ASSESSING THE UPTAKE OF SYSTEM OF RICE INTENSIFICATION PRACTICES THROUGH AN INNOVATION PLATFORM IN OLUCH IRRIGATION SCHEME, RANGWE SUB COUNTY, KENYA

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A Thesis Submitted to the Graduate School in Partial Fulfilment of the Requirements for the Doctor of Philosophy Degree in Agricultural and Rural Innovations Studies of Egerton University

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DECLARATION AND RECOMMENDATION

Declaration

I hereby declare that this thesis is my original work and has not been submitted or published in any form for an award of a degree in this or any other University.

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Recommendation

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DEDICATION

I dedicate this work to my late mother Paulina Akuku and late brother Elijah Omondi, who ensured that I got the initial roots of education for enhancing well-being. To my family members, the constant source of inspiration.

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ABSTRACT

Globally, sustainable intensification in rice growing systems and practices has been accelerating in response to the declining productivity trends and the high market demand, particularly in Sub-Saharan Africa where uptake of improved technology is low. However, in Oluch irrigation scheme, Rangwe Sub-County, Kenya, weak networks and low innovative capacity are associated with smallholder rice farmers' which has significantly contributed to limited uptake of system of rice intensification (SRI) technology. This study sought to assess the uptake of SRI through a facilitated innovation platform (IP) to promote uptake of the technology in an interactive manner, with an aim of boosting the knowledge and skills in the intensification of rice production. The study adopted action learning research design where an IP was established to facilitate participatory learning and uptake of SRI in the scheme. A sample size of 101 farmers were selected from a population of 369 smallholder rice farmers to participate in the baseline survey. Out of the 101 farmers sampled for the baseline survey, 24 farmers were selected for the IP. Data was collected using structured questionnaires, FGD guides, observation checklists, and key informant interviews. Tests for validity and reliability were conducted using Cronbach's Alpha (coefficient of 0.82). SPSS was used for quantitative data analysis, while R-software was used for Social Network Analysis. Inferential statistical approaches used were Chi-Square, Correlation and Multiple Linear Regression models were used for the analysis of quantitative data. All statistical tests were conducted at the 5% level of significance. At baseline, farmers identified several complex and competing challenges that required the action of multiple stakeholders. Study findings showed very limited implementation of SRI practices. Integration of SRI through IP approach was found to be effective among smallholder rice farmers in Oluch. The IP, and the establishment of rice growing demonstration plot in a commonly identified Block BL 5.1 enabled stakeholders to work in a structured, more effective manner with greater effect towards SRI uptake. Given this observation, the study concluded that if facilitated properly through the IP, farmers who normally experience low productivity and earn low income can overcome challenges and increase their productivity thus enhancing their income. Similarly, farmers would have a greater opportunity to interact among themselves and with other stakeholders to address production challenges associated with demands of food and nutrition insecurity, SDGs and Vision 2030. Based on the findings, this study recommends a need for policies within the rice sector that supports facilitation of stakeholder networks such as IP approaches to enhance farmers' innovative capacities to promote production.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF PLATES

LIST OF ABBREVIATIONS AND ACRONYMS

AEZ	Agro-Ecological Zone
AfDB	Africa Development Bank
AIS	Agricultural Innovation Systems
AGRA	Alliance for a Green Revolution in Africa
AWD	Alternate Wetting and Drying
ASARECA	Association for Strengthening Agricultural Research in Eastern and Central Africa
CAADP	Comprehensive Africa Agricultural Development Program
CBO	Community Based Organization
CDA	County Director of Agriculture
CIG	Common Interest Group
FAO	Food and Agriculture Organization of the United Nations
FGD	Focus Group Discussions
GOK	Government of Kenya
ICIPE	International Centre of Insect Physiology and Ecology
IWUA	Irrigation Water Users Association
JICA	Japanese International Cooperation Agency
KALRO	Kenya Agricultural and Livestock Research Organization
KOSFIP	Kimira-Oluch Smallholder Farm Improvement project
MA	Millennium Ecosystem Assessment
MEWNR	Ministry of Environment, Water and Natural Resources
MOAL&F	Ministry of Agriculture, Livestock and Fisheries
NALEP	National Agriculture and Livestock Extension Programme
NASEP	National Agricultural Sector Extension Policy
NEMA	National Environmental Management Authority
NACOSTI	National Commission for Science Technology and Innovations
NERICA	New Rice for Arica
NGOs	Non-Governmental Organizations
NIB	National Irrigation Board
NRDS	National Rice Development Strategy
NRPU	National Rice Promotion Unit
OL-IWUA	Oluch Irrigation Water Users Association
PAR	Participatory Action Research

SDGs	Sustainable Development Goals
SPSS	Statistical Package for Social Sciences
SCAO	Sub-County Agricultural Officer
SRI	System of Rice Intensification
SSA	Sub-Saharan Africa
UNDP	United Nations Development Programme
WARDA	West Africa Rice Development Agency
WARMA	Water Resource Management Authority

CHAPTER ONE
INTRODUCTION

1.1 Background of the Study

Rice is a staple food crop demanded in the global fight against hunger and may be used to improve food and nutrition security and incomes, especially in low and middle-income countries (Demont, 2013; Omondi *et al.*, 2013). Globally, rice feeds over 50 percent of the world population (Ndiiri *et al*., 2013a). As a cash crop, it is also considered as a strategic commodity in economic development of producer countries (Muthayya *et al*., 2014; Seck *et al*., 2013). Rice farming is undertaken in many parts of the world and in varied ecosystems due to its versatility (Giraud, 2013; Omondi *et al*., 2013). Currently, rice is one of the most favoured grains for human consumption globally, with only five percent used as livestock feed compared to maize (67%) and wheat (27%) grains (Mohanty, 2013).

Rice is cultivated on approximately 162 million hectares globally, and an annual production of over 750 million metric tons in 2019. Currently, rice is one of the major grain crops worldwide with over 90 percent of global production and consumption within the Asia-Pacific region (FAOSTAT, 2020). Within the next three decades, an estimated 28 percent increase in demand for rice is anticipated globally (Alexandratos, 2012). However, the devastating impact of climate change poses a huge threat to global rice production, with an estimated decline in rice yields of up to 5 - 13% by 2060 (Chandio *et al*., 2020; Chen *et al*., 2020) under the present structure of rice cropping systems and scarcity of global water resources. However, the subsequent impact production in Africa which accounts for about 3.5% of global rice production will be potentially substantial, about 24% decline in productivity by 2070 (van Oort *et al*., 2018). Consequently, there has been renewed interest in developing technological innovations for rice cropping systems in leading rice producing countries to meet increasing global demand.

The growth in global rice production has been marginal in the past few decades, with several countries like China, Thailand and Indonesia experiencing yield stagnation (Peng *et al*., 2009). In 2011, the acreage under rice and yield quantities were 161 million ha and 719 million tons respectively, which only increased to 162 million ha and 755 million tons. However, there was substantial growth in rice production in Africa form an acreage and yield of 10.6 million ha and 25.5 million tons respectively in 2011 to 17.1 million ha and 38.7 million tons (FAOSTAT, 2020).

The inconsistent trends in rice production have been characterised by decline in water resources, reduction in arable land, shortage of labour, environmental degradation and climate change (Africa Rice, 2008; Chauhan *et al*., 2017; Chen *et al*., 2020; Van Nguyen *et al.*, 2006). Importantly, population growth has resulted in more than a five-fold growth in consumer demand, especially for high-quality rice grown from low-yielding varieties (Mohanty, 2013). To date, basic research in the development of high-yielding rice varieties, novel agronomic and crop management practices including the use of nitrogen fertilizers and irrigation water management have demonstrated potential to improve rice productivity in several settings (Peng *et al*., 2009; Thakur *et al*., 2020). More recently, sustainable agricultural practices to boost global rice productivity and allow optimal use of scarce water resources have gained prominence in rice producing countries, chief among them, sustainable rice intensification.

Globally scientists have developed a three-pronged approach to narrow the yield gap based on the green revolution principles (Mango *et al*., 2017). The first approach involves targeting the carrier technology itself (rice) whereby concerted efforts are being made through varietal improvements in breeding stations resulting in breeder, foundation and certified/quality seeds. The second approach targets the manufacture and preparation of support technologies such as fertilizers, both organic and inorganic, pesticides, fungicides and herbicides. The third approach is the improvement on technological practices of how the carrier technology should be produced in order to improve yields. Countries in Africa have released several varieties of rice that are resistant to diseases, pests, drought, lodging, and are high (Atera *et al*., 2018). New Rice for Africa (NERICA) is a perfect example that was released in 1996 (Takahashi, 2013). These varieties have been accompanied by other technological packages of how they should be produced (Hinnou *et al*., 2018). These technological packages that accompanied the green revolution are referred to in this thesis as the conventional approach or practices. This conventional approach of producing rice was based on the green revolution principle of increasing unit yield of paddy through the use of high yielding varieties (HYV), increased use of water and use of chemical fertilizers. However, this conventional approach of rice production has fallen short of meeting the current rice demand-yield gaps the experienced in Africa (FAO, 2017).

An improvement on the conventional approach of producing rice was made in the 1980's by a French Priest, Father Henri de Laulani in Madagascar to establish sustainable and scientific and agronomically-sound agricultural practices that would guarantee improved rice productivity under optimal use of capital and labour, reduced input costs and minimal resources, especially water (Toungos, 2018). This new approach, now widely known as the System of Rice Intensification (SRI), is a combination of several environmentally friendly practices. The System of Rice Intensification harmonizes specific aspects required for growth including soil, water, light and plant, thus allowing rice fields to achieve their fullest potential, which is often unexploited through the use of inappropriate farming techniques (Zotoglo, 2011). As opposed to traditional rice production, system of rice intensification involves alternate wetting and drying (AWD) of rice fields (Omwenga *et al*., 2014). To date, the use of system of rice intensification has gained prominence in several rice producing countries, and research and demonstration plots have demonstrated the resource-saving and environment-friendly benefits of SRI techniques in comparison to typical conventional or traditional rice production practices (Namara *et al*., 2013; Sato *et al.,* 2007; Sinha *et al*., 2007). The genesis of SRI and its technological package is described in detail in chapter two.

African governments, scientists, donors and development partners alike identify low rice yields in Africa as a priority problem that needs addressing (Tollens *et al*., 2013). Rice growing nations in Africa recently highly prioritised to develop local rice sector as an important driver of the fight against national food and nutrition insecurity, and a vehicle for improved livelihoods, reduced poverty and subsequently economic growth. Notably, this has been deemed achievable through leveraging on innovative approaches in production systems (FAO, 2017). The increased demand for rice in Africa can be attributed to population upsurge, urbanization and rise in people's disposable income (Ndiiri *et al*., 2013b). Rice productivity remains low in Africa despite increasing rice acreage in the continent. In 2016, the average rice yield in Africa was approximately 2.5 tons/ha, approximately half the global average production levels of about 4.8 tons/ha. Africa produced 32 million tons of rice and imported 20 million tons in 2017 to bridge the gap between demand and supply (FAO, 2017). Increasing rice production in Africa is of urgent necessity calling for alternative approaches to improving productivity such as sustainable intensification (Pretty *et al*., 2011; Roling *et al*, 2000).

In Kenya, rice is the third most important food grain after maize and wheat. Approximately eighty percent of rice production in Kenya is done under the conventional approach of continuous flooding of the rice fields (Mati *et al*., 2011a). The conventional practice relies on heavy external inputs such as fertilizer and pesticides and also requires intensive labour due to lack of mechanization to maintain the rice fields consequently leading to low yields averaging 2.5-3 tons/ha. Rice productivity fluctuates over the years and is persistently low, a sign of limited adoption of productivity enhancing technologies (Ndiiri *et al*., 2013b). Demand for rice in Kenya since 2010 to 2016 has always been above its estimated national production. According to government of Kenya statistics (GOK, 2015), the shortfall is met through imports at a heavy cost to the country. This Kenyan case mirrors what happens elsewhere in Africa and worldwide in the rice sub-sector.

System of Rice Intensification (SRI) approach was introduced in Mwea Rice Irrigation Scheme in July 2009 making Kenya one of the top forty countries to validate it's benefits (Mati *et al*., 2011a). SRI has the potential to achieve higher yields and incomes with less inputs, and generally less labour and additional socio-economic benefits (Uprety, 2013). SRI was introduced in Mwea Rice Irrigation Scheme through supported basic research by the Japanese International Cooperation Agency (JICA) where farmers were heavily involved in the on-farm research activities leading to a better understanding of the SRI technology and hence its widespread adoption in the scheme. The Mwea rice farmers realized the benefits of SRI characterized by improved yields and reduction in production costs and reduced drudgery. Similarly, the technology was introduced in Ahero, West Kano, and Bunyala Rice Irrigation Schemes since 2015 through a team of scientists/researchers from Jomo Kenyatta University of Agriculture and Technology (JKUAT) and other stakeholders (Mati *et al*., 2011a). Subsequently farmers registered impressive results as indicated by improved yields estimated at 3.5 tons/ha and a reduction in production costs (Mati *et al*., 2011a). It was therefore assumed that smallholder rice farmers in Oluch would easily take up SRI technology, which gives them more output from the same area of land while reducing environmental degradation and increasing natural capital flow of ecosystem service (Conway *et al*., 2010; Pretty, 1995).

The SRI technology was consequently introduced in Oluch Irrigation Scheme through conventional public extension service from the Ministry of Agriculture, Livestock and Fisheries (MOAL&F). However, the impressive results in Mwea, Ahero, West Kano and Bunyala Rice Irrigation Schemes have not been achieved in Oluch since farmers did not follow the controlled research guidelines but adapted some aspects of SRI technology and also maintained aspects of conventional rice production such as flooding and random planting. To achieve anticipated results in Oluch, the researcher reintroduced SRI technology through action research facilitated by an innovation platform. Integration of SRI in Mwea was done through a well-structured method under which farmers went through intensive training before going to the field. After assessing the positive effects of SRI in Mwea, the technology was transferred to Oluch with no proper implementation approach to smallholder rice farmers in Oluch. The intended outcome was not achieved, and this became the subject of investigation after realizing the method of implementation was not effective.

The challenges that constrain rice growing in Kenya and in Oluch irrigation scheme specifically can be overcome by implementing an Agricultural Innovation Systems (AIS) model. Agricultural Innovation System comprises a set of actors, enterprises, organizations and individuals, who collectively generate, disseminate, adapt and use knowledge and information of socio-economic significance, together with the policies and institutional context that control how different interactions and processes are undertaken. The AIS model functions as a network of multi-stakeholders who are focused on developing new products, processes, and new forms of organization into economic use, together with the institutions and policies that affect their behaviour and performance (World Bank, 2006). This model contains an innovation platform (IP) which Homann-Kee Tui *et al*. (2013) refer to as a space for learning, action and change. Within the context of this study, it referred to bringing together stakeholders of diverse talents and complementary skills involved in the rice production system in Oluch through an action learning process to interact and foster innovation to facilitate uptake of SRI technology.

Smallholder farmers in Oluch irrigation scheme faced several competing challenges. It was evident than no single challenge was exceedingly predominant, and which required the action of only a single stakeholder. Instead, the nature of challenges was multi-faceted, at every step of the production to marketing chain farmers experienced constraints, all of which have emerged as equally important to them. The innovation platform approach is a promising approach for technology uptake: by bringing together multiple stakeholders within the rice value chain, the goal of achieving improved rice productivity and subsequently improved livelihoods was within reach as constraints can be actioned through information exchange within the platform. Consequently, an IP was a most reliable approach to promote rice productivity at Oluch scheme. The use of an innovation platform is a perspective of Agricultural Innovation Systems approach that is all inclusive. The aim was to enhance the uptake of the SRI technology among the smallholder farmers of the scheme.

1.2 Statement of the Problem

Irrigated rice production was introduced in Oluch Irrigation scheme, Homa-bay County, Kenya, to boost food security and improve incomes among the smallholder farmers. However, food insecurity and poverty still prevail in the area due to the continuing low productivity levels (2.5-3 tons) despite the high potential (5 tons/ha) for rice production that can be realized in the scheme (AFDB, 2006; Government of Kenya, 2015). The System of Rice Intensification was launched in Oluch irrigation scheme without engaging the farmers in the controlled step by step guidelines used by JICA and JKUAT scientists while introducing SRI and understanding of how the technology works as applied earlier in Mwea Irrigation Scheme. However, in Oluch, farmers were not taken through gradual learning and introduction of SRI practices which entails line planting of young healthy seedlings, mechanical weeding, intermittent watering and maintaining soil health organically. Consequently, low uptake and limited rice productivity was observed in Oluch. It was against this background that this study sought to investigate if the use of an innovative approach through a facilitated innovation platform would bring a change in uptake of the SRI technology practices and in turn boost rice productivity. There has never been such a platform in the Oluch scheme with regard to uptake of SRI practices through action learning process. This study thus sought to address this gap by assessing the uptake of SRI through a facilitated IP to spur rice productivity in Oluch irrigation scheme, Rangwe Sub-County of Homabay County, Kenya.

1.3 Purpose of the study

The purpose of this study was to assess the uptake of SRI practices through an Innovation Platform (IP) intended to boost rice productivity and improve farmers' livelihoods in Oluch irrigation scheme, Rangwe Sub-County of Homabay County, Kenya. It was intended to demonstrate to the sponsors of the scheme: African Development Bank (AfDB) and National Government; the County Government of Homabay, researchers, farmers, input and service providers and other stakeholders how the uptake of SRI technology through facilitated IP could boost rice productivity and consequently impact positively on the farmer's livelihoods.

1.4 Objectives of the Study

The objectives of the study were to:

i. Describe the socio-economic characteristics of smallholder rice farmers in Oluch irrigation scheme, Rangwe Sub-County, Kenya.

ii. Identify the technological, knowledge, market based, financial, economic and interactional challenges in the uptake of SRI practices in Oluch irrigation scheme, Rangwe Sub-County, Kenya.
iii. Establish an Innovation Platform for SRI uptake in Oluch irrigation scheme, Rangwe Sub-County, Kenya.
iv. Determine multi-stakeholder network features that effectively promote SRI uptake in Oluch irrigation scheme, Rangwe Sub-County, Kenya.
v. Determine how the networks in the Innovation Platform influence the uptake of SRI practices in Oluch irrigation scheme, Rangwe Sub-County, Kenya.
vi. Determine the influence of facilitated Innovation Platform for networking and capacity building on uptake of SRI practices in Oluch irrigation scheme, Rangwe Sub-County, Kenya.

1.5 Research Questions

The following research questions were addressed:

i. What are the socio-economic characteristics of smallholder rice farmers in Oluch irrigation scheme, Rangwe Sub-County, Kenya?
ii. Which are the significant technological, market, economic, knowledge based, challenges to uptake of SRI practices in Oluch irrigation scheme, Rangwe Sub-County, Kenya?
iii. How does an Innovation Platform build capacity for uptake of SRI?
iv. What multi-stakeholder network features effectively promote SRI uptake in Oluch irrigation scheme, Rangwe Sub-County, Kenya?
v. How does the networks in the Innovation Platform influence the uptake of SRI in Oluch irrigation scheme, Rangwe Sub-County, Kenya?
vi. How does Innovation Platform for networking and capacity building facilitate uptake of SRI practices in Oluch irrigation scheme, Rangwe Sub-County, Kenya?

1.6 Significance of the Study

The study was designed to assess the uptake of SRI through an Innovation Platform to spur productivity among smallholder rice farmers in the Oluch irrigation scheme in Rangwe Sub-County, Kenya. The empirical findings from this research are of direct benefit to farmers, extensionists, researchers and policy makers. For farmers, the interactive learning and networking in the innovation platform build their innovative capacity and directly benefit them by applying SRI practices into their existing farming system to boost rice productivity. The extension system is already benefiting by having an alternative extension methodology to facilitate and enhance their services. The researchers are benefiting by acquiring new body of knowledge of how to conduct similar studies and contribute to the ongoing literature on outcomes of SRI technology. Furthermore, researchers now have a platform by which to disseminate their new technologies to a wide range of stakeholders. This study provides evidence on which policies that support innovation in rice farming can be based. Importantly, the study provides a building block for adaptive agricultural innovation policies to deal with the uncertainty of innovation uptake processes.

1.7 Scope of the Study

This study was carried out in Oluch Irrigation Scheme in Rangwe Sub-County, Homabay County, Kenya, from November 2017 to September 2019. The study specifically focused on interactive learning processes among stakeholders in the Innovation Platform to promote uptake of SRI practices that spur rice productivity. The variables studied mainly included the technological code of SRI which touches particularly on how they should be applied to increase rice production.

1.8 Assumptions of the Study

This study was carried out under these key assumptions:

i. The level of uptake of SRI practices leads to increased productivity and reduction in production cost all other factors held constant.

ii. The stakeholders in the rice value chain in Oluch scheme in Rangwe Sub-County were willing to participate in the innovation platform.

1.9 Limitations of the Study

The study had four limitations:

i. The inherent biases or weakness associated with single observer studies. This was overcome through methodological triangulation.

ii. The participatory action research design involves a lot of triangulation in terms of data collection tools and methods necessitating application of multiple procedures for data analysis which used a lot of time in the long iterative processes of action learning before generating findings and drawing conclusions to the study. To counter this, the researcher occasionally employed methods such as on the spot analysis to save on time and other resources.

iii. Some private millers became sceptical of participating in the study when they realized farmers were sensitized about sale of by-products such as bran and husks which they used to leave at the mills and were being sold by millers. This was counteracted by selecting their representative as a participant in the SRI innovation platform where more information was gathered about processors as key value chain actors which changed their perceptions.

iv. There was also limitation of authenticity. Some governmental statistics were not accurate as they were just documented in order to meet official targets. This was navigated through referencing of different authentic sources including FAOSTAT, related research articles/publications and policy documents.

1.10 Definition of Terms

The following definitions of key terms were adopted for this study.

Action-research: Refers to a process where the main aim is to establish a change (the action) and learn from that change (the research), thereby not having a limited focus on generating new information (KIT *et al*., 2012). The term is used in the same context for this study.

Agricultural Innovation System (AIS): this is a set of organizations and individuals who work collaboratively to generate, disseminate, adapt and use knowledge and information of socioeconomic significance, as well as the policy and institutional context that governs the way such interactions and processes take place (Klerkx *et al.*, 2020; Rajalahti *et al*., 2008; World Bank, 2012). In this study, AIS was used in the same context.

Conventional rice production system: this is a high-input low-output system of rice production which mines the soil hence resulting in ecosystem imbalance. It is characterized by heavy input use, high labour demands, planting of overgrown seedlings, flooding paddies and manual field operations such as hand weeding, dibbling and manual harvesting (Andow *et al*., 1998; Chapagain, 2017).

Ecosystem services: These refer to the direct and indirect benefits people accrue from the functioning of an ecosystem (Costanza *et al*., 1997; Millennium Ecosystem Assessment, 2005). In this study context, it referred to the benefits people derive directly or indirectly from the scheme ecosystem.

Interactions: is the action that occurs when at least two actors have an effect on each another. In this context it referred to influence of innovation platform participants on each other in an action learning process to enhance innovative capacity of smallholder rice farmers for uptake of SRI practices.

Innovation: Refers to the successful combination of improved or new technology in the form of technical devices (hardware'), novel practices, learning processes and approaches of thinking ('software'), and new organizational arrangements and institutions and ('orgware') (Smits *et al*., 2004). In this study, it referred to the Innovation platform creation and SRI uptake through interactive learning process among the different actors within the rice value chain in Oluch aimed at improving rice productivity.

Innovative capacity: Is the ability of the stakeholders to introduce and use new knowledge, ideas or ways of doing things to bring social, economic and institutional change. In this study it referred to ability of innovation stakeholder to introduce and use new knowledge, ideas or ways of doing things to build smallholder rice farmers' innovative capacity for uptake of SRI practices

Innovation Platform (IP): Homann-Kee Tui *et al*. (2013) define an innovation platform as a space for learning, and a vehicle to spur action and bring about change. In this context, it referred to bringing together stakeholders of diverse talents and complementary skills involved in rice value chain; through an action learning process to interact and foster innovation to facilitate uptake of SRI technology.

Innovation System: Refers to a system of various actors, individuals, enterprises and organizations who work together to deliver better products, better processes, and novel forms of organization into economic use. It also encompasses the organizations and policy frameworks that affect the action and performance of the various actors in the system (World Bank, 2006). The term is used in the same context in this study.

Networks: These refer to the set of inter-relationships, interactions and connections that exist between different who have various reasons to connect (Wenger *et al*., 2011). In this study it referred to the set of nodes (stakeholders) and links between the nodes which promoted mutual learning.

Productivity: Is used synonymously to mean the same as agricultural productivity. In the context of this study, it means productivity in terms of the level of rice production per unit area under SRI practices.

Social capital: According to Scoones (1998) social capital refers to anticipated collective or economic benefits as a result of the cooperation between various individuals and groups with a common interest. In this study it referred to the extent and availability of connections to stakeholders, membership of formalized associations like IWUA and producer group such as rice CIGs that may promote smallholder rice farmer's productivity.

Social Network Analysis: Is focused on the structure of relationships between people or entity of concern (Monge *et al*., 2003). In the context of this study, it focused on the relationship structures among stakeholders in the Innovation Platform.

Sustainable agricultural intensification: is defined as improving agricultural productivity per unit area without increasing the area under cultivation, whilst reducing the adverse impact to the environment (Haggar *et al*., 2020). In this study, it referred to producing more rice per unit area of land while reducing the negative environmental impacts through SRI.

Systems perspective: Involves study of a system whilst having defined goals, objectives and boundaries, structure, and function of the system. As such, problems can be visualised through a bigger picture and in a holistic way, whilst recognizing the existing complexities and uncertainties of natural and human systems (Tow *et al*., 2011). The term is used in the same context in this study.

System of Rice Intensification (SRI): is an Agro-ecological method that enables farmers to achieve higher yields and incomes with low inputs and a variety of additional socio-economic benefits. It thus both improve productivity and provision of ecosystem services (Uprety, 2013). It is characterized by line planting of young healthy seedlings at wider spacing which permits mechanization of field operations such as weeding and harvesting (Uphoff, 2003). The term SRI is used in the same context in this study.

Systems thinking: Is defined as thinking about the system as a whole instead of its elements as separate entities, emphasizing the inherent relationships between the components of the system within the physical, social and environmental contexts (Cabrera *et al*., 2008). In this context, it referred to the new partnerships between farmers and other stakeholders in the IP action learning process.

Stakeholder: Refers to any individual, enterprise, organization or group with interests, shares or investment in a specific entity, field or industry (Stein, 2013). In this context, it referred to an agency, individual, group or organization involved in or has an interest in the rice value chain in Oluch scheme.

Uptake: Is a practice operationally defined as access, acceptance and immediate use of a technology (Alexander *et al*., 2020; Kuehne *et al*., 2017). In this study, uptake is used in the context of SRI practices by smallholder farmers in Oluch scheme.

Value chain: Refers to the broad spectrum of activities necessary to develop a service or product from conception to delivery to consumers. It transcends all the intermediary phases of production and final disposal after use (Kaplinsky *et al*., 2000). In this context, it referred to how the IP facilitated three interlinked functions in the rice value chain including creating space for learning and joint innovation, governance and advocacy to secure policy influence in rice production.

CHAPTER TWO
LITERATURE REVIEW

2.1 Introduction

This chapter presents a review of literature that was relevant to this study and includes theoretical basis for the work. The literature gives an overview of global rice production trends, highlights on smallholders and rice farming in Kenya, systems of rice production including SRI, suitability of innovation platform in SRI technology uptake, action learning for SRI uptake, and the chapter ends with theoretical and conceptual framework.

2.2 Overview of Global Rice Production Trends

Cultivated Rice (*Oryza sativa L.)* is an important agricultural food crop in the global fight against hunger. Rice is the main source of calories and protein for at least half of the global population, mainly driven by changing consumer preferences in both high and low-income economies (Chauhan *et al*., 2017; Song, 2003). The area under rice represents 29 percent of the total output of grain crops worldwide with Africa accounting for about 10 to 13 percent (FAO, 2017). Within the next decade, the exponential population growth is anticipated to realise an increased demand for rice, with more than 3.5 billion people in 2025 depending on rice as staple food (Song, 2003). To date, the demand for rice has witnessed an exponential growth in recent years, hence contributing significantly to the current strategic food security planning policies for several countries.

By 2016, the global rice productivity was estimated at 741.3 million tons , harvested from 164 million hectares, with China and India dominating most of the production, accounting for at least 50 percent (FAO, 2016). In Sub-Saharan Africa (SSA), rice production more than doubled in the last three decades, from 8.6 to 21.6 million metric tons between 1980 and 2006 (Atera *et al*., 2018). The recent increase in rice productivity is attributed to increased acreage under cultivated rice, exponential urban population growth, changing consumer preferences and affordability for most households owing to increased incomes. (Balasubramanian *et al*., 2007; Kijima *et al*., 2006). The variance in productivity especially between Asia and Africa can be linked to difference in cropping systems. For instance, Becker *et al.*(2001) reported that up to 90 percent of all rice cultivation in Asia is undertaken under paddy field conditions; in contrast, only about 60 percent of rice cultivation undertaken in SSA is done in upland ecosystems.
Figure 1 shows that productivity in Africa and East Africa in particular, is much lower averaging 2.6 metric tons/ha and 2.9 metric tons/ha respectively against the world average of

4.8 metric ton/ha. Kenya's productivity is above Africa and East Africa productivity levels (FAO, 2017). The growing demand for rice has influenced increasing quantities of rice grown under different production systems with smallholder farmers playing a critical role. Urbanization, increasing per capita consumption and high population growth have been identified as potential drivers of global rice demand. Increasing rice productivity in Africa needs alternative approaches to improve productivity such as sustainable intensification (Pretty *et al*., 2011; Roling *et al*., 2000).

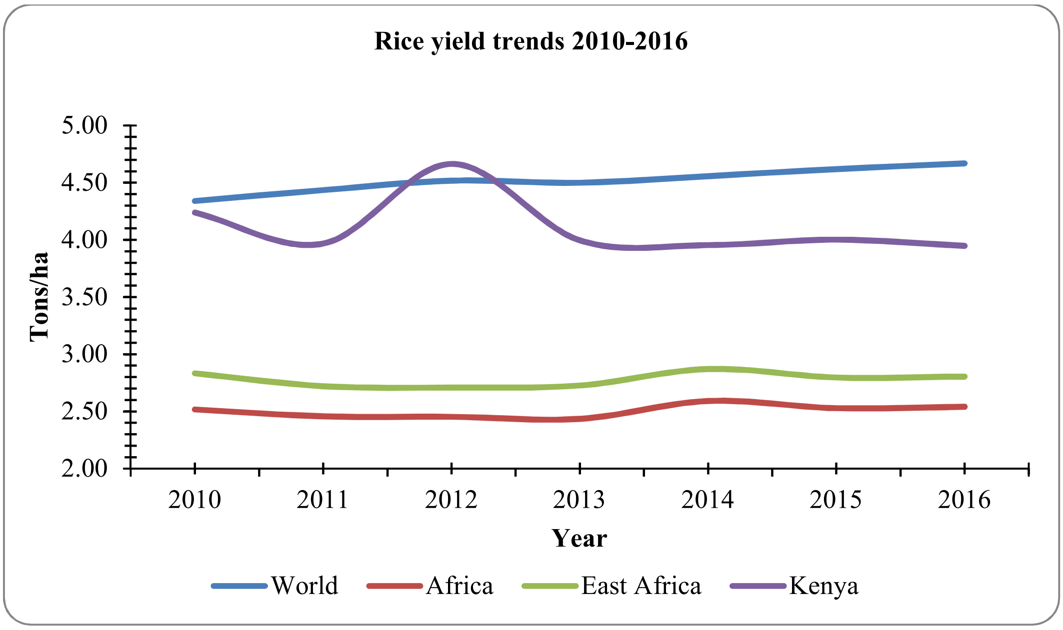

Figure 1. Rice Yield Trends 2010 – 2016

Source: Food and Agriculture Organization (2017)

Rice importation in Africa accounts for at least one third of rice traded in the global market. Even in rice producing countries, imported rice account for a significant percentage of domestic consumption, most of which is shipped from Thailand (60 percent), China (22 percent) and Pakistan (9 percent) (FAO, 2017). This is in contrast to the Africa Rice estimated rice productivity potential in sub-Saharan Africa lowlands of about 130 million hectares (Africa Rice, 2008). In Kenya, at least 70% of imported rice is exported from Pakistan, mainly the Pakistan IRRI-6 rice variety (Kenya National bureau of Statistics, 2016).

Rice is grown in over 75 percent of the African countries, although this supplies only approximately 70 percent of the rice consumed within the continent (Africa Rice Centre, 2013). Currently, rice consumption per capita averages 27kg, compared to an average 100kg per capita consumption in Asia (Africa Rice centre, 2013). However, there are substantial disparities in rice consumption even within Africa, with most of the rice consumption as staple food in West and North African populations. With an average 4.5 percent consumption growth rate per annum, and a population of about 800 million people, demand and productivity gaps are glaring.

To meet gaps in rice demand and productivity, significant research in Africa has aimed at developing improved high-yielding rice varieties. The New Rice for Africa (NERICA) for instance, established through collaboration from the International Rice Research Institute (IRRI) and the West Africa Rice Development Association (WARDA) has spearheaded research into high yielding varieties within the continent (Tollens *et al*., 2013). NERICA variety was developed as a cross between African and Asian rice varieties, to guarantee early maturity, and yield maximum output under low input requirements and local stress. The WARDA and IRRI collaborative efforts yield rice variety suitable for both upland and lowland rice ecologies. To date, more than 3,000 family lines of NERICA varieties have been developed for cultivation in both uplands and lowlands regions in Africa. The NERICA 1, 2, 3 and 4 comprise the most the top varieties planted by farmers in West Africa (FAO, 2017). Ecological variations across SAA has spurred the development of region specific varieties; NERICA 1, 2, 3 and 4 are most commonly cultivated in West Africa (FAO, 2017), Uganda released the "NARIC–3" NERICA variety in 2003, while several countries including Kenya, Tanzania, Ethiopia, Malawi, Mozambique and Madagascar are evaluating potential high yielding NERICA varieties for future use (Africa Rice centre, 2013).

Despite the growing demand of rice worldwide in the last three decades, its production has increased at marginal levels in comparison to the global demand, raising important questions world food security as a sustainable development agenda. Yield gaps are observed in several rice growing countries, majorly attributed to climate change, socio-economic, and technical constraints. Adverse soil and weather conditions, reduced water for irrigation, pests and diseases, labour shortages especially owing to high disease burden in sub-Saharan Africa have largely accounted for the poor harvests in low productivity but high potential rice growing countries (Duwayri *et al*., 2000). Currently, global rice trade accounts for only 7% of total global production. The global rice market is also characterized by a high level of concentration with only five leading rice exporters, mainly Thailand, Vietnam, India, USA and Pakistan, who collectively account for more than two-thirds (66 percent) of rice exports globally (FAO, 2016).

2.2.1 Rice Production in Kenya

Rice farming was introduced in Kenya in the 19th century by Asians. Currently, it is one of the three main important staple food and cash crops after maize and wheat in the country. In addition to food and income, rice provides animal feed and employment to an estimated half-million people and taking up an estimated 20 percent of cultivated land (FAO, 2017). Annual rice consumption in Kenya in 2016 was estimated at 816,972 metric tons and surpassed its production which is about 141,490 metric tons as shown in Figure 2 due to increasing population, urbanization and change in eating habits (Diagne *et al*., 2010; FAO, 2017). This consumption is projected to increase by 12 percent per annum. The deficit is met through imports valued at over 9 billion Kenya shillings annually (Mohanty, 2013). The domestic production of rice is increasing marginally whereas the consumption and import quantities are rising steadily as shown in Figure 2. However, the quantity of rice exported from Kenya is relatively insignificant in comparison to the quantity imported as indicated in Figure 2.

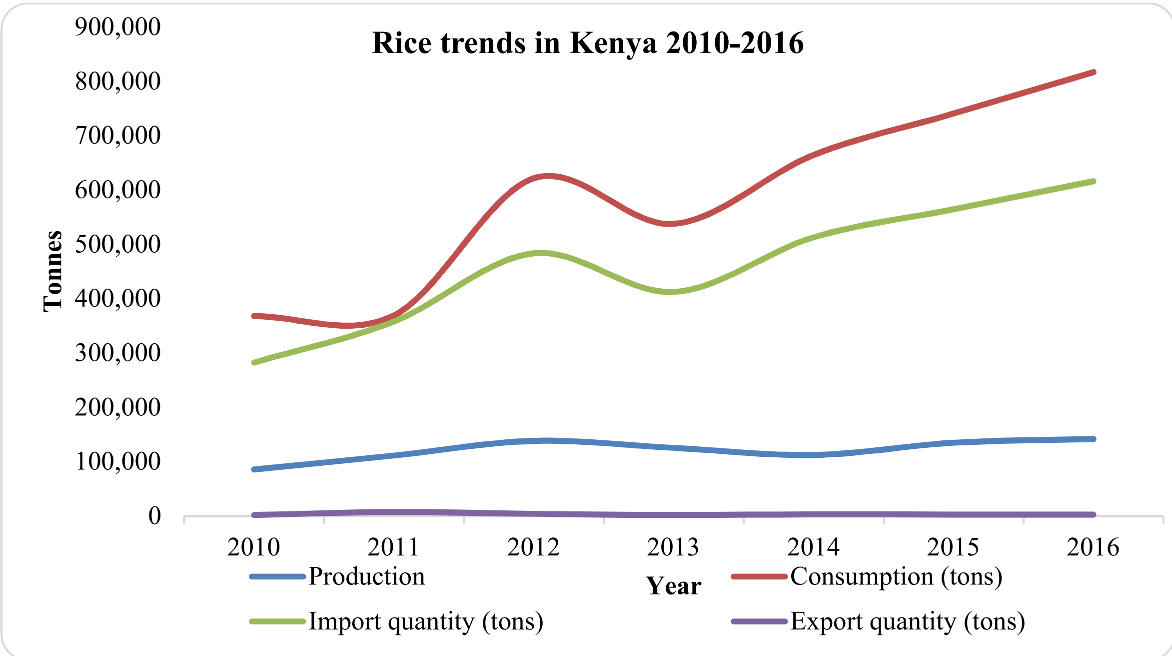

Figure 2. **Rice production, consumption, import and export trends in Kenya 2010 -2016**

Source: Food and Agriculture Organization (2017)

There has been an increasing trend in the area covered by rice since 2010. This is due to increased government investment in irrigation infrastructure as well as research that has enabled rice production under rain fed conditions in the past few years. This has led to the increase in area harvested from approximately 20,000 hectares in 2010 to nearly 35,000 hectares in 2016 as shown in Figure 3.

On the other hand, the import value of rice in Kenya has been rising steadily from 2010 to 2016. However, the export value has remained constant and insignificant from 2010 to 2016 as presented in as shown in Figure 4.

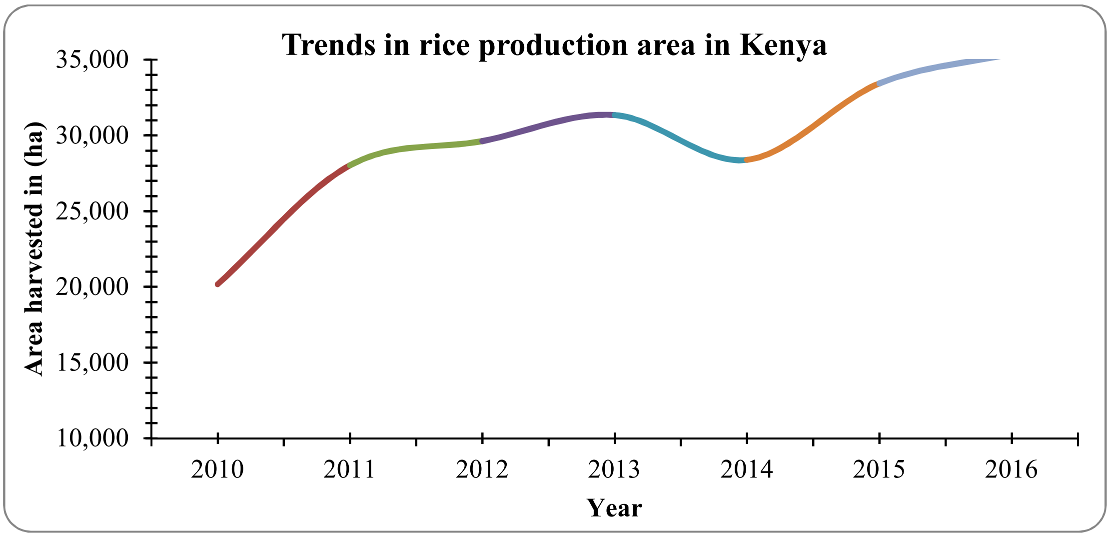

Figure 3. **Trends in rice production area in Kenya**

Source: Food and Agriculture Organization (2017)

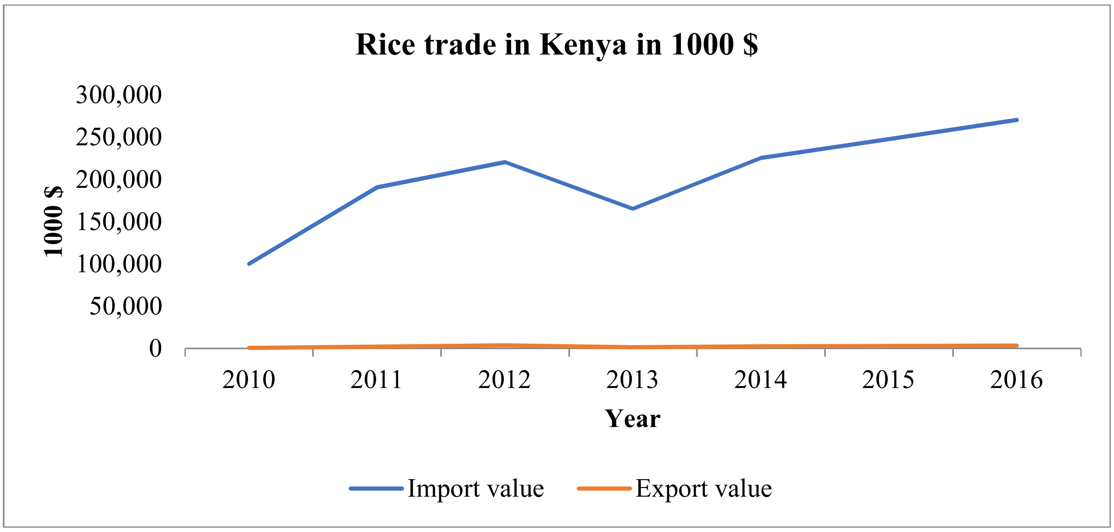

Figure 4. Rice import and export values in Kenya.

Source: Food and Agriculture Organization (2017)

According to the Montpellier (2013), the smallholder farmers are accosted a wide spectrum of challenges related to production and marketing to sustainably intensifying their production. Most commonly, they face challenges of inadequate land tenure, poor market structures, limited access to financial and credit resources, limited labour, inadequate knowledge and skills, malfunctioning input and output markets and inconsistent policy environment (Diagne, *et al*., 2010). These impediments call for an approach which generates innovation from the process of networking among different actors in the value chain and interactive learning (Kapiriri *et al*., 2012). Moreover, the collective action from the diverse set of actors links technological progress with organizational, institutional, and policy, institutional and/or organizational innovations (Asenso-Okyere *et al*., 2008). Such an approach that has recently been introduced by scientists is an innovation platform (Griggs *et al*., 2013).

Approximately 80 percent of rice is conventionally grown under irrigation by small scale farmers in Western, Eastern and Coastal parts of Kenya who operate in smallholdings of approximately two hectares (Omondi *et al.,* 2013). The main rice growing regions are Mwea in Kirinyaga County, Ahero in Kisumu County, Yala Swamp in Siaya, Bunyala in Busia County and Msambweni in Kwale County. In several smallholder irrigation schemes, rice is produced small quantities especially along river. Such irrigation schemes include Kore, Alungo, Nyachoda, Wanjare, Anyiko, and Gem-Rae in the western Kenya region and Kipini, Malindi, Shimoni and Vanga located at the coastal Kenya (Government of Kenya, 2015). Within irrigable ecosystems, rice production is largely conventional, mainly characterised by continuous flooding, high water-holding capacity soils and a continuous supply of water. The Ahero, West Kano and Bunyala irrigation schemes in western Kenya and Mwea irrigation scheme in Eastern Kenya region are the largest local rice producers (GoK 2015). Currently, the irrigation schemes occasionally ration water supply to the paddy fields during seasons of drought, a detriment to desired productivity levels.

Most small-scale farmers' in rice growing regions are resource-poor and encounter a diverse set of production challenges which hinder adoption of sustainable technologies (Perret *et al*., 2006). Akram-Lodhi (2008) and McMichael (2009) reported that improved technologies are key factors in addressing challenges of smallholder farmers, and boosting smallholder productivity. Further empirical evidence asserts that emphasis should be focused on promoting sustainable intensification technologies such as SRI (Daily *et al*., 2000). The findings of Mati *et al*. (2011) show that investments in intensification practices significantly improve ecosystem services and productivity and hence economic payoffs.

Despite the validated benefits of SRI, its uptake by most smallholder farmers in the Sub-Saharan Africa (SSA) countries has been low (Mishra *et al*., 2006; Seck *et al*., 2013). The potential for rice production in Oluch irrigation scheme in Homabay County where this study was conducted has not been fully exploited. The production technology in the scheme is majorly conventional practices characterized by low yields from flooded paddy fields and heavy use of external inputs such as fertilizer, pesticides and intensive labour requirements which results in high production costs and poor ecosystem services. Uphoff (2003) argues that System of Rice Intensification (SRI) increases rice yields based on improved ecosystem benefits. This study follows the SRI from its introduction in Kenya to date by unpacking its technological package, the institutional framework within which it was disseminated to farmers and how farmers internalized it in their farming practices.

2.3 Systems of Rice Production in Kenya

Two main rice production systems are found in Kenya, namely, the conventional system based on the Green Revolution approach and System of Rice Intensification. A system in the context of the study refers to the technology package which consists of interacting elements. Perret and Stevens (2006) posit that farmers' adoption of technologies and innovation is mainly influenced by their socio-economic characteristics, willingness to pay for the technology and property rights to resources and collective community action.

2.3.1 Conventional System of Rice Production

Rice production in Kenya is presently based mostly on the conventional method of continuously flooding paddy fields (Evans *et al*., 2018). The conventional practice of rice production is a high input low output system. It is characterized by low yields from flooded paddy fields and heavy use of external inputs which results in high production costs and poor ecosystem services (GoK, 2015); it also requires intensive labour due to lack of mechanization to maintain the rice fields consequently leading to low yields and subsequent reduction in farmers' gross margins (profitability). Mati *et al.* (2009) postulate that this method is not sustainable where there already exists competition for water among smallholder farmers within the scheme for other enterprises, particularly horticultural crops. Hence, innovative methods for improving the efficiency for water use are imperative for sustainable rice production. An alternative approach to improve rice productivity is the system of rice intensification, which by its nature reduces external inputs, water requirements and reduces drudgery. SRI technology is advocated for smallholder rice farmers in Oluch Irrigation Scheme to address the production challenges they encounter.

2.3.2 System of Rice Intensification – SRI

System of rice intensification (SRI) is a methodology or agricultural innovation in rice production whose suite of practices have been demonstrated to produce healthier and higher yielding rice plants under minimal water use and optimal use of inputs (Uprety, 2013). Subsequently, high yields from SRI have been linked to improved livelihoods among farmers. SRI leverages on sound scientific principles to improve the growing environment of rice plants, above and below the ground. SRI farmers focus on the management of plant, soil, water, and nutrients to stimulate the growth of healthier plants with better root systems and subsequently promote the activity of beneficial soil organisms. To date, the potential of SRI cultivation practices and benefits accrued to farmers and the environment has been demonstrated in over 50 countries worldwide, including the major rice producers like Thailand, Indonesia, India and China, in Africa, Madagascar, Kenya, Zambia, Gambia among others (Glover, 2011; Katambara *et al*., 2013; Toungos, 2018).

The system of rice intensification is a component of Sustainable Intensification (SI). The need to pursue appropriate strategies for sustainable intensification of agricultural production has emerged as an important consideration for agricultural sectors globally (Montpellier, 2013). The literature on intensification in developing countries, both sustainable and ecological, has been skewed toward improving productivity or farmers income from without increasing area under cultivation. Consequently, sustainable intensification requires productivity innovation, comprising improving crop management practices, developing better varieties, use of fertilizers; natural resource management (NRM) innovation comprising intermittent irrigation, erosion control, reforestation;, and institutional innovation (partnerships, inputs, services, policy, social infrastructure, market access, access to inputs and services and access to credit) (Pretty *et al*., 2011; Tittonell, 2014; Vanlauwe *et al*., 2014). Hounkonnou *et al.*(2012) in their studies on innovation systems approach to institutional change for smallholder development in West Africa, noted that sustainable intensification especially in smallholder farming is an important vehicle to achieve the current 2050 global cereal requirements and to alleviate the ever-increasing poverty burden in SSA. The sustainable intensification approach is explored in this study from both ecosystem services and intensification perspectives to natural resource management with respect to rice production in Oluch Irrigation Scheme.

According to Tubiello *et al.* (2015), smallholder farmers in developing countries face unprecedented challenges owing to climate change, which has led to unsustainable cultivation practices, increased land degradation, and endangered bio-diversity. This paradigm of sustainable intensification is a practical approach to achieve the goal of intensifying food production whilst guaranteeing sustainability of the natural resources (Fish *et al.*, 2014; Griggs *et al.*, 2013). Sustainable Intensification endeavours to produce higher yields, better net incomes and improved livelihoods without increasing existing agricultural land, while reducing overreliance on inorganic fertilizers, pesticides and reducing greenhouse gas emissions. This is done efficiently and in a resilient way so as to contribute to the stock of natural capital. Sustainable intensification is a combination of genetic and ecological intensification approaches, within enabling environments created by processes of socio-economic intensification. These components are combined as a holistic framework to develop relevant solutions to facilitate improved agricultural productivity.

According to Pretty *et al.* (2011), sustainable intensification is a product of the application of technological and socio-economic approaches, with the main tenet being ecological and genetic intensification. The ecological approach involves application of agricultural ecological processes and genetic approach utilizes plant breeding. Socio-economic intensification on the other hand provides an enabling environment to enhance the uptake of an agricultural technology and subsequently establish markets for the product of sustainable intensification. Pioneered as an innovation in the highlands of Madagascar in the mid-1980s, the system of rice intensification has distinguished itself with features including line planting, transplanting of young and healthy seedlings, mechanical weeding, maintaining a non-flooded moist field condition and organic management of the soil health (Nyang'au *et al.*, 2013; Takahashi, 2013; Uphoff, 2003).

Uprety (2013) maintains that SRI is a superior innovative approach for rice cultivation which enables farmers to realize improved yields and higher net incomes under optimal use of resources; efficient use of water resources, high potential seed, reduced and sustainable use of agrochemicals and reduces labour. There is also an additional benefit of working in upright posture for farm laborers' by use of weeding and harvesting machines (Uprety, 2013). According to Uphoff (2003), SRI makes farming systems less vulnerable to shocks and stresses, therefore having the potential to improve the livelihoods of smallholder farmers (Akram-Lodhi *et al.*, 2008; McMichael, 2009). Nyang'au *et al.* (2013) noted that components of SRI maintain the health of farmers, particularly women. SRI enhances farmers' creativity and enables them to view their farms as ecosystems that require thoughtful management, thus increasing their innovative capacity for uptake of the technology. The potential and promise of SRI practices have been validated in several countries in sub-Saharan Africa (Uphoff, 2003). By 2010, Kenya was the 39th country to substantiate the benefits from SRI (Mati *et al*., 2011). The uptake and spread of SRI by its nature involves both processes of adaptation and adoption, making the initial learning phase costly (Uphoff, 2003).

Mati *et al*. (2011) assessed the technical and socio-economic issues affecting introduction and promotion of SRI in Mwea Irrigation Scheme, Kenya. Findings from two early phase trials showed significant yield increase of 84 percent and 100 percent in amount of harvested paddy. These findings further showed higher returns on investment from system of rice intensification compared to standard conventional approach, at least three-fold higher net farmer incomes. The pioneer farmers however faced difficulty convincing their immediate family members to adopt SRI technologies notwithstanding the positive income gains that resulted from SRI practices.

Deb *et al.* (2012) in a field experiment compared the effects of age of seedlings at the time of transplanting on tillering abilities, the panicle density, grain counts per hill and yield per unit of land area in SRI rain-fed farms in Eastern India. They established that SRI drastically reduced seed and water requirements but necessitated frequent weeding due to the increased growth of weeds. The higher labour cost for weed control is reported to be more than offset by significantly greater grain output. The findings of their study also showed that SRI improved the mean panicle density when transplanted seedlings were not younger than 18 days, but differential responses were also observed across varieties; the number of productive tillers per hill is significantly less in single seedling transplants (SST) than that of multiple seedling transplants (MST) of 28-day-old seedlings of both upland and lowland varieties. The findings further showed a marginally higher grain yield per unit area from young SRI transplants of lowland variety, compared to those transplanted at least 28 days after germination. On the other hand, a decline in grain yield was observed from older seedling transplants in the upland varieties. However, older transplants planted as multiple seedlings per hill had similar yield with younger transplants planted singly.

Takahashi (2013) empirically explored factors shaping SRI's adoption and discontinuance in Indonesia using Multivariate regression analysis models. The study noted a sharp decline in the use of SRI among the Indonesian farmers over time. Various reasons were fronted for the

decline in the uptake of SRI: unreliable access to irrigation water, learning the SRI method was knowledge intensive requiring greater effort, care and time. The reasons above made SRI implementation more uncertain, especially among farmers unsure of how much time was necessary to devote to rice cultivating owing to other competing activities. The study findings further confirmed that risk aversion was an important cause for the low uptake. Risk aversion among the farmers significantly reduced the probability of implementing any of the individual system of rice intensification practices. However, after accounting for the previous year's effects of risk aversion, risk aversion was not an important predictor of the decision-making process, whether to continue or discontinue SRI practices. Farmers' ambiguity preferences had no statistically significant influence in farmers' decision-making process on the use of all SRI practices, except alternate wetting and drying, that was dependent on coordination of irrigation between farmers, hence there was an increased likelihood of actual effective implementation.
The Indonesian study findings further showed that access to irrigation is a significant factor in the use of SRI and its continuance. The study established that an innovation platform was effective in strengthening networks and interactions to foster innovations that build capacity of smallholder rice farmers for uptake of SRI to spur rice productivity in Oluch Irrigation Scheme.

2.4 The Suitability of Innovation Platform in Technology Uptake

Innovation is an idea, practice or object perceived as new by an individual or other unit of adoption (Heeks *et al*., 2013). Innovation is considered a key driver of economic growth and community development. Central to an innovation system is learning which accumulates knowledge. In this study, the system of rice intensification is an innovation that needs to be adapted and adopted by farmers in Oluch Irrigation Scheme. According to Furman *et al.* (2002) innovative capacity is the ability of stakeholders to successfully introduce an innovation so as to facilitate social, economic and institutional change. Innovation capacity development comes under the rubric of an innovation system approach stipulating innovation as an outcome of interactive learning in networks.

It is assumed that inadequate capacity of smallholders for uptake of SRI practices is partly based on the nature and strength of the relationships and links with other stakeholders, and their ability to pull the human and social capital. Batterink *et al.* (2010) assert that scarcity of resources had less to do with technology uptake intrinsically but rather with 'capacity scarcity' to innovate (Cadilhon, 2013). Addressing scarcity entails the development of an 'innovation capacity' which consists of: the context specific range of skills, actors, practices, routines, institutions and policies needed to put knowledge into productive use (Batterink *et al.,* 2010; Heeks *et al.*, 2013).

According to Cadilhon (2013), inclusive development and sustainable rural livelihoods can be achieved when people and organizations address their challenges collectively, create and share knowledge through action learning and joint solutions that have impact. This study brought stakeholders in the rice sub sector under an innovation platform where knowledge about SRI was co-created, shared, disseminated and applied (Lawson *et al*., 1999; McGrath, 2001). The common pursuit of networks and collaborative relationships through establishment of Innovation platform is trending in community organizing for technology uptake and sustainable development.

An innovation platform (IP) is a multi-actor network established to support and take actions contributing innovation. Kilelu *et al.* (2013) emphasized the role of IPs in connecting the different dimensions by establishing effective interactive learning and interactions where farmers acquired knowledge and skills relevant to their production scenarios. According to Tenywa (2011) and Cadilhon (2013), an Innovation Platform comprises of a group of individuals with similar goal, but different backgrounds and interests within a space that promotes interactive learning and change. Innovation platform activities include learning opportunities aimed at ensuring a common understanding of major concepts, and joint actions of stakeholders. Innovation platforms constitute actors such as farmers, extension agents, researchers, processors, traders, public and private sector agents who discuss and address SRI uptake.

Innovation platforms have demonstrated success in facilitating technology uptake in SSA. In West Africa, the Alliance for Green Revolution in Africa (AGRA) applied a facilitator approach in strengthening locally based institutions capacity and building working links among the institutions and with farmer organizations. The support intensified the existing relationships among the stakeholders, whilst ensuring a sustainable scaling out process within an enabling government policy framework (Martey *et al.,* 2014). The programme made significant progress in creating public-private partnerships which mobilized outside financial resources, thus enabling establishment of Agro-dealer's networks and seed companies. In addition, farmers experienced significant increases in yields hence improved income, nutrition and sustainable livelihoods. Notably, findings showed increased farmers' cooperative bargaining power and enhanced their human and social capital, consistent with previous findings (Pretty *et al*., 2011).

The local community's perceptions and understanding of sustainable practices are critical while addressing the issue of sustainable intensification technologies. It is widely acknowledged that communities have intrinsic knowledge and inborn adaptive capacities for developing strategies to cope with challenges in agricultural production. Thus, it is important to get information from rural farmers and what they know about sustainable practices (Mutekwa, 2009). SRI is knowledge and management intensive, hence uptake faces barriers which are unrelated to the limitations of the technology. Scaling up thus requires adapting knowledge and innovations to variable conditions of the end-users, farmers and institutions. Uptake and application of innovations to different contexts requires understanding the knowledge and principles underlying such innovation. The understanding was achievable through capacity building via action learning (Westermann *et al*., 2015).

Amha *et al.* (2013) documented the processes, lessons and challenges encountered from the use of an innovation platform for participatory tree nursery establishment and management schemes in Ethiopia. Despite high initial interest showed most stakeholders in the formation of the IP, tensions were established amongst members of the innovation platform due to disagreeable timelines. Consequently, the establishment and management of community nurseries in both watersheds was a labour intensive and inefficient venture despite large number of stakeholders involved in the IP activities. Most IP members were hesitant to implement the formulated local by-laws whenever they were violated due to unequal participation of members. Notably, recognition of active IP members through standing ovation and certification did not bring a long-lasting outcome.

Kilelu *et al.* (2013) explored characteristics and functioning of innovation platforms facilitated through East African Dairy Development program in Kenya. The results showed that functions of the platforms were not only limited to knowledge distribution and use but also fostering interaction among the diverse actors. The findings also showed that innovation platform accelerated multiple stakeholder linkages through an iterative process where diverse actors of complementary skills and competencies are mobilized. These linkages spurred positive outcomes at social, technological and institutional levels. However, it was established that tensions emerged within the platforms in disconcerting manner and hence affected the innovation process.

Schut and colleagues identified opportunities and challenges for Innovation Platforms relative to their institutional embedding in agricultural research for development (ARD) systems. (Schut *et al*., 2016). Their work further analysed the dynamics of IPs in the agricultural research for development context. The results demonstrated that most actors within the innovation understood the advantages brought by IPs. However, significant progress was derailed by personal and individual interests and preferences, that often misalign with the IP needs and interests. Schut and colleagues further established that the focus on a specific commodity was necessary to bring on board interrelated stakeholders and enhance the prospects of collaboration for collective action. On the contrary, innovation platforms with open entry points had higher risks of scanty focus and rare ground for collective action given the broad range of interests and topics from multiple stakeholders. In several contexts, IPs have been leveraged upon as a vehicle to enhance capacity to generate and respond to change and enhance technology transfer and adoption at the farm level. However, the focus on enhancing capacity at the systems level to continuously identify, analyse and solve technological and non-technological agricultural challenges is widely underachieved. The study showed that most innovation platform facilitators had a background in natural science but showed a lack of competence in facilitating interactive, multi-stakeholder processes.

According to Schut *et al.* (2016), the performance of IPs largely depends on the unique dynamics of learning process within the platform, alongside the context of the identified problem, more specifically the socio-economic and Agro-ecological contexts. The traditional assumption that 'experts know it all' was challenged to a limited extent in current IP practice since most stakeholders are still locked into existing division of roles and mutual dependencies and expectations due to inappropriate tackling of structural power inequalities between stakeholders, integration of expert and lay competences, and equal interaction and collaboration. Institutional dimensions of agricultural innovation were presently addressed to a much lesser extent. Van Rooyen *et al.* (2017) concludes that IPs succeed in bringing together non-traditional stakeholders and harness the interrelationships between players to work toward stakeholder agreed goals.

Recent empirical evidence further emphasizes on adaptive management of innovation platforms, acknowledging the role of both the networks within the innovation systems, the environment (context) and their interaction (Klerkx *et al.*, 2010). Klerkx and colleagues established that to have a more conducive environment for the uptake of a technology, adaptive innovation management is necessary, where constant reflection by the innovation actors takes place. Van Rooyen *et al.* (2017) confirms that the interconnectedness of the different actors is often neglected in several agricultural contexts, hence a limited interaction between actors. However, at the institutionalization of an innovation platform, an environment in which actors can learn and build their adaptive capacity is created. Findings from the application of innovation platforms for improved irrigation scheme management in southern Africa emphasize that actors within innovation platforms may exhibit limited interaction leading to the absence of learning and the intended beneficial outcomes (van Rooyen *et al.,* 2017). Importantly, Klerkx *et al.* (2010) emphasize on the need for policies to support the emergence of instruments of change as innovation platforms.

2.5 Action Learning Process for SRI Innovation

Bradbury (2015) suggests that action learning focuses on learning through action. Action learning also refers to group learning that enables development of people and organizations. It is a form of experiential learning hence emphasizes the aspect of learning by doing something different rather than just learning by doing (Coghlan *et al.,* 2012). Action learning process is beneficial to research and enhances innovation capability of organizations in an inter-organizational setting with primary outcome of improved action and individual and collective understanding. The study would adopt action learning in strengthening networks and interactions to foster innovations that build capacity of smallholder rice farmers in the Oluch scheme. To improve information for productivity there is a need to build capacity at all levels (Chapman, 2005). This calls for institutional changes that allows for interactive learning so as to forward innovative solutions that meet local needs and overcome barriers to SRI uptake and scaling.

Action research approaches create knowledge, propose and implement change; and improve practice and performance of technology like SRI (Coghlan *et al*., 2012; Franzel *et al*., 2001). Action learning is widely acknowledged as an appropriate educational process for innovation which allows participants to study their own actions and experiences to improve performance. This has been linked to its approach toward facilitating individual reflection and review of the action taken and key learning points arising as a guide to future action and improvement of performance (Coghlan *et al*., 2012). To better understand what to change so as to improve the performance in Agriculture and Rural Development organizations, Innovation systems approach has recently been proposed (Asenso-Okyere *et al.*, 2008). The array of social networks within which innovation actors, individuals or organizations, interact with one another has emerged as an important element of any innovation system. (Fritsch *et al*., 2007; Malerba, 2005; Rycroft *et al*., 1999). Social networks can define, limit, or enhance an individual's opportunities for social learning by influencing membership or participation in a given innovation process, thereby affecting access to knowledge (Bandiera *et al*., 2006; Munshi, 2004; Spielman *et al*., 2010).

The innovation systems approach leverages on the stakeholder interactions, knowledge sharing, and a continuous learning process to address important issues, especially, the capacity of the different stakeholders to learn, change and innovate; the nature of iterative and interactive learning processes among innovation agents; and the types of interventions that enhance such capacities and processes. Action learning can be used in implementing the action learning process (Bradbury, 2015). It is a means of engaging the participating organizations and individuals around the ideas, questions and actions forwarded on problems hence have a practical learning experience (Pedler *et al*., 2008). Through participatory learning, individuals and institutions are able to make decisions about policies and processes that affect their production.

2.6 Theoretical Framework

This study was premised on Theory of Change (TOC) model as proposed by Kurt Lewin (Shirey, 2013) and Social Network Theory (SNT) advanced by Wasserman *et al.* (1994). Also relevant to this study was the agricultural innovation systems (AIS) theory. The relevance of the theories was premised on the fact that they focused on changes that occur in systems through interactions of components and actors to bring desired outcomes.

The theory of change proposes three stages of change: unfreezing, changing, and refreezing as shown in Figure 5. The strength of this theory is its three stages mentioned which serves as a guide across time. The process of change in rice development is derived from the existing situation characterized by high Input use and low output production system which reduces the farmers' gross margins (profitability). SRI advocates for a desired level of behaviour which would result in low Input use, high productivity and reduced production costs.

Theory of change was best suited for the present study as a monitoring, evaluation and learning system that combines indicators of progress in research along with indicators of change by providing links between activities, outcomes, impact and context of an intervention (De Silva *et al*., 2014). Similarly, emphasized that the outcomes in TOC must be linked with indicators that operationalize and make them comprehensible in real, observable and measurable terms. As proponents of the theory, Thornton *et al.* (2017) asserted that TOC provides a detailed narrative description of an intervention impact pathway and how changes are anticipated to happen, based on assumptions made by stakeholders.

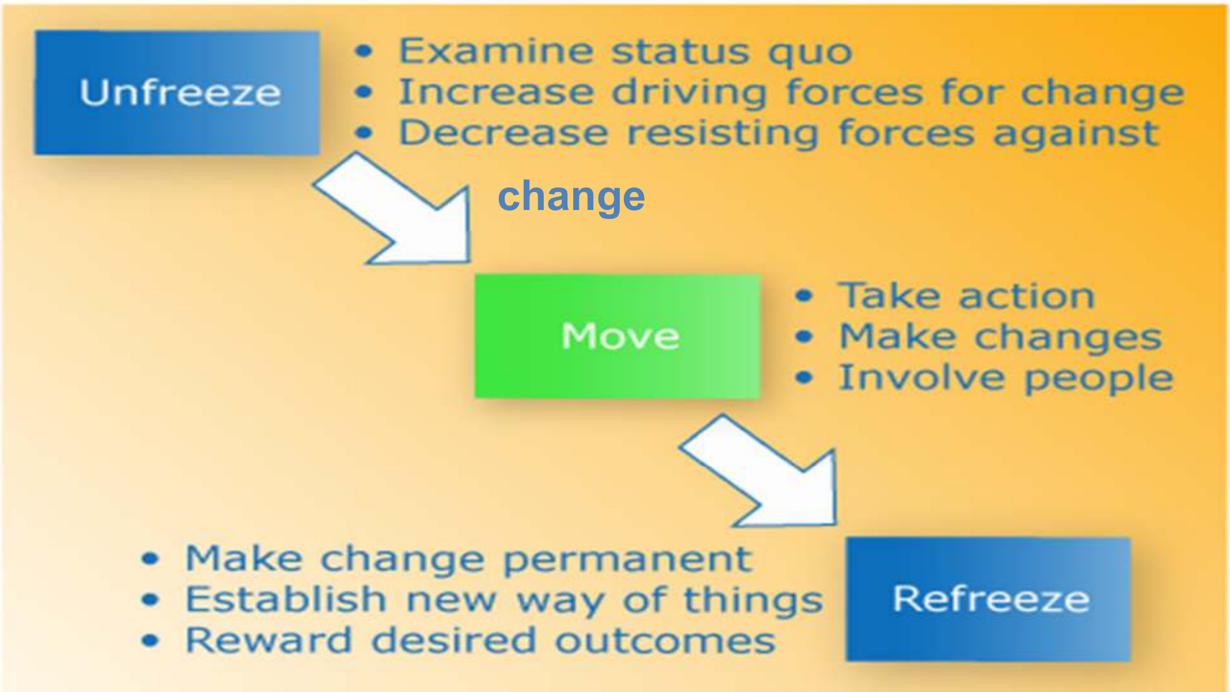

Figure 5. The change theory model

The Social Network Theory (SNT) advocates that an individual cannot succeed alone unless they work with others as indicated in Figure 6. The theory views social relationships in terms of nodes and ties that exist among the actors in a system. The social network approach suggests that the ability of individuals to influence their success lies more within the structure of their networks and relationships and ties with other actors within the network (Wasserman *et al*., 1994). The implication of Faust's observation for the current study is that farmers with wider social networks are likely to have many sources of information about rice farming. This approach emphasizes that new knowledge and innovative capabilities are developed through interactions between individuals and organizations. The SNT is relevant for this study for analysing the relationships and knowledge flows among stakeholders in the innovation platform and identifying the weak networks and links to improve capacity for scaling and uptake of SRI. Additionally, social networks can define, limit, or enhance an individual's opportunities for social learning by influencing membership or participation in a given innovation process, thereby affecting access to knowledge.

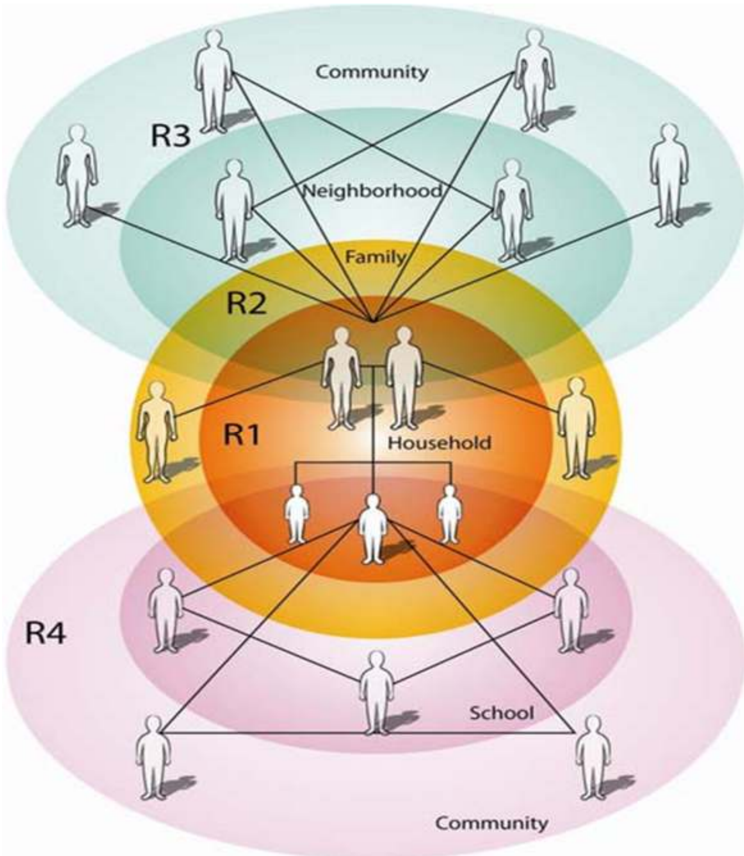

Figure 6. **An illustration of the Social Network Theory**

Agricultural innovation systems theory (AIS) posits that in a system, interactions occur between the components and among the elements of the components. An essential aspect of the AIS theory is describing and analysing the interactions that exist between the components of innovation system and among the actors, with the ultimate goal to understand the system dynamics. The AIS perspective therefore refers to the need to involve all actors in an innovation system that contributes to inclusive development (World Bank, 2006a). The agricultural innovations systems theory is relevant for this study for describing and analysing the interactions among the actors in the rice value chain in Oluch irrigation scheme and knowledge flows among stakeholders in the Innovation Platform and identifying the weak networks and links to improve capacity for uptake of SRI.

According to Wood *et al.* (2014), the AIS sheds light on the roles and responsibilities of individuals and organizations; requisite actions, the interactions and stakeholders within the system that condition behaviours and practices. It is also contended that AIS can be a key driver for the adoption of agricultural innovations in SSA that is characterised by low levels of adoption of agricultural technologies. For example, in Kenya, agricultural production continues to be characterized by low use of productivity enhancing technologies (Birch, 2018). Thus, AIS was pertinent for the present study to gauge how the interaction of various actors in the IP action learning process shaped the SRI technology uptake.

2.7 Conceptual Framework

The conceptual framework is derived from the Change Model, Social Network and Agricultural Innovation Systems theories considering the fact that the farmers in Oluch scheme are presently (unfreezing) producing rice in a manner that does not give them good output. The study which adopts the Action Research process is designed to initially assess the status of the target farmers and measure changes in their uptake levels of SRI after a series of treatments and finally measure possible learning and changes that occur in the dependent variables. The action learning model depicted in Figure 7 shows the start of the action learning research where a baseline is carried out to profile the local context of Oluch Irrigation Scheme. The baseline is then followed by the first action learning process that involves the establishment of an Innovation Platform. The second action learning process involves using Innovation Platform as an intervention to facilitate uptake of SRI in the scheme. After the intervention, changes in uptake of SRI practices and rice productivity are the expected outcomes of the research.

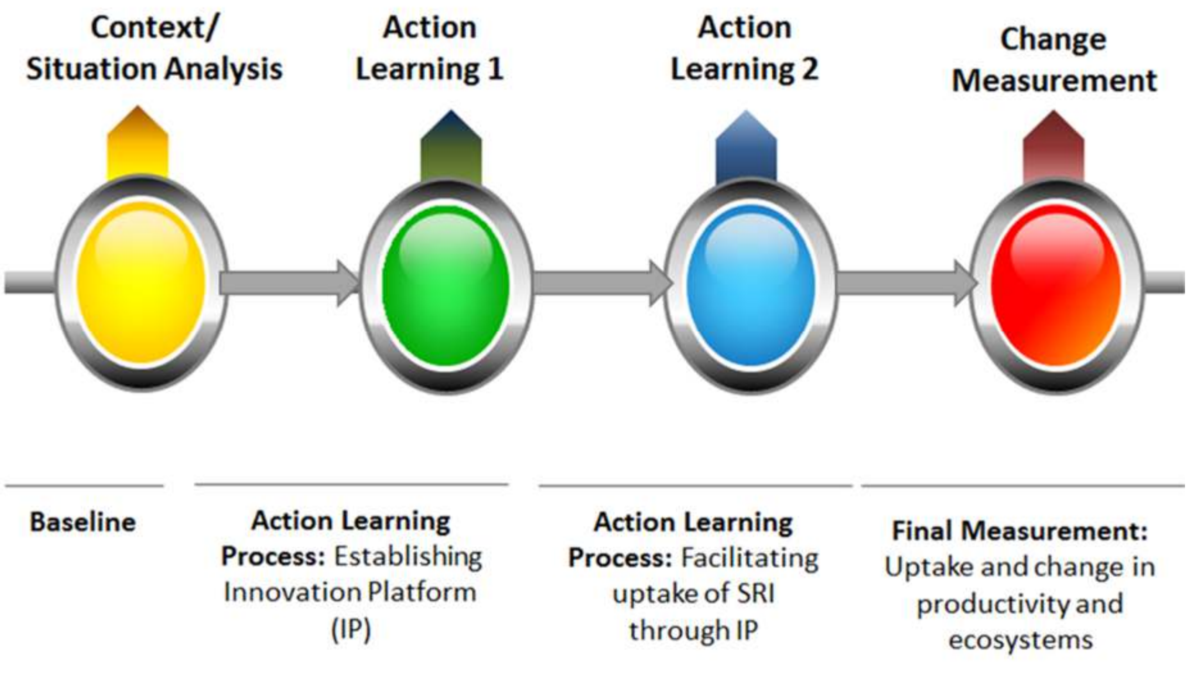

Figure 7. **The action learning model: Depicting the baseline, action learning process and final outcome designed by the researcher based on Lewin's Theory of Change**

The researcher introduced an Innovation Platform through which actors networked and innovate in an action learning process to build capacities for uptake of SRI (changing) which will lead them to the outcome through individual and collective action as advanced in the Social Network Theory (refreezing). At the refreezing stage, the stakeholders in the innovation platform focused on reinforcing, stabilizing and solidifying the innovation (SRI) for change. Which is currently being done by government extension through involving SRI experienced farmers in extension system encouraging peer–peer learning and extension. The changes made to rice farming practices, institutional frameworks and farmers' perceptions are accepted and refrozen as the new status quo. The dependent variable (outcome) for the study was the uptake of SRI observed after farmers' participation in the innovation platform as shown in Figure 8.

The dependent variable was measured in terms of level of change in farm practices including line planting of young healthy seedlings, intermittent watering, mechanical weeding, and organic manure; production per unit area of rice; change in levels of incomes from rice and production costs. The independent variable is the Innovation Platform which was an intervention used in facilitation of action learning process and the farmer's socio-economic characteristics. The effectiveness of the intervention was measured by the number, type and roles of participating stakeholders; and their networks based on capacity building, stakeholders support for farmers, cohesion and information and communication among actors. However, uptake of SRI would also be influenced by socio-economic characteristics of respondents which were referred to as intervening variables. There was also likelihood that farmers outside the Innovation Platform accessed the knowledge through spill over effect. This was evidenced by IP farmer participants reaching out to fellow farmers in the non-sampled blocks and in the neighbouring Kimira scheme.

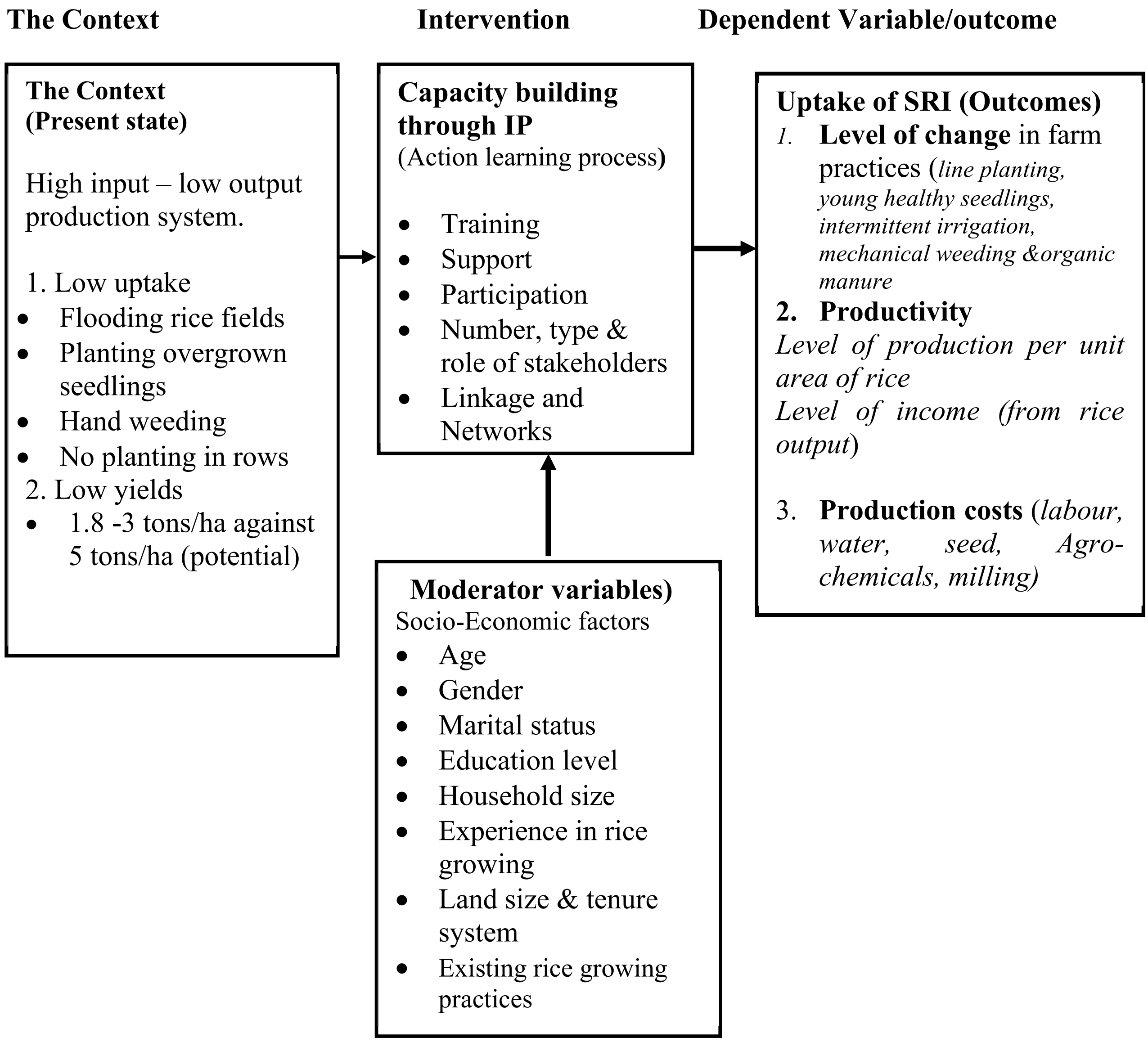

Figure 8. **Conceptual Framework showing Independent, Dependent and Intervening Variables**

CHAPTER THREE
RESEARCH METHODOLOGY

3.1 Introduction

This chapter discusses the research procedure used in the study. It covers research design, study location, study population, sampling procedure and sample size, instrumentation including reliability and validity determination of the instruments. The chapter further details data collection procedures and statistical analysis methods.

3.2 Research Design

This study employed an Action Research (AR) design which allowed for participatory learning processes based on a logically linked cyclical pattern of identifying an issue, collecting baseline measures, introducing and implementing change and re-measuring (Brydon-Miller *et al*., 2014; Pretty, 1995; Zuber-Skerrit *et al*., 2007). Action research is a pluralistic orientation to knowledge creation and social change in which the action researcher and research participants collaborate in the diagnosis of a problem and in the development of a solution based on the diagnosis (Bradbury, 2015; MacDonald, 2012). Action Research provided a knowledge exchange platform by strengthening innovation networks for enhancing innovative capacities of smallholder rice farmers for uptake of SRI practices to spur rice productivity. This was relevant for this study because the study identified the research problem in collaboration with those affected, gathered baseline data to portray the situation as it existed, actions and networks and knowledge exchange among stakeholders for promoting productivity among smallholder rice farmers in Oluch Irrigation Scheme.

According to Barral *et al.* (2012) the great importance of farmer surveys in applied social research is that it encompasses any measurement that aims to gather the qualitative information needed to understand processes and the quantified information needed to measure these processes and getting feedback about the outcomes from respondents. Fraenkel *et al.* (2000) assert that surveys are important tools in social research to describe the characteristics of a population under study. Survey research design allows for a variety of methods to recruit participants, collect data and utilize different methods of instrumentation. Additionally, surveys can employ both quantitative and qualitative research strategies, also used in exploring human behaviour.

Based on the baseline findings, an innovation platform consisting of the relevant stakeholders was established which created an opportunity for interactive learning, knowledge co-creation, sharing and dissemination to enhance smallholder rice farmers' innovative capacity for uptake of SRI. An end line survey was conducted after action learning process to assess if learning took place.

3.3 Location of the Study

The study was undertaken in Oluch irrigation scheme of Rangwe Sub-County in Homabay County of western Kenya. The map of the study location is indicated in Figure 9.

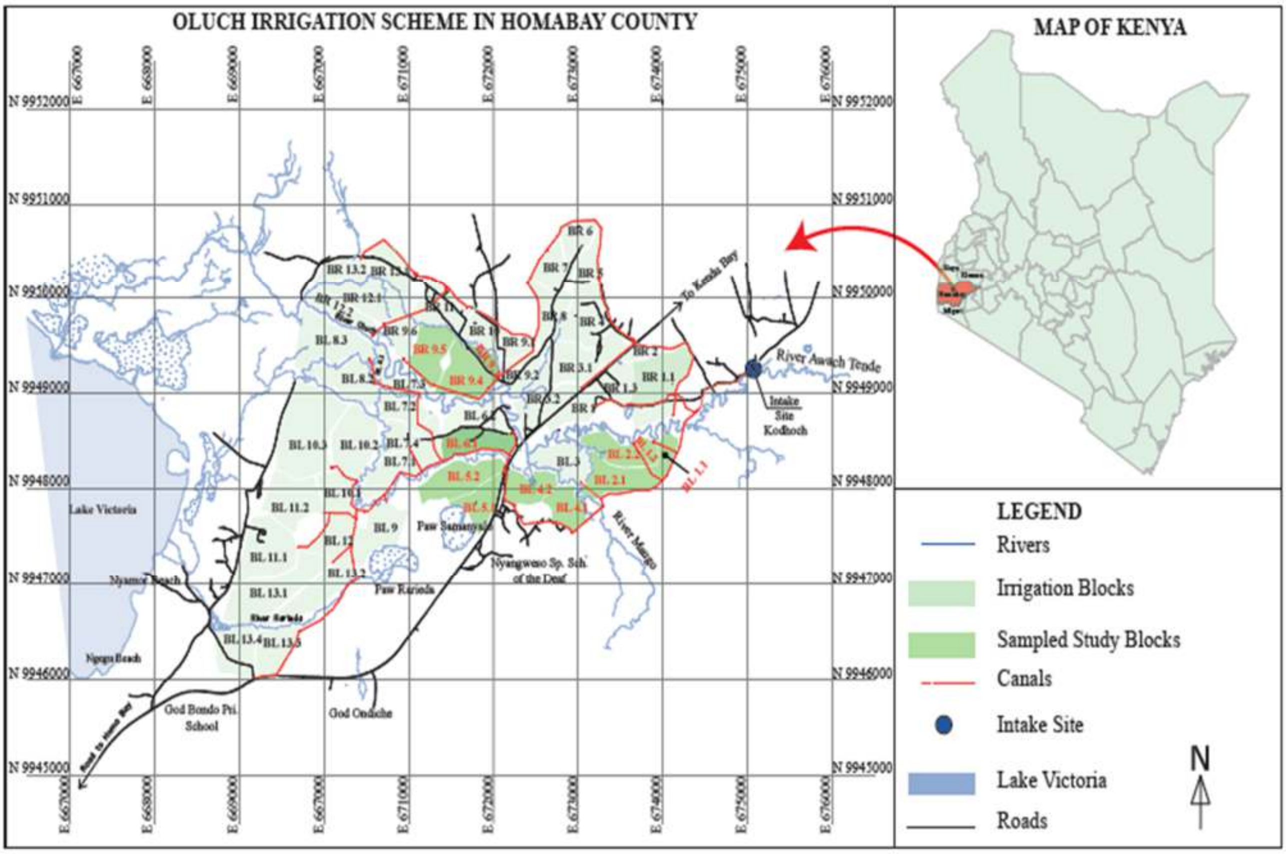

Figure 9. **Map Showing Location of Oluch Irrigation Scheme**

Source: Government of Kenya, Kimira-Oluch Smallholder Farm Improvement Project (KOSFIP) Office

The reason for selecting this research location was because there existed rice farming under limited System of Rice Intensification practices. The promising SRI technology had been introduced through the national extension system with minimal success. The Scheme covers a gross area of approximately 1308 ha (only 666 ha is irrigated) (AFDB, 2006) and comprises of

53 irrigation blocks spread within Kochia East, Kochia West, Kagan East and West and Wadhgone-Nyongo Wards. The scheme lies within an altitude of 230-456 m above sea level and latitude 23^0 E and 45^0 N.

The scheme occupies Agro-ecological zones (AEZs) Lower Midland (LM1 - LM5). Rainfall patterns in this area exhibit a bi-modal distribution, with annual rainfall ranging from 740-1200mm per annum, alongside high temperatures of about 30^0C. However, the short rains hardly sustain substantial crop production (Government of Kenya, 2014). Auma *et al.* (2017) noted that average land size operated by the entire households in the scheme ranged between 0.028 – 13 hectares, with a mean of 1.87 hectares. The main soil types in the study area are clay loams and black cotton soils (vertisols) in areas adjacent to the Lake. Subsistence farming (irrigated horticulture, maize and local cattle) dominates the scheme. Low agricultural productivity is experienced in the scheme despite the great potential offered by the irrigation infrastructure, to transform livelihoods and contribute to a significant reduction in the incidence of poverty of about 70% (AfDB, 2006). Odoyo (2013) in his study established that some parts of the scheme are prone to natural occurrences of climate variability such as floods which led to cost escalation in production through mitigation measures.

3.4 Target Population

The study focused on 369 smallholder rice growing farmers in 12 irrigation blocks who were all registered with Oluch Irrigation Water User's Association (OL-IWUA) for water use in Oluch irrigation scheme, Homa-Bay County (GOK, 2015). These were the first target for baseline survey which enabled the researcher to learn about production levels under conventional practices. These smallholder rice farmers were also targeted because they are the SRI practices uptake units and effective learning is reflected in their change in terms of knowledge and skills attained and use. Other targeted population comprised of stakeholders in the rice value chain in the scheme including agricultural extension, input dealers, traders, private millers, irrigation project implementing team (KOSFIP), local administration and KALRO and LBDA, all playing different roles in the rice value chain. The Innovation Platform was created for this target population to facilitate learning and uptake of SRI practices.

3.5 Formation of the Innovation Platform

Using the target population and baseline findings, an Innovation Platform was formed to facilitate action learning process and use of SRI. The Innovation Platform was established through an inaugural workshop by involving key stakeholders (farmers, government service providers, traders, KOSFIP, private organizations and technical people) along the rice value chain in Oluch Irrigation Scheme. After the establishment of the IP, data was analysed with respect to the stakeholder's roles, interests, objectives, networks, resources, interventions, and the significance of those interventions. Data was analysed using descriptive statistics to conduct stakeholder analysis; and inferential statistics including correlations and linear regressions. Activities of the IP were implemented in a timeline. According to Cadilhon (2013) Innovation Platform facilitates interactions between stakeholders and contributes to jointly identifying and solving problems and explores opportunities through communication, negotiation, information sharing and understanding. Kemmis *et al.* (2005) further asserted that Innovation Platform brings about shared ownership of the research projects, community-based analysis of social problems and community action.

3.6 Sampling Procedure and Sample Size

This study purposively sampled Oluch irrigation scheme to assess the uptake of SRI practices through a facilitated Innovation Platform because most farmers engage in smallholder rice production but under limited SRI practices. Rice farmers were purposively sampled for inclusion into the study. A purposive sample is a non-random sample selected because prior knowledge suggests that those selected have the needed information (Fraenkel *et al*., 2000). The selection criteria entailed whether farmer was actively growing rice and registered by IWUA for irrigation water use as stated in the IWUA By-Laws.

Rice farming in Oluch is organized in blocks based on their positioning to the main irrigation canals. Blocks to the left of the main canal are abbreviated as BL, those to the right are abbreviated as BR and the ones in the middle of the two main canals are named BM, and each abbreviation is followed by numerical figures for ease of identification as shown in Table 1. There is a total of 53 irrigation blocks in the scheme. Amongst the 53 blocks, there are only 12 major rice producing blocks in the scheme (Figure 9). Although only 12 blocks were studied, the risk of bias in such a sampling strategy was minimized by selecting these blocks which were sufficiently advanced in the process of rice value chain and thus provided adequate depth of diverse experiences to elucidate the innovation process. Reconnaissance survey in 2017 revealed that rice is grown in theses blocks as a major food and cash crop. All the 12 blocks were sampled purposively given the fact that they are the most active blocks in rice farming as compared to the other blocks. A block is composed of about 25 to 30 smallholder rice farmers. A cluster sampling technique was used to select rice producing farmers as respondents in the baseline survey. A cluster was represented by a block as indicated in Table 1.

Table 1: Proportionate Cluster Sampling of Rice Farmers

Block	**Population of rice farmers per block**	**Percentage distribution of rice farmers**	**Sample size**
BL 1.1	32	8.7	9
BL 1.2	30	8.1	8
BL 2.1	25	6.8	7
BL 2.2	31	8.4	8
BL 4.1	28	7.6	8
BL 4.2	31	8.4	8
BL 5.1	32	8.7	9
BL 5.2	27	7.3	7
BL 6.2	35	9.5	10
BR 1.2	30	8.1	8
BR 9.4	33	8.9	9
BR 9.5	35	9.5	10
Total	**369**	**100**	**101**

3.6.1 Sampling Respondents for Baseline Study

At the baseline study, a simple random sampling technique was used to sample farmers from each block proportionally as already described and shown in Table 1. The results from the baseline study informed the composition of the Innovation Platform participants during its formation.

In this study, the total population of registered rice producing farmers in the scheme was 369 at the time of start of the study, and as per the Oluch Irrigation Water Users Association (OL-IWUA), KOSFIP and MOAL&F records. The study adopted a sample size determination formula by Kothari (2004). According to Kothari (2004), sample size determination in case of finite population is calculated using the formula shown:

$$n = \frac{z^2 * p * q * N}{e^2(N-1) + e^2 * p * q}$$

Where:

z = the standard variate at 95% confidence interval

p = expected prevalence of population (0.1)

q = 1- p (0.9)

e = acceptable error of 5% (level of significance)

N = size of population (369)

The sample size is thus derived below:

$$n = \frac{1.96^2 * 0.1 * 0.9 * 369}{0.05^2(369-1) + 0.05^2 * 0.1 * 0.9} = 100.79 \cong 101$$

A sample size of 101 respondents was used for baseline survey. Cluster sampling ensured that all blocks were represented in the sample in proportion to their number in the population. In this study, the blocks were the clusters as already shown in Table 1.

3.6.2 Selection of Innovation Platform Participants

To select participants for action learning process, farmers in each block were engaged to select two representatives to participate in the Innovation Platform. According to Garforth (2011), it is important to give the farmers a chance to select their representation in project/group activities in order to succeed. The study involved action learning research by establishing an innovation platform. The platform brought in equal representation from across the 12 blocks where rice is majorly grown, in addition to the relevant stakeholders that were identified in the baseline survey. To gather information from each block, two (2) farmers were nominated through discussion with members from each block, this allowed for selection of twenty-four (24) farmers for action learning in the IP. The number was adequate since a qualitative study involves small groups/number of subjects operating and interacting in a particular environment, and requires that the researcher attempt to provide insight into behaviours pattern that occur among a specific number of subjects at one given time, in a specific setting, yet yield representative results (Craig, 2009). After learning in the platform, each block representatives got back to their respective blocks and implemented SRI technological codes and re-trained other members in the process. The stakeholders were identified in the form of organizations and institutions that are involved in rice value chain in the scheme. Each of the stakeholder organizations/institutions nominated their representatives to the innovation platform.

For triangulation purposes, FGDs, KIIs and field visits were held with members within the platform. According to Craig (2009) triangulation occurs when multiple forms of data, when analysed, show similar results, thus confirming the researcher's findings. The purpose was to make each have a role in the innovation platform. One representative each was drawn from the following organizations: County agricultural extension (technical and advisory services), Input suppliers (provision of farm Inputs), traders (market for rice produce and by-products), processors (milling of rice), irrigation project implementing team (KOSFIP – support the platform on legal aspects for water use and linkages), local administration (mobilization of the community, security of the scheme, policy implementation and conflict resolution), KALRO researchers (new technology, provision of certified seed, pest and disease control). The logical plan in Table 2 explains the methodology employed to sample the participants of the study based on specific data collection methods. The reiterated data collection process made it possible to track changes during the participatory action research process. Minichiello *et al.* (2008) argue that interviews are preferred in filling knowledge gap, particularly if complex behaviours are to be investigated.

Table 2: Sample Combinations at Baseline, IP Participant's Selection and End line Studies

Data collection Method	Number of Participants/respondents
Baseline Survey	101 Smallholder rice farmers
Key Informant Interviews	17 Stakeholder organizations' representatives
Focus Group Discussions	30 Both male and female smallholder farmers
Action Learning	24 Smallholder rice farmers equally representing 12 Blocks
Total	**172**

3.6.3 Sampling End line Study Participants

An end line survey study was conducted amongst the 24 IP farmer participants and 17 key informants purposefully sampled who were representatives of each stakeholder institution/organizations (mentioned in section 3.5) and had the knowledge on issues influencing farming and livelihoods in the study area. This study was used to assess the influence of the facilitated IP intervention on the uptake of SRI practices to spur rice productivity in the scheme. Two farmers from each of the 12 blocks who practiced SRI after learning from their fellow IP participants were also sampled and interviewed during end line survey. Two gender separated Focus Group Discussions (FGDs) each consisting of 12 participants were conducted targeting rice farmers who had participated in the IP and non-IP participants. This was meant to capture information on levels of uptake of SRI practices and use and the benefits derived.

3.7 Instrumentation

In this study various tools were used for data collection. A semi-structured questionnaire (Appendix A) administered on face-to-face basis was used to collect baseline data from sampled smallholder rice farmers in the study area. Kathuri *et al.* (1993) assert that questionnaires are appropriate for collecting basic descriptive information from a large sample. The questionnaire was designed with open and closed ended items capturing interval, nominal, and ordinal data; and each item addressed the specific research objectives and questions of the study. Part 1 of the questionnaire elicited information on socio-economic characteristics of smallholder rice farmers; Part II was used to generate data on challenges of SRI uptake and copying strategies and knowledge gaps in applying SRI practices by smallholders. The same questionnaire used at baseline was adapted for end line survey to capture the outcomes of action learning of the SRI practices after IP intervention.

Focus Group Discussion guides (Appendix B) were used for group discussions with stakeholders along the rice value chain in the study area. The discussions were conducted to validate data collected using questionnaire. FGDs were conducted before and after the IP intervention. FGDs were also aimed to support the participants to apply resilience and utilize reflection to improve their learning experience since learning is the best resource for exploring some challenge to accepted ideas of 'what works' as noted by Hall *et al.* (2013) and Hattie *et al.* (2010). Makini *et al.* (2013a) further emphasizes that FGDs aim to acquire in-depth understanding of an issue and not to generalize. A total of seven FGDs were conducted. Three FGDs of 10 participants each were conducted (one for female, one for male farmers, and a third one for both male and female) respondents to validate baseline data. Four FGDs were held with IP participants to discuss the influence of IP, benefits of SRI uptake, knowledge gaps, outcomes and challenges encountered with the innovation process.

Interview schedule was used to conduct key informant interviews with key informants. Interviews are appropriate in action research, allowing for in-depth understanding of processes and issues, often based on a small sample size (Young *et al*., 2018). King *et al.* (2018) posit that key informants are representatives of organizations considered influential in a project and are often sought by researchers to provide knowledge and information related to project being promoted within a community (McKenna *et al*., 2013). In this study, key informants were organizations having professional roles, expertise and awareness about SRI and were influential in the rice value chain in Oluch. Thus, their perspectives about what is important and would work best for a community must be carefully considered. Key informant interviews were used to obtain information from KALRO-Kibos (rice seed breeder and multiplier), MOAL&F (extension), Awendo Agrovets (farm inputs), NIB-Ahero (improved rice technologies including SRI), Nyabon machineries (farm machineries), Baraka fertilizers Company (pelleted rice fertilizer). LBDA (buyer, processor, and marketer). They provided knowledge and information related to SRI uptake, challenges and copying strategies, policy framework and strategies for sustainability. Farmer interviews aimed at changes in rice farming practices.

A Checklist (Appendix C) was used for data collection during field visits to the sampled 12 rice growing blocks. Field visits were conducted to observe the SRI practices implemented by farmers after IP intervention. Participatory observation is a purposeful and systematic way of observing an interaction or phenomena as it takes place (Kumar, 2012). The focus was to establish changes brought about by implementation of SRI in the rice growing blocks. Checklists of reflective questions were used to allow IP participants think back and compare their experiences before and after participation in the IP while focusing on study objectives and research questions. According to Barbour (2001), checklists of reflective questions provide rich data with enormous potential for comparison.

Social Network Analysis tool was used to determine the social networks and associations which supported the process of interactive learning and main points of intervention which influenced the quality of outcomes in collaborative approach. Questions were structured to measure quality of social networks, relationships, and strength of information exchange among stakeholders needed to achieve collective action and facilitate SRI technology dissemination and uptake. Network visualization maps were used to illustrate stakeholder interactions based on their primary roles in the IP particularly knowledge exchange; and resource requirements including input supply and service provision, market access and policy by-law. Ramirez (2013) argues that the exchange of information, knowledge and ideas is embedded within the networks and interactions that exist between different stakeholders, which is main approach by which the social networks influence and shape new technologies. According to Makini *et al.* (2013), social network analysis provides a baseline against which to plan and prioritize the appropriate changes to improve knowledge flows and improve effectiveness of formal and informal networks.

3.7.1 Validity

Validity refers to the degree in which study findings represent the actual phenomenon under study (Fraenkel *et al*., 2000). The instruments were checked for validity by the two supervisors and other experts in innovation and action research in the Department of Agricultural Education and Extension. Methodological triangulation of the multiple methods (Survey FGDs and KII) used in the study was employed for construct and face validity (Creswell *et al*., 2000). Internal validity was further ascertained through random selection of the study participants for baseline survey. Content validity was ascertained by determining whether the content that the instruments contained was an adequate sample of the domain of the subject matter they were supposed to represent. Validation ensures that the items adequately represent concepts that cover all relevant issues under investigation (Kathuri *et al*., 1993).

Validity was however increased by an iterative process whereby feedback loops were built into the data collection procedure during the interactive learning in the IP. A series of interviews were undertaken with farmer-participants, to ensure that the interpretations of the data were valid and fit with the farmers' and other stakeholders' understandings. Then researcher could feedback the findings at intervals in the process and used them to design a later interview. This ensured findings truly reflected views of the respondents. Evaluating the research from within its context was important for stakeholders and researcher because they needed different kinds of knowledge and this allowed them to know 'what it is by what it does' and by how much, and motivation to change after the intervention. The study could inform which aspect of the intervention participants and researcher believed were the key levers for change.

3.7.2 Reliability

The questionnaire was pilot-tested in Ahero Rice Irrigation Scheme, Kisumu County using a purposive sample of 30 smallholder rice farmers in order to measure the degree to which it yielded consistent results on repeated trials (Orodho, 2003; Silverman, 2013). Ahero Scheme was chosen because it lies in the same Agro-ecological zone; farmers had similar characteristics to those in the study area and produced rice through irrigation as in the Oluch Scheme. Ahero Scheme was far away to avoid contamination through farmer interactions. Cronbach's Alpha Coefficient was used for testing internal consistency. This was considered appropriate because Cronbach's Alpha is normally used as an estimate of reliability in the areas of study concerned with measurement of capacities, knowledge, attitudes, and behaviour. A reliability coefficient of 0.82 was obtained. Taber (2018) and Sijtsma (2009) recommend that Cronbach's alpha coefficient values of at least 0.70 are satisfactory. Cross-referencing of data from different methods also added to the overall reliability of the research process (Silverman, 2013).

3.8 Data Collection Procedure

The researcher obtained required approval from the Graduate School at Egerton University and the National Commission for Science, Technology, and Innovations (NACOSTI). Data collection began with a baseline survey for situational analysis by conducting interviews for smallholder rice farmers. The Rangwe Sub-County Agricultural Officer (SCAO) was informed to allow access of smallholder rice farmers. The Ward Agricultural Extension Officer (WAEO) and KOSFIP Office provided the researcher with an authentic list of rice farmers and other stakeholders which formed the sampling frame. In the field, the data collection team worked closely with irrigation block leaders and WAEO in identification of sampled respondents. Appointments were made with farmers before the visits, and farmers were omitted from survey sample if absent for three consecutive meetings. The researcher set specific dates to meet the respondents and administered the questionnaire face to face with the assistance of trained enumerators.

Two enumerators were trained by the researcher for two days on data collection procedures and aims of this research. Thereafter, both enumerators were involved in the pilot study at Ahero irrigation scheme to gain familiarity with the nature of data to be collected. It was a pre-requisite for enumerators to be knowledgeable about the block positions, local language, and culture of the respondents at Oluch irrigation scheme. In addition, enumerators were trained on confidentiality and obtaining consent from study participants, which was required from each farmer participant prior to taking part in the study. During data collection, confidentiality was observed and assured to the respondents.

Farmers and stakeholders in the Oluch Scheme were engaged through participatory meetings to obtain information on farmer knowledge and experiences on rice production practices. Surveys, FGDs and KIIs were carried out with the rice farmers and stakeholders within the platform to seek their views concerning challenges and coping strategies, opportunities, and benefits of producing rice using SRI practices in Oluch scheme. After action learning process, farmers implemented SRI in their blocks in the first season. The process of action learning and implementation of SRI occurred sequentially in three consecutive seasons. Data collection ended with an end line survey after the intervention.

Stakeholder analysis was done to identify the relevant stakeholders in the rice value chain who were engaged in FGDs to obtain the required data. The sampled farmers established rice fields using SRI practices. The application of SRI practices was accompanied by monitoring through field/home visits to observe and verify the application of what was learnt in the farm context, and the subsequent changes in productivity and ecosystem conservation indicators. The innovations and their implications were discussed and reflected upon within the Innovation Platform meeting forums.

3.9 Data Analysis

The researcher used both descriptive and inferential statistics to analyse qualitative and quantitative data gathered during the research process. Data summary and analysis was done using the Statistical Package for Social Sciences (SPSS software, version 26), while Social Network Analysis was done using R-software (*i-graph Library*). Descriptive statistics comprised frequencies, percentages, means and standard deviations and cross tabulations presented in tables, graphs, and charts. inferential statistics included Chi-Square, Correlations, Multiple Linear regressions, ANOVA, Stakeholder analysis, and cost benefit analysis (CBA). All the inferential statistics were interpreted at 5% level of significance. Data from open ended questions were summarized into themes and analysed using thematic content analysis. Methods of analysis for each research question are discussed in subsequent sections and summary of data analysis is presented in Table 3.

3.9.1 Analysis of objective one

Quantitative data from the baseline survey was summarized using descriptive statistics for participant and farming characteristics. This aimed at determining the farmer's socio-economic characteristics that could influence the uptake of SRI practices. Qualitative data generated through FGDs, and field observations were summarized in terms of frequency distributions, percentages, and cross tabulations. Qualitative data from open ended questions were summarized into themes. Data summary was done using the Statistical Package for Social Scientists (SPSS).

3.9.2 Analysis of objective two

To achieve objective two which was to identify challenges and benefits of producing rice under conventional and SRI practices respectively, quantitative, and qualitative data was collected at two levels. Level one was data collected through the baseline survey and level two was from action learning processes (intervention) facilitated by the innovation platform. The responses from the Likert scale rating were subjected to factor analysis to bring out the underlying structure of challenges and benefits.

3.9.3 Analysis of objective three

The third objective of the study was to establish an Innovation Platform for SRI uptake in Oluch irrigation scheme, in Rangwe Sub-County, Kenya. The IP was established by involving key stakeholders in a workshop comprising of twenty-four farmers, County government service providers, research, private sector notably traders, processors and technical people, through which later they selected their leaders. After formation of IP and using stakeholders' information, data was analysed with respect to their roles, interests, objectives, networks, resources, and the significance of those interventions. Data was analysed using descriptive statistics to conduct stakeholder analysis; and the inferential statistics used included correlations and linear regressions. Activities of the IP were implemented in a timeline, hence analysis of the activities in the IP followed the same trend.

3.9.4 Analysis of objective four

The fourth objective was to determine the multi-stakeholder network features that effectively promote SRI uptake in Oluch irrigation Scheme. In order to observe information sharing among the stakeholders, a network analysis for receiving and sending information among stakeholders based on their primary roles was configured using the observations in the questionnaire. The analysis was performed using the *i-graph* package in R software which needs data to be in a special format based on an adjacency matrix (a square matrix of rows and columns each with entries that represent either sending or receiving information). The thickness of edges (lines connecting stakeholders) was informative of the degree or strength of information sharing while the proximity of stakeholders in the network was informative of how any two stakeholders interact closely in IP or the rice value chain. Data analysis in the IP was an ongoing iterative process relying on social network analysis and action learning tools.

Descriptive statistics including means and standard deviations was used to summarize the data. The strength of information sharing between any two stakeholders was rated on a scale between one and ten with a higher rating indicating a greater degree of information sharing between stakeholders. To compare whether information sharing was greater among farmers or between farmer and other stakeholders, a test for difference in proportions (Z-tests) were performed at the 5% level of significance.

3.9.5 Analysis of objective five

To analyse how the networks in the IP influenced the uptake of SRI, a correlation analysis was performed of SRI uptake and innovation platform characteristics to summarize data and any visual patterns before exploring the relationship between innovation platform characteristics and the uptake of SRI. Correlations were considered to be significant at the 5% level of significance. A multiple linear regression model was fitted to evaluate which specific IP variables were important explanatory variables of SRI uptake among farmers. This sought to answer how features of the multi-stakeholder network promoted the uptake of SRI. The outcome variable was the level of SRI uptake measured as a composite variable comprising degree of the uptake of each of the individual five SRI practices. The explanatory variables for the regression model included the level of interaction with each of the stakeholders in the platform and the number of high interactions with stakeholders. All tests of hypotheses were performed at the 5% level of significance. This analysis was performed using R studio software.

3.9.6 Analysis of objective six

The sixth objective was to analyse the influence of the facilitated innovation platform for networking and capacity building on uptake of SRI practices in Oluch irrigation scheme. The IP influence was established by comparing the information using observations in the baseline questionnaire and the end line questionnaire after the IP intervention. These include changes in knowledge and technology use through capacity building and dissemination, area under rice production, production costs, level of income and the effect of technology practices on rice productivity and revenue; and any other additional changes that might have occurred as a result of spill over effect of the IP approach.

Multiple Linear Regression was applied to test the influence of the facilitated IP on uptake of SRI practices. Multiple Linear Regression is a statistical tool used to examine how multiple independent variables are related to a dependent variable (Higgins, 2005). It helps to understand how much the dependent variable would change when the independent variables change, by first establishing whether there is a linear relationship between the independent and dependent variables in a dependent linear regression model and then determine the strength of relationships. Chi-square tests of association were also conducted for categorical data, that is Innovation Platform participation and levels of income. T-tests were used to test the hypothesis of a difference in acreage under rice and level of income.

Quantitative data was summarized using descriptive statistics including means, standard deviations and proportions. For categorical data for example association between IP participation and level of income, chi-square tests of association were used. Figures visualized as Box plots and radar charts were also used to visualize quantitative data. A Z-test analysis for difference in proportions was used to compare the level of uptake of each of the SRI practices at baseline and end line. A cost benefit analysis (CBA) was performed to determine the productivity and revenue return. This involved computing estimated costs for each of the activities before and after the introduction of SRI. All tests of general assumption were performed at the 5% level of significance. A summary of the data analysis procedures is presented in Table 3 below.

Table 3: **Summary of Data Analysis**

	Research Questions	Independent Variables	Dependent variables	Statistical procedures
RQ.1	What are the socio-economic characteristics of smallholder rice farmers in Oluch irrigation scheme?	Socioeconomic characteristics	N/A	Frequencies, percentages, Means

RQ.2	Which are the significant challenges to the uptake of SRI practices in Oluch scheme?	Challenges experienced in rice production	Uptake of SRI	• Descriptive statistics (means, frequencies) • Chi-square tests
RQ.3	How does an Innovation Platform function build capacity for uptake of SRI?	Capacity building through action learning process Determinants of IP functioning	Uptake of SRI	• Social network analysis (SNA) • Stakeholder analysis • On the spot analysis
RQ.4	What multi-stakeholder network features effectively promote SRI uptake in Oluch Scheme, Rangwe Sub-County?	Multi-stakeholder Network features	SRI Uptake - Level of change in farm practices - Level of change in household income, area	• Descriptive statistics • SNA • Z-test • Multiple linear regression
RQ 5	How do the networks in the IP influence the uptake of SRI	IP network features	SRI Uptake	• Correlations • Linear regressions • Z-tests
RQ 6	How does Innovation Platform for networking and capacity building facilitate uptake of SRI practices in Oluch irrigation Scheme?	Innovation platform	Uptake of SRI practices - rice productivity and revenue	Descriptive statistics (means and proportions) Multiple Linear Regression Chi-square, Cross-tabulation T-tests, Z-tests, ANOVA Cost benefit analysis (CBA)

CHAPTER FOUR
RESULTS AND DISCUSSION

4.1 Introduction

This study assessed the uptake of system of rice intensification practices (SRI) through a facilitated Innovation Platform (IP) comprised of stakeholders in the rice value chain in Oluch Irrigation Scheme in Rangwe Sub-County of Homabay County, Kenya. The results are organized in two main parts. The first part presents the baseline survey findings which portray the situation as it existed, eliciting information on farmers' socio-economic characteristics and results of the second objective which was to identify the challenges of SRI uptake and coping strategies. The second part presents results of the intervention with respect to study objectives three, four five and six which were the formation of Innovation Platform for action learning processes, determine the features of multi-stakeholder networks that enhanced farmers' innovative capacities for uptake of SRI practices, determine how the IP networks influence SRI uptake and lastly objective six which sought to determine the influence of facilitated innovation platform on uptake of SRI farming practices.

4.2 Socio-economic characteristics of the rice farmers in Oluch Irrigation Scheme

This section presents a description of the socio-economic and demographic characteristics of smallholder rice farmers at Oluch Irrigation Scheme. Issa *et al.* (2016) noted that in agricultural information use studies, farmers socio-economic and demographic characteristics are important metrics to better understand their contribution toward information use behaviours (Issa *et al.*, 2016). The key variables of interest included gender, age, level of formal education attained, marital status, average household size, number of years the farmer has been growing rice, average land size and tenure system and existing rice growing practices. Importantly, these characteristics may influence the uptake of the intervention technology as outlined in empirical literature. The findings based on descriptive statistical analysis using frequency tables and figures are presented in subsequent subsections.

4.2.1 Distribution of respondents by gender

Gender is an important construct in learning and sharing of information and decision making both at household and farm levels, especially in relation to factors of production and adoption of agricultural technologies. Gender as a source of knowledge and power differentials that shape actors' behaviour can serve as an organizing tool for, innovation (Padmanabhan, 2002). Ouma *et al.* (2014) in their study in Dissemination and Uptake of 'Push-pull' Technology in

Lambwe Valley, Kenya established that female farmers had wider social networks and source of information about new agricultural technologies than their male counterparts. Gender participation may also promote increased interaction between stakeholders including farmers and generate important tacit knowledge. The study looked at gender through a baseline survey and results are presented in Figure 10.

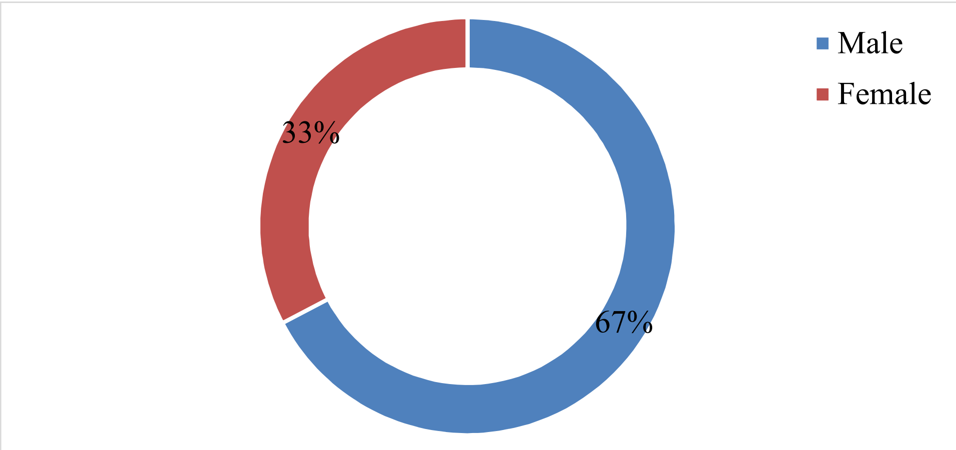

***Figure 10.* Distribution of Respondents by Gender**

Figure 10 shows the overall gender distribution of the respondents. Results show higher male representation of 68 (67%) of the respondents whereas female respondents were 33 (33%). This means that most farmers in Oluch irrigation scheme are male. Qualitative results from Focus Group Discussions (FGDs) and Key Informant Interviews (KII) revealed that rice farming is a labour-intensive undertaking. Data also show that some activities in the farm are a preserve for men and the male youth according to division of labour by gender. These activities include primary and secondary land preparation using rotavators or Oxen-ploughs, watering, and bird scaring. A male participant in a FGD confirmed that male farmers (including male youths) were more skilled in bird scaring than their female counterparts. Thus, in terms of labour division, women preferred working more on other food crops to meet household food security first while men adventured more into rice farming. According to Kingiri (2013), the gender dimension of agricultural production is epitomized in the roles and activities undertaken to address social and economic needs through agricultural production systems. (Kingiri, 2013; World Bank, 2006). Gender plays a critical role in agricultural and rural innovations (Beuchelt, 2016; Kingiri, 2010; World Bank, 2006a) thus efforts should be made to engender innovation processes.

4.2.2 Age of the respondents

Age, as a moderator variable, may influence both household and farm level decisions with respect to adoption of agricultural technologies, and those that underlie empowerment such as membership to farmer groups, leadership roles and participation in social networks (Taiy, 2009). The age categories of rice growing farmers are presented in Table 4.

Table 4: Distribution of respondents by age

Age Category	Frequency	Percentage (%)
19 – 29	8	7.9
30 – 39	33	32.7
40 – 49	32	31.7
50 – 59	21	20.8
60 +	7	6.9
Total	**101**	**100.0**

The results indicated that majority (64%) of the respondents were aged between 30-49 years which is considered the active farming age in rural communities. The results corroborate previous findings by Olwande *et al.* (2009) in Kenya. The elderly and the young were very few; their categories were represented by 7 percent and 8 percent, respectively. According to this study age influenced the learning, uptake, and application of SRI practices in rice production. Earlier empirical studies established that in normal circumstances, older farmers are less inclined to accept new agricultural technologies especially where the technology is knowledge intensive and labour demanding as compared to younger farmers (Davis *et al*., 2016; Duveskog *et al*., 2011).

Chianu *et al.* (2005) in a Nigerian study established that the likelihood of adoption of fertilizer was higher with increased targeting of younger farmers. Similarly, highest adoption, practice and realization of greater impact of agricultural technologies are found within the middle-aged farmers (Davis *et al.* 2009). Epeju (2003) in his study found out that farmers in the 41-80 years age category (43%) of the total respondents grew sweet potatoes because most persons in this age group controlled the factors of production. On the basis of the study findings and empirical literature, this implies that SRI technology is increasingly adopted by middle aged farmers. This satisfies a priori expectation because increase in age would tend to enhance agricultural innovation adoption. From the previous studies as reported, age of the respondent is important in decision making pertaining to the engagement in the farming activities.

4.2.3 Education level attained by respondents

Education level was considered an important parameter in this study since the activities related to learning, sharing and uptake of technologies requires some level of comprehension. According to Kilelu *et al.* (2013) innovations require combination of the hardware, software and orgware to effectively participate in the interactive learning processes in the innovation platform geared towards uptake of SRI. Opara (2010) asserted that education enables the individual farmers to know how to seek for and apply information on improved farm practices. Similarly, Nyagaka *et al.* (2009) observed that farmers with higher level of education tend to be more efficient in production since education equips the farmers with ability to perceive, interpret and respond to new information and improved technology much faster than their counterparts.

However, lack of education may exclude smallholder farmers from being active participants in development. In this case, data was sought on respondents' highest level of formal education attained. This was expected to guide the researcher on the ability of the respondent in learning, sharing and application of the SRI practices and outcomes. Thus, in the Agricultural Innovations Systems perspective context, farmers with basic literacy level and above were expected to benefit from the action learning process and build their capacity to innovate. A recent National Panel Survey conducted in Uganda by Kasirye (2013) and identified several constraints to Agricultural Technology Adoption. Study findings showed that farmers with higher education attainments were mor likely to use fertilizers and improved seeds. Sinjaa *et al.* (2004) in their study on farmer perception of technology and its impact on technology uptake, established that perception was significant in uptake of technology although in different attributes. A study on adoption of Upland rice practices by smallholder rice farmers in Central-West Brazil revealed that farmer's education positively affects the adoption of better cultivation practices (Strauss *et al.*, 1991). This implies that building innovative capacities of smallholder rice farmers by strengthening innovation networks is key to facilitating uptake of SRI practices. Summary of highest level of education of rice growing farmers are presented in Table 5.

Table 5: Education level of the respondents

Education level	Male		Female		Frequency Total	Percentage (%) Total
	Frequency	%	Frequency	%		
None	0	0	2	5.9	2	2.0
Primary	42	62.7	21	61.7	63	62.4
Secondary	18	26.9	9	26.5	27	26.7
Post-secondary	7	10.4	2	5.9	9	8.9
Total	67	100	34	100	101	100

Table 5 shows that out of the 101 respondents, more than half (62.7%) male and 61.7 percent female respondents in the study area had completed the primary level of education. Less than 50 percent of both male and female respondents had attained secondary level of education and above. The results indicate that the literacy level was moderate among the smallholder rice farmers. This finding is consistent with previous findings by Khandker *et al.* (2018), Ugochukwu *et al.* (2018) and Lin (1991) who contend that farmer illiteracy is brings about a lack of choice which is largely attributed to inadequate (or lack of) either technical, epistemological or prudential knowledge. Consequently, an illiterate farmer is less likely to adopt an improved agricultural technology compared to a literate counterpart. A similar observation was made by Asudi *et al.* (2015) that education of smallholder farmers is one way that can be used to cope with farming constraints such as diseases.

4.2.4 Marital status of the respondents in the Oluch Irrigation Scheme

Marital status has an influence on gender roles such as decision making over land use, division of labour and participation in innovation processes (Al-Taiy, 2009). Marriage ascribes familial responsibilities to individuals and therefore becomes more serious in terms of their participation in socio-economic networks that give them access to more information and income to meet their responsibilities. Marital status is significantly associated with agricultural information use (Opara, 2010). Furthermore, married farmers are likely to be under pressure to produce more, not only for family consumption but also for sale. The desire to produce more could lead to agricultural information seeking and use. Similarly, the availability of family labour could be an incentive to the married farmer to cultivate more crops and to use agricultural information/innovations. The respondents were asked to state their marital status which was captured in discrete categories. The findings are presented in Figure 11.

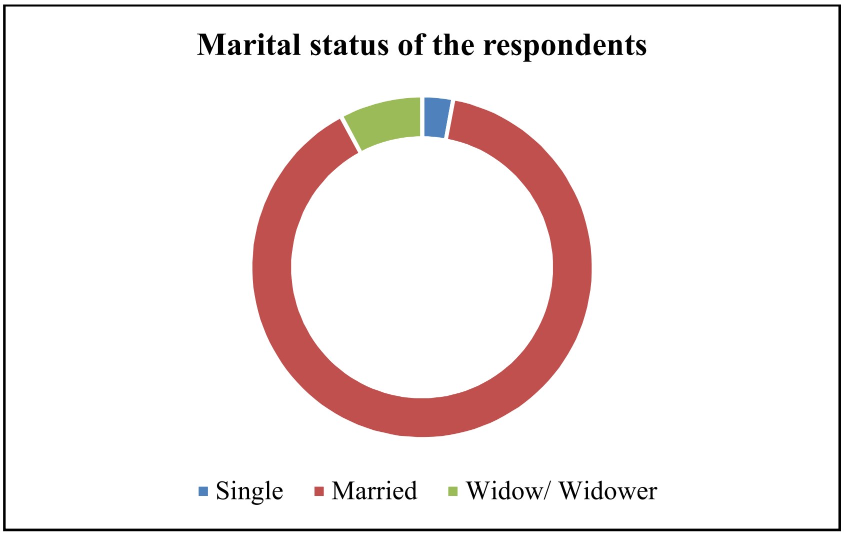

Figure 11. Marital status of the respondents

The results in Figure 11 indicate that most of the respondents (89%) in the study area were married, 7.8 percent were widows/widowers, and only 3 (3%) of the respondents were single. These findings suggest that rice farming was mainly carried out by married and slightly older persons.

4.2.5 Household size and experience in rice farming

Household size was considered an important variable in this study as it may influence farmers' both household and farm level decision-making process of agricultural technology adoption with respect to allocation of resources, enterprise selection and participation in social networks based on the theory of reasoned action (Ajzen, 2011). The respondents were asked to indicate their household size. Results presented in Table 6 show that the household size of most respondents in Oluch Irrigation Scheme ranges between 6 to 10. This represents more than half (52.5%) of the sampled respondents.

Table 6: Farmer household size characteristics

		Frequency	Percentage
Household size.	1-5	42	41.6
	6-10	53	52.5
	Above 10	6	5.9

Household size of 1 to 5 registered members was represented by 41.6 percent of the respondents, while only 5.9 percent of the farmers interviewed had large household sizes of more than 10 members. Further investigations in FGDs showed that households of large sizes are likely to benefit from family labour during peak periods of weeding, bird scaring and harvesting as compared to those of small household sizes. A similar observation was made by Olawuyi (2018) who established that large household size could be an opportunity for smallholder farmers to access family labour easily, while it could also have a consequential spill-over effect on the households' food security considering the small economies of scale. Similarly, a recent study on the determinants of crop farmers' participation in agricultural insurance showed that household size was found to be insignificant in influencing the farmers' participation in agricultural insurance scheme.

4.2.6 Rice farming experience in Oluch Irrigation Scheme

Previous farming experience may influence demand and uptake of agricultural technologies. Naseem *et al.* (1999) identified previous experience with fertilizer as one among several factors that influenced the fertilizer use intensity among smallholder arable crop farmers in developing countries in Sub-Saharan Africa (SSA). Farmer experience with price of fertilizer, output price of crops and prices of other Inputs that substitute for fertilizer and experience in prediction of rainfall pattern are factors that affect fertilizer demand in SSA. These findings further showed that majority of farmers surveyed have relatively substantial experience in rice farming as indicated in

Table **7**.

Table 7: Rice farming experience expressed as a percentage

Rice farming experience (years)	Frequency	Percentage
0-5 years	25	24.8
6-10 years	30	29.7
>10 years	46	45.5

The results in

Table **7** show that about 45.5 percent of the sampled population has been growing rice for over 10 years, whereas a minority of the study population represented by 24.8 percent had grown rice for less than 5 years. This implies introduction of SRI practices could easily be adopted through participatory action learning in the IP since rice farming is compatible with farmers' own practice.

4.2.7 Farm size

Farm size is an important factor in agricultural technology adoption because it determines the scale of operation, the size of farm owned by the farmers is a vital natural asset that determines the farming system that can be utilized and output that can be obtained from the land. This portends that by facilitating networks for innovation, smallholder rice farmers would come together to interact and innovate, and provide a platform mostly found in large farms or supra-groups to benefit from economies of scale. Such benefits would encompass bulk purchase of inputs, collective marketing of farm produce, improved access to loans and credit and dissemination of technical information which requires integrative solutions. According to Atera *et al.* (2018), large rice farms offer opportunity for greater efficiency in irrigation water use. The study anticipated that by taking advantage of economies of scale rice farmers would exploit available resources and improve rice productivity.

Farmers were asked to indicate the total size of rice plots they cultivate. Responses were analysed using frequency tables and recorded in Table 8. More than half of the sampled population (51.5 percent) indicated that they cultivated rice on small land parcels for ease of manual operations. This agrees with a recent report (Government of Kenya, 2015) that most rice plots are highly fragmented consequently not economically viable. Further, respondents were asked to indicate the average farm sizes under rice crop. Descriptive analysis findings are presented in Table 8.

Table 8: Average Farm size in study area

Average farm size (hectares)	Frequency	Percent
1.101 - 0.50	28	27.8
0.601 – 1.00	52	51.5
1.101 – 1.50	12	11.8
>1.50	09	8.9

Total	101	100.0

The results summarized in Table 8 indicate that most of the rice farm sizes ranged between 0.5 and 2.5 hectares. On average, farmers surveyed owned about 0.6 hectares of land, implying that rice production in Oluch Irrigation Scheme is characterized by small land holdings. This is a small number and could be attributed to the fact that under the predominant conventional rice farming system, most farmers in the study area fragmented rice fields into smaller parcels for ease of manual farm operations such as hand weeding and oxen ploughing.

These findings are in agreement with a number of empirical findings such as that conducted in Homabay County (Rao *et al*., 2015) which revealed that average land size owned by farmers was 1.18 ha. Similarly, Mathenge *et al.* (2010) noted that 95 percent of smallholder farmers in Kenya work on less than four hectares of land. Furthermore, FAO (2015b) report stated that small farm households work on land smaller than 2 hectares, and that several of them are resource poor and food insecure with limited access to services. The same observations are corroborated by Majiwa (2017) (Majiwa, 2017)who noted that there is rapid shrinking of African farm sizes with a bearing on productivity. Fischer *et al.* (2009) further asserts that rice production is associated with a unique combination of tiny field sizes.

Afolami *et al.* (2012) in their Nigerian study reported 1.72 and 1.64 hectares as farm size among cooperative and non-cooperative rice farmers respectively. Similar results were found by Wanyoike (2004) that farm size had a significant influence on adoption of Calliandra in male managed farms in Embu District, Kenya. A recent World Bank report stated that nowhere is the lack of assets greater than in SSA, where land sizes in many of the densely populated areas are unsustainably small and falling thus limits productivity and access to better options (McMichael, 2009). The same report indicated that farm size is also a major challenge in other parts of the world particularly Asia. This is in agreement with Abdulmalik *et al. (*2013) who established that farm size was a significant variable that influenced participation of farmers in agricultural insurance scheme in Nigeria. A study in Senegal by Colen *et al*. (2013) further established that larger land sizes are associated with higher yields and a higher marketing surplus, and that the positive links between land assets and market participation is found all over Africa. Typical examples are for rice in Madagascar, wheat in Ethiopia and maize in Kenya. FAO (2009) and Ferris (2011) report on innovation in family farming indicated that access to quality and public services generally increases with farm size, as services often focus on key food security crops such as maize and rice or on export crops that generate foreign exchange income.

4.2.8 Land tenure system in the study location

Farm ownership is a significant variable that may influence agricultural technology adoption and the probability of participation of the farmers in agricultural schemes through social networks. Farm ownership is also important in that famers with title deeds to their land have more control over farming operations. For example, a farmer can make choices on the duration technology is used on the farm and farm enterprise selection. Land tenure system was looked at as a predictor of the type of farming system practiced by farmers in the study area. Gicheru (2016) found that land ownership was a barrier to uptake of SRI technology in Mwea rice scheme, as farmers who had leased farms found that levelling a leased farm for just a season in order to practice SRI was a costly venture, more so if the lease was only for a season or not subject to renewal. The same study also noted that farmers with little land entitlement lacked collateral to access loans and credit from financial institutions and therefore were unable to invest in SRI technology. The study subjects were asked to indicate the tenure status of rice farms and results are presented in Table 9.

Table 9: Land Tenure system in the study location

Tenure	Frequency	Percent
Owned with title deed	7	6.9
Owned without title deed	72	71.3
Rented	22	21.8
Total	101	100.0

Table 9 reveals that majority 71.3 percent of the respondents in the study area owned farms without title deeds. Only 7 (6.9%) respondents out of the 101 had title deed for their land parcels, whereas 22 respondents cultivated their rice on rented farms. Rice farms were rented on cash or share cropping basis where the former is a common feature. Renting-in enables farmers to increase their farm sizes to boost rice production. On the other hand, renting-out land either on cash or share cropping basis gave farmers opportunity to acquire needed Inputs and services from relevant stakeholders. A recent Nigerian study found that farm ownership was a significant variable that influenced participation of farmers in agricultural insurance scheme in Nigeria (Abdulmalik *et al.,* 2013). Further investigation in FGDs with farmers in Oluch scheme revealed that lack of land ownership entitlements coupled with customary laws of land inheritance were demotivating factors to agricultural technology adoption.

4.2.9 Membership of social group

Farmer groups may impact uptake of agricultural technologies to enhance agricultural productivity, commercialization and linking farmers to markets through collective action. Bantilan *et al.* (2008) noted that farmers participating in multiple networks are likely to be most empowered and are more inclined to seek greater decision-making roles. According to Mwaura (2014) membership to farmer groups in Uganda was observed to lead to achievement of higher yields for banana and cassava. However, negative impacts were also observed for beans and maize. This means that by facilitating networks for innovation, smallholder rice farmers would come together to interact and innovate and provide a platform to direct efforts in ensuring the efficacy of the strategy in enhancing rice productivity thereby improving the welfare of farmers. Farmers were asked to state whether they participated in social groups and the duration each had participated in the groups. Table 10 reflects the results.

Table 10: Membership of social group expressed in percentage

Membership of Social Group (year)	Frequency	Percent
0-5	57	56.44
6-10	31	30.69
11-15	8	7.92
>15	5	4.95
Total	**101**	**100.0**
Mean	(5.60 years)	

The study established that majority (56.44%) of the total respondents were had been involved as members of farming associations for no more than five years. Also, only 8 respondents representing 7.92 percent of the total respondents were in the category of 11-15 years and above. The average year of membership of association among farmers was about 5 years. The result implies that rice farmers in Oluch scheme have moderate social interaction and as such social capital accumulation among farming households was below average.

4.2.10 Existing SRI practices and influencing factors

The study investigated SRI baseline practices of sampled smallholder rice farmers with specific focus on five SRI technological codes including: line planting, planting young healthy seedlings, intermittent watering, mechanical weeding, and application of organic manure. These practices were looked at to find out what the smallholders currently do and what they do not do at what scale and to use the results to provide a basis for comparison of what they are going to do after introducing SRI through innovation platform (IP). This would give clear comparison between the baseline and end line results. Figure 13 presents the results of this investigation.

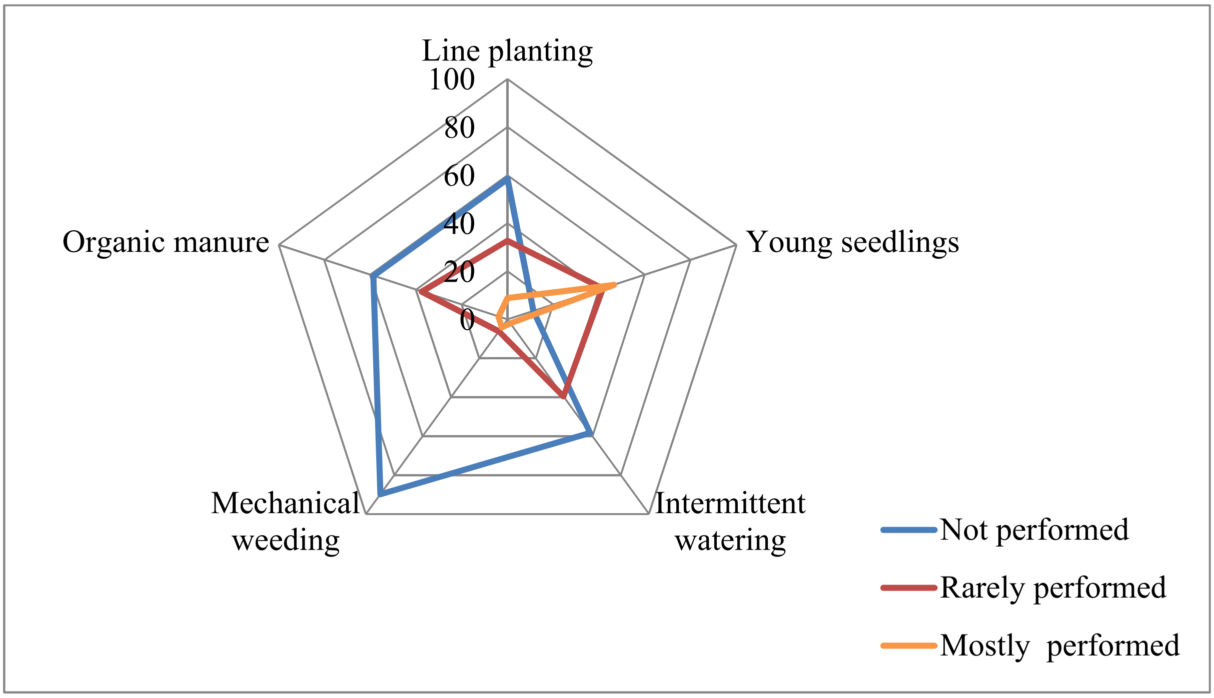

Figure 12. **Levels of Performance of Existing SRI Practices at Baseline**

Figure 12 shows mapping and analysis of levels of performance of existing SRI technological codes based on a scale of 1 – 3. A general low performance of each practice was observed among smallholder rice farmers in the study area.

i. Line planting

Figure 13 shows that a high proportion of farmers did not perform line planting as reported by 58.4 percent of the study population. Another 32.7 percent reported that they rarely performed line planting and only 8.9 percent reported they mostly performed line planting, giving an indication of their low knowledge base and skills on SRI package. This agrees with previous findings from a study on enablers to the uptake of SRI in Kenya which established that smallholder rice farmers are constrained by lack of knowledge on SRI practices which hinders its uptake to spur productivity (Gicheru, 2016). Focus Group Discussions confirmed that low knowledge levels on SRI contribute to limited uptake of the technology practices. Besides this, lack of hands-on training leaves farmers with no option but just to continue with traditional or conventional practices. Additionally, low performance on line planting limits promotion of mechanization in the scheme which further translates into high labour costs.

ii. Planting of young healthy seedlings

The results indicate that 47 (46.5%) of the respondents mostly planted young and healthy seedlings. About 41.6 percent rarely planted young healthy seedlings, while only 11.9 percent of the farmers never planted young and healthy seedlings. Planting young and healthy seedlings determined good yield potentials for rice production. Similar findings were reported in studies in Indonesia and India (Hidayati *et al.*, 2016; Thakur *et al.*, 2011) that planting young healthy seedlings results in high number of productive tillers per hill with better grain filling resulting in high productivity and more farm income. Therefore, by strengthening interactions through action learning the study hoped to improve smallholders' knowledge for applying SRI technological codes in rice farming to spur rice productivity.

iii. Intermittent watering

Majority (58.4%) of the study participants did not perform intermittent watering, while 19.5 percent rarely performed intermittent watering and only a negligible number (2%) performed intermittent watering. Focus group discussions confirmed that most famers often flood the rice fields from land preparation all through to maturity of rice plants. Additionally, field observations established limited practices of alternate wetting and drying (AWD) of the rice farms in the scheme. Key informant interview participants noted that occasional heavy rains experienced in the scheme led to poor drainage which influenced the watering regime with a bearing on field activities. The findings corroborate the study results conducted in Cambodia (Lee *et al*., 2018) which established that timely water management with alternate flooding and drying was among the most difficult practices for farmers.

iv. Application of organic manure

More than half (58.6%) of the study participants did not apply organic manure in rice farms, fewer respondents (37.4%) rarely applied organic manure and a minority (4%) mostly applies organic manure. Discussion within FGDs revealed that negligible number of farmers applies organic manure. An extensionist revealed that use of organic manure has another cash value. Through formal and informal personal observations, the researcher noted that rice stoves were in high demand as livestock feed. An indication that some farmers have 'distanced' themselves from use of manure in rice farming in favour of chemical fertilizers, a case of 'decomposing' this SRI technological codes.

v. Practice of mechanical weeding

Majority (89.8%) of the study subjects did not practice mechanical weeding, while 6 percent rarely performed mechanical weeding, only 2 (2 %) of the respondents mostly practiced mechanical weeding at baseline. Generally, mechanical operations remained low-keyed in the scheme due to unavailability, inaccessibility and unaffordability of mechanization services and support, which further exacerbates low production of rice. The findings corroborate a recent Government of Kenya report (2015) that County government availed one tractor per Sub-county for hire at subsidized rates. However, the demand was overwhelming, and most farmers resorted to hiring private tractor services.

4.2.11 Existing institutional networks supporting smallholder rice farmers

Institutional support may impact on uptake of agricultural technologies to enhance agricultural productivity, commercialization and linking farmers to markets through collective action. The study sought to establish the institutional support framework in the rice value chain within the study area to understand the multi-stakeholder network features that could be leveraged on to enhance the uptake of SRI through establishment of innovation platform. The study looked at three aspects of support to smallholder rice farmers' i) who provides support in the activities that smallholder rice farmers do ii) Nature of support and iii) the extent to which farmers prefer the supporting institution. Study findings are presented in Figure 13.

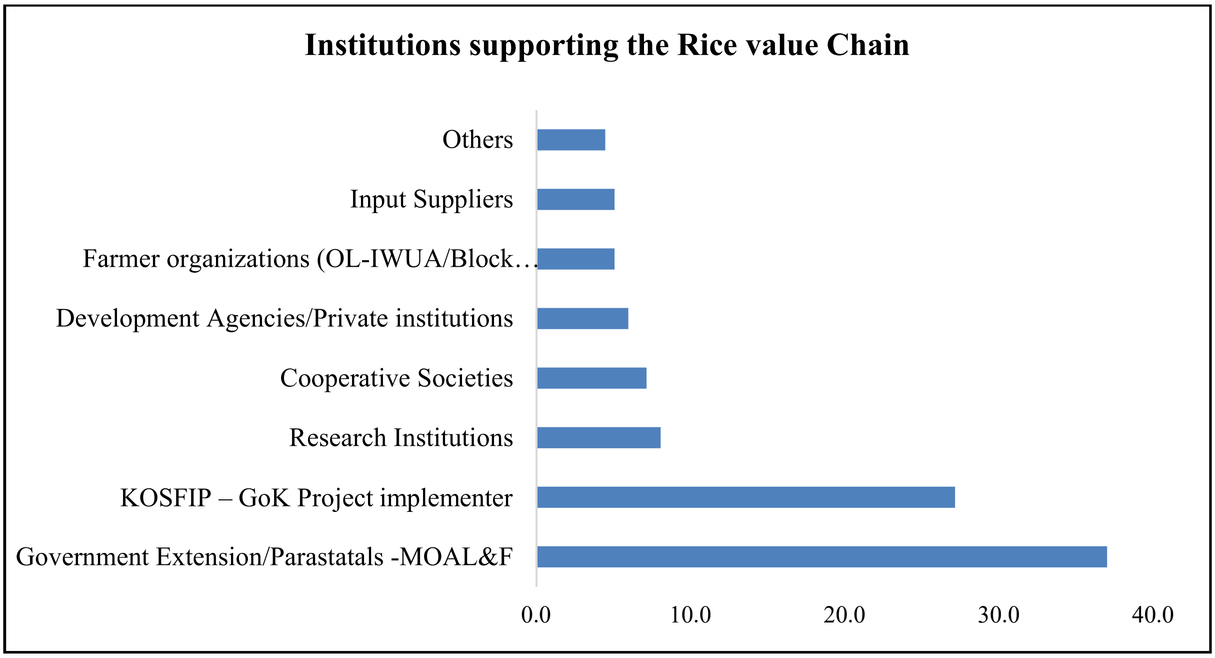

Figure 13. **Institutions supporting the rice value chain at the baseline**

It is evident from Figure 13 that there was substantial government and government affiliated agencies involvement in the rice value chain within the study area, cited by more than half (57.2%) of the respondents. The MOAL&F being the primary contact with the farmers through extensionists and the Kimira Oluch Smallholder Farm Improvement Project (KOSFIP) as the project implementer explains the nature of the farmers' responses. Other institutions involved include research institutions (8%), cooperative societies (7.2%), developmental agencies (6%), farmer organizations like OL-IWUA (5%) and various Input and output market suppliers (5%). Generally, the findings indicate few actors and low support levels by the institutions, an indication of weak networks among them.

4.2.12 Support offered by institutions in the rice value chain

Institutional support may influence both adoption and impact of agricultural technologies to occur. Bantilan *et al.* (2008) noted that institutional support improves access to resources and further expands choices available to each smallholder farmer. Descriptive analysis of the nature of support offered by the institutions illustrated in Figure 14 revealed that training comprises the largest (43%) support received on rice production practices. Training is provided mainly by MOAL&F, KOSFIP and research institutions. Inadequate knowledge and skills are the most commonly cited challenge facing farmers, although this the most commonly offered support from the various stakeholders involved in the rice value chain.

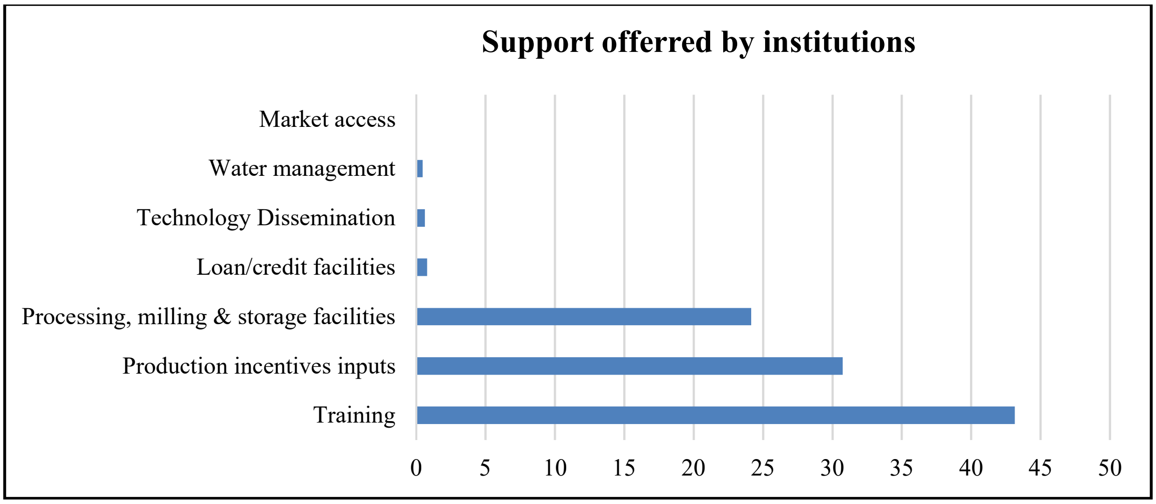

Figure 14. **Support offered by institutions in the rice value chain**

Provision of inputs for production (31%) and access to processing, storage, and market facilities (24%) account for the second and third most commonly offered support to farmers by support institutions. Notably, there is limited support in terms of loans and credit facilities to farmers, water management and limited or no support in linking farmers to the markets. It was therefore hoped that strengthening partnerships would offer opportunities for smallholder rice farmers to access Inputs to enhance their productivity and consequently improve livelihoods.

4.2.13 Preferred institution in providing support at baseline

Knowing farmer preference may influence provision of institutional support and targeting for effective and efficient utilization of resources and services. Farmers were asked to indicate to what extent they prefer the institutions giving them support. Results are presented in Figure 15.

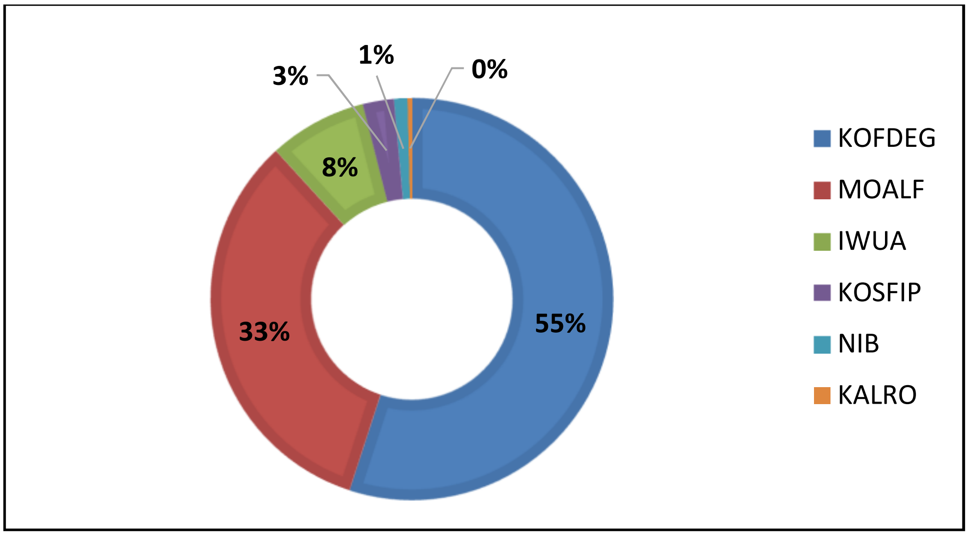

Figure 15. Farmer preferred institution in providing support at baseline

The results in Figure 15 show fewer institutions offering limited support under weak networks. However, the institutional networks included a narrowed range of relationships in the rice value chain. The results show preference of only one private institution (KOFDEG). Important concepts relating to smallholders include opportunities for access to inputs and market, loans and credit, water management, processing, information dissemination. The findings agree with Kidula (2017) that linkages are expected to create an opportunity for County governments to support capacity building for other partners to access networks by providing facilities and an enabling environment. According to Bantilan *et al.* (2008) governments should undertake policy initiatives to boost the private sector participation by addressing institutional, policy and legal barriers. It was therefore expected that strengthening institutional networks through innovation platform may foster new knowledge and links to enhance access to social capital for facilitating uptake of SRI to boost productivity. Further discussion through FGDs and KII revealed most respondents indicated KOFDEG (55%) and the Ministry of Agriculture, Livestock and Fisheries (MOALF) (33%) and IWUA were the most preferred institutions in giving support including sharing of information. Notably, research institutions like KALRO and National Irrigation Board (NIB) were least preferred in sharing information.

4.3 Challenges to Uptake of SRI and Coping Strategies in Oluch Scheme

The second objective of the study was to look at the challenges and copying strategies the smallholder rice farmers have in the study of SRI technology. Data was collected using a survey, FGDs, KIIs and field observations. Plate 1 shows inspection of rice field during baseline survey to verify some of the challenges in rice production. The results obtained from these processes are presented in Figure 16.

Plate 1: **Inspection of rice field during Baseline Survey**

Photo by Rose Apodo on 20/11/2017

4.3.1 Farmers' challenges to the uptake of SRI

This study investigated the various challenges which impeded the uptake of SRI at Oluch. Several studies have demonstrated technology adoption in sub-Saharan African is significantly influenced several factors, but which vary across geographical regions and sometimes from one commodity value chain to another. Subsequently, an understanding of how each variable affected SRI uptake allowed implementing actors, stakeholders, to refine their strategies on the basis of the quantitative and qualitative findings.

Figure 16 shows that five of these challenges are critical to rice production in Oluch irrigation scheme which comprised inadequate knowledge, labour shortage and high expenditure, weak stakeholder networks; pests and diseases; and high cost of Inputs. From the findings presented in Figure 16, there is evidently no single challenge that largely accounted for a significant proportion of the constraints affecting farmers practicing SRI method. Notably, farmers are affected by multiple complex, and competing challenges thus limiting their opportunities for uptake of SRI practices albeit at different levels. This agrees with a recent report (Government of Kenya, 2015) that famers are affected by numerous challenges in applying improved technologies which calls for innovative approaches to address them.

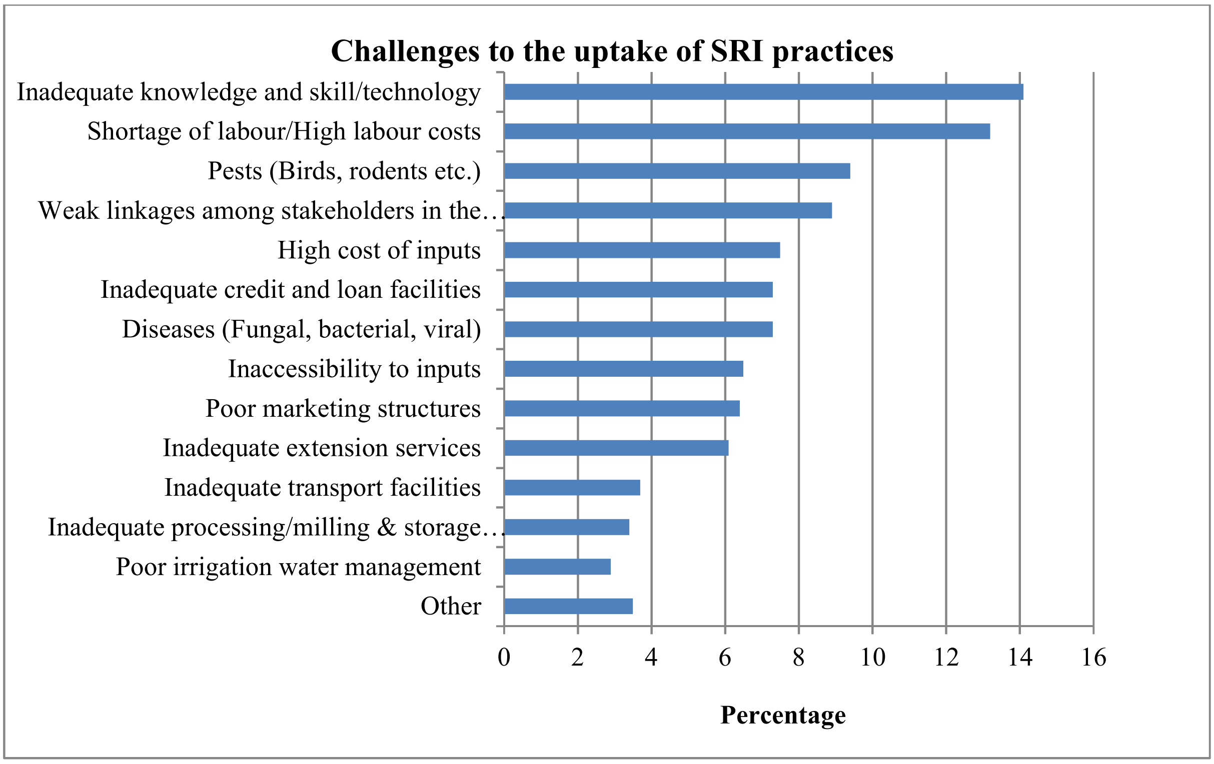

Figure 16. **Challenges to uptake of SRI practices in Oluch Irrigation Scheme**

All the challenges indicated in Figure 16 have significantly impeded rice production levels in Oluch irrigation scheme. Additionally, the challenges restrict SRI uptake and create hindrances to obtain potential yields. Pokhrel *et al.* (2007) observed that such challenges combined with little market information and lack of produce handling facilities; further weaken farmers' position along the value chain. The summary of these production challenges enables understanding the reasons for the current low rice productivity and incomes in the scheme. This further guided on the necessity for interactive learning which is key for farmers in making informed decisions as pertains their rice farming activities.

The study examined the extent to which each challenge constrains smallholder rice production in the scheme. Categorization of the multiple responses was done, and respondents were further asked to rank them using a 3-point Likert scale rating as mild, serious and very serious challenge. The results are summarized and presented in Table 11 below.

Table 11: Distribution of Respondents according to Categories of Challenges of SRI Uptake

Challenge Category	Mild challenge (%)	Serious challenge (%)	Very serious challenge (%)
Insufficient knowledge and skills about SRI	10 (9.9)	46 (45.5)	45 (44.5)
Poor market structure (price fluctuations, access, channels, distance, and transport.	15 (19.8)	33 (32.6)	53 (52.8)
High cost of production	24 (23.7)	41 (40.5)	36 (35.6)
Pests and Diseases	29 (28.7)	44 (39.6)	36 (31.6)
Inaccessibility of credit/loan facilities	26 (29.7)	45 (44.5)	30 (29.7)
External factors	30 (29.7)	43 (42.5)	28 (27.0)

Note: Multiple Responses. N = 101.

i. Insufficient knowledge and skills about SRI technology

The findings in Table 11 show that most of the study participants (90.0%) reported that insufficient knowledge and skills on SRI technology posed a serious challenge to the uptake of the technology. Inadequate knowledge and skills were identified as a very serious challenge to uptake of SRI practices. The study findings revealed other related constraints including inadequate information dissemination through public extension service, conflicting information on SRI from different sources including neighbours and mass media, lack of hands-on training which further limits the chances for SRI uptake by a given farmer. Low knowledge levels had effect on irrigation water management leading to competition for water

use and illegal diversions. Another reason for excessive water-use in rice cultivation was that farmers kept the main fields flooded for longer time during preparation before rice sowing so most of the water may be lost through runoff, evaporation, percolation, and seepage.
Weak networks among innovation stakeholders (farmers and their organizations, advisory services, research institutes, private enterprises, financial institutions, and others) in the rice value chain was mentioned repeatedly as a serious challenge in knowledge dissemination. This has resulted in dysfunctional innovation system that is unresponsive to farmers' needs which manifested in low uptake rates of SRI practices by farmers and marginal rice productivity increases, with often limited impact on improving livelihoods (Feder *et al*., 2006). A similar observation was made by Gicheru (2016) that smallholder rice farmers encounter barriers related to knowledge that hinder the uptake of SRI in Mwea irrigation scheme. Further field observations revealed that SRI practices were adopted at different levels based on knowledge opportunities and challenges of each farmer. This means that interactions in facilitated innovation platform would offer opportunities to build smallholders' innovative capacity for uptake of SRI to spur productivity.

Investigations through FGDS emphasized extension services are inadequate and inefficient. A recent county government report concurred that the proportion of extension agents to smallholder farmers is very low, and that each agent serves approximately 2000 farmers in Homabay County (Government of Kenya, 2015). This implies that profitable productivity enhancing technologies such as SRI are not extending into the farming community as anticipated. A Nigerian study on constraints to adoption of innovations among smallholder women farmers in Osun state, Nigeria, revealed that failure of extension workers to reach women where they are was a drawback to uptake of innovation (Ayoade *et al*, 2012). A similar observation was made in Tanzania that ineffective extension services affects uptake of improved farming practices (Concern worlwide, 2008). Other empirical findings have equally emphasized that linking smallholder farmers to different information services, to diverse service providers and to input and output markets is critical for inclusive advisory approaches (Ferris *et al.*, 2014; Sulaiman *et al*, 2012).

Key Informant Interviews provided information that farmer organization in support groups is beneficial in facilitating information exchange from a pool of knowledge about agricultural innovations; and how to leverage on numbers to attain increased productivity including engaging with relevant stakeholders. This finding confirms what Bantilan *et al.* (2008) found that farmers participating in multiple networks are likely to be most empowered and are more inclined to seek greater decision-making roles.

ii. Marketing challenges

Enhancing rice productivity through SRI needs support through a structured marketing system that enables farmers to get better returns on their investment. Farmers were asked if they had any constraint in marketing rice. Table 11 shows that a considerably large number of respondents (85.1%) indicated that market was a very serious challenge, while only 19.8 percent considered marketing as a mild challenge. Marketing measured by access to market, market information, price fluctuations, post-harvest handling, marketing channels and transport services was reported as limiting opportunities for productivity. This agrees with a World Bank Report (World Bank, 2006b) that market is a pull factor for productivity and can accelerate uptake of productivity enhancing technologies such as SRI.

Focus group discussions revealed that majority of the smallholder rice farmers are constrained by poor market structure. Participants in FGD emphasized that they sell rice to get money for other livelihood strategies such as paying school fees, labour, transport services and other necessities but without a well-structured market, farmers are compelled to reduce the acreage under such crop enterprise. Four KII respondents (IWUA marketing committee chairman, researcher, extensionist, and irrigation engineer - (see *Plate 2*) observed that farmers were more market-oriented than production-oriented. The respondents further emphasized that the smallholders were always willing to take up improved agricultural technologies so long as they are assured of ready and remunerative markets, which also curbs post-harvest yield losses and related costs.

These responses imply that a facilitated Innovation platform may be instrumental in strengthening value chain actor networks for marketing rice and that trainings through IP would be significant in influencing market participation in Oluch scheme. Collaboration with Key Informants during the baseline survey yielded useful information for making informed decisions towards improving rice production. *Plate 2* illustrates gathering and exchange of information among KIIs and the researcher on rice field inspection.

Plate 2: Data collection with Key Informants on rice field inspection during baseline survey
Photo by Seline Ouma on 5/10/2019

According to Kunneman (2010) smallholder farmers need access to local and national markets at stable prices in order to increase production. However, the prices should be largely guaranteed by the government through sectoral and national policy guidelines. Additionally, market access requires rural infrastructure, storage facilities, access roads and marketplaces in rural and urban centres.

iii. High cost of production

Findings presented in Table 12, indicated that high cost of production was rated as a very serious challenge by the study subjects. Cost of production measured by Inputs (certified seed, fertilizers, and pesticides), labour, transport, milling services and farm equipment was reported as constraints limiting opportunities for rice productivity in the scheme. Investigations in FGDs revealed farmers expressed their anxiety over adopting SRI practices saying it is intertwined with some extra costs. A Key Informant Interview participant reiterated that if the supply side constraints are not addressed, smallholder farmers will continue wallowing in poverty and will not reap any benefits. This is in contrast with a previous assertion by Uphoff (2003) that there is evidence that uptake of SRI is cost effective. A study conducted by Egerton University's Tegemeo Institute on rice production costs in Kenya, recommended enhancing uptake of the

SRI technology as a strategy for cost reduction to increase rice production and productivity (Gitau *et al*., 2011).

Kenya remains food insecure due to factors such as increased local food prices occasioned by higher input costs (Majiwa, 2017). This implies that improving social capital such as membership in local and supra groups, networks and access to relevant institutions may be an effective way to link smallholder rice farmers to relevant stakeholders for access of needed inputs and market outlets to drive rice production in the scheme. Kunnemann (2009) emphasized that smallholders are the main producers and innovators who need support in order to create a strong dynamic of change. Such measures would include developing local partnerships for action by strengthening innovative capacities.

Focus group discussion participants reported that they embraced practices such as planting rice plots at the same time which enables timely and easy field operations; and cost reduction in bird control, labour, transport, mechanization and also facilitates bulk processing and marketing. Key informants, extension and KALRO reported that farmers organize themselves into labour groups (women/youth or mixed) locally known as 'Sagaa' and share labour on a number of field operations particularly at peak periods such as planting, weeding, and harvesting.

iv. Pest destruction and pest infestation

Pest destruction and disease infestation was ranked by majority (76.1%) as serious to very serious by the study subjects as shown in Table 12. These biotic constraints were reported as limiting opportunities to adoption of SRI in the study area. Discussion by FGDs established that some of the rice farmers reduced acreage under Basmati, Saro 5 and ARIZE Gold varieties which are highly palatable to Quelea birds. This agrees with previous findings by Ayoade and Akintonde (2012) who report that disease and pest attack are major constraints to technology adoption. A study by ICIPE and ILRI in western Kenya on agricultural production and marketing (Rao *et al*., 2015) recommended promotion and utilization of innovations on insect and pest management in collaboration with extension, research, NGOs and the private sector. This implies that building innovative capacities of smallholder rice farmers by strengthening innovation networks is crucial to facilitating uptake of SRI.

Through informal personal observations, it was noted that farmers make technological alternatives such as planting rice varieties which are less palatable to birds such as IR varieties including AT058, Dorado and IR 2793 among others. However, according to researchers, this is a poor option because some of the varieties chosen are low yielding. The high yielding aromatic varieties highly palatable to birds include ARIZE Gold, Basmati, Saro 5 and 'Komboka".

Bird menace was countered through chemical and biological control as well as control through physical scaring using locally made contraptions some of which are shown in Plate 3. According to Government of Kenya report (2015), physical bird scaring is the common practice used in Oluch irrigation Scheme.

Plate 3: Physical bird scaring using moulded mud stones mounted on 'Sanjuras' and Noise (A) and (B) Bird scaring using scarecrows
Photo by Rose Apodo on 20/01/2019

v. External factors

Table 12 shows that external factors were ranked as a major challenge to uptake of SRI practices in the scheme as indicated by 17.87 percent of the study subjects. Discussions by FGDs established that institutions operating under County Government were often less responsive to the needs of the smallholder farmers, even though their rhetoric may sound "smallholder oriented". It was further noted that environmental factors such as climate change and destructive pests (such as Quelea birds and locusts) damage are non-negotiable and extension agents had few means to support farmers to overcome them. This demonstrated greater need for cross-sector collaborative innovation including networks created through interaction to address such constraints.

Improved water management strategies included collective cleaning of blocked irrigation canals and enforcement of IWUA By-laws to control illegal water abstractions by non-IWUA registered farmers. Provision of casual labour to other farms to supplement the household income was also a copying strategy.

vi. Inadequate access to credit facilities

Inadequate access to Credit facilities was ranked as one of the key challenges limiting SRI uptake. A further inquiry in FGDs and KII interviews revealed that farmers faced bureaucratic procedures in seeking out loans. It emerged that inaccessibility to loans by smallholder rice farmers limit their capability to acquire adequate quantities of Inputs, open up large acreages, hire machinery and pay labour costs. The study findings concur with a previous studies in several countries in sub-Saharan Africa including Nigeria and Ghana which found that majority of smallholder farmers could not access loans due to bureaucratic bottlenecks (Anyiro *et al*., 2011; Chauke *et al*., 2013; Dzadze *et al*., 2012). Further empirical findings in different agricultural commodity value chains across Africa affirm that the fear of applying for loans by smallholder farmers is due to lack of collateral and fear of one's property being auctioned when one fails to service the loans within the stipulated time period and general lack of information (Assogba *et al*., 2017; Choudhury *et al*., 2020; Isaga, 2018).

Focus group discussion confirmed that youth faced particular problems in rice farming, and it is the only age category in which agricultural production programmes is still not well streamlined. The discussants emphasized that SRI availed an opportunity for empowerment through capacity building and income generation through labour provision. Of interest was the large number of youths using push-weeders to offer casual labour for rice weeding in the scheme. The findings agree with government of Kenya (2015) that youth is potential resource for developing the agricultural sector for rural development. The FGD discussants gave in depth understanding of the challenges related to access to credit facilities especially for youth due to lack of collaterals, particularly the land tenure system, as more than 90 percent do not possess land title deeds. By engaging in rice farming agronomic activities, the youth generate incomes for improved livelihoods.

Table The study sought to understand copying strategies employed by farmers to navigate through the challenges experienced in the uptake of SRI. The results revealed that each farmer used at least one strategy to solve a challenge. The findings obtained through KIIs, FGDs with youths and the baseline survey are summarized and presented in Table 12.

Table 12: Farmer Coping Strategies to challenges limiting SRI uptake

Challenges	Coping strategies
Insufficient knowledge and skills about SRI	Collective action and social capital build-up where farmers organized themselves in support groups for demand-driven extension services.
Unstable market prices	Store rice for a longer period to fetch better prices * Sell cheaply to rice traders/millers at harvesting
High cost of production including: Inputs (certified seeds, fertilizer, pesticides); Labour	Renting-out land on cash or share cropping basis in exchange of labour for farm operations. Individual arrangement with private millers to access Inputs in exchange of paddy rice at harvesting time. Access Inputs on market days at reduced costs. Seek for government seed and fertilizer subsidies through IWUA and MOAL&F Adopt alternative cheaper forms of labour such as women/youth organized labour support groups. Labour from other villages arranged to meet the demand.
Pest destruction and disease infestation	Improvised bird control measures (Scare crows and sound making devices whirled by wind). Planting fields at the same time, hire labour
Inaccessibility of credit/loan facilities	Bank and Micro-finance facilities. Table Banking (SILK, Roscas)
External factors	Policy lobbying and advocacy for intervention & mitigation Environmental factors are non-negotiable and extension agents had few means to support farmers to overcome them.

The barriers to uptake of SRI in the Oluch Irrigation Scheme could be addressed by enhancing smallholder farmers' capacity through innovation platforms. This enabled acquisition of knowledge and skills for enhancing rice productivity. Demand-driven, pluralistic extension and advisory services became nodes for exchanging information and services that help put knowledge to use. The study established their effective positioning to facilitate and support multi-stakeholder processes and the heterogeneous client base of an agriculture innovation system (Tenywa, 2011). For this study, an innovation platform was considered relevant for addressing low rice productivity in the Oluch scheme by facilitating uptake of SRI.

4.3.3 Suggestions to improve rice productivity in Oluch Scheme

The study sought for any further suggestions from smallholder rice farmers on what can be done to improve rice productivity in Oluch. Data was derived from a baseline survey, FGDs and KIIs. The suggestions provided the basis for the formation of a facilitated Innovation Platform. The results obtained from these processes are presented in Figure 17.

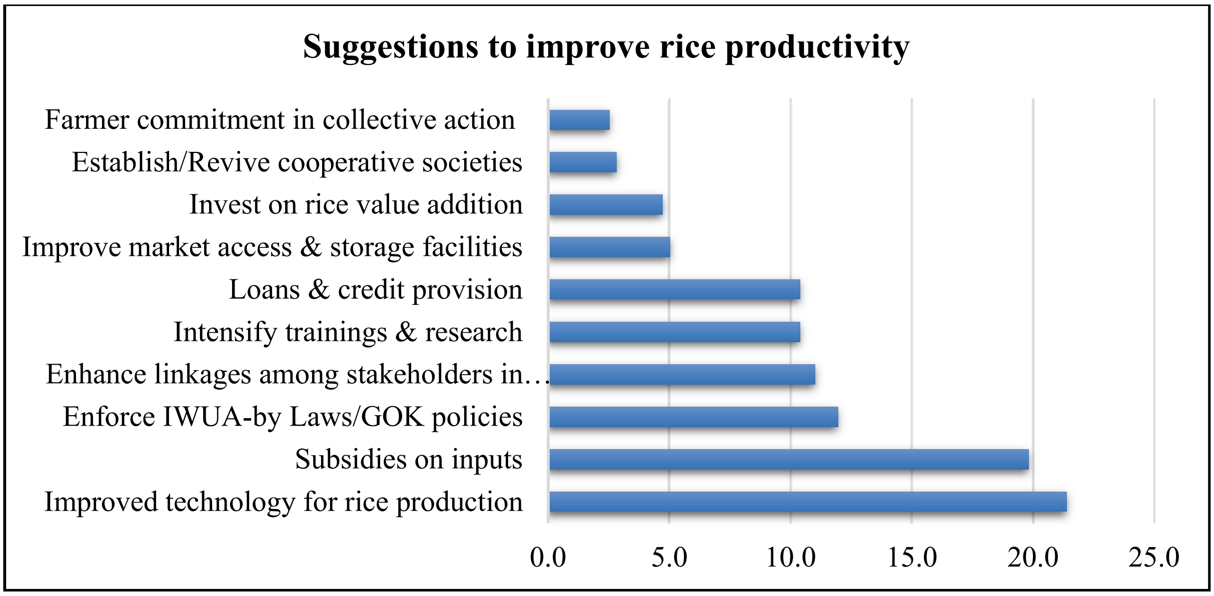

***Figure 17.* Suggestions to improve rice productivity**

Figure 17 shows that two suggestions are significant for improving rice productivity in Oluch. These are utilization of innovative technologies (21%) in rice production and provision of government subsidies to smallholder farmers (19.8%). Other suggestions were strengthening networks among actors in the rice value chain, provision of loans and credits, intensifying trainings through extension service, and enforcing existing policies established by the local farmer association IWUA and the government through the MOALF. As primary actors in the chain, the farmers suggested intensification of trainings and research activities. Additionally, farmers highlighted the need to consider investment on rice value addition, reviving Maugo farmers' co-operatives society, and improvement of farmer commitment through collective action while focusing on youth farmers. It suffices however, the variety of suggestions, stakeholders, and approaches to be involved to address the suggestions to improve rice productivity underpin the need for leveraging on multi-stakeholder networking to adopt the SRI and effectively address/unlock the path to improved rice productivity.

4.3.4 Farmers' level of confidence in applying SRI practices at baseline

The smallholder rice farmers were asked to state their confidence levels in applying the SRI practices with specific emphasis on transplanting young healthy seedlings, plant spacing, planting seedlings on a hill, watering regime, weeding, manure or fertilizer application, and harvesting. The confidence of farmers as primary stakeholders in undertaking these various agronomic practices was key even before introduction of a proposed and better alternative system of rice intensification (Uphoff, 2003). Data was collected using a survey, FGDs and observations. The results would provide a basis for comparison to rate farmers' level of confidence in performing SRI practices after the IP- intervention. Likert scale of 1–5 levels of confidence was used to analyse the information. The results obtained from these processes are presented in Figure 18: Farmer confidence levels in rice production practices.

Figure 18: **Farmer confidence levels in rice production practices**

Efficient rice productivity involved effective implementation of a combination of various rice agronomic practices.

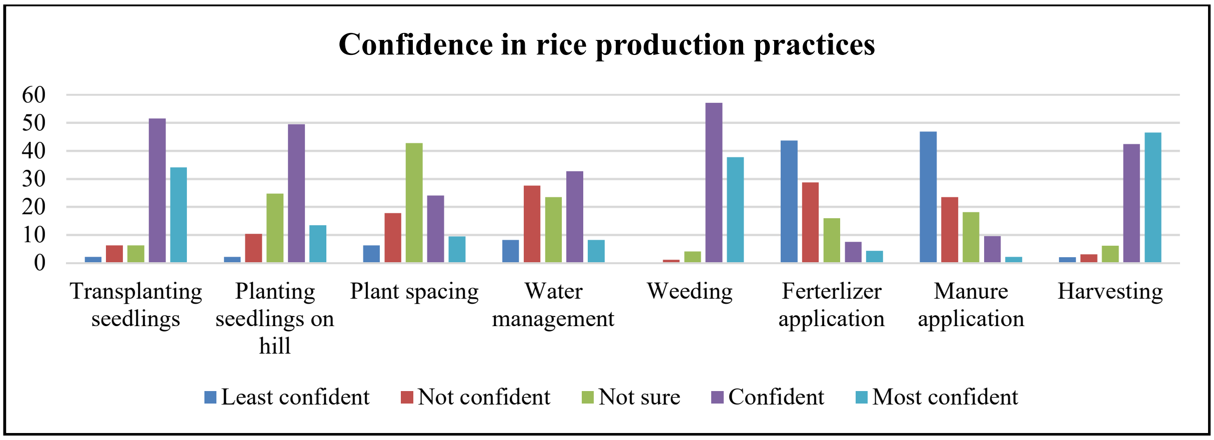

Figure 18: **Farmer confidence levels in rice production practices**

From the findings in ***Figure 18*** farmers expressed confidence about rice harvesting (46.5%), weeding (37.8%) followed by transplanting of seedlings (34%). In each of these instances, more than 75 percent of the respondents expressed confidence in these rice agronomic practices. Farmers were relatively confident on their ability to plant seedlings on a hill, about half (49%) indicating they were confident in this practice. On the other hand, farmers expressed least confidence in fertilizer and manure application, more than half were either least confident or not confident at all. About 42 percent of the farmers were not sure of their ability to effectively achieve the recommended plant spacing as a rice agronomic practice with at least one in every four respondents either not confident or least confident about this practice. While conventional rice production practiced by most farmers is highly reliant on a continuous supply of water for production, more than half of the respondents (59%) were either not sure, least confident, or not confident about requisite water management practices, only slightly above a one-third (41%) expressed confidence in water management practices.

The analyses of variables at baseline revealed that smallholder farmers had a mix of challenges which hampered uptake of SRI technology. To overcome the challenges, the study opted to form a system-based IP approach with farmers at the centre of research intervention. The subsequent section details the IP formation and intervention processes for the uptake of SRI to spur rice productivity in the Oluch Scheme.

4.4 Establishment of Innovation Platform for SRI Uptake

The third objective of the study was to establish an Innovation Platform (IP) to facilitate SRI uptake in Oluch Irrigation Scheme. As stated in the definition of terms, an innovation platform is essentially a space for learning, to implement change and to support the scaling-out and scaling-up of solutions (Makini *et al*., 2013; A. Van Rooyen *et al*., 2007). According to Leeuwis (2013), innovation system framework proposes that on their own, farmers cannot drive technological change but are dependent on a network of actors. Consequently, technological change requires changes in the broader environment involving the network. Thus, alignment of technological change with associated institutional changes is necessary to facilitate the innovation process (Llewellyn *et al*., 2020; Sanginga *et al*., 2009). Members of the IP participated actively and committed to a common cause and perceived the process as their own. (Makini *et al*., 2013).

4.4.1 Theoretical perspective of the innovation platform

Existing literature provides evidence that the use of a facilitated IP can support learning for the uptake and adaptation of the technology. According to Schut *et al.* (2018) and Swaans *et al.*

(2013) the challenges associated with the broader development objectives cannot be addressed through actions taken in isolation by a single sector/stakeholder, or without regard to interacting forces and competing demands, with a strong focus on systems perspective. In the same vein, Neely *et al.* (2015) asserted that inclusivity, contextualization, and importance of local dynamics should be embodied to ensure sustainability of agricultural interventions. Different interventions are context specific and therefore should be promoted within the existing socio-economic and environmental settings. The IP approach has three basic processes/dimensions which distinguish it from other approaches including i) soft transfer; ii) co-creation; and iii) community-based research. The three processes/dimensions are:

Soft-transfer **process:** Research has readily available results that can help solve jointly identified problems by marrying the linear logic of innovation into systems thinking through interactions, and enable researcher move away from the linear Transfer–of-Technology (ToT) model to interacting with technology end users (Paulre, 2004).

Co-creation: integrates scientific and tacit knowledge and occurs after inception of IP when a researcher develops objectives and protocols jointly with the platform participants (Kilelu *et al*., 2013; Nederlof *et al*., 2011; Schut *et al*., 2016; Wielinga *et al*., 2009). The time lapse allowed researcher to understand the context and the demand and gain the trust of stakeholders. This process is based on the researcher's and IP participants' capacity to comprehend the problems and draw solutions collectively. This process may have a self-reinforcing effect of co-creating other ones. Role of IP facilitator is critical in this process.

Community*:* empowered and capability built to conduct their own experimentations which could be endorsed or improved by researchers. Here the focus is on social structures. Such concepts emphasize the primary role of communities within innovation processes including positive deviant; endogenous and social innovation and servers (server - casual labourer in this study) as foundation for sustainability and future learning (Bock, 2012; Pant *et al.*, 2009). Examples in this domain included strengthening IWUA structures and By-laws, endorsing indigenous technical knowledge (ITKs) such as use of wood ash for raising seedlings in nursery beds for quick germination and ease of uprooting during transplanting.

The IP approach focuses on the interaction between soft transfer, knowledge co-creation (domain) and social structures (community). Leeuwis (2002) and Batterink *et al.* (2010) noted that effectiveness of an IP approach to social learning depends on its strength in all the three processes. Oluch smallholder rice farmers were assessed along the three IP processes that suggest the actors may learn, adopt, share, and establish communal structure and knowledge specifically related to sustainable rice production. Analytical framework to study innovation platform functioning for SRI uptake approach is presented in Figure 19.

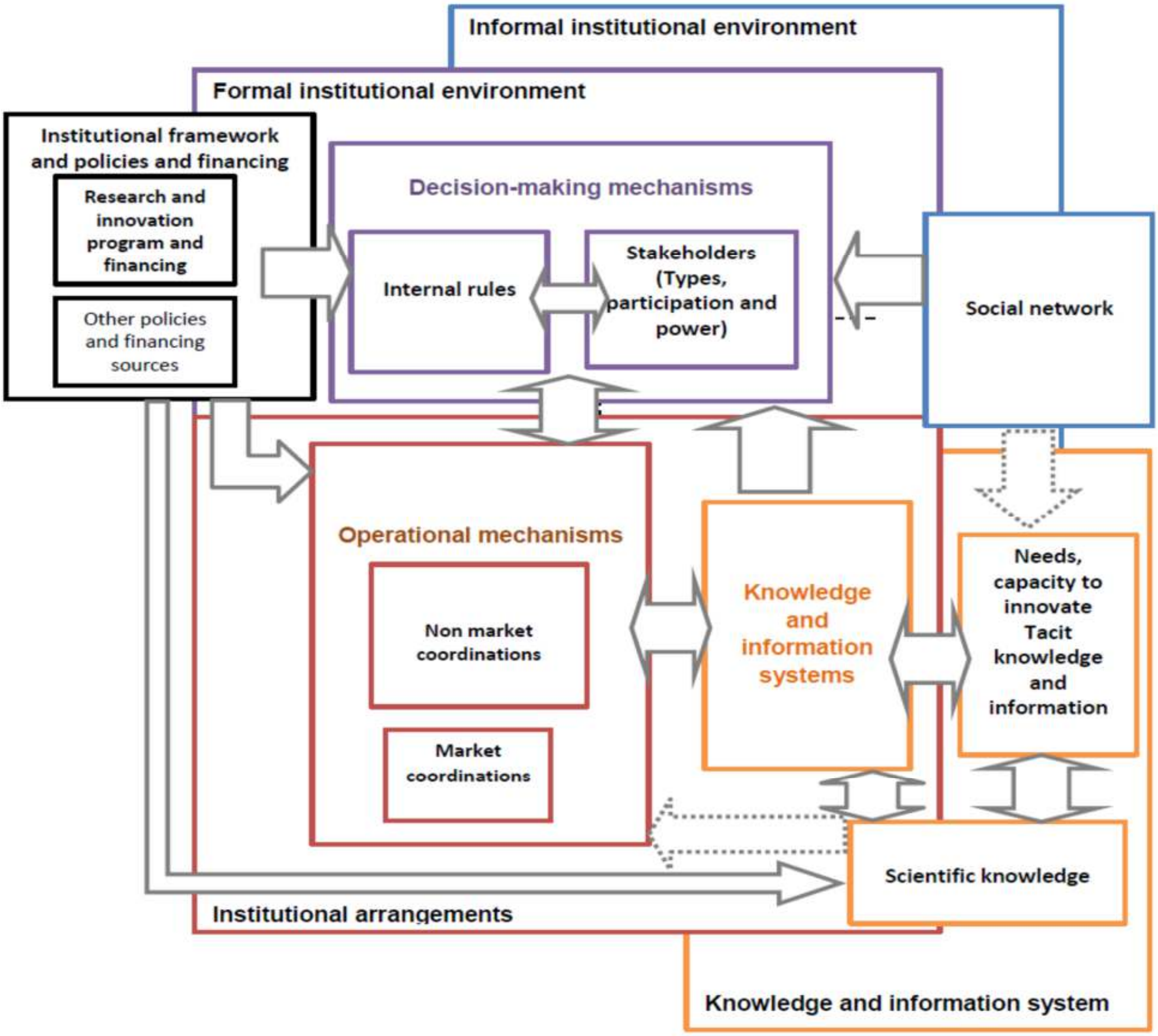

Figure 19. **Analytical framework to study innovation platform functioning.**

Source: Adapted from Mathé *et al.* (2016)

Beyond the formation of the IP, regular IP meetings were conducted with feedback on agreed actions and protocols. To ensure proper functioning of the IP, specific focus was placed on stakeholder participation, commitment, and ownership, information sharing and communication, use of the diversity of knowledge and skills, and reflection, capacity building, and resource mobilization. Members of the IP participated actively, demonstrated by their commitment to a common course hence evidence of perceiving the process as their own. It was observed that there was a continuous effort to ensure all the different actors were involved at all stages. Some institutions like MOAL&F alternative representations in the meeting which sometimes led to delays in making decision. These results emphasized that for IP to function well, there is need to have committed members who participate actively as depicted in Figure 19.

4.4.2 Identification of participants in the IP

Stakeholder analysis was conducted to determine the actors with significant influence on the success of SRI technology intervention in smallholder rice production in Oluch Irrigation Scheme. The study sought to know who is likely to be most affected by the intervention, and how to work with stakeholders with different levels of interest and influence. The analysis was iterative, and data triangulated through FGDs and KII to provide a complete view of the network boundary. The analysis revealed that each stakeholder had singular or cross-cutting roles that ranged from training, financing, production, Inputs, marketing, and others.

According to Prell *et al.* (2009), stakeholder analysis can be used to avoid inflaming conflicts, avoid marginalization of certain groups, and fairly represent diverse interests. This implies that the analysis helps identify which individuals and categories of stakeholders play more central roles in the networks and suggest strategies for inclusion of smallholder rice farmers as well as improve linkages between rice farmers and other value chain actors for increased rice productivity and incomes. The roles of stakeholders represented in the IP is as shown in Table 13.

Table 13: Stakeholders Participating in the Innovation Platform

Participant	Attributes	Interest
Smallholder rice farmers	Producers	Learning about SRI and rice production
KALRO, IFDC, Institutions of higher learning	Public research	Adaption of SRI practices to local context
County- extension and KOSFIP	Public extension	Promote SRI practices
LBDA, traders/vendors, private millers, transporters	Public and private output market and intermediaries	Purchase Processor
AfriTech, Baraka, Bayer Co. Agro-dealers, KFA	Public and private input market suppliers	Input supply
NIB/NIA, IWUA, Local Administration	Public policy By-Laws	Promote irrigation for agriculture
AFC, ROSKAS, Muungano Micro-credit society	Private credit institutions	Advance loans and credit to farmers
KOFDEG	Local NGO	Promotion of agriculture
PhD Fellow	Academic research	Interactive learning

Rice Producers were the primary actors largely represented by smallholder farmers and farmer organizations within Oluch. As producers, farmers formed the first link in the rice value chain whose major roles encompassed rice production, use of production resources and information exchange. The Research and Development community roles entailed provision of technical backstopping, assisting with analysis and identification of opportunities. Notably, a vast amount of information and experience was entrenched in these actors. Output market and market intermediary's stakeholders' roles included marketing and price determination based on supply and demand principles, transporting rice to different market outlets, supply of inputs, market information and linking farmers to support and service providers.

The local government administration (Chief) on their part was responsible for enacting both the national Laws including Agricultural Acts and the IWUA By-Laws. In most cases they are concerned with security matters and conflict resolution within the scheme. The local administration occasionally attended meetings as a development overseer on behalf of the

County government. Policy Enactors representatives articulate to the stakeholders the by-laws that govern irrigation water use and distribution in the scheme. Microfinance and credit offering institutions/organizations provided loans and credit to farmers and inputs suppliers. They trained farmers on credit and loan facilities guidelines in the presence of extension staff and local administrators as a security measure in case of defaults in loan/credit repayments. In some cases, they advanced credit to farmers through input suppliers and private millers and MOUs signed by relevant stakeholders including Sub-County Agricultural officers (SCAO) and Chiefs in the presence of authorized IWUA officials and extension staff, particularly the Sub-County Agribusiness Officer.

The study sought to characterize stakeholders measured by their roles and responsibilities. Each stakeholder stated roles/responsibilities they played in the IP for SRI uptake. Golder *et al.* (2005) emphasized that stakeholder analysis is important in identifying the interests of all stakeholders who may affect or be affected by a project potential conflicts or risks that could compromise the initiative; opportunities and relationships that could be formed by varied participating groups at different stages and strategies for stakeholder engagement. The results show that stakeholders had singular or cross-cutting roles. The summary of these roles and responsibilities are summarized and presented in Table 14.

Table 14: Stakeholder roles in the Innovation Platform

Stakeholder	Attribute	Interest	Resources	Roles
Farmers	Smallholder rice farmers, Primary decision makers	Production of rice	Farm Inputs Farm Labour Land	Application of SRI practices, Knowledge dissemination and Implementation of IWUA-By-Laws
IWUA	Umbrella body for all registered farmers for irrigation water use.	Decision-making, Water management Maintenance of canals. Sourcing for markets, Linkages Revenue collection.	Contributes to drafting By-Laws, Management of IWUA-Building Office and equipment Decision making	Enforcing By-Laws Information sourcing Collaborative activities
KOSFIP	Decision making	Kimira-Oluch Smallholder Farm Improvement Project implementer Decision making Technical Advisor Key linkage provision	Drafting By-Laws Technical Capacity Data sources Financial Input	Irrigation facility IWUA-By-Laws Training Input provision Soil Testing Market Linkage
MOAL&F	Key stakeholder	Extension service provider	Data source, Technical capacity	Dissemination of SRI technology & other extension messages

Stakeholder	Attribute	Interest	Resources	Roles
KALRO-Kibos (Research)	Key stakeholder	Research activities Certified seed, Fertilizers	Technical capacity	Testing of on-farm SRI management practices
Input suppliers: (AfriTech, Baraka, Bayer, Agro-vets, KFA	Facilitators	Sale of assorted farm Inputs	Farm Inputs	Supply of appropriate assorted Inputs (Certified rice seed, Fertilizers, pesticides).
Local Leaders Administration, Chiefs/MCA	Decision makers and Facilitators	Community mobilization and Security	Enforcement of IWUA-By-Laws	Provision of enabling environment.
Local Leaders Administration, Chiefs/MCA	Decision makers and Facilitators	Community mobilization and Security	Enforcement of IWUA-By-Laws	Provision of enabling environment.
Nyabon Machineries	Key stakeholder	Mechanization of rice production	Farm equipment	Provision of farm machinery
National Irrigation Authority (Former NIB)	Policy issues	Policy on irrigation water resources & usage	Advice on policy	Policy
IFDC, Egerton, JKUAT,	Partner Research activities	Training Technology dissemination	Technical capacity Data source	Testing of SRI practices on demo plot
Crop Nuts	Consultant	Training	Market information	Access to market information, linkage

Stakeholder	Attribute	Interest	Resources	Roles
Maugo Co-operative Society (** Inactive)	Local Stakeholder Farmer Co-operative	Storage and Value addition equipment Collective purchase of farm Inputs Access information, loans & credit Collective marketing	Organize trainings Employment Processing	Milling/Processing Access to Inputs
Rice Transporters	Facilitator	Transport rice produce from farms to homes/stores, and from Mills to the Market	Means of transport	Accessing the markets beyond farm gate.
Rice millers: -LBDA and -Private millers	Facilitator	Value addition	Storage and Milling facility Market linkage	Processing, Buying paddy rice, and Market access
Rice Traders	Facilitator	Purchase and sale of rice Market information	Market places and Cash income	Provide market and link producers to institutions and consumers.
Financial/Micro-Credit Institutions - AFC/KFA - Muungano Micro-credit	Facilitator	Access to financial information	Provision of loans	Loans and Credit

The roles exhibited in Table 14 highlights what the stakeholders do through collaboration, interactions, mobilizing and pooling of resources to give support in form of inputs and services, research, guiding policies and by-laws governing scheme operations and maintenance. The collaboration provided an enabling environment for each stakeholder to maximise their potential to achieve the intended objectives.

4.4.3 Inaugural workshop for IP Process

Two inaugural workshops were organized for all the stakeholders to discuss and draw solutions for the challenges limiting SRI uptake in Oluch. The first inaugural workshop was organized to share the baseline findings with stakeholders identified at baseline including: smallholder rice farmers, extension service providers, researchers, private millers/processors, NGOs, farmer organization (IWUA), KOSFIP, Input and output market suppliers, traders, local administration, and private investors active in the scheme. The results of the workshop revealed more challenges, opportunities and more stakeholders were re-identified and invited to participate in the second stakeholder workshop after a fortnight.

The second stakeholder workshop initiated a dialogue process to clarify the different viewpoints, bring evidence to scheme framing strategies and create synergies with locally determined contribution actions. All the workshop participants agreed that improving interaction between farmers and other stakeholders in the innovation platform would heighten the uptake of SRI practices in Oluch. Almost all participants (95%) accented to the need for interaction among the stakeholders in the IP. This agrees with baseline findings that forming an Innovation Platform would greatly facilitate the uptake of SRI practices.

Plate 4 shows the workshop participants at a stakeholder role identification and action planning inaugural meeting at Oluch irrigation scheme.

Plate 4: Stakeholder role identification and action planning for IP formation
Photo by John Serem on 16/11/2018.

4.4.4 Levels of Stakeholders' Participation in the Innovation Platform

The degree of participation by each stakeholder was assessed. The degree of participation may influence the uptake of the intervention technology relative to support given by each stakeholder. Data was collected through survey, FGDs, KIIs and observations. This was measured as a core, active, occasional, peripheral and transactional participant. The stakeholders' participation levels are represented in Figure 19.

Core or primary group consisted of the 24 IP farmer participants; farm Input suppliers, market consumers. The active value chain supporters included extension service providers (MOAL&F), research organizations - KALRO, International Rice Research Institute (IRRI-representative), institutions of higher learning (Egerton, JKUAT, Tom Mboya) financial service providers and NGOs (KOFDEG). Value chain enablers at the Macro-level who are occasional or peripheral participants were mainly policy makers, sponsors, and regulators. The study observed transactional stakeholders linked to the IP indirectly through members of the IP. They broadly included sponsors, supporters, clients such as traders from other areas, and outsiders from other schemes with vested interests.

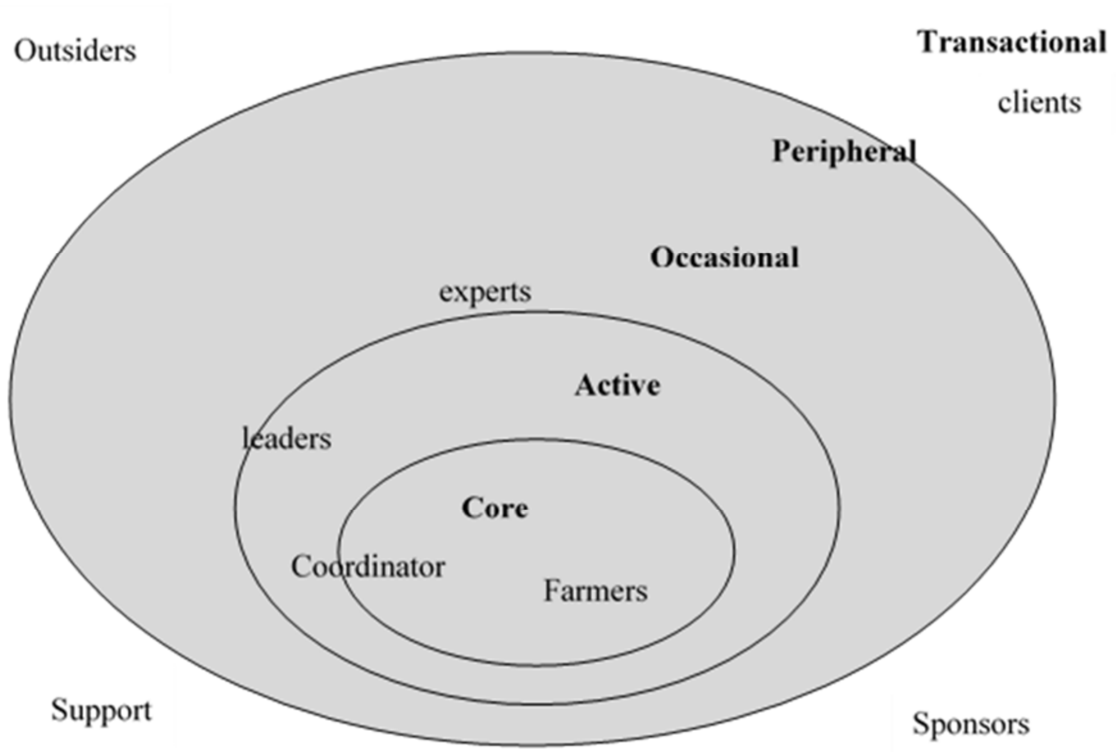

Figure 19: **Levels of Stakeholders' Participation in the Innovation Platform**

The core, active and occasional participants comprised research and development community. The study also observed that there was limited capacity to respond to constraints that are of institutional nature cutting across the value chain. To fill such gap, new partnerships needed to be established and the proportion of Research & Development actors with expertise in these institutional domains was increased. In Oluch, for example, the IP partnered with National Rice Promotion Unit (NRPU) to cater for specific rice policy needs of the Innovation Platform.

The current study established that application of the New Institutional Economic (NIE) based analytical framework led to a better understanding of IP participants' involvement in the different components and allowed the identification of disturbing and unbalanced situations within the platform that could reduce its performance. However, each component and the influence it wields can change depending on the context, the phase of the Innovation Platform and the function emphasized (Wielinga *et al*., 2009).

Participatory action learning empowers groups to collect, analyse and use information to improve their lives and gain more control over decisions which affect them (Mayoux, 2005). As it was expected, the study outcome confirmed improved information through action learning which enhanced smallholder rice farmers' capacity, and thereby increased their bargaining power and ability to influence decision making processes for sustained production and productivity. Action learning process generated new questions and insights and explored opportunities to the present situation (Pedler *et al.,* 2008). The participants of action learning receive guidance from researchers to structure their experiences in rice production. This helped them to describe and label the SRI innovation in their context and realized that they were not alone in experimenting it. All stakeholders came together in an innovation platform to network and innovate in an action learning process to build capacities of smallholder rice farmers and provide support to enhance rice productivity in Oluch Irrigation Scheme.

4.4.5 Timeline activities and outcomes of stakeholders in the IP

Activities of stakeholders and functions of the IP were based on a timeline which ranged from 2017 to 2019 as shown in Figure 20. Existing literature points to a conjecture that the use of a facilitated IP can support learning for the uptake and adaptation of the technology. According to Schut *et al.* (2018) and Swaans *et al.* (2013) the challenges associated with the broader development objectives cannot be addressed through actions taken in isolation by a single sector/stakeholder, or without regard to interacting forces and competing demands, with a strong focus on systems perspective. In the same vein, Neely *et al.* (2015) asserted that inclusivity, contextualization, and importance of local dynamics should be embodied to ensure sustainability of agricultural interventions. Different interventions are context specific and therefore should be promoted within the existing socio-economic and environmental settings.

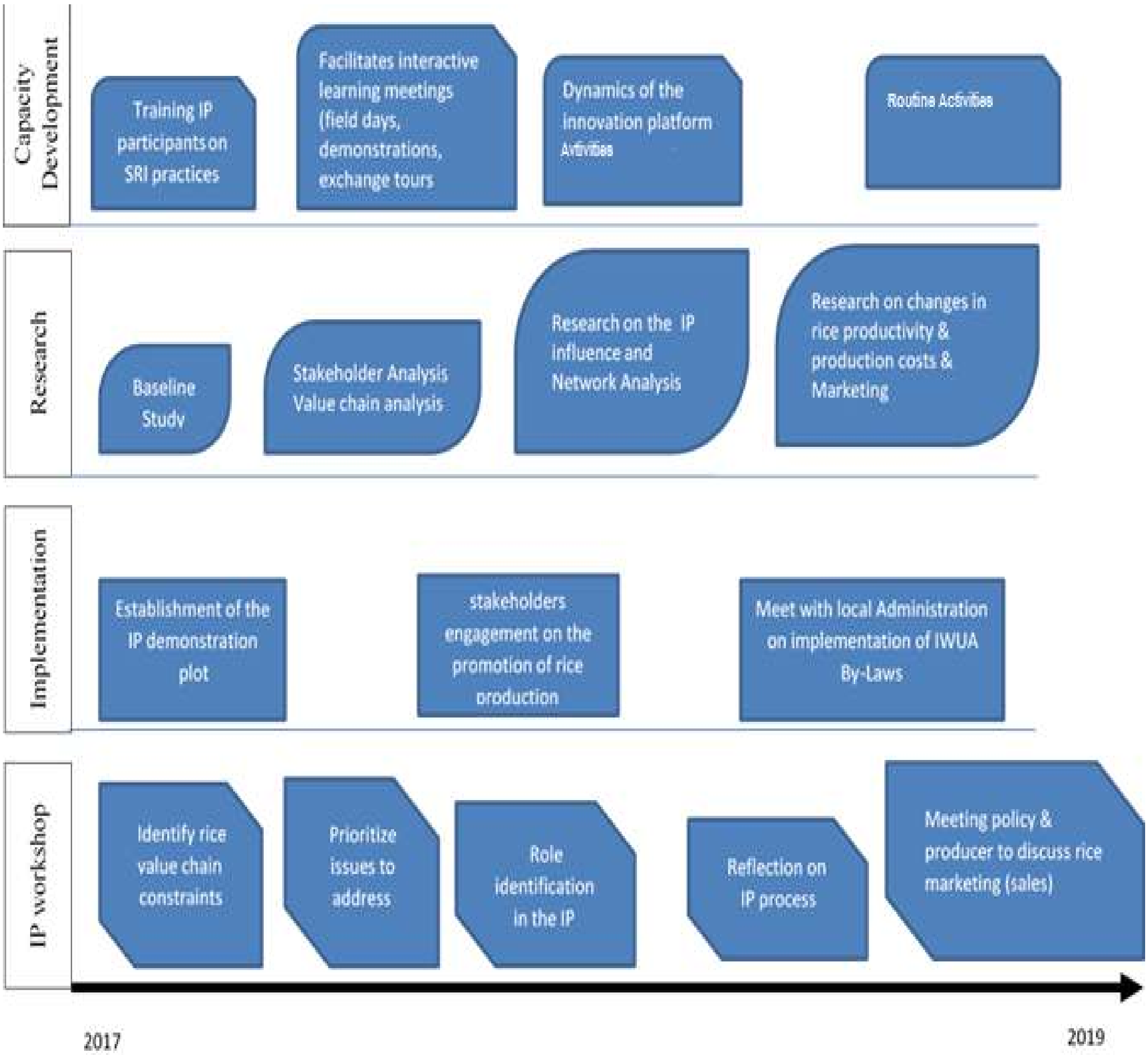

Figure 20. **Timeline of IP activities, key issues discussed and resulting activities (IP workshop implementation, research, and capacity building)**

4.4.5.1 Identification of Innovation Platform demonstration plot

Block BL 1: was unanimously selected for establishment of the IP demonstration plot by farmers and other workshop participants. Its suitability was based on the following criteria: ease of accessibility by farmers from other sampled study blocks, its geographical positioning including close proximity to the main Homabay-Kendu-Bay-Kisumu highway, Oluch irrigation water user's association (OL-IWUA) building for hosting IP forums and a nearby Nyangweso market. Above all, the participants expressed willingness and commitment to collaborate, learn and share information to bring about change. According to Makini *et al.* (2013) the IP site selection should be in response to the need to alleviate the impacts of a certain constraint in a given area or utilization of an existing or emerging opportunity.

4.4.5.2 Learning activities in the Innovation Platform

The IP network facilitated knowledge generation and sharing for SRI uptake, monitoring and evaluation of the innovation process. The action learning process was guided by the researcher in order to improve smallholders' innovative capacities for uptake of SRI practices to boost rice productivity. The study observed joint learning, reflection, experimentation, and adaptation. These phases were repeated other times occurred simultaneously through active collaboration of researcher and smallholder rice farmers, while stressing on co-learning as a key aspect of the research process. The IP facilitated interactive communication, learning and network and promoted joint action among the stakeholders. Participants followed an iterative process and met frequently. Sharing of various resources, explicit and intrinsic knowledge and strengthened networks hastened the rate of innovation. The IP activities that facilitated uptake were achieved through sharing of experiences and innovations through organizing and conducting of demonstrations (Plate 5); farmer exchange tours or cross-visits between communities producing rice (Plate 6), Farmer Field Days and Barazas (Plate 7), interactive meetings and workshops as already indicated in Figure 20.

The action learning process used for uptake of SRI practices comprised five key stages with minor changes of stakeholders' participation at each stage which included: seed bed nursery establishment and management, main field preparation; water management, transplanting, weeding; harvesting, primary processing (including harvesting, threshing, airing, and drying) and marketing. These activities followed the Innovation System's organizing principle as indicated in Figure 21.

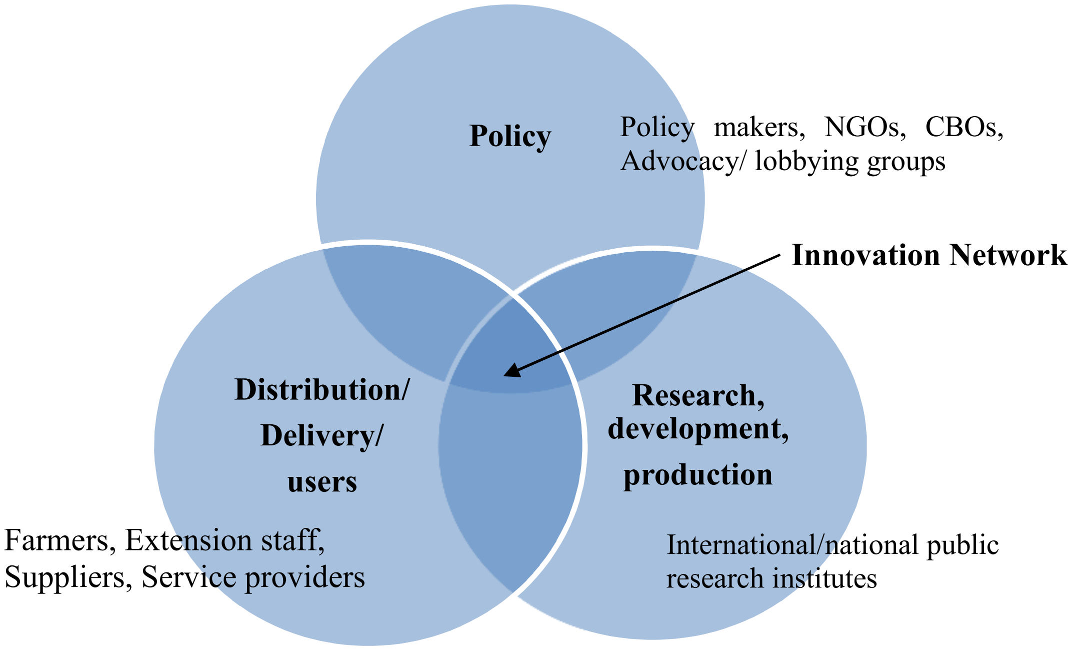

Figure 21. **Innovation System's Organizing principle**

As already mentioned earlier, several learning activities were conducted in the IP during the research period aimed at building innovative capacities of stakeholders for SRI uptake. Actors from the same domain tend to trust each other more and to have a common focus (Makini *et al*., 2013). Across the SRI network, actors who offer support services such as input suppliers, extension, financial institutions, processors and the 'positive deviants' were key in disseminating information about SRI and providing market and credit services for those interested in adopting the technology. This situation had critical implications for the functionality of the SRI network as well as uptake of the SRI practices within Oluch scheme and beyond.

Following the establishment of the innovation platform, various learning activities were commenced, including field preparation for SRI planting; information gathering and sharing; understanding the benefits of SRI, sharing policy considerations, and learning of relevant technologies such as mechanical harvesting and baling of rice stovers (see plates 5-9).

Plate 5: Demonstration on the use of a hand-push paddy weeder at planting in the scheme Photo by William Orodo on 23/03/2018.

Field preparation is demonstrated by Plate 5 where farmers were taught and gathered knowledge on how to do spacing and planting. Right spacing at planting is critical for ease of mechanization at the time of weeding based on Push-weeder specifications. Hands-on learning is considered critical for knowledge acquisition and retention for immediate and later use by learners.

Plate 6. IP Farmer Participant and Block Leader explaining the Benefits of SRI.
Photo by John Serem on 5/09/2018.

Plate *6* shows knowledge and information gathering and exchange during a field day hosted by IP participant and Block leader on SRI plot. The results corroborate with the findings of Murage *et al.* (2019) that field days are an important and effective approach to delivery of information channel about a new technology to majority of farmers within a short time possible and without further field demonstrations. Farmers' participation and interaction in Field days offers a good avenue for interactive learning, knowledge accumulation and subsequent information sharing.

Plate 7. Extension expert addressing Concerns raised about SRI during Rice Field Day at a Baraza Meeting.
Photo by John Serem on 5/09/2018.

Plate 7 further helps to emphasize and clarify information gathered by farmers through questions and answer session during Baraza. Different stakeholders who participated in the field day responded to concerns raised by farmers. Other policy issues were channelled by MOAL&F and local administration to the relevant Government officers and stakeholders.

Plate 8. Mechanized harvesting of rice and baling of stoves
Photo by Matilda Ouma on 20/9/2019.

Plate 8 shows mechanized rice harvesting and gathering of stovers. Harvesters were availed by Nyabon Machineries (stakeholder) as service hire on negotited terms. Farmers had a hands-on experience of using the the machines. The Plate illustrates farmer participation in the harvesting process.

Plate 9. Rice Farmers' Field Tour at Bunyala Rice Irrigation Scheme
Photo by Matilda Ouma on 20/9/2019.

Plate 9 shows rice Farmers' Field Tour at Bunyala Rice Irrigation Scheme for information exchange and learning of specific rice farming activities including land preparation, spacing, and planting, establishing cropping calendar, water management regime and aspects of Co-operative Society with respect to marketing.

4.4.5.3 Outcomes of learning in the IP

The Innovation Platform for facilitating uptake of SRI resulted in the following outcomes. Changes in knowledge and technology use; enhanced stakeholder networking, collaboration and joint extension; acquisition of standards for certification for marketing; synchrony of cropping calendar, growth in networks, expanded access to rice market and opportunities for employment as discussed in the subsequent sections.

Observations of activities in the IP after intervention revealed changes in knowledge and technology use. Bringing on board all relevant rice value chain stakeholders from the start of the research process created a multi-stakeholder forum which ensured optimal knowledge integration, mutual learning processes and appropriate approaches for dissemination of SRI. Knowledge, skills, and ideas gained enabled farmers to navigate through the social and economic challenges encountered through innovative decisions and support from other IP stakeholders. In addition, the IP created an improved learning experience for stakeholders which fosters the development of critical thinking and problem-solving skills; and allows for practical learning, application of knowledge and adopting results in practice.

Through partnerships, it emerged that there was joint extension by farmers, extension staff and private organizations. Using participatory and innovative network-building techniques, the IP stakeholders collectively identified problems and designed solutions to strengthen the knowledge system driven by in-platform expertise and motivation; create opportunities for meaningful dialogue and develop understanding between different actors to facilitate change by building peer networks and connecting partners to help them support each other through training, attending events and sharing experiences. A similar observation was made by Eastwood *et al.* (2017) that complex agricultural innovations (such as SRI) require a collaborative approach for successful innovation and diffusion; and that the need for, and type of, collaboration differs across scales from farm-level (individual learning) to national and global level with issues of skill training and service provider capability (Eastwood *et al.,* 2017). Additionally, public, and private research and extension organizations can work together; however, there are areas where it makes more sense for one party or the other to lead. For SRI farming system, the roles for public extension involved leadership, development of training programmes including support of initiatives such as farmer common interest groups (CIGs) and integration of technology. Among other extension initiatives, IP programmes have been reported as the most successful in facilitating the adoption of innovative technologies, maintaining that they have been successful in changing farmers' attitudes and behaviours. Improved farmers' collaboration and linking farmers, researchers, and extension agents to each other for acquisition of relevant information inputs subsequently led to promoted yields for higher incomes (Makini *et al.,* 2013).

Acquisition of standards for certification for marketing was an outcome that resulted through technical assistance given to farmers participating in the IP. Certification is a critical challenge for smallholder farmers in many developing countries(Soltani *et al.,* 2014). Both national and international certification bodies are extremely expensive for an individual farmer. The IP proposed and established a group certification system as an alternative way, in which farmers' groups consisting of several small-scale producers were co-certified as a unit. The IP stakeholders with national and supra consortia partnerships facilitated affordable access to relevant legal documents and inputs which led them to acquire standards for certification for marketing the scheme produce. The partners in different capacities negotiate with manufacturers and processors to provide smallholder farmers with the inputs they need at affordable prices. This approach supports actors across the evidence and policy systems to understand and address key challenges to SRI technology uptake by building skills and confidence of stakeholders from different disciplines to collaborate with other stakeholders including community, practitioners, policy makers and private sector. Additionally, the technical assistance also enabled farmers to acquire inputs, obtain certification, and training to meet product quality and safety standards which are critical in marketing.

The study observed growth in networks among smallholder rice farmers and other stakeholders for knowledge and empowerment, information exchange and marketing, input access and regulatory and policy issues. Individually, farmers could not effectively participate, thus making it necessary to engage in networks. Innovation platform participants used social networks to access services, reduce risks and acquire information to lower transaction costs/ Stakeholders such as processors entered into production contracts, which sometimes included the supply of inputs, credit, and extension services. Improved coordination and collective decisions along with changes in knowledge acquired through action learning such as scheme routine operations and maintenance.

Synchrony of cropping calendar was promoted in most blocks as a basis for improved abiotic and biotic stresses including pest management particularly the destructive Quelea birds. Synchronized cropping was supported and promoted by IP participants as a key copying strategy against the birds' menace. Synchronization of cropping was widely recognized as a necessary management action related to challenges encountered in rice production in Oluch Scheme. This agrees with findings from a previous review of agricultural research issues raised by the system of rice intensification that combining strategic and on-farm participatory (adaptive) approaches that explore and link bio-physical and socio-economic factors in crop production would permit to unlock currently untapped production potentials of rice crop without extra costs to resource-poor farmers or to the environment (Stoop *et al.*, 2002).

The was substantial improvement in irrigation water management as farmers acquired knowledge on intermittent watering where about 65% of the farmers acknowledged reduction in conflict due to illegal water abstraction and reduction in labour costs due to synchronized mechanized operations such as harvesting. Strengthening interactions through action learning promoted networks that built capabilities for rice productivity.

Other IP related outcomes included the emergence of farmer-to-farmer support system. Some individual IP farmer participants took their time to become innovation champions outside the IP process. Farmer-Farmer extension is a well-known theoretical concept in extension domain and the fact that it is emerging in the Scheme, the extension system (public and private) realizes its emergence as beneficial. These champions worked as boundary spanners, specifically to initiate stakeholder interactions with other non-IP participants in spite of the lack of enabling environment to do so. The resultant high demand for SRI technology in the neighbouring Kimira scheme was attributed to the action of these champions. This outcome agrees with previous observations by Kilelu *et al.* (2013) who note that it is increasingly becoming popular to include 'innovation Champions' within the IP who can either be appointed or emerge more informally.

Moreover, this study observed the emergence positive deviants such as 'SRI brokers' who presented a strategic opportunity for scaling SRI technology in the scheme. Pant *et al.* (2009) in a previous study observed that positive deviants have ingenuity to innovate and deviate from norms particularly when social and organizational environments limit stakeholder interaction for learning and innovation within a platform. Consequently, the collective intelligence of positive deviants can sustain or even stimulate innovation permitting people to experiment new ways of doing things and improve their livelihoods. The exposure and recognition received by such farmers as 'SRI brokers' motivated them and other smallholder farmers for better performance and awards. Acting as role models in the community and farmer organizations such as IWUA and Co-operatives, the 'SRI brokers' were resourceful in organizing and hosting farmer field days and participating in farmer exchange tours. This observation extends previous notion that learning is prerequisite for successful innovations (Kristjanson *et al*., 2009).

Following demonstrations in the IP plots in the first season, there was increased demand for push-weeders among local farmers. This provided an opportunity for local artisans, at the local Nyangweso market to collaborate and innovate to fabricate new machines at affordable costs to promote mechanization of rice farming in Oluch Scheme (see Plate 10).

Plate 10: Local 'Jua-Kali' Artisan fabricating push-weeder (A). Artisan receiving advise from experienced SRI farmers how to modify the push-weeder blades (B)
Photo by Matilda Ouma on 8/03/2018.

The fabrication of simple manual push-weeders by local 'Jua-Kali' artisans demonstrated improvisational and innovative capacities to deal with the technological change. Artisans benefited from new knowledge to diversify their entrepreneurship and increased incomes through networking with innovation platform farmer participants. This contributed to transforming employability for social change in the scheme thus helping youth farmers in

Oluch scheme to use their skills and ideas to tackle social and economic problems to improve quality of life and progress towards sustainable development goals (SDGs). According to Silvia (2010), such opportunities for youth participation within the community is vital to keeping young people in rural areas for gainful employment and secure livelihoods which are vital factors for the inclusion of young people in society.

Baling rice stoves emerged as an important economic activity in the scheme especially by women and youth. Most farmers either sold the by-products (bran, stoves) or used them as animal feed to provide nutritious, high-value animal fodder. This activity enabled farmers increase food and feed production and raises farm incomes. Stover had high cash value as livestock feed and farmers exploited their economic value relative to other uses such as organic manure. Plate 11 shows female youth farmers baling stoves after threshing for sale, and a dairy farmer collecting and stacking stoves in his van.

Plate 11: Baling of Rice Stover by Female Youth Farmers [A] and Farm Gate sales of Rice Stover for livestock stall feeding [B].
Photo by Matilda Ouma on 8/06/2018

Observational Results from the scheme showed the use of wood ash in raising seedlings gained prominence as some rice farmers used wood ash in the preparation of nursery bed. This promoted faster germination of seeds and ease of uprooting seedlings for transplanting. Such farmers claimed the seedlings take shorter duration in the nursery and they make good sales to other farmers who purchase seedlings.

The IP activities offered employment opportunities particularly for the youth who engage in rice agronomic activities such as machine weeding, Boda-Boda transportation. Designing and implementing youth training through face-to-face learning in how to use ‘push-weeders’ strengthens capacity development to meet skills need in rice production. Plate 12 shows youth farmers offering casual labour using locally fabricated push-weeders in the scheme.

Plate 12: Youth farmers offer casual labour using Push-weeders in the scheme
Photo by Matilda Ouma on 16/06/2019

Availability of irrigation water gave opportunity for diversification of crops which further contributes to food and nutrition security and incomes in the Oluch scheme. Other individual innovations were growing of arrow roots and vegetables and green maize by SRI farmers adjacent to the rice plots. The farmers innovatively made the best use of water drained from rice fields to optimize use of irrigation water to grow other crops and enhance natural resource management and ii) effectively make use of the time before the birds start damaging rice crop. Interaction and learning created knowledge hence promoting new methods of arrow root and vegetable farming aimed at maximizing the use of available water rich in nutrients from the rice plots. Plate 13 [A] shows extension Officers sourcing feedback from practice, as youth farmer narrated the benefits of integrating SRI Rice and arrow root farming. Plate 13 [B] on the other hand shows use of drained water for maize farming. The arrow root farming venture for instance was widely taken up by several farmers who benefitted in ways such as selling vegetative seed (suckers) and/or the harvested produce with other farmers in the scheme.

Plate 13: Use of drained water from rice to grow arrow roots and vegetables [A] and for green maize production in Oluch Scheme [B]
Photo by Zachary Odero on 28/07/2019.

4.5 Promoting SRI Uptake through Multi-Stakeholder Networks

The fourth objective sought to determine the multi-stakeholder network features that effectively promote SRI uptake in Oluch. In order to establish the network relationship among farmers and other stakeholder representatives in the IP, a questionnaire was shared among the 24 farmers in the IP together with the number of stakeholder basic network question (see Appendix E). The results of the network relationships as indicated by those involved are presented in Table 15.

Table 15: Strengths of networks among stakeholders

Number of observations		**Observations**	**Sum of observations**	**Average**	**Standard deviation**
Minimum	Maximum				
1	10	1639	5970	3.642	2.419

The total observations made in this networking was 1639 and the networking score ranged from one to ten (1-10). On average the strength of information sharing in this network was 3.6.

4.5.1 Stakeholder interaction analysis

In order to observe information sharing among the stakeholders, a network analysis for receiving and sending information was configured using the observations in the questionnaire. Figure 23 and Figure 24 illustrate this sending and receiving visualization arrangements based on their primary roles in the IP. The ties between any two stakeholders are weighted based on the degree of information sharing (either sending or receiving information) between them. In these network graphs, a classification of different stakeholders is undertaken to allow clearer visualizations of the key interactions within the platform. The three key stakeholder classifications are contextual for the purposes of this study and include: research institutions, input stockists or suppliers and support or service providers. The strongest ties are represented by a dark red line while weaker ties are represented by grey lines.

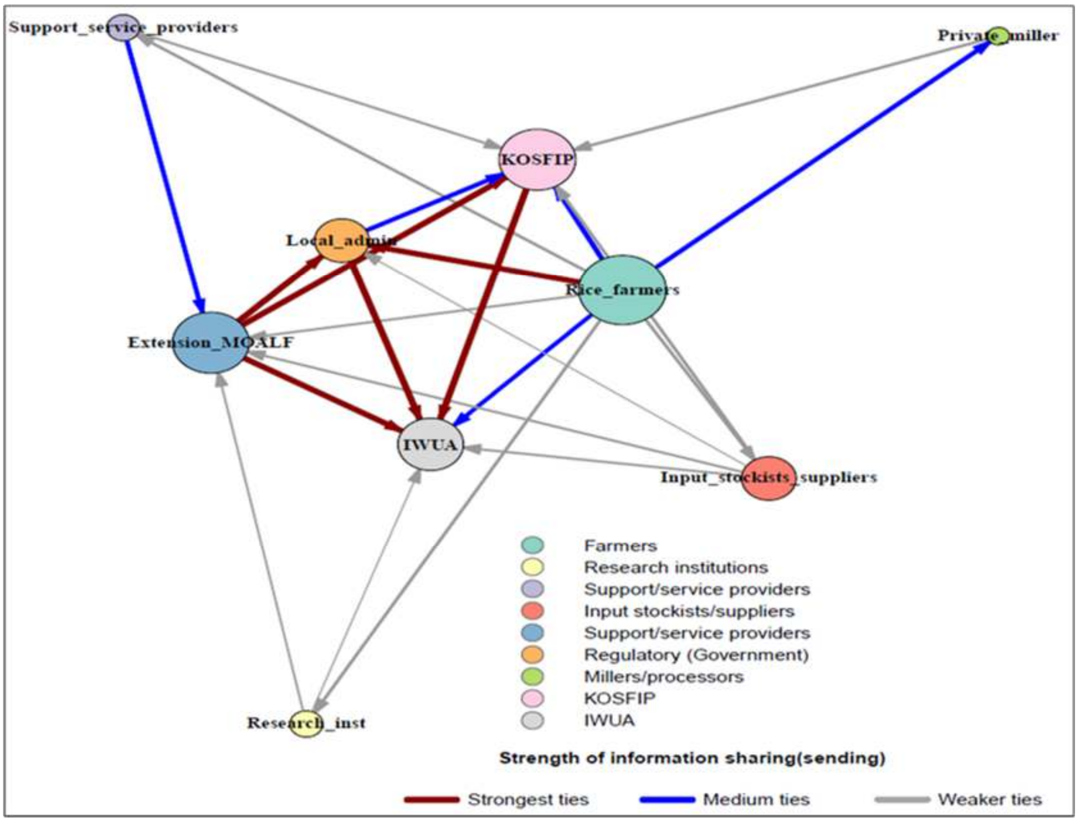

Figure 22: **Multi-stakeholder information sharing (sending) network on the innovation platform**

The network visualization findings in Figure 22 reveal that the strongest ties that depict sending of information between any two stakeholders exist between five key stakeholders, namely, IWUA, extension officers (MOALF), local administration, KOSFIP and rice farmers. This is shown by the proximity of these stakeholders to each other in the network and that the strongest links (thickest lines) in the network only exist between these five stakeholders. Even amongst the stakeholders, farmers, KOSFIP and MOAL&F emerge as the ones who have the highest number of links with other stakeholders in the IP. This observed variability in interactions among different stakeholders is not unique, and is common in agricultural innovation systems owing to their level of integration and the diversity of stakeholders' characteristics such as their motivation and capacity (Sartas *et al*., 2018).

The network map in Figure 23 depicting receiving of information between stakeholders equally shows closer proximity of five stakeholders including IWUA, extension officers (MOALF), local administration, KOSFIP and farmers. In this visualization, the strongest connections are between IWUA and extension officers, IWUA and KOSFIP, and KOSFIP and local administration. In terms of the strongest links between stakeholders, two stakeholders, IWUA and local administration, emerge as having the highest number of strong links with other stakeholders. Notably, for IWUA, these strong links denote strong information sharing with KOSFIP, local administration and MOALF extension officers.

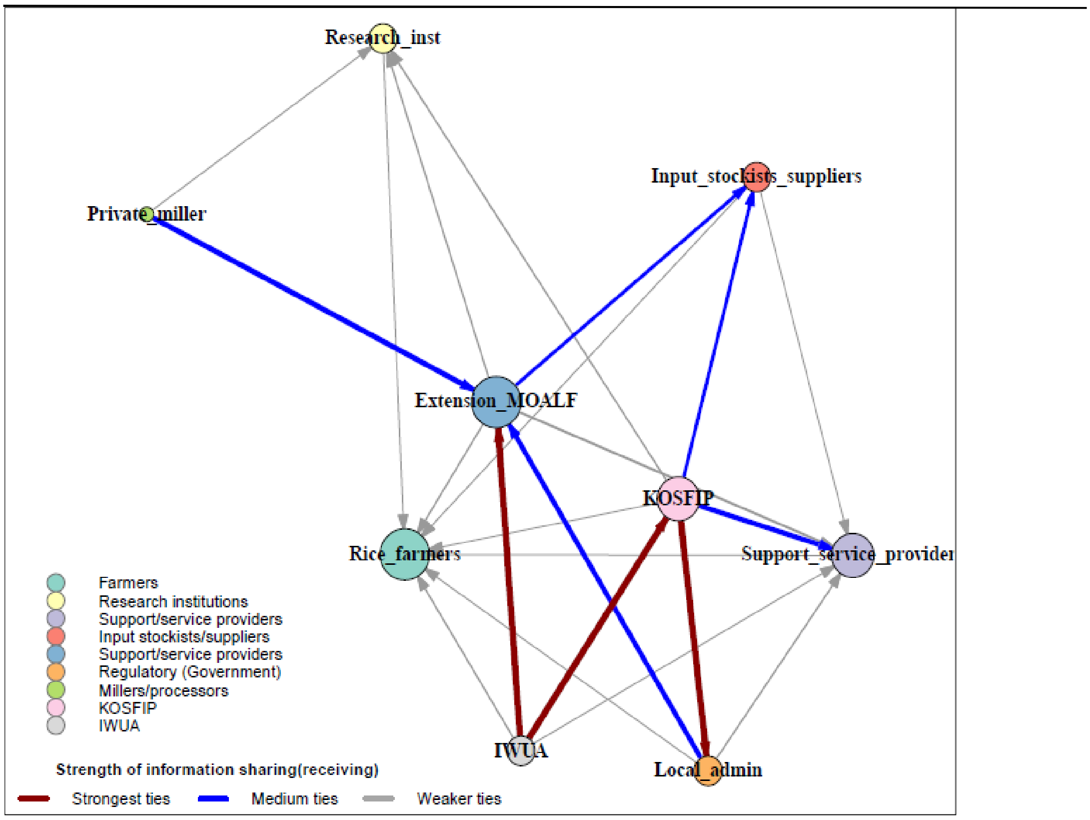

Figure 23. **Multi-stakeholder information sharing (receiving) network on the innovation platform**

The close proximity among a given set of stakeholders in the network maps above reveal the inherent level of integration of different stakeholders in the innovation platform. For instance, KOSFIP as the government implementer of the irrigation project, IWUA as an umbrella body of farmers and extension officers from the MOALF can be viewed as 'closer' to the farmers relative to others owing to their primary roles. In light of this, it is expected that there is greater information flow among these 'key' stakeholders as they are either i) a liaison between farmers and other stakeholders OR ii) the first point of contact for other stakeholders who want to reach farmers.

In terms of proximity to rice farmers, as measured by the level of information sharing among stakeholders, it is notable that extension officers, local administration, KOSFIP and IWUA had the closest connection with farmers. Other stakeholders including research institutions, support/service providers and millers/processors are the furthest in the network. This observation that they are further away from farmers indicates that they are brought aboard the platform by another stakeholder who has very strong direct links with the farmers or the umbrella body of farmers IWUA, for example, KOSFIP or extension officers. This is echoed by Spielman, Ekboir and Davis (2009) who underscore that integration into the multi-stakeholder innovation platforms happens through other stakeholders but depends on the connections among them (Spielman *et al.*, 2009).

On the other hand, it is plausible that motivation, anticipated outcomes, and actors that foster active stakeholder engagement varied between stakeholders and actuated different levels of engagement or influence the breadth and quality of information sharing. As established in this study, Mulema *et al.* (2015) in a previous study of five agricultural research and development multi-stakeholder innovation platforms in the Great Lakes Region of Africa, acknowledge different levels of participation among IP stakeholders. In their findings, they highlight that engagement with other stakeholders are driven by a host of factors including; limited understanding of the IP concept, lack of commitment, lack of resources and unfulfilled expectations of tangible immediate benefits (Mulema *et al.,* 2015).

Both input stockists/suppliers and support and service providers showed different information sharing mechanisms with other stakeholders as in the network map. This is unsurprising as these are a particularly heterogeneous subgroup of different stakeholders most of whom may receive information only from individual farmers or stakeholders. First, input stockists and support/service providers have mostly weak and moderate degree of information sharing with other stakeholders in the IP. This weak interaction is highly plausible as this umbrella classification of stakeholders in these two groups masked the strength of information sharing. Certain individual stakeholders send or receive more information relative to others within the same category whose involvement was minimal as shown in the descriptive statistical analysis. It is notable that support/service providers received more information from different stakeholders than they send while input suppliers have more links characterizing sending of information than are received. This scenario is expected for two reasons; i) for input suppliers, required inputs from farmers are commonly known to them, and often they seek to initiate more key links to enhance efficiency; ii) for service providers, for example microfinance institutions or LBDA, can offer a range of services, and their support services need to be tailored to meet the demands of farmers or other stakeholders and this relies on receiving a wealth of useful information from different sources.

The study findings reveal that information sharing between most stakeholders is either a weak bidirectional one, or at most only one of the links depicting sending or receiving of information is strong or of medium strength. Notably, the strongest bidirectional relationship between any two stakeholders on the IP is between IWUA and KOSFIP and IWUA and MOALF. This shows that IWUA is a central stakeholder in this IP and potentially explains why no strong connections between any stakeholders and farmers are observed as it is the umbrella body of farmers. Further, it is evident that there is consistent sending and receiving of information between these three stakeholders. This finding is explained by the fact that these three stakeholders are the primary link between farmers and all the other stakeholders in the network, information. This high-level feedback mechanism equally shows that strong links with any of these three stakeholders may facilitate better integration of all stakeholders in the IP.

Similar to both network maps is the weak degree of information sharing between most stakeholders, including a few key primary stakeholders. This is attributable to several reasons, but first that since IPs are an improvement over the pre-existing traditional and less inclusive agricultural research and extension approach, interactions between stakeholders are scalable and a weak interaction at a specific time-point is likely to change at the next evaluation time point. Besides, the IP is a social learning platform that brings together diverse actors throughout the value chain who may not previously have collaborated, and therefore weaker links may indicate potential synergies are still being or yet to be harnessed. For example, LBDA is a support/service provider that offers multiple services to farmers and stakeholders including access to markets, rice milling/processing, access to finance and their extensive involvement on this platform can realize benefit to multiple stakeholders. In addition, some stakeholders are only brought onboard by a specific primary stakeholder and depending on their motivation or expected benefits and the strength of relationship with this primary stakeholder, weaker relationships can be evident in their interaction with other stakeholders.

As anticipated, most stakeholders send information to farmers since the IP exists solely to facilitate SRI uptake and improve rice productivity within Oluch irrigation scheme. Besides, the analysis shows that farmers seem to be at the centre of the network in respect to other stakeholders. This is because farmers are the main actors and focus on the SRI Innovation Platform, they learn, decide, and act together. All the technocrats and businesspeople are facilitators of learning and are not in the IP all the time.

The findings further reveal that research institutions and private millers have the least amount of interaction with other stakeholders in the platform. However, this may be unsurprising owing to their position in the rice value chain and their role towards the uptake of SRI. For instance, they probably engage with most farmers through cooperative societies or the other actors in the platform. In addition, some service providers and millers/processors are only involved during harvesting and marketing of rice. Research institutions and private millers alongside input stockists/suppliers and support and service providers are mapped furthest from farmers relative to others whose involvement may only be minimal.

Overall, the network analysis is illustrative of what can be 'done' by mapping key interrelationships and who might be regarded as the most influential to the stakeholders whom they are sending information. Notably, most stakeholders receive information from each other, an evidence of increased interaction through the learning platform. Leeuwis (2013) and Roling (2002) argue that from the interaction, individual actors may develop shared or complementary goals, insights and interests moving towards more collective cognition. This implies that in action/social learning, interaction allows individuals with separate understanding of an issue to form overlapping or shared understanding. Within an IP, learners acquire not only knowledge and skills but also status and privileges that they can employ to the benefit of the IP. Many of these practices learnt are inherently technological involving materials, techniques, tools particularly in the case of agriculture. In this case, the biophysical conditions, materials, and tools available can enable or put limits to who can apply the SRI practices.

In order to (further) appreciate the process of information sharing among stakeholders, further statistical analyses were initiated. First, a frequency table depicting information sharing (sending and receiving) among all stakeholders was constructed. This sharing relationship is summarized and presented in Table 16.

Table 16: Summary of statistics for information sharing among stakeholders

	Sending information		Receiving information	
Stakeholder classification	Mean	SD	Mean	SD
Farmers (all)	7.0	1.7	2.8	1.3
Research institutions	2.6	1.0	4.3	2.5
Support/service providers	2.8	1.1	4.6	2.6
Input stockists/suppliers)	2.9	1.3	5.1	2.7

The results presented in Table 16 show that the highest degree of sending of information in the platform was to farmers. This is purely expected as all stakeholders in the platform send information directly or sometimes indirectly to the farmers. However, the degree of receiving information from farmers was still very low (mean = 2.8). In the platform, input stockists/suppliers send and receive more information on average relative to other stakeholders as indicated in Table 17.

Second, Likert scales ranging from 0 to 10 were constructed to depict sending and receiving information by stakeholders; and on the information sharing characteristics between farmers and stakeholders. Analysis of these scales using a t-test for differences in proportions was carried out and categorized into low, moderate, or high and results presented in Tables 17, 18 and 19.

Table 17: Farmer sending of information characteristics among stakeholders

Degree of sending information	Farmer to farmer (%)	Another stakeholder to farmer (%)	Overall	Test for difference in proportions
Low degree	81.2	1.2	33.5	Test statistic =
Moderate	18.1	53.9	39.5	486.1934
High degree	0.7	44.9	27.0	P-value <0.001

The results in Table 17 show that most (53.9 percent) stakeholders send information to farmers at a moderate degree, and about 44.9 percent of farmers report the sending of information from a given stakeholder to them was relatively high, with negligible, 1.2 percent reporting low degree of sending information. This is expected in the platform since most of the information shared within the platform is aimed at enhancing the capacity of the farmers within the scheme. The results of the chi-square test for a difference in proportions (p-values <0.001) signify evidence of a statistically significant difference in the degree of sending information across stakeholders in the innovation platform.

Table 18: Farmer reception of information characteristics among stakeholders

Degree of receiving information	Farmer to farmer (%)	Another stakeholder and farmer (%)	Overall (%)	Test for difference in proportions
Low degree	78.6	70.8	74.0	Test statistic =
Moderate	21.0	27.2	24.7	7.1016
High degree	0.4	2.0	1.3	P-value = .028702

The results in Table 18 show that, most non-farmer stakeholders in the platform only receive information from farmers to a low degree. Only about 2 percent of farmers acknowledge other stakeholders receive information from them to a high degree while 27.2 percent mention information sharing is only to a moderate degree. Comparatively, only about 24.7 percent of farmers acknowledge a colleague or other non-farmer stakeholder in the platform receive from them on a moderate to high degree. The test of hypothesis for whether the degree of receiving of information varies by the different stakeholder subgroups shows evidence of variation (p-value of 0.028, less than 0.05).

The results shown in Tables 17 and 18 reveals that overall information sharing among farmers is still very low as less than 1 percent send or receive information from one another. Similarly, the characteristics of sharing also indicate this scenario as 67 to 70 percent of the farmers hardly share information. At least 20 percent of farmers share information to a moderate level, while most of the farmers share information only to a low degree. This observation potentially indicates the likelihood that farmers are more inclined to receiving information from non-farmer stakeholders or that most of them are less confident in sharing specific famer-related information with their colleagues that they suppose non-farmer stakeholders would best handle. Table 19 summarizes the information sharing characteristics among non-farmer stakeholders in the Innovation Platform.

Table 19: Information sharing characteristics between non-farmer stakeholders

Degree of sharing information	Sending	Receiving	Overall	Test for difference in proportions
Low degree	69.9	66.2	68.0	Test statistic =
Moderate	12.5	16.2	14.3	0.7762
High degree	17.6	17.6	17.6	P-value = .678358

The findings in Table 19 reveal that there is no evidence of a difference in the degree of sending or receiving information among non-farmer stakeholders (p-value = 0.678). Most (68.0 percent) non-farmer stakeholders share information only to a low degree, with only about 17.6 percent of them acknowledging the existence of a high degree of information sharing between them. Although low, it is evident that non-famer stakeholders interact more strongly amongst themselves. This is potentially likely for two reasons: first, that stakeholders are keen to initiate collaborative networks on how they can benefit each other in the value chain, and secondly, that the initiation of the IP implies that certain core stakeholders including IWUA, KOSFIP, extension officers will be in greater liaison with other stakeholders to bring them to the platform.

4.6 Innovation Platform Characteristics as Predictors of SRI Uptake

The fifth objective of this study was to establish how the networks in the innovation platform influenced the uptake of SRI. To understand this, a linear regression model with SRI uptake as the outcome was constructed. SRI uptake was treated as a composite outcome, i.e., a combination of each famer's uptake of the various SRI practices. There were explanatory variables based on interactions individual farmers had with one another and with other stakeholders and the strength of those interactions. The findings are presented in Table 20.

Table 20: Linear regression results showing IP variables as predictors of SRI uptake

Explanatory variables	Estimate	Std. Error	t-statistic	Pr(>|t|)
(Intercept)	-3.4558	0.6315	-5.4723	0.0001 ***
Other farmers	0.0022	0.0690	0.0321	0.9749
Research institutions	0.0978	0.0449	2.1770	0.0485*
Support service providers	0.0839	0.0506	1.6563	0.1216
Input stockists/suppliers	0.0661	0.0312	2.1164	0.0542*
Extension (MOALF)	0.1013	0.0199	5.0873	0.0002***
IWUA	0.0951	0.0186	5.1127	0.0002***
Local admin	0.0481	0.0361	1.3316	0.2059
Private millers	0.0877	0.0203	4.3264	0.0008***
KOSFIP	0.1022	0.0211	4.8348	0.0003***
Number of high interactions with stakeholders	0.0117	0.0157	0.7493	0.467

From the results shown in Table 20, there is evidence of strong association between high interactions with research institutions, input suppliers, extension officers, IWUA, KOSFIP, and private millers and the uptake of SRI. These findings imply that famers who had stronger interactions with different research institutions in the platform were also better adopters of SRI practice, p-value (0.0485) at the 5% level of significance. On the other hand, every unit increase in strength of information sharing with extension officers was associated with a corresponding increase in uptake of SRI by a given farmer, all other variables held constant. Both extension officers from MOAL&F and research institutions are involved with technology dissemination and therefore farmers who interact more closely with these stakeholders are likely to be more knowledgeable than their colleagues on the implementation of different SRI practices, hence increased uptake overall. The study supports the findings of a Bolivian study (Grootaert *et al.,* 2004) that showed that the numbers of organizations farmers are affiliated with and the intensity of famers' participation in those organizations increases intensity of adoption and play a notable role in increasing innovation.

As observed in the network analysis, IWUA and KOSFIP are key stakeholders in the IP and have the highest number of strong interactions with most non-farmer stakeholders. The results in regression model reveal that there is strong evidence of association between strong farmer relationship with IWUA and the uptake of SRI (model p-value =0.0002). This is explained by the fact that IWUA is the umbrella body of farmers that commonly links farmers with other stakeholders such as KOSFIP and extension officers. It is therefore imperative that farmers who are closely associated with IWUA and KOSFIP are most likely to benefit from services which these stakeholders coordinate such as capacity building, which for this platform are mainly geared toward uptake of SRI for improving rice productivity.

Although certain farmers interact more strongly with fellow farmers, there is no evidence of association between farmer-farmer and the uptake of SRI. This could be explained by the fact that only few farmers are involved in information sharing with their colleagues. Farmers who had stronger interactions with private millers also had significantly higher uptake of SRI. This association was significant at the 5% level of significance (p-value =0.0008). The observation can be explained by the fact that farmers with closer links to private millers (i.e., stronger information sharing) were also likely to be more focused towards improving their rice productivity for commercialization purposes. As such, they are likely to be keen to have greater uptake of SRI practices to improve their productivity.

Overall, it is noteworthy that increased SRI uptake among farmers was associated with a higher degree of information sharing with several different multi-stakeholders in the platform. This is an important finding as it shows that the intended outcome from the established platform is not driven by only a few stakeholders, but different actors in the value chain. Although not accounted for in this model, other individual farmers' characteristics are useful in explaining the variability in the uptake of SRI.

4.6.1 Correlation of SRI Uptake and Innovation Platform Variables

A correlation analysis was done to summarize data and any visual patterns before exploring the relationship between innovation platform characteristics and the uptake of SRI. Table *21* shows the correlation coefficients between any two variables, which depict the strength of association between farmer sharing information with two different stakeholders. Also assessed is whether the fact that a farmer shares information with one stakeholder also implies he shares information strongly with another stakeholder.

Table 21: Correlations Matrix of SRI Uptake and Innovation Platform Characteristics

		Stakeholder									High interaction	SRI Uptake
		1	2	3	4	5	6	7	8	9		
Stakeholder	1	1										
	2	0.02	1									
	3	-0.37	0.10	1								
	4	-0.28	0.15	0.05	1							
	5	-0.13	-0.09	0.23	-0.13	1						
	6	0.10	-0.18	-0.16	-0.07	-0.21	1					
	7	-0.10	0.17	0.13	0.43	0.00	-0.25	1				
	8	0.40	0.30	-0.15	-0.19	-0.13	0.36	0.11	1			
	9	0.21	0.03	-0.24	0.28	-0.48	0.28	0.08	-0.15	1		
High interaction		0.20	0.55	-0.10	0.37	0.15	0.21	0.29	0.34	0.24	1	
SRI Uptake		0.15	0.35*	0.04	0.28	0.06	0.6**	0.25	0.6**	0.4*	0.73***	1

Key: Stakeholders: 1 – Other farmers; 2- Research institutions; 3- Support/service providers; 4- Input suppliers; 5- MOALF; 6- IWUA; 7- Local administration; 8- Private millers; 9- KOSFIP; * show statistically significant correlations

The results in Table *21* show that strong information sharing with different stakeholders was positively and significantly associated with the uptake of SRI. The study findings reveal that the highest correlation was 0.73, relating SRI uptake and a number of very strong interactions with stakeholders. This implies that farmers with high number of very strong interactions with stakeholders were also likely to be adopters of SRI. In addition, SRI uptake was also positively and significantly correlated with information sharing with research institutions, IWUA, KOSFIP and private millers.

A test of significance was done to test whether there was an association between SRI uptake and innovation platform variables. The results are presented in a corelation plot displayed in Figure 24. Statistically significant correlations at the 5% level of significance are presented as coloured boxes, while stronger associations are depicted by the darker boxes.

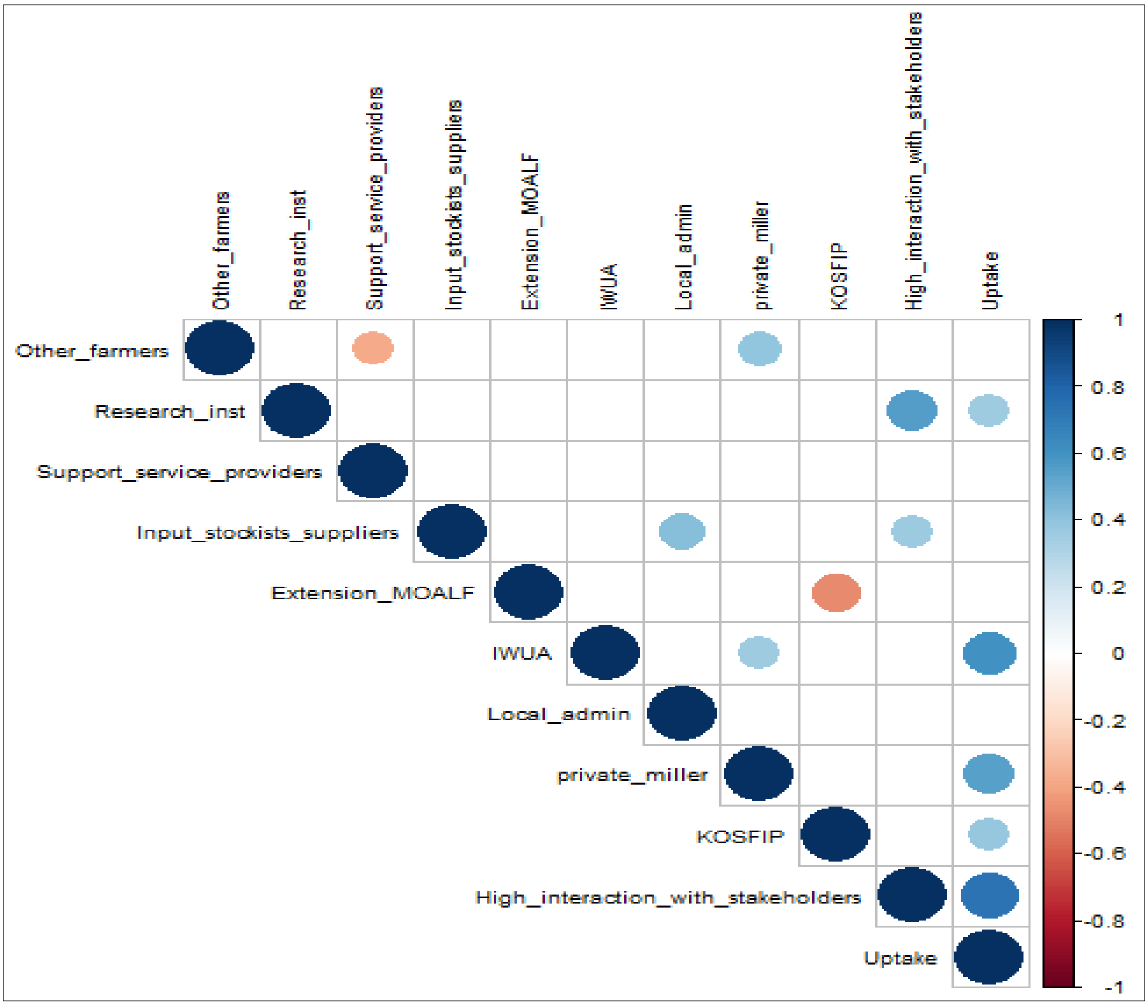

***Figure 24.* Correlation plot of SRI uptake and IP variables**

As seen in Figure 24, statistically significant correlations are shown as coloured boxes while empty non-coloured boxes represent non-significant correlations. However, of importance is the association between the uptake of SRI and specific variables of the IP. Figure 24 shows that there are only few statistically significant correlations in the correlation plot. In this study, the number of significant correlations can be considered a proxy for more collaborative participation within the IP, that is, there is a greater link or information flow between any two stakeholders.

The results in Figure 24 further show that for most farmers, a high level of information sharing with one stakeholder does not necessarily translate to a closer link with another stakeholder. For instance, it is anticipated that farmers will have strong links with IWUA and extension officers at the same time and although it is evident (as shown in the network analysis) that both links exist, the correlation analysis does not show (no strong significant positive correlation) that these links are both high at the same time, which is expected only in an ideal setting. As such, it is observed that so far, more collaborative participation, especially non-farmer stakeholder collaborative participation is yet to be realized in the IP. This observation supports arguments in previous studies that IPs may not automatically lead to more collaborations (Faysse, 2006; Warner, 2005), although synergies can be harnessed to enhance adoption of technologies and improve agricultural productivity.

Time elapse can be a possible explanation for the observed insignificant results, given that the influence of multi-stakeholder platform activities are reportedly observed after a time lag (Aw-Hassan, 2008; Zornes *et al*., 2016). However, it is noted that knowledge exchange networks previously inexistent prior to the institution of the IP are now existent, in agreement with previous empirical evidence from DRC, Rwanda, and Burundi that showed a decrease in the number of knowledge exchange networks and ties between stakeholders (Sartas *et al*., 2018). Overall, there was a positive weak correlation between a farmer's relationships with any two stakeholders. The highest negative correlation between any two stakeholders was -0.48, between KOSFIP and extension officers, implying that farmers who had a strong degree of information sharing with extension officers had a weak information sharing pattern with KOSFIP. This was bound to occur since KOSFIP, and extension officers are closely connected stakeholders. KOSFIP works with smallholder farmers through extension and IWUA. For example, organization and implementation of farmer related activities such as demonstrations, meetings, field days, exchange tours and trainings are normally done collaboratively by

KOSFIP and extension staff and therefore it is likely that close connection with only extension as one of these stakeholders is sufficient to receive pertinent information.

4.6.2 Sustainability of the SRI innovation platform in Oluch Scheme

Innovation platforms can be temporary, existing for the length of time until the common goal for which it was established is solved. The activeness of the rice value chain is what would contribute to its sustainability. To enable sustainability of the innovation platform, the researcher envisions a shift in responsibility in coordination to the farmer organization IWUA and extension. This shift in responsibility contributes to sustainability through capacity building, active participation, and ownership. The partnership would see the commercial activities done by LBDA, Private millers and traders which has good network with the farmers. Through the networks relevant interactions were traced and facilitated to support learning among actors in the IP. According to Flor (2016), an important consideration for sustainability is the capacity of implementers and facilitators towards engaging networks particularly towards effective coordination and monitoring of complex and emergent processes that were triggered. However, recent empirical evidence suggests that the sustainability of an IP can be undermined by several constraints. First, the expectation of immediate benefits, material and/or economic, from different stakeholders can be unrealistic and inconsistent with the key objectives of the IP. In a recent study of stakeholder participation in IPs in the Great Lakes region, Mulema *et al.* (2015) reported that farmers within some IPs expected to receive economic and material incentives including agricultural inputs or monetary benefits in order to participate in the platform. On the other hand, traders and processors expecting to be in good business immediately stopped participating upon realization that the anticipated benefits are long distant (Mulema *et al*., 2016).

4.6.3 Maintenance of SRI results

At the end of the study, sustainability issues were discussed, and strategies developed. These include institutionalization and mainstreaming of SRI practices in rice cultivation where capacity building is key for project success and sustainability, and establishment of effective and regular feedback mechanisms. Importantly, provision of timely and on-going support (technical, managerial, and moral) and the mobilization of key stakeholders (including policy) and networks to support change processes will be necessary for sustainability. Sanya *et al.* (2017) emphasized that these stakeholders are key in disseminating information about SRI and providing credit and market services for those interested in investing at any segment of the rice value chain. This situation has critical implications for the functionality of the innovation platform networks as well as uptake of SRI.

4.7 Influence of Facilitated Innovation Platform for Networking and Capacity Building on Uptake of SRI Practices

An end line study was conducted to investigate the influence of the facilitated Innovation Platform on uptake of SRI practices among the smallholder rice farmers to address objective six. Achievement of this objective entailed examining: i) the data on level of uptake of SRI practices at end line compared to baseline because of what they learnt in the IP. ii) Changes that occurred as a result of application of SRI practices learnt in the IP; with respect to the area under rice production; level of income; and effect of SRI practices on rice productivity and revenue. A structured questionnaire was used to capture this end line data after participation in the facilitated Innovation Platform (Appendix D). Both quantitative and qualitative data was obtained and analyzed. The results are presented in the succeeding sub-sections.

4.7.1 Level of uptake of SRI practices at end line

Of interest was the finding on level of uptake of SRI practices at end line compared to baseline as a result of what farmers do differently based on the interactive learning outcomes in the facilitated innovation platform. The results using radar chart are presented in Figure 25 below.

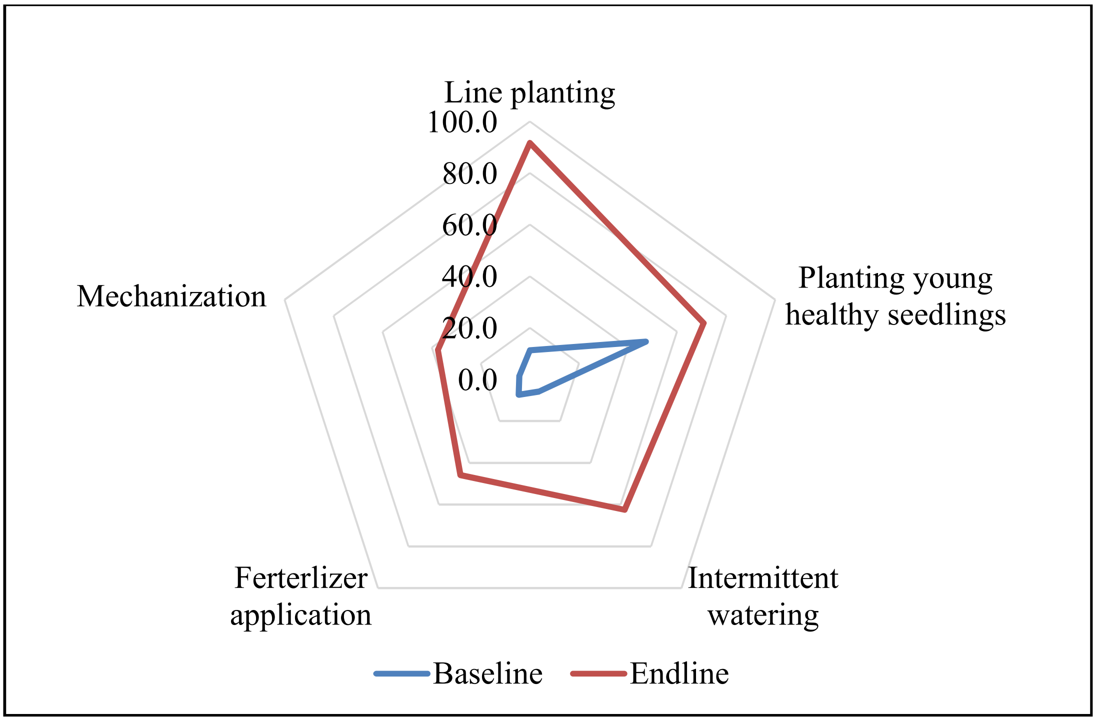

Figure 25: **Radar chart for the comparative analysis of the uptake of key SRI practices at baseline and end** line

The study findings reveal an increased uptake overall for each of the five different SRI practices. As shown in Figure 25, the greatest increase is observed in the uptake of line planting and intermittent watering, at least 80 percent and 57 percent increase respectively. On the other hand, there was only about 23 percent increase in the practice of planting young and healthy seedlings. However, this is unsurprising because at baseline, it was the most commonly practiced of the five SRI practices.

Although there was increased practice of the application of fertilizers and mechanization among farmers, more than half of the farmers have still not yet embraced these practices. First, the increase is because the IP has enabled farmers to have increased access to inputs like rice specific bulleted fertilizers provided by Baraka fertilizers Company which were previously inaccessible or otherwise hard to access. Also, firms such as *Nyabon Machineries* were brought on board and demonstrated the use of machines like rice weeders and harvesters that have shown high potential to improve the farmer's productivity and solve shortage of labour issues. However, it is noteworthy that the associated costs to the farmer relative to buying of fertilizers or buying/hiring of machinery constrains the uptake of these two practices compared with the top three SRI practices in terms of uptake.

The study further tested the hypothesis whether the percentage increase in the uptake of SRI practices from baseline was significant. A Z-test for the difference in proportions was performed and the findings are presented in Table 22.

Table 22: Test for difference in uptake of SRI at baseline and end line

	Assessment		Test for the difference in proportions	
	Baseline	End line	Z- Test statistic	P-value
Line planting	11.3	91.7	-6.82	< 0.0001
Planting young healthy seedlings	47.2	70.8	-3.39	0.001
Intermittent watering	5.8	62.5	-8.45	< 0.0001
Fertilizer application	7.4	45.8	-6.15	< 0.0001
Mechanization	4.3	37.5	-5.77	< 0.0001

The findings in Table 22 reveal that for all of the five SRI practices, there is a statistically significant increase from baseline to end line at the 5 percent level of significance, as evidenced by all p-values less than 0.05. This implies that within the period of the implementation of the IP activities, farmer's innovative capacity and confidence in the different SRI practices has improved, contributing to the uptake.

4.7.3 Farm area under rice

Farm size and ownership are important factors in agricultural technology uptake especially as it determined the scale of operation. Moreover, this was an important indicator for the improvement or decline in rice production. Measurements of farm size were compared before and after participation in the IP. Results are presented in Figure 26 below.

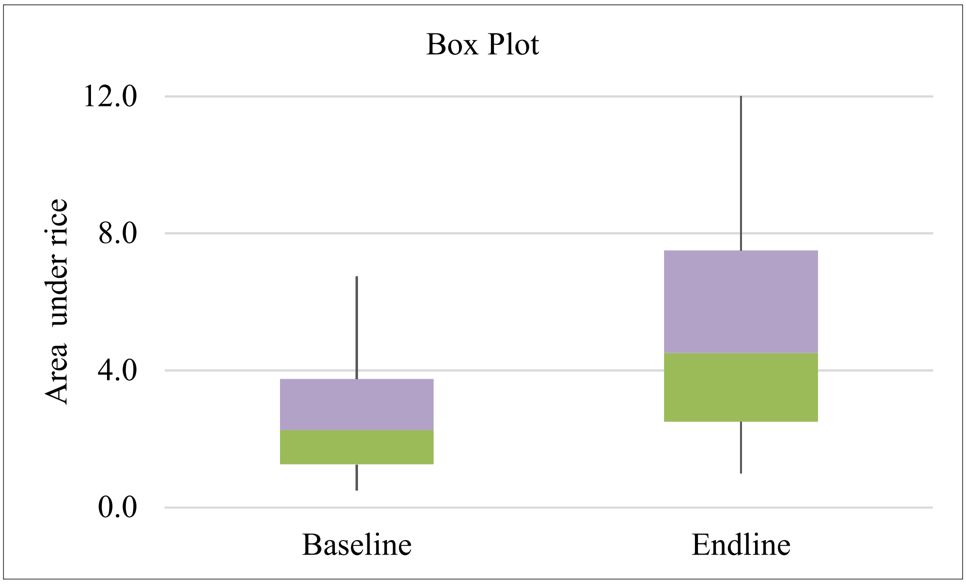

***Figure 26.* A comparison of farm size between baseline and end line**

Tenure system was found to influence access to loans and credits and control over farming operations based on informed choices on the duration technology is used and farm enterprise selection. The results presented by box plots in Figure 26 shows overlaps in acreage sizes between the baseline and end line after participation in the IP. However, farmers who were members of the IP had on average 2.27 acres which is a higher farm size under rice compared to acreage at baseline before participation in the IP which averaged 1.375 acres under rice. The results therefore confirm that the difference in acreage between baseline and end line are attributed to IP intervention. An independent T-test was further used to compare acreage before and after the IP intervention. The results are presented in Table 23.

Table 23: Independent T-test for Area under Rice for end line IP and before IP intervention

Levene's Test for Equality of Variances			t-test for Equality of Means					
	F	Sig.	t	df	Sig. (2-tailed)	Mean Diff	95% CI Difference	
							Lower	Upper
Equal variances assumed	1.002	0.325	2.25	31	0.031	0.895	0.084	1.706
Equal variances not assumed			2.56	15.05	0.022	0.895	0.149	1.641

An independent sample T-test results in Table 23 indicated that the difference in area under rice after the IP intervention and before IP intervention was statistically significant at the 5 percent level of significance (t=2.2495, df=31, P-Value=0.031). It can be inferred that the differences in the end line and baseline acreages under rice were statistically significant and not due to chance. The baseline study before the IP implementation revealed that the mean farm size was 1.88 acres, and which increased to 2.2 acres after farmers' participation in the IP. These results show that there was an increase in farm size under rice following the establishment and implementation of the innovation platform.

A possible explanation for the increased in acreages under rice could be due to the benefits realized as a result of the IP intervention. The IP stakeholders in the rice value chain addressed some of the identified complex challenges that cut across all the rice growing blocks. The complex challenges encountered by smallholder rice farmers under conventional rice production system broadly included bio-physical, socio-technical, economic, and institutional challenges.

4.7.4 Level of income

The level of income of a farmer is a measure of social welfare of the farmer. For confirmatory test, a Chi-square test of association between the innovation platform membership and level of income was conducted. The result of the analysis of the association is presented in Table 24.

Table 24: Chi-Square Tests of Association between IP participation and Level of income.

	Value	df	Asymptotic Significance
Pearson Chi-Square	11.814[a]	3	.008
Likelihood Ratio	12.968	3	.005
N of Valid Cases	40		

a. 4 cells (50.0%) have expected count less than 5. The minimum expected count is .38.

The results in Table 24 revealed a strong significant association (χ^2= 11.814, df=3, P-value=0.008). The results in Table 25 confirms that high number of IP farmer participants at end line are in high average level of income while majority of the IP participants at baseline have Low level of income. A further confirmatory test of for IP participation and level of income was carried out through Cross-tabulation. The Cross-tabulation analysis of IP participation and Level of income is presented in Table 25.

Table 25: Cross tabulation of IP participation and Level of income

		Income level of the farmer			Total
		Low	Average	High	
Membership	IP	5	18	2	25
	Non-IP	11	4	0	15
	Total	16	22	2	40

A comparison was done between the results of proportion of farmers who practiced SRI at the baseline and at the end line (for IP end line and IP baseliner). Analysis of proportion of farmers practicing SRI at baseline and end line is presented in Table 26.

Table 26: Proportion of farmers practicing SRI at baseline and end line

Membership		Proportion of farmers practicing SRI	
		Mean	Standard Deviation
Baseline		18.3%	20.1%
End line	Non-IP	34.9%	18.5%
	IP	55.7%	23.4%

Table 26 shows the mean proportion of farmers who practiced SRI at the baseline and end line. At baseline, there was very limited uptake with only about 18.3 percent of the farmers having practiced SRI. On the other hand, the proportion of IP members who practiced SRI was higher at end line, with substantial differences between those who participated in the IP and those who acquired knowledge of SRI practices from fellow farmers (55.7 percent vs 34.9 precent). The distribution of the proportion of farmers practicing SRI at baseline and end line (IP and Non-IP) is shown in Figure 27.

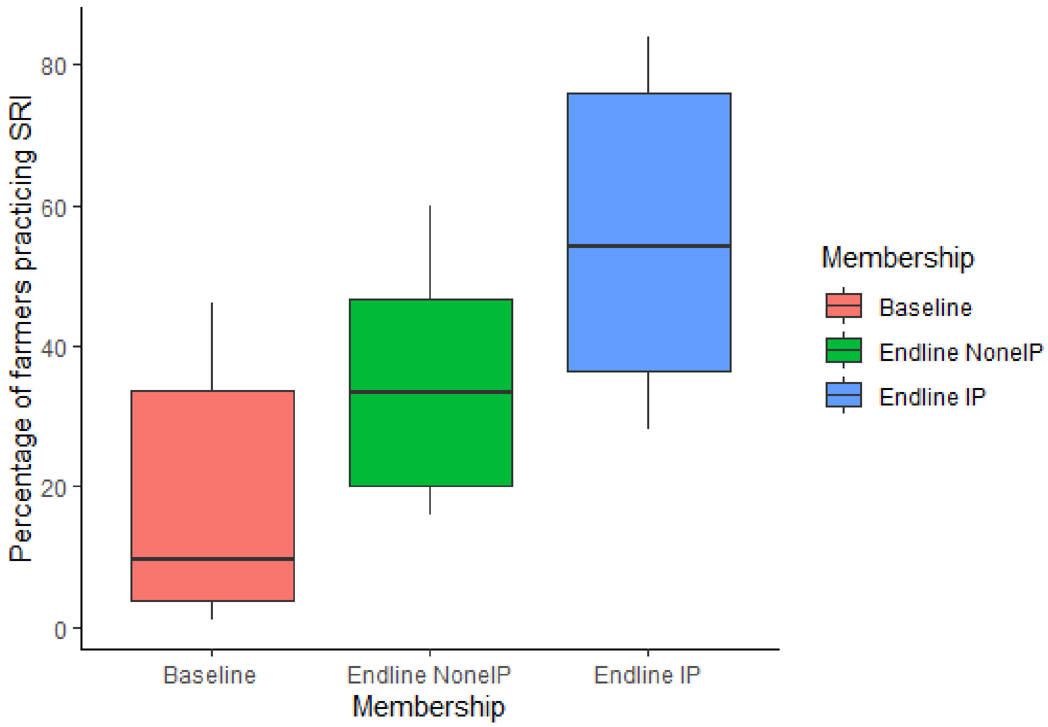

Figure 27. **Distribution of Farmers practicing SRI at Baseline and End line**

A further exploration of the uptake of individual SRI practices showed significant improvement in uptake. The uptake of individual SRI practices ranged from 1 percent to 26 percent at baseline, while at end line, the activity the lowest uptake was 26 percent, and the highest was about 8 percent. A One-Way Analysis of Variance was carried to test for differences between application of SRI practices at baseline and end line. The results are shown in Table 27.

Table 27: Analysis of variance on SRI practice at baseline and end line

	Df	Sum Sq.	Mean Sq.	F value	Pr(>F)
Participation in IP	2	4213	2106.7	4.81	0.0243 *
Residuals	15	6569	437.9		

Significance level: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘’ 1

The analysis of variance of application of SRI practices results in Table 27 revealed that there was a statistically significant difference in SRI application at the base line and at the end line (P-Value= 0.0243). The findings corroborate previous assertion by Coghlan and Rigg (2012) that the action learning approach creates knowledge, implements change, and improves practice and performance of a technology.

A Tukey Multiple Mean Comparison (TMMC) was carried out to assess for uptake differences at end line and baseline among the various categories of farmers, IP and non-IP. The results are presented in Table 28.

Table 28: Tukey Multiple Mean Comparison on SRI practices

	diff	*Lower limit	*Upper limit	P-value
End line (Non-IP) - Baseline	16.6333	-14.7498	48.0165	0.3773
End line (IP) - Baseline	37.4000	6.0168	68.7832	0.0191*
End line (IP) - End line (non-IP)	20.7667	-10.6165	52.1498	0.2307

95% family-wise confidence level

A Tukey multiple mean comparison (TMMC) presented in Table 28 showed a statistically significant difference in uptake between the baseline and end line (IP) (P-value = 0.0191). On the other hand, there was no significant difference between end line (IP) and end line (Non-IP) (P-value =0.2307), also there was no significant difference between the baseline and end line (non-IP) (P-value = 0.3773). Non-IP participants assessed at end line comprised smallholder farmers who practiced SRI at end line having acquired this knowledge farmers who were members of the innovation platform. The insignificant difference in uptake between IP and non-IP farmers at end line suggests the effectiveness of farmer-farmer information sharing. Moreover, findings from the FDGs revealed that most farmers adopted the recommended SRI practices.

The farmers reported that they practiced line planting using the recommended spacing which they found to be more profitable compared to random planting. However, some of them still practiced the old methods as illustrated. The respondents also reported that they used certified seeds, established their own nurseries and planted seedlings at the recommended time period (8 – 12/14 days). The importance of water control, use of fertilizer and weeding were also highlighted as key for increased production. Most FGD discussants (89 percent) reported that they completely adopted line planting based on the benefits derived from it; however, some (11 percent) still practiced random planting since not all household members had changed their practices, or they had not navigated through location-specific challenges such as market and credit constraints, flooding/heavy rains, pests and diseases, labour, financing etcetera affecting rice production. A summary of the whole change process developed and experienced through the innovation platform is presented in Figure 28.

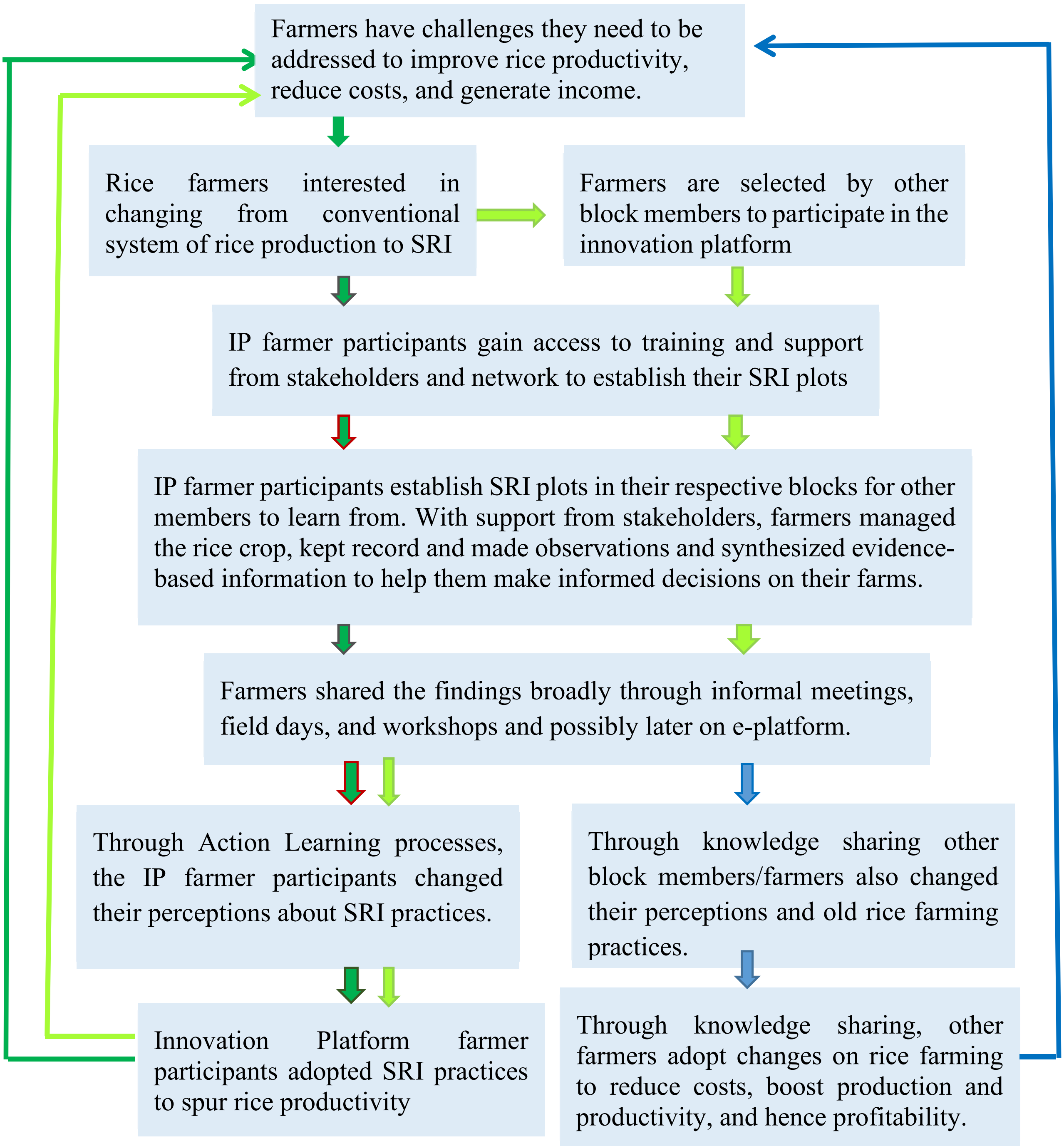

Figure 28: **A Model reflecting the Theory of Change developed and experienced in the IP**

The model in Figure 28 shows the change process as facilitated by the Innovation platform. The model is important because it had implications in what farmers learnt and employed, and how interested farmers were to learn collaboratively and interactively about SRI and. Through action learning processes, the IP farmer participants changed their perceptions about SRI practices. Similarly, through knowledge sharing other rice farmers also changed their perceptions and embraced SRI practices to boost rice production and productivity and improve livelihoods. The smallholder farmers explored the existing opportunities to address the challenges. This agrees with previous findings by Flor (2016) that in growth of networks and inclusion of various types of stakeholders, topics relevant to the composition of social, technical, organizational and institutional change are addressed. Similarly, Hall (2006) emphasized that strengthening networks and interaction between stakeholders is key to improved efficiency and effectiveness of agriculture and rural development (ARD) efforts.

In enhancing learning and interaction, frequent network forums were held including informal meetings, field days, farm visits besides the main facilitation workshops and lately on e-platform. The forums were appropriate in sharing knowledge and experiences among farmers and thereby developed strategies to spur rice productivity. In assessing the networks, the linkage between theory and practice, randomly selected blocks and SRI plots were visited by IP stakeholders including the SRI Champions. The visits heightened interactions and enabled participants to share experiences, learn and nurture new knowledge for enhancing innovative capacities for SRI uptake. Field observations made were both impressive and surprising. Of particular interest were the farmers who had 'distanced' and 're-designed' the SRI technological codes to suit their circumstances. Change developed and experienced in the facilitated IP shows that the action learning approach is better implemented with this focus on learning for innovation rather than the on the spread of 'best bet' technologies.

4.7.5 Effect of SRI practices on rice productivity and revenue

In order to further look at the influences of the facilitated Innovation Platform, information gotten from the 24 Innovation Platform farmer participants were subjected to some statistical procedures including (i) Cost benefit analysis (CBA) and (ii) Thematic Stakeholder Benefits.
To compare the changes in rice productivity and production costs before and after farmers' participation in the innovation platform, a questionnaire was shared among the 24 IP farmer participants. The platform farmer participants were asked to quantify the rice yields and income from rice in the observation checklist at end line after the implementation of SRI. The end line

data was computed to compare the mean production, total cost and revenue earned for three consecutive seasons.

4.7.5.1 Cost benefits analysis of SRI practices in rice production

The cost benefit analysis (CBA) was performed to determine the productivity and revenue return. Productivity here was computed based on one acre as area of production. The cost of operations was recorded based on the current market price at the time of data collection and used to compute productivity and revenue. The reference years of computing the CBA was 2016 (before the IP formation) and 2019 (after the IP intervention). The result of the cost benefit analysis (CBA) is summarized and shown in Table 29.

Table 29: **Estimated cost benefit analysis for rice production**

Activity	**Without SRI**		**With SRI**	
	2016	**2019**	**2016**	**2019**
Land preparation	14,500	19,000	14,500	19,000
Planting	4,900	7,500	4,900	11,110
Fertilizer application				4,750
Weeding	4,000	6,000	4,000	1,300
Pesticides and fungicides				1,650
Irrigation (flooding)	2,000	2,000	2,000	2,300
Bird scaring	1,000	3,000	1,000	3,000
Harvesting and husking	4960	5,420	4,960	8,040
Production costs per acre	31,360	42,920	31,360	51,150
Yields	24	24	24	41
Revenue and returns on investment.				
- Paddy rice	33,600	48000	33600	82,000
- Milled rice	163,200	192,000	163200	328,000
- Return per shilling invested	0.0714	0.1184	0.0714	0.6031
(paddy)	4.2041	3.4734	4.2041	5.412
- Return per shilling invested				
(milled)				

The CBA results corroborates with the findings of Mati *et al.* (2011) which assessed the technical and socio-economic issues affecting introduction and promotion of SRI in Mwea Irrigation Scheme, Kenya. Impressive results were obtained from the two farmer trials, showing the equivalent of 84 percent and 100 percent increases in paddy harvested from the trial fields. The findings of the study revealed that a simple cost benefit analysis (CBA) of returns on investment of SRI practice compared with conventional methods showed that farmer incomes (profit) almost tripled.

Considering a case where no SRI practices used that is the farmers maintained their usual way of operation, the cost of operations increased from 2016 to 2019 by 37 percent (that is from KES 31,360 to KES 42,920 per acre) the increase in the cost of operation here is as a result of increase in the market prices for most input production. On the other hand, the revenue that the farmers get when they sell paddy increased by 43 percent (that is KES 33,600 to KES 48,000 per acre). This was as a result of the increase in market prices per unit of paddy. However, the revenue of the farmers when they sell white milled rice increased by 18 percent from 2016 to 2019 (that is KES 163,200 to KES 192,000). This increase was also as a result of increase in milling price. The return per shilling invested when farmer sell paddy (KES 0.0714 in 2016 and KES 0.1184 in 2019) was quite low compared to when they sell white milled rice (KES 4.2041 in 2016 and KES 3.4734 in 2019). The reduction in return per shilling is a wakeup call to investors in rice production to improve efficiency in the value chain for rice farming to remain profitable. This necessitates the implementation of the SRI practices.

When SRI practices are used in rice production, the cost of operations shoots exponentially by 63 percent on average from 2016 to 2019 (that is KES 31,360 to KES 51,150 per acre). The increase here is as a result of more input supplies required when SRI practices are used such as fertilizers, machinery and fungicides/pesticides. Despite high cost of production, productivity increased when SRI practices are used (that is from 24 bag to 41 bags (paddy) per acre) this in return increases revenue. The return per shilling when SRI practices were used increased from 4.2041 to 4.7393.

Based on their own measurements of paddy yields and revenue generated, the IP actors were convinced that the participating farmers were in fact reducing their cost of rice production significantly. In the subsequent seasons, new actors have joined the collaboration network and have started producing rice under SRI system within the framework provided by the government extension. Currently the FFS approach is used for promoting SRI in the neighbouring Kimira irrigation scheme but using the Innovation Platform experienced farmers as facilitators.

4.7.5.2 Benefits accrued by stakeholders through participation in the SRI IP

The innovation platform established by the researcher at Oluch irrigation scheme has enhanced stakeholder engagement in the rice value chain, and for each actor in the platform, a summary of benefits is presented in Table 30.

Table 30: Stakeholder benefits from participation in the Innovation Platform

Stakeholder	Benefits (immediate)	Other benefits	Long-term/foreseen benefits
Farmers	• Enhanced innovative capacities to collectively articulate demand • Strengthened networks • Reduced production costs • Improved rice yields • Access to markets • Inputs easily accessed • Skills acquired • Motivation to participate in contractual markets • Confidence in participation • Knowledge 'hubs'	• Positive deviants actively networking with non-IP participants • Use ITK in nursery bed preparation • Farmer-farmer extension • Farmers stock inputs on behalf of suppliers •	• Economic, social and technical empowerment
Local administration	• Participation and collaboration • Facilitation of learning		
IWUA	• Networking for innovation and information. • Facilitation of learning		• Sustainable structure

Stakeholder	Benefits (immediate)	Other benefits	Long-term/ foreseen benefits
KOSFIP	• Improved service delivery		• Established institutional structures
Extension officers (MOAL&F)	• Farmer-to-farmer extension up-scaling. • Reach out to more clients	• Formation of farmer field schools (FFS)	• Creation of demand driven extension and feedback
Private millers	• New market opportunities • Easy access of produce from farmers	• Sale of rice by-products	• Large scale processing
Research institutions	• Better outreach to farmers		• Creation of demand driven research and feedback
Input suppliers	• Better understanding of the demand and supply of inputs to farmers.		
Service providers	• Demand driven service delivery		
All stakeholders	Enhanced information flow across all stakeholders. Creation of an enabling environment for collaboration Knowledge of value of IPs. Informed decision making through joint learning. Ability to dialogue Growth in Networks		• Participatory Policy making.

The other benefits relate to any indirect benefits accrued to any stakeholder that were initially unforeseen at the planning stage of the IP. The study findings indicate the benefits of the IP are highly variable, most of which are accrued to the farmer. This is expected since the farmers are the centrepiece of innovation platform in terms of the uptake of the new system, SRI, to improve rice productivity within the scheme. It is notable that all stakeholders derive benefits from the interaction within the platform, some of which are common to all stakeholders.

The extensive benefits are also associated with the diversity and high number of stakeholders in the rice value chain that were involved in the IP launched at Oluch irrigation scheme. This observation disagrees with previous findings from a large study of the impact of innovation platforms among 1200 households, across nine African countries. The authors established that IPs with many different stakeholders are less successful in promoting agricultural technologies, and only those that had more active members were very successful (Pamuk *et al.,* 2019). However, previous empirical evidence equally points out high variability on the impact and benefits from the innovation platforms (Pamuk *et al.,* 2014), suggesting that the findings from this study are entirely expected.

It is likely the benefits derived from this platform may be different from those accrued to stakeholders from other IPs in different settings for several reasons. First, this study focuses on small-scale farmers, and the rice value chain, a different research focus from other value chain IPs including dairy, banana, potato and maize IPs that have been studied elsewhere in sub-Saharan Africa (Jarial *et al.*, 2015; Mulema *et al.,* 2015; Sartas *et al.*, 2018). On the other hand, characteristics of the IP (Sartas *et al.,* 2018), differences in regions and target populations (Pamuk *et al.,* 2015) and variations in the approach of implementing the IP (Pamuk *et al.,* 2019) have a role in explaining the potential benefits that can be derived by any stakeholder.

CHAPTER FIVE

SUMMARY, CONLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This chapter presents a summary of the study, conclusions with highlights on some theoretical and practical implications of the findings and recommendations drawn from it and suggestions on areas for further research.

5.2 Summary of the Study

The purpose of this study was to assess the uptake of SRI practices through a facilitated Innovation Platform intended to boost rice productivity and improve farmers' livelihoods in Oluch irrigation scheme, Rangwe Sub-County of Homabay County. The anticipation was that the study would demonstrate how interaction in the innovation platform promotes learning and uptake of SRI to spur rice productivity for improved livelihoods. The study adopted an action research design that allowed for participatory learning processes based on the cycle of identifying an issue, collecting baseline measures, introducing and implementing change and re-measuring. The study employed both qualitative and quantitative data collection and analysis procedures.

The stakeholders were purposively selected from their respective organizations and institutions. Simple random sampling technique was used to select 101 smallholder rice farmers from the target population for the survey study. Twenty-four IP farmer participants representing the 12 blocks were sampled for participation in the IP and to implement the SRI practices. Baseline data collection was conducted using structured questionnaire; FGD guides, KIIs and observation checklists. The information gathered was organized, crosschecked and validated with information from the baseline survey, FGDs, observations made, and action learning based on objectives, research questions and theoretical framework. Qualitative data gathered iteratively throughout the IP intervention period was analysed using qualitative data analysis procedures including Stakeholder Analysis, Social Network Analysis, and institutional analysis; Cost benefit analysis was also used to depict changes in production, productivity and incomes. Quantitative data analysis was performed using both R studio software and SPSS. Specifically, the statistical tests performed including Z-tests, ANOVA, Chi-square tests, and T-tests at a significance level, $\alpha = 0.05$.

The study revealed that smallholder rice farmers were constrained by a mix of different challenges key ones being inaccessibility and high costs of inputs, labour, inadequate knowledge, skills and information asymmetry; fewer and weak networks among stakeholders in the rice value chain was indicated by low accessibility and affordability of farm inputs, equipment, poor access to loan and credit facilities and poor market structures. The weak networks also reduced farmers bargaining power and denied them opportunity of participation in decision making forums that would be of benefit to them as producers and entrepreneurs.

This study demonstrated that despite the availability of the irrigation infrastructure at baseline, the challenges experienced by famers impacted negatively on SRI uptake contributing to low rice production and productivity as measured by cost and levels of production and revenue. However, study findings revealed that farmers employed coping strategies to navigate through the challenges. Some of these included self-organization into support groups to organize for cheaper and alternative forms of labour, share from a pool of knowledge, and seek for help in form of smart subsidies from public and private institutions. Other farmers resorted to renting-in or out of their farmlands on cash or share basis, whereas some exploited ever available opportunity to work as casual labourers in the rice fields to supplement their cash income.

The study established that the Innovation Platform was an effective approach for strengthening stakeholder collaboration and networking. The IP facilitated interactive learning, capacity building, knowledge flows and strengthening of networks that promoted uptake of SRI. Based on the existing networks, the collective learning process initiated enhanced innovative capacities for scaling and uptake of SRI practices to spur rice productivity within Oluch irrigation scheme. Consequently, this research demonstrated observable changes in SRI technology adoption, knowledge level and farm yields.

Throughout the duration of implementation of the IP, there were observable growth in networks among stakeholders, especially between farmers and other stakeholders. This was equally affected by increased collective decision making among actors in the rice value chain. Notably, in addition to what was obviously possible outcomes, other outcomes were observed and realized, most of which benefitted the smallholder farmers. On several occasions, farmers trained within the IP were useful in disseminating knowledge alongside extension officers to promote the uptake of SRI. In other instances, a few farmers were contracted by input suppliers to be stockists while the increased demand for farm machinery led to the fabrication of items including push-weeders by Jua-kali Artisans.

This study demonstrated the potential of a facilitated IP in improving the productivity of smallholder rice farmers. The uptake of the different SRI practices increased by at least 30 percent from baseline. However, there was evidence of variability in the uptake of the different SRI practices, most of which were practiced depending on the ease of implementation and resource constraints. Mechanization and fertilizer application were the least implemented SRI practices at end line, as these are associated with a cost aspect not within reach of most of the smallholder farmers. On the other hand, the practice of line planting, transplanting of young healthy seedlings and intermittent watering were the most practiced among farmers following implementation of the IP as these are least associated with cost or resource constraints to the farmer. As such, the adoption of new technology is not only dependent on enhancing farmer's level of knowledge and capacity but also how they could possibly overcome technology adoption resource constraints.

Strong farmer interaction with stakeholders in the IP was associated with high levels of uptake of SRI practices. The most influential interactions predictive of high SRI uptake among farmers was stronger interaction with IWUA, KOSFIP, extension officers and input stockists/suppliers. It is noteworthy that when farmers had increased interaction with several stakeholders, their SRI uptake was very high. This is a phenomenon where farmers leverage more fully the multi-stakeholder characteristics of the IP as intended to enhance their capacity and subsequently improve rice productivity.

A network analysis showed information sharing in the innovation platform was centralized among five key stakeholder including farmers, IWUA, KOSFIP, extension officers and local administration. IWUA was the most central stakeholder with the strongest interaction with most stakeholders in the platform. Through IWUA, farmers had a greater capacity to negotiate with other non-farmer stakeholders. In terms of sustainability of the innovation platform, it is therefore likely IWUA will play a key role.

The study findings revealed that there is comparatively greater interaction among non-farmer stakeholders than among farmers themselves in the network. Although weaker interaction farmer-farmer interaction in the IP could be attributed to several reasons including farmers level of confidence, capacity, level of knowledge or farmer level socio-economic characteristics, there is potential to exploit the IP to improve this low-level interaction. The need for increased farmer-farmer interaction is twofold: first, when farmers interact more among themselves in the IP, there is increased likelihood that they are also more likely to interact with other non-IP farmers in the scheme. Secondly, improved interactions at the farmer level translates to faster and improved knowledge exchange within the scheme overall.

The findings of this study have shown a positive impact of the innovation platform on facilitation of collaboration, networking, and interactions to build capabilities to innovate for uptake of SRI practices to spur rice productivity. This study traced the changes in rice production practices and related costs; productivity and income levels of smallholder rice farmers who participated in the facilitated innovation platform. This was meant to establish the influence of facilitated innovation platform on uptake of SRI among smallholder rice farmers strengthening innovative capacity of smallholder rice farmers for uptake of SRI practices and possible spill over effects in Oluch Irrigation scheme.

The innovation platform facilitated interactive learning among the IP participants. The IP farmer participants were able to implement every step of SRI practice as they learnt. The observed that changes occurred even before completion of the IP learning process. As they learnt, farmers from the neighbouring plots and other observers began to implement some of the SRI practices stepwise in their respective rice plots. This implied that farmer participants were able to see the differences between their old practice of rice production and the new technology (SRI) while learning processes were still going on. Therefore, the IP strengthened systemic capacity to innovate leading to uptake and scaling of SRI to spur rice productivity.
The study established a strong association between the innovation platform membership and level of income, with majority of innovation platform farmer members having higher levels of compared to fellow non-IP participants who had lower incomes. Such differences were attributed to the influence of the Innovation Platform. Moreover, there was a significant improvement in the level of adoption of SRI practices from baseline at the end of the study further confirming IP influence on uptake of SRI practices. The study observed a higher proportion of IP participants applying SRI practices relative to non-IP participants at end line compared to baseline. The IP intervention therefore facilitated the interactive learning processes and problem solving at local level. This confirms the suitability of innovation

platform in enhancing innovative capacity intended for uptake of SRI practices to spur rice production and productivity in Oluch scheme.

The study revealed changes in rice yields and productivity under SRI system, decreased production costs and subsequent increase in revenue. The return per shilling invested when SRI is used was higher than production under conventional system. A greater margin of return per shilling was realised when rice was sold as white rice (processed) instead of being sold as paddy. The observed changes also led to changed perceptions about SRI technology. The positive changes attracted other individuals including youth and women to engage in rice production in Oluch Scheme.

The study revealed statistically significant influence of Innovation Platform intervention on uptake of SRI practices as depicted by the following statistics: average increase in farm size under rice after the platform intervention. An independent sample T-test for significance revealed that average farm size under rice increased after farmers' participation in the IP. The mean value at start was lower than mean value at end-line implying that the change in acreage under rice is attributed to influence of the IP intervention.

5.3 Conclusions

The following conclusions are made based on the study findings:

i. Smallholder farmers comprise a heterogenous subgroup of farmers relative to their socio-economic characteristics, with respect to gender, age, education level, marital status farm size, household size, farming experience and group participation.

ii. Several challenges constrain the uptake of SRI practices among smallholder rice farmers including weak extension networks, inadequate knowledge and skills, inaccessibility and high costs of inputs, labour, poor access to loans and credit facilities and poor market structures and farmers employed various copying strategies in response to the challenges.

iii. Key determinants of IP functioning for SRI uptake include stakeholder participation, information sharing and communication, resource mobilization, use of the diversity of knowledge and skills, reflection, capacity building, commitment and ownership.

iv. Interaction of smallholder rice farmers in innovation platform networks creates opportunities for farmers' empowerment that allow for collaboration and interaction, thus prompting innovation to address challenges and promote SRI uptake to spur rice productivity.

v. Innovation platforms foster an efficient and effective collaborative and interactive learning process to build smallholder rice farmers' innovative capacities for uptake of SRI practices. Efficiency can be demonstrated in the high degree of information sharing between IP stakeholders as part of interactive learning.

vi. An innovation platform is a plausible extension approach for scaling SRI in rice growing systems besides creating a better demand driven research/extension feedback interventions given the positive influence of interactive learning on SRI uptake.

5. 4 Recommendations

Based on the conclusions, the following are the recommendations of the study.

i. There is need for researchers and extension agents to be cognisant of the identified farmer socio-economic characteristic that may influence their involvement in participatory research and extension activities for uptake and scaling of SRI in the study area.

ii. Extension service providers need to use participatory innovation platform approaches for problem identification and generating solutions to address them. This would ensure that farmers understand and contribute to their own problems and ownership of practices and strategies developed.

iii. There is need for the SRI Innovation Platform to be more inclusive by involving other stakeholders including Supra groups and the emerging SMEs whose roles were identified later during the action learning process. This would ensure further strengthened linkages and facilitation role of other stakeholders and the IP.

iv. The MOAL&F and County government of Homabay should set up a specific board to ensure policies that create opportunities for smallholder rice farmers' empowerment though collaboration and networking to help them navigate through the challenges limiting SRI uptake to spur rice productivity.

v. Both County government of Homabay and the National Government should develop policies for marketing paddy and white rice, especially advocating for processing paddy within the County to enable farmers generate more income from both white rice and by-products.

vi. The MOAL&F should promote the IP approach in extension service given its demonstrable impact in productivity and incomes and a positive change in rice farming system. For instance, there is need to expand SRI to other localities particularly the twin neighbouring Kimira scheme where rice farmers have expressed great demand for SRI technology.

5.5 Suggestions for Further Research

On the basis of the findings, this identified the following gaps for further research:

i. Further research should be done regarding farmer characteristics as determinants of SRI uptake.

ii. A study should be conducted to assess the sustainability of innovation platforms to drive technology uptake among smallholder farmers.

iii. Conduct an in-depth exploration of the role of farmer-to-farmer extension on SRI uptake vis-à-vis the public extension.

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APPENDICES

Appendix A: Interview Schedule for Smallholder Rice Farmers

Introduction

The purpose of this baseline survey is to provide a basis upon which change was measured. It will elicit information on the challenges farmers have under conventional rice production practices and farmers' knowledge gaps in rice intensification practices and also identify relevant stakeholders for establishment of an Innovation Platform to create an opportunity for interactive learning to facilitate uptake of SRI to spur rice productivity in Oluch scheme. Therefore, your honesty in answering the questions was critical to this study. Your responses will be treated with utmost confidence and used strictly for the purpose of this study.

Section A: Household Characteristics

1. Age of the farmer: _________________ (years)

2. Sex of household head   Male   Female

3. What is the highest level of formal education attained?
    - None
    - Primary
    - Secondary
    - Post-secondary

4. Marital status of respondent:
    - Single
    - Married
    - Separated/divorced
    - Widow/widower

5. Who in your household mainly makes main decisions on how your main household resources are used?
    Husband   Wife   Joint (husband, wife and children)

6. Who in your household mainly makes main decisions on agricultural technologies?
    Husband   Wife   Joint (husband, wife and children)

 b). Who does most of the work on rice on-farm activities?   Men   Women   Both

7. Household size
    - 1-5
    - 6-10
    - Above 10

8. How long have you been involved in rice farming?
    - 0-5 years
    - 6-10 years
    - More than 10 years

9. Farm size? Owned __________, rented__________, Total _________ (acres)

10. Land tenure system: Owned with title deed Owned without title deed Rented

11. Do you belong to other social groups other than block membership? Yes No

12. What is the importance/benefits of rice as part of household crop enterprise?
Food security
Income
Fodder (stoves, bran)
Other (specify) ____

13. Indicate the average quantity of rice produced, consumed, sold and income generated in the
last three seasons before intervention.

Quantity of rice (Kgs)	Produced	Consumed	Sold	Income (Ksh.)
Season 1				
Season 2				
Season 3				

14. What rice production practices/system do you use?

Conventional practices System of rice intensification (SRI)

SECTION B: Challenges and Benefits of Producing Rice under Conventional Production System

15. a. What challenges do you experience in producing rice under conventional system?
____
____

b. What strategies you have adopted to cope with the mentioned challenges?
____
____

16. What are the benefits of producing rice under conventional system?

____

17. Use tick (√) to indicate how often you perform the following rice production practices e on your farm? **Key: not performed = 1, rarely performed = 2, mostly performed = 3**

Rice production practice	1	2	3
Planting: Dibbling			
: Line planting			

Planting young seedlings			
Planting old seedlings			
Irrigation: Flooding			
: Intermittent watering			
Weeding: Mechanical			
: Chemical			
: Manual			
Manure application			
Fertilizer application			

18. How confidently do you carry out the following rice production practices? (***Tick as appropriate)***

Practice	Least confident	Not Confident	Not sure	confident	Most confident
1. Transplanting young seedlings					
2. Planting seedlings per hill					
3. Plant to plant distance- (spacing)					
4. Water management regime					
5. Weeding					
1. Fertilizer application					
7. Manure application					
8.. Harvesting					

SECTION C: Enhancing Smallholder Rice Farmers' Capacity through Innovation Platform.

19. Name the institutions supporting you in the rice value chain in Oluch scheme and tick the appropriate support they offer to you.

Institution	Production Incentives Inputs (seed, fertilizer, pesticides	Training	Market access	Processing	Loan/ Credit	Technology Dissemination	Other (specify)

20. From your responses in Q. 19, enumerate the three most preferred institutions in sharing of information____

21. How useful is the information received in helping you understand the following aspects of rice production practices. (1 = None, 2 = Low, 3 = medium, 4= high, 5 = very high).

Aspect of rice production	**Level of practice of rice management**				
	1	**2**	**3**	**4**	**5**
Land preparation					
Planting rice plot					
Spacing of seedlings					
Weeding					
Maintaining plot					
Harvesting rice					
Processing rice					
Utilizing rice products					

Section D: Innovation Platform for SRI Uptake

22. Have you heard of SRI? Yes No.

If yes, what was the source of information? ______________________________

Do you practice SRI? Yes No

If yes, what benefits do you experience in producing rice under SRI system? ____

____

If No, give reasons ____

23. Improving interaction of stakeholders and farmers through a learning process can enhance capacity for uptake of SRI practices. (Please indicate your level of agreement).

- ❑ Strongly agree
- ❑ Agree
- ❑ Not sure
- ❑ Disagree
- ❑ Strongly disagree

23. Give three main suggestions for improving rice productivity in Oluch scheme? ____

____

THANK YOU FOR PARTICIPATING IN THIS STUDY

Appendix B: Focus Group Discussion Guide

Some of the questions will emerge to clarify issues which are not clear from the baseline survey.

1. What are the challenges the farmers encounter in implementing rice production practices in Oluch scheme?
2. How do you cope with the mentioned challenges?
3. Who are the stakeholders working with you in the rice production in Oluch Scheme?
4. What are their roles?
5. What is the rice production practices you use in Oluch (probe for system used)?
6. What are the benefits of the practices? (Probe: other farmers learning from++++ them, adoption of the practices by other farmers not in the platform, causal work opportunities for the youth, others?
7. What challenges did you encounter as an actor in working with others?
8. What do you do individually to try and gain more yields?
9. What were the challenges in obtaining the yields?

Appendix C: Observation Checklist for Field Visit

1. **Level of implementation of SRI practices**

   Tick appropriately the level at which the farmer implements the following practices (1 represent lowest level of implementation while 5 represent the highest level of implementation)

SRI Practices		**Implementation of SRI practice**					
		1	**2**	**3**	**4**	**5**	**Comments**
Planting method	Dibbling						
	Line planting						
Planting material	Young healthy seedling						
	Overgrown seedlings						
Irrigation	Flooding						
	Intermittent watering						
Weeding	Mechanical						
	Chemical						
	Manual						
Soil fertility	Manure application						
	Fertilizer application						
	Both manure & fertilizer application						
Average Yield obtained (Kg/area)							

Appendix D: Assessing Influence of Innovation Platform on SRI Uptake (End Line Study)

Innovation Platform Farmer Participants and non-IP participant rice farmers

Section A: Household Characteristics

1. Age of the farmer: ________________ (years)

2. Sex of household head   Male   Female

3. What is the highest level of formal education attained?
   None
   Primary
   Secondary
   Post-secondary

4. Marital status of respondent:
   Single
   Married
   Separated/divorced
   Widow/widower

5. Household size
   1-5
   6-10
   Above 10

6. How long have you been involved in rice farming?
   0-5 years
   6-10 years
   More than 10 years

7. Farm size? Owned __________, rented__________, Total _________ (acres)

8. Land tenure system: Owned with title deed Owned without title deed Rented

9. What is your income level?   Low   Average   High

10. Do you belong to any social grouping other than the Innovation Platform and block? membership? Yes   No

11. Use tick (√) to indicate how often you perform the following rice production practices

on your farming the last two years? **Key: not performed = 1, rarely performed = 2, mostly performed = 3**

Rice production practice	**1**	**2**	**3**
Planting young healthy seedlings (8-14 days old)			
Line planting			
Intermittent watering			
Weeding: Mechanical			
: Chemical			
: Manual			
Fertilizer application			

12. Have your farming practices changed before the last two years? Yes No

13. If yes, explain which practices have changed. ________________________________

____

14. Are there any benefits/advantages you have seen due to the change mentioned above?

____

____

15. How confidently do you carry out the following rice production practices? (***Tick as appropriate)***

Practice	Least confident	Not Confident	Not sure	Confident	Most confident
1. Transplanting young seedlings					
2. Planting seedlings per hill					
3. Plant to plant distance- (spacing)					
4. Water management regime					
5. Weeding					
6. Fertilizer application					
7. Harvesting					

Appendix E: End line Survey Questionnaire

Section A: Household Characteristics

1. Farm size? Owned __________, rented__________, Total _________ (acres)
2. Land tenure system: Owned with title deed Owned without title deed Rented
3. What is your income level? Low Average High
4. Do you belong to any social grouping other than the IP and block membership? Yes No
5. b). If Yes, what benefits do you drive from the group(s)
   a. ____________________
   b. ____________________
   c. ____________________
6. How many stakeholders do you interact with during the period of the rice innovation platform? What was his/her role in the IP? What was the purpose/benefit for the interaction? What was the frequency of the interaction?

	Stakeholder's Name	Interaction (Y/N)	Who has the stakeholder interacted with in the rice value chain? (*1 = Farmer 2 = Miller 3 =KOSFIP 4 =Extension, 5 =Research, 6 = Trader 7 =Agrovet 8 =Baraka 9= Transporter 10. Admin 11 =Maugo 12=IWUA 13=LBDA 14 =Bayer 15 = KFA 16=Financial 17=NIB* 18 = *NARIGP 19 =Nyabon 20=Other (specify)*	Frequency *1 =once 2 = twice 3=more frequent)*	Purpose of the interaction	How satisfied are you with the interaction? 1 = V. satisfied 2 = Satisfied 3 = Neutral 4 = Unsatisfied 5 = V. unsatisfied
1						
2						
3						
4						

Appendix F: A Check List for the Cost Benefit Analysis Data

Instruction: Indicate the average quantity of rice produced, consumed, sold and income generated in the last three seasons after intervention.

Activity	**Unit**	**Unit Cost**	**Estimated Cost**	
			2016	**2019**
Land rent				
Ploughing				
Harrowing				
Rotavating				
Subtotal				
Nursery				
Planting (Broadcasting)				
Line Planting				
Planting fertilizer 50kg per acre				
Planting fertilizer application				
Seed (certified)				
Seed (recycled)				
Subtotal				
Topdressing fertilizer				
Topdressing fertilizer Application				
Irrigation (Flooding)				
Irrigation (intermittent)				
Manual Weeding				
Mechanical Weeding				
Pesticides & fungicides				
Pesticides & fungicides Application				
Bird Scaring				
Harvesting				
Transport to miller per Bag				
Drying Per Bag				
Milling per kg				
Subtotal				
Production costs per acre				
Yield paddy Bags per acre (Productivity)				
Number of 2kg tins per bag				

Cost of paddy per 2k tin				
Revenue paddy per acre				
Cost of milled 2kg tin				
Revenue of milled rice per acre				
Return per shilling invested (paddy)				
Return per shilling invested (milled rice)				

Appendix G: Elements of Social Network Analysis used in the Study

Element	Definition
Node	Any individual/organization or other entity of interest
Tie	Links between nodes which denote interaction between nodes and actors
Arc	A Tie with direction
Edge	A Tie without direction
Ego	Actor of interest within a network
Alter	In a tie linking an ego to another node, the other node is referred to as an alter
Network	Geographical representation of relationships that displays points to represent nodes and lines to represent ties
Network size	Total number of nodes in a network
Ego network	Network that only shows direct ties to the ego and not between alters
Network centralization	Degree to which a network revolves around a single node
Geodesic distance	The length of the shortest path between two nodes
Network density	Nodes that are actually tied as a proportion of all possible ties in a network. The density measures the 'proportion of ties that are present' in a dichotomous relation.

Source: Borgatti *et al*., (2002); Hanneman & Riddle (2005)

Appendix H: Matrix of Rice Value Chain Stakeholders in Oluch Irrigation Scheme

Stakeholder	Attribute	Interest	Resources	Impacts
RICE – Farmers (CIG)	Smallholder rice farmers, Primary decision makers	Production of rice	Land Labour Farm Inputs	Participation in the Innovation platform. Application of SRI practices. Implementation of IWUA-By-Laws
IWUA	Umbrella body for all registered farmers for irrigation water use.	Decision-making Water management Maintenance of canals. Sourcing for markets, Linkages	Drafting By-Laws Management IWUA-Building, Office equipment Decision making	Enforcing by-Laws Information sourcing Collaborative activities
KOSFIP	Decision making	Irrigation Infrastructural facility implementer Decision making Technical Advisor Key linkage provision	Drafting By-Laws Technical Capacity Data source	Irrigation facility IWUA-By-Laws Training Input provision Soil Testing Market Linkage
MOAL&F	Main stakeholder	Extension service provider	Data source, Technical capacity	Dissemination of SRI technology & other extension messages
KALRO-Kibos and Kisii (Research)	Key stakeholder	Research activities Certified seed Recommended fertilizers	Technical capacity	Testing of on-farm SRI management practices
Input suppliers: (AfriTech, Baraka, Bayer, Agro-vets, KFA	Facilitators	Sale of assorted farm Inputs	Farm Inputs	Supply of appropriate assorted Inputs (Certified rice seed, Fertilizers, pesticides).
Local leaders Administration (Kagan, Kochia Karachuonyo)	Decision makers and Facilitators	Community mobilization and Security	Enforcement of IWUA- By-Laws	Provision of enabling environment.

Nyabon Machineries	Key stakeholder	Mechanization of rice production	Farm equipment	Provision of farm machinery
NIA (Former NIB)	Policy issues	Policy on irrigation water resources	Advice on policy	Policy
IFDC, Egerton, JKUAT	Partner Research activities	Training Technology dissemination	Technical capacity Data source	Testing of SRI practices on demo plot
Crop Nuts	Consultant	Training	Market information	Access to market information
Maugo Cooperative Society (** Inactive)	Local Stakeholder	Storage and Value addition equipment Collective purchase of farm Inputs Access information, loans & credit	Organize trainings Employment	Milling/Processing Access to Inputs
Rice Transporters	Facilitator	Transport rice produce from farms to homes/stores, and from Mills to the Markets	Means of transport	Enable rice farmers' access markets beyond farm gate.
Rice millers: -LBDA & -Private millers	Facilitator	Value addition	Storage and Milling facility Market linkage	Processing, Buying paddy rice, & Market access
Rice Traders	Facilitator	Purchase and sale of rice	Market places & Cash income	Provide market and link producers to institutions and consumers.
Financial/Micro-Credit Institutions - AFC, - Micro-credit	Facilitator	Access to financial information	Provision of loans	Loans and Credit

Appendix I: Letter of Research Authorization

NATIONAL COMMISSION FOR SCIENCE, TECHNOLOGY AND INNOVATION

Telephone:+254-20-2213471,
2241349,3310571,2219420
Fax:+254-20-318245,318249
Email: dg@nacosti.go.ke
Website : www.nacosti.go.ke
When replying please quote

NACOSTI, Upper Kabete
Off Waiyaki Way
P.O. Box 30623-00100
NAIROBI-KENYA

Ref. No. **NACOSTI/P/18/71198/24644**

Date: **24th August, 2018**

Matilda Auma Ouma
Egerton University
P.O. Box 536-20115
NJORO.

RE: RESEARCH AUTHORIZATION

Following your application for authority to carry out research on ***"Uptake of system of rice intensification practices through an innovation platform in Oluch irrigation scheme, Rangwe Sub County, Kenya,"*** I am pleased to inform you that you have been authorized to undertake research in **Homa Bay County** for the period ending **23rd August, 2019.**

You are advised to report to **the County Commissioner and the County Director of Education, Homa Bay County** before embarking on the research project.

Kindly note that, as an applicant who has been licensed under the Science, Technology and Innovation Act, 2013 to conduct research in Kenya, you shall deposit **a copy** of the final research report to the Commission within **one year** of completion. The soft copy of the same should be submitted through the Online Research Information System.

BONIFACE WANYAMA
FOR: DIRECTOR-GENERAL/CEO

Copy to:

The County Commissioner
Homa Bay County.

The County Director of Education
Homa Bay County.

National Commission for Science, Technology and Innovation is ISO9001:2008 Certified

Appendix J: Research Permit

THIS IS TO CERTIFY THAT:
MS. MATILDA AUMA OUMA
of EGERTON UNIVERSITY, 0-40601
Bondo,has been permitted to conduct
research in *Homabay County*

on the topic: *UPTAKE OF SYSTEM OF RICE INTENSIFICATION PRACTICES THROUGH AN INNOVATION PLATFORM IN OLUCH IRRIGATION SCHEME, RANGWE SUB COUNTY, KENYA*

for the period ending:
23rd August,2019

Permit No : NACOSTI/P/18/71198/24644
Date Of Issue : 24th August,2018
Fee Recieved :Ksh 2000

....
Applicant's Signature

....
Director General
National Commission for Science, Technology & Innovation

CONDITIONS

1. The License is valid for the proposed research, research site specified period.
2. Both the Licence and any rights thereunder are non-transferable.
3. Upon request of the Commission, the Licensee shall submit a progress report.
4. The Licensee shall report to the County Director of Education and County Governor in the area of research before commencement of the research.
5. Excavation, filming and collection of specimens are subject to further permissions from relevant Government agencies.
6. This Licence does not give authority to transfer research materials.
7. The Licensee shall submit two (2) hard copies and upload a soft copy of their final report.
8. The Commission reserves the right to modify the conditions of this Licence including its cancellation without prior notice.

REPUBLIC OF KENYA

NACOSTI

National Commission for Science, Technology and Innovation

RESEARCH CLEARANCE PERMIT

Serial No.A 20351

CONDITIONS: see back page

Appendix K: Publications

Ouma et al., Cogent Food & Agriculture (2020), 6: 1832399
https://doi.org/10.1080/23311932.2020.1832399

cogent food & agriculture

FOOD SCIENCE & TECHNOLOGY | RESEARCH ARTICLE

Innovation platform for improving rice marketing decisions among smallholder farmers in Homa-Bay County, Kenya

Matilda A. Ouma[1,2]*, Christopher A. Onyango[3], Justus M. Ombati[4] and Nelson Mango[5]

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Reviewing editor:
Fatih Yildiz, Food Engineering and Biotechnology, Middle East Technical University, Ankara, TURKEY

Additional information is available at the end of the article

Abstract: Smallholder farmers are normally faced with making a decision on market participation and consequently choosing the appropriate marketing channel for their agricultural produce. This study focuses on how a multi-stakeholder innovation platform approach for improving the uptake of System of Rice Intensification and rice productivity influences marketing decisions among smallholder rice farmers. The study relies on primary data collected from 102 households in Homa-Bay County, Kenya. Logistic and multinomial logistic regression models were used in the analysis. The practice of system of rice intensification, membership to farmer groups, frequency of access to extension services, distance to the nearest market and access to transportation facilities were important determinants to market participation among farmers. A farmers' choice of marketing channel was commonly influenced by size of land under rice cultivation, access to transport facilities and whether rice was to be sold collectively or individually. We therefore conclude that the multi-stakeholder innovation platform approach improves decision making in marketing. We thus recommend that governments embrace multi-stakeholder Innovation Platforms as a framework for

Matilda A. Ouma

ABOUT THE AUTHOR

Ms Matilda A. Ouma is an agricultural extension and rural innovation specialist. Over the years she has done a lot of work in participatory technology development and dissemination. As extension scientists she has been involved in capacity building of farmers and stakeholders in various agricultural projects in many parts of Kenya. Over the years her research work has been in agriculture and rural innovation covering the following areas, effectiveness of Participatory Video in Learning and Dissemination of 'Push-Pull' Technology among Smallholder Sorghum Farmers, and Innovation Platforms for Market Development and Market-led Technology Adoption. Her current environmental orientation is research in climate smart technologies.

PUBLIC INTEREST STATEMENT

The fact that the Sustainable Development Goals are not to be met is not due to a lack of appropriate technologies or the lack of scientific expertise—but rather the very low rate of adoption of technologies. With this, we do not say that the scientific community is "off the hook" and we can blame the small scale subsistence farmer for their rather lethargic adoption rates—it is most probably our own limited understanding of the adoption/innovation process and the incentives for investment and production beyond the household's immediate needs. In this paper, we examine how decision-making in marketing can be improved through the multi-stakeholder innovation platform approach in the context of smallholder rice farming. Specifically, we explore how innovation platform activities such as trainings, extension reinforcement, improving market information and transport access and other activities influence rice market participation and choice of markets.

Journal of Experimental Agriculture International

42(12): 13-25, 2020; Article no.JEAI.65581
ISSN: 2457-0591
(Past name: American Journal of Experimental Agriculture, Past ISSN: 2231-0606)

Challenges and Coping Strategies in the Uptake of the System of Rice Intensification Practices in Oluch Irrigation Scheme, Homa-Bay County, Kenya

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[2]Department of Agricultural Education and Extension, Egerton University, P. O. Box 536 –20115, Egerton, Njoro, Kenya.

Authors' contributions

This paper is a result of collaborative effort among all authors. Author MAO designed the study, collected and analysed data and wrote the first draft of the manuscript. Authors JMO and CAO reviewed the study design, guided in data collection, analysis and report writing. All authors read and approved the final manuscript.

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Original Research Article

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ABSTRACT

System of rice intensification (SRI) is a novel technological approach aimed at improving rice productivity using environmental-friendly and cost-effective agronomic practices. Although its utility has been demonstrated in several settings in sub-Saharan Africa, its implementation is still considerably low. This study explored the challenges faced and coping strategies used by Kenyan smallholder farmers who contribute substantially to domestic rice production, in the uptake of SRI practices in rural setting in the western part of the country where it was previously been introduced. The study involved a survey of 101 smallholder rice farmers in Oluch Irrigation Scheme in Homabay County, to understand the challenges and coping strategies to the uptake of the system of rice intensification practices. Descriptive and inferential statistical analysis was done to guide in summarising the results using the SPSS package. The findings revealed that a host of challenges impede the acceptance of SRI in Oluch irrigation scheme, mainly insufficient knowledge, shortage

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Appendix L: Analysis code for Network analysis and regression analysis

```
#**************************************************************************
# This is an R-script with code to undertake key analysis in the thesis: Linear regression,
# correlation and Social Network analysis
#**************************************************************************

#************ Load relevant libraries required for analysis
library(readxl)
if(!require(corrplot)) install.packages("corrplot"); library("corrplot")
if(!require(Hmisc)) install.packages("Hmisc"); library("Hmisc")

#***********Set working directory containing required files
  setwd("C:/Users/Matilda Ouma")

# **********Import dataset into R
 uptakeanalysisdata = read_xlsx("uptake_vs_network_analysis.xlsx", col_names = T,
sheet="Sheet2")

  cor(uptakeanalysisdata[,-c(1,2)])

# Compute and visualize the correlation matrix a sa first step
  cormat= rcorr(as.matrix(uptakeanalysisdata[,-c(1,2)]))
  View(cormat$r)

# **************************
#Compute the correlation matrix and a matrix of p-values from the test
#whether the correlations are significant or not. This is done by writing a function
#flattenCorrMatrix to obtain the # matrix; cormat : matrix of the correlation coefficients;
#pmat : matrix of the correlation # p-values
#************************
 flattenCorrMatrix <- function(cormat, pmat) {
  ut <- upper.tri(cormat)
  data.frame(
   row = rownames(cormat)[row(cormat)[ut]],
   column = rownames(cormat)[col(cormat)[ut]],
   cor  =(cormat)[ut],
   p = pmat[ut]
  )
 }
 cormat= rcorr(as.matrix(uptakeanalysisdata[,-c(1,2,13)]))
 flattenCorrMatrix(cormat$r, cormat$P)

 View(as.data.frame(cbind(cormat$r, cormat$P)))

# *******The code below produces correlation plot
 cormat1= cor(uptakeanalysisdata[,-c(1,2,13)])
 corrplot(cormat1, type = "upper", order = "hclust",
      tl.col = "black", tl.srt = 90 , tl.cex = 0.4)
```

```
#****combine correlogram with the significance test; Insig correlations are crossed
 png(file = "corrplot_1.png", width = 600, height = 600)
 corrplot(cormat$r, type="upper",
        p.mat = cormat$P,  sig.level = 0.1, insig = "blank",
        tl.col = "black", tl.srt = 90 , tl.cex = 0.8, cl.align.text = "r")
 dev.off()

 #************ Insignificant correlations are leaved blank
 corrplot(cormat$r, type="upper", order="hclust",
        p.mat = cormat$P, sig.level = 0.01, insig = "blank")

#**************************************************************************
# Fit a linear regression model
#**************************************************************************
linearmodel = lm(log(Uptake) ~  Other_farmers + Research_inst +
                 Support_service_providers+Input_stockists_suppliers+
                 Extension_MOALF    +IWUA+        Local_admin+private_miller+
                 KOSFIP+
                 High_interaction_with_stakeholders,    data = uptakeanalysisdata)
#****************************************************
# Display model summary
#****************************************************
summary(linearmodel)
coef(summary(linearmodel))[,4]

#****************************************************
# visualize model results in a tabular format
#****************************************************
View(coef(summary(linearmodel)))
```

Network analysis

```
#**** Import relevant libraries

library(readxl)

library(igraph)

if(!require("RColorBrewer")) install.packages("RColorBrewer"); library(RColorBrewer)

if(!require("stringr")) install.packages("stringr"); library(stringr)

if(!require("BBmisc")) install.packages("BBmisc"); library(BBmisc)

#***********Set working directory containing required files
  setwd("C:/Users/Matilda Ouma")


#*** Import datasets

nodes <- read_xlsx("networkdata_edited_with_IWUA.xlsx", col_names = T, sheet
="Stakeholder_nodes_classif8")
```

```
links_cols <- read_xlsx("networkdata_edited_with_IWUA.xlsx", col_names=T, sheet =
"Stakeholder_edges_cols_classif8")

links_rows <- read_xlsx("networkdata_edited_with_IWUA.xlsx", col_names=T, sheet =
"Stakeholder_edges_rows_classif8")

stakeholder_matrix1 <- as.data.frame(read_xlsx("networkdata_edited_with_IWUA.xlsx",
col_names = T, sheet ="stakeholder_matrix1"))

stakeholder_matrix2 <- as.data.frame(read_xlsx("networkdata_edited_with_IWUA.xlsx",
col_names = T, sheet ="stakeholder_matrix2"))

#****************************

# Data wrangling

#******************************

# remove zeros, i.e same relationship

links_cols <- links_cols[!links_cols$weight==0,]

links_rows <- links_rows[!links_rows$weight==0,]

# Compute node degrees (#links) and use that to set node size:

deg <- degree(net_cols, mode= "all")

V(net_cols)$size <- deg*2


deg_new <- degree(net_cols_new, mode= "all")

V(net_cols_new)$size <- deg_new*2




# Set edge width based on weight:

E(net_cols)$width      <- E(net_cols)$weight/2.5

E(net_cols_new)$width   <- E(net_cols_new)$weight/2.5


colrs_palette        <- brewer.pal(n = 9, name = "Set3")

V(net_cols)$color     <- colrs_palette[V(net_cols_new)$stakeholder_type_1]

V(net_cols_new)$color <- colrs_palette[V(net_cols_new)$stakeholder_type_1]


# Set the network layout:

graph_attr(net_cols, "layout")      <- layout_randomly #layout_in_circle

ecol_cols <- rep("gray60", ecount(net_cols))

ecol_cols[unlist(E(net_cols)[weight>=10])] <- "darkred"

table(E(net_cols)$weight)
```

```
plot(net_cols_new, edge.arrow.size=.1, vertex.label.cex=1,vertex.label.font=2, edge.color=
ecol_cols_new,     vertex.label.color="black", vertex.label.degree = pi/2, layout= l_fr1)

legend(x=-1.5, y=-0.3, c("Farmers", "Research institutions","Support/service providers",

                    "Input stockists/suppliers", "Support/service providers",

   "Regulatory (Government)","Millers/processors","KOSFIP", "IWUA"), pch=21, y.intersp = 0.15,
x.intersp = 0.5,       col="#777777", pt.bg=colrs_palette, pt.cex=2, cex=0.85, bty="n", ncol=1,     )

legend(x=-1.6, y=-1.4, c("Strongest ties","Medium ties", "Weaker ties"),
text.width=c(0,0.12,0.1), bty = "n",       x.intersp=0.3,       xjust=0, yjust=0,       col =
c("darkred","blue", "gray65"),       lwd=4, cex = 0.85, xpd = TRUE, horiz=TRUE, seg.len = 0.3)


text(x=-0.8, y=-1.0, labels = "Strength of information sharing(receiving)",

    cex=0.8, font = 2)


#*********************************************************************

# Row wise analysis

#*********************************************************************

net_rows      <- graph_from_data_frame(d=links_rows, vertices=nodes, directed=T)

net_rows      <- simplify(net_rows, remove.multiple = F, remove.loops = T)

# Compute node degrees (#links) and use that to set node size:

deg <- degree(net_rows, mode= "all")

V(net_rows)$size <- deg*2.5

# Set edge width based on weight:

E(net_rows)$width       <- E(net_rows)$weight/2.8

colrs_palette <- brewer.pal(n = 9, name = "Set3")

V(net_rows)$color <- colrs_palette[V(net_rows)$stakeholder_type_1]

# Set the network layout:

graph_attr(net_rows, "layout")      <- layout_in_circle

par(mar=rep(0,4))

ecol_rows <- rep("gray60", ecount(net_rows))

ecol_rows[unlist(E(net_rows)[weight==13])] <- "darkred"

ecol_rows_new <- rep("gray60", ecount(net_rows_new))

ecol_rows_new[unlist(E(net_rows_new)[weight==13])] <- "darkred"

ecol_rows_new[unlist(E(net_rows_new)[weight ==9.1 | weight ==10])] <- "blue"
```

```r
plot(net_rows, edge.arrow.size=.1, vertex.label.cex=.8,vertex.label.font=2, edge.color= ecol_rows,     vertex.label.color="black", vertex.label.dist = -0.8, vertex.label.degree = pi/2)

table(E(net_rows_new)$weight)

plot(net_rows_new, edge.arrow.size=.1, vertex.label.cex=.8,vertex.label.font=2, edge.color= ecol_rows_new,

    vertex.label.color="black",  vertex.label.degree = pi/2, layout = layout_with_mds)

legend(x=-1.65, y=-0.3, c("Extension service providers", "Support/service providers","Input suppliers/stockists", "KOSFIP","Millers/processors","Regulatory (Government)",

                    "Research institutions","Rice farmers", "IWUA"), pch=21, y.intersp = 0.2, x.intersp = 0.5,      col="#777777", pt.bg=colrs_palette, pt.cex=2, cex=0.8, bty="n", ncol=1, xjust = 0)


legend(x=-1.65, y=-1.7, c("Strongest ties","Medium ties", "Weaker ties"),

      text.width=c(0,0.12,0.1), bty = "n",      x.intersp=0.1,      xjust=0, yjust=0,

      col = c("darkred","blue", "gray65"),      lwd=4, cex = 0.85, xpd = TRUE, horiz=TRUE, seg.len = 0.45)


text(x=-0.9, y=-1.25, labels = "Strength of information sharing(sending)",     cex=0.8, font = 2)
```