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ECONOMICS OF THE SYSTEM OF RICE INTENSIFICATION ON PRODUCTIVITY OF RICE AMONG SMALLHOLDER FARMERS OF MWEA IRRIGATION SCHEME, KENYA

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DECLARATION

This thesis is my original work and has not been presented elsewhere for a degree or any other award.

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DEDICATION

This work is dedicated to my family for their support and sacrifice towards my education. A special gratitude goes to my parents, Ben Kaloi and Margret Kaloi for their words of encouragement. My siblings have never left my side and are very special.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS AND ACROYNIMS

ASDS	Agricultural Sector Development Strategy
BLUE	Best Linear Unbiased Estimator
BRRI	Bangladesh Rice Research Institute
GDP	Gross Domestic Product
GM	Gross Margins
EDU	Education
GOK	Government of Kenya
FAO	Food and Agriculture Organization
ICT	Information Communication Technology
KES	Kenya Shillings
MIS	Mwea Irrigation Scheme
MOA	Ministry of Agriculture
NHRRC	National Hybrid Rice Research Centre
NACOSTI	National Commission for Science, Technology and Innovation
OCC	Occupation
OLS	Ordinary Least Square
SDGS	Sustainable Development Goals
SEU	Subjective Expected Utility
SPSS	Statistical Package for Social Sciences
SRA	Strategy for Revitalizing Agriculture
SRI	System of Rice Intensification
TFC	Total Fixed Cost
VMP	Value of Marginal Product
WUA	Water Users Association

DEFINITION OF TERMS

Alternate wetting and drying: This is a water saving technique in paddy fields where water is applied to the field a number of days after disappearance of ponded water. SRI uses this concept to save on water use

Food Security : A situation that exist when all people, all times have physical, social, economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active healthy life (FAO, 2011). Use of SRI in Mwea contribute to food security through increased yields.

Household: Refers to people living together and eating from the same pot at the time of study. Households in this study were used as the reference point for gathering data.

Labour Intensive : Requiring or using more labour relative to capital (Ndirangu, 2015). Rice growing is requires a lot of labour during critical filed management activities.

Livelihood: Comprises the capabilities, assets (including both material and social resources) and activities for a means of living (FAO, 2011). The main livelihood activity in Mwea Irrigation Scheme is rice production.

Productivity: Is the improved household income as a result of reduced cost of production and improved efficiency in the farm. The improved productivity of rice in Mwea Irrigation Scheme is expected following adoption of SRI

System of Rice Intensification: is a farming methodology aimed at increasing the yield of rice produced in farming. It is a low-water method that uses younger seedlings singly spaced and typically hand weeded with special tools (Dobermann, 2004). The study intends to promote adoption of SRI in MIS.

ABSTRACT

Rice farming has received considerable attention in developing countries and particularly in Kenya due to its impact on smallholders' income and food security. Irrigated rice is the largest consumer of water and its sustainability is threatened by water shortage. This has necessitated the development of alternative irrigation water systems that use less water with high yields such as the System of Rice Intensification (SRI). This study sought to evaluate the effects of (SRI) on farm level rice productivity in Mwea Irrigation Scheme. The specific objectives were: to evaluate the determinants of SRI adoption, to determine the factors that influence rice productivity under SRI and Conventional Flooding (CF) and to compare the profitability of SRI and CF. Stratified sampling was used to obtain 364 smallholder rice farmers. A semi-structured questionnaire was administered to these farmers to collect primary data. The results showed that age, farm size, household size, distance from the canal, education, access to credit services, access to extension services, and years spent in rice farming positively and significantly influenced the adoption of SRI. Further, household size, involvement in off-farm work, farmer experience, distance from the canal, access to extension services, credit access and labor use significantly affects rice productivity. The findings further revealed that the returns of SRI were higher by 41,770 compared to CF although it was more labour intensive during critical periods of field operations. The study recommends that the government and other stakeholders should devise strategies to promote adoption of SRI to increase productivity of the rice crop and hence food security locally and nationally. Additionally, the rice farmers to be encouraged by extension service providers to concentrate on formal training, participation in farmers field schools, implementing better farming technology (e.g. SRI) and adoption of appropriate water conservation practices for enhanced productivity. Finally based on the unique circumstances of the farmers, the stakeholders should strive to promote adoption of SRI over CF to improve returns from rice

CHAPTER ONE
INTRODUCTION

1.0 Background of the Study

Globally rice is one of the staple food to more than 50% of the world's population. The annual world production of milled rice currently stands at 700 million metric tons and a harvested area standing at 165 million ha (FAOSTAT, 2019). Because of the large rice surface and particularly water demanding, it is estimated that irrigated rice receives about 40% of the global water used for irrigation purposes (Boubacar *et al.*, 2016). Improvement of irrigated rice is becoming more urgent since 15-20 million ha of irrigated rice could suffer because of water scarcity by 2025 (Njuki & Bravo-Ureta, 2018).

Rice is the most rapidly growing food source to most of the African countries with the consumption levels among the low-income strata, providing the bulk of dietary energy to the growing population (Thakur *et al.*, 2015). In 2012, the production of paddy rice was approximated at about 24 million tons in Sub Saharan Africa (SSA). About 60% of consumption was satisfied by local production resulting in the importation of about 10-12 MT year (Yokouchi & Saito, 2016). Demand for rice is projected to increase by 30 MT by 2035 and there is potential in Africa to reduce the gap between supply and demand through increased domestic production (Seck *et al*., 2011).

The Kenya government identified agriculture as a key sector of focus in its 2008 blueprint for economic and social development, followed by a revision of the Strategy for Revitalizing Agriculture (SRA) which was adopted to create improved agricultural legislation. In 2010 the SRA originally intended to run from 2004 -2014, was superseded by the agricultural sector development Strategy 2010-2020 (ASDS) that foresees a food secure and prosperous nation by 2030 and aims to achieve a paradigm shift from subsistence to commercial agriculture. The ASDC was intended to increase the gains made in SRA. The overall goal of the strategy was to transform Kenya's agricultural sector into a profitable, commercially oriented and internationally and regionally competitive economic activity. Despite these efforts, the strategic plan was not able to chart the course of rice production in Kenya (GoK, 2008).

Rice farming in Kenya started back in 1907 from Asia (GoK, 2008). Many regions grow rice for their home consumption, however Kenya for a long time has regarded rice as a cash crop. The long-held perception is rapidly changing. Many communities are now appreciating rice as a food crop for their home consumption. This perception has influenced the balance between production and consumption. Rice estimates are done by the National Irrigation Board (NIB) and the Ministry of Agriculture (MoA). The estimates from MoA are usually larger than the NIB. The reason being that MoA includes non-NIB irrigated productions. These include small scale irrigation schemes and private rice irrigation enterprises that are established by other agencies such as The Lake Basin Development Authority.

Kenya has a potential of about 1 million ha rain-fed for rice production and approximately 540,000 ha irrigable (Atera *et al*.,2018). However, one of the challenges plaguing the rice subsector is erratic rainfalls in some of the potential areas (Nyamai *et al*., 2012). For instance, the water shortage in the Mwea Irrigation Scheme (MIS) forced the Water Users Association (WUA) to reduce the amount of water available for irrigation translating to reduced yields (Onyango, 2014).

The consumption of rice in Kenya is estimated at 300,000 metric tons as compared to the annual production range of 100,000 to 150,000 metric tons with the big deficit being met through importation (Atera *et al*., 2018). There are four irrigation schemes currently producing rice in Kenya. Mwea accounts for 78% of the irrigated area, 88% of production and 98% of the gross value output (Atera *et al.*, 2018). The other rice-producing schemes include West Kano, Bunyala and Ahero (Omondi & Shikuku, 2013). The schemes have the following coverage. West Kano and Ahero (3520 ha), Mwea Irrigation Scheme (9000 ha) and Bunyala Irrigation Scheme (516 ha). The total coverage area in Kenya is approximately 13,000 ha (GoK, 2008).

Technologies that drastically improve water use efficiency are increasingly being adopted (Thakur *et al*., 2015). Various methods have been used to reduce water usage in rice production (Denkyirah, 2015). One of the most tried methods was the Green revolution in Asia, which involved a series of research and technology transfer initiatives (Kassam *et al*., 2011). This innovation involved the development of high yielding varieties of cereal grains and modernization of farmland management techniques (Rahman, 2017). The Green Revolution was very effective and successful in Asia whereby many farmers were able to adopt the technology (Thakur *et* al., 2015). However, the innovation was not able to help many African countries farmers due to limited infrastructure and financial constraints (Ndiiri *et al*., 2013). Aerobic rice is another water-saving technology for irrigated and rain fed conditions that uses external inputs such as supplementary irrigation (Mote *et al*., 2017). Traditionally, this method has been practiced in rainfed uplands and rain-fed shallow lowlands areas of Asia (Singh *et al*., 2017).

The other innovation is the system of Rice Intensification (SRI). From the farmers' perspective, SRI can be defined as the use of existing assets differently yet increasing the outputs and reducing water use while maintaining the quality of the grain (Katambara *et al.*, 2013). It can be inferred from Stoop, (2003) that SRI is a concept on the manipulation of agronomic practices to attain higher rice yields with the use of minimal resources such as agrochemicals, seeds, and water (No continuous flooding in SRI as compared to traditional methods). On the other hand, SRI is regarded as a standard package of specific practices that significantly reflect local conditions (Dobermann, 2004). SRI is gaining popularity in all rice-growing areas of the world and that farmers can grow more rice with less water (Sudeep, 2010).

The key components of SRI include; water management which is practiced by keeping the soil drained and saturated rather than continuous flooding during the vegetative growth period. The SRI modifies farm practices for managing water use, nutrients and soils. The two possibilities suggested for water management in SRI involves the use of little quantity of water daily but leaving the fields dry for short periods (2-7 days) to the point of surface cracking. The other one is flooding and drying the fields for alternating periods of 3-6 days each (Namara, Weligamage, & Barker, 2003). The second component is the planting method which involves spacing configurations and age of seedlings. In SRI, seedlings are transplanted 8-15 days after germination (Thura, 2010). Some studies suggest a line spacing of 30cm x 30cm. The spacing could be based on the local edaphic conditions but it has to facilitate weeding (Uphoff, N. & Thiyagarajan, 2005). The third component is weed control which is best done ten days after transplanting and then weeding every ten days until canopy closure.

The fourth component is soil fertility management. Most farmers use compost or organic manure but the amount applied varies in terms of its availability and also because there is no fixed recommended rate to follow (Ndiiri *et al*., 2013)

The traditional method of rice growing involves continuous flooding (CF) during the vegetative growth with draining of the water during the grain ripening stage, which is a common practice in all the rice-growing schemes in Kenya (Omwenga *et al*., 2014). The CF method is thus associated with higher water usage and occasioned by losses through percolation, seepage, and evaporation (Paredes *et al.*, 2017). With improved innovative water management technologies such as SRI, the current irrigation potentials can be increased to about 1.3 million hectares (Amos, 2014).

1.2 Statement of the problem

Efforts to increase rice production has not yielded much with the continued use of traditional methods that are often costly to smallholders. To achieve the self-sufficiency of rice in Kenya, more innovative practices such as SRI that reduces water use have been introduced to enhance sustainable production. The demand for irrigation water far exceeds the amount of water available for irrigation yet little has been done to ensure efficient use in rice production. Alternative production practices such as SRI benefits have not been fully investigated especially on adoption, productivity, and profitability. The study therefore comes in handy to bridge the knowledge gaps and contribute to the literature on the economics of SRI among smallholders'.

1.3.1 General objective of the study

The general objective of this study was to evaluate the effects of SRI on farm level rice productivity in the Mwea Irrigation Scheme.

1.3.2 The specific objectives

1. To evaluate the determinants of SRI uptake among Smallholders in the Mwea Irrigation Scheme.
2. To determine factors influencing rice productivity under SRI and CF among smallholders in Mwea Irrigation Scheme.
3. To compare the profitability of rice grown under SRI and CF methods in Mwea Irrigation Scheme.

1.4 Research questions

1. What are the determinants of SRI uptake among smallholders in the Mwea Irrigation Scheme?
2. What are the factors influencing rice productivity under SRI and CF in Mwea Irrigation Scheme?
3. How does the profitability of SRI and CF methods compare among Smallholder in Mwea Irrigation Scheme?

1.5 Justification and significance of the study

In a bid to address challenges facing smallholder farmers, sustainable agricultural practices have become the most ideal means to promote agricultural development (Denkyirah, 2015). Consequently, SRI has been promoted as a promising technology to Kenya's struggling rice industry. There are more concerns about food security as outlined in the food and nutrition policies (FAO, 2011). The adoption of innovative technology appears to be a viable means of attaining socio-economic development in Kenya. Smallholders' awareness and application of SRI can be of great importance in improving rice production in Kenya. This could be one of the areas of focus to help the Government of Kenya attain one of its ‘Big 4 Agenda ‘that is food security as well as attaining the Sustainable Development Goals (SDGs) of poverty eradication. In assessing the profitability of different practices, it helps farmers incorporate more effective and informed strategies in programs meant to improve rice production. Consequently, by analyzing the determinants of adoption, it will make stakeholders make more informed decisions in coming up with corrective measures that address factors that negatively affect the adoption of SRI.

CHAPTER TWO
LITERATURE REVIEW

2.1 Review of system of rice intensification

This demand for water resources is becoming intense due to population pressure, the inefficiencies of the developed water infrastructures and competition among different users and uses. Rice currently consumes the largest of the water available for irrigation (Namara *et al.*, 2003). The system of rice intensification was synthesized in the 1980s by Henri de Laulanie who came to Madagascar from France (Stoop, 2003). He worked with Malagasy farmers to improve their agricultural systems and particularly rice production. In China, the first trials were conducted in Nanjing Agricultural University, followed by evaluations at the China National Hybrid Rice Research and Development Centre (Wang *et al.*, 2018). The results from the field trials encouraged more farmers to seek information from farmers who had successfully adopted the SRI. In Cambodia, farmers practicing SRI were found to have better resource endowment than other farmers (Katambara *et al.,* 2013).

A new line of criticism has emerged which concedes that SRI methods can be beneficial for small and poor farmers enabling them to raise their productivity at a lower cost. SRI is considered to introduce changes in a range of management practices (Kassam *et al*., 2011). These consist of early transplanting of young seedlings, weeding by use of mechanical weeders, use of organics efficient water use, alternate wet and drying and single seedling with wider spacing (Lee & Kobayashi, 2017). Proponents of SRI consider it to be beneficial on high yields and greater water productivity (Mote *et al.*, 2017). Nevertheless, previous studies also showed some skepticism regarding the increased production through the adoption of SRI technology. Most of these studies articles were published in the mid-2000s (Dobermann, 2004). One of the recent studies by Varma, (2017b) shows that SRI offers economic and environmental benefits but the expense of employment. Despite the criticism, SRI is gaining popularity and farmers are practicing all the principles. SRI methods have been adopted in more than 50 countries (Arsil *et al*.,2019).

SRI in Kenya was formally introduced in August 2009. Data on the actual level of SRI adoption in Kenya is estimated to be over 3000 in MIS (Ndirangu, 2015). the information available has attracted various policymakers and the efforts are being made by various states to promote SRI in Kenya (Kathia *et al.*, 2019). The first field experiments were conducted at Mwea Irrigation Agricultural Development (MIAD) Centre. Farmers who adopted the method have seen their rice yields go high with water-saving (Ndiiri *et al.*, 2013). Moreover, rice grown under SRI matures faster and has a hard grain which then when milled, does not easily break.

2.2 SRI Practices

The knowledge on SRI practices is still evolving and concerns are more about improving productivity of land, labor, and nutrients. The main components of SRI are soil fertility management, water management (Irrigation), weed control and planting methods (Namara *et al.*, 2003). In SRI, seedlings are transplanted 8-15 days after germination. This is much earlier than the usual three to four weeks. Besides, Transplanting should be done carefully and immediately, preferably 15-30 minutes after uprooting on texturally fine soils. One or two seedlings are transplanted per hill not in clumps of more than two seedlings as usually done. Planting is done on a square of 25 x 25cm, or even larger space (Thura, 2010) or even larger (up to 50 x 50cm) which is much wider than the usual (Namara *et al.*, 2003). Some studies also suggest 30 x 30cm in the main season and 25 x 25cm in the offseason as the most appropriate spacing. The spacing could be based on the local edaphic conditions but it has to facilitate weeding (Uphoff & Thiyagarajan, 2005).

Weed control is best done ten days after transplanting and then weeding every ten days until canopy closure. Weeding is done not only to control weeds but also to aerate the soils. Most farmers use compost/ manure, the amount applied varies in terms of its availability and also because there is no fixed recommended rate to follow (Thura, 2010). Nutrients added to the soil should be preferably in the form of organic matter like compost or mulch. The use of organic fertilizers should be gradually avoided or minimized as the nutrient of the soil develops.

SRI is considered to be environmentally friendly and high yielding technology (Kassam *et al.*, 2011). The study further reveals that SRI elements can be used to enhance the production of other crops such as wheat and sugarcane. Therefore the impact of SRI ideas could be extended beyond rice (Choudhary *et al.*, 2018). Nevertheless, the study was not able to show the extent to which the labour required for SRI management would diminish as farmers gained confidence in the methods to reduce labour inputs and while raising labour productivity. SRI technologies can be able to raise yields to double the present world average without relying on external inputs (Ndirangu, 2015). The study further revealed that there was a positive perception of SRI among farmers. However, the study failed to capture water management practices and land leveling practices and cost reduction practices.

Engaging multi-stakeholders in training, adaptive research, and dissemination of knowledge fast-tracks the adoption of SRI (Palis *et al.,* 2017). It also reduces fuel and labour consumption, especially in the deep irrigation systems. SRI is a practice that has proven to be very effective in saving water and increasing rice yields in many parts of the world (Katambara *et al.*, 2013). The study further notes that the practice is spreading and has been adopted in many parts of the world. For developing countries like Tanzania and Kenya, food consumed in major urban centers is produced by subsistence farmers whose yields are low and the whole population is vulnerable to climate change. Thus the need to embark on technologies and farming practices that ensure more food production while using less water (Katambara *et al*., 2013). Agricultural training is a potentially effective method to diffuse relevant technologies to increase productivity (Nakano *et al.,* 2018*)*.

2.3 Determinants of adoption

Considerable literature exists in explaining factors that influence the adoption decisions using different econometric techniques. Most of the recent and previous studies have shown that farm-specific, household characteristics and institutional factors have a significant influence on the adoption of farm technologies (Danso-abbeam *et al.,* 2018). The analysis of the determinants of adoption of improved maize varieties (IVM) among farmers in the northern region of Ghana revealed that variables such as the age of the household size, level of experience, farm workshops attendance, the number of years in formal education, availability of labour and extension contact influence the adoption of IVM (Danso-Abbeam *et al.,* 2014) . The study further posited that household size, distance to farm plots and membership of farmer-based organizations are significant determinants of the intensity of IMV adoption.

The welfare impacts of SRI showed that all combinations of SRI individually and as a group (Water management, plant management, and soil management) had an impact on productivity (Varma 2017a). The results of the multinomial endogenous treatment effects model showed that household assets, irrigation and access to information increased the likelihood of household households adopting SRI whereas the size of the landholding, number of years households stayed in paddy cultivation decreased the likelihood of adopting SRI. The productivity of rice farmers in southwest Nigeria using the Endogenous Switching regression model showed that farmers' location income, interest rates, rice farming experience and the distance to the source of credit are statistically significant determinants of the amount of credit received (Ojo , 2019) . The findings further showed that facilitating farmers' access to credit will improve rice productivity. The study suggested that the government and development partners needed to work together to improve the conditions for credit access to rice farmers and especially the review of the interest rates. Additionally, the study recommended the intensification of paddy rice inorder to meet the increasing demand, improve production and income.

Paltasingh & Goyari, (2018) analyzed the effects of education on-farm productivity using endogenous switching regression, the results showed that a minimum threshold level of education significantly influenced the adoption of modern varieties. Also, the study found the evidence in support of Schultz hypothesis that says education enhances farm productivity in the case of adopters of modern technology. The study suggests that farmers field schools to be implemented along with an extensive network in the study region. An evaluations of ecosystem.

The impacts of SRI adoption on rice yields and household income indicated that there was no significant differences between adopters and non –adopters while comparing mean yield and income levels (Noltze, 2012) . The results was due to negative selection bias, Smallholders with less than average yields adopted SRI more on small plots. The results further suggested that SRI may not be of benefit when compared to CF rice grown under best management practices and in favourable conditions. Myint & Napasintuwong, (2016) assessed the economic benefits to farmers and identify factors contributing to the wider adoption of Paw San Rice. The results revealed that price and revenue of paw San rice cultivation are significantly higher than the non-Paw rice variety. Education plays a key role in agricultural development. There exists a threshold for the effect of education on agricultural productivity change (Fung-Mey, 2009).

The determinants of technology adoption and how it affects farmers' welfare in Uganda and Tanzania include farm size, contact with the government agencies, credit access, and the number of improved seed varieties. The results showed that households who used improved seed varieties tend to be different from those that do not. They also have higher consumption expenditure. The results further indicated the potentials of the improved seed varieties in helping the households in especially in rural areas increasing their welfare.

Gicheru (2016) examined the barriers and enablers to the adoption of SRI in MIS. The results showed that most barriers occur during the dissemination of SRI. Additionally, barriers to the uptake of the technology were identified as lack of formal SRI training, high cost of rice production and failure to involve key stakeholders. Moreover, the study noted that most barriers to SRI adoption were intertwined thus focusing on a single barrier would be Myopic. These correlations implied that the benefits under SRI are key motivators for adoption.

Okoh (2010) reviewed types of integrated farming systems and their impact on income. The study revealed that farm cash income was significantly influenced by the farmers' years of experience, education level, types of integration and cost of farm inputs. The results indicated that farm cash income could be increased through the provision of subsidies for farm inputs to reduce the cost of production. Besides, there was a need to enlighten the farmer's knowledge and technical skills. Nzonzo (2016) examined the adoption of technologies in irrigated rice production in Mwea. The study findings showed that the major barriers facing adoption were lack of training and lack of ICT skills. Onyeneke (2017) analyzed factors associated with the adoption of improved rice production technologies. The results indicated that socioeconomic factors such as age, income, cooperative membership, household size, and level of education, number of contacts with the extension agent and farm size affected adoption.

An independent double hurdle model was used to examine the decision variables that influence fertilizer adoption and optimal intensity (Akpan *et al.* 2012). Empirical estimates of the first hurdle showed that family size, farm size perceived price of fertilizer years in farming business value of crop output and decision to own goats and sheep kept by farmers are significant decision variables that influenced the probability of adopting fertilizer by farming households. Estimates of the second hurdle revealed that the decision to use the optimum intensity of fertilizer by farming households' heads was influenced by age, farm size, gender and the perceived price of fertilizer. Newman *et al*. (2003) analyzed factors influencing Irish household's decisions to purchase prepared meals and how much to spend on the food items. Adoption studies show that young farmers have more information regarding new practices and that they are willing to take risks (Sudeep, 2010). This finding concurs with the findings of State & Iheanancho (2017) that young farmers are innovative and active at farm work as compared to old farmers who are weak and are no longer in their productive stage. Zaixing (2010) found that male managers had a higher adoption probability of agricultural technologies than female managers.

A study conducted by Kassie *et al* (2015) reported that males are more likely to adopt agricultural practices as compared to females. Farmers with a large family size are likely to adopt technology because of cheap labour availability (Sudeep, 2010). It has been demonstrated that SRI is labour intensive (Doberman,2004 and Adedoyin *et al.,* 2016). Thus SRI is more likely to be adopted by farmers with large family sizes. Households with higher education levels are likely to adopt new technology because education increases the farmers' ability to understand technology and apply (Uphoff, & Thiyagarajan, 2005). Additionally, educated farmers are likely to adopt new agricultural technologies more easily compared to traditional methods (Voh 1982).

Income generated through off-farm activities helps to meet the capital costs for the implementation of new agricultural technology (Adesina & Zinnah, 1993). It also reduces the risks associated with experimenting with new technologies (Sudeep, 2010). Farmers with big farms, generally one hectare and above are believed to be rich in terms of landholdings. Farmers with large farms are risk-takers and try new technologies (Kebede *et al.*,1990).

Training on SRI, Nursery management, compost production, and other practices could influence SRI adoption positively (Sudeep, 2010). Participation in agricultural training programs increases SRI adoption (Namara *et al*., 2003). Sudeep (2010) used focused group discussion to determine the constraints associated with the adoption of SRI in Eastern Nepal. Farmers listed water management as the topmost constraints for SRI adoption.

Katambara *et al.*, (2013) noted that SRI requires intermittent flooding in the land; if the land has limited irrigation facilities then it becomes difficult to practice SRI. More investment is needed in water management for large scale adoption of SRI (Uphoff, 2005). Lack of institutional support is also the limiting factor for large scale adoption of SRI (Njuki & Bravo-Ureta, 2018). The importance of data on the adoption of technology is widely recognized in the literature (Singh *et al*., 2017; Kebede *et al.*, 1990) and SRI in particular (Namara *et al*., 2003). The awareness of SRI is a necessary condition for its adoption (Poornima Varma, 2017b). Various studies have pointed out the constraints faced by farmers in adopting SRI Some farmers in India had discontinued the adoption of SRI citing difficulty in accessing laborers as one of the main reasons (Kassie *et al*., 2015; Paredes *et al*., 2017).

2.4 SRI and labour distribution.

In some countries like Kenya, the cost of high production at the farm level has been attributed to the migration of the young people who then provide labour in the rice farms (Ndiiri *et al*., 2013). Men, women, and children are involved in rice production in various levels. Men are mainly in land preparation (leveling and ploughing) and transportation whereas women and children are involved in weeding, planting, bird scaring, harvesting, threshing and drying (GoK, 2008). Low adoption of agricultural technologies has been associated with gender-related issues (Kirby *et al*, 2017). Women hardly attend seminars or training workshops yet they are the central players in rice production. This is likely to have adverse effects on the adoption and upscaling of rice technologies. The deliberate targeting of women and children for capacity building and technology transfer will enhance productivity. A study by Khan *et al*., (2016) showed that respective gender roles in the family and on the farm seem to explain some of this difference. Men have a greater say on how the family spends income. Accordingly, men tend to have a higher willingness to pay for attributes that increase income or reduce cash costs. Women contribute to a large share of labour for transplanting rice, much of which is unpaid labour works. Female seems to value labour saving significantly more than their male counterpart. The study further notes that although men in the family have more say, women do influence the adoption of new technology. The major constraint that faced SRI farmers was the weed menace, high labour requirement for weeding and poor land drainage (Ndiiri *et al.*, 2013). The study further indicated that the most pressing constraint faced by SRI farmers was the high cost of agrochemicals. Lack of water was also ranked as the most pressing constraints.

Male and female farmers share many tasks in both SRI and conventional flooding (Resurreccion *et al.*, 2008) . Men, however, perform land preparation tasks while seedling preparation and weeding are commonly assigned to women. All others –harvesting, uprooting, transplanting are generally shared tasks. The study also reveals that uprooting and transplanting are increasingly left to older women. This concurs with the findings from Dobermann (2004) who argues that the decision to adopt SRI was less contentious between women and men contrary to their earlier expectations. In other cases, men seemed to care less about farming in general, including SRI, most likely due to improved incomes coming from non-farm occupations. Ben *et al*. (2017) observed that men were mostly involved in land preparation which involved leveling and ploughing. Children were involved in planting, weeding, and bird scaring.

2.5 Theoretical review

Farmers choose the system for which they obtain the highest expected utility (Roussy *et al.*,2014). Smallholders Farmer's perception is to maximize on their perceived utility. This research will be based on the subjective expected utility framework. The individual expected utility of innovation can be approximated (Equation 1, 2)

$$SEU(\pi) = \sum_i p_i^t \, U(\pi i) \qquad (1)$$

$$U(\pi) = \frac{\pi^{1-RRA}}{1-RRA} \qquad (2)$$

Where pi = the probability of the state of nature i for the profit (π_i); RRA= the relative risk aversion coefficient and SEU is the subjective expected utility. When farmers have a choice, they do select the alternative with the highest utility (Equation 3). Based on the random utility theory, the global utility of a system is composed of the utility of each characteristic of the cropping system. Although profit could be one of the characteristics, farmers also maximize their utility based on other factors such as agronomic and technical.

$$U_k > U_j \qquad (3)$$

WhereU=U($t_1, t_2, \ldots, t_r$)+ε (4)

$t_1, t_2 \ldots\ldots t_r$ Corresponds to the r characteristics of innovation while the error term (ε) depicts the individual determinants.

2.6 Conceptual framework

Figure 1 indicates the conceptual framework for this study. It is conceptualized that Education level, household size, Gender, Income, Farmer experience, farm size, Age, extension services, training, gender, education, household size, household income, farmer experience, farm size, labour, input costs, credit access, and extension services affects the adoption of SRI. Labour use affects rice productivity and profitability. Increasing government involvement among smallholder rice farmers has the potential to lift them to better income levels through improved rice productivity and surplus production

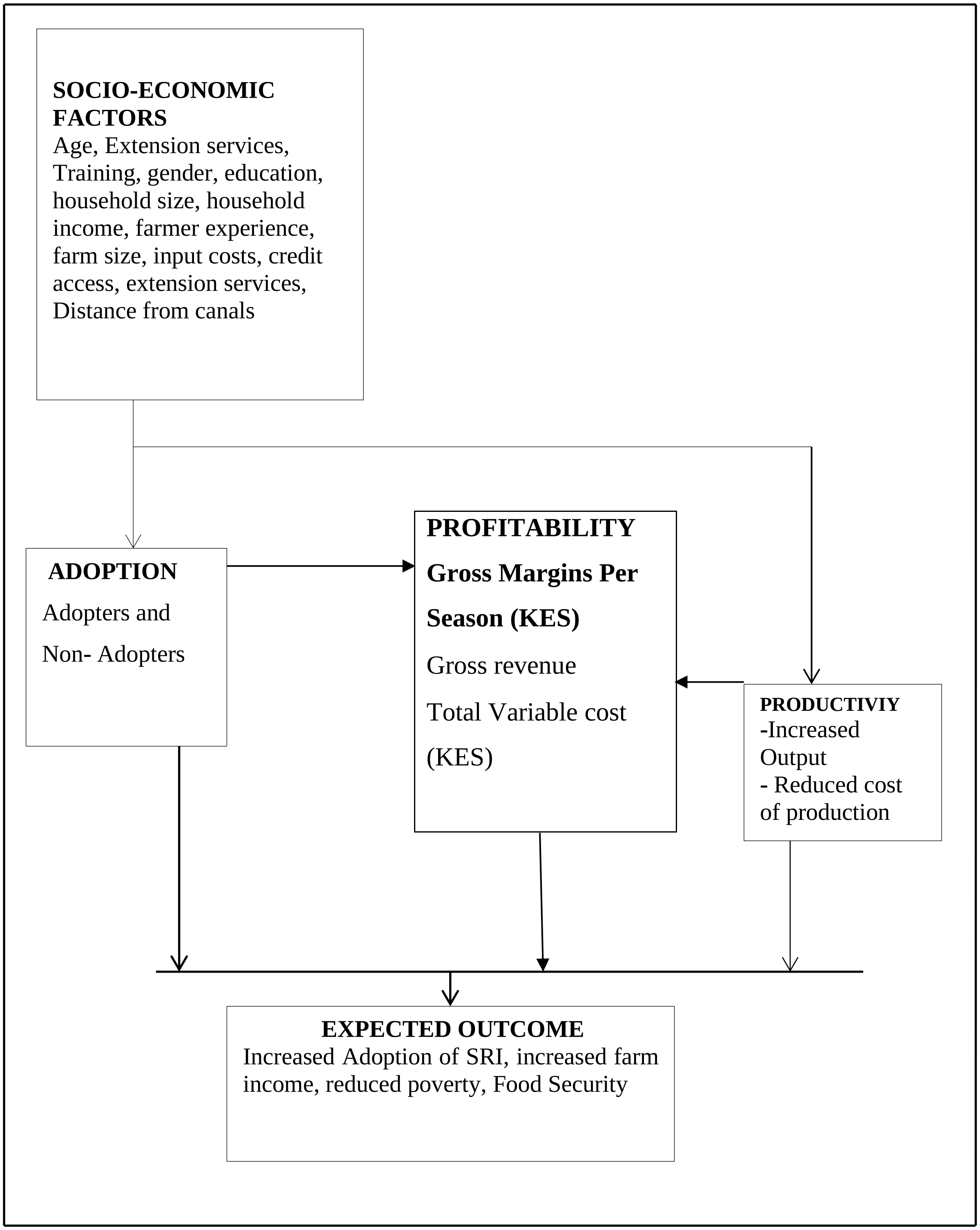

Figure 2. 1: Conceptual Framework

2.7 Summary of literature review and research gap

While Worldwide adoption of SRI started three decades ago, its knowledge is still evolving and therefore its implementation and sustainability still need investigation (Poornima Varma, 2017b). A review of other studies also shows that the global demand for irrigation water is proportional to the demand for food to feed the growing population (Mati *et al.*, 2011). The traditional practice of continuous flooding becomes technically unfavorable to this current environment of limited water resources (Mohammed, 2018).

Many empirical studies have investigated the issue of adoption ((Kinuthia, 2015, Varma, 2017b, and Noltze, 2012). However alternative production practices such as SRI have not yet been fully investigated especially on adoption, productivity, and profitability. Previous studies on SRI in Mwea Irrigation Scheme include [(Ndirangu, 2015) and (Ndiiri *et al*., 2013)]. Authors such as Ndiiri *et al*. (2013) focused on the constraints and the returns associated with SRI while Ndirangu (2015) focused on the perceptions of SRI. From these studies, little has been done or investigated on determinants of SRI in Mwea Irrigation Scheme. The knowledge on SRI is still scanty especially on the application of econometric modeling. This, therefore, provides a strong case of argument of using SRI to generate information on productivity, profitability, and determinants of adoption with a view of driving policy recommendations and filling the information gap in Kenya.

CHAPTER THREE
RESEARCH METHODOLOGY

3.1 Study area

This research was conducted in Kirinyaga County and specifically Mwea Irrigation Scheme (MIS). MIS is one of the seven public irrigation schemes in Kenya. The scheme is located to the Central part of Kenya, about 100 Kilometers' North-East of Kenya's capital city Nairobi.

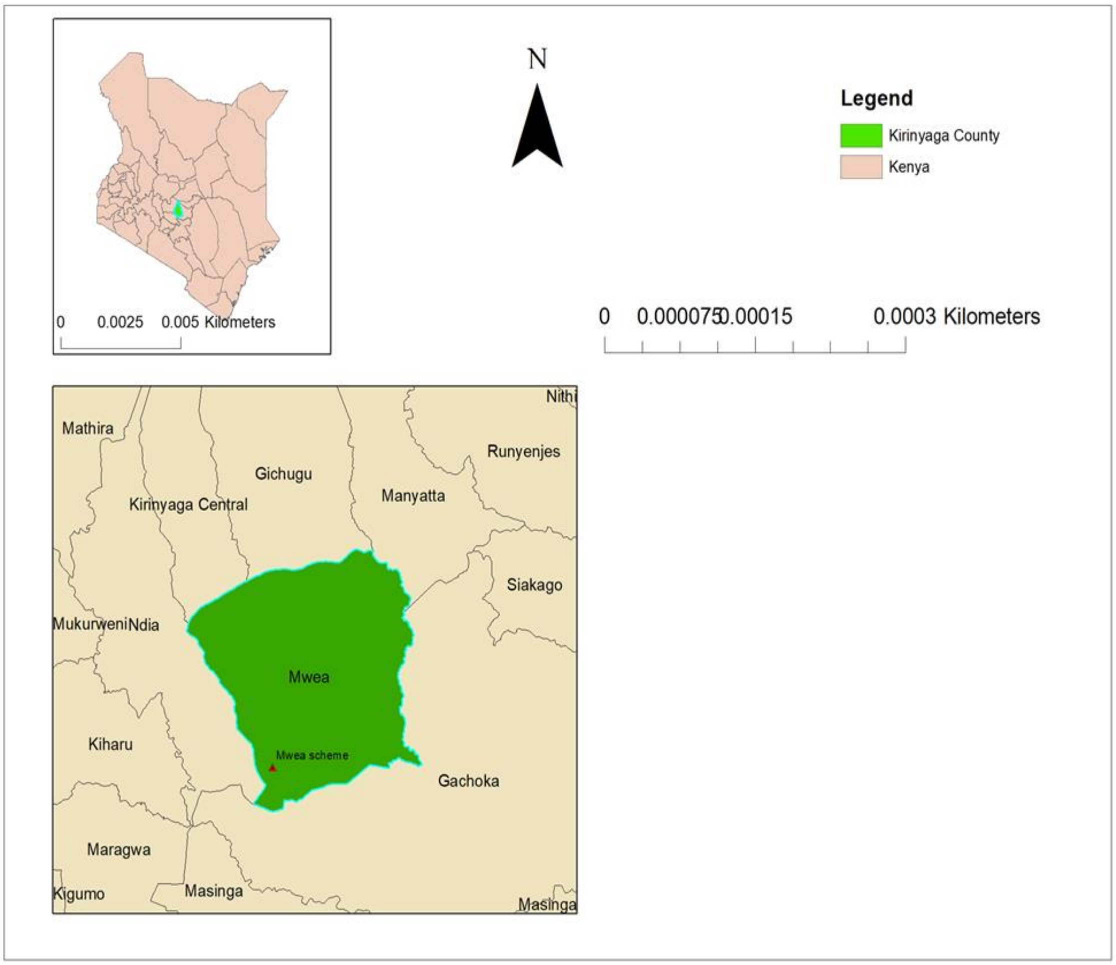

Figure 3. 1: Map of Mwea irrigation Scheme in Kirinyaga County

The scheme occupies the lower altitude zones of the region with expansive low marshy areas. The altitude ranges from 1,000-2,200m above the sea level, with temperatures ranging between 15 ℃ and 30℃. Rain seasons in the region are usually two, the long rains occurs between March and May, while the short rains occurs in October/December. The Soils are Vertisols (black cotton soils).The main agricultural activity is mono-cropping.

Rice is thus grown in paddies that are irrigated for a period of six months. The main sources of water to the scheme are River Nyamindi and River Thiba which are tributaries of river Tana. There are currently over 52 villages with approximately 7320 households within the main scheme as listed in the National Irrigation Board website.

3.2 Research design

The study adopted a cross-sectional survey design. This enabled the study of groups that covers the wide geographical area of Mwea irrigation scheme. In addition, it enabled the researcher to observe more variables at the point in time. It was also useful in describing the relationship between two or more variables. The cross sectional design was used to measure the differences between the adopters and the non-adopters of SRI. The study employed both qualitative and quantitative approaches to analyze data on the economics of SRI among smallholders in MIS. More specifically, a quantitative approach was used to establish the relationship between variables in the data collected in MIS.

3.3 Target population

Target population refers to the whole set of units for which the data collected are to be used to make inferences (Mohammed, 2018). The target population for this study was therefore rice growing areas in Kirinyaga County. Mwea irrigation scheme is selected as the accessible population. Sampling was done in all administrative areas within Mwea Scheme.

3.4 Sampling procedure

The respondents were selected using stratified random sampling. This was done with the aid of the twenty rice units as strata. Twelve units were randomly selected from the twenty units which are within the four major rice-producing blocks in the irrigation scheme. The major blocks include Karaba, Tebere, Wamumu, and Thiba. Thirty (30) smallholder rice farmers were selected per unit and about ninety-one (91) per block were sampled to give a total of three hundred and sixty-four (364) respondents.

3.5 Sample size

The sample size (n) of a population below ten thousand was arrived based on the formulae given in Equation below. Krejcie and Morgan formula (1970).

$$n = \frac{X^2NP(1-P)}{d^2(N-1) + X^2P\,(1-P)} \qquad (5)$$

Where n is sample size,

N is population size,

X^2 is the value of Chi-Square for 1 degree of freedom at the desired Confidence level (3.841)

P is the population proportion (Assumed to be 0.5 since this would provide the maximum sample size)

d is the degree of accuracy expressed as a proportion (0.5)

Therefore sample size (n) = $\frac{3.841 \text{ x } 7320\text{x}0.5\ (1-0.5)}{(0.05)^2(7320-1)+3.841X0.50(1-0.5)}$

$= \frac{7029.03}{19.25775} = 364.99$

= The computed sample size, n, was 365 households.

3.6 Data Collection procedures

Data collection was done with the primary objective targeted to meet the objectives of this study using a semi structured questionnaire. The questionnaire was classified into sections which include the characteristics of the smallholder farmers' e.g. their gender, age, monthly income, household size, years spent in rice farming and whether they accessed credit services for rice farming . The others sections include the cost of seeds, fertilizers, labor requirement, rice outputs and returns. The researcher acquired a letter of authorization for field data collection from The National Commission for Science, Technology and Innovation (NACOSTI). An introductory letter to the respondents was drafted elaborating on the purpose of the study and therefore guaranteeing the confidentiality of the information. The data collection process was conducted in Mwea irrigation scheme where majority of the households were confined.

3.7 Data analysis

This study adopted both descriptive and inferential method of data analysis. The questionnaire was coded according to each variable of study to reduce the error margin and assure accuracy during analysis. Data was analyzed using statistical package for social sciences (SPSS) program and STATA version 13. The results were presented using tables and charts to give a pictorial view of research findings for correlations. The qualitative data was used to complement quantitative data by providing in-depth descriptions.

3.8.1 Determinants of SRI adoption

In order to determine the factors that influence adoption of the system of rice intensification, a binary logistics regression model through the maximum likelihood estimation procedures was used. The dependent variable is the adoption of SRI by the smallholder farmers. The probability of farmers choosing SRI was given the value of 1 while otherwise was given the value of 0.

The model relates the probability of the predictor variable to the independent variables, such that the probability lies between 0 and 1. The logistic probability function for the farmers who choose to adopt SRI can be represented as a latent variable y_1^*, the observed explanatory variables, x_i and an error term ε_i :

$$y_1^* = x_i' \beta + \varepsilon_i \quad (6)$$

The adoption of SRI can be expressed by a binary model with two given answers: if yes, y=1 and otherwise, y=0 the probability of y=1 is described by a general formula as shown in equation 7.

$$P_r(Y_i = 1l\ x_i) = G(x_i, \beta) \quad (7)$$

G is a may be specified as follows:

$$\Pr(Adopt = 1) = G(\beta_o + \beta_1 x_1 + \dots\dots\dots\dots\ \beta_k x_k + e) \quad (8)$$

Where the $\Pr(Adopt = 1)$ measures the probability of SRI adoption by the individual smallholder farmer given the explanatory variables x_i………,x_k. The β_o is the intercept

and$\beta_1 \dots \beta_k$ are the estimated parameters for the explanatory variables while e is the error term. The model is based on the logistic distribution.

$$G(z) = \frac{\exp(z)}{1 + \exp(z)} \quad (9)$$

3.8.2 Analysis of factors influencing rice productivity

The switching regression model was used to compare the rice productivity of the farm households who participated in SRI and CF. a switching regression consists of two stages. The first stage is based on a dichotomous choice criterion function. The farmer evaluates on whether or not to adopt SRI practices on the basis of resource endowment. The adoption, I^*_{SRI} is compared to the expected utility of using CF practices I^*_{CF}. The farmers will adopt SRI if, $I^*_{SRI} > I^*_{CF}$. And will not adopt if $I^*_{SRI} \leq I^*_{CF}$

The first stage equation can be written in a simplified form as:

$$I^* = S' \alpha + \varepsilon_v \quad (10)$$

$$\text{I} = 1 \text{ if } I^*_{SRI} > I^*_{CF}. \quad (11)$$

$$\text{I} = 0 \text{ if } I^*_{SRI} \leq I^*_{CF} \quad (12)$$

Where vector S includes farm and household characteristics, α is a vector of parameters to be estimated, and ε_v is a random error term with mean zero and variance σ^2 .

In the second stage, two regime equations can be specified explaining the results of the estimated criterion function. The relationship variables X and the outcome Y can be represented as $Y = f(X)$ and specified for each regime as:

$$Y_{SRI} = X' \beta_{SRI} + \varepsilon_S \text{ If I} = 1, \quad (13)$$

$$Y_{CF} = X' \beta_{CF} + \varepsilon_C \;\; if \; I = 0 \quad (14)$$

β_{SRI} and β_{CF} are parameters to be estimated. The variables in X' and S' are allowed to overlap, proper identification requires at least one variable S' that does not appear in X' Therefore the criterion function is estimated based on the exogenous variables specified in the regime equation. The counterfactual outcomes (observed and unobserved) for the adopters and non-adopters can be estimated using endogenous switching regression model (Lokshin, 1977).

SRI plots with adoption (Observed):

$$E(Y_{SRI} \; l \; I = 1) = X' \beta_{SRI} + \sigma_{Sv} \lambda_S \quad (15)$$

SRI plots with no adoption (Counterfactual):

$$E\ (Y_{CF}\ l\ I = 1\ ) = X'\ \beta_{CF} + \sigma_{cv}\ \lambda_S \tag{16}$$

CF plots without adoption of SRI practices (Observed):

$$E\ (Y_{CF} l\ I = 0\ ) = \ X'\ \beta_{CF} + \ \ \sigma_{cv}\ \lambda_c \tag{17}$$

CF plots with adoption of SRI (Counterfactual):

$$E(Y_{SRI}\ l\ I = 0\ ) = \ X'\ \beta_{SRI} + \ \sigma_{sv}\ \lambda_c \tag{18}$$

Equations (17) and (18) can be used to derive unbiased treatment effects ATT and control for observed and unobserved heterogeneity (Noltze, 2012).

ATT= $E(Y_{SRI}\ l\ \ I = 1)$ - $E\ (Y_{CF}\ l\ I = 1\ )$ (19)

ATU = $E\ (Y_{CF} l\ I = 0\ )$ - $E(Y_{SRI}\ l\ I = 0\ )$ (20)

3.8.3 Analysis of gross margin

In order to compare profitability of SRI and conventional flooding, the gross margins will be used in the study. The model calculates the variable cost. These costs are summed to derive the total cost of production per hectare basis. Variable cost refers to those costs which vary directly according to the level of production of grown rice. These costs include hired labour, fertilizer, manure, pesticides, machinery operating costs and others. The gross margins are the difference between the gross returns and the total variable costs.

Gross margin is thus stated as;

Gross margins=$Total\ revenue - Total\ variable\ cost$ (21)

Gross margin percentage= $\frac{Total\ Revenue - Total\ variable\ Cost}{Total\ Revenue}$ (22)

Profit is given by

$$\pi = \text{GM} - \ \text{TFC} \tag{23}$$

Where π = Profit $GM = \ \ Gross\ Margins$ $TFC = \ Total\ fixed\ costs$

3.9 Variables description

The variables in Table 3.1 shows their description, measurement and their expected signs.

Table 3. 1 Variable description

Variable	Description	Measurement	Expected Sign
Smallholders rice productivity	This variable entails yields per unit of production.	Kgs/Ha	+
Age	Age records the age of the farmer	Number of Years	-
Gender	Gender is a variable that shows the gender of the adopter and non-adopter	1 for male 2 for female	+/-
Family size	Records the number of family members living in the same household	Number of family members	+
Education level	Households level of Education	No formal education, Primary Education Secondary education Tertiary institution	+
Off -farm occupation	Measures engagement in off-farm activities	Trader Civil servant Others	+
Farm Size	This variable indexes households with farms under rice production	Number of Acres	+
Training	This variable indexes number of trainings on SRI	Number of trainings	+
Profitability	Gross margins less variable cost	Kenya shillings per household.	+
household engaged in SRI	This variable indexes household in SRI.	1 Yes O otherwise	+
Access to credit	Whether households access credit	Access Does not Access	+
Distance from the canal	This variables measures distance in Kilometers	Distance in Kilometers	+

CHAPTER FOUR

RESULTS

4.1 Introduction

This chapter examines the findings of the study and covers the following sub-sections: Biodata of the respondents, descriptive statistics and the econometric models results. The results are summarized using tables, charts and figures.

4.1.1 Reliability and validity of instrument.

Validity is the extent to which an instrument measures what it purports to measure (Gebremariam *et al*., 2017) In this study measurement instruments were validated through discussion with supervisors who were experts in adoption studies, water resource management and food production. Cronbach's statistic was used to test reliability. The Cronbach's was used to calculate the internal consistency coefficient of the 70 items included in the questionnaire. Some studies offered indications of alpha having a cut-off or a threshold as acceptable, sufficient or acceptable level. This was normally seen alpha ≥ 0.7 (Taber, 2018). Alpha was therefore used as an indicator of reliability. The results of the Cronbach's reliability test showed that the items were satisfactory. The alpha values in this study were described as relatively high (0.745-0.895) as indicated in the table 4.1.

Table 4. 1 : Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	No of Items
.745	.895	70

4.1.2 Testing for Multicollinearity

A diagnostic test of multicollinearity was carried out on the independent variables to assess the suitability for inclusion in the empirical model. The multicollinearity was tested using the correlation matrix for the variables that influenced the adoption of SRI in Mwea irrigation scheme. The existence of multicollinearity means that there is a perfect linear relationship among the independent variables. In the presence of multicollinearity, the regression coefficients of the independent variables are indeterminate and their standard errors are infinite or if determinate, then they poses a large errors. Thus the coefficients cannot be estimated with great accuracy. Marital status and age were correlated using Pearson correlation coefficient of + or – 0.5 and above to imply the existence of multicollinearity. It became clear that the model was suffering from multicollinearity problems; as a result, the marital status was dropped from the model since it was found to have a high correlation with the age of the farmer. The omission solved the multicollinearity (Appendix 2).

4.1.3 Testing for heteroscedasticity- Breusch-Pagan test

Breusch-Pagan test and White man test were used to test the presence of heteroscedasticity. Breusch-Pagan test helps to check the alternative hypothesis versus the null hypothesis. The null hypothesis indicates that the error variances are all equal (homoscedasticity), whereas the alternative hypothesis indicates that the error variances are multicative function of one or two variables (heteroscedasticity) as indicated in figure 4.2. The results (Appendix 5) showed that the probability value of the chi-square statistics is less than 0.05. Therefore the null hypothesis of the constant variance can be rejected at 5% level of significance. This implies the presence of heteroscedasticity in the residuals.

4.1.4: White test for heteroscedasticity

Similar to the results of the Breusch-Pagan test, here too the p>chi2= 0.000. Thus the null hypothesis of the constant variance can be rejected at 5% of level of significance. This implies the presence of heteroscedasticity (Appendix 4).

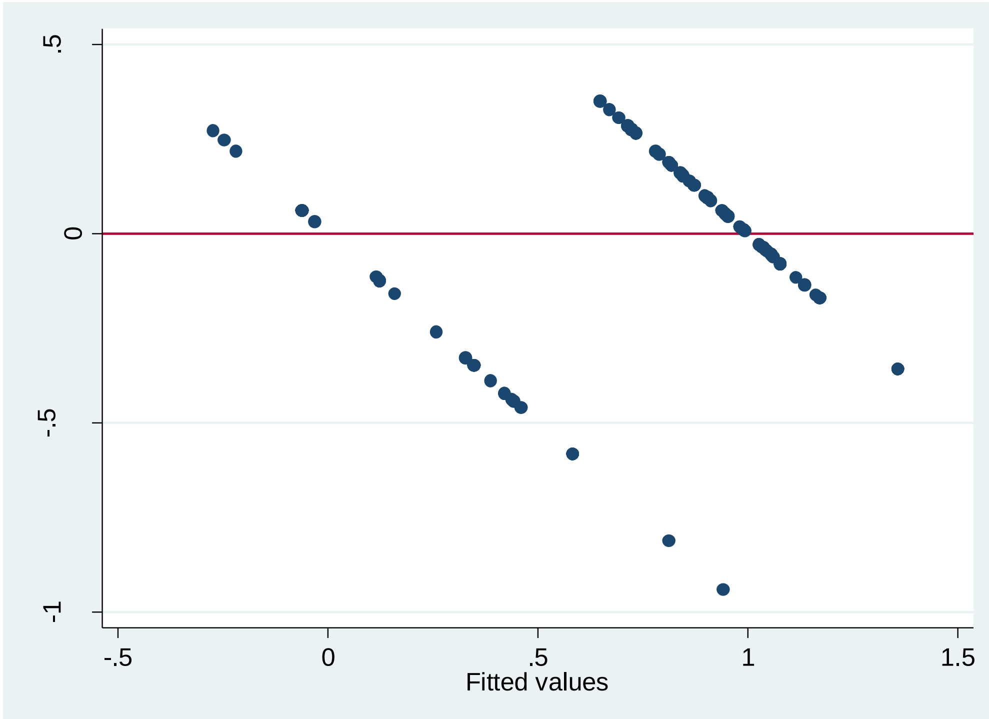

Figure 4. 1: Graphical representation of heteroscedasticity

4.2 Correction heteroscedasticity

Heteroscedasticity exists when a sequence of random variables has different variances. This violates the assumption of equal variances in the least square estimation. Consequences of heteroscedasticity are that the OLS estimates are no longer BLUE (best linear unbiased estimator). The standard errors will be unreliable which will further cause biasness in the confidence intervals and thein the test results. Correction of heteroscedasticity was achieved by generating the robust standard errors after the logistic regression (Appendix 6).

4.3 Correlation analysis for SRI practices

The correlation analysis results for the SRI practices are presented.The variables were significant at 1%. This showed a positive correlation on SRI practices. The mutual interdependence among the use of shallow planting, wider spacing, the use of organic manure and the alternate wetting and drying backs SRI in predicting the improved rice production technologies as shown in figure 4.3.

	Transplanting 8-15 days old seedlings	Alternate wetting and drying	Wider spacing	The use of organic manure	Shallow planting
Transplanting 8-15 days old seedlings	1	✓	✓		
Alternate wetting and drying	✓	1		✓	
Wider spacing	✓		1		✓
The use of organic manure		✓	✓	1	✓
Shallow planting	✓		✓		1

Figure 4. 2: Correlation analysis for SRI practices

The joint interdependence of the SRI practices, points out that the likelihood of adopting any of the practices is co-dependent on the decision of whether to adopt another practice or not. All the pairwise coefficients of the practices are positive.

First, the study observed that the adoption decision exhibit a strong relationship between transplanting 8-15 days old seedlings and alternate wetting and wider spacing of seedlings, The use of organic manure and wider planting.

Transplanting of young seedlings and shallow planting are statistically significant ($p<0.01$) the correlation between use of young seedlings and shallow planting indicates that farmers who adopts shallow planting also use 10-15 days old seedlings. Transplanting of 8-15 days old seedling is positively correlated with the alternate wetting and drying (Figure 4.2). The use of organic manure and shallow transplanting were statistically significant. This implies that farmers who practice shallow planting are also likely to apply organic manure.

4.4 Characteristics of the respondent according to adoption status

The socio-economic characteristics of the smallholder rice farmers affects their farming operations directly or indirectly. The results revealed that majority of the respondents in the study area were males constituting 73.09 % of the sampled population while the females were 38.1% as shown in table 4.2. This indicates that rice farming in the study area is carried out by more males as compared to females. Therefore gender is an important factor in adoption of climate smart technologies. The results agrees with the findings of Khan *et* al. (2016) who evaluated the male and female willingness to pay for direct seeded rice which is a climate smart technology. The results found that the gender differences had a significant role in influencing the use of drum seeded rice. For instance women contributed more labour in rice transplanting much of which is unpaid labour. Therefore it was not surprising that women embraced the adoption of drum seeders than their male counterparts.

In MIS, there are two main varieties of rice grown Basmati 370 and Basmati 217. The results revealed that 64.9% of the farmers were cultivating Basmati 370 while 34.8% were cultivating Basmati 217 (Figure 4.4). Similarly Omwenga et al. (2014) noted that the common variety of rice grown in MIS was Basmati 370.

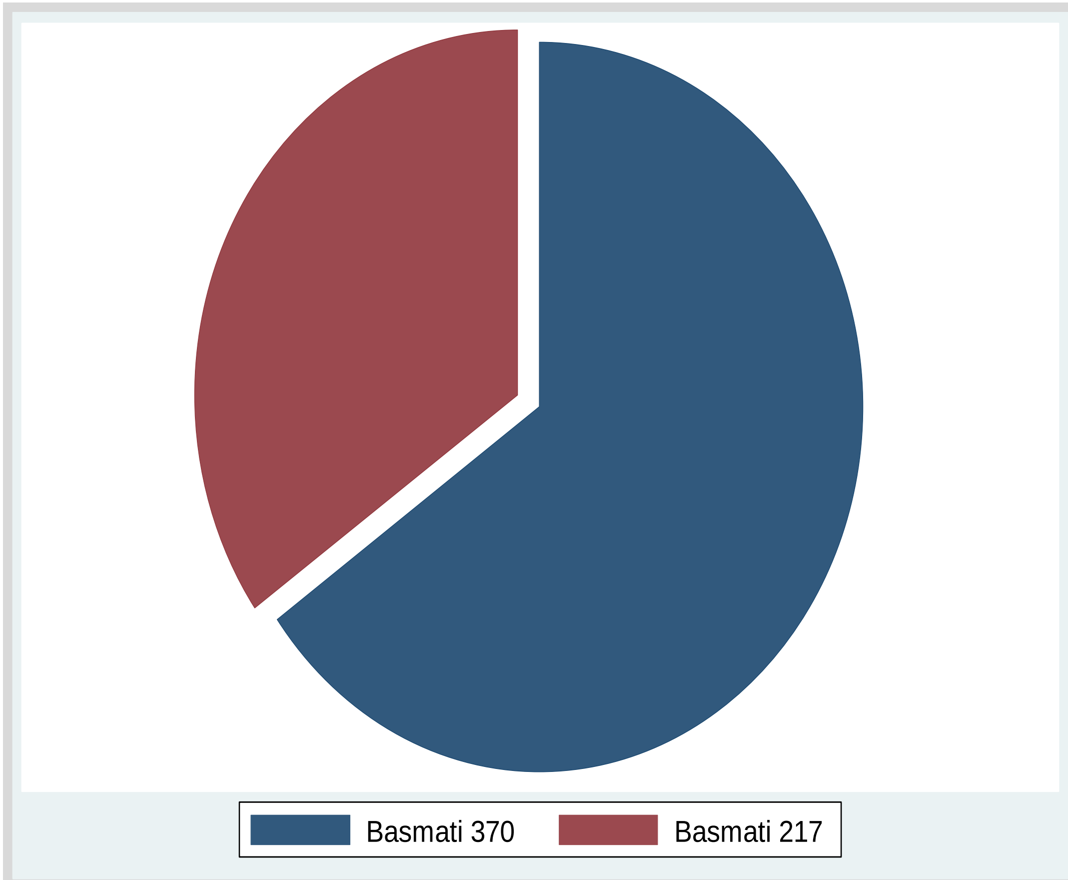

Figure 4. 3: Rice Varieties grown

The number for SRI adopters and the non- adopters were 259 (71.15%) and 105 (28.85%) respectively (Table 4.2). The mean age of the respondent was 42 years with a relatively high proportion of middle age rice farmers among the respondents (Table 4.2). The results showed that young farmers are actively involved in farm operations. In addition, their productivity is at peak thus of great in rice production. The study asked respondents to indicate their marital status. Majority of the respondents were married (71%) and 29 % were single. The results showed that more than two thirds of the interviewees in the irrigation scheme were family people while the rest were living as single persons. Further, the results revealed that 56.33% of adopters had obtained primary education, 79.17% obtained secondary level and 97.37% had achieved tertiary education. Among the non-adopters, 43.67% obtained primary education, 20.83% achieved secondary education and 2.63% had tertiary education. The results were significant implying that the majority of the adopters had acquired formal education as compared to non-adopters. It was also observed that the mean household size for the adopters was 4.12 and 5.12 for the non –

adopters. The results were significant revealing that the non-adopters had relatively large-sized households than the non-adopters. Analysis of the occupation showed that 88.42% of the adopters were undertaking casual work, 3.86% were livestock keepers while 91.43% of the non-adopters were casual workers and 75.57% were livestock keepers. The results were significant showing that most of the non-adopters of SRI were undertaking off-farm occupations.

Additionally, the findings revealed that the average distance from the canal for the adopters of SRI was 5 km and 4 Km for the non-adopters. The results were significant, implying that the adopters were far from the water source as compared to no-adopters.

The mean farm size for the SRI farmers was 1.5 ha and 2.1 ha for the non-adopters. The findings were significant confirming that the non-adopters had large holdings as compared to adopters of SRI. The monthly income of the respondents' was tabulated in Kenya Shillings (KES). The average monthly income of the adopters was KES 40,374.52 while the average monthly income for the non-adopters was KES 33,761.90. The results were significant. This implied that SRI adopters had a higher monthly income than the non-adopters.

The study assessed the years that farmers were involved in rice farming. The results showed that the adopters of SRI spent 6.2 years in rice farming while the non-adopters spent 8.1 years in rice farming. The mean difference in the two groups was significant indicating that adopters were less experienced in rice farming as compared to the non-adopters. The results further showed that 92.66% of the adopters received extension services while 7.34% did not receive extension services. For the non-adopters, 69.52% reported that they received extension services while 30.48% did not receive extension services. The results were significant showing that most of adopters receive extension services as compared to non-adopters. The study asked the respondents to indicate whether they accessed credit services in their rice farms. The results showed that 33.98% of the adopters received credit services while 66.02% reported that they did not receive credit services. It was observed that 91.43% of the non-adopters reported that they did not receive credit services while 8.57% reported having received credit services. The results were significant implying that the majority of the smallholders did have access to credit Services in the study area.

Table 4. 2: Description analysis for adopters and non-adopters of SRI

Variable	Adopters n=259	Non-adopters n=105	Pooled Mean n=364	*t*/*Chi* value
Age (Mean age)	42	41	41	52.4***
Gender				
Female (%)	22.39	31.43	38.1	3.25
Male (%)	77.61	68.57	73.09	
Education level (%)				
Primary	56.33	43.67	43.41	159.60 ***
secondary	79.17	20.83	46.15	
post-secondary	97.37	2.63	10.44	
Household size	4.12	5.2	5.0	48.08 ***
Farm Size (Ha)	1.5	2.1	1.8	15.85 ***
Monthly Income (KES)	40374.52	33761.90	37,068.21	47.70 ***
Years in paddy farming	6.2	8.1	7.1	27.08 ***
Access to extension services	92.66	69.52	81.09	33.21 ***
Casual work	88.42	91.43	89.93	11.36 ***
Livestock keeping	3.86	7.57	5.72	
Others	7.72	1.0	4.36	
Credit Access	33.98	91.43	62.705	98.65 ***
Distance to Canal	5.48	4.17	4.83	3.59 ***

Note: *** , ** denote significance at 1%, 5% respectively

4.5 Determinants of SRI Adoption

The determinants of SRI adoption were analyzed using a Binary logistic regression model. The smallholder farmers were classified as either adopters or non-adopters of the SRI technology compared to conventional flooding (CF). The likelihood ratio estimates in Table 4.3 shows that all the Chi-square statistics are significant. This shows that the binary logistics model was the most appropriate in explaining the determinants of SRI adoption. The model accounted for 77.8% of the variation between SRI and CF. eight out of the twelve variables were highly significant.

Age of the respondent was found to have a significant influence on adoption of SRI at 1 % significant level and the marginal effect of 5.02 (Table 4.3). The results indicated that the majority of the smallholder farmers were in their active years of farming. A situation that was likely to favor the adoption of SRI. Older farmers may be more conservative and they do not want to change their farming practices from CF to SRI.

Household size was significant at 1% with a positive coefficient of 1.895. The marginal effect was -1.55. The findings shows that family size influences the adoption of SRI positively (Table 4.3) this means that an increase in household size by 1% will increase the adoption of SRI by 1.895 %. This is signifies that SRI is labour intensive and therefore large families attract labour required in nursery preparation, land leveling after rotavation, transplanting young seedlings and weeding.

Farm size was significant at 1% with a positive marginal effect of 5.02 (Table 4.3). When the farm size is increased by 1% the adoption of SRI will increase by 2.499 %. Farmers with large holdings are likely to experiment on new technologies in small fields before adopting in large scale. Off-farm work was significant at 1% with a positive coefficient of 3.95. The results revealed that smallholders who are engaged in other off-farm activities are likely to adopt SRI than those who concentrated entirely on rice farming. An increase in off-farm work by 1% increases the adoption of SRI by 3.95%.

Experience in paddy farming was statistically significant at 1% with a positive coefficient of 0.409. The results imply that an increase in farmer's experiences increases the adoption of SRI technology. When the farm size increases by 1%, adoption of SRI increases by 0.409%. Farmers endowed with knowledge and experience easily understand or grasp the new technologies. The average distance from the canal was significant at 5% with a positive coefficient (1.354). An increase in the distance from the canal, increases the adoption of SRI by 1.354. This implies that as the distance increases, less water is available for the SRI farmers who then become more efficient in using their inputs like water in rice production. This implied that those farmers who were far away from the canals had higher adoption status than those near the canals.

It was also revealed from the regression results that access to extension services was significant at 1% with a positive coefficient of 7.809. The marginal effect was -5.24 (Table 4.3). The findings showed that an increase in extension services by 1% will, in turn, increase the adoption of SRI by 7.809%. The results imply that farmers who have access to extension have a higher probability of adopting SRI since extension services serve as an important source of information on agricultural production.

Access to credit facilities was significant at 1% with a positive coefficient of 8.1. The results from the binary logistic model imply that when credit access increases by 1% the adoption of SRI also increases by 8.1% (Table 4.3). Therefore credit is an important determinant in the adoption of SRI.

Table 4. 3: Binary Logistic regression results

Variables	Coef.	Std. Err.	Z	P>z
Gender of the	1.017	0.679	1.5	0.134
Age	-0.138	0.043	-3.22	0.001***
Marital Status	-3.737	1.144	-3.27	0.415
Education	-0.378	0.661	-0.57	0.568
Household Size	1.895	0.322	5.88	0.000***
Farm size	2.499	0.498	5.02	0.000***
Monthly income	0.000	0.000	0.69	0.492
Off farm work	3.953	0.847	4.67	0.000***
Years of rice farming	0.409	0.121	3.38	0.001***
Extension services	7.809	1.659	4.71	0.000***
Credit access	8.714	1.664	5.24	0.000***
Distance from Canal	1.354	0.303	4.47	0.000***
_cons	-8.316	3.449	-2.41	0.016**

Number of obs =364 LR chi2 (11) = 340.60 **Prob > chi2** = 0.0000
Log likelihood = -48.378857 **Pseudo R2** = 0.7788

Note: ******* and ****** denote significance at 1% and 5%

4.6 Endogenous switching regression results for rice productivity

The Wald test is significant at 1% (Table 4.4) indicating the goodness of fit for the econometric model. The results indicated that there is endogeneity problem and therefore the use of the endogenous switching regression is justified. The likelihood ratio test of independence of the selection and outcome equations indicates that the null hypothesis can be rejected. This shows that SRI participation is positively correlated with the rice yields. The results in Table 4.4 indicated that the positive and significant determinants of rice productivity are; Age of the farmer, household size, average monthly income, off-farm work, farm size, Years in rice farming, distance from the canal, access to extension services, credit access and labor use.

The household size has a positive coefficient and statistically significant at 1% with a positive coefficient. This shows that large households with labor endowment are important in adoption of SRI. Thus more of family labor are more likely to be engaged in farm activities. The off farm work has a positive coefficient (1.427958) and is statistically significant at 1%. The results shows that adoption of SRI influences rice productivity. The same applies to rice production under CF. This shows that rice farming is labor intensive and there family labor influences production. Access to credit by the smallholder farmers had a positive coefficient (table 4.4) and is statistically significant at 1% for the adopters of SRI.

Marital status of the household head is statistically significant at 1% for the adopters of SRI and has a marginal effect of -3.27 (Table 4.3). The distance from the canal influences rice production positively. It is significant at 10 %. As the distance increases from the canals, farmers are keener to use resources efficiently such as water in the production of rice. The years in rice farming is statistically significant for the SRI and CF regimes, however it has a negative sign coefficient for the SRI regime. Access to extension services has a positive coefficient and is statistically significant at 1% for the selection equation, the results implies that the value of providing farmers with skills and new production techniques such as SRI improves on yields and minimize on production constraints.

Table 4. 4 : Endogenous Switching regression results

participation in SRI			SRI Regime		CF Regime	
Variables	**Coeff**	**P>z**	**Coeff**	**P>z**	**Coeff**	**P>z**
Age	0.05086	0.009***	-0.13	0.241	-0.01	0.919
Education	-0.17852	0.501	2.26	0.175	-1.38	0.041
Marital Status	-2.54	0.00***	5.19	0.09**	-4.35	0.001***
Household Size	0.85	0.00***	0.63	0.583	1.70	0.000***
Average Monthly income	-1.40	0.434	0.02	0.011**	5.83E-05	0.083
Off- farm work	1.42	0.00***	-7.54	0.00***	3.78	0.000***
Farm size	0.33	0.231	0.62	0.662	1.60	0.004**
Years in rice farming	-0.14	0.014**	1.15	0.003**	-0.49	0.003**
Distance from the canal	0.74	0.00***	-2.29	0.003**	0.66	0.038
Extension Services	2.63	0.00***	-5.70	0.096	3.83	0.008**
Credit Access	4.02	0.00***	-13.29	0.000***	2.67	0.063
Labor use	3.90	0.00***	0.01	0.000***	4.74E-05	0.058
Wald Chi2 (13)	613.52					
Prob> chi2	0.000					
Log likelihood	-1250.87					
Rho1	-0.231					
Rho 2	0.210					
Sigma	7.5318					
Lambda	-1.7449					

LR test of indep. eqns. (rho = 0): χ =2.06 Prob > chi2 = 0.1509 *** 1%, ** 5% level of significance

The farm size is statistically significant at 5% for the CF regime, the choice of adoption SRI was significantly influenced by farm size. Increase in the farm size increases the probability of adopting the water saving technology and thus increase in rice production. The small land holdings hinders the practicing of a new technology compared to large farm holdings. The results also shows that there is a positive relationship between adoption of the alternate wetting and drying technology and smallholders' rice production (Table 4.4). Thus increasing the income generation activities in the rural areas will pave way for the adoption of SRI. Labour is statistically significant at 1% for the SRI regime. Increasing labour input by 1% would increase the rice yields by 0.027% on average (Table 4.4).

4.7 Analysis of gross margins for SRI and CF

In this section, the profits of the adopters and the non-adopters of SRI was determined. To determine the profitability levels of the two groups, attempts were made to estimate the gross margins from the rice farming. This is due to the fact that the fixed costs of the smallholder farmers were negligible. The mean cost of production in one hectare of rice was calculated (figure 4.5).

The SRI farmers used KES 1,282.83 on purchase of seeds for planting one hectare compared to conventional flooding farmers who used KES 2,276.66. Therefore the SRI farmers saved KES 993.83 per hectare over conventional flooding. With the application of fertilizer, SRI recorded the highest cost of KES 6,026.27 compared to conventional flooding where it was KES 2,639.49 therefore CF farmers saved KES 3386.78 per hectare. The cost of ploughing for the SRI farmers was KES 4797.16 while in CF it was KES 5797.16 (Appendix 7). The difference in the cost of ploughing was KES 1,000. The difference on cost of ploughing between the SRI and CF farmers was positively significant and therefore it had a positive influence on profitability.

In the CF method, the Cost of herbicides was KES 300.61 while in SRI the cost was KES 613.50 per hectare. The CF farmers saved herbicides cost of KES 312.89 over the SRI farmers. The difference in the cost of herbicides was significant and this implied that herbicide cost had a positive influence on the profitability of rice farming. On the cost of insecticides, the SRI farmers used KES 479.25 compared to CF farmers who used KES 527.33. The SRI farmers saved KES 214.44. On the cost of insecticides, the SRI farmers used KES 479.25 while the CF farmers used KES 527.33. The SRI farmers saved KES

48.08. The cost of ploughing for SRI and CF were KES 4797.16 and 5697.16 respectively. The smallholder farmers practicing SRI saved KES 900. The cost of rotavation for SRI and conventional flooding was the same (KES 5,328.28). The cost of land levelling for SRI was KES 1609.3 while the cost for CF was KES 1150. The results implied that SRI farmers saved KES 459.3 (Appendix 6).

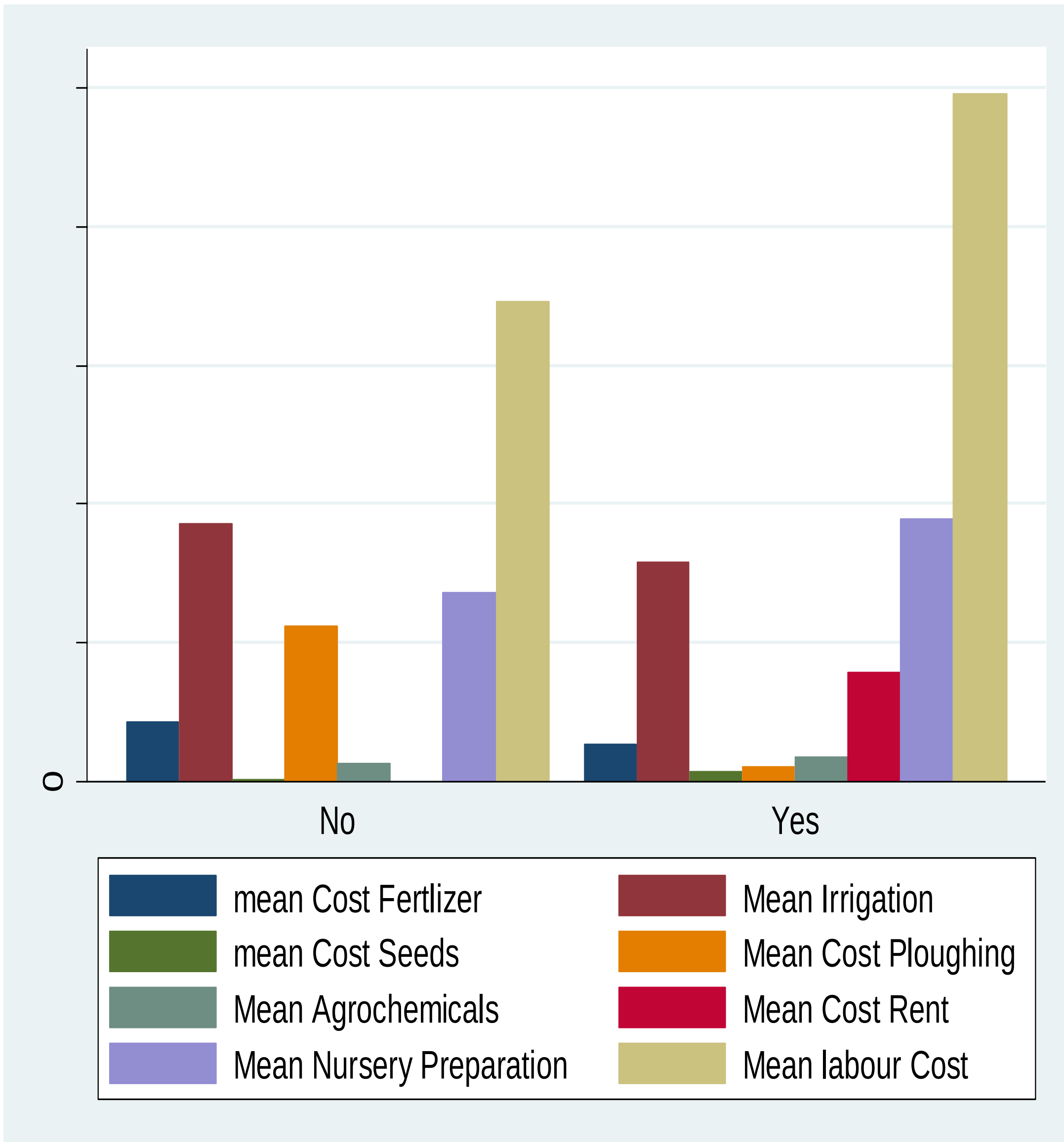

Figure 4. 4: Mean Cost for Adopters and Non-Adopters

Analysis of gross margins revealed that the average variable cost per hectare for the adopters of SRI was KES 54,564.07 and the gross revenue was KES 118,408 with gross margins of KES 63,843.93 per hectare per season. On the other hand the variable cost for the CF was 44,252.42 with gross revenue of 74,784 and gross margins of KES 30,351.58 per hectare (Table 4.5). Further, it was revealed that SRI technology is more profitable than the old practices (CF) in the study area.

Table 4. 5 : Summary of gross margin analysis for SRI and CF

	SRI	CF	T test	P VALUE
Bags harvested	19	12	-16.68	0.00***
Farm gate price(per bag)	6,232	6,232	-0.02	0.00***
Gross revenue	**118,408**	**74,784**		
Total Variable cost (KES)	**54,564.07**	**52,710.39**		
Gross Margins Per Season (KES)	**63,843.93**	**22,073.61**		

CHAPTER FIVE

DISCUSSION, CONCLUSION AND RECOMMENDATIONS

5.1 Overview

The chapter contains the discussion, conclusions and recommendations deduced from the results of the preceding chapters.

5.1.1 Determinants of SRI adoption

The study sought to find out whether the adoption of SRI practices leads to improved rice productivity as opposed to adoption of CF. Age of the farmer was found to have a negative relationship on adoption of SRI. Age is considered to be an indicator of willingness to adopt agricultural technologies on the assumption that young people are more likely to adopt improved technological practices than old people. Farmers from a higher age group may be more conservative and they do not want to switch their farming system from Conventional flooding to SRI. While the younger counterparts' preferred SRI due to their familiarity with the technology information. These findings are consistence with findings of Nelson *etl al.* (2018) who reported that age had a negative influence on the adoption of small scale irrigation farming. The results of Binary regression model implied that the odds of adoption were higher in young farmers as compared to older farmers. Additionally, Varma, (2016) noted that young farmers had greater access to information that could assist in adopting new agricultural technologies as compared to older farmers. However the findings disagrees with studies of Himire *et al.*, (2015) who reported that household characteristics such as age and labour have no significant effect on adoption.

Involvement in off farm income generating activities plays a bigger role in adoption of SRI practices. The availability of off- farm income can offset credit constraints while enhancing the capacity to bear risk. The off-farm income sources increased the farmer's capacity to purchase more agricultural inputs such pesticides and herbicides. According to Pereira & Marques, (2017) smallholder farmers with off farm income had higher adoption to their counterparts without off-farm income. The off-farm income significantly and positively influenced the adoption of SRI. This implies that farmers used money generated from off farm income activities to purchase farm inputs and therefore contributing to the adoption of SRI. This conforms to the priori expectation. In addition the finding is corroborated with the assertions of Danso-abbeam *et al.* (2018) who reported that off-farm work had a positive influence on adoption of maize varieties in the northern region of Ghana. Similar results were reported by Kebede *et al.* (1990) that adoption was positively and significantly influenced by other income generating activities. When a farmer is wealthier, he is likely to adopt new technologies than farmers with a single source of income. Off farm income is an important strategy of overcoming credit constraints by smallholder farmers. Further, it provides farmers with liquid capital for purchasing farm inputs such as fertilizers and improved seeds (Mwangi & Kariuki, 2015). Similar results were reported by Diiro, (2009) that there was higher adoption and spending's on purchased inputs among farmers with off-farm income as compared to their counterparts with no off-farm incomes. However, the findings disagrees with those of Goodwin *et al*. (2016) who noted that pursuit of off-farm income may undermine the adoption of new technologies by reducing the amount of family labour allocated to farming enterprises.

Access to extension services had a positive impact on adoption of SRI. This implied that as the number of trainings on SRI increases, farmers were keener to adopt new technologies such as SRI. Smallholder farmers who received advisory services on SRI were assumed to receive the education on the benefits associated with SRI such as increased yield produced and reduced cost of production, thus enhancing their decisions. Literate farmers are better able to process information and search for suitable agricultural technologies to improve their paddy production. This implies that majority of the SRI farmers were well trained and had a better understanding of paddy production technologies as compared to non- adopters. These results are similar to findings of Himire *et al.*(2015) that education of a farmer affect adoption of improved rice varieties. Also similar results were reported by Chandio & Jiang, (2018). Further, the findings agrees with those of Warsanga *et al.* (2017) who noted that highly trained farmers were more likely to adopt farm management practices that improves their level of efficiency. According to Mburu *et al.* (2014), the level of literacy among smallholders determines the rate and the extent of adoption of new technologies. When the level of education is higher, then the uptake of new practices is enhanced at the farm level. Additionally, farmers who had higher level of training were technically efficient than those with less training. In general, farmers who are well trained have the ability to perceive, interpret and respond to information and adopt practices such as SRI compared to their counterparts who are less trained.

Household size had a positive relationship with the adoption of SRI. This implies that an increase in household size increased the adoption of SRI. Farmers who had large holdings were likely to adopt SRI as they can afford to devote their lands to try new practices such as SRI unlike those farmers with less farm size. Technologies that are lumpy, for instance those that require mechanized equipment requires economies of size in order to realize profitability (Mwangi & Kariuki, 2015). Transplanting time had a negative effect on adoption of SRI. These imply that increase in transplanting time decrease the probability of adopting SRI technology among small scale farmers. Similar results were found by Ches & Yamaji, (2016) indicating transplanting time have effect on adoption of SRI practice. Also Kathia *et al*.(2019) indicated that transplanting affects adoption of SRI.

Access to extension showed a positive relationship with adoption of SRI. It was therefore a key aspect in the adoption of new practices as farmers who had access to extension services had higher probability of adopting SRI since extension services served as an important source of information on agricultural production. Farmers who had significant extension contacts had better chances to be aware of various management practices that they can use to increase production. Extension agents act as a link between the adopters of a specific technology and the innovators who happens to be the researchers. The extension officers targets specific farmers (Farmers who interacts with other farmers) who have direct influence to other farmers in their areas of farming (Mwangi & Kariuki, 2015). Many studies have reported a positive relationship between adoption and extension services. Kehinde & Adeyemo (2017) for instances that technologies uptake can be improved through enlightenment programmes by effective and efficient extension services. Frequent contacts between the extension agents and the farmers will enhance farmer exposure to production packages and reduce dis-adoption. The results further showed that access to extension had positive relationship with adoption of Cocoa based farming practices. Similarly, Ahmed & Anang (2019) indicated that access to extension positively affects adoption of improved varieties of maize.

The distance of the canal from the farm had an influence on the adoption of SRI. As the distance increased, the SRI farmers became more efficient in using their inputs like water in rice production. This implied that those farmers who were far away from the canals had higher adoption status than those near the canals. The wide spread of alternate wetting and drying was not surprising, as this practice saved water and especially in MIS. Water shortage is a critical constraint in MIS. Before the inception of SRI, water shortage had forced some farmers to grow rice in non-flooded conditions. Similar results were reported by (Sinyolo & Mudhara, 2018) who found that differences in water access has an effect on adoption of farming technology. As the distance increases, the SRI farmers became more efficient in using their inputs like water in rice production.

Wider spacing indicated positive relationship on adoption of SRI. These has an implication on yield with wider spacing being related to higher productivity. As wide spacing is adopted the seeds required would be less, further it is easy to produce quality seeds. Similar results have been reported by (Onyeneke, 2017) who showed that seed rate has positive effect on adoption of improved technologies in rice production among farmers in Imo estate, Nigeria. Also (Meshram et al., 2012) showed that cropping rate is among the factors that affected adoption of paddy rice.

Use of organic manure had a positive effect on adoption of SRI. These findings shows that use of organic manure has an effect on adoption of SRI. Farmers using organic manure report high output. Similar results were reported by Arsil *et al.* (2019) that reported a positive relationship between SRI practices and adoption of the technology. Alternative wetting indicated positive relationship with adoption of SRI. These imply that alternative wetting is among rice farming practices that attract farmers into SRI. Similar results were reported by Mohanty *et al*. (2019) who indicated that use of alternative wetting increase soil water conservation measures hence adoption of SRI.

5.1.2 Factors influencing rice productivity under SRI and Conventional flooding

Household head marital status negatively affect rice productivity under both SRI and convectional flooding. These findings imply that marital responsibilities with the associated cultural and religious practices of seclusion that prevented farmers from out-door direct field production activities. Similar results were reported by Ayoola & Dangbegno (2011) that gender influenced rice productivity negatively. The study further noted that gender is however a critical cross-cutting factor in the innovation process that aims at enhancing equity among the male and female farmers. Gender equity in farming ensures that there was relative access to necessary resources and programmes targeted at promoting food security and poverty reduction. These results contradicts the findings of Ojo (2019) who reported that marital status of household had a positive influence on productivity of rice farmers in South West of Nigeria.

Household size positively affect rice productivity. This imply that increase in household size increase output. These can be attributed to the fact that production of rice requires more labor that is supplied from the family. Similar findings by Amare, Asfaw, & Shiferaw. (2012) found a positive relationship between the size of household and productivity of farmers in various technology. Also Moti Jaleta, Menale Kassie.(2015) found that household size had positive influence on productivity of improved maize varieties. Off farm work positively affect productivity in SRI and CF. this implies that the household's heads whose main job is farming are less likely to adopt SRI than the part time farmers. This may be related to access to frequent outside contacts through off farm activities and therefore access to information flow. In addition, the risky perceptions of farmers who entirely depend on farm incomes may be hesitant to adopt new technologies such as SRI. The household size for the non-adopters is statistically significant, implying that household size was an important factor in decision making among the smallholders who were the non-adopters of SRI. The off farm income was statistically significant this can be explained by fact that earnings from off farm work are used to purchase farm inputs thereby enhancing productivity. Kinuthia. (2015) indicated that off farm activities affected productivity of non-adopters of improved agricultural technologies. Also similar results were found Poornima. (2017) that of farm activities have positive effects on rice yield and household income.

Experience in rice farming positively affect productivity of rice under SRI. Farmers who are experienced in farming have access to information on production as compared to farmers with low experience in farming. These leads to improved decision on adoption of farming technologies. In addition, farmers with more years of farming are efficient in terms of resource allocation, probably due to their enhanced managerial ability. Moreover, experienced farmers have a tendency of resource mobilization and using it efficiently. These results are similar to findings of Myint & Napasintuwon (2016) who reported that Paw rice adoption can be accelerated by promoting it to farmers with higher experience. Varma (2017) indicated that the number of years spent in agriculture affects rice productivity positively. Also Paudel et *al.* (2019) indicated that experience in rice farming positively effects on rice productivity of adopters of improved technologies.

Distance from canal affects productivity under SRI. This results imply that increase in distance from water source decreases productivity under SRI regime. Farmers in far distances from water source have likelihood experiencing water shortages which on the other hand reduce the output. If the distance from the canal increases by one Kilometer then the probability of a farmer adopting SRI increases by 0.74. Therefore, farmers who are distanced from the canal have a higher adoption rate for water saving technologies than farmers who are near the canals. Those farmers who are near the canals, their adoption level is lower than others. Similar findings were found by Kamoshita et al. (2018) that distance from water sources negatively affected rice productivity. Pede et al. (2018) further showed that location of the farmer to water source has effect on level of productivity.

Access to extension services positively affects rice productivity under continuous flooding. This implies that farmers with access to extension service are able to acquire trainings on methods of rice production. In addition, farmers are usually informed of the existence and the effectiveness of the new technologies such SRI. The extension agents act as the links between the innovators and the users of the new technology. This helps to reduce the cost of transaction when training on the new practices.

Similar findings were reported by Kinuthia (2015) that access to extension affects productivity of new varieties. Varma. (2017) also reported that access to extension services positively affects rice productivity and income consecutively. Further Abdulai & Huffman. (2014) indicated that access to extesnsion positively affects productivity of adopters and non-adopters of the new technologies.

Access to credit affects productivity under SRI. Credit is an important factor in agricultural production. Farmers with access to credit have high likelihood of increasing production. Credit is accessed by having membership in co-operative or any other financial organization. Credit facilitates the purchase of farm inputs like farm machinery, fertilizer, seeds and herbicides. They have capital investment in new technologies in farming. Similar results were reported by Abdulai & Huffman. (2014) that found access to credit has a relationship with productivity of rice farmers.

Labour use significantly affects productivity under SRI positively. Holding other variables constant, the probability of adopting SRI increases labor use while improving on rice production. SRI is labor intensive therefore labor is integral variable to determine the productivity of the technology. Thus the probability of adopting a technology depends on the family members who actively provide farm labor. Some of the SRI components that are labour intensive include manure application, transplanting of seedlings, land levelling and weeding. In a scenario where labor use is high farmers tend to be reluctant on adopting a technology. These findings are consistence to findings of Canon, Halid, & Daud. (2018) that found labor affects productivity of rice among smallholder farmers. The results were consistent with the findings of Adesina & Zinnah, (1993), Sudeep, (2010) and Karubanga *et al.*(2019).

5.1.3 Profitability of rice grown under SRI and conventional flooding methods

The study estimated profitability of SRI and convection flooding. Results showed that SRI was profitable than convectional flooding for farmers in the study area. Bwala & John (2018) found that profitability of paddy rice was high than in convectional flooding. Chidiebere et al. (2019) found that Swamp production systems had the highest return per hectare followed by lowland production systems and upland production systems. The study also found that rice production using the swamp production system is profitable and would ensure increased production and higher returns to the farmers. Farmers using new technologies have high returns. A study by Lucky et al. (2018) found that farmers using new varieties of rice had higher profitability than farmers using inferior varieties.

The cost of rent and labour accounted for more than 50% of the total cost of production for the entire season while for the non-adopters the cost of bird scaring, cost of rent and cost of seeds were the major constituents. This implies that labour as an input is the most costly item in the study area. Households with larger labor endowments are likely to adopt water conservation practices such as SRI while those with labor constraints may opt not to adopt the technology. In the study area, SRI is a more labor intensive technology as compared to CF. Labor requirement is high during land levelling, rotavation and transplanting of seedlings. Additionally labor is required for both practices during bird scaring and harvesting. The finding is in consonance with the finding of Bwala & John (2018) , who reported that the cost of labour accounted for the largest proportion of the total variable cost. The results further showed that large amounts of resources are invested on labour requirements. The study disagreed with Adhikari & Lamichhane (2019) who analyzed the adoption of improved maize varieties, the results indicated that human the cost of tractor and bullock accounted for about 25% of the total wheat production cost. In addition the cost of human labour in wheat production accounted for 18% of the total cost.

5.2 Conclusion

Rice is one of the food crops in Kenya. In the recent years there has been increase in importation as a result of increased consumption. The demand is outpacing supply. Advancement in the adoption of alternative production practices such as SRI will enhance sustainable rice production, increasing smallholders' income and improving food security. The main objective of the study was to evaluate the effects of the System of Rice Intensification (SRI) on farm level rice productivity in Mwea Irrigation Scheme. In achieving this objective, the following specific objectives were undertaken; to determine the effects of selected determinants on adoption of SRI, to determine the factors that influence rice productivity under SRI and Conventional Flooding (CF) and to compare the profitability of SRI and CF. The findings of the study were as follows.

The findings from the descriptive statistics showed that majority of the smallholder farmers were males. Their female counterparts engaged in other off farm income activities. Therefore is need to engage more women in rice farming and in adoption of rice technologies such as SRI. The results from the Binary logistics model showed that the following factors had influence on the adoption of SRI technology; age, farm size, household size, distance from the canal, education, access to credit services, access to extension services, and years in rice farming were found to positively and significantly influence the adoption of SRI. The education level, farm size, household size, age, years in rice farming, distance from the canal and access to extension services determines the farmers' adoption decisions.

From the findings above, the study concludes that age of the farmer is an important factor in adoption of SRI. Farmers in their active age preferred SRI due to their familiarity with the technology information. While the old farmers are more conservative and they do not want to switch from their traditional practices. Education of the farmer is an important factor in adoption. Literate farmers are better able to process information and search for suitable agricultural technologies to improve their paddy production. This implies that majority of the SRI farmers were literate and had a better understanding of paddy production technologies. Monthly income from the farm, livestock and other crops influences the adoption of SRI. The income increases the adoption by enabling purchase of pesticides, herbicides and fertilizers. Similarly, experience in rice farming is an important factor in adoption of modern agricultural technologies that could impact positively on food security. Additionally, unlike the previous studies that showed a positive relationship between education of the farmer and adoption of modern technologies, the findings of this study showed that the education of the stallholders' in MIS was not affecting the adoption of SRI. This is because SRI is a farmer centric innovation whose success depends on the farmers' motivation and skills levels rather than education levels.

The second objective assessed the factors influencing rice productivity under SRI and CF. the results of econometric modelling showed that household size, involvement in off-farm work, farmer experience, distance from the canal, access to extension services, credit access and labor use affects rice productivity significantly. These findings suggest that paying attention to these factors is a good strategy to enhance rice productivity among smallholders in Mwea Irrigation Scheme.

The third objective compared the profitability of SRI and CF. The study established the cost and returns under the two practices. In addition, a comparative analysis of gross margins was used to determine the profitability of each practice. It was established that both CF and SRI had higher returns than costs. Therefore it makes it profitable to use either SRI or CF. Secondly, the returns of SRI outweigh the returns of CF thus making SRI more profitable. Both CF and SRI Farmers ranked the cost of inputs such as labour use, cost of fertilizer and cost of seeds as the major institutional constraints. However it was noted that SRI is more labour intensive as compared CF. The labour requirement of SRI is during the initial stages of land preparation and weeding. According to smallholder farmers in MIS, bird scaring and weeding were the main challenges with the SRI and CF methods. The use of rotary weeder on farm weeding will reduce the cost incurred while purchasing the agrochemicals. The study therefore concludes that rice production in Mwea Irrigation Scheme by use of SRI is more profitable compared to old practices such as CF. Hence SRI is an important set of practices that should be encouraged among the farmers, considering the fact that rice is one of the major staple food crops in Kenya. The promotion of improved rice technologies such as SRI will increase rice production among smallholder rice farmers. In addition it will increase the affordability and availability of the grain, enhance income generation among the smallholder farmers and improve food security both at the household and national levels.

5.3 Policy Recommendations

Several lessons have emerged from this study. The study gives the following recommendations that will improve rice productivity and food security in Kenya.

First, the results revealed that access to extension services need to be tackled comprehensively. Formal training of smallholder farmers can be integrated through the already existing programmes. Intensifying trainings in all the SRI practices will promote adoption. In addition formation farmer field schools will promote farmer to farmer knowledge sharing and thus promote the adoption SRI. Raising farmers' awareness of water conservation practices will enhance the adoption of SRI. This can be achieved through intensive training by the extension officers and farmer to farmer knowledge sharing on SRI practices. The government and other stakeholders should devise strategies to promote adoption of SRI to increase productivity of the rice crop and hence food security locally and nationally.

The study also found that access to credit by smallholders in MIS is a good strategy to improve rice productivity. Therefore to improve rice productivity in Kenya, the government and development partners should work together to improve access to suitable agricultural credit. This can be realized by formation of more farmer cooperatives in the study area. The rice farmers can be encouraged by extension service providers to concentrate of formal training, participation in FFS, implementing better farming technology (e.g. SRI) and adoption of appropriate water conservation practices for enhanced productivity.

Although the SRI and CF practices were both profitable in Mwea Irrigation Scheme, farmers should be encouraged to adopt SRI. This is because SRI appears to be more profitable as compared to CF. This will enhance intensification of rice farming in Kenya to meet its increasing rice demand. Additionally, it will improve smallholders' productivity and incomes.

The cost of inputs for the two practices was high. Therefore the government of Kenya should help in subsidizing inputs such as fertilizer. This will enable famers to acquire the necessary inputs and lower the cost of production. This is based on the fact that MIS smallholder farmers ranked cost of inputs as the most pressing institutional constraints. There is need to develop effective mechanisms of enhancing bird scaring. This is because the study revealed that bird infestations on the rice fields was one of the major challenges facing the smallholder farmers practicing both CF and SRI. Based on the unique circumstances of the farmers, the stakeholders should strive to promote adoption of SRI over CF to improve returns from rice farming.

5.4 Proposed further research

For further research, the study suggest the following:

This study focused on adoption, productivity and profitability of the system of rice intensification in Mwea irrigation scheme. However there is scanty related research done in other rice irrigation schemes in Kenya. Therefore future studies can focus on the levels of SRI adoption, productivity and profitability in other rice growing schemes in Kenya. Additionally, the studies can compare MIS with other schemes in terms of adoption and productivity.

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APPENDICES

APPENDIX 1: QUESTIONNAIRE

I am Kaloi Francis Kadipo a student at the University of Embu studying Master of Science in Agricultural economics. As part of the University requirements, am expected to carry out research in my area of choice 'Economics of the system of rice intensification on rice productivity in Mwea Irrigation Scheme' which has necessitated this study. I have therefore designed the following questionnaire for the study on the above topic. The information provided will be treated with confidentiality.

I will appreciate if you fill this questionnaire. I expect your kind cooperation.

PART I: Background Information

Date ……………………………………………………………………..

Questionnaire Code No. ……………………………………………….

Respondent Name ……………………………………………………..

Kindly tick where appropriate. √

Gender of household head	1 = Male ( )	0 = Female ( )
SRI farmer	1= Yes ( )	0 = No ( )
Age	(Years)………………	
Marital Status	1=Single ( ) 2=Married ( ) 3=Divorced/separated ( )	
Level of education	1=No formal education ( ) 2=Primary education ( ) 3=Secondary education ( ) 4=Tertiary Institution ( )	
Total number of household members	………………	
Farm size	Hectares ………………..	
Average monthly income	Kenya shillings …………….	
Distance from Main canal	Kilometres…………	
Off-farm income sources	1=Self-employment 2 = Salaried job 3 = wages 4 = Carpentry 5 = Others (specify)……………	

PART 11 : FARM CHARACTERISTICS

11. For how long have you been engaged paddy farming? …………………………..

12. For what purpose do you use income from off-farm activities?

    1= To buy food ( ) 2= To purchase farm inputs ( ) 3= Others (Specify) …………………

13. How did you acquire land for paddy farming?

    1= Purchased ( ) 2= Rented ( ) 3= Lease ( ) 4 = Others (Specify) …………………

SRI Adoption and extension services

14. Do you get advisory services from extension officers on SRI ?

    1= Yes ( ) 2= No ( )

15. From which source do you get extension services on SRI?

    1= NIB ( ) 2= NGOs ( ) 3= Others (Specify) …………………

16. What types of services did you receive from extension officers?

    1= Plant spacing ( ) 2= Paddy variety ( ) Fertilizer application ( ) 3= Others (Specify) …………………

17. Indicate the SRI practices adopted in your farm.

SRI Packages	Adoption (√ **)**
Transplanting 8-15 days old seedling	1= Yes ( ) 2= No ( )
Shallow planting	1= Yes ( ) 2= No ( )
Wider spacing	1= Yes ( ) 2= No ( )
Use of organics	1= Yes ( ) 2= No ( )
Alternate wetting and drying	1= Yes ( ) 2= No ( )

18. Did you come across weed problem in paddy cultivation?

    1= Yes ( ) 2=No ( )

19. If yes, how did you solve the weed problem?

    1= Hand weeding ( ) 2= Use of herbicides ( )

20. Have you obtained credit for paddy production under SRI?

    1= Yes ( ) 2= No ( )

21. If yes, what are the sources of credit?

    1= Loan from banks ( ) 2= Cooperative societies ( ) 3= others (Specify) …………………

22. Is there any market available for farm inputs? 1= Yes ( ) No= ( )

23. If Yes, How many Kilometers from the market? ……………………

PART IV: COST OF INPUTS FOR RICE PRODUCTION

A. Information on Cost of Rice Seeds

Kindly fill the table below

	SRI			Conventional flooding		
Varieties	**Quantity (Kg)/ Ha**	**Unit price (KES)**	**Total price (KES)**	**Quantity (Kg)/ Ha**	**Unit price (KES)**	**Total price (KES)**
Basmati 370						
Basmati 217						
BW 196						
Others						

B. Information on Cost of Agrochemicals

Kindly fill the table below

	SRI				Conventional flooding	
Chemical	**Quantity**	**Unit price (KES)**	**Total price (KES)**	**Quantity (KES)/ Ha**	**Unit price (KES)**	**Total price (KES)**
Fertilizer						
Basal (kg/ha)						
Sulphate of Ammonia (kg/ha)						
Urea (kg/ha)						
Herbicides (Litre/Acre)						
Insecticides (Litre/Acre)						

C. Data on Labour use for System of Rice Intensification

Kindly fill the table below

Labour Charges	**Amount per worker (KES)**	**Man-days**	**No. of operation**	**Women Num.**	**Men Num.**	**Children Num.**
Land Preparation						
Ploughing						
Rotavation						
Chemical Application						
1^{st} Fertilizer application						
2^{nd} Fertilizer application						
Herbicide application						
Before ploughing						
Pre-emergence						
Post-emergence						
Transplanting						
Bird scaring						
Harvesting						
Threshing						
Drying						
Bagging						
Transportation to milling factories						

D. Data on Labour use Conventional flooding

Kindly fill the table below

Labour Charges	**Amount per worker (KES)**	**Man-days**	**No. of family labour used**	**No. of hired labour used**	**Women Num.**	**Men Num.**	**Children Num.**
Land Preparation							
Ploughing							
Rotavation							

Chemical Application							
Fertilizer application							
1st application							
2nd application							
Herbicide application							
Before ploughing							
Pre-emergence							
Post-emergence							
Insecticide Application							
Planting							
Nursery							
Transplanting							
Bird scaring							
Harvesting							
Threshing							
Drying							
Bagging							
Transportation to milling factories							

Weeding

	Weeding		Manual	Weeder alone	Weeder & Manual
		SRI			
		Non-SRI			
	How often do you weed and how many days after Transplantation?		SRI	Non-SRI	labour required

					(No. of persons)
			No. of days	No.of days	
		1st Weeding			
		2nd Weeding			
		3rd Weeding			
	Indicate the number of working hours for one weeding per acre.	SRI: hours …… Days…… Non-SRI: hours …. Days…….			

E. Information on Land

Indicate the number of acreage under rice production	1= SRI …………………………. 2= NON-SRI …………………
What is the cost of rent per season?	…………………………………… ……………………………………

Other Costs

Items	Total cost (Ksh)
Irrigation fee	
Repair and maintenance	
Transport of agrochemical inputs	
Equipment hiring	
Rice bags	

Other Cost …………………

F. Total Revenue (System of rice intensification)

	SRI	CF
How many bags of Paddy rice were harvested per acre in the last season?		
When was your harvest (Month,Year) ?		
What was the expected harvest per acre?		
What is the average price per bag of paddy rice?		

APPENDIX 2: Correlation Matrix for Determinants

	Gender Household head	Age	Marital Status	Education	Household size	Farm size	Average Monthly Income	Off farm income	Years in Rice farming	How Land was acquired	Advisory on SRI	Credit Access	Solved weed
Gender Household head	1.000												
Age	-0.015	1.00											
Marital Status	-0.142	0.54	1.00										
Education	-0.029	0.11	-0.02	1.000									
Household size	0.121	0.22	-0.24	0.010	1.000								
Farm size	-0.268	0.21	-0.01	0.038	0.4483	1.0000							
Average Monthly income	-0.0877	-0.2959	-0.3193	0.1958	0.1671	0.1372	1.0000						
Off farm income	0.0519	-0.1498	0.2216	0.0597	-0.2302	-0.3147	-0.2275	1.0000					
Years in rice farming	-0.0017	0.2337	0.2270	0.0742	0.3469	0.3150	-0.1970	0.4595	1.0000				
How land was acquired	-0.262	0.0106	0.1775	-0.2729	-0.3485	0.1630	-0.0514	-0.1734	-0.2325	1.0000			
Advisory On SRI	0.2605	0.0715	-0.2639	0.1351	0.1358	-0.0426	0.0813	-0.1322	-0.0766	-0.3933	1.0000		
Credit Access	0.2030	0.0055	-0.1691	0.2878	-0.0825	-0.2255	0.2853	-0.1692	-0.1589	-0.0132	-0.0124	1.0000	

APPENDIX 3: Correlation Matrix for the SRI Practices

		Transplanting 8-15 days old seedlings	Shallow_planting	Wider spacing	The use of organic manure	Alternate wetting and drying
Transplanting 8-15 days old seedlings	Pearson Correlation	1	-.253**	.047	-.020	.248**
	Sig. (2-tailed)		.000	.401	.725	.000
	N	341	319	319	318	319
Shallow_planting	Pearson Correlation	-.253**	1	-.156**	-.168**	-.218**
	Sig. (2-tailed)	.000		.005	.003	.000
	N	319	319	319	318	319
Wider spacing	Pearson Correlation	.047	-.156**	1	-.070	-.024
	Sig. (2-tailed)	.401	.005		.213	.663
	N	319	319	319	318	319
The use of organic manure	Pearson Correlation	-.020	-.168**	-.070	1	.048
	Sig. (2-tailed)	.725	.003	.213		.396
	N	318	318	318	318	318
Alternate wetting and drying	Pearson Correlation	.248**	-.218**	-.024	.048	1
	Sig. (2-tailed)	.000	.000	.663	.396	
	N	319	319	319	318	319

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

APPENDIX 4: White test for heteroscedasticity

White's test for Ho: homoscedasticity

against Ha: unrestricted heteroscedasticity

chi2(63) = 318.00

Prob > chi2 = 0.0000

Cameron & Trivedi's decomposition of IM-test

Source chi2 df p

Heteroskedasticity 318.00 63 0.0000

Skewness 40.44 14 0.0002

Kurtosis 3.80 1 0.0513

Total 362.24 78 0.0000

APPENDIX 5: Breusch-Pagan / Cook-Weisberg test for heteroscedasticity

Breusch-Pagan / Cook-Weisberg test for heteroscedasticity
Ho: Constant variance
Variables: fitted values of SRI_Adoption
chi2(1) = 4.38
Prob > chi2 = 0.0364

APPENDIX 6: Correction for Heteroscedasticity

Logistic regression	Number of obs =	364	
	Wald chi2(8) =	15.07	
	Prob > chi2 =	0.0578	
Log pseudolikelihood = -50.012344	Pseudo R2 =	0.6753	
Robust			
SRI_Farm Coef. Std. Err.	z	P>z [95% Conf.	Interval]
Gender_H -.2530902 .3305936	-0.77	0.444 -.9010418	.3948613
Land_pad 4.974959 2.605513	1.91	0.056 -.1317528	10.08167
Advisory 15.65906 6.431932	2.43	0.015 3.0527	28.26541
Transpla -5.721025 2.252202	-2.54	0.011 -10.13526	-1.306791
Shallow_ 10.27781 4.898595	2.10	0.036 .6767393	19.87888
Wider_sp 18.61116 7.861317	2.37	0.018 3.203261	34.01906
Use_Orga 16.28224 6.814162	2.39	0.017 2.926731	29.63776
Alternat 3.254597 1.024524	3.18	0.001 1.246567	5.262626
_cons -48.03702 21.04447	-2.28	0.022 -89.28342	-6.790622

APPENDIX 7: Gross margin analysis for SRI and CF

	SRI	CF
Bags harvested	19	12
Farm gate price(per bag)	6,232	6,232
Gross revenue	**118,408**	**74,784**
VARIABLE COST		
Cost of seeds	1,282.83	2,276.66
Cost of fertilizer	6,026.27	2,639.49
Cost of herbicides	613.50	300.61
Cost of Insecticides	479.25	527.33
Cost of Ploughing (KES)	4797.16	5797.16
Cost of Rotavation (KES)	5,328.28	5,328.2
Cost of land leveling (KES)	1609.3	1150
Labor cost fertilizer application (KES)	621.1	1021.1
Labor cost herbicide application (KES)	1463.2	616.63
Cost of Nursery preparation	3,463.02	4,463.21
Cost of transplanting KES)	5330	5,330
Cost of bird scaring (KES)	9,033	9,033
Cost of threshing (KES)	900.16	1725
Cost of drying (KES)	1,925	1,925
Cost irrigation (KES)	3,325	2,210
Cost of rent (KES)	8,367	8,367
Total Variable cost (KES)	**54,564.07**	**52,710.39**
Gross Margins Per Season (KES)	**63,843.93**	**22,073.61**