and satellites, single high quality images covering thousand of square miles

iii. **Permanent record -** After an image is obtained, it serves as a permanent record of a landscape at a point in time which agriculture changes can be monitored and evaluated.

iv. **Mapping base -** Certain types of remote sensing imagery are, in essence, pictorial maps of the landscape and after rectification (if needed), allow for precise measurement (such as field acreages) to be made on the imagery, which could be time-consuming on ground surveys. These images may also aid ground data sampling by serving as a base map for location agriculture features while in the field, and also as a base for the selection of ground sampling point or areas.

v. **Cost savings -** The costs are relatively small when compared with the benefits, which can be obtained form interpretation of satellite imagery.

vi. **Real-time capability -** The rapidly with which imagery can be obtained and interpreted may help to eliminate the lock of timeliness which plagues, so many agricultural survey.

vii. Other advantages of Remote Sensing Technology include the following;

- ❖ Easy data acquisition over inaccessible areas
- ❖ Data acquisition at different scales and resolutions
- ❖ The images are analyzed in the laboratory, thus reducing the amount of fieldwork.
- ❖ Colour composites can be produced from three individual band images, which provide better details of the area then a single band image or aerial photograph.
- ❖ The potential for accelerated survey;
- ❖ Capability to achieve synoptic view under relatively uniform illumination conditions;
- ❖ Availability of multi-spectral data providing increased information;
- ❖ Capability of repetitive coverage to depict seasonal and long term changes;
- ❖ Permitting direct measurement of several important agro-physical parameters which are used in crop yield prediction;
- ❖ Relatively inexpensive - monitoring from space;
- ❖ Remotely sensed data provide a permanent record.

It is necessary to note that land use data collected at ground level is certainly not eliminated by the use of Remote Sensing, but it greatly improves the efficiency with which ground data can be collected. This is to say that the application of Remote Sensing technique in the study of human activities on the environment adds to our abilities, it does not replace traditional ones but it may often enhance them.

E. <u>The use of hyper-spectral imaging in agriculture</u>

Townsend (1999) stated that adjustment and adaptability are cardinal to success in farming, and farmers are now using technology to produce more with less. Farmers are converting unproductive land to cropland, either in marketable crops or those that can be used to feed the increasing numbers of livestock. Land management practices are changing dramatically, particularly in most agricultural regions of the world, where farmers are using more low- or no-till seeding methods, allowing them to put less land in fallow and more in production. Pastureland is being improved to increase its value and utility to livestock operations.

The agricultural community is using earth observation information for a variety of purposes. Farmers are interested in crop conditions, soil conditions, and recommendations for remedial action. In the developed nations, insurance companies are interested in evaluating crop damage for insurance claims. Commodity brokers are interested in forecasting crop quality, yield prediction, and inventory. Hyper-spectral imaging will have a particular enabling impact on precision agriculture. Balaselvakumar (2002) further explained that precision agriculture is the technique of managing each part of a field differently and in the most effective way. Information on the performance and potential production of each part of the field is collected, monitored, and analyzed so that informed management decisions can be made. The result is potentially increased yields with less input and reduced impact on the environment.

2.7.4 Geographic Information Systems (GIS)

According to Burrough, (1986), the advent of affordable and powerful computers over the last few decades has allowed for the development of innovative software applications for the storage, analysis, and display of geographic data. Many of these applications belong to a group of software known as Geographic Information Systems (GIS). Geographic Information System (GIS) can be defined as "computerized tools for the acquisition, storage, checking, integration, manipulation, analysis and display of data that are spatially referenced to the earth".

Kufoniyi (1998) stated that, GIS operates mainly with digital information although other data sets can always be integrated. In view of this, a combination of GIS and Remote Sensing provides very essential means of obtaining the best information that might be desirable. Applications of GIS to agricultural research and related areas of rural development are limited only by the human imagination and by the quality and resolution of available data.

Furthermore, GIS as a computer-based framework, have an ideal environment that allows different kinds of information to be geographically tagged ("geo-referenced") and displayed together on a single map (Figures 12 and 13). Users can then combine two or more distinct data sets to view relationships between selected social or biophysical factors: crops, livestock, forests, soils, waterways, climate, topography, population distribution, income patterns, education levels, roads, land tenure, administrative boundaries, and so on. GIS thus provides dynamic tools for analysis and reanalysis, making and remaking maps, mixing and matching different kinds of information depending on what is of interest.

Holmes (1990) stated that during the past two decades, GIS applications in agriculture have revolutionized how scientists use spatially oriented information for increased food production. Around the world these tools are now in daily use by diverse specialists: agriculturists, meteorologists, geologists, hydrologists, economists, demographers, disaster relief workers, wildlife conservationists, ecologists, foresters, botanists, and plant breeders, in addition to cartographers and geographers. GIS tools allow these users to rapidly organize, integrate, and visualize various kinds of biophysical and socio-economic data. The resulting electronic maps serve as a workspace for creative analysis and problem solving. A related domain of GIS work is the exploration of new land use opportunities, especially for agricultural development. Agriculture and related natural resources, being spread over a multitude of locations and elevations around the globe, are intensely spatial in nature, lending them well to GIS analysis. Such analysis helps scientists, planners, policy makers, and others grasp the complex links between farming and environmental health.

According to Joseph (2000), GIS has evolved rapidly within production agriculture. In less than 2 decades the application has moved from inception to operational reality. Its current expression emphasises the generation of yield maps by linking GPS with yield monitors. Valuable insight is gained by visualizing field variability, particularly when yield maps for several years are considered. More advanced applications involve analysing soil nutrient maps to derive a prescription map used in variable rate fertilizer control.

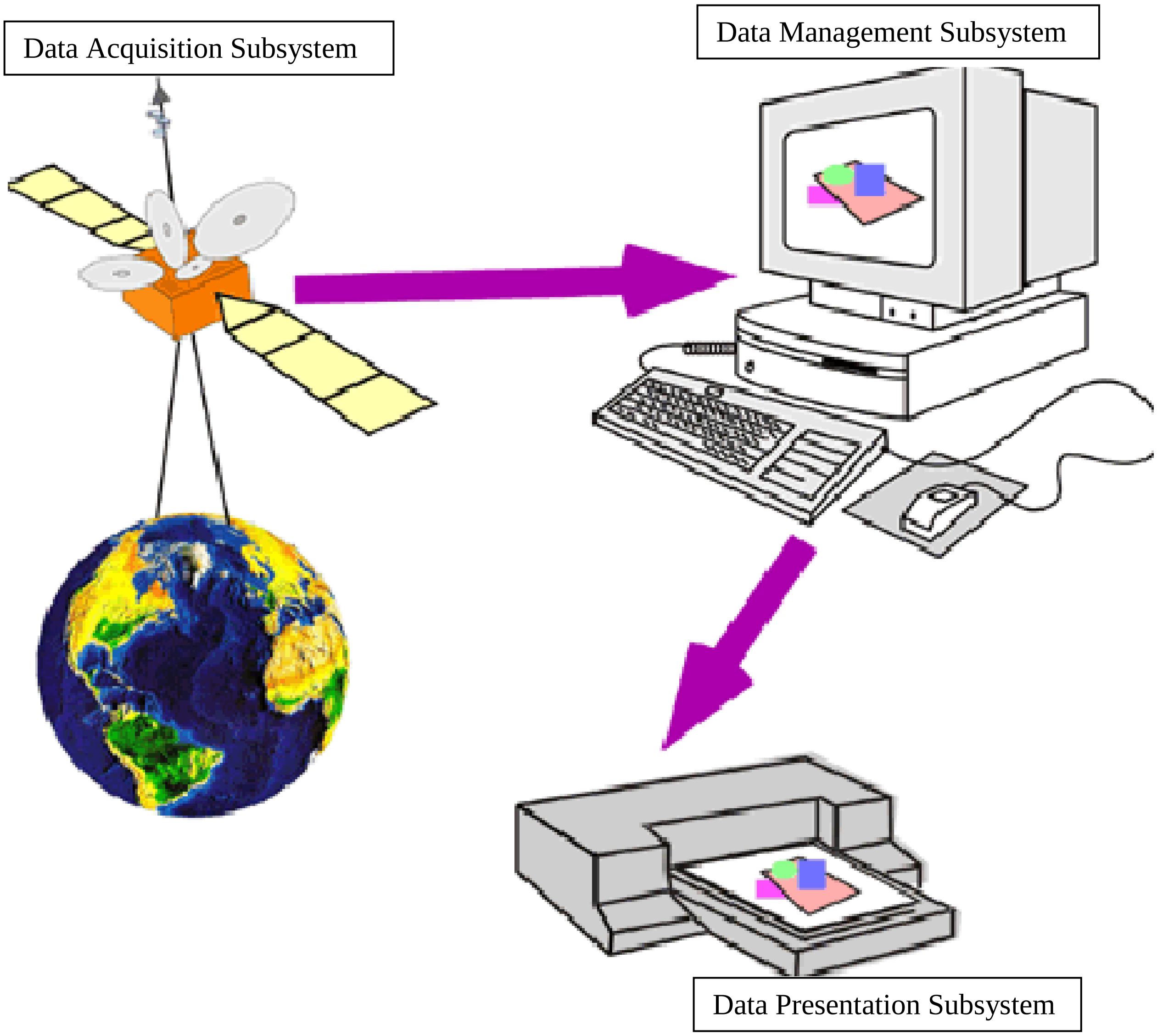


Figure 12. Major Subsystems of GIS (after Burrough, 1986)

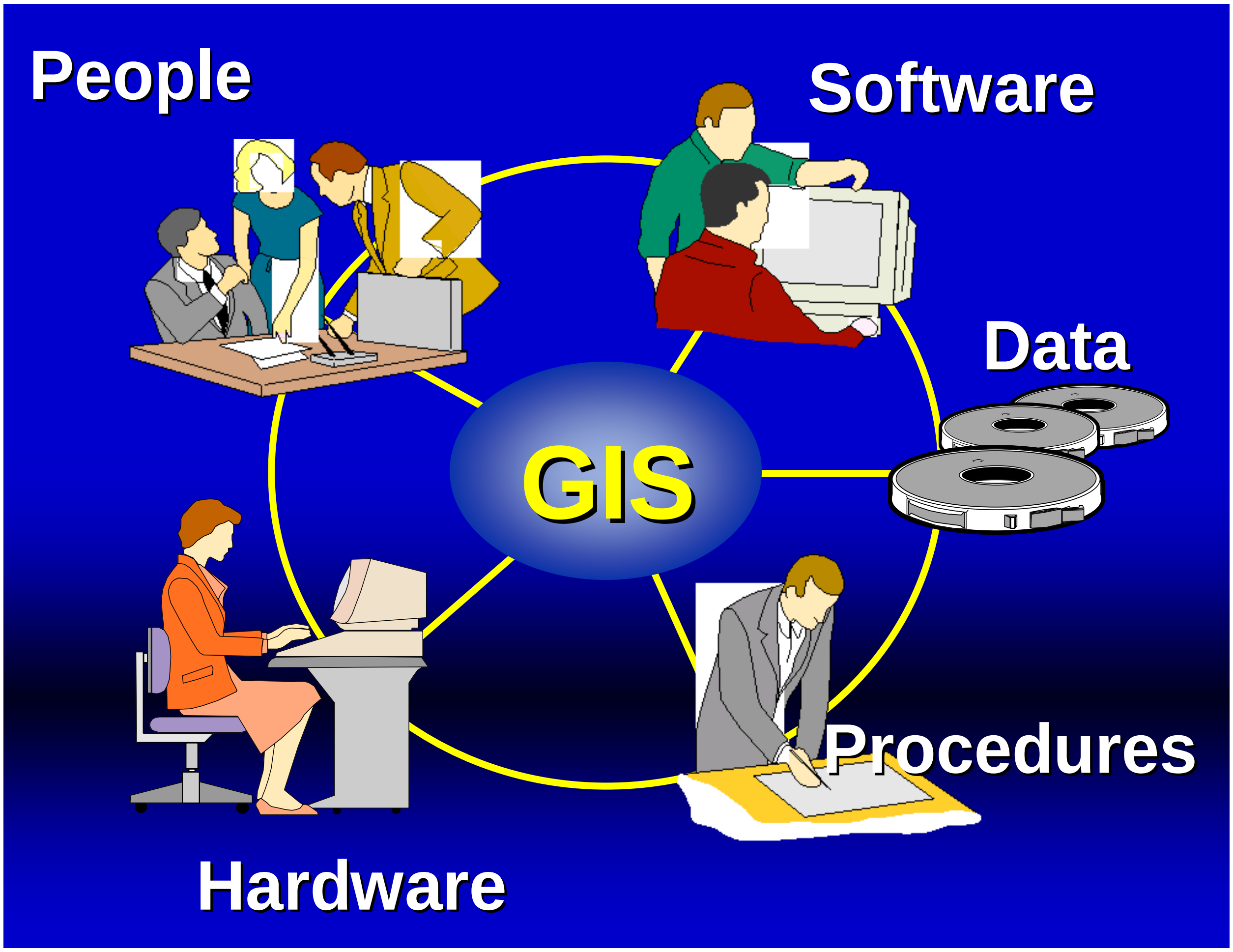


Figure 13. Ideal Remote Sensing and GIS Environment (after Burrough, 1986)

Deckshatulu and George (1993) maintained that, in the past, the appraisal of agricultural land use and other areas of interest were based largely on the use of the conventional methods for data acquisition. Although results were produced and conclusions made, the methodology proved to be cost involving in terms of resources, energy, time and risk. However, the constraints of the conventional methods calls for the appraisal of the remote sensing and GIS techniques which are the most-powerful, modern, efficient, and cost-effective methods of generating agricultural land use data. The greatest advantages of these technologies are that, they provide permanent synoptic, spatial and temporal record of an environment, be it rural or urban, which permits rapid in-house assessment of resources with reduced fieldwork and highly verifiable and more consistent results.

Thus, application of Satellite Remote Sensing in detecting, monitoring and mapping agricultural land use have modernized, simplified and eased the work that would otherwise be executed through conventional methods. Agricultural land use data acquired from various Remote Sensing techniques have proved in the literature to be very useful in providing impetus for agricultural land use system analysis in the Lower River Benue Basin.

He added that GIS provide an essential technology for considering the interaction between spatial distributions of resources. GIS are now established as a common feature of both management and research in areas such as; natural resource inventory; mineral exploration; primary production estimation and natural hazard evolution. Probably the biggest problem in a GIS is the base maps that the software uses to perform its analysis. The deficiency of these maps or updated ones is the main reason for using remotely sensed data as a consistent source of information. The results of visual image interpretation and digital processing can now fulfil a number of functions within a GIS.

Burrough (1986) reiterated that geographical information systems provide an essential technology for considering the interaction between spatial distributions of resources. GIS are now established as a common feature of both management and research in areas such as; natural resource inventory; mineral exploration; primary production estimation and natural hazard evolution. Remotely sensed data on the other hand, provide the most accurate input into a GIS. Thus, with further advances in satellite technology for Remote Sensing, which facilitates a rapid repetitive inventory of the earth's surface for further processing with GIS technology, support for decision-making is now fully facilitated. To make the best for data generation and manipulation, GIS needs to be combined with Remote Sensing. Probably the biggest problem in a geographic information system is the base maps that the software uses to perform its analysis. The deficiency of these maps or updated ones is the main reason for using remotely sensed data as a consistent source of information. The results of visual image interpretation and digital processing can now fulfil a number of functions within a GIS.

The information used in land use research and management usually comes from multiple sources. Typical among them are scientific databases, technical papers, census surveys, satellite and other remote-sensing images, economic forecasts, and reports of specialized agencies. Formats are often incompatible, though, or the data may be at different time and space scales, making comparative analysis difficult. The major strength of GIS is its ability to integrate and graphically represent such data. GIS also allows users to push analysis beyond the current "real" state of the landscape. With modeling tools linked to or integrated with GIS, researchers can simulate and investigate alternative future states. These may be based on government policy options, economic growth projections, climate change scenarios, or other variables. Much of the strength of GIS, then, lies in its ability to tackle questions that begin with "What if ...?"

According to Kufoniyi (1998), Nigeria and most of the African countries have now introduced Geographic Information Systems development specifically for sustainable land use planning and environmental management. The recent land resources management practices using GIS and LIS technology which is championed by the National Space Research and Development Agency and National Centre for Remote Sensing, Jos have made it necessary to have the Geo-Information tools in Nigeria. The Geographic Information System has proved to have potential especially where optimization in decision making is required. It is a reliable tool for development plans and long run programmes. Planners and decision-making professionals sometimes think that, the available resource data are meagre where the evaluation, manipulation and documentation of them can be handled manually.

Atesmachew *et al* (2008) applied GIS for the classification of production systems and determination of grazing pressure in upland of the Awash River Basin Ethiopia and concluded that expansion of cultivation and settlements has increasingly grown in most part of the uplands of Awash River Basin. This expansion has exerted pressure on the existing grazing lands and forests. It is, therefore, a paramount importance to identify suitable land for various uses in optimum utilization while causing minimum impact to the environment. In this study, classification of productive system of the existing land and determination of the grazing pressure was made by incorporating different spatial information using GIS techniques. The result showed that about 70 % of the total land is suitable for rainfed mixed farming system, 9 % for irrigated mixed farming system, 12% for grassland based systems and the remaining 9 % for forest land. The amount of dry matter yield (DM) that can be produced from the land ranges from 591.85 to 2473.72kg/ha/year. The total DM value expected would be 301362 ton/year.

Modern technology for data or information handling depends much on the computer, which calls for skilled personnel, more reliable infrastructure and stable capital. These have compelled Nigeria to step-up efforts towards the full implementation of Geospatial information technology by putting in place relevant structures including the satellite project: Nigeriasat-1. Although, old land use systems remained in use while slowly deteriorating. Growth in the land demand and rates of rural to urban migration has forced the old system of data/information management to change. Going for a more sophisticated system such as a GIS, which are rather costly but efficient and reliable, is the task ahead of land use planners in most states of the federation including Benue State.

Trotter (1991) maintained that the use of Satellite Remote Sensing for data gathering, allied to the introduction of Geographic Information System (GIS) as a powerful tool to process data in conjunction with information collected using traditional field techniques helps overcome traditional data volume constraints. Remotely sensed data as well as traditional techniques permit the preparation of base maps including terrain evaluation, land use classification, land degradation maps and a host of other aspects. Agriculture and associated vegetative phenomena are dynamic; a correct appraisal of conditions at any time is essential for forecasting trends and patterns in land cover, processes and yield/biomass.

The synoptic view and the repetitive cover afforded by satellite data allow multi-temporal observation of seasonal changes. To make best use of such information, it is necessary to combine it with other data. The need for integrating Satellite Remote Sensing, earth-bound survey, cartography, statistical and analytical techniques is readily apparent and is manifest through the adoption of GIS and databases within all agricultural land use assessment methodologies. These systems and methodologies represent an essential tool for the enhancement of agricultural management techniques and structures.

The last decades witnessed revolutionary changes in the approaches related to spatial problems because of incredible progress in automation and computer technology especially with the introduction of modern Geographic Information System (GIS). It is a powerful tool for capturing, storing, analysing, integrating and retrieving spatial and non-spatial geographical data apart from drawing any kind of maps. The development of spatial statistical techniques has been accelerated parallel to this rapid growth of GIS technologies and there is a need to integrate the GIS, spatial statistical techniques and remote sensing.

Advantages of GIS

GIS is broadly defined according to what it does. Thus, the activities normally carried out in a GIS as highlighted by Kufoniyi (1998) include:

i. The measurement of natural and man-made phenomena and processes from a spatial perspective. These measurements emphasize three types of properties commonly associated with these types of systems: elements, attributes, and relationships

ii. The storage of measurements in digital form in a computer database. These measurements are often linked to features on a digital map. The features can be of three types: points, lines, or areas (polygons).

iii. The analysis of collected measurements to produce more data and to discover new relationships by numerically manipulating and modeling different pieces of data.

iv. The depiction of the measured or analyzed data in some type of display - maps, graphs, lists, or summary statistics.

v. New and flexible forms of output such as customized maps (maps tailored to meet user's specific needs) in digital or analogue form, reports, address list etc;

vi. Quick and easy access to large volume of data;

vii. The ability to select terrain detail from the data base by area or theme;

viii. The ability to merge one data set with another;

ix. The means to analyze spatial characteristics of data;

x. The means to search for particular features or characteristics in an area;

xi. The means to up-date data quickly.

Lack of proper land information management systems for settlement, agriculture, livestock, wildlife, mining, etc, is among the factors which affect the development of Nigeria. Many land use systems in the country are subjective to people's need of land for settlements. Fast population growth and the increase of rural-urban migration have forced people to settle on unauthorized or unplanned land. Likewise, inadequate implementation of land utilization types has resulted in land conflicts, double allocation of land plots and squatting. The existing master plans and their preparation systems are too old today to cope with land use dynamics. Process planning is seen as the proper future approach for sustainable land use development in the Lower River Benue Basin as well as Nigeria and many Africa Sub Saharan countries. Inadequate land information systems for sustainable land use management, improper technologies together with funds, make the land problems grow bigger and bigger.

2.7.5 <u>Remote Sensing and GIS Applications in Land Use Studies</u>

Adeniyi (1985) observed that computer assisted classification of Landsat MSS image can provide rapidly, basic up-to-date location-specific as well as quantitative data on broad categorization of land use and land cover for the semi-arid area of Bakolori, Nigeria. He added that the best period for Landsat MSS acquisition for the classification of land use and land cover of the study area is January and February for the dry season inventory and August and September for the wet season inventory.

Using Remote Sensing and GIS for land use and land cover mapping along the Sokoto River, in the north-western part of Nigeria, Omojola and Soneye (1993) demonstrated through visual analysis the usefulness of Landsat MSS in the generation of land use/land cover information in the area. They also demonstrated the relevance of the input of such data for map analysis and presentation in a way that can make the results of resource analysis useful for planning and management process. Thirdly, they demonstrate the capability of interactive Remote Sensing and GIS techniques in the inventory; presentation and analysis of land use and land cover information of the area. The visual interpretation of the enhanced Landsat MSS data provided adequate spectral information required for the mapping of land use and land cover in the study area while the GIS subsystem used afforded easy analysis and presentation of the maps generated through remote sensing techniques.

Using the NigeriaSat-1 data of December 2003 for land use and land cover mapping of an area within Osun State, Oyinloye *et al* (2004) observed that land use and land cover are dynamic phenomena that are characterized by seasonal changes, particularly in south-western Nigeria where farming is both intensive and extensive. They added that in order to effectively manage these phenomena, it is necessary to map the different themes from time to time, as this will provide a good understanding of the land use and land cover pattern of the area. The result of the study as compared to the images of LANDSAT TM of the same are showed that the satellite data is very relevant for land use and land cover mapping.

Raji (2004) also used data from NigeriaSat-1 and appropriate GIS software packages to assess the current and potential land use in the Kadawa sub-sector of the Kano

River Irrigation Project. Existing soil map of Kadawa at 1:25,000 and topographic map at 1:50,000 were digitized and used to obtain the land suitability/potential land use map. Supervised algorithm was employed in the classification of the December 2003 NigeriaSat-1 image of Kadawa area. He noted on the whole that rainfed agriculture remained the predominant land use, accounting for about 50% of the total land area. The different land utilization types within the irrigated areas could not be discriminated at the scale of the image which is32m. Irrigated agriculture accounted for only 5% of the total land area. Assessment of the adequacy of current land use management shows that only 36% of the total land area is properly managed while 41% of the land area is categorized as over-utilized. Within this over-utilized land, the most severe environmental problems such as rising groundwater table and salinity are envisaged to be caused by intensive-use established on soils of moderate and marginal suitability.

Olowolafe (2004) also carried out a study to evaluate the usefulness of NigeriaSat-1 imagery for soil mapping in some parts of the Jos Plateau, Nigeria. The false colour composite print (Bands 1, 2 & 3) was selected since it shows more boundaries and feature differentiation. Visual interpretation was made at a scale of 1:100,000 followed by ground truth verification, while the final map was compiled at a scale of 1: 250,000. Monoscopic interpretation of Landsat ETM and the conventional method involving air-photo interpretation were also employed for comparison. Four main physiographic units were identified and mapped. These were further subdivided into fourteen soil mapping units. The main physiographic units' boundaries are much more deciphered than the soil mapping units' boundaries. The result shows that feature differentiation and soil mapping unit delineation on the NigeriaSat-1 are good. The soil boundaries produced from it shows considerable coincidence with those derived from the conventional air-photo interpretation method. He concluded that, NigeriaSat-1 imagery has a good discriminating capability between different soil types. To some extent, some mapping units are similar in areal coverage on both maps. The differences however, are attributed to the finer resolution of the black and white panchromatic photographs. The 3-band NigeriaSat-1 product compares favourably with the 7-band Landsat ETM imagery in soil mapping. A key issue is that NigeriaSat-1 product has considerable potential for aiding small-scale soil mapping.

The most common conventional methods of collecting data in the research work involving farming systems analysis include the following: surveys (field measurements, interviews and questionnaires); field observation and measurements direct rural rapid appraisal and participatory rural appraisal. Table 10 contained the comparison of the general characteristics of formal and informal field surveys for farming systems (Norman, 1993).

Table 10. Comparing General Characteristics of Formal and Informal Field Surveys for Farming Systems

Characteristic	**Informal**	**Formal**
Background information required	Minimal	Substantial
Time allocation by researchers:		
Preparation	Less	More
Implementation	More	Less
Analysis and writing	Less	More
Total time	Less	More
Hypotheses: Required beforehand	Not essential	Essential
Created during	Yes	No
Likely discipline interaction	More likely	Less likely
Implementation:		
Questionnaire used?	No	Yes
Interviewers	Field Assistants	Mainly enumerators
Potential for creativity/literation	Maximum	Minimal
Potential for learning/verification	Mainly learning	Mainly verification
Potential for representative sample	Less likely	More likely
Potential quality of information:		
Attitudinal	Better	Poorer
Qualitative	Better	Poorer
Quantitative	Poorer	Better
Probability of high: Sampling errors	Higher	Lower
Measurement errors	No difference	No difference
Value of statistical techniques in analysis	Little	Great

Source: Norman (1993)

As contained in the *Integrated Land Resource Survey (ILRS)* which was evolved in Australia in the 1950's, identification of settlements, arable farming and grazing sites using Photographic Remote Sensing technique can enable the interpretation of base images so as to identify different tracts of land with respect to setting intended use. The result of the survey shows that if such imageries are subjected to rigorous interpretation, we could identify boundaries that will show departure from one tract of land and another for different use types. The ILRS employ the use of panchromatic photographs on the scale of 1:500000, which were interpreted using the fundamentals of API and stereoscope to identify and delineate particularly arable farming and grazing sites in Australia. In Nigeria, the ILRS methodology was applied together with the Land capability system of the *United States Department of Agriculture (USDA)* in the northern Nigeria between 1972 and 1978 to identify suitable land for agricultural development. In addition, it was applied in Britain for the planning of routes (tracks) of their rail system of transportation. It was also used successfully in Tanzania to assess the surface soil erosion to determine the appropriate management and control measures.

Furthermore, using *IRS - IA (Indian Remote Sensing)* application for land use and land cover mapping in India, Rao (1996) stressed that land use and land cover inventories are needed for the optimal utilization and management of land Resources of the country. They concluded that Remote Sensing application with IRS - IA data helped generation of district wise land use and land cover maps of the whole country on 1:250,000 scale to serve the requirement of agro-climatic zonal planning, initiated under the planning commission of the Government of India.

Jenabfer (2001) reiterated that land use and land cover data is one of the most important data layer in any Geographic Information System for agriculture resource management. The lack of real-time and reliable data for preparation of land use and land cover maps has made satellite imagery, the only practical source of up-to-date data for such studies .The study area Gilan province, located in north of Iran was selected because of it variable land cover and diverse agricultural activities. Three different seasonal TM data sets acquired between 1991 and 1994, were utilized in the preparation of land use and land cover maps, which comprised seven major classes (24 sub-classes) and four mixed classes. In addition some specific crops like tea and olive were also mapped. The information derived from these maps together with other data such as topography, transportation network, international and provincial boundaries, etc were compiled for use in the envisaged GIS that will eventually have more than 25 different information layers.

Balaselvakumar (2002) employed remote sensing techniques for agriculture survey in India. He maintained that the use of remote sensing technology has rapidly expanded for the development of key sectors in India as such the remote sensing techniques will continue to be very important factor in the improvement of present system of acquiring agricultural data considering the fact that it provides various platforms for agricultural survey. He concluded that satellite imagery has unique ability to provide the actual synoptic views of large area at a time, which is not possible for conventional survey methods and also the process of data acquisition and analysis are very fast through GIS as compared to the conventional methods. The different features of agriculture were acquired by characteristic, spectral reflectance, spectral signature of agriculture and associated phenomena through EMR. In general, the study emphasized the utmost need of timeliness and accuracy of the output generated by remote sensing techniques and its calibration with ground-truth and other information systems like aerial photography and satellite imagery etc. Furthermore, the importance of remote sensing with special reference to agricultural sector involving crop acreage, crop production, rangeland and livestock were discussed in detail.

Satoshi (2003) examined Indian Remote Sensing Satellite (IRS) data to analyze temporal and spatial characteristics of agricultural land use in the semi-arid tropics of India and one of the major cropping season, Rabi (post rainy), was selected to monitor its agricultural activity. In the Rabi season NDVI value of cropped area showed higher amount than that of forest and also those of other categories. The pattern of temporal change of NDVI of each land use category could be approximated as a linear decrease in the latter period of Rabi season. This formation was applicable to correct the difference of date of observation of satellite data to discriminate the cropped area from other land use by NDVI value. The results of application of this method showed that the cropped area in Rabi season had increased double in the period of 1999 to 2002 and the higher rate of increase was indicated at the part of higher land suitability for agricultural purpose estimated by IRS data.

CHAPTER THREE
MATERIALS AND METHODS

3.1 MATERIALS

This study was carried out by integrating a number of techniques including: Satellite Remote Sensing, Geographic Information Systems (GIS) and conventional as well as intensive field surveys and laboratory work. Some of the research materials which were required and also assembled for the study include the collateral dataset as well as satellite and web-based dataset (Plate I).

3.1.1. <u>Collateral Datasets</u>

Relevant literature materials were obtained on agricultural land use systems and about the study area which is the Lower River Benue Basin. Many libraries (including those in Federal University of Agriculture Makurdi, Benue State University Makurdi, College of Agriculture Yandev, University of Jos, and Space Research Library of the National Centre for Remote Sensing, Jos as well as the Indian Institute of Remote Sensing Dehradun) were visited.

Various maps otherwise referred to as the collateral datasets covering the Lower River Benue Basin were gathered, studied and manipulated to extract the desired information. Such datasets as contained in Plate1 included: Topographic map of Makurdi, Sheet 64, covering the part of the Lower Benue River flood plain at the scale of 1:250,000 produced by Federal Surveys, Nigeria (1969) as reprinted in 1992; Geological map of the Makurdi, Sheet 64, at the scale of 1:250,000 produced by Geological Survey of Nigeria (1963); Soil data from the Federal Department of Agriculture and Land Resources (FDALR)

Kaduna and the University of Agriculture Makurdi; and Meteorological data from the Nigerian Meteorological Agency (NIMET), Makurdi Station.

3.1.2. Satellite and Web-Based Datasets

Satellite remote sensing imageries that were obtained for the analysis of agricultural land use systems in the Lower River Benue Basin as contained in Plate I included: NigeriaSat-1 earth observation and medium resolution data of 32m, sheet 251 and dated 2008 of the area obtained from the National Space Research and Development Agency, Abuja; Landsat ETM data of 30m resolution and dated 2004 downloaded through the Global Land Cover Facility (GLCF), University of Maryland USA covering the basin; Shuttle Radar Topographic Mission (SRTM) of 90m resolution from the GLCF as well as Google Earth satellite data of 2008 solely for spatial reference purposes .

Also assembled were related data on the Internet with particular attention to websites that are endowed with materials on river basin agriculture, tropical agricultural systems, terrain characterization, agricultural land use planning, applications of satellite remote sensing and GIS technologies as well as digital terrestrial photographs covering some specific items and features such as the various agricultural systems and practices.

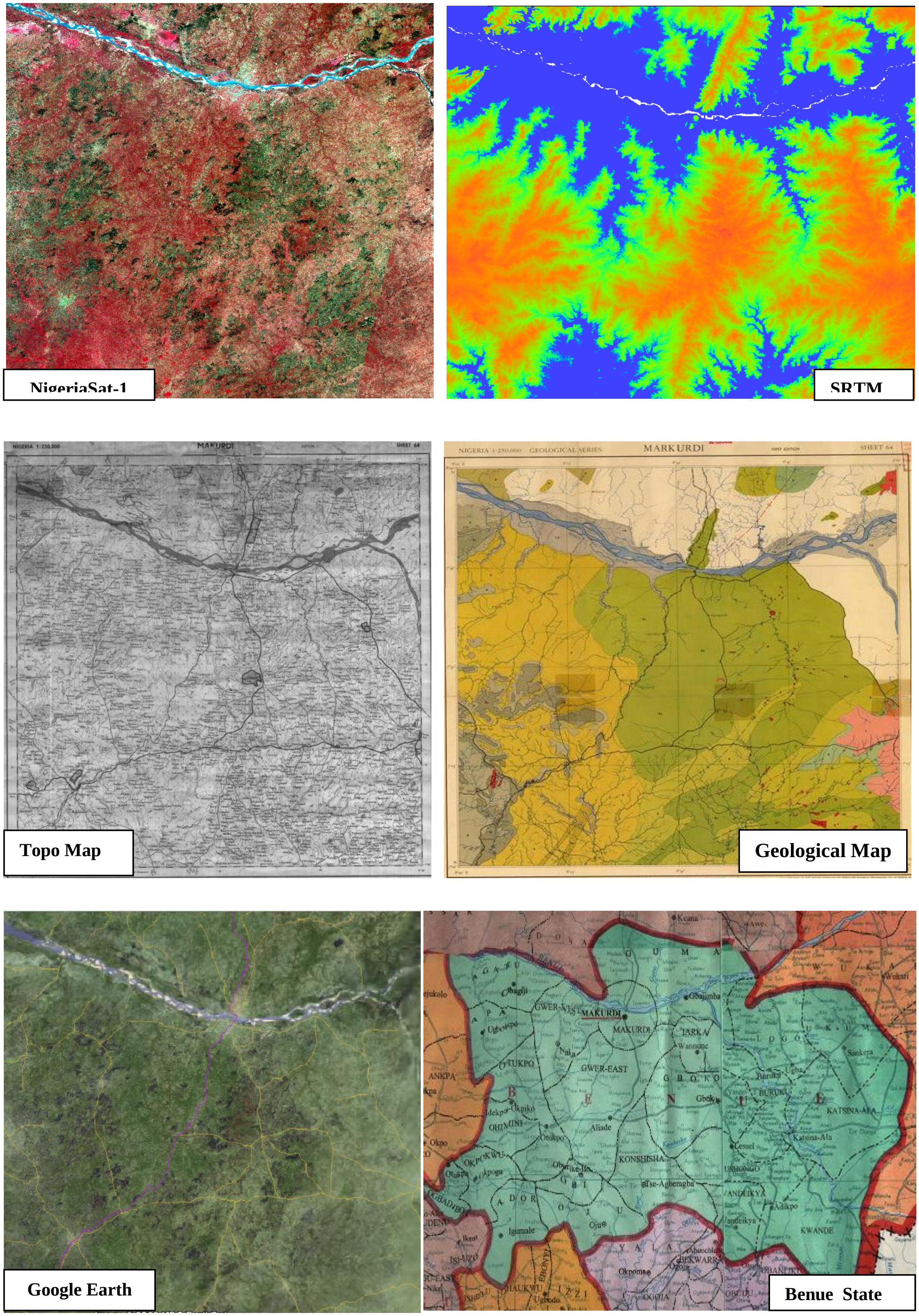


Plate I. Some Imageries and Maps used in the Study

3.2 METHODS

The methods adopted to accomplish the main goal of this study are the normal step-by-step procedures for space-based agricultural and land resources surveys as highlighted below.

3.2.1. Pre-Fieldwork, Initial Preparation and interpretation of satellite imageries

Pre-field or initial indoor preparation included the assemblage and review of the relevant literature materials; visitation to a number of related establishments and organisations for the generation of attribute datasets such as the Benue State Agricultural and Rural Development Authority (BNARDA), University of Agriculture Makurdi, Federal Department of Agricultural Land Resources Kaduna, Lower Benue River Basin Development Authority Makurdi.

Contacts were made with some distinguished experts and professionals in the field of study for the purpose of gathering relevant literature materials and rapid appraisals. This became inevitable because adequate information on the type of crops and their respective pre-harvest acreage in the Lower River Benue Basin is central to the crop production forecasting system and useful for agricultural planning and management.

During the pre-field work and initial preparation, the following actions were taken:

i. Assemblage of ancillary data on climate, soils, vegetation and land use
ii. Acquisition of relevant maps including those of the topography, geology, geomorphology, drainage;
iii. Acquisition of space derived data of NigeriaSat-1, Landsat ETM, Google Earth and Shuttle Radar Topographic Mission;

iv. Acquisition and installation of appropriate software packages such as ILWIS 3.3, Erdas Imagine 8.7, ArcView 3.2, ArcGIS 9.1 and other support packages;

v. Capture of some analogue datasets using appropriate hardware facilities such as workstations, small and large format scanners, digitizers and digital camera.

Interpretation of satellite imageries to generate land use map based on unsupervised classification system and from this a tentative legend of land use categories was composed. The systematic interpretation of satellite imagery involved several basic characteristics of features shown on an image. The exact characteristics useful for any specific task, and the manner, in which they are considered, depend on the field of application. This researcher, used image signals of shape, tone, pattern, shadow, texture, topography, resolution, site and association as registered on the products to delineate and map the agricultural land use systems of the Lower River Benue Basin. Also the processes of satellite image manipulation such as detection, recognition, identification, analysis, deduction, classification and idealization were equally used.

The elements and processes of satellite image interpretation, together with field surveys paved the way for the delineation of the agricultural systems that are operational in the Lower River Benue Basin. The existing agricultural systems in the basin included: Irrigated Farming System (IFS), Plantation or Tree Crop Farming System (PFS), Lowland Rice-based Farming System (LRFS), Upland Cereal and Tuber Based Farming System (UCTFS), Agro-Forestry based Farming System (AFFS), Fishing System (FFS)

3.2.2 Reconnaissance Survey

Reconnaissance Survey was carried out to get acquainted with the area; identification of sample points; field measurements and determination of actual characteristics of features. This was embarked upon to pave the way for a detailed field survey and ground truthing.

3.2.3 Detailed Fieldwork and Surveys

(i) Mapping was carried out on the basis of further observation and surveys in the field. GPS fixes of various sample areas were determined and information on the latitude, longitude, altitude and time compiled. At this stage, supervised classification was accomplished. The Initial map legends were also perfected.

(ii) Questionnaire administration was also embarked upon during the detailed field survey for 250 respondents in the Lower River Benue Basin. The area was delineated into 25 sub-watersheds and copies of the questionnaire were administered to 10 farmers in each of the sub-watershed at locational intervals of 5km. With this, the key attributes of each of the land use units were carefully studied and each major land use types and land utilization categories also defined. The statistical techniques that were used in summarizing the datasets included the measures of central tendencies. The 250 respondents that were interviewed (Plate II) emphasized the need for continuous investigation of the interaction between demographic factors and food availability, including indicators of population structure and potential growth, and for working out operational mechanisms through which to measure population/food supply ratios and vulnerability to food insecurity at the local level and inform related policy actions.

Plate II. Questionnaire Interview with a Respondent at BENCO, near Abinsi

(iii) To complement the questionnaire administration approach, another field data collection technique which is Rapid Rural Appraisal (RRA) method was used to help provide additional information (Plate III), which the satellite imagery and literature materials could not supply. For this purpose information was sought on: Socio-economic characteristics of the farmers; agricultural land use systems and practices; soil management practices; various constraints to sustainable agricultural land use.

Plate III. Rapid Rural Appraisal with the Pastoral Nomads at Katsina-Ala

3.2.4 Digital Image Manipulation and Laboratory Analysis

The satellite imagery of the area and the base maps were interpreted and digitized to delineate the land use and land cover types which were analysed and presented in vector-based GIS using a number of application software packages. At this stage finishing touches were made on the supervised classification and the legend of the various maps; the questionnaire data was also analyzed in relation to the existing agricultural systems in the Lower River Benue Basin; as well as integration of various data sets in a GIS environment.

The various datasets were subjected to appropriate statistical and analytical techniques to show in concrete terms some disparities between variables. Further manipulation and presentation of the research results was undertaken with the aid of Microsoft Word/PageMaker/Excel/SPSS/PowerPoint. The creation of conceptual databases and models was also carried out to demonstrate Entity-Attribute-Relationships as it affects agricultural land use systems in the Lower River Benue Basin.

A. Image processing and analysis

The raw data received from the imaging sensors on the satellite platforms contains flaws and deficiencies. The interpreter tried to overcome these flaws and deficiencies in order to get the originality of the data by undergoing several steps of processing which included: pre-processing, display, enhancement and information extraction/presentation as shown in Figures 14 and 15.

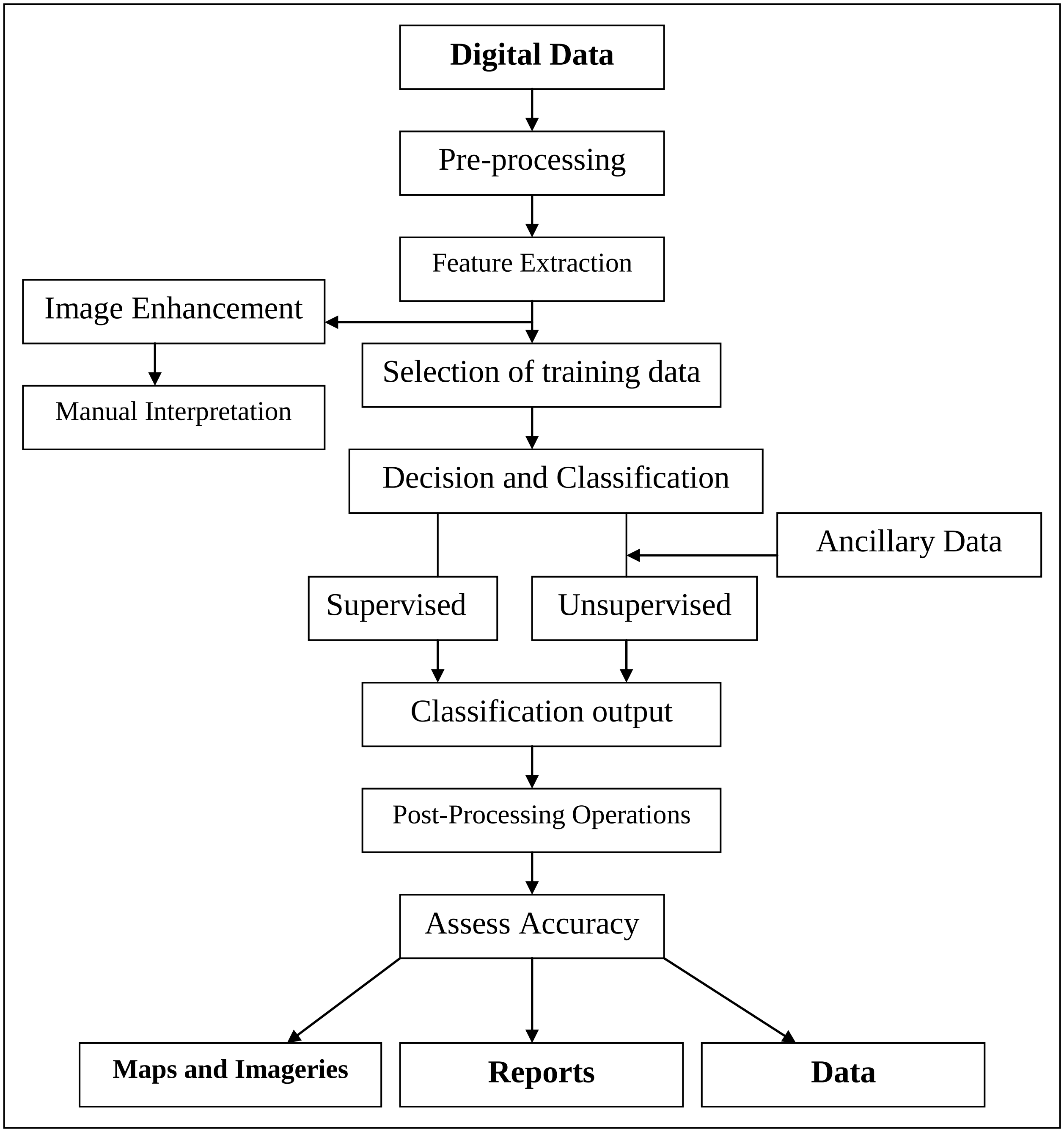


Figure 14. Schematic Diagram of Digital Image Processing and Analysis (after Uchua, 2006)

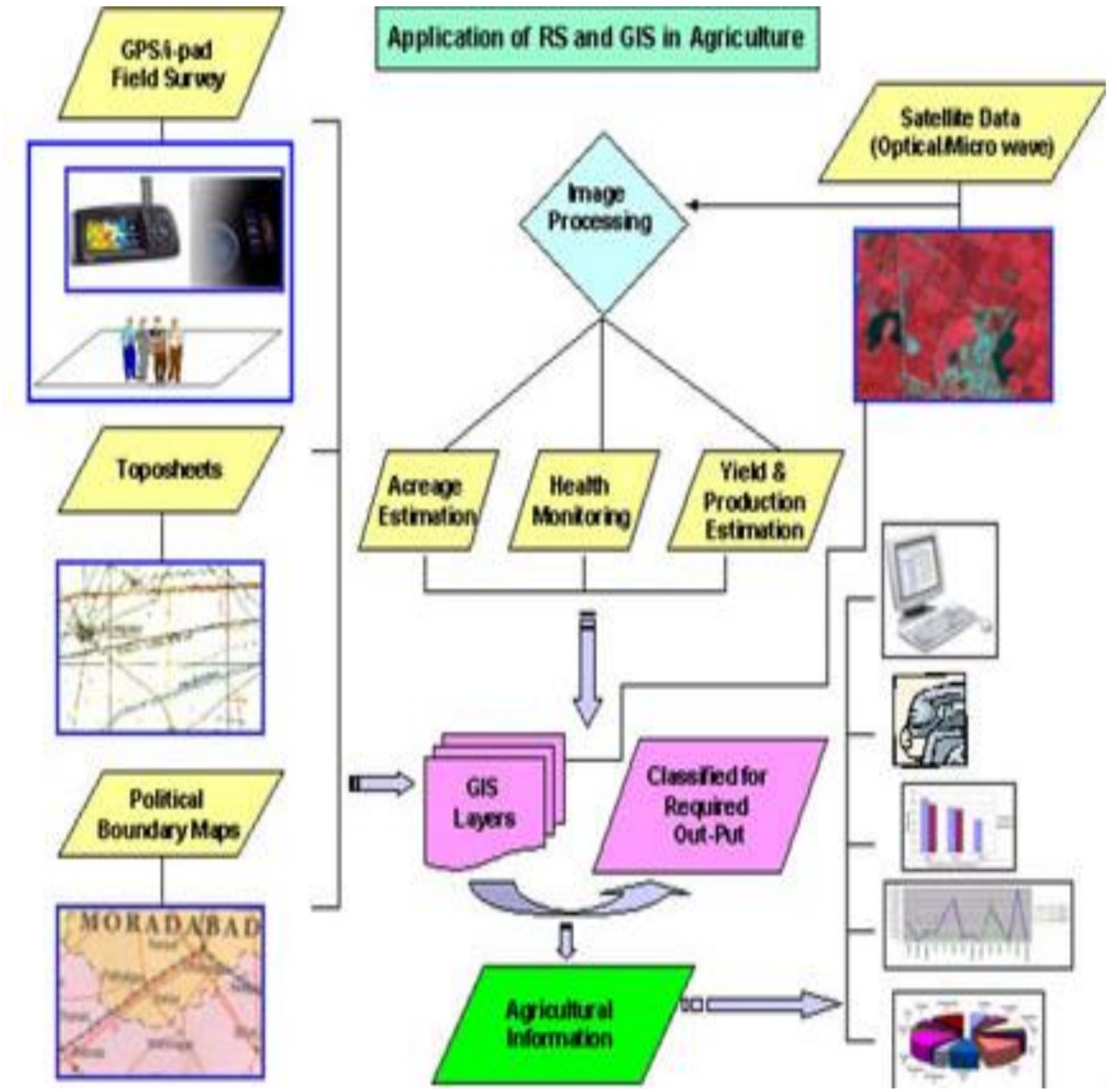


Figure 15. Schematic Flowchart of Remote Sensing and GIS Application in Agriculture (after Hatfield & Pinter, 1993)

B. Analysis of agricultural systems and land use/land cover

On a global and even local scale, the various factors of production (environmental and socio-economic conditions) vary in both space and time. This study therefore strived to tackle issues of agricultural systems analysis in the Lower River Benue flood plain in the following ways;

i. Presentation of GIS maps that showed the distribution and aerial extents of individual land use systems to show the great advantage of the satellite remote sensing and GIS technologies over the conventional land use survey techniques
ii. Each land use system was identified and mapped using supervised and unsupervised classification methods
iii. Each agricultural land use system was characterised in detail using the results of questionnaire administration as well as field measurements and observation
iv. Identification of production constraints lead to suggestions on alternative uses, techniques and practices

In this study, the author relied on the criteria proposed by Anderson et al (2002) to arrive at the land use and land cover classification and mapping in the Lower River Benue Basin that stretched from Gbajimba to Gbagi Ocholi.

C. Generation of slope percent and slope class maps

In preparing the digital slope map, the contours lines were digitized from the topographical map and given appropriate height values they represent. An interpolated height map was created from the contour segment and the output map was a DEM. The height differences in X-direction and Y-direction were calculated through the filter operation using the

DEM as the input map and by selecting linear filter dxdy, the output maps DX and DY were generated.

To calculate the slope map in percentage from the DX and DY maps, the ILWIS command was used: SLOPE_PCT:=(HYP(DX,DY)/30)*100. Here, 30 is the pixel size, HYP is an internal Mapcalc/Tabcalc ILWIS function, and SLOPE_PCT is the output map. The slope map in percentage together with SRTM data formed the basis for further slope computations for agricultural land use analysis in the Lower River Benue Basin.

D. <u>Generation of DEM and 3D Visualization</u>

Digital elevation model (DEM) data which are the sampled arrays of surface elevations in raster form was generated for the Lower River Benue Basin and ranges between 200 to 1100m. The DEM is also used to extract terrain parameters of the LRBB and relate them to the factors influencing the choice of agricultural production systems (Figures 4 and 5).

E. <u>Generation of NDVI</u>

For the calculation of NDVI (Normalized difference vegetation index), the digital data for the study area of at least one time was used. The image was then subjected to NDVI computation using the formulae by (Curran, 1982) below:

$$\text{Normalized Difference Vegetation Index (NDVI):} \quad \frac{IR - R}{IR + R}$$

Where *R* is the Red Band and *IR* is the Infrared Band. The principle behind NDVI is that Channel 1 is in the red-light region of the electromagnetic spectrum where chlorophyll causes considerable absorption of incoming sunlight, whereas Channel 2 is in the near-infrared region of the spectrum where a plant's spongy mesophyll leaf structure creates considerable reflectance.

This relatively simply algorithm produces output values in the range of -1.0 to 1.0. Increasing positive NDVI values, shown in increasing shades of green on the images, indicate increasing amounts of green vegetation. NDVI values near zero and decreasing negative values indicate non-vegetated features such as barren surfaces (rock and soil) and water, snow, ice, and clouds. A high positive correlation of NDVI with forest stand biomass indicates that NDVI could be directly used for biomass estimation under similar environmental conditions.

To measure and map the density of green vegetation across the basin, the researcher used satellite data with distinct wavelengths of visible and near-infrared sunlight that is absorbed and reflected by the plants. Calculating the ratio of the visible and near-infrared light reflected back up to the sensor yielded a number from minus one (-1) to plus one (+1). The result of this calculation is called the Normalized Difference Vegetation Index, or NDVI. An NDVI value of zero means no green vegetation and close to +1 (0.8 - 0.9) indicates the highest possible density of green leaves. The NDVI was computed by calculating the ratio of the VI (vegetation index, that is., the difference between Channel 2 and 1) and the sum of Channels 2 and 1. Thus NDVI = (channel 2 - channel 1) / (channel 2 + channel 1).

F. <u>Analysis of morphometric parameters for the sub-watersheds in the LRBB</u>

The Lower River Benue Basin was delineated into 25 sub-watersheds in accordance to their respective stream network. In order to ascertain the performance of the prevailing agricultural systems especially the irrigated and lowland rice-based systems, about 15 morphometric parameters were identified and analysed for 25 sub-watersheds.

The designation of stream orders is the first step in drainage basin analysis. Since stream segments in each watershed join downstream to form larger streams, the relative importance of each segment can be expressed as a numerical rank or *order* within the stream network. The Strahler stream ordering system used in this study holds that: the smallest headwater segments are assigned *1^{st} order*.

Order increases downstream by 1 whenever two streams of equal order join. For example, two streams of *2^{nd} order* join to form a *3^{rd} order stream*. But the order number does not increase when a lower-order stream joins a higher-order stream. In other words, the first order stream has no tributaries; the second order streams have only first order streams as tributaries; similarly, the third order streams have first and second order streams as tributaries and it continue that way.

The methods prescribed for the calculation of the various parameters for the purpose of morphometric analysis, as contained in Appendix C were adopted from various scholars as follows: stream order (Figure 16), mean stream length and mean bifurcation ratio (Strahler, 1957 and 1964); stream length, stream length ratio, drainage density, stream frequency, drainage texture, form factor and length of overland flow (Horton, 1932 and 1945, Singh and Singh, 1997); bifurcation ratio, relief ratio, elongation ratio and constant of channel maintenance (Schumn, 1956 and Langbein 1947); circulation ratio (Miller, 1953)

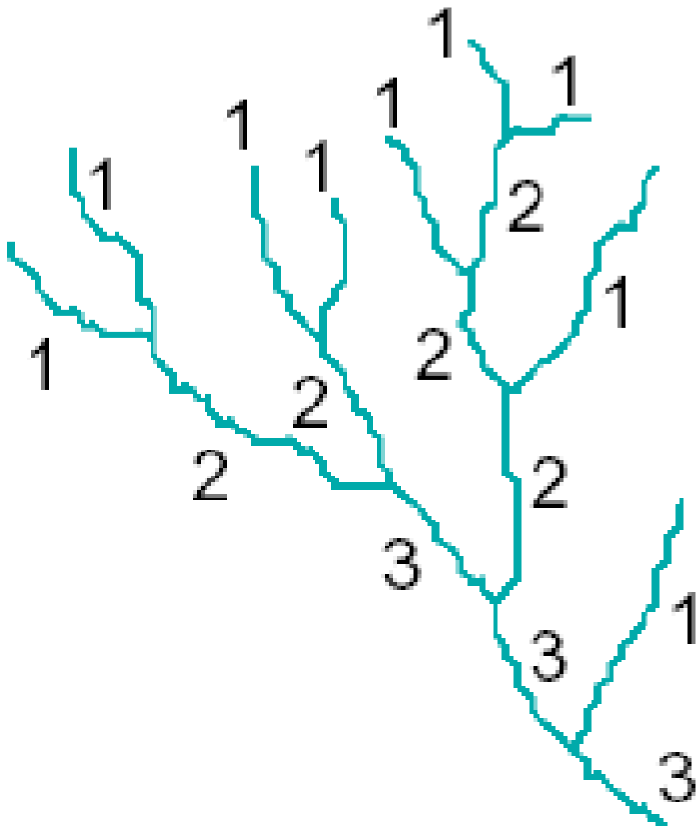


Figure 16. System of Stream Ordering (after Strahler, 1964)

G. Prioritization of the sub-watersheds for improved agricultural production

The drainage, soil, geomorphology and land use are greatly influenced by the terrain features, which in turn reflect on the watershed characteristics. In this study, the Nigeriasat-1 satellite data and the DEM map provided the spatial distribution of these resources and the thematic maps derived using the satellite data were very useful in assessing the 25 sub-watershed rating (Prioritization). Since these factors are interdependent, their integrated study is significantly useful for prioritizing the sub-watersheds. The approach involves identification of sub-watershed with high run-off using the qualitative run-off assessment method. The methodology is based on the assumption that the run-off characters are influenced largely by terrain characteristics such as soil, morphometric parameters, slope and land use and land cover.

H. Database creation on agricultural land use systems in the LRBB

Database creation and design for agricultural land use systems in the flood plain of the Lower Benue River Basin are presented on Table 11 and also illustrated in Figure 17. It addresses the following;

i. Provides a comprehensive framework for the database

ii. Allows the database to be viewed in its entirety so that interaction between elements can be evaluated

iii. Permits identification of potential problems and design alternatives

iv. Identify the essential and correct data and filter out irrelevant data

v. Define updating procedures so that newer data can be incorporated in future.

Table 11: Entity-Attribute Relationship for Agricultural System Analysis in the LRBB

ENTITIES	CROPS	ANIMALS	FARMERS	SETTLEMENT	MARKET	RIVER	TYPE OF ROAD
ATTRIBUTES							
Identity	001	002	003	004	005	006	007
Name	Tubers Cereals Legumes Vegetable	Livestock Birds		Makurdi Gbajimba Abinsi Daudu	Makurdi Gbajimba Abinsi Daudu	R. Benue R.K/Ala R. Mu R.Amire	Major road Minor road
Location	LRBB	LRBB	Makurdi Gbajimba Abinsi Kwatan Sule	Benue State	Makurdi Gbajimba Abinsi Daudu	Benue St.	Benue State
Type	Yam Maize Beans Onions Sugar cane	Cattle Sheep Goat Chicks Guinea fowl	Peasants Nomads	Urban Rural	All day Periodic	All year Season	Tarred Untarred
Area				820.1078 km^2			
Population			109878 Farmers	125513male 114376female			
Length						156km	
Width						2500m	
Class					Agrarian		
Local Govt. Area				Makurdi LGA Guma LGA			

Source: Uchua (2006)

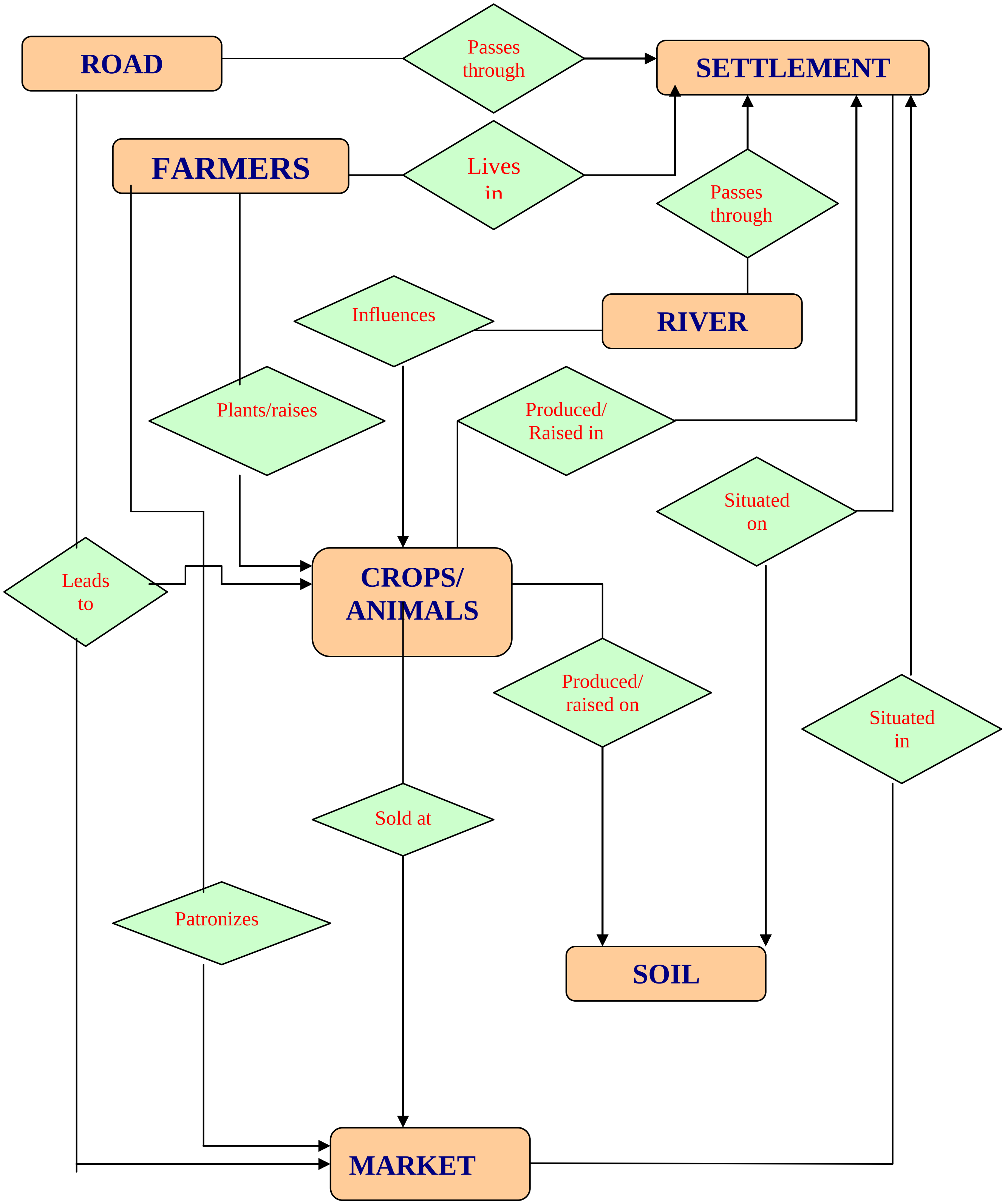


Figure 17. Conceptual Database Model for Agricultural Land Use (after Uchua, 2006)

3.2.5 **Report Preparation and Presentation**

At this concluding stage, the outcome of the material search, field surveys and laboratory manipulation were prepared, compiled and presented in form of text, maps, tables and plates as the final project report titled "Mapping and Analysis of Agricultural Systems in a part of the Lower River Benue Basin, Nigeria".

CHAPTER FOUR

RESULTS OF THE APPLICATION OF SATELLITE REMOTE SENSING AND GIS TECHNOLOGIES IN STUDYING LAND USE AND LANDCOVER

4.1 THE PHYSIOGRAPHIC UNITS OF THE LRBB

Based on terrain characteristics and the variation in the landscape, it was possible to map the Lower River Benue Basin into four major physiographic units so as to characterize the soils depth, slope and drainage of the basin as well as the farming systems that exist in the respective units. The physiographic units which are given in Figures 18 as well as Table 12 are as follows: pediment, buried pediment, alluvial floodplain and valley fills. These units will allow the farmers to evaluate the effect their management activities will have on the structure, composition, and function of the biological and physical components of the system in the various sub-watershed.

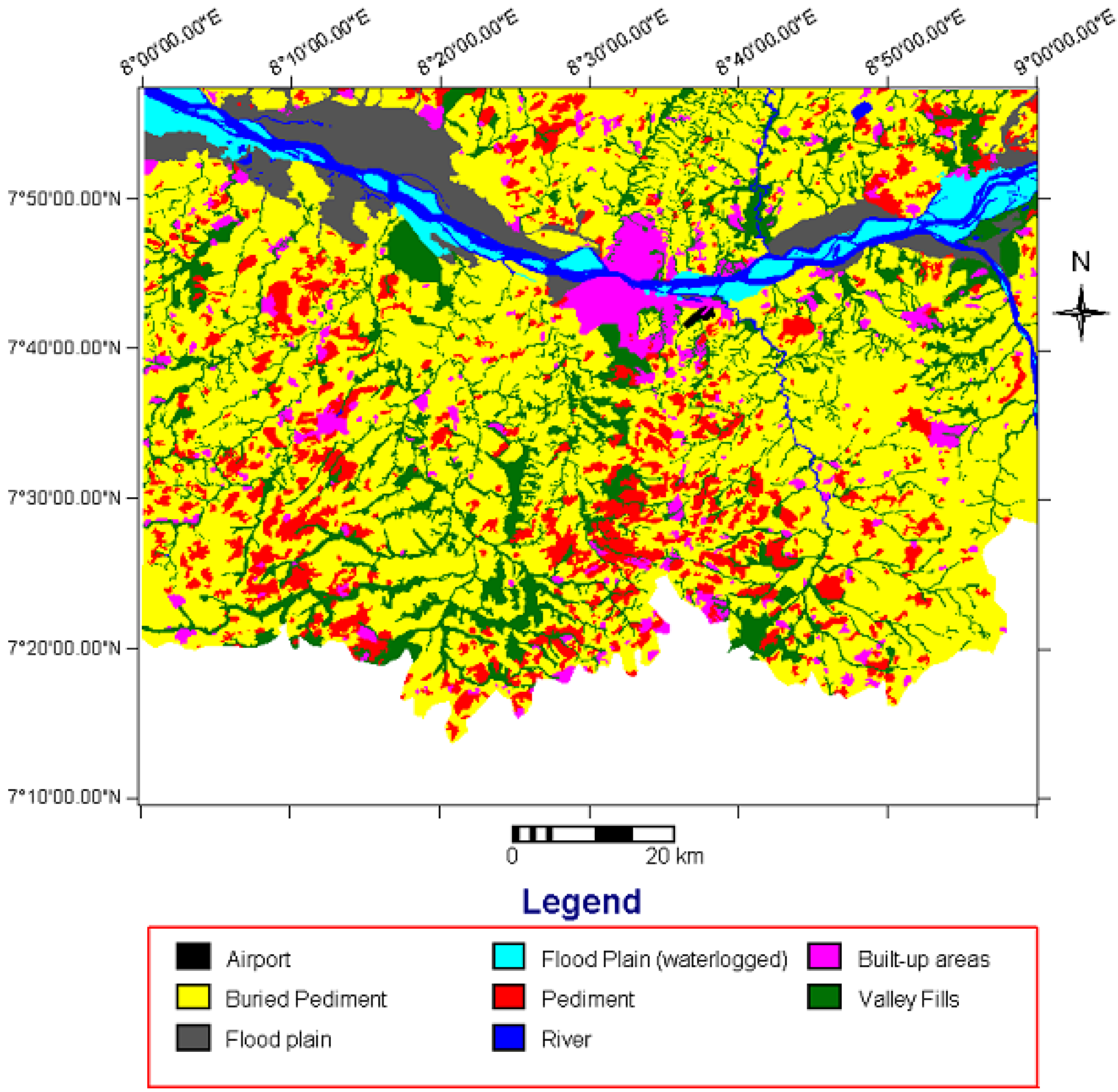


Figure 18. Physiographic Map of the LRBB

Table 12: Area coverage of the Physiographic Units

S/No.	Physiography	Area (Km^2)	Area (%)	Farming System (FS)
1	Pediment	834.95	10.78	Plantation or Tree Crop FS and Agroforestry FS
2	Buried Pediment	4464.34	57.69	Upland Cereal and Tuber FS Agroforestry FS
	Floodplain	436.87	5.65	Lowland Rice-based FS
3	Floodplain (waterlogged)	212.18	2.74	Irrigated FS
4	Valley Fills	1155.18	14.93	Lowland Rice-Based FS
5	River	233.33	3.02	Fishing FS
	Other Features			
6	Airport	4.59	0.06	
7	Built-up areas	397.37	5.13	
	Total	**7738.81**	**100**	

4.1.1 <u>Pediment</u>

This unit comprises of moderate to steep slope and the hilltops are either barren or are covered by vegetation of sparse densities. There is high drainage density indicating moderate to severe erosion. The soil is shallow with a surface texture of clay and sand. The area under this unit as contained in Table 12 occupies about 834.95 sq km, which constitutes 11% of the total area and support plantation and agroforestry farming systems.

4.1.2 <u>Buried Pediment</u>

Buried pediment is used in the basin to describe a well-developed soil or stratum that has subsequently been buried by more recent sediment**.** This unit situates below the pediment having gently to moderate sloping lands. In this study, the buried pediment unit comprises of varying densities of cultivated lands, grazing lands, scrubland and fallow lands, which are well drained with deep soils and moderate rill erosion. It is the predominant unit in the Lower River Benue Basin and covers about 57.69% of the area as contained in Table 12. Agroforestry and Upland Cereal and Tuber based farming systems are extensively carried out in this physiographic unit.

4.1.3 <u>Alluvial Floodplain</u>

Intensive farming is practiced along the floodplains of the Lower Benue River floodplain in Nigeria. The Benue River shapes a corridor of productivity that has, for several years, provided people with dynamic and rich livelihoods, and has made human survival possible even in times of desolate drought. Floodplain pastures of thick grass supported the grazing of livestock, wildlife and nurseries for fish. Irrigated and Lowland rice-based farming systems are operational in the alluvial floodplain unit. Harvested rice fields are grazed by livestock, which in turn fertilized the fields with their manure to support lowland rice-based and irrigated farming systems.

4.1.4 Valley Fills

A valley fill which is an area of low ground with higher surroundings is a depositional feature resulting from filling a low area, usually by eroded material from the pediment (uphill) as the stream overflows its banks. Figures 18 as well as Tables 12 and 13 indicates that the area coverage of the valley fills in the basin is 1155.18 km^2 (14.93%) with gentle sloping surface, very deep soil, imperfectly drained and experiences slight sheet erosion with occasional damaging overflows. Lowland Rice-Based Farming System is largely carried out in this unit.

Table 13. Characterization of the Terrain Parameters in the Physiographic Units

S/No.	Physiographic Units	Area (km^2)	Slope	Soil Depth	Drainage	Erosion Hazard	Damaging Overflow
1	Pediment	834.95	Steep sloping	Shallow	Well	Severe small gullies	Frequent with damage
2	Buried pediment	4464.34	Moderate sloping	Deep	Well	Moderate rill	Frequent with some damage
3	Floodplain	436.87	Very gently sloping	Very seep	Poor	None to slight	None
	Floodplain (waterlogged)	212.18	Nearly level	Very deep	Very poor	None to slight	None
4	Valley fills	1155.18	Gently sloping	Very deep	Imperfect	Slight sheet	Occasional

4.2 DIGITAL ELEVATION MODEL AND 3D VISUALIZATION OF THE AREA

The DEM and three-dimensional (3D) visualization maps (Figures 19 and 20) clearly defined the various positions of all the agricultural land use systems in the Lower River Benue Basin, in relation the topographic features. These maps when studied in relation to slope percent and slope class maps can be of great importance in erosion monitoring and control in the basin. The maps were all produced using satellite remote sensing and GIS techniques.

Within the Lower River Benue Basin, a Digital Surface Model (DSM) which represents the elevations of the reflective surfaces of vegetation, buildings, and other features paved the way for the generation of land use and land cover map of the area.

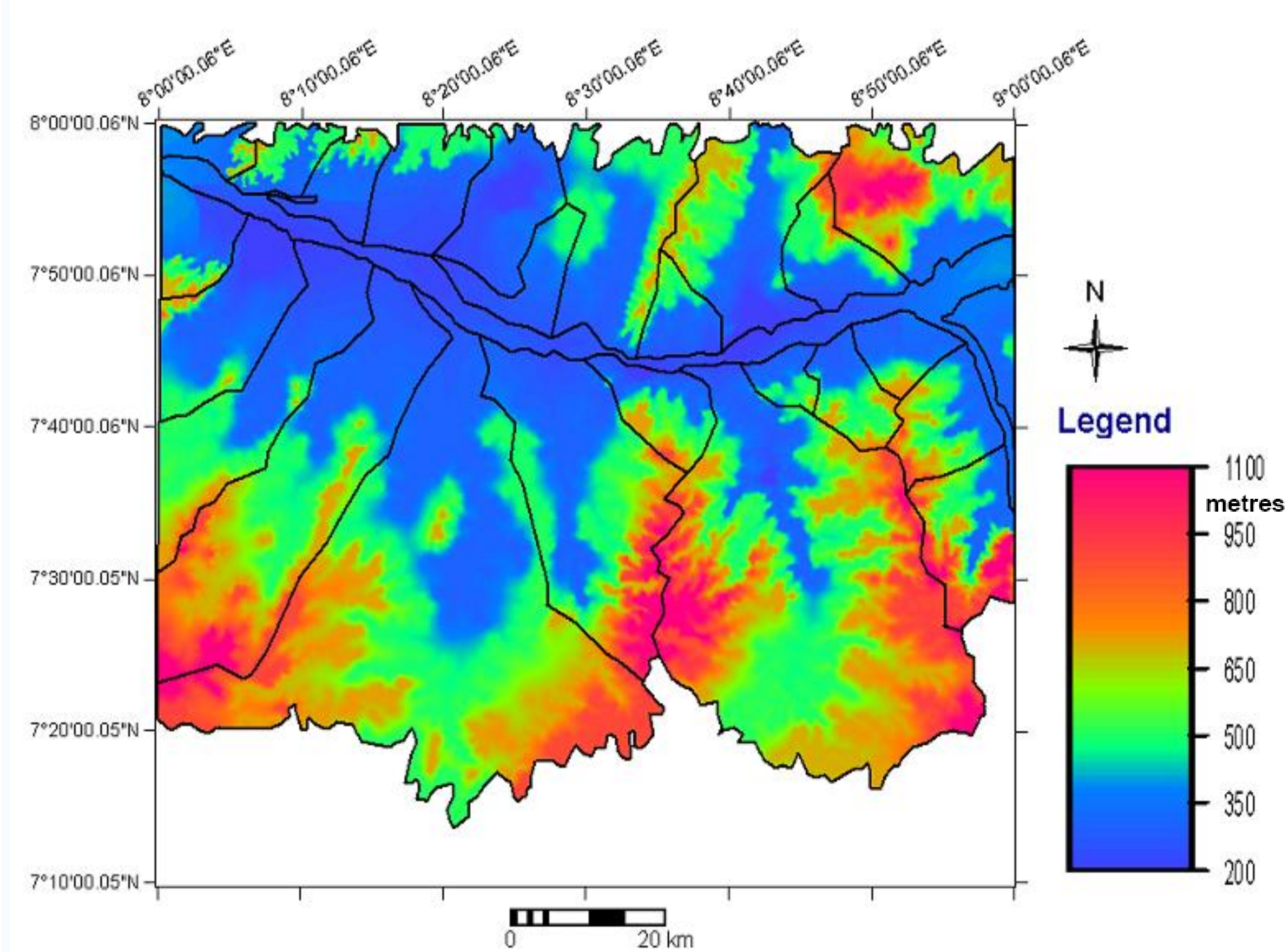


Figure 19. Digital Elevation Model of the Lower Benue River Basin

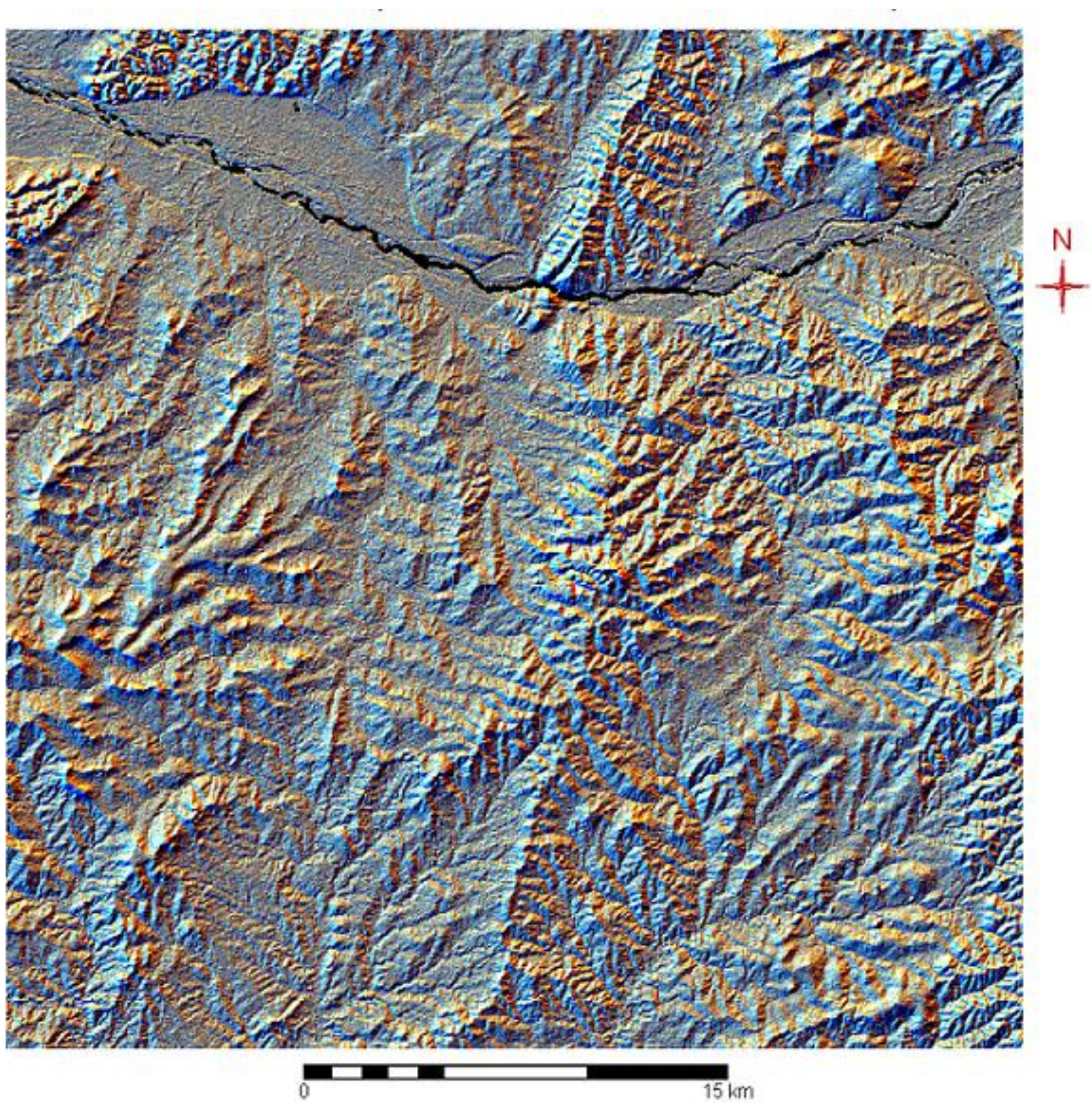
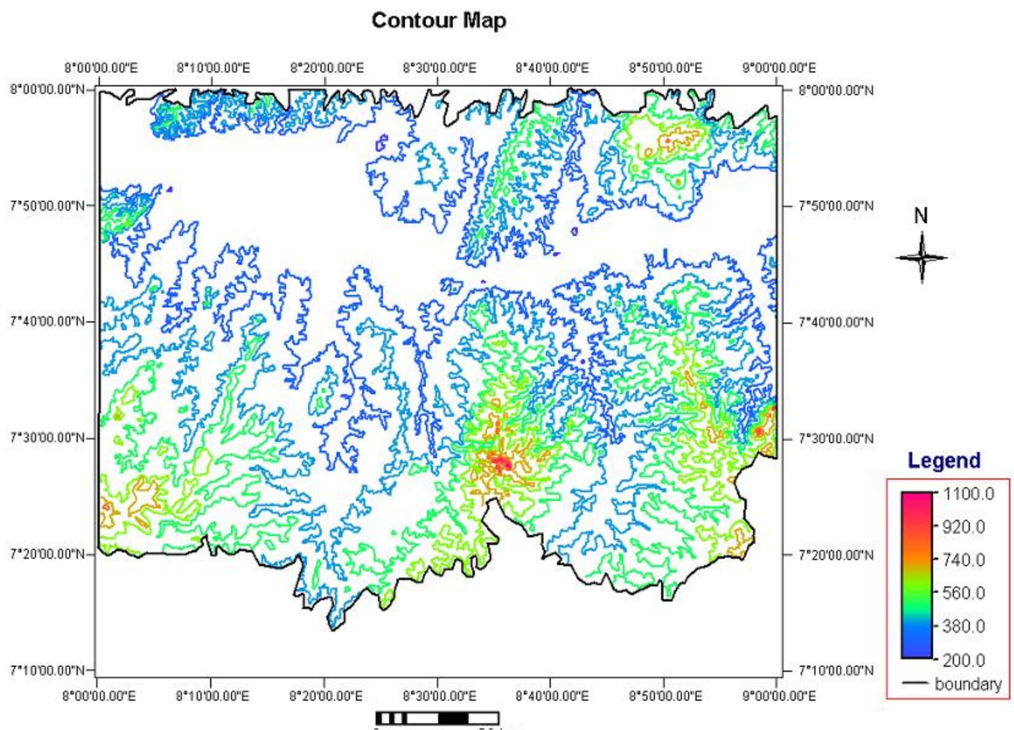


Figure 20: 3D Visualization of the Lower River Benue Basin

4.3. SLOPE PERCENT AND SLOPE CLASS MAP OF THE LRBB

The importance of slope mapping in agricultural land use analysis cannot be over-emphasized since this is the first step towards rationalized use of watershed basins for agriculture. Using the USDA system as contained in Table 14, Figures 21 and 22 the slope of the study area was grouped into various categories ranging from nearly level (<1%) to very steep (>25%). For ease of reference, the slope categories were assigned values, code names and colours in the 25 sub-watersheds of the Lower River Benue Basin.



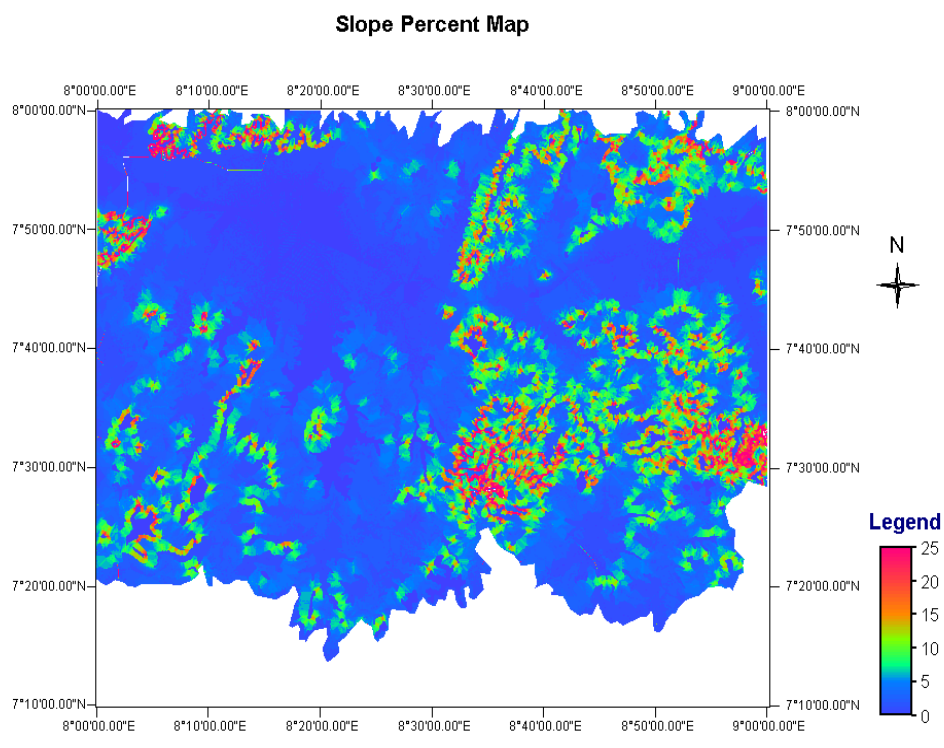


Figure 21. Generation of Contour and Slope Percent Maps

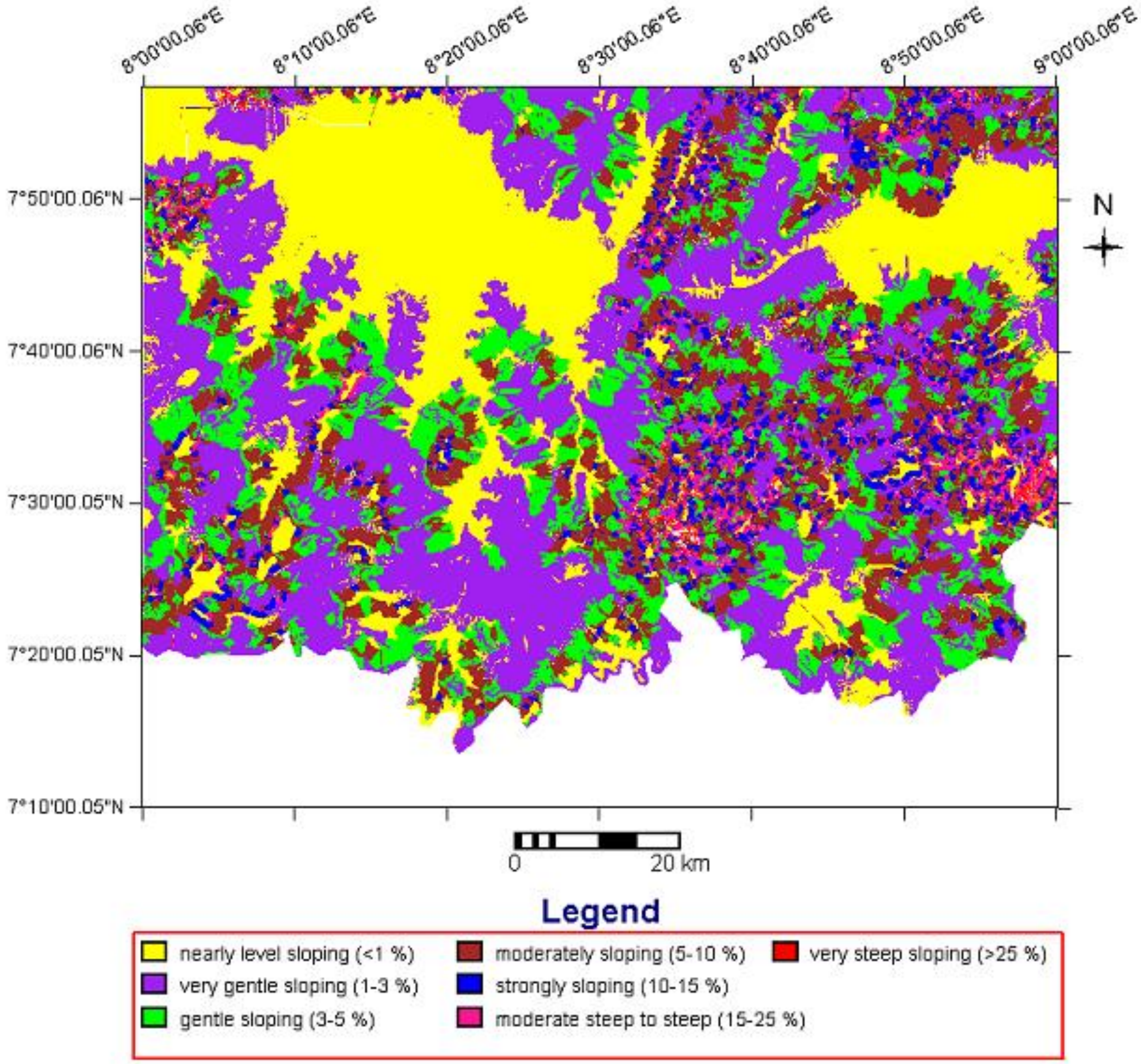


Figure 22. Slope Classes in the 25 Sub-watersheds

Table 14. Area coverage of various Slope Classes and the Farming Systems

S/No	**Slope classes**	**Area Km^2**	**Area (%)**	**Explanation**	**Farming Systems**
1	0-1	1942.83	25.26	Nearly level sloping	Lowland Rice-based FS
2					Lowland Rice-based FS
	1-3	2471.85	32.11	Very gentle sloping	Irrigated FS
3	3-5	1276.08	16.61	Gentle sloping	Irrigated FS
					Upland Cereal and
					Tuber based FS
4	5-10	1337.67	17.39	Moderately sloping	Agroforestry FS
					Upland Cereal and
5	10-15	421.71	5.48	Strongly sloping	Tuber based FS
6	15-25	215.62	2.81	Moderate steep to steep	Agroforestry FS
					Plantation FS
7	>25	26.19	0.34	Very steep sloping	Agroforestry FS
	Total	**7691.95**	**100**		

4.4 NORMALIZED DIFFERENCE VEGETATION INDEX (NDVI) OF THE BASIN

The use of satellite remote sensing and GIS techniques paved the way for the generation of the Normalized Difference Vegetation Index of the Lower River Benue Basin which is a measurement of the ratio of visible to infrared light that is reflected by a plant or simply the measure of the plant vigor, density and spatial distribution. The formula to compute NDVI is as shown below and the computed values for the plant vigor in the basin ranges from -0.49 – 0.01.

The index ranges from -1.0 to +1.0. Where, vegetated areas yield high values because of their relatively high reflectance in the NIR and low reflectance in the visible portions of the electromagnetic spectrum. For instance Water and Clouds reflects higher in the visible portion of the spectrum than NIR, thus they yield negative index values. Rock Outcrops, Bare Soil have similar reflectance values in the two bands and yields vegetation indices near zero.

Vegetated areas reflect very high in the near infrared (NIR) portion of the electromagnetic spectrum and thus yield positive values, with highly vegetated areas including the areas covered by agricultural systems in the LRBB, recorded the highest value of +1. NDVI values obtained from the satellite data were successfully overlaid onto geo-referenced spatial and human ecological data and the results demonstrate that NDVI at such a scale was sufficient to describe variations in vegetation cover of the area (Figure 23).

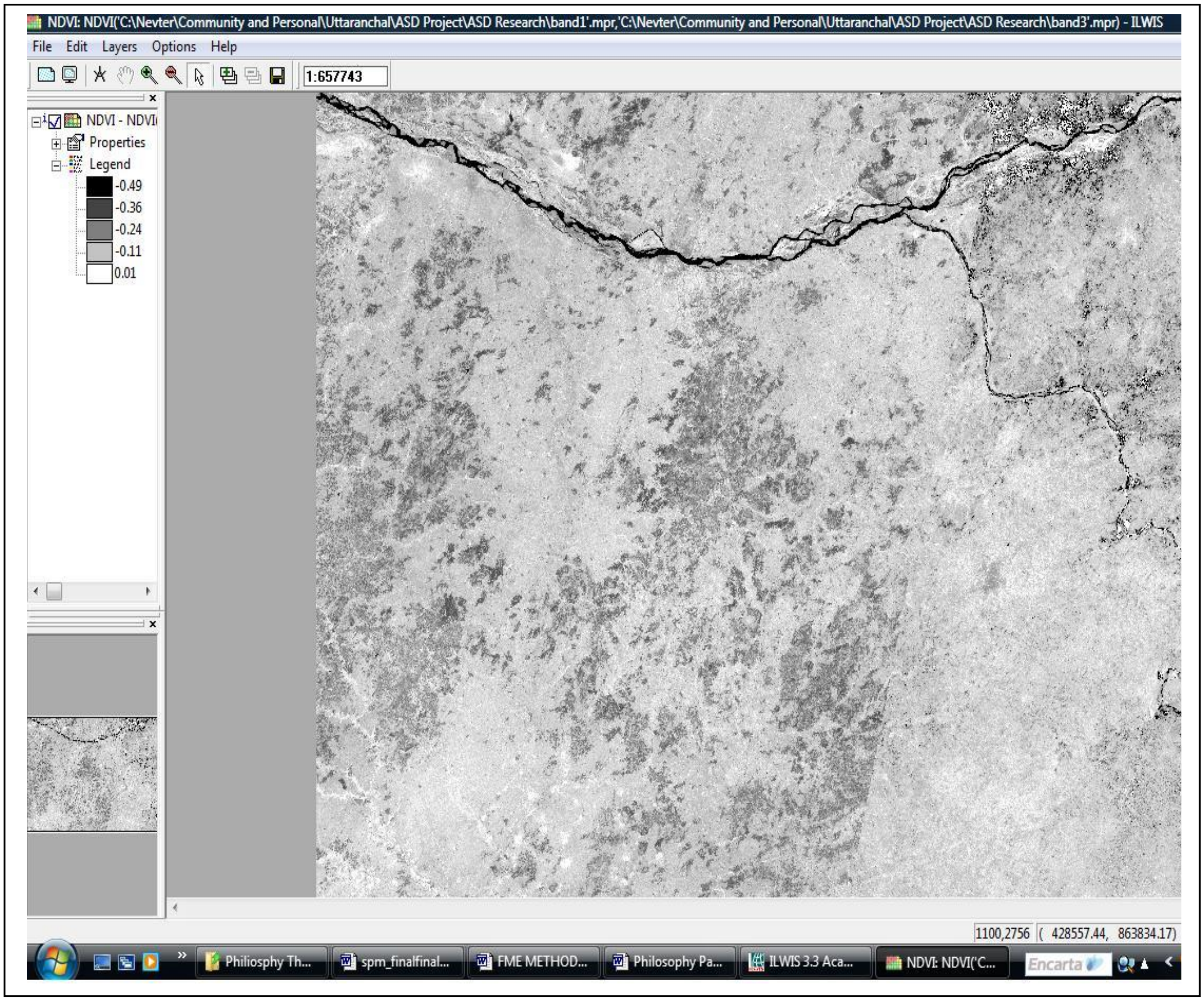


Figure 23. NDVI Map of the Lower River Benue Basin

4.5 THE SUB-WATERSHEDS IN THE LRBB

Using satellite data and appropriate GIS software packages as explained earlier, the 25 sub-watersheds identified and delineated are illustrated in Figures 24. The respective sizes of the sub-watersheds are presented in Table 15 with Gwer sub-watershed occupying the largest area of 20.46% and Owopi the smallest area of 0.63% of the total basin area.

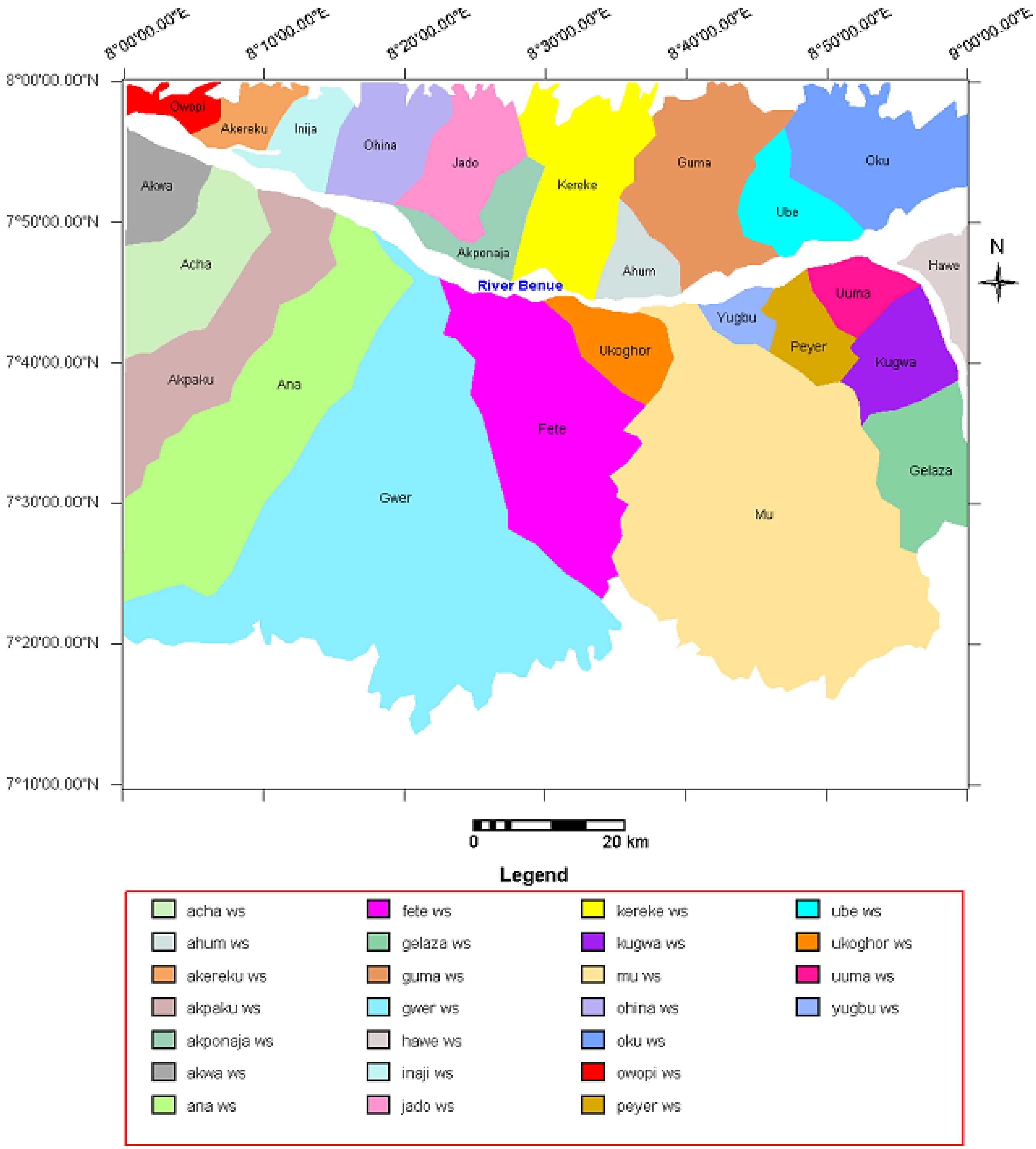


Figure 24: Map of the 25 Sub-watersheds in the Study Area

Table 15. Area Coverage of the 25 Sub-watersheds

S/No	Sub-watershed	Area (Km^2)	Area (ha)	Percentage (%)
1	Acha	259.97	25997	3.38
2	Ahum	86.22	8622	1.12
3	Akereku	73.15	7315	0.95
4	Akpaku	363.83	36383	4.73
5	Akponaja	112.38	11238	1.46
6	Akwa	116.16	11616	1.52
7	Ana	701.74	70174	9.13
8	Fete	582.49	58249	7.58
9	Gelaza	202.13	20213	2.63
10	Guma	343.49	34349	4.47
11	Gwer	1572.47	1,57247	20.46
12	Hawe	72.81	7281	0.95
13	Inaji	99.28	9928	1.29
14	Jado	185.57	18557	2.41
15	Kereke	324.06	32406	4.22
16	Kugwa	157.59	15759	2.05
17	Mu	1394.44	1,39444	18.14
18	Ohina	179.94	17994	2.35
19	Oku	304.97	30497	3.97
20	Owopi	48.41	4841	0.63
21	Peyer	105.82	10582	1.38
22	Ube	133.52	13352	1.74
23	Ukoghor	125.39	12539	1.63
24	Uuma	87.73	8773	1.14
25	Yugbu	51.72	5172	0.67
	Total	**7685.28**	**768528**	**100%**
	Mean	**307.41**	**30741.12**	**4%**

4.6 THE DRAINAGE PATTERN IN THE SUB-WATERSHEDS

The distribution of rivers and streams in the Lower River Benue Basin paved the way for the delineation of each of the 25 sub-watersheds in the basin. Figure 25 shows that Gwer has the largest drainage area of 15724.7 km sq with the 80 total stream segments (Table 18a). This implies that the extent of moisture and wetness in Gwer sub-watershed is higher than any other sub-watershed in the basin and thus, can support agricultural activities all the year round. The overall drainage pattern of the area is dendritic, which is tree-like in shape.

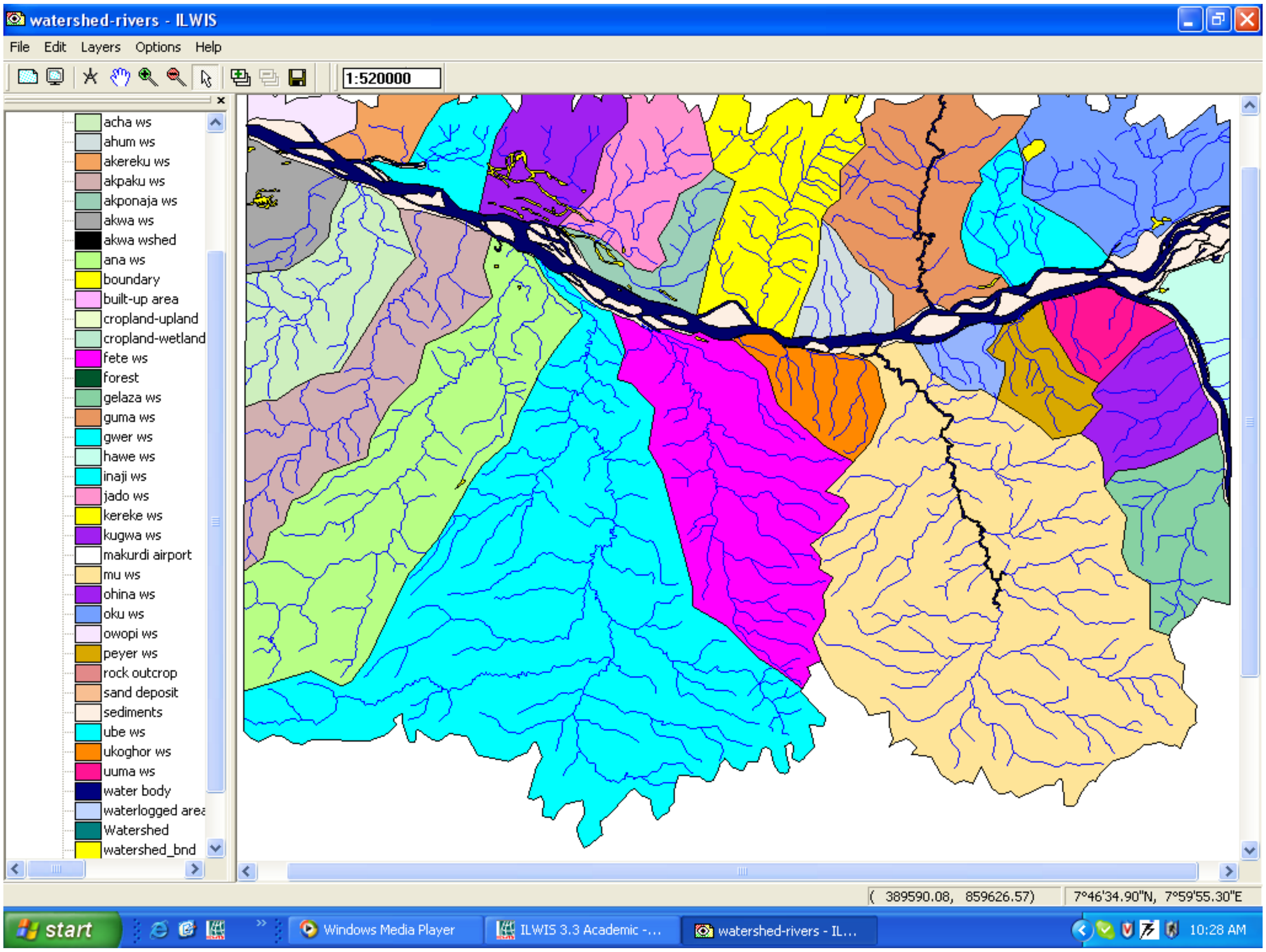


Figure 25. Drainage Pattern and Distribution in the LRBB

4.7 THE DIRECTION OF STREAM FLOW IN THE BASIN

Using the hydro-processing facility of the Integrated Land and Water Information System (ILWIS) software, the various directions of the stream flow in the Lower River Benue Basin were generated as presented in Figure 26. The stream flow directions and area coverage for the eight cardinal points as determined and calculated are illustrated in Table 16. The illustrations shows the direction range to be from 9.31% - 15.50% on the eight cardinal points which portrays a fair spread. The matrix indicates that 15.50% of the stream in the basin flows northwards while 14.21% of the stream flows eastward. The northward and eastward pattern of flow also coincides with the intensity of agricultural activities in the basin.

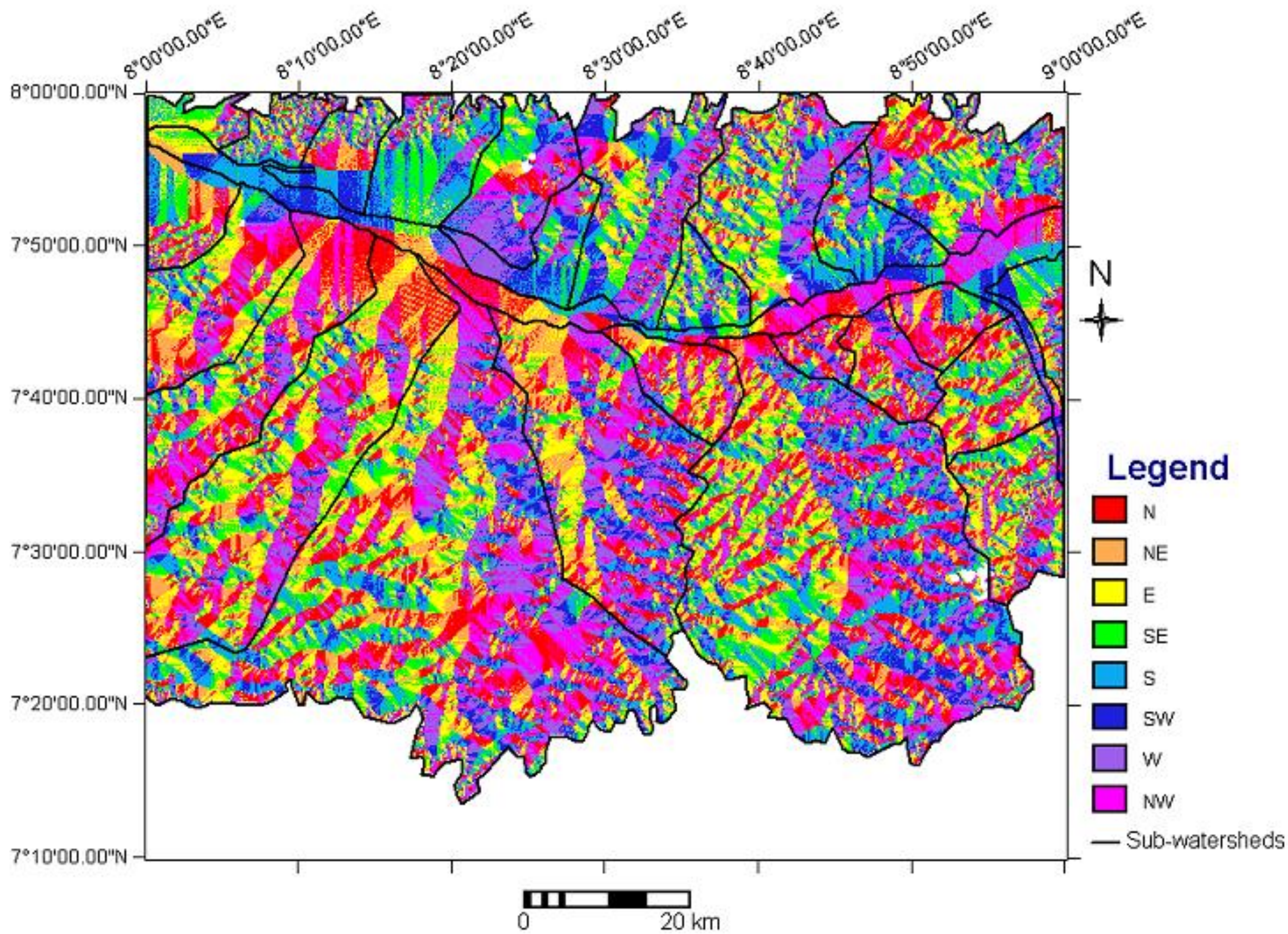


Figure 26. Directions of Stream Flow in the Lower River Benue Basin

Table 16. Direction of Stream Flow in the Sub-watersheds

S/No	**Stream flow direction**	**Area (Km^2)**	**Percentage (%)**
1	N	1247.96	15.5
2	NE	839.86	10.43
3	E	1144.15	14.21
4	SE	820.79	10.2
5	S	1102.04	13.69
6	SW	748.84	9.31
7	W	1125.81	13.98
8	NW	1020.9	12.68
	Total	**8050.35**	**100**

4.8 ACCESS ROADS IN THE SUB-WATERSHEDS

Figure 27 is the infrastructural map which shows the distribution of the communication routes including major road, minor roads and rail track in the Lower River Benue Basin. It therefore indicates that almost all the sub-watersheds in the area are highly accessible. Consequently, movement of farmers as well as of agricultural produce and inputs from homes and farms to the major markets such as Makurdi, Gboko, Otukpo, Lafia, Aliade, Wannune, Daudu, Kadarko and Gbajimba is not difficult.

Apart from the road transportation system, barges, canoes and speedboats are also used to link various settlements across Rivers Benue, Katsina-Ala, Gwer, Mu, Guma and a host of others.

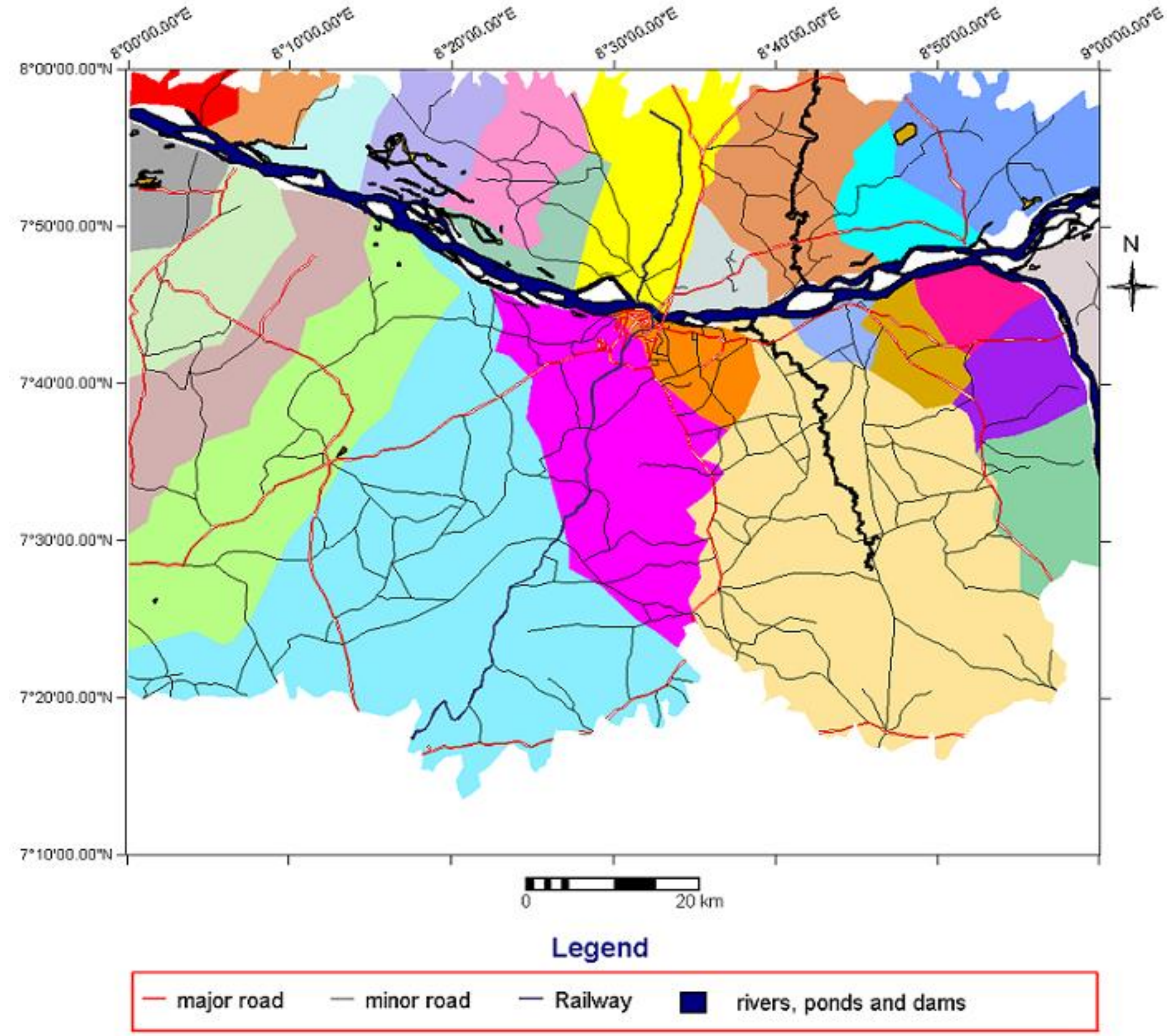


Figure 27. Communication Routes in the 25 Sub-watersheds of LRBB

Note: The names of the shaded parts (sub-watersheds) are contained in Figure 24

4.9 MORPHOMETRIC CHARACTERISTICS OF THE SUB-WATERSHEDS

Satellite data and GIS software packages were used to extract the drainage network upon which the morphometric analysis in the Lower River Benue Basin was based as explained earlier. The result of the calculated parameters including stream order and length, basin area and length, total relief, drainage density and texture, bifurcation ratio, stream frequency, circulation ratio, length of overland flow as well as constant of channel maintenance are presented here.

It was observed that a number of factors have influenced the input, output, and transport of sediment and water in the River Benue drainage basin which include topography, soil type, bedrock type, climate, and vegetation cover. The Dendritic pattern, which dominates the drainage system in the Lower River Benue Basin, is typical of adjusted systems on erodable sediments and uniformly dipping bedrock. The matrix and illustrations containing the morphometric parameters of the drainage in the basin are as presented in Table 18 and Figures 29 and 30. The magnitude of each of the basin parameters involved in this study are described below.

4.9.1 Stream Order

Figure 28 illustrates the order of the streams in all the 25 sub-watersheds of the LRBB. A perusal of Table 18 (a) indicates that out of the 25 sub-watersheds in the area, four sub-watersheds (Gwer, Mu, Fete and Ana) with the highest stream order are designated as 4th order sub-watersheds having a total of 80, 97, 43 and 51 stream segments of all orders respectively. Thus, a combination of segments of all the orders adds up to 597 stream segments with the 1st stream order accounting for 77.5% of all the segments in the study area (Table 17).

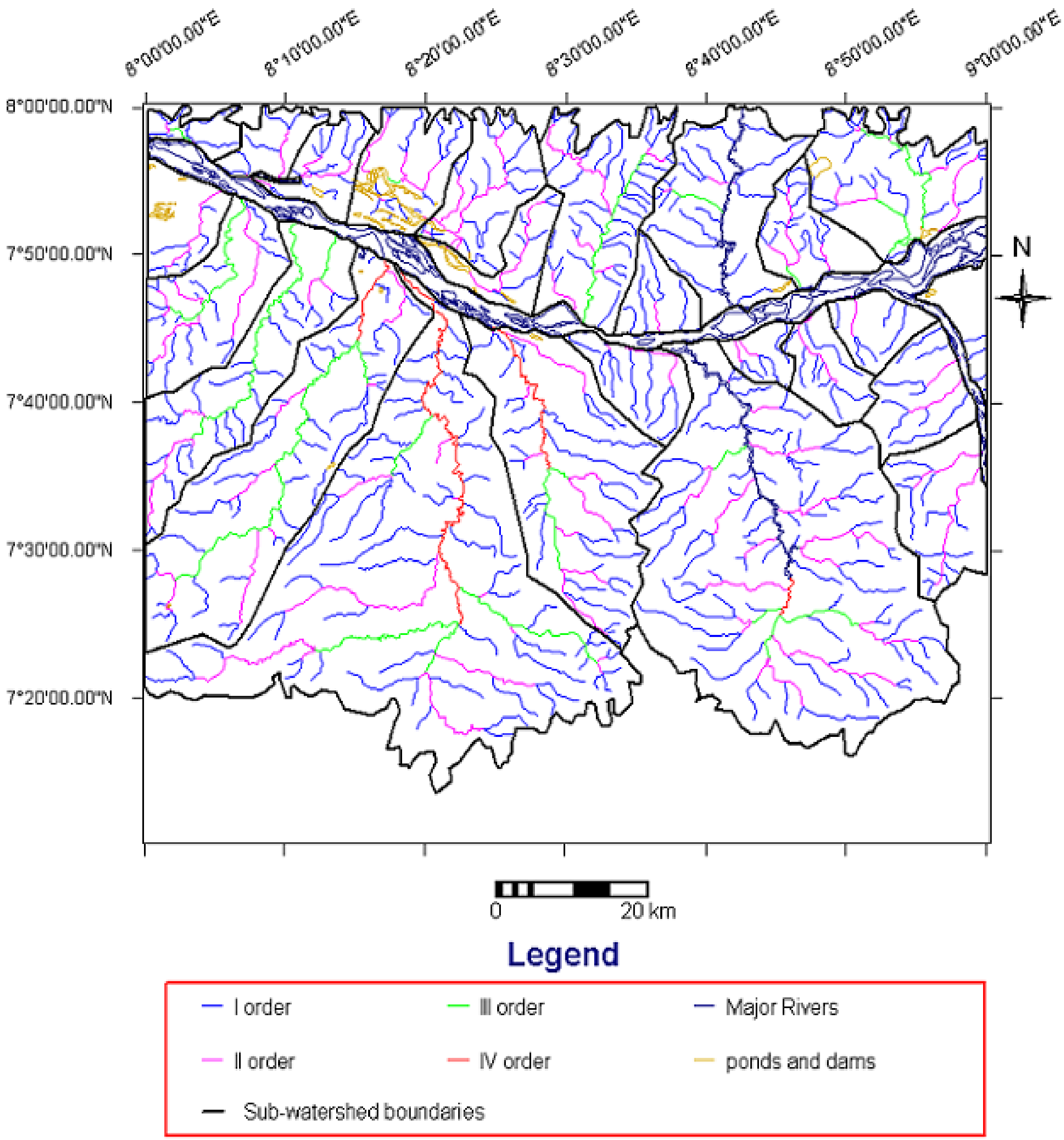


Figure 28. Stream Orders using the Strahler System

Table 17: Stream Orders and Respective Segments in the Sub-watersheds

Stream Orders	Sub-watersheds	Number of Segments	Percentage (%)
1st	25	463	77.5
2nd	24	105	17.6
3rd	14	25	4.2
4th	4	4	0. 7
There are 25 sub-watershed in all		597	100

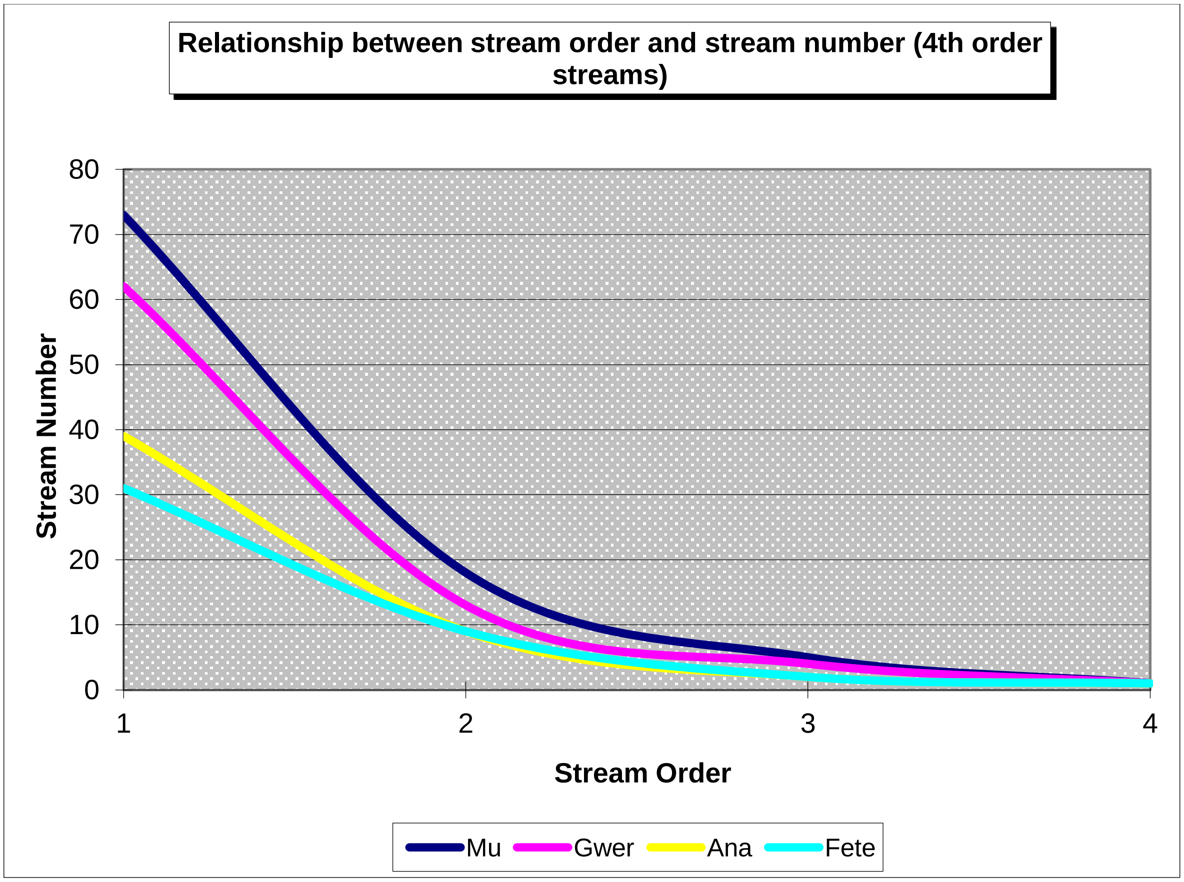


Figure 29: Relationship between Stream Order and Stream Number in Sub-watershed of 4th Order Streams

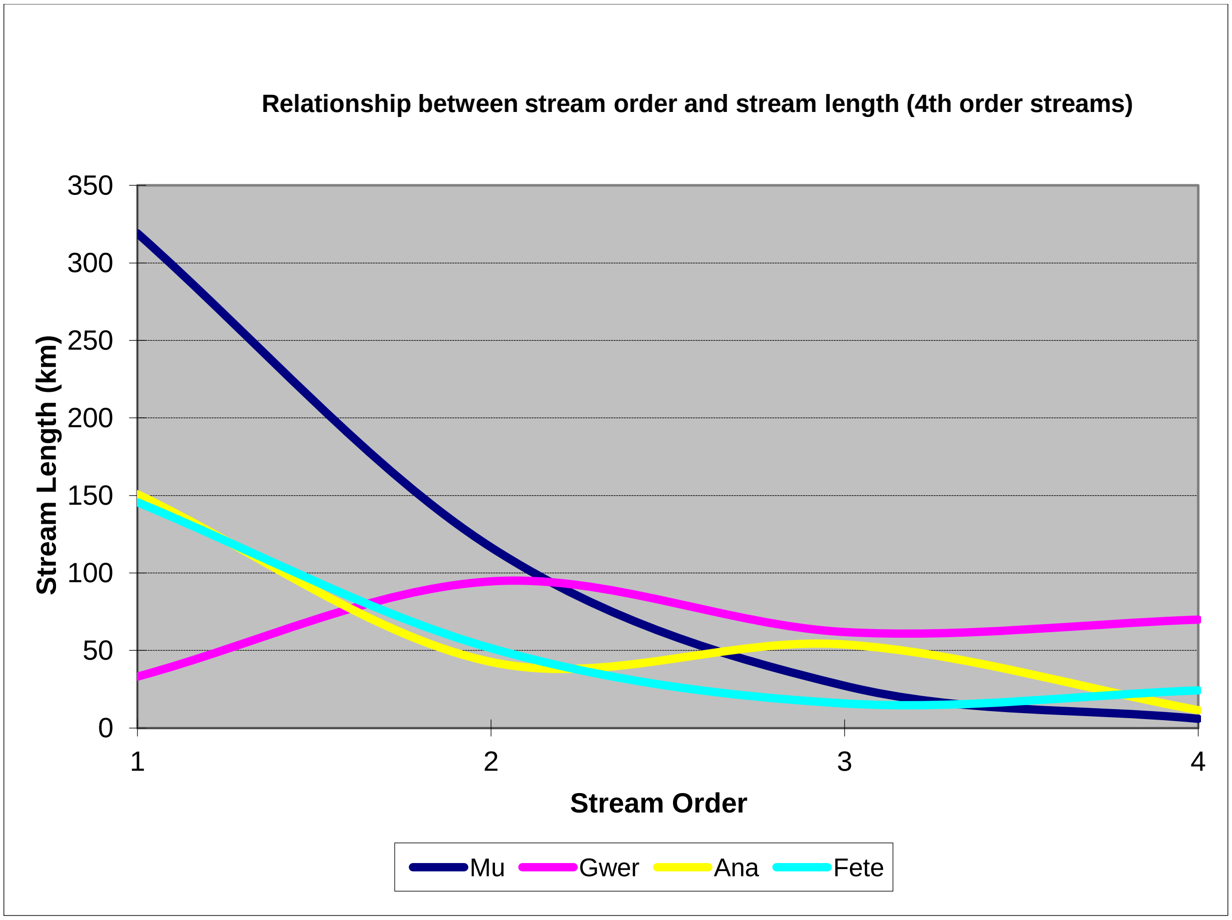


Figure 30. Relationship between Stream Order and Stream Length in Sub-watershed of 4th Order Streams

4.9.2 Total Stream Length

It was observed in the study that the total length of stream segments decreases with stream order. The total stream length of River Mu shows the distribution of the various orders in a decreasing pattern as follows: 1^{st} (319.05km), 2^{nd} (116.46km), 3^{rd} (27.12km) and 4^{th} (5.82km). The deviation from its general behaviour indicates that the terrain is characterized by high relief and/or moderately steep slope, underlain by varying lithology and probable uplift across the basin. The study covering a total of 25 sub-watersheds as shown in Tables 18(a) shows less deviation from the said principle, as the basin relief is generally low.

4.9.3 Mean Stream Length

Table 18(b) indicates that Lsm in these sub-watersheds ranges from 0.53 to 69.9 km for all the orders. Generally, Lsm of any given order is greater than that of lower order in majority of the sub-watersheds with few exceptional cases at the 2^{nd} order (Oku sub-watershed and 6 others), 3^{rd} order (Mu and 4 others) and 4^{th} order (Ana sub-watershed). These anomalies are due largely to variation in slope and the topography.

The Mean Stream Length *(Lsm)* of a channel is a dimensional property and reveals the characteristics of various components of the drainage network and its surface area. Hence, high Lsm values signifies more streams, less infiltration, high overland flow and erosion risk whereas low Lsm indicates few streams, high infiltration and less runoff and minimal erosion. The mean stream length has been calculated by dividing the total stream length of orders by the number of streams in the various sub-watersheds.

Table 18 (a): Matrix of Morphometric Characteristics of the Sub-watersheds in the LBRB

S/No.	SWSD Name	Highest Stream Order	Basin Area (Km^2)	Stream Order				Stream Length (Lu) in km				Perimeter km)	Basin Length (Lb) in km
				1st	2nd	3rd	4th	1st	2nd	3rd	4th		
1	Acha	III	2599.7	21	5	1	-	55.2	37.11	24.3	-	71.91	28.39
2	Akwa	II	1161.6	7	1		-	16.53	13.02	-	-	45.93	14.81
3	Akpaku	III	3638.3	24	5	2	-	82.29	24.57	44.64	-	113.33	45.15
4	Ana	IV	7017.4	39	9	2	1	150.72	42.54	53.79	11.4	140.45	58.32
5	Gwer	IV	15724.7	62	13	4	1	33.09	94.65	61.89	69.9	259.02	61.55
6	Fete	IV	5824.9	31	9	2	1	145.65	51.54	15.9	24.33	120.8	43.07
7	Ukoghor	II	1253.9	8	2	-	-	50.73	11.13	-	-	48.83	16.37
8	Mu	IV	13944.4	73	18	5	1	319.05	116.46	27.12	5.82	180.23	55.94
9	Yugbu	II	517.2	5	2	-	-	18.66	5.88	-	-	33.26	8.59
10	Peyer	II	1058.2	8	1	-	-	36.84	11.22	-	-	45.19	15.16
11	Uuma	II	877.3	5	1	-	-	22.59	4.89	-	-	38.95	10.59
12	Kugwa	II	1575.9	8	2	-	-	43.29	12.09	-	-	53.49	16.99
13	Gelaza	II	2021.3	14	2	-	-	46.53	26.88	-	-	63.68	18.17
14	Hawe	I	728.1	4	-	-	-	8.79	-	-	-	54.75	3.76
15	Oku	III	3059.7	24	7	2	-	83.7	24.33	32.16	-	97.44	19.49
16	Ube	III	1335.2	13	3	1	-	37.77	17.4	2.73	-	53.79	16.50
17	Guma	III	3434.9	19	3	1	-	87.93	4.86	7.08	-	93.82	25.17
18	Ahum	II	862.2	5	1	-	-	31.77	3.87	-	-	41.43	13.43
19	Kereke	III	3240.6	34	6	1	-	120.75	33.3	24	-	107.5	28.63
20	Akponaja	II	1123.8	8	1	-	-	19.89	19.26	-	-	64.98	16.37
21	Jado	III	1855.7	16	3	1	-	59.22	34.14	0.72	-	69.16	20.19
22	Ohina	III	1799.4	14	4	1	-	37.89	21.03	2.13	-	64.13	16.38
23	Inaji	III	992.8	10	3	1	-	36.45	15.18	0.21	-	55.32	13.52
24	Akereku	II	731.5	5	2	-	-	23.04	7.5	-	-	46.57	14.43
25	Owopi	III	484.1	6	2	1	-	25.29	2.1	3.42	-	44.21	9.07

4.9.4 <u>Relief Ratio</u>

Generally, Rh in the study are increases with decreasing drainage area and size of a given drainage basin. In the present study Table 18(b), Rh ranges from 0.01 (Acha and 7 others) to 0.04 (Gelaza) signifying the general flatness to gently sloping nature of the basin.

The elevation difference between the highest and lowest points on the valley floor of a sub-watershed is the Total Relief *(H)*, whereas the ratio of maximum relief to horizontal distance along the longest dimension of the basin parallel to the principal drainage line is Relief Ratio *(Rh)*. It measures the overall steepness of the watershed and is also considered as an indicator for the intensity of erosion process operating on the slope of the basin.

4.9.5 <u>Form Factor</u>

In this study, the values of the Rf are relatively high and show varying degrees of elongation. They range from 1.78 (Akpaku sub-watershed) to moderate – 8.05 (Oku) and then exceptionally to 51.49 (Hawe sub-watershed) as in Table 18(b). Form factor *(Rf)* is the ratio of the basin area to the square of the basin length. The value of the Rf would always be <0.7854 for a perfect circular basin, but the higher the values of the Rf, the more elongated will be the basin as is the case

The sub-watersheds with high Rf have quick run-off, high peak flows of shorter duration, whereas elongated sub-watersheds with low Rf have high stream length, low run-off, lower (flatter) peak flows of longer duration as in the present case. Thus flood flows of the elongated sub-watersheds are easier to manage than those of the circular basins

4.9.6 Circulatory Ratio

In this study, Rc for the sub-watersheds ranges from 2.92 (Gwer sub-watershed) to 7.26 (Uma sub-watershed) contained in Table 18(c), indicating that the area is characterized by low relief and the drainage density is low.

Circulatory ratio *(Rc)* is the ratio of the area of the basin to the area of circle having the same circumference as the perimeter of the basin. The length and frequency of streams, geological structures, land use/land cover, climate, relief and slope of the basin influence it.

4.9.7 Elongation Ratio

In Table 18 (b) the values of the Re range from 8.04 (Akereku sub-watershed) to 18.04 (Gwer sub-watershed) indicating the general low relief and gently sloping nature of the basin. Elongation Ratio *(Re)* is the ratio between the diameter of the circle of the same area as the drainage basin and the maximum length of the basin. A circular basin is more efficient in run-off discharge than an elongated basin.

Table 18 (b): Matrix of Morphometric Characteristics in the Sub-watersheds continued

S/No.	Name of Sub-watersheds	Mean Stream Length (Lsm) km				Stream Length Ratio (RL) km			Total Relief (H) in meters	Relief Ratio (Rh)	Form Factor (Rf)	Elongation Ratio (Re)	Drainage Texture Ratio (Rt)
		1st	2nd	3rd	4th	2nd/1st	3rd/2nd	4th/3rd					
1	Acha	2.63	7.42	24.3	-	0.68	0.67	-	400	0.01	3.23	10.80	0.38
2	Akwa	2.36	13.02	-	-	0.84	-	-	310	0.02	5.29	9.99	0.17
3	Akpaku	3.43	4.91	22.32	-	0.30	1.89	-	367.7	0.01	1.78	10.13	0.27
4	Ana	3.86	4.73	26.89	11.4	0.28	1.29	0.22	534.7	0.01	2.06	12.38	0.36
5	Gwer	0.53	7.28	15.47	69.9	2.95	0.66	1.15	462.6	0.01	4.15	18.04	0.31
6	Fete	4.69	5.73	7.95	24.33	0.36	0.31	1.63	732.2	0.02	3.14	13.16	0.36
7	Ukoghor	6.34	5.57	-	-	0.22	-	-	400	0.02	4.68	9.88	0.20
8	Mu	4.37	6.47	5.42	5.82	0.36	0.23	0.22	900	0.02	4.46	17.82	0.52
9	Yugbu	3.73	2.94	-		0.33	-	-	242.3	0.03	7.01	8.76	0.21
10	Peyer	4.61	11.22	-	-	0.31	-	-	277	0.02	4.60	9.43	0.19
11	Uuma	4.52	4.89	-	-	0.23	-	-	233.7	0.02	7.82	10.27	0.15
12	Kugwa	5.41	6.05	-	-	0.29	-	-	335.4	0.02	5.46	10.87	0.19
13	Gelaza	3.32	13.44	-	-	0.59	-	-	700	0.04	6.12	11.90	0.16
14	Hawe	2.19	-	-	-	8.79	--	-	100	0.03	51.49	15.71	0.07
15	Oku	3.49	3.48	16.08	-	0.29	1.38	-	500	0.03	8.05	14.14	0.34
16	Ube	2.91	5.8	2.73	-	0.47	0.17	-	335.2	0.02	4.90	10.15	0.32
17	Guma	4.63	1.62	7.08	-	0.06	1.83	-	407.4	0.02	5.42	13.19	0.25
18	Ahum	6.35	3.87	-	-	0.13	-	-	243.7	0.02	4.78	9.04	0.14
19	Kereke	3.55	5.55	24.0	-	0.28	0.74	-	228.1	0.01	3.95	12.01	0.38
20	Akponaja	2.49	19.26	-	-	1.02	-	-	142.3	0.01	4.19	9.35	0.14
21	Jado	3.70	11.38	0.72	-	0.59	0.02	-	200	0.01	4.55	10.81	0.29
22	Ohina	2.71	5.26	2.13	-	0.57	0.11	-	141.8	0.01	6.71	11.83	0.29
23	Inaji	3.65	5.06	0.21	-	0.43	0.01	-	238	0.02	5.43	9.67	0.25
24	Akereku	4.61	3.75	-	-	0.34	-	-	221.4	0.02	3.51	8.04	0.15
25	Owopi	4.22	1.05	3.42	-	0.09	3.11	-	200	0.02	5.88	8.25	0.20

4.9.8 Bifurcation Ratio

Lower values of Bifurcation Ratio (Rb) in the LRBB are characteristics of structurally less disturbed watersheds without any distortion in drainage pattern. Table 18(c) shows that Mean Bifurcation Ratio *(Rbm)* of the 25 sub-watersheds is generally low and ranges between 1.5 (Owopi) to 4.67 (Gelaza). Also, elongated sub-watersheds (Gelaza, Hawe, Akponaja, Kereke, Guma and Akwa) have higher Rb than the normal or approximately broad watersheds and would also result in a lower but extended peak flow whereas, the latter with low Rb produces high but sharp peak flow. Furthermore, Variation in Rb represents a pronounced effect on the maximum flood discharge of the watershed, although bulk of the sub-watersheds maintains low Rb. In this study Rb shows only a small variation for different regions on different environment except where powerful geological control dominates, as a high Rb is expected in the areas of steeply dipping rock strata where narrow valleys are confines between the ridges.

Bifurcation Ratio *(Rb)* is the ratio of the number of streams of a given order to the number of streams of the next higher order. For example, trees have a main stem that bifurcates into smaller and smaller branches. The ratio between the branches that are derived from a larger branch or main stem is the bifurcation ratio. Rb is also understood as an index of relief and dissection.

4.9.9 Drainage Density

The D values of the sub-watersheds in the Lower River Benue Basin are contained in Table 18(c). They are low and range between 0.01 (Hawe sub-watershed) to 0.06 km^2 (Owopi sub-watershed) indicating less surface runoff and low erosion risk. The significance of D can be recognized as a factor determining the time of travel by water within the basin which indicates that it varies between 0.55 to 2.09 km^2 in humid region, but much less values than 0.55 km^2 in tropical regions.

Drainage density *(D)* is a measure of the length of stream channel per unit area of drainage basin. It expresses the closeness of spacing of channels. Closer investigations of the processes responsible for drainage density variations have discovered that a number of factors collectively influence stream density in any given area. Thus, it is affected by factors, which control the characteristic length of the stream like topography, resistance to weathering, climate, vegetation, soil infiltration capacity, and geology. In general, low values of D are observed in regions underlain by highly resistant permeable materials with vegetative cover and low relief as is the case in the present study area, whereas high D is observed in the regions of weak and impermeable subsurface material and sparse vegetation and mountainous relief. A high value of the D indicates a relatively high density of streams and thus a rapid stream response to irrigation as well as lowland rice-based farming systems.

4.9.10 **Drainage Texture**

In the LRBB, all the 25 sub-watersheds have very fine drainage texture, as their drainage densities are <1 and ranges from 0.01 to 0.06 km^2 thus signifying high drainage density that is good for both irrigation and upland cereal and tuber base farming.

Drainage texture *(Rt)* is the total number of stream segments of all orders per perimeter of that area. Infiltration capacity is recognized as the single important factor which influences drainage texture and considered the Rt to include drainage density and stream frequency. The researcher has classified drainage texture into very coarse (>1) and very fine (<1).

4.9.11 Stream Frequency

Table 18(c) shows close correlation with the drainage density values of the 25 sub-watersheds indicating the increase in stream population with respect to increase in drainage density. Stream frequency or channel frequency (Fs) is the total number of stream segments of all orders per unit area of the watershed.

4.9.12 Length of Overland Flow

Table 18(c) reveals that Lg is 8.33 in Owopi sub-watershed and up to 50.0 in Hawe sub-watershed. Meanwhile, the direction of the stream flow in the various sub-watersheds of the area is as shown in Figures 26. The stream flow determination was computed through the DEM hydro-processing procedure.

The Length of overland flow *(Lg)* is the length of water over the ground before it gets concentrated into definite stream channels. This factor relates inversely to the average slope of the channel and is quite synonymous with the length of sheet flow to a large degree, and it approximately equals to half of reciprocal of drainage density.

4.9.13 Constant of Channel Maintenance

The value of *C* (16.67) in Owopi sub-watershed means that on an average 16.67 sq m surface is needed in Owopi sub-watershed to support each linear meter of the channel. The inverse of drainage density, as a property is termed constant of channel maintenance *(C)*. It tells the number of sq. m. of watershed surface required to sustain one linear meter of the channel.

Table 18(c). Matrix of Morphometric Characteristics in the Sub-watersheds continued

S/No.	Name of Sub-watersheds	Bifurcation Ratio (Rb)			Mean Bifurcation Ratio (Rbm)	Drainage Density (D) Km^2	Stream Frequency (Fs)	Circularity Ratio (Rc)	Length of overland Flow (Lg)	Constant Channel Maintenance (C)
		$1^{st}/2^{nd}$	$2^{nd}/3^{rd}$	$3^{rd}/4^{th}$						
1	Acha	3.50	2.50	-	3.00	0.04	0.001	6.31	12.50	25.0
2	Akwa	3.50	-	-	3.50	0.03	0.007	6.92	16.67	33.33
3	Akpaku	4.00	1.67	-	2.83	0.04	0.009	3.56	12.50	25.0
4	Ana	3.90	3.00	1.00	2.63	0.04	0.007	4.47	12.50	25.0
5	Gwer	4.43	2.60	2.00	3.01	0.02	0.005	2.92	25.0	50.0
6	Fete	3.10	3.00	1.00	2.37	0.04	0.007	5.01	12.50	25.0
7	Ukoghor	2.67	-	-	2.67	0.05	0.008	6.61	10.0	20.0
8	Mu	3.84	3.00	2.50	3.11	0.03	0.007	5.39	16.67	33.33
9	Yugbu	1.67	-	-	1.67	0.05	0.01	5.87	10.0	20.0
10	Peyer	4.00	-	-	4.00	0.05	0.009	6.51	10.0	20.0
11	Uuma	2.50	-	-	2.50	0.03	0.007	7.26	16.67	33.33
12	Kugwa	2.67	-	-	2.67	0.04	0.006	6.92	12.50	25.0
13	Gelaza	4.67	-	-	4.67	0.04	0.008	6.26	12.50	25.0
14	Hawe	4.00	-	-	4.00	0.01	0.005	3.05	50.0	100.0
15	Oku	3.00	2.33	-	2.67	0.05	0.01	4.05	10.0	20.0
16	Ube	3.25	1.50	-	2.38	0.04	0.01	5.79	12.50	25.0
17	Guma	4.75	1.50	-	3.13	0.03	0.007	4.90	16.67	33.33
18	Ahum	2.50	-	-	2.5	0.04	0.007	6.31	12.50	25.0
19	Kereke	4.86	3.00	-	3.92	0.05	0.01	3.52	10.0	20.0
20	Akponaja	4.00	-	-	4.00	0.03	0.008	3.34	16.67	33.33
21	Jado	4.00	1.50	-	2.75	0.05	0.01	4.87	10.0	20.0
22	Ohina	2.80	2.0	-	2.40	0.03	0.01	5.49	16.67	33.33
23	Inaji	2.50	1.50	-	2.00	0.05	0.01	4.07	10.0	20.0
24	Akereku	1.67	-	-	1.67	0.04	0.009	4.24	12.50	25.0
25	Owopi	2.00	1.00	-	1.50	0.06	0.02	3.11	8.33	16.67

4.10 PRIORITY FOR IMPROVED AGRICULTURAL PRODUCTION IN THE OF LOWER RIVER BENUE BASIN

Using the integrated methods described earlier, the sub-watersheds of the area were prioritized into 4 classes ranging from high priority to least priority (that is, highly critical, critical, slightly critical and not critical) as indicated in Table 20. The statistical matrix of the physiographic units (Table 12), morphometric characteristics (Table 18), distribution of physiographic units (Table 19) and those of the land use and land cover (Tables 21 and 22) were used in the prioritization of the various sub-watersheds as impetus into the analysis of agricultural land use systems in the Lower Benue River basin.

It was gathered in the area during field survey that recently, there has been a growing appreciation of the need to organize communities to work collectively, make sure that beneficiaries have an interest in the work that is done, and ensure that everyone living both at the upper and lower reaches of the watershed benefits from the results of prioritization.

Table 19: Distribution of the Physiographic Units in the Sub-Watersheds for Prioritization

		Mapping Units (%)				**Others**			**Total**
S/No	**SWSD**	Alluvial (Floodplain)	Valley Fills	Buried Pediment	Pediment	River	Built-up Areas	Airport	
1	Acha	11.38	16.52	58.67	8.08	1.17	4.18	-	100
2	Akwa	45.31	3.22	47.31	1.32	0.23	2.61	-	100
3	Akpaku	9.74	11.19	64.33	10.77	0.25	3.72	-	100
4	Ana	1.96	14.48	61.89	17.29	0.26	4.12	-	100
5	Gwer	0.89	21.61	61.26	13.27	0.01	2.96	-	100
6	Fete	1.45	18.54	55.75	17.15	0.05	7.06	-	100
7	Ukoghor	1.43	12.28	30.16	6.01	0.88	45.58	3.66	100
8	Mu	0.73	11.90	69.61	13.24	0.78	3.74	-	100
9	Yugbu	2.90	15.61	59.09	10.86	0.27	11.27	-	100
10	Peyer	3.04	18.54	71.14	1.14	-	6.14	-	100
11	Uuma	17.92	22.42	49.59	6.28	0.03	3.76	-	100
12	Kugwa	0.02	26.33	66.45	2.71	-	4.49	-	100
13	Gelaza	-	9.20	83.37	2.59	-	4.84	-	100
14	Hawe	16.54	31.22	42.08	5.51	0.95	3.70	-	100
15	Oku	11.78	15.68	50.39	15.97	1.99	4.19	-	100
16	Ube	15.19	15.74	54.92	9.92	0.14	4.09	-	100
17	Guma	6.85	21.31	62.35	3.14	2.73	3.62	-	100
18	Ahum	2.94	16.54	52.19	4.19	0.43	23.71	-	100
19	Kereke	2.29	12.63	63.31	5.77	0.15	15.85	-	100
20	Akponaja	36.09	6.12	49.54	6.02	0.54	1.69	-	100
21	Jado	6.38	7.83	66.74	16.54	-	2.51	-	100
22	Ohina	63.27	6.15	19.04	5.87	0.68	4.99	-	100
23	Inaji	80.39	-	14.53	1.47	1.45	2.16	-	100
24	Akereku	53.38	-	37.99	4.39	1.63	2.61	-	100
25	Owopi	7.24	-	74.65	1.79	3.34	12.98	-	100
	Mean	**15.96**	**13.41**	**54.65**	**7.65**	**0.72**	**7.46**	**0.15**	**100**

Table 20: Prioritization of the Sub-watersheds for Improved Agricultural Production

S/No.	Terrain Parameters				Priority	
	Physiography	**Land use and land cover**	**Morphometric Parameters**	**Soil Erodibility**	**Sub-watersheds**	**Priority for Improved Agricultural Production**
1.	Alluvial (floodplain) with very deep soils, nearly level slope	Continuous cropped area, wetland grasses	Low relief, low runoff, broad channels, alluvial deposits	Area of negligible erosion	Inija, Ohina, Akwa, Akponaja, Uuma, Hawe	High Priority (Not Critical)
2.	Valley fill with thick soil cover, gentle slope	Double cropped area, wetland grasses	Low runoff, alluvial deposits, low stream density	Area of slight rill erosion	Hawe, Kugwa, Gwer, Uuma, Guma	Moderate Priority (Low Critical)
3.	Buried pediment with moderate to shallow depth and slope	Single to double cropping, Scrub and grassland	Medium runoff, relief, stream density	Areas of moderate to high erosion	Owopi, Gelaza, Peyer, Mu, Kugwa, Jado, Kereku	Low Priority (Critical)
4.	Pediments with very shallow soil depth, steep slope	Single cropped area, barren Orchards, Scrub and forest	High runoff, high relief, incised channels, sediments removal, high stream density	Area of high gully erosion	Ana, Fete, Jado, Oko, Gwer Akereku, Owopi	Very Low Priority (Highly Critical)

Table 20 shows the interplay of the physiographic, morphometric, soil erodability, land use and land cover parameters as they influence the characteristics of sub-watershed. The Nigeriasat-1 satellite data and the DEM map provided the spatial distribution of these parameters which were very useful in rating the 25 sub-watershed (prioritization). The priority level for improved agricultural production shows that, the highly critical or low priority sub-watersheds are characterized by high run-off, high gully erosion, high stream density, shallow soil depth and steep slopes. They include Ana, Fate, Jado, Gwer, Oko, Akereku and Owopi. The study also identified the least critical or high priority sub-watersheds with low runoff, high alluvial deposit, very deep soils, nearly level slope, broad river channels and negligible erosion menace to include Inija, Ohina, Akwa, Akponaja, Uuma and Hawe (Table 20).

4.11 THE LAND USE AND LAND COVER OF THE AREA

Determination of the land use and land cover of the Lower River Benue Basin was ascertained using appropriate analytical tools such as field survey, satellite imagery, and topographical maps, GIS software packages among others as explained earlier. The results of the exercise are illustrated in Tables 21 and 22 as well as Figures 31. It was observed that, land use is not static in the basin and there is heterogeneity in the land use of the area due primarily to the influence of naturally or human induced factors. Some of the major land use and land cover categories identified in the study include; cropland, built-up areas, water bodies, vegetation, communication routes and bare surfaces.

Table 21 shows that the observed spectral characteristics of cropland include smooth textured farm plots which appeared in a regular pattern in line with land ownership boundaries. The farm boundaries have different tones from the plots themselves with the boundary hedges appearing darker than the plots.

The study also identified rivers, streams, pond and dams as predominant water bodies In terms of water bodies in the area. It was noted that the three major rivers in the area, that is, Rivers Benue, Katsina-Ala and Mu have meandering features and conspicuous shapes and sizes with many stream segments (tributaries). Rivers Benue and Katsina-Ala with deep water appear in darker blue than other rivers and streams due largely to absorption of light by the water thus portraying a low reflectance situation. Shallow or dry rivers and streams have brighter appearance. In some cases, the banks of the rivers show cuttings, which are indicative of erosional features and human activities such as burnt brick industry.

Table 21: Spectral Characteristics of the Land Use and Land Cover in the LRBB

Categories (Level-I)	**Sub-categories (Level-II)**	**Observed Spectral Characteristics**
Cropland	i. Rainfed and upland cultivation ii. Irrigation and valley fills cultivation iii. Orchards	Smooth textured farm plots appeared in a regular pattern. The farm boundaries have different tones from the plots themselves with the boundary hedges appearing darker than the plots.
Built-up areas	i. Major settlement ii. Minor settlements iii. Institutional areas	Defined compounds with fences in some places. Buildings can be seen in cyan tone. Regular arrangement of compounds along river courses and communication routes. Nucleated settlements were also discerned because of the clustered nature of buildings
Water bodies	i. Rivers ii. Streams iii. Ponds and Dams iv. Waterlogged areas	The three major rivers in the area (Benue, Katsina-Ala and Mu) have meandering features and conspicuous shapes and sizes with many tributaries. Rivers Benue and Katsina-Ala with deep water appear darker than other rivers and streams due largely to absorption of light by the water thus portraying a low reflectance situation. Shallow or dry rivers and streams have brighter

		appearance. In some cases, the banks of the rivers show cuttings, which are indicative of erosional features.
Vegetation	i. Forest and woodland ii. Shrubs and grasses	Defined reddish tonal appearance of vegetation in line with the spectral bands of the sensors (green, red and infrared). Evidence of vegetation concentration along the courses of rivers and streams. Recognition clues are tone, pattern and texture.
Communication routes	i. Major roads (tarred) ii. Minor roads (feeder) iii. Footpaths iv. Railway	Smooth textured tiny dark lines connecting several places and criss-crossing one another. Most major roads appear in straight lines with little bends due to plain terrain. Minor roads and footpaths appear faintly but with bright tone.
Bare surfaces	i. Rugged terrain ii. Rock outcrops iii. Sand deposit iv. Erosion sites	Very whitish appearance for sand deposits mostly in the courses of Rivers Benue and Katsina-Ala. Presence of darkish brown portions symbolizing rock outcrops and rugged terrains. Traces of deep cuttings on the sides of the banks of Rivers Benue and Katsina-Ala with coarse texture indicating gully erosion were eminent.

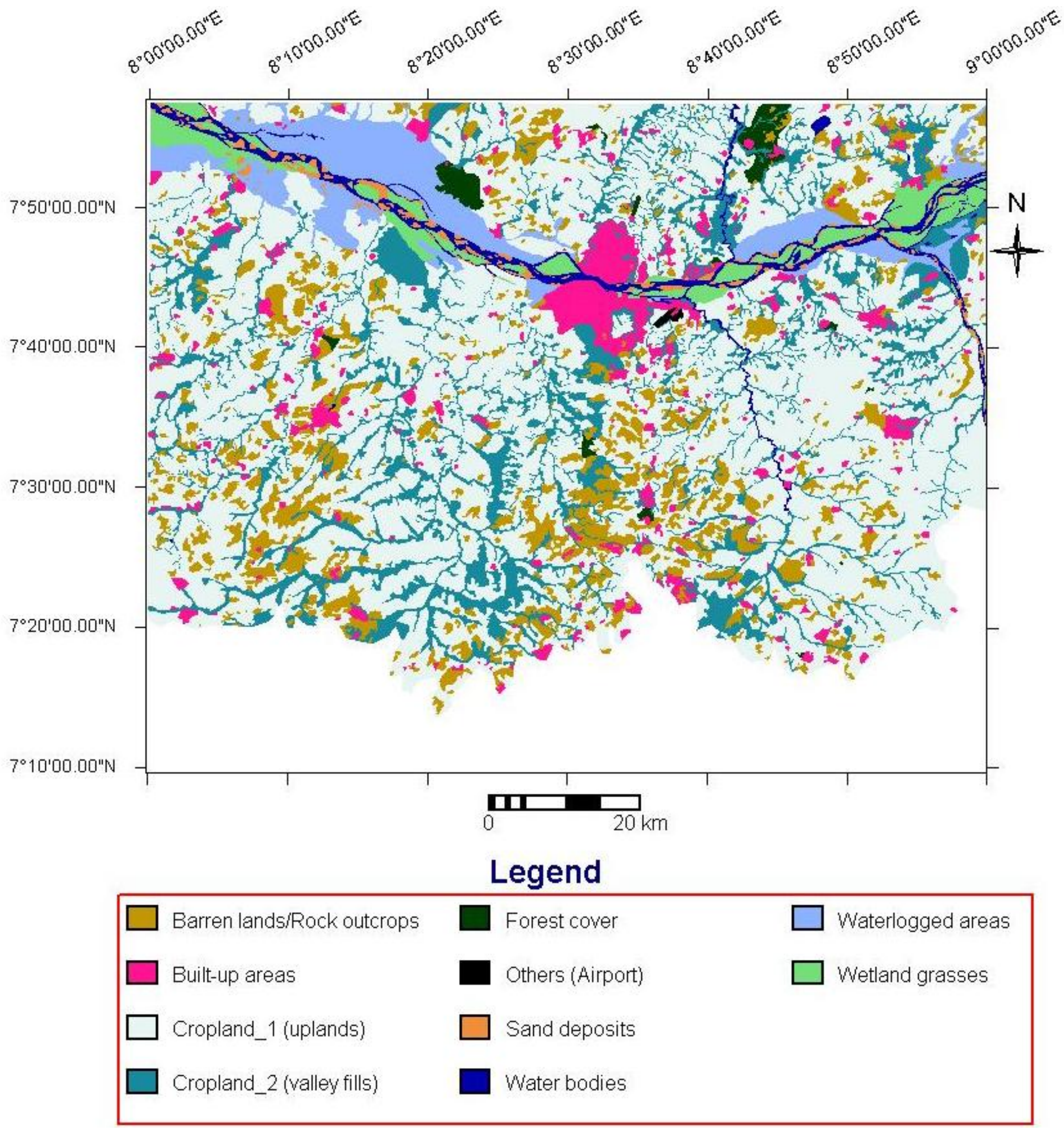


Figure 31. Land Use and Land Cover Map of the LRBB

Table 22. Area Extent of the Land Use and Land Cover in the LRBB

S/No.	Land use and land cover	Area (Km^2)	Area (ha)	Area (%)
1.	Cropland-1 (uplands)	4494.49	449449.73	58.08
2.	Cropland-2 (valley fills)	1136.59	113659.45	14.69
3.	Forest cover	91.11	9111.24	1.18
4.	Wetland grasses	243.67	24366.88	3.15
5.	Waterlogged areas	432.59	43258.65	5.59
6.	Water bodies	162.99	16298.98	2.11
7.	Sand deposits	70.45	7045.09	0.91
8.	Barren lands /Rock out crop	718.12	71812.02	9.28
9.	Built-up areas	383.30	38330.00	4.95
10.	Others (Airport)	4.62	461.65	0.05
	Total	77379.32	773793.69	100%

Note: The shaded portion is upland cropland which dominates the area

4.12 ENVIRONMENTAL CONSTRAINTS TO AGRICULTURAL PRODUCTION IN THE LOWER RIVER BENUE BASIN

4.12.1. Effects of Erosion

Water is the most significant agent of erosion in the Lower River Benue Basin, as streams carry volumes of sediment from the landscape of the arable lands to the Benue and Katsina Ala Rivers each season as part of their load. Slope angles have greatly reduced and valley cross-sections become wider downstream, resulting in expanse of open floodplains. In some upland locations, this has caused incised gullies. Table 23 and Plate IV shows the effect of erosion on riparian vegetation along the bank of River Benue at Gbagi Ocholi.

Human activities in the basin such as clearing of vegetation for cultivation, wanton bush burning, overgrazing, harvesting of sharp sand and burnt bricks works have greatly increased the erosion process.

Plate IV. Effect of Fluvial Erosion on Riparian Vegetation at Gbagi Ocholi

Table 23. Matrix of Farmers' Constraints in the LRBB

	Ratings					
Farmers' Constraints	**Very Severe**	**Severe**	**Little Problem**	**No Problem**	**No Response**	**Total (%)**
Drought	-	-	72	18	-	100
erosion	8	42	32	11	7	100
Soil infertility	-	13	47	22	18	100
Low yield	-	18	56	10	6	100
Pest infection	24	36	25	-	15	100
Food scarcity	-	-	87	9	4	100
Poverty	63	21	16	-	-	100
Health problems	32	45	13	3	7	100
Access to health care facility	54	22	26	-	-	100
Fertilizer availability	42	37	11	-	10	100
Fertilizer cost	66	24	5	5	-	100
Market outlet availability	13	25	12	50	-	100
Market outlet reliability	59	21	17	-	3	100
Access to credit facility	54	20	16	-	10	100
Access to farm machinery	44	39	12	-	5	100
Access to extension services	48	40	9	-	3	100
Labour availability	36	51	3	3	7	100
Access to land	27	32	11	30	-	100

4.12.2. Impacts of Floods on the Farming Systems in the LRBB

When it rains heavily in the Benue Basin, some of the water is retained by the soil, especially when the soil and vegetation cannot absorb all the water; which then runs off the land in quantities that cannot be carried in river channels. These river floods often result from heavy rain, which causes the major rivers in the area such as Benue, Katsina-Ala, Mu, Gwer, and Guma to overflow their banks.

Even though the alluvium deposited by these floods promotes agricultural activities, the level of flood destruction to crops, animals, buildings, bridges/roads and financial losses has remained alarming. Tables 24-26 therefore summarizes the outcome of field surveys into the positive, negative and coping strategies of floods in the basin.

Table 24. Positive impact of Floods in the Lower River Benue Basin

Positive attributes	**Strongly Agree**	**Agree**	**Strongly Disagree**	**Disagree**	**No Idea**	**Total (%)**
Improve fish catch	32	50	5	12	1	100
Improve fertility of the fadama land	47	22	19	10	2	100
Increase in the yield of fadama crops	35	32	17	16	4	100
Affects water level in nearby ponds	67	13	4	15	1	100

Table 25. Negative impacts of Floods in the LRBB

Negative attributes	Strongly Agree	Agree	Strongly Disagree	Disagree	No Idea	Total (%)
Inundated farmlands	87	10	-	3	-	100
Damage crops	63	20	-	15	2	100
Destroy buildings	16	78	-	6	-	100
Destroy livestock	25	30	11	20	14	100
Human death	-	7	74	13	6	100
Collapse bridges	2	18	65	15	-	100
Over flooded roads	4	10	49	30	7	100
Damage Recreational facilities	-	8	52	30	10	100
Damage Health facilities	-	-	47	33	20	100
Disturb School activities	-	5	64	31	-	100
Disturb Social functions	-	2	77	19	2	100
Disturb Festivals	-	2	20	68	10	100
Result in Human disease and pests	40	56	-	3	1	100
Result in Livestock disease and pest	-	38	-	10	52	100
Loss of man hours on farms	72	22	-	-	6	100

Table 26. Floods Coping Strategies

Floods Coping Strategies	**Strongly Agree**	**Agree**	**Strongly Disagree**	**Disagree**	**No Idea**	**Total (%)**
Adaptive farming practices	56	42	-	-	2	100
Taking to other occupations	25	21	40	14	-	100
Temporal relocation	18	14	33	35	-	100
Building flood control structures	10	51	19	10	10	100
Leaving all to fate	47	23	-	18	12	100
Insurance of crops, human lives and live stock	-	-	-	-	100	100
Permanent migration	-	-	49	46	5	100

4.12.3. Pests and Diseases

Although the high temperatures that prevail in the basin favour a variety of crops. The high humidity during rainy periods also favours the development of pathogens, particularly fungi as well as high incidence of pests and diseases. The destructive impact of these pests and diseases on crops and animals in the Benue Basin has been on ascendancy as shown in Table 25.

An effort by farmers to acquire or have access to pesticides and insecticides for the control of this menace has recorded marginal success. For this reason, Agroforestry and multiple cropping systems are being adopted by farmers to avoid colossal losses during harvest.

4.12.4 Weed Dynamics

Good growing conditions for crops virtually always implies good condition for weeds as well hence the weed try to re-establish itself after it has been cut or removed, thereby posing great menace to farmers in the Lower River Benue Basin.

It was observed in the basin that weed is a bigger problem with annual crops than with perennial ones and considerably constrains yield. The on the spot rapid rural appraisal has revealed that in recent times, some farmers are stepping-up effort to introduce herbicides in the management of weeds in their farm plots. These are chemical substances designed to terminate plants, especially weed, or to inhibit their growth. Consequently, there has been a proliferation of Agro-Chemical stores in the basin and they are enjoying heavy patronage from some farmers.

4.12.5 Industrial and Sewage Pollution

Human and domestic waste matter emanating especially from clustered settlements such as Makurdi, Buruku, Gbajimba and Katsina-Ala are great source of pollution into the major rivers and streams. Some industrial pollutants emitted from factories such as Benue Cement Company (Plate V), Benue Breweries Limited, Benue Bottling Company, The Nigerian Bottling Company PLC (Coca Cola), OLAMS Rice Mills usually found their way into the air, agricultural lands, rivers and streams. These exert negative impacts on the existing agricultural systems in the Lower River Benue Basin. Furthermore, the practice affects the quality of drinking water for livestock as well as water for irrigated horticultural activities.

Plate V. Pollution from Benue Cement Company at Yandev near Gboko

CHAPTER FIVE
THE SOCIO-DEMOGRAPHIC CHARACTERISTICS OF FARMERS IN THE LOWER RIVER BENUE BASIN

5.1 BACKGROUND TO THE QUESTIONNAIRE SURVEY

Field verification during this study showed that over 70% of the people in the basin live in rural areas, and almost all of them depend directly on their farm smallholdings for a living. Although many of the able people are migrating to the cities such as Makurdi and Gboko, apparently mainly because they hope for a better standard of living there, it is common knowledge that even in the cities a lot of people still strive to cultivate small plots to supplement some of their food demands. Thus, it is clear that farming is by far the largest economic enterprise in the Lower River Benue Basin (Plate VI), and it is vital for the well-being of the inhabitants.

Plate VI. Interview with a farmer at North-Bank, Makurdi

5.2 BASIC CHARACTERISTICS OF FARMERS

5.2.1 Age Structure of the Respondents

The age structure of the 250 respondents derived from the field survey using structured questionnaire interview and Rural Rapid Appraisal methods is presented in Table 27. It shows that out of the 250 total respondents which comprises of 218 males and 32 females, 29.2% fall within the range of 21 - 40 years age category, 56.8% into the 41 - 60 years age category and 14.0% into the 61 - 80 years category. It was observed during the field surveys that apart from the 14% which is made up mostly of the aged farmers, the rest constitute the more active and productive farming population in the Lower River Benue Basin.

5.2.2 Level of Education of the Respondents

The level of education and the extent of acknowledge and experience of the communities in the Lower River Benue Basin to a greater extent determines receptivity and extent of agricultural and other land use practices as well as the strength of economic motivation. Table 28 contains the various levels of education attained by the respondents in area.

Table 28 shows that 4.8% of the respondents are illiterate. They constitute a meager proportion of the peasant population but interestingly, they are known to have been devising ways of adapting to the changing farming systems as well as some modern agricultural innovations and other land use types. Majority of the respondents (73.2%) have attained secondary education while the remaining 12% have acquired primary, post - secondary and university education.

Table 27. Age Structure of Respondents

Age categories	Frequency	Percentage
21 - 40 years	73	29.2
41 - 60 years	142	56.8
61 - 80 years	35	14.0
Total	**250**	**100%**

Table 28. Level of Education of Farmers in the Lower River Benue Basin

S/N	**Education Level**	**No of Respondents**	**Percentage (%)**
1	Illiterate	12	4.8
2	Nomadic education	4	1.6
3	Quranic Education	2	0.8
4	Primary Education	16	6.4
5	Secondary Education	183	73.2
6	Post-secondary Education	28	11.2
7	University Education	5	2.0
	Total	**250**	**100%**

5.2.3 Household Size and Farm Labour Supply

The average size of the respondents' households is about 12 persons per household comprising of the household head, wife or wives, children and other relations or dependants as illustrated in Table 29. The table also shows the marital status of the 218 male respondents in the Lower Benue River Floodplain while the difference of 32 constitutes the female respondents that are also farming in the Lower River Benue Basin.

Table 29 indicates that about 77.1% male respondents have a wife each, 17.4% have between 2 - 4 wives and then 5.5% are without a wife due largely to some reasons such as divorce, the death of a wife or are yet to marry. Considering the report of the field survey, farm labour supply in the Lower Benue River Floodplain is largely provided by members of the household, that is, the head of the household, wife or wives, children and other dependants. The men engage themselves mainly in farming during the ploughing and planting period, while the women work more during harvesting period.

Farm labour is also supplied through what is called farm labour organization systems. Furthermore, farm labour is hired at times by some well-to-do farmers especially when there are clashes in labour requirements in the cultivation of food crops and cash crops during the same farming season. In order to complement human efforts, tractors and other machinery are used occasionally in farming operations by some farmers to facilitate timely cultivation and harvesting of crops. A summary of household size (averagely 12 persons per household) and labour supply indicates that an average of 8 household members is found to engage in farming activities.

Table 29. Marital Status of the Male Respondents

No of Wives	No of Respondents	Percentage (%)
0	12	5.5
1	168	77.1
2	25	11.5
3	10	4.6
4	3	1.3
Total	**218**	**100%**

5.2.4 Infrastructural and other Facilities in the Lower River Benue Basin

Farm household systems and their immediate external rural environment, including local effects of policies and institutions, markets and information linkages, are interdependent and over time co-evolve in response to changes in population, markets, technologies, policies, institutions and information flows. The infrastructural and other facilities that are found in the Lower River Benue Basin are describe below.

A. Major settlements

There are several other major settlements within the basin besides Makurdi such as Gboko, Katsina-Ala, Wannune, Gbajimba, Aliade, Daudu, Igbor, Abinsi and Naka. Makurdi town which is a part of the area of study happens to be the capital of Benue State and also a Local Government Council.

B. Road network

The towns are well connected by bridges and linked with surfaced access road networks, the major ones being the Makurdi - Wannune - Gboko road, Makurdi- Naka road, Makurdi - Igbor - Aliade road, Makurdi - Daudu - Gbajimba road and several feeder roads linking other minor settlements in the area.

C. Drainage Facilities and hydro electricity supply

The drainage facilities in the Lower River Benue Basin is made up of major and minor bridges, culverts, earth dams/pond/lakes, boreholes, rivers and streams. Table 30 indicates that bridges constitute 9.76% whereas culverts account for 71.54% of the total drainage facilities in the area.

Hydro electricity which is drawn from the National Grid is supplied by the Power Holding Company of Nigeria (formerly NEPA) to most of the major towns and some rural settlements of the area.

D. <u>Health Facilities</u>

Table 31 shows that there are a number of major and minor health facilities in the area ranging from chemists (60.05%) to teaching hospital (Benue State University Teaching Hospital Makurdi). The table also shows that the traditional and spiritual healers constitute 8.93% of the total health facilities in the basin. It was further gathered that very serious cases from small settlements are usually referred to bigger hospitals in Makurdi, Katsina-Ala, Lafia and Gboko.

Table 30. Drainage Facilities

S/N	Drainage Facilities	Frequency of Occurrence	Percentage
1	Major Bridges	39	2.12
2	Minor Bridges	141	7.64
3	Culverts	1320	71.54
4	Earth Dams, Ponds, Lakes	6	0.33
5	Waterfalls	4	0.22
6	Rivers	8	0.43
7	Streams	145	7.86
8	Boreholes	182	9.86
	Total	**1845**	**100**

Table 31. Health Facilities

S/N	Health Facilities	Frequency of Occurrence	Percentage (%)
1	Chemists	215	60.05
2	Dispensaries	32	8.95
3	Clinics	67	18.72
4	Hospitals	12	3.35
5	Traditional Healers	24	6.70
6	Spiritual Healers	8	2.23
	Total	**358**	**100**

E. Educational institutions

The educational institutions present in the area include:

Universities: Federal University of Agriculture Makurdi, Benue State University Makurdi, and University of Mkar near Gboko, consisting of 0.32% of all educational institutions in the area.

Tertiary Colleges: Table 32 shows that the tertiary institutions constitutes 12.68% of all educational institutions in the area: They include; Colleges of Education Katsina-Ala and Oju, College of Agriculture Yandev, Fidel Polytechnic Gboko, Benue Polytechnic Ugbokolo, Schools of Nursing Mkar and Makurdi, Staff Development Centre Makurdi, College of Arts and Professional Studies Makurdi, St. Thomas Aquinas Major Seminary Makurdi.

Primary and Post Primary Schools: There are a host of government and privately owned primary schools as well as post primary educational institutions such as secondary schools and technical colleges. Among these are Federal Government Colleges Vandeikya and Gboko, Government Technical College Makurdi and Minor Catholic Seminary Yandev.

Table 32. Educational Institutions

S/N	Educational Institutions	Frequency of Occurrence	Percentage %	Rank
1	Pre-Primary Schools	158	17.12	2
2	Primary Schools	645	69.88	1
3	Post-Primary Schools/Colleges	102	11.05	3
4	Other Tertiary Institutions	15	1.63	4
5	Universities	3	0.32	5
	Total	**923**	**100**	

F. **<u>Storage and market facilities</u>**

Large grain storage facilities (Silos) are built in Makurdi, Gboko and Katsina-Ala for the preservation of excess grains of cereal and leguminous crops which are kept (stored) by the government/farmers with the hope of disposing of them in times of favourable prices or acute demands. There are also a number of warehouses for the safe keeping and distribution of fertilizer and other farm inputs supplied by BNARDA.

There are different kinds of market facilities in the Lower River Benue Basin. These markets as contained in Table 33 includes: periodic markets that operates once weekly or every after five days such as Ihugh, Korinya, Wannune, Buruku, Igbor, Aliade, Gbajimba, Tyowanye, and Tsekucha which accounted for 94.15%; Daily Markets such as Makurdi Modern Market, Wurukum Market and Gboko Market (4.68%); and special seasonal markets such as Gboko Tomato and Vegetable Market and Zaki Biam Yam Market which have constituted 1.17% .

Table 33. Market Facilities

S/N	Market Facilities	Frequency of Occurrence	Percentage
1	Periodic Markets (once weekly, every after 5 days)	322	94.15
2	Daily Markets	16	4.68
3	Special Seasonal Markets	4	1.17
	Total	**342**	**100**

G. Potable water supply

Most of the major towns in the area have traces of potable water supply. Although rural settlements source their water from bore-holes, tube wells, rivers/streams, surrounding ponds and ditches created during road constructions.

H. Companies and industries

Furthermore, there are some major production companies and industries which are situated within the Lower River Benue Basin. Notable among them include; Benue Cement Company Gboko, Benue Breweries Limited Makurdi, Taraku Oil and Feed Mills Taraku, Nigerian Bottling Company (Coca Cola) Makurdi, Benue Bottling Company Makurdi, OLAMS Rice Mills Makurdi and a host of others.

I. Other infrastructures and amenities

The distribution of other infrastructural facilities and amenities such as social centers, worship centers, major government offices, is contained in Tables 34-37 below.

Table 34. Social Centers

S/N	Social Centers	Frequency of Occurrence	Percentage
1	Viewing Centers	75	44.91
2	Town/Community Halls	28	16.77
3	Cultural dance groups	64	38.32
	Total	**167**	**100**

Table 35. Worship Centers

S/N	Worship Centers	Frequency of Occurrence	Percentage (%)
1	Churches	582	85.34
2	Mosques	14	2.05
3	Shrines	86	12.61
	Total	**682**	**100**

Table 36. Major Government Offices

S/N	Government Offices	Frequency of Occurrence	Percentage
1	LGA Headquarters	8	19.05
2	State Capital	1	2.38
3	Post Offices	10	23.81
4	Courts	23	54.76
	Total	**42**	**100**

Table 37. Other Amenities

S/N	Other Amenities	Frequency of Occurrence	Percentage
1	Telephone facilities	8	7.15
2	Radio and Television Stations	4	3.57
3	Financial Institutions	57	50.89
4	Settlements with Electricity	43	38.39
	Total	**112**	**100**

5.2.5 Sources of Fund for Production and Acquisition of Farm Inputs

The farmers in the area have indicated numerous ways by which they get funds for the procurement of essential agricultural inputs as well as for carrying out other farming operations. Some of the ways illustrated in Table 38 include the following:

(i) Sale of cash crops, livestock and excess farm produce at high demand markets such as Makurdi, Gboko, Wannune, Aliade, Daudu and Gbajimba markets. Some of these markets operate on daily basis whereas others operate on periodic basis such as once a week or having a circle of every five days. About 8 out of 10 farmers adopt this method. Indeed, it is the most used source in the area.

(ii) Loans from Micro finance Banks, agricultural development banks and from existing Farmers Co-operative Societies and local thrifts which operates on short time basis, all account for 50.8% of the respondents.

(iii) Some farmers get aid or assistance from their in-laws as a way of cementing some family ties. The table indicate that 47.2% rely heavily on this source.

(iv) Profit accrued from marketing activities by traders that are part-time farmers constitute 6.4%.

(v) Pensions by retired workers who have at present indulge in farming activities. The proportion of farmers who get funds through pension and profit made from trading is relatively very small that is 5.2%.

(vi) Salaries or wages earned by some serving public and private workers who also engage partly in farming accounted for 44.8% of the respondents.

Table 38. Farmer's Sources of Fund

Sources of Fund	Total Responses per Source	Difference	Percentage of Responses
Sale of excess farm produce	210	40	84.0
Loans (Banks, Cooperative, Friends)	127	123	50.8
Profit from Trading	16	234	6.4
Salaries or Wages	112	138	44.8
Pension	13	237	5.2
Aid from in - laws	118	132	47.2

5.2.6 Agricultural Land Tenure Systems in the Lower River Benue Basin

It is observed that one man (usually the village ruler or family head) exercises the authority to grant land to, or withdraw it from members of the community. It was also gathered that in some other locations, such authority is vested collectively in a group of male elders in the community whose word and action in land matters are generally final. The study also discovered that the communal ownership of land in the basin is fast declining in importance and that the individual ownership is becoming very much on the ascendancy. Much of the erstwhile communally held land is being allocated to individuals or sold to them for private use. This is because the populace is becoming more aware of the immense value of land.

In specific terms, the commonest modes of land transfer in Lower Benue River Basin area and elsewhere include are inheritance (48.4%), borrowing (13.6%), purchasing (18.4%), gift (7.2%) and leasehold (12.4%). Compulsory acquisition by government through its power of eminent domain is also mentioned. The land acquisition modes are presented in Table 39.

Table 39. Sources of Farm Holdings

S/N	**Sources**	**Responses**	**Percentage (%)**
1	Inheritance	121	48.4
2	Borrowing	34	13.6
3	Purchasing	46	18.4
4	Gift	18	7.2
5	Lease hold	31	12.4
	Total	**250**	**100%**

5.2.7 Duration of Farmland Occupancy

It was gathered that the duration of farmers' occupancy on the farm plots varied. It is found that individual farmers have worked on their farm plots between 5 and 32 years. The duration of occupancy is largely dependent upon the prevailing tenurial systems.

5.2.8 Sizes of Farm Holdings

The investigation of farm sizes revealed that about 32% of the respondents cultivated between 4 and 10 hectares of land whereas the majority of the farmers (68%) have farm holdings of less than 4 hectares. A few farmers in the area have shown interest in agricultural mechanization but the practice is yet to be significant. It was gathered that some farmers with formal education have demonstrated their willingness to expand their farming scope provided there is improvement in economic and tenurial conditions as well as the intensification of farm inputs supply, aid from the government and other agro-allied agencies such as BNARDA, BENTHA and others.

5.2.9 Farm Implements (Tools) and Farmland Preparation

Farm tools such as hoe (big and small), cutlass, axe, knife, sickle, tractor and digging mattock (Plates VII and VIII) are used by almost all the peasant farmers in their farming operations. Nevertheless, a meager proportion of well-to-do farmers with farm sizes more than 4 hectares sometimes hire tractors from the Benue State Tractor Hiring Agency (BENTHA) or from their colleagues that have possessed two or more tractors. The farmers also obtain other farming machineries (sprayers, planters and harvesters) as well as agro - chemicals from BNARDA. Farmland preparation and cultivation is proportionately carried out using several methods including burning or by using hand tools, tractors and animal traction.

Plate VII. Native Blacksmiths producing Traditional Farm Tools

Plate VIII. Modern Farm Vehicle (Tractor) used in the Lower River Benue Basin

5.3 SOURCES OF CONFLICT BETWEEN FARMERS AND THE NOMADS

It was gathered from the respondents that the relationship between the farmers, the fishermen, traders, the civil servants and the nomads in the area is generally cordial despite clashes among the groups on rare occasions.

The sources of grievances, misunderstandings and conflicts between farmers and the nomads, among farmers and between other individuals and groups (Table 40) are usually resolved amicably through various channels as presented in Table 41. Some of the peasant farmers interviewed maintained that trampling on the soil (28%) as well as cattle trespassing and crop damage (18.2%) are the frequent source of misunderstanding between the them and the nomads. An interaction with the nomads revealed that lack of grazing fields (36%), difficulty of acquiring grazing land (24%) as well as inflated fines by courts and the local Chiefs for crop damage brings disagreement between them and the farmers.

Table 41 shows that the inhabitants of the Lower Benue River Basin largely resolve their disputes and grievances mutually (98.0%) and in rare instances, channel them mostly through the chiefs (96%), the elders (89.2%) and the village council (78.8%). There are also some few instances when the respondents have taken their disputes straight to the police and courts accounting for 23.2% and 12.8% respectively. It was observed that, in order to avoid conflict with the pastoral nomads, farmers in the area have fenced most of their farm plots so that the livestock of the nomads will not graze on their crops.

Table 40. Sources of Conflicts between Farmers and Nomads in the LRBB

Pastoralists			Farmers		
Sources of Conflict	**Respondents**	**%**	**Sources of Conflict**	**Respondents**	**%**
Blockage of cattle tract by the farmers	2	8.0	Cattle trespassing and crop damage	41	18.2
Lack of grazing fields	9	36.0	Settlement in forbidden areas	38	16.9
Difficulty in acquiring farmland	6	24.0	Selling of dead animals	57	25.3
Burning of bush and farmland by the farmers	3	12.0	Trampling on soil by cattle	63	28.0
Inflated fines by court and local chiefs for crop damage	5	20.0	Attack on farm settlements	26	11.6
Total	**25**	**100**		**225**	**100**

Table 41. Channels of Conflict Resolution in the LRBB

Channels	Response per 250 Respondents	Difference	Percentage Response
The Elders	223	27	89.2
The Chief	241	9	96.4
The village council	197	53	78.8
The police	58	192	23.2
The courts	32	218	12.8
The Religions leaders	175	75	70.0
Mutual	245	5	98.0

5.4 TRANSPORTATION OF FARM PRODUCE ACROSS THE MAJOR RIVERS

The prevailing mode of transporting both people and goods from one place to the other in the study area depends largely on the factor of accessibility. Thus, most of the places that are highly accessible and well connected with good roads have motor vehicles, motor bikes and bicycles as stable means of transportation. On the other hand, those places that are too remote and linked by footpaths and feeder roads rely greatly on the use of motorbikes and bicycles as means of conveying people and goods to desired destinations.

For very short distances within the towns and villages, wheelbarrows and trucks are used to carry goods. Furthermore, the people that have settled right on the flood plain of the river system such as Makurdi, Katsina-Ala, Gbajimba, Buruku and Gbagi Ocholi usually use speedboats, canoes and barges to convey people and farm produce to the other banks of the rivers as well as travel to other settlements along the river banks (Plate IX). Alternatively, other people indulge in the use of very big calabashes to aid them swim across the river channels.

Plate IX. Transportation of People, Farm Produce and Vehicles across River Katsina-Ala by Barges at Buruku

5.5 OFF-FARM ACTIVITIES IN THE LOWER RIVER BENUE BASIN

It was gathered that most of the farmers who do not engage in dry season farming usually spend their break time in carrying out alternative activities complementary to their farming operations. Such off-farm activities include the following:

(a) Burnt brick industry: It was observed during field verification and surveys that burnt brick industry has remained on ascendancy in the basin but precisely along the courses of the major such as Rivers Benue, Katsina-Ala, Mu, Gwer, Guma and other major streams. The high cost of cement blocks generally in the country have compelled most people to resort to alternative block making options. The adverse effect of this activity is the fast degradation of the banks of the rivers in the basin, and thus limits the extent of irrigation agriculture along the banks.

(b) Trading and Crafts: Some of the inhabitants of the area indulge in trading of the agro-allied products and packaged processed articles at big markets which are situated within the basin. Other people engaged in activities such as tailoring, photographing, blacksmithing, auto mechanics, vulcanizing, commercial driving, artisan activities including the production of mats, farm implements, baskets and a host of many others.

(**c**) **Salary and Wages Jobs:** For the fact that Makurdi the Benue State capital together with other major towns such as Gboko, Otukpo, Aliade, Katsina-Ala, Wannune and Adikpo are situated in the study area, good number of inhabitants engages in public and private sector paid jobs. These jobs include teaching, civil service at the state and local government levels.

(d) Sand Harvesting: During the dry season, some idle farmers spent bulk of their time in harvesting the sand which has been deposited along the channels of Rivers Benue, Katsina-Ala, Mu, Gwer and Guma. The sand is used for various construction purposes such as blocks making, buildings, road construction, bridges, culverts, and pottery.

CHAPTER SIX
THE AGRICULTURAL SYSTEMS AND PRACTICES IN THE LOWER RIVER BENUE BASIN

6.1 TYPES OF AGRICULTURAL SYSTEMS

The types of farming systems which are operational in the Lower River Benue Basin as identified in the study are contained in Figure 32 and Table 42 below and they include the following:

a) Irrigated Farming System (IFS)

b) Plantation or Tree Crop Farming System (PFS)

c) Lowland Rice-based Farming System (LRFS)

d) Upland Cereal and Tuber Based Farming System (UCTFS)

e) Agro-Forestry based Farming System (AFFS)

f) Fishing Farming System (FFS)

g) Livestock and Mixed Farming System (LMFS)

The peasant farmers in the Lower River Benue Plains have been growing a range of crops which include millet, maize, sorghum, cassava, groundnut, sugar-cane, cowpeas, cotton, potatoes, onions, pepper, tomatoes and beans. Others are tree crops such as mango, guava, orange, pineapple, cashew and banana, which are usually planted as orchards or found in compounds among the various settlements in the area and in some few cases along the courses of major rivers and streams.

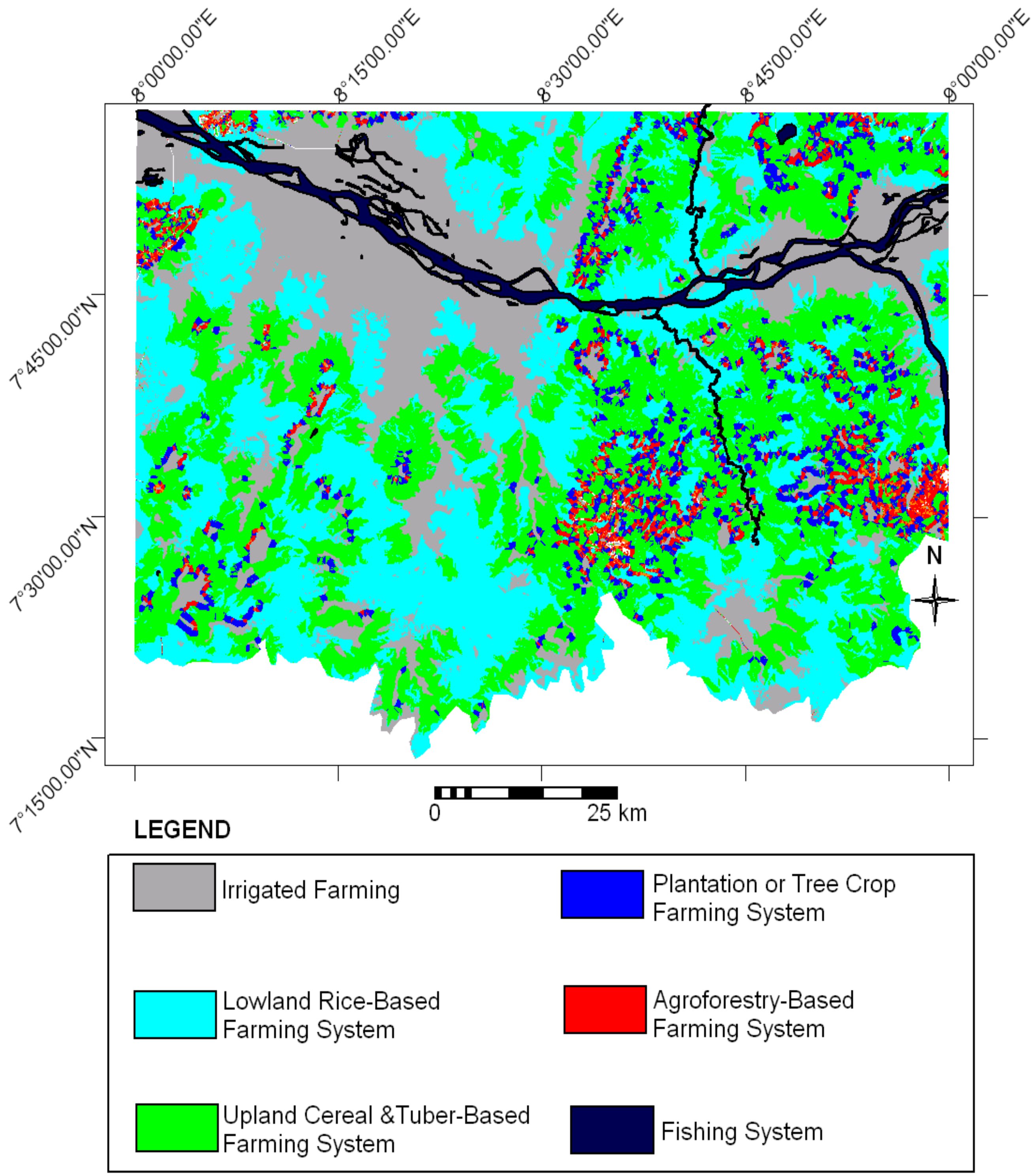


Figure 32. Agricultural Systems in the Lower River Benue Basin

Table 42. Characteristics of the Agricultural Systems in the Lower River Benue Basin

S/N	Agricultural Systems	Physical Parameters							
		Area Coverage (%)	Physiographic Unit	Morphometric Parameters	Slope (%)	Soil Depth (cm)	Soil Drainage Condition	Evidence of Erosion	Level of Farmland Management
1	Irrigated Farming System (IFS)	23.26	Alluvial Plains/ Valley Fills	Flat relief (1-80m), low runoff, broad channels, high alluvial deposit	Nearly level to very gentle sloping (1-3%)	Very Deep (>100 cm)	Poorly to imperfectly drained	Area of negligible erosion to slight sheet	Least to low management level
2	Lowland Rice-based Farming System (LRFS)	30.11	Alluvial Plains/ Valley Fills	Flat relief, low runoff, broad channels, high alluvial deposits	Nearly level to Very Gentle sloping (1-3%)	Very Deep (>100)	Imperfectly to poorly drained	Slight sheet to none erosion	Low Management Level
3	Upland Cereal and Tuber Based Farming System (UCTFS)	34.0	Buried Pediment/ Valley fills	Gentle relief (81-160m) Medium runoff, moderate stream density	Gentle to Moderately sloping (3-10%)	Deep to very deep (80-100 cm)	Well to poorly drained	Moderate rill to slight erosion	Moderate Management Level
4	Plantation or Tree Crop Farming System (PFS)	5.42	Buried Pediment	Gentle relief Medium runoff, moderate stream density	Moderately to strongly sloping (5-15%)	Deep (50-80 cm)	Well drained	Moderate rills	Moderate Management Level
5	Agro-Forestry based Farming System (AFFS)	3.15	Pediment	Hilly undulating relief, (16-240m) Medium runoff, wide gullies, high stream density	Moderately Steep to steep sloping (5-15%)	Very Shallow (<20cm)	Very Well drained	Severe small gullies	High Management Level
6	Fishing system (FFS)	4.06	River Channels and Ponds	Flat relief, low runoff, broad channels, high alluvial deposit	Nearly Level (<1%)	Very Deep (>100 cm)	Poorly drained	Area of negligible erosion	Least Management Level
	Total	100%							

6.2 IRRIGATED FARMING SYSTEM

The irrigated farming system comprises small and large-scale irrigation schemes, extensive riverine and flood recession-based irrigation. It was observed that in the Lower River Benue Basin, the Irrigated Farming System is operational in many locations (Figure 33), supplemented by rainfed cropping. About 23.26% of the surface area is engaged in ths system.

Crop failure is generally not a problem in this system because of the perennial nature of the River Benue flow. During field surveys, it was gathered that most of the large scale irrigation schemes in the basin situated at Makurdi, Katsina-Ala, Jato-Aka, Buruku and Gbagi Ocholi which are supported by the Lower Benue River Basin Development Authority, are currently in crisis, due to lack of instrumentation and poor management.

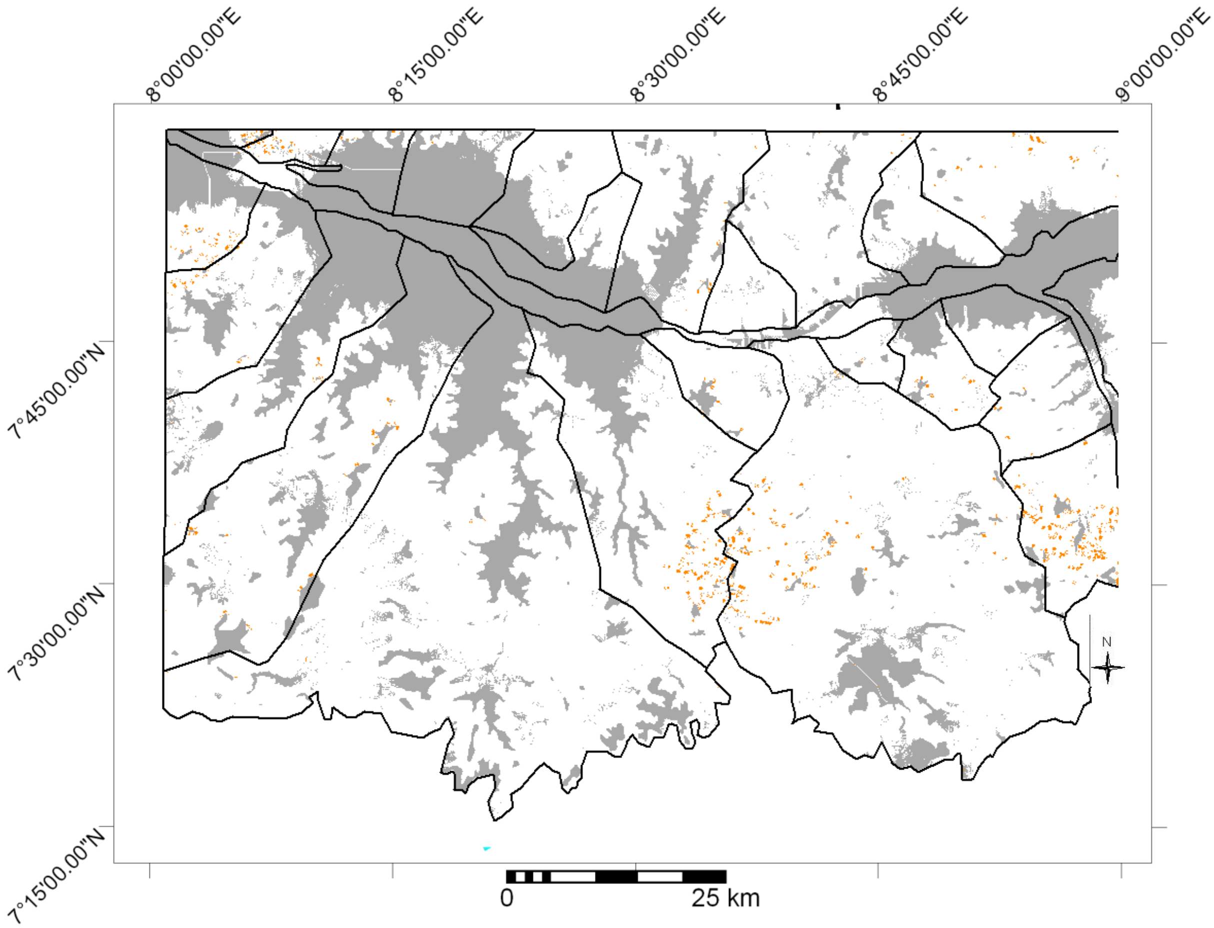


Figure 33. Areas where Irrigated Farming System is practiced

6.2.1 **Physical Characteristics of Irrigated Farming System**

This system of farming is found near Rivers Benue, Katsina-Ala, Mu, Gwer and Guma, other rivers, streams and various confluences in the basin as well as in large flat wetland areas. The physiographic unit of the area is expanse of alluvial plains and valley fills which are characterized by nearly level to very gentle slope (1-3%), flat relief, low runoff, high alluvial deposit and negligible erosion. They are also poorly to imperfectly drained.

Deep alluvial soils are characteristics of this farming system and are invariably of better inherent fertility than those of the upland cereal and tuber crop farms. Although to enhance double or continuous cropping regime, chemical fertilizers, animal manure, household and crop wastes and plant ashes are proportionally used. There is a micro-climatic effect experienced around the areas surrounding the banks of the major rivers. The cool breeze that is experienced at the river banks differentiates the climate of the immediate environment with that of other places within the area of study.

Some common irrigation methods in the area include run-of-the river type and open dug and tube wells. The water yield of such wells can be just enough to irrigate few hectares. In most cases pumping machines are used by farmers for water lifting either straight from the River Benue and other rivers/streams, from local canals and wells to various farm plots. Generally, standards of water management in the basin vary considerably among farmers especially in very small schemes where farmers use pumping machines in lifting the water. Sometimes more than half of the harvested water for irrigation is wasted as there is no water recycling mechanisms.

Vegetables, maize, pepper and a host of many other crops are grown in the basin (Plate X and XI) hence there is no total reliance on a particular crop but a mixture of several others. Smallholder farmers specializing in vegetable, maize as well as sugar cane production is particularly prominent. It was further gathered that, crop rotation and cultivation of subsistence and cash crop are common in this system.

This farming system experiences a number of problems including water shortages during the dry season, pumping machine breakdown and deteriorating input/output price ratios. Weed control is continuous because the favourable moisture conditions enable constant weed seed germination and plant growth hence irrigation water also carries with it weed seeds which continuously infest the farm.

Most farming operations under the irrigated system are performed manually with locally made implements such as hoes, cutlass, mattock and sickle, although little mechanization is found among some well-to-do farmers working on government sponsored schemes. Really, the use of modern implements is not only expensive, it has high energy requirements but also requires sizable farm holdings.

Plate X. Irrigated Pumpkins at the Bank of River Benue at North Bank, Makurdi

Plate XI. Irrigated Mixed Cropping of Okra, Maize and Sugarcane at North Bank, Makurdi

6.2.2 Socio-Economic Characteristics of Irrigated Farming System

Farm size of individual farmers under the irrigated farming system in the Lower River Benue Basin is invariably small (0.5-2.0 hectares). Land is mostly owned by landlords with few cases of inheritance. Table 42 shows that this system occupies about 23.26% of the cultivated area under study. Irrigated holdings vary in sizes because a few farmers produce on subsistence level while a many others on commercial basis.

The degree of commercialization in the Lower River Benue Basin is quite high because irrigated farms are normally accessible and generally found in favourable areas. At Benco near Abinsi, smallholder farmers specializing in vegetable and maize production are particularly commercialized. This system has some things in common with the lowland rice-based farming system except that the latter relied heavily on one crop which is rice.

In the basin, there is great variation in labour input depending on household size and economic position of the farmers. It was also observed in the field that 65% of respondents in this farming system lift irrigation water into their various farmlands by pumping machines while 35% lift theirs by hand which is very labour intensive. Because of multiple cropping, and the presence of crops throughout the year, there is constant need for labour which is sourced from households or hired.

Mixed cropping which involved the planting of quick growing and quick maturing crops between slow growing and slow maturing crops on the same farmland is commonly practiced under the irrigated farming system. Maize for instance, is inter-cropped with upland rice and okra, in which case both maize and okra are harvested before rice. Some cropping combinations that are also operational include sugarcane with tomatoes (Plate XII), pepper with tobacco, tobacco with pumpkins, sugarcane with oil-palm, sugarcane with cassava, and sugarcane with banana.

Plate XII. Sugarcane intercropped with Tomatoes and Plantain at Buruku

6.3 LOWLAND RICE-BASED FARMING SYSTEM (LRFS)

Rice was observed to be one of the most dominant crops cultivated by farmers in the area largely due to the expanse of the floodplain along Rivers Benue and Katsina-Ala as well as favourable moisture conditions (Figure 34). The Lower River Benue Basin supports extensive rice production as human food both for subsistence and commercial basis.

Table 42 shows that lowland rice-based farming system accounts for about 30.11% of the total area under study. Plate XII depicts that rice is well cultivated at the lowlands of Makurdi, Adi-Etulo and Gbagi Ocholi. Rice-based production systems provide not only food, but also the main source of income and employment opportunities for about a million peasant farmers in the basin.

There are several groups of key constraints that were identified in the basin as contributing to the rice yield gap, ranging from the biophysical to the institutional. These are indicated below;

i. Biophysical (weather, soil, water, pest pressure, weeds).

ii. Technical/management (labour availability, timing of operations, tillage, variety or seed selection, nutrients, weeds, pests, and post-harvest management).

iii. Socio-economic (social and economic status, farmers' cultural traditions, commitments and obligations, knowledge, family size and farm profitability).

iv. Institutional and Policy (government policy, rice price, credit facilities, input supply, land tenure system, markets, Research, Development and Extension - RD&E).

v. Technology learning and linkages (competence and resources of extension staff, RD&E integration, limited use of Farmer Field Schools, knowledge and skills, linkages among public, private and NGO extension programmes).

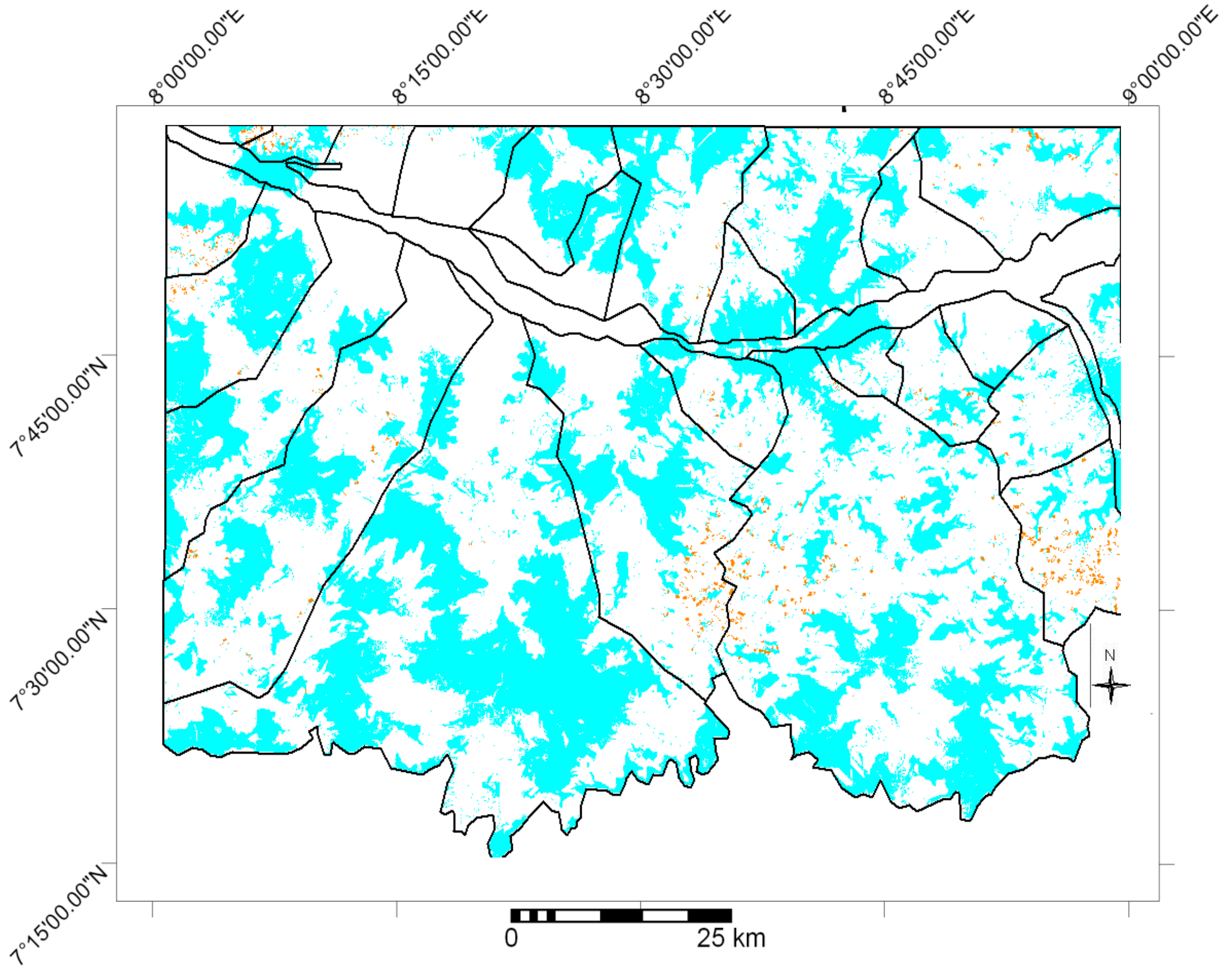


Figure 34. Areas where Lowland Rice-Based Farming System is Practiced

6.3.1 <u>Physical and Agro-Technical Aspects of the LRFS</u>

Lowland rice, which is the most commonly grown type in the Lower River Benue Basin, is cultivated on the moist alluvial soil and almost all cultivation is performed by hand. Rice is grown in many different parts of the landscape (pediment, buried pediment, valley fills and alluvial plains) and each segment has slight different physiologic and hydrologic characteristics as contained on Table 42.

It was gathered during field investigation that, the higher fields at the pediment segment have water constraint because rainfall is the only source of water and it is largely lost to runoff and percolation whereas the much lower fields (alluvial plains) receive, in addition to the same amount of rainwater, runoff and lateral percolating water from the higher fields. Consequently, there are fewer water constraints in the lower fields and as such double or triple cropping pattern has been sustained. Lowland rice that is grown in a flooded field, or paddy, is kept under water during most of the growing season and it is drained only at harvest time. A few varieties, known as upland rice, do not necessarily require excess moisture or flooding.

Water management for the lowland rice farming system is greatly influenced by the amount of rainfall, soil depth and the flat terrain. In the Lower River Benue Basin the farmers develop puddle which can reduce runoff and enhance rainfall storage. The structure of the soil becomes compact thus it reduces infiltration and deep percolation.

In order to effectively manage the rice crop the peasant farmers in the Lower River Benue Basin have developed rice planting, harvesting, storing and marketing techniques which conform with the local situations. For example one option to establish a seedbed and transplant as soon as enough water has accumulated at the beginning of the rains, whereas others broadcast the seedlings in the rainy season after proper land preparation. The farmers lamented that rice transplanting mechanism is a highly labour intensive task for which the family labour supply always remain inadequate.

There is generally multiple rice cropping in the basin, although some parts of the basin have single but shorter season. Production of rice is concentrated in the lower terrace of the major and minor rivers where the slope is flat or nearly level and soil depth is high. These areas are surrounded by upland areas where the production of rainfed cereal and tuber crops dominates.

An interaction with farmers in the field revealed that in favourable conditions, rice needs only about three months between sowing and harvesting, and three or even four crops can be harvested annually depending on the amount of moisture. Timing is of utmost importance and because of that harvesting and planting is designed by farmers to coincide with water availability, favourable weather and labour availability.

There are several varieties of rice which are planted in the area, all belonging to the family Poaceae (Gramineae). Short-grain rice, which is 4 mm long; medium-grain rice, which is 6 mm long; and long-grain rice, which is over 8 mm long are all cultivated by different farmers in the study area (Plate XIII). To a larger extent, most of the farmers grow transplanted rice shoots in the flooded paddies rather that the broadcast method.

The prevalence of pest in the basin hardly takes the epidemic proportion. The prevailing varieties of rice, that is the short, medium or long grains have developed different pest and disease resistance. Some modern High Yielding Variety (HYV) cultivated in the area need rather sophisticated pest and disease control such as insecticides and pesticides which is often beyond the economic reach of the average farmers. In order to effectively manage this menace in the basin the farmers do plant non-rice crops so as to break the pest cycles and secondly they acquire new varieties which have differential pest and disease tolerance and resistance levels. There is no problem with rice harvesting and post harvest operations as majority of the farmers (56%) practice the mono-cropping system. Farmers that practice multiple cropping systems there is frequently a time constraint for harvest and post-harvest operations such as drying, bagging and transport.

The existing rice varieties provide low but stable yields considering the ecological changes of the Rivers Benue, Katsina-Ala and Mu. With the introduction of some modern HYV the farmers have been experiencing spectacular increases in rice crop yields which can help address the issues of poverty reduction and food security. Good understanding of the drainage regime and other terrain characteristics will remain the surest way to guarantee sustainable rice production in the area.

Plate XIII. Rice Cultivation in the Lower River Benue Basin at North-Bank, Makurdi

6.3.2. Socio-Economic Aspects of the Lowland Rice-Based Farming System

Several forms of land ownership and tenancy that are found in the basin influence the lowland rice-based farming system. Prominent among them are inheritance (48.4%), purchase (18.4%), leasehold (12.4%) and borrowing (13.6%). Ownership patterns have had different effects on the character of production and productivity of rice. It is evident in the basin that the factor of small farm sizes ranging from 4 to 10 hectares and land ownership has made some farmers and tenants to keep lagging behind in adopting new farm technology and mechanization.

In lowland rice-based farming system, labour is needed during land preparation, transplanting, harvesting and post-harvesting activities. The household comprising of the head, wife or wives, children and dependants, is the main unit of production; it contributes 75% of labour requirements, although some external labour is used during seasons of peak labour requirements, thus invariably creating labour peaks and constraints. Recent introduction of new HYV by a few farmers are making labour less demanding. Women in the area play a significant role in all the facets of lowland rice-based farming particularly during transplanting and hand weeding.

Operating a rice-based farming system in the basin has formed a way of life rather than an economic activity until recently. The carrying-capacity of the land, farm size, total land area and environmental deterioration in the basin do not make for high income and wages of the peasant farmers. Subsistence rice production is predominant as bulk of the harvested output is eaten within the household and by hired laborers. Because of this, production and population trends have been parallel. Most rice farmers produce sufficient for subsistence and a small surplus for sale.

Because rice is easily stored and transported, access to markets is not usually a major problem as the people and goods are transported across the major rivers using canoe, speed boats and barges. In terms of inputs the farmers are increasingly becoming more dependent on external inputs such as chemical fertilizer like NPK and Urea, improved seedlings of rice that are quick maturing, credit facilities from farmers' cooperatives societies and modern farm implements including herbicides and pesticides sprayers.

6.4 UPLAND CEREAL AND TUBER BASED FARMING SYSTEM (UCTFS)

This system of farming, developed in the guinea savanna zone where land, is largely under permanent cultivation with little integration between crop activities and livestock. Production of cereal and tuber crops for self-sufficiency forms the backbone of this system. Figure 35 illustrates the upland areas used for cereal and tuber crop production. However, farmers in the study area face problems of ever-decreasing soil fertility, unreliable rainfall, environmental deterioration, inefficient markets and high prices of agricultural inputs. The farming system is intensive and on small-scale level and farmers here rarely have the objective of maximizing production of any particular crop.

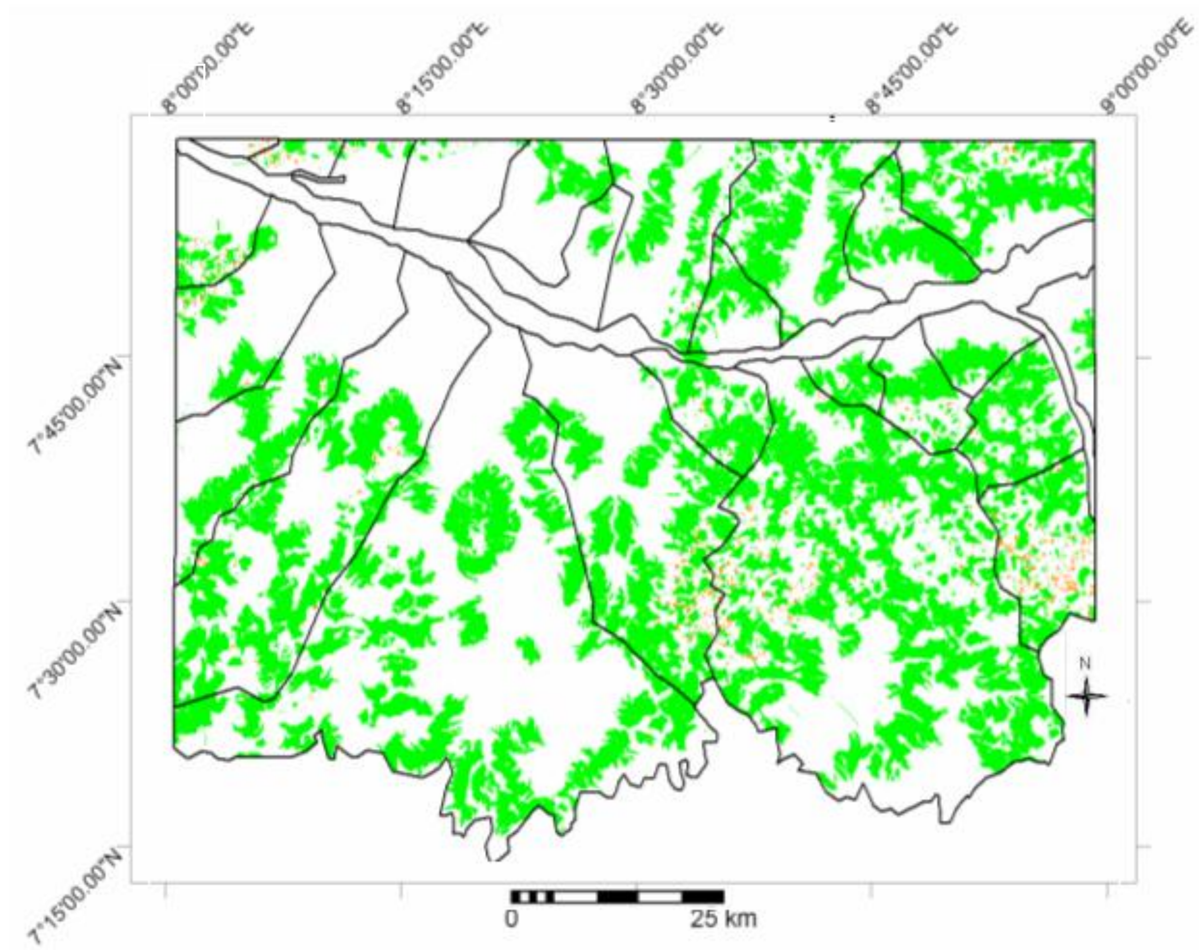


Figure 35. Areas where Upland Cereal and Tuber Based Farming System is practiced

6.4.1 **Physical and Agro-Technical Characteristics of UCTFS**

The physical characteristics of the land use for this system of farming have been illustrated in Table 42. The cereal-tuber system in the Lower River Benue Basin is under tremendous environmental pressure. Thus it requires land management practices including high fertilizer or manure application to improve the crop yield. Upland soils deteriorate rapidly under continuous cultivation and with little fertility maintenance especially under the present population pressure. In the basin, there is close correlation between crop yield and the length of moisture season as well as total rainfall. In terms of fallow and rotation system, about 23% of the farmers in the basin achieve a more stable system by subjecting their farmlands to one or two years fallow. Table 43 on the agricultural practices in the basin, show that 74% of farmers practice a type of crop rotation whereas 82.4% practice mono-cropping in some locations, to maintain soil fertility.

There are good existing methods of soil fertility maintenance in the cereal-tuber farming system as manuring includes the use of animal excrement, green manure, mulching and chemical fertilizer. Crop husbandry and agronomic management is evident in the Lower River Benue Basin, though farming activities in the area are mainly manual while animal draught power is marginal. Crops are produced using a mixture of traditional and modern methods which often results in an imbalance.. To enhance high yield productivity of cereal and tuber crops, farmers in the basin have to;

i. Use better varieties and quality seed

ii. Adopt better plant population and timing management,

iii. Adopt better manuring and fertilizer practices as well as mechanization

iv. Devise better storage mechanisms and efficient weed control methods

Without external inputs, productivity and sustainability of upland cereal-tuber farming system in the Lower River Benue Basin has recently been on the decline. However, a few of the farmers are able to access external inputs. The production of such famers has remained stable and/or increasing thereby improving their farm income.

Table 43. Farming Practices Adopted by Farmers

S/N	Farming Practices	Respondents		Difference
		Number (No.)	**Percentage (%)**	
1	Mixed cropping	242	96.8	8 (3.2%)
2	Crop rotation	185	74.0	65 (26.0%)
3	Monocropping	206	82.4	44 (17.6%)

Plate XIV. Cassava (Tuber crop) Farm at Uchi Mbakor

Plate XV. Sorghum (Cereal Crop) Farm at Uchi-Mbakor

6.4.2. Socio-Economic Characteristics of the UCTFS

The cash crops that are dominantly cultivated in this UCTFS include yams, groundnuts, sorghum, cassava, melon and a host of many others (Plates XIV and XV). Nevertheless, the introduction of some cash crops has not profoundly changed the character of subsistence production in the basin. Commercial crops have sometimes disrupted the system by severely overexploiting soil resources or by commanding a disproportional part of labour resources resulting in large-scale land mining and environmental deterioration. Some methods of crop propagation used in the basin include; seedage, natural propagules, layerage, cottage, graftage, separation and division.

It was gathered in the field that the major source of labour in this system is the family labour comprising of the household head, wife or wives, children and dependants. The average number of farm labour per household is 8 persons. Farm labour pressure has compelled 17.4% farmers to indulge in polygamous family system and 12.8% hire labour especially at periods when demand for labour attain critical peaks during land preparation, planting, weeding, harvesting and even for post harvest activities.

It was also observed that farmers in the area usually operate a unique system of farm labour organization. This is a system where farmers usually come together under one umbrella and work rotationally on the farm plots of members. They sometimes hire-out their labour at a fee. This system is called *Ihumbe* in Tiv, *Gaiya* in Hausa or in some cases *Gandu.*

It is also found that farm size and ownership for the cereal-tuber system is determined by population and the amount of land that is available for cultivation. Majority of the farmers (68%) in the basin have farm holdings of less than 4 hectares and they acquire their farm land through inheritance while only 32% have between 4 and 10 hectares. About 5% of the farming population has shown interest in agricultural mechanization but the practice is yet to be significant. It was revealed that over 92% of the farmers with formal education have demonstrated their willingness to expand their farming scope provided there are improvements in economic and tenurial conditions as well as intensification of the supply of farm inputs.

The output of the cereal-tuber system often provides a farm income at commercial level but where farm sizes are small (1-4 hectares) it provides at subsistence level or below. Consequently an important part of household family labour is used in off-farm activities to acquire minimum subsistence income.

6.5 PLANTATION OR TREE CROP FARMING SYSTEM (PTFS)

Spurred by increasing social, population, and economic pressures, tree crop farming system in the study area is in a state of very active development. There is greater use of high-yielding varieties, more productive methods of management, and shorter replanting cycles, together with increased interest in intercropping.

This farming system typically involves small-to-moderate plot sizes, a mix of economic trees in association with a variety of perennial and annual crops. Together, they provide food and income for the peasant farmers. This system is known for the production of perennial industrial tree or shrub crops; notably coconut, oranges, guava, mangos, cashew, oil palm, plantain, pineapple, and sugarcane, as well as some roots and tuber crops such as yams, cassava, potatoes and cocoyam.

The smallholder plantation farming system provides the farmer with a mix of food and cash crops that offer a large degree of self-sufficiency. Harvests and consequent income are dispersed throughout the year and provide greater stability than is possible with only one or two annual crops. Furthermore, the mix of trees offers almost complete protection to the soil, sustains the nutrient cycle, and eliminates the need for cultivation implicit in the production of annual food crops. In the PTFS system, emphasis is given to raise a multiple tree crop with the sole objective of maximizing profit. It involves not only cultivation of crops but also processing, packaging and transporting the product.

The main trends affecting the PTFS relate to: population pressure on natural resources, declining terms of trade and market share, dismantling of parastatal input supply and marketing services, and marginal involvement of the public sector through industrial crop research and extension. The result has been increasing poverty and growing social conflict between tree crop owners and migrant workers. Despite the problems referred to above, the PTFS is a high potential system and its growth prospects in the medium term are sound.

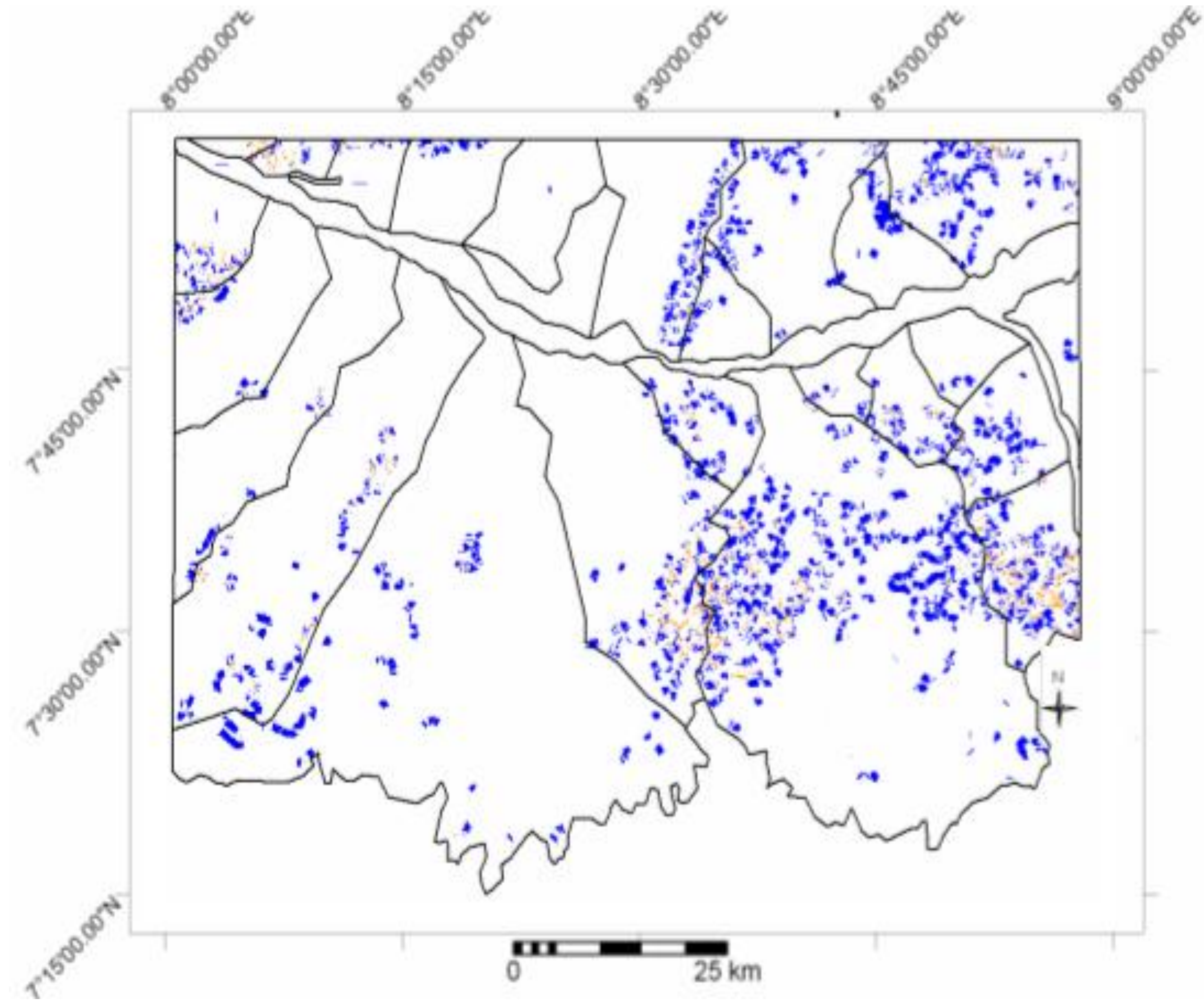


Figure 36. Areas where Plantation or Tree Crop Farming System is Practiced.

6.5.1. <u>Physical Characteristics of Plantation or Tree Crop Farming System</u>

The smallholder farmers in the basin are inherently weak in crop husbandry or management in terms of timely bush clearing, mulching and pruning. They are less well prepared for the task of transforming natural conditions by conscious human effort and of improving yields by the proper maintenance of the plants. In the Lower River Benue Basin, food crops are inter-planted between tree crops and are grown mainly for subsistence, also there are few instances where livestock are raised.

Plate XVI. Oil Palm Plantation at Idye-Makurdi

6.5.2 Socio-Economic Characteristics of Plantation or Tree Crops System

The production and processing of most of the tree crops in the Lower River Benue Basin is carried out largely by the individual farmer and his household. But in some cases where the process is quite complicated and cannot effectively be done on a small scale by the farmer, then a communal, hired labour or co-operative effort becomes necessary such as oil palm, oranges, sugar cane, mangoes amongst others.

Labour requirements in this system are spread fairly evenly over the year once the trees have been planted as the initial planting and maintenance requires much more labour than subsequent years. The input-output relationships in smallholder tree crop production show that the marginal returns for extra labour can be quite high as some extra weeding, mulching, pruning, harvesting and processing has shown to have high returns.

It was gathered during field surveys that income in this system of farming depends basically on the number of tree stands in production, their yield, and the price per standard measure. Since neither tree crop nor food crop failure is common in the basin, price fluctuations for industrial crops constitute the main source of vulnerability. The incidence of poverty tends to be concentrated among very small farmers and agricultural workers, but growth potential of the system is moderately high.

Field surveys have shown that plantation crop farmers are generally semi skilled for know-how and technology required for production and processing is less shallow. Interestingly, farmers in the basin are highly skilled in choosing optimum crops, crop site and crop mixtures, particularly in multi-storey cropping with perennial and food crops.

Animal rearing (mostly for meat and milk) is an important supplementary activity of smallholder plantation crop farmers in the Lower River Benue Basin, often taking the form of tall tree crops with grazing underneath or in-between.

It was also observed that some tree crops such as plantain, mango, cashew, guava, orange and pawpaw are planted specifically along the corridors of Rivers Benue, Katsina-Ala, Mu, Gwer and Guma as well as the flood plain of the river systems (Plate XVI).

6.6 AGROFORESTRY-BASED FARMING SYSTEM (AFFS)

In this system of farming, trees are grown on the same land as crops and/or animals either in a spatial arrangement or in a time sequence, and in which there are both ecological and economic interactions between the tree and non-tree components. Agroforestry is considered largely as the new word for an age-old practice of having trees in the agricultural landscape. It has become more refined in meaning and now connotes trees with a purpose such that the land-use system yields both a food product and a tree product, each meeting the needs of the user of the system. At the same time, the agro-forestry system in the basin is stabilizing in its impact on the environment and stable in its output of products.

Agroforestry is a system of agricultural land use widely practiced in the Lower River Benue Basin. It is, at the same time, a food and tree-product production system. It is not a single commodity nor a single management practice but rather a complex interacting set of subsystems, components, and practices suited to a particular environment and needs.

Some major aspects of farming under this system as observed in the basin include home gardens, shade tree based system, and fodder tree based system and dispersed trees in annual crop field. In this system, there is good utilization of available land, of labour and capital resources as well as a complementary ecological relationship between trees, crops and/or livestock which leads to a more sustainable and profitable system.

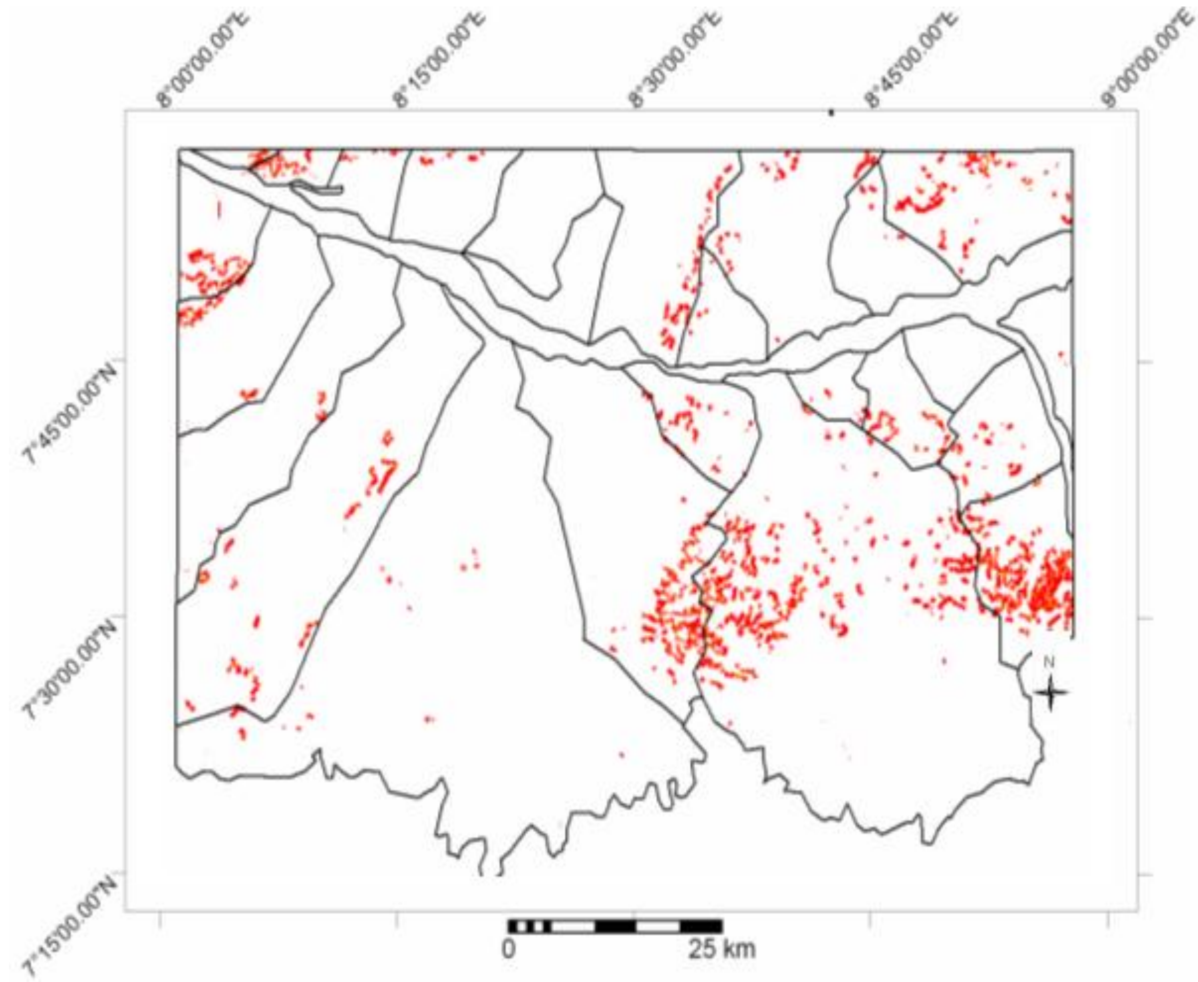


Figure 37. Areas where Agroforestry-Based Farming System is Practiced

6.6.1 Physical Characteristics of Agroforestry-Based Farming System

Integration of annual and perennial crops indicates that, this system of tree and annual crop combination farming has created a multi-species plant community which can improve productivity in a sustainable manner where the nutrients cycle is enhanced and soil moisture is conserved (Plates XVII and XVIII). The farmers in the Lower River Benue Basin tend to have a good idea of what the outcome is of the competitive and other interaction forces in a mixed plant community.

The characteristics of trees for agroforestry system in the Lower River Benue Basin indicates that the trees are characterized by lengthy biological and economic life cycles and once trees are established on the land, they become a permanent and dominant feature of the land. Most of these characteristics were seen to be unfavourable to the annual food-crop farmer who is more interested in quick, immediate returns and in year-year flexibility in choosing crops.

The characteristics of annual crops for agroforestry in the basin indicates that, annual crops that are grown in an agroforestry system are aggressive in growth, shade tolerant, have strong root systems and quick maturing which are best preferred so as to avoid competition unduly with the trees, example is cowpea crop.

The crop and tree husbandry in agroforestry farming system in the Lower River Benue Basin shows that, the permanent woody structure of trees, with dormant buds, affords wide choice management techniques with which to modify their shapes, growth patterns and flowering behaviour. The farmers in the area also indulge in the pruning of trees with cutlasses and sickles to avoid interference with annual crop growth thus, resulting in a balanced system in agroforestry.

Another tool for managing annual crops in the basin involves changing the plant population and plant configuration to discourage close proximity as well as advances in cultivar selection and tree crop breeding/nursery. To ensure highest crop yields in the agroforestry system, attention must be given to earliness, drought and shade tolerance, pest and disease tolerance, and of course, yield potential.

The soil fertility management under the agroforestry system presents a situation where the need for total reliance on chemical fertilizer is drastically reduced in the Lower River Benue Basin. This is because the planted trees have been pumping-up and recycling nutrients, which can fix nitrogen as acquisition of external inputs by farmers in the area poses considerable difficulty. It was also observed that conscious afforestation efforts are been carried out in some places. This, according to the respondents could help in checking the menace of soil erosion and keep some loosed soils together.

Plate XVII. Agroforestry System (Oil Palm/Sugarcane) at Adi-Etulo

Plate XVIII. Agroforestry (Oranges/Sorghum/Soyabeans) at Tse-kucha

6.6.2. Socio-Economic Characteristics of Agroforestry-Based Farming System

In terms of farm size and ownership, agroforestry farming system is commonly practiced on small farmlands of just about one to two hectares and where there are no land tenure problems. It was gathered that farmers are quite reluctant to plant trees if they are not the land owners; hence they want to harvest the crops they cultivate. With increasing human population density, however, the fallow periods are progressively being reduced and the rising quest for agricultural land under this system is heightening to constant land disputes among individuals and communities.

The degree of commercialization in the Lower Benue River Basin under the agroforestry systems has been at the subsistence system and low level as there is rarely enough land for surplus production due to pressure on land demands.

Regarding to the production and income patterns, it was observed that, income is generated from the three main components of this system, that is, from the trees, the annual crops or the livestock component. The income gets to the farmers in form of food, fuel-wood, char-coal and little cash. Economic tree products and livestock are the main source of cash, which is in very short supply because few households have cash crops and good market outlets are distant. Poverty is extensive, and in some places very severe.

In terms of the labour economy, agroforestry system is labour intensive. It is important that the labour requirements of the different farm components (trees, annual crops, and livestock) are in harmony with one another hence there is no interference so much with other farm activities.

Considering the skills of agroforestry farmers, it was gathered during field investigations that, the farmers in the Lower River Benue Basin possess good traditional knowledge and skills of land use and crop potential necessary to decide which specie can best be planted where. With the recent interest in agroforestry, the Benue State Ministry of Forestry and Animal Resources and the Department of Forestry and Wildlife of the University of Agriculture Makurdi are making several attempts to inventorize and modernize the traditional agroforestry practices and skills.

6.7 FISHING FARMING SYSTEM

This system involves households that depend on major rivers such as Rivers Benue, Katsina Ala, Mu, Gwer, Guma and other minor rivers and streams for fishing (Figure 38 and Plates XIX and XX). Their livelihood is based on artisanal fishing supplemented by annual crop production, sometimes in multi-storied tree crop gardens with root crops under coconuts, fruit trees, plus some animal production. This system of fishing includes river fishing from boats, net fishing from lakes/ponds/earth dams, setting of nets and traps along portions of still river waters. Poultry and goats are the main domestic animals also accommodated by the fishermen.

Off-farm opportunities are connected with tourist resorts along the Rivers Benue and Katsina Ala beaches and with large tree crop estates. Although socio-economic differentiation is considerable, the current prevalence of poverty is only moderate. Some inhabitants of the area on part-time basis carry out fishing activities apart from farming and trading while a meager proportion of the population mainly consisting of the Jukuns and Tivs practice fishing as occupation and on full time basis. They use canoe and big calabashes to lay their nets and other fishing traps. They confirm to have been making good catches and also generating meaningful income from it. Men, women and children were actively seen at some fishing grounds. An interaction with them revealed that they are usually more successful in fishing during peaks of the rainy and the dry seasons.

The Lower River Benue Basin has all the natural potentials for fish capture and fish culture. There are several species of fishes in Rivers Benue and Katsina together with their tributaries (Plates XIX and XX). The morphometric analysis has shown that there are a total of 1374 stream segments and at least 20 lakes and ponds large enough for the promotion of capture fisheries. Rapid appraisal revealed that in 1992, the area had only 37 fish ponds, but with the promotion of aquaculture, mobilization and construction of demonstration ponds by BNARDA and other government agencies, the people of the area have widely accepted aquaculture. The result is that the study area now has 174 private fish ponds that are operational, 10 demonstration ponds and 22 Special Programme for Food Security (SPFS) fish ponds in the area. All these ponds are stocked with improved species of fishes which are being produced by the Benue State Ministry of Animal and Forest resources. However one problem of fisheries in the basin is the absence of improved fishing methods resulting in the use of obnoxious fishing methods.

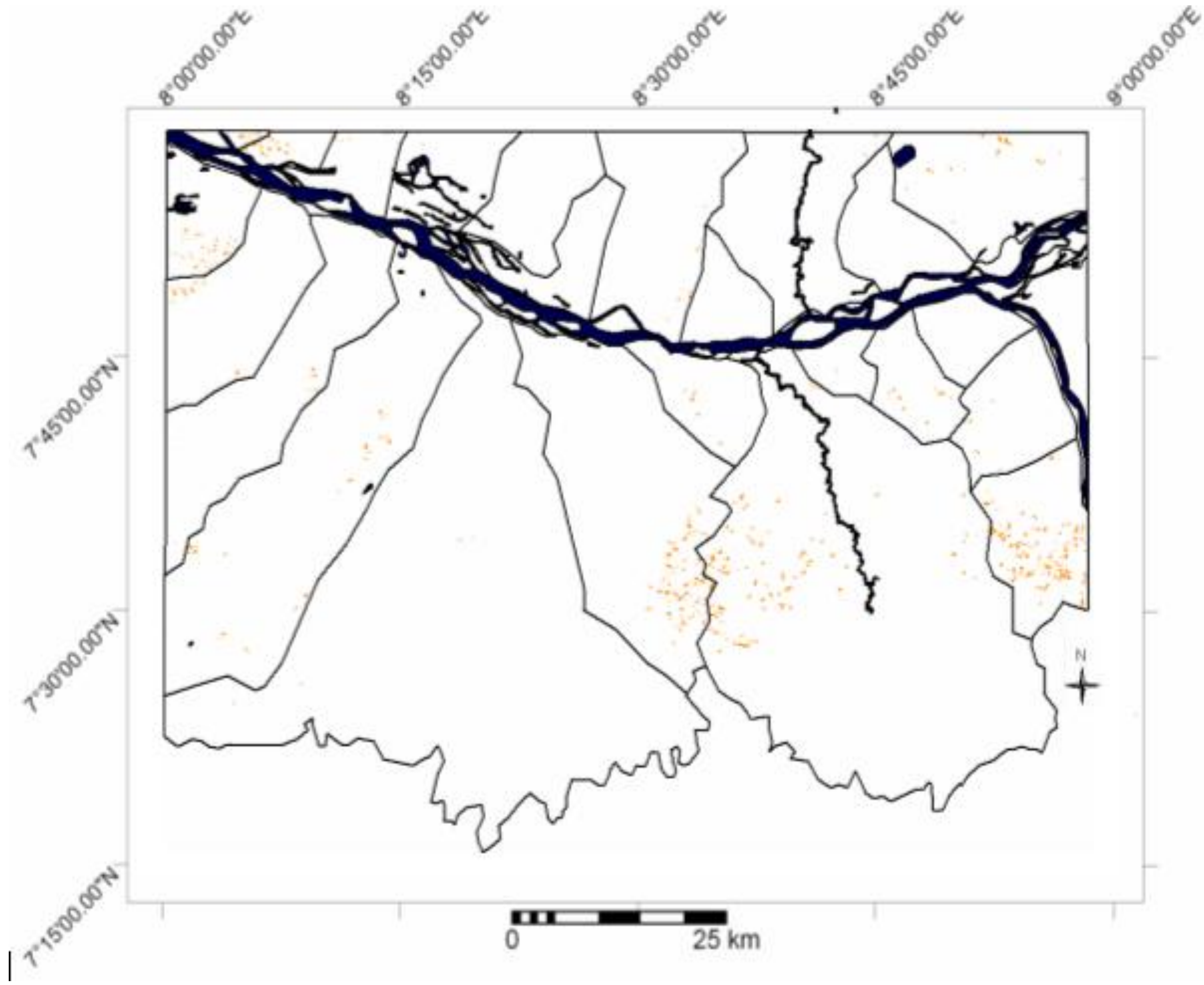


Figure 38. Areas where Fishing Activities takes place in the Lower River Benue Basin

Plate XIX. Fishing Activities at the Confluence of Rivers Benue and Katsina Ala at Gbajimba

Plate XX. Fresh Fish stand at Buruku Market

6.8 LIVESTOCK AND MIXED FARMING SYSTEM

Livestock ownership is variable, but a high proportion of farmers keep a few goats or sheep, perhaps averaging about 6-10 animals per household, and also some good quantity of poultry. A sizable number of cattle and donkeys are owned by a smaller proportion of migrant Fulani nomad farmers. The amount of their flock depends on the incidence of trypanosomiasis, and other factors.

In the Lower River Benue Basin, livestock are not usually closely integrated into the farming system, being mainly grazed on communal grazing lands, often by herdsmen from a different tribe usually the Fulanis (Plates XXI and XXII). They may graze fodder crops, stubbles and other crop residues after harvest. Cultivators sometimes provide incentives to the herdsmen to herd their cattle on the stubble so that the herds would drop dungs to manure the farmland.

6.8.1 Livestock Farming

Livestock are kept in the area just like in many other places for subsistence (meat and milk products), offspring, transportation (camels, donkeys), land preparation (oxen, camels), sale or exchange, savings, bride-wealth and insurance against crop failure. The nomad population generally lives permanently in villages, although part of their herds may continue to migrate seasonally in the care of herd-boys.

The main source of vulnerability is drought, leading to weak animals and the distress sale of assets. During the driest period of the year, the pastoralists move further south to the Cereal-Root Crop Mixed System areas and they return north during the rainy season. Poverty is extensive, and often severe. The potential for poverty reduction is only moderate.

Plate XXI. Livestock Grazing at Fiidi near Makurdi Airport

Plate XXII. Livestock Transhumance towards River Mu

Farmers under considerable land pressure in the basin have adopted methods of making larger quantities of manure in small enclosures that are then used to manure larger areas. Socio-economic differentiation is considerable - many herders have lost most of their animals due to stock theft, riverine pest and diseases. The nomads who constitute a segment of the migrant population of the Lower River Benue Plains rear livestock such as cattle, sheep, goats, and guinea fowl almost and so on. Some of these animals are also domesticated by other inhabitants of the area particularly goats, sheep, guinea fowl, chicken and dogs, although not reared in meaningful commercial quantities as done by the nomads.

Ranching is a popular system in the Lower River Benue Basin. More intensive pasture development is successful only when the initial soil fertility is high and the stocking rate is carefully controlled, otherwise severe economic and environmental problems may arise. Excessive and uncontrolled grazing in the basin has caused many problems of soil and environmental degradation. Excessive grazing in the basin has depleted the vegetation cover, changed the species composition, exposed soil to high intensity rains and sunshine, which have compacted the surface soil layer and decreased the infiltration rate of the surface soil layer.

6.8.2 Mixed Farming

In the mixed farming system both the cultivation of crops and the raising of livestock are carried out at a time. Some of the crops grown by the farmer are used both as food for his household and for feeding his livestock. In other instances, both crops and livestock are kept on the same farm, and each part of the system contributes in some measure to the other.

The system of mixed farming in the area enables the farmer to enrich his soil by applying the manure he collects from the livestock pens (Plate XXIII). In the areas that have long been densely populated especially around Makurdi town, the farmers who own livestock have developed their own methods of permanent agriculture by the use of manure, including latrine manure, compound sweepings, and cattle dung partly from their own cattle and partly from Fulani pastoralists who were paid to graze their cattle on the stubbles after harvest.

It was also observed that the plantation of tree crops is mixed with rearing of livestock such as cattle, sheep, goats and donkeys as well as the cultivation of some cereals and leguminous crops. In the mixed farming system, the population densities, proportion of cultivated land and crop density are small to medium. Although, there is still room for further expansion as well as intensification, this system occupies a small proportion of land and is not widely distributed in the basin. Consequently, it could not be mapped as an entity.

Plate XXIII. Mixed Farming of Mango and Livestock at Angahar-Anor

CHAPTER SEVEN
SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

7.1 SUMMARY OF FINDINGS

A number of research techniques including Satellite Remote Sensing, Geographic Information Systems (GIS) as well as intensive field surveys and digital laboratory work have been integrated in the study. This, to a greater extent, paved the way for the identification and effective analysis of the existing agricultural systems in the Lower River Benue Basin. Consequently, the following agricultural systems were classified and mapped: irrigated system, lowland rice-based system, upland cereal and tuber crop system, plantation or tree crop system, agroforestry system, fishing and livestock systems.

To develop the farming systems knowledge base, the researcher blended information from Geographic Information Systems (GIS), farming system studies, decentralized attribute datasets and expert knowledge from previous studies. After the global forces driving the pattern in farming systems were identified, multi-faceted approaches were adopted to identify the characteristics and extent of each farming system in the basin. For this purpose, the researcher used the FAO farming systems classification maps as a base and added other GIS layers as relevant, including irrigation, environmental constraints, cultivated extent, and livestock and human population. The findings of this study can be summarized as stated below.

Lowland rice production is very high, but there are evident difficulties such as limited land available for agricultural expansion, declining soil fertility and, in some places, rice yields approaching their known ceilings. It is reasonable to expect that in the next three decades, as population grows, the basin will become a major importer of food and animal feed. In the lowland rice farming system, income security in the smallholder sector depend increasingly on crop intensification as well as diversification into higher value crops, such as vegetables, citrus and feed, and into small livestock production and on-farm aquaculture. Along with that, farmers need improved extension, financial and marketing systems, and greater integration into the non-farm economy.

Furthermore, there are excellent prospects about the upland cereal and root-based system, but it has suffered from poorer production, transport and communications infrastructure. Nevertheless, in some parts of the LRBB, there is great scope for expansion and intensification of cereal and root crop production. The main constraints are the lack of infrastructure, mainly roads to markets and suitable production technologies.

Also, crop farming in the study area varies widely in its scope, ranging from intensively managed small plots to commercial farms covering tens of hectares. Successful crop farmers in the area have developed customary expertise at selecting the varieties of plants that can adapt to their soils and environment. As such they have acquired skills over the years in preparing the soil and in planting, growing, protecting, harvesting, and storing the crops. They are also able to control weeds, insects, and diseases, and marketing skills to enable them to gain reasonable returns from their crops.

However, the scale of crop production in the area is limited because the character of the lack of mechanization which could enhance production on a large scale. This is to say that the level of technology has not been sufficiently high to mechanize on a large scale especially as the majority of holdings are too small and cheap labour so abundant that it is not economical to mechanize under prevailing conditions.

Indeed, the study shows that a farming system is the closest representation we have of how farmers think and make decisions. The experience in the study indicates that without relevant information, agricultural development programmes can go badly awry or crooked. It goes beyond the traditional commodity, or disciplinary approach that focused on ways of increasing yields, as if that were the only important consideration farmers make. Differences in the farming system account for a major part of the variation in farm management decisions in the area.

The farming systems present an average size of 5 ha, ranging from 5 ha to 20 ha. Spatial analysis shows that only the largest farms, cattle producers, represent a homogeneous physical environment. The spatial distribution of the individual farming systems shows that middle-size farms are located on the most suitable soils along the courses of Rivers Benue, Katsina-Ala, Mu and Gwer. The agricultural area covers 50% of the available basin area. In coincidence with this result, total farm income is closely related to agricultural area. Per hectare profit is higher in lowland rice and cereal-tuber farming systems, with higher incidence of intensive land use activities. The system of analysis adopted for this study has been able to characterise the basin down to the level of the individual farming system.

It is noted that this study shows that over 70% of the people in the area live in rural areas, and almost all of them depend directly on their small farm holdings for a living. Although many people are moving to the cities such as Makurdi and Gboko, apparently mainly because they hope for a better standard of living there, it is common knowledge that even in the cities many people still try to cultivate small plots to supplement some of their food demands. Thus, it is clear that farming is by far the largest economic enterprise area, and it is vital for the well-being of most people

7.2 CONCLUSIONS

From this study certain conclusions can be drawn as describe below.

First, the need for optimal use of land has never been greater than at present, when rapid population growth and urban expansion are turning land into a relatively scarce commodity for agriculture. On this basis, the use of remote sensing technology has been rapidly expanded for the development of key sectors including agriculture. This study concluded that satellite remote sensing technique will continue to be a very important factor in the improvement of present system of generating agricultural information. Satellite remote sensing provides various platforms for agricultural surveys especially as it relates to agricultural land use systems. Satellite imagery has unique ability to provide the actual synoptic views of large area at a time, which is not possible for conventional survey methods and also the process of data acquisition and analysis is very fast through Geographic Information System as compared to the conventional methods. The different features of agriculture are acquired by characteristic, spectral reflectance, spectral signature of agricultural features and associated phenomena through EMR. In general the research emphasizes the utmost need of timeliness and accuracy of the output generated by remote sensing techniques and its calibration with ground-truth and other information systems like shuttle radar topographic mission and satellite imagery.

Secondly, crop production and animal rearing remains the ‘mainstay’ of the economy of the inhabitants of the Lower River Benue Basin. In spite of its strategic importance, agriculture in the area is in the hands of resource poor farmers who rely mainly on traditional practices for cultivation, processing and storage. There is a low level of agricultural mechanization, poor land management and high cost of agricultural input. All these have contributed to low productivity, poor pricing of produce and low earnings from agriculture. The major task of government which is to improve food and nutritional security as well as the income for the people has not transcended to reality in the basin.

Thirdly, the farming systems described in this study provide a snapshot of dynamic systems that are constantly evolving. Both endogenous factors (household goals, labour, technologies in use and the resource base) and exogenous factors (market development, shifts in demand, agricultural services and policies, the dissemination of new technologies and the availability of market and policy information) drive the evolution of individual farms and, collectively, the overall farming system.

Fourthly, Plantation or Tree Crop farming is very popular in the Lower River Benue Basin and accounts for 5.42% of the overall farming systems (Table 42 and Figure 36). It also plays a very important role in the economy of the area. Tree crops compete favourably with other non-tree crops in terms of cash income to the farmers. However, preferences are in some cases given to the non-tree crops such as rice (30.11%), cereal and tuber (34%) systems as evidenced by land area and attention that is devoted to their productions. The tree crops have the potential to tilt this competition in their favour when production, processing and market constraints are properly addressed as the post harvest losses will be reduced and income further boosted through the provision of improved seedlings and other inputs.

Fifthly, the issue of poor feeder roads that determines market accessibility in the Lower River Benue Basin, hits the far rural farmers worst of all. This group depend only on food crops as their source of farm income; consequently problems of transportation and marketing have resulted to either spoilage or sales at ridiculously low prices in the villages thereby leading to reduced peasant income. Therefore, development of good road infrastructure is a prerequisite for achieving their food security. There is the need to improve their processing and storage facilities so as to reduce wastage and prevent selling at prices that does not guarantee maximum returns to labour. At the peak of rainy season with resultant floods, it becomes difficult to transport farm produce to the market for sale. Policies to mop up excess supply during harvest at reasonable prices in the villages are inevitable.

Sixthly, the study reveals that the traditional cropping system in the area involves the permanent cultivation of some fields, usually near the house compound, and the maintenance of soil fertility through manuring. Farm plots that are further away are cultivated for a few years, after which soil fertility is restored primarily through fallowing. The fields near the compound are usually common fields used for food crops, whereas the fields further away that are cultivated intermittently are used more for cash crops.

Seventhly, this study shows that there is a tremendous variation in the type of agricultural production systems practised in the basin. Interaction with the respondents during field surveys shows that farmers make their decision based on economic frame conditions, household characteristics (Tables 27 – 29) and the natural resource base. These factors, together with household production objectives, form the basis for household decision making. Households decide on what to produce, how to produce, and how much to produce. These choices which to some extent have environmental consequences, do determine the quantities and quality of the products offered at the market.

Finally, the study has shown that to contribute positively to sustainable agricultural development in the Lower River Benue Basin and in any other physiographic unit in Nigeria, space-based methods of satellite remote sensing and GIS must contribute to the betterment of food security and income of poor peasant farmers supported by small farms using traditional or existing technology and internally generated resources. Farming is today an economically, socially and environmentally sensitive sector. Satellite imagery now underpins an objective, global and precise approach to resource management and has become crucial to agricultural inventories, crop forecasts, monitoring crop health and soil moisture.

7.3 RECOMMENDATIONS

Agricultural production systems in the Lower River Benue Basin face many challenges. Some of these are traditional practices for cultivation, processing and storage, low level agricultural mechanization, poor pricing of produce and low earnings from agriculture, among others. Consequently, the creation of an enabling environment by the relevant authorities shall pave the way for economic growth and development, which will support wealth creation to improve the living standard of the people in the basin. Also, with the right policies and investment by the local, state and federal government in floodplain agriculture, the dominant outcome could be increased food and feed production of vegetables, cereals, tubers and tree crops.

Farm households in the Lower River Benue Basin can achieve significant improvements in economic and nutritional status through modifications in their approach to soil, crop and pest management. These changes in the farming system would minimize input costs, create a more even distribution of the workload throughout the year, improve the effect of chemical fertilizers and organic materials, reduce weed pressure and the need for insect and disease control activities, and lead to higher and more stable yields. To this end several packages of practices can be recommended for land resources management on a long-term basis as agriculture in the area has not been economically efficient due to its subsistent nature. Consequently, there is a need to think of some actions that would sustain agricultural production in the basin.

A. The prevailing agricultural land use in the basin shows that a chunk of the cultivated lands falls under single cropped area. Such land has to be brought under double or continuous cropping. The limitation, which has been encountered in such area, is lack of irrigation schemes. Giant effort has to be made to develop means of irrigation on priority basis especially now that there are traces of global food shortages. A judicious crop rotation and efficient use of water can have far reaching effects in the development of single cropping areas into double cropping.

B. The suitable land near the settlements having feasibility of transportation to the nearby markets should be taken up for horticultural pursuits. A few patches which are lying as fallow can be brought under agro-horticulture. The selection of crop species has to be made in view of the local environment and economic demands.

C. The study reveals that the Lower River Benue Basin has low forest vegetation, low afforestation programmes and little agroforestry farming activities (3.15%) as indicated in Table 42. Consequently, intensive and extensive agro-forestry programmes should be taken up with the active co-operation and participation of the local people. The seedlings should be acquired by government agencies and distributed to farmers for raising tree species mainly on the boundaries of their fields so as to produce firewood which will in turn save the natural vegetation from wanton destruction. The plantation on the vacant lands generally should consist of economic tree species such as mango, cashew, orange, guava, palm trees, and coconut. Planting of suitable tree species that will yield fruits, firewood and fodder in the shortest possible time, need to be given highest priority as this will serve as a viable source of energy in the villages. For this purpose, *Eucalyptus*, *Acacia* and such other suitable species are suggested.

D. There are sand deposits, rocky outcrops, rugged surfaces, bare terrain and erosion in the Lower River Benue Basin. These features need greater attention because of the prevailing scarcity of agricultural land in the area. Hence, development of the bare and erosive surfaces shall not only meet the local requirements of small timber, fuel and fodder, it will provide protection against soil degradation and will help in conservation of soil moisture as well.

E. Plantation of soil binding grasses and trees along the river courses and other erosion sites has become inevitable. It is suggested that intensive plantation of suitable soil binding grasses and trees should be carried out.

F. It is also suggested that the cottage industries, animal husbandry and crafts pursuits should be encouraged, to supplement the income of rural peasant farmers in the area.

G. Monitoring of the surface runoff of Rivers Benue, Katsina-Ala, Mu, Gewr, Guma and a host of several streams in the basin. Need to protect the river banks from degradation by regulating the activities of burnt bricks workers, monitoring bad farming practices as well as wanton scooping of building or construction materials along the river banks.

H. The equilibrium between the number of livestock and the capacity of grazing pasture in the area has to be maintained. Also, cordial relationship between the peasant farmers and pastoral nomads be encouraged.

I. Need for various tiers of government and the organized private sector to vigorously pursue the Millennium Development Goals (MDG) that relates to accelerated agricultural production, food security and poverty reduction.

J. There is the need for good agricultural practices in the Lower River Benue Basin because such practices are based on the application of available knowledge to the utilization of the natural resource base in a sustainable way for the production of safe, healthy food and non-food agricultural products, in a humane manner, while achieving economic viability and social stability. The underlying theme is one of knowing, understanding, planning, measuring, recording, and managing to achieve identified social, environmental and production goals. This requires a sound and comprehensive management strategy and the capability for responsive tactical adjustments as circumstances change. Success depends upon developing the skill and knowledge bases, on continuous recording and analysis of performance, and the use of expert advice as required.

Some of the actions that are needed in the course of adopting good agricultural practices for the sustainability of the prevailing farming systems in the Lower River Benue Basin just as it is applicable in other parts of the world are as highlighted below;

i. *Soil management*:- Soil management will maintain and improve soil fertility by minimizing losses of soil, nutrients, and agrochemicals through erosion, runoff and leaching into surface or ground water.

ii. *Water management*:- Careful management of water resources and efficient use of water for rainfed crop and pasture production, for irrigation where applicable, and for livestock, are criteria for good agricultural practice.

iii. *Crop and fodder production*:- Harvesting of all crop and animal products removes their nutrient content from the site and must ultimately be replaced to maintain long-term productivity. Application of fertilizers, organic and inorganic, in a balanced fashion, with appropriate methods and equipment and at adequate intervals to replace nutrients extracted by harvest or lost during production. Also, rotation of livestock on pastures to allow for healthy re-growth of pasture.

iv. *Crop protection*:- Maintenance of crop health is essential for successful farming for both yield and quality of produce. This requires long-term strategies to manage risks by the use of disease- and pest-resistant crops, crop and pasture rotations, disease breaks for susceptible crops, and the minimal use of agrochemicals to control weeds, pests, and diseases following the principles of Integrated Pest Management.

v. *Animal production and health*:- Livestock require adequate space, feed, and water for welfare and productivity. Chemical and biological contaminants in livestock feeds are avoided to maintain animal health and/or to prevent their entry into the food chain.

vi. *Harvest and on-farm processing and storage*:- Harvesting must conform to regulations relating to pre-harvest intervals for agrochemicals and withholding periods for veterinary medicines. Food produce should be stored under appropriate conditions of temperature and humidity in space designed and reserved for that purpose.

vii. *Energy and waste management*:-. Farming produces by-products, some of which are potential pollutants of soil, water, or air. The production of these by-products should be minimized.

viii. *Human welfare, health, and safety*:- The social and economic welfare of farmers, farm workers, and their local communities must always be a priority. Health and safety of farmers are important concerns for those involved in farming operations so due care and diligence is required at all times.

To achieve the recommendations discussed above, there is the need to establish research and training facilities. To this end, a strong farming system research capability must be established and encouraged among researchers in all agro-allied educational and research institutions in the study area, to work with farmers, extension workers, and others in the areas identified as needing urgent attention. Strong on-station backup component research is also needed. Also, results and findings of all agricultural related researches and development projects, whether they succeed or fail, should be published and made widely available. This will enable the coming generation to learn from the successes and failures so as to devise the possible way forward.

Furthermore, excellent training facilities must be established or strengthened, preferably at the national level down to the local levels, to train land use, farming system researchers, extension, and other stakeholders to carry out these programs. For further improvement in the use of satellite remote sensing technology and GIS technologies in various agricultural fields, it is pertinent to reach out to the National Space Research and Development Agency, the National Centre for Remote Sensing and other space related institutions.

7.4 CONTRIBUTIONS OF THE STUDY TO KNOWLEDGE

The distinct contributions of this study to knowledge afford evidence of originality by the discovery of new facts are highlighted below.

i. The study has clearly shown that Geographic Information System and satellite remote sensing data can provide the requisite environment for effective agricultural systems analysis as a basis for proper land use planning and agricultural intensification targeted at addressing issues of food security and poverty reduction in the Lower River Benue Basin.

The study also showed that those constraints of the conventional methods could be overcomed by satellite remote sensing and GIS technologies which are very powerful, modern, efficient and cost effective techniques that have proven to be time, risk, cost and energy saving.

ii. The study has clearly identified classified and mapped eight agricultural systems in the basin. These include: irrigated, lowland rice-based, upland cereal and tuber based, plantation or tree crop, agroforestry, fishing, livestock and mixed systems.

iii. Special types of map of the identified farming systems including; DEM, 3Dvisualization, NDVI, sub-watersheds, stream order, stream flow direction, physiographic units, slope classes, land use and land cover which have not existed before in the area have been generated, possible adjustment strategies proffered, and relationships between variables were as well established. The summation of these actions will contribute in no small measure to providing a database about agricultural productions in the Lower River Benue Basin and consequently assist in future decision making for sustainable agricultural productivity in Nigeria.

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WORLDWIDE WEB (WWW) SITES VISITED

A. Agricultural Systems and Land Resources

i. http://precision.ag.ohio-state.edu/~precisfm/library- Precision Agriculture

ii. http://edc.usgs.gov/products/elevation/gtopo30/gtopo30.html- EROS free DEM of the whole world

iii. http://www.rst.gsfc.nasa.gov - Remote sensing Tutorials

iv. http://www.mars.jrs.it - Monitoring Agriculture with Remote Sensing

v. http://www.fao.org - Food and Agricultural Organization Bulletins

vi. http://www.benuestate.com - Profile of Benue State, Nigeria

vii. http://www.glovis.usgs.gov - Global Visualization Viewer for free Ortho-rectified Landsat data

viii. http://www.edu.usgs.gov/product/elevation/gtopo30/wo20n40.html - Site for digital elevation model (DEM) of the globe, EROS Data Centre, Sioux Fall Corolado, USA

ix. http://www.fao.org/landandwater/agll/agromaps/interactive/index.jsp

x. http://www.ifpri.org/

xi. http://www.sage.wisc.edu/

xii. http://www.ciat.cgiar.org/access/index.htm

xiii. http://apps.fao.org/page/collections?subset=agriculture – Agricultural Development

xiv. http://ec.europa.eu/comm/eurostat/ramon/nuts/splash_regions.html

xv. http://www.eusoils.jrc.it/esdb_archive/EuDASM/Africa/images/maps

xvi. http://www.nal.usda.gov/afsic/pubs/terms/srb9902.shtml - Sustainable Agriculture

xvii. http://www.nal.usda.gov/afsic/pubs/edtr/EDTR2009.shtml - Education and Training Opportunities in Sustainable Agriculture

xviii. http://www.nal.usda.gov/afsic/pubs/tracing/tracing.shtml

xix. http://www.sare.org/publications/exploring.htm

xx. http://attra.ncat.org/fundamental.html

xxi. http://www.foodalliance.org/ - Food Alliance

xxii. http://foodafrica.nri.org – Food Africa Programme

B. Geographical Information System (GIS)

i. http://www.gisdevelopment.net/application/environment/overview/mi03148.htm - GIS Development

ii. http://www.geovista.psu.edu/sites/geocomp99/Gc99/010/gc_010.htm - Measuring GIS accessibility

iii. http://www.utdallas.edu/~briggs/poec6381.html

iv. http://www.usgs.gov/research/gis/ - USGS GIS and Research Office

v. http://www.gislinx.com/ - Geographic Information Systems

vi. http://www.curtin.edu.au/curtin/dept/smec/ipd/

vii. http://www.urisa.org/GISDatabase.html - Geographic Information Systems Databases

viii. http://www.divcom.otago.ac.nz:800/gistutor/

ix. http://www.ecoman.une.edu.au/iBRMSAL/GIS/GISTOC.htm

x. http://www.ncgia.ucsb.edu/other_sites.html

xi. http://www.bbq.ncgia.ucsb.edu/education/curricular/giscc/cc_outline

xii. http://www.geog.ubc.ca/courses/klink/gis.notes/ncgia/toc.html

C. Remote Sensing Technology (RST)

i. http://www.itc.nl/library/srtm.asp - Shuttle Radar Topographic Mission

ii. http://www2.jpl.nasa.gov/srtm - Shuttle Radar Topographic Mission

iii. http://www.glcf.umiacs.umd.edu - Global Land Cover Facility for free Landsat data and SRTM

iv. http://www.gvm.sai.jrc.it/glc2000/defaultGLC2000.htm - Global Land cover

v. http://www..ccrs.nrcan.gc.ca/ccrs/edure/tutorial/

vi. http://research.umbc.edu/~tben-ja1/index.html

vii. http://rst.gsfc.nasa.gov/TofC/table.html

viii. http://http2.brunel.ac.uk:8080/depts/geo/satmarks/Teach.html

ix. http://www.ciesin.org/TG/RS/RS-home.html

x. http://www.crisp.nus.edu.sg/

xi. http://hawaii.ivv.nasa.gov/space/hawaii/vfts/kilauea/radar_ex/intro.html

xii. http://ftp.geog.ucl.ac.be/~patrick/geogr/Eteledetec.html - remote sensing index

xiii. http:// www.esrin.esa.it - Eurpopean Space Agency

xiv. http://geo.arc.nasa.gov - NASA program

xv. http://www.spot.com - French satellite SPOT

xvi. http://www.nasda.go.jp/ - Japan space agency

xvii. http://www.rka.ru./ Russian Space Agency (RSA)

xviii. http://www.coresw.com - Russian imagery source

xix. http://www.space.gc.ca/ - Canadian Space Agency (CSA)

xx. http://www.ccrs.nrcan.gc.ca/ccrs/ - Canada Center for Remote Sensing

xxi. http://www.inpe.br/ - National Institute for Space Research (Brazil)

xxii. http://www.asprs.org - American Society

xxiii. http://www.man.ac.uk - Manshester Univ.

xxiv. http://www.idrisi.clarku.edu - Idrisi site

xxv. http://www.amazon.com - Bookstore

xxvi. http://www.brevard.cc.fl.us/BTR_- Labs/bober/martin/rs/overview.htm

D. Global Positioning System (GPS)

i. http://www.utexas.edu/depts/grg/ggcraft/notes/gps/gps.html - GPS Spacecrafts

ii. http://www.inmet.com/gps/fsections/aa_f0.htm - Global Positioning System

iii. http://www.inmet.com/~pwt/gps_nav.html - Global Positioning System - Navigation

iv. http://www.aero.org/publications/GPSPRIMER/index.html - GPS Primer

v. http://www.synapse.net/!dbartlett/gpsutm.htm - Universal Traverse Mercator

vi. http://webphysics.iupui.edu/gpnew/cp_gp0.htm - Web Atmospheric Physics

APPENDICES

APPENDIX A: STRUCTURED QUESTIONNAIRE FOR THE GENERATION OF ATTRIBUTE DATASETS FROM THE FARMERS.

TOPIC: MAPPING AND ANALYSIS OF AGRICULTURAL SYSTEMS IN A PART OF THE LOWER RIVER BENUE BASIN, NIGERIA

PREAMBLE

It is against the backdrop of the usefulness of Satellite Remote Sensing and Geographic Information System (GIS) in land resources inventorying, monitoring, evaluation and management that this research seeks to carryout the analysis of agricultural systems in the Lower River Benue Basin, Nigeria. Consequently, questionnaire interview has been structured for 250 respondents to help generate additional information about the cultural, social and economic set-up of the inhabitants of the basin, which obviously remote sensing and GIS technologies cannot provide. The exercise is purely for academic purpose, thus, information that would be supplied by the respondents will be treated with highest level of confidentiality**.**

LOCATION

Name of the Location---------------------------------LGA--

Town--Ward--

No of Houses----------------------------Quality of Houses---

Estimated Population---------------------Nearest Physical Feature-----------------------------------

GPS: Latitude----------------------Longitude-----------------------Altitude------------------------

CHARACTERISTICS OF RESPONDENTS

1. Name of respondents--

2. State of Origin--

3. Sex (a) Male [ ] (b) Female [ ]

4. Age of Respondent: ------------------------years, Religion--------------------------------------

5. Size of household: Wife-------(b) Children-----------(c) Other dependants-------------------

6. Educational Status---

7. What is your principal occupation---

INFRASTRUCTURE AND AMENITIES

1. No of Educational Institutions (a) Nursery Schools (b) Primary Schools

(c) Secondary Schools (d) Tertiary Schools

2. No of Health Facilities (a) Chemists (b) Dispensary (c) Clinics

(d) Hospitals (e) Traditional Healers (f) Spiritual Healers

3. No of Worship Centers (a) Shrines (b) Churches (c) Mosques

4. No of Markets (a) Periodic Markets (b) Daily Markets

5. No of Social Centers (a) Viewing Centers (b) Town Halls

6. No of (a) Culverts (b) Bridges

7. Other amenities (a) Telephone (b) Bore hole (c) Financial Institutions

8. List Government Offices in the area---

SOCIO-ECONOMIC ACTIVITIES

A. CROP FARMING

1. State the nature of your farming

(a) Upland---------------------(b) Fadama/Irrigation------------------(c) Both-------------------

If Irrigation, what type of irrigation system (a) Traditional (b) Mechanized

If Mechanized, what method do you adopt (a) Sprinkler (b) Canals

What time do you irrigate (a) Strictly dry season (b) Parts of rainy season

2. Are you an indigene, settler or migrant farmer? If migrant or settler farmer, where are you from?--

3. How long have you been farming in the area? -----------------------------------Years

4. How do you get your farmland? (a) Hired (b) Leased (c) Purchased (d) Inherited

5. How do you prepare your farmland?

(a) Burning (b) Tractor (c) Hand Tools (d) animal traction

6. What is the approximate size of your farm holding? --

6 What predominant crops do you grow including time of cultivation/harvest

Crops	Time of Cultivation	Time of Harvest	Yields	Annual Income generated	Yield Comparison Past/Present
Yams					
Cassava					
Potatoes					
Water Yams					
Rice					
Maize					
Sorghum					
Beans					
Groundnuts					
Cowpea					

Sugarcane

Beniseed

Pepper

Tomatoes

Tobacco

Spinach

Pumpkin Leaves

Banana

Plantain

Garden Eggs

---

* *Yield Comparison Past/Present (Better, Same, Worst)*

8. What crops have you stopped growing recently? --

Give reasons--

9. How do you get farm labour?--

How many labourers per farming season? ---

10. What are the farming/agricultural systems that are common in the area------------------

----

11. Please give a description of the system of farming you adopt-----------------------------

----

12. Which farming implements (tools) do you use?

(a) Local/Existing tools e.g. --

(b) Modern/Improved tools e.g. ---

13. Do you own or hire a tractor?-----------------------------Cost------------------------------------

14. What do you normally use to improve the condition of your soil? -------------------------

(a) Organic Fertilizer (b) Naturally (c) Chemical fertilizer

If chemical fertilizer, give the type, quantity, time of application, method

Types of chemical fertilizer	Quantity (bags	Time of application	Method of application

15. Are you farming for (a) subsistence (b) commercial (c) both

If commercial, which major market do you go?---

16. Do you experience pest/disease infestation? (a) Yes (b) No

If yes, how often?--------------------------what period of the year?------------------------------

What type of treatment do you give the pest/disease?---

17. Do you use improved or local varieties of seedlings?--

From where do you get the seedlings?--

B. ANIMAL FARMING

1. Do you practice mixed farming, that is, crop production and animal rearing?

If yes, give the names and quantities of domestic animals you rear

S/N	Animal	Numbers	Income
1	Cattle		
2	Goats		
3	Sheep		
4	Pigs		
5	Chicken		
6	Rabbits		
7	Ducks		
8	Guinea Fowl		
9	Dog		
10	Pigeon		
11	Ostrich		
12	Turkey		

2. Do you rear them for (a) commercial purpose (b) household consumption

3. What is the relationship between farmers and nomads in the area? -----------------------------

   If not cordial, what are the causes of their differences? ---

----

4. Do you carry out fishing activities? (a) Yes (b) No

5. What time of the year is the major fishing season (a) Wet Season (b) Dry Season

6. What are the methods of fishing?

   (a) Nets (b) Calabash (c) Trawlers (d) Lines and Hooks (e) Poison (f) Dynamite

7. What is your annual income from fishing?

   (a) <50 000 (b) 51 000-100 000 (c) 101 000-200 000 (d) >201 000

8. How does flood affect fishing in the area? (a) Positively (b) Negatively

C. CULTURAL ATTRIBUTES

1. What are the prominent ethnic groups in the area?---

2. How are disputes generally resolved in the area?

   (a) Elders [ ] (b) The Chiefs [ ] (c) Courts [ ] (d) Area Councils [ ]

   (e) Police [ ] (f) Others [ ] Please specify ---

3. What are the major cultural activities of the area? ---

5. What are the agricultural development institutions that support your farming?

   ----

6. Do you get credit facilities for farming? (a) Yes (b) No

   If yes, from where?---

7. Do you belong to any co-operative society? Yes/No Give Name-----------------------------

   If Yes, What is its name--

8. What are the benefits you derive from the Co-operative society---------------------------------

   ----

9. How has the Lower Benue River Basin Development Authority positively affect your farming operations?

   (a) Made me cultivates crops all year round [ ]

   (b) Increased my yield of crops [ ]

   (c) Enable me received fertilizer every year [ ]

   (d) Visited by extension workers every time [ ]

   (e) Doubled or tremendously increased my income [ ]

10. What are the negative effects of the Lower Benue River Basin?

(a) Vulnerable to flooding [ ]

(b) Increased land pressure [ ]

(c) Out migration of villagers [ ]

(d) Reduced income [ ]

(e) Others, specify [ ]

11. Mention the common means of transporting goods and people in the area--------------------

----

FLOOD CHARACTERISTICS AND REGIME

1. Do you experience flood at all (a) Yes (b) No

If Yes, how often

(a) Once a year (b) Once in 5 years (c) Once in 10 years (d) >10 years

2. Which period of the year do you experience flood

(a) January-March (b) April-June (c) July-September (d) October-December

3. What period of the day do you experience flood

(a) Morning (b) Afternoon (c) Evening (d) Night

4. In your view, what are the causes of the flood?

(a) Rain (b) Distant water from upstream (c) Collapse of dams (d)Excess water from dams

5. How long does the flood water last in your area

(a) 1 day (b) 1 week (c) 1 month (d) 2 months and above

A. POSITIVE IMPACT OF FLOOD

6. Tick the positive impact of flooding in the area

(a) Improve fish catch

(b) Improve the fertility of the arable lands

(c) Increase the yield of fadama crops

(d) Affect the water level in the nearby ponds

B. NEGATIVE IMPACT OF FLOOD

7. Tick the aspects of flood damages in the area

(a) Inundated farmlands

(b) Damage crops

(c) Destroy buildings

(d) Destroy livestock

(e) Human deaths

(f) Collapse bridges and culverts

(g) Over flooded roads

(h) Recreation facilities

(i) Health facilities

(j) School facilities and activities

(k) Social functions

(l) Festivals

(m) Produce human diseases and pests

(n) Produce livestock disease and pests

(o) Loss of man hours on farms, businesses and offices

C. COPING STRATEGIES

8. What are the coping strategies against flooding?

(a) Adaptive farming practices

(b) Taking to other occupation

(c) Temporal relocation

(d) Building flood control structures

(e) Resting to fate

(f) Insurance of crops, human lives, livestock and properties

(g) Permanent migration

9. Rating of possible associated problems or constraints in the area.

Problems	*Rating*			
	Very Severe	*Severe*	*Little Problem*	*No Problem*
Drought				
Erosion				
Soil infertility				
Low yield				
Pest infestation				
Food Scarcity				
Poverty				
Health Problem				
Access to health care facility				
Fertilizer availability				

Fertilizer cost

Market outlet availability

Market outlet reliability

Access to credit facility

Access to farm machinery

Access to extension services

Labour availability

Access to land

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36. Any other special observations or comments that could be helpful to the study ----------

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Thank you most sincerely for your co-operation.

Kenneth Abaagu Uchua

(B.Sc Geography, M.Sc Land Resources)

PGES/UJ/13427/02

APPENDIX B: GPS FIXES AND ATTRIBUTE DATA OF SOME SAMPLED LOCATIONS IN THE LOWER RIVER BENUE BASIN

LOCATION	TOWN	WARD	LGA	NO OF HOUSES	QUALITY OF HOUSES	POPULATION	LATITUDE	LONGITUDE	ALTITUDE
NEW BRIDGE	NORTH BANK	NORTH BANK	MKD	> 300,000	Zinc	>50,000	7°44.769 N	8°32.585E	69M
OLD BRIDGE	NORTH BANK	NORTH BANK	MKD	> 300,000	Zinc	> 50,000	7°44.667 N	8°32.563E	90M
BURUKU	BURUKU	MBAAPEN	BURUKU	500	Zinc	5000	7°27.450 N	9°12.359E	94M
BURUKU	BURUKU	MBAAPEN	BURUKU	4000	Zinc / thatched	150000	7°27.457 N	9°12.380E	88M
ABUKU	ABUKU	BINEV	BURUKU	400	Zinc / thatched	100000	7°27.809 N	9°12.626E	90M
BURUKU	UGAH	MBAIKONGU	BURUKU	600	Zinc / thatched	500	7°22.062 N	9°19.095E	95M
DIAKA	UGAH	MBAIKONGU	BURUKU	320	Zinc / thatched	750	7°22.060 N	9°19.095E	100M
ADI	ADI	ETULO	BURUKU	3000	Zinc / thatched	400000	7°10.976 N	9°15.273E	105M
ADAGBU	ADI	ETULO	BURUKU	30	Zinc / thatched	350	7°11.470 N	9°15.604E	108M
AYAKU	BURUKU	MBATIEV/ MBAAPEN	BURUKU	100	Zinc / thatched	1000	7°27.454 N	9°12.360E	93M
BURUKU	ADAGBU	ETULO	BURUKU	750	Zinc / thatched	400	7°11.470 N	9°15.604E	108M
BURUKU	ABUKU	ETULO	BURUKU	60	Zinc	5000	7°27.816 N	9°12.608E	81M
DIAKA	UGA/ UJITON	MBAIKONGU	BURUKU	2000	Zinc / thatched	150000	7°22.061 N	9°19.095E	96M
UGAH	UGAH	ETULO	BURUKU	50	Zinc / thatched	500	7°24.261 N	9°16.095E	97
ABUKU	ABUKU	BINEV	BURUKU	2000	Zinc / thatched	20000	7°27.810 N	9°12.625E	96M
ALEIGBA	JOO MBATYO UGH	IKURAV TIEV II	KATSINA ALA	3000	Zinc / thatched	250,000	7°15.330 N	9°20.432E	101M
ZEGE AKERA	IKOWE	IKURAV TIEV I	KATSINA ALA	1000	Zinc / thatched	3500	7°18.194 N	9°20.774E	97M
IKOWE RIVER SIDE	ALIGBA	IKURAV TIEV II	KATSINA ALA	50	Zinc / thatched	500	7°15.194 N	9°20.774E	97M
MBAHAN	MBAHAN	MICHILIE	KATSINA ALA	80	Zinc / thatched	600	7°05.437 N	9°21.174E	124M
ANGAHA RANOR	OGBOMA BRIDGE	MBAGEN	KATSINA ALA	130	Thatched	750	7°08.715 N	9°16.800E	115M
MBAHAN	KATSINA ALA	MICHILIE	KATSINA ALA	4000	Zinc / thatched	450000	7°05.436 N	9°21.177E	126M
MBAHAN	ABA	MICHILIE	KATSINA ALA	70	Zinc / thatched	37	7°05.443 N	9°21.171E	118M

AKETA	KATSINA ALA	AKETA	KATSINA ALA	70	Zinc / thatched	800	7°11.802 N	9°16.845E	105M
ADAGUNDU	ADAGUNDU	KATSINA ALA	KATSINA ALA	159	thatched	600	7°12.209 N	9°16.769E	107M
TYULEN	TYULEN	AGASHA	GUMA	250	Zinc / thatched	500	7°43.437 N	8°57.850E	78M
BENCO	ABINSI	ABINSI	GUMA	2000	Zinc / thatched	700	7°45.390 N	8°44.188E	72M
TYULEN	TYULEN	AGASHA	GUMA	600	Zinc / thatched	1000	7°43.410 N	8°57.833E	77M
TYULEN	TYULEN	KAMBEE	GUMA	4000	Zinc / thatched	10000	7°43.417 N	8°57.860E	76M
GBAJIMBA	GBAJIMBA	NDZOROV	GUMA	400	Zinc / thatched	5000	7°49.185 N	8°51.556E	107M
GBAJIMBA	GBAJIMBA	NDZOROV	GUMA	250	Zinc / thatched	3000	7°49.185 N	8°51.556E	107M
TYULEN	TYULEN	KAMBEE	GUMA	590	Zinc / thatched	2500	7°43.424 N	8°57.834E	79M
TYULEN	TYULEN	KAMBEE	GUMA	50	Zinc	500	7°43.410 N	8°57.835E	77M
ANUHA	ANUHA	NJOROV	GUMA	100	Zinc / thatched	1500	7°48.255 N	8°52.688E	86M
GBAJIMBA	GBAJIMBA	NJOROV	GUMA	500	Zinc / thatched	2500	7°49.185 N	8°51.556E	107M
GBAJIMBA	GBAJIMBA	NOUQOV	GUMA	4015	Zinc / thatched	2100	7°49.183 N	8°51.556E	101M
KOTI	KOTI	TONDO II	KWANDE	2200	Zinc	200000	6°46.751 N	9°13.551E	228M
KOTI	KOTI SHANGEV	TONDO II	KWANDE	2500	Zinc	2100	6°46.651 N	9°13.051E	226M
JATO AKA	JATO AKA	IYAV	KWANDE	2500	Zinc / thatched	300000	6°53.395 N	9°30.974E	174M
ICHEMBE	JATO AKA	KUMA KURAV	KWANDE	1000	Zinc / thatched	5000	6°53.723 N	9°30.9415 E	168M
TICHA MBAPEU	SATI	TONDO 1	KWANDE	400	Zinc / thatched	3000	6°44.857 N	9°13.006E	224M
GBAJI OCHOLI	AGAGBE NAKA	SENGEV	GWER WEST	800	Zinc / thatched	6000	7°51.837 N	8°12.317E	68M
GBAJI OCHOLI	GBAJIOC HOLI	SENGEV	GWER WEST	50	Thatched	5000	7°51.827 N	8°12.337E	62M

APPENDIX C: FORMULAE FOR THE COMPUTATION OF MORPHOMETRIC PARAMETERS

S/N	***Morphometric Parameters***	***Formula***	***Reference***
1	*Stream Order*	*Hierarchical rank*	*Strahler (1964)*
2	*Stream Length (Lu)*	*Length of the stream*	*Horton (1945)*
3	*Mean Stream Length (Lsm)*	*Lsm=Lu/Nu* *Where, Lsm = Mean Stream Length* *Lu = Total stream length of order 'u'* *Nu = Total no. of stream segments of order 'u'*	*Strahler (1964)*
4	*Stream Length Ratio (RL)*	*RL=Lu/Lu-1* *Where, RL = Stream Length Ratio* *Lu = The total stream length of order 'u'* *Lu-1 = The total stream length of its next lower order*	*Horton (1945)*
5	*Bifurcation Ratio (Rb)*	*Rb=Nu/Nu+1* *Where, Rb = Bifurcation Ratio* *Nu = Total no. of stream segments of order 'u'* *Nu+1 = Number of segments of the next higher order*	*Schumn (1956)*
6	*Mean bifurcation Ratio (Rbm)*	*Rbm=Average of bifurcation ratios of all orders*	*Strahler (1957)*
7	*Relief Ratio (Rh)*	*Rh=H/Lb* *Where, Rh = Relief Ratio* *H = Total relief (Relative relief) of the basin in kilometer* *Lb = Basin Length*	*Schumn (1956)*
8	*Drainage Density (D)*	*D=Lu/A* *Where, D = Drainage Density* *Lu = The total stream length of all orders* *A = Area of the basin (km^2)*	*Horton (1932)*
9	*Stream Frequency (Fs)*	*Fs=Nu/A* *Where, Fs = Stream Frequency* *Nu = Total number of streams of all orders* *A = Area of the basin (km^2)*	*Horton (1932)*
10	*Drainage Texture (Rt)*	*Rt=Nu/P* *Where, Rt = Drainage Texture* *Nu = Total number of streams of all orders* *P = Perimeter (km)*	*Horton (1945)*
11	*Form Factor (Rf)*	$Rf=A/Lb^2$ *Where, Rf = Form Factor* *A = Area of the basin (km^2)* Lb^2 *= Square of basin length*	*Horton (1932)*
12	*Circularity Ratio (Rc)*	$Rc=4*Pi*A/P^2$ *Where, Rc = Circularity Ratio* *Pi = 'Pi' value i.e. 3.14* *A = Area of the basin (km^2)* *P = Perimeter (km)*	*Miller (1953)*
13	*Elongation Ratio (Re)*	$Re=2\sqrt{(A/Pi*1/Lb)}$ *Where, Re = Elongation Ratio* *A = Area of the basin (km^2)* *Pi = 'Pi' value i.e. 3.14* *Lb = Basin Length*	*Schumn (1956)*
14	*Length of overland flow (Lg)*	*Lg=1/D*2* *Where, Lg = Length of overland flow* *D = Drainage Density*	*Horton (1945)*
15	*Constant Channel Maintenance (C)*	*C=1/D* *Where, C = Constant Channel Maintenance* *D = Drainage Density*	*Schumn (1956)*

APPENDIX D: NIGERIASAT-1 SATELLITE IMAGERY USED IN THE STUDY