Pan African University
Institute of Water
and Energy Sciences

PAN-AFRICAN UNIVERSITY
INSTITUTE FOR WATER AND ENERGY SCIENCES
(including CLIMATE CHANGE)

Master Dissertation

Submitted in partial fulfillment of the requirements for the Master degree in

Water Engineering

Presented by

Muhammad Tukur BAYERO

Assessing the Sustainability of Drainage System in Irrigated Agricultural Land: A Case Study of Kano River Irrigation Scheme in Nigeria

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Assessing the Sustainability of Drainage System in Irrigated Agricultural Land: A Case Study of Kano River Irrigation Scheme in Nigeria

A Thesis or dissertation submitted to the PAN AFRICAN UNIVERSITY INSTITUTE OF WATER AND ENERGY SCIENCES (including CLIMATE CHANGE)

In Partial Fulfillment of the Requirements for the Master of Science (M.Sc.) Degree

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(B.Eng. Water Resources and Environmental Engineering)

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Date: 03/09/2019

September 2019

Pan African University

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DEDICATION

Dedicated to the loving memory of my father and my dear mother. You are not here to enjoy the fruits, Dad, but Mum is here, and I made it as always. Every inch of my success will always be for you.

STATEMENT OF THE AUTHOR

By my signature below, I declare that this thesis is my work. I have followed all ethical principles of scholarship in the preparation, data collection, data analysis, and completion of this thesis. I have given all scholarly matter recognition through accurate citations and references. I affirm that I have cited and referenced all sources used in this document. I have made every effort to avoid plagiarism.

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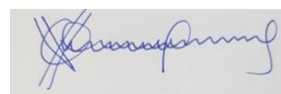

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BIOGRAPHICAL SKETCH

Muhammad Tukur holds a bachelor's degree in Water Resources and Environmental Engineering from the University of Ahmadu Bello University Zaria, Nigeria in 2015. Having graduated the top of his class, he finds, passion in rural water supply and sanitation and that shaped his choice of PAUWES. He worked with a consortium of UNICEF, UKaid, USAID, and Rural Water Supply and Sanitation Agency (RUWASSA) as a Site Supervisor**,** before joining PAUWES. The interdisciplinary nature of PAUWES has taken him to over ten countries for summer schools, workshops and, conferences in Turkey, Germany, The Netherlands, Italy, and the Czech Republic. He served as a Research professional at the Islamic Development Bank (IsDB) Headquarters in Jeddah, Saudi Arabia. While at IsDB, he participated in several seminars on SDGs with UN, Youth employability with UNESCO, ILO, UNICEF, AfDB, ADB, GIZ, and IsDB as well as training on developmental projects and project cycle. His research examined 'Agricultural land drainage for sustaining irrigated agriculture in the Kano River Irrigation Scheme in Nigeria' producing a Thesis and Knowledge product for Bank's intervention. Muhammad's ambition is to leverage his gained experience to inform the policymakers, developmental organizations, private sectors and, at the grassroots level on water security in Africa, and achieving the 2063 Agenda as well as the SDGs. As next step, he will go to where his career leads him while continuing as an entrepreneur because he believes there are many opportunities out there.

ACKNOWLEDGEMENTS

The journey of my study in the Pan African University Institute of Water and Energy Sciences (including climate change) has been an eventful one, and I enjoyed every bit of it, especially the challenges. To begin with, I want to give honor to whom honor is due by thanking the African Union (AU) for initiating this program, the German government, and Algerian Government for proving support in cash and kind. We will pass on the excellent knowledge and character.

Moving straight to my research, the research to practice (res2prac) conference, which brought together practitioners and scholars was indeed a big success to the institute. The fruits of the conference will forever be my most significant take home. I consider lucky to be among the students that researched with the Islamic Development Bank (IsDB), having selected a thematic of interest to study. It was the first of its kind and a multiple wins for the institute, IsDB and myself. My sincere gratitude goes to the support and capacity development received; I would not have gotten better.

My heartfelt gratitude and, appreciation goes to Mr. Bakhodir Mirzaev, my supervisor, my supporter and, my challenger. This M.Sc would never have been possible without your help and tenacious encouragement. Thank you for the quizzes that always reminded me about the subject of drainage. Your inputs were priceless, not a surprise; you got them from the best players in the subject and your long-standing experience through your career. It kept me on track and made me think outside the box. The development arena is hard, yet, he made it very easy for me. I received lectures, training, and, personal advice that shaped me into a real professional. I will keep thanking you until I seize to exist.

I am grateful to my co-supervisor, and teacher Dr. Amos T. Kabo-Bah, who set the track of my research when I was building it from scratch. He made me realized that I have to lead my research and get the guidance only after getting consistent results. His M.Sc and Ph.D. stories shared with me and my classmates have been a driving force to push under all circumstances. Thank you for giving me opportunities to improve my knowledge of modeling and data analysis.

I thank Dr. Frank van Steenbergen, who is part of the team that developed the DRAINFRAME approach I adopted in this study. It was initially very ambiguous until I reached out to him with the help of my supervisor. I am glad he explained to me, and he is ready to improve the framework to include the trending issues of climate change together with my team here in IsDB.

I thank all my lecturers and PAUWES administration, the quality of education and welfare was equal to none. I felt educated and loved like I never left my home country. If I am to write names, no name will be left unwritten.

I thank Professor Muzahid Ali for sharing great scientific insights and materials on research methodology of case study analysis during my writing. Thank you for the many jokes ‘with two cookies’ that helped me laugh off my worries as I worked on my M.Sc research, together with Dr. Ima Kashim, Dr. Mustapha Diallo and, Dr. Ahmed Rufa’i. I felt like your biological son and can never thank you enough.

In PAUWES, I met people from all part of Africa, who was as curious and ready to learn as I was. I thank all colleagues in the Water Engineering Track specifically and 4th cohort in general. Special thanks go to Brother Oumar-Alfaroukh who stood by my side through thick and thin. I will dearly miss of them.

Many thanks to FMWR, HJRBDA, and TRIMING staff who made life better during my field visit to KRIP. Despite the lack of data, I received tremendous support and cooperation during surveys, interviews, and observation. My work wouldn’t have been possible without your help.

My eternal gratitude goes to my family “the Bayero’s” who had to sacrifice so much to enable

I thank my big brother, Abdulwasiu (Hafiz), you are playing the role of my late father. You have made me stronger than one can imagine. Many thanks to my brother friend Nazifi, my friend, who made so many changes and pushed so many limits to support my M.Sc.

My M.Sc. journey followed a narrow alley whose course had been foreseen by great people I was fortunate to meet in life. Professor Abubakar Ismail, Professor Joseph Adelegan, Professor Svat Matula, Dr. Markéta Miháliková, Engr. Sami Faruqi, Dr. Nizar Zaied, and Br. Olatunji Yusuf.

Finally, It was all by the will Allah that this study was possible. Alhamdulillah

ABBREVIATIONS AND ACRONYMS

CEC: Cation Exchange Capacity

DC: Distributary Canals

DEM: Digital Elevation Model

DRAINFRAME: Drainage Analytical Framework

FC: Field Canal

FGN: Federal Government of Nigeria

FMARD: Federal Ministry of Agriculture and Rural Development

FMWR: Federal Ministry of Water Resources

FTO: Field Turn Out gates

FW: Future With Project

FWO: Future Without Project

GIS: Geographic Information System

HJRBDA: Hadejia Jama'are River Basin Development Authority

HVIP: Hadejia Valley Irrigation Project

ISF: Irrigation Service Fees

KRIP – Kano River Irrigation Project

LC: Lateral canal

LULC: Land Use and Land Cover

MC: Main Canal

NDMI: Normalized Difference Moisture Index

NDVI: Normalized Difference Vegetation Index

NDWI: Normalized Difference Water Index

NFI: Net Farm Income

NSR: Night Storage Reservoir

RBDA: River Basin Development Authorities

SAR: Sodium Adsorption Ratio

STO: Sector Turn Out gates

TRIMING: Transforming Irrigation Management in Nigeria Project

WL: Waterlogging areas

WTP: Willingness to Pay

WUA: Water Users Association

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ABSTRACT

Large scale public irrigation schemes in Nigeria are underperforming despite the high investment cost and several institutions managing the projects. In fact, out of about 62 reviewed public irrigation schemes managed by 12 River Basin Development Authorities, some 90% of the area under irrigation is under only three projects and two RBDAs. Nigeria needs irrigated agriculture, like never before, to meet the food and fiber demand of the growing hungry and poor population to achieve zero hunger by 2030. To do so, different kinds of innovative approach and interventions must be employed to succeed in this ambitious target. Hence the study was undertaken. The DRAINFRAME approach was used in problem identification to understand the drainage related problem integrating the water managers and water users, i.e. stakeholders. Field study and semi-structured interviews with stakeholders provided relevant information that informed the direction and in-depth understanding of the problem. Remote Sensing (RS) and Geographic Information System (GIS) techniques were used to estimate the Land Use and Land Cover (LULC) trends and waterlogging areas within the KRIP command area, and the Net Farm Income (NFI) was calculated to evaluate the agricultural benefits. Our findings indicate that the agricultural land drainage in the KRIP command areas is the source of water for unauthorized drainage water reuse, farmers consider it as fertile land for cultivation, and it is highly infested with aquatic weed. From the analysis of LULC trend, it was found out that agricultural land and built-up areas have increased by 43.47 Km^2 and 8.19 Km^2 between 1988 and 2018 respectively indicating that agricultural development and infrastructure development is taking place. Estimation of the waterlogged regions within LULC classes showed that agricultural lands are most affected and covered 48% of the total waterlogged area. Also, it was found that seepage and leakage of the unlined irrigation canals could be occurring at least 50 meters on both sides of the canals which was estimated to be 29.18% of the total buffered area. Furthermore, NFI of average landholding of 0.46 ha is high enough to encourage paying for more Irrigation Service Fee (ISF) for efficient operation and maintenance that will result in increased agricultural productivity. Based on our findings, agricultural land drainage in KRIP command area is used in the wrong way for good purposes, i.e. cultivation and drainage water reuse. As a consequence, waterlogging situations are dominant especially during the wet season. This will lead to secondary salinity if nothing is done thereby reducing that land fertility. The KRIP, although, poorly performing, was found to provide agricultural benefits. Therefore, irrigated agriculture if adequately managed, will not only be sustainable but also help in meeting the food and fiber demand. The knowledge and recommendations generated in this research is useful for decision-makers, development institutions, water managers and water users.

CHAPTER ONE: INTRODUCTION

1.1 Background

The recent report by FAO (2018) on the state of food security in the world showed about 821 million people do not have enough food to eat, two billion people suffer from malnutrition, and the numbers are rising. In the Bloomberg Problem Solved Series about food production, it was highlighted that if we do not change our consumer behavior, we will need to produce as much food in the next 40 years as we did in the past 8000 years. In an attempt to increase food production, it is pertinent to pinpoint all the factors underlying short term operations and long term strategies that will bring about improved food security (Medici & Wrachien, 2016). Drainage of agricultural lands is crucial and has been identified as an instrument for growth in production, a safeguard for sustainable investment in irrigation projects, and a tool for conservation of land resources (Molle et al., 2015; Ritzema, 2007; Ritzema & Schultz, 2011). Also, about 90% of the food production increase is expected to come from existing cultivated land with a water management system (Jaleta, 2013). Be that as it may, over 73% of the world's total cultivated area, that is approximately (1.5 billion ha) exploited without irrigation and drainage management system and contributes to about 40% of crop output. It is noteworthy that irrigation and drainage facilities provide about 45% and 15% of crop output, respectively (Medici & Wrachien, 2016). These numbers indicate that the provision of more irrigation and drainage systems are arguably the way to ensure food security in the world.

FAO (2018) reported that sub-Saharan Africa (SSA) has the most significant potential for expanding irrigated agriculture in the world. Yet, only one-fifth of the potential irrigable area has been developed despite its enormous land and water resources. This suggests that more irrigation in SSA, will increase agricultural productivity, crop diversification, and help ensure food security in the region Tefera and Cho, (2017).

Egypt is an exceptional example, despite being one of the top water-stressed areas in the world with annual rainfall ranging between almost nothing in the south to 180 mm on the North Coast. The Nile River remains the only source of freshwater. However, it maintains a remarkable record in irrigated agriculture, almost 99.8 percent of the cultivated area, to produce food and fiber for the whole country and beyond (IPPTRID & NWRC, 2007). However, irrigated agriculture faces the challenge of balancing productivity with environmental pressures emanating from drainage problems. Therefore, it was concluded that drainage must be regarded as a cornerstone of integrated water resources management (Shalaby *et al.*, 2004).

Agriculture was and is still the cornerstone of the Nigerian economy irrespective of the crude oil it currently dependance. According to Aigbokhan (2001), agriculture contributes 63% and 54% to the Gross Domestic Product in the 1950s and 1960s, respectively. Also, 65% of the Nigerian labor force is employed in agriculture (Emeka,2007). Despite being the most populous country with the highest GDP in Africa, a record maintained for so long a time, more than half the population lives in rural areas with extreme hunger and poverty (below USD 1.9 per day) (World Bank, 2018). In 2011, Nigeria record 325,000 ha of irrigated areas (ICID,2018). Yet that less than one-tenth of irrigation potential in the country (You et al. 2011). The reasons of low irrigation and poor management of the irrigation schemes do not have direct answers (Takeshima & Adesugba, 2014) and studies should be more directed towards holistic problem analysis rather than looking from one perspective.

According to the review of public irrigation schemes in Nigeria (FAO & FMWR, 2004), Kano River Irrigation Project (KRIP) is the first, largest and said to be the best performing irrigation project in Nigeria. KRIP has been in existence for over four decades and has not met up to ten percent of the design capacity. The dominant problems range from water distribution, water management, waterlogging, salinity, sodicity, reduced fertility, obliteration of the irrigation and drainage infrastructure to mention a few. There have been many interventions with the largest been TRIMING, which started in 2014. However, there is a need to look beyond projects and understand the root cause of persistent failure of the irrigation schemes.

In this context, agricultural land drainage is explored in the KRIP command area to highlight it is potential to safeguard irrigated agriculture using the Drainage Integrated Analytical Framework (DRAINFRAME). This is a framework-specific to agricultural drainage in the context of Integrated Water Resources Management, which offers a useful approach and methodology to analyze water management situations in an integrated manner. The DRAINFRAME method is discussed in the preceding chapters. This work will attempt to point out the role drainage plays in the Kano River Irrigation Project, and results obtained will provide guidance for better planning and decision making in irrigation and drainage projects or interventions.

1.2 Problem Statement

Out of the 62 public irrigation schemes in Nigeria, three projects account for 90 % of the irrigated area. In all cases, none of the irrigation schemes is operating effectively; not even the top-ranked, which is the Kano River Irrigation Project (FAO & FMWR,2004). The public irrigation sector accounts for only 13% of the total irrigated area and less than 1% of the agricultural area (You et al., 2011).

KRIP have been operating at low capacity for over four decades with most of the irrigation network dilapidated, weed-infested, or silted up (Oyebode et al., 2014). The water distribution system in KRIP is gravity-based from Tiga reservoir, which is the irrigation water source for 48 sectors 19 km away. A common problem in water distribution is the inability of tail-end users to receive water. Irrigation scheduling, as well as operation and management, have long deviated from the project operation standard. As a consequence, waterlogging and salinization are setting in and will continue if nothing is done. Furthermore, there is a more significant threat to the water availability of Tiga reservoir with the current plan to generate electricity despite the KRIP planned phase two project (HJRBDA, 2018).

Many studies have been carried out by institutions and researchers. However, most of the studies were tailored towards the physical evaluation (soil fertility, crop cultivation, crop multiplication, water quality, sedimentation studies) and farmers evaluation (farmers livelihood, economic and financial analysis) of the scheme and conclusions with recommendations that are more or less generic.

Paucity of research exists on water use system, management, and monitoring looking from an integrated perspective seeking stakeholders participation at all levels and in all aspects. Drainage Integrated Analytical Framework (DRAINFRAME) could be one fo such approach that we identified and used for this study. DRAINFRAME is a systematic approach that allows thinking and discussions of trade-offs. Although DRAINFRAME is applied on KRIP at the later stage of TRIMING intervention when a major decision has been taken on project preparation, our results can be used in future development projects or even as a guide during the implementation stage of the intervention.

1.3 Research Questions and Objectives

1.3.1 Main research question

The overarching research question for the study is;

What are the potentials of agricultural drainage in sustaining irrigated agriculture in the Kano River Irrigation?

1.3.2 Specific research questions

1. What is the drainage typology in the Kano River Irrigation Project?
2. How does inadequate drainage affect irrigated agriculture in the Kano River Irrigation Project command area?
3. How are agricultural benefits derived from drainage system management?

1.3.3 Main objective

The main objective of the study is to highlight the potential of agricultural drainage for sustaining irrigated agriculture in the Kano River Irrigation Project.

1.3.4 Specific objectives

1. To review and evaluate the drainage type in Kano River Irrigation Project.
2. To assess the impacts of drainage using remotely sensed data and GIS techniques.
3. To evaluate the agricultural benefits of drainage system management.

1.4 The rationale of the study

In the past, and up until now, irrigated agriculture is low SSA compared to Semi-arid and Arid zones in Africa. In Nigeria, for example, irrigation is less than 0.5 percent of the total agricultural land equipped for irrigation (Takeshima and Adesugba, 2014). That is about 2.3 million ha of land, with over 1 million ha in the north (FAO, 2019). Achieving the SDGs agenda by 2030 is an ambitious but not impossible undertaking. The case of SDG 2, which is set to address food security, comes with many challenges in SSA. Such as underutilization of the agricultural potentialities despite the high increase in demand for food. It is not a coincidence that funding for agriculture, food security, and rural development by development banks and development organizations.

Many drainage projects that are not adequately managed often lead to too many negative side-effects (Blann et al., 2009).Agricultural land drainage profession has lost some credibility, especially in industrialized countries around the world (Oosterbaan, 1991). However, many countries around the world, such as in Africa, especially the ones in arid zone practicing irrigated agriculture, benefit from agricultural land drainage. Egypt stands out as a role model in drainage development, where irrigated agriculture was not possible without well-conceived drainage to control the twin problem of salinity and waterlogging. Irrigated agriculture is increasing in the region. Hence, it is timely to highlight the issues of agricultural land drainage at all levels. This is an opportunity to work within Africa and bring expertise from Africa, to make better a food secured Africa that we want sustainably. The study will, therefore, contribute to the sustainable developments goals, particularly goals one, two, six, and thirteen as well as the first aspiration of agenda 2063 for inclusive growth and sustainable development.

1.5 Thesis Outline

This thesis has six chapters. Chapter 1 presents a general background, problem statement, objectives of the study, as well as its relevance to Nigeria's public irrigation schemes. The literature review on exploring the relevant theories and published research work is covered in Chapter 2. Chapter 3 adequately described the study area. Chapter 4 discusses the materials and methods applied in collecting, preparing, and analyzing data. Chapter 5 presents the results and discussion. Finally, Chapter 6 presents the general summary, conclusions, as well as the recommendations for future research.

1.6 Encountered Research Obstacles

My time in Nigeria was relatively short, and I arrived during the 2019 gubernatorial elections, which shorten my data collection time. The preferred scheme for my research was the Bakolori Irrigation Scheme in Zamfara State, which was not possible to visit due to the insecurity status of the insurgency going on. I failed to secure adequate inputs data for water balance and modeling for the initially proposed three irrigation schemes (Kano River Irrigation Scheme, Hadejia Valley Irrigation Scheme, and Bakolori Irrigation Scheme). At last, I settled to work in the Kano River Irrigation Scheme. It was ranked to be the best in a review of public irrigation schemes in Nigeria in 2014. I could get some data which were irrelevant and could not get as simple as the layout of the project, which I ended up working on. This explains the differences in my proposal and the actual research work. However, the obstacles did not compromise the overall research objective.

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

Reviewed literature drew from several primary and grey sources. However, the dearth of research in drainage and drainage related issues, especially in Nigeria, extended our search beyond the last decade. The main keywords of our search include; irrigation, drainage, land drainage, agricultural land drainage, drainage management, and water management all used in combination vis-à-vis the case study area and beyond. The leaders in the field of drainage research became a guide by digging into their works, and the organizations where they are mostly employed are well-known internationally. The articles studied are scattered over various types of journals like Irrigation and Drainage Engineering, Irrigation and Drainage Systems, Agricultural Water Management, ICID Bulletin; conference proceedings; annual reports; reports from international organization like FAO, ICID, ILRI, IPTRID, IWMI; government documents, theses, dissertations, project documents, databases like ScienceDirect, Google Scholar, AJOL, AGRICOLA, AGRIS, CAB Abstract.

2.2 Agricultural Land Drainage

The term 'land' and 'agricultural' drainage are used interchangeably in the literature (Scheumann, 2015). The word 'drainage' is ambiguous and could be understood differently in different disciples of geography, pedology, engineering, or hydrology. An encompassing system definition by (Oosterbaan, 1991) states, 'Agricultural land drainage systems are systems by which the flow of water from the land is made easier so that the agriculture can benefit from the effects of the subsequently reduced degree of water-logging and the subsequently reduced presence of soluble toxic substances". (ICID, 1979) defined and drainage as 'the removal of excess surface and subsurface water from the land to enhance crop growth, including the removal of soluble salts from the soil. Naturally, drained areas subjected to irrigated agriculture are prone to salinity and waterlogging. Hence, it requires artificial drainage in water management systems to be sustainable (Ritzema & Schultz, 2011; Vlotman, 2017). Globally, gravity or flood irrigation, despite identified as inefficient remains the most practiced (Frisvold, Sanchez, Gollehon, Megdal, & Brown, 2018). For instance, in southern Europe and the western United States, most irrigation has been based on gravity-fed systems (Masseroni et al., 2017). According to ICID, (2018) latest estimate, only 10% of world 1815.756 million ha arable and the permanent cropped area is drained mostly in developed countries, consequently, the twin problem of salinity and waterlogging problems affect between 10 to 16% of these areas because natural drainage is not sufficient for controlling soil salinity levels (Ritzema, 2016). With over 324 million hectares are equipped for irrigation, and 275 million ha are under irrigation (FAO, 2014), it was estimated that existing systems would have to be replaced or modernized in about 30 million ha with another 30 million ha provided with new systems. The average cost as estimated is around € 1,250/ha which will require an investment of about € 19 billion or € 475 million annually over the next 40 years and even more if this is re-calculated (Ritzema, 2014). Irrigation was not possible in Egypt until drainage systems were provided (Hussein, n.d.). Currently, over 2.4 million ha the area have improved drainage and 1.9 million is provided with subsurface pipe drainage (Molle et al., 2015). Intensive irrigated agriculture has gone to the point of hydrological cycle modification (Foster et al., 2018), and care must be taken to look from a basin-wide approach.

In the international water discourse, drainage has not gained the necessary attention until recently (Scheumann and Freisem, 2001), drainage was brought up and firmly placed in Integrated Water Resources Management (IWRM) at the ninth International Drainage Workshop (IDW9, 2003) in Utrecht, the Netherlands. By the 12th International Drainage Workshop (IDW), 23-26 June 2014, St. Petersburg, Russia, the theme focused on drainage on waterlogged agricultural areas with most of the cases turning around the sustainability of irrigated agriculture (Vlotman, 2017).

According to the latest (ICID,2018) estimate of world irrigated areas, about 0.325 million ha of areas are irrigated in 2010 in Nigeria. Despite being an active member of ICID since 1970 and represented in many working groups, the estimated artificially drained regions are yet to be available. The level of salinity and waterlogging in KRIP is not sufficiently studied. Few studies like that of (Jibrin et al., 2008; Adamu et al., 2014) assessed the fertility status at the irrigation project area, (Maina & Amin, 2012) evaluated the soil salinity levels at Kadawa sector of KRIP, (Adamu et al., 2014) assessed the fertility status at the Kadawa sector of KRIP and (Sanda and Dibal, 2014; Mohammed et al., 2015) assessed the irrigation water quality all at Kadawa sector of KRIP. The trend of research being carried out in the KRIP is concentrated in the Kadawa sector because of the research station of the Institute for Agricultural Research (IAR), Ahmadu Bello University, Zaria. All studies highlighted above report tolerable but not allowable levels of salinity, fertility, and irrigation water quality. A survey conducted during 2006/2007 irrigation season to assess the condition of drainage facilities of Kore sector of KRIP (Salisu et al.,2014) surveyed 378 field drains and 46 collector drains out of which 53.44 % are not functioning as a result of blockage, cropping, waterlogging, weed infestation and merger with the rest of the farmland. Also, current hydraulic capacity of the drainage in the Kore sector were evaluated against the design carrying capacity (Oyebode et al., 2014). The results showed that carrying capacities of the field drains are 0.16, 0.49 and 0.54 m^3/s as sampled in three sections of the Kore sector surpassing the design value of $0.03 m^3/s$. In general, drainage related problems researched in KRIP were purely scientific based. To the best of our knowledge and extensive literature research, specific drainage management issues from the engineering perspective is a novel area in KRIP and should be given attention.

2.3 Benefits of drainage

Drainage is vital as a water management measure to protect irrigated lands against waterlogging and salinity. According to Ritzema et al., (2006), the installation of drainage systems over the last 50 years not only prevent waterlogging and root zone salinity, but it also increases crop yield and rural income. The cost-effectiveness of the drainage systems has been demonstrated in the work of (Ritzema and Schultz, 2011). Waterlogging and salinization have been reported to be a threat to some 100-120 million ha of irrigated land in arid and semi-arid regions, and an estimated 20-30 million ha are severely affected. The problem is growing by 0.5-1.0 million ha per year (FAO, 2001; FAO, 2002 and FAO, 2011). Some of the benefits of drainage and drainage interventions around the world have proven to be promising as will be highlighted with the following experiences.There is abundant evidence of drainage benefits across the globe (Ritzema, 2016). Notably, the countries that have one form of drainage intervention or research on drainage have well-documented results of successful (sub)surface drainage installation.

In India, the RAJAD Drainage Research Project to solve the problem of soil salinization in the Chambai command area, Rajasthan. The project was implemented on 50 – 180 ha experimental site to test subsurface drainage systems from the perspective of water table control, cost-effectiveness, and crop yield. The analysis showed improvements in quality of produce, improved water table control, crop diversification and 150 to 180 percent cropping intensities. Farmer's return of investment in drainage if fully financed, would be 240 percent. The installation cost stands at US$ 815 / ha with 28 percent internal rate of return (FAO, 2001).

In Egypt, the story of irrigation and drainage has exceeded centuries of development. The Egyptian Public Authority for Drainage Projects (EPADP) builds on average 65,000 hectares annually and, rehabilitates on average, 28,000 hectares old systems (Abdel-Dayem et al., 2007).

At present, it runs the National Agricultural subsurface Drainage , Phase 3 project. The success is behind a nationwide monitoring programme installation of subsurface drainage which resulted in an average 30% decrease in the depth of the groundwater levels, a 35–50% decrease in the areas affected by soil salinity, 10 – 30 % yield increase for a variety of crops, US$ 200 – 375 (25 – 40%) of net farm income per hectare.

2.4 Drainage Integrated Analytical Framework (DRAINFRAME)

The Drainage Integrated Analytical Framework (DRAINFRAME) originated from a collaborative Work program between the World Bank's Agriculture and Rural Development Department and the Irrigation and Water Engineering group at Wageningen University, the Netherlands (Pant, 2000 and Knegt, 2000). The study involved six country cases studies covering different drainage situations followed by literature review, field study plan, workshop with key stakeholders from each country with representatives from the World Bank, the Food and Agriculture Organization, the International Institute for Land Reclamation and Improvement, the International Programme for Technology and Research in Irrigation and Drainage and the Wageningen University. The study was reviewed by internal and external reviewers' and first presented to the public at the *Ninth International Drainage Workshop*, in Utrecht, the Netherlands (Abdel-dayam et al., 2004). DRAINFRAME was developed explicitly for planning drainage interventions from an integrated perspective through a framework of trade-offs related to the different functions and values associated with the drainage of thinking, and a systematic methodology (Abdel-Dayem et al., 2004, 2005).

2.4.1 Functions and values analysis and assessment

The DRAINFRAME is a tool that operationalizes the approach by analysis of functions of a natural resources system and assessment of the values attributed to those functions by their stakeholders. The study and assessment procedure is embedded in a participatory planning process and recognizes three main settings (Figure 2.1): (i) the resources subsystem (ii) societal subsystem (iii) land and water control subsystem

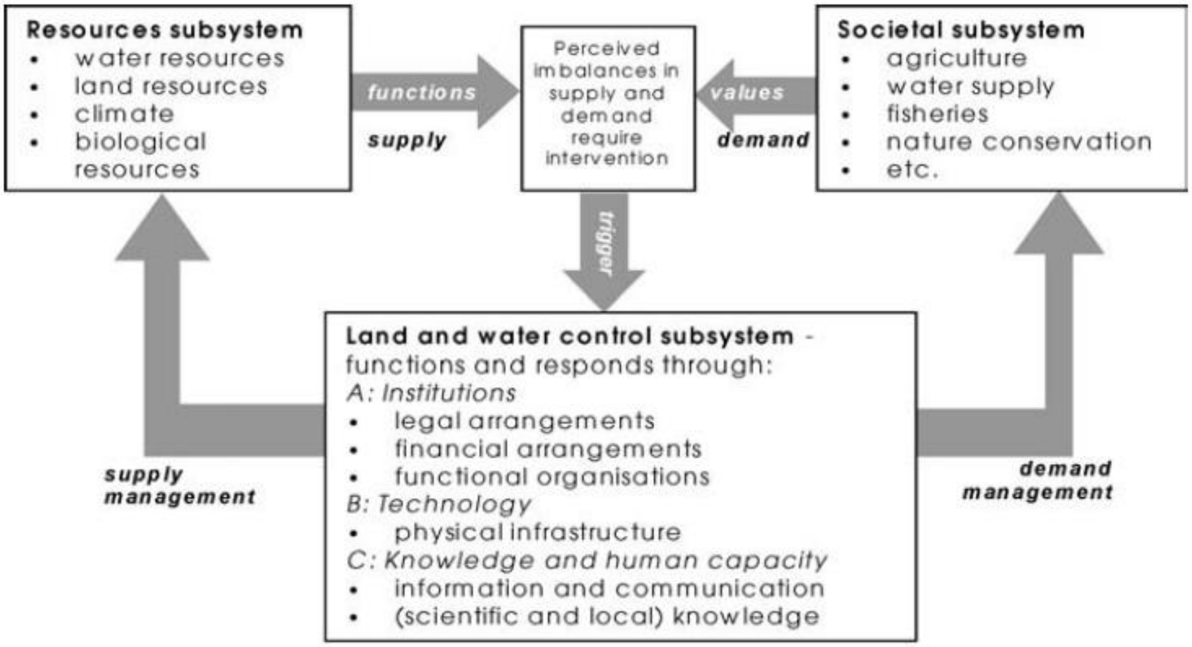

Figure 2.1: Functions and values analysis and assessment

Source: Adapted from (Slootweg et al., 2001)

The goods and services that natural resource systems provide and perform are called '*Functions*'. The simplified classification of R S de Groot (1992) combined with the theoretically and more appropriate classification of W T de Groot (1992), provides four distinct categories of environmental functions: production; processing and regulation; carrying; and signification functions (Slootweg et al., 2001).

1. Production functions refer to the ability of the natural environment to generate useful products for humanity.
2. Processing and regulation functions relate to the maintenance of ecosystem support systems.
3. Carrying functions are related to space or a substrate that is suitable for specific activities and for which there may be a demand and,
4. Signification functions refer to the social values that are ascribed to nature itself and other features of the landscape, including the human-constructed landscape.

2.4.2 Application of DRAINFRAME

The DRAINFRAME approach has been tested in three world Bank-funded projects in real-life situations. The result of this innovative approach always identifies the landscapes, functions, issues, and stakeholders in an integrated manner and easy way for policy and decision making. The stage of a given project does not qualify or disqualify the application of DRAINFRAME as it has been demonstrated to be applied in any case concerning the mandate of the project and policies of the region as will be presented in the following sections.

(a) The Mahmoudiya command area situated in the Nile Delta in Egypt.

This area is part of the Integrated Irrigation Improvement and Management Project (IIIMP), co-financed by the government of Egypt, KfW, the Netherlands government, and a donor aid from the World Bank. KfW and the government of the Netherlands. The command area spans 200 000 ha and lies with the Nile Delta. The project utilized directly the problem analysis flowchart and mapping of landscape, functions, issues, and stakeholders following Fahmy (2005) was produced (Figure 2.2). Although the team could not arrive at a satisfactory institutional analysis mainly because of time constraints, vital questions raised found answers that enhanced the IIIMP. The questions raised were based on the projects inherent problems and IIIMP description;

1. Does the IIIMP recognize the diversity of water management situations and adapt its measures to the different situations?
2. Does IIIMP take into account the different functions of water, inside and outside the project area, their respective stakeholders and their values?
3. Are the IIIMP measures contributing to solving the basic problems of the area?
4. Will there be a systematic assessment of the impacts of the proposed measures on stakeholders inside and outside the project area?
5. Are mitigating measure considered in case of adverse effects for stakeholders inside and outside the project area?
6. Will institutions be established and function, which reflect the representation of stakeholders in planning and decision making?

The mandate of the Ministry of Water Resources and Irrigation was key in answering the questions, and this should be the case in any country. However, many countries do not even have a clear mandate. In Nigeria, for example, National water policy and strategies are well documented but the implementation is still yet to become fruition.

The IIMP project is tailored towards water quantity management in the project area for agricultural use. Therefore, questions 1 and 2 could not find answer. Questions 3 and 4 addressed part of the issues of salinity hazard and water distribution inequity and water quality remains unresolved. The EIA resulted to an Environmental Management plan to take care of question 5, and the formulation of Water Users Association and Collectors Users Association who will be involved in planning and decision making was considered for question 6. This is a case of DRAINFRAME application in an intervention project.

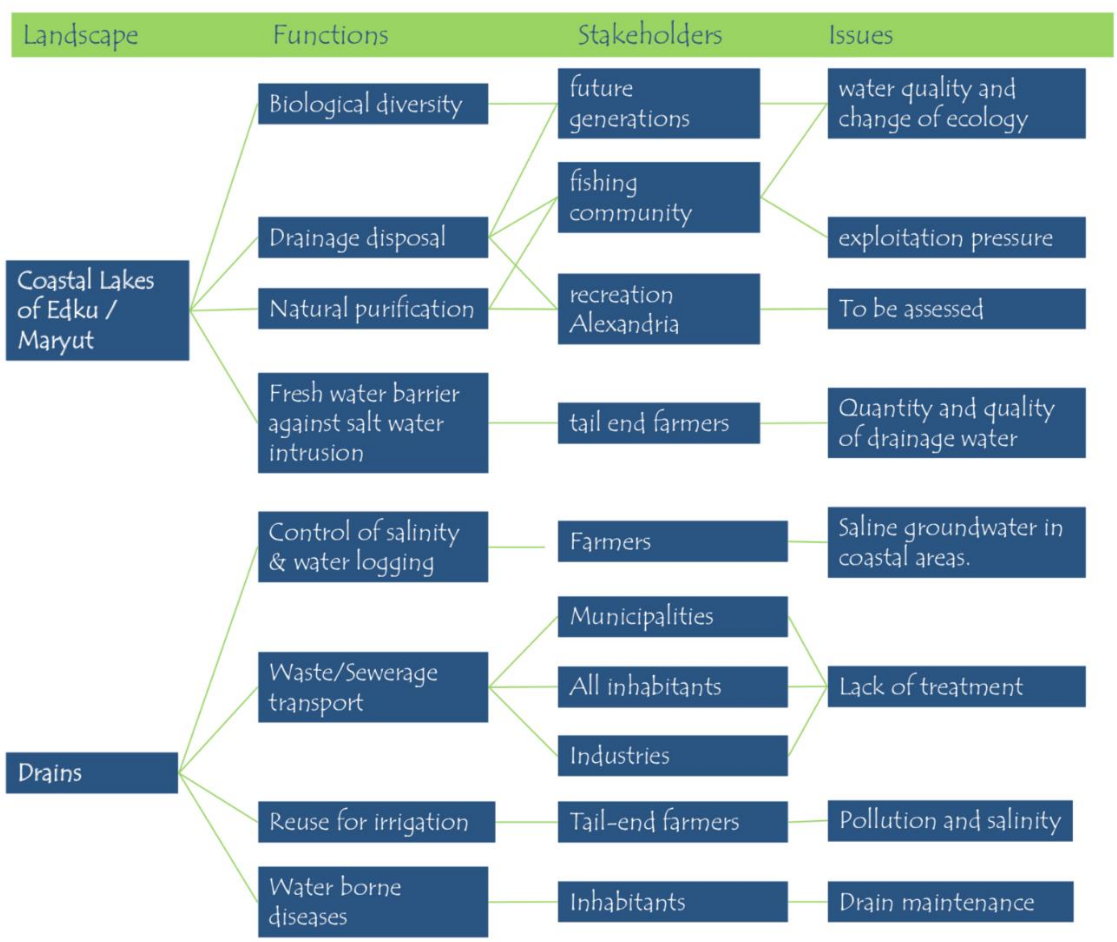

Figure 2.2: Flowchart and mapping of landscape, functions, issues and stakeholders

Source: Adopted from (Christen et al., 2005)

(b) Drainage Master Plan for the Indus Basin located in Pakistan, which offered an opportunity for a rapid DRAINFRAME appraisal at a strategic policy level.

The DRAINFRAME methodology applied for the Kotri Basin revealed the issues in water management and landscapes were well-connected with specific sets of functions. It was summarized that the underlying causes of these issues were in three precise levels:

1. The constraining resources (like limited water availability);
2. Water use practices that are inappropriate (like inefficient irrigation practices); and
3. Inadequate water management institutions and arrangements. Based on the analysis of the main issues.

(c) West Delta Water Conservation and Irrigation Rehabilitation Project which is situated on the western fringes of the Nile Delta in Egypt, in which the DRAINFRAME analysis contributed to an impact assessment process from a strategic plan to actual project design. The impact of alternative project concept was quantified using innovative part of this DRAINFRAME and expected changes occurred in the resources system, and description of their effects on functions of resources, and the impact on societal values of these functions were highlighted. It is noteworthy to mention that simple mathematical equations were utilized with two computational (One simulates water availability and yields relations for the entire Nile Delta, the other model simulates groundwater behavior in the West Delta region, including the project area under the influence of groundwater exploitation) (Slootweg et al., 2007).

Two cases studies in Egypt and Pakistan showed the value and appreciation of the DRAINFRAME concept and its usefulness as a tool to integrate all functions, stakeholders and issues raised by the stakeholders. Based on these successes, Christen et al., (2005) investigated the DRAINFRAME and European Union Water Framework Directive as an option to apply in Australia. Since DRAINFRAME is already a potential tool and framework that will help to achieve IWRM, the investigation concluded that combining DRAINFRAME and the European Union Water Framework Directive could be used to make the Living Murry (Murray Darling Basin) objectives.

2.5 Application Remote sensing and GIS in irrigation drainage studies

In any irrigated agriculture especially in arid and semi-arid regions and with the percentage of surface irrigation standing at over 80 % (FAO, 2014; ICID, 2018), waterlogging and salinization are predominant(Ritzema, 2016; Ritzema & Schultz, 2011; Singh, 2018). To use remote sensing and GIS for impact assessment, we reviewed the most recent studies on the use of remote sensing and GIS techniques in drainage studies.

Remote Sensing (RS) and Geographical Information System (GIS) have widely been applied to the various analysis of earth surface with changing space and time (Sahu, 2014). The development of remote sensing technology has provided an economic and verified efficient way for land cover monitoring. For instance, the monitoring of cropland changes along the Nile river in Egypt over past three decades (1984–2015) using remote sensing technology was carried out by (Xu et al., 2017) to ascertain the remarkable influence of anthropogenic activities and climate change. A significant study gap in South Africa on uncertainties in investment and policymaking led to mapping irrigated areas in Limpopo Province (Cai, Magidi, Nhamo, & van Koppen, 2016). In India, RS and GIS were used to assess surface and sub-surface waterlogged areas in irrigation command areas of Bihar state (Chowdary et al., 2008). The study highlighted that RS and GIS techniques are excellent alternatives for conventional mapping techniques, which requires a long time and more resources in monitoring and mapping of surface and sub-surface waterlogged areas. The management of salinization and drainage problems in irrigated areas with RS and GIS techniques was demonstrated by Singh, (2018). Drainage studies have become easier even at regional scales in recent time. Also, the spatiotemporal dynamics of waterlogged areas can be monitored with Landsat imagery. A study in Bangladesh demonstrated the use of Landsat imagery from 1973 to 2015 using the random forest algorithm in R studio (Islam et al., 2018). Studies in mountainous regions where accessibility is highly limited have been carried out around the globe using remote sensing, and GIS techniques to assess LULC changes for example (Yi et al.,2016) evaluated the effect of landscape patterns in the mountainous area.

RS is an indirect method of monitoring with sensors, some indices such as NDVI, NDWI and, NDMI are handy in estimating waterlogging (Ganie & Nusrath, 2016; Kaushik et al., 2018; Sahu, 2014).

Not many RS and GIS application in irrigation studies have been done in Nigeria, especially in the KRIP command areas. However, with the TRIMING transformation in progress, few studies have been made but mostly yet to be in public disclosure. Therefore, our estimation of waterlogging areas in the KRIP command area becomes a contribution and tool that will be handy to policymakers, water managers, water users, and, development organizations.

2.6 Participatory Irrigation Management (PIM)

According to David Groenfeldt in a World Bank publication of Case Studies in Participatory Irrigation Management (PIM) (World Bank, 2000), the term PIM, can be defined the involvement of irrigation users at all levels and, participation in all aspects of irrigation management. In this context, all aspects include the initial planning and design of new irrigation projects or improvements, the construction, supervision, financing, decision rules, operation, maintenance, monitoring, and evaluation of the system. Also, all levels refer to the full physical limits of the irrigation system, up to the policy level in the capital city, say federal. Any management function, including the setting of policies, can and should have a participatory dimension to it.

According to Musa (2001), National Council of Water Resources (NCWR) mandated the adoption of PIM in all public irrigation schemes in Nigeria. Before that time, participation has been broadly defined by the World bank since 1992. PIM was implemented in different stages and under various collaborations by Centre de coopération internationale en recherche agronomique pour le développement (CIRAD)in 1993 as (Agency Farmer Joint Management) AFJM (Othman and Abubakar, 2004) in KRIP. The impact of PIM in KRIP is positive on crop diversification, increased income, increased yield, and food security. In an unpublished Ph.D. Dissertation, Salisu (2015) studied the impact of PIM on the livelihood of Water Users in KRIP. The study indicates a high level of participation (84%) by the surveyed farmers to PIM. Activities include clearance of the weed-infested and silted up canals (FCs and DCs).

The TRIMING project introduced in chapter three of this report designed a model for the implementation of PIM based on a thorough survey. The survey employed several matrices and questionnaires in parallel with capacity building to identify the level at which water managers and users understand their roles. The studies revealed a significant contradiction in the current perceptions of the functions of the Water Users and Water Managers (the Agency). The tasks of Water Users and Water Managers are no only unclear but are not defined by the water managers. The improved proposed structure of PIM for KRIP and HVIP is shown below.

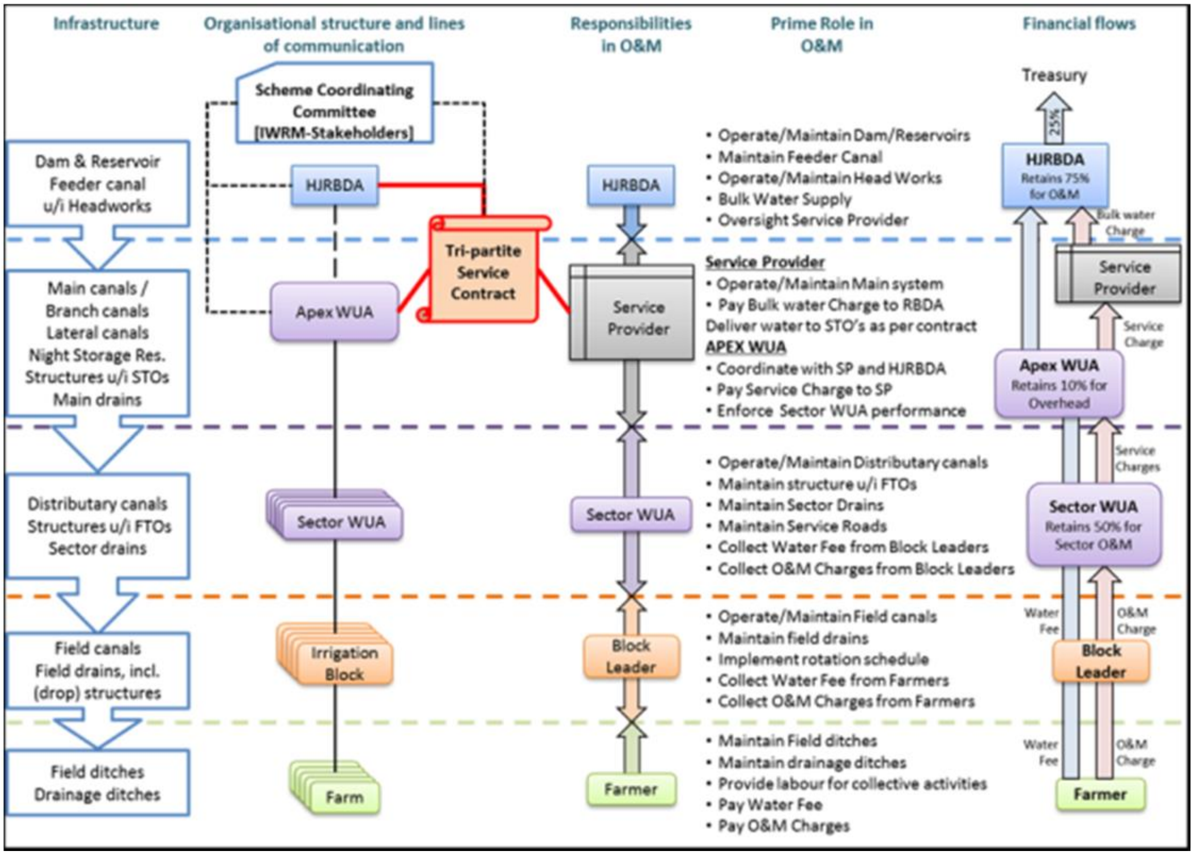

Figure 2.3: Improved PIM structure for KRIP and HVIP

Source: (FMWR, 2016)

2.7 Waterlogging and Salinity and Sodicity

The current irrigation practice in KRIP has contributed to the rise of the groundwater enhanced by the cropping of rice, which requires permanent wetting through the growing phase. According to (Shevah, 1993) in the feasibility report for the extension of KRIP, the major causes of salinity and waterlogging are irrigation over the crop water requirements and the high seepage from the unlined tertiary and field canals. Other problems identified by various researches carried out in KRIP are inadequate drainage and over the use of organic fertilizers by farmers (Maina & Amin, 2012), poor quality of drainage water used for irrigation (Sanda & Dibal, 2014). In a draft feasibility study on the Transformation of Irrigation Management in Nigeria. Detailed and extensive soil salinity and sodicity analysis were conducted. The study compared the salinity and sodicity of 1974 and 2015 to assess the level to which the soil has become saline and sodic. The Cation Exchange Capacity (CEC), Exchangeable Sodium Percentage (ESP), Electrical Conductivity of a saturated soil extract (ECse), Sodium Adsorption Ratio (SAR) were calculated (Table). The survey examined irrigated and non-irrigated area for comparison of results. Although all average values present an encouraging situation, the local values are well above limits and deteriorating exists and will escalate if left with any mitigation measures. The distribution of parameters tested (Apendix 1) within the scheme are presented spatially to highlight the overall situation.

Table 2.1: The comparison of soil salinity and sodicity parameters of 1973 and 2015

Soil Salinity and Sodicity Parameters	1973	2015
pH KCl 1:5	5.61	6.90
ECse (dS/m)	0.49	3.44
SAR	0.28	0.25
ESP (%)	6.40	4.52
Na (cmol+/kg)	0.31	0.34
Ca (cmol+/kg)	1.96	2.71

Source: (FMWR, 2016)

Some of the recommendations drawn from the analysis include;

1. Institution of a monitoring system to monitor soil and irrigation water.
2. Management practices such as cropping patterns, crop rotation, under-irrigation (to reduce waterlogging), over-irrigation combined with controlled drainage (for leaching requirement) will help in curtailing the aggravated consequence.
3. Sodic soils are difficult and costly to remediate. Hence, prevention is pertinent and will preserve the soil as well as the accompanying cost of restoration.

2.8 Cropping Pattern

The present cropping pattern in KRIP was based on the crop production data provided by HJRBDA over the last ten years. It is observed that cropping patterns in the original project feasibility studies (NEDECO 1974,) of the previous four decades is very different from what is practiced at present. For instance, rice is the dominant wet season, and crops like wheat and vegetables are also grown. Consequently, rice is grown in dry seasons, and this is contrary to the original cropping pattern of the scheme. This is one of the main issues identified during the field study. Lack of water sufficiency to tail-end farmers is one of the consequences of such action. The projected cropping pattern of KRIP after rehabilitation and full completion (Table 2.2) of the scheme is estimated in the recent feasibility report of TRIMING in 2016 (FMWR, 2016). This is also in line with data provided by HJRBDA; Table 4.8 shows the current cropping pattern.

Table 2.2: Projected cropping pattern after rehabilitation and full completion of the scheme

Crop	Dry season	Wet Season
Rice	-	6,989
Sorghum	1,891	4,728
Maize	-	1,891
Tomato	4,728	1,891
Legumes/Oilseed	1,130	1,891
Vegetables	2,837	-
Onion	3,782	-
Cowpea	3,022	-
Fallow	1,932	1,932
Total arable land	19,322	19,322
Cropped area	17,391	17.391

Source: (FAO & FMWR, 2016)

Table 2.3: Present cropping pattern of KRIP

Crop	Dry season	Wet Season
Rice	5,200	13,300
Sorghum	-	234
Maize	2,500	2,600
Tomato	3,000	1,891
Legumes/Oilseed	-	50
Vegetables	176	-
Onion	1,300	-
Wheat	1,550	-
Cowpea	120	95
Fallow	65	11
Cropped area	13,991	16,169

Source: (HJRBDA crop production 2017/2018 dry and 2018 wet seasons)

2.9 Crop yield response function

The cropping pattern of FWO is expected to remain the same without an improved irrigation water supply and drainage infrastructure, proper operation and maintenance as well as monitoring of the overall scheme performance. However, the cropping intensity is likely to be altered by increased waterlogging and salinity, which will bring about a decrease in crop productivity.

Maas and Hoffman (1977) developed a salt tolerance function of crops subjected to salinity. They suggested that salt tolerance of a crop is described by plotting its relative yield as a continuous function of soil salinity. The best application of this function can be seen in the report of crop salt tolerance under controlled field conditions in The Netherlands, Arjen et al., (2016). The response function follows a sigmoidal relationship for most crops. Hence, they further proposed that a tolerance plateau with zero slopes and, a concentration-dependent line with slope indicating the yield reduction per increase in salinity be represented by the response curve. The threshold limit represents the point at which the two lines intersects. That implies that the maximum soil salinity does not reduce crop yield below that which is obtained under non-saline conditions. Relative yield (Y_r) for soil salinities beyond the threshold can be estimated with the following equation:

$Y_r = 100 - b\,(EC_e - a)$--(1)

Where: EC_e = (1 dS/m =1 mmho/cm)

a = the salinity threshold (dS/m = 1 mmho/cm);

b = the slope (dS/m)

NB: EC_e is the mean electrical conductivity of a saturated paste taken from the root zone.

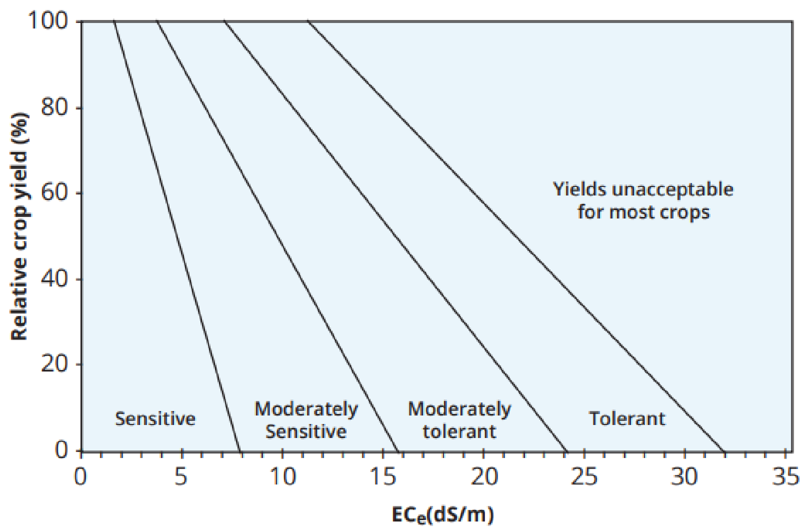

Figure 2.4: Division for classifying crop tolerance to salinity

Source: (Maas and Hoffman, 1977)

In the revised version of Irrigation and Drainage Paper No. 29 of FAO, the extensive list of crop salt tolerance data was published. Later on, Maas and Grattan (1999) have updated and published records of salt tolerance data with explanatory sections.

2.10 Research Gaps

Agriculture was and is still the cornerstone of the Nigerian economy irrespective of the crude oil it currently dependence. According to Aigbokhan (2001), agriculture contributes 63% and 54% to the Gross Domestic Product in the 1950s and 1960s, respectively. Also, 65% of the Nigerian labor force is employed in agriculture (Emeka,2007). The situation is not the same as the discovery of oil and other factors like poor management of the over-aged infrastructure and absence of monitoring of environmental matrices across the board.

KRIP is the first public irrigation scheme in Nigeria, and all other projects were modeled based on the lessons learned. Based on the reviewed literature, research in KRIP (Mohammed, 2015; Jibrin et al., 2008; Maina & Amin, 2012; Oyebode et al., (2014) is tailored towards the physical evaluation (soil fertility, crop cultivation, crop multiplication, water quality, sedimentation studies) and farmers evaluation (farmers livelihood,economic and financial analysis) of the scheme and conclusions with recommendations that are more generic. There is a paucity of research to look at the water use system, management, monitoring, and looking from an integrated perspective. Only one study attempts to look at the water use system integrating stakeholder participation (Ahmad, et al, 2018). We identified the DRAINFRAME a systematic approach which dares to look at all the costs and benefits of drainage as well as the problems and opportunities in an integrated manner. Although the time and resources within the research of this study is limited, we have attempted to do justice with the available data generated.

CHAPTER THREE: METHODS

3.1 Study area

3.1.1 General description

The area is located in the Kano State of Nigeria in Bunkure, Kura and Garun Malam Local Government Area of Kano State between latitudes 11° 30' and 12° 03'N and longitudes 8° 30' and 9° 40'E (NEDECO, 1974) Kano River Irrigation Project, Phase I (KRIP I) is part of the Kano River Project which began in 1965 as a pilot project. A study in 1972 due to the growing need of irrigated crop cultivation led to the institution of three models of public irrigation schemes, and Kano River Irrigation Scheme forms part (NINCID, 2015) According to the review of public irrigation sector in Nigeria by (FAO & FMWR, 2004), KRIP rank the best based on the set criteria 40% of which goes to technical. The Kano River Project envisaged the development of 180,000 Acres (72,840 Ha) for irrigated agriculture along the Kano River. The study area covers potentially irrigable land of 22,000 Ha, which forms the study area. To this end, the area developed for irrigation is 16,500 Ha while the area cropped ranges between 13,900 ha for dry season and 16,450 Ha in wet seasons. KRIP I is a unique design, in that, the entire water distribution network operates on gravity owing to the elevation of 440 meters above sea level, with a minimum of the supply dam at 506.50 meters (HJRBDA, 2015).

The irrigable land is situated about 19 km away from the Tiga dam shown in Figure. The project is divided by the River Shimar into East and West branch according to their geographical locations. The west branch is 13,630 Ha in extent and bound by the Kano river and Shimar on the Western side and Eastern side respectively. The East branch 6,648 Ha in extent and lies to the East side of River Shimar and Gayere branch which takes off upstream of the Garum Baba Regulator serves three sectors. The project has a total of 48 sectors developed and spread within the West, East, and Gayere branch as at the time of writing this thesis. Tiga Dam is the source of irrigation water to the project site through the Ruwan Kanya Reservoir and the 18 km long main canal II, which splits into West and East branch canals.

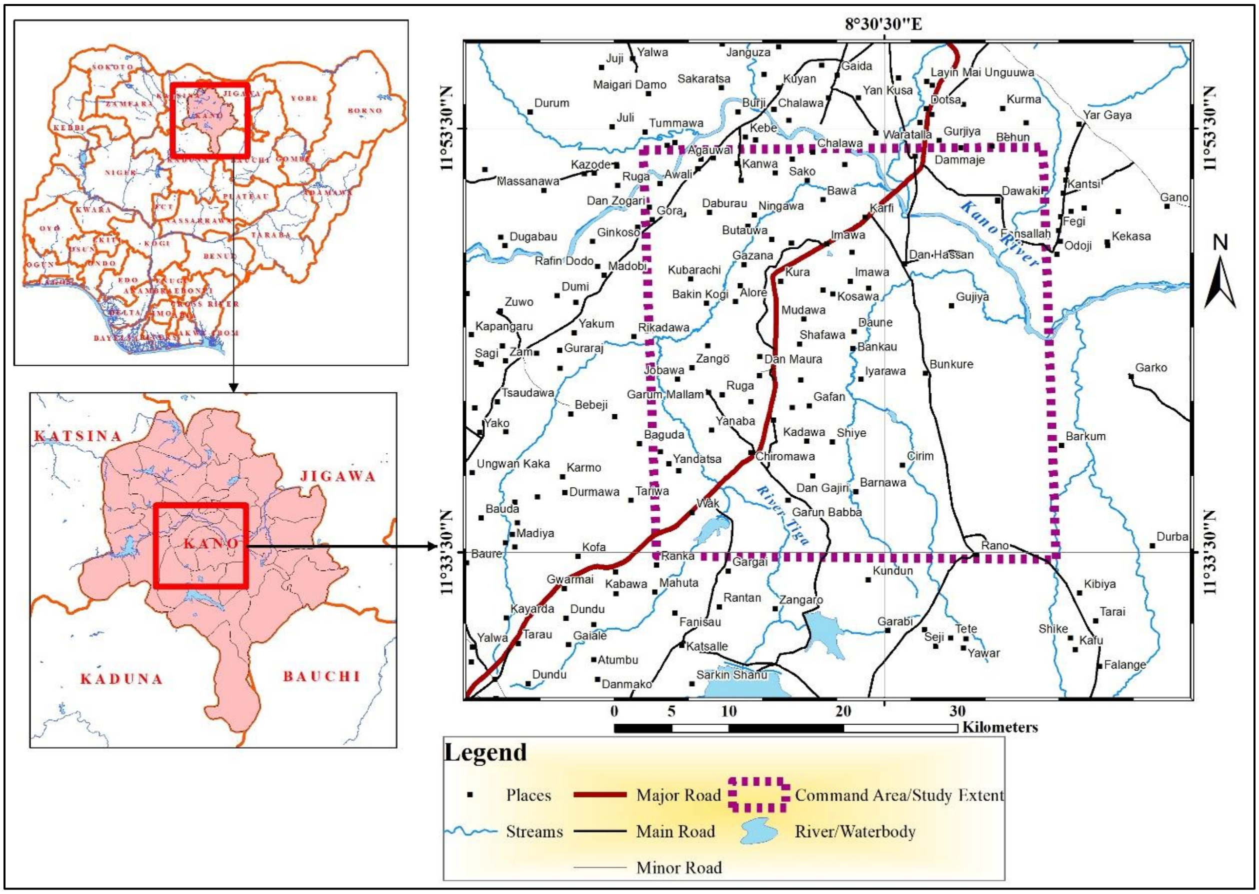

Figure 3.1: The location of the Kano River Irrigation Project Command Area

Source: (Author, 2019)

These are then distributed to all sectors, to sector turnouts, to distributor canals, to field canals and siphoned to blocks or farmlands. The excess is designed to be collected from the end of the field through field drains to collector drains to main drains and back to the kano river as shown in Figure 3.2. Irrigation is not feasible during the night; hence, eight-night storage reservoirs have been planned to store water and release them during the day for irrigation.

3.1.2 Agro-Climatology

Monitoring of climatological parameters in the study area is rarely happening. Therefore, most research adopts satellite or remotely sensed data which is not accurate, and Kano is described in general. According to the agroecological zoning of Nigeria, KRIP is located in the semi-arid region and the classified by Koppen's as Aw. as the tropical dry-wet type. The location experiences four seasons, but mainly two seasons (wet and dry) closely associated with the Inter-Tropical Discontinuity (ITD) zone movement, *Rani* (warm and dry), *Damina* (wet and warm), *Kaka* (cool and dry) and *Bazara* (hot and dry). Rainfall annual mean varies from about 884mm to 600mm in the north to 1200mm in the south. Rain is more in five months (May-September) with August, recording the highest amount and mean annual temperature ranges from 26°C - 33 C. The yearly rainfall amount in Kano is increasing, especially in July and August.

Mohammed et al., (2015).

3.1.3 Soils

The soils analyses of NEDECO in 1974 is the most reliable source of soil information of KRIP I. It has got the details of profile description which is according to the outline given in soil survey manual of the United States Department of Agriculture and soil analyses with annex and land suitability map which we studied to provide this description. The project was developed on the crystalline pre-Cambrian rocks of a basement complex. Rocks types are schist, pegmatite, aplite, granites, gneisses, glimmerschist, quartzites and quartz/ The soils are classified according to their physiography as

1. The upland plain – well-drained, deep, loamy sand, sloping topography;
2. The higher terrace – well-drained, deep, loamy sand, sloping topography;
3. The lower terrace - moderately to poorly drained, deep, loamy sand, irregular topography.

In general, about 90% of the soil was found to be well-drained loamy sand of various depths over laterite or bottom rock, Hence, very suitable for irrigation.

3.1.4 Water resources availability in the reservoir

Tiga reservoir has a capacity of about 1.9 BCM. It was constructed to serve the whole KRIP, water supply for Kano State, and mandatory release downstream (HJRBDA, 2006). The reservoir levels monitored overtime was used to simulate for 40 years period to understand the future dynamics (Figure 3.3). The results show fluctuations in reservoir levels and reduction in 2065 as compared to 2035. This could possibly be as a result of higher demand expectations with time (FMWR, 2016).

3.2 Methodology

Impact of drainage on KRIP was evaluated using the approach of DRAINFRAME (as mentioned in study approach in chapter one and highlighted in the second chapter of this report) an innovative framework, which incorporates, the resources subsystem, societal subsystem, and the land and water control subsystem in a systematic manner. Economic and financial analysis to estimate agricultural benefits and the principle of Participatory Irrigation Management (PIM) forms part of the holistic approach to drainage issues addressed in this study. It should be observed that the stiudy does not include instutional, climate change and policy dimensions such as the study conducted by Mirzaev, 2009. The conceptual flow of the study is shown below (Figure 3.2)

1. To review and evaluate the drainage type in Kano River Irrigation Project.
2. To assess the impacts of drainage using remotely sensed data and GIS techniques.
3. To evaluate the agricultural benefits of drainage system management.

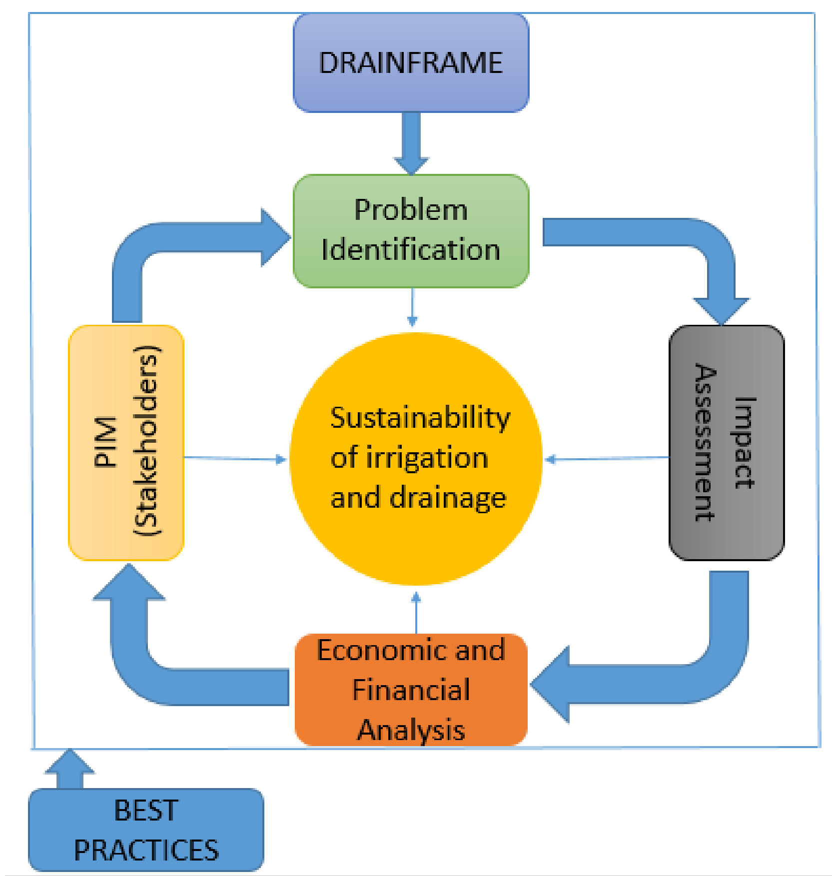

Figure 3.2: General conceptual flow of study approach

Source: (Author, 2019)

3.3 Problem Identification

3.3.1 Methodological approach

This study adopted a qualitative study approach using semi-structured interview, focused group discussion, physical observations, and relevant documents to collect primary data for Kano River Irrigation Scheme in regarding the drainage system. The use of qualitative research was appropriate because such studies are based on exploration (Franfort-Nichimias & Nachmais, 2008), which was the essence in problem (opportunity) identification component of the DRAINFRAME. The absence of technical monitoring data to do a quantitative analysis also informed the choice of the qualitative approach to investigate the raw problem. The idea of employing qualitative research is to **purposefully select** participants or sites (or documents or visual material) that will best help the researcher understand the problem and provide the answer to the research questions raised (Creswell, 2014).

3.3.2 Sample

The problem identification of any drainage related issues will have to be holistic (Abdel-dayam et al., 2004). Therefore, our sample (Table 4.1) cut across various stakeholders to have, to a given extent within the scope of the study a holistic problem identification from top-bottom or bottom-top. In general, the samples from 1 to 10 are considered as water managers, while the samples in 11, 12 and collection of WUA are considered to water users

Letter of introduction was collected from PAUWES and submitted to the Ministers, Federal Ministry of Water Resources (FMWR) and Federal Ministry of Agriculture and Rural Development (FMARD), Institute for Agricultural Research (IAR), Samaru,Zaria,Nigeria, National Agricultural Extension & Research Liaison Services (NAERLS), Samaru, Zaria, Nigeria The International Institute of Tropical Agriculture (IITA) Hotoro, Kano, Nigeria and The Nigerian Meteorological Agency. The letters were directed to the various department relevant to irrigation and drainage. At FMWR, the letter was sent to the director of Irrigation and Drainage. Two letters of introduction to the River Basin Development Authority and TRIMING project office was written to allow me entry into the study area.

Table 3.1: Sample for problem identification

Stakeholders	Designation	
Federal Ministry, Water Resources (FMWR) (Department of Irrigation and Drainage)	1. Director 2. Deputy Director	semi-structured interview
Federal Ministry, Agriculture, and Rural Development (FMARD) (Federal Department of Agricultural Land Resources)	3. Director	semi-structured interview
Hadejia Jama'are River Basin Development Authority (HJRBDA)	4. Managing Director 5. Executive Director (Engineering) 6. Operation and Maintenance (Engineering) 7. Project Manager KRIP	semi-structured interview
Kano River Irrigation Scheme Office	8. Head, Operation, and Maintenance 9. Head, Agriculture 10. Irrigator	semi-structured interview
Water Users Association (Apex)	11. Chairman 12. Secretary	Semi-structured interview
Water Users Association (Sectors and Blocks) covering the 48 or 49 sectors	Chairmen (10) Secretaries (10)	Focused group discussion

Source: (Author, 2019)

The letters were addressed to the Managing Director, HJRBDA and the Project Coordinator,TRIMING. The Managing Director assigned to me the team from the engineering department and KRIP irrigation office for swift conduct of my field study. All of the selected stakeholders for the field study, semi-structured interviews, and focused group discussions have in-depth knowledge of the scheme. All have working experience of 15 to 30 years, and except for the WUA samples, others have university degrees. The sampling technique employed was a snowball sampling technique characteristic of case study approach (Small, 2009; Yin, 1994). This sampling technique identifies beforehand
subcategories of the group being studied and select a given number from each subgroup. Hence, the sample size cannot be predicted before the study. However, initial sample selection was directed on general inclusion criteria based on the institutions involved with irrigation and agriculture in Nigeria. Theoretical sampling was applied by theme emerging from informal and key informant interviews while collecting data collection and analysis. The same sampling was reported according to (Strauss and Cobin, 1990; Glaser and Strauss, 1967) that theoretical sampling is directed towards an emerging theme from concurrent data collection and analysis. Sampling continues within the limited field study time until minimum sufficient data required for the description of the study problem was reached. According to (Creswell, 2014) qualitative researchers organize their data into an abstract unit of information from theme bottom up to and, build patterns and categories. This bottom-up process is inductive and requires working back and forth between themes that keep emerging. Then the researcher looked back deductively at the data to see the missing gap until saturation.

3.3.3 Data Collection

Parallel to the seven (7) weeks (March 12, 2019, to May 6, 2019) field visit in Nigeria, informal interviews were first conducted at the Federal Ministry of Water Resources, the lead agency responsible for irrigation and drainage to identify and understand the challenges in drainage management at the institutional level. Kano River Irrigation Project under Hadejia Jama'are River Basin was selected based on the recommendation of the FMWR staff as the best for drainage investigation.

Data collection happened for four productive weeks. Respondents were convinced to opt for the option of the face-to-face interview due to the nature of the study. When not possible, telephone interviews were conducted. Follow up phone call continued, especially during the writing of the thesis to clarify some ambiguity. Semi-structured interviews for about one hour for FMWR and HJRBDA was conducted in offices at Abuja and Kano respectively. While semi-structured interviews for Kano River Irrigation Scheme Office, Water Users Association Apex and Water Users Association in sectors were conducted in the field (irrigation command area), this was the most crucial part of my study because it allows physical observations of irrigation and drainage infrastructure and real-life problem identification of drainage related issues. The FMARD could not be visited for the semi-structured interview, although, the informal discussion conducted was sufficient.

The interview protocol guide for situation-specific (Maxwell, 2005) was adopted for all the respondents during the interviewing process. The guide is also recommended by Spradley (1980) as it allows for expressions of experiences and stories. A convergent interview technique was employed and found appropriate for the interview because the study was exploratory and allow gradual convergence as the research data is interpreted (Boyatzis, 1998).

The introduction part of the interview was explained to all respondents that the focus of the research is to understand the drainage and drainage related problems, for example, institutional roles at the federal level, management roles at river basin level, WUA roles at all levels and farmers role at farm level concerning drainage management. Interview questions asked about: the challenges in the past and main impacts of drainage management, the cropping system, and design of the irrigation and drainage system. Also, the operation and maintenance procedures adopted in the management (Soil and Water) of the drainage systems in your irrigation processes agricultural production, recent cases of policies and interventions and irrigation schemes and the decisions that went into the most recent adoption of the operation and maintenance procedures for irrigation processes and soil and water management.

3.3.4 Data Analysis

According to Creswell (2014), the steps for analyzing various qualitative data should be specified. In this context, the DRAINFRAME was suitable for this research and, therefore used in analyzing the collected data from interviews, documents, and physical observations. Data analysis proceed hand-in-hand because text and image data collected are so rich and dense. Therefore, proper identification of what is useful for the research must be considered (Guest,MacQueen, & Namey, 2012). In qualitative research, many themes and, but the impact of this process is to integrate the data into a small number of themes, of say five to seven themes (Wisdom & Creswell, 2013). The conversations during semi-structured interviews meetings happened in English at the ministries and the River Basin Development Authority, and mostly in the *Hausa* language with the farmers and irrigators. The interview notes and audio record read and heard back and forth to capture the emerging themes. In an ideal situation, coding software should be learned utilized. However, the time of the research and, specifically, the data collected did not permit the researcher to go to that length. The researcher happened to speak the *Hausa* language as a mother tongue. That played a role (Creswell, 2014) in analyzing the interview notes and audio record. Uncertainties and biases were avoided as much as possible by verifying and linking with literature.

3.3.5 Ethical Considerations

As highlighted, before going to the study area, the permission needed was obtained following the due process, as highlighted in the sampling section of this report. Also, the identity of the respondents remains anonymous to maintain secrecy and protect any vulnerable person (Wisdom & Creswell, 2013). Hiding identities became necessary due to the nature of the irrigation scheme studied, which is public and, indeed, sensitive in the Nigerian context. Some respondents did not take part in the interviews, and some declined audio recording during the meetings. Hence, notes were taken in such cases.

Interestingly, most of the respondents that refused the audio recordings provided rich and vital information that would not have emerged in a recorded condition. Thus, analysis and interpretation were also made anonymous with identification known only to the researcher. The final data analysis used summaries of the results from field and interviews. In the end, all recordings were transferred into a computer with an administrative password and deleted after the thesis defense.

3.4 Impact assessment

3.4.1 Methodological flowchart

The methodological flowchart (Figure 4.3) summarizes the method used in assessing the impact of waterlogging and LULC trend within and beyond the KRIP command. Series of dataset were collected to produce the waterlogging area as well as the LULC maps of the KRIP command area.

These include DEM, Landsat Landsat (TM), Landsat 8, ground truth points, existing soil suitability maps, KRIP base maps for soil salinity and fertility of KRIP intervention feasibility, soil sampling points and various statistics from literature.

The mapping procedure included data collection, processing, accuracy assessments, and map generation as detailed in the flow-chart in figure 4.3. Three indices; NDVI, NDWI, NDMI, were produced based Lansat 8 image of 2018 using map algebra in ArcGIS (ArcMap 10.5) and used as input data in WL map generation. Also, the relief, slope, and landforms map were produced using the DEM and hydro-processing tool in ILWIS (Integrated Land and Water Information System) for drainage network extraction, slope, and catchment analysis considering the entire watershed covering the KRIP command area. The settlement density, canal density, and canal buffer maps were also produced as input data. According to Sahu (2014), there is a strong correlation and strength of association for relief, slope, embankment density, settlement density, canal density, NDVI, NDWI, and NDMI by up to 99% level of significance. Again, canal density was found to be proportionate with the waterlogged areas, and waterlogged areas within the canal buffer were estimated.

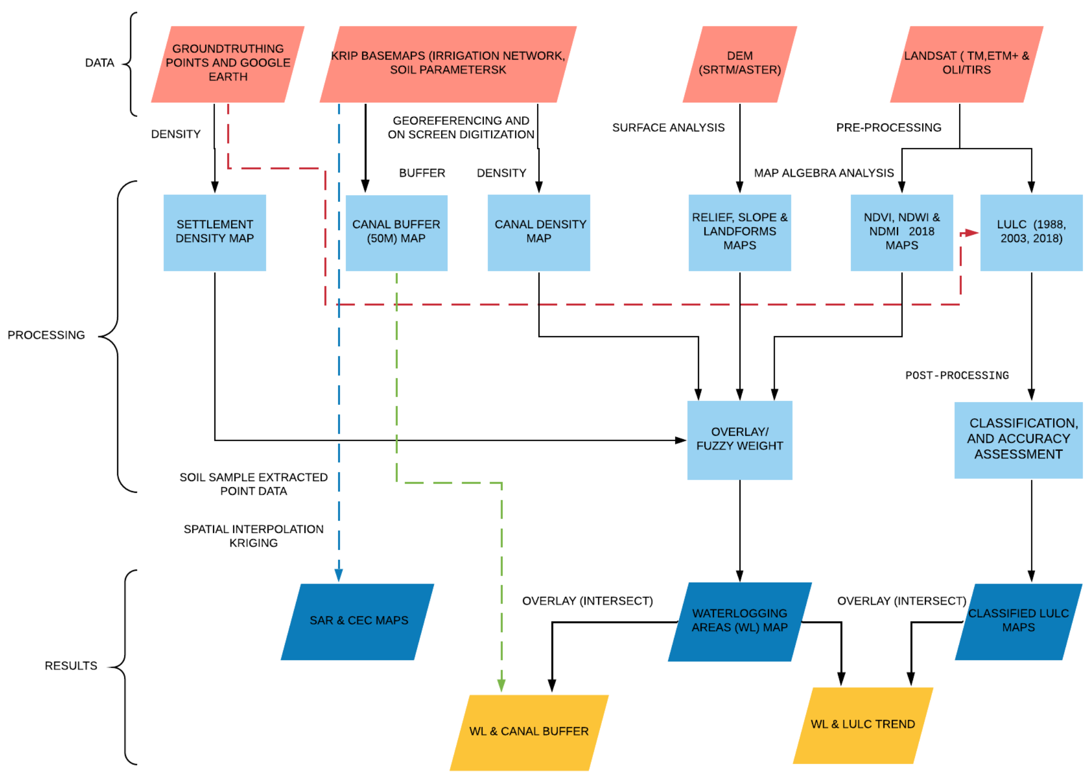

Figure 3.3: Methodological flowchart of the steps in estimating waterlogging areas and LULC trend in KRIP

3.4.2 Satellite Data acquisition and analysis

The satellite data used for LULC consist of cloud-free Landsat imagery for 1988, 2003, and 2018 with a spatial resolution of 30 m and temporal resolution of 16 days (Table 4.2). To cover the KRIP command area, only one scene was required (Figure 4.4). Many Landsat scenes were downloaded from 1988 to 2018 from the United States Geological Survey's (USGS) Earth-explorer website to select the scenes with less cloud cover. The most suitable images were those with cloud cover less than 10% and mostly found during the dry periods between October to December and January to march. These correspond to dry periods in northern Nigeria. According to the study conducted by Sexton et al., (2013) remote sensing images from the growing season can maximize spectral differences and give better accuracies in dry seasons as supported by Pax-Lenney and Woodcock (1997). Therefore, to produce the NDVI, NDWI and NDMI maps, the Landsat 8 imagery for 2018 (for dry and wet season) was acquired. However, the dry season Landsat 8 imagery, which is in the same period as that used for LULC classification was utilized to ensure uniformity during overlay operation. The metadata is shown in Table 4.2. Digital Elevation Model (DEM) data downloaded from Shuttle Radar Topographic Mission (SRTM) data released by NASA and distributed by the USGS through (ftp://edcsgs9.cr.usgs.gov/pub/data/srtm/version1/) of the study region were 30m and 90 m resolution. The data comes in two formats, arc-formatted ASCII and GeoTIFF.The 30 m DEM was used for slope, relief, and landforms definition in the basin. The watershed used for these analyses was processed using ILWIS, and hydro-processing analysis was done subsequently for drainage network extract and the basin above definitions. The 90 m DEM was used to produce the three-dimensional model and profile projection of the landscape of KRIP command area in Surfer 12 application interface using DEM and shapefile of rivers as draping features.

Table 3.2: Metadata of Landsat imagery for LULC Classification and Digital Elevation Model

Data type	**Year**	**Number of Scene**	**Path & Row**	**Resolution**	**Source(s)**
Landsat 5 (TM)	1988	1	p188, r052	30m	USGS

Landsat 5 (TM)	2003	1	p188, r052	30m	USGS
Landsat 8 OLI	2018	1	p188, r052	30m	USGS
DEM – SRTM 30m and 90m	2018			30m, 90m	USGS
KRIP Base maps (Irrigation network)	2016			1:250,000	FMWR
GPS Coordinates	2019				Garmin GPS Device

TM = Thematic Mapper

OLI = Operation Land Imager

Source: USGS Earth Explorer Landsat archive (https://earthexplorer.usgs.gov)

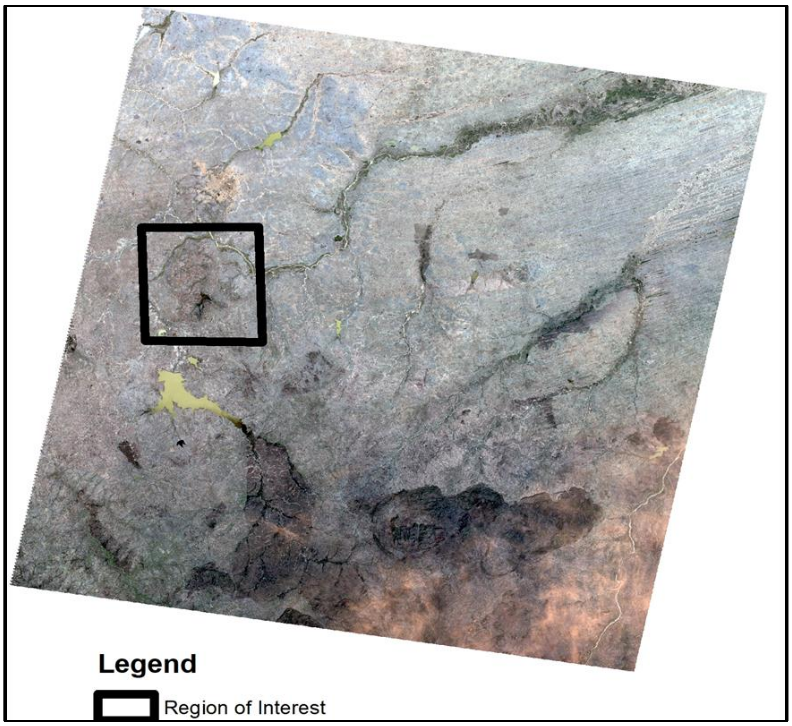

Figure 3.4: Landsat Scene Covering Region of Interest p188/r052

Source: (Author, 2019)

Table 3.3: Metadata of Landsat image for NDVI, NDWI and NDMI indexes

Data type	Year	Number of Scene	Path & Row	Resolution	Source
Landsat 8 OLI	27-12-2018	1	p188, r052	30m	USGS
Landsat 8 OLI	04-07-2018	1	p188, r052	30m	USGS

Source: USGS Earth Explorer Landsat archive (https://earthexplorer.usgs.gov)

3.4.3 Ground truth data collection

Groud truth data (Figure 4.5) were collected during the field study. At least four points from each sector were captured using handheld GPS and recorded and an application on the android called SW Maps. The GPS collected coordinates were utilized for the research due to internet inaccessibility to use the android application efficiently. Ground truth points were collected to gain an understanding of the ground situation (Cai et al., 2016) and also identify some features within the LULC classes which will help during supervised classification and to accurately process the final products.

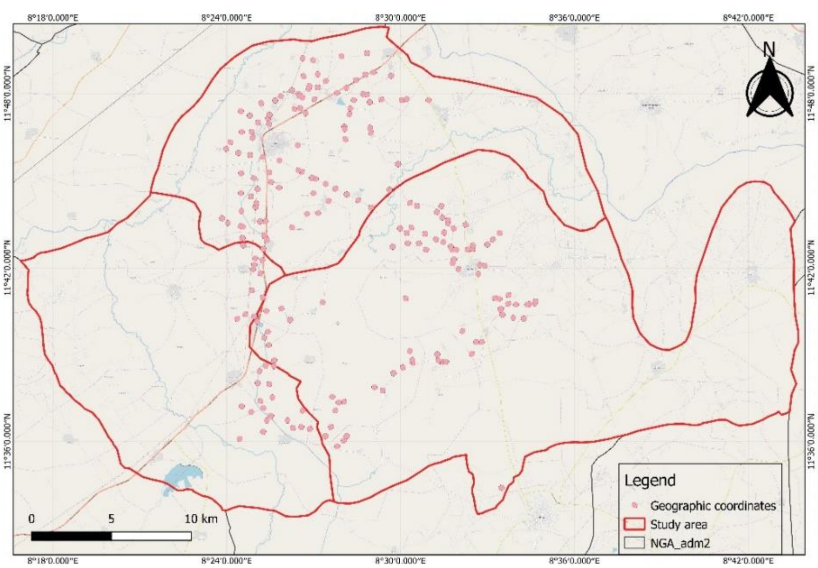

Figure 3.5: Ground Truth points collected within the KRIP command area
Source: (Author, 2019)

3.4.4 LULC Classification

The study of LULC change widely carried out to compare present and historical data that are made available through the ground, airborne, and satellite means. The integrated techniques of RS and GIS provide some of the most accurate and essential information over time, which enables us to know the changes and their extent of area, and the trend of change (Nath et al., 2018). Many studies like that of (Islam et al.,2018; Dey et al., 2004 & Okada et al., 2004) explored LULC related to surface and Ocean.

Supervised (Maximum Likelihood Classification) was employed, this was carried out on the satellite images covering the study periods. A supervised classification which included field visit observation points and ground truth data for identification of LULC classes (Table 4.4). The classification scheme was developed to include the three general categories of LULC i.e. cropland, water, and non-cropland (Xu et al., 2017). However, definitions and final selection was based on existing classes in LULC classification previously done in the region, Nigerian topographic classification, physical LULC features identified and noted during field study, LULC trend in Nigeria from the USGS Atlas for West Africa (https://eros.usgs.gov/westafrica/land-cover/land-use-land-cover-and-trends-nigeria) (CILSS, 2016) and the descriptions of Food and Agriculture Organization (FAO) (http://faostat.fao.org/site/375/default.aspx, entry ‘Agricultural area’) some LULC. The region of interest was created from the map of the study area using a vector frame in ArcGIS 10.5 software environment and saved as shapefile. The clustered features were used to reclassify the images by introducing a maximum likelihood classifier, which classifies the pixels related to the maximum probability of similarity with a specific class. The degree of accuracy of each classified image was evaluated by a set of 240 ground truth and other random points based on the number of classes (40 points per class). These reference points were overlaid on the images, and each location was designated to one of the land-use classes.

The KRIP Layout maps were obtained from KRIP feasibility report of TRIMING and imported into ArcGIS environment. They were rectified (projected coordinate system, UTM WGS1984 zone 32) to the salient land-use layer with the nearest neighbor resampling (RMSE<0.5pixels, or <15m).

Table 3.4: Land Use and Land Cover Classes

LULC class	Categories	Description
Built-up area	Residential, Commercial, Work construction, Industrial, Recreational and educational	Public, private, government, and commercial estates, Shopping malls, markets, stores, warehouses, trade-fair centers. Production sites, manufacturing factories for textiles, plastics and leather products, Government facilities, and settlement.
Bare Surfaces	Open land and non-vegetated land.	Bare surfaces, sand deposits, rock outcrops, accumulation of sediments from river erosional and denudation processes. Man, also influenced this LULC class.
Vegetation	Thick forest, trees Light.	Evergreen forest and mixed forests with a higher density of trees, fallow lands
Grassland	shrubs, grasses.	Type of vegetation found in waterlogged/riverside areas. Alluvial scrublands.
Water bodies	Wetlands, ponds, rivers, streams, dams.	Areas covered by open water such as river, Ponds, Lagoons, dam, reservoirs and water-logged area.
Agricultural Land	Cultivations, farmlands	Croplands, irrigated lands, Gardens, and plantations

3.4.5 Accuracy assessment

The extensive use of LULC classification has been demonstrated in chapter two of this report. Thematic maps produced are handy for policy and decision making as well as interventions. Mapping and monitoring irrigated lands, and indirect measurements of salinity and waterlogging have been proven to be improved with the improvements in the RS and GIS techniques. However, many errors are bound to happen during classification. It could be geometric errors or human errors during classification. The overall accuracy must not be less than 85% according to USGS classification scheme. And confirmed by (Ahmad et al., 2017).

The landscape in the study area consists of a mixture of built-up area, vegetation,

an agricultural area, reconstructed area, water bodies, and barren land, as highlighted in the LULC classes, respectively. Despite the ground truth data available, the google earth was used to visualize the classes during classification to reduce the producer's accuracy. Therefore, Google earth served as a visualization and validation tool.

The errors are quantified statistically by the overall accuracy, users accuracy, producers accuracy and Kappa Coefficient (K). While the overall accuracy is the total accuracy of the classification, the user's accuracy is the probability that a land cover class developed on a class represent the right pixel and, producers accuracy is the probability that a land-use of an area is classified correctly. The Kappa coefficient should be higher than 0.80. It is a multivariate technique employed in accuracy assessment.

3.4.6 NDVI, NDWI, NDWI, and other data input

The methodological approach shown in figure 4.3 is the direction of the method employed to achieve our objective. The DEM was obtained and processed using ArcGIS 10.5 and ILWIS software to produce, a relief map representing the variations of elevation and contour lines within the study area; a slope map depicting the slope variations; the landforms map to showing the plains and terraces (based on the soil suitability map of KRIP) and variations in elevations within the command area; settlement density map within the command area; canal density map.

Thereafter, with the Landsat 8 acquired images as shown in the metadata in Table 4.3 and the ArcGIS 10.5 software, the NDVI, NDWI, and NDMI were prepared using the formula presented in Table 4.5.

The NDVI was developed by Tucker (1979) using the red and near-infrared band of light to measure the vegetation cover and water bodies over the earth surface (Jackson & Huete, 1991). Following Tucker (1979), the range of NDVI was found to be from –1 (presence of large deepwater bodies) to +1 (dense vegetation). Many studies worked on the range of values of water; Holben (1986) found the value of -0.257 to represent values for LULC for water; Dwivedi and Screeniwas (2002) also used Landsat TM considering the NDVI value of 0.13 to separate vegetated areas from waterlogged areas. Again, Ganie and Nusrath, (2016) determined the typical values of NDVI and their results indicate 0.7 of dense vegetation, 0.025 for dry, bare soil, 0.002 for clouds, -0.046 for snow and ice and, -0.257 for water. The NDVI value of water for Ganie and Nusrath, (2016) corresponds to that reported by Holben (1986). The Landsat 8 band composition (Table 4.6) differ from other Landsat series, TM and Enhanced Thematic Mapper Plus (ETM+) bands. Hence, the change in the formula in Table 4.5.

Table 3.5: Map Algebra Expression for NDVI, NDWI, and NDMI

Indices	**Map Algebra Expression**
NDMI=	Float(band5-band6)/Float(band5+band6)
NDWI index=	Float(band3-band5)/ Float(band3+band5)
NDVI=	Float(band5-band4)/ Float(band5+band4)

Source: (Author, 2019)

Table 3.6: Spectral characteristics of Landsat 8

Bands	**Wavelength**	**Resolution**
Band 1 - Coastal aerosol	0.43 – 0.45	30
Band 2 – Blue Band 3 - Green	0.45 – 0.51 0.53 – 0.59	30 30
Band 4 – Red	0.64 – 0.67	30
Band 5 – Near Infrared (NIR)	0.85 – 0.88	30
Band 6 – SWIR 1	1.57 – 1.65	30
Band 7 – SWIR 2	2.11 – 2.29	30
Band 8 – Panchromatic	0.50 – 0.68	30
Band 9 - Cirrus	1.36 – 1.38	30
Band 10 – Thermal Infrared (TIRS) 1	10.60 – 11.19	100, 30
Band 11 – Thermal Infrared (TIRS) 2	11.50 – 12.52	100, 30

Source: (USGS, 2019)

Normalized Difference Water Index (NDWI) was developed by McFeeters (1996) and improved by Xu (2006). NDWI is used to achieve the signature differences between water and other targets. The range of NDWI similar to NDVI -1 to +1, but shows the opposite result. According to Chowdary (2008), +1 depicts the presence of extensive deep water bodies while -1 signifies vegetation cover. Chowdary (2008) reported that waterlogged areas range from 0 to +1 for the NDWI. The NDWI is a better water absorption index than NDVI (Sims & Gamon, 2003) as per Sims and Gamon (2003), the NDWI is an appropriate water absorption index in comparison with

NDVI. The NDWI was modified to improve the accuracy of water absorption following the research of GAO (1996) and Huang et al., (2009) and called it $NDWI_{GAO}$. The Near-infrared (NIR) and Middle-infrared were used instead of the green band of the TM data. It was used by Wilson and Sader (2002) as the Normalised Difference Moisture Index (NDMI) for soil moisture investigation. They concluded that $NDWI_{GAO}$ and NDMI are theoretically similar for surface wetness spatial variations. Similar to NDWI, NDMI ranges from -1 to +1 and high values indicate the existence of more soil moisture while low values indicate low soil moisture.

The CAD file of KRIP irrigation network (irrigation and drainage canal) was imported into the ArcGIS 10.5 environment. Most of the canals are unlined and some of the lined canals are in obliteration. Hence, a canal buffer of 50 m on either side of the canal was prepared to assess the likely impact of seepage and leakage with the irrigation network. This is similar to the study by Kaushik et al., (2018) in assessing the impact of canal network on surface waterlogging using RS in Rohtak district, India.

3.5 Economic and Financial analysis

The economic[1] and financial[2] benefits of agricultural drainage projects are estimated primarily to quantify the increase in agricultural production, crop diversification opportunities, and improved food security (Molen et al., 2007) as reported in the FAO guidelines and computer program for the design and planning of land drainage. These drainage benefits are a comparison of economic and financial benefits “with (FW)” and “without project (FWO).” (Musa, et al., 2014) Carried out an economic analysis of crop production under Jibiya irrigation project in Nigeria to estimate the financial benefits of the agricultural output using farm budgeting model. The major problem faced by farmers in that project are, inadequate capital, shortage of fertilizers, pests and diseases, lack of loans and yet, they enjoyed net return in investment of 1.01 (naira). In this context, the researcher compared benefits in economic and financial terms of the FW and FWO, in which drainage projects to control waterlogging and soil salinity in arid and semi-arid regions often implies a

[1] Economic analyses compare the benefits and costs to the whole economy.

[2] Financial analyses of the project compare benefits and costs to the or individuals and enterprise.

significant decrease in yields. This decrease was estimated with crop salt tolerance data (FAO, 2002b) (http://www.fao.org/3/y4263e/y4263e0e.htm). The data of crops in this context are detailed in the Appendix. Incremental benefit, as well as secondary benefits related to, lower incidence of water-borne diseases and improved access to villages, are expected but in FW. All quantifiable benefits were based on current economic and financial farmgate prices for products sold or used internationally and locally applied to the estimated production costs. Local prices collected from local markets were also used to estimate the benefits of onions, vegetables, tomatoes, and sorghum. The changes in costs of production, including for example O&M costs, can be deducted from the gross benefit to determine the net incremental benefit. The ratios of gross farm benefits to investment, and the net farm benefit to investment according to (Ochs and Bishay, 1992) were used.

The economic pricing derived from the most recent World Bank commodity price projections. Since 2018 was considered for our analysis, the latest predictions for October 2018 was adopted.

The sea freight, insurance, border charges, local transportation, handling and, for some commodities like rice, processing fee were factored in to adjust the international price. The result of the derivation of farmgate prices for rice, maize, soya beans, wheat, and main fertilizers are detailed in the Appendix. Local prices are estimated based on the prices of products sold in the local markets within the Kano region. 1 USD = NGN 306.4 (https://www.cbn.gov.ng/rates/ExchRateByCurrency.asp) as at the time of writing this report. The variations in markets, however, requires applying the standard conversion factor (SCF) of 0.97, which reflects the exchange rate in Nigeria, which varies with official exchange rates. According to the HJRDBA estimates of labor cost, around NGN 700 per day is common. However, high rate of unemployment can lower the price to around NGN 400 – 500. Hence, a shadow wage rate of 70% was used to determine the economic value of labor.

The smallholder data portrait based on small family farms in Nigeria by FAO for 2018 was also employed to support the economic and financial analysis. Although the data provided is based on constant 2009 international USD, the data served as a guide in estimations and assumptions. The data portrait currently offers data to nineteen countries. Figure 4.6 shows data for Nigeria

3.5.1 Crop budgets

Crop budgets are required to estimate the agricultural benefits in KRIP (Musa et al., 2014; Molen et al., 2007). Nine major crops as per the crop production and cropping pattern provided by HJRBDA were selected and crop budgets based on the farm gate prices (in constant terms) and the local costs in local markets. We assumed that amount would remain unchanged from their present values; hence, futuristic predictions were not in the analysis since an intervention project is ongoing. All information on crop yields and input use, labor requirements, wages rates, and other costs were adopted and adjusted to the current situation from the draft feasibility report of irrigation development of KRIP and HVIP (FMWR, 2016). In the same report, it was forecasted that crop yields would reduce every year by 1% in the next 30 years. The average crop yield in the FWO, the average crop yield is estimated using the crop yield response function after Maas and Hoffman (1977) and detailed in Appendix. In a report of crop salt tolerance under controlled field conditions in The Netherlands, Arjen et al., (2016) adopted the same function based on trials conducted at Salt Farm Texel. Average crop yield for FW situation was estimated based on the data collected from HJRBDA and the crop budgets in the feasibility reports of TRIMING project feasibility report. In the same report, the TRIMING intervention is envisaged to bring about a steady increase in crop yield by 1% per annum provided improved crop varieties, improved cropping patterns, regularly monitoring and evaluation and other production techniques are put in place. In an ideal condition, the crop budget tool developed by FAO in 2014 in the crop budget manual (http://www.fao.org/3/a-bp850e.pdf) should be utilized for this analysis. Nevertheless, the same input data and procedure were utilized, and the crop budget was computed manually with the Excel tool.

The culture of inheritance (*gado*) has led to landholdings fragmentation to the extent that mechanized farming is challenging to implement[3]. Hence, labor is done by the farmers manually by the family or hired labor. Some farmers in the scheme with more prominent land holdings utilize hired machinery for land preparation, and this is accounted for in the land preparation cost as per the estimations provided by TRIMING. Other assumptions made in the crop budgets include

[3] The fragmentation of landholdings due to inheritance affect the agricultural modernization in KRIP. This is in agreement with the findings of (Olawepo & Ibrahim, 2013)

exclusion of interest rates. Farmers in KRIP have an average holdings of 0.46 ha[4], due to the nature of farmers in the KRIP

3.5.2 Farm budget and agricultural farm benefits.

Farm budget analysis was done to estimate the farm incomes based on the crop budget, cropping pattern, and average landholding of 0.46 ha in the KRIP. The crop areas were calculated and applied to the financial and economical crop budget calculated to derive the likely net returns to the farmers for 2018 data in the present, FWO and FW project situations. The net farm incomes were obtained after deducting fixed costs[5]. The net returns were obtained for both before and after the irrigation fees which is meant for annual maintenance of cost of the irrigation and drainage systems in addition to the yearly budget allocation[6]. Gert et al., (2016) estimated farm financial margins and irrigation service fee (ISF) as a percentage of gross margin before deduction of ISF for three scenarios. In this context, we adopted the assumptions made in the recent economic and financial analysis in the feasibility study of irrigation development of KRIP and HVIP project (FMWR,2016); that the ISF was calculated as direct financial operation, maintenance, and management costs of the system less labor input by farmers for maintenance of distributory canals, field canals and, field drains. Also, to account for the loss command and fallow areas and, crops cultivation diversification as per season, which makes about 10% of the land not been cultivated, then ISF collection rate would reach 90%. That means if 25% is remitted to the government, the ISF should be in the range of NGN 15,000 to14,000. The ISF amount is within the willingness to pay to provide labor in kind (Table 4.9) by the farmers in KRIP. The computations were based on the Farm Budget Model. model used by (Musa et al., 2014) for the economic appraisal of crop production under Jibiya irrigation scheme.

NFI = GFI - VC – FC ---(2)

[4] In the economic and financial analysis of the draft feasilbility report of irrigation development of KRIP and HVIP (FMWR, 2016)

[5] Farm tools and other equipments. The cost of land rent was not included since most of the farmers either own or inherit their plots (FMWR, 2016)

[6] There is yearly budget allocation for the rehabilitation of the irrigation and drainage systems from the federal government. However, the claimed amount in the last ten years cannot be clearly traced to the rehabilitations carried out in the scheme. There have been a number of rehabilitations (desilting of of main irrigation canals), many of the documentations were reported to have been burnt during a fire outbreak at the HJRBDA headquaters in Hotoro, Kano, Nigeria. (Personal communication with HJRBDA staff)

Where: NFI = net farm income

GFI = gross farm income which gives the farm product value

VC = variable cost, which is the production cost, which includes the cost of labor, seed, fertilizer, and other costs.

FC= Fixed cost e.g. land preparation, such as siphon tubes, and etc.

Table 3.7: Willingness to pay and willingness to provide labor (in-kind)

Number of respondents	Average WTP NGN per ha per season	Average Labour days/ month per ha	Median WTP / season	Median Labour days/ months per ha
96	9,131	8.18	7,500	5.00

Source: (FMWR, 2016)

CHAPTER 4: RESULTS AND DISCUSSION

4.1 The typology of drainage in the Kano River Irrigation Project.

This section contains the findings of the semi-structured interviews, focused group discussions, physical observations from the irrigation and drainage infrastructure conducted during seven (7) weeks (March 12, 2019, to May 6, 2019) in Nigeria. The study adopted the DRAINFRAME approach similar to that of Rapid Assessment of Egypt's irrigation and drainage which was conducted during May and June in 2004, following the Irrigation Improvement Project (IIP) to assist the Government of Egypt to plan and design the Integrated Irrigation Improvement and Management Project (IIIMP) (Abdel-Dayem *et al.,* 2004). The TRIMING project described in chapter three of this report fits perfectly in the case of the Kano River Irrigation Project. Also, this section forms part of the qualitative phase of the study, as described in chapter four of this report. Further to the applied DRAINFRAME approach, the study was sequentially carried out as such: reconnaissance and informal interviews to gain an understanding of drainage related problems; mapping of landscape and identification of associated functions; investigating upstream and downstream stakeholders; appraisal of irrigation and drainage types and systems, and analysis of the problems and opportunities.

The outcome for informal interviews conducted at the apex ministries responsible for irrigation and drainage, i.e., Federal Ministry of Water Resources (FMWR) and Federal Ministry of Agriculture and Rural Development (FMARD) triggered the semi-structured interviews with stakeholders, focused group discussions with irrigation agency staff, Water Users Association (WUA) and farmers. Mapping of the landscape from an engineering perspective identifies three main landscapes: irrigation system, the drainage system, and agricultural land.

The main activities from an engineering perspective were the problem and opportunity analysis that allowed the identification of the existing problems related to water management, and drainage management, and elaborated on the inherent causes of those problems. In this context, the study focused on the quantification of the anticipated changes that have occurred for long term irrigation, in this case, 30 years period resulting from technical interventions and, day to day maintenance of the irrigation scheme. Also, the mode of water delivery procedures on-farm and at drainage level which ensures: equity of water distribution from head to tail end, proper irrigation scheduling, water availability, agricultural practices recommended for the scheme, project management of the system, project monitoring, and evaluation, agrarian productivity, and benefits, etc.

4.1.1 Landscape

The main landscapes in the hydrological system in the Kano River Irrigation Project from an engineering perspective were identified to be irrigation system, the drainage system, and irrigated agricultural land. These are similar to the main landscapes in the hydrological system associated with the Mahmoudia canal (FAO, 2005). The table 5.1 summarizes the main landscapes while figure 5.1 attempts to describe the profile section from the highest to the lowest elevation and the three-dimensional (3D) section of the landscape produced in Surfer 12 application interface using DEM and shapefile of rivers command area as draping features.

Table 5.1: Landscape types from the engineering perspective

Main Landscapes	Sub-Landscapes
Irrigation system	Main canal (MCs) Distributary canal (DCs) Field canal (FCs)
Drainage system	Main drainage Collector drains Field drains
Irrigated agricultural Land	Command areas Loss command areas[7] Off-command areas[8]

Field survey (2019)

[7] These are areas within the command areas that are not irrigated because the water delivery no longer supply irrigation water. Most of those areas are now developed as settlements.

[8] These are areas outside the command areas. However, there are major users of the both irrigation and drainage water. The mode of irrigation they employ is most pumps. A farmer confessed that the off-command users benefit more from the irrigation project (Field study, 2019)

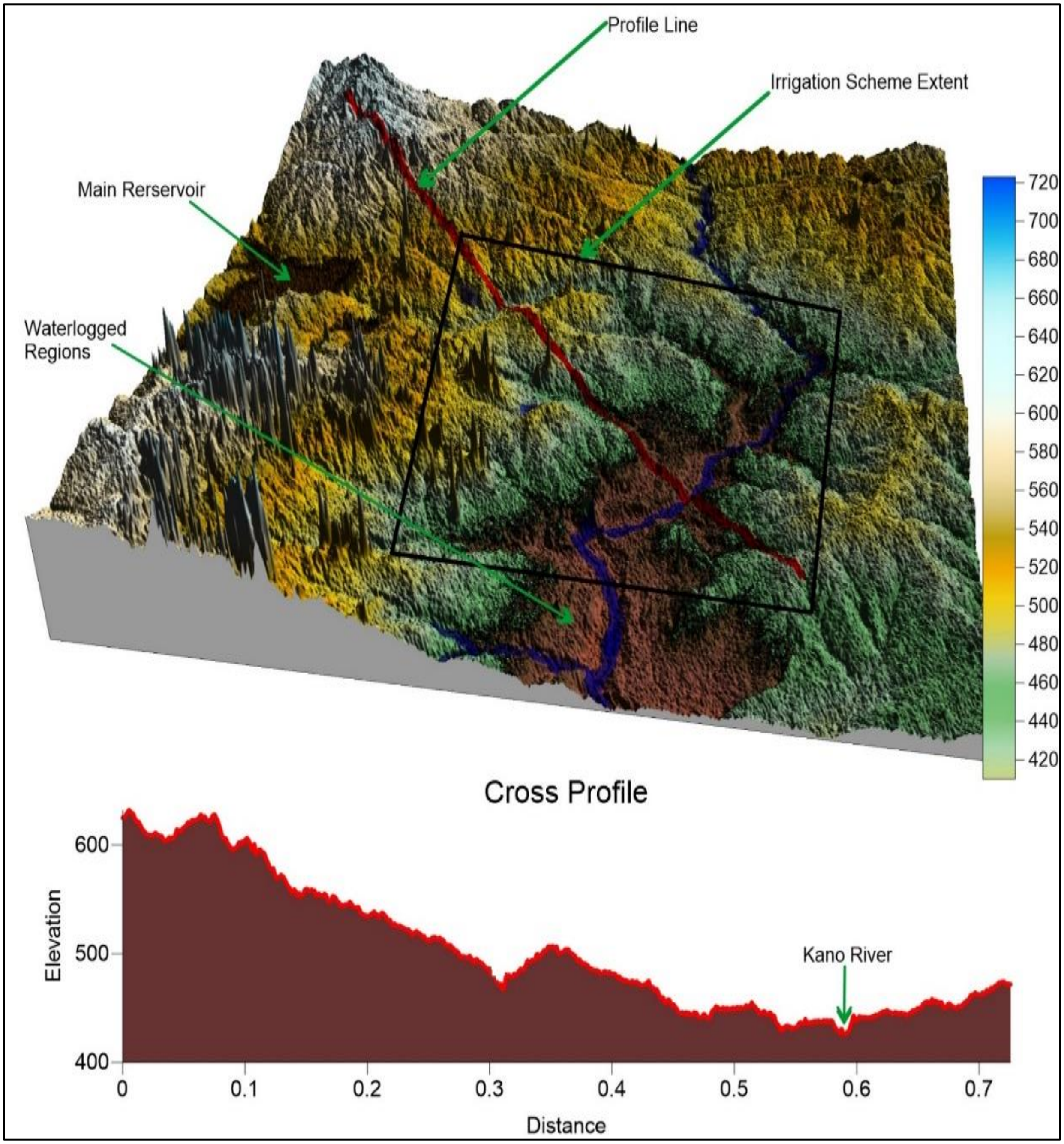

Figure 4.1: Three-dimensional and cross profile of the KRIP command area

Source: (Author, 2019)

4.1.2 Landscape Functions, Values analysis, and Stakeholders

The work on functions evaluation as a framework done by Slootweg et al., (2001) identifies the types of functions applicable to landscapes. Various functions were identified against the main and sub-landscapes of KRIP.

1. **Irrigation system**

The irrigation system functions as a processing and regulation function, which is the conveyance of water supply to the irrigated agricultural lands. Water is supplied by gravity from Tiga reservoir passing through Ruwan Kanya a balancing reservoir. There, water is released for supply to the Kano region. The conveyance continues until the water reaches the 47 sectors received through what is called STO. Release of water from the Tiga reservoir at present does not follow the original irrigation system management schedule (Figure 5.2). The operation procedure is straightforward to follow; unfortunately, that is an ideal situation for the scheme. Water level monitoring of the reservoir gauge daily. However, the rating curve is not employed whatsoever in making any calculation to release water. Releases are made on what they call "turning the gates" by experience. Regrettably, all regulators were equipped with lifting gates, but most have been destroyed. In principle, lifting and water release have been going on in the scheme based on accumulated experience. However, the system is more significant than the irrigators, and that becomes impossible to manage.

The Operation and Maintenance Manuals that were prepared for the schemes provide clear guidance on how the operations are to be done; in short this comprises of:
On a weekly basis:
1. During week x, 'from the field to the dam': determine "what volume is needed next week":
   a. Determine for each sector the actually cropped area per type of crop;
   b. With the actual meteorological data and parameters such as crops, crop growth stage, cropped areas per crop, soil parameters etc.) determine the sector crop water requirements;
   c. Determine the overall scheme irrigation supply requirements - taking into account the water losses from the dam to the plant (efficiencies), and
   d. convey that to dam operators and canal gate operators for next week's releases;
2. During week x plus 1, 'from the dam to the field': "what are we distributing this week":
   a. Dam operator releases the requested discharge into the main canal;
   b. Zonal Offices set the branch canal gates to the required discharges (and measure that);
   c. Zonal Offices set the Sector Turn Out gates to the required discharge for each sector with the aid of the STO measurement gates, and
   d. Zonal Offices set the Field Turn Out gates to the required discharge for each field.

Figure 4.2: Operation and Maintenance Manual for KRIP

Source: (FAO & FMWR, 2016)

As the water gets to the STO, the field irrigators who are the staff of HJRBDA are expected to open the gates. Opening of the gates has based on ISF payment, and only sectors that pay will get water irrespective of the release balance. WTP for ISF is even higher than NGN 2,500 per hectare per season or NGN 5,000 per season currently charged. In worst cases, the farm (called block) of the farmer that refuse payment is blocked to allow other farmers to get water.

Since the scheme is gravity-fed, water is delivered about 0.5 m above the ground level to allow using siphons to irrigate their land. However, with the obliterated state of the FCs that procedure is difficult to follow. While some farmers can siphon water, usually head-end farmers, the tail-end farmers need to divert water to their lands by making a hole below the FC or removing the soil to allow free flow of water. All of these disrupted practices contribute to further destruction of the FC. Although pumps are not permitted anywhere within the vicinity of the scheme, the off command users are masters of using a pump to irrigate. The rate of drainage water abstraction (which is called unauthorized drainage water reuse) has contributed to the areas cultivated in within and outside the scheme. Needless to say that it is good for the economic welfare of the farmer's livelihood, but it is a setback to the overall aim to which the scheme was initially set up.

In an ideal situation, irrigation is not possible at night. Therefore, there are currently five NSR operating to balance the overall irrigation water requirement. However, due to the irregular terrain of the scheme, it is no longer possible to follow that rule. Night irrigation is a common practice, especially for the tail end farmers.

The estimated stakeholders in KRIP was determined based on the average landholding. The total irrigated area for 2017/2018 dry season was extracted from the HJRBDA annual crop production divided by the average landholding to give. i.e., 13911 ha divided by 0.46 ha, which is approximately 30,300 farmers. Most, if not all, the farmers within the scheme depend on irrigated agriculture as their first livelihood.

The values derived from the irrigation system is the increase in economic income from the use of irrigation water.

2. Drainage system

The drainage system functions as a carrying function, which removes the excess drainage water. Also, the drainage system features as a processing function to improve soil conditions and trafficability. In KRIP the drainage system illegally features as a production function. Farmers recognize the meaning of a drainage system which they call '*Maraga*' or '*Fita waje*.' It means 'reduction' or 'going out' in the *Hausa language*. The meaning of drainage is apparent even at the grassroots. However, the drainage is always considered as extra land to most of the KRIP farmers. As highlighted in chapter three, the drainage system in the KRIP command area is an open drain. The scheme drainage system is oriented to drain towards the Shimar River, which is the central divide between the Western and Eastern command areas of the scheme. River Shimar joins the Hadejia River just outside the command area on the northern side of the project. While the sectors located on the western side of the WBC are draining into the Kano River following small streams. All drainage water flows by gravity following the design of the scheme.

The excessive sedimentation in most of the drains is in obliteration. Hence, the flow is now mostly taking place underground making the groundwater table close to the ground surface; thereby, surface drainage does not work well. The need to install subsurface drainage systems, though a costly investment, is already recommended by the groundwater and drainage hydraulic parameter studies of (Oyebode et al., 2014; Sobowale et al., 2014). Despite the high cost of investment in sub-surface drainage systems installations, the return of investment is attractive, and the systems are cost-effective (H. Ritzema, 2007; H. Ritzema & Schultz, 2011). However, in the current TRIMING project, the concrete lining is planned, which will reduce the seepage, and underground flow field and collector drains.

The estimated stakeholders in KRIP was determined based on the average landholding. The total irrigated area for 2017/2018 dry season was extracted from the HJRBDA annual crop production divided by the average landholding to give. i.e., 13911 ha divided by 0.46 ha, which is approximately 30300 farmers. In addition to farmers, there is a high number of fishers utilizing the main drains for fish traps. As highlighted in chapter three of this report, the estimate within the area for Tiga dam include 5000 fishers, 225 tonnes catch, and an estimated value of N11,250,00.00 (HJRBDA, 2006). The farmers and fishers and within and beyond the scheme depend on irrigated agriculture as their first livelihood.

The values derived from the drainage system is the increase in agricultural productivity due to improved soil conditions and trafficability as well as economic income to the fishermen.

3. Irrigated agricultural lands

The agricultural lands feature as a production function by providing agricultural productivity. The soil of the areas in KRIP is documented. As highlighted in chapter two of this report, in general, the soil is predominantly loamy, deep, well to moderately naturally drained in about 90% of the area. Knowledge about the groundwater table rises from 10-12 m to 1 m and, less below ground level as reported in EIA of Kano KRIP (Simon, 1997). The soil salinity and soil fertility status of the scheme was reported to be tolerable. To this end, data were collected from 1973 to 2015 (Table 3.2 and appendix) from HJRBDA and the data from the works of Jibrin et al., (2008), (Maina & Amin, 2012) and, Adamu et al., (2014). The soil salinity and fertility generally vary within the scheme. The development of the sectors started as far back as 1970, and the last sector to be developed was in 2008 (HJRBDA, 2019). Since the data of soil salinity and fertility have spatial coordinates. We extracted produced maps showing the spatial distribution using interpolation based on the periods (Kriging) and map prepared can be seen in the appendix.

The land is cultivated throughout the year both dry and wet season. Some farmers reported three to four crop rotations in a year. Rice, Maize, Wheat, Onions and, Tomato are the main crops along with Sorghum, Vegetables (Carrot, Cucumber, and Okro), Cowpea, and Millet. The most common type of irrigation practice in KRIP is Basin irrigation. The traditional belief of '*more water gives more crop*' is inherent in the farmers. We asked a farmer to explain the effect of waterlogging on crop productivity, and he was affirmative that waterlogging gives more yield[9].

The crop yields are considered to be erratic relative to yields around the world. For instance, average crop yields for rice is 4.3 tonnes/ha against 3.3 tonnes/ha in Egypt, while the yield for wheat is just 2.4 tonnes/ha against 3.3tonnes/ha according to the Economic Co-operation and Development (OECD) and the Food and Agriculture Organization of the United Nations (FAO) agricultural outlook for world cereal 2019 projections (OECD/FAO & Asia, 2017).

The stakeholders are common to those in the irrigation systems. Also, the unofficial drainage water reuse farmers contribute to the stakeholders.

[9] Farmers create what they call, 'Artificial waterlogging by intentionally blocking their field drains to keep the water in the farm. However, the crop water requirements of some crops are high, irrigation should be based on "when and how much to irrigate"

The value derived increases farm incomes through increased agricultural productivity. More net farm income is envisaged after the successful completion of the TRIMING project.

4.1.3 Problems and Opportunities

The functions and, values analysis, and stakeholder's identification of the main landscapes generated key findings categorized into problems and opportunities. The summary of responses coming from water users and water managers indicate (Figure 5.3) that most of the answers came from the water users. In most cases, it is difficult to meet water managers and, even more, challenging to make a call interview.

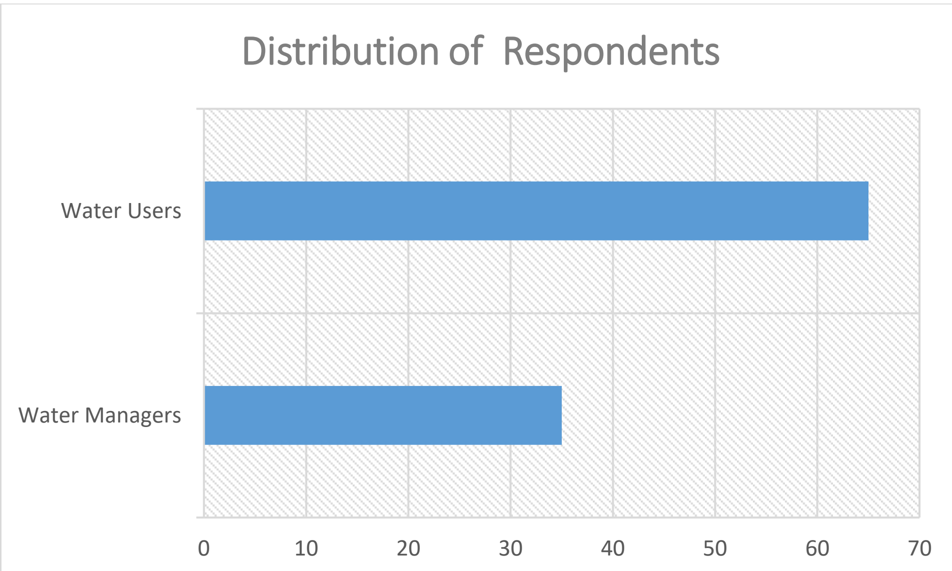

Figure 4.3: Water Users and managers response rate

Source: (Survey, 2019)

Our problems and opportunities analysis based on engineering perspective generated key findings summarized in table 5.2.

Table 5.2: Problems and Opportunities in KRIP based on engineering perspective

Problems	Opportunities
1. Competition for water	1. Equity of water distribution
2. Poor water conveyance and distribution	2. Monitoring and measurements
3. Farmers ignorance	3. Technical knowledge
4. Absence of monitoring	4. Cost-effectiveness
5. Management characteristics	5. Extension services

Source: (Survey, 2019)

The problem and opportunity analysis focused on the identified landscapes in the KRIP from an engineering perspective. Consolidating the problems and opportunities into the major landscapes of the KRIP command area will bring better highlight on how to address the problem and seize the opportunities.

1. Irrigation system

The irrigation scheduling and changes in the cropping pattern have led to a water distribution problem. Therefore, the is high competition among head-end and tail-end farmers. In addition, deterioration of the drainage system and malfunctioning of the check gates contribute to the water distribution problem. Since the gates are controlled manually, any farmer can release or block the gates to ensure water reaches his land. Head-end farmers are fond of taking the maximum water by all means and water takes time to reach or does not reach all the tail - end users. To this end, it is principally difficult to convince a farmer that irrigation is based on crop water requirement and driven by irrigation scheduling timing. Irrigation is not possible at night; however, night irrigation has become a habit especially for the tail-end users.

Ignorance among farmers on irrigation scheduling ("when" to irrigate and "how much") has been registered, the same applies to the water managers. Irrigation water is released based on an experienced guess or whenever it deemed fit for the irrigator.

The characteristics of water managers revealed that most of them have a background in disciplines far from agriculture, irrigation and drainage subjects. Hence, one should expect a lack of expertise in the system.

2. Drainage system

The drainage system popularly known as "*maraga*" design is well described in chapter three. It has been reported that there is inadequacy in the design of the collector drains (HJRBDA,1984). However, the same report explains tolerance. Our investigation reveals that the most fertile land in the KRIP command area is the silted up main drains and are cultivated all year round. In fact, one must be influential to own the so-called silted up main drains.

There is another form of water conflict among farmers, fishers, and herdsmen. Most of the access roads are been cultivated by farmers, this is forcing the herdsmen to use part of the land to find the way, and the result is always conflicts and destruction of the unlined and even lined canals. Consequently, the fishers make fish traps at the opening of the main drains which reduces or block drainage water flow. This could be one of the issues that contribute to the waterlogging especially around the drains.

In trying to highlight the effect of waterlogging, a farmer confirmed that most of the waterlogging conditions observed in the lands of the head-end farmers are artificially induced. The farmers plant rice and intentionally divert excess water to their lands at the detriment of mid and tail-end farmers. Consequently, the unmeasured seepage losses and leakages from the canal network invariably result in even more water losses.

3. **Irrigated agricultural lands**

Improper irrigation and drainage practices in the KRIP command area translates into waterlogging. When waterlogging conditions remain, the water table increases and secondary salinity sets in. In fact, farming operations and mechanization become difficult. Our findings reveal that monitoring of the soil and other environmental matrices has no place in the KRIP command area. To the best of our knowledge, Soil testing is done in research institutions or universities which are located several kilometers away. An average farmer is already challenged to get the basic input (seed, fertilizer, pesticides, herbicides, etc.) for agricultural production and soil analysis is the last thing he would want to hear. This suggests that only by seeing the impact in a pilot field or demonstrating the cost-effectiveness of soil monitoring will farmers believe.

4.1.4 Summary of analysis

The discussion attempts to analyze the problems and opportunities associated with water management in the KRIP command area. The issues discussed underwent a rigorous but rapid study, and conclusions have been drawn through the DRAINFRAME systematic landscape approach from the engineering perspective. The approach has the advantage of looking at the drainage system, irrigation system, and irrigated agricultural land holistically. Hence, if carefully integrated, no stone will be left unturned. The trend of current and past irrigation and drainage projects have always been separate entities but often have the same ultimate goals. In Nigeria, there has been merging and demerging from one ministry to another which have led to fragmentations in the irrigated agriculture. DRAINFRAME provides the opportunity for the use of this systematic approach in practice to improve and encourage integration in irrigation and drainage processes. The quantification of the likely impact of inadequate drainage systems identified will be discussed in the preceding sections.

4.2 LULC analysis in the Kano River Irrigation Scheme Command Area

4.2.1 Accuracy assessments and Kappa statistics

Accuracy assessment is required to assess how accurate the LULC maps have been classified. This is obtained by the overall accuracies of the classified images of the Multi-temporal Landsat satellite data used for classification (Nath et al., 2018; Ahmad et al.,2017 & Fichera et al., 2012). The overall accuracy (see Table 5.3) is higher compared to the minimum acceptable standard of the USGS classification scheme, which is greater than or equal to 85%. The results of the accuracies for this study indicate that the LULC changes have been accurately identified and adequately extracted. The results of the overall accuracies were, 91%, 92% and 97% for the LULC classified maps of 1988, 2003 and, 2018 respectively. The user and producer accuracy for the six classes ranged from 81 to 100% and 69 to 100% respectively (Table 5.4). The Kappa statistics coefficient values ranged from 0.89 to 0.98 which is in line with the minimum of 0.80 (Carletta, 1996).

Table 5.3: Overall accuracy and Kappa coefficient of LULC maps

Years	Overall Accuracy (%)	Kappa Coefficient (%)
1988	91.53	89.87
2003	92.95	95.08
2018	97.40	98.30

Source: (Author, 2019)

Table 5.4: Producers and User Accuracy of LULC maps

LULC Classes	1988		2003		2018	
	Producers Accuracy (%)	**User Accuracy (%)**	**Producers Accuracy (%)**	**User Accuracy (%)**	**Producers Accuracy (%)**	**User Accuracy (%)**
Agricultural Land	77	100	69.3	100	96.54	100
Baresurfaces	87.33	98.11	90.2	100	100	98.6
Built up	95.33	99.33	100	98.77	91.33	100
Grassland	91.43	100	92.43	81.43	100	97.2
Vegetation	88.57	93.94	95.71	100	87.22	100
Waterbody	69.22	98.2	87.56	100	99.3	98.6

Source: (Author, 2019)

A close look at the results suggests that LULC classification using the Landsat 8 is more accurate compared to LULC classification using a later series of Landsat image. The overall accuracy of LULC classified map of 1988 (Landsat 5 TM) is 91%; 2003 (Landsat 5 TM) is 92% and, 2018 (Landsat 8 OLI) is 97%. Similarly, the Kappa coefficient results showed improvement from 89% through 98% from 1988 to 2018. The classification was a rather difficult process when trying to place a class correctly. However, the ground-truthing and Google Earth helped in verification and visualization of identified and reference points during the study visit. In this context, the accuracy assessment of the classified data of 1988 (Landsat 5 TM), 2003 (Landsat 5 TM), and 2018 (Landsat 8 OLI) confirmed that the results are reasonable and satisfactory for the present investigation. Hence, we can conclude that the LULC maps can be used for intervention and further change analysis in the Kano River Irrigation command area.

4.2.2 Land Use and Land Cover (LULC) maps of KRIP command area

The definitions and the basis on which the LULC classes were adopted for this study have been defined in chapter four of this report. Land use and Land cover are often used interchangeably. In this context, following Setiawan et al., (2015) we consider Land use as the use to which land is put and the complex interaction between human and biophysical environment while the Land cover is basically describing the biophysical state of earth's surface and immediate subsurface (Turner, 1995).

According to our LULC classes, Land use includes agricultural land and built up while bare surfaces, grassland, vegetation, and water body forms the Landcover. The LULC maps (see figure 5.4) are prepared for 1988, 2003 and 2018 for the KRIP command area. West command area of KRIP is more developed and agricultural areas are more concentrated and the entire command area is covered with other vegetation and grassland. The observed agricultural land within the Kano River is due to the intensive off-command agricultural activities which were observed to have. increased the area cropped in the KRIP using the drainage water or abstracting directly from the Kano River. The characteristics of each land use and land cover type are summarized in table 5.5. The LULC study of Odunuga et al., (2011) also showed the high percentage for agricultural land in the entire Hadejia-Jama'are River Basin.

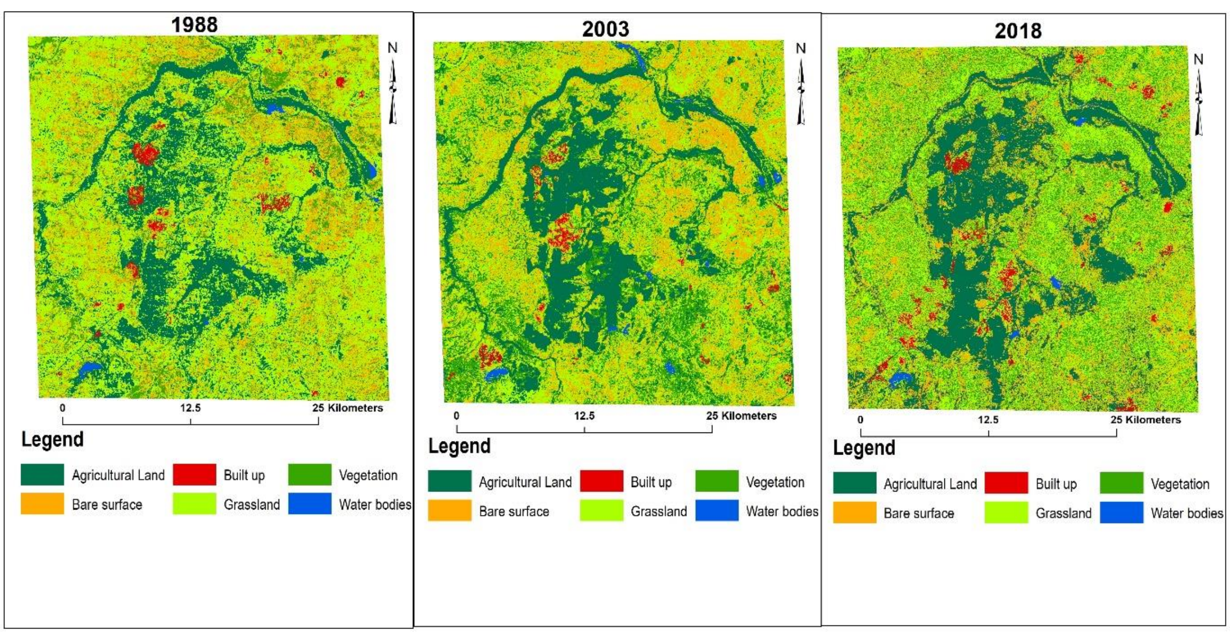

Figure 4.4: LULC maps of the KRIP command area

Source: (Author, 2019)

Table 5.5: Land Use Land Cover characteristics in the KRIP command area

LULC Classes	Area (Km^2)			Area (%)		
	1988	2003	2018	1988	2003	2018
Agricultural Land	262.83	278.18	306.3	21.58	22.84	25.15
Bare surfaces	275.12	257.7	242.48	22.59	21.16	19.91
Built up	10.46	12.8	18.65	0.86	1.05	1.53
Grassland	420.76	559.99	407.51	34.55	45.98	33.46
Vegetation	241.73	104.39	238.71	19.85	8.57	19.6
Waterbody	7.01	4.85	4.27	0.58	0.4	0.35
	1217.91	1217.91	1217.92	100	100	100

Source: (Author, 2019)

4.2.3 Land Use and Land Cover (LULC) map 1988

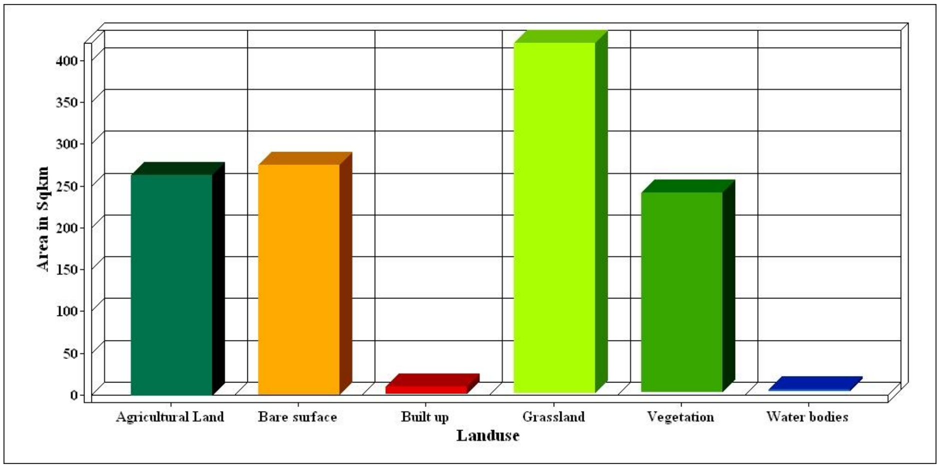

Figure 4.5: LULC area in 1988

Source: (Author, 2019)

Figure 5.5 shows the distribution of LULC areas in KRIP in 1988. Grassland dominates (420.76 Km^2) followed by bare surface (275.12 Km^2) and agricultural land (278.18 Km^2) representing 35%, 22%, and 23% respectively. The vegetation covers about (241.73 Km^2) while built-up areas and water bodies are least represented (10% and 7%) in the command area.

4.2.4 Land Use and Land Cover (LULC) map 2003

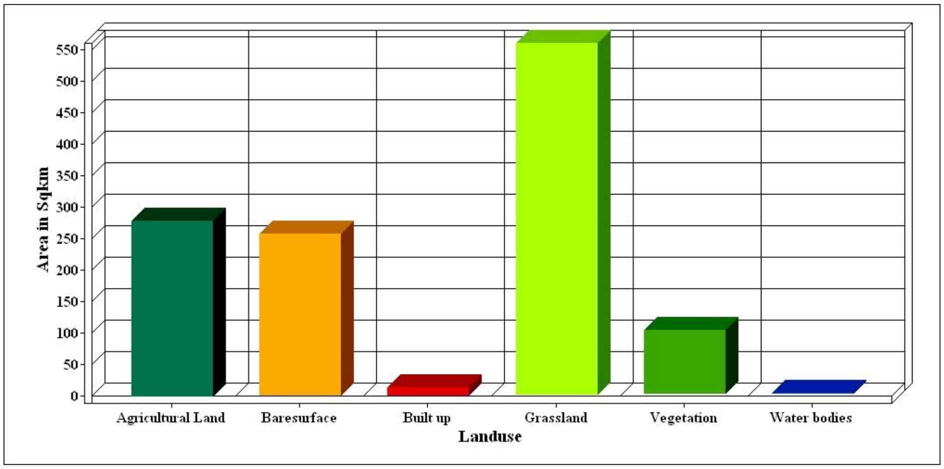

Figure 4.6: LULC area in 2003

Source: (Author, 2019)

Figure 5.6 shows the LULC occupied area distribution in 2003. The dominant land use and land cover were grasslands (599.99 Km^2) and agricultural land (278.18 Km^2) followed by bare surface (257.70 Km^2) representing 46%, 22%, and 21% respectively. Built-up areas (12.8 Km^2) and water bodies (4.85 Km^2) represent 1% and 0.4% respectively.

4.2.5 Land Use and Land Cover (LULC) map 2018

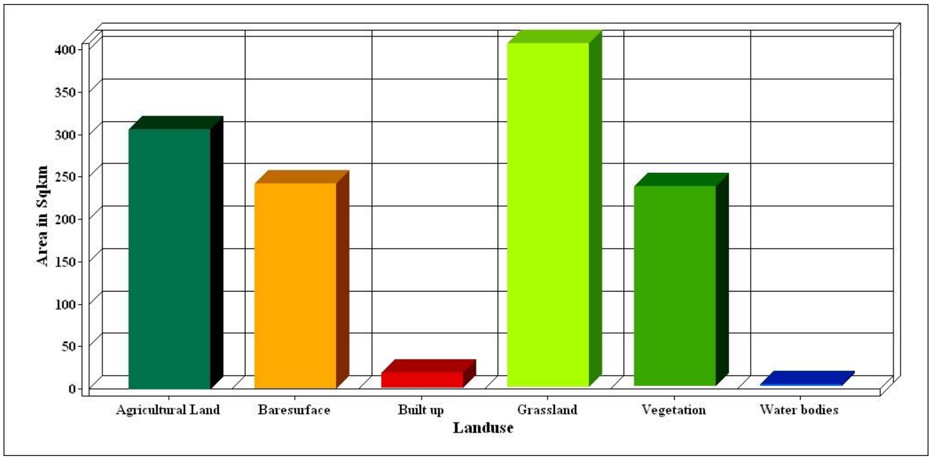

Figure 6.7: LULC area in 2018

Source: (Author, 2019)

Figure 5.7 shows the LULC occupied area distribution in 2018. The dominant land use and land cover were grasslands (407.51 Km^2) and agricultural land (306.30 Km^2) followed by bare surface (242.48 Km^2) representing 33%, 25%, and 20% respectively. Built-up areas (18.50 Km^2) and water bodies (4.27 Km^2) constitutes 1.53% and 0.35% respectively.

4.3 Land Use and Land Cover (LULC) trends

The Land Use and Land Cover evolution in the KRIP from 1988 to 2018 are represented in Table 5.5. The area difference for fifteen years period (1988 to 2003 and 2003 to 2018) and thirty years period (1988 to 2018) were calculated using excel to trace the LULC trend in the KRIP command area.

Table 5.6: Land Use and Land Cover trend from 1988 to 2018

	Area Difference		
LULC Classes	1988 - 2003	2003 - 2018	1988 - 2018
Agricultural Land	15.35	28.12	43.47
Bare surfaces	-17.42	-15.22	-32.64
Built up	2.34	5.85	8.19
Grassland	139.23	-152.48	-13.25
Vegetation	-137.34	134.32	-3.02
Waterbodies	-2.16	-0.58	-2.74

Source: (Author, 2019)

4.3.1 LULC trend from 1988 to 2003

The LULC area difference (Table 5.6) from 1988 to 2003 in the KRIP command area showed that high increase (139.23 Km^2) and decrease (137.34 Km^2) in grassland and vegetation respectively. Similarly, agricultural areas (15.35 Km^2) increased while bare surfaces (17.42 Km^2) decreased. Also, built-up areas (2.34 Km^2) increased, and water bodies (2.16 Km^2) decreased the least.

In general, Kano State is well known for agricultural production even before the development of KRIP. Hence, the distribution of LULC for the year 1988 makes sense and represents the quick response of the KRIP (phase I) following the drought experienced in the 1970s. From the LULC map, it is noticed that agricultural areas are concentrated along the southern and northern part of the command area indicating the earlier sectors develop. Some of the sectors developed in the 1970s include Kadawa, Kosawa, and Kore Sectors all in the west branch.

4.3.2 LULC trend from 2003 to 2018

The LULC area difference (Table 5.6) from 2003 to 2018 in the KRIP command area showed that high decrease (152.48 Km^2) and increase (137.34 Km^2) in grassland and vegetation respectively. Agricultural areas (28.12 Km^2) increased while bare surfaces (15.22 Km^2) decreased. Also, built-up areas (5.85 Km^2) increased, and water bodies (0.58Km^2) decreased the least. In the span of the fifteen years from 2003 to 2018, the changes in the Land Use and Land Cover were affected by many inconsistencies like; the change of merging and re-merging of FMWR and FMARD, the change in governance from military to democratic regime, the change in major revenue generation from agriculture to crude oil; the steady inflation rate to mention a few inflation. All the aforementioned changes have an indirect consequence on the land use and land cover within the KRIP command area.

4.3.3 LULC trend from 1988 to 2018

The LULC area difference (Table 5.6) from 1988 to 2018 in the KRIP command area covered a period of three decades. It showed that the agricultural land has increased by (43.47 Km^2) while bare surface decreased by (32.64 Km^2). Built-up areas increased by (8.19 Km^2) while grassland, vegetation and water bodies all decreased by (13.25 Km^2), (3.02 Km^2) and (2.74 Km^2) respectively. The changes observed clearly shows that agricultural areas development is taking place. This is in line with the KRIP command area development which is going on with recent sectors been developed in 2008. The decreased in the bare surface is justified by the aforementioned increase of agricultural areas and the increase in built-up areas is generally observed close to settlements. As the population is increasing, people tend to build houses within or beside their lands. There is observed decreased in grassland and vegetation as well as water bodies.

We can highlight that agricultural production is generally increasing, and this is in agreement with the crop production data (HJRBDA, 2018); bare surfaces have been replaced by agricultural lands; the decrease in grassland and vegetation suggests high deforestation and overgrazing; increased built-up areas depicts population growth, and urbanization and reduction of water bodies can be viewed from many angles. Excessive sedimentation of canals within and outside the command area, seepage, and losses to the groundwater increased water demand due to increased population and the agricultural regions are possible implications to the water bodies decrease in the KRIP command area.

4.4 NDVI, NDWI and NDMI 2018 maps

The Normalized Difference Vegetation Index (NDVI), Normalized Difference Water Index (NDWI) and Normalized Difference Moisture Difference Index (NDMI) were based on the Landsat 8 imagery acquired using a certain formula during the wet and dry season period of 2018 as shown in Table 4.3. The indices are important factors for water moisture detection and give an estimation of waterlogging areas within the certain defined threshold in the KRIP command area. In this context, the NDVI, NDWI and NDMI indices used for further analysis were that of the dry season for practical purpose and uniformity during overlay operations. All indices vary from +1 to -1 as shown in Figure 5.8 and Figure 5.9 for dry and wet season respectively.

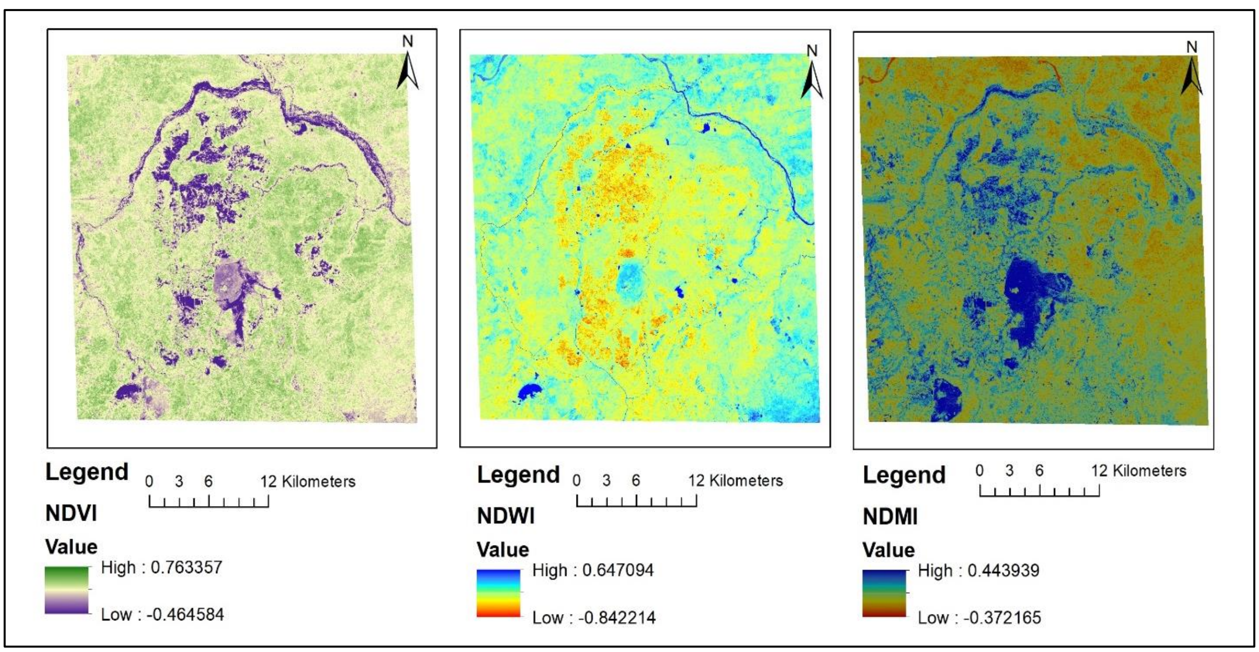

Figure 4.8: NDVI, NDMI, and NDWI for dry season

Source: (Author, 2019)

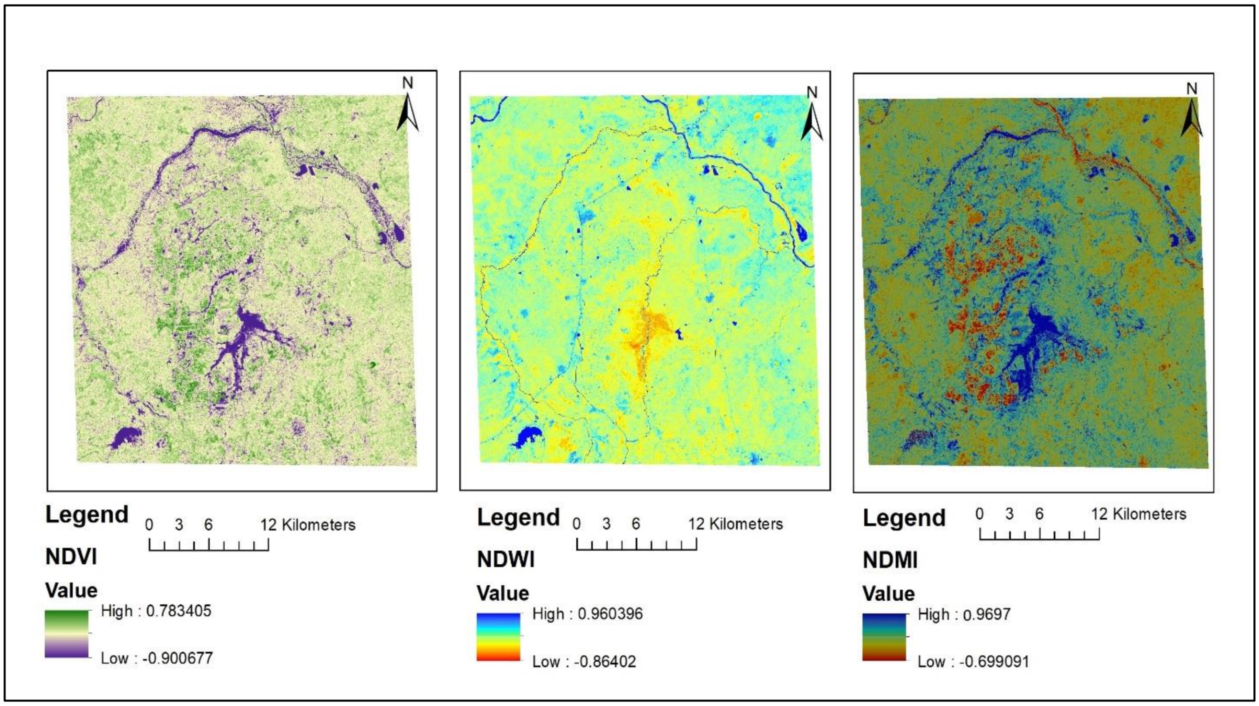

Figure 4.9: NDVI, NDMI and NDWI for wet season

Source: (Author, 2019)

The figure 5.8 shows the ranges of values for all indices in the dry season and there the values of NDVI ranges from -0.46 to +0.76, NDWI ranges from – 0.84 to + 0.64 and NDMI ranges from - 0.37 to + 0.44. figure 5.9 shows the ranges of values for all indices in the wet season and there the values of NDVI ranges from - 0.90 to +0.78, NDWI ranges from – 0.86 to + 0.96 and NDMI ranges from - 0.69 to + 0.97.

The value of NDVI (for wet season), ranges from - 0.90 to + 0.78 reveals that there is dense forest cover as well as deep water bodies. In this case, values high near + 0.78 indicate the presence of agricultural land, grassland, and vegetation while least values near – 0.90 indicate the presence of water bodies. Similarly, high values for NDWI (– 0.86 to + 0.96) and NDMI (- 0.69 to + 0.97) are observed. The value of NDVI (for dry season), ranges from -0.46 to +0.76 reveals that there is dense forest cover as well as deep water bodies. In this case, values high near + 0.76 indicate the presence of agricultural land, grassland, and vegetation while least values near – 0.46 indicate the presence of water bodies. Similarly, high values for NDWI (– 0.84 to + 0.64) and NDMI (- 0.37 to + 0.44) were observed.

Since KRIP is an irrigation scheme and most agricultural production takes place during the dry period. The waterlogging areas estimate in this context is estimated for the dry period to remove the effect of rainfall contribution in calculating the indices. Many thresholds of NDVI, NDWI, and NDMI for waterlogged areas have been reported in the literature as a highlight in chapter four. In general, all indices in dry season presents ranges indicating waterlogging which is clearly the dominant problem in KRIP. The month of December was purposely selected because it is the mid-point between the end of the rainy season (mostly October) and the onset of the rainy season (mostly March). Therefore, the indices are considered to be used in further analysis and estimation of waterlogging areas in the KRIP command area.

4.5 Other data input for waterlogging areas estimation

The methodology employed for the estimation of waterlogging areas in the KRIP command area combined several approaches. However, most came from the studies conducted by Sahu, (2014), Kaushik et al., (2018) and from several other studies. As highlighted in chapter four, the relief, landforms, slope, canal density, settlement density, canal buffer maps (2018) are essential input in waterlogging areas estimation and showed a high correlation. Figure 5.10, Figure 5.11, and Figure 5.12 show the maps aforementioned.

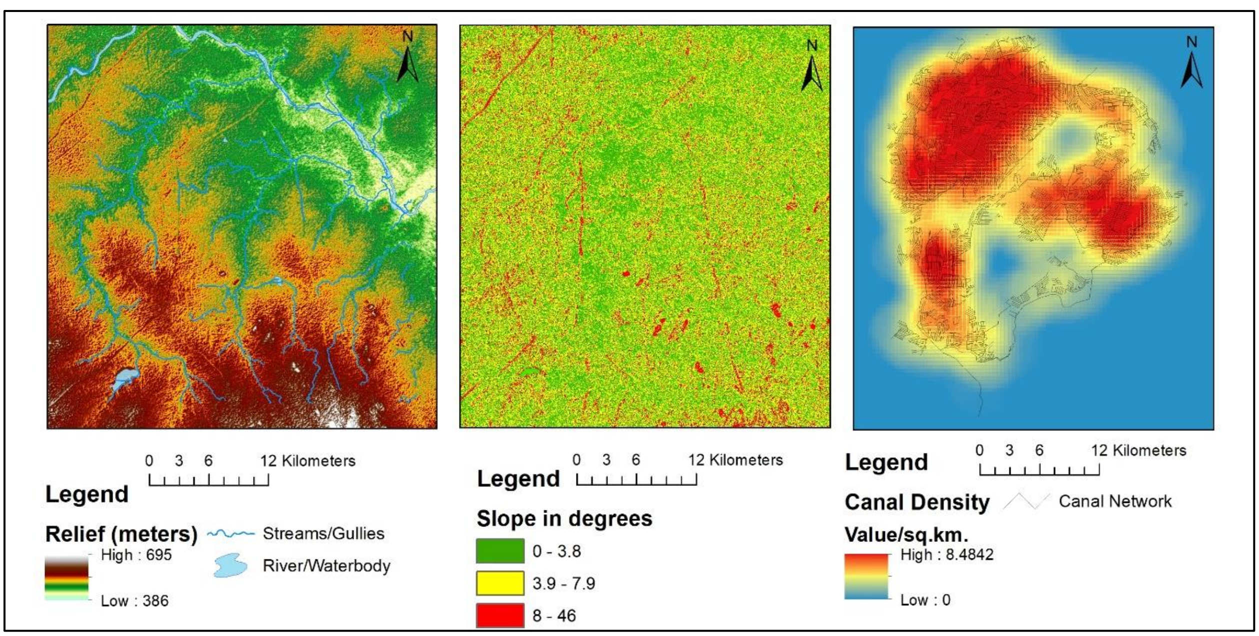

Figure 4.104 Relief, Slope and Canal density based on SRTM 30 m and Irrigation network shapefile of KRIP

Source: (Author, 2019)

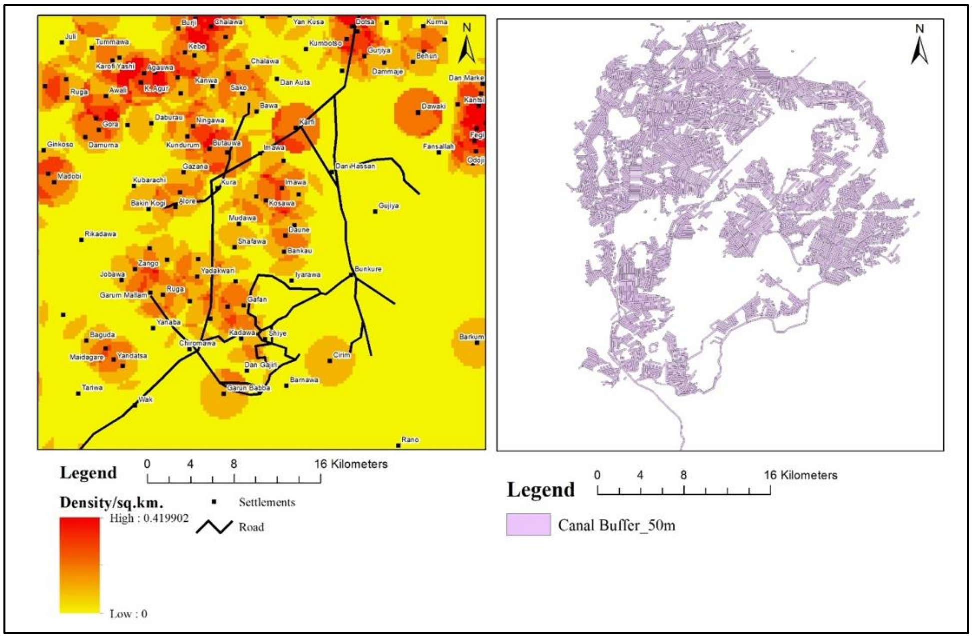

Figure 5.11: Settlement density based on SRTM 30 m and Canal Buffer (50 m) based on Irrigation network shapefile of KRIP

Source: (Author, 2019)

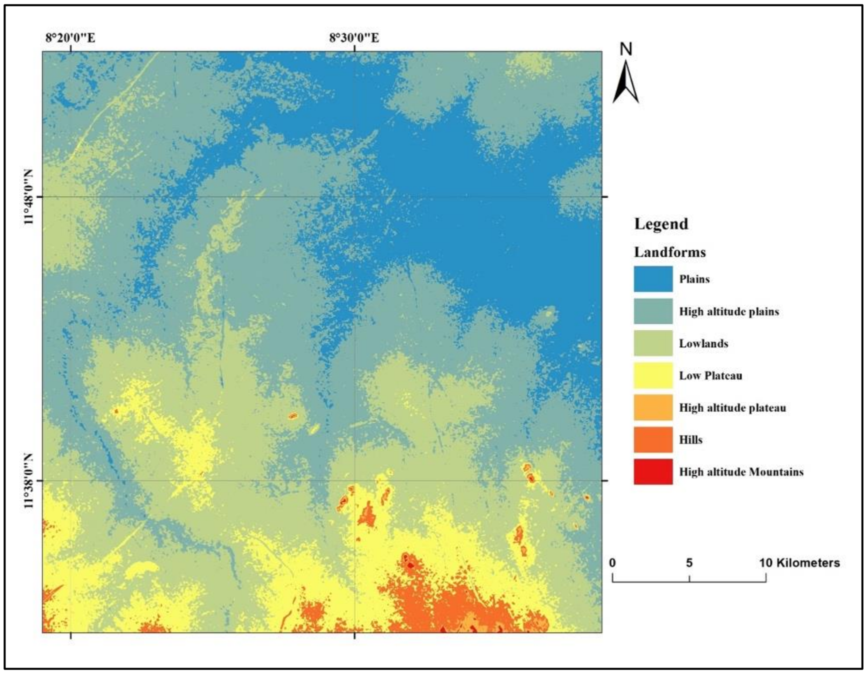

Figure 4.12: Landforms classification based on soil suitability map of KRIP based on SRTM 30 m DEM

Source: (Author, 2019)

The elevation of the KRIP command area ranges between 386 to 695 m based on the relief map. Here elevations have reference points to which measurements are taken. In topographic surveys, such reference points are taken into account to ascertain the actual elevations. The slope map prepared show variation in degree and KRIP command area lies within 0 to 3.8 degrees. To maintain the steady slope within the command areas, there are drop structures provided at every point based on the profile to maintain a steady slope for gravity-fed irrigation that it is. Canal density map show is high (up to 8.48 km^2) but settlement density is quite low and less that one square kilometers square (0.42 Km^2).

The landforms classification is based on DEM and following Maybeck et al., (2001) and Iwahashi and Pike (2007). It presents relief classes which fall with the elevation of the DEM. Moore et al. (1991) stated that the spatial distribution of topographic attributes can be used as an indirect measure of the spatial variability of hydrological, geomorphologic and biological processes. This gives a good advantage in terms of fast estimates and relatively east modeling process. In this context, landform classification was done to demarcate the plains and terraces which are areas where irrigation takes places better. Since it basically depicts elevation, it was used in the estimation of waterlogged areas.

It is noteworthy to mention that all input data are within the same period to ensure all conditions for overlay and intersection are well represented with less variation.

4.6 Assessment of waterlogged surface areas in the KRIP command area

4.6.1 Waterlogging areas of the KRIP command area

Information waterlogged irrigated areas can be estimated in several ways. For instance, irrigated areas can be mapped out with only Normalized Difference Vegetation Index (NDVI). However, a threshold has to be stated and relevant information such as hydrology, cropping pattern, types of crop grown, land use and land cover, soil information must be known. As shown from our Methodological flowchart of the steps in estimating waterlogging areas and LULC trend in KRIP in chapter four, the waterlogging areas were mapped out based on relevant information collected and relationships among factors studied. Equal weights were assigned to relief, slope, landforms, settlement density, canal density, NDVI, NDWI and NDMI maps after thresholding and vectorization. The result is what we present as the estimated waterlogging areas within and beyond the KRIP command area in Figure 5.13. . However, further analysis is done to have a better estimation of waterlogged areas within the irrigation network and for each land use and land cover within the KRIP command area.

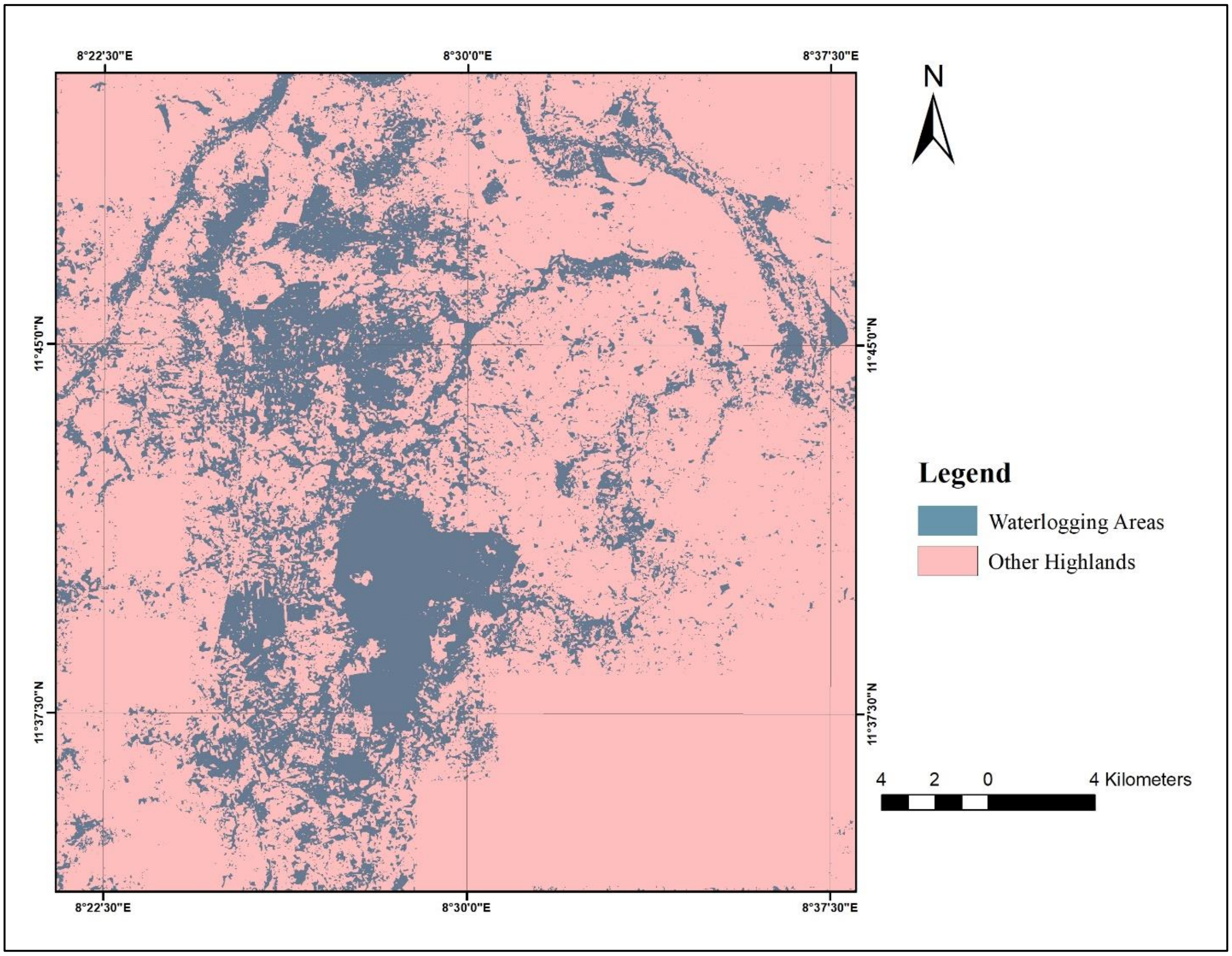

Figure 4.12: Waterlogging areas within and beyond KRIP command area

Source: (Author, 2019)

4.6.2 Waterlogged areas within land use and land cover in the KRIP command area

In order to estimate the waterlogged areas within the KRIP command area, the LULC for 2018 was overlaid on the maps of the waterlogging area. The intersection of each land use and land cover classes with the waterlogging area maps give the estimate of percentage affected areas as shown in figure 5.13 and figure 5.14. Within the waterlogging areas, agricultural land use covers the highest area of 135.55 Km^2, that is 48% of the total land use and land cover. Bare surface covers 47.17 Km^2 which is 16.86%. Grassland and vegetation cover 56.76 Km^2 and 33.11 Km^2 which is 20.30% and 11.84% respectively. The least waterlogged areas within the LULC were built up areas (5.17 Km^2) and water bodies (1.92%) which are 1.85% and 0.69% respectively.

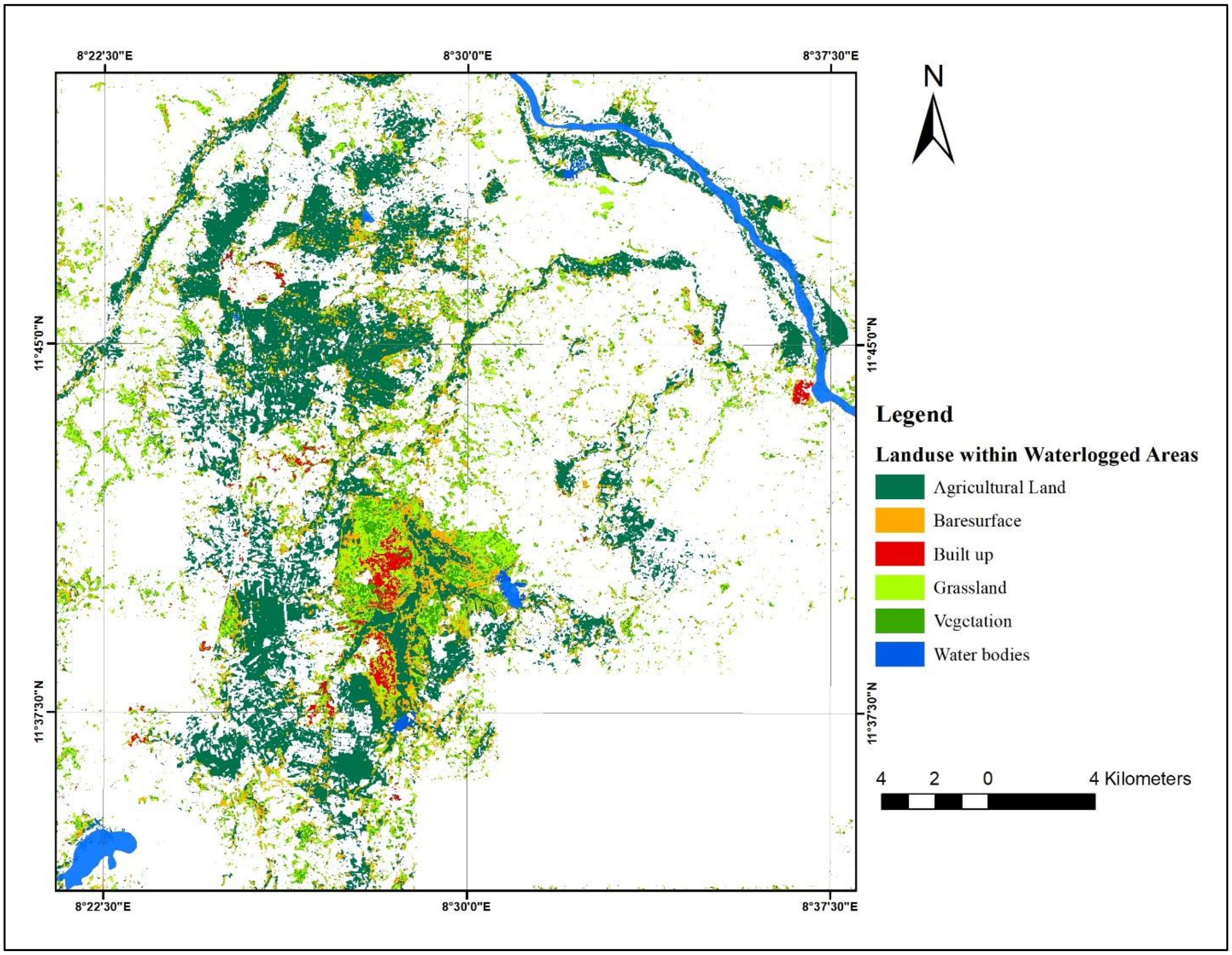

Figure 4.13: Land Use and Land Cover within the waterlogging areas

Source: (Author, 2019)

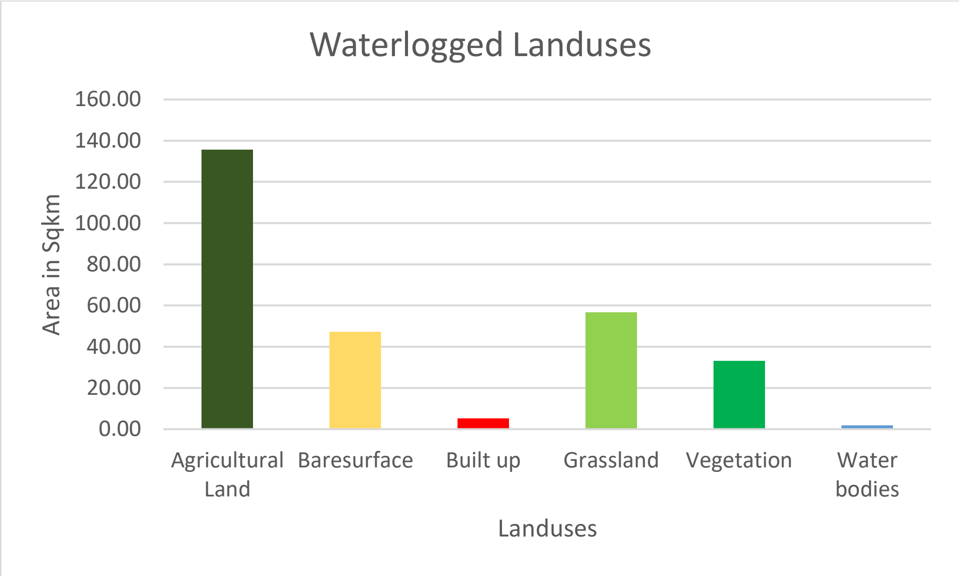

Figure 4.14: Land Use and Land cover distribution within the waterlogging areas

Source: (Author, 2019)

4.6.3 Waterlogged areas within irrigation network (canal buffer 50m) in the KRIP command area

The KRIP command area has an extensive irrigation network consisting of irrigation and drainage canals. The irrigation network is clearly dense in the northeastern parts which are called the west branch canal region. The intersection surface waterlogging area and canal buffer map set at 50 m from either side was carried out and results obtained is presented in table 5.7.

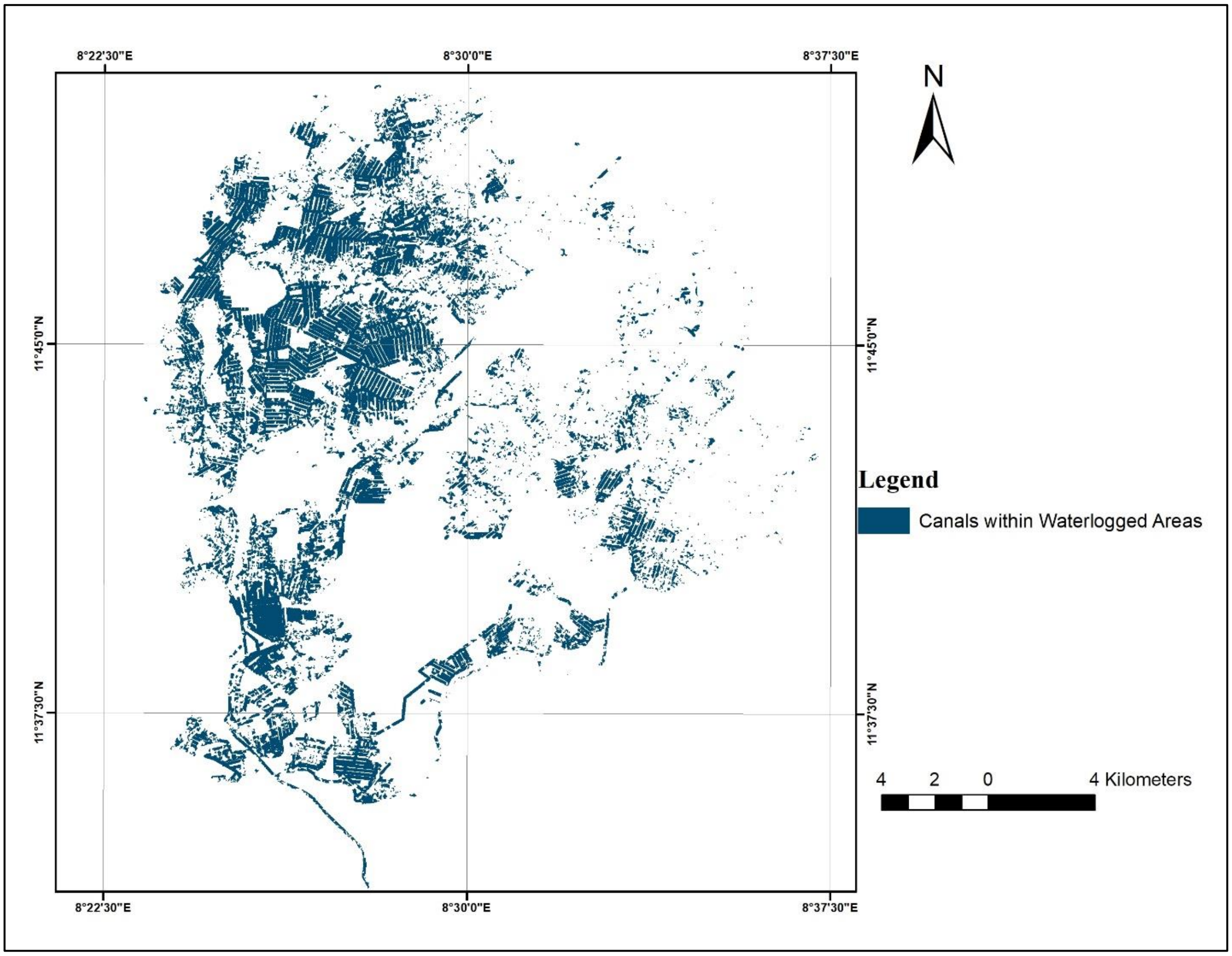

Figure 4.15: Waterlogged areas within the canal buffer (50 m)

Source: (Author, 2019)

Table 5.7: Waterlogged area within canal buffer (50 m)

Area (50m Buffer) sqkm	Area (within Waterlogged) sqkm	% within Waterlogged
244.04	71.20	29.18

Source: (Author, 2019)

The canals in KRIP command area are mostly unlined except the main canals and some of the distributary canals. The results presented indicate the total area (244.04 Km^2) covered by the irrigation network with 50 m buffer on either side and the waterlogged area within the canal is 71.20 Km^2 which is almost 30% of the buffered area.

Leakages and seepage from canals have been observed and can contribute to the waterlogging persisting in the area especially during wet seasons. In addition to the rainfall, there is continuous water released from Tiga reservoir during the wet season to the KRIP command area. The poor condition of the drainage canals to convey water effectively out of the command area becomes a problem resulting in secondary salinization of the soil due to the increased groundwater table.

4.7 Uncertainties in mapping

The accuracy assessment for the LULC mapping indicates overall accuracies of over 90%, 92% and 97% for the LULC maps of 1988, 2003 and 2018 respectively. Using ground truthing points and google earth for visualization during classification also ensured better mapping accuracy, However, there were still data that were underestimated and overestimated as compared to the general knowledge of the KRIP command area for three decades. Although the study area was considered beyond the KRIP command area, the agricultural land areas 262.83 km^2 for 1988, and 278.18 km^2 for 2003 are abnormally high. The area of 306.30 km^2 for 2018 is reasonable and corresponds to the estimated cultivated area within and outside the KRIP command area (FMWR, 2004 and FAO, 2004). This is due to errors in classification which arise from the point of class selection to the end of classification. In an ideal condition, the interval of a period of fifteen years for classification is exceptionally long, shorter periods of say not more than five years should have been considered.

Thresholding of the NDVI, NDWI, and NDMI indices in this study follows a generic method, visual interpretation by collecting many spectral signatures for many years and characterizing the typology of vegetation and water response within the KRIP command area would yield a better result. Also, exploring RS and GIS on KRIP is not typical and not enough studies are available to compare the findings of this study.

4.8 Economic and Financial analysis

The objective of economic and financial analysis to quantify the agricultural benefits of crop production. In this context, detailed local data for the crop production in the KRIP scheme was collected from HJRBDA, literature, government databases (Central Bank of Nigeria, Federal Ministry of Finance, National Bureau of Statistics), FAO and, the world bank. To achieve our objective, the main component of the considered were cropping pattern, crop budgets, crop yield response, and farm budget. The details of the method and derivation of financial farmgate prices for internationally traded commodities are detailed in chapter four and appendix.

4.8.1 Derivation of Financial and Economic Farmgate Prices for Internationally Traded Commodities

Financial and economic farmgate prices were derived for internationally traded commodities. However, not all commodities produced in the KRIP scheme were derived internationally. Therefore, local crop data were collected and compared with the international data when available. The local prices for commodities are used directly in the absence of international prices. Figure 5.16 shows the variation of the local prices, local farmgate prices (Authors calculation) and international farmgate prices.

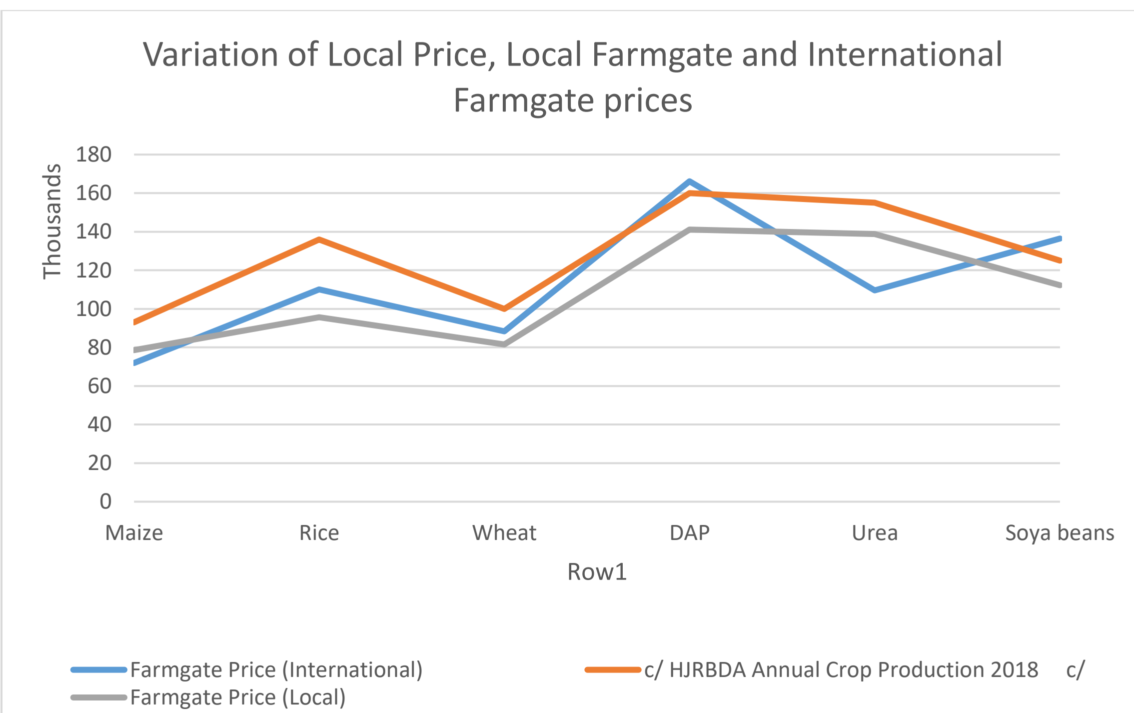

Figure 4.16: Variations between local prices, local farmgate prices (Authors calculation) and international farmgate prices

Source: (Author, 2019) based on 2018 data

4.8.2 Cropping patterns and crop budgets

To estimate the crop budget for each crop per hectare, the cropping pattern is important to provide the cropping period as described in chapter four. All crops grown in the KRIP command area during the wet and dry season are identified and featured for crop budget estimates. The major crops grown in wet season are maize, sorghum, rice, legumes/oilseed while major crops grown in the dry season are wheat, maize, rice, tomato, onions, and vegetables.

Crop budgets were calculated based on crop yields, crop input, produce prices, produce input, wages rates as well as labor and machinery requirements in financial and economic terms with all the fixed and variable costs detailed in the appendix. For instance, figures 5.17 and 5.18 show the financial and economic crop budget for rice for the present, future without project (FWO) and future with (FW) project respectively.

Crop Budget for Rice per Hectare (Financial)										
		Present Situation			Without Project			With Project		
Item	Unit	Unit/ha	Price (NGN)	Value (NGN)	Unit/ha	Price (NGN)	Value (NGN)	Unit/ha	Price (NGN)	**Value (NGN)**
RETURNS										
Rice	tonne	3.50	104,999	367,497	2.70	104,999	283,497	5.00	104,999	524,995
Crop residue	tonne	2.50	5,000	12,500	1.90	5,000	9,500	3.50	5,000	17,500
Gross Returns				**379,997**			**292,997**			**542,495**
VARIABLE COSTS										
Materials										
Seed	Kg	30.00	250	7,500	30.00	250	7,500	60.00	250	15,000
Fertilizer										
Urea	Kg	150.00	110	16,500	150.00	110	16,500	200.00	110	22,000
NPK	Kg	200.00	167	33,400	200.00	167	33,400	200.00	167	33,400
Manure	tonne	2.00	1,000	2,000	2.00	1,000	2,000	2.00	1,000	2,000
Chemicals										
Herbicides	litre	3.00	1,000	3,000	3.00	1,000	3,000	4.00	1,000	4,000
Pesticides	litre	2.00	1,000	2,000	2.00	1,000	2,000	3.00	1,000	3,000
Other inputs	LS	1.00	2,500	2,500	1.00	2,500	2,500	2.00	2,500	5,000
sub-total				**66,900**			**66,900**			**84,400**
Labour										
Family										
Planting	day	5.00	Nil	Nil	5.00	Nil	Nil	5.00	Nil	Nil
Weeding	day	5.00	Nil	Nil	5.00	Nil	Nil	5.00	Nil	Nil
Other field tasks	day	5.00	Nil	Nil	5.00	Nil	Nil	5.00	Nil	Nil
harvesting	day	10.00	Nil	Nil	10.00	Nil	Nil	5.00	Nil	Nil
Post-harvest tasks	day	10.00	Nil	Nil	10.00	Nil	Nil	5.00	Nil	Nil
Hired Labour										
All activities	day	25.00	600	15,000	25.00	600	15,000	75.00	600	45,000
Sub-total		60.00		**15,000**	60.00		**15,000**	100.00		**45,000**
Oxen/Machinery Hire										
Land Preparation	day	1.00	15,000	15,000	1.00	15,000	15,000	1.00	15,000	15,000
Transport to store	tonne	3.50	1,250	4,375	2.70	1,250	3,375	5.00	1,250	6,250
sub-total				**19,375**			**18,375**			**21,250**
Total Variable Costs				**101,275**			**100,275**			**150,650**
GROSS MARGIN				**278,722**			**192,722**			**391,845**

Figure 4.17: Financial crop budget for rice per hectare

Source: (Author, 2019) based on 2018 data

Crop Budget for Rice per Hectare (Economic)										
		Present Situation			Without Project			With Project		
Item	Unit	Unit/ha	Price (NGN)	Value (NGN)	Unit/ha	Price (NGN)	Value (NGN)	Unit/ha	Price (NGN)	**Value (NGN)**
RETURNS										
Rice	tonne	3.50	85,771	300,199	2.70	85,771	231,582	5.00	85,771	428,855
Crop residue	tonne	2.50	5,000	12,500	1.90	5,000	9,500	3.50	5,000	17,500
Gross Returns				**312,699**			**241,082**			**446,355**
VARIABLE COSTS										
Materials										
Seed	Kg	30.00	70	2,112	30.00	250	7,500	60.00	250	15,000
Fertilizer										
Urea	Kg	150.00	105	15,750	150.00	105	15,750	200.00	105	21,000
NPK	Kg	200.00	160	32,000	200.00	160	32,000	200.00	160	32,000
Manure	tonne	2.00	1,500	3,000	2.00	1,000	2,000	2.00	1,000	2,000
Chemicals										
Herbicides	litre	3.00	1,000	3,000	3.00	1,000	3,000	4.00	1,000	4,000
Pesticides	litre	2.00	1,000	2,000	2.00	1,000	2,000	3.00	1,000	3,000
Other inputs	LS	1.00	2,500	2,500	1.00	2,500	2,500	2.00	2,500	5,000
sub-total				**60,362**			**64,750**			**82,000**
Labour										
Family										
Planting	day	5.00	400	2,000	5.00	400	2,000	5.00	400	2,000
Weeding	day	5.00	400	2,000	5.00	400	2,000	5.00	400	2,000
Other field tasks	day	5.00	400	2,000	5.00	400	2,000	5.00	400	2,000
harvesting	day	10.00	400	4,000	10.00	400	4,000	5.00	400	2,000
Post-harvest tasks	day	10.00	400	4,000	10.00	400	4,000	5.00	400	2,000
Hired Labour				-			-		400	-
All activities	day	25.00	400	10,000	25.00	400	10,000	75.00	400	30,000
Sub-total		60.00	400	**24,000**	60.00		**24,000**	100.00		**40,000**
Oxen/Machinery Hire										
Land Preparation	day	1.00	15,000	15,000	1.00	15,000	15,000	1.00	15,000	15,000
Transport to store	tonne	3.50	1,213	4,246	2.70	1,213	3,275	5.00	1,213	6,065
sub-total				**19,246**			**18,275**			**21,065**
Total Variable Costs				**103,608**			**107,025**			**143,065**
GROSS MARGIN				**209,091**			**134,057**			**303,290**

Figure 4.18: Economic crop budget for rice per hectare

Source: (Author, 2019) based on 2018 data

The results obtained after crop budgets per hectare for each crop are gross margins (total variable cost less returns). In simple terms, deducting all production costs from revenues assuming that farmgate and local prices will remain constant for the present value.

Financial net returns in the present and FW situation show a significant improvement from NGN 278,722 to NGN 391, 845 while FWO (estimate is explained in the next section) situation show a significant decrease in net returns of NGN 192, 722. Similarly, economic net returns in the present and FW situation show a significant improvement from NGN 209,091 to NGN 303,290 while FWO situation show a significant decrease in net returns of NGN 134, 057.

In should be well noted that this is an ideal condition where average inputs for crop production are available and estimation is based on net return per hectare. In a normal condition, majority of the farmers do not hold up to one hectare of land and do not have all the input required for an optimal production.

4.8.2 Crop yield response

When management of irrigation and drainage is reduced or absent, the crop yield is expected to reduce due to waterlogging and salinity. The decrease in yield is estimated with the crop salt-tolerant data established by FAO, (2002b) detailed in chapter four of this report. To use the crop yield response function, the present crop yield was compared against the annex provided by FAO and typical EC_e (the mean electrical conductivity of a saturated paste taken from the root zone) averages from recent soil analysis in the KRIP command area. The average EC_e from soil analysis conducted in the entire KRIP command area in 2015 were obtained. Other values of EC_e obtained from soil salinity assessment of Kadawa sector by Maina & Amin, (2012) were also adopted. The tables 5.8, 5.9 and 5.10 shows the results of percentage relative yield (Yr) was crossed for the corresponding EC_e values.

Table 5.8: Crop yield response (EC_e 3.44 = dS/m)

Crop Name	100	b	a	EC_e	(EC_e - a) = c	(b * c) = d	(100 - d) = Yr
Corn	100	12	1.7	3.44	1.74	20.88	79.12
Corn (forage)	100	7.4	1.8	3.44	1.64	12.136	87.864
Rice, paddy	100	12	3	3.44	0.44	5.28	94.72
Cucumber	100	13	2.5	3.44	0.94	12.22	87.78
Onion (bulb)	100	16	1.2	3.44	2.24	35.84	64.16
Tomato	100	9.9	2.5	3.44	0.94	9.306	90.694
Okra	100	0	0	3.44	3.44	0	100
Carrot	100	14	1	3.44	2.44	34.16	65.84
Cabbage	100	9.7	1.8	3.44	1.64	15.908	84.092

Source: (Author’s calculation, 2019)

Table 5.9: Crop yield response (EC_e 2.40 = dS/m)

Crop Name	100	b	a	EC_e	(EC_e - a) = c	(b * c) = d	(100 - d) = Yr
Corn	100	12	1.7	2.4	0.7	8.4	91.6
Corn (forage)	100	7.4	1.8	2.4	0.6	4.44	95.56
Onion (bulb)	100	16	1.2	2.4	1.2	19.2	80.8
Okra	100	0	0	2.4	2.4	0	100
Carrot	100	14	1	2.4	1.4	19.6	80.4
Cabbage	100	9.7	1.8	2.4	0.6	5.82	94.18

Source: (Author's calculation, 2019)

Table 5.10: Crop yield response (EC_e 2.40 = dS/m)

	100	b	a	EC_e	(EC_e - a) = c	(b * c) = d	(100 - d) = Yr
Corn	100	12	1.7	1.98	0.28	3.36	96.64
Corn (forage)	100	7.4	1.8	1.98	0.18	1.332	98.668
Onion (bulb)	100	16	1.2	1.98	0.78	12.48	87.52
Okra	100	0	0	1.98	1.98	0	100
Carrot	100	14	1	1.98	0.98	13.72	86.28
Cabbage	100	9.7	1.8	1.98	0.18	1.746	98.254

Source: (Author's calculation, 2019)

where a = the salinity threshold expressed in dS/m; b = the slope expressed in percent per dS/m; and EC_e = the mean electrical conductivity of a saturated paste taken from the root zone.

The threshold and slope values were taken directly from the salt tolerance data from the FAO, (2002) Irrigation and Drainage paper 61, Annex 1. The salinity threshold ranges from 0 to 1.8 dS/m and the slope ranges from 0 to 9.7 dS/m. The results obtained for relative yield ranges from 64.16 % to 100% for ECe of 3.44 dS/m; ranges from 80.4% to 100% for 2.4 dS/m and ranges from 86.28% to 100% for 1.98 dS/m respectively.

The results indicate that most of the crops salt tolerance ranges between sensitive (S), moderately sensitive (MS) and moderately tolerant (MT). Therefore, factoring the effect during the financial and economic analysis was a key step in quantifying the agricultural benefits.

4.8.3 Farm budget and agricultural benefit

The objective of farm budget is to evaluate the agricultural benefit derived from crop production. In this context, we are focused on the economic and financial benefits of agricultural drainage (irrigation in this case) projects and the potential increase in agricultural production, and crop diversification opportunities. The detailed method is a combination of guidelines and previous studies. However, the results are presented in tables 5.11 and 5.12.

Table 5.11: Financial Farm Budget for KRIP scheme (2018)

Farm Size		0.46 ha			0.46 ha			0.46 ha	
		Present Situation			Without Project			With Project	
Cropping Pattern	Area/ha	Gross Margin per ha	Financial Gross Margin	Area/ha	Gross Margin per ha	Financial Gross Margin	Area/ha	Gross Margin per ha	Financial Gross Margin
Crop									
Wet season									
Maize	0.02	97,098	1,942	0.02	66,268	1,325	0.06	247,395	14,844
Sorghum	0.02	23,800	476	0.02	19,863	397	0.14	57,200	8,008
Rice	0.4	278,722	111,489	0.4	192,722	77,089	0.14	391,845	54,858
Tomato a/		221,000	-		177,050	-	0.06	425,100	25,506
Legumes / oilseeds	0.01	97,629	976	0.01	84,605	846	0.06	169,436	10,166
Sub-total	0.46		114,883	0.46		79,658	0.46		113,382
Dry season									
Maize	0.08	97,098	7,768	0.08	66,268	5,301		247,395	-
Sorghum		23,800	-		19,863	-	0.06	57,200	3,432
Rice	0.01	278,722	2,787	0.01	192,722	1,927		391,845	-
Tomato b/	0.29	221,000	64,090	0.29	177,050	51,345	0.14	425,100	59,514
Cowpea	0.02	97,629	1,953	0.02	84,605	1,692	0.06	169,436	10,166
Wheat	0.02	135,309	2,706	0.02	101,474	2,029		203,948	-
Onion	0.01	349,875	3,499	0.01	310,275	3,103	0.12	494,200	59,304
Vegetables	0.02	289,200	5,784	0.02	217,325	4,347	0.09	373,600	33,624
Sub-total	0.46		88,587	0.46		69,744	0.46		166,040
Farm Gross Margin			203,469			149,402			279,422
Less Fixed Costs									
Land Rent		5,000			5,000			5,000	
Farm tools 1/ and other expenses	1.00	10,000	10,000	1.00	10,000	10,000	2.50	10,000	25,000
Sub-total		-	10,000			10,000			25,000
Net Farm Returns			193,469			139,402			254,422
Irrigation O&M Fees 2/	0.92	5,000	4,600	0.92	5,000	4,600	0.92	15,000	13,800
Net Farm Returns (after irrigation O&M)			188,869			134,802			240,622
Irrigation Fees as % Net Farm Returns (before fees)			**2%**			**3%**			**5%**

Source: (Author's calculation, 2019)

Table 5.12: Economic Farm Budget for KRIP scheme (2018)

Farm Size		0.46 ha			0.46 ha			0.46 ha	
		Present Situation			Without Project			With Project	
Cropping Pattern	Area/ha	Gross Margin per ha	Economic Gross Margin	Area/ha	Gross Margin per ha	Economic Gross Margin	Area/ha	Gross Margin per ha	Economic Gross Margin
Crop									
Wet season									
Maize	0.02	97,778	1,956	0.02	74,517	1,490	0.06	249,890	14,993
Sorghum	0.02	7,944	159	0.02	5,630	113	0.14	40,781	5,709
Rice	0.4	209,091	83,636	0.4	134,057	53,623	0.14	303,290	42,461
Tomato a/		222,875	-		177,125	-	0.06	441,125	26,468
Legumes / oilseeds	0.01	93,698	937	0.01	80,759	808	0.06	168,836	10,130
Sub-total	0.46		86,688	0.46		56,033	0.46		99,761
Dry season									
Maize	0.08	97,778	7,822	0.08	74,517	5,961		249,890	-
Sorghum		7,944	-		5,630	-	0.06	40,781	2,447
Rice	0.01	209,091	2,091	0.01	134,057	1,341		303,290	-
Tomato b/	0.29	222,875	64,634	0.29	177,125	51,366	0.14	441,125	61,758
Cowpea	0.02	93,698	1,874	0.02	80,759	1,615	0.06	168,836	10,130
Wheat	0.02	124,354	2,487	0.02	93,470	1,869		195,090	-
Onion	0.01	340,350	3,404	0.01	335,550	3,356	0.12	485,625	58,275
Vegetables	0.02	239,055	4,781	0.02	179,588	3,592	0.09	315,490	28,394
Sub-total	0.46		87,092	0.46		69,100	0.46		161,004
Farm Gross Margin			173,780			125,133			260,765
Less Fixed Costs									
Land Rent		5,000			5,000			5,000	
Farm tools 1/ and other expenses	1.00	10,000	10,000	1.00	10,000	10,000	2.50	10,000	25,000
Sub-total		-	10,000			10,000			25,000
Net Farm Returns			163,780			115,133			235,765
Irrigation O&M Fees 2/	0.92	5,000	4,600	0.92	5,000	4,600	0.92	15,000	13,800
Net Farm Returns (after irrigation O&M)			159,180			110,533			221,965
Irrigation Fees as % Net Farm Returns (before fees)			**3%**			**4%**			**6%**

Source: (Author's calculation, 2019)

The farm budget analysis was based on the average farm size (0.46 ha), cropping pattern and crop budgets analysis already discussed and analyzed in chapters four and five of the report. The analysis was done to evaluate in economic and financial terms the impact of the KRIP on farm incomes and highlight the cost of operation and maintenance of irrigation and drainage system and potential for improving farm incomes and maintaining the system.

The average landholding was distributed based on the cropping pattern of the KRIP scheme against the economic and financial gross margins to derive the estimated net returns to the farmers in the present, FWO, and FW project situations. Net farm income is calculated using equation (2), therefore the fixed and variable cost was deducted from the gross farm margin (income).

For the year 2018, the net farm income (financial) for farmers in KRIP scheme with an average landholding of 0.46 ha was **NGN 193, 469, NGN 139,402 and, NGN 254,422** for the present, FWO and, FW before ISF respectively. The net farm income after ISF was **NGN 188, 869, NGN 134,802 and, NGN 240,622** respectively.

That means higher fixed cost, variable cost, and ISF for operation and maintenance will yield NFI of NGN 193, 469 for just 2% of the ISF in the present situation; reduce to NGN 139, 402 for 3% of the ISF in the FWO situation and increase to NGN 254, 422 for up to 5% of the ISF in FW situation.

A similar trend for ISF is observed for economic farm budget where NFI of NGN 163,780 for just 3% of the ISF in the present situation; reduce to NGN 125,113 for 4% of the ISF in the FWO situation and increase to NGN 235,765 for up to 5% of the ISF in FW situation.

We can conclude that operation and maintenance with monitoring require both human and financial resources. The farmers are willing to pay more both in cash and kind and the ISF money can be managed properly with the current ongoing transformation project recommendation of involving service providers (private sector). In addition, with the recent commitment of the Federal Government of Nigeria (FGN) to bring back agriculture and feed the country and beyond, there is a likelihood of improvement. The yearly allocation (see figure 5.18) for rehabilitation and maintenance of irrigation and drainage infrastructure in the KRIP, though no full knowledge of how it is used is known within the context of this study, could also be one of the ways to ensure proper operation, maintenance, and management of the scheme.

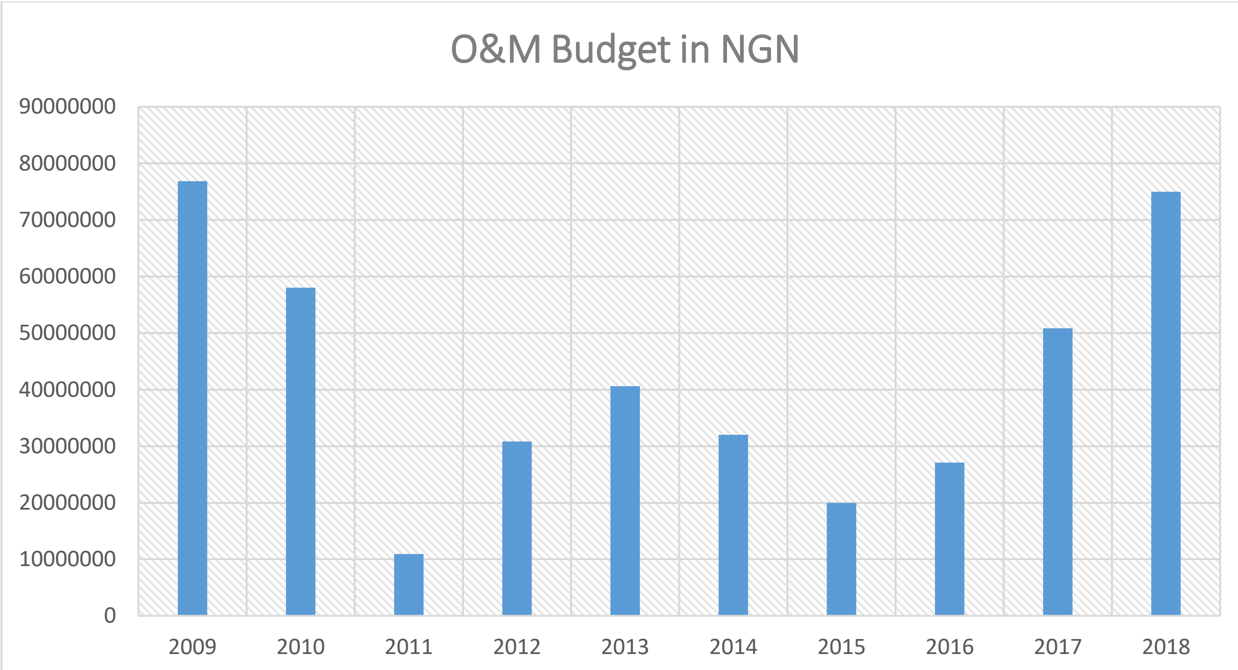

Figure 4.18: Yearly allocation for rehabilitation of irrigation and drainage systems for KRIP
Source: (Budget office of the Federation, FGN)

4.9 Farmer's perception of Participatory Irrigation Management (PIM)

We have earlier defined PIM and highlighted the studies conducted in the KRIP as well as the TRIMING PIM strengthening structure which the intervention set to address. However, within the context of our study, we conducted a rapid participatory research approach employing the DRAINFRAME methodology and the opportunity to seek the farmer's perception on PIM was available. One of the advantages of the DRAINFRAME approach is the qualitative nature i.e. information can be generated qualitatively in-depth (Abdeldayem et al., 2005).

A main drainage in Kosawa Sector (Pegin Malu) on the west side of KRIP command area was selected based on the following criteria; (i) major constraint in agricultural production (ii) willingness of the farmer’s adjacent to the main drain to participate (ten farmers) (iii) farmers understanding and experience of PIM.

In conducting a field demonstration after an awareness workshop, it was clear that flexibility is required to link research, practice, and decision making through localized processes like traditional participatory approach. This is because the dynamics of problems are unique and vary from one sector to another. Therefore, set-theoretical standards are often ideal and should be replaced with real situations and tacit knowledge of the farmers.

Haruna (2015) reported based on the surveyed farmers in KRIP that 84% and 46% participate in field canal and distributary canals weeding and clearing. Participation is usually on a worst-case scenario base rather than routine activity. This suggests that farmers are willing to manage the irrigation without any influence by the water managers. In the end, irrigation is a means of livelihood to most of the farmers. Therefore, the will to participate will always be there, and water managers should leverage on a traditional participatory approach.

4.9.1 Major Constraint in agricultural production

The case of Kosawa sector is unique and indicate the best example of drainage induced waterlogging in the KRIP command area. The main drain selected is silted and infested with aquatic weed. However, a simple effort would see it cleared, and drainage water could flow. According to the farmers, it is impossible to cultivate the lands during the wet season. The lands become completely flooded and water level reaches the chest level when one is standing in the middle of the agricultural area[10]. Interestingly, a farmer in the sector was found building a wall around his land to keep the water away which he considered a solution to the persistent waterlogging. The farmers contributed money and hired an excavator to clean up the main drain which was a solution only for agricultural production during the late dry season (Late December to Early March). The field drains and even collector drains are used for crop cultivation and when they exist, they are usually unlined. Waterlogging and flooding still happen and production yields are usually low indicating possible secondary salinity.

4.9.2 Willingness of the farmer's adjacent to the drain to participate (ten farmers)

The farmers selected are willing to participate in the study which they believe will solve the problem of persistent waterlogging in the Kosawa sector (Pegin Malu). During the problem identification phase, and informal focused group discussion in the form of a workshop was conducted with the ten farmers in attendance. After the workshop, a date was scheduled to carry out a joint routine monitoring demonstration.

[10] A testimony by the ten farmers participating in the study.

4.9.3 Farmers understanding and experience of PIM

According to the ten farmers, the concept of PIM has been in existence long before the KRIP started. It is traditionally called "*aikin gayya*" which literally means, "work of invitation". Prior to a work, an announcement is made, and invitees present will work tirelessly. All the farmers reported between 20 to 30 years' experience and a sound understanding of traditional and present-day PIM.

4.9.4 Lessons learned from participatory irrigation approach

The major lessons learned in this approach are itemized based on Kosawa sector (Pegin Malu) experience.

1. Routine maintenance saves time, money and ensures year-round agricultural production.

Instead of worse-case maintenance, routine maintenance will solve the problem of having to live with waterlogging and flooding.

2. Drainage systems are meant to convey the excess drainage water on the surface and control the high groundwater table.

Cultivation in the main drains, joining the field drains with the farmlands and using collector drains for irrigation contributes to the siltation of the main drains.

3. Standardization to flexibility

Instead of standardized design and implementation practices, a sector-based approach is recommended to solve local problems. However, building around lands as seen in the Kosawa Sector will not solve the problem of waterlogging.

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The main objective of the study is to evaluate the drainage typology and benefits along with the impacts on irrigated lands to explore the potential of agricultural land drainage in sustaining irrigated agriculture in the Kano River Irrigation (KRIP). To achieve this, the DRAINFRAME approach from the engineering perspective was adopted to guide the research in a systematic manner.

First and foremost, field survey and semi-structured interviews were conducted, and problems and opportunities analysis was done. It has been found that the KRIP command area has three main landscapes: irrigation system, the drainage system and the agricultural land from the perspective of engineering and linking the functions and stakeholders served by the values of those functions. Identification of these landscapes helped to better analyze the problems and opportunities in the KRIP command area. Results of analysis of irrigation systems highlighted: poor water conveyance and distribution, absence of monitoring of water release, and high competition among water users. It has been found that drainage systems are used as extra fertile land to cultivate all year round. However, most of the drainage systems are waterlogged or infested with weed making it impossible to drain excess water or to cultivate. It was also found that drainage water is reused unofficially. Hence, many agricultural productions take place outside the command area. The consequence of improper irrigation and drainage practice became a burden for agricultural land. Waterlogging and secondary salinity were identified as key issues especially during the wet season. It was clear that technical knowledge, equity in water distribution, cost-effectiveness, monitoring, and measurements are opportunities that can be leveraged to end farmers ignorance and management characteristics problems. The identification of these problems helped to better the impacts and how it can be assessed within the time of the research and with the available data.

To assess the impact of drainage in the KRIP command area, waterlogging along with land use and land cover changes are important factors controlling the natural drainage and artificial drainage in the command area. Although monitoring data were unavailable, we found that combining remotely sensed data and our collected field data served the purpose. The remote sensing (RS) and GIS techniques are the state of the art means of monitoring environmental matrices widely in recent years. In this context, we acquired Landsat satellite images (Landsat 5 TM for the year 1988 and 2003 and, Landsat 8 OLI for the years 2018), Digital Elevation Model (DEM), ground truth data and KRIP base maps. Also, we acquired wet and dry season Landsat 8 OLI for December and July 2018 to calculate the NDVI, NDWI, and NDMI indices for the estimated waterlogging areas. First, land use and land cover classification were done to assess the land-use trend. The results show that within three decades 1988 to 2018, land use and land cover classes like bare surfaces, grassland, vegetation and water bodies have decreased in area by 32.64 Km^2, 13.25 Km^2, 3.03 $Km^{2,}$ and 2.74 Km^2 respectively. Agricultural land has been remarkably increased by 43.47 Km^2 and the built-up regions also increased by 8.19 Km^2. The LULC trend may be explained by the conversion of vegetation and grassland for agricultural production and infrastructure development. However, decreasing water bodies may be due to siltation and evaporation in reservoir and canals, rainfall variability (Mohammed et al., 2015) and water use pressure which will be worst with the plan hydropower development of 10 megawatts (FMWR, 2016).

It has been found that vegetation, water, and moisture indices are good indirect ways of waterlogged areas identification. The results obtained for NDVI ranges from -0.46 to +0.76, NDWI ranges from – 0.84 to + 0.64 and NDMI ranges from - 0.37 to + 0.44 in the dry season. The values of NDVI ranges from - 0.90 to +0.78, NDWI ranges from – 0.86 to + 0.96 and NDMI ranges from - 0.69 to + 0.97 in the wet season. The results indicate the presence of dense forest as well as deep water bodies. The water ranges for water thresholds applied for the identification of waterlogged areas.

To assess the surface waterlogged areas, other spatial topographic attributes have been found to give a good measure of spatial variability of hydrological, geomorphological and biological processes and correlate significantly with the indices aforementioned. Hence, relief, slope, landforms, canal density, and settlement density were mapped. Also, the canal buffer of 50 m was mapped to estimate waterlogged areas within the irrigation network and for each land use and land cover class with the LULC maps. One should note that all maps are from 2018, and equal weight was assigned for fuzzy overlay. The results showed that 279.79 km^2 of the total area of 1217.91 Km^2 considered are waterlogging areas. Upon intersecting the map of the waterlogging area and LULC for 2018, it was found that agricultural land covers 48%, bare surface cover 16.86%, grassland cover 20.30% and vegetation cover 11.84%. The least waterlogged areas within the LULC were built-up areas and water bodies, covering 1.85% and 0.69% respectively.

Subsequently, the waterlogging area map was intersected with the canal buffer (50 m either side) to estimate the waterlogged areas with the canal buffer. The results showed that area buffered cover 244.04 Km^2 and 71.20 Km^2 (29.18%) was within the waterlogging areas. One should note that the mapping process using remotely sensed data have uncertainties despite the high accuracies of assessment of 90%, 92%, and 97%.

The net farm income (NFI) is important to highlight the agricultural benefits. In this context, the crop budget for each crop was derived for the present, FWO and FW situation factoring the crop yield response, cropping pattern, farm size (0.46 ha) as well as international and local traded commodity prices. The results showed that NFI for average farm size of 0.46 ha was NGN 193, 469, NGN 139,402 and, NGN 254,422 for the present, FWO, and FW. The percentage of irrigation fees (ISF) was evaluated to understand the increase in NFI in the present, FWO, and FW situation. It was found that paying more ISF in the FW results to higher NFI.

To operationalize Participatory Irrigation Management (PIM) in the Kosawa sector of KRIP. We adopted and improved the traditional participatory approach called "*aikin gayya*". We selected ten farmers based on agricultural production constraint, willingness to participate, and proximity to the drainage canal in the Kosawa Sector (*Pegin Malu*). It was found that set theoretical standards are often ideal and should be replaced with real situations and tacit knowledge of the farmers. With proper capacity building, farmers can carry out routine maintenance without having to wait for the agency (water managers).

In the end, the study demonstrates the use of DRAINFRAME as a useful approach and systematic to analyze the drainage problems, opportunities, impacts, and benefits in the KRIP command area. It has been shown that agricultural land drainage has the potential to sustain the irrigated agriculture of the Kano River Irrigation Project, taking into account the highlighted findings of this research. It is noteworthy that stakeholder's participation in this study provided relevant and peculiar information which drives the key findings of this research, especially in problem identification.

5.2 Recommendations

At the end of the research, we came up with the following recommendations based on the limitations of the study and suggestions for further studies.

- Drainage should be treated as an integrated part of water management along with irrigation because both have a similar ultimate goal.
- The monitoring of water releases from the reservoir to agricultural lands should be done routinely in order to know the water balance and track the unauthorized drainage water reuse. This requires improved hydro-meteorological services, and control devices which are often not available in public irrigation projects as in the case of KRIP.
- Observations wells and soil/water testing laboratories should be instituted to control the water table and monitor the soil and water quality. The cost of maintenance should be generated from operation and maintenance cost and government allocations.
- Building capacity of fragmented institutions, unaware water users, and untrained water managers on the need for drainage for sustainable irrigated agriculture with localized and tacit knowledge is pertinent.
- Most of the data were collected from HJRBDA records, government reports, published research journals, and the Federal Ministry of Water Resources. Therefore, the availability and accuracy of data may be the sources of errors in our analysis.
- There is uncertainty in the use of low resolution remotely sensed data and indices-based analysis in this study. The use of latest and more accurate methods such as eddy covariance and hyperspectral data from the Earth Observation System (EOS) may further improve the assessment of the hydrological condition of irrigated lands.
- Young researchers are encouraged to carry out studies that are real, will address a problem, or can be commercialized. By so doing, the products from the research can be used immediately by decision-makers, development institutions, and project managers to address the pressing issues that we face, especially in developing and least-developed countries.

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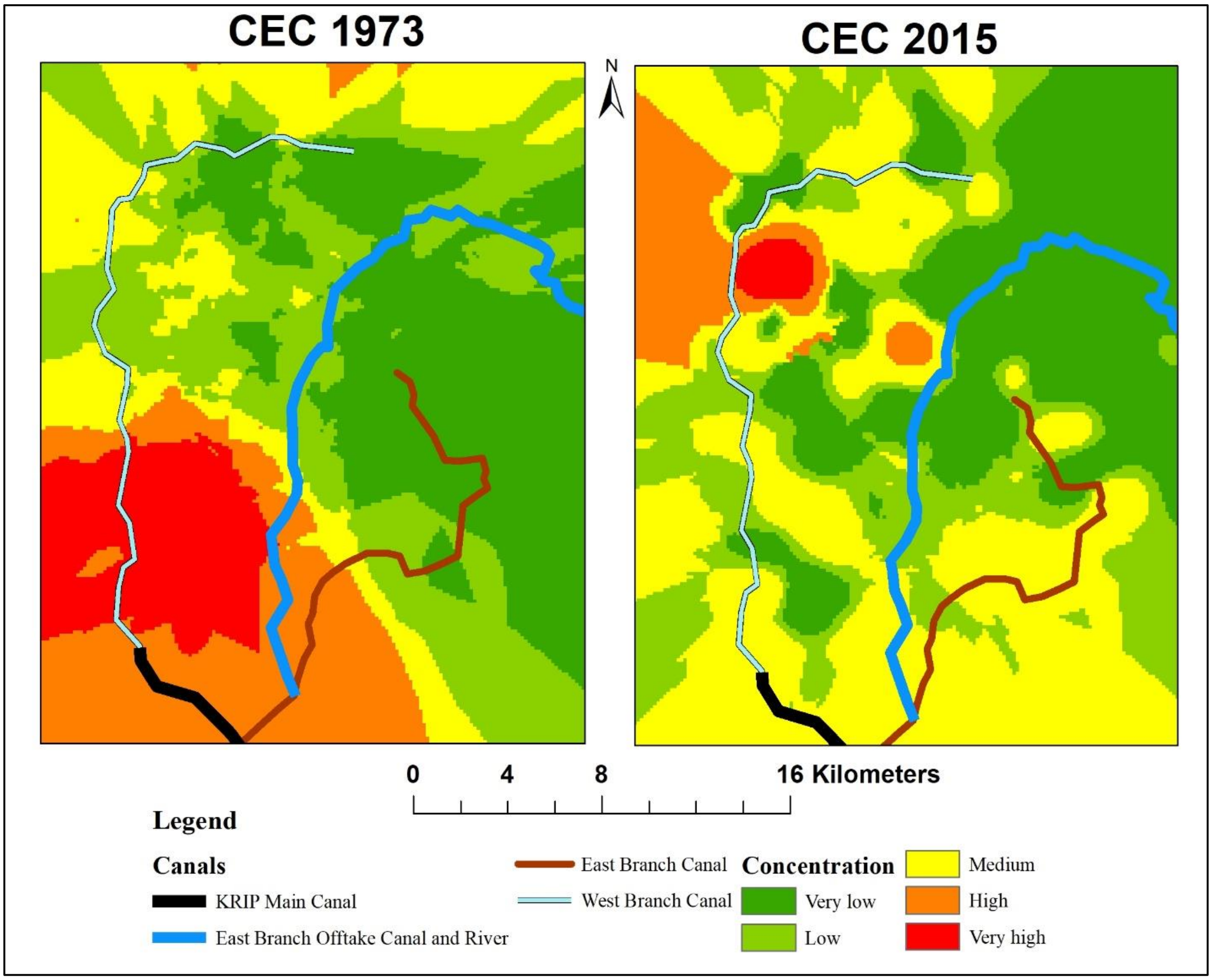
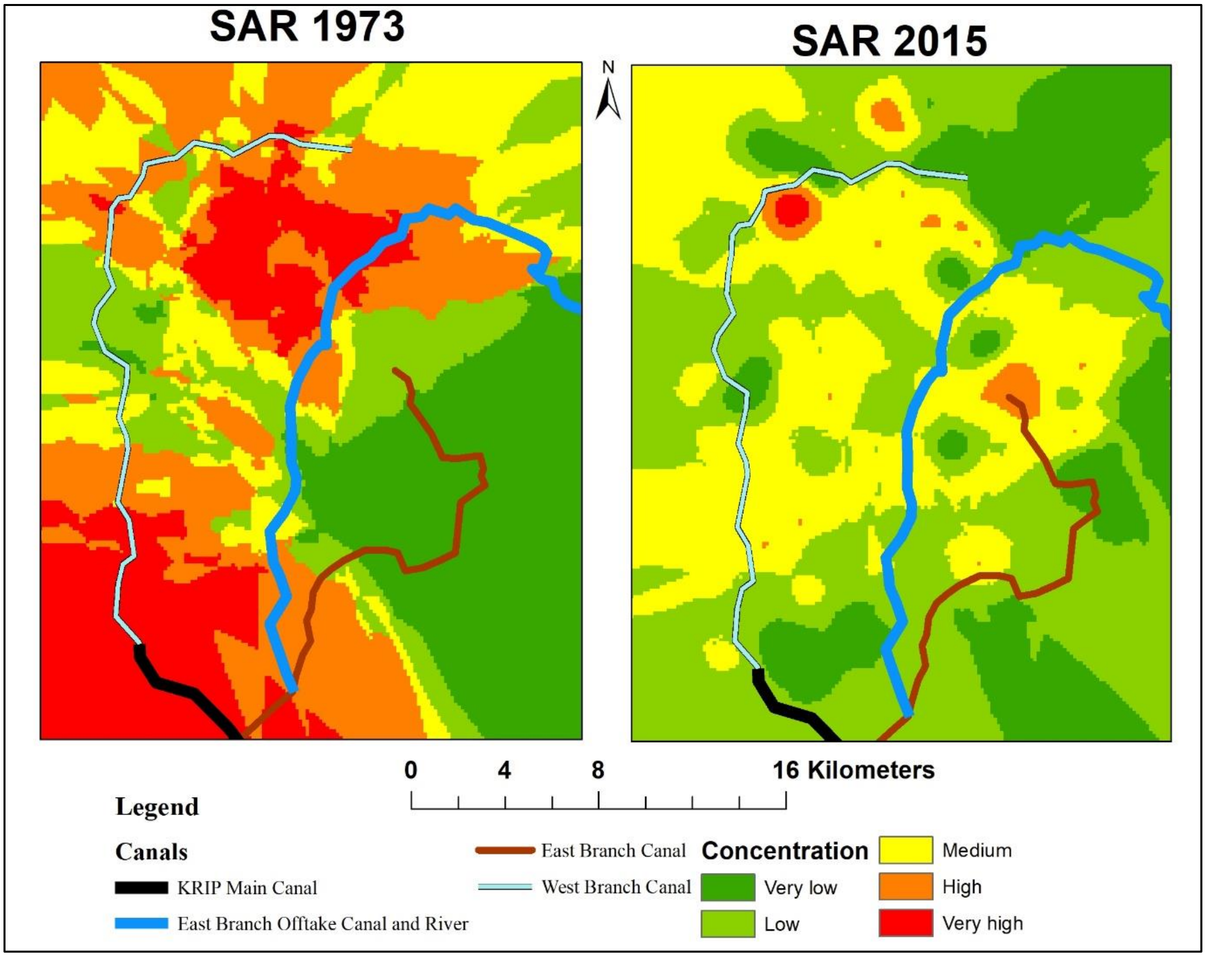
APPENDICES

Appendix 1: Soil Fertility, Salinity and Sodicity Maps





Appendix 2: Crop Salt Tolerence

Common Name	Tolerence based on	Threshold (ECe) dS/m §	Slope % per dS/m	Rating ¶	References
Corn‡‡	Ear FW	1.7	12	MS	Bernstein & Ayars, 1949b; Kaddah & Ghowail, 1964
Corn (forage)††	Shoot DW	1.8	7.4	MS	Hassan et al., 1970b; Ravikovitch, 1973; Ravikovitch & Porath, 1967
Rice, paddy	Grain yield	3.0§§	12§§	S	Ehrler, 1960; Narale et al., 1969; Pearson, 1959; Venkateswarlu et al., 1972
Sorghum	Grain yield	6.8	16	MT	Francois et al., 1984
Soybean	Seed yield	5	20	MT	Abel & McKenzie, 1964; Bernstein et al., 1955; Bernstein & Ogata, 1966
Wheat	Grain yield	6	7.1	MT	Asana & Kale, 1965; Ayers et al., 1952; Hayward & Uhvits, 1944
Cowpea	Seed yield	4.9	12	MT	West & Francois, 1982
Cucumber	Fruit yield	2.5	13	MS	Osawa, 1965; Ploegman & Bierhuizen, 1970
Onion (bulb)	Bulb yield	1.2	16	S	Bernstein & Ayars, 1953b; Bernstein et al., 1974; Hoffman & Rawlins, 1971; Osawa, 1965
Tomato	Fruit yield	2.5	9.9	MS	Bierhuizen & Ploeman, 1967; Hayward & Long, 1943; Lyon, 1941; Shalhevet & Yaron, 1973
Okra	Pod yield	-	-	MS	Masih et al., 1978; Paliwal & Maliwal, 1972
Carrot	Storage root	1	14	S	Bernstein & Ayars, 1953a; Bernstein et al., 1974; Lagerwerff & Holland, 1960; Magistad et al., 1943; Osawa, 1965
Cabbage	Head FW	1.8	9.7	MS	Bernstein & Ayars, 1949a; Bernstein et al., 1974; Osawa, 1965

For soil salinities exceeding the threshold of any given crop, relative yield (Yr) can be estimated with the following equation:

Yr = 100 - b(ECe - a)

Appendix 3: Extracted Soil Sampling Points

	x	y
1	437492.5	1306226
2	439805.9	1306747
3	437216.7	1305269
4	436298.6	1302708
5	434804.8	1301414
6	439559.4	1305203
7	436880.4	1304498
8	442055.7	1305908
9	440196.9	1304460
10	440834.2	1303594
11	441440.7	1302512
12	440008.4	1301434
13	437997.9	1300357
14	440309.8	1299951
15	441649.5	1300319
16	442504.5	1301862
17	443388.7	1302817
18	444392.5	1302661
19	442024	1305229
20	443517.7	1306740
21	442758.5	1307513
22	444249.4	1307572
23	445406.9	1308342
24	446163.2	1305963
25	444519	1305286
26	443543.1	1304022
27	443970.5	1304824
28	438855.9	1303351
29	445126.3	1304575
30	445581.3	1303802
31	446096.8	1302782
32	446825.3	1301792
33	445728.2	1300837
34	448012.9	1302284
35	446828.5	1303614
36	448626.5	1305279
37	452611.3	1304624
38	454791	1297209
39	453479.5	1295327
40	451562.7	1295731
41	451168.5	1296627
42	449128.9	1296322
43	448154.9	1296293
44	447213.6	1297560
45	446966.2	1295306
46	444385.5	1298770
47	442654.1	1300533
48	437904.6	1299400
49	438267.2	1298102
50	436806.8	1298321
51	435223.3	1297830
52	435006.5	1296070
53	436465.6	1295172
54	436310.6	1293844
55	436701.5	1296919
56	437591.8	1296392
57	438425.4	1296244
58	440436.4	1295365
59	441300.7	1296209
60	442822.9	1295273
61	441848.5	1296996
62	441563.1	1298106
63	442254.5	1298834
64	443805.3	1297868
65	439759.9	1302282
66	445637.3	1293255
67	439885.1	1292798
68	440025.8	1291222
69	436547.4	1291930
70	436344.1	1290938
71	437434.7	1289827
72	437582.4	1291753
73	438212.6	1290526
74	439189.2	1289911
75	437605.6	1289010
76	437747.8	1288222
77	439820.1	1288976
78	437544.4	1287172
79	439471.3	1287109
80	438002.4	1286091
81	441625	1285238
82	444705.3	1286662
83	446807.8	1288263
84	449856.5	1288316
85	449004.7	1294941
86	450413.9	1295114
87	449319.2	1293861
88	450872	1293888
89	451502.8	1292690
90	450724.6	1291612
91	451788.4	1291435
92	452678.4	1290442
93	454232.4	1291111
94	455326	1291693
95	442252.7	1282465
96	441332.7	1282787
97	438431	1284660
98	437308.5	1284313
99	439407.3	1283783
100	435783.8	1284257
101	438644.8	1305289

Appendix 4: Derivation of Economic and Financial Farmgate Prices for internationally and locally traded commodities

Derivation of Financial Economic Farmgate Prices for Internationally Traded Commodities

Item	Maize		Rice		Wheat		DAP		Urea		Soya beans	
	Financial	Economic	Financial	Economic	Financial	Economic	Financial	Economic	Financial	Economic	Financial	Economic
	US$ per tonne											
Projected World Price for Year 2018 1/	169	169	435	435	218	218	414	414	254	254	425	425
Quality Adjustment Factor 2/	0.90	0.90	0.95	0.95	0.90	0.90	1.00	1.00	1.00	1.00	0.85	0.85
Projected Price for Nigerian Product	152	152	413	413	196	196	414	414	254	254	361	361
International Freight and Insurance	38	38	57	57	34	34	69	69	53	53	45	45
CIF Price, Lagos	190	190	470	470	230	230	483	483	307	307	406	406
Exchange Rate : US$ = Naira 306.4	Naira per tonne											
CIF Price, Lagos	58,247	58,247	144,085	144,085	70,533	70,533	147,991	147,991	94,065	94,065	124,475	124,475
Import Duties/Levy a/	2,912.33		28816.92		7053.33		7,399.56		4,703.24		1244.75	
Border Charges, Handling and Storage b/	3,000	2,910	3,000	2,910	3,000	2,910	3,000	2,910	3,000	2,910	3,000	2,910
Transport/ Handling Costs between Lagos and Kano	8,500	8,245	8,500	8,245	8,500	8,245	8,500	8,245	8,500	8,245	8,500	8,245
Commodity Price, ex - Mill or Local Market	72,659	69,402	184,402	155,240	89,087	81,688	166,891	159,146	110,268	105,220	137,220	135,630
Processing Ratio 3/	1.00	1.00	0.67	0.67	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Processing/Administration Costs 4/			9,600	9,312								
Value of Secondary Product 5/			3,200	3,200								
Local Mill or Local Market Price, Kano	72,659	69401.64	123,549	104,011	89,087	81688.28	166,891	159146.2	110,268	105219.8	137,221	135,631
Transport/ Handling Costs to/from Kura	750	728	750	728	750	728	750	728	750	728	728	728
Farmgate Price (International)	71,909	68,674	109,999	90,771	88,337	80,960	166,141	158,418	109,518	104,492	136,493	134,903
c/ HJRBDA Annual Crop Production 2018 c/	93,000		136,000		100,000		160,000		155,000		125,000	
Farmgate Price (Local)	78,588		95,683		81,447		141,100		138,797		112,255	

CIF (Cost, Insurance and Freight)

1/ World Bank Commodities price forecast (constant US dollars) Released 29/10/2018 (World Bank, 2018)
Maize (US), no. 2, yellow, f.o.b. US Gulf ports.
Rice (Thailand), 5% broken, white rice (WR), milled, indicative price based on weekly surveys of export transactions, government standard, f.o.b. Bangkok.
Wheat (US), no. 1, hard red winter, ordinary protein, export price delivered at the US Gulf port for prompt or 30 days shipment.
Urea, (Ukraine), from 2015, f.o.b. Black Sea. Previously, (Black Sea), bulk, spot, f.o.b. Black Sea (primarily Yuzhnyy) beginning July 1991; for 1985-91 (June) f.o.b. Eastern Europe
DAP (diammonium phosphate), from 2015, spot, f.o.b. US Gulf. Previously, standard size, bulk, spot, f.o.b. US Gulf.

2/ Reflects the estimated differencein quality between theinternational traded and locally produced commodity.
3/ Processing ratio (out-turn) for milled produce.
4/ Rice processing cos ts include both processing and administration expenses.
5/ Value of any economically useful products obtained through processing

a/ Import Duties/Levy FGN, Federal Ministry of Finance, (Nigeria Customs Service, NCS)
Maize (Corn), (not in seed), 1005100000, 5%
All Rice (broken, milled, white rice) 10% : Rice in the husk (paddy or rough) 20%
Wheat ; Soya beans 10%
Groundnut 5%
DAP & Urea 5%

b/ DB2019: Nigeria reduced the time needed to export and import by implementing joint inspections. Applies to Kano and Lagos (World Bank)

c/ HJRBDA Annual Crop Production 2018

APPENDIX 5: Economic and Financial Crop budgets for crops grown in KRIP

Crop Budget for Maize per Hectare (Financial)

		Present Situation			Without Project			With Project		
Item	Unit	Unit/ha	Price (NGN)	Value (NGN)	Unit/ha	Price (NGN)	Value (NGN)	Unit/ha	Price (NGN)	**Value (NGN)**
RETURNS										
Maize	tonne	2.50	66,909	167,273	2.00	66,909	133,818	5.00	66,909	334,545
Stalks	tonne	1.80	5,000	9,000	1.70	5,000	8,500	4.50	5,000	22,500
Gross Returns				**176,273**			**142,318**			**357,045**
VARIABLE COSTS										
Materials										
Seed	Kg	25.00	200	5,000	25.00	200	5,000	25.00	200	5,000
Fertilizer										
Urea	Kg	100.00	110	11,000	100.00	110	11,000	150.00	110	16,500
NPK	Kg	150.00	167	25,050	150.00	167	25,050	200.00	167	33,400
Manure	tonne	2.00	1,000	2,000	2.00	1,000	2,000	2.00	1,000	2,000
Chemicals										
Herbicides	litre	2.00	1,000	2,000	2.00	1,000	2,000	3.00	1,000	3,000
Pesticides	litre	0.50	1,000	500	1.00	1,000	1,000	1.00	1,000	1,000
Other inputs	LS	1.00	2,500	2,500	1.00	2,500	2,500	1.00	2,500	2,500
sub-total				**48,050**			**48,550**			**63,400**
Labour										
Family										
Planting	day	5.00	Nil	Nil	5.00	Nil	Nil	5.00	Nil	Nil
Weeding	day	5.00	Nil	Nil	5.00	Nil	Nil	5.00	Nil	Nil
Other field tasks	day	5.00	Nil	Nil	5.00	Nil	Nil	5.00	Nil	Nil
harvesting	day	5.00	Nil	Nil	5.00	Nil	Nil	5.00	Nil	Nil
Post-harvest tasks	day	5.00	Nil	Nil	5.00	Nil	Nil	5.00	Nil	Nil
Hired Labour										
All activities	day	30.00	600	18,000	25.00	600	15,000	50.00	600	30,000
Sub-total				**18,000**			**15,000**			**30,000**
Oxen/Machinery Hire										
Land Preparation	day	1.00	10,000	10,000	1.00	10,000	10,000	1.00	10,000	10,000
Transport to store	tonne	2.50	1,250	3,125	2.00	1,250	2,500	5.00	1,250	6,250
sub-total				**13,125**			**12,500**			**16,250**
Total Variable Costs				**79,175**			**76,050**			**109,650**
GROSS MARGIN				**97,098**			**66,268**			**247,395**

				Crop Budget for Maize per Hectare (Economic)						
			Present Situation			Without Project			With Project	
Item	Unit	Unit/ha	Price (NGN)	Value (NGN)	Unit/ha	Price (NGN)	Value (NGN)	Unit/ha	Price (NGN)	**Value (NGN)**
RETURNS										
Maize	tonne	2.50	63,674	159,185	2.00	66,909	133,818	5.00	66,909	334,545
Stalks	tonne	1.80	5,000	9,000	1.70	5,000	8,500	4.50	5,000	22,500
Gross Returns				**168,185**			**142,318**			**357,045**
VARIABLE COSTS										
Materials										
Seed	Kg	25.00	67	1,675	25.00	67	1,675	25.00	108	2,700
Fertilizer										
Urea	Kg	100.00	105	10,500	100.00	105	10,500	150.00	105	15,750
NPK	Kg	150.00	160	24,000	150.00	160	24,000	200.00	160	32,000
Manure	tonne	2.00	1,500	3,000	2.00	1,500	3,000	2.00	1,500	3,000
Chemicals										
Herbicides	litre	2.00	1,000	2,000	2.00	1,000	2,000	3.00	1,000	3,000
Pesticides	litre	0.50	1,000	500	0.50	1,000	500	0.50	1,000	500
Other inputs	LS	1.00	2,500	2,500	1.00	2,500	2,500	1.00	2,500	2,500
sub-total				**44,175**			**44,175**			**59,450**
Labour										
Family										
Planting	day	5.00	400	2,000	5.00	400	2,000	5.00	400	2,000
Weeding	day	5.00	400	2,000	5.00	400	2,000	5.00	400	2,000
Other field tasks	day	5.00	400	2,000	5.00	400	2,000	5.00	400	2,000
harvesting	day	5.00	400	2,000	5.00	400	2,000	5.00	400	2,000
Post-harvest tasks	day	5.00	400	2,000	5.00	400	2,000	5.00	400	2,000
Hired Labour										
All activities	day	30.00	400	12,000	25.00	400	10,000	50.00	400	20,000
Sub-total		55.00		**22,000**	50.00		**20,000**	75.00		**30,000**
Oxen/Machinery Hire										
Land Preparation	day	1.00	1,200	1,200	1.00	1,200	1,200	1.00	11,640	11,640
Transport to store	tonne	2.50	1,213	3,033	2.00	1,213	2,426	5.00	1,213	6,065
sub-total				**4,233**			**3,626**			**17,705**
Total Variable Costs				**70,408**			**67,801**			**107,155**
GROSS MARGIN				**97,778**			**74,517**			**249,890**

				Crop Budget for sorghum per Hectare (Financial)						
			Present Situation			Without Project			With Project	
Item	Unit	Unit/ha	Price (NGN)	Value (NGN)	Unit/ha	Price (NGN)	Value (NGN)	Unit/ha	Price (NGN)	**Value (NGN)**
RETURNS										
Sorghum	tonne	1.20	45,000	54,000	1.15	45,000	51,750	2.20	45,000	99,000
Crop residue	tonne	1.10	5,000	5,500	1.10	5,000	5,500	1.98	5,000	9,900
Gross Returns				**59,500**			**57,250**			**108,900**
VARIABLE COSTS										
Materials										
Seed	Kg	15.00	250	3,750	15.00	250	3,750	15.00	250	3,750
Fertilizer										
Urea	Kg			-			-	100.00	110	11,000
NPK	Kg	100.00	167	16,700	100.00	167	16,700	100.00	167	16,700
Manure	tonne	1.00	1,000	1,000	1.00	1,000	1,000	2.00	1,000	2,000
Chemicals										
Herbicides	litre	1.00	1,000	1,000	1.00	1,000	1,000	2.00	1,000	2,000
Pesticides	litre	0.50	1,000	500	1.00	1,000	1,000	1.00	1,000	1,000
Other inputs	LS	0.50	2,500	1,250	1.00	2,500	2,500	1.00	2,500	2,500
sub-total				**24,200**			**25,950**			**38,950**
Labour										
Family										
Planting	day	5.00	Nil	Nil	5.00	Nil	Nil	5.00	Nil	Nil
Weeding	day	10.00	Nil	Nil	8.00	Nil	Nil	15.00	Nil	Nil
Other field tasks	day	5.00	Nil	Nil	5.00	Nil	Nil	5.00	Nil	Nil
harvesting	day	15.00	Nil	Nil	13.00	Nil	Nil	20.00	Nil	Nil
Post-harvest tasks	day	5.00	Nil	Nil	5.00	Nil	Nil	10.00	Nil	Nil
Hired Labour										
All activities	day	40.00		-	36.00		-	55.00		-
Sub-total				**-**			**-**			**-**
Oxen/Machinery Hire										
Land Preparation	day	1.00	10,000	10,000	1.00	10,000	10,000	1.00	10,000	10,000
Transport to store	tonne	1.20	1,250	1,500	1.15	1,250	1,438	2.20	1,250	2,750
sub-total				**11,500**			**11,438**			**12,750**
Total Variable Costs				**35,700**			**37,388**			**51,700**
GROSS MARGIN				**23,800**			**19,863**			**57,200**

Crop Budget for Sorghum per Hectare (Economic)

Item	Unit	Present Situation			Without Project			With Project		
		Unit/ha	Price (NGN)	Value (NGN)	Unit/ha	Price (NGN)	Value (NGN)	Unit/ha	Price (NGN)	**Value (NGN)**
RETURNS										
Sorghum	tonne	1.20	44,500	53,400	1.15	44,500	51,175	2.20	44,500	97,900
Crop residue	tonne	1.10	5,000	5,500	1.10	5,000	5,500	1.98	5,000	9,900
Gross Returns				**58,900**			**56,675**			**107,800**
VARIABLE COSTS										
Materials										
Seed	Kg	15.00	250	3,750	15.00	250	3,750	15.00	250	3,750
Fertilizer										
Urea	Kg			-			-	100.00	105	10,500
NPK	Kg	100.00	160	16,000	100.00	160	16,000	100.00	106	10,600
Manure	tonne	1.00	1,000	1,000	1.00	1,000	1,000	2.00	1,000	2,000
Chemicals										
Herbicides	litre	1.00	1,000	1,000	1.00	1,000	1,000	2.00	1,000	2,000
Pesticides	litre	0.50	1,000	500	1.00	1,000	1,000	1.00	1,000	1,000
Other inputs	LS	0.50	2,500	1,250	1.00	2,500	2,500	1.00	2,500	2,500
sub-total				**23,500**			**25,250**			**32,350**
Labour										
Family										
Planting	day	5.00	400	2,000	5.00	400	2,000	5.00	400	2,000
Weeding	day	10.00	400	4,000	8.00	400	3,200	15.00	400	6,000
Other field tasks	day	5.00	400	2,000	5.00	400	2,000	5.00	400	2,000
harvesting	day	15.00	400	6,000	13.00	400	5,200	20.00	400	8,000
Post-harvest tasks	day	5.00	400	2,000	5.00	400	2,000	10.00	400	4,000
Hired Labour										
All activities	day		400	-			-			-
Sub-total		40.00		**16,000**	36.00		**14,400**	55.00		**22,000**
Oxen/Machinery Hire										
Land Preparation	day	1.00	10,000	10,000	1.00	10,000	10,000	1.00	10,000	10,000
Transport to store	tonne	1.20	1,213	1,456	1.15	1,213	1,395	2.20	1,213	2,669
sub-total				**11,456**			**11,395**			**12,669**
Total Variable Costs				**50,956**			**51,045**			**67,019**
GROSS MARGIN				**7,944**			**5,630**			**40,781**

Crop Budget for Rice per Hectare (Financial)

Item	Unit	Present Situation			Without Project			With Project		
		Unit/ha	Price (NGN)	Value (NGN)	Unit/ha	Price (NGN)	Value (NGN)	Unit/ha	Price (NGN)	**Value (NGN)**
RETURNS										
Rice	tonne	3.50	104,999	367,497	2.70	104,999	283,497	5.00	104,999	524,995
Crop residue	tonne	2.50	5,000	12,500	1.90	5,000	9,500	3.50	5,000	17,500
Gross Returns				**379,997**			**292,997**			**542,495**
VARIABLE COSTS										
Materials										
Seed	Kg	30.00	250	7,500	30.00	250	7,500	60.00	250	15,000
Fertilizer										
Urea	Kg	150.00	110	16,500	150.00	110	16,500	200.00	110	22,000
NPK	Kg	200.00	167	33,400	200.00	167	33,400	200.00	167	33,400
Manure	tonne	2.00	1,000	2,000	2.00	1,000	2,000	2.00	1,000	2,000
Chemicals										
Herbicides	litre	3.00	1,000	3,000	3.00	1,000	3,000	4.00	1,000	4,000
Pesticides	litre	2.00	1,000	2,000	2.00	1,000	2,000	3.00	1,000	3,000
Other inputs	LS	1.00	2,500	2,500	1.00	2,500	2,500	2.00	2,500	5,000
sub-total				**66,900**			**66,900**			**84,400**
Labour										
Family										
Planting	day	5.00	Nil	Nil	5.00	Nil	Nil	5.00	Nil	Nil
Weeding	day	5.00	Nil	Nil	5.00	Nil	Nil	5.00	Nil	Nil
Other field tasks	day	5.00	Nil	Nil	5.00	Nil	Nil	5.00	Nil	Nil
harvesting	day	10.00	Nil	Nil	10.00	Nil	Nil	5.00	Nil	Nil
Post-harvest tasks	day	10.00	Nil	Nil	10.00	Nil	Nil	5.00	Nil	Nil
Hired Labour										
All activities	day	25.00	600	15,000	25.00	600	15,000	75.00	600	45,000
Sub-total		60.00		**15,000**	60.00		**15,000**	100.00		**45,000**
Oxen/Machinery Hire										
Land Preparation	day	1.00	15,000	15,000	1.00	15,000	15,000	1.00	15,000	15,000
Transport to store	tonne	3.50	1,250	4,375	2.70	1,250	3,375	5.00	1,250	6,250
sub-total				**19,375**			**18,375**			**21,250**
Total Variable Costs				**101,275**			**100,275**			**150,650**
GROSS MARGIN				**278,722**			**192,722**			**391,845**

Crop Budget for Rice per Hectare (Economic)										
		Present Situation			Without Project			With Project		
Item	Unit	Unit/ha	Price (NGN)	Value (NGN)	Unit/ha	Price (NGN)	Value (NGN)	Unit/ha	Price (NGN)	**Value (NGN)**
RETURNS										
Rice	tonne	3.50	85,771	300,199	2.70	85,771	231,582	5.00	85,771	428,855
Crop residue	tonne	2.50	5,000	12,500	1.90	5,000	9,500	3.50	5,000	17,500
Gross Returns				**312,699**			**241,082**			**446,355**
VARIABLE COSTS										
Materials										
Seed	Kg	30.00	70	2,112	30.00	250	7,500	60.00	250	15,000
Fertilizer										
Urea	Kg	150.00	105	15,750	150.00	105	15,750	200.00	105	21,000
NPK	Kg	200.00	160	32,000	200.00	160	32,000	200.00	160	32,000
Manure	tonne	2.00	1,500	3,000	2.00	1,000	2,000	2.00	1,000	2,000
Chemicals										
Herbicides	litre	3.00	1,000	3,000	3.00	1,000	3,000	4.00	1,000	4,000
Pesticides	litre	2.00	1,000	2,000	2.00	1,000	2,000	3.00	1,000	3,000
Other inputs	LS	1.00	2,500	2,500	1.00	2,500	2,500	2.00	2,500	5,000
sub-total				**60,362**			**64,750**			**82,000**
Labour										
Family										
Planting	day	5.00	400	2,000	5.00	400	2,000	5.00	400	2,000
Weeding	day	5.00	400	2,000	5.00	400	2,000	5.00	400	2,000
Other field tasks	day	5.00	400	2,000	5.00	400	2,000	5.00	400	2,000
harvesting	day	10.00	400	4,000	10.00	400	4,000	5.00	400	2,000
Post-harvest tasks	day	10.00	400	4,000	10.00	400	4,000	5.00	400	2,000
Hired Labour				-			-		400	-
All activities	day	25.00	400	10,000	25.00	400	10,000	75.00	400	30,000
Sub-total		60.00	400	**24,000**	60.00		**24,000**	100.00		**40,000**
Oxen/Machinery Hire										
Land Preparation	day	1.00	15,000	15,000	1.00	15,000	15,000	1.00	15,000	15,000
Transport to store	tonne	3.50	1,213	4,246	2.70	1,213	3,275	5.00	1,213	6,065
sub-total				**19,246**			**18,275**			**21,065**
Total Variable Costs				**103,608**			**107,025**			**143,065**
GROSS MARGIN				**209,091**			**134,057**			**303,290**

Crop Budget for Vegetables per Hectare (Financial)										
		Present Situation			Without Project			With Project		
Item	Unit	Unit/ha	Price (NGN)	Value (NGN)	Unit/ha	Price (NGN)	Value (NGN)	Unit/ha	Price (NGN)	**Value (NGN)**
RETURNS										
Vegetables 1/	tonne	15.00	30,000	450,000	12.50	30,000	375,000	20.00	30,000	600,000
crop residue	tonne	1.80		-			-			-
Gross Returns				**450,000**			**375,000**			**600,000**
VARIABLE COSTS										
Materials										
Seed	Kg	6.00	5,000	30,000	6.00	5,000	30,000	8.00	5,000	40,000
Fertilizer										
Urea	Kg	50.00	110	5,500	50.00	110	5,500	150.00	110	16,500
NPK	Kg	150.00	167	25,050	150.00	167	25,050	200.00	167	33,400
Manure	tonne	10.00	1,000	10,000	10.00	1,000	10,000	10.00	1,000	10,000
Chemicals										
Herbicides	litre	1.00	1,000	1,000	1.00	1,000	1,000	1.00	1,000	1,000
Pesticides	litre	2.00	1,000	2,000	2.00	1,000	2,000	2.00	1,000	2,000
Other inputs	LS	1.00	2,500	2,500	1.00	2,500	2,500	1.00	2,500	2,500
sub-total				**76,050**			**76,050**			**105,400**
Labour										
Family										
Planting	day	15.00	Nil	Nil	10.00	Nil	Nil	20.00	Nil	Nil
Weeding	day	10.00	Nil	Nil	10.00	Nil	Nil	12.00	Nil	Nil
Other field tasks	day	10.00	Nil	Nil	10.00	Nil	Nil	15.00	Nil	Nil
harvesting	day		Nil	Nil		Nil	Nil		Nil	Nil
Post-harvest tasks	day	10.00	Nil	Nil	10.00	Nil	Nil	20.00	Nil	Nil
Hired Labour										
All activities	day	50.00	600	30,000	50.00	600	30,000	100.00	600	60,000
Sub-total		95.00		**30,000**	90.00		**30,000**	167.00		**60,000**
Oxen/Machinery Hire										
Land Preparation	day	30.00	1,200	36,000	30.00	1,200	36,000	30.00	1,200	36,000
Transport to store	tonne	15.00	1,250	18,750	12.50	1,250	15,625	20.00	1,250	25,000
sub-total				**54,750**			**51,625**			**61,000**
Total Variable Costs				**160,800**			**157,675**			**226,400**
GROSS MARGIN				**289,200**			**217,325**			**373,600**

1/ Vegetables/ Cabbage, Okra, Cucumber and carrots

Crop Budget for Vegetables per Hectare (Economic)

Item	Unit	Present Situation			Without Project			With Project		
		Unit/ha	Price (NGN)	Value (NGN)	Unit/ha	Price (NGN)	Value (NGN)	Unit/ha	Price (NGN)	**Value (NGN)**
RETURNS										
Vegetables 1/	tonne	15.00	25,000	375,000	12.50	25,000	312,500	20.00	25,000	500,000
crop residue	tonne	1.80		-			-			-
Gross Returns				**375,000**			**312,500**			**500,000**
VARIABLE COSTS										
Materials										
Seed	Kg	6.00	2,000	12,000	6.00	2,000	12,000	8.00	2,000	16,000
Fertilizer										
Urea	Kg	50.00	105	5,250	50.00	105	5,250	150.00	105	15,750
NPK	Kg	150.00	160	24,000	150.00	160	24,000	200.00	160	32,000
Manure	tonne	10.00	1,500	15,000	10.00	1,500	15,000	10.00	1,500	15,000
Chemicals										
Herbicides	litre	1.00	1,000	1,000	1.00	1,000	1,000	1.00	1,000	1,000
Pesticides	litre	2.00	1,000	2,000	2.00	1,000	2,000	2.00	1,000	2,000
Other inputs	LS	1.00	2,500	2,500	1.00	2,500	2,500	1.00	2,500	2,500
sub-total				**61,750**			**61,750**			**84,250**
Labour										
Family										
Planting	day	15.00	400	Nil	10.00	400	Nil	20.00	400	Nil
Weeding	day	10.00	400	Nil	10.00	400	Nil	12.00	400	Nil
Other field tasks	day	10.00	400	Nil	10.00	400	Nil	15.00	400	Nil
harvesting	day		400	Nil		400	Nil		400	Nil
Post-harvest tasks	day	10.00	400	Nil	10.00	400	Nil	20.00	400	Nil
Hired Labour										
All activities	day	50.00	400	20,000	50.00	400	20,000	100.00	400	40,000
Sub-total		95.00		**20,000**	90.00		**20,000**	167.00		**40,000**
Oxen/Machinery Hire										
Land Preparation	day	30.00	1,200	36,000	30.00	1,200	36,000	30.00	1,200	36,000
Transport to store	tonne	15.00	1,213	18,195	12.50	1,213	15,163	20.00	1,213	24,260
sub-total				**54,195**			**51,163**			**60,260**
Total Variable Costs				**135,945**			**132,913**			**184,510**
GROSS MARGIN				**239,055**			**179,588**			**315,490**

1/ Vegetables/ Cabbage, Okra, Cucumber and carrots

Crop Budget for Wheat per Hectare (Financial)

Item	Unit	Present Situation			Without Project			With Project		
		Unit/ha	Price (NGN)	Value (NGN)	Unit/ha	Price (NGN)	Value (NGN)	Unit/ha	Price (NGN)	**Value (NGN)**
RETURNS										
Wheat	tonne	2.40	83,337	200,009	2.00	83,337	166,674	4.00	83,337	333,348
Crop residue	tonne	2.20	5,000	11,000	2.00	5,000	10,000	3.00	5,000	15,000
Gross Returns				**211,009**			**176,674**			**348,348**
VARIABLE COSTS										
Materials										
Seed	Kg	40.00	350	14,000	40.00	350	14,000	50.00	350	17,500
Fertilizer										
Urea	Kg	50.00	110	5,500	50.00	110	5,500	150.00	110	16,500
NPK	Kg	100.00	167	16,700	100.00	167	16,700	200.00	167	33,400
Manure	tonne	2.00	1,500	3,000	2.00	1,500	3,000	5.00	1,500	7,500
Chemicals										
Herbicides	litre	3.00	1,000	3,000	3.00	1,000	3,000	3.00	1,000	3,000
Pesticides	litre	1.00	1,000	1,000	1.00	1,000	1,000	2.00	1,000	2,000
Other inputs	LS	1.00	2,500	2,500	1.00	2,500	2,500	1.00	2,500	2,500
sub-total				**45,700**			**45,700**			**82,400**
Labour										
Family										
Planting	day	5.00	Nil	Nil	5.00	Nil	Nil	5.00	Nil	Nil
Weeding	day	5.00	Nil	Nil	5.00	Nil	Nil	5.00	Nil	Nil
Other field tasks	day	5.00	Nil	Nil	5.00	Nil	Nil	5.00	Nil	Nil
harvesting	day	5.00	Nil	Nil	5.00	Nil	Nil	5.00	Nil	Nil
Post-harvest tasks	day	5.00	Nil	Nil	5.00	Nil	Nil	5.00	Nil	Nil
Hired Labour										
All activities	day	25.00	600	15,000	25.00	600	15,000	75.00	600	45,000
Sub-total		50.00		**15,000**	50.00		**15,000**	100.00		**45,000**
Oxen/Machinery Hire										
Land Preparation	day	1.00	12,000	12,000	1.00	12,000	12,000	1.00	12,000	12,000
Transport to store	tonne	2.40	1,250	3,000	2.00	1,250	2,500	4.00	1,250	5,000
sub-total				**15,000**			**14,500**			**17,000**
Total Variable Costs				**75,700**			**75,200**			**144,400**
GROSS MARGIN				**135,309**			**101,474**			**203,948**

Crop Budget for wheat per Hectare (Economic)										
			Present Situation			Without Project			With Project	
Item	Unit	Unit/ha	Price (NGN)	Value (NGN)	Unit/ha	Price (NGN)	Value (NGN)	Unit/ha	Price (NGN)	**Value (NGN)**
RETURNS										
Wheat	tonne	2.40	75,960	182,304	2.00	75,960	151,920	4.00	75,960	303,840
Crop residue	tonne	2.20	5,000	11,000	2.00	5,000	10,000	3.00	5,000	15,000
Gross Returns				**193,304**			**161,920**			**318,840**
VARIABLE COSTS										
Materials										
Seed	Kg	40.00	80	3,200	40.00	80	3,200	50.00	80	4,000
Fertilizer										
Urea	Kg	50.00	105	5,250	50.00	105	5,250	150.00	105	15,750
NPK	Kg	100.00	160	16,000	100.00	160	16,000	200.00	160	32,000
Manure	tonne	2.00	1,500	3,000	2.00	1,500	3,000	5.00	1,500	7,500
Chemicals										
Herbicides	litre	3.00	1,000	3,000	3.00	1,000	3,000	3.00	1,000	3,000
Pesticides	litre	1.00	1,000	1,000	1.00	1,000	1,000	2.00	1,000	2,000
Other inputs	LS	1.00	2,500	2,500	1.00	2,500	2,500	1.00	2,500	2,500
sub-total				**33,950**			**33,950**			**66,750**
Labour										
Family										
Planting	day	5.00	400	2,000	5.00	400	2,000	5.00	400	2,000
Weeding	day	5.00	400	2,000	5.00	400	2,000	5.00	400	2,000
Other field tasks	day	5.00	400	2,000	5.00	400	2,000	5.00	400	2,000
harvesting	day	5.00	400	2,000	5.00	400	2,000	5.00	400	2,000
Post-harvest tasks	day	5.00	400	2,000	5.00	400	2,000	5.00	400	2,000
Hired Labour				-			-			
All activities	day	25.00	400	10,000	25.00	400	10,000	75.00	400	30,000
Sub-total		50.00		**20,000**	50.00		**20,000**	100.00		**40,000**
Oxen/Machinery Hire										
Land Preparation	day	1.00	12,000	12,000	1.00	12,000	12,000	1.00	12,000	12,000
Transport to store	tonne	2.40	1,250	3,000	2.00	1,250	2,500	4.00	1,250	5,000
sub-total				**15,000**			**14,500**			**17,000**
Total Variable Costs				**68,950**			**68,450**			**123,750**
GROSS MARGIN				**124,354**			**93,470**			**195,090**

Crop Budget for Tomato per Hectare (Financial)										
			Present Situation			Without Project			With Project	
Item	Unit	Unit/ha	Price (NGN)	Value (NGN)	Unit/ha	Price (NGN)	Value (NGN)	Unit/ha	Price (NGN)	**Value (NGN)**
RETURNS										
Tomato	tonne	15.00	23,000	345,000	12.50	23,000	287,500	30.00	23,000	690,000
Crop residue	tonne			-		5,000	-		5,000	-
Gross Returns				**345,000**			**287,500**			**690,000**
VARIABLE COSTS										
Materials										
Seed	Kg	5.00	2,000	10,000	5.00	2,000	10,000	5.00	5,500	27,500
Fertilizer										
Urea	Kg	25.00	110	2,750	25.00	110	2,750	75.00	110	8,250
NPK	Kg	50.00	167	8,350	50.00	167	8,350	150.00	167	25,050
Manure	tonne	1.00	1,000	1,000	1.00	1,000	1,000	3.00	1,000	3,000
Chemicals										
Herbicides	litre	0.50	1,000	500	1.00	1,000	1,000	1.00	1,000	1,000
Pesticides	litre	1.00	1,000	1,000	1.00	1,000	1,000	1.00	1,000	1,000
Other inputs	LS	1.00	2,500	2,500	1.00	2,500	2,500	1.00	2,500	2,500
sub-total				**26,100**			**26,600**			**68,300**
Labour										
Family										
Planting	day			Nil		Nil	Nil		Nil	Nil
Weeding	day			Nil		Nil	Nil		Nil	Nil
Other field tasks	day			Nil		Nil	Nil		Nil	Nil
harvesting	day	5.00		Nil	5.00	Nil	Nil	5.00	Nil	Nil
Post-harvest tasks	day	5.00		Nil	5.00	Nil	Nil	5.00	Nil	Nil
Hired Labour				-						
All activities	day	57.00	1,200	68,400	48.00	1,200	57,600	123.00	1,200	147,600
Sub-total		67.00		**68,400**	58.00		**57,600**	133.00		**147,600**
Oxen/Machinery Hire										
Land Preparation	day	1.00	10,000	10,000	1.00	10,000	10,000	1.00	10,000	10,000
Transport to store	tonne	15.00	1,300	19,500	12.50	1,300	16,250	30.00	1,300	39,000
sub-total				**29,500**			**26,250**			**49,000**
Total Variable Costs				**124,000**			**110,450**			**264,900**
GROSS MARGIN				**221,000**			**177,050**			**425,100**

Crop Budget for tomato per Hectare (Economic)										
		Present Situation			Without Project			With Project		
Item	Unit	Unit/ha	Price (NGN)	Value (NGN)	Unit/ha	Price (NGN)	Value (NGN)	Unit/ha	Price (NGN)	**Value (NGN)**
RETURNS										
Tomato 1/	tonne	15.00	23,000	345,000	12.50	23,000	287,500	30.00	23,000	690,000
Crop residue	tonne			-		5,000	-		5,000	-
Gross Returns				**345,000**			**287,500**			**690,000**
VARIABLE COSTS										
Materials										
Seed	Kg	5.00	2,000	10,000	5.00	2,000	10,000	5.00	5,500	27,500
Fertilizer										
Urea	Kg	25.00	105	2,625	25.00	105	2,625	75.00	105	7,875
NPK	Kg	50.00	160	8,000	50.00	160	8,000	150.00	160	24,000
Manure	tonne	1.00	1,000	1,000	1.00	1,000	1,000	3.00	1,000	3,000
Chemicals										
Herbicides	litre	0.50	1,000	500	1.00	1,000	1,000	1.00	1,000	1,000
Pesticides	litre	1.00	1,000	1,000	1.00	1,000	1,000	1.00	1,000	1,000
Other inputs	LS	1.00	2,500	2,500	1.00	2,500	2,500	1.00	2,500	2,500
sub-total				**25,625**			**26,125**			**66,875**
Labour										
Family										
Planting	day									
Weeding	day									
Other field tasks	day									
harvesting	day	5.00	1,000	5,000	5.00	1,000	5,000	5.00	1,000	5,000
Post-harvest tasks	day	5.00	1,000	5,000	5.00	1,000	5,000	5.00	1,000	5,000
Hired Labour				-						
All activities	day	57.00	1,000	57,000	48.00	1,000	48,000	123.00	1,000	123,000
Sub-total		67.00		**67,000**	58.00		**58,000**	133.00		**133,000**
Oxen/Machinery Hire										
Land Preparation	day	1.00	10,000	10,000	1.00	10,000	10,000	1.00	10,000	10,000
Transport to store	tonne	15.00	1,300	19,500	12.50	1,300	16,250	30.00	1,300	39,000
sub-total				**29,500**			**26,250**			**49,000**
Total Variable Costs				**122,125**			**110,375**			**248,875**
GROSS MARGIN				**222,875**			**177,125**			**441,125**

Crop Budget for Onions per Hectare (Financial)										
		Present Situation			Without Project			With Project		
Item	Unit	Unit/ha	Price (NGN)	Value (NGN)	Unit/ha	Price (NGN)	Value (NGN)	Unit/ha	Price (NGN)	**Value (NGN)**
RETURNS										
Onions	tonne	19.50	25,350	494,325	17.50	25,350	443,625	30.00	25,350	760,500
Crop residue	tonne			-		5,000	-		5,000	-
Gross Returns				**494,325**			**443,625**			**760,500**
VARIABLE COSTS										
Materials										
Seed	Kg	5.00	2,000	10,000	5.00	2,000	10,000	5.00	5,500	27,500
Fertilizer										
Urea	Kg	25.00	110	2,750	25.00	110	2,750	75.00	110	8,250
NPK	Kg	50.00	167	8,350	50.00	167	8,350	150.00	167	25,050
Manure	tonne	1.00	1,000	1,000	1.00	1,000	1,000	3.00	1,000	3,000
Chemicals										
Herbicides	litre	0.50	1,000	500	1.00	1,000	1,000	1.00	1,000	1,000
Pesticides	litre	1.00	1,000	1,000	1.00	1,000	1,000	1.00	1,000	1,000
Other inputs	LS	1.00	2,500	2,500	1.00	2,500	2,500	1.00	2,500	2,500
sub-total				**26,100**			**26,600**			**68,300**
Labour										
Family										
Planting	day									
Weeding	day									
Other field tasks	day									
harvesting	day	5.00		-	5.00		-		1,000	-
Post-harvest tasks	day	5.00		-	5.00		-		1,000	-
Hired Labour				-						
All activities	day	57.00	1,000	57,000	48.00	1,000	48,000	123.00	1,000	123,000
Sub-total		67.00		**57,000**	58.00		**48,000**	123.00		**123,000**
Oxen/Machinery Hire										
Land Preparation	day	30.00	1,200	36,000	30.00	1,200	36,000	30.00	1,200	36,000
Transport to store	tonne	19.50	1,300	25,350	17.50	1,300	22,750	30.00	1,300	39,000
sub-total				**61,350**			**58,750**			**75,000**
Total Variable Costs				**144,450**			**133,350**			**266,300**
GROSS MARGIN				**349,875**			**310,275**			**494,200**

				Crop Budget for Onions per Hectare (Economic)						
			Present Situation			Without Project			With Project	
Item	Unit	Unit/ha	Price (NGN)	Value (NGN)	Unit/ha	Price (NGN)	Value (NGN)	Unit/ha	Price (NGN)	**Value (NGN)**
RETURNS										
Onions	tonne	19.50	25,350	494,325	17.50	25,350	443,625	30.00	25,350	760,500
Crop residue	tonne			-		5,000	-		5,000	-
Gross Returns				**494,325**			**443,625**			**760,500**
VARIABLE COSTS										
Materials										
Seed	Kg	5.00	2,000	10,000	5.00	2,000	10,000	5.00	5,500	27,500
Fertilizer										
Urea	Kg	25.00	105	2,625	25.00	105	2,625	75.00	105	7,875
NPK	Kg	50.00	160	8,000	50.00	160	8,000	150.00	160	24,000
Manure	tonne	1.00	1,000	1,000	1.00	1,000	1,000	3.00	1,000	3,000
Chemicals										
Herbicides	litre	0.50	1,000	500	1.00	1,000	1,000	1.00	1,000	1,000
Pesticides	litre	1.00	1,000	1,000	1.00	1,000	1,000	1.00	1,000	1,000
Other inputs	LS	1.00	2,500	2,500	1.00	2,500	2,500	1.00	2,500	2,500
sub-total				**25,625**			**26,125**			**66,875**
Labour										
Family										
Planting	day									
Weeding	day									
Other field tasks	day									
harvesting	day	5.00	1,000	5,000	5.00	1,000	5,000	5.00	1,000	5,000
Post-harvest tasks	day	5.00	1,000	5,000	5.00	1,000	5,000	5.00	1,000	5,000
Hired Labour				-						
All activities	day	57.00	1,000	57,000	48.00	1,000	48,000	123.00	1,000	123,000
Sub-total		67.00		**67,000**	58.00		**58,000**	133.00		**133,000**
Oxen/Machinery Hire										
Land Preparation	day	30.00	1,200	36,000	30.00	10,000	1,200	30.00	1,200	36,000
Transport to store	tonne	19.50	1,300	25,350	17.50	1,300	22,750	30.00	1,300	39,000
sub-total				**61,350**			**23,950**			**75,000**
Total Variable Costs				**153,975**			**108,075**			**274,875**
GROSS MARGIN				**340,350**			**335,550**			**485,625**

				Crop Budget for Pulses/Oil seeds per Hectare (Financial)						
			Present Situation			Without Project			With Project	
Item	Unit	Unit/ha	Price (NGN)	Value (NGN)	Unit/ha	Price (NGN)	Value (NGN)	Unit/ha	Price (NGN)	**Value (NGN)**
RETURNS										
Soyabean/ Cowpea 1/	tonne	1.15	131,493	151,217	1.05	131,493	138,068	2.00	131,493	262,986
Crop residue	tonne	0.30	4,000	1,200	0.30	4,000	1,200	1.00	4,000	4,000
Gross Returns				**152,417**			**139,268**			**266,986**
VARIABLE COSTS										
Materials										
Seed	Kg	30.00	250	7,500	30.00	250	7,500	30.00	250	7,500
Fertilizer										
Urea	Kg			-			-			-
NPK	Kg	50.00	167	8,350	50.00	167	8,350	150.00	167	25,050
Manure	tonne	1.00	1,000	1,000	1.00	1,000	1,000	2.00	1,000	2,000
Chemicals										
Herbicides	litre		1,000	-		1,000	-	1.00	1,000	1,000
Pesticides	litre	1.00	1,000	1,000	1.00	1,000	1,000	3.00	1,000	3,000
Other inputs	LS	1.00	2,500	2,500	1.00	2,500	2,500	1.00	2,500	2,500
sub-total				**20,350**			**20,350**			**41,050**
Labour										
Family										
Planting	day	5.00	Nil	Nil	5.00	Nil	Nil	5.00	Nil	Nil
Weeding	day	5.00	Nil	Nil	5.00	Nil	Nil	5.00	Nil	Nil
Other field tasks	day	5.00	Nil	Nil	5.00	Nil	Nil	5.00	Nil	Nil
harvesting	day	5.00	Nil	Nil	5.00	Nil	Nil	5.00	Nil	Nil
Post-harvest tasks	day	5.00	Nil	Nil	5.00	Nil	Nil	5.00	Nil	Nil
Hired Labour										
All activities	day	15.00	600	9,000	15.00	600	9,000	50.00	600	30,000
Sub-total		40.00		**9,000**			**9,000**			**30,000**
Oxen/Machinery Hire										
Land Preparation	day	20.00	1,200	24,000	20.00	1,200	24,000	20.00	1,200	24,000
Transport to store	tonne	1.15	1,250	1,438	1.05	1,250	1,313	2.00	1,250	2,500
sub-total				**25,438**			**25,313**			**26,500**
Total Variable Costs				**54,788**			**54,663**			**97,550**
GROSS MARGIN				**97,629**			**84,605**			**169,436**
1/ Soya bean and Cowpea										

EconomicCrop Budget: Pulses/ Oil seeds (NGN per ha)				**Crop Budget for Pulses/Oil seeds per Hectare (Economic)**						
			Present Situation			Without Project			With Project	
Item	Unit	Unit/ha	Price (NGN)	Value (NGN)	Unit/ha	Price (NGN)	Value (NGN)	Unit/ha	Price (NGN)	**Value (NGN)**
RETURNS										
Soyabean/ Cowpea 1/	tonne	1.15	130,631	150,226	1.05	130,631	137,163	2.00	130,631	261,262
Crop residue	tonne	0.30	4,000	1,200	0.30	4,000	1,200	1.00	4,000	4,000
Gross Returns				**151,426**			**138,363**			**265,262**
VARIABLE COSTS										
Materials										
Seed	Kg	30.00	111	3,333	30.00	111	3,330	30.00	250	7,500
Fertilizer										
Urea	Kg		105	-		105	-			-
NPK	Kg	50.00	160	8,000	50.00	160	8,000	150.00	160	24,000
Manure	tonne	1.00	1,500	1,500	1.00	1,500	1,500	2.00	1,000	2,000
Chemicals										
Herbicides	litre		1,000	-		1,000	-	1.00	1,000	1,000
Pesticides	litre	1.00	1,000	1,000	1.00	1,000	1,000	3.00	1,000	3,000
Other inputs	LS	1.00	2,500	2,500	1.00	2,500	2,500	1.00	2,500	2,500
sub-total				**16,333**			**16,330**			**40,000**
Labour										
Family										
Planting	day	5.00	400	2,000	5.00	400	2,000	5.00	400	2,000
Weeding	day	5.00	400	2,000	5.00	400	2,000	5.00	400	2,000
Other field tasks	day	5.00	400	2,000	5.00	400	2,000	5.00	400	2,000
harvesting	day	5.00	400	2,000	5.00	400	2,000	5.00	400	2,000
Post-harvest tasks	day	5.00	400	2,000	5.00	400	2,000	5.00	400	2,000
Hired Labour										
All activities	day	15.00	400	6,000	15.00	400	6,000	50.00	400	20,000
Sub-total		40.00		**16,000**	40.00		**16,000**	75.00		**30,000**
Oxen/Machinery Hire										
Land Preparation	day	20.00	1,200	24,000	20.00	1,200	24,000	20.00	1,200	24,000
Transport to store	tonne	1.15	1,213	1,395	1.05	1,213	1,274	2.00	1,213	2,426
sub-total				**25,395**			**25,274**			**26,426**
Total Variable Costs				**57,728**			**57,604**			**96,426**
GROSS MARGIN				**93,698**			**80,759**			**168,836**
1/ Soya bean and Cowpea										

Farm Size		0.46 ha			0.46 ha			0.46 ha	
		Present Situation			Without Project			With Project	
Cropping Pattern	Area/ha	Gross Margin per ha	Financial Gross Margin	Area/ha	Gross Margin per ha	Financial Gross Margin	Area/ha	Gross Margin per ha	Financial Gross Margin
Crop									
Wet season									
Maize	0.02	97,098	1,942	0.02	66,268	1,325	0.06	247,395	14,844
Sorghum	0.02	23,800	476	0.02	19,863	397	0.14	57,200	8,008
Rice	0.4	278,722	111,489	0.4	192,722	77,089	0.14	391,845	54,858
Tomato a/		221,000	-		177,050	-	0.06	425,100	25,506
Legumes / oilseeds	0.01	97,629	976	0.01	84,605	846	0.06	169,436	10,166
Sub-total	0.46		114,883	0.46		79,658	0.46		113,382
Dry season									
Maize	0.08	97,098	7,768	0.08	66,268	5,301		247,395	-
Sorghum		23,800	-		19,863	-	0.06	57,200	3,432
Rice	0.01	278,722	2,787	0.01	192,722	1,927		391,845	-
Tomato b/	0.29	221,000	64,090	0.29	177,050	51,345	0.14	425,100	59,514
Cowpea	0.02	97,629	1,953	0.02	84,605	1,692	0.06	169,436	10,166
Wheat	0.02	135,309	2,706	0.02	101,474	2,029		203,948	-
Onion	0.01	349,875	3,499	0.01	310,275	3,103	0.12	494,200	59,304
Vegetables	0.02	289,200	5,784	0.02	217,325	4,347	0.09	373,600	33,624
Sub-total	0.46		88,587	0.46		69,744	0.46		166,040
Farm Gross Margin			203,469			149,402			279,422
Less Fixed Costs									
Land Rent		5,000			5,000			5,000	
Farm tools 1/ and other expenses	1.00	10,000	10,000	1.00	10,000	10,000	2.50	10,000	25,000
Sub-total		-	10,000			10,000			25,000
Net Farm Returns			193,469			139,402			254,422
Irrigation O&M Fees 2/	0.92	5,000	4,600	0.92	5,000	4,600	0.92	15,000	13,800
Net Farm Returns (after irrigation O&M)			188,869			134,802			240,622
Irrigation Fees as % Net Farm Returns (before fees)			**2%**			**3%**			**5%**

Farm Size		0.46 ha			0.46 ha			0.46 ha	
		Present Situation			Without Project			With Project	
Cropping Pattern	Area/ha	Gross Margin per ha	Economic Gross Margin	Area/ha	Gross Margin per ha	Economic Gross Margin	Area/ha	Gross Margin per ha	Economic Gross Margin
Crop									
Wet season									
Maize	0.02	97,778	1,956	0.02	74,517	1,490	0.06	249,890	14,993
Sorghum	0.02	7,944	159	0.02	5,630	113	0.14	40,781	5,709
Rice	0.4	209,091	83,636	0.4	134,057	53,623	0.14	303,290	42,461
Tomato a/		222,875	-		177,125	-	0.06	441,125	26,468
Legumes / oilseeds	0.01	93,698	937	0.01	80,759	808	0.06	168,836	10,130
Sub-total	0.46		86,688	0.46		56,033	0.46		99,761
Dry season									
Maize	0.08	97,778	7,822	0.08	74,517	5,961		249,890	-
Sorghum		7,944	-		5,630	-	0.06	40,781	2,447
Rice	0.01	209,091	2,091	0.01	134,057	1,341		303,290	-
Tomato b/	0.29	222,875	64,634	0.29	177,125	51,366	0.14	441,125	61,758
Cowpea	0.02	93,698	1,874	0.02	80,759	1,615	0.06	168,836	10,130
Wheat	0.02	124,354	2,487	0.02	93,470	1,869		195,090	-
Onion	0.01	340,350	3,404	0.01	335,550	3,356	0.12	485,625	58,275
Vegetables	0.02	239,055	4,781	0.02	179,588	3,592	0.09	315,490	28,394
Sub-total	0.46		87,092	0.46		69,100	0.46		161,004
Farm Gross Margin			173,780			125,133			260,765
Less Fixed Costs									
Land Rent		5,000			5,000			5,000	
Farm tools 1/ and other expenses	1.00	10,000	10,000	1.00	10,000	10,000	2.50	10,000	25,000
Sub-total		-	10,000			10,000			25,000
Net Farm Returns			163,780			115,133			235,765
Irrigation O&M Fees 2/	0.92	5,000	4,600	0.92	5,000	4,600	0.92	15,000	13,800
Net Farm Returns (after irrigation O&M)			159,180			110,533			221,965
Irrigation Fees as % Net Farm Returns (before fees)			**3%**			**4%**			**6%**

APPENDIX 6: Semi-Structured Interview Questions

Introduction

Dear Sir/Ma/Malam/Malama/Alhaji/Hajiya

I am a postgraduate student of Water Engineering, Pan African University Institute of Water and Energy Sciences (including climate change), working on the potential of agricultural drainage systems to sustain irrigated agriculture in KRIP.

• The objective of the study is to gather information about the drainage practices and management in this sector of irrigation.

• The purpose and format of my visit**:**

1. I am doing a study on drainage practices and management in KRIP. The study will evaluate the impact, problems, and opportunities of the agricultural drainage system.

2. I am going to ask some questions about your perspectives drainage and drainage related issues.

3. The discussion should take less than an hour.

Please, provide all the necessary information required in the questionnaire. All information will be treated with the utmost confidentiality and will strictly be used for research purpose.

Interview Protocol

Subject ID #_____________________

Irrigation Personnel of Kano River Irrigation Project (KRIP)

1. Tell me about yourself? How did you get involved with the Kano River Irrigation Project?
2. What are the drainage practices that you employ in your irrigation processes?
3. What are the operation and maintenance procedures that you have adopted in the management (Soil and Water) of the drainage systems in your irrigation processes?
4. Describe the decisions that went into the most recent adoption of the operation and maintenance procedures for irrigation processes and soil and water management?

The Federal Ministry of Water Resources (FMWR)/ Federal Ministry of Agriculture and Rural Development (FMARD)

1. Tell me about yourself? How did you get involved with the drainage issues pertaining the formal Irrigation Projects?
2. Tell me about management three most recent cases of irrigation schemes' adoption of operation and maintenance procedures in the management of soil and water?

3. Tell me about the three most recent cases of policies and interventions and irrigation schemes response to the adopting of operation and maintenance in the management of soil and water.

Hadejia Jama'are River Basin Development Authorities (HJRBDA)

1. Tell me about yourself? How did you get involved with the River Basin Development Authority?
2. What are the drainage mandates that you employ in irrigation processes?
3. What are the operation and maintenance procedures that you have adopted in the management (Soil and Water) of the drainage systems in your irrigation processes?
4. Describe the decisions that went into the most recent adoption of the operation and maintenance procedures for irrigation processes and soil and water management?

Water Users Association (WUA)

1. Tell me about yourself? How did you get involved with Water Users Association?
2. What are the drainage issues that you discuss in your committee?
3. What are the operation and maintenance procedures that you have adopted in the management (Soil and Water) of the drainage systems in your irrigation processes?
4. Describe the decisions that went into the most recent adoption of the operation and maintenance procedures for irrigation processes and soil and water management?

Supplementary Questions

1. What is the general description and history of KRIP?
2. Which strategies and policy measures have been taken in ministry/HJRBDA/KRIP to sustain the effects of the drainage and drainage-related problems?
3. Which actors are involved in implementing strategies and policy measures which were taken in the ministry?
4. What changed in the cropping system and design of the irrigation and drainage system since inception?
5. What are the challenges in the past and main impacts of drainage management on agricultural production, water use efficiency, and water quality?
6. What are the farmers' problems and perceptions of the drainage management, and what are the main factors that drive them to participate in drainage management?
7. What are the participatory roles of farmers in drainage management?
8. Who is responsible for drainage management? Who pays for drainage?
9. What are recent developments on conserving agricultural land?
10. What are the interventions currently ongoing and underway?

APPENDIX 7: Letters of Introduction to TRIMING, FMWR, and Institute of Agricultural Research

FEDERAL MINISTRY OF WATER RESOURCES

OLD SECRETARIAT, AREA 1, P. M. B. 159, GARKI - ABUJA

Irrigation & Drainage Department

Telegrams__________

Telephone__________

Ref. No. FMWR/ID/S/12/T/76

Date: 14th March, 2019

The Project Coordinator,
TRIMING
Plot 1402, Abba Kyari Street,
Off Adesoji Aderem Street,
Apo, Abuja.

RE: INTRODUCTION LETTER:
MR. BAYERO MUHAMMAD TUKUR

The Pan African Institute of Water and Energy Sciences (PAUWES) has written the Ministry on behalf of **Mr. Bayero Muhammad Tukur**, a student currently undergoing Master programme in Water Science Engineering Track at PAUWES Institute in Algeria. He wishes to collect data from some projects under TRIMING to be used for his Master thesis.

2. Kindly accord him necessary support to ensure the success of the exercise

3. Thank you and best regards.

original Copy Collected by me.

EOOluniyi
Engr. (Mrs.) E. O. Oluniyi
Ag. Director (Irrigation & Driange)
For: Honourable Minister

15/03/19

Pan African University
PAU Institute of Water and Energy Sciences

PAU Institute of Water and Energy Sciences, (including Climate Change) PAUWES
c/o Université Abou Bekr Belkaid Tlemcen, B.P. 119, Campus Chetouane, 13000 Tlemcen, Algeria
Phone: +213 40 91 31 88
director@pauwes.univ-tlemcen.dz
http://pauwes.univ-tlemcen.dz

Ref. 247/PAUWES/2019

RECEIVED 18 MAR 2019 Irrigation Research Programme IAR/ABU, Zaria.

Date: March 07th, 2019

From:
Prof. Abdellatif Zerga
Director of PAUWES

EXECUTIVE DIRECTOR

To:
Institute for Agricultural Research (IAR), Samaru – Zaria
Institute for Agricultural Research PO Box 1044,
Samaru, Zaria – Nigeria

Subject **Introduction Letter**

Dear Sir/Madame,

The Pan African University Institute of Water and Energy Sciences (including Climate Change) (PAUWES) is located on the campus of the University of Tlemcen, Algeria.

PAUWES is one of the five hubs of the Pan African University established under the African Union aimed at revitalizing African higher education and at boosting research and postgraduate training. PAUWES is the fourth institute after the Institute of Governance, Humanities and Social Sciences (PAUGHSS) at the University of Yaounde II in Cameroon; the Institute of Basic Sciences, Technology and Innovation (PAUSTI) at Jomo Kenyatta University of Agriculture and Technology in Kenya; and the Institute of Life and Earth Sciences (PAULESI) at the University of Ibadan in Nigeria.

The PAUWES Institute offers graduate students access to leading academic teaching, research and hands-on training in areas vital to the future of African development – water, energy and the challenge of climate change.

In this context, the student at PAUWES, **Mr. Bayero Muhammad Tukur** from Nigeria, preparing a Master in Water Science, Engineering Track wishes to collect data in your institution for his Master thesis.

In this regard, we are addressing to you **Mr. Bayero Muhammad Tukur** for your kind consideration to collect data in your institution.

Thank you in advance as we hope for your valuable cooperation.

Sincerely,

Prof. Abdellatif Zerga,
Director of PAUWES

University of Tlemcen * PAUWES * Pan African University *

DIRECTOR
Institute For Agric. Research.
Ahmadu Bello University,
Zaria – Nigeria.

PL, Irrigation Res. Program
Attend to him, PE

FEDERAL MINISTRY OF WATER RESOURCES

OLD SECRETARIAT, AREA 1, P. M. B. 159, GARKI - ABUJA

Irrigation & Drainage Department

Telegrams

Telephone

Ref. No. FMWR/ID/S/12/T/76

Date: 14th March, 2019

HADEJIA-JAMA'ARE RIVER BASIN DEV. AUTHORITY
MD'S OFFICE
20 MAR 2019
RECEIVED

The Managing Director,
Hadejia-Jama' are River Basin Development Authority,
Maiduguri Road, Kano.
Kano State.

RE: INTRODUCTION LETTER:
MR. BAYERO MUHAMMAD TUKUR

The Pan African Institute of Water and Energy Sciences (PAUWES) has written the Ministry on behalf of **Mr. Bayero Muhammad Tukur**, a student currently undergoing Master programme in Water Science Engineering Track at PAUWES Institute in Algeria. He wishes to collect data from your Basin Development Authority to be used for his Master thesis.

2. He is to visit Kano Irrigation Project and any other relevant Scheme in your Command Area.

3. Kindly accord him necessary support to ensure the success of the exercise

4. Thank you and best regards.

Engr. (Mrs.) E. O. Oluniyi
Ag. Director (Irrigation & Driange)
For: Honourable Minister

ED(E)
Pls. note and handle
MD 25/03

AD(O/M)
Pls handle accordingly
ED(E) 21/3/19

75

Pan African University
Institute of Water
and Energy Sciences

Ref. 246/PAUWES/2019

FEDERAL MINISTRY OF WATER RESOURCES
HM Office
13 MAR 2019
Received

PAU Institute of Water and Energy Sciences,
(including Climate Change) PAUWES
c/o Université Abou Bekr Belkaid Tlemcen,
B.P. 119, Campus Chetouane,
13000 Tlemcen, Algeria
Phone: +213 40 91 31 88
director@pauwes.univ-tlemcen.dz
http://pauwes.univ-tlemcen.dz

Date: March 07th, 2019

From:
Prof. Abdellatif Zerga
Director of PAUWES

Honourable Minister
To: Federal Ministry of Water Resources, Irrigation and Drainage Department
Block A1, A2, Area 1 Secretariat,
P.M.B 159, Abuja, Nigeria

Attn: Irrigation and Drainage Dept.

Subject Introduction Letter

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Sincerely,

University of Tlemcen – Pan African University – PAUWES

Prof. Abdellatif Zerga,
Director of PAUWES