SOIL LIMITS, SOCIO-ECONOMIC CONSTRAINTS AND SUSTAINABLE RICE FARMING IN KANO RIVER BASIN PROJECT, NIGERIA

BY

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(04/68MN003)

A Thesis Submitted to the Department of Geography and Environmental Management Faculty of Social Sciences in Partial Fulfillment for the Award of the Degree of Doctor of Philosophy in Geography

University of Ilorin, Ilorin,

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May 2018

CERTIFICATION

This certifies that this thesis has been read and approved as meeting the requirement of the Department of Geography and Environmental Management, University of Ilorin, Ilorin, Nigeria for the award of Ph.D. Geography.

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DEDICATION

This research is dedicated to my beloved children Hafsat Ali Bala, Musa Ali Bala, Umar Ali Bala and Abdullahi Ali Bala, my wife Wasila Umar Wudil and in memory of my late mother and father Hajiya Hafsatu Dauda Daura and Alhaji Musa Danbalange.

DECLARATION

I, Ibrahim, Ali Bala hereby declare that this thesis titled Analysis of Soil Limits and Socio-economic Constraints to Sustainable Rice Farming in Kano River Basin Project, Nigeria, is a record of my research work. It has neither been presented nor accepted in any previous application for higher degree. All sources of information have been specifically acknowledged.

In addition to the above, the research work has been ethically approved by the University Ethical Review Committee.

IBRAHIM, A B.

ACKNOWLEDGEMENT

My foremost and profound gratitude goes to Almighty Allah who created me; give me love, protection and encouragement throughout my life. I would like to express my sincere gratitude to the project supervisor Dr. E. O. Oriola, and all my lecturers whose their constructive and scholarly criticism have made this thesis a reasonable structure; their efforts encouragement, guidance and useful correction offered throughout the research work are greatly appreciated.

I wish to extend my gratitude to Professor R. A. Olawepo for advice and encouragement to enroll for this Ph.D. programme. My appreciation also goes to Professor Sadiya Sani Daura of Department of English and European Language, Bayero University, Kano, Dr. Lawan Shu'aibu of Department of English Federal University, Dutse, Jigawa State, for correction of English language grammatical error which made this research a viable literature and Dr. Hussein Ibrahim of Department of Agricultural Economics Federal University, Dutsin-Ma, Katsina State. Similarly, I extend my gratitude to staffs of Hadejia-Jama'are River Basin Development Authority for the provision of research literature and conveyance to assist in various field-works.

The acknowledgement would not be complete if failed to acknowledge the Kano State Government and management of Sa'adatu Rimi College of Education for allowing me to go for further studies as well as sponsoring the studies as an in service.

I am indebted to those whom I did mention. I regret my in ability to acknowledge others who have might contributed. However, errors, misinterpretation and viewers expression are my responsibility.

Ibrahim, Ali Bala

ABSTRACT

Rice is a staple food in high demand by households, but local production in Nigeria has not met the demand for rice consumption. The reasons for this were often connected with edaphic and human factors. This study therefore, examined soil and socio-economic constraints to irrigated rice production in the Kano River Project Phase I. The objectives were to: (i) assess the nature and variation in physico-chemical properties of soils in the study area; (ii) examine the relationship between input costs and net-profit of irrigated rice production systems; (iii) assess the constraints of rice farming; (iv) examine the factors that affect farmers' adjustments to project inputs recommendation for rice farming; and (v) assess the sustainability and optimization of irrigated rice production systems. Purposive sampling technique was used to select two irrigated soil units in Kura and Bunkure irrigation layouts. Ten hectares were demarcated on Pab and Pab/Pb Complex soils in the two layouts and their corresponding adjacent non-irrigated lands for comparison. Purposive sampling was also used to pick 10 of the 58 settlements in the study area. Copies of a structured questionnaire were administered to 1,730 registered irrigated rice farmers in the two soil units. Descriptive and inferential statistics including simple percentages and goal programming were employed. The findings of the study were that the soils are generally sandy (69% to 79%). All the parameters of the two irrigated soil units exhibited homogeneity (C.V < 33%). Eight of the twenty-one soil parameters in irrigated soil were not significantly different from non-irrigated soil in Pab soil of Kura ($p < 1.73$), but in Bunkure only six parameters were not different ($p < 1.73$). Five soil parameters each in irrigated Pab/Pb complex soil of Kura and Bunkure were not different ($p < 1.73$) from those in non-irrigated fields, the other sixteen parameters were significantly different ($p > 1.73$); there is positive correlation ($r = 0.52$) between rice input costs and net-profit. Covariance analysis showed positive linear relationship in eight rice-farming settlements (Kura +834,785,050.54, Bunkure +209,427,795.38, Danhasan +1,760,623,900.02, Yadakwari +120,170,201.29, Gafan +732,997,522.32, Imawa +401,864,387.19, Kosawa +1,474,231,798.99, Makwaro +127,780,984.59) and negative in two Babbabgiji -707,072,102.23 and Kadawa -192,341,627.88); nitrogen ($0.06g/kg^{-}1$) and organic matter ($0.8g/kg^{-1}$) fell below threshold levels of $2.0g/kg^{-1}$ and 68.8 g/kg^{-1}, respectively and the factors that affect farmers' adjustments to project inputs recommendation for rice farming; inputs costing (24.54%), farming knowledge (21.50%), technical farming experience (16.24%), modern techniques (16.21%) and labour input (10.30%) were the factors that contributed 88.77% of the input variance adjustment to rice production; and sustainability index ($Z_0 = 348 > 0$) indicated that the present irrigated rice production system is not sustainable. Optimization procedure showed that 97.13% sustainability in rice production can be achieved. The study concluded that irrigated rice production in the Kano River Project I were constrained by soil nitrogen, organic matter content and five socio-economic factors. It is therefore recommended that nitrogen, organic matter input optimizations coupled with education of farmers on modern input techniques should be improved.

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CHAPTER ONE

INTRODUCTION

1.1 Background to the Study

In the late 1960s, before the diversification of the Nigerian economy to the oil sector, the Federal Government was involved in the concept of river basin system development which began with the establishment of the Lake Chad Basin Commission in 1964. The oil boom and Sahelian drought of the 1970s made Federal Government of Nigeria view irrigation as the technical solution to increasing food production. This thus made the Food and Agricultural Organization (FAO) and the United States Agency for International Development (USAID) conduct studies in the 1970s and identified attractive sites for large-scale irrigation scheme such as the Bakalori Scheme, Kano River Project I scheme and Chad Basin scheme all in the sub-arid and sub-humid agro-ecological zones of Nigeria (Nigerian National Committee on Irrigation and Drainage, 2008). The success of these pilot schemes coupled with five-year drought (1970-1975) led to the establishment of eleven river basin development authorities, purposely for irrigation and food production (Adams, 1985; Salau, 1990). By mid-1980s, 187 small scales, 117 medium and large scales formal irrigation projects were established in the country (Ejieji and Amodu, 2008). However, these projects performed below expectations, partly because of water resources conflicts that emerged with high intensity coupled with budgetary difficulties (Nwa *et al.*, 1999).

A river basin is critical in rural areas where it is playing a significant role in the process of global economic growth, social and sustainable development. It contributes greatly to the provision of foods and industrial raw materials. According to the Earthscan (1984), 15 percent of world's agriculture with benefit from irrigation contributes 40 percent to the world food supplies. Consequently, many researchers and theorists consider river basin as a priority sector for development planning. As Newson (1997) noted, the degree of people's interest in commitment and willingness to invest in irrigation is dependent on how it is perceived to enhance or diminish their lives. Irrigation to Guijt and Thompson (1994) is not necessarily beneficial, yet Turner (1994) saw it as a development panacea, which if properly utilized according to Oriola (2006) will assist in addressing the growing challenges of unemployment, migration and food security in Third World countries which is reducing at unprecedented rates (Todaro and Stephen, 2009).

River basins have over the years been serving as a conducive environment for the cultivation of cereals and vegetables. Rice, one of the significant tropical cereals, is cultivated in the river basin. It supplies a quarter of entire caloric intake of the human race. It serves as staple food for many people than any other crop and about 90% is grown and consumed in South and South-east Asian basins, a major center of the world population (Cartling, 1999).

Rice belongs to the genus *oryza* of the two main contingents: *sativa* in Asia and *glaberrima* in Africa. It is known to be a semi-aquatic *graminaceous* crop of the great diversity. It is established in a greater complex range of environmental conditions and yields more food per hectare than any other cereals (Leong 1976). Rice sustains millions of subsistence farmers in South, South-east Asia and West Africa; it provides 20% of the world's dietary energy supply followed by wheat which supplies 19% and maize 5% (FAO, 2004).

Although rice is a fascinating crop of great importance in Asia and West Africa, it was strangely neglected by research workers and agricultural planners in the past on the basis of environmental conditioning. Hence, rice technology has been introduced as irrigation-based cultivation in these parts of the world.

1.2 Statement of the Research Problem

In Nigeria, despite the government investment in river basin resources development, the efficiency of river basin irrigation projects and their impact on crop production are yet to achieve the desired result, as farm outputs are erratic and of varying quality and quantity. These identified problems, therefore call for the attention of empirical studies of river basin irrigation management. Studies relating to soil monitoring and evaluation of its suitable performance within river basins are few not only in Nigeria and many other the tropical African countries.

Furthermore, studies on river basin irrigation and the contemporary assessment of its management systems with both physical and social frameworks require holistic re-examination. This is because modern irrigation schemes lack an identity of communal national effort which seemingly characterized earlier eras; this is partly due to the marked regional disparities in technological expertise, mainly because of inconsistency in government policy and poor funding of various agricultural projects (Newson 1997).

Rural communities have little incentive to bring forward their own river basin irrigation development at a scale which could improve national economic performance; some form of imposition by extension workers is noticeable to provide development alternatives. Two important questions emerge as Newson (1997) puts it: Is large-scale irrigation a good scheme? Does convergent technology negate local variation in an environment? This study is designed to address these issues as they affect the stakeholders in river basin project development, maintenance and operation.

1.3 **Research Questions**

Five questions are pertinent to this study. They are on basin edaphic properties and socio-economic constraints to agricultural potential of rice producing soils in large irrigation project such as Kano River Project I (KRP1).

i. What is the nature of soil and variation in its physico-chemical properties ?

ii. What is the relationship between cost of inputs and net profit of irrigated rice production in Kano River Project I?

iii. What is the level of farmers' adjustment to project recommendation to rice farm inputs of the study area?

iv. What are the constraints confronting rice farmers efficiency and effectiveness in the study area?

v. To what extent has rice production been sustainable?

1.4 **The Aim and Objectives**

The aim of the study is to examine soil limits and socio-economic constraints to the production of rice under irrigation in the Kano River Project Phase I; with a view to establishing a pragmatic approach to determine sustainable rice production. The specific objectives are to:

i. assess the nature of soil and variation of the physico-chemical properties;

ii. examine the relationship between cost of inputs and net profit of irrigated rice production system;

iii. examine the factors that affect the level of farmers adjustments to project recommendation of rice farming inputs;

iv. identify the constraints of rice farming in the study area; and

v. assess the sustainability of irrigated rice production systems in the study area.

1.5 **Justification of the Study**

Pressure on land resources and demand for food has resulted in the increase of agricultural land use and intensive agriculture (Houghton, 1994; Geissen *et al,* 2009). Geissen *et al.*, (2009) observed that intensive land use may cause an important change in physical and chemical characteristics that can affect soil fertility, increase soil erosion and soil compaction.

Many studies have been conducted on Kano River Project since its inception. They include development of water resources to control flood and annual inundation of fertile land along rivers (FAO, 1965), detailed study for developing the Kano River Project (NEDECO, 1976a), problems and problem solving of irrigation in tropical Africa, South of the Sahara (Adams and Groove, 1984) among others. All these works were carried out long ago and this reason justifies the current research. The evaluation of the research all over the world in the 1990s have shown the wider dimension in their success or failure as evidenced in the reports of repeated economic under-performance of large-scale irrigation and the deficit of agricultural production (Kimmage, and Adams, 1992). Most of these studies laid emphasis on human aspect with regard to the success or failure of the irrigation scheme on the basis of adjustment to social change.

Other studies also focused on the physical aspect which included land evaluation for irrigation rice production in Kadawa, Kano State (Alonge, 1985), assessment of changes in selected soil properties in Kano River Project 1 Kadawa site (Tafon, 1999), the effect of irrigation on some soil characteristics in the Kano River Project 1 (Salihu, 2001).

Realizing that any types of research related to irrigation schemes in Nigeria are either planned (large scale) or unplanned (small scale), the need is urgent at this stage of our national development to evaluate the relevance of large irrigation schemes on the basis of multidisciplinary approach (physical and human aspects) because techno-centric solution would not be adequate for river basin assessment. Furthermore, other disciplines are also relevant to assess the human and environmental diversity of river basin resources. In fact, evidence reported from the literature on Kano River Project I, show that more investigation on irrigation schemes is necessary because the crops production target and soil parameters are not sustainable.

Biswas (1990) raised the issue of regular monitoring and evaluation process as unambiguously identifies the impact of many irrigation projects in Asia. Essiet (1987) high lighted the need for soil and water monitoring studies as the two components that are very often neglected in most post-project assessment exercise once in every 5 years. Similarly, Sahrawat and Diatta, (1992) recommended studies on changes in the application of soil nutrients such as N_2, P, K^+, Ca^{2+}, Mg^{2+}, and Zinc at different spatial gradient locations after fallow for 5-7 years.

Newson (1997) mentioned the need to study the important elements of any river basin development scheme to the point where they can be interactively managed through time to reflect the changing needs of the society and the environment; he further recommended technical facilitation of sustainable development of basin's resources for controlling studies of soil loss by erosion and salinization.

Biswas (1990) also lamented that for large-scale irrigation to be actualized; the actual impact of irrigation on the environment and on the community is often overlooked once the irrigation projects become operational. Even when environmental impact assessment is carried out at the project planning stage, follow-up studies are rarely carried out. Pescod (1990) suggests that sometimes the success of a particular project can be improved by ex-factor evaluation if it identifies, for example, a deficiency in social acceptance or understanding of a development and recommends further public education.

Finally, Ibrahim (2007) concluded that the relationship between technical progress and benefit distribution associated with irrigation project shows a significant difference in crops production, while peasants' socio-economic constraints and technical efficiency in production technologies were not considered in many studies.

Up till now, very few works have been documented on soil quality changes in relation to peasants' socio-economic constraints and variation in technical efficiency in Kano River Project I.This research will add to the existing knowledge on rice cultivation on irrigated soils through highlights of ways to enhance outputs and productivity. For example, by exploring rice production system, Nigeria would be saved from spending $700 million per annum on rice importation (Daily Triumph, 2011). The finding of this research will also assist policy makers to formulate a policy that will make Nigeria net exporter of rice and contribute to the global food supply of which 1.2 billion people live in hunger (FAO, 2009). As observed by WARDA (2007) cited in Olabode (2014) there was a significant improvement in rice production in Nigeria in the 1980s and declined in the 1990s and 2000s when the demand for rice increased, meaning that soil improvement and extensive rice cultivation must be enhanced. The research will support the recent Federal Government's intention to boost rice production through a policy where 65,000 farms have been selected to benefit from $500,000,000 (Ogbey, 2012).

In summary, the study aims to provide a lead way to determine the status of irrigated rice production system using three competing goals; farmers' income, food security, and sustainability of soil ecological parameters. The findings of this study will guide the policy makers, rice research institutes and seed breeder companies on the issues of evolution and adoption of the preferred traits, sustainability, and exploitation of the potentials of the river basin irrigation project. In addition to that, the validation of irrigated rice will be assessed on the basis of technical feasibility, economic profitability and social acceptability of the available rice varieties.

1.6 **Scope of the Study**

The research is designed to cover Kano River Project Phase I, especially the farmers in the settlements within the jurisdiction of Bunkure, Garun Malam, and Kura local government areas. The micro-spatial unit is decided upon to reduce the shortcoming of data availability and information on a large-scale. This study considers the human and environmental diversity in Nigerian rural areas as noted by Adedayo (2003).

Analysis of soil limits and socio-economic constraints to the farmers engaged in irrigated rice cultivation in the Kano River Project Phase I are within the scope of this study such structure , macro and micro elements. Therefore changes in soil characteristics ranges from soil structure , macro and micro elements since the inception of the project were examined. A consequence of management techniques on input/output is part of the scope. The study also includes farming methods constraint to rice farmers and sustainability of the rice production systems. However, cultivation methods, harvesting, and marketing are not included in this study.

1.7.0 **The Study Area**

1.7.1 **Kano River Project: Historical Development**

Since the early days of colonial rule, discussions were on how to improve farming in densely populated areas, where much fertile land could be cultivated only once a year because of limited rainfall (Palmer-Jones, 1977). The Federal Military Government eventually decided that it would tackle those problems by introducing large-scale irrigation in the North by 1970. The pilot phase of the Kano River Project was started at Kadawa South-west of Kano (Baba, 1989).

The project is a large-scale, capital-intensive irrigation scheme designed to cover 58,000 acres of land in Kano State. The Kano State Government established the Kadawa Irrigation Scheme in 1970 and the Bagauda Lake in 1974. The project came under the authority of the Hadejia Jama'are River Basin Development Authority (HJRBDA) in 1976 so as to run the affairs of the Kano River Project I and was the first of several such schemes which eventually covered 146,000 acres in Kano State. The project started in 1971 and the initial research was conducted in 1976-77 when the scheme was still in its first phase and restricted to 3000 acres. Now Kano River Project I has 22,000 hectares of irrigable land.

The study area for this research work consists of three local government areas, namely Bunkure, Garun Malam and Kura local governments. An area geographically confined within Kano River Project Phase I (Figure 1).

1.7.2 **Geography of the Study Area**

The study area lies in latitude $11^0 30'$ and $12^0 03'$ North of the equator and longitude 8^0 20' and $9^0 40'$ East of Greenwich Meridian locating the data collecting center as shown in figure 1. The total land mass covers about 60,000 hectares. The position of the Tiga Dam reservoir lies between latitude $11^0 15'$ and longitude $11^0 29'$ North of equator and longitude $8^0 16'$ and $8^0 38'$ East of Greenwich Meridian. It is about 40.42km long and 24.24km at its widest point and covers an area of 176km^2. The Dam was initially designed to hold 2 billion cubic meters of water. It was however, reduced due to the technical reasons to 1.5 billion cubic meter water storage capacity.

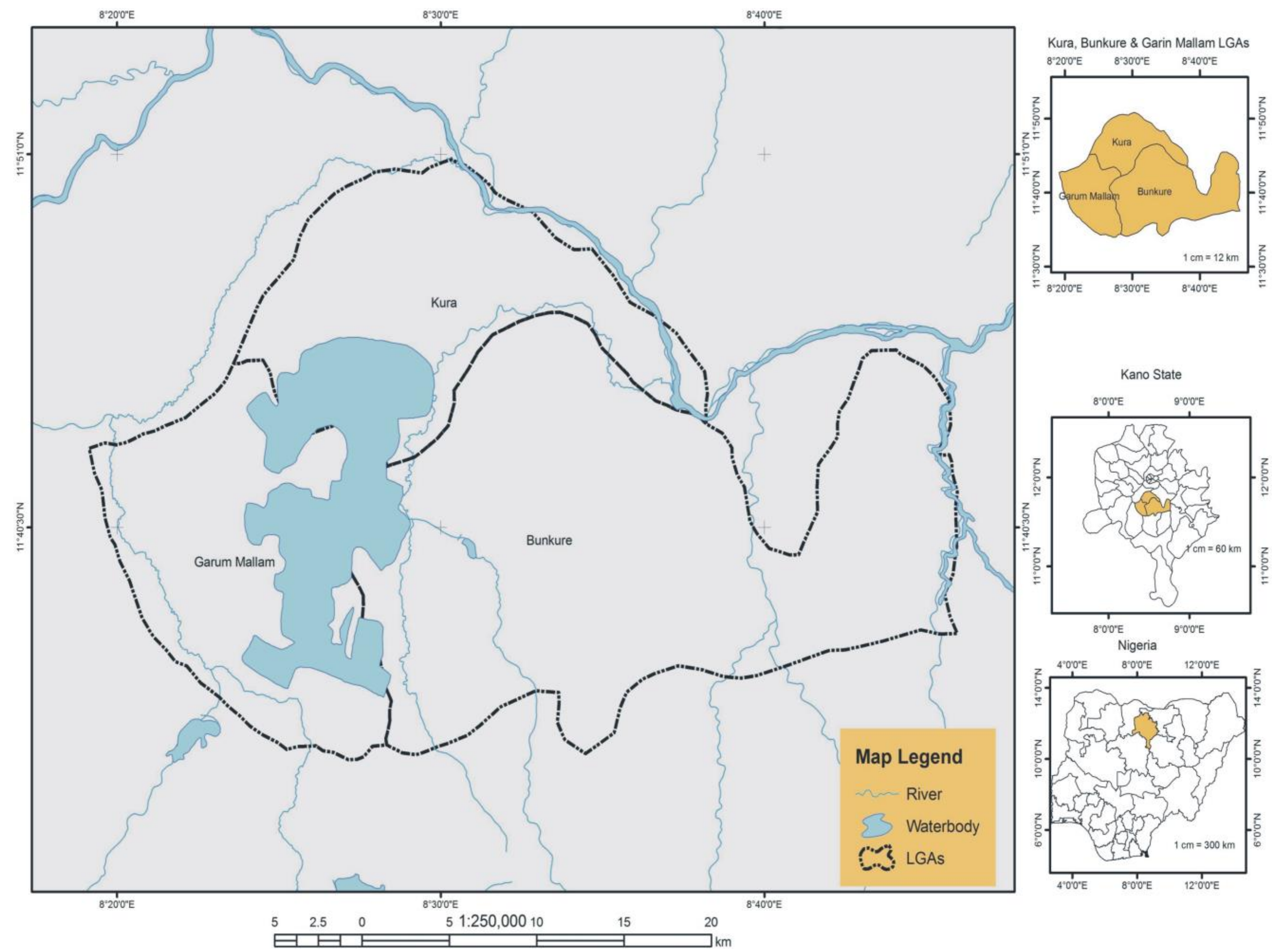


Figure 1: Location of Local Government Areas of the Study Area

Source: KANGIS 2017

1.7.3 Relief and Drainage

The relief of the project area can be described under two distinct zones: the high plains and the lower Chad plains.

The high plain is part of the Hausa highland whose elevations range between 450 and 700 meters above sea level and occupies the western part of the project area. The high plains are areas of low relative relief usually less than 30 meters except where group hills occur. In other words, there are few isolated group of hills that rose more than 100 meters above the plains. Most of the hills (both grouped and isolated) as reported by Olofin (1987) are outcrops of the rocks of the basement complex over which the plains developed.

The lower Chad plains: The lowest relief unit of Kano River Project and consists of the plain developed essentially on a sedimentary structure that is referred to Chad Formation. The unit also includes the transition plains west of Hydro-Geological Divide which developed on the rocks of the basement complex. They are lower than 450meter above sea level and they belong to the Chad Formation (Olofin, 1987). These plains provide the surface land for irrigation of the study area.

The natural drainage drains towards the northeast i.e. to Lake Chad, although the headstreams rise from the south, south-west, and west. The Kano River rises from the foot slopes of Jos Plateau from the south and flows generally to north and northeast (Olofin, 1987). This river provides water for irrigation of the project area of Kano River Project I.

1.7.4 Climate

The climate can be classified as tropical dry and wet type; the annual mean rainfall is between 500mm and 900mm. A period between mid-May and mid-October is regarded as wet season. Leows and Ologe (1981) mentioned that the rainfall is characterized by heavy storms whose average intensity is about 500mmhr-^{1}.

Leows and Ologe (1981) also described that the area has two main seasons, the cool dry season which lasts from November to February during which the mean monthly temperature is between 23^{0}c and 26^{0}c with an annual range of 13^{0}c. The Harmattan winds prevail at this time. This period is usually followed by hot and dry seasons which last from March to mid-May. The mean monthly temperature during this period is in excess of 30^{0}c and a daily range is up to 20^{0}c. The second is followed by wet season which is warm with a mean monthly temperature of about 26^{0}c and annual range of about 10^{0}c increasing to 13^{0}c in September.

Evapotranspiration is generally very high throughout the year since potential evapotranspiration is not less than 120mm for any month between June and September, but in dry year positive water balance may occur in July and August with the mean annual evapotranspiration is in excess of 180mm (Leows and Ologe, 1981). This prevailing climate condition is an asset for inducing agricultural production with irrigation technology in place.

1.7.5 **Geology**

The study area is underlain by dissected peneplain developed on the crystalline Pre-Cambrian rocks of the basement complex which consists of dominant rock types of various descriptions such as granite, gneisses and schists, glimmer, and quartzites. Veins of pegmatite, aplite, and quartz are found frequently. The inselbergs in the area are granite course porphyroblastic with large feldspar and phenocrysts. They are considered to belong to the Older Granites which are an intrusion in the older metamorphic rocks (NEDECO, 1974) and overlain in many areas by moderately thick regolith derived from the wind drifted materials up to a meter thick (Leows and Ologi 1981). The thick regolith facilitates the development of fertile soils for a variety of agricultural crops including rice.

NEDECO (1974) detected different geological formation apart from basement complex of different rock types and minerals as follows:

- development of a weathered zone of the lateritic layer of an average thickness of 0.91meter – 1.52meter;
- a top layer of unconsolidated material of various composition and origins overlying the laterite of 0.30meter – 6.1meter and more;
- older alluvial deposits underlying aeolian drift of the subsoil which consists mainly of sandy, clay and loams or sandy and clay characterized by strong iron mottling with red and reddish brown colour;
- the younger aeolian deposits commonly referred to as drift sands which spread over the country mainly in the late Pleistocene / early Holocene;
- and finally, the youngest alluvial deposits along the Kano River which form the very fine to fine texture sands in pools and depressions of fine-textured clay are formed.

Table 1 shows the description of geological formation and parent material mineralogical and chemical composition of the Kano river basin irrigation project.

Table 1: Geology Formation and Parent Material Development in Kano River Project I

Geological Formation	Parent Material
Peneplain of the Pre-Cambrian Basement Complex	Unconsolidated material of aeolian / alluvial/colluvial origin over weathered solid metamorphic rocks; mainly gneisses, schists, and quartzites
Pleistocene alluvial terrace	Alluvial with aeolian component; mainly sands, loams and clay
Holocene alluvial terrace and recent floodplain	Alluvial sands, clay, and some gravels

Source: NEDECO (1974)

1.7.6 **Soils**

The soil of Kano River Project area belongs to Entric Cambisol in FAO/UNESCO system. They are moderately deep and well drained with sandy, loamy texture surface layer and clay loam textured subsoil. Maurya (1993) noted that most of the soils are underlain by iron pan at a depth below 80cm-150cm which form the impermeable layer. The depths of the soils are shallow and make it waterlog easily during the wet season. The character of the soil makes the environment conducive to rice cultivation.

The soils of the study area had been developed and described according to physiography by NEDECO (1974) and differentiated into four soil types as the soil of the upland, the soil of the high terrace, the soil of the lower terrace and eroded soils and rock outcrop. But with regard to this study poorly drained soils of the upland are interested in this study because these are the soil recommended for rice production by NEDECO (1974).

1.7.7 **Vegetation**

The natural vegetation of Kano is the Sudan Savanna type. The trees are usually characterized by broad canopies and they are hardly taller than 20 meters. In the study area, five different types of vegetation can be distinguished as reported by NEDECO (1974).

i. The **cultivated parkland** is dominant in the project area and most of the irrigation lands are located in it and it is under permanent cultivation with some area reserved for land fallow and useful trees that are left standing or planted. Typical trees of this environment are the *Pakia clappertoniana* (locust tree), *Butyrosperum pereedoxum* (shea), *Acacia Albida* (winter thorn) and *Vitex doniana* (black blum). The averag*e density* of the trees is 2 – 3 trees per acre. In and near villages *Adansonia digitata, Phonix nucifera, Barassus aethiopum* are common. Along the many cattle tracks in the study area are *Acacia pinnata, Zizupus spinachristi*, *Pilostigma reticulate* and

Dichrostachus glomerata. Typical grasses are *Chloris pilosa*, *Andropogon gayanus* (gwamba grass) and *Cyperus species.* Imperata *Cylindrica* (spear grasses) often grows abundantly on soils with a slightly impeded, intermediate drainage (units Pa_3, HTa_3 and Pab).

ii. An **open savanna woodland** occurs in the Bunkure Forest Reserve which vegetation pattern had been changed considerably by frequent burning and grazing. Common species are *Combretum glutinosum, Terminalia avicenniodes, Commiphora Africa, Sclerocarrya birrea* (fruit), *Ximenia Americana* (spiny plum), *Annona senegalensis* (wild custard apple), *Guiera senegalensis* (Egyptian mimosa). Along the gullies, there is a higher stand of trees apart from the above-mentioned species, such as *Daniela oliveri* and *Khaja senegalinsis* (mahogany).

iii. **The low shrub** is extensively used for grazing and eroded bad land along streams and gullies both are characterized by a higher run-off, poor drainage and sun aerated soil which after the rain dries out rapidly; *Acacia seyal* (flowers and leaves) *Balanites aegyptica* (desert date) and *Cassia singuana* are abundant. In some places *Tamarindus indica* (unripe pods), *Anogeissus leicocarpus* and *Diospyrus Mespilformis* are common.

iv. **Scrub woodland** is around Garun Babba settlement. It is found in places where fallow growth develops with common species as *Piliostigmareticulate, Pilirostigma thonnigii* (pods), *Combretum glutinosum, Annonasenegalinsis, Diospyrus Mespilformis* and others. The preserved trees are mainly *Perkia clappertoniana, Barassus aethiopum,* and *Butyrosperum pereedoxum.*

v. **Low grass-scrub land** is found on the poorly drained soils of the recent terrace (unit LTb) along the Shimar and the Kano River. The scrubs that have developed there are mainly *Mimosapigra.* Other, grass species are *Andropogon gayanus, Eragrostis ciliaris, Brachiari Stigmatisata and Penicum Laetum* etc. (NEDECO, 1974). These grasses are hardly growing taller than 1.5 meters at maturity except in water favoured spot areas (Olofin, 1987). The vegetal covers permit the cycling of soil nutrients effectively and thus pose no problem to the use of farm machinery in the study area.

1.7.7 **Economic Activities**

The economic activity of the residents is predominantly agriculture; some also engage in fishing. The nonfarm activities include trading, weaving, butchering, barbing, electric work, maintenance of automobiles, animal rearing, building, Qur'an teaching, sewing and rice milling. These activities are performed mostly during the dry season; in recent times increasing demand for such services has made them essentially available every time.

1.7.9 **Justification of Choice of the Study Area**

The Kano River Project was chosen for this study because of the following reasons:

i. it is the largest in scale (about 12,000ha See Figure 2), capital-intensive, technically complex and partly mechanized irrigation project in Nigeria introduced to modernize farming system (Adams, 1991);

ii. the Kano River Project is one of the alternative strategies to improve rain-fed agriculture, increase use of modern fertilizer, feeder roads, and improve access to remote areas which were neglected as components of rural development;

iii. the introduction of river project in Kano shows that the government believes that the best way to improve productivity and reduce poverty is by bringing modern technology and skilled advisers into rural areas of Kano River Project 1 (Baba, 1989);

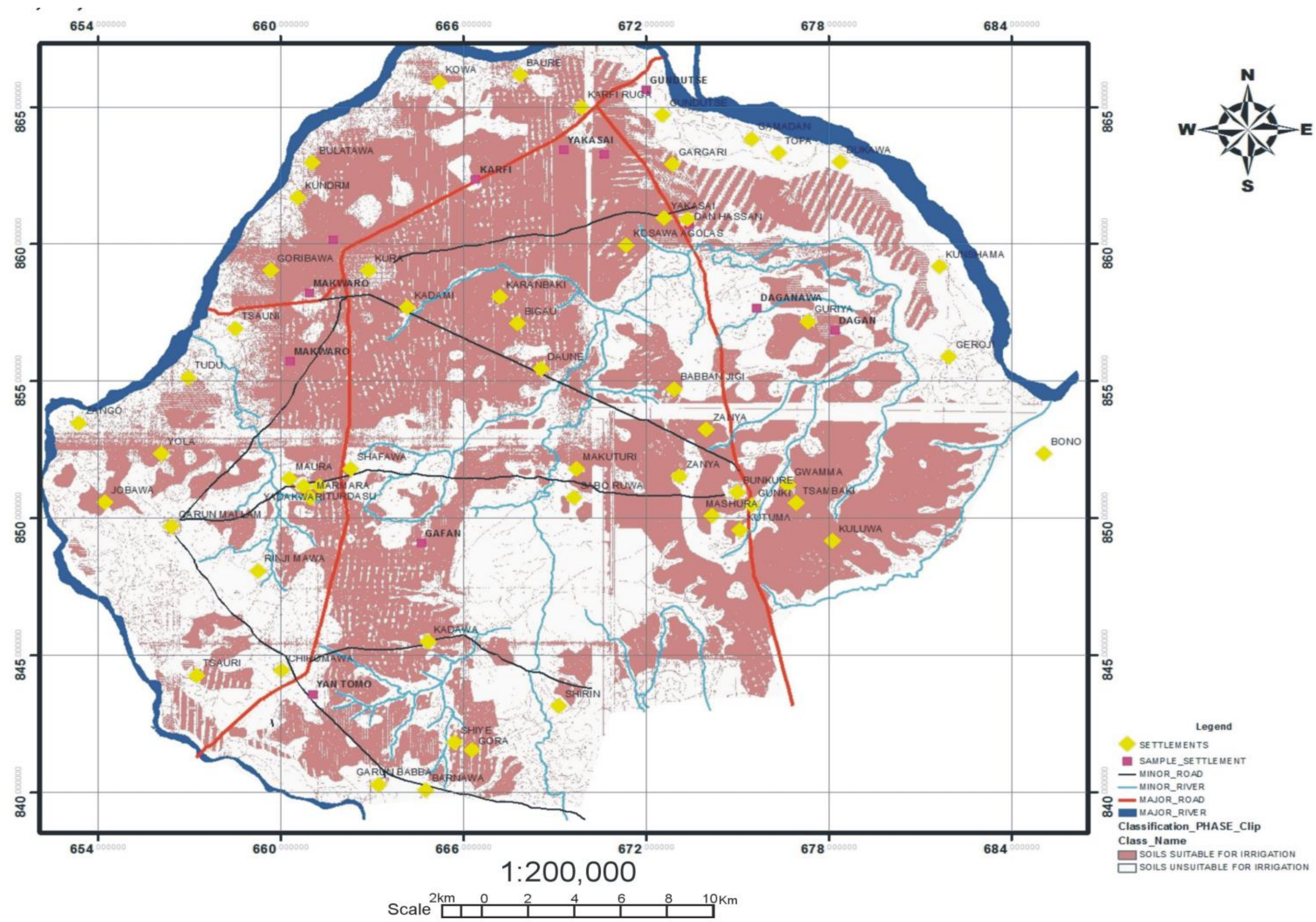


Figure 2: Study Site

Source: KANGIS 2017

iv. millions of Naira had been committed to developing irrigation in Kano River Project for land clearing of field structure, resettlement, and infrastructures which include canals, electricity etc. Some researchers perceived large-scale irrigation as having failed to reduce food deficit or increase food productivity in Africa; Kano River Project 1 is among the least criticized irrigation projects in Africa. This reason justified the choice of Kano River Project I as the study area.

The poor performance of large-scale irrigation project in Africa convinced Kimmage (1991) to recommend small-scale irrigation since large-scale irrigation cannot be able to provide food security. Newson (1997) saw the recommendation of Kimmage (1991) as misguided for people to think of small-scale irrigation as the universal solution which is alternative to large-scale irrigation in future.

Based on the above, Kano River Project Phase I is purposely selected among the other irrigation projects in Nigeria to examine the soil property changes and socio-economic constraints that can affect the functionality and sustainability of river basin irrigation system.

1.7.10 **Justification of Rice as crop for the study**

Among various crops recommended for cultivation in Kano River Project I rice (*oriza sativa*) was chosen for this study based on the following facts:

1. according to Leong (1976) rice is grown rapidly in tropical conditions and has greater yields per hectare than any other cereal and Nigeria is geographically located in tropical Africa;
2. Nigeria is Africa's foremost consumer and producer of rice and is also among the leading rice importers in the world (USAID 2009);
3. is a stable food that is consumed by every Nigeria and according to USAID (2009) it is an important food security crop;

4. Rice is an economically important commodity in Nigeria. It is cultivated in almost all the States of Nigeria (FMAWR 2007);
5. Nigeria is the second largest importer of rice in the world, spending more than 356 billion naira (2.24 billion US dollars) annually on rice import (FMARD, 2011);
6. Over the years, rice has become an important component of the Nigerian diet especially for the urban dwellers one of the reasons why Kano River Project I was established i.e. to perform such function for urban Kano;
7. Akanji (1995) noted that the rise in demand for rice in Nigeria is attributed to population growth, increase in levels of income and rapid urbanization and its attendant changes in family occupational structures;
8. yields and output must be raised to meet the rapid demand of population increase, in order to reduce dependency on import rice and save the country billions of Naira spends for rice importation annually.

CHAPTER TWO

CONCEPTUAL ISSUES, THEORETICAL FRAMEWORK, AND LITERATURE REVIEW

2.1 Conceptual Issues

2.1.1 Irrigation

The concept of basin irrigation has been viewed and described by many scholars as a process of applying water to the farmland for crops production using surface water such as reservoirs, streams, channels etc., or subsurface water like tube wells, well-boring, wash bore wells and shallow aquifers. Oguntoyinbo (1971) describes it as the response to flood control and inadequate water for agriculture. Punial and Pande (1979) view it as a condition necessary for insufficient rainfall and poor distribution of rainfall in the agricultural producing area. Shanan (1987) defines irrigation as 'the application of water to the land for purpose of supplying moisture essential for plant growth'. Similarly, Daniel (1987) observes it in a dry condition due to evaporative demand of the atmosphere which continuously creates stress for plants and therefore requires water. Omara-Ojugu (1992) views irrigation as a supply of surplus water in order to supplements rain or groundwater to sustain crop production. Finally, Ibrahim and Abdulkadir (2010) described irrigation as those practices by human agency that are adapted to supply water to an area so as to reduce the length and the frequency of the periods in which a lack of soil moisture is the limiting factor to plants growth. The main theme of these definitions is central to the artificial water supply to sustain crop production in the area of an annual deficit of water supply and distribution.

2.1.2 **Irrigation Management**

The management of river basin natural resources has been translated into several large-scale irrigation projects. Irrigation management has been defined by the International Irrigation Management Institute (I.I.M.I, 1991) as the process by which organizations or individuals set the objectives of a system, determine appropriate conditions, identify, mobilize and use resources to attain these objectives and ensure that all activities are carried out without any adverse effect. Newson (1997) defines irrigation management as the human intervention to modify the spatial and temporal distribution of water occurring in natural channels, depressions, drainage ways or aquifers and manipulation of all or parts of this water to improve production of agricultural crops and enhance the growth of other desirable crops. This simple technical statement when superimposed upon the drastic needs of the world's drylands in developing countries to feed growing populations and human tradition of hydraulic civilizations helps to explain why the government so avidly pursue the development of irrigation potential for food production.

2.1.3 **Sustainable Development**

In an effort to link the issues of environmental stability and economic development, the Brundtland Commission published a report in 1987 titled 'Our Common Future'. This report provided the definition of sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (United Nations General Assembly, 1987, p. 43). Even though the concept is vague according to Rachel (2015) but it aims to maintain economic advancement and progress while protecting the long-term value of the environment; it provides a framework for the integration of environmental policies and development strategies" (United Nations General Assembly, 1987).

Although there are many definitions of sustainable development; the most often used definition is the one proposed by the Brundtland Commission (Cerin, 2006; Dernbach, 1998; Dernbach, 2003 and Stoddart, 2011). The definition implies to achieve the overall goal of sustainable development (SD) which concern with long-term stability of the economy and environment through the integration and acknowledgment of economic, environmental, and social concerns throughout the decision-making process.

2.1.4 **Efficiency**

Pestieau and Tulkens (1993) define efficiency as the degree to which the observed use of resources to produce outputs of a given quality matches the optimal use of resources. The work of Farrel (1957) defines efficiency of a firm for this study into separate concepts as follows:

a. Technical efficiency measures or product efficiency measures: The firm uses available inputs in order to achieve outputs and products. It determines firm maximum outputs using a given factor of production;

b. Allocative efficiency measures: the point of maximum profitability at a given market prices for inputs and products. It determines how the factors of production are used in proportions that ensure maximum outputs at a given market prices;

c. Scale efficiency is the extent to which a production unit can take advantage of the return to scale by altering its size toward optimum scale. Chun (2005) defines scale efficiency as the most productive scale size.

The fundamental idea of measuring all efficiency is the goods quantity and services per unit of input. Efficiency can be measured in terms of two separate concepts (technical and allocative efficiency). Technical efficiency (TE) measures the ability of the firm to use available inputs to produce a maximum output. While allocative efficiency (AE) measures how far a firm is away from the point of maximum profitability given by the use of existing market price of inputs and products. According to Dalton (2004), efficiency analysis is concerned with measuring the distance between a frontier by industries and firms by leaders, who efficiently allocate inputs in a nonwasteful manner to achieve successful optimization process. The Farrell (1957) stimulated interest in the area of production frontier estimation and led to the development of several techniques for the measurement of technical, allocative and economic efficiency.

The Cambridge Economic Policy Associates (2003) reveals that the product of the two measurements of efficiency (technical and allocative) gives overall economic (or cost) efficiency (EE) using the formula:

EE = TE*AE

While:

EE = Economic Efficiency

TE = Technical Efficiency

AE = Allocative Efficiency

This implies that for a firm to have overall efficiency or a 100 percent score in economic efficiency; the firm must be efficient in both technical and allocative efficiency or must score 100 percent in both technical and allocative. Aigner *et al.*, (1977) claimed that the measures cannot be applied to production function which conforms to the law of variable proportions and can be depicted graphically.

2.2 Theoretical Framework

Theories are sets of statements about the relationship that have been established with a certain level of confidence and which establish the basis for future investigations (Adedayo 2003). The important theoretical basis for this kind of research work include but limited to the following:

2.2.1 **Input-Output Model of Agricultural Investment**

This is a concept formulated by considering areas as points, such as like Von Thunen Locational Model. In this model, the distribution of farmers and factors of agricultural products are treated as if they were at a series of discontinuous points with zero transport cost separating them.

The simplest and commonest types of input-output models for inter-industrial activities were first developed by Leotieff (1953) as a device for examining natural economics. Chenery and Clark (1959) wrote input-output models in group production activities into a number of sectors, e.g. agriculture, manufacturing industries, services, and finished goods. These have subsequently been developed into techniques for analyzing economics at the regional level by Isaard (1960) and Moses (1960). These models are relatively technically complex based on an input-output matrix.

This model was used for comprehension of the distribution of agricultural production by Peterson and Heady (1956), and Carter and Heady (1959). They used the models to analyze the interrelationships and the degree of interdependence among the various regional and commodity sectors of agriculture and the effect of policy changes on the patterns of agricultural production. More recent studies based on input-output analysis are that of Jasbir Singh *et al.,* (1985) who identified the changes in agricultural productivity as affected by various inputs as well as by interrelationships and the degree of interdependence among them. It has been observed that the major attribute of this model is that it provides a detailed description of the interrelationship and linkages between the output and various input elements. To sum up, the input-output models explicitly recognize that changes in production in one sector are inevitably affected production in many other sectors and a corresponding variation in the inputs in these sectors. Jasbir Singh and

Dhillon (1994) observe that this model has proved very useful in the tasks of studying the impact of the determinants of the attributes for planning economic development and analyzing the locational implications of economic development in a region. Besides these, the model is particularly valuable for determining the impact of increased investment in one region or sector of the economic activity. The model takes into consideration for determining the profitable level of input use/cost. As observed by Emery *et al.*, (2005) it is justified that profit will be maximized in any production when there is equality between marginal product (MP) (increase of output that result by the addition of one quantity of input) and average product (AP) (total output divided by its total variable quantity of input) and zero marginal products (MP). This implies that the marginal value product (MVP) is equal to marginal input cost (MIC). This shows the rational area of the input-output known as a production function. This area of input-output used is referred to as stage II of the production function that is an area between maximum average product (MAP) and maximum total product (MTP). Emery *et al.*, (2005) used it to illustrate the production function and law of diminishing returns used quantity of seed planted and quantity of corn harvested (figure 3).

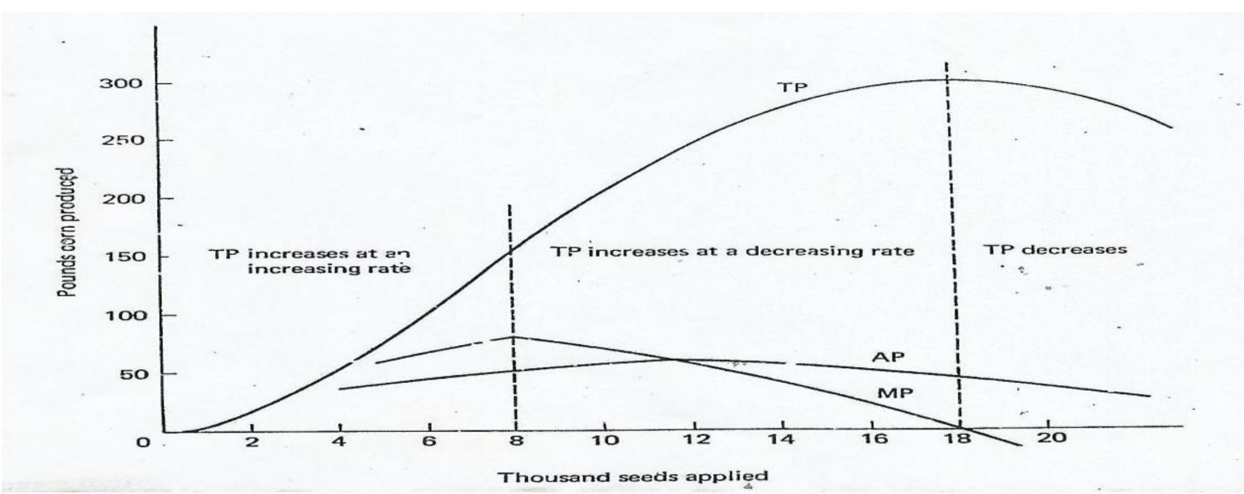


Figure 3: Inputs and outputs explained the production function and law of diminishing returns

2.2.2 **Decision Making Model**

Ultimately, the aggregate of an agricultural location pattern is the result of the aggregation of a large number of individual decisions of farmers. Economic factor alone does not influence a farmer's decision; social and psychological factors (non-economic variables) also play an important role in determining his decisions. In fact, the process of decision making is in many ways the most fundamental of all because this brings to light some interesting problems of the agricultural pattern.

Decision-making models based on behavioural concept were developed in the study of Wolpert (1964) which dealt with the problem of optimizing production, which suggested that actual decisions will be different from the decision of the economic man of a particular interest. The concept of economic man is a normative one because he takes decisions under the rational assumption of obtaining the optimum benefit.

In an investigation of farming in central Sweden, Wolpert (1964) made an attempt to compare spatial variations in the actual labour productivity per farm with a pattern that would exist if all the farmers were economic men (optimizers) i.e. potential labour productivity. The pattern of potential labour productivity represents the decision making to use optimum resources at the disposal of farmers possessing superhuman powers as does the economic man. Wolpert (1964) suggested that the gap between the actual and potential (optimum) labour productivity expresses the extent to which the farmer deviates from latter. Besides, Wolpert (1964) demonstrated that the decision-making process has a spatial dimension and some of the elements affecting this process may be expected to differ spatially among different people. Therefore, the investigation referred has been extended to the spatial dimension. The concept is used in this study for the interpretation of the behaviour of a community in the geographic region since the results and consequences of decision making of a community are more easily observable on the landscape.

The decision-making model is regarded whether or not to produce. The level of production depends upon the various costs of production and return expected in the market. Emery *et al*., 2005) also justified the need to make a rational decision in which profit will be maximized when the increase in total costs (TC) result from a one-unit increase in production that is the marginal cost (MC) and the corresponding increase in total revenue (TR) which is the marginal revenue (MR). Therefore, profit will be maximized when marginal cost (MC) is equal to marginal revenue (MR).

2.2.3 **Diffusion Model of Agricultural Innovation and Technology**

The extent of visual information about the environment is too small to make a rapid learning of farming development, besides other sources of information which comprises the interaction between farmers and diffusion of learning information, experiences, and new ideas from innovating centers with groups of farmers. The Oxford English Dictionary (2005) defines diffusion as spreading; dispersion; wide distribution, dissemination, and the condition of being diffused. Investigations concerning the dissemination of various phenomena over the surface of the earth formed the basis of major geographical, historical, archaeological, sociological and epidemiological research efforts since the 1920s. The main aim of diffusion analysis was to account for the dispersal of cultural traits, agricultural or diseases from a given origin. In the United States, the Berkeley group led by Carl O. Saner played an important role in the development of diffusion type analysis in American Geography (Clark 1954).

Roggers (1962) reviewed many of such studies, whose aim was being the innovations of new agricultural techniques. Again these studies had shown that in areas whereas mass communications provide the information, it is usually the personal contact that minimizes resistance to new ideas. Hagerstrad (1953) was the first geographer to develop a model to describe the diffusion of an innovation over space. Hagerstrad (1953) put forward the idea from a historical study of Turnerian schools, and the geographical studies of diffusion of the Berkely School. Hagerstrad (1952) diffusion models of early 1950s are outstanding and formed the basis of most geographical models building effort since then. Hagerstrad (1953) developed a four-stage model explaining the diffusion process; namely the primary, the diffusion, the condensation and saturation

In 1953 Hagerstrand selected the Ashby District of South Central Sweden to study the spatial pattern of acceptance of various new agricultural practices by the local farmer. He designed three models to stimulate the diffusion pattern over space, and one of the models fitted the observed diffusion patterns of a number of innovations which was well remarkably.

The Hagerstrand's Model was applied to the diffusion of technical innovations and applied for understanding the popularity of a particular type of cropping pattern based on the spread of information. Information concerning innovations is disseminated by using the medium of communication by stems through information flows namely, technological channels of communications and personal contacts for mass communications.

2.3 **Literature Review**

2.3.1 **Planning and Utilization of River Basin Resources**

The River basin is often the most appropriate unit for managing water and land resources to gain the full benefits of multipurpose use and to coordinate the activities of various agencies and other bodies interested in resources utilization for their different purposes.

Newson (1997) asks the question, 'is there a rationale by which the terminology of water (basin) development could have a more acceptable social focus when viewed from the center and periphery of a developing nations'? Marchand and Toorstra (1986) first demand the treatment of the entire river basin as an ecosystem and developed this theme through a set of impact matrixes and provided guidelines for river basin management now available in Newson (1997) as:

- preservation or improvement of spontaneous functions fulfilled by the river such as restoring erosion/sedimentation processes, through countering increased silt loads cause by upstream erosion (improvement of watershed management) and preserving the self-purifying capacity of the river, through combating pollution (water treatment plants, at the source and anti-pollution measures);
- development of sustainable intensive exploitation functions by developing small-scale projects such as irrigation, fishponds, and forestry;
- provide a guiding principle for regional planning which can be used to intensify or introduce intensive land and water use systems at locations within the best soil and superior climatologically and market conditions.

River basin development continues albeit at different rates and taking different forms. It is tempting to say that the problems faced by those developing river basin resources in developing countries are not different from those in developed countries. River basin regional development is feasible with the integrated contribution of resources management for rural, human, urban and water. The real issue, therefore, of sustainable river basin management, wherever it is, requires an application of the knowledge of rural, water, urban and human resources management for regional river basin development against an informed perception of the enormity of the resources integration required (Figure 4).

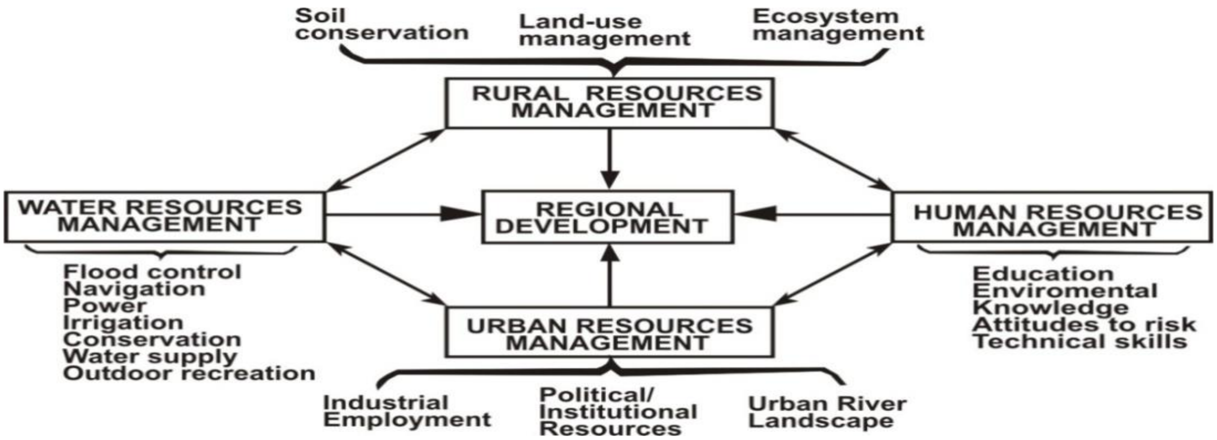


Figure 4: River Basin Management (Adopted from Newson, 1997)

Holistic thinking has a special visionary role in helping politicians and other people to understand that rapid 'fixes' are impossible, but that strategies can, and must keep us on the rails. Newson (1997) indicated that it is appropriate to judge the degree at which river basin management has followed the forms of sustainability laid out by Pearce (1993). Newson (1997) was of the opinion that the important element of any river basin development scheme must be refined to the point where they can be interactively managed over time to reflect changing needs of society and the environment. He further explains that a system which is destabilized physically (geomorphological) is much more difficult to restore than a chemically polluted system. Napier (1990) revealed the successful soil conservation programme that can be used to tackle the problem and instability of river basin as:

- development of a political constituency which supports action to reduce the social, economic and environmental costs of soil erosion;
- allocation of extensive human and economic resources on a long-term basis by national governments to finance soil conservation programme;
- creation of government agencies commissioned to address soil erosion problems with sufficient autonomy to be immune from short-term political influences;

- development of well-trained professionals to staff soil-conservation agencies;
- development of informing farmed farm population which is aware of the causes and remedies of soil erosion; development of a stewardship orientation among land operators to protect soil and water resources;
- creation of national policies which place a high priority on protection of soil and water resources; creation of national agricultural development and soil conservation policies and programmes which are consistent and complementarity;
- creation of national environmental policies which are consistent and complementarity;
- development of physical and social scientists who are committed to the generation scientific information which will contribute to the creation, implementation and continual modification of soil and water conservation policies and programmes;
- creation of an interdisciplinary professional society committed to the maintenance of the environmental integrity of soil and water resources; and
- the emergence of political leadership which will be willing to implement policies and programmes which some segments of the agricultural population will find oppressive.

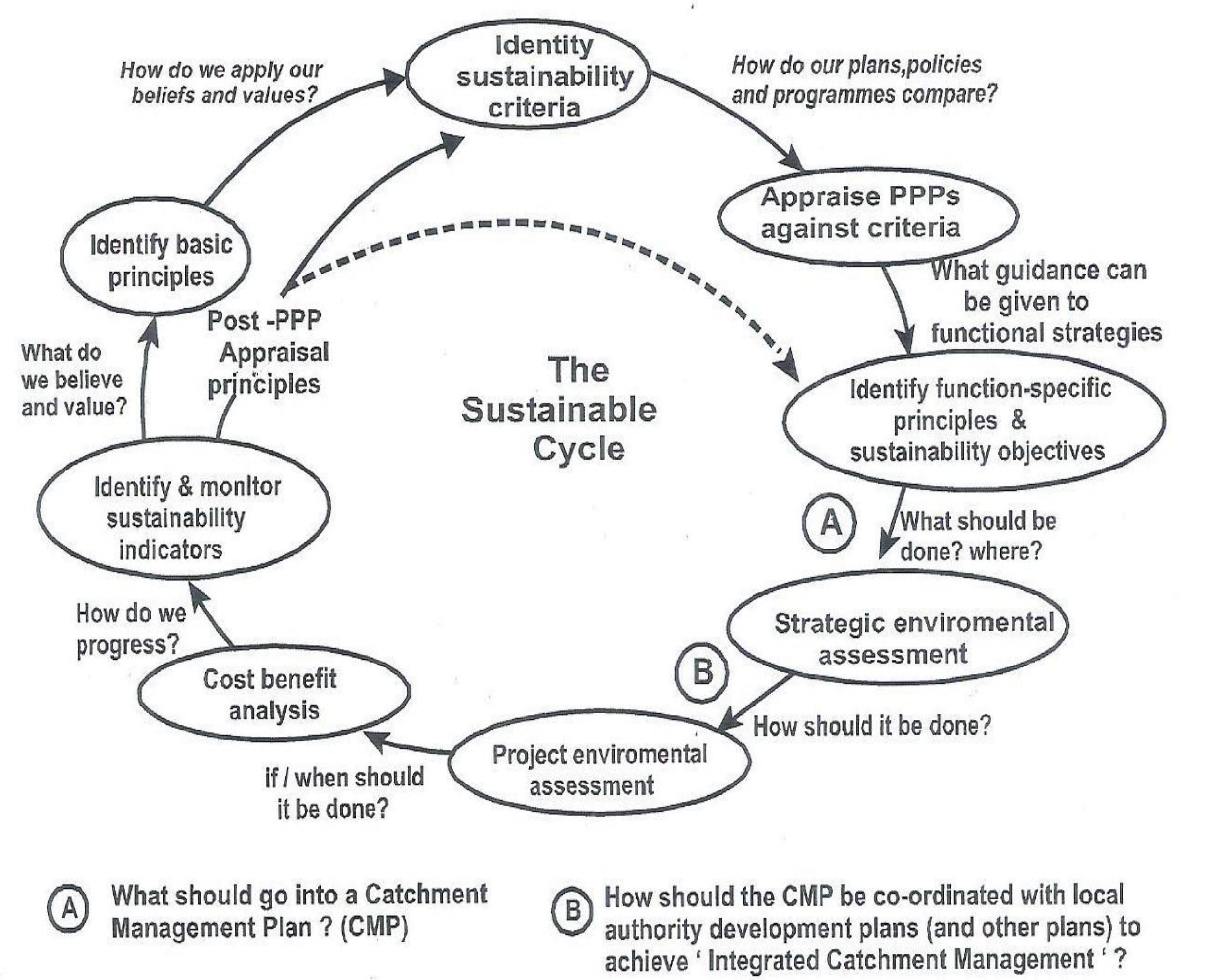
Reference was made of water pollution as a technical problem in basin management and restoration of unpolluted condition as a challenge to law and to economics as much as it is to science. Restoration of a physically degraded river system is a daunting task and the requirement to do so should be avoided by anticipation and good science.

2.3.2 **Sustainability in River Basin Planning**

Buller (1996) commented that catchment planning is a half step to sustainable water management. Buller (1996) made this claim on the grounds that catchment planning in its current form gives weight to system parameters, negotiates strategies at a local level and integrates the planning and management of land and water. Base on this it is, therefore, necessary to examine the degree to which river basin management has followed the forms of sustainability laid out by Pearce (1993) which show how far the National Rivers Authority had complied with sustainable agenda at the time of its evolution to the Environmental Agency in England and Wales.

The caution was clearly stated but the agenda is complex and checks are everywhere in the literature of official agencies. For example, the United Kingdom Environmental Act 1990 states that the mission of the Environmental Agency is to protect or enhance the environment to make a contribution towards attaining the objective of achieving sustainable development that was considered appropriate.

In this spirit, Newson (1997) reported that the Themes Region of National Authority was launched in 1995 with fully consulted Themes 21 document in which all the authority's duties are given sustainability principles and practice. Sustainability in practice in figure 6 illustrates sustainability in cyclic form. It explains what should go into river basin catchment management plan and how the river basin catchment management plans can be coordinated with a local authority river basin management plan to achieve an integrated river basin catchment management. Figure 5 is taken from Thames 21 document and shows the key questions (cyclicity) of corporate sustainability.



Fi

gure 5: Sustainability in practice (Source: Thames Region, National Rivers Authority, 1996).

Figure 7 shows sustainability in Practice with the transition to sustainable programme in UK water. It illustrated the present situation of single functional investment through, asset management, river basin catchment management planning and river basin land use planning and control to achieve integrated river basin catchment planning for future sustainable development for the water environment. Gardiner (1996) developed the relationship further. He illustrates the general pathways towards sustainable development which illustrated in Figure 6.

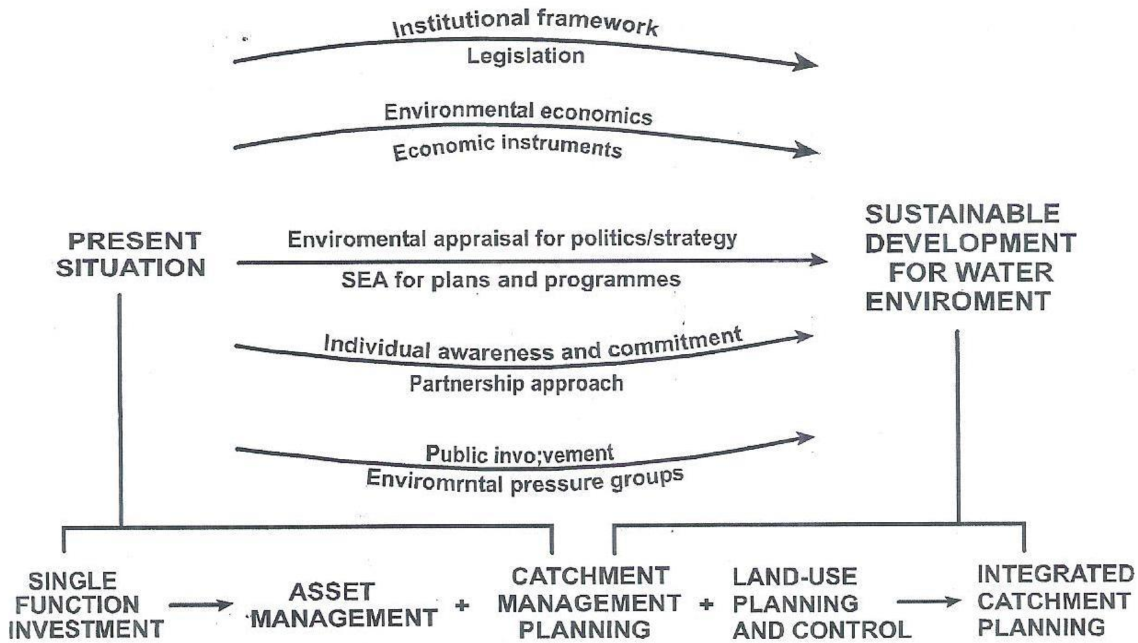


Figure 7: Sustainability in Practice, Transition to Sustainable Programme.
Source: Gardiner (1996)

2.3.3 **Technical Issues in River Basin Management**

The technical problems facing the management of the river basin include restoration of rivers wetlands and to lay emphasis on the overall ecosystem approach and as a warning that developed nations which have damaged the spontaneous regulators of their river basins are now making large investments in reinstating them.

The first area of technical facilitation required by sustainable development of the basin's resources is that of controlling soil loss by erosion and salinization. Soil erosion becomes a problem when its rate accelerates above that of other landscape development processes (Newson, 1997). Land resources can be damaged by soil loss from pollution, human settlement, soil erosion and declined by soil fertility status when their rates are accelerated above that of landscape development processes. Soil loss becomes visible, it becomes a river basin management problem when it constraints agricultural production and leads to river and reservoir sedimentation. Exploitation of the river basin can damage the soil through mismanagement of the interface system between lithosphere, biosphere and the atmosphere which takes many forms (Figure 7).

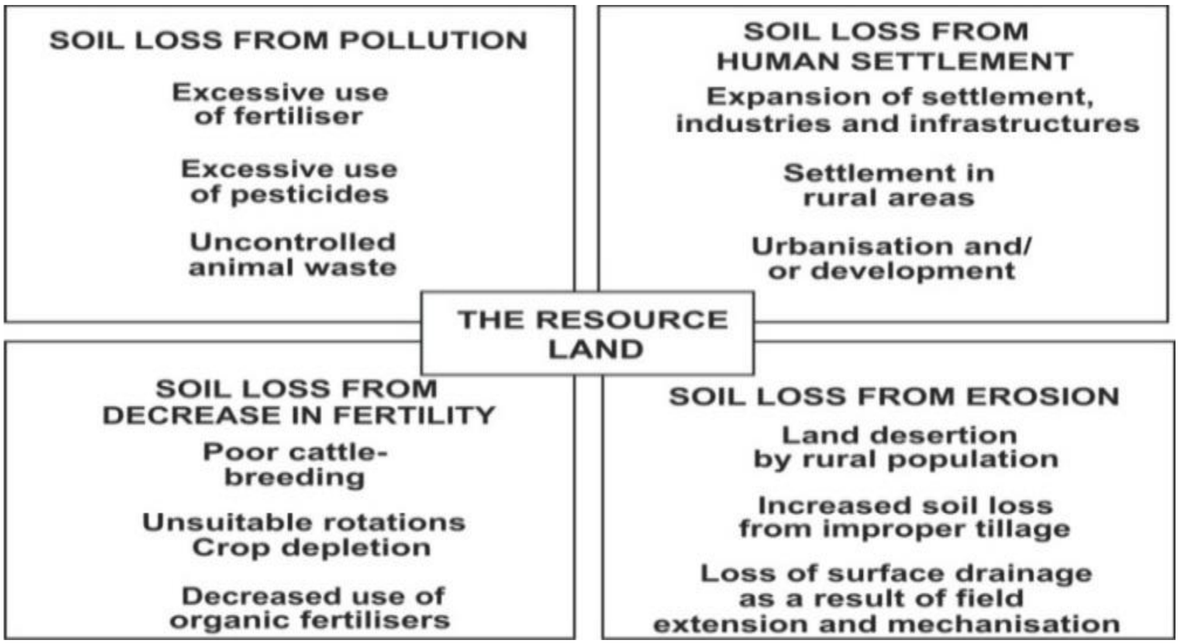


Figure 7: Mismanagement of Land Resources: (modified by Newson (1997) after Guerrieri and Vianello, 1990).

2.3.4 **River Basin Development Authorities in Africa**

Agriculture still dominates mankind's use of fresh water. In other words, a major proportion of the water used is by irrigated agriculture. According to Earthcan (1984), no any other economic activity uses as much water per unit area as in agricultural application. It is reported by Earthcan (1984) that yet 15% of the world's agriculture which benefits from irrigation contributes 40% of the world's food supplies. Figure 8 illustrates water used and returns from agriculture in developing and developed world; it shows that United State of America and the United Kingdom have the lowest water use and higher returns from agriculture than any country in the world per annum. While in the semi-arid area, there is highest water use and less return from agriculture per hectare.

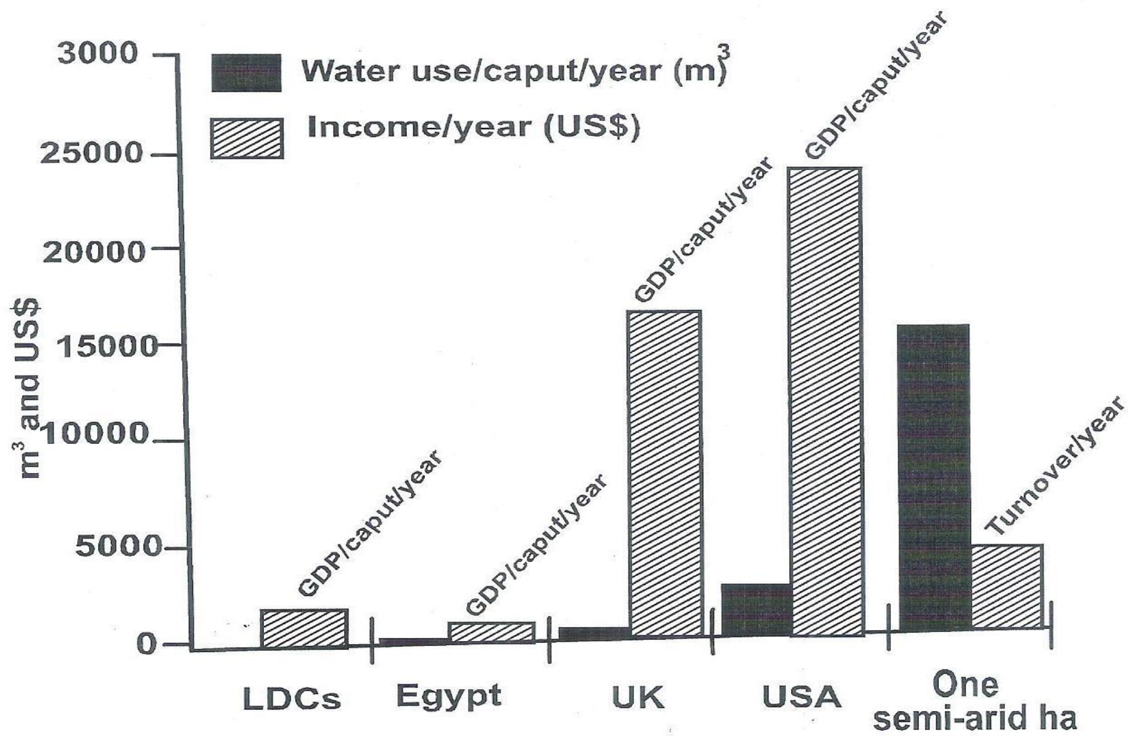


Figure 8: Irrigation and water use

Source: Earthcan (1984) and Modified by Allen (1992)

Chamber (1988) presents three domains of irrigation system: physical, human and bio-economic which emphasize their interactions should be given equal attention in the investigation of the feasibility of irrigation scheme and detailed planning. Figure 9 illustrates the linkages of the three domains that interact to develop an irrigation scheme system boundary. Newson (1997) emphasize for the wider need of comprehensive irrigation development planning using these three domains than merely via physical consideration alone. Other factors such as human (irrigation staff and farmers) and bio-economy (crops, livestock and market) facilitate the operation of irrigation scheme and sustainable development of edaphic factor.

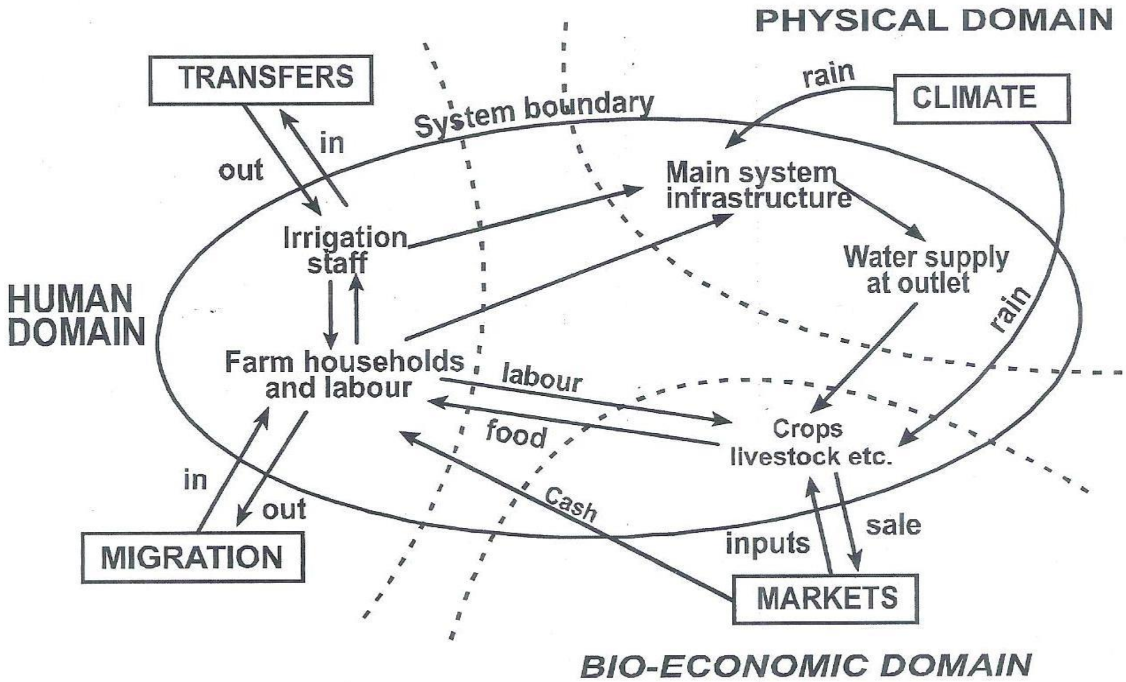


Figure 9: The domains of irrigation and their linkages (Source: Chambers 1988).

Considering the seemingly difficult task of integrating river basin management across nine nation's boundaries in the case of the Nile, the study briefly investigated the two model river basin authorities within national boundaries elsewhere in Africa. The Awash Valley Authority in Ethiopia reported by Winid (1986) and the Tana and Athi River Development Authority in Kenya reported by Rowntree (1990) show poor performance in food production. According to Salau (1990), Nigeria is also a nation with a success and failure in river basin planning apart from Kano River Project 1 that was least criticized; all other irrigation projects failed to provide sufficient food production in Nigeria (Ibrahim, 2007).

The calculation of benefits/costs ratios for river basin development in the Awash, according to the Winid (1986) markedly influenced by the balance between the cultivation of food and cash industrial crops. To date, the latter dominate this, in turn, determines the fate, in the development of native nomadic pastoralists who must be settled to form a labour force joined by other migrants from troubled region of Ethiopia. However, the Awash schemes for resettlements failed with the true costs of resettlement soaring. No attempt was made to integrate an improved traditional livestock sector with plantation of irrigated agriculture.

The study of Tana and Athi River Basin Development Authority (TARDA) was conducted by Rowntree (1990) and reveals that TARDA does not represent an effective framework for regional planning, neither on its own or through integration with district focus policy. Both are controlled by top-down planning, by political allegiance to the power elite and by the interests of foreign aid agencies. It may represent a forum through which technocratic solution to resources development can be promulgated but it is unlikely to achieve the type of grassroots development that is essential to effect lasting development programmes.

2.3.5 Failures of River Basin Authorities in Nigeria

River Basin Development Authorities (RBDA) in Nigeria date from 1960. In 1976 an extraordinary wide brief was laid down by the government on water resources development and flood protection. The wide brief also included watershed management (including afforestation), control of pollution, resettlement, land clearance, agricultural research, crop processing and rural water supply (Newson, 1997). Adams (1985) discusses the performance of River Basin Development Authority (R.B.D.A.) and reveals the shortcomings as follows:

a. Over-reliance on large projects: dam construction and irrigation development.
b. Inadequate economic, environmental and social appraisal.
c. Ineffective population resettlement.
d. Inadequate attention to watershed management and pollution control.
e. State and Federal rivalry as an obstruction to progress.

Salau (1990) demonstrated the mismatch between administrative and river basin boundaries and pointed to the need for R.B.D.As to have properly trained, properly remunerated personnel, as well as more power relative to the corporations.

Newson (1997) draws out certain common constraints on institutional river basin management in those developing countries with drylands resettlement problem:

a. In the last analysis, the control is in the hand of those creating the new settlements (e.g. dam-building) are always liable to be forsaken once farming begins.

b. If not overly centralized, multiagency authorities can potentially deliver a unified picture to the people on the ground; however, if they have forcibly moved from the humid (zones, or settled from a dry land nomadic lifestyle, there are still problems without much expensive attention to patterns of tenure, infrastructure and time).

c. Newly emerged nations, particularly those facing problems of infant democracy or totalitarian control often are troubled by regional rebellion verging on civil war. Local participation is therefore particularly difficult to realize. There are cultural clashes within the local population and within government, and the ministries are keener to compete than to collaborate.

d. The use of foreign finance, foreign expertise, and foreign personnel often with the aim of growing exotic crops for foreign consumption and supply of electricity to distant cities further threatens the local element of development schemes so widely seen as desirable.

2.3.6 **Constraint for Large-Scale Irrigation Schemes Management in Africa**

The drastic needs of the world's drylands for food to feed growing populations and the human tradition of hydraulic civilizations help explain why governments in all developing countries so avidly pursue the development of irrigation potential. Carter (1992) identified some of the reasons for poor performance of large-scale irrigation project as follows:

a. Problems at Conception and Planning Stage: such as inadequacy of conventional criteria for project acceptance; lower yields than anticipated in project plans; generally over-optimistic projection of benefits at conception/feasibility stage.

b. Inherent difficulties: such as problems of soil suitability and soil variability.

c. Financial/economic problems: very high development costs per hectare; inadequate importance attached to the funding of post-construction activities; heavy cost and low level of performance of irrigation agencies; Difficulties of collecting water charges.

The difficulties of irrigated agriculture are perhaps the most immediate of all global environmental problems. Carter (1992) lists the true parameters of irrigation potential that can be used to achieve better performance of river basin resources. This list forms the urgent research agenda for hydrologists, agricultural scientists, and more crucial social scientists. The list also forms the simplistic strategy that explains the potentiality of irrigation development which may be a viable option.

Chamber (1988) drew up the social balance sheet of large-scale irrigation for the poor farmers of the developing world which shows gains and losses by the poor under large-scale irrigation. Irrigation is not necessarily beneficial according to Guijt and Thompson (1994), yet it is seen as a development panacea (Oriola, 2006). Turner (1994) introduced another theme issue of land use policy on small-scale irrigation which is alternatives to large-scale irrigation.

After review of river basin development authorities in Africa; the main issue of large-scale irrigation schemes was, in fact, a target of economic success. For example, the Gezira Irrigation Scheme in Sudan was quoted as a model similar to Tennessee Valley Authority was developed after completion of Sennar Dam on the Blue Nile in 1925. The crops cultivated were cotton for export and cash for farmers' income. Sorghum is the national food stable in Sudan which served as food security and hyacinth bean is also served as animal fodder for livestock. Crops rotations involved using the simple local farming method. Davies (1986) further explains that the scheme performed well because it provided food security for humans and animals. It kept cultivation methods as simple as possible and incorporated a profit–sharing arrangement that gave incentives to the people; it also eliminated the possibility of landowners taking over the benefit of farming.

The pre-requisite of successful irrigation settlement is land reforms as Cumming *et al.*, (1989) made a clear description for Mexico; where rich farmers in irrigated areas dominate the best land which is four times the land of poor farmers leading to unusual quilt pattern of holdings and settling immigrants on small plots.

2.3.7 **Benefits and Problems of Irrigation Practice**

According to Olivier (1967) irrigation as an ancient practice is dated back to before the dawn of history and mentions that Egypt claims to have the oldest dam built over 5000 years ago to store drinking water and for irrigation, the Wadi Garawi about 125 kilometers south of Cairo in third or fourth Dynasty 2,686 – 2,160BC. Olivier (1967) also indicates that sophisticated irrigation schemes existed in the lower Euphrates Valley between 4,000 and 6000 years ago.

U.S. Bureau of Reclamation (1960) observed after 15 years of Colombia Basin Project; the population of the area multiplied 2.8 times; the number of business in the irrigated area had multiplied 17 times; non farm use of electricity increased by 515% whilst farm use increased by 1,106%; takes from retail sales had an annual growth rate of 15%.

In Pakistan Basin Irrigation Project, Alexandra and partners (1967) reported that irrigation practice had achieved a nutrient level of 2,200 calories production per day for a climatic environment with a mean annual temperature of 25^0c; and food production was risen from 5 million metric tons to 20 million metric tones per year to satisfy medium demand. In the Snowy

Mountain of Australia, Olivier (1967) mentioned the corresponding estimated national gross value of irrigation production in 1965 to the US $800 million per annum.

In another literature, Olivier (1987) reported that the value of sugar and molasses exports in 1984 from Swaziland amounted to 141 million Emalgeni (Swaziland currency) or about 42% of the small country's total exports. He also mentioned that three modern sugar mills were established by the Common Wealth Development Corporation (C.D.C) as a result of the Swaziland Irrigation Project known as Mhlume canal irrigation scheme. The industries had the capacity of more than 300,000 tones of sugar production per annum and employed about 5000 persons and 50,000 people depend in whole or impact on this production using irrigation.

Without statistical records over the years from the work of Gettinger (1997) and HJRBDA (2004), irrigation practice has made progressive improvement for the living standard of the farming communities in the following areas:

- provides all year round occupation and wealth to many farmers and their families;
- agricultural mechanization reduce labour cost in agricultural investment e.g. tractors replace animal draft power;
- greater physical production as farmers maximize farm production of food and cash crops valued in billions of Naira annually;
- generates many metric tones of crop residue which is used as fodder in the livestock sub-sector of the economy;
- provides millions man-days employment to farm labour annually;
- contributes toward enhancing significant national food security;
- provides raw materials for agro-based industries and created a good environment for the establishment of many cottage industries in the country;

- provides employment to many women in local processing and marketing of agricultural commodities, and finally
- provides employment to many crop commodity merchants and brokers nationwide.

There have been so many scholarly works on the obstacle to irrigation practice. Clevance (1979) has shown that increasing agricultural growth rates requires a multifaceted attack on a number of interrelated problems ranging from land tenure arrangements to government pricing policies. The study made by Ajala (2001) reveals that these constraints affect the participation of private sector in funding irrigation development which is minimal because of its low return (benefits). The investment to irrigation potential is low because of low incentive package receive by prospective private investors, promoters, and practitioners. In line with the review of the past report works various constraints for irrigation practice are presented as follows.

a. Technological change

Technological change is a key factor in agricultural growth. An agronomical advance in irrigated agriculture has been one of the major driving forces behind dramatic increases in cereal and vegetable production in Nigeria over the past 40 years. Galadima (2001) reported that several technologies have been disseminated to the farmers in crops sub-sector, which has invariably enjoyed intense extension intervention, among the other subsector; as a consequence modest growth rate of about 4% per annum was achieved during the period 1989- 94 with low adoption rate and average yields less than 50% of potential yields. Clevance (1979) also noted that it is difficult to convince farmers to change especially if they are illiterate and unacquainted with high yielding methods of production.

b. Agricultural Inputs supply and Distribution

Agricultural inputs have many constraints which directly or indirectly affect the performance of extensive irrigation project. Abubakar and Abdullahi (2001) reported the major constraint affecting irrigation inputs supply and distribution in Nigeria prior to deregulation were: inadequate and irregular funding of the agencies involved in seed production i.e. research institutions, the national seed services and the ADPs etc. lack of proper coordination, monitoring and evaluation of efforts of these agencies, as well as a clear cut definition of the roles, so as to prevent duplication of the roles; lack of seed processing equipment and other infrastructure facilities; inadequate and untimely provision of improved seeds to farmers; insufficient sales, promotion and retail outlets.

The more serious constraints under the deregulated system were caused by inadequate supply which in turn result primary from three factors mentioned by Abubakar and Abdullahi (2001): government has not made accurate estimate of the hectares under cultivation in the country; soil tests were usually not conducted to determine the soil nutrient status and thus the quantity required; government and private supplies did not have sufficient funds to procure the quantities of fertilizer that could ensure abundant supply.

c. Low funding of Agricultural Research

Clevance (1979) mentioned that an effective national research programme requires locally trained technicians whose salaries are high enough to keep them from emigrating and researchers must have access to journals, abstracts, and other publication. All these cost money and has a low visibility effort with along pay off period, research is often given a low priority by politicians whose outlook tends to be short-run in many Third World Countries.

d. Lack of Extension Services

The results of agricultural research are likely to reach many farmers unless extension personnel takes these results to the field. The country's extension agent has been an important agent of change. ILO and UNESCO (1977) observed ineffectiveness of extension personnel in which village level extension worker found it difficult role of introducing new concepts and techniques to farmers. Similarly, FAO (1976) observed the technical inadequate and incompetent with little training received and neglected the economic and social aspect of extension worker, and also there is little teaching equipment to build technological changes to farmers.

e. Agricultural Education

Clavence (1979) reported that educational system in developing countries is typically neglected agriculture at all levels. Most of the school curriculums are urban oriented even in rural areas (Todaro and Smith, 2009). The school garden is designed to give students experience with simple farm technology are often so poorly managed that they reinforce negative attitude toward agriculture as a low-status occupation. Working in the school garden has been used as a form of punishment and Clavence (1979) also mentions the negligence of continuing education to upgrade skills that introduce extension agents to new technology or acquaint them with crops whose importance in the economy is increasing. Ajala (2001) observed that low level of education on the benefits of irrigation potential and simple farm management affect the commercial production of irrigation farm output in Nigeria.

f. Mechanization

Ladeinde (1996) observed some limitations for irrigation mechanization in Nigeria as high purchase price of imported tractors in the absence of credit facilities to smallholder farmers; unavailability and technological know-how to properly utilize machines to suit the farming practices in Nigeria; lack of skilled operators culminating inability to repair and maintain these machines; lack of repair and replacement parts as well as lack of sustainable extension services. Tractor power farming with its greater output capacity may culminate in dismal yield performance due to a wide range of reasons put forward by Oni (2001) which included: fragmented farm holdings of small scale farmers which are not conducive to mechanization; ineffective tractor hiring service; proliferation of makers and types of farm tractor; inadequate extension services for on-farm adaptive research (OFAR), lack of skills to operate, repair and maintain the machines and hence their sporadic break down; lack of credit guarantee schemes and insurance against natural disasters; lack of ancillary industries to fabricate common replacement spare parts like bolts and nuts, shear bolts, coupling pins, tensions and linkage bars etc.; escalating purchase prices of tractors, implements and other equipment and their replacement parts; and lack of managerial skills to properly suit the machinery to the farming enterprises.

g. Land Tenure

In most of the third world countries the land tenure structure is a major obstacle to agricultural development (Clavence, 1979)). There are two important dimensions of this problem: land tenure arrangement per se (i.e. the form in which agricultural land is held freehold leasehold etc.) and the distribution of agricultural land. Land is a scarce resource in the world. Most of the land distributions to farmers represent a quilt pattern holding in which poor farmer manage small marginal farm-land, while rich farmers occupied the most suitable and large farmlands (Cumming *et al.*,1989).

h. Production Credit

Government neglect of agricultural sector is usually reflected in the distribution of credit granted by public financial institutions (Okoro, 2004). Lipton (1976) small farmer generally have no access to bank credit unless they are landowners, because of the administrative costs of processing loan. Applications are high to the small amount requested by farmers with only 1-2 hectares of land. Small loans are unprofitable to commercial banks and even government development banks must keep administrative costs down if they are to become financially self-reliant covering all costs from the margin between their borrowing and lending rates and leaving some resources for expansion.

i. Market and Storage

If market and storage problems are neglected in commodity production programmes, farmers (rationally) may not respond to market incentives for increasing production. Hayami and Ruttan (1971) observed that the output does not increase because the pressures on the distribution network may result in high spoilage rates. Clavence (1979) reported that lack of storage facilities do not only results in crop damage but also contribute to extreme seasonal price fluctuations as commodities glut market after harvest time but on short supply several months later; and lack of nationwide market price information system can lead farmers to make incorrect decisions regarding which crops to plant when to sell and the desirability of on-farm or community level storage facilities.

j. Price Policy

Governments in developing countries influence the prices of farm outputs in a variety of ways. Clavence (1979) argues that the low prices paid to farmers had a negative effect on production, administrative control in developing countries are not always effective in keeping prices low to consumers; but all government encouragement on commodity production can be neglected by inappropriate pricing policies. Aderinola (2001) reveals insufficient remunerative prices of extra output generated by the irrigation projects as constraints to its sustainability.

k. Institutional Weakness

Government institutions in many countries are very weak in relation to the separation of planning agency from decision machinery of government; failure of planners, administrators, and political leaders to engage in a continuous internal communication about goals and strategies and internal transfer of institutional planning practices and organizational arrangements that may be inappropriate to local conditions.

In addition, there has been much concerned about incompetent and unqualified civil servants, cumbersome bureaucratic procedures excessive caution and resistance to innovation and change; inter-ministerial personal departmental rivalries (e.g. Finance ministries and planning agencies) are often conflicting rather than cooperative forces in Nigeria. Lack of commitment to National goals as opposed to the regional department or simply private objectives on the part of political leaders and government bureaucrats and finally, in accordance with lack of national as opposed to personal interest, the political and bureaucratic corruption that is pervasive living in government. Galadima (2001) reported major reasons attributed to the failure of past efforts to large-scale irrigation development as inappropriate or inconsistent irrigated agriculture and economic policies; poorly developed irrigation infrastructure; high transport and transaction cost for agro-inputs and products; low investment in agricultural research and extension; low general education levels among the farm families; difficulties arise from economic crisis adjustment; failing market prices of agricultural commodities due to poor national price policy.

Benefits of irrigation farming can arise from an increased value of output or from reduced costs of production that hampered by the above constraints.

2.4 **Irrigation and Rice Cultivation**

The fundamental environmental factor that differentiates rice cultural types that are not upland or irrigated is the depth and duration of flooding (Catling, 1999). Rice scientists recognized five major rice growing environments: irrigated (sub-divided by temperature regime), rain-fed lowland (by drought, submergence and waterlogging), deep water (by water depth), upland (by length of growing season) and tidal wetlands (by the presence of salinity and soil problem) (Khush, 1984). These classifications clarify the effects of flooding depth on plant type and growth duration as shown in table 2.1.

Table 2.1: Typical Water Depths of Lowland Rice Environment

S/No.	**Rice Environment**	**Water depth (cm)**
1.	Rain-fed lowland shallow	<25
2.	Rain-fed medium deep waterlogged	25-50 (overlap with deep water)
3.	Deepwater	50-100
4.	Very Deepwater	>100
5.	Tidal wetlands	Tidal fluctuations(overlap with deep water)
nm		

Source: Khush (1984)

This useful and tidy classification clarify many confusing concepts and terminologies of the rice environment but Catling (1999) observed considerable overlaps between categories not the least in respect of rice water depth. As Garrity (1984) pointed out, the recognition by plant breeders of certain water depth boundaries has given rise to a bewildering array of names. This is particularly true. The critical depth range of 50-100cm which has been variously referred to as deep, semi-deep, medium deep, intermediate and shallow deep (Catling, 1999).

2.4.1 **Socio-Economic Condition of Rice Farmers**

a. **Landholding and Rice Farmers in River Basin System**

In the Ganges-Brahmaputra Basin, the average farm size differs from one district to another. Intensive studies of individual villages revealed mean farm sizes of 1.01ha at Daudkandi

(Bhuiya and Elahi, 1984), 0.90ha in Sychet District (Ahsan *et al.*, 1978), and 0.58ha at Bhaimara (Jansen, 1987).

In India, farm size in Assam varied from 1.0ha to 7.7ha (ICAR, 1987), where 30% of the households owned more than 4ha (Saikia and Phukani, 1986). Farm size in North Bihar, Uttah Pradesh, and West Bengal revealed that 73-76% of the households cultivated <1.0ha and only 13-14% cultivated >1.0ha (Grosvenor-Alsop and Sharma, 1988). In two villages studied in the Hooghly District of West Bengal, 80% of the households owned < 1.0ha at Pearapur and 55% owned < 1.0ha at Kadarnagar (University of Kalyani, 1989). Such low average farm size does not mean that there are no large-scale farmers (Catling, 1999). Clay (1982) reported that although in the Kosi region of north Bihar 60% of the households had < 1.0ha, however, some large estates had more than 1000ha. Individual landholdings of 100ha or more were found in Bangladesh.

The average farm holding at Irrawaddy and Burma was considerably larger because land fragmentation is less when compared with other countries (Cheng, 1968). In the Chao Phraya Basin and Thailand, the average cultivated area of Tontan field near Ayutthaya villages per households was 4.4ha but at the level of individual fields, marked by low bunds was 0.08-3.2ha (Catling, 1999). In the Central Region, farm size average 4.5ha, with 22% of farms >6.4ha mean field size was 1.57ha. In the Southern Region average farm size of 7.0ha was identified by Catling, (1999) and 50% >6.4ha. The assessment of land tenure was done by Catling, (1999) in which 35-45% owner, 36-49% owner-tenants and 16% pure tenant. The most leased land occurred as rented out at a fixed rate through some share-cropping.

At the Mekong and Red Basin in Vietnam and Cambodia Jujisaka (1988) reported that the new government in Vietnam and Cambodia instituted a solidarity group known as Krom Samakki. It was 10-15 farm families collectively cultivated 15ha tract of land, sharing the resources of draught animals, implements, and labour; the krom structure was set aside to care for widows, orphans and the disabled from war.

According to McIntire (1986), traditional landholdings was usually about 1.5ha in size and from surveys of eight areas in the West African delta, the size of rice soil parcels varied from 0.8 to 4.4ha. Vallee and Voung (1978) also reported a farm size of 4.0ha in South Mopti (Mali), which was too large for only two men in a family to manage effectively and properly. The farm holding size varies from 5.1 to 9.2ha with the total average for all zones of 7.1ha in the zone. The smallest farms were <1.0ha in size and the largest >30ha. In Nigeria the average farm holding in some selected rice farming of Kano River Project I reported by Ibrahim (2007) was range from 0.4ha – 2.0ha, the large farm size was 3.0ha.

b. **Rice Farming Family**

The average family size in the Ganges-Brahmaputra Basin that was engaged in rice cultivation ranged from 5 at Bhaimara and Habiganj (Jansen 1987; Ahsan *et al.* 1978) to 7 at Daudkandi and Tatulia (Bhuiyan and Elahi, 1984). In the West Bengal studies, there was an average family size of 6. The 30-36% of populations engaged in rice farming was below 14 years accounted for 30-36%, 57-63% was 15-59 years and only 7% were older than 60% years (Ramakrishna Mission, 1988 and University of Kalyani, 1989).

Catling, (1999) reported that in the Chao Phraya Basin and Thailand, there was 5.2-6.2 persons/homestead; males and females are in ratio 1:1. About 18% of the population was more than 50 years of age and labour equivalent per farm vary between 2.4-2.9.

The farming family of the Mekong and Red Basin of Vietnam and Cambodia are subsistence farmers while the household's size averaged 5.2 persons. The typical farm size was between 2.5 and 3.0ha which were to be sufficient for a single family to handle (NDDT, 1974).

Several socio-economic studies of rice farmers were reported briefly by Vallee and Vuong (1978), McIntire (1986) and Nyanteng *et al.*, (1986), but the picture which emerged was somewhat inconsistent, especially with regard to family and farm size. Vallee and Vuong (1978) recorded a mean family size of 10 with 30% of families having a single male member and the working population represented just 26% of the family, while many farmers were in the 40-70 age groups. On the other hand, Nyanteng *et al.* (1986) reported a household's size of 12-15 headed by a male member, a family of fewer than 10 members is very rare.

Labour for rice farming operation is usually provided from family. The amount of labour provided by the family is determined by composition and size of the farm household. However, it is expected that hired labour augments family labour in a situation of a family labour shortage.

2.4.2 **Rice Breeding and Varietal Improvement in West Africa**

According to Catling (1999), the common breeder objective is usually to breed for higher stable yield and improve a special trait or weakness in existing cultivars. Once the relevant plant characters are known better, the locally adapted cultivars are more effectively used and improvement in just one or two key traits subsists. Plant characters regarded by various plant breeders that are important in selecting important traits are economic, yield, survival and pest resistance/tolerance traits.

A partial list of characters referred in the literature of Catling (1999) is used to select for all or even most of these traits. These competing characters are involved in different strategies of environmental flood adoption. These four major characters (economic, yield-related, survival and pest resistance/tolerance traits) are considered to solve the severity of rice cultivation problems including pest which according to Johnson (1992) generally increase with an intensification of production systems and increase in fertilizer and pesticides use. It was reported by WARD (1992) that an estimated four million tons of rice are lost annually to weeds, insects, and diseases in Africa; additional losses are caused by nematodes, rodents and birds. These are the reasons West Africa rice farmers adopted several improved rice varieties with moderate resistance to drought and blast (disease) in the region because of their earliness and higher yields under improved management condition.

a. **Development of Improved Rice Varieties**

One of the major goals of rice agricultural production is to develop higher and more stable yielding of rice varieties adopted by different rice ecosystems (upland and low-land hydromorphic soils) in order to cater for all levels of rice farm management. According to WARDA (1992), it is indicated that most of the rice farmers are likely to continue with local inputs systems cultivation, while some rice farmers are making transition to higher input intensive rice production systems.

The improved rice varieties are expected to perform very well and better up compare with local varieties under low inputs farm management. WARDA (1992) opined that the improved rice varieties should respond to better farm management with regard to the addition of nitrogen as well as tolerant to drought, flooding, adverse soil effect, insect pests and diseases as most adopted by local varieties.

b. **Farmers' Knowledge and Preferences for Rice Variety Characteristics in West Africa**

WARDA (1992) admitted that the adoption rate of new rice varieties is often low because rice farmers lack preferred traits which will improve their farm management advantage that will give them higher yields and income. To address the above problems, rice farmers' survey was initiated by WARDA in West African countries and conducted by Adesina and Jones (1992) to identified the diversity characteristics of rice germ-plasm and determine farmers' knowledge and preferences for specific varietal traits. The summary of the results showed that farmers considered that local varieties had several advantages over improved varieties, particularly in terms of plant height, resistance to shattering, panicle length and exertion, competitiveness with weeds, tillering capacity and good aroma. It is environmentally interesting that rice farmers did not perceive a distinctive yield or income advantages for improved varieties over local varieties. WARDA (1992) assessed the relative importance of agronomic and post-harvest traits in adoption decisions on rice varieties. Summaries of farmers' responses on varietal traits considered very important, important, or minor important included yield, tillering capacity, drought tolerance, panicle exertion, resistance to shattering, tall height, medium height, medium crop duration, a good test, ease of cooking, ease of milling and good aroma.

Despite the preferred traits required by farmers; rice yield is affected strongly by natural hazards of an unstable environment and erratic early season rainfall, flooding and several pests such as outbreaks of Ragged Stunt Virus (RSV). In Bangladesh, average yields are highest in years with good early rains and favourable flooding patterns as reported by Catling (1983).

Unfortunately, one of the myths of rice is that traditional cultivars do not respond to fertilizer and there has been considerable controversy as to whether it is worth to applying N and P fertilizer to floating rice. But as Puckridge and Thongbai (1988) pointed out, while researchers argued and debated, many farmers are applying fertilizer to their fields every year as a standard practice.

In order to solve the problems of rice varieties mentioned above; WARDA (1992) conducted experimental rice research trials as follow: Jones and Sahrawat (1992) conducted a research to upgrade level of varietal resistance to climate change and diseases which included breeding trials of drought-resistant upland rice varieties and produced FAROS 302 and WAB 326 rice varieties among others; Jones *et al*,. (1992) conducted a breeding trial for diseases resistance rice varieties and produced WAB 100-BB-21-HI, ITA 118 and IRAT 144 rice varieties among others. Jones and Heinrich (1992) conducted another breeding trial for insect pest resistance rice varieties on the African white borer (*Maliarpha separatella*), African pink borer (*Sesamia zacconius*) and stalk-eye fly (*Diopsis longicornis*) and produced moroberakan, modeka D, LAC 23 and ITA 112 rice varieties among others.

From these variety trials, a comprehensive database was developed on the major local varieties cultivated by farmers in West Africa and farmers' preference profiles for different agronomic and post-harvest traits were compiled. The results of rice experimental research trials had been scrutinized and developed a database on the varietal preferences of rice farmers in West Africa which was submitted to rice breeding companies for commercial rice hybrid seeds production.

2.4.3 **Rice Cultivation, Marketing and Food Security in Nigeria**

Historically, the government of Nigeria withdrew from the rice value chain during the petroleum market plunged in 1982 (Ammani, 2013). Trade deficits, budget deficits, inflation, the balance of payments problems, and other symptoms of economic decline became seriously manifest in the 1980s (Osaghae, 1995). This drastically reduced Nigeria's ability to finance imports, including food, leading to persistent current account deficits and the accumulation of unpaid trade bills (Osuntogun *et al.*, 1997).

Schultz (1976) argued that much of the difference in the economic performance of the agricultural sector is a consequence of poor governments' intervention in agriculture. As observed by Idachaba (2002), attempts towards explaining the widening gap between findings of agricultural research and disappointing results on farmers' fields have led to a consensus that policy being implemented were the principal constraint facing agriculture in Nigeria.

The difficult and painful experience of 2008 food scarcity raised the issue of Nigerian dependency on rice importation from Thailand and Vietnam. Rice imports in 2008 and 2009 remained stable in Nigeria due to stabilization of Naira which appreciated against US dollar as a result of high petroleum price. This made Federal Government overlook the 2008 food scarcity and continued to purchase rice in the international market.

Despite the Nigeria's economic stability during 2008 food scarcity, the government was able to demonstrate the capacity to identify physical and human resources to implement emergency and long-term measures for rice production.

The government implemented emergency measures which include reduction of taxation of rice imports and reinstated import duties in late 2008. Ambitious long-term measures adopted to strengthen self-sufficiency in rice in 2008 include subsidized seeds and fertilizer, as well as the provision of credit to producers.

Authorities have supported the extension of irrigated land areas and constructed rice mills. It also attracted trade partners from foreign countries to invest in the rice business by facilitating their access to land and labour for rice production and milling. The government and private partners were able to mobilize significant resources to implement short and medium-term measures to rice production.

Following the government implemented emergency measures as result of 2008 food scarcity; the annual rate of increase of Nigeria's rice production has risen significantly. However, the increases in local consumption hamper local production to make a significant and lasting impact on self-sufficiency in rice production.

In 2010, imports began to increase again because international rice prices fell. The increase in Nigerian rice production has not led to a lasting reduction in Nigeria's dependence on international rice imports as the population was increasing. Even the installed higher capacity rice processing mills in Nigeria have led to increasing the level of rough rice demand from neighboring countries; because the local farmers were not able to close the gap of rice deficit.

Local Rice Production in Nigeria

Rice production in Nigeria was analysed by Ammani (2013). His study reveals that rice production from 1986 to 2010 had accelerated growth rate (Instantaneous Growth Rate (IGR) of 2.2%; Cumulative Growth Rate (CGR) of 2.2%); rice hectarage (IGR 3.7%; CGR 3.8%); rice importation (IGR 8.5%; CGR8.9%); expenditure on rice importation (IGR 10.6%; CGR 11.2%) and rice consumption (IGR 3.4%; CGR 3.5%) along side a significant deceleration in rice yield (IGR -1.4%; CGR -201.4%) (See Table 2.2). This explained that there was slightly accelerated growth in rice production over the study period. The mean annual domestic rice production is estimated as 3,037,746.80Mt. The maximum and minimum annual domestic rice production over the study period were 4,179,000Mt (in 2008) and 1,416,320Mt (in 1986) respectively. Nigeria has maintained a steady 2.2% growth rate in domestic rice production over the period 1986-2010.

Table 2.2: Rice Production and Imports in Nigeria (1986-2010) in Metric Tones

S/No	Parameter	IGR (%)	CGR (%)	Annual Average	Maximum Average	Minimum Average
1	Rice Production	2.2	2.2	3,037,746.80Mt	4,179,000Mt (2008)	1,416,320Mt (1986)
2	Rice Area (Hectarage)	3.7	3.8	1,859,624Ha	2,725,000Ha (2006)	700,000Ha (1986)
3	Rice Yield	-1.4	-201.4	1.70MT/Ha	2.39MT/Ha (1987)	1.30Mt/Ha (2001&2007)
4	Rice Import	8.5	8.9	789,377.24Mt	1,885,334Mt (2010)	200,000Mt (1988)
5	Value of Rice Import	10.6	11.2	US$ 261.89 million	US$ 824.41 million (2010)	US$ 55 million (1988)
6	Domestic Rice Consumption	3.4	3.5	3,827,124.04Mt	5,150,815Mt (2008)	1,736,320Mt (1986)

Source: Ammani (2013)

Onu *et al.* (2015) reveal that the growth trend of rice production in Nigeria per annum within the period 1980-2013 shown an instantaneous growth rate of 4.8% and the growth rate of rice production in Nigeria has a compound growth rate of 4.92% (Table 2.3).

Between 1980 and 2013, a total of 60,111,000 metric tons of rice was domestically produced in Nigeria. The mean quantity of rice production in Nigeria between 1980 and 2013 was 8,587,286 tons, while the mean change in rice production within the same year was 1,586,333 tons. The growth rate (GR) of rice production varied from a minimum of -2.73 percent between the years 2000- 2004 to a maximum of 94.99 percent between the years 1985- 1989. The overall average growth rate of rice production between the year 1980 and 2013 was 31 percent.

Table 2.3: Rice Production and Imports in Nigeria within (1980 – 2013) in Metric Tones

Years	Quantity of Rice Production	Quantity of Rice Imported	Change in Rice Production	Change in Rice Imported	% Change in Rice Production	% Change in Rice Imported
1980-1984	2,936,000	3278,000	-	-	-	-
1985-1989	5,725,000	2,181,000	2,789,000	-1,097,000	94.99	-33.47
1990-1994	8,662,000	1,642,000	2,937,000	-539,000	51.30	-24.71
1995-1999	9,517,000	3,231,000	855,000	1,589,000	9.87	96.77
2000-2004	9,257,000	7,870,000	-260,000	4,639,000	-2.73	143.58
2005-2009	11,560,000	8,450,000	2,303,000	580,000	24.88	7.37
2010-2013	12,454,000	13,111,500	894,000	4,661,500	7.73	55.17
Total	**60,111,000**	**39,763,500**	**9,518,000**	**9,833,500**	-	-
Mean	**8,587,286**	**5,680,500**	**1,586,333**	**1,638,917**	**31**	**41**

Source: Onu *et al.* (2015)

The result further indicated that rice production showed heterogeneity in growth between 1980 and 2013. However, the growth rate for domestic rice production is inadequate for local consumption because of the gap between local production and demand. In Nigeria to bridge the gap between local production and demand the government has to maintain a steady growth rate of more than 2.2% in domestic rice production in the future.

Rice Hectarage in Nigeria

According to Ammani (2013), Nigeria is experiencing an increase in rice production. This increase is due to a hectrage extension rather than intensification of rice production system. This indicates that over the period 1986-2010, rice producing area in Nigeria had an annual instantaneous growth rate of 3.7%; and a compound growth rate of 3.8% (table 2.2). This concluded that there was a slightly accelerated growth in rice hectarage over the study period.

The average annual rice production area is estimated as 1,859,624ha. The maximum and minimum annual rice hectarage over the study period were 2,725,000ha (in 2006) and 700,000ha (in 1986) respectively (Table 2.2). When these findings were reviewed in light of the previous land use for rice production, it has shown that rice production is increasing at a steady rate of 2.2%.

Nigeria Rice Importation and Expenditure (1980 - 2013)

Ammani (2013) observed rice imports in Nigeria between 1986 and 2010 had an annual instantaneous increase of about 8.5% annually (Table 2.2). This reveals that there was a significant increase in rice importation over the study period. The average annual quantity of rice imported into Nigeria was estimated to be 789,377.24 ton. Similarly, Onu *et al.,* (2015) reveal that between 1980 and 2013 the rate of growth in rice imports between 1980 and 2013 was relatively higher than the growth rate in rice production within the same period. The result also showed that between 1980 and 2013, a total of 39,763,500Mt of rice was imported into the country which implied 5,680,500Mt has imported annually. Based on the imports, Ammani (2013) reported that the rice imports in Nigeria had an annual significant acceleration in the value of importation over the study period (1986-2010). The average annual value of rice imported in Nigeria within the period was estimated to be US$ 261.89 million. The highest (US$ 824.4 million) was recorded in 2010 and the least was recorded in 1988 (Table 2.2). Nigeria has spent more than US$ 6.5 billion of her scarce foreign exchange on rice importation.

Rice Consumption in Nigeria

The quantity of rice consumed in Nigeria increasing at 3.4% annually (Ammani, 2013). The average annual quantity of rice consumed in Nigeria is estimated as 3,827,124.04 ton. The maximum consumption was in 2008 of rice consumed over the study period were 5,150,815 ton (in 2008) and 1,736,320 ton (in 1986) respectively. Thus, more than 20% of the rice consumed in Nigeria was imported.

Recommendation on rice importation in Nigeria

Based on the review of the main lesson derivable from the rice production and consumption in Nigeria, the following recommendations have been made:

- the free market approach alone cannot stimulate local agricultural production in Nigeria where farmers producing under low-technology-agriculture are allowed to compete with farmers of advanced-technology-agriculture. Therefore, there is a need for government to restrict rice importation to protect local rice producers so that they can survive competition from advanced agricultural producers. This will enable local rice producers to gradually overcome their weakness and compete globally (Ammani, 2013).
- Government policies should advocate measures significantly to reduce price and non-price factors that contribute for rice imports in Nigeria in both short and long terms; such measures include import taxes and provision of credit and subsidies to rice farmers (Onu *et al.*, 2015).

2.5.1 Reaction of Some Soil Properties under Irrigation System

Generally, soils evaluation for West Africa is very important because according to WARDA (1992) the soils have Nitrogen and Phosphorus deficiency which are the most important constraints to rice production. WARDA (1992) also reported that Nitrogen deficiency occurs throughout West Africa, but is most severe in the savanna zone; Phosphorus deficiency is a serious problem in the forest zone and in acidic uplands; in the lowland and irrigated ecologies, iron toxicity is the most important nutrient disorder and development of improved varietal tolerance is considered the most practical solution to this problem for resources poor farmers. WARDA (1992) once again found phosphorous as the limiting nutrient in the acid soils of West

Africa's humid forest zone because of iron and aluminum reduction in the soil. The Association in 1992 reported that iron toxicity tolerance is a major nutrient disorder of lowland and irrigated rice in West Africa and recommended varietal tolerance that is practical and low-cost means of increasing rice productivity in the iron toxic environment.

Soil fertility evaluation remains the most variable tool in assessing soil condition as a guide to elucidating processes that could lead to increased soil productivity. Daniel (1987) mentioned the problem facing irrigated agriculture include removal of the fine particles of soil by wind, rain and irrigation water and asserts that soils cultivated for many years have shown decline of soil fertility status notably organic matter, C.E.C, phosphorous, nitrogen, and potassium. Daniel (1987) measured the effects of continuous irrigation on soil properties in Sudan savanna in Kano, Nigeria using three physiographic units which corresponded with three soil types identified in Tomas, Ladi, and Ballauda as shown in table 2.4.

Table 2.4: Comparison of Pre and Post-Irrigated Soil Properties in Tomas Irrigation Project

		Tomas Series			**Ladi Series**			**Ballauda Series**		
S/No	**Soil Property**	**Pre-Irr**	**Post-Irr**	**t-value**	**Pre-Irr**	**Post-Irr**	**t-value**	**Pre-Irr**	**Post-Irr**	**t-value**
1.	Sand %	69	86	8.09*	86	93	12.78*	88	90	8. 69*
2.	Silt %	14	7	4.22*	4.0	3	0.76	6	5	0. 63
3.	Clay %	17	5	7.46*	10	4	2. 55	6	5	0.42
4.	pH	6.4	7.4	2.36	6.6	7.2	1.17	6.1	6.7	2.18
5.	Ex. Ca^{2+} & Mg^{2+}	5.94	1.08	6.21*	4.4	1.02	6.55*	2.75	1.04	4.2
6.	Ex. K_2O	0.26	0.16	1.03	2.73	0.25	3.85*	1.16	0.3	4.86*
7.	Ex. Na^+	0.4	0. 59	0.96	0.2	0. 6	0. 62	0.11	0.92	13.23*
8.	C.E.C.	12.09	6.66	1.68	1.13	4.77	7.55*	0.3	3.55	49.48*
9.	Carbon %	0.24	0.05	0.79	0.21	0.07	2.93*	0.00	0.06	1.59
10.	Total K_2O	187	587	1.42	47	460	8.14*	23	830	13.9*
11.	Total P_2O_5	37	501	3.61*	17	1080	4.28*	12	1426	13.03*
12.	Available K_2O	42	129	1.27	23	80	1.73	0	160	4.62*
13.	Available P_2O_5	7	67	7.47	3	38	2.6	2	49	3.90*
14.	Elect. Conductivity	0.04	0.11	1.41	0.04	0.07	0.48	0.03	0.04	3. 69*
15.	Base Saturation	74	28	8.22*	89	0.07	8.41*	0.03	0.04	0.2

Source: Daniel (1987) Critical Levels: *5% (2.776)

Daniel, (1987) compared the soil properties of pre and post-irrigation in Tomas irrigation area. The result showed that the total sand fraction increased from 69% at pre-irrigation to 86% at post irrigational assessment. All the two soil series (Ladi and Ballauda) total sand fraction increased as a result of the irrigation practice. The silt and clay content decreased in all the three soil series. The result also revealed that some elements such as exchangeable sodium, total nitrogen, available phosphorus, and pH increased tremendously in some of the soils, while others such as calcium, magnesium and potassium and organic matter content decreased substantially.

Oriola (2005) studies the impact of an irrigation project on the soil environment and socio-economic status of farmers in Oke-Oyi, Ilorin Kwara State. The result of the study revealed that there is 20% increase in the proportion of the clay particles in the irrigated soils when compared with non-irrigated soils. The differences in the values of the basic soil nutrients in the top and subsoils in irrigated and non-irrigated soils are many.

Newson (1997) observed and asserted that soil can be lost by erosion and declined in soil fertility status when its rate of development processes accelerated above that of other landscape. The erosion can damage soil land resources and constraint agricultural production that lead to poor economic function. The result of erosion always undermines soil condition and land productivity through land degradation and saline exhibit significant reactions explain as follows:

Soil Salinity

The salinity of irrigation water is the sum of all the ionized dissolved salts in water with reference to specific ions present (James, 1988). The electrical conductivity of irrigation water is often used to characterize salinity and water quality since the ability to conduct electricity is directly related to the number of ions present. Irrigation water tends to dissolve rock salt vigorously and increases its concentration with a high rate of evaporation and absorbs in small proportion what is needed by the plants. According to Wolfang Flaig (1979), Vogg (1983) and Kolawole (1994) cited in Oriola (2005) excessive salts are dissolving and found in irrigated fields causing salinization of the irrigated soils. Its rate of accumulation depends on surface temperature, the chemical composition of rock and availability of water (Shanan, 1987).

Soil salinity is an important constraint to irrigated rice production in the Sahelian area and Dungkuh *et al.,* (1992) observed that most irrigation schemes tend to accumulate critical concentration of salt in the topsoil, particularly if the drainage is poor. This changes the quality of irrigation water which according to James (1988) influences crops physiology and yields, plant cell enlargement and division, production of proteins and nucleic acids which retarded plant physiological processes and visible injury symptoms such as leaf which normally occur as extremely high level.

Waterlogging

According to Shanan (1987) waterlogging is a process whereby the groundwater level rises and lies more than two meters from the ground surface. It is often responsible for irrigation canals leakage, wastage dump in the canal distribution networks, over-irrigation and scanty suitable drainage facilities (Ahmed, 1994). The rising of water table has been reported by Shanan (1987) to be 30-40cm in Pakistan and Ahmed (1994) notices peak rising of 40-70cm at the Kano River Project 1 in ten years; these results in a reduction of soil air space and nitrogen loss through leaching making the soil unproductive.

Toxicity

According to James (1988) toxicity occurs when the accumulation of an ion becomes large enough to cause leaf burn (i.e. drying of the leaf tissues). A chemical analysis is needed to identify toxic ion. Sodium, chloride, and boron are the most common phyto toxin (plant toxin) found in irrigation environment. The water of Kano River Project 1 is classified in lowest U.S.D.A. salinity and sodium class (SI - CL); Boron (< 0.1 ppm B) is very low (NEDECO, 1974). The studies conducted by Danbaba *et al.,* (2010) reveal significant effect of high concentration of toxic on grain quality attributes to lowland rice varieties in nutrient agar solution.

2.6 **Sustainable Agricultural System**

The vision for agriculture can be achieved to make agriculture productive, environmentally sensitive and capable of preserving social fabric of rural communities. It is evident that regenerative resources conserving technologies and practice can bring both environmental and economic benefits to farmers' communities and nations at large. According to Dent and Young (1987), agriculture can only be persistent and sustainable when resources conserving technologies are developed and used by local institutions and groups who are supported by external research, extension, and creation of enabling atmosphere in institutions.

2.6.1 **Goal of Sustainable Agriculture**

The basic challenge for sustainable agriculture is to make better use of internal resources. This can be done by minimizing the external inputs by regenerating internal resources more effectively or by combinations of both. A sustainable agriculture, therefore, is any system of food or fiber production that systematically pursues the following goals as put forward by Pretty (1995):

- incorporation of natural processes such as nutrient cycling, nitrogen fixation and pest-predator relationships into agricultural production processes;
- a reduction in the use of those off-farm external and 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;

- an equitable access to production resources and opportunities and a progress towards more socially just forms of agriculture;
- a greater productive use of local knowledge and practices, including innovative approaches not yet fully understood by scientists or widely adopted by farmers;
- an increase in self-reliance among farmers and rural people,
- an improvement in the match between cropping patterns and the productive potential and environmental constraints of climate and landscape to ensure the long-term sustainability of current production levels;
- profitable and efficient production with an emphasis on integrated farm management and the conservation of soil, water, energy and biological resources.

To achieve these goals some indicators become relevant in both the physical and sociological realm of the system.

2.6.2 **Sustainable Indicators in Irrigation System**

Sustainability is assessed over several dimensions as multifaceted in nature. Pannell and Sihilizzi (1997) noted that it can be indicated by economic, social and biophysical aspects of a system and according to Glen and Pannel (1998) it can also be indicated by some aspect of policy performance or management strategy. With regard to the socio-economic indicators of sustainability, Gomez *et al.,* (1996) mentioned the following:

a. Socio-Economic Indicators:

i. Productivity measures such as net return to land, net return to labour, total factor productivity and yield;

ii. Stability measures such as coefficient of variation of productivity measures, coefficient of variation of net benefits, diversity of enterprises and net returns in worst 20 of trials;

b. Resources Conservation Indicators:

i. Quantity of the resource such as soil loss, woody perennial population, soil nutrient loss, turbidity index, erosion ability index and ecological diversity;

ii. Quality of resources such as topography, soil stability, nutrient cycling, bio-resources recycling, C:N ratio (organic carbon), soil compaction, Calico index for soil biological activity, ground cover and water stress. Other sets of indicators identified for sustainability assessment in agro-ecosystems by Isaac and Swift (1994) are as follows:

c. Cropping System Scale: the ratio of annual yield to the potential target yield, soil pH and exchangeable Al_3 content, soil loss and compaction, ratio of microbial biomass to soil organic matter, abundance of key pests and weed diseases, profit of farm production, nutritional status of household, drinking water quality, sources and availability of fuels.

d. Village Catchment Scale such as; bound rationality version of economic efficiency, bound rationality version of social welfare, the ratio of aggrading and degrading land area, stream turbidity, nutrient composition and acidity, nutritional status, human diseases and disease vectors, biodiversity, and complexity.

These indicators can be measured at a point over a period of time. An important aspect of choices of the indicator will be based on an evaluation that will allow for different studies comparable across many study sites. Andriasse (1993) mentioned that it is not possible to measure all indicators but those selected must be easy to measure, respond easily to change over time, and have no unambiguous boundaries that are not directly related to the requirement for sustainability.

2.6.3 **Measurement of Sustainability in Agricultural System**

Methodological approaches and techniques for single or composite indicators to assess agricultural sustainability include the following:

i. Total Factor Productivity (TFP)

Total factor productivity was proposed by Lyman and Herdt (1989) and Ehui and Spencer (1993). The TFP approaches is used to measure the rate of change of an index of output divided by an index of inputs at two given period of time, t_o and $t_{i.}$ A given production system will be sustainable if it produces at the moment t_1 the same amount of outputs as the moment t_o. Such a static approach does incorporate the continuous reciprocal action which occurs during the process of agricultural production.

ii. Goal Programming Model

It is possible to measure the effects on the sustainability of a production system of any change in technical production, in relation to the introduction of new technologies or the level of resources available. Goal Programming Model is mostly used for measurement of sustainability on the basis of a system approach. The approach incorporates inputs and outputs coefficient into the analysis. Hence Manyong and Degand (1995) mentioned the dynamic and form that base the incorporation of sustainability concept into analysis and forecasting of agricultural sustainability.

iv. Fuzzy Logic

The method is based on the premise that the border between sustainability and unsustainability is not sharp but fuzzy. This means that according to Kuswandari (2004) it is not possible to determine exact reference values for sustainability, and scientific evaluation of uncertainty must always be considered in the procedure of sustainability assessment.

v. Energy Balance Analysis

The method was used by Zincl *et al.,* (2004) to compare the sustainability of traditional and modern agricultural systems. It has the advantage of expressing all inputs and outputs parameters in the same unit. It quantifies the inputs/outputs ratio and compares different farming systems for assessing sustainability, but it must be combined with complementary techniques to cover the various facets of the sustainability concept.

vi. Yield Gap Analysis

This method does not indicate sustainable yield level. It points at levels of crop productivity higher than farmers' yields, which could be achievable with additional inputs and improved management practices. Zincl *et al*., (2004) indicates that a farmer can raise the farm yield to a higher level economically profitable and environmentally sustainable.

vii. Response Induced Sustainability Evaluation Model (RISE)

The RISE Model allows a sustainability assessment of agricultural enterprise in a holistic way based on 12 indicators covering ecological, economic and social aspects (Hani *et al.* 2003). The main objective of the sustainability assessment is the identification of strengths as well as bottlenecks and weaknesses with regard to the sustainability of the enterprise.

viii. Hierarchical Ranking

This method quantifies and ranks variables such as biodiversity, the maturity of ecosystems, energy ratio and soil accumulation over time. Others not readily quantifiable have value ascribed to them for computation. Senanayake (1991) noted that variables can be organized as a ranked system which classifies the agricultural system as either sustainable or not sustainable. The advantage of the method is that it will enable changes in the degree of sustainability within any farming system to be measured and evaluated in a systematic manner.

xi. Land Evaluation Principle

Food and Agricultural Organization (FAO) of the United Nations in 1976 put forward two basic approaches to land evaluation, namely, two-stage approach and parallel approach (FAO, 1976). In the two-stage approach, the first stage attempts, basic survey of physical resources, such as soil and site/slope characteristics (land capability survey). In the second stage, an analysis of socio-economic resources, such as the input and output data (land economic evaluation) is carried out. This approach has a clear-cut sequence of survey and absence of overlapping in the field-by-field survey.

The parallel approach collectively studies physical conditions, socio-economic circumstances, and their concurrent influence on land utilization. This integrated approach gives more comprehensive information in a shorter period. It is useful in micro-level agricultural planning development.

The FAO (1976) land evaluation process and procedure will be employed in this study. The procedures will, however, make modification in line with local needs and problem as required by the physical conditions, socio-economic factors, land utilization types, crops raised and farm management practices among others. Singh Jasbir *et al.*, (1988) sustainability rating index could be relevant to this study.

The methodology and schemes of land suitability evaluation and its classification adopted by Singh Jasbir *et al.*, (1988) are:

$$\text{Sustainability Rating Index} = \frac{\text{Actual Yield of Crop a}}{\begin{array}{c}\text{Potential production of crop}\\ \text{Under optimal conditions on a good quality land}\end{array}} \times 100$$

Sustainability rating index of for arable land is calculated with the help with equation above.

With regard to the environmental/ecological sustainability, the thresholds for the environmental indicators were obtained from the rating for soil fertility classes in the Nigerian Savanna by Esu (1991) as shown in Table 2.5.

Table 2.5: Rating for Soil Fertility Classes in the Nigerian Savanna

Parameters	Low	Medium	High
Organic Matter (g/kg^{-1})	1 – 12.29	12.30 – 47.30	68.80
Total Nitrogen (g/kg^{-1})	< 1.50	1.50 – 2.0	> 2.0
Available Phosphorous (mg/kg^{-1})	< 10.0	10.0 – 20.0	> 20.0
Available Potassium (cmol/kg^{-1})	< 0.15	0.15 – 0.30	> 0.30
Exchangeable Calcium (cmol/kg^{-1})	< 2.0	2.0 – 5.0	> 5.0
Exchangeable Magnesium (cmol/kg^{-1})	< 0.30	0.3 – 10.0	> 10.0
Cation Exchange Capacity (kg^{-1})	< 6.0	6.0 – 12.0	> 12.0

Source: Esu (1991)

For the purpose of this study total factor productivity and goal programming model were used in the analysis of the data.

2.7 **Technical Efficiency Estimation in Agriculture**

According to Jafarullah and Premachandra (2003), there are two approaches that have been heavily used in the estimation of technical efficiency in production. The first approach is the stochastic production frontier (SPF) developed independently by Aigner *et al.*, (1977) and Meeuseen and van den Broeck (1978). The second approach is data envelopment analysis (DEA) developed by Charnes *et al.*, (1972) and there is another approach which is not popularly used is the statistical deterministic production frontier developed by Afriat (1972). The stochastic and statistical approaches utilize a parametric function to represent production frontier, while DEA is based on linear programming technique which is a non-parametric method. All the three methods can either be stochastic or deterministic. The production function in DEA and the one suggested by Afriat (1972) are deterministic because they assign any deviations from the frontier, even those due to random factors to inefficiency. While SPF permits production frontier to be sensitive to random shocks by including conventional random error term in the specification of the production frontier. This is as a result that only deviations caused by the controllable decision are attributed to inefficiency.

CHAPTER THREE

METHODOLOGY

3.1 **Data required:** The data can be broadly classified into the soil and socio-economic data.

a. **Soil Data**:

- **s**oil physical properties: soil structure, particle size, and bulk density;
- soil chemical properties such as exchangeable acidity/base electrical conductivity, cation exchangeable capacity (CEC), organic carbon, available phosphorous and total Nitrogen.
- soil fertility rating in Nigerian savanna.

b. **Socio-economic Data**:

- socio-economic characteristics of the respondents;
- farmland ownership and tenancy;
- integrated pest management and crop protection;
- improved rice varieties;
- input utilization for rice production and net returns;
- major constraints and factors affecting the area of cultivation.

3.2 **Sources of Data**

The above data were generated from both primary and secondary sources:

3.2.1 **Primary Source**

The primary data were collected from fields through the use of a well-structured questionnaire consisting of open and close-ended questions. Soil samples were also collected from irrigation farm layout.

3.2.2 **Secondary Source**

To complement the information collected from the field, the general features and characteristics of the study area were obtained from relevant textbook such as Regenerating

Agriculture, Deep-water Rice etc. journals such as The Nigerian Geographical Journal, Environmental Journal and Journal of Sustainable Agriculture among others.

3.3 **Sampling Techniques**

This involves getting representative samples for the study so as to ensure that sufficient information is collected within the study area for equity and justice. Samples were collected from both human and physical aspects of the study area.

3.3.1 **Soil Sampling Techniques**

Based on NEDECO (1976c) Soil Report on Kano River Project I; the soil series found suitable for rice production were Pab, Pab/Pb Complex, Pb, HTb and LTb. Two soil series Pab and Pab/Pb Complex were purposively selected for this research. These two soil series were all identified in the two branches of irrigation layout that is Kura and Bunkure. All the two soil series are widespread with large space hectares.

In Kura branch, ten sectors were purposively selected from irrigated and adjacent non-irrigated lands of Pab soil series for comparison (See Table 3.1).

Table 3.1: Sectoral Distribution of Pab Soil Series Cultivated in Kura Branch

S/No.	Name of the Sector	Elevation	Latitude	Longitude	Sample Size (ha)
1.	Agolas II	461	11^0.26’	8^0.26’	26.0*
2.	Agolas IV	471	11^0.46’	8^0.26’	7.8
3.	Azore II	476	11^0.44’	8^0.24’	5.48
4.	Bugau	464	11^0.44’	8^0.28’	5.1
5	Butalawa	467	11^0.48’	8^0.25’	8.0*
6.	Dalili	479	11^0.47’	8^0.25’	6.0
7.	Gori North	469	11^0.47’	8^0.24’	37.21*
8.	Gori South	474	11^0.46’	8^0.24’	16.0*
9.	Karfi	455	11^0.49’	8^0.28’	16.0*
10.	Majabo	468	11^0.48’	8^0.26’	20.0*
11.	Mudawa	470	11^0.44’	8^0.26’	15.0*
12.	Rakauna	476	11^0.46’	8^0.24’	17.8*
13.	Yakasai Gilmor	466	11^0.48’	8^0.271’	22.2*
14.	Yakasai N /Ruwa	450	11^0.47’	8^0.26’	32.0*
	Total				**326.59**

***Source**: Hadejia-Jama’are River Basin Development Authority (2017)* * Ten selected sectors

Likewise, in the Pab/Pb Complex soil series of Kura branch, ten sectors were also purposively selected from irrigated and adjacent non-irrigated lands (See Table 3.2).

Table 3.2: Sectoral Distribution of Pab/Pb Complex Soil Cultivated in Kura Branch

S/No.	Name of the Sector	Elevation	Latitude	Longitude	Sample Size Surveyed
1.	Agalawa	495	11^{0}.45’	8^{0}.25’	3.0*
2.	Agolas I	464	11^{0}.45’	8^{0}.25’	4.0*
3.	Azore I	475	11^{0}.43’	8^{0}.24’	7.0*
4.	Dakasoye	482	11^{0}.43’	8^{0}.26’	13.0*
5.	Dankabo	452	11^{0}.47’	8^{0}.28’	4.0*
6.	Danmaura	476	11^{0}.42’	8^{0}.25’	3.0*
7.	Domawa	461	11^{0}.45’	8^{0}.27’	1.0
8..	Fegin Malu	450	11^{0}.46’	8^{0}.29’	4.0*
9.	Gafan A	493	11^{0}.40’	8^{0}.25’	3.0*
10.	Gafan B	487	11^{0}.40’	8^{0}.26’	3.0*
11.	Guraza	461	11^{0}.45’	8^{0}.27’	1.0
12.	Kirya	463	11^{0}.48’	8^{0}.27’	2.0
13..	Makwaro East	472	11^{0}.45’	8^{0}.25’	1.0
14.	Makwaro Tudu	471	11^{0}.44’	8^{0}.25’	1.0
15.	Raje	492	11^{0}.40’	8^{0}.25’	1.0
16.	Rigar Fako	464	11^{0}.47’	8^{0}.26’	3.0*
17.	Samawa	482	11^{0}.43’	8^{0}.25’	1.0
18.	Unguwar Kudu	472	11^{0}.41’	8^{0}.26’	2.0
19.	Yadakwari	486	11^{0}.42’	8^{0}.24’	1.0
	Total				**61**

***Source**: Hadejia-Jama’are River Basin Development Authority (2017)*

* Ten sectors purposively selected

In Pab soil series at Bunkure branch, ten hectares were systematically selected from irrigated and adjacent non-irrigated lands for comparison (See Table 3.3). Eight hectares were selected in Dorawa sector and two hectares were selected in Shiye / Chirin sector.

Table 3.3: Sectoral Distribution of Pab Soil Cultivated in Bunkure Branch

S/No.	Name of the Sector	Elevation	Latitude	Longitude	Sample Size Surveyed
1.	Dorawa	473	11^{0}.42’	8^{0}.32’	79.20
2.	Shiye / Chirin	487	11^{0}.42’	8^{0}.32’	4.80
	Subtotal				**84.0**

***Source**: Hadejia-Jama’are River Basin Development Authority (2017)*

In the Pab/Pb Complex soil series of Bunkure branch, the ten hectares were also systematically selected from irrigated and adjacent non-irrigated lands for comparison (See Table 3.4). This implied that one hectare was selected from each sector with exception of Kadawa North, Kadawa South and Yantomo in which two sectors were selected from each one of them.

Table 3.8: Sectoral Distribution of Pab/Pb Soil Cultivated in Bunkure Branch

S/No.	Name of the Sector	Elevation	Latitude	Longitude	Sample Size Surveyed
1.	Barnawa	493	11^0.34'	8^0.27'	12.10
2.	Kadawa North	494	11^0.39'	8^0.25'	25.0
3.	Kadawa South	489	11^0.38'	8^0.25'	15.71
4.	Kode	485	11^0.38'	8^0.25'	2.80
5.	Lautaye	480	11^0.41'	8^0.33'	3.08
6.	Turba	479	11^0.40'	8^0.33'	2.02
7.	Yantoma	493	11^0.36'	8^0.25'	18.48
	Total				**79.190**

Source*: Hadejia-Jama'are River Basin Development Authority (2017)*

In each of the soil sample site, one grid cell of 100mx100m were marked and soil samples were collected randomly in five points and a composite was prepared from the depth of 0-20cm topsoil because the root of rice plants are normally concentrated within this soil profile where the bulk of soil nutrients content is located (Ferguson and Harget, 2009).

3.3.2 **Questionnaire Administration**

Within Kano River Project Phase I, there are 58 settlements of different status. Ten (10) settlements with a high number of head of households that are engaged in irrigated rice farming and belong to Water Users Association (Table 3.5) were purposively selected for the study. The 10 settlements are presented Figure 10.

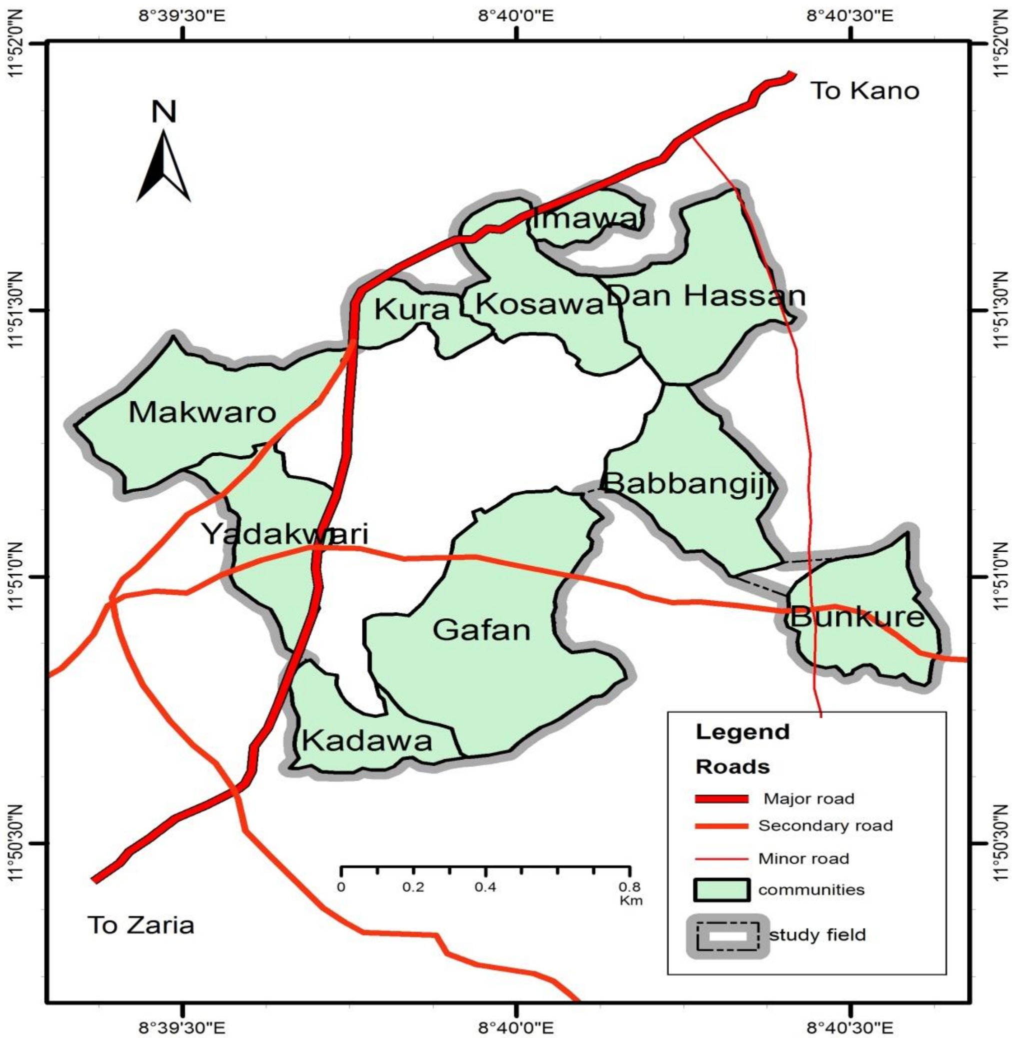


Figure 10: Study Settlement

The respondents were selected from within landowners and tenants and farm size as operationalized by Shand and Kalirajan (1991) in their cross-sectional study of farmers in a mature irrigation project in Kelanta, Malaysia.

All 1,730 head of households that registered with the Water Users Association from the 10 rice farming settlements they were administered. to complete with the help of research assistants who are familiar with the area and understand the language. The researcher identified and interviewed the 40 respondents from whom farmlands soil samples were collected.

Table 3.5: Registered Household Heads, Land Ownership and Farm Size

Serial No.	Rice Farming Settlement	Household Head Number	Land Owner				Land Tenant			
			< 1ha	1ha -2ha	> 2ha	Sub-total	< 1ha	1ha -2ha	> 2ha	Sub-total
1.	Kura	**513**	150	93	10	**253**	120	60	80	**260**
2.	Bunkure	**105**	47	4	0	**51**	36	18	0	**54**
3.	Danhasan	**281**	13	140	0	**153**	48	80	0	**128**
4.	Yadakwari	**243**	120	13	0	**133**	60	50	0	**110**
5.	Babbangiji	**205**	55	40	0	**95**	10	100	0	**110**
6.	Kadawa	**58**	18	5	0	**23**	26	9	0	**35**
7.	Gafan	**46**	10	8	0	**18**	21	7	0	**28**
8.	Imawa	**113**	15	23	10	**38**	10	40	25	**75**
9.	Kosawa	**85**	15	30	10	**55**	5	10	15	**30**
10.	Makwaro	**81**	25	15	8	**48**	15	5	13	**33**
	Total	**1,730**	**468**	**361**	**38**	**867**	**351**	**379**	**133**	**863**

Source*: Water Users Association Office (2017)*

From 1,730 copies of questionnaires that were distributed in the ten settlements, 1,636 copies were completed and found useful for research analysis.

3.4. **Laboratory Analysis**

Soil samples collected were air-dried, grand and sieved for laboratory analysis:

In the soils laboratory, the following soil physical properties were analyzed: particle size distribution was determined using the hydrometer method as described by Boyoucous (Gee and Bauder, 1986). Bulk density was determined by core method and total porosity was calculated assuming a particle density of 2.65g/cm as determined by Amana *et al.*, (2012); the size distribution aggregate was measured using wet sieving through a series of sieve (2.0, 1.0. 0.5, 0.25). The percentage water aggregate was determined using the model of Van Bowel (1950) as modified by Kemper and Roseau (1986) to determine the mean weight diameter of the wet stable aggregate.

Chemical properties analyzed include the soil organic carbon was determined by Walkey – Black method (Nelson and Sommer, 1996). The total nitrogen (TN) was determined by Kjeldahl and Bremner, (1996) method. Soil pH and electrical conductivity were measured by pH method (Rhoades, 1996) in soil water solution. Available phosphorous was extracted using Bry-1 extracting method (Bray and Kurtz, 1994). Ca^{2+} and Mg^{2+} were read by atomic absorption spectrometer while K^+ and N^+ were also read with a flame photometer. Cation exchange capacity (CEC) was calculated as a ratio of exchange bases to the effective cation exchange capacity (ECEC) express in percentage.

3.5 **Data Analytical Techniques**

The analytical techniques employed were based on the objectives of the study. Data were subjected to descriptive and inferential statistical methods.

3.5.1 **The Descriptive Method** included percentage, mean and mode.

3.5.2 **Inferential Methods** used were:

3.5.2a **Coefficient of Variation**:

This analytical technique was used to express the variability or homogeneity of soil physical and chemical characteristics obtained by converting the standard deviation of each soil property to a percentage of the mean of each soil property as employed by Olabode (2014) in soil suitability assessment for sustainable rice production in Patigi Kwara State Nigeria. It was also used to achieve objective 1. The coefficient of variation is expressed as:

$$V = \frac{S}{m} \times 100$$

Where: V = Coefficient of Variation

S = Standard Deviation

m = mean

3.5.2b **Student's t-test**:

This technique was used to determine the significant difference of sample means of soil parameters. Oriola (2005) used it to compare two sample means of irrigated and non-irrigated datasets in his study on analysis of the impact of the irrigation project on the soil environment and socio-economic status of farmers in Okey-Oyi Ilorin, Kwara State. It was also used to achieve objective 1. The student t-test formula is:

$$\text{'t'} = \sqrt{\frac{((x - \acute{X})^2 + (y - |)^2)}{n_x + n_y - 2}}$$

Where: $\acute{X}$ = mean of x variable

| = mean of y variable

$\sum$ = sum of deviation

n = number of sample variable

3.5.2c **Product Moment Correlation Coefficient**:

The Person Product Moment Correlation Coefficient (r) was used to determine the correlation coefficient of the farm input costs and a net profit of rice produced among peasant farmers as used by Ibrahim (2007) in the analysis of farm input costs and net profit in Kano irrigation project. This was used to accomplish objective 2. The correlation coefficient formula is:

$$Rxy = \frac{\sum^{N}(X-X)(y-y)}{Nsxsy}$$

Where: x = Total cost of inputs

y = the net income accrued from the production of rice crop

sx = the standard deviation of the total cost of inputs.

Sy = the standard deviation of net income

N = Number of the sample observed.

To test the significance, t is the statistical formula: $t = r \dfrac{n - 2}{1 - r^2}$

3.5.2d **Covariance Analysis**:

Covariance analysis was used to evaluate the inputs and outputs of rice produced under irrigation farm management. This analytical technique was selected because it is one of the techniques that Shand and Kalijaran (1991) used in the cross-sectional study of samples of farmers from a mature irrigation project in Malaysia to identify the significant differences in production cost of new rice technology (variety) and net profits distribution among peasant socio-economic groups within the irrigation project. It was used to achieve objective 2.

For this, the average sum of the products of every individual's x-deviation score (cost of inputs) and y-deviation score (rice farm production profit) serve as cost and profit thresholds of rice production. A numerical score index of rice farming community that reflects both the direction and magnitude of the statistical relation of x and y is of the form shown below:

$$C_{XY} = \frac{\sum (x_{1} - x)(y_{1} - y)}{N}$$

Where: C_{XY} =covariance of the relation x and y.

x_1 = cost of production using technologies

y_1 = benefit or net income.

N = total observation of the respondents.

3.5.2e **Factor Analysis:**

This technique is considered to be one of the most suitable tools for reducing a large data set of this nature to a small number of limiting factors. It was used to examine adjustment level to irrigation project farming inputs recommendation as well as identifying the spatial dimension of farming factors that account for variations and segregation in the patterns of peasant socio-economic differential performance in rice production input cost system to achieve objective 3 and 4. Ibrahim (2007) used it in the analysis of agricultural inputs and benefits distribution from agricultural modernization in Kano River Project I. The factor analysis is expressed mathematically as;

$f = \sum wj\ wj = W_1X_1 + W_2X_2 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots W_n\ X_n \ldots\ldots 1$

Where = Wn – Wn = Factor weight (that is a value given to assist in determining the scores for a given factor).

$X_1\ X_n$ = farm management variables such as labour (in Man-days), quantity of seed, fertilizer, agro-chemicals; labour cost, seed, fertilizer, agro-chemicals; farm size, farming experience, household size, extension contact, level of education, land ownership, and crop diversification).

A varimax rotation was applied to the 16x16 data matrix involving modern agricultural components (inputs and costs), and its performance in 10 settlements, in Kano River project I. The analysis has applied to the factor cost of variable agricultural inputs for irrigated rice production. The model was broken down into a series of operational steps for rice variable crop cultivated at the project site. These started with: 1. the original data matrix 2; correlation matrix 3; the initially derived factor matrix 4; transformed or rotated factor matrix and 5; a listing of factor scores.

Despite a different number of computer programs available to carry out factor analysis, in this research attention was focused on the use of SPSS system. The emphasis here is placed on the geographical significance of the computer prints out. This package was used to obtain a variable list, the correlation matrix, communalities, factor loading eigenvalues, the percentage of variance, explained by each factor scores and factor loading based on some type of rotational solution, to examine rice variable input factors at the project site.

Rice Production Variables for Factor Analysis

The variables used as input into the factor analysis were considered by developing a variable to depict rice agricultural inputs and technical efficiency. The original variables listed cover a wide range of physical and human characteristics of rice farming practice. The set of variables contain 16 indices; each measured in relation to their distribution on 10 settlements as indicated in table 3.6.

Table 3.6: Rice Production Variable Input Lists

Definition of Determinant of Rice Production Variable Inputs per Hectare	
Input Variables	
1.	Labour (Man-hours)
2.	Labour (Man-days)
3.	Seed (Kg/ha)
4.	Fertilizer (Kg/ha)
5.	Agro-Chemicals (Lt/ha)
Economic / CostVariables	
6.	Cost of Labour (Man-days)
7.	Cost of Seed
8.	Cost of Fertilizer
9.	Cost of Agro-Chemicals
Sociological / Technical Efficiency Variables	
10.	Farm Size (ha)
11.	Farming Experience (Age of the Farmer)
12.	Household Size (No. of Persons)
13.	Extension Contact (No. of Visit)
14.	Higher Education
15.	Land Ownership
16.	Crop Diversification

All variables of rice production (quantity of inputs and socio-economic) are expected to contribute directly to the extent of farmers' net profits and sustainable effects, which vary according to variation in the settlement farming indices.

3.5.2f **Sustainability Index**:

A sustainability index (Z_0) was used to assess the sustainability of the present system (S_0) for rice crop production. A total of seven indicators of sustainability were used to obtain the value of the sustainability index. Two of these indicators were for an economic yield of rice per hectare and adequate farm income. The environmental indicators are: maintaining an acceptable level of soil pH, organic matter, nitrogen, phosphorous and potassium in the soils. The indicators were chosen on the basis of the recommendation of environmental and economic variables for monitoring and evaluation schedules under land resources evaluation (Essient 1987) and Fadama II project (PCU, 2002). The measurement for indicators was compared with a threshold level (a_i) specified in table 3.7 and 3.8 to determine the level of achievement, over achievement (p_1) or underachievement (n_i) as the case might be expressed in percentage respectively to overcome their differences in units (Rehma and Romero, 1984). The percentages were summed up to obtain a value for Z_0 which indicates whether the system is sustainable or not. The S_0 is sustainable if the value of Z_0 is equal to zero, implying that all threshold levels should be achieved completely.

Table 3.7: Thresholds Levels for the Environmental Indicators

Indicators	**Unit**	**Threshold Levels**
pH	nil	6.5 – most crops do well within a range of 6 – 7.
Nitrogen	g/kg^{-1}	2.0 – a value above 2.0 is very high and can lead to an extension of vegetative growth of crops
Phosphorous	mg/kg^{-1}	20.0 – any value above 20.0 is high and can lead to a reduction in crop yield.
Organic Carbon	g/kg^{-1}	68.8 – any value above this limit is considered very high and nitrogen mineralization is reduced.
Potassium	$cmol/kg^{-1}$	0.30 - any value above this limit can lead to a reduction in crop yield.

Source: PCU (2002)

The economic indicators considered are presented in table 3.8. The threshold level for the yield indicator is the potential yield per hectare of rice as obtained from Hadejia-Jama'are River Basin Authority Dry Season Rice Area Cropped Survey, Cost and Yield 2016/2017.

Table 3.8: Thresholds Levels for the Economic Indicators

Indicator	**Unit**	**Threshold Levels**
Yield	Kg	Potential Yield Kg per hectare
Farm Income	₦	5% better than average net farm income among the rice farmers.
Cost of Inputs	₦	5% better than the average cost of inputs among the rice farmers.

Source: Hadejia-Jama'are River Basin Authority (2017)

A final assessment of the sustainability of the present (S_0) value was done by comparing the value of the sustainability index of the present system (Z_0) with that of the improved system

(Z_1) obtained after optimization using goal programming method. Mayong and Degand (1995) used sustainability index method of farming systems in Central Africa. Both Z_0 and Z_1 are specified below to achieve objective 5:

$$Z_0 \text{ or } Z_1 = \sum_{i=1}^{8} n_i (p_i) \, y/a_i * 100 \ldots\ldots\ldots\ldots\ldots\ldots 1$$

3.5.2g **Goal Programming**

According to Baker *et al*., (1998) Goal Programming (GP) Model was an efficient tool for integrating agro-ecological (environmental) and socio-economic data and explore possibilities for sustainable agriculture. The model can manipulate data for linear programming to find the greatest value of unknown solution which is subjected to the given condition. It solves the problems with an aim to maximize or minimize a certain quantity of either profit or loss. It can also solve problems that have two unknown linear constraints and multi-objective problems. It dates back to Charnes *et al.*, (1972) seminar presentation work. Njiti and Sharpe (1994) mentioned that GP has required the assumption of traditional programming models in addition to linearity, additivity, divisibility, determinism and homogeneity assumptions that include:

- in the course of production process different units of outputs will be produced;
- the confine allocated land units will be executed as planned on schedule by all management activities;
- there are realistic budget and expected revenue;
- all production goals are realistic;
- the scope of the decision maker is based on all resources and environmental constraint;
- all available land types are obtained for the intended uses and their known location and size;
- all weights attached to deviational variables reflect accurate rankings among respective goals.

Weighted Goal Programming (WGP) was among the Goal Programming models that were utilized for this study instead of Lexicographic Goal Programming (LGP) because less time and data are required and considers all goals simultaneously in a composite objective function. In mathematical terms, the model has adapted from Njiti and Sharpe (1994) and modified to be represented as follows.

$$\text{Minimize } Z_1 = \sum_{I=1}^{g} (\acute{\alpha}_i.n_i + \acute{\alpha}_i.p_i) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 2$$

Subject to

$$\sum_{I=1}^{g} A_{ij} X_j + n_i - p_i = a_i \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3$$

$$\sum_{J=1}^{m} A_{kj} X_j \leq b_k \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 4$$

$X_j\, n_i p_i \geq 0$ for all j and i

Where:

Z_1 = Function of objectives that includes the total cost of production per hectare of the crop enterprise as well as the positive and negative deviations for the goals respectively (Njiti and Sharpe, 1994 and Adejobi, 2004).

n_i= negative deviation if a_i under-achieved

p_i = positive deviation if a_i is over-achieved

$\acute{\alpha}_i$= weight or relative importance attached to deviation n_i and p_i

A_{ij} = matrix of a_{ij}

a_{ij}= marginal contribution of x_j for achieving goal a_i

a_i = aspiration or threshold level for the ith goal

x_j = jth crop production activity

A_{ij}= coefficient of the use b_k for the jth crop production activity

b_k = level of the kth resource available

m = number of resources

g = number of goals

$n_i * p_i = 0$

The condition ($n_i * p_i = 0$) implies that the product of the deviations must be equal to zero for any goal. The WGP model specified above was used for assessment of the sustainability of rice production under river basin irrigation project. All the eight indicators of sustainability were treated as a goal (g) to be achieved. The threshold level determined for each indicator was target or aspiration level (a_1) for its corresponding goal respectively in the goal programming model to achieving objective 4 and 5.

The objective function was to minimize the positive (p_i) and negative (n_i) deviation attached to the goals. A weight of equal importance was attached to the economic and environmental goals because each one of them is considered very important for the sustainability of rice production system (Table 3.9). A weight of zero is attached to pH goal due to the condition ($p_i * n_i = 0$) earlier specified.

Table 3.9: Thresholds Levels for the Economic and Environmental Indicators

Goal Target	Achievement of Goal Statement	Objective Function to Minimize	Deviational Variable in Objective Function	Priority Level	Weight
Maximize the yield of rice	Achievement of the potential crop yield per hectare	Under-achievement	n_i	1	5
Maximize the farm income	Achievement of the desired level of income	Under-achievement	n_i	1	5
Maintain soil health and reduce environment al impacts	Maintain acceptable level of: Organic matter Nitrogen Phosphorous Potassium	Under achievement Under achieved Over achieved Over achieved	n_i n_i p_i p_i	1 1 1 1	5 5 5 5
Improve soil fertility	Maintain acceptable level of soil pH	Neither under nor over-achievement	$p_i * n_i$	1	0

CHAPTER FOUR

SOIL CONSTRAINT TO SUSTAINABLE IRRIGATED RICE PRODUCTION IN KANO RIVER PROJECT I

4.1 Nature and Characteristics of Pab Soil Unit under Rice Production in Kano River Project I

The variables in the irrigated and adjacent non-irrigated soils of Kano River Project I was assessed and presented in table 4.1a and appendix ii.

4.1a Pab Soil Unit in Kura

The physical properties of the irrigated soils have high sand content (80%) compare with non-irrigated soil (74%). The sand content of the irrigated soil ranged between 76% and 83% and the non-irrigated soil ranged between 74% and 79%. The silt content of the two sites was 13%. They are similar and constant with ranged in irrigated soil between 11% and 15%, while in the non-irrigated soil it was between 12% and 14%. Clay proportion varies, the irrigated soil contained 7% and non-irrigated soil contained11%. The clay content ranged from 6% to 9% in irrigated soil, while in the non-irrigated soil it was from 7% to 14%. The soil physical property has been modified because of the continuous mechanical cultivation of the irrigated soil and this resulted in the different of the sand fraction which was 76% in non-irrigated soil and 80% in irrigated soil. Unlikely, there was deterioration in the clay fraction from 11% in the non-irrigated soil to 7% in irrigated soil. This result is in similar to the finding of Daniel (1987) report which showed a similar trend in clay content. This result was formed as a result of the elluviation process down the soil profile.

The bulk density of non-irrigated soil was slightly higher 1.43mg/m^3 when compared with the mean value of 1.4mg/m^3 in the irrigated soil. There was a difference in the range of bulk density from 1.0 to 1.8 in irrigated soil and from 1.2 mg/m^3 to 1.7 mg/m^3 in the non-irrigated soil. This corroborated the observation of Olaitan *et al.,* (1988) in one of their studies where they mentioned that bulk density in the sand, loams, and sandy loams have bulk density ranged between 1.20 mg/m^3 and 1.80 mg/m^3.

Similarly, the results of water holding capacity were higher in non-irrigated soil with a mean value of 7.36% compared with 6.8% of irrigated soil and the range varied from 6.3% to 7.4% in the irrigated soil to 6.5% and 8.1% in non-irrigated soil. This is probably because cultivation brings about a reduction in the amount of organic matter and the soil becomes compact. This leads to increase in bulk density and reduces pore space that would hold soil water and air. Generally, all the physical parameters analyzed in the study exhibited homogeneity in both irrigated and non-irrigated soils (Table 4.1a).

Table 4.1a: Characteristics and Properties of Irrigated and Non-Irrigated Pab Soil Unit in Kura Branch

	Irrigated Soil				**Non-Irrigated Soil**			
Physical Properties	**Mean**	**Min**	**Max**	**C.V.**	**Mean**	**Min**	**Max**	**C.V.**
% Sand	80.0	76.0	83.0	2.38	76.0	74.0	79.0	1.71
% Silt	13.0	11.0	15.0	8.94	13.0	12.0	14.0	4.36
% Clay	7.0	6.0	9.0	12.78	11.0	7.0	14.0	15.61
Bulk Density mg/m^3	1.4	1.0	1.8	16.90	1.43	1.2	1.7	7.91
% Water Holding Capacity	6.8	6.3	7.4	3.89	7.36	6.5	8.1	5.08
Macro-Nutrients	**Mean**	**Min**	**Max**	**C.V.**	**Mean**	**Min**	**Max**	**C.V.**
pH	6.44	5.84	6.9	4.52	6.31	6.15	6.59	1.84
Exchange Acidity H^+	0.17	0.11	0.23	16.65	0.17	0.13	0.21	11.45
Exchange Ca^{2+} cmol/kg	3.17	1.58	4.76	26.74	2.67	1.2	3.64	22.15
Exchange Mg^{2+} cmol/kg	0.88	0.49	1.21	22.36	1.04	0.7	1.3	13.71
Exchange Na^+ cmol/kg	0.15	0.12	0.18	10.25	0.62	0.57	0.67	4.20
Exchange K^+ cmol/kg	0.62	0.47	0.77	11.31	0.83	0.51	1.15	18.07
Cation Exchange Capacity	6.63	5.81	7.45	6.30	6.20	5.1	7.37	8.62
Base Saturation	75.84	65.46	88.58	7.07	75.85	65.61	88.54	7.27
Organic Matter %	0.69	0.65	0.73	2.92	1.11	0.93	1.25	7.05
Total Nitrogen	0.046	0.02	0.074	27.03	0.06	0.038	0.084	18.13
Available Phosphorous	32.03	28.14	35.05	6.03	20.68	18.38	22.88	5.09
Micro-Nutrients	**Mean**	**Min**	**Max**	**C.V.**	**Mean**	**Min**	**Max**	**C.V.**
Copper meq/100g	5.51	4.55	6	9.02	7.30	7.0	7.6	1.94
Manganese meq/100g	5.62	5.2	6.2	5.42	4.41	4.3	4.6	1.82
Iron meq/100g	3.08	2.52	3.51	7.89	6.24	5.82	6.83	4.40
Zinc meq/100g	5.88	5.32	6.59	6.01	5.88	5.24	6.52	5.11
Boron meq/100g	0.41	0.38	0.44	4.11	0.70	0.65	0.76	3.56

Source: Author's Data Analysis (2017) ***** Highly Variable C.V. > 33.33%

The soil pH in irrigated and non-irrigated soils show the slight difference (6.64 in irrigated soil and 6.31 in non-irrigated soils) because the soil parameter shares the same parent material and climatic condition. The pH ranges showed slight acidic indicator to slight alkaline (5.84 to 6.90 in irrigated soil and 6.15 to 6.59 in non-irrigated soil). This soil property exhibited homogeneity in both irrigated and non-irrigated soil as shown in table 4.1a.

The exchange acidity exhibited spatial homogeneity in both irrigated and non-irrigated soil. Despite the fact, they exhibited similar mean value; but their parametric values ranged varied slightly accordingly (0.11 to 0.23 in irrigated soil and 0.13 to 0.21 in non-irrigated soil) because the soils are derived from the similar parent material.

The value of the cation exchange capacity ranged between 5.81 and 7.45 in irrigated soil and 5.1 and 7.37 in non-irrigated soil with a C.V. value of 6.3% and 8.6% in both irrigated and non-irrigated soils respectively as shown in Table 4.1a.

Base saturation ranged between 65.46% and 88.58% in irrigated soil, whiles the content in non-irrigated soil ranged between 65.61% and 88.54%. Similarly, the soil parameter exhibited spatial homogeneity in both soil sample sites.

The content of the organic matter ranged between 0.65% and 0.73% in irrigated soil and 0.93% and 1.25% in non-irrigated soil and exhibited homogeneity in both irrigated and non-irrigated soils. The mean value of organic matter was higher in the non-irrigated soil compared with irrigated soil because of crop removal after harvest and the nature and rate of biochemical reaction are higher with increasing temperature.

The value of total N_2 ranged between 0.02 and 0.074 in irrigated soil and 0.052 and 0.084 in non-irrigated soil and the variables exhibited homogeneity. The content of nitrogen in the irrigated soil was lower because of leaching as results of infiltration, crop removal after harvest and excessive waterlog drained out from the irrigation farmland.

Available phosphorous ranged between 28.14 and 35.05 in irrigated soil and 18.38 and 22.88 in non-irrigated soil and both soils exhibited spatial homogeneity (Table 4.1a). The content of available phosphorus was higher in the irrigated soil than in non-irrigated soil because of the application of N.P.K. chemical fertilizer.

The content of copper in the non-irrigated soil was higher (7.30meq/100g) than in irrigated soil (5.50 meq/100g) because the soil pH was lower in the non-irrigated soil as Olaitan *et al.,* (1988) observed that any soil with low soil pH has a higher content of copper. Manganese has higher content in the irrigated soil compared with non-irrigated soil because the acidic nature of the irrigated soil farmland often stimulates the production of manganese (Olaitan *et al.,* 1988). The content of iron in the irrigated soil was lower when compared with non-irrigated soil because excessive zinc in the non-irrigated soil might have interfered with iron production as mention by Olaitan *et al.,* (1988). The content of zinc was similar in the irrigated compared with non-irrigated soil, perhaps it always replenishes by addition of crop residue in the irrigated soil. Finally, boron content was higher in the non-irrigated soil than in irrigated soil because of higher content of organic matter reservoir in the non-irrigated soil. All the micro-nutrient elements in the irrigated and non-irrigated soils exhibited spatial homogeneity because the soils have similar parent material and climatic condition (Table 4.1a).

The assessment of irrigated and non-irrigated properties of Pab soil of Kura branch, the sand, pH and available phosphorus increased tremendously, while clay, magnesium, exchange potassium, organic matter and base saturation decreased substantially. These findings were similar to the finding of Daniel (1987) in the Tomas irrigation project in the Sudan Savanna of Kano State; however, the results of silt, calcium, and C.E.C. were contrary to his findings.

4.1b **Pab Soil Unit in Bunkure**

The result of the laboratory analysis of Pab soil unit in Bunkure is presented in table 4.1b. The proportion of the sand in irrigated soil was higher (69%) than in non- irrigated soil (68%). The silt content was higher in irrigated soil than in non-irrigated soil. The clay content was lower in the irrigated soil compared with non-irrigated soil. The bulk density and water holding capacity were higher in irrigated soil than in non-irrigated soil. All the parameters of soil physical properties exhibited homogeneity. The physical properties have been adjusted because of the combined effort of traditional and mechanical land cultivation.

The results of soil chemical properties revealed that soil pH indicated slightly acidic in the both irrigated and non-irrigated soils. Its content was slightly higher in the non-irrigated soils and both variables exhibited spatial homogeneity. Likewise, exchange acidity showed slight different between soil samples and exhibited homogeneity. The exchangeable cation elements were all greater in non-irrigated soil compared with irrigated soil. All the exchangeable cation elements exhibited spatial homogeneity in both irrigated and non-irrigated soils. The exchangeable cation elements were not being altered because there was intensive land cultivation.

The cation exchange capacity content was higher in non-irrigated soil compared with irrigated soil because of traditional land tillage and mixed cropping (rice production in the rainy season and any other crop of farmer's choice in the dry season). This attribute exhibited homogeneity in both soils.

The content of base saturation in non-irrigated soil was above that of irrigated soil because of organic manure is used to replenish soil bases which are removed by the plant during harvest. The attribute exhibited homogeneity in both soils as shown in table 4.1b.

Organic matter content was higher in the irrigated soil when compared with non-irrigated soil and both of the soils also exhibited spatial homogeneity; this was because of higher application of organic manure and crop residue in the irrigated soil.

Total N_2 was higher in non-irrigated soil compared with irrigated soil. This implied that there were leaching and burning of plant residue in the irrigated soil and both of the soil samples exhibited spatial homogeneity (Table 4.1b).

Table 4.1b: Characteristics and Properties of Irrigated and Non-Irrigated Pab Soil Unit in Bunkure Branch

	Irrigated Soil				**Non-Irrigated Soil**			
Physical Properties	**Mean**	**Min.**	**Max.**	**C.V.**	**Mean**	**Min.**	**Max.m**	**C.V.**
% Sand	69.0	57.0	75.0	6.33	68.0	61.0	74.0	5.58
% Silt	26.0	24.0	31.0	6.97	25.0	22.0	28.0	5.93
% Clay	5.0	6.0	8.0	6.71	7.0	6.0	8.0	10.15
Bulk Density mg/m^3	0.80	0.74	0.89	4.77	0.50	0.42	0.6	10.43
% Water Holding Capacity	9.81	7.84	11.76	9.18	9.5	7.69	11.45	9.92
Macro-Nutrients	**Mean**	**Min.**	**Max.**	**C.V.**	**Mean**	**Min.**	**Max.**	**C.V.**
pH	6.44	5.66	7.18	6.55	6.61	5.83	7.39	6.67
Exchange Acidity H^+	0.45	0.28	0.58	15.84	0.38	0.31	0.42	7.22
Exchange Ca^{2+} cmol/kg	2.42	1.92	2.9	9.49	2.58	2.04	3.34	14.16
Exchange Mg^{2+} cmol/kg	0.83	0.72	0.94	8.85	1.04	0.82	1.22	10.40
Exchange Na^+ cmol/kg	0.09	0.08	0.096	6.86	0.13	0.12	0.15	8.27
Exchange K^+ cmol/kg	0.33	0.17	0.55	32.78	0.66	0.52	0.78	9.22
Cation Exchange Capacity	5.81	5.07	7.26	12.81	7.13	6.14	8.03	6.85
Base Saturation %	57.34	48.25	63.18	6.55	61.80	59.46	64.83	2.10
Organic Matter %	1.72	1.22	2.2	16.33	0.99	0.64	1.36	18.60
Total Nitrogen	0.07	0.03	0.09	21.97	0.11	0.08	0.13	12.23
Available Phosphorous	31.03	29.62	32.24	2.06	29.31	28.4	30.19	1.41
Micro-Nutrients	**Mean**	**Min.**	**Max.**	**C.V.**	**Mean**	**Min.**	**Max.**	**C.V.**
Copper meq/100g	7.23	6.39	8.42	8.35	5.46	4.47	6.55	8.71
Manganese meq/100g	6.67	5.77	7.75	9.89	6.67	5.87	7.47	5.88
Iron meq/100g	4.62	3.72	5.49	14.23	3.08	2.63	3.51	6.62
Zinc meq/100g	3.52	2.75	4.77	17.15	5.88	4.97	6.86	9.11
Boron meq/100g	0.80	0.68	0.95	10.69	0.5	0.47	0.56	5.80

Source: Author's Data Analysis (2017) ***** Highly Variable C.V. > 33.0%

Available phosphorous was relatively higher in irrigated soil compared with non-irrigated soil. This result indicates that available phosphorus was applied using N.P.K. chemical fertilizer and organic matter. Both soil samples exhibited spatial homogeneity of irrigated and non-irrigated soils as shown in table 4.1b.

All the contents of micro-nutrients elements were relatively high in the irrigated soil samples with exception of manganese and zinc which have higher content in the non-irrigated soil sample. This was because of higher application of organic manure which is a major reservoir of micro-nutrient. All the micro-nutrient parameters exhibited spatial homogeneity (See Table 4.1b)

4.1c **Differences in the Characteristics of Pab Soil Unit under Rice Production in Kano River Project I**

Table 4.1c presents the results of the student‘t’ test performed on the soil samples from Kura and Bunkure irrigated and non-irrigated rice soil farmlands. All the physical properties of irrigated and non-irrigated were significantly different with exception of silt and bulk density in the Kura branch and these parameters (silt and bulk density) in Bunkure branch were also alike in both irrigated and non-irrigated soils and all the other parameters were significantly different. The findings of this study were similar to the work of Daniel (1987) in which the results of t-value differed in sand and clay.

All the micro-nutrient irrigated and non-irrigated were different with exception of pH, exchange acidity, calcium and base saturation. While the laboratory results of micro-nutrients in the Bunkure branch were different with exception of soil pH and calcium. These findings were similar to the work of Daniel (1987) reports in which the elements that were different included pH, exchange magnesium, exchange sodium, exchange potassium, cation exchange capacity, available phosphorus and base saturation.

The laboratory results of all the macro-nutrients revealed significant differences in both Kura and Bunkure with exception of boron in Kura branch and manganese in Bunkure branch as shown in table 4.1c.

Table 4.1c: Comparison of Non-Irrigated and Irrigated Pab Soil Properties

	Kura Pab Soil Unit			Bunkure Pab Soil Unit		
Soil Properties	**Non-Irrigated**	**Irrigated**	**t-value**	**Non-Irrigated**	**Irrigated**	**t-value**
% Sand	76	80	5.0*	68.0	69.0	0.71
% Silt	13	12.5	1.23	25.0	26.0	2.53*
% Clay	11.04	7.0	6.24*	7.0	5.0	0.38
Bulk Density mg/m^3	1.43	1.4	0.29	0.50	0.42	13.98*
% Water Holding Capacity	7.34	6.8	3.69*	9.5	7.69	0.71
Macro-Nutrients	**Non-Irrigated**	**Irrigated**	**t-value**	**Non-Irrigated**	**Irrigated**	**t-value**
pH	6.33	6.44	1.04	6.61	5.83	0.84
Exchange Acidity H^+	0.17	0.17	0.66	0.38	0.31	2.96*
Exchange Ca^{2+} cmol/kg	2.67	3.17	1.39	2.58	2.04	1.10
Exchange Mg^{2+} cmol/kg	1.04	0.88	1.98*	1.04	0.82	4.80*
Exchange Na^+ cmol/kg	0.62	0.16	47.36*	0.13	0.12	11.42*
Exchange K^+ cmol/kg	0.83	0.62	3.89	0.66	0.52	7.95*
Cation Exchange Capacity	6.20	6.63	1.89*	7.13	6.14	3.74*
Base Saturation	75.86	75.84	0.001	61.80	59.46	3.57*
Organic Matter %	1.11	0.69	15.72*	0.99	0.64	6.53*
Total Nitrogen	0.06	0.05	2.31*	0.11	0.08	5.25*
Available Phosphorous	20.68	32.03	15.47*	29.31	28.4	6.78*
Micro-Nutrients	**Non-Irrigated**	**Irrigated**	**t-value**	**Non-Irrigated**	**Irrigated**	**t-value**
Copper meq/100g	7.30	5.51	10.39*	5.46	4.47	10.39*
Manganese meq/100g	4.41	5.62	11.45*	6.67	5.87	11.45*
Iron meq/100g	6.24	3.08	5.49*	3.08	2.63	25.78*
Zinc meq/100g	5.88	5.88	4.77*	5.88	4.97	0.039
Boron meq/100g	0.69	0.41	0.95	0.5	0.47	29.52*

Source: Author's Data Analysis (2017) ***** Critical Level: 5% (1.73)

4.2 **Nature and Characteristics of Pab/Pb Soil Complex Unit under Rice Production in Kano River Project I**

The variables in the irrigated and non-irrigated soils of Kano River Project I was assessed and presented in table 4.2a.

4.2a **Pab/Pb Soil Complex Soil Unit in Kura**

The second soil unit recognized in Kura branch was Pab/Pb Complex. This irrigated soil was heavily sandier compared with non-irrigated soils. The irrigated soil proportion ranged from

76% to 82% compared with non-irrigated which ranged from 71% to 78% and all the variables exhibited homogeneity in both the soils. The proportion of silt content of the irrigated soil was less compared with non-irrigated soil and showed homogeneity in both irrigated and non-irrigated soil. The clay content was the same in quantity without any significant change of their mean values; it showed homogeneity in both soils. The physical properties were transformed because of continues mechanized cultivation. When compared the data between irrigated and non-irrigated soils, the content of sand was increased, while the content of silt particle was decreased. The bulk density was greater in irrigated soil compared with non-irrigated soil because cultivation reduces the amount of organic matter in the soil and increase bulk density. The water holding capacity was greater in non-irrigated soil compared with irrigated soil. This was because intensive cultivation reduces the soil pore space, increase bulk density and soil compactness. All attributes of the physical property exhibited spatial homogeneity in both soils (Table 4.2a).

The chemical properties of the soil are presented in table 4.2a. The soil pH content was 6.85 in irrigated soil and 7.02 in the non-irrigated soil. This indicated that there was low organic matter in the non-irrigated soil and farmers applied organic manure and chemical fertilizer. Both the soil samples exhibited homogeneity. While the mean values of the exchange acidity remain the same and exhibited homogeneity in both irrigated and non-irrigated soils.

The content of exchangeable cation showed that Ca^{2+} and Mg^{2+} were higher in the irrigated soil compared with non-irrigated soil probably because 1.22m CaCO3 is available down the soil profile (NEDECO, 1976) and mechanical tillage makes the soil to expose the $CaCO_3$ and Mg was provided by the use of organic manure. While Na^+ and K^+ content were lower in irrigated soil compared with non-irrigated soil because these elements were washed away when the excess irrigation water was drained out of the farmlands. All the parameters of exchangeable cation exhibited homogeneity in both irrigated and non-irrigated soils with exception of Mg of the non-irrigated soil. The cation exchange capacity was also slightly greater in the irrigated soil compared with non-irrigated soil because of application of manure and chemical fertilizer to replace the removed cations by leaching and plant tissues and all variables exhibited homogeneity in both soils. The based saturation and organic matter were higher in the irrigated soils compared with non-irrigated soil because all organic carbon and bases removed by leaching and plant tissues were replenished and the attributes exhibited spatial homogeneity in both soil samples.

Table 4.2a: Characteristics and Properties of Irrigated and Non-Irrigated Pab/Pb Soil Complex in Kura

	Irrigated				Non-Irrigated			
Physical Properties	**Mean**	**Min.**	**Max.**	**C.V.**	**Mean**	**Min.**	**Max.**	**C.V.**
% Sand	78.0	76.0	82.0	2.55	74.0	71.0	78.0	2.56
% Silt	15.0	12.0	17.0	9.13	19.0	18.0	20.0	3.33
% Clay	7.0	6.0	8.0	9.66	7.0	6.0	8.0	11.07
Bulk Density mg/m^3	1.5	1.3	1.8	10.12	1.2	1.0	1.4	9.86
% Water Holding Capacity	7.2	6.6	7.8	5.82	8.1	7.8	8.5	2.34
Macro-Nutrients	**Mean**	**Min.**	**Max.**	**C.V.**	**Mean**	**Min.**	**Max.**	**C.V.**
pH	6.85	6.23	7.62	6.63	7.02	6.3	8.06	8.32
Exchange Acidity H^+	0.33	0.3	0.36	5.30	0.33	0.29	0.35	4.98
Exchange Ca^{2+} cmol/kg	3.5	3.0	4.2	9.88	3.08	2.75	3.40	6.69
Exchange Mg^{2+} cmol/kg	1.46	1.3	1.68	8.92	1.03	0.12	1.34	33.07*
Exchange Na^+ cmol/kg	0.19	0.16	0.21	7.35	0.23	0.18	0.28	11.17
Exchange K^+ cmol/kg	0.36	0.27	0.46	16.93	0.85	0.78	0.91	4.08
Cation Exchange Capacity	7.18	6.49	7.78	5.36	7.10	6.49	7.45	4.14
Base Saturation	76.57	64.48	83.23	6.56	75.27	64.16	83.78	6.41
Organic Matter %	0.93	0.66	1.21	20.09	0.69	0.55	0.84	11.59
Total Nitrogen	0.035	0.024	0.046	17.21	0.19	0.06	0.65	123.88*
Available Phosphorous	35.34	31.65	38.27	5.52	38.79	35.65	42.4	4.15
Micro-Nutrients	**Mean**	**Min.**	**Max.**	**C.V.**	**Mean**	**Min.**	**Max.**	**C.V.**
Copper meq/100g	10.92	10.41	11.74	3.47	9.09	7.8	11.0	8.51
Manganese meq/100g	3.33	2.81	3.87	10.07	4.44	4.0	4.86	5.68
Iron meq/100g	4.78	3.85	7.0	18.66	3.44	0.6	7.06	42.65*
Zinc meq/100g	4.71	3.67	5.53	12.89	7.06	6.77	7.42	2.61
Boron meq/100g	0.6	0.45	0.7	12.52	0.73	0.65	0.82	5.91

Source: Author's Data Analysis (2017) ***** Highly Variable C.V. > 33.0%

Total nitrogen and available phosphorous were low in the irrigated soil compared with non-irrigated soil because of intensive cultivation and higher crop removal, leaching, and erosion when excessive irrigation water was drained away from the farmland. Phosphoros exhibited spatial variability in both soil samples, while total nitrogen exhibited spatial homogeneity in irrigating soil and variability in the non-irrigated soil.

Among the micronutrients, the mean values of copper and iron were greater in the irrigated soil compared with non-irrigated soil because low soil pH always enhance availability of copper (Olaitan *et al.,* 1988)), while the soil of the area was derived from the basement complex which is reached in iron and the acidic nature of the soil made it to reacted with more iron to fix soil phosphate as also mentioned by Olaitan *et al.,* (1988). The mean value of other micro-nutrient parameters which were greater in non-irrigated soils included manganese, zinc and boron because lower soil acidity always increases manganese in the soil, higher application of the farmyard manure and organic residue added zinc to the soil and boro was fixed in irrigated because of its higher acidity in the irrigated soil. All the other parameters showed spatial homogeneity in both irrigated and non-irrigated soils with exception of iron in non-irrigated soil (Table 4.2a).

The results of irrigated soils of Pab/Pb soil complex were homogeneous with exception of exchange magnesium, total nitrogen, and iron in the non-irrigated soils.

4.2b **Pab/Pb Soil Complex Soil Unit in Bunkure**

The second soil series recognized in Bunkure branch was Pab/Pb Complex. This irrigated soil proportion was heavily sandier compared with non-irrigated soils. The irrigated soil ranged between 68% and 75% compared with non-irrigated which ranged between 66% and 74% and all the variables exhibited homogeneity in both the soils. The proportion of silt content of the irrigated soil was less compared with non-irrigated soil and showed homogeneity in both irrigated and non-irrigated soil. The clay content was the same in quantity without any difference in their mean values; it showed homogeneity in both soils. The physical properties of this soil unit have been adjusted by the use of mechanical and local farm implements in which sand particles have been increased, while silt content fell from 23% to 21% and these indicated the very slow formation of clay minerals in the soil. The bulk density was greater in irrigated soil compared with non-irrigated soil because heavy tractors cultivation compact soil and plant tissues reduce the amount of organic matter in the soil and as a result bulk density was higher. The attributes of the soils bulk density showed spatial homogeneity in both soils (Table 4.2b). The water holding capacity was greater in the irrigated soil compared with non-irrigated soil. This implies that there were higher organic matters in the non-irrigated soil compared with irrigated soil; this paved way for the soil pore space for water and have made irrigated soil with higher water retention capacity.

Table 4.2b: Characteristic and Properties of Irrigated and Non-Irrigated Pab/Pb Complex Soil in Bunkure

	Irrigated				**Non-Irrigated**			
Physical Properties	**Mean**	**Min.**	**Max.**	**C.V.**	**Mean**	**Min.**	**Max.**	**C.V.**
Sand	72.0	68.0	75.0	2.42	70.0	66.0	74.0	2.78
% Silt	21.0	18.0	24.0	7.06	23.0	22.0	24.0	2.10
% Clay	7.0	6.0	8.0	6.67	7.0	6.0	8.0	7.06
Bulk Density mg/m^3	0.69	0.6	0.8	6.67	0.38	0.32	0.46	8.88
% Water Holding Capacity	8.08	6.8	10.2	10.10	7.70	6.5	9.4	9.04
Macro-Nutrients	**Mean**	**Min.**	**Max.**	**C.V.**	**Mean**	**Min.**	**Max.**	**C.V.**
pH	6.40	5.81	7.27	5.47	7.76	7.12	8.71	4.91
Exchange Acidity H^+	0.17	0.16	0.18	2.86	0.17	0.16	0.19	4.91
Exchange Ca^{2+} cmol/kg	3.25	2.93	3.72	5.83	2.59	1.95	3.52	14.54
Exchange Mg^{2+} cmol/kg	1.22	1.15	1.45	6.72	0.86	0.78	0.96	5.09
Exchange Na^+ cmol/kg	0.17	0.16	0.18	2.86	0.43	0.35	0.52	9.69
Exchange K^+ cmol/kg	0.71	0.65	0.77	4.21	0.94	0.78	1.17	9.95
Cation Exchange Capacity	7.73	6.68	9.25	7.99	7.35	6.65	8.36	5.58
Base Saturation %	67.13	62.96	76.04	4.82	65.24	60.24	72.67	4.57
Organic Matter %	0.93	0.81	1.13	8.32	1.24	1.11	1.41	5.84
Total Nitrogen	0.07	0.06	0.08	10.0	0.03	0.02	0.06	31.15
Available Phosphorous	18.45	16.47	21.45	6.47	14.05	11.75	17.58	9.95
Micro-Nutrients	**Mean**	**Min.**	**Max.**	**C.V.**	**Mean**	**Min.**	**Max.**	**C.V.**
Copper meq/100g	5.32	4.75	6.12	6.19	8.72	7.24	10.91	10.10
Manganese meq/100g	4.25	3.45	5.34	10.70	5.32	4.42	6.72	10.36
Iron meq/100g	4.53	4.13	5.17	5.52	6.01	5.45	6.83	5.51
Zinc meq/100g	9.20	8.33	10.46	5.56	5.76	5.36	6.53	4.95
Boron meq/100g	0.68	0.6	0.8	7.06	0.4	0.38	0.43	3.03

Source: Author's Data Analysis (2017) ***** Highly Variable C.V. > 33.0%

For the chemical properties, the pH values recorded revealed the mean value of 6.40 for irrigated soil and 7.12 in non-irrigated soil because of the hydrolysis of some cation in the soil and replaced by hydrogen ion which forms as a result of waterlogging condition. Both soil samples exhibited spatial homogeneity. Similarly, exchange acidity values are the same for both irrigated and non-irrigated soil samples and they are spatially homogeneous.

The exchangeable cation that has higher content in irrigated soil than non-irrigated soil samples included exchange calcium and magnesium because of farmers higher application of organic and chemical fertilizer, while Na^+ and K^+ were less in irrigated soil compared with non-irrigated soil because of leaching, crop removal and erosion. All parameters of the exchangeable cation exhibited homogeneity. Cation exchange capacity content tested was highly recorded in the irrigated soil because of replenishment by the use of commercial fertilizer and organic matter. The cations of both soils exhibited spatial homogeneity.

Base saturation, total nitrogen, and available phosphorus have a high content in irrigated soil because of application of nitrogenous and phosphatic fertilizer, crop residue and manure in the irrigated soil. All the three parameters exhibited spatial homogeneity in both soil samples. The content of the organic matter in irrigated soil was lower compared with non-irrigated soil because of continuous cultivation, crop removal and leaching down soil profiles. The attribute exhibited homogeneity in both soil samples (table 4.2b).

The results of all the micronutrients examined were lower in the irrigated soil compared with non-irrigated soil with the exception of zinc because of the low organic matter in the irrigated soil that results from hydrolysis of soluble salts from fertilizer and mineralization of organic matter to acid. This increased of acid may lead to the decrease of copper, manganese iron, and boron. All parameters of the micronutrients exhibited homogeneity as shown in table 4.2b.

The results of Pab/Pb soils in the Bunkure branch have shown that sand, bulk density, water holding capacity, calcium, magnesium, C.E.C., base saturation, nitrogen, phosphorous and zinc have higher content in the irrigated soils than those in the non-irrigated soils. While in irrigated soils those with low content were silt, pH, exchange acidity, exchange sodium and potassium, organic matter, copper, manganese, iron, and boron.

4.2c **Differences in the Characteristics of Pab/Pb Complex Soil Unit under Rice Production in Kano River Project I**

The table 4.2c presents the results of the student't' test examined on the soil samples from Kura and Bunkure irrigated rice soil farmlands. Among the physical properties, significant differences were established between irrigated and non-irrigated soil of Kura and Bunkure with exception of clay content. But in Bunkure a similar trend was exhibited except the content of water holding capacity that was not different in the two farmlands. From the eleven chemical properties analyzed, seven properties exhibited significant differences. These properties are those that are critically affected crop growth, development, and productivity. In Bunkure the trend was the same but pH value was also significantly different. Similarly, all micro-nutrients in Kura and Bunkure Pab/Pb complex irrigation soil were significantly different from non-irrigated soils.

These findings were similar to the work of Daniel (1987) in which the results of t-value were in line with findings of these properties: sand, silt, soil pH, exchange calcium, magnesium, sodium and potassium, cation exchange capacity and available phosphorus were statistically significantly different The results that were contrary to the findings of Daniel (1987) were clay, organic matter and base saturation were not significantly different.

The t-test results of Bunkure Pab/Pb soil show all the soil parameters were statistically different with exception of clay, water holding capacity, exchange acidity, cation exchange capacity and base saturation. The findings of the t-test were similar to the work of Daniel (1987) which included sand, silt, exchange calcium, exchange magnesium, exchange sodium, exchange potassium, cation exchange capacity and available phosphorus and base saturation. The findings that were contrary to the work of Daniel (1987) were soil pH and organic matter.

Table 4.2c: Comparison of Non-Irrigated and Irrigated Pab/Pb Soil Complex Unit Properties

	Kura Pab/Pb Series			Bunkure Pab/Pb Series		
Physical Properties	**Non-Irrigated**	**Irrigated**	**t-value**	**Non-Irrigated**	**Irrigated**	**t-value**
% Sand	74.0	78	4.35*	70.0	72.0	2.46*
% Silt	19.0	15	8.09*	23.0	21.0	4.77*
% Clay	7.0	6.9	0.29	7.0	7.0	0.43
Bulk Density mg/m^3	1.2	1.5	4.74*	0.38	0.69	16.09*
% Water Holding Capacity	8.1	7.2	6.03*	7.70	8.08	1.06
Macro-Nutrients	**Non-Irrigated**	**Irrigated**	**t-value**	**Non-Irrigated**	**Irrigated**	**t-value**
pH	7.02	6.85	0.70	7.76	6.40	7.86*
Exchange Acidity H^+	0.33	0.33	0.49	0.17	0.17	0.35
Exchange Ca^{2+} cmol/kg	3.08	3.5	3.21*	2.59	3.25	4.69*
Exchange Mg^{2+} cmol/kg	1.034	1.46	3.49*	0.86	1.22	11.52*
Exchange Na^+ cmol/kg	0.23	0.19	4.05*	0.43	0.17	18.54*
Exchange K^+ cmol/kg	0.85	0.36	20.49*	0.94	0.71	7.09*
Cation Exchange Capacity	7.1	7.184	0.51	7.35	7.73	1.55
Base Saturation	75.27	76.57	0.58	65.24	67.13	1.29
Organic Matter %	0.69	0.93	3.60*	1.24	0.93	8.86*
Total Nitrogen	0.187	0.035	1.97*	0.03	0.07	9.27*
Available Phosphorous	38.79	35.34	3.99*	14.05	18.45	7.12*
Micro-Nutrients	**Non-Irrigated**	**Irrigated**	**t-value**	**Non-Irrigated**	**Irrigated**	**t-value**
Copper meq/100g	9.09	10.92	6.42*	8.72	5.32	10.84*
Manganese meq/100g	4.44	3.33	7.73*	5.32	4.25	4.52*
Iron meq/100g	3.44	4.784	2.38*	6.01	4.53	10.73*
Zinc meq/100g	7.06	4.71	11.64*	5.76	9.20	17.61*
Boron meq/100g	0.73	0.6	4.59*	0.4	0.68	17.07*

Source: Author's Data Analysis (2017) ***** Critical Level: 5% (1.73)

In conclusion, the majority of soils parameters tested in the laboratory exhibited uniformity and homogeneity of the coefficient of variability. The results of t-test established the fact that there were significant differences in almost majority of the soil parameters.

4.3 **Fertility Indices of Soils under Rice Production in Kano Rive Project I**

At the inception of Kano River Project I, the soils of the Project Area was found to contain moderate P_2O_5 rates that could raise phosphate content to a satisfactory level for rice plant growth, but the potassium in the irrigation water was also sufficient for rice cultivation. However, the prolonged traditional agriculture has depleted the soil of basic chemical elements and deficient in boron.

4.3.1 **Nutrient Deficiency in Irrigated Soils under Rice Production in Kano Rive Project I**

The results of the soil analysis for the fertility indices for rice cultivation in the project are presented in table 4.3a. Organic matter content of the soil was very low, the total nitrogen of the soil was very low too; while phosphorous and potassium were high and soil pH was neutral.

Table 4.3a: Nutrient Deficients in Soil Suitable for Rice Cultivation

Indices	Target *	Pab Kura	Pab Bunkure	Pab/Pb Kura	Pab/Pb Bunkure	Mean
Organic Matter (gkg^{-1})	68.8	0.69	0.64	0.93	0.93	0.80
Nitrogen (gkg^{-1})	2.0	0.05	0.08	0.035	0.07	0.059
Phosphorous (gkg^{-1})	20.0	32.035	28.40	35.34	18.45	28.56
Potassium (gkg^{-1})	0.3	0.62	0.52	0.36	0.71	0.55
pH	6.5	6.5	5.83	6.85	6.40	6.40

Source: Author's Data Analysis (2017)

* Etsu (1991) Rating for Soil Fertility Classes in the Nigerian Savanna

Using soils properties fertility indices, it is evident according to Etsu (1991) that the Kano River Project 1 soils for rice cultivation are generally low in nitrogen soil fertility index. This result corroborated with earlier reports of WARDA (1992), Mustapha and Nnelee (2007) that tropical soils were intrinsically low in nitrogen and pH of the soil was within acceptable limit suitable for rice growth.

4.3.2 **Farmers Fertility Enhancement and Maintenance Strategy in Kano Rive Project I**

In converting nutrient deficiency, the farmers (13.81%) often interact with agricultural extension workers for advice. Another (16.19%) of them visit agricultural research institutions nearby for the solution of their agricultural problem, while the majority of the farmers (63.81%)

rely on the experience of family and friends, very few (1.89%) rely on information disseminated from agriculturally related programmes from mass media (Table 4.3b).

Table 4.3b: Farmers Enhancement to Convert Nutrient Deficiency

S/No.	Enhancement to Nutrient Deficiency	No.	%
a.	Consult extension officer	226	13.81
b.	Ask question to media agricultural programmes	31	1.89
c.	Consult family and friends	1,044	63.81
d.	Advise from agricultural research institutions	335	20.49
	Total	**1,636**	**100.00**

Source: Author's Data Analysis (2017)

From the results of the questionnaire administered in table 4.3c larger proportion of the farmers (40.46%) have used organic manure to improve the fertility status of the soil, chemical fertilizer is being used by 34.18% of the farmers and 25.36% of them combined organic and chemical fertilizer.

Table 4.3c: Farmers Fertility Maintenance Strategy

S/No.	Fertility Maintenance	No.	%
a.	Chemical Fertilizer application	559	34.18
b.	Organic manure application	662	40.46
c.	Combination of a. & b.	415	25.36
	Total	**1,636**	**100.00**

Source: Author's Data Analysis (2017)

4.4 Sustainability and Factors for Improvement of Rice Production System

This study observes that there has been a decline in soil organic matter and soil structure because of the intensive rice cultivation. The rate of decline in organic matter and soil structure could be expected because of low of organic residues produced in the case of fertilizer applied for rice cultivation. This indicates that the organic matter level and soil tillage could be kept at a satisfactory level for sustainable rice crop production.

The soil is viewed as a resource that has the potentiality of contributing to present and future income to farmers as well as food security. The principle underlying the optimum fertilizer application is when fertilizer input is applied to the point where the added cost (marginal revenue product) is equal to the added return (marginal revenue product). The explanation for the practice of sustainable rice production is stated as follows:

4.4.1 **Factors for Improvement of Rice Production System**

The major factors responsible for the improvement of rice production include:

i. Land: The land areas cultivated were intensively used and increased up to the area were irrigation layout is not designed because of the mounting demographic pressure and complicated tenure arrangement in the irrigation project. The increase in the land size of irrigation project may not be possible because the layouts are designed contained 22,000ha only. Furthermore, it is common practice to use the land twice during the dry season and once in the rainy season. They cultivated the first set of crops after rains have ceased and harvested during December. The second set of crops are then planted and harvested before and during the first month of the rainy season (May). The implication of these practices is that the irrigated soils have no longer time to recuperate after a period of cropping. In addition, the fertility of irrigated soils is limited and declined; this resulted in low rice crop yield. Therefore alternative farming practices are needed to improve the productivity of the soil to achieve soils sustainability and self-reliance in rice production that Nigeria currently wants to enjoy.

ii. There is an increase of rice crop yield as the Farros rice varieties have been introduced into the project area. Thus, the production system can make a better use of the market and production environment to improve the sustainability of the irrigated soils.

iii. The reduction in the level of external inputs especially chemical fertilizers and an increase of organic manure to supplement the limited nutrient content of the soils.

iv. The removal from the crops enterprises any combination that does not contribute to the sustainability of the system.

4.4.2 **Optimization of Rice Farms Plan**

The optimal rice farm plan (S_i) was generated using Goal Programming Matrix presented as appendix ii and graphical solution using linear programming of inequalities which also presented as appendix iii and iv. The linear programming inequalities equations were used to optimize the current system of rice production (S_o) which was not sustainable.

i. Resources Allocation for Rice Production System

The resources in the model include land, labour, UREA and NPK Fertilizer, agro-chemicals and seeds. The pattern of resources utilization that led to optimal rice farm plan shows that only three resources were fully utilized. These are pesticides, Jamila (local variety) seed and land. The non- fully utilized resources included labour, organic manure, UREA and NPK Fertilizer and Farros (improved variety) seed. This implies that given optimal rice farm plan, these resources were not a constraint to irrigated rice production in the study area.

4.4.3 **Goal Programming Matrix**

The model (Goal Programming Matrix see appendix iii) determines the optimum allocation of resources under a specific condition. In other words, it is called linear programming because all conditions are expressed in the form of linear relationships, analogous to a linear equation, but in fact, called inequalities which are programmed with specific parameters.

Generally, several variables (allocations) are involved and the mathematical manipulation required for their solution which is complex and tedious without the use of a computer. But fortunately, the basic idea underlying the model can be illustrated graphically by involving two or more variables (Hammond and McCullargh, 1978).

The study has found out that the farmers of Kano River Project I cultivated 772.50ha with Jamila (local variety) and Farros (improved variety) in 2014/2015 cropping season. Other inputs cost (machinery, seeds, chemicals, labour, and marketing) were estimated to be ₦140,561.13 and ₦176,941.66 for Jamila and Faros respectively. The farmers were able to raise ₦150,400.41 and harvested averagely 3,872.96kg of Jamila rice and 4,681.59kg of Faro rice per hectare. All these were subjected to the following conditions identified by the study from the data tabulated from the questionnaire administered. The results of the analysis revealed the following:

i. A standard labour requirement per hectare is 10 man-days per hectare and there were 10 men each working for 120 days in the farm on the ratio 1:2.
ii. Lands utilized were in the ratio 2:1.
iii. Average fertilizers inputs applied were 8.6 bags (430kg, 2.5UREA: 3.0 NPK)) on the ratio of 1.1:1.03.
iv. Inputs of organic manure were 1,406.25 and 1,896.08 on the ratio of 1.2:0.85.
v. Inputs of nitrogen were 241.06kg and 325.02 on the ratio of 1.2:0.89.
vi. Inputs of phosphorous were 49.90kg and 42.65kg on the ratio of 0.94:1.10.
vii. Inputs of potassium were 48.86kg and 41.88kg on the ratio of 0.96:1.12.
viii. Other minor inputs cost were on the estimated to be ₦150.00 and ₦100.00 daily, while total cost was on the ratio1.07:0.85 per hectare.
ix. Average net profits per hectare were ₦79,244.41and were achieved on the ratio of 0.94:1.10.

Based on the conditions of the present system (S_o), Goal Programming Model was used to estimate the improved system (S_i) in order to maintain and subsequently optimize the level of rice yields, farmers' income base on the profitable division of land between rice varieties and acceptable level of soils nutrients.

By setting out the constraints as linear inequalities, the two sides of the equation are not required to be equal. Let the average under Jamila local rice be x_1 and under Faros be x_2 then:

- Farmers' respondents cultivated not more than 564.15ha from 772.50ha.

Therefore $\mathbf{2x_1 + x_2 \leq 772.50}$ **1_{st} constraint**

- Each hectare of land farmers utilized 10 man-days out of the available 120 days.

Therefore $\mathbf{x_1 + 2x_2 \leq 1200}$ **2_{nd} constraint**

- Each hectare consumed ₦150.00 for Jamila rice and ₦200.00 for Faros rice worth

of other inputs on the available ₦150,400.41 spent for rice production per hectare.

Therefore $\mathbf{150x_1 + 200x_2 \leq 150{,}400.41;}$ **or** $\mathbf{1.5x_1 + 2x_2 \leq 1{,}504}$ **3_{rd} constraint**

- Each hectare of land applied 8.60kg on the average of fertilizer.

Therefore $\mathbf{1.1x_1 + 1.03x_2 \leq 8.60}$ **(430kg)** **4_{th} constraint**

- Each hectare of land applied organic manure on the average of 1,6879.50kg.

Therefore $\mathbf{1.2x_1 + 0.85x_2 \leq 1{,}687.50}$ **5_{th} constraint**

- Each hectare of land applied nitrogen on the average of 289.27g/kg.

Therefore $\mathbf{1.2x_1 + 0.89x_2 \leq 289.27}$ **6_{th} constraint**

- Each hectare of land applied phosphorous on the average of 46.91kg.

Therefore $\mathbf{0.94x_1 + 1.10x_2 \leq 46.91}$ **7_{th} constraint**

- Each hectare of land applied potassium on the average of 46.91kg.

Therefore $\mathbf{0.96x_1 + 1.12x_2 \leq 46.91}$ **8_{th} constraint**

- Each hectare of land applied rice seed on the average of 27.76kg.

Therefore $\mathbf{1.1x_1 + x_2 \leq 27.76}$ **9_{th} constraint**

- Each 75kg of un-mill rice were sold on the average of ₦5,154.55 on the ratio of ₦130:₦100.

Therefore $\mathbf{130x_1 + 100x_2 \leq 5{,}154.55,}$ **or** $\mathbf{1.3x_1 + x_2 \leq 51.55}$ **10_{th} constraint**

Farm inputs and achievements of different rice production systems are expressed in constant ratios forming the linear equation constraints and are presented in table 4.4a.

Table 4.4a: Farm inputs and Goal Achievement under Different Systems of Rice Production

Variable Inputs	**Present System**	**Linear Equation Constraint**
Inputs Cost (₦)	150,400.41	$1.07x_1+0.85x_2 \leq 150{,}400.41$
Income (₦)	79,244.49	$0.94x_1+1.1x_2 \leq 79{,}244.49$
Rice Yield (kg)	4,260.26	$1.1x_1+0.91x_2 \leq 4{,}260.26$
Organic Matter (kg)	1,687.50kg = 9.72 gkg^{-1}	$1.2x_1+0.86x_2 \leq 1{,}687.50$
Nitrogen (kg)	289.27kg = 0.47 gkg^{-1}	$1.2x_1+0.92x_2 \leq 289.27$
Phosphorous (kg)	46.91kg =31.18gkg^{-1}	$0.94x_1+1.1x_2 \leq 46.91$
Potassium (kg)	46.90kg = 0.52cmol/kg	$0.96x_1+1.12x_2 \leq 46.91$
Fertilizer (Bags) UREA = 2.5: NPK = 3.0	8.60 = 430kg 3.91 = 175.95kg UREA 4.69 = 93.8kg N_2: 46.9 P: 46.9 K	$1.1x_1+1.04x_2 \leq 8.60$ $1.1x_1+1.04x_2 \leq 269.78$ $1.1x_1+1.03x_2 \leq 46.9$kg
Variable Inputs	**Improved System**	**Linear Equation Constraint**
Inputs Cost (₦)	157,920.43	$1.12x_1+0.893x_2 \leq 157{,}920.43$
Income (₦)	83,206.72	$0.99x_1 + 1.16x_2 \leq 83{,}206.72$
Rice Yield (kg)	4,517.99	$1.104x_1 + 0.914x_2 \leq 4{,}517.99$
Organic Matter (kg)	11,809.08kg = 69.14gkg^{-1}	$7.2x_1 + 5.1x_2 \leq 11{,}809.08$
Nitrogen (kg)	1,298.64kg = 2.1 gkg^{-1}	$4.2x_1 + 3.2x_2 \leq 1{,}298.64$
Phosphorous (kg)	33.10kg =22.0gkg^{-1}	$0.28x_1+ 0.32x_2 \leq 33.10$
Potassium (kg)	28.87kg = 0.32cmol/kg	$0.38x_1+ 0.43x_2 \leq 28.87$
Fertilizer (Bags) UREA = 25: NPK = 3.0	28.0 = 1,400kg 25 = 1,250kg UREA 3.0 = 20kg N_2:10kgP:10kgK	$3.32x_1+3.14x_2 \leq 26.0$ $4.2x_1 + 3.2x_2 \leq 1{,}250$ $0.28x_1+ 0.32x_2 \leq 33.1$ kg; $0.38x_1+ 0.43x_2 \leq 28.87$

Source: Author's Data Analysis (2017) * UREA = 45kg/50kg and NPK = 20:10:10kg/50kg

4.4.4 **Goal Target**

Base on the above conditions of the objective functions that constraints irrigated rice production system, the research studied under or over achievement of goals as follows:

Economic Goal Target: income (₦83,206.72); yield of Jamila Rice variety (4,500kg); yield of Faros rice variety (4,500kg).

Ecological Goal Target: organic matter (68.8kg); nitrogen (2.0g/kg); phosphorous (20.0g/kg); potassium (0.30cmol/kg); and finally, soils pH (6.50).

4.4.5 **Assessment of Sustainability of Irrigated Rice Production System**

The assessment of the sustainability of the rice production system is given by the value of the sustainability index Z_o and Z_1 in table 4.4b. The result for each indicator in column 5 gives the percentage performance of the present production (so) prior to optimization of the model. The result should be interpreted as follows: when the deviation is n_i (that is to minimize the under-achievement of the target level of goal), the desired percentage in column 7 should be greater than or equal to 100; when the deviation is p_i (that is to minimize the over-achievement of the target level of a goal), the desired percentage should be less than or equal to 100. However, when the deviation is $n_i + p_i$ (that is neither under nor over-achievement), the deviation is to equal to 100.

Table 4.4b: Assessment of Sustainability of Irrigated Rice Production System

Indicator (1)	Deviation (2)	Target(3)	Present System (So)		Improved System (Si)	
			Achieved (4)	4/3*100 (5)	Achieved (6)	6/3*100 (7)
Income (₦)	n_i	83,206.72	79,244.49	95(5)	82,080.13	99(1)
Yield of Jamila Rice (Kg)	n_i	4,500	3,872.96	85(15)	4,365.0	97(3)
Yield of Farros Rice (Kg)	p_i	4,500	4,681.56	104(4)	4,860.0	108(8)
Organic Matter (gKg^{-1})	n_i	68.8	0.8	1(99)	70.0	102(2)
Nitrogen (gKg^{-1})	n_i	2.0	0.059	3(97)	2.01	105(5)
Phosphorous (gKg^{-1})	p_i	20.0	28.56	143(43)	20.1	105(5)
Potassium (gKg^{-1})	p_i	0.3	0.55	183(83)	0.31	103(3)
pH	$n_i + p_i$	6.5	6.38	98(2)	6.5	100(0)
		0	$Z_0 = 348$*		$Z_1 = 10$*	

Source: Author's Data Analysis (2017)

Note: The figures in parentheses are the percentage level of goal under or over achievement.

The value of Z_0 and Z_1 were calculated by summing the percentage level of under-achievement and over-achievement of each goal from its target or threshold for the goals with n_i (under-achievement) and p_i (over-achievement) specified respectively in the deviation column in table 4.4b. For the goal with $n_i + p_i$ (under nor over-achievement) specified in the deviation column in table 4.4b, either the percentage level of goal under-achievement or over achievement as the case may be was summed up. The present system (S_0) achieved 95% of the income goal implying that the income goal was under-achieved by 5%. This is because the local rice variety cultivating in the study area is long grain which attracted higher market demand that is why it reached up to this level of income. The yield goal for Jamila local rice was under-achieved by

15%, the Faros rice is over-achieved by 4% respectively. The organic matter was achieved by 99%, nitrogen by 97%. While phosphorous and potassium were over-achieved by 43%, 83% and pH was under-achieved by2% respectively.

In the present system, the sum of deviations Z_0 = 348. This indicated that the present system was not sustainable for rice production since the criteria for sustainability (sum of deviations) is equal to zero (Z_0 = 0). The expectation for irrigated local rice production system will not sustain the income of irrigated rice farmer in long run without improvement in good soil management practiced introduced. The tonnage market price of local variety was higher than improved variety because consumers preferred local variety because it is long grain and easier for cooking. The situation is critical for the yield obtained was far below potential recommendation by NEDECO consultant. The environmental goal showed negative imbalance for the phosphorous and potassium because it was over applied by farmers in the soils. On this basis, 62.5% of the indicators were less than 100% of the required level. While three indicators (Faros rice variety, phosphorous and potassium) were at more than 100% of the requirement goals (Table 4.4c).

Table 4.4c: Frequency of Indicators of Sustainability

% Range of Sustainability	**Present System (S_0)**		**Improved System (S_1)**	
	Frequency	%	**Frequency**	%
>105	2	25.0	1	12.50
100 – 105	1	12. 5	5	62.50
<100	5	62.50	2	25.0
Total	**8**	**100**	**100**	**100**

Source: Author's Data Analysis (2017)

This results can lead to nutrient loading in the resources of the soil if appropriate mitigation measures are not taken. However, this implies that the usage of phosphorous and potassium fertilizer by farmers should be reduced as the fixed phosphorous and potassium in the soil gradually mineralized to the available rice crop.

Optimizing the present system (S_0) using goal programming may maintain the optimal system (S_1) and subsequently improve the sustainability of the rice production system under large-scale irrigation project of Kano River Project I (Table 4.4b column 6 and 7). The income goal was under- achieved by 1% and Jamila rice yield was achieved by 3%, Faros rice was over-achieved by 8%. The organic matter, nitrogen, phosphorous and potassium were also over-achieved by 2%, 5%, 5% and 3%. The pH goal was fully achieved. An analysis of the value of $Z_1 = 10$ shows that there is an improvement in the sustainability of the rice production system, as the sum of the deviation was reduced by 97.13%. The details are as follows:

1. There is improved sustainability for the following indicators: yield of Faros rice, organic matter, nitrogen, phosphorous and potassium;
2. Total sustainability for the pH indicator;
3. Sustainability with 99% increase in the income indicator; and
4. There is no sustainability for the Jamila local rice variety.

The new classification system for S_1 (table 4.4c) showed that 75% of the indicators were within acceptable limits of sustainability and two of the indicator was less than 100% of the required goal compared to S_0. Improvement in the current system (S_0) will result in the maximum profitable division of land (optimum land area cultivated) to be 30ha for Jamila local rice variety and 700ha for Faros rice variety and 42.50ha would be left uncultivated because of the limited labour and other inputs resources. There is a need to improve the usage of nitrogenous fertilizer (UREA) to be 1,025.75kg for Jamila local rice variety and 1,337.98kg for Faros rice variety. Phosphorous fertilizer needs to be reduced to 33.60kg for Jamila and 28.72kg for Faros. Potassium fertilizer needs to be reduced to 31.01kg for Jamila and 26.58kg for Faros. This implies that reduction in the use of external inputs such as phosphorous and potassium fertilizer (NPK) is recommended. The organic manure would be applied to be 9,792.51kg for Jamila local rice variety and 13,824.72kg for Faros rice variety.

4.4.6. **Goal Attainment of Irrigated Rice Production System by Peasant Farmers**

The extent of goal attainment by rice farmers was analyzed using Goal Programming (G.P.) Model to identify feasible levels of attainments and probably compromises among the goals. This is because according to Rehman and Romero (1993), the G.P. technique operations the Simonian 'satisfying' approach to the achievement of farmer objectives (Simon, 1995). If farmer set targets for achievement, an acceptable solution is found by minimizing the deviations from the set of targets. From the table 4.4b, about 97.13% of the goals specified were fully achieved. The economic goal of Faros rice output was over-achieved while the income goal was under-achieved was by 1% level from the target. This deviation may not adversely affect the rice farmers' income. When Goal Programming Model technique is utilized (especially weight goal programming model) short-run profit could be used for the attainment of other goals (Wallace and Moss, 2002). In this regard, the result of weight goal programming model is realistic considering the fact that the under-achieved goals that have indifferent dimensions are incorporated in the model. For environmental goals, the organic matter, N, P and K goals were over-achieved, then finally, pH was also achieved (Table 4.4d).

Table 4.4d: Goal Achievement by Irrigated Rice Farmers

S/No.	Goals	Target	Under Achievement	Over Achievement
1.	Income Goal ₦	₦83,206.72	₦1,126.59	0
2.	Yield of Jamila Rice (Kg)	4,500	135kg	0
3.	Yield of Farros Rice (Kg)	4,500	0	360kg
4.	Organic Matter (gKg^{-1})	68.8	0	1.2gkg^{-1}
5.	Nitrogen (gKg^{-1})	2.0	0	0.01gkg^{-1}
6.	Phosphorous (gKg^{-1})	20.0	0	0.1 gkg^{-1}
7.	Potassium (gKg^{-1})	0.3	0	0.01gkg^{-1}
n	pH	6.5	0	0

Source: Author's Data Analysis (2017)

CHAPTER FIVE

SOCIO-ECONOMIC CONSTRAINT TO IRRIGATED RICE PRODUCTION IN KANO RIVER PROJECT I

5.1 Farmers Socio-economic and Demographic Characteristics

Kano River Project 1 was established to boost food production and promote both national and peasant income to generate poverty alleviation and industrial raw materials. It was observed during the fieldwork that all the 1,636 farmers reside in the irrigation project area are male. This may be due to cultural and religious (Islamic) believe of the people of the study area which prohibits women to move out freely and engage in certain outdoor business activities such as farming. However, female in the study area dominate indoor economic activities. The Muslim practice of female seclusion can be an explanation. The description and explained of socio-economic characteristics of irrigated rice farmers are presented in the following tables.

Table 5.1a peasants age distribution of the of irrigated rice farmers, the majority are within the range of 20 – 60 years and the mean age is 36.93, the modal age class is 16 – 55 years. This result was in line with findings of Ramakrishna Mission (1988) and University of Kalyani (1989) which reported that in the West Bengal studies majority of the population were aged between 15 and 59 years and only 7% were older than 60 years and it is also similar to the finding of Catling (1999) who reported that about 18% of the population was more than 50 years i.e. 82% were less than 50 years. The findings of Vallee Vuong (1978) are contrary to the finding of this study who reported that many farmers were old age ranged between 40 and 70 years (age group). Generally, a large number of respondents are relatively young and middle age and constituted more than 98.58% of the total respondents, who actively engaged in rice farming system in the project area. This might contribute to providing available family labour force from households. This has implication to the supply of farming labour. However, considerable numbers of the older farmers have involved also in irrigated rice farming.

Table 5.1a: Age group of the farmers in 2017

S/No.	Age Group	No.	%
a.	16 - 35 Years	951	58.10
b.	36 - 55 Years	622	40.48
c.	56 - 75 Years	63	3.85
	Total	**1,636**	**100.0**

Source: Author's Data Analysis (2017)

Table 5.1b shows the number of farmers that have immediate families in which more than 85% were married. This has also contributed to the production of young ones for free family farm labour force. Most of the single respondents cultivate land purposely for increasing additional diet for family consumption and their personal income.

Table 5.1b: Marital status of farmers

S/No.	Marital status	No.	%
a.	Single	241	14.74
b.	Married	1,395	85.26
	Total	**1,636**	**100.0**

Source: Author's Data Analysis (2017)

The respondents have one form of education or the other. Islamic education is the most prevalent form of education. All the respondents acquired Arabic and Islamic education, this implies that a good number of farmers read and comprehend extension guides written in Ajami which is the Hausa language written in Arabic. Table 5.1c shows respondents level of education, all the respondents have acquired Arabic and Islamic education, 42.38% of the respondents restricted themselves to Arabic and Islamic education only (without attended west education) likewise 22.38% of them acquired adult education. Some farmers have acquired formal education up to primary education (8.10%), secondary education (12.83%) and even tertiary education (14.76%) which included 2.86% of university graduates.

Table 5.1c: Educational Attainment of Farmers

S/No.	Educational Level	No.	%
a.	Arabic and Islamic education	693	42.38
b.	Adult education	366	22.38
c.	Primary education	133	8.10
d.	Secondary education	203	12.38
e	Post-secondary education	195	11.90
f.	University	47	2.86
g.	None of the above	0	0.00
	Total	**1,636**	**100.0**

Source: Author's Data Analysis (2017)

Large household sizes are quite common in the northern parts of Nigeria. Kano River Basin Irrigation Project is a Muslim polygamous community in which up to four wives could be marriage by the individual. Table 5.1d shows 68.09% of respondents married either one or two wives, while 14.75% of the respondents were single including both bachelors and widows.

Table 5.1d: Number of Farmers' Wives

S/No.	Wives	No.	%
a.	One	616	37.62
b.	Two	499	30.47
c.	Three	141	8.62
d.	Four	139	8.52
e.	None	241	14.75
	Total	**1,636**	**100.0**

Source: Author's Data Analysis (2017)

Table 5.1e reveals that some farmers have dependent children and independent children living in farmers' houses and served as free labour on rice farms. This study indicates that majority of the farmers have not given birth to children that are available or not available for farm work.

Farmers that have male children capable of farm work included 36.67% and farmers that have female children capable of farm work included 7.62%; while some farmers have male children not capable of farm work included 48.13% and others farmers have female children not capable of farm work included 38.09%.

Some farmers that have no dependent male children capable of farm work included 32.86% and farmers who's have female dependent children capable of farm work included 6.67%; while others farmers who have dependent male children not capable of farm work (20.0%) and farmers who have no dependent female children capable of farm work were 18.10%. This indicates that respondents were depended on hired labour for farming activities.

Table 5.1e: Farmers' Children Capable or not Capable of Farm Work

S/No.	Children Available for Farm Work	Male	%	Female	%
a.	One to three	553	33.81	125	7.62
b.	Four to six	47	2.86	0	0.00
c.	None	1,036	63.33	1,511	92.38
	Total	**1,636**	**100.0**	**1,636**	**100.0**
S/No.	**Children not Available for Farm Work**	**Male**	**%**	**Female**	**%**
a.	One to three 56	616	37.64	608	37.14
b.	Four to six	171	10.48	15	0.95
c.	None	849	51.87	1,013	61.91
	Total	**1,636**	**100.0**	**1,636**	**100.0**
S/No.	**Dependent Children Available for Farm Work**	**Male**	**%**	**Female**	**%**
a.	One to three	491	30.00	109	6.67
b.	Four to six	47	2.86	0	0.00
c.	None	1,098	67.14	1, 527	93.33
	Total	**1,636**	**100.0**	**1,636**	**100.0**
S/No.	**Dependent Children Available for Farm Work**	**Male**	**%**	**Female**	**%**
a.	One to three	265	16.19	296	18.10
b.	Four to six	62	3.81	0	0.00
c.	None	1,309	80.00	1, 340	81.90
	Total	**1,636**	**100.0**	**1,636**	**100.0**

Source: Author's Data Analysis (2017)

Among the respondents, the average household size was 6 people and modal family size was 4 people; some have 12 people per household. This finding is in line with finding of Bhuiyan and Elahi (1984), Ahsan *et al.,* (1978), Jansen (1987), Ramakrishna Mission (1988) and University of Kalyani (1989) which reported that in West Bengal studies there was average family size of 6 which accounted for 30-36% of the population. It is also contrary to the findings of Valley and Vuong (1978), Nyanteng *et al.,* (1986) and McIntire (1986) which reported the mean family size of 10 and accounted for 30% of the population. These results indicate that the family sizes were low because the young generations are independent and engage in the labour market at less than 18 years i.e. age of 16. Later on, they have taken part of the farming activities inform of hired labour which was more pronounced in the study area. The little numbers of people per household were not essential to supply substantial farm labour from family members.

Crop production is the major (primary) occupation of the respondents that is taking place in both dry and rainy seasons. None farm occupation is the secondary economic activities which engage as a part-time together with farming activity as shown in table 5.1f. Trading alone accounted for 42.38%, civil work accounted for 4.76%. Other economic activities (52.86%) such as carpentry and joinery, tailoring, barbing, farm labour (peasantry), and motor vehicles maintenance were engaged in addition to farming activities.

Table 5.1f: Non-farm Occupation of Farmers

S/No.	Occupation	No.	%
a.	Trading	693	42.38
b.	Civil Work	78	4.76
c.	Handicraft or others	865	52.86
	Total	**1,636**	**100.0**

Source: Author's Data Analysis (2017)

5.2 Farm Land Ownership Size and Tenancy in Kano River Project I

According to Clavence (1979) land tenur**e** is a major obstacle to agricultural development in Third World countries. There are two important dimensions of this problem: land tenure arrangements per see (i.e. the form in which agricultural land is held – free holding, lease etc.) and distribution of agricultural land.

Land change ownership permanently through inheritance, gift and purchase and can also secure temporarily through tenancy, lease, pledge, share-cropping and loan. For the purpose of this research, land tenure arrangement is divided into landowner (land acquired through inheritance, gift, and purchase) and tenant (which secured land through tenancy, lease, pledge, share- cropping and loan). It was well known to the researcher that these different land tenure systems were directly or indirectly affecting agriculture and rural development.

Despite the land ownership and utilization, available land is also distributed to farmers by the government through Hadejia Jama'are River Basin Development Authority and Kano State Agriculture and Rural Development Agency (KNARDA) which are allocated on application annually. Table 5.2a shows fragmentation of farm plots size distributed to the respondents, the majority of the respondents about 56.24% occupied less than 1ha of the total land cultivated, 34.78% of the respondents occupied 1ha – 2ha and the remaining 8.98% occupied 2ha and above. No respondents occupied more than 3 hectares. This finding is in line with the findings of Grosvenor-Alsop and Sharma (1998), Clay (1982) and University of Kalyani (1989). It is contrary to the finding of NDDT (1974), McIntire (1986) and Vallee and Voung (1978).

Table 5.2a: Fragmentation of Farm Plots Utilization

S/No.	Farms Ownership	Total	%
a.	Less than 1hectare	920	56.24
b.	1 hectare - 2 hectares	569	34.78
c.	Above 2 hectares	147	8.98
	Total	**1,636**	**100.0**

Source: Author's Data Analysis (2017)

This has been clear on table 5.2b which shows the distribution of respondents according to farmland ownership and utilization pattern of farmers' socio-economic groups' and farm size (farm plots) cultivated. It was investigated that land tenure secured through inheritance does not permit easy transfer of farm to nonfamily members in the study area. The analysis of land ownership reveals that 38.49% of the respondents were landowners and 61.51% of the respondents were tenants. The table reveals that 62.86% of the landowners and 49.52% of tenants secured less than 1ha of land, 33.92% of landowners and 35.24% of tenants secured 1ha– 2ha as well 2.86% of landowners and 15.24% of tenants secured land above 2ha.

Table 5.2b: Farmers' Socio-Economic Groups Farms Ownership Size and Tenancy

S/No.	Farms Utilization	Land Owner (ha)	%	Land Tenant (ha)	%
a.	Less than 1hectare	136.51	62.86	171.83	49.52
b.	1 hectare - 2 hectares	74.45	34.28	122.28	35.24
c.	Above 2 hectares	6.21	2.86	52.87	15.24
	Total	**217.17**	**100.0**	**346.98**	**100.0**

Source: Author's Data Analysis (2017)

The total land areas cultivated for 2014 / 2015irrigated rice cropping season was 772.50ha, in which 564.15ha (73.03%) were cultivated by irrigated rice farmers that utilized Pab and Pab/Pb soils in Kura and Bunkure, then 201.09ha (26.03%) were cultivated by respondents farmers that irrigated rice on Pb soil. Table 5.2c shows farm size cultivation by peasant socio-economic groups. Landowners cultivated 217.17ha (38.49%) and tenants cultivated 346.98ha (61.51%). The mean land size was 0.72ha and modal land size was 0.4ha (1 acre). This indicates that majority of the respondents were smallholder farmers, still, respondents utilized full mechanization to overcome the limitation of scale operation of the farming system that causes low benefit due small-scale production.

Table 5.2c: Peasant Socio-economic Groups Farm Size Utilized in 2014/2015 Cropping Season

S/No.	Settlement	Total Land (ha)	Land Owner (ha)	%	Land Tenant (ha)	%
1.	Kura	109.41	34.19	31.25	75.22	68.75
2.	Bunkure	53.37	35.69	66.88	17.68	33.12
3.	Danhasan	61.48	20.64	33.57	40.84	66.43
4.	Yadakwari	31.53	15.26	48.40	16.27	51.60
5.	Gajingiri	99.07	24.67	24.90	74.40	75.10
6.	Kadawa	41.54	19.57	47.11	21.97	52.89
7.	Gafan	23.08	8.70	37.68	14.380	62.32
8.	Imawa	71.50	24.0	44.44	38.25	55.56
9.	Kosawa	46.51	20.04	43.08	26.47	56.92
10.	Makwaro	34.30	10.03	29.25	24.27	70.75
	Total	**564.15**	**217.17**	**100.0**	**346.98**	**100.0**
		100.0%	**38.49%**		**61.51%**	

Source: Author's Data Analysis (2017)

Table 5.2c presents the ownership of the farmlands utilized for 2014 / 2015 irrigated rice farming season. Kura has 109.41ha and only 31.25% of the farmers cultivated by the landowner, the other 75.22% were cultivated by tenant farmers. This was the trend in all other settlements in the study settlements with exception of Bunkure where more than 68.75% of the farmlands were cultivated by landowners. This indicates that land tenure is changing toward commercial farmland ownership with 61.51% of the total land size were cultivated by land tenants.

Table 5.2d shows membership of co-operative societies of the respondents. The majority of respondents belong to Water Users Association as well as Labour Ring Association (communal labour in The Hausa language '*kungiyar aikin gayya*'). These co-operative societies were essentially used for labour intensive farming activities such as manual land preparation, weeding, transplanting, and irrigation. The formation of the associations is a requirement of Federal Government for benefitting National Irrigation Development Project. Table 5.2d shows that 58.10% of the respondents registered with the association between the years 2000 – 2009; after the completion and final development of the remaining 7,000ha in 2006 of the Kano River Project I. The remaining 33.80% of the respondents were registered with the association between 2010 to date.

Table 5.2d: Respondents Membership Registration of Co-operative Association

S/No.	Years of Membership Association	No.	%
a.	1990 - 1999 Years	132	8.10
b.	2000 - 2009 Years	951	58.10
c.	2010 to Date	553	33.80
	Total	**1,636**	**100.0**

Source: Author's Data Analysis (2017)

5.3 Integrated Pest Management and Crop Protection in Kano River Project I

Weeds, diseases, insects, nematodes, and birds are among the environmental constraints to rice production in the rice-growing ecosystem. The severity of the pest problems generally increases with the intensification of production systems and growth for fertilizer and pesticides used (WARDA, 1992).

Farmers indicated bird invasion is the major constraint (63.81%) and pest problem affecting rice production (See table 5.3a). Farmers control this menace by bird chasing using 192 man-day labours per hectare which accounted for 32.27% of the average farm labour input utilization as shown in table 5.5e, followed by insects with 20.95%, then weeds which accounted for 10.48% of the respondents. The menace of insects and weeds are controlled by using various effective pesticides as shown in table 5.3f.

Table 5.3a: The Important Pest Problems

S/No.	Pest Problems	No.	%
a.	Weed	172	10.48
b.	Bird	1,044	63.81
c.	Bush rat	77	4.76
d.	Insect pest	343	20.95
	Total	**1,636**	**100.0**

Source: Author's Data Analysis (2017)

Table 5.3b shows weeds control in the irrigated farm using farm inputs and implements. The respondents about 60.0% used herbicides to control weed pests, 26.67% of respondents used a combination of hand pulling and hoes and 11.43% used hoe to control weeds.

Table 5.3b: Weed Control in Rice Farmland using Implements

S/No.	Weed Control Inputs and Implements	No.	%
a.	Hand pulling	31	1.90
b.	Hoes	187	11.43
c.	Herbicides	982	60.00
d.	Combination of a and b	436	26.67
	Total	**1,636**	**100.0**

Source: Author's Data Analysis (2017)

It has been indicated that farmers have been modernized in their farming practice because the majority of them used external inputs (herbicides) as a method to control weeds in their irrigated rice farms.

Insect pests and other natural enemies vary in species composition and population levels, as well as time and space across the study area. Table 5.3c shows factors attracted insect pests to rice farmland. The respondents were able to recognize the presence of certain weeds (49.04%) attracted insects to collect nectar from weeds' flowers, drought occurrence (10.48%), soil fertility (10.0%) and soil types (6.67%). All these factors were cited by farmer respondents. These three factors (soil types, soil fertility and presence of standing water) attracted weeds germination and growth in the rice farmland.

Table 5.3c: Factors Attracted Insect Pests to Rice Farmland

S/No.	Factors	No.	%
a.	Soil type	109	6.67
b.	Soil fertility	164	10.00
c.	Drought occurrence	171	10.48
d.	Standing water	390	23.81
e.	Presence of certain weeds	802	49.04
	Total	**1,636**	**100.0**

Source: Author's Data Analysis (2017)

In developing rice production, it is necessary to consider the crop within the context of the range of agricultural activities performed by rice households in protecting the crop from weeds infestation in the study area.

Table 5.3d shows reasons for insufficient control to weeds infestation in which 48.57% of the respondents believed low capital to purchase enough herbicides were the major reason for insufficient weeds control.

Cost of labour (29.52%) and a shortage of labour (21.91%) have indicated that the respondents have no enough family labour that is why they relied heavily on hired labour. The scarcity of family labour caused a high demand for hired labour force this has led to the exorbitant price.

Table 5.3d: Causes of Insufficient Control to Weeds Infestation

S/No.	Causes	No.	%
a.	Shortage of labour	358	21.91
b.	Low Capital to purchase herbicides	795	48.57
c.	Cost per labour	483	29.52
	Total	**1,636**	**100.0**

Source: Author's Data Analysis (2017)

Table 5.3e shows insect control methods on rice field; 66.66% of the farmers' sprayed insecticides on weed species which attracted insect pest species, 27.62% of the respondents applied rice variety that resists insect pests and diseases. Other respondents (5.72%) used one traditional method or another such as some herbs in the farmland which their odours repel insects in the rice farmland. This method is not effective compared with other modern methods.

Table 5.3e: Insect Control Methods on Rice Field

S/No.	Insect Control Methods	No.	%
a.	Laying plant leaves on rice field	53	3.21
b.	Traditional herbalist	40	2.51
c.	Use of insecticides	1,091	66.66
d.	Diseases resist variety	452	27.62
	Total	**1,636**	**100.0**

Source: Author's Data Analysis (2017)

Information gathered in table 5.3e shows the number of days hand weeding was carried out after transplanting of the seedling. Respondents used four weeks (45.24%), five weeks (30.95%), six weeks (10.48%), three weeks (7.32%). Likewise, 6.01% of the respondents did not use hand weeding because of intensive application of herbicides.

Table 5.3e: Number of Hand weeding Days Transplanting

S/No.	Hand weeding Days	No.	%
a.	None	98	6.01
b.	Three weeks	120	7.32
c.	Four weeks	740	45.24
d.	Five weeks	506	30.95
e.	Six weeks	172	10.48
	Total	**1,636**	**100.0**

Source: Author's Data Analysis (2017)

The table indicates that the herbicides applied by farmers are not enough to terminate weeds germination on rice farmland.With increasing demographic pressure in the study area, farming systems are undergoing intensification by applying both chemical fertilizers and pesticides to maintain the potentiality of sustainable rice production.

Table 5.3f shows farmers choice of pesticides effective for rice production. The respondents recognized pesticides like Mocozobe Powder (17.55%), Orizo Plus (15.91%), Glylesell (10.97%), Best (10.42%), Termicides (6.40%), Delvap (6.40%) and D. D. Force (5.86%) as the major pesticides applied by the respondents. These seven pesticides mentioned were cited by more than 50% of the total respondents.

Table 5.3f: Pesticides Found Effective for Rice Farming

S/No.	Pesticides	No.	%
a.	Best	171	10.42
b.	Bruta Force	45	2.74
c.	Butter Force	46	2.81
d.	Crush	45	2.74
e.	D.D. Force	96	5.86
f.	DelForce	12	0.74
g.	Delvap	102	6.22
h.	Grammerzone	72	4.39
i.	Gylesell	180	10.97
j.	Kombat	39	2.38
k.	Macozobe Powder	286	17.55
l.	No Pest	18	1.09
m.	Numining/ Lumining	36	2.19
n.	Orizo Plus	260	15.91
o.	Pestes A.C.	66	4.02
p.	Protor Care	9	0.55
q.	Rocket	49	3.01
r.	Termicides	104	6.40
	Total	**1,636**	**100.0**

Source: Author’s Data Analysis (2017)

Although most rice farmers were aware of the effect of various pests and diseases on rice production as indicated in the tables previously discussed. This reason made irrigated rice farmers to apply available pesticides to overcome their farming problems which related to pests infestation.

5.4 **Development of Improved Rice Varieties**

The adoption rate of new rice varieties is often low because farmers lack the preferred traits. The result of this study was summarized and showed that local varieties had several advantages over improved varieties particularly in terms of panicle exertion, drought tolerance, insects and diseases tolerance and no grain per panicle. Interestingly, farmers did not perceive a distinct yield advantage for improved rice varieties over local ones because the local variety attracted higher consumer price over improved variety.

The finding of this research is not similar to the findings of Adesina and Jones (1992) on the farmers' comparison between local and improved varieties because rice farmers have considered that improved rice variety has many advantages over local ones in all traits with exception of four traits previously discussed and explained in this study and shown in table 5.4a.

Rice farmers recognized plant height with 47.14% respondents cited for improved varieties, 31.43% respondents cited for local varieties and 21.43% observed no differences between the varieties (improved and local). In terms of resistance to the shattering trait, 55.22% of the respondents identified improved varieties, 21.43% of the respondents identified local varieties, 20.47% observed no difference between the varieties and 2.85% recognized not applicable. In case of weed competitiveness, 59.07% respondents chose improved varieties, while 22.85% of the farmers observed no differences between varieties and 15.23% only cited local varieties. There were no much differences in terms of drought tolerance because 55.71% of the farmers observed no differences between varieties, 23.81% considered local varieties and 19.05% recognized improved varieties. Insects and diseases tolerance traits were computed, 37.62% of the respondents observed no difference between varieties, 30.86% of them choose local varieties and 28.10% were accounted for improved varieties.

Panicle length determined the quantity of rice grain per panicle. The panicle is the flower cluster along the stem of rice; it is the host of rice grain, like cob for maize grain and expresses the yield per rice plant. The respondents' farmers cited improved varieties (44.29%), local varieties (28.57%), few of them (14.76%) observed no differences and other respondents (12.38%) observed the varieties not applicable. Panicle exertion refers to the ability of rice plant to germinate and develop flower cluster of rice. Farmers' respondents (36.19%) recognized panicle exertion for local varieties; the proportion of farmers that observed no differences between varieties and other (20.0%) cited improved varieties, 34.29% observed no difference between varieties and 9.52% observed not applicable. Tillering capacity means germination of plant branches from a bud on the leaf axils of the main cum; farmers chose improved varieties which accounted for 47.14%, local variety accounted for 21.91% and 20.95% of the respondents observed no difference and 10.0% observed not applicable between varieties.

No grain per panicle was not differently identified on rice plants by 37.14% of the respondents; 36.19% of them identified no grain for local varieties and 22.86% recognized no grain for improved varieties and 3.81 % observed it as not applicable. Early maturity was highly recognized for improved varieties (58.57%) followed by local varieties (30.0%), then 5.71% observed not applicable. The variety with high yield was cited by respondents for improved variety (58.57%), local varieties (29.52%) and other respondents (10.48%) not observed any differences between the varieties.

With regard to post-harvest traits, the majority of the respondents recognized improved varieties more than local ones. Good aroma traits were cited by 54.29% respondents for improved varieties, 25.24% of respondents were cited for local varieties and 20.47% of them observed no differences for different varieties. Ease of cooking was cited by 66.62% respondents for improved varieties, local varieties were identified by 16.69% and 13.83% of the farmers observed no differences between varieties and 2.86% of farmers were observed it not applicable.

Table 5.4a: Farmers Knowledge and Preferences for Rice Varietal characters

S/No.	**Agronomic Traits**	**Local**	**%**	**Improved**	**%**	**Not Diff.**	**%**	**Not Appl.**	**%**
a.	Plant height	514	31.43	771	47.14	351	21.43	0	0.0
b.	Resistance to shattering	351	21.43	903	55.22	335	20.47	47	2.86
c.	Weed competitiveness	249	15.23	967	59.07	373	22.85	47	2.85
d.	Drought tolerance	390	23.81	312	19.05	911	55.71	23	1.43
e.	Insect & diseases tolerance	505	30.86	460	28.10	648	37.62	23	1.42
f.	Panicle length	467	28.57	724	44.29	242	14.76	203	12.38
g.	Panicle exertion	592	36.19	327	20.00	561	34.29	156	9.52
h.	Tillaring capacity	359	21.91	773	47.14	343	20.95	164	10.0
i.	No grain per panicle	592	36.19	374	22.86	607	37.14	63	3.81
j.	Early maturity	491	30.00	959	58.57	93	5.71	93	5.71
k.	Yield	483	29.52	958	58.57	172	10.48	23	1.43
S/No.	**Post Harvest Traits**	**Local**	**%**	**Improved**	**%**	**Not Diff.**	**%**	**Not Appl.**	**%**
a.	Good aroma	413	25.24	888	54.29	335	20.47	0	0.0
b.	Ease of cooking	273	16.69	1,090	66.62	226	13.83	47	2.86
c.	Taste	244	14.94	1,119	68.37	226	13.83	47	2.86
d.	Ease of milling	280	17.14	850	54.76	506	30.95	0	0.0
e.	Ease of threshing	210	12.86	1,084	66.19	249	15.24	93	5.71

Source: Author's Data Analysis (2017)

*Not Diff. = Not Difference *Not Appl. = Not Applicable

Rice taste identified by 68.37% of the respondents for improved varieties, 14.94% of farmers were cited for local varieties and 13.83% of them observed no differences among the varieties. Ease of milling was accounted for 54.76% for improved varieties, 30.95% of the respondents observed no differences between varieties and 17.14% of farmers cited local varieties. Ease of threshing was recognized for improved varieties (66.19%) by farmers, some respondents (15.24%) observed no difference between varieties and others respondents (12.86%) cited local varieties.

Rice is established in a greater complex range of environmental conditions than any other crops. Rice can be grown in upland at an altitude of 3,000m, tidal swamps, deep water areas, rain-fed lowlands and irrigated areas. In this study area, rice can be grown in ecosystems: upland, high terrace and lower terrace, and their altitude vary from one place to another.

Farmers were assessed to identify the desirable traits which can be adapted to their rice ecosystems. Table 5.4b presented the summary of farmers' responses reacted to the rice varietal traits that were either considered definitely favourable (important) or definitely unfavourable (not important or not applicable). The attitude of farmers toward the rice traits under investigation was examined and listed as highly important, important, moderately important and not applicable to the rice ecosystem.

The results of table 5.4b show farmers assessment of agronomic trait for plant tallness was considered moderately important (40.0%); some of the respondents considered rice plant height as highly important (38.57%) and other respondents considered it as important (21.43%). Medium height rice plant assessment was recognized as highly important (39.71%); some farmers assessed it as moderately important (35.24%), others assessed it as important (25.71%). Short height rice plants were identified as important (68.57%), moderately important (23.33%) and highly important (8.10%). This indicates that farmers cultivate rice on different altitudes and water regimes. The farmers consider rice plant tallness as moderately important this means that farmers cultivate upland rice; those farmers considered it highly important they cultivate lowland rice and those considered it important they cultivate on high terrace land.

The results of rice plant duration (the period from planting to harvesting) assessment was revealed in which long duration varieties were considered moderately important (57.62%); some respondents considered it important (23.81%) and others considered it highly important (17.57%).

Medium duration varieties were cited as important by 46.67% of the respondents, 38.10% of the farmers cited it as highly important and 15.23% of them cited it as moderately important. Short duration varieties were identified by farmers as important (40.0%), highly important (34.29%) moderately important and not applicable (11.43%). This result showed that medium and short height varietal traits were more desirable to farmers in the study area.

Table 5.4b: Assessment of Rice Plant Agronomic and Post-Harvest Traits

Rice Plant Height	**Highly Imp**	**%**	**Imp**	**%**	**Moderate Imp**	**%**	**Not Appl**	**%**
Tall	631	38.57	351	21.43	654	40.00	0	0.00
Medium	638	39.71	421	25.71	577	35.24	0	0.00
Short	133	8.10	1,122	68.57	381	23.33	0	0.00
Rice Plant Duration	**Highly Imp**	**%**	**Imp**	**%**	**Moderate Imp**	**%**	**Not Appl**	**%**
Long	288	17.57	389	23.81	959	57.62	0	0.00
Medium	623	38.10	764	46.67	249	15.23	0	0.00
Short	561	34.29	654	40.00	187	11.43	234	14.28
Other Plant Traits	**Highly Imp**	**%**	**Imp**	**%**	**Moderate Imp**	**%**	**Not Appl**	**%**
Yield	1,371	83.81	265	16.19	0	0.00	0	0.00
Tillering capacity	140	8.57	737	44.76	608	37.14	151	9.25
Panicle exertion	343	20.95	939	57.44	307	18.75	47	2.86
Drought tolerance	421	25.71	841	51.43	329	20.10	45	2.76
Resistance to shatter	755	46.19	304	18.57	577	35.24	0	0.00
Weed competitions	717	43.81	538	32.86	288	17.62	93	5.71
Insect pest tolerance	351	21.45	747	45.66	497	30.38	41	2.51
Diseases tolerance	499	30.47	623	38.10	374	22.86	140	8.57
Post Harvest Traits	**Highly Imp**	**%**	**Imp**	**%**	**Moderate Imp**	**%**	**Not Appl**	**%**
Good aroma	351	21.43	849	51.91	436	26.66	0	0.00
Ease of cooking	312	19.05	942	57.62	382	23.33	0	0.00
Good Taste	577	35.24	841	51.43	218	13.33	0	0.00
Ease of milling	405	24.76	919	56.19	312	19.05	0	0.00

Source: Author’s Data Analysis (2017)

Note: Imp = Important; Appl = Applicable

Other agronomic traits assessed by this study include the following: the yield of rice was desirable in which 83.81% of respondents cited it as highly important and only 16.19% considered it important. Tillering capacity was recognized by farmers as important (44.76%), moderately important (37.14%), highly important (8.57%) and not applicable (2.86%). This indicated that farmers did not highly desire this trait because it caused rice wilt by moving air especially to rice variety that produced heavier panicles. Panicle exertion assessed important (57.44%) by respondents; some cited it highly important (20.95%) and others respondents cited it moderately important (18.75%). In terms of drought tolerance, 51.43% of the respondents cited the trait as important, 25.75% of farmers cited it highly important and 20.10% of them considered it moderately important and 2.76% considered it not applicable. Farmers assessed resistance to shattering as highly important (46.19%), moderately (35.24%) and important (18.57%). Varieties that compete with weeds are preferred by farmers as highly important (43.81%), important (32.86%) and others cited it moderately important (17.62%) and few of them cited it not applicable (5.71%). Insect tolerance rice variety trait was assessed by farmers as important (45.66%), moderately important (30.38%) and 21.45% considered it moderately important. Diseases tolerance trait was assessed in which 38.10% of the respondents cited the trait as important; 30.47% cited it as highly important and 22.86% were cited for moderately important.

The assessment of the post-harvest traits shows that majority of the respondents desired these traits (post-harvest) because rice millers and consumers preferred these traits for milling and consumptions. The results of this study showed good aroma was preferred as important (51.91%) by respondents, some farmers cited the trait as moderately important (26.66%) and others respondents cited it as highly important (21.43%); these traits are demanded consumers and it attracted a higher price. Ease of cooking trait was computed in which 57.62% of the respondents accounted the trait as important, 23.33% of the farmers cited it as moderately important and 19.05% of them cited for highly important. The taste was also a trait identified by this study. Farmers recognized taste trait as important (51.43%), some of the respondents considered it highly important (35.24%) and others cited it as moderately important (13.33%). Finally, the study reveals that 56.19% of the respondents considered ease of milling traits as important, 24.76% of them considered it highly important and 19.05% considered it moderately important. Rice millers desired this trait because of easy milling and packaging to consumers in urban Kano without breakage.

These findings are similar to the findings of the assessed farmers' responses for the importance of agronomic and post-harvest traits identified by Adesina and Jones (1992). The traits that are similar to the findings of this study included yield, tillering capacity, drought tolerance, panicle exertion, resistance to shattering, plant height (medium and tallness), duration (long and medium) good aroma, ease of cooking, ease of milling and good taste; while other traits were contrary to the findings of Adesina and Jones (1992) cross-sectional study.

From this study, a comprehensive database can be developed on the major traits of local and improved varieties cultivated by farmers in the surveyed area. Farmers' preference profiles for different agronomic and post-harvest traits were compiled. This kind of study has a considerable interest to rice breeders in the project area and can be expanded over the years to involve national researchers in the development of a database on the varietal preference of rice farmers in Nigeria.

The ability of rice research institutes to develop and produce new improved rice varieties that tolerate ecosystem–specific stresses along the irrigation project is inhibited by lack of certain morpho-agronomic traits. A multidisciplinary study is needed to measure the yield response of improved varieties and identified key traits which enhance adaptability to a specific ecosystem of the project area.

5.5 **Input and Cost Levels of Rice Production under Irrigation Scheme per Hectare**

The fixed and variable inputs of rice production include land, labour hour required, fertilizer (NPK and urea), pesticides and seeds.

1. Land: About 564.15ha of rice farms were cultivated by farmers' respondents. The cultivated land range was 0.4ha – 3.0ha with a mean of 1.35ha farm plot and model land size was 0.4ha. The maximum farm size was taken as the limit of land available for cultivation as specified as a land constraint.
2. Seed: Both local and improved rice seed varieties were utilized by farmers. The usage of seed from the previous harvest is very common practice among rice farmers in the study area. At present two common rice varieties (Jamila and Faros) were cultivated by farmers and described as follows:

a. Faro's variety: it is breeder seed foundation variety (seed pollinated) introduced to the project area from Rice Research Institute Badegi, Niger State. Farmers cultivate it for three yield period until its yield degenerated before another seed would be repurchased. It has a growing period of 30 + 120 days (30 days in the nursery). This variety produces medium stiff straw with narrow leaves. Yields are higher than the two local variety varieties. The grains are medium and of good quality. Faros 52 (wilted) and Faros 57 (toast) are two different types of Faros varieties introduced into the irrigation project area. They have a higher yield than local varieties, but Faros 52 wilts by wind and cause rice lost. Toast (Faros 57) has a long stiff straw with heavy panicle which makes it break and fall down on the ground and usually rat destroy it, and if it breaks at the immature stage it rotten and also cause rice lost.

b. Jamila (beauty) variety: it is local variety, yet it is not known from where this variety came to the project site. It is believed that this variety was evolved as a result of cross-pollination between Yar'das variety and Farros variety. It has a growing period of 30 + 115 days (30 days in the nursery). The research reveals that this variety produces long stiff straw with broad leaves. Yields are higher; the grains are long and farmers like to produce this variety because of its higher demand by rice consumers in the urban Kano.

In all the two varieties, 25kg was planted in one acre for the nursery which is eventually transplanted in one hectare. This is to give enough space for the application of other inputs. Table 5.5a shows quantity and cost of seed for rice production per hectare. The result of the analysis shows that about 65.24% of the respondents used ≤ 25kg of seed per hectare, some 33.33% of the farmers used 26kg – 50kg and few of them about 1.43% used 51kg – 75kg per hectare.

Table 5.5a: Quantity and Cost of Seed Input Utilization for Rice Production

S/No.	Quantity of Seed Applied	No.	%
a.	≤25Kg	1,067	65.24
b.	26Kg =50Kg	545	33.33
c.	51Kg =75Kg	24	1.43
	Total	**1,636**	**100.0**
S/No.	**Cost of Seed**	**No.**	**%**
a.	₦1,500.00 - ₦3,000.00	77	4.76
b.	₦3,001.00 - ₦4,500.00	343	20.95
c.	₦4,501.00 - ₦6,000.00	569	34.76
d.	₦6,001.00 - ₦7,500.00	647	39.52
	Total	**1,636**	**100.0**

Source: Author’s Data Analysis (2017)

In term of cost of seed, most of the farmers about 39.52% of them purchased seeds between ₦6,001 - ₦7,500, 34.76% of farmers purchased seeds between ₦4,501 - ₦6,000, 20.95% of them purchased seed between ₦3,001 - ₦4,500, few of them about 4.76% purchased seed between ₦1,501 - ₦3,000; this was because seeds supply were scarce in irrigation season and farmers were not able to purchased 25kg at higher price.

The seed was introduced into the model in order to see its level of utilization. The value in the model represents the recommended seed per hectare for rice cropping activity.

3. Fertilizer: Both organic and inorganic fertilizers were utilized for rice production by rice farmers. The major chemical fertilizer used is the NPK (20:10:10) and UREA (45) brands. Table 4.2.5b

shows that 49.93% of the respondents applied less than or equal to 250kg per hectare, while 37.58% of the farmers applied 251kg – 350kg; 12.53% of them applied 351Kg – 450Kg. The cost of fertilizer applied shows that 56.14% of the respondents spent ₦16,500 - ₦27,500, 27.93% spent ₦27,501 - ₦38,500 and few of them about 15.93% spent ₦38,501 - ₦49,500. This implies that the chemical fertilizer input was used to improve and maintain soil fertility status and this determined nutrient constraints of N, P and K requirement for rice production activity.

Table 5.5b: Quantity and Cost of Fertilizer Input Utilization for Rice Production

S/No.	Quantity of Fertilizer	No.	%
a.	≤ 250Kg	817	49.93
b.	251Kg - 350Kg	615	37.54
c.	351Kg - 450Kg	204	12.53
	Total	**1,636**	**100.0**
S/No.	**Cost of Fertilizer**	**No.**	**%**
a.	₦16,500.00 - ₦27,500.00	919	56.14
b.	₦27,501.00 - ₦38,500.00	457	27.93
c.	₦38,501.00 - ₦49,500.00	260	15.93
	Total	**1,636**	**100.0**

Source: Author's Data Analysis (2017)

4. Pests and diseases control: The levels of agro-chemicals utilized are quite substantial. However, zero level of agro-chemicals application was observed for some farmers. The major agro-chemical brands used were: Mocozobe Powder, Orizo Plus, Gylesell, Best, Termicides, Delvap and D.D. Force (See table 5.3h).

Table 5.5c shows quantity and cost of pesticides (insecticides and herbicides) for rice production per hectare. The result shows 54.29% of the respondents applied between 6–7 litres (Lt) of agro-chemicals; 34.76% of farmers applied 4–5 Lt and 10.95% of them applied 2–3 Lt.

The cost of pesticides mentioned by the 49.05% of the respondents was between ₦3,001.00 - ₦5,000.00 per hectare; 33.81% of the farmers spent between ₦1,000 - ₦3,000; 13.08% of them spent ₦5,001.00 - ₦7,000.00 and 4.06% of them spent ₦7,001.00 - ₦9,000.00.

Table 5.5c: Quantity and Cost of Insecticides and Herbicides for Rice Production

S/No.	Quantity of insecticides and Herbicides (Lt.) Applied	No.	%
a.	2 – 3	179	10.95
b.	4 – 5	569	34.76
c.	6 – 7	888	54.29
	Total	**1,636**	**100.0**
S/No.	**Cost of Insecticides and Herbicides Applied**	**No.**	**%**
a.	≤ ₦3,000.00	553	33.81
b.	₦3,001.00 - ₦5,000.00	803	49.05
c.	₦5,001.00 - ₦7,000.00	214	13.08
d.	₦7,001.00 - ₦9,000.00	66	4.06
	Total	**1,636**	**100.0**

Source: Author's Data Analysis (2017)

5. Labour: Both family and hired labours were utilized for rice production. An average rate of ₦500 was paid for man-day of labour. The average household was found to be 6 and it was made up of 6.24 man equivalents and each assumed to be capable of working for 5 hours on the farm per day. This indicating that a total of 187.20 man-days per month were available. However, due to ill health exhaustion and other incidentals of life only about 60% efficiency was assumed for the available family labour in each month (112.32man-days) or 18.72 man-days in man equivalents per week as shown in table 5.5d.

Table 5.5d: Household Composition and the Derived Labour in Man Equivalent

Household Structure	Average Household	Conversion Factor	Labour in Man Equivalent
Working Adult Male	1.6	1.0	1.60
Male Youth	2.3	0.75	1.73
Working Adult Female	1.88	0.75	1.41
Female Youth	2.0	0.75	1.50
Total	**7.78**	**-**	**6.24**

Source: Author's Data Analysis (2017)

Secondly, the labour available per period of irrigation season was computed to be:

January – April: 120 man-days x 6.24 x 0.60 = 449.28 man-days.

Firstly, the conversion factor according to Norman (1973) was used to convert the household size into man equivalent. The factor 1.00 and 0.75 were used to convert a working male adult/youth, working female adult/youth respectively into their man equivalents as shown in table 5.5d.

This indicates that there was a shortage of family labour in the project area because the rice farming family would not be capable to raise 595.60 man-days as shown in table 5.5c. However, due to the ill health exhaustion and other incidentals of life, the farmers were able to raise 449.28 man-days and 146.32 labour man equivalents were required from hire labour services to produce an equivalent 4,500Kg per hectare. But the project office has recommended the standard labour of 10 man-days (total 1200 man-days in four months). This indicates that there was a shortage of 750.72 man-days require as from hire labour. This forms the basis of labour constraint in the model.

Table 5.5e presented the average farm inputs utilization of different input stages for rice production in terms of labour required in man-day and labour cost requirement per hectare. The study reveals that farmers provide average labour input of 595.60 man-days per hectare. Bird chasing required 192 man-days which is 32.27% of the total labour required. Water application (irrigation) required 180 man-days which accounted for 30.25% of the total labour force; weeding required 78 man-days which accounted for 13.11%. Harvesting and drying required 44.0 man-days and indicated 7.40% of the total labour, sowing and nursery required 34 man-days accounted for 5.71% of the total man-days, leveling and discing required 25 man-days accounted for 4.20%; transplanting of seedling required 17 man-days accounted for 2.86 %. Pesticides and herbicides application required 11 man-days accounted for 1.85%. Fertilizing and transportation of rice outputs each required 8 man-days accounted for 1.35%. Other included harrowing and transportation of harvest home and each required 3 man-days and accounted for 0.50% of the total labour force.

The average cost of labour for rice production per hectare was ₦56,708.29. Mechanical land preparation attracted highest cost (₦13,381.56) which accounted for 23.58% of the total cost, followed by harvesting and drying which accounted for 19.41%, water application (irrigation) accounted for 12.93%, pesticides and herbicides application accounted for 12.41%, Others labour input costs each accounted for less than 6.0% included: transplanting of seedlings (5.49%), leveling and discing (5.11%), transportation of rice harvest to home (4.70%), sowing of seed (2.87%), fertilizing (2.31%) and weeding (2.10%).

Table 5.5e: Average Farm Labour Input Utilization for Rice Production per Hectare

Farm Input	Labour (Man-day)	%	Cost(₦)	%
Harrowing (Mechanical land preparation)	3	0.50	13,381.56	23.58
Leveling and discing (Manual land preparation)	25	4.20	2,895.95	5.11
Seed sowing and nursering required	34	5.71	1,626.74	2.87
Transplanting of seedling	17	2.86	3,110.47	5.49
Fertilizing	8	1.35	1,310.93	2.31
Weeding	78	13.11	1,191.39	2.10.
Pesticides and insecticides	11	1.85	7,037.24	12.41
Water application (irrigation)	180	30.25	7,329.26	12.93
Bird Chasing	192	32.27	5,155.29	9.09
Harvesting and bagging	44	7.40	11,005.56	19.41
Transportation	3	0.50	2,663.56	4.70
Total	**595.60**	**100.0**	**56,707.95**	**100.0**

Source: Author's Data Analysis (2017)

In conclusion, rice requires about twice as much water application than any other crops and birds invaders are the most disastrous issue in Kano River Project I. this is the reason why farmers required higher labour for water application and bird chasing which accounted for 62.52% of the total labour applied. This was also recommended by NEDECO (1974) as to increase the crop yields and net return using man-day per hectare on the growing on soils should be encouraged because this can favours good soils suitability.

6. Rice Output: Output refers to the quantity of rice harvested from a given farmland in the study area. An average quantity of rice harvested was 4.26 ton per hectare. Table 5.5f shows quantity,

total cost and a net profit of rice harvested per hectare. The result reveals that 38.10% of the respondents harvested 1,050kg – 2,500Kg, 37.14% of the farmers harvested between 4,050kg – 4,500kg, 12.86% of them harvested between 2,550kg – 4,000kg and 11.90% among them harvested 5,550kg and above.

The total cost of rice production varies from farmers; 30.95% of the respondents spent between ₦170,001.00 – ₦190,000.00, 27.14% of the farmers spent less than ₦100,001.00 - ₦120,000.00; 25.24% of them spent between ₦150,001.00 - ₦170,000.00 and 16.67% of them spent ₦120,001.00 - ₦150,000.00.

Table 5.5f: Rice Output and Net Profit

S/No.	Quantity of Rice Harvested	No.	%
a.	1,050 Kg – 2,500Kg	623	38.10
b.	2,550Kg - 4,000Kg	210	12.86
c.	4,050Kg - 5,500Kg	608	37.14
d.	5,550Kg and Above	195	11.90
	Total	**1,636**	**100.0**
S/No.	**Total Cost of Production**	**No.**	**%**
a.	₦100,001.00 - ₦120,000.00	444	27.14
b.	₦120,001.00 - ₦150,000.00	273	16.67
c.	₦150,001.00 - ₦170,000.00	413	25.24
d.	₦170,001.00 - ₦190,000.00	506	30.95
	Total	**1,636**	**100.0**
S/No.	**Farmers' Net Profit**	**No.**	**%**
a.	₦35,000.00 - ₦50,000.00	132	8.10
b.	₦50,001.00 - ₦65,000.00	514	31.43
c.	₦65,001.00 - ₦80,000.00	567	34.67
d.	₦80,001.00 - ₦95,000.00	210	12.86
e.	₦95,001.00 - ₦110,000.00	156	9.52
f.	₦110,001.00and Above	57	3.42
	Total	**1,636**	**100.0**

Source: Author's Data Analysis (2017)

The farmers' net profit was computed as 34.67% of the respondents acquired profit between ₦65,001.00 - ₦80,000.00, 31.43% of the farmers acquired profit between ₦50,001.00 - ₦65,000.00 profit; 12.86% of them acquired profit between ₦80,001.00 - ₦95,000.00; 9.52% of the farmers acquired profit between ₦95,001.00 - ₦110,000.00, 8.10% acquired profit between ₦35,001.00 - ₦50,000.00 and finally, few of them about 3.33% acquired profit between ₦110,001.00 and above because these farmers were able to store their harvest until the rice market price was higher.

Farmers' have commented and explained they have achieved good rice harvest and none of them responded their farm output as poor or very poor. This is because farmers used family or cheap labour from their relatives known as communal labour (called *aikin gayya* in Hausa language). The cost of these labours utilized was also incorporated to farmers' benefit with the exclusion of mechanical land preparation; all other non-hired labours utilized were within communal labour type.

5.6 Mean Values of Inputs-Outputs Levels of Cost and Return Analysis of Rice Production

In any production process, costs are incurred in productivity; output and return are earned from the sales of output. The total output of crop produced valued at the prevailing average market price for the rice crop was used in the analysis for cost and returns. It is imperative to note that an insight during irrigation season indicates that the price of the crop fluctuated very widely as presented in table 5.6a.

Table 5.6a: Average Rice Sale Price

S/No.	Sale Price	No.	%
1.	₦4,001.00 - ₦5,000.00	327	20.0
2.	₦5,001.00 - ₦6,000.00	764	46.67
3.	₦6,001.00 - ₦7,000.00	171	10.48
4.	Above ₦7,000.00	374	22.85
	Total	**1,636**	**100.0**

Source: Author's Data Analysis (2017)

The result shows that majority of the farmers 46.67% sold their rice harvest between ₦5,001.00 - ₦6,000.00. Some farmers about 22.0% of them sold their rice harvest above

₦7,000.00, 20.0% of farmers sold their rice output between ₦4,001.00 - ₦5,000.00. Others about 10.48% of the respondents sold their harvest between ₦6,001.00 - ₦7,000.00. Some farmers were able to store their rice harvest for few months until the market price is high to make enough profit.

The result for costs and returns analysis is presented in table 5.6b and shows that variable cost dominated the cost of production by accounting 53.13% of the total cost of production. The fixed cost apart from the depreciated cost of hoes, Cutlass, desilting of irrigation canals which are difficult to calculate by farmers were ignored in the total cost of production. The fixed cost included land rent for tenant farmers and water fee charged to project office that was calculated to be 34.91% of the total cost of production.

Table 5.6b: Cost and Return Analysis of Rice Production per Hectare under Irrigation

S/No.	Cost and Return Variable	Cost and Return (₦)	%
a.	**Gross Value of Output (₦)**	**229,644.90**	**100.0**
b.	**Variable Cost Component**	**Variable Cost (₦)**	**%**
i.	Seed	5,040.29	5.15
ii.	Fertilizer: NPK & Urea	30,687.58	31.35
iii.	Agro-chemicals	5,464.59	5.58
iv.	Labour	56,707.41	57.92
c.	**Total Variable Cost**	**97,900.41**	**100.0**
d.	**Fixed Cost Component**	**Fixed Cost (₦)**	**%**
i.	Land rent	50,000.00	95.24
ii.	Water fee	2,500.00	4.76
e.	**Total Fixed Cost**	**52,500.00**	**100.0**
f.	**Total Cost (c + e)**	**150,400.41**	**66.21**
g.	**Net Farm Income (a – f)**	**79,244.49**	**33.79**

Source: Author’s Data Analysis (2017)

Labour inputs dominated variable cost component. It accounted for 57.92% of the total variable cost. This was as a result of higher demand of man-days and hours used for farming operation, such as land preparation, transplanting, weeding water application and harvesting (See Table 5.6b). Despite the fact there is yearly fertilizer application; chemical fertilizer input was the second dominated variable cost component. This implies that there is a decline of soil fertility status because of continued use of land for irrigation purposes for more than four decades (since

1974) without proper nourishment this accounted for 31.35% of the total variable cost. An average total cost of ₦150,400.41 was calculated from the summation of the average fixed cost of ₦52,500.00 (34.91%) and average total variable cost of ₦97,900.41 was incurred per hectare respectively in the production of rice. This termed cost constraint in the model. The result of this analysis also showed that the average net return of ₦79,244.49 per hectare was obtained.

Annual yields and net returns variation were examined for irrigated rice farming systems under different input rates per hectare. Farmers who strongly seek to reduce risk or variation in net returns prefer to use recommended fertilizer application rate on rice production or to diversify with soya beans in order to manage the soil sustainably.

Potential annual net return distributions for rice cropping sequence under inputs scenario of Jamila and Faros varieties were examined for variability. A general overview of the summary of statistics of the resources inputs and yields characteristic of the irrigated rice farming is presented in table 5.6c.

Table 5.6c compares the means, minimums, maximums, standard deviations and coefficient of variation statistics of rice production inputs and output per hectare. Although examining average net returns and selected net returns and selected costs are useful, it is important to recognize that each input level and cropping sequence have a different amount of risk (variability in yield and net returns) which can be important factor in rice production input level decision.

Yield distribution characteristics and yield response for rice cropping have indicated farmers' differences of nitrogen fertilizer application per hectare. The average yield for rice cropping varies with the application of fertilizer rate. Therefore, it is important a comparison of net returns for each settlements cropping sequence was included together with costs for nitrogen.

The potential annual yields, net returns, average net returns, standard deviation, the coefficient of variation for average yields of each rice community cropping system under different nitrogen fertilizer rates were examined. The farmers used both UREA and N.P.K. fertilizers. The results indicated that farmers used both two fertilizers between 110.19Kg to 429.240Kg at a cost between ₦12,561.66 to ₦47,216.00 to achieve a reasonable 3.15 tons to a higher variable output of 5.63 tons per hectare. The possible returns preferred strategies for risk preference level for rice production profitable to farmers indicated average tons of 4.26 using 282.kg fertilizer at a cost of ₦30,687.3 to achieved ₦79,244.99 profit which is perhaps justifiable to environmental concern and farmers' net profit (See table 5.5b and Appendix v for consideration). This implicates the quantity and cost of fertilizer input and a net profit of irrigated rice farmers and showed higher variability, while farmers received homogeneous rice yield because farmers share a similar environment and technical farming experience (Table 5.6c).

Table 5.6c: Yields and Net Returns characterizations of Rice Production under Irrigation

S/No.	Production Variable	Minimum	Maximum	Mean	Std. Deviation	Coeff. of Variation
1.	Output (ton)	3.15	5.63	4.26	0.67	15.71%
2.	Fertilizer (Kg)	110.19	429.74	281.56	341.66	59.98%
3.	Cost of fertilizer (₦)	12,561.66	47,216.00	30,687.3	23.81	55.61%
4.	Net return	35,994.61	111,174.20	79,244.49	40,851.05	244.47%

Source: Author's Data Analysis (2017) *Highly Significance C. V. > 33.0%

5.7 **Rice Production Pattern and Spatial Distribution of Cost of Inputs and Net Profit**

Rice production is based upon the physical and technical relationship which exists between the output and input. Deciding on the level of inputs must relate to the cost of various inputs as well as the return from the product must be taken into consideration in determining the most profitable inputs use. Similarly, farmers deciding upon the level of production depend upon the various cost of production and the return expected from the market.

The result of product moment correlation coefficient of input costs and net profit among the rice communities in the study area were computed to be 0.52 with a calculated t value of 1.69 which was less than critical t value of 2.23 at 95% and N was equal to 10. This indicates that there was positive correlation coefficient between the cost of inputs and net profit (Table 5.7a).

Table 5.7a: Product Moment Correlation Coefficient between cost of inputs and Net Profit

S/No	Settlement	No.	x	y	(x - x)	(y – ý)	$(x - x)^2$	$(y – ý)^2$
1.	Kura	489	183,916.29	104,151.64	33,515.88	79,244.49	1,123,314,212.17	6,279,689,195.36
2.	Bunkure	274	145,514.77	36,378.50	-4,885.64	-42,865.99	23,869,478.21	1,837,493,098.68
3.	Danhasan	265	109,692.23	35,994.61	-40,708.18	-43,249.88	1,657,155,918.91	1,870,552,120.01
4.	Yadakwari	230	147,150.10	42,272.57	-3,250.31	-36,971.92	10,564,515.10	1,366,922,868.45
5.	Babbangiji	197	171717.68	46,075.51	21,317.27	-33,168.98	454,426,000.25	1,100,181,234.24
6.	Kadawa	145	133,147.27	90,392.70	-17,253.14	11,148.21	297,670,839.86	124,282,586.20
7.	Gafan	120	122,775.08	52,710.96	-27,625.33	-26,533.53	763,158,857.61	704,028,214.26
8.	Imawa	116	169,580.0	100,196.75	19,179.59	20,953.26	367,856,672.57	439,039,104.63
9.	Kosawa	85	166,108.34	173,097.20	15,707.93	93,852.71	246,739,064.89	8,808,331,174.34
10.	Makwaro	74	154,402.34	111,174.33	4,001.93	31,929.84	16,015,443.73	1,019,514,682.43
	Mean Deviation		**150,400.41**	**79,244.49**	**Total**		**4,960,169,808.88**	**17,276,580,591.65**

Source: Author's Data Analysis (2017)

Standard Deviation (ó) for x variables = 22,271.44 and for y variables = 41,565.11

Product Moment Correlation Coefficient (r) = 0.52

With the concurrent introduction of different rice crop production technology (breeder seeds) in the project area, the study reveals that the significant differences in output might be expected because of heterogeneous rice production technology utilized by different socio-economic groups. The mean deviation of ₦150,4001.41 serves as inputs cost threshold level, while the mean deviation of ₦79,244.49 serves as profit threshold level (See Table 4.7a). The result of analysis from table 4.7b reveals that the covariance analysis showed positive linear relationship for Kura, Imawa, Kosawa and Makwaro communities because their farm inputs and net profit are above threshold levels of inputs cost (mean Deviation of input cost) and net profit (mean Deviation of profit) their inputs cost and net profit exhibited positive sign); it showed positive linear relationship for Bunkure, Danhasan, Yadakwari, and Gafan communities because their farm inputs cost and profit were below threshold levels of cost of inputs and net profit and their inputs cost and net profit exhibited negative signs. The result of the covariance analysis showed negative linear relationship for Babbangiji because the cost of inputs showed positive sign indicated that it was above the threshold level of inputs cost and showed negative sign of net profit indicated that it was below net profit threshold level. The result also showed negative relationship for Kadawa because their cost of inputs showed negative sign indicated that it was below the threshold level for inputs cost and net profit exhibited positive sign because it was above the threshold level of net profit. This showed Kura, Imawa, Kosawa and Makwaro communities were the most sustainable rice farmers because their cost of inputs and net profit were above threshold levels using both local and modern fertilizers to maximize their rice farming profit.

A glance at table 5.7b and figure 11 shows that the sustainable rice farming settlements were Kura, Imawa, Kosawa and Makwaro because their cost of inputs and their net profit were higher above threshold levels. Some farming communities like Bunkure, Danhasan, Yadakwari and Gafan fold within the category of lower cost of inputs below a threshold level and low net profit below a threshold level. Another rice farming community was Kadawa which was in the category of low cost of inputs below a threshold level and higher net profit above a threshold level. The last one was the Babbangiji settlement which its cost was above a threshold level and its profit was below a threshold level.

Table 5.7b: Covariance Analysis of Cost of Inputs and Net Profit of Rice Production

S/No	Settlement	No.	x	y	(x - x)	(y – ý)
1.	Kura	489	183,916.29	104,151.64	33,515.88	24,907.15
2.	Bunkure	274	145,514.77	36,378.50	-4,885.64	-42,865.99
3.	Danhasan	265	109,692.23	35,994.61	-40,708.18	-43,249.88
4.	Yadakwari	230	147,150.10	42,272.57	-3,250.31	-36,971.92
5.	Babbangiji	197	171,717.68	46,075.51	21,317.27	-33,168.98
6.	Kadawa	145	133,147.27	90,392.70	-17,253.14	11,148.21
7.	Gafan	120	122,775.08	52,710.96	-27,625.33	-26,533.53
8.	Imawa	116	169,580.0	100,196.75	19,179.59	20,953.26
9.	Kosawa	85	166,108.34	173,097.20	15,707.93	93,852.71
10.	Makwaro	74	154,402.34	111,174.33	4,001.93	31,929.84
	Mean Deviation		**150,400.41**	**79,244.49**		

Source: Author's Data Analysis (2017) x = Cost of Inputs y = Net Profit

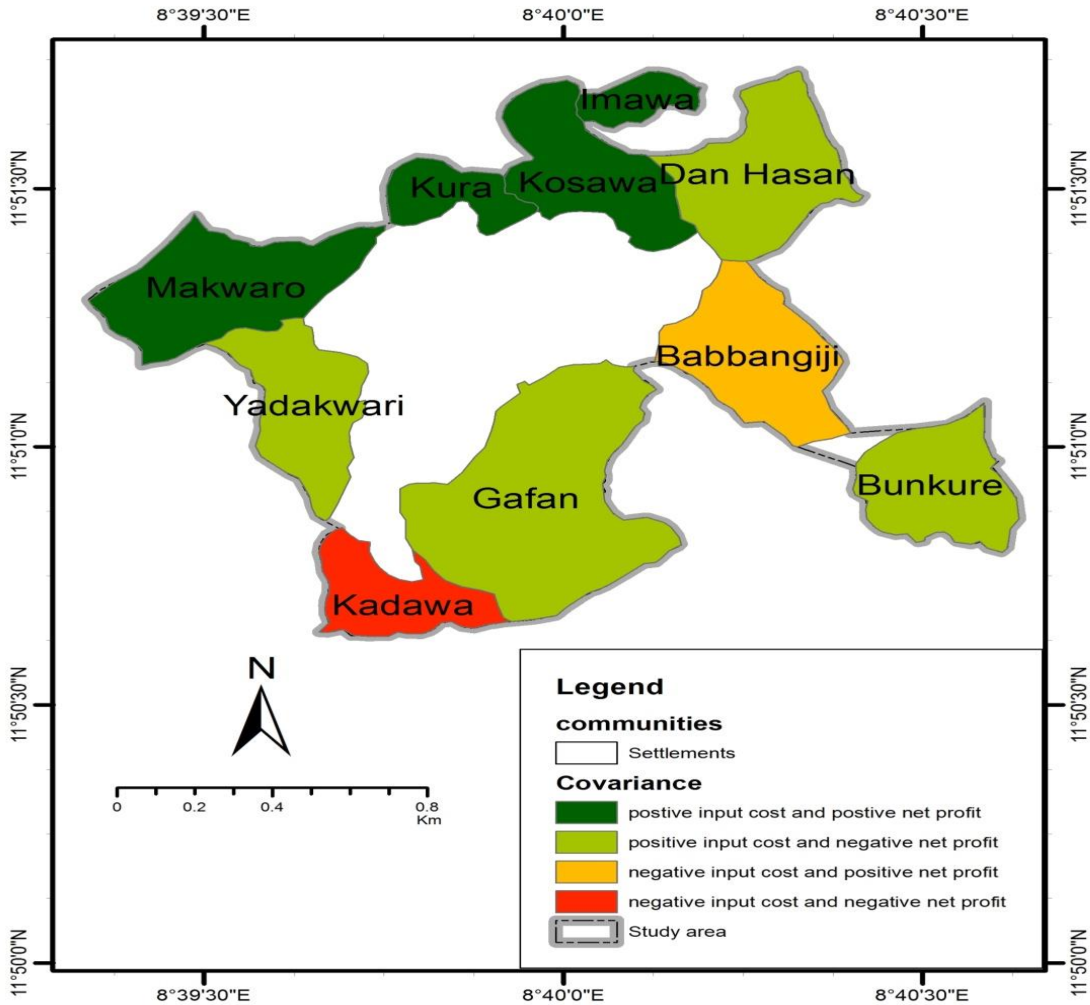


Figure 11: Sustainable Rice Farming Settlements with Regard to Economic Threshold Levels

5.8 **Pattern and Distribution of Factors Resulted from Rotated Correlation Matrix of Irrigated Rice Production**

The factor analysis was conducted and the result was displayed in table 5.8a using rotated correlation matrix (See appendix iv for data used for correlation matrix of factor analysis). The result indicates that the relative importance of factors with an eigenvalue greater than 0.50 were extracted which accounted for 88.76 of the total variance in inputs matrix in the original 16 variables as Catll (1978) argues against the use of one value and suggests that other estimates should also be used (Table 5.8a). As such this produces circular reasoning since communality is the sum of square loading, which is not known until the factor have been determined.

Table 5.8a: Rotated Correlation Matrix for Factor Scores Results from Rice Production

S/No.	Variables	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
1.	Labour (Man- hour)	0.236	-0.479	0.047	0.163	**0.816**
2.	Labour (Man- day)	**0.618**	0.284	0.352	0.189	**0.52**
3.	Seed (Kg)	0.195	0.136	**0.929**	0.191	0.104
4.	Fertilizer (Kg)	**0.918**	-0.002	0.077	0.245	0.16
5.	Agro-chemical (Lt)	**0.622**	0.047	0.145	**0.62**	0.216
6.	Cost of labour	**0.503**	-0.248	0.25	**0.723**	-0.122
7.	Cost of seed	0.386	-0.596	0.489	0.345	-0.333
8.	Cost of fertilizer	**0.909**	0.016	0.098	0.231	0.19
9.	Cost of Agro-chemical	**0.585**	0.425	0.273	0.201	**0.563**
10.	Farm size (Ha)	**0.741**	-0.125	-0.036	-0.082	-0.046
11.	Farming experience	-0.007	-0.118	**0.946**	-0.078	0.069
12.	Household size	0.016	**0.908**	0.202	-0.063	0.038
13.	Extension contact	0.186	**0.726**	-0.342	-0.27	-0.242
14.	Higher education	-0.187	**0.862**	-0.143	0.409	-0.129
15.	Land ownership	-0.153	-0.04	-0.04	-0.865	-0.25
16.	Crop diversification	0.101	**0.621**	0.346	-0.557	0.059
Total Eigen value		3.927	3.438	2.598	2.593	1.648
% Variance		24.543	21.496	16.236	16.208	10.299
% Cumulative variance		24.543	46.034	62.269	78.477	88.776

Source: Author's Data Analysis (2017)

The factors encompass the entire variables instrument in sustainable agricultural development, although the contribution of the variables differs between the factor variables. This showed that factors are significant for the explanation of the variation of sustainable rice development pattern of this study. The varimax rotated factor loading of the data set revealed the following explanation (See Table 5.8a).

Thus far, these five components of factors influence farmers' decision to cultivate irrigated rice in Kano River Project I and are summarized and presented in table 5.8b. From this analysis, it implies that most of the respondents were motivated to rice production because of the role played by these five factors. They also facilitate technical and modern inputs advantages introduced by irrigation project which also contributed to farmers' income. These five factors are explained as follows:

Table 5.8b: Factors Affecting the Farmers' Variation in Irrigated Rice Production System

Factor Description	Factor	Loading	% Variation Explanation
Factor 1: Dimension of inputs costing advantage	Labour (Man-day)	0.618	The loading of the factor 1 dimension was accounted for the percentage variance of **24.543%**.
	Fertilizer (Kg)	0.918	
	Agro-chemicals (Lt)	0.622	
	Labour cost (₦)	0.503	
	Fertilizer cost (₦)	0.909	
	Agro-chemicals cost (₦)	0. 585	
	Farm Size (ha)	0.741	
Factor 2: Dimension of farming Knowledge advantage	Household size	0.908	The loading of the factor 2 dimension was accounted for the percentage variance of **21.496%.**
	Extension contact	0.726	
	Higher education	0.862	
	Crops diversification	0.621	
Factor 3: Dimension of technical farming experience advatange	Seed (Kg)	0.929	The loading of factor 3 dimension was accounted for the percentage variance of **16.236%**.
	Farming Experience	0.946	
Factor 4: Dimension of modern techniques Advantage	Agro-chemicals (Lt)	0.62	The loading of factor 4 dimension was accounted for the percentage variance of **16.208%**.
	Labour cost (man-day)	0.723	
Factor 5: Dimension of labour input Advantage	Labour (Man-hour)	0.816	The loading of factor 5 dimension was accounted for the percentage variance of **10.299%**.
	Labour (Man-day)	0.52	
	Agro-chemicals cost (₦)	0.563	

Source: Author's Data Analysis (2017)

Factor 1 accounted for 24.543% of the total variance and showed high positive loading on labour cost for fertilizer and agrochemicals applied which formed the modern inputs required for that facilitate rice cultivation. The factor showed positive relation to labour inputs cost per farm size for quantities of fertilizer and agro-chemicals and termed **Dimension of inputs costing advantage**.

Factor 2 accounted for 21.496% of the total variance loaded positively on extension contact; higher education attended and crop diversification. This marked positive relationship between household size and farming knowledge acquired. This factor termed **Dimension of farming knowledge advantage**.

Factor 3 accounted for 16.236% which explained significant positive loading on rice hybrid seed selection which affected the output of rice. This marked positive relationship with farming experience which determines the best hybrid tolerating soil environment. This termed **Dimension of technical farming experience advantage**.

Factor 4 on the other hand, accounted for 16.208% of the total variance and exhibited higher positive loading on quantities and cost of labour of agrochemicals applied for prevention of grasses and other herbs competing of space for water and soil nutrients. This marked positive relation with the quantity of fertilizer applied and termed **Dimension of modern techniques advantage**.

Factor 5 accounted for 10.2999% of the total variance loaded positively on the quantity of labour per man-days (eight hours of work by an average man). The ratio of hired to total labour has a negative effect on rice production. It marked positive relation with the quantity of labour and labour cost per hour. This termed **Dimension of labour inputs advantage**.

The result of the factor scores have been studied and shown to express the identified score for each settlement pattern for the use of rice agricultural inputs. The result of factor scores have been manipulated and modified from statistical significant factors for irrigated rice production system in Kano River Project I. The factor scores for rice production presented in table 5.8c express the identified score for each settlement pattern for the use of irrigated rice production variable inputs matrix.

The results of the five factor scores have been studied and identified for each settlement, then modified from statistical to geographical distribution of the Kano River Project I to show the pattern for irrigated rice agricultural inputs (Table 5.8c).

Table 5.8c: Factors Scores for Rice Production System under Irrigation Scheme

S/No.	Settlements	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
1.	Kura	0.68011	-0.83342	-0.21896	0.9382	-0.23995
2.	Bunkure	-0.74549	-1.07796	-0.64791	1.31032	-1.52123
3.	Yadakwari	-0.86595	0.3799	-1.23171	-1.4352	-0.30109
4.	Danhasan	-0.89554	1.9934	0.66584	1.45286	0.22307
5.	Babbangiji	1.57343	0.90647	-0.71828	-0.44792	-0.28495
6.	Kadawa	-0.9663	-0.23375	0.50098	-0.248	1.54616
7.	Gafan	-0.85281	0.09768	0.29119	-1.25151	-0.90292
8.	Imawa	1.36095	0.59352	-0.31406	0.13727	0.28401
9.	Kosawa	0.6622	-0.66751	2.28941	-0.60285	-0.49788
10.	Makwaro	0.0494	-1.15833	-0.6165	0.14684	1.69477

Source: Author’s Data Analysis (2017)

The pattern of factor 1 (Dimension of inputs costing advantage) was heavily loaded on two settlements as shown in table 5.8c and figure 12. These were Babbangiji and Imawa. These were the settlements with a higher positive score in which rice farmer utilized high farm inputs of fertilizer, agrochemicals, and labour at less cost because they produced rice at long-run investment; the settlements with moderately positive scores were Makwaro, Kosawa and Kura. Likewise, the settlements with moderately negative scores were Bunkure, Gafan, Yadakwari, Kadawa, and Danhasan.

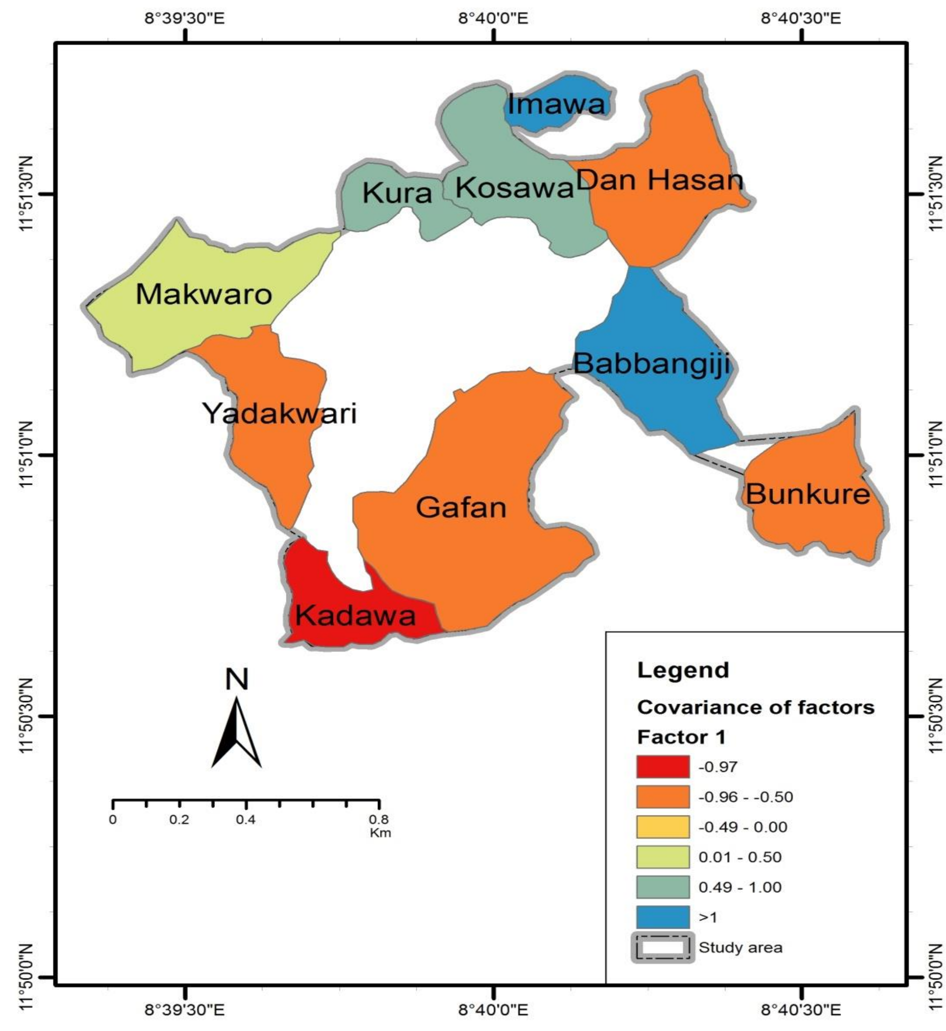


Figure 12: Map of Factor One Scored for 2016 / 2017 Sustainable Rice Farming

The pattern of factor 2 (Dimension of farming knowledge advantage) have a higher positive score on one settlement named Danhasan; this was the settlement that has a higher attendance of higher education, consultation of extension workers and applied crop diversification. The settlement with moderately positive scores was Babbangiji and the settlements with low positive scores were Yadakwari, Imawa and Gafan. Other settlements with negative scores were Kadawa with higher negative, Kosawa and Kura with moderately negative scores and Bunkure and Makwaro with low negative scores as shown in table 5.8c and figure 13.

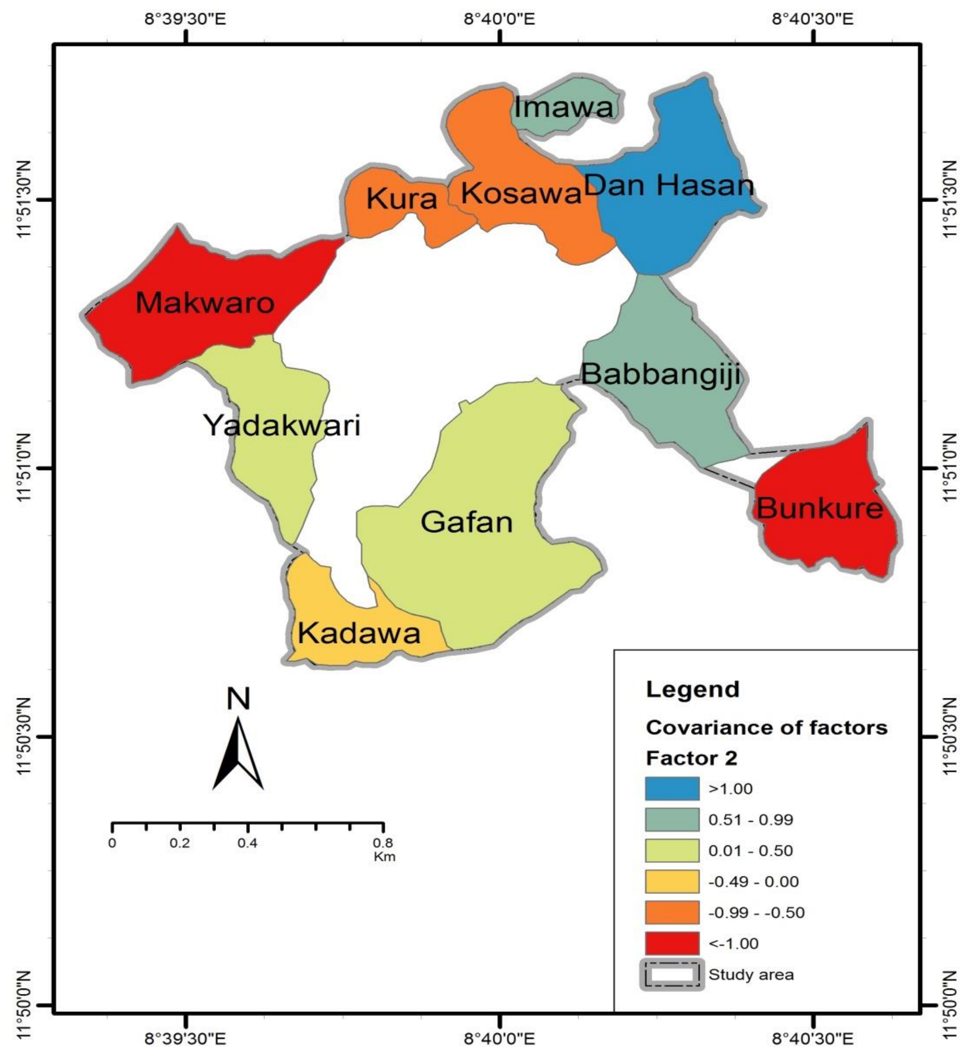


Figure 13: Map of Factor Two Scored for 2016 / 2017 Sustainable Rice Farming

The pattern of factor 3 (Dimension of technical farming experience advantage), this factor was heavily loaded on Kosawa. This settlement was the most highly utilized young age farmers and old ones were consulted for their farming experience in the study communities and have a positive effect on labour supply and utilization for high rice production. Settlements with positively moderate scores were Danhasan and Kadawa, while Gafan was the settlements with positive low scores. Other settlements with negative scores were Kura and Imawa with high negative scores, Makwaro, Bunkure and Babbangiji scored moderately negative scores Yadakwari scored low negative scores as shown in table 5.8c and figure 14.

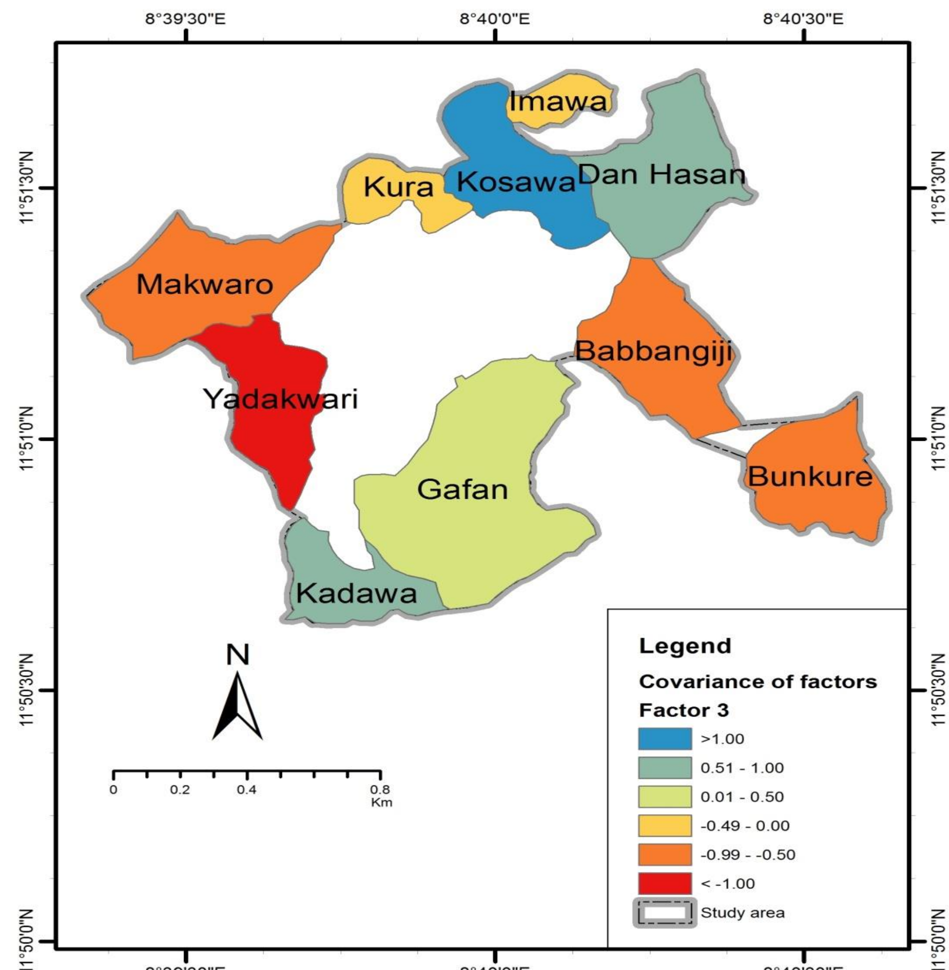


Figure 14: Map of Factor Three Scored for 2016 / 2017 Sustainable Rice Farming

The pattern of factor 4 (Dimension of modern techniques advantage) has higher positive scores on Bunkure and Danhasan. These settlements have high utilization of agrochemicals and mechanical means for land tillage and performed very well to save labour cost by weeding and fertilization annually. The settlement with a moderately positive score was Kura and the settlements with low positive scores were Imawa and Makwaro. The settlements with negative scores were Babbangiji and Kadawa have high negative scores, Kosawa with a moderate negative score and Yadakwari and Gafan with a low negative score (See Table 5.8c and figure 15).

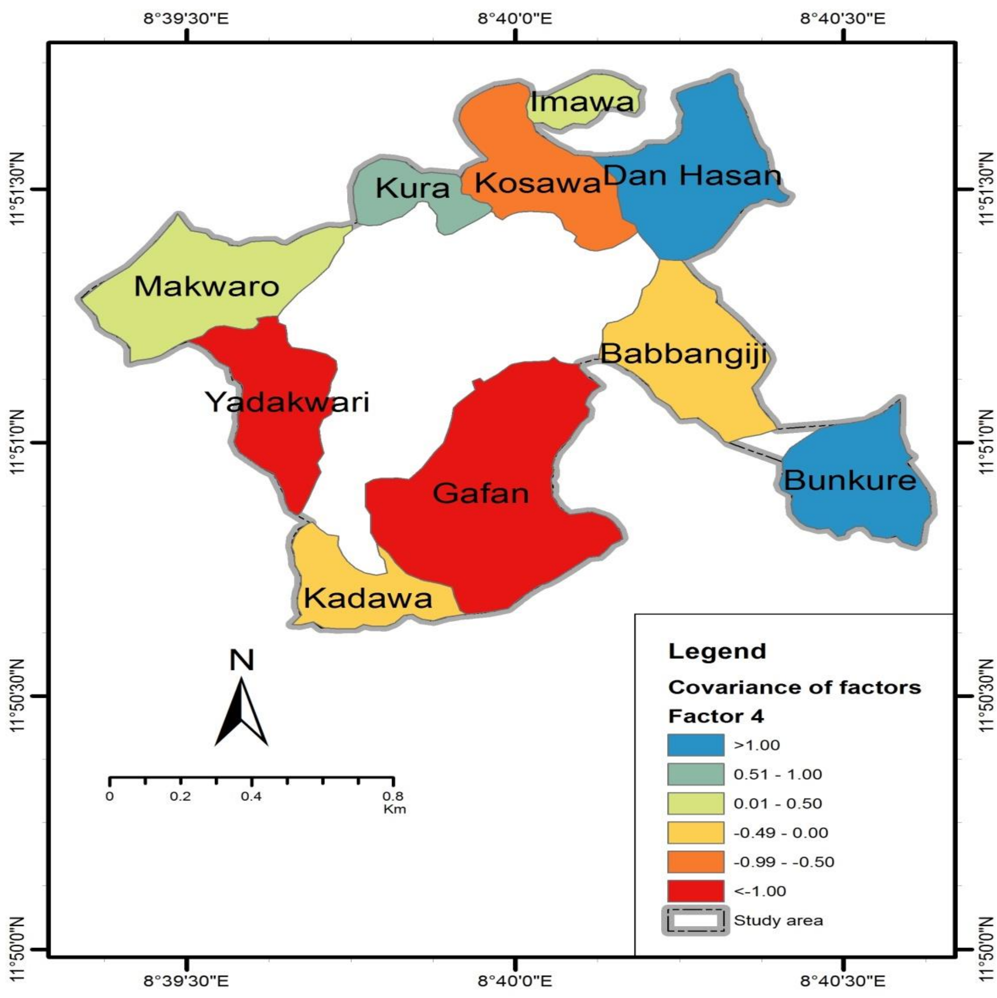


Figure 15: Map of Factor Four Scored for 2016 / 2017 Sustainable Rice Farming

The pattern of factor 5 (Dimension of labour input advantage) as shown in table 5.8c and figure 16.This shows the high positive scores on Makwaro and Kadawa. These settlements have high utilization for labour in man-day for manual land preparation, transplanting of rice seedlings, manual weeding, and harvesting. This variable has a high positive effect on farm production because men are not adequate and capable enough to supplement farm machinery. The settlements with low positive score were Danhasan and Imawa. The settlements with negative scores were Kura and Yadakwari, Kosawa and Gafan with a moderate negative score, Bunkure and Babbangiji with the low negative score.

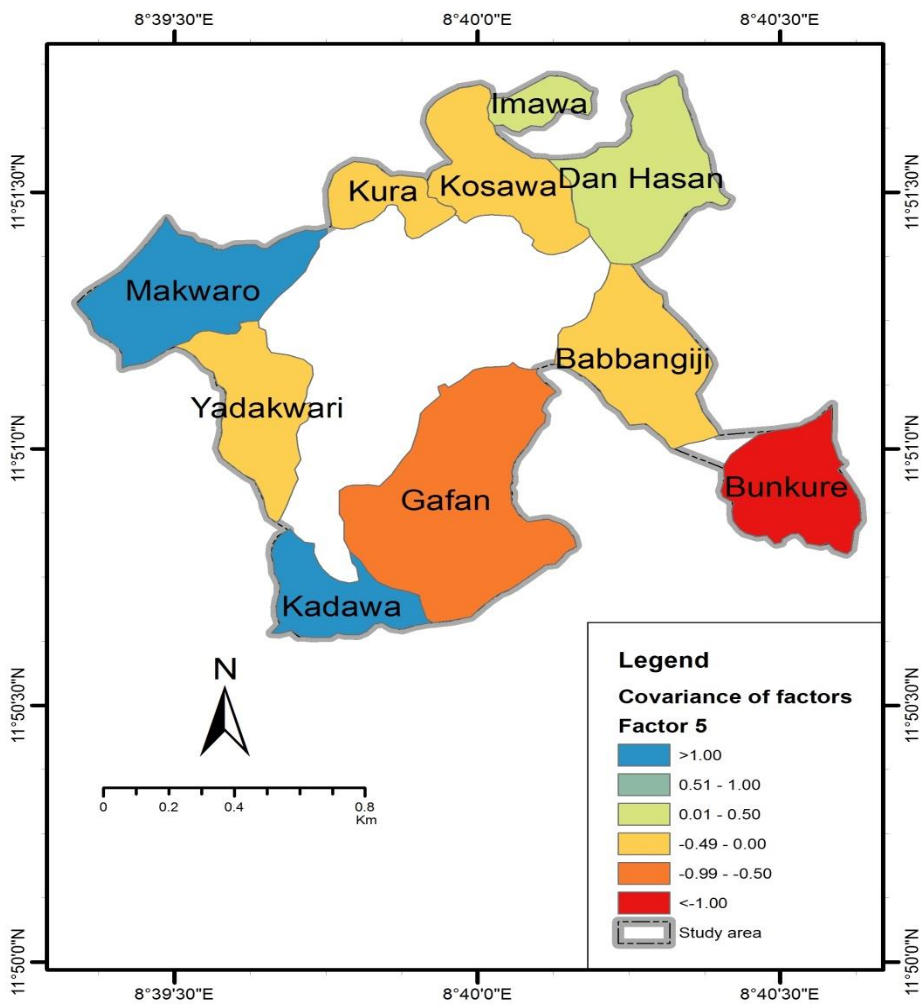


Figure 16: Map of Factor Five Scored for 2016 / 2017 Sustainable Rice Farming

5.9 **Factors Affecting Rural Development and Welfare Affecting the Area of Cultivation and Yield**

A clear understanding of the rural environmental diversity of rice production communities and problems in the rice ecosystems are essential to determining appropriate rural development strategies in the study area. The characterization of the rural production constraints was initiated and surveyed in the 1970s by the project consultant the Netherland Development Company in selected sites of the project area. Although the problems confronting irrigated rice production at Kano River Project I was identified by farmers are presented in 5.9a. The table shows that there were no higher level problems in irrigated rice production in the study area. More than proportionate (50%) of the farmers indicated the there were no major problems confronting irrigated rice production in Kano River Project I.

Table 5.9a: Major Problems Confronting Rice Farmers

Constraint	Very Imp	%	Imp	%	Less Imp	%	Not Imp	%
Available land	234	14.28	335	20.48	499	30.48	568	34.76
Available labour	280	17.14	467	28.57	157	9.52	733	44.76
Available credit	665	33.33	190	9.52	266	13.33	874	43.81
Available Farm implements	545	33.33	165	10.00	226	13.81	701	42.85
Inadequate fertilizer	614	31.43	225	15.71	617	37.71	280	17.14
Lack of extension service	405	24.76	203	12.38	522	31.91	506	30.95
Shortage of irrigation H_2o	467	28.57	343	20.95	125	7.61	701	42.86
Pests and diseases	405	24.76	156	9.52	296	18.10	779	47.62
Transport problems	467	28.57	172	10.48	327	20.00	670	40.95
Low market price	452	27.62	304	18.57	148	9.05	732	44.76

Source: Author's Data Analysis (2017) **Note**: Imp = Important

Among the studied farmers 34.76% of them identified non-available land as very important and important, while 65.24% of the farmers identified it as less important and not important. Some 45.71% of farmers recognized non-available labour as very important and important, while 54.28% of them recognized it as less important and not important. About 42.85% of farmers considered available credit as very important and important, similarly, 51.14% of the farmers considered available credit as less important and non-important. The low market was cited by the 46.19% of farmers as very important and important; likewise, 52.86% of them revealed it as less important and important. Some 37.14% of farmers indicated that lack of extension service as very important and important, then the majority of them indicated it as less important and not important. Among the respondents 49.52% admitted that shortage of irrigation water was very important and important, others about 50.48% admitted it as less important and non important. Pests and diseases were identified by 34.28% of farmers as very important and important; therefore the majority of them about 65.72% identified it as less important and not important. Transport problem was recognized by 39.05% of the respondents as very important and important, similarly, the majority of them about 60.95% recognized it as less important and not important. Finally, non-available farm implements were observed by 43.33% of the farmers as very important and important, while 56.67% of them observed it as less important and not important.

As could be noted, most of the problems put forward by the farmers could be analyzed within the context of farmers operational level. When the farmers asked to proffer solution to their problems as shown in table 4.9b.

Table 5.9b: Suggest Ways to Remedy the Rice Farming Constraints

S/No.	Constraints	No.	%
a.	Available land	0	0.00
b.	Cheap and available labour	0	0.00
c.	Available credit	21	1.25
d.	High market rice price	26	1.61
e.	Adequate fertilizer	561	34.29
f.	Available extension services	0	0.00
g.	Available irrigation water	0	0.00
h.	Available pesticides and insecticides	327	20.00
i.	Adequate transport facilities	0	0.00
k.	Available farm implements	0	0.00
l.	No constraint	701	42.85
	Total	**1,636**	**100.0**

Source: Author’s Data Analysis (2017)

The farmers simply mentioned adequate fertilizer by 34.29% of them, 20.0% indicated available pests and herbicides. Some 1.61% and 1.25% of them mentioned the high market price and available credit. Majority of them about 42.85% did not identify any problem as farming constraints. This point to the fact that farmers level of awareness with regard to a better perception of themselves and their problems is very low due to perhaps their low level of formal education (only 22% of them acquired tertiary education as shown in table 5.1c). The evidence from table 5.9b has shown that the project is not constraint by any of the items above in the context of farmers operational level of irrigated rice production in Kano River Project I.

Table 5.9c shows the desire of economic position of rice farmers in the irrigation project. The analysis reveals that 40.0% of respondents cited negligence of local rice in favour of the export crop because imported rice make local rice unprofitable. Similarly, some of them about 32.38% cited that other profitable crops make paddy production neglected. This indicates the farmers are interested in farm income about 62.38% are looking for farm profit. About 19.05% of them were unsatisfied with rice price because it did not cover the cost of inputs and few of them about 8.57% cited land allocated to rice production are unsuitable to other crops because of its waterlog condition character.

Table 5.9c: Economic Desire of Rice Farmers

S/No.	Farmers Desire	No.	%
a.	Negligence in favour of export crops	654	40.00
b.	Land allocated are unsuitable for other crops	140	8.57
c.	Unsatisfied rice sale price to cover cost of inputs	312	19.05
d.	Other profitable crops make paddy be neglected	530	32.38
	Total	**1,636**	**100.00**

Source: Author's Data Analysis (2017)

Table 5.9d shows farmers satisfactory condition of paddy cultivation with regard to land tenure and investment which were exploitative to farmers land utilization for rice production. The study reveals that 71.43% of farmers were unsatisfied with unstable finance which affecting their rice farming investment and 28.57% of the respondents were unsatisfied with the exploitative condition of land holding and tenancy.

Table 5.9d: Unsatisfactory Condition of Paddy Cultivation

S/No.	Condition of Farmers with Land Tenure	No.	%
a.	Exploitative condition for holding farmland	467	28.57
b.	Instable finance affect farm investment	1,169	71.43
	Total	**1,636**	**100.0**

Source: Author's Data Analysis (2017)

Uneconomic division of land because of the law of inheritance necessitate a division of land property and result in successive generation inheriting smaller and smallest piece of land which make crop production difficult. Majority of the landholding was acquired through inheritance in the study area.

The views of the farmers for economic small land holding acquired by inheritance were displayed in table 5.9e. The small fragmentation of land acquired by inheritance led to a waste of land as viewed by 45.24% of the respondents, while some 34.76% of farmers viewed it as a limitation to the use of farm machinery and 20.0% of them viewed it as loss of time because it inhibits scale efficiency.

Table 5.9e: Uneconomic Small Landholding inheritance Lead to:

S/No.	Small Landholding inheritance	No.	%
a.	Wastage of land	740	45.24
b.	Loss of time	327	20.00
c.	Limit the use of machinery	569	34.76
	Total	**1,636**	**100.0**

Source: Author's Data Analysis (2017)

One of the problems affecting rice farming investment is access to production credit. The reasons for tenants inaccessibility to production credit was displayed in table 5.9f. The result of the study reveals that 42.38% of the respondents identified the high administrative cost of loan procession, while 22.86% of the farmers identified that commercial banks were not provided small loan because it is unprofitable, similarly, 29.05% of them considered that cooperative society credit was not enough to cover the cost of inputs and 5.71% of them cited high banks administrative cost.

Table 5.9f: Reason for Tenants Inaccessibility to Production Credit

S/No.	Reason	No.	%
a.	Administrative cost of loan procession is high	693	42.38
b.	Small loan unprofitable to commercial banks	374	22.86
c.	Banks do not keep administrative cost down	94	5.71
d.	Cooperative credits not cover cost of inputs	475	29.05
	Total	**1,636**	**100.0**

Source: Author's Data Analysis (2017)

Farmers are a rational being because they decide upon the level of inputs until they produce at a point of diminishing return. Their view with regard to sufficient and attractive better economic condition for paddy cultivation is presented in table 5.9g. The study reveals that 68.57% of the respondents cited increase yield at decreasing cost of production and 31.43% of the respondents cited high profit with cheap rice to consumers.

Table 5.9g: Sufficient and Attractive Better Economic Condition for Paddy Cultivation

S/No.	Economic Condition for Paddy Production	No.	%
a.	High profit with cheap rice to consumers	514	31.43
b.	Increase yield at decrease cost of production	1,122	68.57
	Total	**1,636**	**100.0**

Source: Author's Data Analysis (2017)

The farmers' decision regarding whether to produce or not is contravened by limited access to the market. The result is presented in table 5.9i in which farmers' decision shows that 89.05% of the respondents strongly agree (41.43%) and agree (47.62%) and few of them about 10.62% disagreed that production could be a contravention by the limited market.

Table 5.9h: Decision Making on Farm Produce Contravene by Limited Access to Market

S/No.	Decision-Making Contravene by Market	No.	%
a.	Strongly agree	678	41.43
b.	Agree	779	47.62
c.	Disagree	179	10.62
d.	Strongly disagree	0	0.00
	Total	**1,636**	**100.0**

Source: Author's Data Analysis (2017)

CHAPTER SIX

SUMMARY OF FINDINGS, CONCLUSION AND RECOMMENDATION

6.1 Summary of the major findings

The study examined soil and socio-economic constraints to irrigated rice production in the Kano River Project Phase I. This thesis is fundamentally important to sustainable irrigated rice production system in the study area. It aims to provide a purpose that irrigated rice production system management starategies can achieve three competing goals of farmers' income, food security and sustainability of soil ecological parameters. This study enables and guides rice farmers, irrigation project managers, researchers, rice seed breeders and policy makers on the issues of evolution and adoption of the preferred rice traits, sustainability and exploitation of the potentials of the river basin irrigation project. In addition, it assesses the validation of irrigated rice production system on the basis of technical feasibility, economic profitability and social acceptability of the available rice varieties.

Kano River Project I is the study area for this study and it is under management of Hadejia-Jama'are River Basin Authority. The irrigation project is divided and managed into east and west branches headquarters in Kura and Bunkure where soil and socio-economic data were collected using purposive sampling technique. Ten hectares (10ha) each demarcated on Pab and Pab/Pb Complex soils and their corresponding ten hectares (10ha) each adjacent non-irrigated lands on Pab and Pab/Pb Complex soils for comparison. Purposive sampling was also used to pick 10 of the 58 settlements in the study area. Copies of a structured questionnaire were administered to 1,730 registered irrigated rice farmers in the two soil unit areas.

The study employed both descriptive and inferential statistics in order to analyse, summarize and presented various data acquired in tabular form. Coefficient of variation (C.V) was employed to measure the relative and spatial variation of data. Other inferential techniques used student ‘t’ test, product moment correlation, covariance, sustainability index and goal programming.

In view of the above analytical techniques employed to analyse the data. the soils data are generally sandy (69% to 79%) and all the parameters of the two irrigated soils units exhibited homogeneity (C.V < 33%). Eight of the twenty-one soil parameters in irrigated soils were not significantly different from non-irrigated soils in Pab soil of Kura ($p < 1.73$) but in Bunkure only six parameters were not different ($p < 1.73$). Five soil parameters each in irrigated Pab/Pb complex soil of Kura and Bunkure were not different ($p < 1.73$) from those in non-irrigated fields, the other sixteen parameters were significantly different ($p >1.73$). In both the two soil units there were generally very low organic matter (0.8g/kg^{-1}) and total nitrogen (0.059g/kg^{-}1), while phosphorous (28.58 g/kg$^{-)}$1 and potassium (0.55 g/kg^{-}) were high and pH (6.40) was neutral.

The pattern of resources utilization that led to the optimal rice plan production showed that only three resources were fully utilized. These resources included pesticides, rice seeds, and land. The used of organic manure (1,687.50kg) was very common and the average quantity of UREA ((289.27Kg), Phosphorous (46.28kg) and Potassium (45.37Kg). The fertilizers applied were not below the recommended rate per hectare for rice production in the study area. The constraints for returns to irrigated rice production were inadequate cheap breeder seed, fertilizers, and pesticides.

Sustainability of the present irrigated rice production system is not sustainable because the sum of diviation of sustainability index was 348 which greater than zero. After optimization, the economic goal (yield of rice) was under- achieved by 3% for Jamila rice, while Faros rice was over-achieved by 8% from the target, while income goal was under-achieved by about 1% from the target. For environment goal, organic matter was overachieved by 2%; nitrogen was over-achieved by 5%;

phosphorous was over by achieved by 5%; potassium was over- achieved by 3% and the pH was fully achieved.

The inclusion or consideration of environmental goals in farm plan is not antagonistic to the profit maximization objective of the average rice farmer in the study area. About 75.0% of the goals considered in the study area were met by optimal rice farm plan derived from the goal programming model.

The present system of productivity of rice in the study area was unsustainable because 62.50% of the sustainability indicators were not up to 100% of the required level. Optimizing the present rice production system using Goal Programming Model shows that there is an improvement in the sustainability of the system as the sum of deviations was reduced to 10 from 348 and achieved 97.13%. The new classification of the system for the improved system shows that 100% of the indicators were within acceptable limits of sustainability.

Improvement in the sustainability of the production system would result in the decrease of land area cultivated from 772.5ha by 5.50% (42.50ha) because of the limited labour and other inputs resources. After optimization, the profitable divisf land utilization shall be 30.0ha for Jamila rice variety cultivation and 700.0ha for Faros rice production.

The results generated from questionnaire administration indicate that an average rice farmer in the study area was about 37 years old, a male that had both Arabic and Islamic, adult education up to primary school education, with an average of about 6 household members who are family labour and also engaged in a nonfarm occupation such as trading and handicraft work.

A rice farmer cultivates about 0.72ha of land and owns up to 2 plots of rice farm acquired through inheritance and tenancy and member of cooperative society. A total land area cultivated for

2014/2015 cropping season was 772.5ha and 564.15ha (73.03%) was cultivated by 1,636 irrigated rice farmers' respondents with a mean value of 0.72ha and modal farm size was 0.4ha.

The adoption rate of new rice variety was low because farmers lack the knowledge to assess the preferred traits of agronomic and post-harvest traits. Similarly, local rice variety attracted higher consumer price because its long grain and utilized small quantity of chemical fertilizer compared with improved varieties.

Farm labour inputs of 595.60 man-days were calculated for the production of irrigated rice per hectare; family labour accounted for 61% of the total labour force to produce an average total of 4.26 tons of rice per hectare in the study area. Birds were the most important pest problem among the environmental constraint to rice production in the study area and that is why birds chasing attracted 32.27% of the total labour force.

Variable cost dominated the total cost of production which accounted for 53.13% of the total cost of production. The labour input dominated the variable cost component. It accounted for 57.92% of the total variable cost, while the cost of land rent dominated fixed cost component and accounted for 95.24% of the total fixed cost. A total variable cost of ₦97,900.41 and total fixed cost of ₦52,500.00 (34.91% of the total cost) respectively were incurred per hectare. The average cost was ₦150,400.41; the highest average cost was accounted to Kura rice farming community and the least average cost was accounted to Danhasan rice farming community.

The total average return was ₦229,644.90; the highest average return was accounted to Kosawa rice farming community and least average return was accounted to Danhasan rice farming community. The average net return was ₦79,244.49; the highest average net return was accounted to Kosawa rice farming community and least average return was accounted to Danhasan rice farming community.

There is positive correlation (r = 0.52) at 95% confidence level between the cost of inputs and net profit for irrigated rice production in the study area. The covariance analysis showed positive linear relationship in eight rice-farming settlements and negative in two rice-farming settlements. The result showed that Kura, Imawa, Kosawa and Makwaro communities were the most sustainable rice farmers because their cost of inputs and net profit were above threshold levels.

The factor dimensions were significant with an eigenvalue greater than 0.50 which together accounted for 88.776% of the total variance. Other factors were also significant for rice production which accounted for the remaining 11.224%. The pattern of factor 1dimension of inputs costing advantage (24.543%) was heavily loaded on Babbangiji and Imawa settlements. The farmers of these settlements have fully utilized farm inputs level at less cost. The factor 2 dimension of farming knowledge advantage (21.496%) was heavily loaded on Danhasan community. The farmers of these communities have a higher attendance of high education and extension workers consultation. The factor 3 dimension of technical farming experience (16.236%) was heavily loaded on Kosawa settlement. The farmers of this community have highly utilized young age farmers and old ones were integrated to enhance the sustainability of rice production. The factor 4 dimension of modern techniques advantage (16.208%) has higher positive scores on Bunkure and Danhasan. These settlements have high utilization of agro-chemicals and mechanical means for land tillage and performed very well to save labour cost for weeding and fertilizer annually. The factor 5 dimension of labour inputs (10.299%) showed high positive scores on Makwaro and Kadawa. These settlements have high utilization for labour in man-days for manual land preparation, transplanting of rice seedlings, manual weeding, and harvesting.

Nitrogen, organic matter and five factors listed from factor analysis constrained irrigated rice production system. Although all the problems confronting irrigated rice farming mentioned to the farmers by the researcher in Kano River Project I was not up to 50% important. When the farmers asked to proffer solution to these problems, they simply suggest adequate fertilizer and pesticides (64.29% of them). While 42.85% of the farmers suggested that they don't have any problems with regard to irrigated rice production in the study area.

6.2 **Conclusion**

This study observed Kano River Project I as an effective framework for rural/regional development planning because it is controlled by down–top planning which is promulgated by technocratic solution to rural land resources and achieved grass root development that is so essential to farmers' incomes which is used to raise their standard of living and provide food security that feed the urban populace of urban Kano and other cities of Nigeria.

Based on the results of this study, it is concluded that the sustainability of rice production can be improved through better management of natural resources especially nitrogen and organic matter content of the soil, inputs costing, farming knowledge, technical farming experience, modern techniques and labour inputs were the major constraints cononting peasant socio-economic groups. Broadly, the irrigated rice production technology improved significantly and directly with medium size group of three to five acres and has strongest motivation and capacity for an efficient and sustainable production system. Hence, for the system to achieve sustainable rice production, the study recommends the following.

6.3 **Recommendations**

The following recommendations are based on the findings from this study.

1. The extent of integration and accessibility of farm input supplies directly affected utilization of variable inputs of irrigated rice farming. There is a need to upgrade Kano State Agricultural Supply Company (KASCO) to provide large-scale subsidized farm inputs such as fertilizer, pesticides, and

farm machines implements to facilitate irrigated rice production system of irrigated rice farming settlements.

2. Short courses or training session that will address the education of farmers on modern input techniques should be improved as the field needs of rice farming as obtainable under the advisory and capacity building component should be organized by Agricultural Development Project (ADP) and Kano State Agriculture and Rural Development Agency (KNARDA). This will enhance the effectiveness and efficiency of the long run farming by enabling farmers to make better decisions and allocate production inputs resources more effectively and efficiently.
3. The improvement in the sustainability of rice production system was associated with a reduction in the usage of external inorganic inputs especially chemical fertilizers. Thus, there is a need to sensitized rice farmers on the availability of affordable industrially manufactured organic manure such as Rootlizer, Nomau and Fertiplus. These fertilizers can enhance the productivity of rice farmland; in order to bring the irrigated rice production system to a state of sustainability through recommended nitrogen and organic matter input optimization.
4. There is need to reduce land use intensity associated with improvement in the sustainability of the production system because optimizing the present rice production system shows that there is a need for the improvement of the sustainability of the rice production system as the sum of deviations is reduced by 97.13% from 348 to 10. This point to the fact rice farmers should be educated on long-term participatory soil improvement and management strategies, such as integrated soil fertility management (I.S.F.M.). This practice would help promote land regeneration and ultimately the yields obtained would be increased.
5. Despite the fact that, the results of student’s t-test have shown significant changes in the soils parameters; there is a need for periodic monitoring and evaluation of environmental parameters

because soil nutrient can easily change. There is a need for regular or occasional soil monitoring in the irrigated rice farmlands so that the productivity of rice farmlands will not be affected by low soil yield performance. The monitoring and evaluation can be conducted or supervised by Kano State Agriculture and Rural Development Agency (KNARDA). This will provide an early warning signal for any reduction in land quality or soil fertility status. Such parameters to be monitored include the soil pH, salinity level, organic matter, phosphorous, nitrogen, potassium, cation exchange capacity among others.

6.4 Suggestion for Further Reading

The study provided some insight on the sustainability of optimal irrigated rice production farm plan. However, further research is required in the following areas;

1. A study that will include more crops apart from rice should be conducted to provide further insight on the effect of crops productions on environmental goals and profit maximization objectives.
2. There is a need for the study that would examine possibilities of rice farmers' opinion on land consolidation in the irrigated farming communities.
3. A study that will assess the sustainability of rice production systems over a period of time can also be conducted to obtain a realistic behavior of the relevant indicators of sustainability with respect to time.
4. It is difficult in the absence of further analysis to resolve the differences in technical and environmental efficiency, among peasant socio-economic groups applying new rice crop technology (faros variety) in the study area, but the explanation is needed. If the problem is motivational the gap will be difficult to close, but if it is by differences in technical farming knowledge, it should be possible to achieve some improvement through detail examination of performance and extension advice.

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APPENDIX 1

QUESTIONNAIRE

DEPARTMENT OF GEOGRAPHY AND ENVIRONMENTAL MANAGENENT

FACULTY OF SOCIAL SCIENCES

UNIVERSITY OF ILORIN, KWARA STATE NIGERIA

RESEARCH QUESTIONNAIRE

Sir,

REQUEST FOR FILLING OF RESEARCH QUESTIONNAIRE

This questionnaire is intended for research on Analysis of Soil Limits and Socio-Economic Constraints on Sustainable Rice Farming in Kano River Basin Project, Nigeria.

Your community is one of the settlements selected to administer the Questionnaire for this research. Your honest response will be appreciated.

The information supplied will be kept confidential and use for the research purpose only.

Thanks.

Yours faithfully

IBRAHIM, Ali Bala

08161297479

Farmer's Socio-Economic Back Ground

1. Age of farmers this year……………………….2. Gender a. Male ( ) b. Female ( )

3. Marital status of farmers. a. Single ( ) b. Married ( ) c. Divorce ( ) () d. Widow ( ) e. separated ()

4. Highest Education attainment:

a. Arabic school ( ) b. Adult Education ( ) c. Primary Education ( ) d. Secondary Education ( ) f. Post secondary school ( ) g. University ( ) h. None of the above ( )

5. Nonfarm occupation

a. Trading ( ) b. Civil work ( ) Factory work ( ) d. Handicraft or others ( )

6. Are you Native of the village/town you live in presently a. Yes ( ) b. No ( )

7. Household composition

S/No.	**Categories**	**No. of Male**	**No. of Female**
i.	Spouse		
ii.	Children (capable of farm work)		
iii.	Children (not capable of farm work)		
iv.	Dependent (capable of farm work)		
v.	Dependent (not capable of farm work)		

8. Indicate the period (in years from 2014) of membership association you belong to:

No. of years of Membership	**Water user association**	**Credit group**	**Communal labour**	**Others**

Farmers Farm Plot

9. Farm plot location

Plot Size	Plot No.	Block No.	Sector No.	Zone No.	Village Location	L.G.A.

10. Indicate farm plots ownership (peasant socio-economic groups)

Plot/Land	Inheritance	Gift	Purchase	Pledge	Lease	Share Crop	Tenant	Loan
Plot Size								
Plot No.								

11. Specific distance (km) of the plot farm from:-

a. The farmers house (km) b. Project office (km) c. nearest market (km)

d. Nearest motor-able public read (km)

Section B

Use Rapid Rural Appraisal Techniques and Socio-economic Criteria for the Study

Cropping System

12. Which range of crops most cultivate in order of priority in your rice farm

	Maize	Onion	Pepper	Tomato	Water melon	Sugar cane
Output						
Priority Rank						

13. How do you control level of water?

a. Through run-off ( ) b. through flow ( ) c. Use pumping machine ( )

14. Tillage technology a. hand ( ) b. Oxen ( ) c. Small tractor ( ) d. Full mechanization ( )

15. What is your major farm work off season?

a. rice milling ( ) b. Land preparation for next season cultivation ( ) c. livestock raising ( )

Development and Integrated Pest Management

16. Indicate the most important pest problems affecting rice production in your farm

a. Weed ( ) b. Bird ( ) c. Bush rat ( ) d. Insect pest ( )

17. What method use to control weeds.

a. Use long duration fallow ( ) b. Practice linked with soil tillage c. Use date of planting ( )

d. Use crop association ( )

18. Indicate relied weed control on farm inputs and implements.

a. Hand pulling ( ) b. hoes c. herbicides ( ) d. Combination of a and b ( )

19. What are the factors that cause insects problems in rice fields?

a. Soil type ( ) b. fertility ( ) c. drought occurrence ( )

c. standing water ( ) d. Presence of certain weeds ( )

20. What are insect control methods in your rice field?

a. disposal of lemon in field ( ) b. pouring hot water or destroying termites hills ( )

c. laying plant leaves on rice field ( ) d. Traditional herbalist ( ) e. Use of insecticides ( )

f. Get rice variety that resists various insects' diseases.

Soil Fertility Management

21. The fertility of your rice farm can be maintained through:

a. fertilizer application ( ) b. organic manure ( ) c. a. & b. ( ) d. Others specify ( )

22. What measures do you take to remedies the nutrient deficiency?

a. Consult extension officer ( ) b. Ask question to mass media agricultural programmes ( )

c. Consult friends and family ( ) d. Report to agricultural research institution ( )

Development of Improved Rice Varieties

23. Indicate the choice of traits between local varieties with improved varieties

Compares Local and Improved Varieties					
S/No.	**Trait**	**Local**	**Improved**	**Not difference**	**Not applicable**
1.	Agronomic Trait				
a.	Plant height				
b.	Resistance to shattering				
c.	Weed competitiveness				
d.	Panicle length				
e.	Panicle exertion				
f.	Tillering capacity				
g.	No grains per panicle				
h.	Yield				
i.	Drought tolerance				
j.	Insect pest/disease tolerance				
k.	Early maturity				
	Post harvest traits				
l.	Good aroma				
m.	Ease of cooking				
n.	Taste				
o.	Ease of milling				
p.	Ease of threshing				

24. Assess the importance of rice traits

Farmers Assessment of Improved Rice Varieties					
S/No.	**Agronomic traits**	**Highly Important**	**Important**	**Moderately Important**	**Not applicable**
a.	Yield				
b.	Tillering capacity				
c.	Drought tolerance				
d.	Panicle exertion				
e.	Resistance to shattering				
f.	Pant height				
i.	Tall				
ii.	Medium				
iii.	Short				
g.	Crop duration				
i.	Long				
ii.	Medium				
iii.	Short				
h.	Weed competitiveness				
i.	Insect pest tolerance				
j.	Disease tolerance				
	Post harvest traits:				
k.	Good aroma				
l.	Ease of cooking				
m.	Taste				
n.	Ease of milling				

Crop Protection

24. Weeds are not sufficiently control to prevent significant yield losses because of

a. Shortage of labour ( )   b. Low capital to purchase herbicides' ( )

c. Costing of chemicals   d. Cost per labour ( )

26. Pesticides found effective for control of rice pests are:

a……………………………………………..b…………………………………………………

c…………………………………………………   d……………………………………………….

27. In how many days hand weeding should be done after seeding or transplanting

a. Two weeks ( ) b. Three weeks ( ) c. Four weeks ( ) d. Five weeks ( ) e. Six weeks ( )

Input Utilization for Rice Production

28. Input per acre: Harrowing

Farm Size (Acre)		**Labour Input per Hour**			**Cost of Labour Input (₦)**		
Plot No.	**Plot size**	**A.M.**	**A.F.**	**C.**	**A.M.**	**A.F.**	**C.**

A.M. = Adult Male, A.F. = Adult female, C. = Children,

Note: **Same to the following tables**

29. Input per acre: Leveling

Farm Size (Acre)		Labour Input per Hour			Cost of Labour Input (₦)		
Plot No.	Plot size	A.M.	A.F.	C.	A.M.	A.F.	C.

30. Input per acre: Sowing

Farm Size (Acre)		Labour Input per Hour			Cost of Labour Input (₦)		
Plot No.	Plot size	A.M.	A.F.	C.	A.M.	A.F.	C.

31. Input per acre: Growing seedling

Farm Size (Acre)		Labour Input per Hour			Cost of Labour Input (₦)		
Plot No.	Plot size	A.M.	A.F.	C.	A.M.	A.F.	C.

32. Input per acre: Application of pesticides

Farm Size (Acre)		Labour Input per Hour			Cost of Labour Input (₦)		
Plot No.	Plot size	A.M.	A.F.	C.	A.M.	A.F.	C.

33. Input per acre: Fertilizing / Manure

Farm Size (Acre)		Labour Input per Hour			Cost of Labour Input (₦)		
Plot No.	Plot size	A.M.	A.F.	C.	A.M.	A.F.	C.

34. Input per acre: Weeding

Farm Size (Acre)		Labour Input per Hour			Cost of Labour Input (₦)		
Plot No.	Plot size	A.M.	A.F.	C.	A.M.	A.F.	C.

35. Input per acre: Application of water

Farm Size (Acre)		Labour Input per Hour			Cost of Labour Input (₦)		
Plot No.	Plot size	A.M.	A.F.	C.	A.M.	A.F.	C.

36. Labour input per acre: Harvesting

Farm Size (Acre)		Labour Input per Hour			Cost of Labour Input (₦)		
Plot No.	**Plot size**	**A.M.**	**A.F.**	**C.**	**A.M.**	**A.F.**	**C.**

37. Input per acre: Drying of harvest

Farm Size (Acre)		Labour Input per Hour			Cost of Labour Input (₦)		
Plot No.	**Plot size**	**A.M.**	**A.F.**	**C.**	**A.M.**	**A.F.**	**C.**

38. Input per acre: Transportation to home

Farm Size (Acre)		Labour Input per Hour			Cost of Labour Input (₦)		
Plot No.	**Plot size**	**A.M.**	**A.F.**	**C.**	**A.M.**	**A.F.**	**C.**

39. Input per acre: Milling

Farm Size (Acre)		Labour Input per Hour			Cost of Labour Input (₦)		
Plot No.	**Plot size**	**A.M.**	**A.F.**	**C.**	**A.M.**	**A.F.**	**C.**

40. Input per acre: Packaging and marketing

Farm Size (Acre)		Labour Input per Hour			Cost of Labour Input (₦)		
Plot No.	**Plot size**	**A.M.**	**A.F.**	**C.**	**A.M.**	**A.F.**	**C.**

41 Input per acre: Others specify……………………………………………..

Farm Size (Acre)		Labour Input per Hour			Cost of Labour Input (₦)		
Plot No.	**Plot size**	**A.M.**	**A.F.**	**C.**	**A.M.**	**A.F.**	**C.**

42. Quantity of insecticides / pesticides

Plot No.	**Type of insecticides**	**Quantity (Litre)**	**Cost per litre (₦)**

43. Application of Fertilizer / Manure

Plot No.	Type of fertilizer	Quantity (Kg)	Cost (₦)

44. Quantity of Seeds

Plot No.	Type of Seeds	Quantity (milk tin) / Kg	Cost (₦)

Output of Rice

45. Quantity of rice harvested

		1st Harvest period		2nd Harvest period	
Plot No.	**Plot size**	**No. of bags harvest**	**No. of bags sold**	**No. of bags harvest**	**No.of bags sold**

46. Value of rice produced

Plot No.	Plot size (acre)	Total production	Total cost of prod	Sold price	Net Profit

47. What is your comment on the harvest?

a. Excellent ( ) b. Very good ( ) c. Good ( ) d. Poor ( ) e. Very poor ( )

48. Indicate the major constraint confronting rice farmers' rice fields

S/No.	Constraints	V. Important	Important	Less important	Not important
1.	Non available land				
2.	Non available labour				
3.	Non available credit				
4.	Low market price				
5.	In adequate fertilizer				
6.	Lack of extension service				
7.	Shortage of irrigation water				
8.	Pests and diseases				
9.	Transport Problems				
10.	Non available farm implements				

49. Suggest some ways to ameliorate the constraints and problems.

……

……

……

……

Rural Development and Welfare as Affecting the Area of Cultivation and Yield per Hectare

50. What make you unsatisfactory with economic position of rice cultivars?

a. Negligence of paddy in favour of export crops.

b. Most the land allocated to the paddy are under condition which is unsuitable to alternative crops.

c. Unsatisfactory price of paddy to cover the cost of inputs.

d. Attraction of other profitable crops makes paddy cultivation perish in the irrigation project.

51. What is the unsatisfactory condition of paddy cultivation with regard to land tenure

a .Condition under which cultivators hold land is unsatisfactory and exploitative

b. financial instability affect farm investment and budgeting

52. Uneconomic fragmentation of land because of inheritance result in smaller and smallest pieces of land inherited by successive generation leads to:

a. Wastage of land ( ) b. Loss of time ( ) c. Limit the of machinery ( )

53. Why farmers have no access to production credit unless they are land owners because of:

a. Administrative and cost of procession loan is high

b. Small loan are unprofitable to commercial banks.

c. Banks cannot keep administrative cost down covering and leaving resources for expanding

d. Cooperative / credit societies financial assistance to farmers not cover all costs of inputs

54. It is difficult to estimate with any accuracy the cost of production or reconcile some of the labour figure as varied with farm and farm since it is cultivated with family labour working at uncertain times.

a. strongly agreed b. Agree c. Disagree d. Strongly disagree

55. Betterment of economic condition of paddy cultivation must be sufficient and attractive to producers through.

a. Greater production profit with cheap rice to consumer

b. Increased yield per hectare at decrease cost of production

56. Home consumption of rice production or trading off of surplus is either of:

a. All Produced b. $^{1}/_{4}$ Produced c. $^{1}/_{6}$ Produced d. $^{1}/_{8}$ Produced e. $^{1}/_{10}$ Produced

57. Decision making on farm produce is contravene by limited access to market and project office.

a. strongly agreed b. Agree c. Disagree d. strongly disagree

58. What kind of substance imported by soil water that affects your rice field?

a. Salinity b. Iron toxicity c. Zinc toxicity d. None

59. What measures have you used to ameliorate the situation?

a. Use high yield varieties that tolerate those substances.

b. Report to the project office for soil and water evaluation.

c. Stop cultivation until the irrigation water is refreshed regularly.

Thanks for the cooperation.

APPENDIX II: Irrigated Soil Properties of Kano River Project I

Physico-Chemical Properties of Pab Irrigated Top Soil at Kano River Project I (0 – 15cm)

Irrigation Sectors in Kura Branch	**Latitude (Degree)**	**Longitude (Degree)**	**Elevation Metre**	**Sand (%)**	**Silt (%)**	**Clay (%)**	**B/D** mg/m^3	**WHC (%)**	**pH**	H^+	Ca^{2+} cmol/kg	Mg^{2+} cmol/kg	Na^+ cmol/kg	K^+ cmol/kg	**CE**
Agolas II	11^{0}.26’	8^{0}.26’	461	83	15	9	1.8	7.4	6.62	0.23	4.76	1.14	0.18	0.77	7.4
Butalawa	110.48’	8^{0}.25’	467	81	13	6	1.4	6.7	6.38	0.17	3.17	1.01	0.15	0.62	6.6
Gori North	110.47’	8^{0}.24’	474	76	11	6	1.2	6.3	6.32	0.11	1.58	0.49	0.12	0.47	5.8
Gori South	11^{0}.46’	8^{0}.24’	474	82	13	7	1.4	6.8	6.44	0.17	3.17	0.88	0.15	0.62	6.6
Karfi	11^{0}.49’	8^{0}.28’	455	80	12	6	1.3	6.6	6.14	0.15	4.21	0.79	0.14	0.57	6.5
Majabo	11^{0}.48’	8^{0}.26’	468	80	11	7	1.2	7.0	6.5	0.16	2.6.5	0.74	0.14	0.65	6.5
Mudawa	11^{0}.44’	8^{0}.26’	470	79	13	7	1.3	6.8	6.8	0.16	3.0	0.8	0.14	0.61	6.5
Rakauna	11^{0}.46’	8^{0}.24’	476	79	12	7	1.3	6.8	6.48	0.17	2.8	0.81	0.14	0.61	6.5
Yakasai Gilmor	11^{0}.48’	8^{0}.27’	466	79	12	8	1.8	6.8	6.9	0.17	2.9	1.21	0.14	0.62	7.2
Yakasai N/Ruwa	11^{0}.47’	8^{0}.26’	450	78	13	7	1.5	6.8	5.84	0.17	2.9	0.94	0.16	0.61	6.5
Sectors in Bunkure	**Latitude**	**Longitude**	**Elevation**	**Sand**	**Silt**	**Clay**	**B/D**	**WHC**	**pH**	H^+	Ca^{2+}	Mg^{2+}	Na^+	K^+	**CE**
Dorawa I	11^{0}.42’	8^{0}.32’	473	75	31	8	0.89	11.76	7.18	0.58	2.9	0.91	0.09	0.38	7.2
Dorawa II	11^{0}.42’	8^{0}.32’	473	67	26	7	0.77	9.8	6.48	0.50	2.44	0.84	0.09	0.34	6.5
Dorawa III	11^{0}.42’	8^{0}.32’	473	57	24	6	0.74	7.84	5.66	0.31	1.92	0.74	0.08	0.27	5.8
Dorawa IV	11^{0}.42’	8^{0}.32’	473	67	27	7	0.8	9.8	6.44	0.45	2.42	0.83	0.09	0.33	6.5
DorawaV	11^{0}.42’	8^{0}.32’	473	64	26	6	0.8	9.74	6.19	0.41	2.26	0.94	0.08	0.22	5.0
Dorawa VI	11^{0}.42’	8^{0}.32’	473	69	26	7	0.78	10.21	6.10	0.48	2.56	0.82	0.09	0.17	5.3
Dorawa VII	11^{0}.42’	8^{0}.32’	473	66	29	7	0.793	9.92	6.24	0.45	2.41	0.74	0.08	0.31	5.2
Dorawa VIII	11^{0}.42’	8^{0}.32’	473	66	26		0.84	9.32	7.06	0.45	2.41	0.86	0.08	0.27	7.0
Shiye / Chirin I	11^{0}.42’	8^{0}.32’	487	68	27	7	0.80	9.82	6.47	0.46	2.46	0.91	0.08	0.55	6.1
Shiye / Chirin II	11^{0}.42’	8^{0}.32’	487	67	28	7	0.81	9.88	6.59	0.46	2.43	0.72	0.09	0.47	5.2

Physico-Chemical Properties of Pab/Pb Irrigated Top Soil at Kano River Project I (0 – 15cm)

Sectors in Kura	**Latitude**	**Longitude**	**Elevation**	**Sand**	**Silt**	**Clay**	**B/D**	**WHC**	**pH**	H^+	Ca^{2+}	Mg^{2+}	Na^+	K^+	**CE**
Agalawa	11^{0}.45’	8^{0}.25’	495	82	17	8	1.8	7.8	7.62	0.35	4.2	1.68	0.21	0.43	7.6
Agolas I	11^{0}.45’	8^{0}.25’	464	79	16	7	1.6	7.4	7.24	0.34	3.7	1.5	0.2	0.4	7.4
Azore I	11^{0}.43’	8^{0}.24’	475	77	15	7	1.5	7.2	6.75	0.33	3.5	1.46	0.19	0.36	7.1
Dakasoye	11^{0}.43’	8^{0}.26’	482	76	15	7	1.3	7	6.41	0.33	3.1	1.34	0.19	0.34	7.1
Dankabo	11^{0}.47’	8^{0}.25’	452	76	12	6	1.3	6.6	6.23	0.3	3	1.32	0.16	0.27	6.4
Danmaura	11^{0}.42’	8^{0}.28’	476	78	15	7	1.5	7.2	6.85	0.33	3.5	1.46	0.19	0.36	7.1
Fegin Malu	11^{0}.46’	8^{0}.29’	450	78	14	6	1.4	6.8	6.77	0.34	3.6	1.6	0.17	0.46	6.8
Gafan A	11^{0}.40’	8^{0}.25	493	81	16	8	1.4	6.68	7.47	0.36	3.3	1.3	0.19	0.38	7.7
Gafan B	11^{0}.40’	8^{0}.26’	487	77	16	7	1.6	7.8	6.48	0.31	3.8	1.62	0.19	0.27	7.4
Rigar Fako	11^{0}.47’	8^{0}.26’	464	76	14	6	1.6	7.52	6.68	0.31	3.3	1.32	0.21	0.33	6.7
Sectors in Bunkure	**Latitude**	**Longitude**	**Elevation**	**Sand**	**Silt**	**Clay**	**B/D**	**WHC**	**pH**	H^+	Ca^{2+}	Mg^{2+}	Na^+	K^+	**CE**
Barnawa	11^{0}.34’	8^{0}.27’	493	75	24	8	0.8	10.2	7.27	0.18	3.72	1.45	0.18	0.77	9.2
Kadawa North I	11^{0}.39’	8^{0}.25’	494	73	21	6	0.6	8.30	6.57	0.17	3.34	1.15	0.17	0.74	8.0
Kadawa North II	11^{0}.39’	8^{0}.25’	494	68	18	7	0.7	6.80	5.81	0.16	2.93	1.15	0.16	0.65	6.6
Kadawa South I	11^{0}.38’	8^{0}.25’	489	72	21	7	0.7	8.43	6.55	0.17	3.33	1.25	0.17	0.72	7.9
Kadawa South II	11^{0}.38’	8^{0}.25’	489	71	20	7	0.6	7.84	6.31	0.17	3.2	1.18	0.17	0.70	7.5
Kode	11^{0}.38’	8^{0}.25’	485	70	19	8	0.6	7.69	6.22	0.18	3.15	1.19	0.17	0.69	7.4
Lautaye	11^{0}.41’	8^{0}.33’	480	71	20	6	0.8	7.99	6.36	0.16	3.23	1.21	0.17	0.75	7.6
Turba	11^{0}.40’	8^{0}.33’	479	71	21	9	0.8	7.84	6.23	0.17	3.19	1.19	0.17	0.70	7.5
Yantomo I	11^{0}.36’	8^{0}.25’	493	70	19	6	0.7	7.84	6.29	0.17	3.19	1.20	0.16	0.69	7.5
Yantomo II	11^{0}.36’	8^{0}.25’	493	72	20	8	0.6	7.89	6.32	0.16	3.20	1.20	0.17	0.70	7.5

B/D – Bulk Density, WHC – Water Holding Capacity, pH – Acidity or Alkalinity Level, H^+ - Exchange Acidity, Ca^{2+} - Exchange Calcium, Mg^{2}+ - Exchange Magnesium, Na^+ - Exchange Sodium, K^+ -
Matter, N_2 – Total Nitrogen, P – Phosphorous, Cu^{2+} - Cupper, Mn^{2+} - Manganese, Fe^{2+} - Iron, Zn^{2+} - Zinc and B^+

APPENDIX III: Non-Irrigated Soil Properties of Kano River Project I

Physico-Chemical Properties of Pab Non-Irrigated Top Soil at Kano River Project I (														
Irrigation Sectors in Kura Branch	**Latitude (Degree)**	**Longitude (Degree)**	**Elevation Metre**	**Sand** (%)	**Silt** (%)	**Clay** (%)	**B/D** mg/m^3	**WHC** (%)	**pH**	H^+	Ca^{2+} cmol/kg	Mg^{2+} cmol/kg	Na^+ cmol/kg	
Agolas II	11^0.26’	8^0.26’	461	79	14	14	1.2	8.1	6.45	0.21	3.64	1.3	0.67	
Butalawa	110.48’	8^0.25’	467	75	13	12	1.7	7.6	6.3	0.17	3.17	1.12	0.62	
Gori North	110.47’	8^0.24’	474	74	12	7	1.4	6.5	6.15	0.13	1.2	0.7	0.57	
Gori South	11^0.46’	8^0.24’	474	76	13	11	1.4	7.4	6.30	0.17	2.67	1.04	0.62	
Karfi	11^0.49’	8^0.28’	455	75	12	10	1. 5	7.2	6.25	0.16	2.35	0.95	0.60	
Majabo	11^0.48’	8^0.26’	468	75	12	10	1.4	7. 5	6.59	0.18	2.87	1.12	0.59	
Mudawa	11^0.44’	8^0.26’	470	77	12	12	1. 5	7.4	6.38	0.17	2.73	1.04	0.65	
Rakauna	11^0.46’	8^0.24’	476	76	14	11	1.4	7.3	6.33	0.19	2.65	1.04	0.62	
Yakasai Gilmor	11^0.48’	8^0.27’	466	75	13	11	1.4	7.4	6.23	0.18	2.75	1.06	0.62	
Yakasai N/Ruwa	11^0.47’	8^0.26’	450	76	13	12	1.4	7.4	6.35	0.17	2.71	1.06	0.63	
Sectors in Bunkure	**Latitude**	**Longitude**	**Elevation**	**Sand**	**Silt**	**Clay**	**B/D**	**WHC**	**pH**	H^+	Ca^{2+}	Mg^{2+}	Na^+	
Dorawa I	11^0.42’	8^0.32’	473	74	28	8	0.6	11.45	7.39	0.4	3.16	1.22	0.15	
Dorawa II	11^0.42’	8^0.32’	473	69	25	6	0.48	9.36	6.61	0.31	2.54	1.08	0.12	
Dorawa III	11^0.42’	8^0.32’	473	61	22	7	0.42	7.69	5.83	0.42	2.04	0.82	0.12	
Dorawa IV	11^0.42’	8^0.32’	473	68	25	7	0.5	9.5	6.61	0.38	2.58	1.04	0.13	
DorawaV	11^0.42’	8^0.32’	473	66	24	6	0.48	8.67	7	0.37	2.39	0.98	0.12	
Dorawa VI	11^0.42’	8^0.32’	473	65	26	8	0.56	9.78	6.74	0.39	3.34	0.9	0.14	
Dorawa VII	11^0.42’	8^0.32’	473	70	24	7	0.52	10.33	6.74	0.38	2.48	1.12	0.15	
Dorawa VIII	11^0.42’	8^0.32’	473	71	26	7	0.44	8.96	6.78	0.38	2.39	1.09	0.13	
Shiye / Chirin I	11^0.42’	8^0.32’	487	72	25	6	0.47	9.64	6.52	0.38	2.39	1.08	0.13	
Shiye / Chirin II	11^0.42’	8^0.32’	487	64	25	7	0.54	9.62	5.9	0.36	2.49	1.07	0.14	
Physico-Chemical Properties of Pab/Pb Non-Irrigated Top Soil at Kano River Project														
Sectors in Bunkure	**Latitude**	**Longitude**	**Elevation**	**Sand**	**Silt**	**Clay**	**B/D**	**WHC**	**pH**	H^+	Ca^{2+}	Mg^{2+}	Na^+	**K**
Agalawa	11^0.45’	8^0.25’	495	78	20	8	1.4	8.5	8.06	0.35	3.4	1.34	0.28	0.9
Agolas I	11^0.45’	8^0.25’	464	75	19	8	1.3	8.1	7.71	0.32	3.3	1.31	0.24	0.8
Azore I	11^0.43’	8^0.24’	475	74	19	7	1.3	8.1	6.65	0.34	3	1.25	0.23	0.8
Dakasoye	11^0.43’	8^0.26’	482	72	19	6	1.1	8	6.35	0.33	2.95	0.12	0.22	0.8
Dankabo	11^0.47’	8^0.25’	452	71	18	8	1.3	7.8	6.33	0.29	2.75	1.15	0.18	0.7
Danmaura	11^0.42’	8^0.28’	476	74	19	7	1.1	8.1	7	0.32	3.08	1.03	0.23	0.8
Fegin Malu	11^0.46’	8^0.29’	450	73	19	6	1.2	8.2	7.2	0.33	3.02	0.97	0.22	0.8
Gafan A	11^0.40’	8^0.25	493	73	19	7	1.1	8.3	7.1	0.33	2.96	1.12	0.26	0.8
Gafan B	11^0.40’	8^0.26’	487	74	18	6	1.2	8	6.3	0.34	2.94	0.81	0.21	0.8
Rigar Fako	11^0. 47’	8^0.26’	464	76	20	7	1	7.9	7.5	0.31	3.4	1.24	0.23	0.8
Sectors in Bunkure	**Latitude**	**Longitude**	**Elevation**	**Sand**	**Silt**	**Clay**	**B/D**	**WHC**	**pH**	H^+	Ca^{2+}	Mg^{2+}	Na^+	**K**
Barnawa	11^0.34’	8^0.27’	493	74	24	8	0.46	9.4	8.71	0.19	3.52	0.96	0.52	1.1
Kadawa North I	11^0.39’	8^0.25’	494	70	23	7	0.41	8.1	7.93	0.16	2.78	0.9	0.45	0.9
Kadawa North II	11^0.39’	8^0.25’	494	66	22	6	0.32	6.5	7.12	0.16	1.95	0.78	0.35	0.7
Kadawa South I	11^0.38’	8^0.25’	489	70	23	7	0.39	8.0	7.92	0.17	2.75	0.88	0.44	0.9
Kadawa South II	11^0.38’	8^0.25’	489	69	23	6.67	0.37	7.53	7.65	0.16	2.49	0.85	0.41	0.9
Kode	11^0.38’	8^0.25’	485	68	22	6.56	0.36	7.34	7.56	0.16	2.39	0.84	0.40	0.8
Lautaye	11^0.41’	8^0.33’	480	69	22	6.74	0.37	7.62	7.71	0.16	2.54	0.85	0.42	0.9
Turba	11^0.40’	8^0.33’	479	68	22	6.65	0.37	7.50	7.64	0.16	2.47	0.84	0.41	0.9
Yantomo I	11^0.36’	8^0.25’	493	68	23	6.65	0.37	7.49	7.64	0.16	2.47	0.84	0.41	0.9
Yantomo II	11^0.36’	8^0.25’	493	70.	22	6.68	0.37	7.54	7.67	0.18	2.50	0.85	0.41	0.9

B/D – Bulk Density, WHC – Water Holding Capacity, pH – Acidity or Alkalinity Level, H^+ - Exchange Acidity, Ca^{2+} - Exchange Calcium, Mg^{2+} - Exchange Magnesium, Na^+ - Excha
Organic Matter, N_2 – Total Nitrogen, P – Phosphorous, Cu^{2+} - Cupper, Mn^{2+} - Manganese, Fe^{2+} - Iron, Zn^{2+} - Zinc and B^+

Appendix iv

Rice Variable Average Inputs Matrix

Variable Input	Value of x_1	Value of x_2	Mean
Inputs Cost (₦)	140,561.13	176,941. 66	150,400.41
Income (₦)	84,302.65	72,040.45	79,244.49
Rice Yield (kg)	3,872.96	4,681.56	4,277.26
Manure (kg)	1,406.25	1,896.08	1,687.50kg Applied from Manure Produced 0.80 gkg^{-1} Organic Matter inthe soil
Nitrogen (kg)	241.06	325.02	289.27kg Applied from Chemical fertilizer Produced 0.059 gkg^{-1} Nitrogen in the soil
Phosphorous (kg)	49.90	42. 65	46.28kg Applied Produced 28.55gkg^{-1} from Chemical fertilizer Phosphoros in the soil
Potassium (kg)	48.86	41.88	45.37kg Applied from Chemical fertilizer Produced 0.55cmol/kg Potassium in the soil
Fertilizer (Bags) UREA = 2.5: NPK = 3.0	8.20 3.73: 4.47	9.0 4.09: 4.91	8.60 = 430kg 3.91 = 175.95kg UREA 4.69 = 93.8kg N_2: 46.9 P: 46.9 K
Fertilizer (kg) UREA & NPK = 2.5: 3.0	410.0 186.36:223.64	450.0 204.54:245.46	430.0 195.45:234. 50
Labour Man-days	1,052	1,348	1,200
Land Size (ha)	515	257.50	386.25
Seed (kg)	52.88	50.0	561.44
Sold Price	5,924.77	4,405.59	5,165.18

Note that let average under Jamila local rice be x_1 and under Farox be x_2

Income Matrix

$$\begin{array}{l} \\ \text{Land Size (ha)} \\ \text{Sold Price (₦)} \\ \text{Gross Revenue (₦)} \\ \text{Income (₦)} \end{array} \begin{array}{c} \begin{array}{cc} x_1 & x_2 \end{array} \\ \begin{bmatrix} 515.0 & 257.50 \\ 5,924.77 & 4,405.59 \\ 224,863.78 & 248,982.11 \\ 84,302.65 & 2,040.49 \end{bmatrix} \end{array}$$

Cost and Benefit Matrix

$$\begin{array}{l} \\ \text{Input Cost (₦)} \\ \text{Income (₦)} \end{array} \begin{array}{c} \begin{array}{cc} x_1 & x_2 \end{array} \\ \begin{bmatrix} 140,561.13 & 176,941.66 \\ 84,302.65 & 72,040.49 \end{bmatrix} \end{array}$$

Gross Revenue Matrix

x_1 x_2

$$\begin{array}{l} \text{Yield (₦)} \\ \text{Price (₦)} \end{array} \begin{bmatrix} 3,872.96 & 4,681.56 \\ 5,924.77 & 4,405.59 \end{bmatrix}$$

Yield Matrix

$$\begin{array}{lc} & \begin{array}{cc} \mathbf{x_1} & \mathbf{x_2} \end{array} \\ \begin{array}{l} \text{Yield (kg)} \\ \text{Seed (Kg)} \\ \text{Fertilizer (kg)} \\ \text{Organic Manure (kg)} \end{array} & \begin{bmatrix} 3,872.96 & 4,681.56 \\ 52.88 & 50.0 \\ 8.20 & 9.0 \\ 1,406.20 & 1,896.50 \end{bmatrix} \end{array}$$

Organic Matter Input Matrix

$$\begin{array}{lc} & \begin{array}{cc} \mathbf{x_1} & \mathbf{x_2} \end{array} \\ \begin{array}{l} \text{Phosphoros (kg)} \\ \text{Nitrogen (Kg)} \\ \text{Fertilizer (kg)} \end{array} & \begin{bmatrix} 49.96 & 46.65 \\ 241.06 & 352.02 \\ 386.50 & 442.50 \end{bmatrix} \end{array}$$

Nitrogen Input Matrix

$$\begin{array}{lc} & \begin{array}{cc} \mathbf{x_1} & \mathbf{x_2} \end{array} \\ \begin{array}{l} \text{Nitrogen (Kg)} \\ \text{Fertilizer (kg)} \end{array} & \begin{bmatrix} 241.06 & 352.02 \\ 386.50 & 442.50 \end{bmatrix} \end{array}$$

Phosphoros Input Matrix

$$\begin{array}{lc} & \begin{array}{cc} \mathbf{x_1} & \mathbf{x_2} \end{array} \\ \begin{array}{l} \text{Fertilizer (Kg)} \\ \text{Phosphoros (kg)} \end{array} & \begin{bmatrix} 386.50 & 442.50 \\ 49.90 & 46.65 \end{bmatrix} \end{array}$$

Potassium Input Matrix

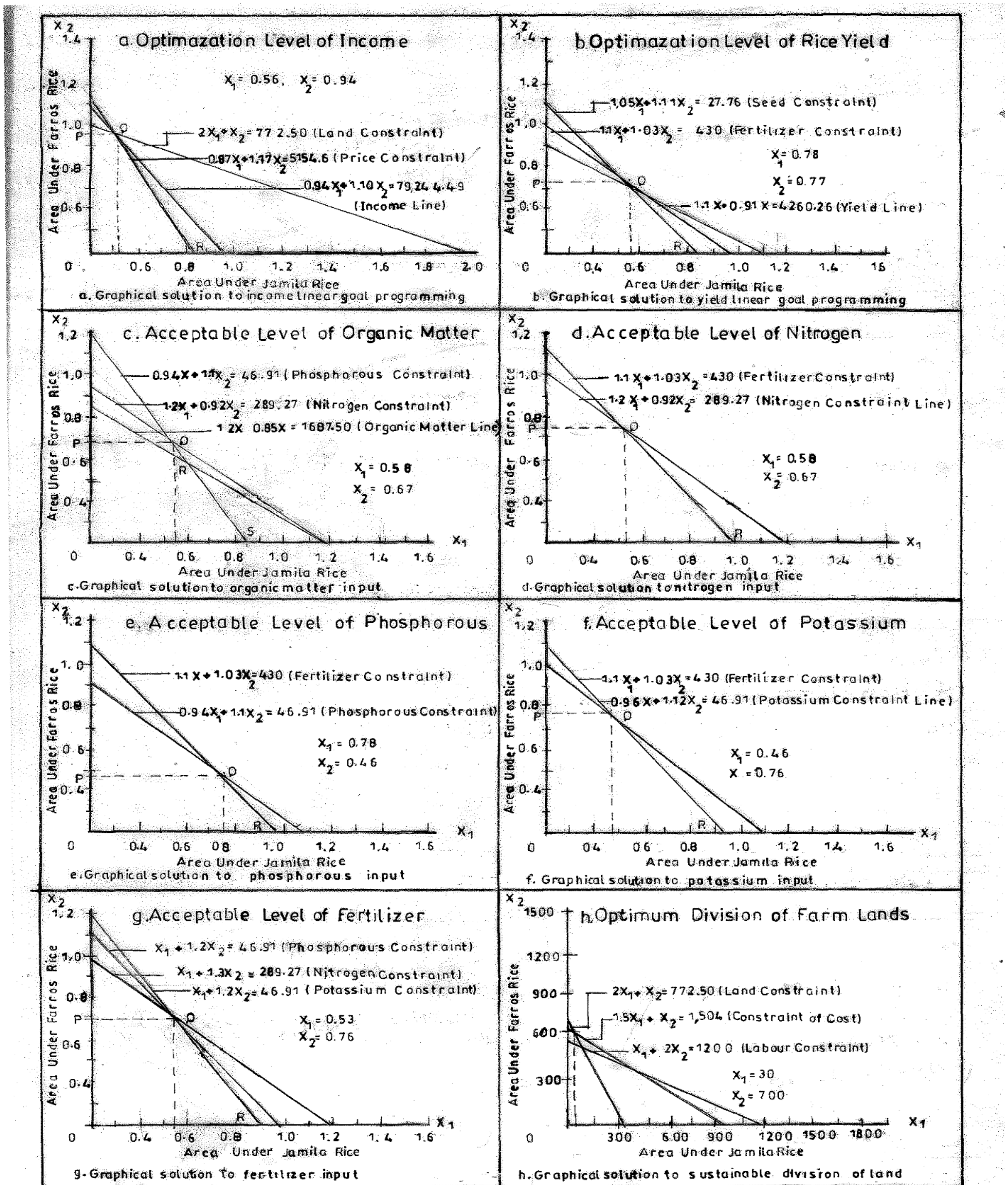
$$\begin{array}{lc} & \begin{array}{cc} \mathbf{x_1} & \mathbf{x_2} \end{array} \\ \begin{array}{l} \text{Fertilizer (Kg)} \\ \text{Potassium (kg)} \end{array} & \begin{bmatrix} 386.50 & 442.50 \\ 49.90 & 46.65 \end{bmatrix} \end{array}$$

Chemical Fertilizer Input Matrix

$$\begin{array}{lc} & \begin{array}{cc} \mathbf{x_1} & \mathbf{x_2} \end{array} \\ \begin{array}{l} \text{Phosphoros (kg)} \\ \text{Potassium (Kg)} \\ \text{Nitrogen (kg)} \end{array} & \begin{bmatrix} 49.96 & 46.65 \\ 49.90 & 46.65 \\ 241.06 & 52.02 \end{bmatrix} \end{array}$$

Appendix v

Graphical Solution to Linear Goal Programming Problems for Rice Production



Appendix vi

Solution to Objective Function (Z) of Linear Goal Programming Constraints from Appendix ii

a. Optimization Level of Income Goal To minimize the under-achievement of income goal. The greatest acceptable value of $(x_1 + x_2)$ is to use the income line equation: $0.94x_1 + 1.1x_2 \leq 79{,}244.49$ To maximize profit a line would be drawn parallel to the equation line away from the origin (zero position). The most profitable equation: $0.99x_1 + 1.16x_2 \leq 83{,}206.72$ **Profitable Division of Rice income:** **Jamila = ₦84,047.19kg;** **Faros = ₦71,729.93**	**b. Optimization Level of Rice Yield Goal** To minimize the under-achievement of rice yield goal. The greatest acceptable value of $(x_1 + x_2)$ is to use the rice yield line equation: $1.1x_1 + 0.91x_2 \leq 4{,}260.26$ To maximize rice yield, a line should be drawn parallel to the equation line away from the origin (zero position). The yield division equation: $1.104x_1 + 0.914x_2 \leq 4{,}517.99$ **Yield Division of rice varieties cultivated:** **Jamila: 4,090.91kg;** **Faros: 4,945.06kg**
c. Acceptable Level of Organic Matter Goal To minimize the under-achievement of organic matter content. The greatest acceptable value of $(x_1 + x_2)$ is to use the organic matter line equation: $1.2x_1 + 0.85x_2 \leq 1{,}687.50$ To maximize organic matter content in the soil a line should be drawn parallel to the equation line away from the origin (zero position). The increase of organic matter content equation: $7.2x_1 + 5.1x_2 \leq 11{,}809.08$. **It needs to apply 11,809.08kg of animal dung to achieve 69.14g/kg of organic matter content in the soil ($x_1 = 6{,}912.63$kg, $x_2 = 4{,}896.45$kg).**	**a. Acceptable Level of Nitrogen Goal** To minimize the under-achievement of nitrogen content. The greatest acceptable value of $(x_1 + x_2)$ is to use the nitrogen line equation: $1.2x_1 + 0.92x_2 \leq 289.50$. To maximize nitrogen content in the soil a line should be drawn parallel to the equation line away from the origin (zero position). The increase of nitrogen content equation: $4.2x_1 + 3.2x_2 \leq 1{,}298.64$kg of UREA (45%) **It needs to apply 1,298.64kg of UREA (45%) fertilizer to achieved 2.11g/kg of Nitrogen content in the soil ($x_1 = 737.07$kg, $x_2 = 561.58$kg).**
b. Acceptable Level of Phosphorous Goal To minimize the over- achievement of phosphorous content. The greatest acceptable value of $(x_1 + x_2)$ is to use the phosphorous line equation: $0.94x_1 + 1.1x_2 \leq 46.91$ To minimize phosphorous content in the soil a line should be drawn parallel to the equation line toward the origin (zero position). The decrease of phosphorous content equation: $0.28x_1 + 0.32x_2 \leq 33.10$NPK (20:10:10) **It needs to apply 33.10kg of NPK (20:10:10) fertilizer to achieved 22.0g/kg of Phosphorous content in the soil ($x_1 = 15.45$kg, $x_2 = 17.65$kg).**	**c. Acceptable Level of Potassium Goal** To minimize the over-achievement of Potassium content. The greatest acceptable value of $(x_1 + x_2)$ is to use the Potassium line equation: $0.96x_1 + 1.12x_2 \leq 46.91$ To minimize Potassium content in the soil a line should be drawn parallel to the equation line toward the origin (zero position). The decrease of Potassium content equation: $0.38x_1 + 0.43x_2 \leq 28.87$kg of NPK (20:10:10) **It needs to apply 28.87kg of NPK (20:10:10) fertilizer to achieved 0.32cmol/kg of Potasium content in the soil ($x_1 = 13.54$kg, $x_2 = 15.33$kg).**
d. Acceptable Level of Fertilizer Goal To minimize the over-achievement of phosphorous and Potassium content, then under-achievement of nitrogen. The greatest acceptable value of $(x_1 + x_2)$ for the three nutrient (nitrogen, phosphorous and Potassium) line equations is to: increase level of nitrogen from 289.50kg - 1,298.64kg; decrease level of phosphorous from 46.91kg - 33.10kg; and decrease level of Potassium from 46.91kg - 28.87kg.	**i. The Optimum Division of Land between Jamila and Faros Rice Varieties for Sustainability and food security** The achievement of optimization of land utilization between Jamila and Faros rice production in the irrigation project is to allocate 30ha to Jamila variety and 700ha to Faros variety. The remainder of 42.50ha will be left uncultivated because of the limit of labour and other input resources. The division of land is summarized below: Jamila Rice Variety (x_1) = 30ha Faros Rice Variety (x_2) = 700ha Fallow Land Size = 42.50ha Total land Utilized for 2016/2017 = 772.50ha

Appendix vi

Data used for Correlation Matrix for Factor Analysis

Variable Inputs	Kura	Bunkure	Yadakwari	Danhasan	Gajingiri	Kadawa	Gafan	Imawa	Kosawa	Makwaro
Labour (Man-hour)	363.97	189.27	160.02	196.57	254.22	433.54	135.27	314.94	241.20	640.56
Labour (Man-day)	120.50	85.37	96.74	135.62	140.29	115.82	83.46	129.51	135.22	122.15
Seed (Kg)	37.42	30.52	12.44	54.13	33.33	43.84	37.78	45.24	74.13	32.63
Fertilizer (Kg)	425.0	193.0	110.19	235.33	429.24	171.25	201.87	413.25	320.74	315.75
Agro-chemical (Lt)	6.12	4.48	2.05	4.98	5.67	4.80	2.55	5.87	4.28	4.05
Cost of labour (₦)	72,755	64,414	42,932	57,855	59,250	51,079	40,282	57,500	64,080	56,550
Cost of seed (₦)	7,016.8	7,243.4	1,944.5	2,553.1	4,250.4	5,080.2	3,961.2	5,613.5	8,259.4	4,725.7
Cost of fertilizer (₦)	46,750	19,300	12,561.66	26,266	47,216	18,837	22,205	45,457	35,248	34,575
Cost of Agro-chemic (₦)	4,884.5	2,057.1	1,296.3	7,975.2	8,500.7	5,650.4	3,825.2	8,508.8	6,020.4	6,051.
Farm Size (Ha)	0.92	1.21	1.54	0.53	2.00	0.45	0.30	2.40	2.35	1.81
Farming experience	36.93	34.50	31.00	38.00	35.80	39.40	39.20	33.33	45.30	36.30
Household size	4.38	3.55	7.80	12.30	7.30	3.60	7.20	8.00	7.80	4.30
Extension contact	0.00	0.20	0.25	0.33	0.60	0.00	0.50	0.33	0.00	0.00
Higher education	0.1	0.20	0.14	0.50	0.20	0.00	0.16	0.16	0.00	0.00
Land owner ship	0.47	0.36	0.64	0.33	0.55	0.50	0.66	0.31	0.49	0.38
Crop diversification	0.25	0.16	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.16

Source: Author's Data Analysis (2016)