ADOPTION OF SYSTEM OF RICE INTENSIFICATION AND IMPACT ON YIELD IN MBARALI DISTRICT IN MBEYA, TANZANIA

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A DISSERTATION SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN AGRICULTURAL ECONOMICS OF SOKOINE UNIVERSITY OF AGRICULTURE. MOROGORO, TANZANIA.

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ABSTRACT

Rice yields in developing countries in general and specifically in Tanzania remain low due to limited adoption of new innovations by smallholder rice farmers. The System of Rice Intensification (SRI) is believed to have promising potential for increasing rice yields. However, the factors influencing the adoption decisions as well as adoption impacts have been a subject of debate. This study was conducted to analyse the adoption of SRI and its impact on rice yields in Mbarali District. Specifically, the study focused on determining the extent of SRI components adoption by smallholder rice farmers, analysing the factors affecting SRI components adoption decisions and determining the impacts of adopted SRI component combinations on rice yields. Data were collected from three irrigation schemes involving 318 smallholder rice farmers. The extent of SRI components adoption was estimated as a percentage of area under rice production allocated to SRI by smallholder rice farmer. Multinomial endogenous treatment effect model was used to analyse the determinants of SRI component combinations adoption and the impact of the adopted packages on rice yields. The study findings indicate that on average SRI adopters allocate about 73% of rice cultivated land on SRI. The likelihood of smallholder rice farmers adopting SRI component combinations is significantly determined by education level of the household heard, active family labour force size, experience in rice production, access to off farm activities, farm size, farm level status, adequate availability of water for irrigation, access to credit facilities and information from formal sources. Furthermore, the results reveal that all SRI component combinations have a positive and significant impact on yields although on their impact differ in magnitude. The highest rice yields (41%) are obtained when the full package comprising all components (plant, soil and water management) is adopted, hence future interventions with comprehensive SRI package are recommended.

DECLARATION

I, **Amos Ndabila**, do hereby declare to the Senate of Sokoine University of Agriculture that this dissertation is my own original work done within the period of registration and that it has neither been submitted nor being concurrently submitted in any other institution.

Amos Ndabila **Date**

(MSc. Candidate)

The declaration above is confirmed by;

Prof. G.I. Mlay **Date**

(Supervisor)

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DEDICATION

This work is dedicated to Almighty God under whose care I was able to finish it successfully. Secondly, to my lovely family, my wife Zena and my children Jacquiline, Eugen and Jadin.

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LIST OF ABBREVIATIONS AND SYMBOLS

AAEA	Agricultural and Applied Economics Association
ASDS	Agricultural Sector Development Strategy
DED	District Executive Director
EUCORD	European Cooperative for Rural Development
FAO	Food and Agriculture Organization
FFS	Farmers Field School
GDP	Gross Domestic Product
ICM	Integrated Crop Management
IFPRI	International Food Policy Research Institute
MAFAP	Monitoring and Analysis of Food and Agricultural Policies
MAFSC	Ministry of Agriculture Food Security and Cooperatives
MMNL	Mixed Multinomial Logit
MNEM	Multinomial Endogenous Model
MVP	Multivariate probit
NBS	National Bureau of Statistics
NRDS	National Rice Development Strategy
PNAS	Proceedings of the National Academy of Sciences
PPS	Probability Proportional to Size
PSM	Propensity score matching
QR	Qualitative Response
RDD	Regression Discontinuity Design

RJOAS	Russian Journal of Agricultural and Socio- Economic Sciences
ROSCAs	Rotating Saving and Credit Associations
RUDI	Rural –Urban Development Initiative
RUM	Random Utility Model
SACCOS	Savings and Credit Cooperative Society
SAP	Sustainable Agricultural Practices
SARO	Semi Aromantic
SQRT	Square root
SRI	System of Rice Intensification
SSA	Sub-Saharan Africa
TAS	Tanzanian Shillings
TNIC	Tanzania National Irrigation Commission
URT	United Republic of Tanzania
USA	United States of America
USDA	United States Department of Agriculture
WAEA	World Agricultural Economics Association

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background Information

Rice (*Oryza sativa* L.) is the world's second most consumed cereal after wheat. More than half of the world population depends on rice for about 80% of the calorie requirements (Ben *et al.*, 2015). In Tanzania, it is the second most important cereal crop after maize (FAO, 2015). Tanzania is the second largest rice producer in Southern and Eastern Africa after Madagascar with cultivated area of about 1.5 million ha, equivalent to 8.8% of the annual cultivated area, annual production of about 1.4 million tones and an average annual production growth rate of 5% (URT, 2017; USDA, 2018). Smallholder rice farmers account for 18% and 90% of farming households and annual rice planted area in the country respectively, with plot ranging in size from 0.5 to 3 hectares of land per household (FAO, 2015). Rice subsector is among the major sources of employment, income and food security for Tanzania farming households and provides broader beneficial impacts on the rural economy through stimulating local markets and wages (Filipski *et al.*, 2013).

In spite of the increase in the amount of rice production and the importance of rice subsector in Tanzania, rice yield productivity is lower than in most neighbouring countries and one of the lowest in the world due to predominantly rain fed production, the limited adoption and availability of improved cultivars, the minimal use of fertilizers and traditional planting techniques (Mwatawala, 2015; Ngalapa *et al.*, 2014). It is estimated that about 90% of rice farmers in the country use recycled seeds and only 10% use certified seeds. It is estimated that about 15% of farmers use fertilizers at an average of 8 kg/ha compared to 100 kg/ha in Kenya and 120 kg/ha in South Africa (Bonifance *et al.*, 2015). This affects the yield level of rice in the country which is low ranging between 1.6

to 2.4 tonnes/ha compared to 2.5 tonnes/ha for Africa as whole and 4.7 tonnes/ha in Asia (URT, 2017; FAO, 2017).

In Tanzania, rice is grown under irrigated and rain-fed systems. The irrigated rice accounts for 26% of the planted area with yields ranging from 2.5 to 4.0 tones/ha, while rain-fed covers 74% with yields ranging from 1.0 to 1.4 tones/ ha (FAO, 2015). The utilization of the potential area for irrigated agriculture is very low. It is estimated that 29.4 million hectares are suitable for irrigated agriculture but only 460 000 hectares equivalent to 1.5% of the area has been utilized, the percentage which is lower compared to an average of 4% for Sub-Saharan Africa (SSA) (Kadigi *et al*., 2012; Burney *et al*., 2013; TNIC, 2016).

In 2010, the Ministry of Agriculture, Food Security and Cooperatives (MAFSC) launched the National Rice Development Strategy (NRDS) whose vision is to ensure that the subsistence dominated rice sub sector is transformed into commercial and viable production system through improvement in irrigation and agronomic practices (Barriero-Hurle 2012; URT-NRDS, 2010). This was a follow up to the launch of Agricultural Sector Development Strategy phase one (ASDS I) of 2002 which was dedicated to the creation of enabling environment for productivity and profitability improvement within agricultural sector. Moreover, enhanced rice productivity and profitability have been proposed by the Tanzanian 2010 irrigation policy, National agriculture policy of 2013 and Agricultural Sector Development Programme phase two (ASDP II) (URT, 2010; URT, 2013; URT, 2016). However, how irrigated rice agriculture, can be balanced in a manner that it produces more output with low amount of water utilization and inputs is a challenge (Kadigi *et al.,* 2004).

The Systems of rice intensification (SRI), which was developed in Madagascar in the early 1980s by late Fr. Henri de Laulanie, has been acknowledged worldwide as one of rice cultivation practices that is characterized by water saving principles during rice production process and has become more suited in many rice production systems due to the stresses imposed on the already stressed water resources (Tusekelege *et al*., 2014; Katambara *et al*., 2013). It is a practice that involves the change of management and farming practices for plant management (younger age seedling transplanting and single widely spaced transplants), soil management (early and regular weeding and increased use of organic fertilizer to enhance soil fertility) and water management leading to an increase in yield by more than 64% compared to conventional methods (Takahashi and Barrett, 2014; Varma, 2017). However, it is knowledge intensive and commonly requires more labour for field preparation, early transplanting, water management and weeding (Barrett *et al.*, 2016; Takahashi, 2013). According to Takahashi (2013), 62% and 17% more labour is needed for weeding and transplanting in SRI respectively.

SRI is also acknowledged in Tanzanian irrigation policy of 2010 as its components of plant management, soil management and water management, increase rice productivity which in turn improves food security and increases smallholder farmers' income (URT, 2010). Despite its increase in rice productivity results, it is not effectively used by smallholder rice farmers in Tanzania (Katambara *et al*., 2013). Smallholder rice farmers still operate and produce in subsistence level in which productivity, profitability and farm income have not effectively been increased (Mwatawala, 2015). Therefore, this study investigated on the SRI method with the focus on anlaysing the factors affecting the adoption of its components and the impact of the adopted components on yield to smallholder farmers.

1.2 Problem Statement and Justification

The System of Rice Intensification (SRI) has been acknowledged worldwide as the rice production practice which is characterized by increased rice productivity with less seeds, water, chemical fertilizers and pesticides use. Although SRI is knowledge and labour intensive, high yields up to more than 7.5tonnes/ha with more than 60% saving on other inputs and increased profits associated with SRI have been revealed by a number of scholarly studies (Varma, 2017; Ijogu, 2016; Barrett *et al.*, 2016; Tusekelege *et al*., 2014; Katambara *et al*., 2013; Devi and Ponnarasi, 2009). Nevertheless, its adoption in most developing countries is very low (Barrett *et al.,* 2016; Katambara *et al.,* 2013). Its slow uptake by smallholder farmers raises questions about whether this new rice production method really offers all the total factor productivity gains as on station and on farm trials from several countries in Africa and Asia have revealed.

Barrett *et al.* (2016) argue that, within SRI adopters, there is significant difference in extent of adoption of SRI components. In addition Takahashi and Barrett (2014), reveal that, SRI impact on yields, may result from varying degrees of adherence to SRI practices which are tested, modified and adopted by farmers as they see fit according to the local conditions. Despite a number of promising benefits offered by SRI as revealed in several studies, there is limited empirical evidence on determinants affecting the decisions to adopt individual as well as the combinations of SRI components and their impact on rice yields to smallholder farmers in Tanzania. Therefore, this study contributes to the knowledge by analyzing various determinants affecting the adoption of SRI components, as well as their combinations and their impacts on rice yields in Mbarali irrigation schemes. The findings may be used by the stakeholders involved in strategies and policy making in rice subsector improvement at local and national levels.

1.3 Study Objectives

1.3.1 General objective

The overall objective of this study was to analyze the adoption of SRI and its impact on yield in irrigation schemes in Mbarali District.

1.3.2 Specific objectives

Specifically the study sought to:

i. To determine the extent of SRI components adoption by smallholder rice farmers in Mbarali District.
ii. To analyze the determinants of SRI components adoption by smallholder farmers in the study area.
iii. To analyze the impact of SRI components adoption on yield.

1.4 Research Hypotheses

This study was guided by the following hypotheses;

i. Household socio-economic, farm characteristics and institutional factors have no influence on SRI components adoption.
ii. Adoption of SRI components has no impact on yield.

1.5 Organization of the Dissertation

This dissertation is organized into five chapters. The first chapter comprises the background to the study, the problem statement and its justification, research objectives and tested hypotheses. Theoretical and empirical literature have been reviewed in the second chapter. The third chapter presents the methodology used in the study for data collection and analysis and a description of the study area. The results and discussion of the findings are presented in fourth chapter, while the fifth chapter presents conclusion and recommendations.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Theoretical Framework

This study is based on adoption and firm theories. The rationale behind this is, farmers first decide whether or not to adopt an agricultural technology and the decision made influences the production processes and profitability.

2.1.1 Adoption theory

The adoption theory assumes that, a farmer is an individual and chooses to adopt a new technology on the basis of rational calculations, given a set of ranked preferences and access to full information (Ngwira *et al*., 2014; Hailu *et al.*, 2014). Furthermore, risks and uncertainty considerations play a crucial role for technology adoption decision (Mwangi and Kariuki, 2015; Negatu and Parikh, 1999). In line with this therefore, a farmer is more inclined to adopt SRI if the practice is perceived to have low risk and has positive effect on rice yields.

2.1.2 Theory of the firm

The theory of the firm assumes that profit maximization is the only relevant goal in production and other possible goals such as obtaining power or prestige are treated as unimportant. In this theory, production is refered as the process of combining and coordinating materials and forces in creation of some good(s) and services (Nicholoson and Snyder, 2005). In this context, therefore, a farmer is more likely to adopt SRI component combinations only if they have positive effect on profitability.

According to Sadoulet and Janvry (1995), a production function of the firm is given by:

$h(q,x,z) = 0$..(1)

where q is output quantity for single product firm, x is the vector of variable input quantities (such as labour, fertilizer, water, pesticides, seeds and hours of rented tractor use) which can be purchased in the desired quantities, z is fixed factor quantities that cannot be acquired in the time span analyzed (such as land, equipment and infrastructure). If w and p are the prices of inputs and outputs, respectively, the producer's restricted profit (profit which only variable costs are subtracted from gross revenues) is given by:

$\pi = p'q - w'x$..(2)

The producer is assumed to choose the combination of variable inputs and outputs that will maximize profit subject to the technology constraint such that:

$Max_{(x,q)}\, p'q - w'x, \;\; s.t.\, h(q, x, z) = 0$..(3)

From the first order condition for profit maximization the following indirect profit functon is obtained $\pi\,(p,w,z)$.

2.2 Adoption of Agricultural Technologies Among Smallholder Farmers

The economic development literatures have focused on the need to address fundamental constraints in moving out of poverty in general and improving productivity of smallholder agriculture in particular. Increasing agricultural productivity is critical to meet expected rising demand for agricultural products (Hailu *et al.*,2014). Agricultural technologies are seen as an important route to move out of poverty in most developing countries (Mwangi and Kariuki, 2015).

According to Muzari *et al*. (2012) and Lowenberg-DeBoer, 2000, the most common areas of agricultural technology development and promotion for crops include new varieties development; plant management; soil management; weed and pest management; irrigation and water management. Through improved input-output relationships, new technologies tend to raise output and reduce average cost of production which in turn results in substantial gains in farm income (Hailu *et al.,*2014). Mwangi and Kariuki (2015) argue that, adoption of improved agricultural technologies has been associated with higher earnings and lower poverty; improved nutritional status; lower staple food prices and increased employment opportunities.

Despite many proven technologies and improved farming practices hold great promise for boosting agricultural production and reducing poverty in developing countries, the adoption of such technologies by smallholder farmers in Sub Saharan Africa, has been slow, (Duflo *et al.,* 2011; Udry, 2010). The low adoption rates have resulted in persistent low agricultural productivity in the region (Pan *et al.,*2015).

Various literatures have documented the factors that determine the agricultural technology adoption (Kariyasa and Dewi, 2011; Ukudugu *et al*., 2012; Teklewold *et al.*, 2013; Ngwira *et al*., 2014). Loevinsohn *et al*. (2013), argue that, farmers' decision about whether and how to adopt new technology is conditioned by the dynamic interaction between characteristics of the technology itself and the array of conditions and circumstances. The diffusion itself results from a series of individual decisions to begin using the new technology, which are often the result of a comparison of the uncertain benefits of the new technology with the uncertain costs of adopting it (Barret *et al*., 2016).

In economic analysis of technology adoption, the main concern is the explanation of adoption behavior in relation to personal characteristics and endowments, imperfect information, risk, uncertainty, institutional constraints, input availability, and infrastructure (Varma, 2017; Mwangi and Kariuki, 2015; Manda *et al.*, 2015; Uaiene, 2009). Moreover, social network and leaning have been included in the categories of factors determining adoption of agricultural technology (Barret *et al.*, 2016). The studies categorize the agricultural technology adoption determinants into different classes. For instance, Akudugu *et al*. (2012), grouped the determinants of agricultural technology adoption into four categories which are technological factors, economic factors, institutional factors and household specific factors. The agricultural technology adoption factors also are grouped into economic, social and institutional factors (Kariyasa and Dewi, 2011). Ngwira *et al*. (2014) categorized the factors into farmer characteristics, farm characteristics, institutional characteristics and managerial while Teklewold *et al.* (2013), classified the factors into social capital, farm and household characteristics, institutional and economic constraints factors.

Inspite of many categories for grouping factors of agricultural technology adoption, there is no clear distinguishing features between variables in each category. Categorization of variables is done to suit the current technology being investigated, the location, the specific preference, or even to suit client needs (Mwangi and Kariuki, 2015). For instance the level of education of a farmer has been classified as a human capital by some researchers (Keelan *et al*., 2014; Mignouna, 2011), while others have classifed it as a household specific factor (Varma, 2017; Manda *et al.*, 2015). However, the most important concern in the research, researchers wish to find variables that can provide the best predictions (Green, 2012; Mishra and Min, 2010).

2.2.1 Household characteristics and their influence on agricultural technology adoption

Household specific characteristics are assumed to have a significant influence on farmer's decision to adopt new technologies. Most adoption studies have attempted to measure household characteristics through the farmer's age and experience in agricultural production, education and household size (Mignouna *et al.,* 2011; Teklewold *et al.,* 2013 Kassie *et al.,* 2013; Keelan *et al*., 2014; Varma,2017). Adoption of agricultural technology may be aﬀected by age because older farmers are assumed to have gained knowledge and experience over time and are better able to evaluate technology information than younger farmers (Kassie *et al*., 2013; Mignouna *et al.*, 2011; Kariyasa and Dewi, 2011). However, younger farmers due to their behaviour of risk taking can be more flexible in adopting innovations than older ones (Manda *et al*., 2015). Adesina and Zinnah (1993) argue that as farmers grow older, there is an increase in risk aversion and a decrease interest in longterm inverstiment in the farm, while on other hand younger farmers are typically less risk averse and are more willing to try new technologies. Mignouna *et al*. (2011), Kariyasa and Dewi (2011), Kassie *et al*. (2013) and Watcharaanantapong *et al*.(2014) found positive relationship between age and adoption decisions while (Teklewold *et al*., 2013) found a negative relationship between age and adoption of multiple sustainable agricultural practices (SAPs) in rural Ethiopia and suggest that, the negative relationship between the two is influenced by crop stress risk averse of older farmers in the study area which causes them to be unwilling and relactant to change from old practices to new ones.

Education of the farmer has been assumed to have a positive influence on farmer's decision to adopt new technology since education of the farmer increases his/her ability to obtain, process and use information relevant to adoption of a new technology

(Mignouna *et al.,* 2011). In this context, households with more educated household members who are involved in decision making are expected to be more aware of the benefits of new technologies and may increase the likelihood of technology (ies) adoption since more education influences farmers' attitudes and thoughts making them more open, rational and able to analyze the benefits of the new technology (Manda *et al.,*2015, Mwangi and Kariuki, 2015). For instance Manda *et al*. (2015), found the positive relationship between education and adoption of Sustainable agricultural practices for maize production in rural Zambia. On other hand, there are authors who reported significant negative effect of education in relation to agricultural techologies adoption (Samiee *et al*., 2009; Uematsu and Mishra, 2010). For instance, Uematsu and Mishra (2010), in studying the effect of education on technology adoption, reported a negative influence of formal education towards adopting genetically modified crops since smallholder farmers with formal education prefered off farm activities than working on farms.

Labour endowment may be captured using household and active family labour force size (Varma, 2017). Household size determines adoption process of labour intensive technologies as a larger household have the capacity to relax high labour demand during introduction of new technology (Mwangi and Kariuki, 2015). This means that, the larger the family, the more labour is available for agricultural production (Manda *et al*., 2015). However, large family size may increase dependency ratio as may comprise more non working household members (Kassie *et al.,*2014). Asfaw *et al*. (2011), argue that not only the family size matters in agricultural technology adoption, but the number of active family members plays a great role for decision making in agricultural technology adoption. Therefore, family size may not always be a good proxy of labour availability and that a more precise proxy is active labour force. Teklewold *et al*. (2013), Noltze *et al*.

(2012) and Varma (2017), documented positive relationship between household size and agriculutural technology adoption in their studies of adoption of multiple sustainable agricultural practices in rural Ethiopia, natural resource management technologies adoption in Timor Leste and adoption of SRI in India respectively. Furthermore, findings from Asfaw *et al*. (2011) study, indicated positive and significant effect of active family labour force size and agricultural technology adoption in Ethiopia.

2.2.2 Farm characteristics and their influence on agricultural technology adoption

Plot characteristics are significant determinants of adoption. Farm size, physical appearance (level status) of the farm, water availability for irrigation and farm location are important plot characteristics which influence the adoption of agricultural technologies (Varma, 2017; Manda *et al.*, 2015; Teklewold *et al.*, 2013). Mandal *et al*. (2015) argue that, larger area can be allocated by farmers for improved technology only if they have enough land to make a trial for a new technology. However, households with relatively more land may use less intensive farming methods than those with less land (Kassie *et al*., 2013). On other hand, Ngwira *et al.* (2014), argue that farmers with less farm size are more likely to adopt intensive agricutural technology compared to those with large farm size. The effect of farm size on agricultural technologies adoption therefore, depends on respective type of techology (Ngwira *et al*., 2014). For instance agricultural mechanization technology is more likely to be adopted by farmer having more farm size than those with less land holding Watcharaanantapong *et al*. (2014). Uaiene *et al*. (2009), Mignouna *et al*. (2011), Ngwira *et al.* (2014) and Manda *et al*. (2015) reported a positive relationship between farm size and adoption of agricultural mechanization in Mozambique, imazapyr-resistant maize technology in Western Kenya, conservation agriculture in Malawi and SAPs in rural Zambia respectively. Contrary,Varma (2017), found negative relationship between the two in his study on adoption of SRI in India. Other studies have reported insignificant or neutral land size relationship with adoption. For instance Kariyasa and Dewi (2011), noted that land size has no significant effect on the degree of integrated crop management (ICM) adoption for Indonesian farmers.

Physical appearance of the farm plays an essential role in decision making for adoption of agricultural technology. According to Manda *et al*. (2015) and Teklewold *et al.* (2013), plots with steep slopes are susceptible to run off and soil erosion which may lead in adopting the technology such as cover plants to reduce the effects. According to Varma (2017), poor land terrain is one of the most important deterrents of adoption of SRI in India.

Adquate water availability for irrigation plays an important role in agricultural production. Noltze *et al.* (2012) argue that, although some agricultural technologies and practices such as SRI require less water, timely and adquate amount of water is required. In line with this, many studies have highlighted the importance of water availability through irrigation as important factor in influencing decision to adopt farming technologies (Noltze *et al*., 2012; Takahashi, 2013; Castle *et al*., 2016; Varma, 2017). The availability of water for irrigation has been postulated to have a positive impact on irrigated agricultural technologies adoption due to the increased intensity and need of irrigated agricultural production to increase yield and gross farm income (Takahashi, 2013; Castle *et al*., 2016).

Moreover, Takahashi (2013), documented that, location of the farm relative to irrigation scheme direction has significant effect on decision of adopting agricultural technologies. Due to unequal water availability in irrigation schemes, farmers whose farms are located in uptreaam have comparative advantage for adopting agricultural technologies related with irrigation than those in downstream (Ghosal and Yihdego, 2016). In studying adoption, diffusion and impact of SRI in rural Bangladesh, Barret *et al*. (2016), reported that, farmers in neighbouring plots need to agree on timing of irrigation to enable water availability for irrigation and reveal that unavailability of water in all plots on time, affects timely land preparation and transplanting as recommended by the SRI technique, hence affecting its adoption.

2.2.3 Access to off farm activities and assets and their influence on agricultural technology adoption

Access to oﬀ-farm income and assets owned by a farmer are important measures of household wealth and can therefore influence the household decision making in agricultural technology adoption due to facilitation of timely farm activities acomplishment (Mwangi and Kariuki, 2015; Teklewold *et al*., 2013). Off farm activities and income have been shown to influence technology adoption decision and can be positive or negative. Diiro (2013), documented that off farm activities generate income which acts as an important source of capital for overcoming credit constraints faced by the rural households in many developing countries and acts as a substitute for borrowed capital in rural economies where credit markets are either missing or dysfunctional. Notze *et al.* (2012), reported that off- farm income is expected to provide farmers with liquid capital for purchasing productivity enhancing inputs such as improved seed and fertilizers. For instance, in studying the impact of off-farm earnings on the intensity of improved maize varieties adoption and maize farming productivity in Uganda, Diiro (2013) reported a significantly higher adoption intensity and expenditure on purchased inputs among households with off-farm income compared to their counterparts without off- farm income.

On other hand, Mathenge *et al*. (2014) and Manda *et al*. (2015), documented the negative effect of off farm activities and income on decision to adopt improved agricultural technologies. Manda *et al*. (2015) argue that, the relationship between off farm income and technology adoption can be negative because off-farm activities divert time and effort away from agricultural activities and reduce availability of labour. Therefore, better access to off-farm activities might divert the resources away from agriculture to off farm activities, resulting in less resource allocation for farm activities.

The ability of the farming households to cope up with production is influenced by an increase in stock of productive assets which may provide the capital or may be used to accomplish the farm activities (Gebremariam and Wünscherb, 2016). The ability of doing farm activities due to productive assets own may inturn influence the household decision in agricultural technology adoption. In the adoption studies of SRI in India and SAPs in Ghana, Varama (2017) and Gebremariam and Wünscherb (2016) respectively, noted the significant and positive effect of owned assets by farmers on adoption.

2.2.4 Access to extension services, information and credit and their influence on agricultural technology adoption

Access to extension services, information and credit have been found to influence technology adoption. Farmers are usually informed about the existence as well as the effective use and benefits of new technology through extension agents who act as a link between researchers and users of that technology (Mwangi and Kariuki, 2015). Extension is a source of information for many farmers, either directly, through contact with extension agents, or indirectly, through farmers who have prior exposure transmitting information to other farmers. The direct contact between extension agents and farmers is measured by the frequency of extension contact related to respective agricultural technology, while indirectly through other farmers is a purposeful way of gathering information which includes that acquired from social networks (Manda *et al.,* 2015; Teklewold *et al.,* 2013). Barret *et al*. (2016), in studying the SRI adoption and diffusion in rural Bangladesh reported that, access to extension services helps to reduce transaction cost which would be incurred when passing information on the new technology to a large heterogeneous population of farmers in the study area. Most authors have documented a positive and significant relationship between access to extension services and technology adoption in agriculture (Castle *et al.,*2016; Gebremariam and Wünscherb, 2016; Manda *et al.,* 2015; Hairu *et al.,* 2014; Notze *et al.*, 2012; Mignouna *et al*., 2011; Uaiene *et al*., 2009). However, Varma (2017) and Teklewold *et al*. (2013), found the insignificant relation in terms of number of extension agents contantact with farmers and adoption of agricultural technology.

Information acquisition about a new technology is another factor that determines its adoption. This enables farmers to learn about the existence of as well as the effective use of technology and hence facilitates its adoption (Mwangi and Kariuki, 2015). According to Barrett *et al*. (2016), farmers only adopt technologies they are aware of or have heard about them and which are perceived to reduce the production uncertainty. In this regard, the individual's assessment may change from purely subjective to objective over time. Nevertheless access to information about a technology does not necessarily mean it will be adopted by all farmers. The study by Uaiene *et al.* (2009), suggests that, this simply implies that farmers may perceive the technology and objectively evaluate it differently than scientists. Access to information may also result to disadoption of the technology. For instance, Barrett *et al.* (2016) argue that, where experience within the general population about a specific technology is limited, more information induces negative attitudes towards its adoption. That is probably due to more information with unclear explanation about the technology exposes an even bigger information vacuum, hence increasing the perception of the risk associated with it. However, many authors reported a significant and positive impact of accessibility to information on adoption of agricultural technologies (Varma, 2017; Castle *et al*.,2016; Barrett *et al.*, 2016; Manda *et al.*, 2015; Teklewold *et al*., 2013).

Credit access has been reported to stimulate technology adoption since it reduces liquidity problems that households face while intending to purchase agricultural inputs and financing farm activities. Hailu *et al*. (2014) found that, access to credit paves the way for timely application of inputs and acomplishment of various farm tasks, thereby increasing the overall productivity and farm income. In line with the argument by Hailu *et al*. (2014), Okuthe *et al*. (2013) reported significant positive effect of access to credit in adoption of improved sorghum varieties and technologies by smallholder farmers in South-Western Kenya. Furthermore, the significant and positive relationship between acess to credit and adoption is revealed by Alcon *et al*. (2011), in their study on adoption of drip irrigation technology in South Eastern Spain. However, access to credit has been found to be gender biased in some countries where female-headed households are discriminated by credit institutions, and as such they are unable to finance yield raising technologies, leading to low adoption rates (Muzari *et al.*, 2013).

2.3 System of Rice Intensification

SRI involves changing a range of rice management practices in which the management of soil, water, plant and nutrients is altered in order to achieve greater root growth and to nurture microbial diversity resulting in healthier soil and plant conditions. The SRI practices enhance the rice plants' growing conditions by reducing the recovery time seedlings need after transplanting; reducing crowding and competition; promoting greater root development; and optimizing soil and water conditions (Barrett *et al*., 2016). As opposed to conventional rice production, SRI involves transplanting seedlings at an early stage (8-15 days seedling), transplanting a single seedling per hole within 30 minutes of removal from the nursery, wider spacing of 25 cm x 25 cm, rotary weeding to promote soil aeration which invigorate microbial activities and promote a healthy root system, increased use of organic fertilizer to enhance soil fertility and intermittent water application, so that soil is kept moist but not flooded (Barrett *et al*., 2016; Ijogu, 2016; Tusekelege *et al*., 2014; Katambara *et al.*, 2013).

SRI has been acknowledged worldwide by various literatures as a rice cultivation practice that is characterized by water and inputs saving practices during rice production process. However, it is knowledge and labour intensive technique (Barrett *et al.*, 2016; Takahashi, 2013). Since its introduction by Fr. Henri de Laulanie S.J. in 1980s in rural Madagascar after a series of observations from farmers' fields and his experiments with various practices of the crop, SRI practices have been widely promoted globally (Barrett *et al.*, 2004; Katambara *et al*., 2013; Barrett *et al.*, 2016). However, the factors influencing the adoption as well as adoption impacts have been a subject of debate (Varma, 2017; Noltze *et al.*, 2013).

In studying SRI adoption, diffusion and impact in Rural Bangladesh, Barrett *et al.* (2016), found that, there is significant difference in adoption among farmers in terms of SRI components. The results reveal that most farmers in the study area follow transplanting age of seedlings, number of seedlings per hole and irrigation as recommended. However, findings indicate that as the days went on a large number of farmers disadopted some SRI practices or abandoned all practices due to disagreement with neighbours about timing of irrigation. Evidence from various studies (Ijogu, 2016; Takahashi and Barrett, 2014; Styger *et al*., 2011; Barrett *et al.*, 2004), show a yield gain of above 60% in SRI production. However Barrett *et al.* (2004) reported the risk associated with early transplanting and water management changes limits SRI adoption among farmers in Malagasy.

Devi and Ponnarasi (2009), in studying the economics of modern rice production technology and its adoption in Tamil Nadu argue that, total cost of production per hectare in the study area was lower by 10% in SRI method compared to conventional method but costs of machine, labour and fertilizers were observed to be higher in SRI method compared to conventional method. Durga and Kumar (2013) in analysing the economics of SRI in South India found that, farmers in conventional method incur more costs than those using SRI methods. However, Durga and Kumar (2013), found that fertilizer costs were lower in SRI compared to conventional method due to higher dose of fertilizer requirement in conventional method of rice production. These results on fertilizer costs contradict those found by Devi and Ponnarasi (2009). Varma (2017) in studying adoption of SRI and its impacts on yield and household income, found that the welfare impacts of SRI adoption for all combinations of SRI individually and as a group had an impact on yield. However, the study revealed that the impact of SRI adoption on household income was quite mixed. Contrary to other studies such as Devi and Ponnarasi (2009), Durga and Kumar (2013) and Varma (2017), whose findings revealed that under SRI the yield is higher while the total cost of rice production is lower compared to conventional method, Tusekelege *et al*. (2014), argue that, the yield is higher in SRI than in conventional but the total cost of rice production per hectare is also high in SRI than in conventional method. However, the study concluded that, due to high yield, SRI technique of rice production is more profitable compared to the conventional practices. The adoption of SRI practices and impact of adoption, therefore tend to vary (Notze *et al*., 2012).

The variation in adoption, yield, costs and profitability in rice production methods is attributed by the characteristic of the farms, ecological differences and implementation strategies (Noltze *et al.*, 2013; Barret *et al*., 2004). Moreover, Noltze *et al*. (2012) suggest that, contradictory findings about SRI impacts may be due to farmers' adoption of SRI components and practices in different combinations. Noltze *et al*. (2013), argue that, more researched evidences on making conclusions about SRI technique in rice production for respective ecologies are necessary. Despite several empirical documentations on SRI and a number of promising benefits it offers, there is scant and limited empirical evidences on the determinants of its components adoption and impact on yield to smallholder rice farmers in Mbarali District. This study was intended to address this knowledge gap.

2.4 Analytical Techniques for Agricultural Technology Adoption and Impact in Multiple Alternatives

In descrete choice,an individual makes choice between alternatives which can be binary or unordered multinomial or ordered multinomial. In unordered multinomial case, the observed response is simply a label for the selected choice and numerical assignments are not meaningful in this setting (Green, 2012). Although numerical outcomes are merely labels of some non quantitative outcome, the analysis in unordered multinomial is nonetheless have a regresson style motivation and models are based on the idea that factors such as household socioeconomic factors, technological, institutional and environmental factors are relevant in explaining the consistent and unbiased parameter estimates as the maximum likelihood estimation of observed choices (Beyene and Belay, 2013; Ghosal and Yihdego, 2016; Green, 2012). The alternative chosen by an individual inturn has an effect on the outcome of interst (Manda *et al*., 2015; Notze *et al.*, 2012)

2.4.1 Analytical techniques for agricultural technology adoption in multiple alternatives

When farmers face more than two choices for technology adoption, multinomial models are more appropriate. Multinomial analytical techniques include models such as multivariet probit model, multinomial endogenous treatment effects and multinomial endogeneous switching regresion model (Gebremariam and Wünscherb, 2016; Mutenji *et al*., 2016; Manda *et al*., 2015; Teklewold *et al*., 2013; Green,2012; Deb and Trivedi, 2006b). The multivariate probit (MVP) is the econometric technique which simulteneously models the effect of the set of explatory variables on each of the practices while allowing the unmeasured factors (error terms) to be freely correlated due to complementarities and substitutabillities between different practices (Kassie *et al.*,2013).

However, Kassie *et al*.(2014), argue that farmers may endogenously self-select adoption or non-adoption and decisions are likely to be influenced systematically by observed and unobservable characteristics. Farmers may decide to adopt a technology based on unobservable factors such as their innate managerial and technical abilities in understanding and using the technology (Abdulai and Huffman, 2014).

The multinomial endogeneous models such as multinomial endogenous treatment effects and multinomial endogeneous switching regresion are the new selection bias correction models which take into account the interdependence of the adoption decisions and selection bias as a result of observed and unobserved characteristics (Varma, 2017; Mutenji *et al*., 2016; Gebremariam and Wünscherb, 2016; Di Falco and Veronesi, 2013; Notze *et al.,* 2012). Although these models are similar as both account for multiple selection scenario and selection bias resulting from observed and unobserved characteristics, they have substantial difference in computation and implementation. Deb and Trivedi (2006b) and Manda *et al*. (2015), documented that, compared with the computationally cumbersome of multinomial endogenous switching regression model, the multinomial endogenous treatment effect model is easier to implement and allows the distribution of endogenous treatment and outcome to be specified using latent factor structure, there by allowing a distinction to be made between selection on unobservables and observables.

2.4.2 Analytical techniques on impact of agricultural technology adoption

The impact of adopted technology on the outcome of interest may be analyzed using quasi experimental designs by identifying a comparison group that is as similar as possible to the treatment group in terms of baseline (pre-intervention) characteristics (Ghosal and Yihdego, 2016). The comparison group which is created using various methods such as propensity score matching (PSM) and regression discontinuity design (RDD), captures what would have been the outcomes if the technology had not been adopted (the counterfactual) (Takahashi, 2013). Hence the technology adopted can be said to have caused any difference in outcome variable between the adopters (treated group) and non adopters as the comparison group (Takahashi and Barrett, 2014; Kassie *et al*., 2014).

The impact analysis techniques using counterfactual group reduces the risk of selection bias that may be caused with the possibility of those who choose to adopt the technology being systematically different from non adopters and the observed outcome between the two groups in the indicator of interest may be due to imperfect match than caused by adoption. However, the main drawback of these impact analytical techniques relies on matching individuals on the basis of observable characteristics linked to predict likelihood of adoption (Khandker *et al*., 2010). The presence of any unobserved characteristics that affect participation in the practice and which change over time, lead to biased estimates and thus affect the observed outcome of interest and conclusion (White and Sabarwal, 2014). Hence, to account for endogeneity and self selection bias, various literatures (Di

Falco and Veronesi, 2013; Abdulai and Huffman, 2014; Manda *et al.*, 2015; Gebremariam and Wünscherb, 2016; Varma, 2017) recommend the use of multinomial endogenous analytical methods which take into consideration for endogeneity and self selection factors among farmers.

Therefore, due to self selection in multiple scenario of SRI component combinations and the fact that the unobserved factors such as technical management and ability of farmers in understanding new practices and information asymmetry can affect decision to adopt SRI component combination and also have influence on outcome variable(yield), the determinants of SRI components adoption and impact of the adopted component combinations on yield were addressed by Multinomial endogenous treatment effects model in its two stages.

CHAPTER THREE

3.0 RESEARCH METHODOLOGY

3.1 Conceptual Framework

Rice productivity is highly influenced by irrigation and agronomic practices adopted such as SRI (Varma, 2017; Durga and Kumar, 2013; Notze *et al.*, 2012). However, the decision of farmer to adopt SRI components may be determined by household socioeconomic characteristics such as education level of household head, experience in rice production, access to off farm activities and income, farm assets and active family labour force; Farm characteristics which include farm size, farm level status, location of the farm in irrigation scheme and availability of water for irrigation; and institutional factors such as access to credit, extension services and information. Then the adopted SRI components affect the rice yield (Fig.1)

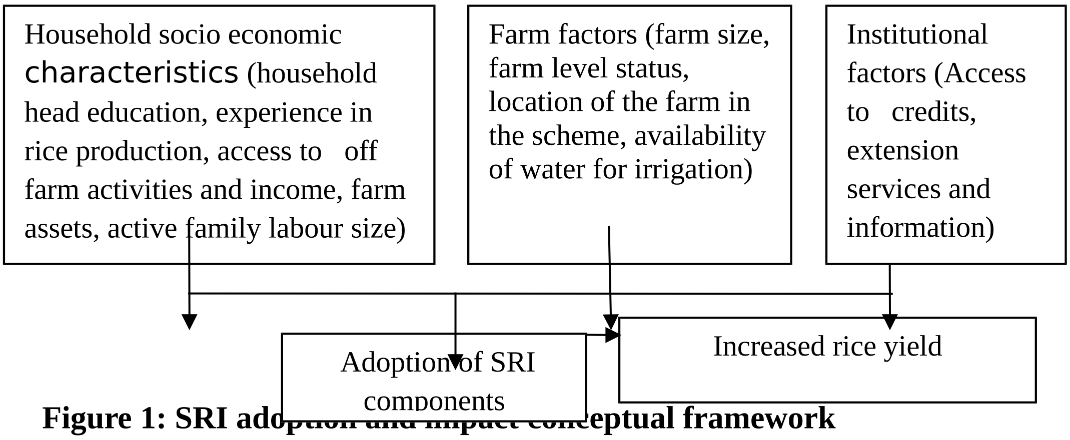

Figure 1: SRI adoption and impact conceptual framework
Source: (Field data, 2018)

3.2 Theoretical Model

3.2.1 Rondum utility model (RUM)

According to *homus economicus* assumption for an individual choice, if a person chooses a particular action or object it means the action or object maximizes the utility of that person. According to Nicholoson and Snyder (2005), utility is the overall satisfaction which an individual gains from making a certain choice. The i^{th} smallholder rice farmer therefore, chooses SRI component combination j, instead of implementing any other practice k, if and only if utility derived by the chosen SRI component combination j is higher than that derived through implementation of any other practice k ($U_{ij}>U_{ik}$), where $k \neq j$.

The utility derived by i^{th} smallholder rice farmer from making a certain choice of SRI component combination j, is presented in equation 3:

$$U^*_{ij} = z'_i\alpha_j + \eta_{ij} \qquad (4)$$

Where,

U^*_{ij} = Utility derived by i^{th} smallholder rice farmer from making choice of j^{th} SRI component combination.

z'_i = A vector of explanatory variables which affect the probability of choosing SRI component combination j which in this study include: Education level of smallholder rice farmer, size of active family labour force, experience in rice production, value of farm assets owned, access to off farm activities, rice farm size, level status of the farm field, location of the farm in irrigation scheme, adequate availability of water for irrigation, credit facilities availability, number of farmers contact with extension agent and information about SRI.

α_j = A column vector of parameters associated with the explanatory variables.

η_{ij} = Error term for i^{th} smallholder rice farmer associated with j^{th} SRI component combination.

3.3 Methods of Analysis

The data analysis was based on descriptive statistics and multinomial basing on two stage sampling design using stata. Comparison of means was done using t-test and Chi square test was used to determine the existence of association between qualitative variables. The details of analytical methods by objectives are presented below.

3.3.1 Extent of SRI components adoption by smallholder rice farmers

The extent of SRI components adoption was estimated as a percentage of area under rice production allocated to SRI, by smallholder rice farmer. The SRI adoption in this study was considered as the choice of five combinations comprising three major SRI components of plant management, soil management and water management. From smallholder farmers adopting SRI from partial to complete package adoption, the percentage of allocated area to SRI relative to total rice cultivated land by smallholder farmer was estimated.

3.3.2 Determinants of SRI components adoption and impact of adopted component combinations on yield

In adopting SRI technique, smallholder farmers self select to adopt or not to adopt a respective SRI component combination among four SRI component combinations (Plant management; plant and soil management; plant and water management; and plant, soil and water management combination). In choosing the SRI component combination to adopt, the decisions are likely to be influenced by unobserved factors such as ability of farmers in understanding SRI package combinations and information asymmetry about SRI that can affect decision to adopt SRI component combination and also have influence on outcome variable (rice yield). In this context therefore, to disentangle the pure effects of adoption, the determinants of SRI components adoption and impact of adopted component combinations on yield were addressed by multinomial endogenous treatment effects model in its first and second stages respectively.

3.3.2.1 Determinants of SRI components adoption

In first stage, SRI major components (plant management, soil management and water management) combinations were assumed to be chosen by smallholder farmer through comparison of alternative combinations for farmer's utility maximization. The i[th] farmer therefore chooses a SRI component combination j, over any alternative combination k, if $U_{ij}>U_{ik}$, $k\neq j$.

Let U_{ij} denote the utility associated with the j[th] SRI practice, where j=0,1, 2, 3,4 for farmer i:

$U^*_{ij} = z'_i\alpha_j + \Sigma^j_{k=1}\delta_j l_{ij} + \eta_{ij}$ .... (5)

Where:

z'_i = Household socioeconomic, institutional and farm factors affecting decision for j[th] SRI component combinations adoption (Table 1).

α_j = Corresponding parameters associated with j^{th} SRI component combination.

η_{ij} = Error term for i^{th} smallholder rice farmer associated with j^{th} SRI component combination.

l_{ij}= Latent factor that incorporates the unobserved or unquantifiable characteristics (ability of farmers in understanding SRI package combinations and information asymmetry about SRI) and these unobservable can affect decision to adopt SRI component combinations and also have influence on rice yield as outcome variable.

While U^*_{ij} is not observed, we observe the choice of SRI component combinations in the form of binary variables d_{ij} which are collected by a vector, $d_{ij}= d_{i1}, d_{i2},..., d_{iJ}$. Similarly, let $l_{ij} = l_{i1}, l_{i2},\ldots\ldots\ldots\ l_{iJ}$. In this therefore, the probability of treatment can be represented as:

$Pr (d_{ij} \mid z_i, l_i) = g(z_{i1}\alpha_1+ \delta_1 l_{i1} + z_{i2}\ \alpha_2 + \delta_2\ l_{i2}\ ....+ z'_{ij}\alpha_j + \delta_j l_{ij}$..................................(6)

Where: d_{ij} = The observable binary variables representing the choice of SRI component combination as a vector of $d_{ij} = (d_{i1}, d_{i2},...,d_{iJ})$,

l_{ij} = Latent factor incorporating unobserved or unquantifiable characteristics

$l_{ij} = (l_{i1}, l_{i2},..., l_{iJ})$.

g = Appropriate Multinomial probability distribution which has a Mixed Multinomial Logit(MMNL) structure, defined as:

$$Pr (d_{ij} \mid z_i, l_i) = \frac{Exp (z'_i\alpha_j + \delta_j l_{ij})}{1+ \Sigma^J_{j=1} exp (z'_i\alpha_j + \delta_j l_{ij})} \qquad ....(7)$$

Specification and description of variables expected to influence SRI component combinations adoption

Based on economic theory and empirical studies on adoption, various socioeconomic characteristics (education of smallholder farmer, active of family labour force size, experience in rice farming, value of farm assets owned and accessibility to off farm activities); farm characteristics (farm size, level of the farm, location of the farm in the irrigation scheme and adequate availability of water for irrigation) and institutional factors (credit facilities availability, number of extension agencies contacts and training on rice production and accessibility to information about SRI) expected to be the driving factors for decisions on SRI component combinations adoption in the study area. The variables are presented and described as follows:

Education level of smallholder farmer: A dummy variable assigned a value of one if smallholder farmer has post primary school education and zero if has no formal education or has primary education. Education level of smallholder farmer expected to have a positive effect on SRI components adoption decision since those farmers with post primary school education are expected to have more ability to obtain, process and use information relevant to adoption of SRI component combinations and more aware of adoption benefits (Mignouna *et al.*, 2011; Manda *et al.*,2015).

Size of active family labour force: This variable was measured as a count variable by taking the number of household members involved in rice farming activities. The variable was expected to affect SRI component combinations adoption positively. This is because, larger size of active family labour force relaxes high labour demand technologies like SRI (Asfaw *et al*., 2011).

Experience in terms of years in rice production: The relationship between the experience in rice farming and SRI adoption was captured by number of years in rice production. The influence of experience in rice production on SRI adoption expected to be indeterminate. Experienced farmers may be better in evaluating technology than younger farmers hence more likely to adopt SRI (Kassie *et al*., 2013). Contrary, more experienced farmers may be less responsive to change from conventional to SRI technique (Varma, 2017).

Value of farm assets: This is the total value of farm assets owned by smallholder farmer such as hand hoe, oxen, ploughs, powertilers and tractors. The value of an asset was measured as continuous variable using market price of the respective farm asset. Farm assets value is the proxy for wealth of household which may provide capital to enable timely accomplishment of farm practices and coping with production risk associated with delay in crop production (Teklewold *et al.,* 2013). Farmers with low total value of farm assets therefore, were anticipated to be less likely to adopt SRI components.

Access to off farm activities: It was specified as a dummy variable taking the value of one if the smallholder farmer has access to off farm activities and zero otherwise. Off farm activities generate income which is expected to provide farmers with liquid capital for farm activities accomplishment. This therefore may increase the likelihood decision of farmers to adopt SRI compared to those without access to off farm activities (Notze *et al.,* 2012). However, access to off-farm activities might divert the resources away from agriculture to off farm activities, resulting in less resource allocation for farm activities and thus less likelihood of adoption of labour intensive technology such as SRI (Mathenge *et al.,* 2014). Following these arguments, the effect of access to off farm activities in SRI component combinations adoption was expected to be indeterminate.

Farm size: It is a continuous variable, which represents the total area under rice in hectares. Larger area can be allocated by farmers for improved technology only if they have enough land hence increasing the likelihood of adoption (Manda *et al.,* 2015). However the owners of relatively more land may prefer to use less intensive farming methods compared to owners of less land farmers (Kassie *et al*., 2013). The effect of farm size on SRI components adoption therefore, is postulated indeterminate.

Level of the farm: This is the physical appearance of rice plot. Level of the farm was measured as dummy variable with a value of one if the farm is leveled, zero if not levelled. As the leveled farms enable the control of water for irrigation and early seedlings transplanting (Notze *et al*., 2012), it was predicted that farmers whose farms have been leveled are more likely to adopt SRI components than those whose farms are unleveled.

Water availability for irrigation: It was captured as the dummy variable taking the value of one if water was available for irrigation when needed and if water is not available when needed for irrigation. It is expected that, smallholder farmers whose farms get water when needed for irrigation are more likely to adopt SRI components. This is due to the fact that water availability when needed reduces the water risk which may occur due to wetting and drying practices in rice production using SRI technique hence increasing the possibility of smallholder rice farmers to adopt SRI package combinations (Takahashi, 2013).

Location of the farm in irrigation scheme: This is the position of a rice farm in relation to water flow direction in the irrigation scheme where the farm may be at upstream or downstream. The variable was measured as dummy variable with one value if the farm is located at upstream and zero otherwise. In most irrigation schemes, farmers whose farms are located in upstream have comparative advantage of getting water than those in downstream (Ghosal and Yihdego, 2016). Thus, it was expected that, upstream location of the smallholder's farm increases the likelihood of SRI components adoption relative to downstream location.

Access to Extension services and information: For the farmer to be aware of the benefits of a new technology like SRI, the access to information and extension services play a great role (Notze *et al.*, 2012). The accessibility of extension services is proxied by the number of contacts smallholder rice farmers had with extension agents per cropping season. It was anticipated that since SRI is the knowledge based technique, the number of contacts with extension staff, positively influence the decision to adopt the technique components.

In line with extension services, the accessibility to information was specified as dummy variable taking the value of one if the smallholder farmer had information concerning SRI from government or development partners and zero otherwise. It was postulated that accessibility to information about SRI from government or development partners increases the likelihood of its component combinations adoption.

Access to credit: This was captured as a dummy variable taking the value of one if the respondent accessed credit in terms of cash or inputs (seeds, fertilizers and herbicides) in respective cropping season and zero otherwise. Credit is an important source of working capital which may be used to accomplish various farming activities and reduces the liquidity problem that could be faced by smallholder farmer in farming practices (Hailu *et al*., 2014; Okuthe *et al*., 2013). In this context, it was predicted that smallholder farmers who have access to credit are more likely to adopt SRI components than those who have no access to credit.

Table 1: Summary of explanatory variables for SRI component combinations choice

Variable name	Type of the variable	Expected Effect
Socioeconomic Factors		
Education level of smallholder rice farmer(z_1)	Dummy	+
Size of active family labour force. (z_2)	Count	+
Experience in rice production (z_3)	Continuous	$\pm$
Value of farm Assets owned (z_4)	Continuous	+
Access to off-farm activities (z_5)	Dummy	$\pm$
Farm Factors		
Rice farm size (ha) (z_6)	Continuous	$\pm$
Level of the farm (z_7)	Dummy	+
Location of the farm in irrigation scheme (z_8)	Dummy	+
Adequate availability of water for irrigation (z_9)	Dummy	+
Institutional Factors		
Credit facilities availability (z_{10})	Dummy	+
Number of farmers contacts with extension agents (z_{11})	Continuous	+
Information about SRI (z_{12})	Dummy	+

3.3.2.2 Impact of SRI components adoption on yield

The impact of adopted SRI component combinations on yield is proxied by the effect of adopted SRI components package on rice yields per hectare. The study estimates the productivity in terms of rice yields per hectare and identifies which package(s) produced the highest impact on yield. The impact of adopted SRI component combinations on outcome variable (Natural logarithm of rice yield was used because yield is non negative variable), was undertaken in the multinomial endogenous treatment effects model second stage by using the outcome equation, which is defined as:

$$E(y_i \mid d_i, x_i, l_i) = x_i'\beta_i + \Sigma^J_{j=1} \gamma_j d_{ij} + \Sigma^J_{j=1}\lambda_j l_{ij} \quad \text{...(8)}$$

Where: y_i = Rice yield for farmer i

x_i = set of exogenous variables (education level of smallholder rice farmer, size of active, family labour force, experience in rice production, value of farm Assets owned, access to off-farm activities, rice farm size, level of the farm, location of the farm in irrigation scheme, adequate availability of water for irrigation, credit facilities availability, number of farmers contacts with extension agents and information about SRI)with associated parameter vectors β_i,

d_{ij} = The observable binary variables representing the choice of SRI component combinations as a vector of $d_{ij} = (d_{i1}, d_{i2},...,d_{iJ})$

γ_j = Treatment effects relative to the control group (i.e. SRI non-adopters),

l_{ij} = Latent factor incorporating unobserved or unquantifiable characteristics $l_{ij} = (l_{i1}, l_{i2},..., l_{iJ})$.

λ_j = Factor-loading parameter which indicates the positive or negative correlation between the adoption of SRI component combinations and rice yields through unobserved characteristics.

Since outcome variable (the rice yield) is continuous variable, the normal (Gaussian) distribution function was assumed.

3.4 Description of the Study Area

This study was conducted in Mbarali Distirict, Mbeya Region, Southern Highlands of Tanzania. Geographically, Mbarali District lies between latitudes 7^0 and 9^0 South of the Equator and between longitude $33^0.8$ and 35^0 East of Greenwich. The District is bordered by Iringa Rural in the North - East, Wang'ombe District in the South - East, Makete District in the South, Mbeya Rural District in the West and Chunya District in the North. The District has 16 000 square kilometres, among which 4 755 square kilometres is suitable for agricultural production. The area is characterized by flat land and rice production in irrigation schemes is the most economic activity, accounting for 26%

(52 000 ha) of the total arable land potential for agriculture in the District (Mbarali, 2016). Indiarangi, Fayadume, and mwendambio are the mostly local rice varieties grown while SARO5 is the improved variety mostly grown in the district.

According to 2012 National Population and Housing Census, the District had 20 Wards, 99 villages and a population of 300 517 people, out of whom 145 867 (48.5%) were males and 154 650 (51.5%) were females. The total households were 69 888 with 46% of the total population working force.

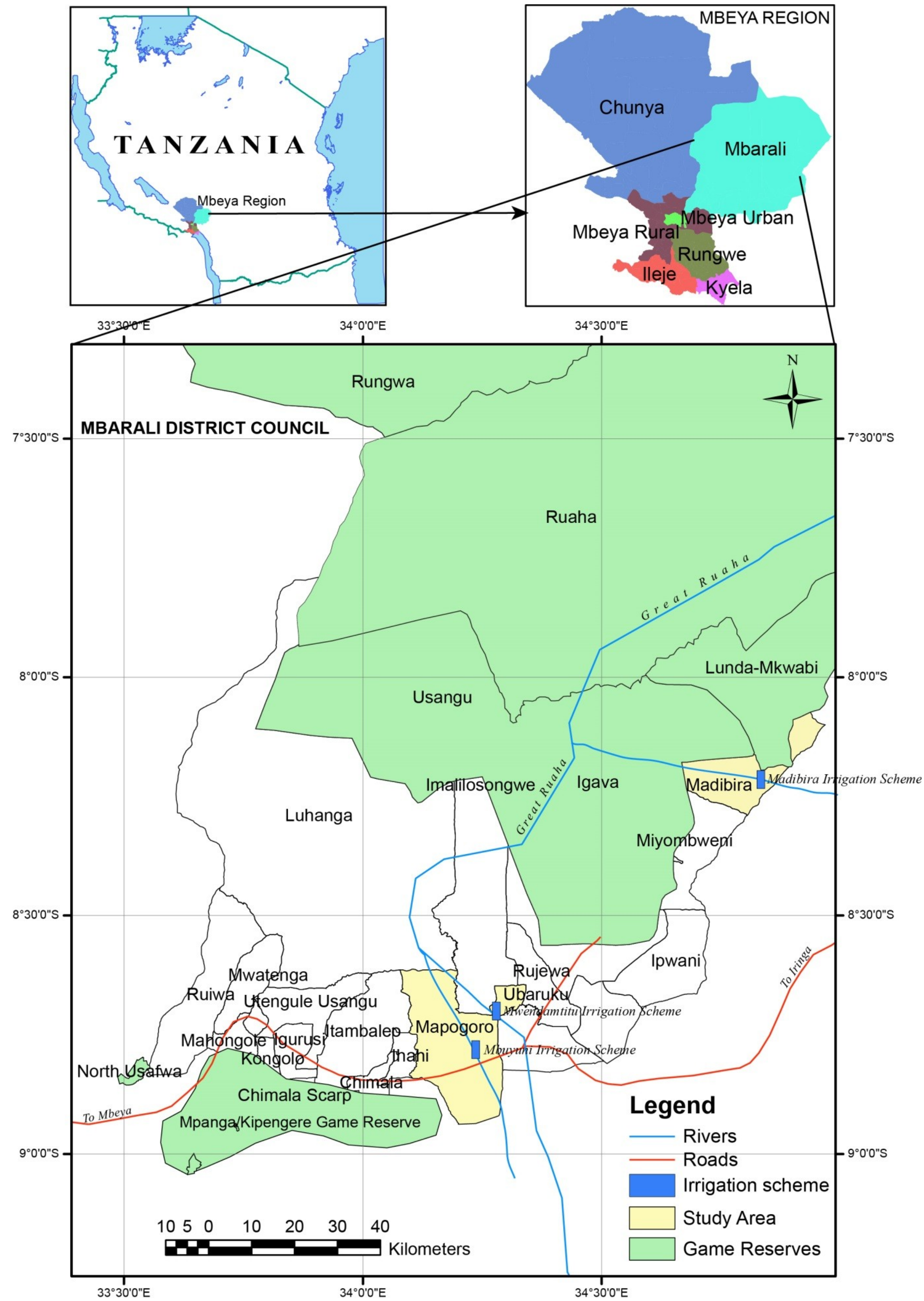

Figure 2: Representation of the study area

3.5 Research Design

3.5.1 Sampling procedure and sample size

The target population in this study was smallholder rice farmers in irrigation schemes in Mbarali District. Two stage sampling design was used. In the first stage, three (3) irrigation schemes were selected out of 31 irrigation schemes using probability proportional to size (PPS) and following cumulative method (Appendix 1).

In the second stage simple random sampling was used in selecting 106 (with stratification of 53 SRI adopter and 53 SRI non adopters) smallholder farmers from each irrigation scheme selected in first stage (Table 2).

The sample size of 379 was obtained using formula as adopted from Kothari (2004);

$$n_s = \frac{Z^2 pgN}{e^2(N-1) + Z^2 pg} \quad \text{......(9)}$$

$$n_s = \frac{1.96^2 * 0.5 * 0.5 * 27\,526}{0.05^2(27\,526-1) + 1.96^2 * 0.5 * 0.5} = 378.8859342 \approx 379$$

where:

n_s = Sample size

N= Total study population

Z= Standard variate at a given confidence level

p =sample proportion

g = 1-p

e = acceptable error (the precision)

In this study, sample proportion of 0.5 and 95% confidence interval were used which led to Z= 1.96; g =0.5 and e = + 5%. However, due to time and financial resource constraints, the sample size was reduced to 318. The sample was stratified into two groups of smallholder farmers who were SRI users and non users.

Table 2: Irrigation schemes used for the study

Irrigation scheme	Number of respondents		
	SRI adopters	SRI non adopters	Total
Mbuyuni	53	53	106
Madibira	53	53	106
Mwendamtitu	53	53	106
Total	**159**	**159**	**318**

3.5.2 Data collection methods

This study was a cross sectional which involved the collection of data from the smallholder rice farmers in irrigation schemes for a single cropping season of 2016/17. Primary data were collected using structured questionnaire which was administered to respondents through face to face interviews. The interviewed respondents were the heads of the households chosen to be part of the sample. The spouse or any senior family member who directly involved in rice farming was interviewed in the absence of the household's head. The questionnaire was designed to capture data on various determinants affecting the adoption of SRI major components, as well as their combinations and impacts on rice yields to smallholder farmers.

The collected data included smallholder farmers characteristics data (education level, active family labours, experience in rice farming, value of farm assets owned and access to off farm activities), credit and extension services data (credit facilities availability and number of extension agencies contacts with smallholder farmers and training on rice production), farm characteristics data (farm size, farm level status, location of the farm in the scheme and irrigation water availability), adopted SRI components and rice yields. Data from key informants were collected using a checklist so as to complement with information from individual smallholder farmers.

3.5.3 Data processing and analysis

Prior to analysis, data from the field were processed. This involved the questions coding, data cleaning and entry. In addition new variables were created when necessary. The created variables include: Plant management package variable was created from field data for smallholder rice farmers who practice early rice seedlings transplanting in 8-15 days, transplanting a single seedling per hole and wider spacing of 25 cm x 25 cm; Plant and soil management components combination variable was created from smallholder rice farmers information who apply plant management practices plus early and regular (about three times or more) weeding per cropping season and use of organic fertilizers to enhance soil fertility; plant and water management package was formulated from smallholder farmers who apply plant management practices plus intermittent water application (wetting and drying of rice field so that soil is kept moist but not flooded); while plant, soil and water management combination was created from farmers' information applying plant, soil and water management practices as recommended in SRI. Furthermore, the household active labour force size variable was created from the number of household members involved in farming activities for four months or more in a single cropping season. The output and inputs average prices were used in computation of revenue and variable costs respectively. Furthermore, the restricted profit was calculated as the difference between revenue and variable costs. The processed data were analyzed to get descriptive statistics results and econometric analysis parameter estimates.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Pattern of SRI Adoption

The adoption of SRI is not a simple yes or no decision. SRI is introduced in packages that include three components of plant, soil and water management. The adoption pattern of SRI component combinations in the study area is presented in Fig. 3. The results indicate that, partial adoption of SRI practices dominates. Among farmers using SRI, only 37% was found to adopt a full package comprising of plant, soil and water management practices. Plant management only is the least adopted SRI component, being used by only 17% of SRI adopters.

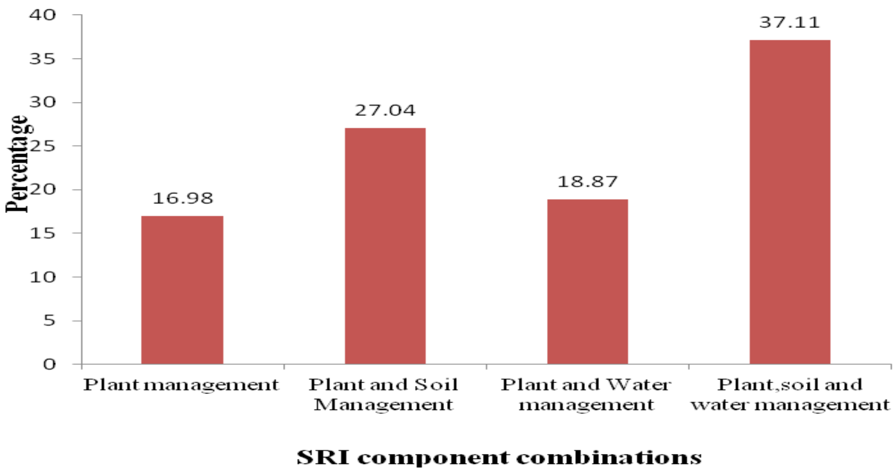

Figure 3: Pattern of SRI Adoption

4.2 Characterization of Sampled Households

Socio-economic characteristics have significant implications on how the household behaves in production. These variables can influence negatively or positively, the process of decision making on rice production technology adoption and the level of output in rice farms. The categorical and continuous socio economic characteristics of sample households are presented in Tables 3 and 4 respectively.

4.2.1 Level of education of sample households

Education level influences attitudes and thought making in analyzing the benefits of new technology. The results indicate that adopters have higher proportion of household heads with post primary education (22%) compared to about 11% of non-adopters (Table 3) and the association between level of education and adoption of SRI is statistically significant at 1% of probability level according to Chi-square test. This suggests that education level might be associated with decision to adopt SRI components.

4.2.2 Access to off farm activities

The income from off farm activities is expected to provide farmers with liquid capital for financing rice production activities. Additionally, off farm income of the household may affect the likelihood of agricultural technology adoption by providing the source of cash flow to buffer the risk associated with agricultural product on failure due to the adopted technology. The results show that about 61/% of adopters had access to off farm activities and income, while for non adopters about 50% had accessibility to off farm activities and income (Table 3). Chi-square test indicates the statistically significant association between adoption of SRI package combinations and accessibility to off farm activities at 5% level of probability. This contradicts with Varma (2017), whose results revealed that access to off farm activities was generally better among the SRI non adopters in India. The distribution of SRI adopters across the components show that plant and water adopters have minimum accessibility to off farm activities (9%) while plant, soil and water management adopters have the maximum accessibility (26%).

Table 3: SRI adoption Status by level of Education and access to off farm activities

Variable	Category	Non adopters (n=159)	Adopters					χ^2-Value
			Plant Mgt (n_1 =27)	Plant and soil Mgt (n_2=43)	Plant and water Mgt (n_3=30)	Plant, soil and water Mgt (n_4=59)	All SRI adopters (n=159)	
Education level	Up to Primary	142 (89.31)	22	35	24	43	124(77.99)	11.394***
	Above primary	17(10.70)	5	8	6	16	35(22.01)	
Access to off farm activities	Had access	80(50.31)	17	24	14	42	97(61.01)	5.238**
	Had no access	79(49.69)	10	19	16	17	62(38.99)	

** and *** denote significance level at 5% and 1% respectively; values in brackets are percentages; Mgt means management

4.2.3 Active family labour force

The size of active family labour force which is proxied by a number of family members with ability to work on rice production activities, is very essential in rice production, particularly in high labour demand practices like SRI. The results (Table 4) show that the mean active labour force size is 2 persons for non adopters and 3 persons for adopters. The difference is statistically significant at 1% level of probability supporting the importance of family labour for adoption of SRI components. This result is consistent with Asfaw *et al*. (2011), who found the significant mean difference of active family labour force of adopters and non adopters of improved agricultural technology in Ethiopia. Moreover study findings of Langyintuo and Mungoma (2008), revealed the statistically significant mean difference for labour force between improved maize variety technology adopters and non adopters in Zambia.

Table 4: SRI adoption Status by labour availability, experience and value of farm assets

Variable	Non adopters (n=159)	Adopters				
		Plant Mgt (n_1 =27)	Plant and soil Mgt (n_2=43)	Plant and water Mgt (n_3=30)	Plant, soil and water Mgt (n_4=59)	All SRI adopters (n=159)
Active family labour force size (Persons)	2 (0.607)	3 (1.372) ***	3 (1.363) ***	3 (0.923) ***	3 (1.430) ***	3 (1.314) ***
Experience in rice production (Years)	3.4 (1.299)	3.5 (1.341)	3.9 (1.298) **	4.1 (1.155) ***	3.6 (1.276)	3.8 (1.280) **
Farm assets value (TAS million)	2.40 (3.637)	5.53 (4.006) ***	3.38 (11.400) **	4.67 (9.923) **	6.02 (5.595) ***	4.03 (8.248) **

Each SRI package is compared with base category (non adopters); ** and *** denote significance level at 5% and 1% respectively; Standard Deviations have been given in parentheses; Mgt means management.

4.2.4 Experience in rice production

As documented by various literatures, the experience in agriculture influences the decision making for agricultural technology adoption. In this study to capture how experience in agriculture relates with SRI adoption, the variable on number of years in rice production was included. The results show that on average, SRI adopters have more rice farming experience than non adopters. Moreover, the study findings indicate that the plant and water management adopters are the most experienced followed by plant and soil management adopters, plant, and soil and water management adopters. Those adopting only plant management or plant and water management are not different from non adopters in terms of years of experience in rice production (Table 4). The similar results on agricultural technology adoption and experiences in farming were revealed by Kassie *et al.* (2013) who reported that, the adopters of interrelated sustainable agricultural practices in smallholder systems in rural Tanzania are more experienced than non adopters.

4.2.5 Value of farm assets

Value of farm assets is a measure of wealth of a household. The variation in wealth among farmers may lead to differences in ability to cope with production resource requirements and risk, ultimately influence the decision making on SRI component combinations adoption. The findings from this study indicate that, on average the value of farm assets owned by non adopters of SRI is less as compared to that of adopters and the difference is statistically significant for all SRI package adopters. Comparing among adopters, the results show that the adopters of all SRI components combination have the highest value of farm assets of about 6 million Tanzanian shillings (Table 4). The higher value of farm assets of SRI adopters might be due to SRI requirements on timely land preparation and transplanting which necessitate the smallholder farmer to own the farm equipments and implements. In line with this result, Asfaw *et al*. (2011), found that the Agricultural technology non adopters in Ethiopia had less assets compared to adopters and Varma (2017), noted less farm assets among SRI non adopters compared to their counterparts SRI adopters in India.

4.3 Farm Characteristics

4.3.1 Farm level status

Rice field level data were captured basing on farmers' own statements combined with a visual plot inspection during the survey. The study findings indicate that most of the SRI adopters' farms have been leveled (94%) while most of those of non adopters' are dominated with unleveled status (55%). The association between farm level status and adoption of SRI is statistically significant at 1% (Table 5), supporting the importance of good plot level status for adoption of SRI practices such as young seedlings transplanting, proper water control and early transplanting facilitation.

4.3.2 Rice farms location in the irrigation schemes

Rice farm in the irrigation schemes are at different locations. As far as this study is concerned, the location of the sample households' rice farms was classified into two main groups of either upstream or downstream location. The results show that more rice farms in the schemes are found in upstream. More farms of SRI adopters are located in upstream compared to those of non adopters. The results indicate that, the association between adoption of SRI and location of the farm in irrigation scheme is statistically significant at 5% of probability (Table5). The few farmers among two groups in downstream, may reflect the scarcity of water for irrigation in downstream of the schemes.

Table 5: Farm characteristics of sample households

Variable	**Category**	**Non adopters (n=159)**	**Adopters**					**χ^2-Value**
			Plant Mgt (n_1 =27)	**Plant and soil Mgt (n_2=43)**	**Plant and water Mgt (n_3=30)**	**Plant, soil and water Mgt (n_4=59)**	**All SRI adopters (n=159)**	
Farm level status	Leveled	71(44.65)	26	38	28	57	149(93.71)	70.478***
	Not leveled	88(55.35)	1	5	2	2	10(6.29)	
Farm location	Upstream	109(68.55)	21	35	19	52	127(79.87)	5.888**
	Downstream	50(31.45)	6	8	11	7	32(20.13)	

Adequate availability of Water for irrigation	Available	69(43.40)	21	37	30	59	147(92.45)	85.518***
	Not available	90(56.60)	6	6	0	0	12(7.55)	

** and *** denote significance level at 5% and 1% respectively; values in brackets are percentages; Mgt means management

4.3.3 Water availability in irrigation schemes

Adequate and timely water availability in the irrigation schemes is among the core factors in rice production. The discussion with farmers reveal that farmers could not adopt SRI at all or abandon some components due to the constraint of inadequate and untimely water availability for rice irrigation. Among the sample households, about 92% and 43% of adopters and non adopters respectively get water for irrigation on time when needed (Table 5). The association of adequate water availability for irrigation and adoption of SRI is statistically significant at 1% level of probability. High percentage of irrigation water availability on time for adopters could be because of SRI drying and wetting requirements which necessitate the collaboration among farmers of nearby farm plots to pump water in plots at the same time. Barrett *et al.* (2016) argue that if water is not available on time due to the constraints in the irrigation system, land preparation and transplanting cannot be as timely as recommended for SRI.

4.3.4 Farm size of sample households

According to FAO (2015), smallholder rice farmers in Tanzania occupy 0.5 to 3ha of land per household. In line with FAO (2015), this study findings show that in the study area sample farmers are primarily small scale rice growers with an average farm size of less than 2.3 hectares (Fig. 4).

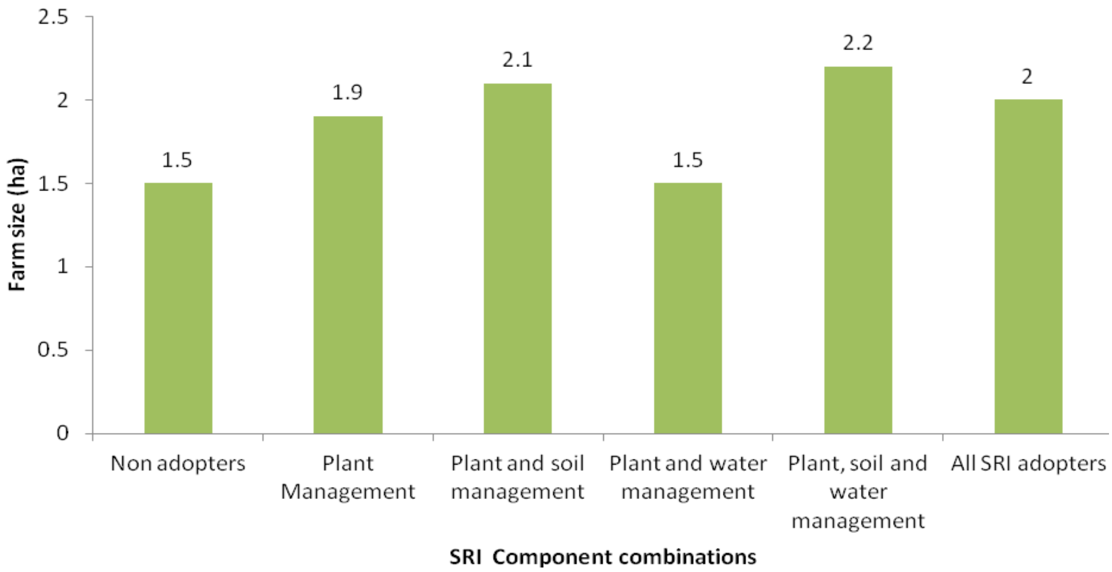

Figure 4: Farm size of the sample households by SRI components adoption

The results reveal that, on average SRI adopters own larger rice farms compared to non adopters. The results are consistent with Notze *et al.* (2012) whose findings indicate that the SRI adopters own larger farms than non adopters in Timor Leste.

4.4 Institutional Factors

4.4.1 Access to credit

Liquidity constraints relaxation in rice production may be facilitated by access to agricultural credit. Credit paves the way for timely accomplishment of various farm tasks through provision of fund which enables farmer to purchase agricultural inputs and financing farm activities. This was elicited during the interviews by asking farmers whether they have access to credit from formal institutions such as SACCOS, banks or irrigation schemes and from informal source (local lenders). The study findings (Table 6),

Table 6: Institutional characteristics of the sample households

Variable	Category	Non adopters (n=159)	Adopters					χ^2-Value
			Plant Mgt (n_1 =27)	Plant and soil Mgt (n_2=43	Plant and water Mgt (n_3=30	Plant, soil and water Mgt (n_4=59	All SRI adopters (n=159)	

Access to credit facilities	Accessible	87(54.72)	18	31	23	43	115(72.33)	9.466***
	Not accessible	72(45.28)	9	12	7	16	44(27.67)	
Access to Extension service	Yes	71(44.65)	23	29	20	53	125(78.62)	35.489***
	No	88(55.35)	4	14	10	6	34(21.38)	
Information about SRI	Yes	83(52.20)	23	33	25	57	138(86.79)	44.015***
	No	76(47.80)	4	10	5	2	21(13.21)	

*** denotes significance level at 1%; values in brackets are percentages; Mgt means management

indicate that about 72% and 55% of SRI adopters and non adopters have access to credits respectively and the association between credit access and SRI adoption is statistically significant at 1% level of probability. Comparison among the SRI component combinations adopters shows that, in 2016/2017 cropping season, farmers who adopted comprehensive SRI package (plant, soil and water management) had highest percentage of farmers with access to credit. Irrigation schemes play a great role as formal agricultural credit source while local lenders is the major informal agricultural credit source used by smallholder rice farmers in the study area (Table 7).

Table 7: Credit services and other sources of information

Variable	**Category**	**Non adopters**	**Adopters**					**χ^2-Value**
			Plant Mgt	**Plant and soil Mgt**	**Plant and water Mgt**	**Plant, soil and water Mgt**	**Total adopters**	
Source of credit (n=202)	Financial institution	15(17.24)	2	4	3	5	14(12.17)	24.574***
	Irrigation Scheme	36(41.38)	14	14	7	31	66(57.39)	
	Local lenders	36(41.38)	2	13	13	7	35(30.44)	
Total		**87(100)**	**18**	**31**	**23**	**43**	**115(100)**	
Main purpose of the credit (n= 202)	Payment of labour	27(31.03)	3	7	10	9	29(25.22)	0.040
	Buying fertilizers	60(68.97)	15	24	13	34	86(74.78)	
Total		**87(100)**	**18**	**31**	**23**	**43**	**115(100)**	
Reasons for not using credit (n=114)	No need for credit	23(31.94)	5	8	5	8	26(61.90)	27.444***
	Fear of inability to pay	39(54.17)	2	3	2	3	10(23.81)	

	Lack of asset for collateral	10(13.89)	2	1	0	3	6(14.29)	
Total		**72(100)**	**9**	**12**	**7**	**14**	**42(100)**	
Other sources of SRI information (n= 98)	Friends	54(71.05)	4	7	4	1	16(72.73)	1.300
	Relatives	22(28.95)	1	3	1	1	6(27.27)	
Total		**76(100)**	**5**	**10**	**5**	**2**	**22(100)**	

******* denotes significance level at 1%**;** Values in brackets are percentages; Mgt means management

However, smallholder rice farmers who did not use agricultural credit in 2016/17 cropping season had different reasons which led for agricultural credit unused. The majority of non SRI adopters claimed that they did not use agricultural credit due to fear of inability to pay back the loan. The fear of inability to pay back the loan for non SRI adopters might be the unpredictable harvests due to inadequate irrigation water availability. On other hand, the major reason for not using agricultural credit for SRI adopters was because they did not need agricultural credit in the respective cropping season. This may reflect that SRI adopters have higher capital compared to non adopters.

4.4.2 Access to extension and information services

Access to extension and information enable farmers to be aware on the benefits of a new agricultural technology. Extension service is a source of information for many farmers, either directly, through contact with extension agents, or indirectly, through farmers who have prior exposure transmitting information to other farmers. As expected, the results (Table 6) reveal that, more SRI adopters (79%) had access to extension services compared to non-adopters (45%) and the association between extension services and SRI adoption is statistically significant at 1% level of probability.

Acquisition of information about a new technology is another factor that may determine adoption of technology. This enables farmers to learn about the existence as well as the effective use of technology thus facilitating its adoption since farmers adopt only the technology they are aware of or have heard about it. The study findings reveal that few non adopters (52%) obtain information about SRI from government or development partner agents compared to 87% of adopters (Table 6). The higher percentage of SRI adopters with information access, might be facilitated by more contact frequencies with government and development partners extension agents, hence reflecting more exposure to information on SRI technique. However, smallholder farmers who do not access SRI information from government or private extension agents may have information from other sources. This is possibly because, farmers may get information concerning agricultural technology directly from extension agents, or indirectly, through farmers who have prior exposure transmitting information to other farmers. The results show that 98 sample smallholder farmers got information about SRI from fellow farmers and relatives (Table 7). The comparison between adopters and non adopters indicates that few SRI adopters got information from other sources (22%). Furthermore, the results show that other source of information about SRI is not statistically associated with SRI components adoption status.

In line with access to extension services and information, on average SRI non adopters are visited and trained less on rice production by extension agents than their counterpart adopters in a single cropping season (Fig.5). This is in line with Varma (2017), who found low frequency of extension agents contact with non SRI adopters in India compared to adopters.

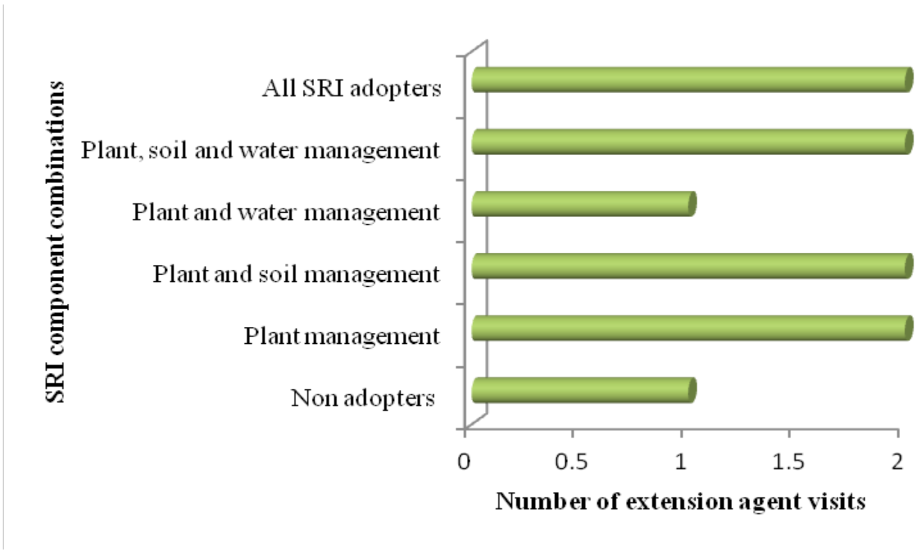

Figure 5: Number of extension agents contact with smallholder farmers and training on rice production per cropping season

4.5 Rice Yields and Costs of Production

In line with previous studies which documented the increased productivity of rice in SRI, these study findings reveal that on average yields of all SRI adopted combinations were higher compared with non adopted. The average rice yield for non SRI adopters was about 4.0 tones/ha (Table 8), which is statistically significant lower than for adopters of SRI. The highest yield (about 7 tones/ha) was obtained when all SRI practices were adopted. The research findings by Takahashi (2013), in studying the roles of risk and ambiguity of SRI adoption in Indonesia, revealed the average of 3.0 tones/ha and 5.5 tones/ha for non SRI adopters and adopters respectively. Moreover Tusekelege *et al.* (2014), found the higher rice yield for SRI adopters (8.5 tones/ha) compared to 6.9 tones/ha for non adopters using researcher controlled comparative analysis of SRI in Kilosa and Mvomero Districts in Morogoro, Tanzania.

Table 8: Rice yield, production cost and Profitability of SRI and Convetional practices

Variable	Adopters

	Non adopters (n=159)	Plant Mgt (n_1 =27)	Plant and soil Mgt (n_2=43)	Plant and water Mgt (n_3=30)	Plant, soil and water Mgt (n_4=59)	All SRI adopters (n=159)
Rice yield (tones/ha)	3.99(0.956)	5.77	5.78	5.93	7.16	6.32 (0.567) ***
Revenue (TAS/ha)	2 916 690 (820 460)	4 217 870	4 225 180	4 334 830	5 233 960	4 619 920 (1 190 262.10) ***
Input cost (TAS/ha)	441025 (157744.19)	601225	485900	436950	507300	504175 (191170.35) ***
Labour cost (TAS/ha)	1089550 (187448.588)	2 156 525	1 422 350	1 348 100	1 486 925	1 556 975 (301460) ***
Total variable cost (TAS/ha)	1 530 575 (1 066 152.5)	2 757 750	1 908 250	1 785 050	1 994 225	2 061 150 (1 404 642.50) ***
Unit variable cost (TAS/Kg)	384(139.12)	478	330	301	279	326 (114.62) ***
Gross profit (TAS/ha)	1 386 115 (204 393.20)	1 460 120	2 316 930	2 549 780	3 239 705	2 558 770 (1 160 957.73) ***
Gross profit per kg((TAS)	347(89.10)	253	401	430	452	405 (72.10) ***

Each SRI packages are compared with base category (non adopters) using t-test; *** denotes significance level at 1%; Standard Deviations have been given in parentheses; Mgt means management; GM means Gross margin.

The costs of production incurred were categorized into input and labour costs. Seeds, fertilizers, manure and water charges expenses were included in input costs category. On other hand labour costs included expenses on ploughing, harrowing, seedlings transplanting, weeding, birds scaring, harvesting and bagging. The results indicate that although production cost per hectare for conventional method of rice production is lower than for SRI, on average the production cost per kilogram of rice output is higher for SRI non adopters compared to their counterpart adopters (Table 8). This study finding in cost of production for SRI non users and users concurs with Tusekelege *et al.* (2014) and Durga and Kumar (2013). However, labour costs per hectare are higher for SRI adopters (about 76% of the total production cost) compared to 71% of the total production cost for non SRI adopters (Table 8). The results conform to prior expectation that SRI is more labour intensive compared to conventional practice. In the study area, on average, SRI non adopters are less profitable (347 TAS/Kg) compared to adopters (405 TAS/Kg). The higher rice gross profit for SRI adopters might be contributed by higher rice yields due to adopted SRI package combinations.

4.6 Extent of SRI Components Adoption

In agricultural technology adoption, farmers first decide whether or not to adopt an agricultural technology package(s) and then decide the amount of land to allocated for the adopted technology.

4.6.1 Allocated land on SRI rice production method

Land is important in technology adoption decisions such as SRI. As in other agricultural technologies adoption, farmers after deciding whether to adopt the SRI package or not, decide how much land to allocate for adopted component combinations. The study findings reveal that, on average the SRI adopter farmer allocates about 73% of the rice cultivated land on SRI production technique. Possibly this percentage of land allocated for SRI technique by smallholder farmers, could be due to the fact that SRI have specific requirements such as leveled farm and water availability when it is on need, which are not fulfilled by the whole smallholder farmer's plot(s) conditions. The most comprehensive SRI package comprising the combination of all three components, is the mostly common SRI package practiced by smallholder rice farmers in the study area, being practiced in 27% of the rice cultivated area, followed by plant and soil management package which comprises 20% of area under rice (Fig. 6).

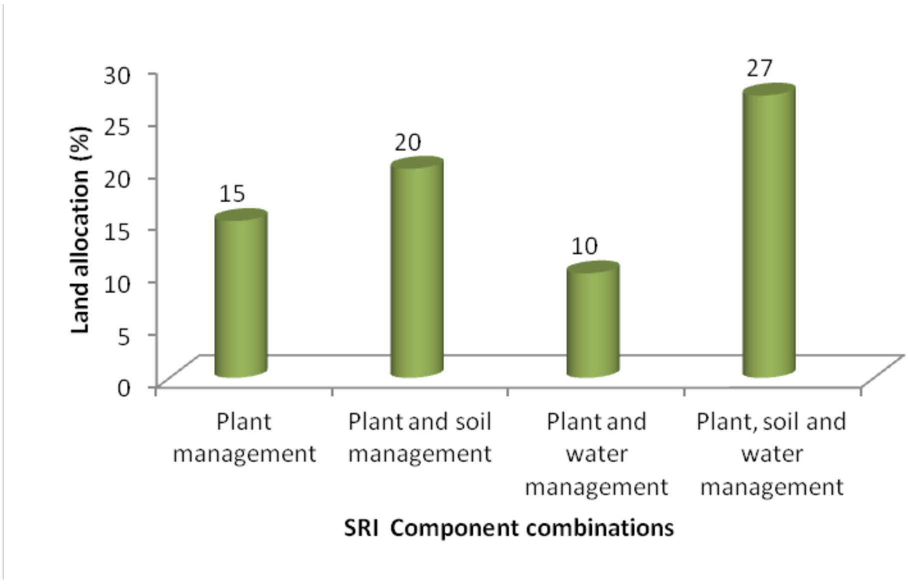

Figure 6: Land allocation on SRI production

The least practiced package is that of plant and water management which is employed in only 10%. This might be due to the constraint of water control in irrigation schemes due to difficult in collaboration agreements among farmers of nearby plots of land for wetting and drying practices at the same time in SRI technique as documented by Barrett *et al*. (2016).

4.7 Determinants of SRI Components Adoption

The effects of determinants of SRI component combinations adoption vary across SRI component combinations. Parameter estimates of the multinomial logit model of the plot and household level determinants of SRI components adoption with non adoption of any SRI component as the base category are presented in Table 9. The model fits the data very well with the Wald test, Chi^2 = 310.342; Prob>0.000 indicating that the null hypothesis that all the coefficients are jointly equal to zero is rejected.

As it was assumed by various literatures for farmer's education to influence positively the likelihood on decision to adopt new technology, this study findings reveal the positive and significant influence of education level on the decision to adopt SRI package combinations. The positive effect of education on SRI adoption may reflect Mwangi and

Kariuki (2015) argument that, more education influences farmers' attitudes and thoughts making them more open, rational and able to analyze the benefits of the new agricultural technology. Specifically the results show that the rice farmers with education above primary level are more likely to adopt plant and water management package in rice production using SRI technique. Concurring with this study, Manda *et al.* (2015) and Mignouna *et al.* (2011) documented positive and significant relationship between the education and adoption of SAPs in rural Zambia na Imazapyr-resistant maize technologies in Western Kenya respectively.

As expected, positive and significant effect of family labour force size on adoption of SRI component combinations has been revealed by study findings. The results indicate that, the increase of family labour force involved in rice production activities increases the likelihood decision to adopt SRI component combinations. Probably, the positive and significant relation of family labour force size and adoption of SRI packages could be caused by high labour requirement of SRI. In initial phase of SRI adoption, smallholder farmers depend on family labour which cannot easily be replaced by hired labour, because of specific knowledge, training, and experience required. This might be due to the fact that, in the SRI training sessions, farmers are advised to first gain experience with SRI themselves, before involving the hired labours as documented by Notze *et al.* (2012).

Experience on rice production is positive in influencing the likelihood of the decision to adopt SRI packages. This implies that more experienced smallholder rice farmers are likely to adopt SRI components compared to less experienced farmers. However, this result is statistically significant in the case of the adoption of plant and soil management and plant plus water management packages only. Notwithstanding there are studies that argue for less experienced farmers to be more flexible in adopting new innovation in agriculture (Teklewold *et al.*, 2013; Varma, 2017), on other hand there is an argument that more experienced farmers are better able to evaluate technology information hence likely to adopt (Kassie *et al*., 2013; Mignouna *et al*., 2011). Consistent with early studies such as Kasie *et al.* (2013), this result also adds to the evidence of the positive effects of experience on adoption of technologies in multiple scenarios.

The effect of access to off farm activities on the adoption of SRI components is mixed. Three packages of plant management only; plant and soil management only; and comprehensive combination of plant, soil and water management adoption have been significantly influenced by the accessibility of smallholder farmers to off farm activities. However, while plant management and plant plus soil management packages are positively and significantly influenced by access to off farm activities, the comprehensive package of plant, soil and water management adoption is negatively related to off farm activities.

Table 9: Mixed multinomial logit model estimates of adoption of SRI components in Mbarali District (Baseline category is non-adoption of SRI)

	SRI components			
Variable	**Plant management**	**Plant and soil management**	**Plant and water management**	**Plant, soil and water management**
Education	-0.045(0.697)	0.439(0.594)	1.208(0.367) **	0.674(0.537)
Active family labour size	1.728(0.306) ***	1.642(0.291) ***	1.738(0.330) ***	1.850(0.295) ***
Experience in rice production	0.113(0.209)	0.357(0.185) *	0.533(0.224) **	0.134(0.183)
Access to off-farm activities	12.314(0.550) ***	12.708(0.483) ***	0.001(0.571)	-2.540(0.504) ***
Farm assets value	0.149 (0.119)	0.053(0.099)	-0.041(0.112)	0.012(0.103)
Farm size	-0.090(0.079)	-0.091(0.067)	-0.337(0.109) ***	-0.061(0.064)
Adequate availability of Water for irrigation	-0.338 (0.833)	1.267(0.721) *	15.348(326.478)	15.448(299.764)
Farm level status	3.142(1.164) ***	1.667(0.700) **	2.363(1.054) **	2.105(0.953) **
Farm location	0.360(0.728)	0.527(0.605)	-0.874(0.708)	0.756(0.645)
Access to credit facilities	1.486(0.669) **	0.750(0.596)	0.265(0.716)	1.671(0.589) ***
Number of extension agencies visits and training on rice production	0.129(0.264)	-0.039(0.232)	-0.458(0.286)	0.235(0.231)
Access to information about SRI from government /Development agents	1.691(0.887) *	0.314(0.689)	0.771(0.843)	2.015(0.988) **

χ^2 = 310.342; Prob> 0.000 ; Cox and Snell Pseudo R^2=62.30
*****<0.01, **<0.05, *<0.1;** Standard errors have been given in the brackets

The positive and significant effect of access to off farm activities suggests that, off farm activities may generate off farm income which acts as an important strategy for overcoming credit constraints faced by smallholder rice farmers in the study area. The income from off farm activities may provide farmers with liquid capital for covering expenses on farm preparation, transplanting and frequently weeding hence enhancing the adoption of plant management and plant plus soil management SRI packages. On other hand, the negative relation between off farm activities and comprehensive package of SRI comprising plant, soil and water management, possibly is caused by diversion of time and efforts from rice production, which reduces the household labour allocated to rice farming activities using SRI technique. This study result is in line with Diiro (2013), who found positive effect for off farm activities and agricultural technology adoption and Mathenge *et al.* (2014), Manda *et al.* (2015) and Varma (2017) whose findings indicate negative relation between the two.

The results show that, land is important determinant for decision in SRI packages adoption. The study findings indicate that, farmers with more land are less likely to adopt SRI packages than those with less land. Specifically, the farm size is significantly and negatively related with adoption of plant and water management combination only. The results are in agreement with Varma (2017), Gebremariam and Wünscherb (2016) and Teklewold *et al*.(2013) whose findings revealed similar results and argue that it could be due to smallholder farmers tend to achieve food security by sustainably intensifying production in their small lands. On other hand, these results are contrary to study findings by Manda *et al.* (2015), on agricultural technology adoption in general and Notze *et al.* (2012), for the SRI context in specific, who found the land to have positive effect on sustainable agricultural practices (SAPs) and SRI packages adoption respectively.

Adequate availability of water for irrigation when required is positively and significantly influences the adoption of plant and soil management package. This probably is due to the fact that timely water availability reduces yield risk associated with early and timely seedling transplanting. Also suggests the vital role of better irrigation facilities availability in adoption of SRI packages. In line with adequate water availability is leveling of rice fields. The results indicate that level status of rice farm is positive and statistically significant in affecting the adoption decision of all SRI packages. The farm level status result is consistent with Takahashi and Barrett (2014), who documented that, in rice production using SRI technique, leveled farm is necessary as it facilitates the proper young seedlings transplanting and water control. The positive and significant effect of credit on the adoption of the SRI packages is as expected. Specifically, credit is positively related with plant management component, as well as with all comprehensive package which contains all the three components of SRI (Plant, soil and water management). This result is explained by the economic theory which posits credits to be one of the most important aspects to fuel technology adoption in developing countries. This study finding is consistent with the findings by Teklewold *et al*. (2013); Okuthe *et al*. (2013) and Gebremariam and Wünscherb (2016).

Consistent with earlier work on agricultural technology adoption in general such as Manda *et al*. (2015) as well as in the specific context of SRI (Varma, 2017; Barrett *et al*., 2016; Notze *et al*., 2012), the study findings indicate the positive influence of access to information on SRI component combinations adoption. Specifically the positive and significant effect of access to information on SRI adoption has been revealed in two SRI component combinations of plant management only and comprehensive combination of plant, soil and water management.

Despite the descriptive statistic analysis indicated significant differences between SRI adopters and non adopters on extension agents contact with smallholder farmers, value of farm assets and farm location in the scheme, in this study these variables have statistically insignificant effect on SRI components adoption decision. For extension agents contact with smallholder farmers, this may be surprising, given that SRI is a knowledge intensive technology.

The frequency of extension agents contact with smallholder rice farmers, was expected to have significant and positive effect to SRI components adoption. However, in contrary the results reveal insignificant relation between the two. This result is consistent with Teklewold *et al*. (2013) and Varma (2017), but contradicts with Manda *et al*. (2015). This may reflect that it is not the frequency of extension contact per se which affects adoption, but the quality of the extension services provided to smallholder farmers. The insignificant result for value of farm asset variable is not surprising since apart from the higher labour requirements, SRI is a low external inputs technology so that it does not necessarily depend on farm assets value as the measure of wealth of the household. The insignificant relation of SRI components adoption and location of the farm in the irrigation scheme may imply that rice production using SRI technique depends on other necessary rice plot conditions such as rice field level status and timely and adequate water availability irrespective of rice plot location in the irrigation scheme.

The effects of determinants of SRI component combination adoption therefore, vary across SRI component combination and thus this might be a reason for decision of farmers to adopt some of the SRI components.

4.8 Impact of adopted SRI components on rice yields

Variation of SRI impact on yields may result from varying degrees of adherence to SRI practices. Analysis results on impact of adopted SRI component combinations on yield are presented in Table 10.

The results indicate that on average, SRI adopters have higher yield compared to non adopters and the results are statistically significant for all combinations of SRI components. Control variable and their effect on rice yield are presented in appendix 3. In addition, the evidence of negative selection bias has been indicated by factor loadings (**λ)** suggesting that unobserved determinants that increase the likelihood of adopting SRI components are associated with lower levels of rice yields than those expected under random assignment to the SRI component combinations adoption status.

The highest rice yield increase per hectare is about 41%, which is obtained when all SRI components are adopted. There is about 28% increase in rice yields, when only plant and water management combination is adoption. Although the gain in yield is lower than that obtained when all SRI components are adopted, it is higher than the gain obtained when plant management only and plant plus soil management practices are adopted. The yields gain in about 22% and 24% has been revealed when plant management only and plant management in combination with soil management practices are adopted respectively.

This study results for yield gain when all SRI components are adopted is in line with Gebremariam and Wünscherb (2016), who found that there are highest payoffs in net crop income in Ghana when all SAPs are adopted.

Table 10: Impact estimates of adopted SRI components on rice yields

SRI component combination	**Ln rice yield per ha**		
	Coefficient	**Robust SE**	**Significance p>|z|**
Plant management	0.2154	0.1141	0.059 *
Plant and soil management	0.2375	0.1375	0.084*
Plant and water management	0.2816	0.0815	0.001***
Plant, soil and water management	0.4112	0.0916	0.000***
Selection terms (λ)			
Plant management	-1.0675	0.3112	0.001***
Plant and soil management	-0.7905	0.2311	0.001***
Plant and water management	-0.8288	0.2765	0.003***
Plant, soil and water management	-1.3676	0.3348	0.000***
Insigma	-1.0128	0.2424	0.000***

The baseline is farm households that did not adopt any SRI component combination**; *P<0.1; ***P<0.01.**

On other hand the results are contrary to the few studies in agricultural technology adoption in multiple scenarios. For example, in Ethiopia, Di Falco and Veronesi (2013), reported that, climate change adaptation strategies that are more comprehensive do not always provide higher revenues when compared to less comprehensive adopted packages. Furthermore, Varma (2017), noted the significant highest rice yields when plant and water management package was adopted in India. The variation in yields gain due to package(s) adopted probably reflects the differences in agronomic characteristics, agro ecological and implementation strategies in respective location. Additionally, the highest average rice yield due to comprehensive adoption of all SRI component combinations may reflect the crucial of all components of SRI technique in rice production. For instance, intermittent irrigation aims to tackle various challenges such as the loss of soil quality and water scarcity, whereas early transplanting and wide spacing are both meant to boost tillering. Additionally the use of organic fertilizer, such as compost or manure and regular weeding can help to stimulate growth- promoting soil bacteria and soil aeration improvement respectively (Noltze *et al.*, 2012).

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusion

This study aimed at analysing the adoption of SRI and its impact on rice yield in Mbarali District. Specifically, it focused on determining the extent of SRI components adoption by smallholder rice farmers, analysing the factors that drive farmers on SRI components adoption decisions and determining the impact of adopted SRI components combinations on rice yields.

The study found that, in the study area majority of SRI users partially adopt SRI and on average the smallholder farmers allocate a portion of land (about 73% of the rice cultivated land) on SRI rice production practices. The findings indicate that, the effect of determinants of SRI component combination adoption vary across SRI component combination. Specifically, the decision to adopt different combinations of SRI components is influenced by education level of farmer, size of active family labour force, access to off farm activities, experience in rice production, farm size, farm level status and adequate availability of water for irrigation when is needed, access to credit facilities and information concerning SRI from government and development partners.

With regard to impact of SRI on yield, the results suggest that even the partial adoption of SRI practices can have an impact on rice yield. The comprehensive package comprising all three SRI components (plant, soil and water management) generates the highest rice yields implying the necessity of fully SRI package adoption than partially adoption among smallholder rice farmers.

5.2 Recommendation

Based on the empirical findings reported in this dissertation preceding conclusion and study limitation, the following recommendations are forwarded:

5.2.1 Policy implication

i. This study has found evidence that on average adopters of SRI component combinations have higher yield compared to non adopters. This has encouraging message for policy makers, program designers, implementers and funding agencies to take proper action in supporting rice production using SRI to achieve the intended goals in rice productivity. Furthermore, the adoption of comprehensive package comprising all SRI components has indicated the highest gain in yield; this has important policy implications that, the future interventions with comprehensive SRI package are inevitable.

ii. The findings revealed that, adoption of SRI packages is facilitated by accessibility and availability of agricultural credit and information. Therefore, the government financial institutions and other stakeholders should provide agricultural credit support through creation of conducive environments for cash credit and inputs to smallholder rice farmers. Farmers need also to be encouraged to form or join into farmers' organizations to improved access to credit, networking and create social capital that can make them benefit from sharing agricultural information.

iii. Since leveling of rice farms has shown the positive and significant influence on adoption of SRI as it facilitates proper water control and early seedling transplanting, it is recommended that government and agricultural stakeholders should support irrigation schemes in terms of fund for farm leveling.

5.2.2 Future studies

i. It is recommended to conduct further study focusing on adoption of SRI components and the impact of the adopted components on income.

ii. Further researches on the best ways of extension services delivery to smallholder rice farmers and proper model for research-extension linkages are recommended.

iii. Furthermore, despite the outcomes from this study may be applied to different agro ecological and socioeconomic environments, further research focusing on SRI adoption and impact in specific agro ecological and socioeconomic environments is encouraged.

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APPENDICES

Appendix 1: Implementation of PPS

The PPS involved listing all irrigation schemes onto which rice is produced, identifying the population size in each irrigation scheme (number of beneficiaries), calculating successive cumulative totals in each irrigation scheme, computing sampling interval (SI) and probability of each irrigation scheme being sampled (Prob 1) and probability of each individual being sampled in each irrigation scheme (Prob 2).

SI was computed as the ratio of cumulative total population to number of irrigation schemes to be sampled that is,

$$\frac{\text{Cumulative total population}}{\text{Number of irrigation schemes to be sampled}} = \frac{27\,426}{3} = 9\,142 \ldots\ldots\ldots\ldots\ldots (3)$$

The probabilities of each irrigation scheme to be sample and of each individual being sampled in each irrigation scheme were calculated by:

$$\text{Prob 1} = \frac{\text{Irrigation scheme population} \times \text{Number irrigation schemes to be sampled}}{\text{Total Population}} \ldots. (4)$$

and $$\text{Prob 2} = \frac{\text{Number of individuals sampled in each irrigation scheme}}{\text{Irrigation scheme population}} \ldots\ldots\ldots\ldots\ldots (5)$$

In implementing PPS method, the last step was the generation of Random numbers and the one which is equal or less than the SI was selected as the Random Start (RS) and the first cluster to be sampled contained that cumulative population. The selected Random Start was 5660.

Then the series of: RS; RS + SI; RS + 2SI; …. RS+ (d-1)*SI, where‘d’ was the number of clusters, were computed. The first three values in the series were 5660; 5 660+ 9 142= 14 802 and 5 660 + 2*9 142 = 23 944. The number in the series corresponded with the cumulative totals for Mbuyuni, Madibira and Mwendamtitu irrigation schemes respectively. In that regard therefore Mbuyuni, Madibira and Mwendamtitu irrigation schemes were sampled in the first stage.

Table 11: Implementation of PPS

Irrigation Scheme	Population size	Cumulative Total	Farmers per irrigation scheme	Prob 1	Prob 2	Overall Weight
Gwiri	2 600	2 600	106	0.283	0.041	86.21
Ipatagwa	565	3 165	106	0.062	0.188	86.21
Ruanda Majenje	992	4 157	106	0.109	0.107	86.21
Majengo	294	4 451	106	0.032	0.361	86.21
Herman	120	4 571	106	0.013	0.883	86.21
Mbuyuni	1 105	5 676	106	0.121	0.096	86.21*
Kapunga S/H	860	6 536	106	0.094	0.123	86.21
Motombaya	2 930	9 466	106	0.320	0.036	86.21
Kongolo Mswiswi	214	9 680	106	0.023	0.495	86.21
Kapyo	486	10 166	106	0.053	0.218	86.21
Lyanyura	830	10 996	106	0.091	0.128	86.21
Maendeleo	850	11 846	106	0.093	0.125	86.21
Matebete	436	12 282	106	0.048	0.243	86.21
Nguvu kazi	150	12 432	106	0.016	0.707	86.21
Njombe	145	12 577	106	0.016	0.731	86.21
Mwendamtitu	2 340	14 917	106	0.255	0.045	86.21*
Isenyela	1 800	16 717	106	0.196	0.059	86.21
Chang'ombe	364	17 081	106	0.040	0.291	86.21
Chamoto Batania	123	17 204	106	0.013	0.862	86.21
Chosi	570	17 774	106	0.062	0.186	86.21
Gonakovagogolo	750	18 524	106	0.082	0.141	86.21
Uturo	1 200	19 724	106	0.131	0.088	86.21
Igumbilo Isitu	475	20 199	106	0.052	0.223	86.21
Njalalila	450	20 649	106	0.049	0.236	86.21
Msesule	302	20 951	106	0.033	0.351	86.21
Madibira	3112	24 063	106	0.340	0.034	86.21*
Ibohora	147	24 210	106	0.016	0.721	86.21
WIA – Mahango	764	24 974	106	0.084	0.139	86.21
Chimba chimba	1 418	26 392	106	0.155	0.075	86.21
Mtemela/Mhwela	752	27 144	106	0.082	0.141	86.21
Igomelo	382	27 526	106	0.042	0.277	86.21

Source: Mbarali District Council Office and self computation
***The selected irrigation schemes**

Since PPS method was used, in the second stage the same number of respondents (106 smallholder rice farmers) was selected from each sampled irrigation scheme in first stage. In PPS, the second stage compensates the first stage hence enabling each smallholder farmer in the population of smallholder farmers to have the same probability of being sampled.

Appendix 2: Mean and Median for Farm size, Farm assets value, Revenue, Costs and Profit

Variable	SRI non adopters			SRI adopters		
	Mean	Median	Std	Mean	Median	Std
Farm size (ha)	1.5	1.2	1.179	2.01	1.6	1.647
Farm assets value(TAS million	2.41	0.024	3.637	6	4.03	8.248
Rice yields (Tones/ha)	3.99	3.90	0.956	6.32	6.25	0.567
Revenue (TAS /ha)	2 916 690	2 850 900	820 460	4 619 920	4 568 750	1 190 262.10
Input cost (TAS/ha)	441025	441250	157744.19	504175	487500	191170.25
Labour cost(TAS/ha)	1 089 550	1 013 750	187448.59	1 450 300	1 387 500	301460
Total variable cost(TAS/ha)	1 530 575	1 455 000	1 066 152.5	1 954 475	1 875 000	1 404 642.50
Unit cost (TAS/Kg)	384	373	139.12	326	300	114.62
Gross profit TAS/ha	1386115	1395900	204393.20	2558770	2693750	1160957.73
Gross profit per kg(TAS)	347	358	89.10	405	431	72.10

Std denotes Standare deviation.

Appendix 3: Control variable and their effect on rice yield

Variables	Ln rice yield per ha
Education level of household head	0.023(0.036)
Access to off farm activities	-0.089(0.037)**
Active family labour size	0.036(0.019)*
Experience in rice production	0.006(0.015)
Value of farm assets	0.011(0.008)
Level status of the farm	-0.033(0.057)
Farm location in the scheme	-0.011(0.024)
Adequate water availability for irrigation when is on need	-0.069(0.059)
Plot size in irrigation scheme	-0.006(0.006)
Access to credit	-0.003(0.043)
Frequency of extension agents contact with smallholder farmers	0.003(0.020)

$^{**}P<0.05$; $^{*}P<0.1$; Robust standard errors have been given in the brackets.

Appendix 4: Questionnaire for Smallholder rice farmers in Irrigation schemes

1.0 General Information

1.1 Code number..Date...

1.2 Name of interviewer...

1.3 Name of Ward..............................Village...........................Scheme.............................

2.0 Household Information

May you give details of personal particulars of all household members beginning with the head of the household?

S/N	Name of HH member	Relationship to HH head	Sex 1=M 2=F	Age	Education level 0= No Education 1= Primary 2=Secondary 3= Diploma 4= First Degree and above	Involment in farming activities	Off farm activities and income 1=Yes 2=No
	1	2	3	4	5	6	7
2.1							
2.2							
2.3							
2.4							
2.5							
2.6							

Column (2): Relationship to head of household

1= Head of Household 4= Father/Mother

2=Spouse 5= Grandson/Grand daughter

3=Son/daughter 6= Other relative

Column (6): **Involvement in farming activities**

1= If household member participates fully in farming activities for four months or more in single cropping season.

2 = If household member participates in farming activities below four months in single cropping season

3 = If household member does not participate in farming activities.

3.0 Current household farm assets holding

Asset	Did your household own the following asset? (1=yes 2=no)	Unit	Amount (number)	Average current market value/unit (TZS)
Oxen,				
Plough				
Powertiler and its implements				
Tractor and its implements				
Animalcart				

Handhoe				
Others(Specify)				
Total Value				

4.0 Farm characteristics and Rice production

4.1 May you give the following information concerning farm characteristics and production?

Plot No	Where the plot is. 1=In scheme 2=Outside scheme	Location within scheme 1-Upstream 2-Downstream	Plot size in Acre	Level status 1= Leveled 2=Not leveled	Ownership 1 =Owned 2=Rented	Crop grown in 2016/17 Season	For rice plot, Method used in rice production 1=Conventional 2=SRI	Yield

4.2 For how many years do you produce rice? ....years

4.3 For the land allocated to SRI, what Components of SRI do you apply?

SRI Component	Plant management			Soil management		Water management
	Transplanting younger seedlings (8 to 15days)	Transplanting single seedling per hole	Transplanting in wider spacing (25 × 25 cm)	Using organic matter for fertility increase	Practicing mechanical weeding at regular intervals	Alternate wetting and drying irrigation method

4.4 What were the costs of rice production per acre for the last production season 2016/2017?

Cost item		SRI			Conventional		
		2016/2017			2016/2017		
	Units	Q	Unit cost	Total	Q	Unit cost	**Total**
Inputs							
Seeds							
Fertilizers							
Manure							

Water charge							
Sub total							
Labour charges							
Ploughing							
Harrowing							
Planting							
Weeding 1							
Weeding 2							
Birds scaring							
Bagging							
Harvesting							
Sub total							
Others (specify)							
Total Cost							

4.5 What were the Minimum and maximum prices of rice (paddy) for last production season (2016/2017)

Season (2016/2017)	Price per bag (TZS)		
	Minimum	Maximum	Average price

5.0 Water for Irrigation

5.1 What is the main source of water used in rice irrigation in your scheme? 1= River(s) ___ 2=Pond ___ 3= others (Specify)...

5.2 Is water available throughout the rice production season? 1=Yes ___ 2= No ___

5.3 Is the adequate water available when is needed for irrigation? 1= Yes ___ 2= No ___

6.0 Provision of Services for rice Production

a. Information on SRI and Extension services

6.1 Did you get information on SRI from government / Development agent sources?

1= Yes ___ 2= No ___

6.2 If no in 6.1 above, where did you get information about SRI for the first time? 1= Friend___ 2=Relative ___ 3= Radio/ TV___ 4= Newspapers___ 5=Others (Specify)..

6.3 Did you get extension services during the 2016/2017 production season?

1= Yes ___ 2 = No ___

6.4 If yes, in (6.3) how frequently do the extension agents visit you per cropping season for rice production advice and training? 1= Once___ 2= Twice ___ 3= Three times ___ 4= Four times___ 5 =Others Specify ___ ....

b. Credit services

6.5 Have you ever used credit for rice production activities in 2015/2016 and 2016/ 2017 production seasons? 1= Yes ___ 2 = No ___

6.6 If yes in (6.5), May you give the following details please!

Source of credit **(K1 below)**	Purpose of credit **(K2 below)**	Total Amount in TZS	Interest rate (%)/annum	Amount paid in TZS	Amount Unpaid in TZS

K1: Source of credit: 1= SACCOS 2= Bank 3=Scheme 4= Local lenders 5= Others (specify)...

K2: Main purpose of credit: 1= Payment for labour 2= Buying fertilizers 3= Buying seeds 4= others (specify)...

6.7 If you did not use credit, What was your main reason? 1= No need for credit___ 2=No one to give credit___ 3= Fear of inability to pay___ 4= Lack of asset for collateral___ 6=High interest rate ___ 6=Others (Specify)............................

6.8 Have you ever failed to pay back your agricultural debts as per contract?

1= Yes ___ 2 = No ___

6.9 If yes in (6.7) What were the main three reasons for unpaid amount?

1...2..3.................................

7.0 Any comments concerning SRI/Conventional practices in rice production:

....

....

....

....

Thank you very much for your Co-operation

Appendix 5: Checklist of key informants for irrigation scheme stakeholders/ irrigation scheme leaders and government officials

Section I: General Information

1. Name of the respondent
2. Job title

3. Organization

Section II: Rice production issues in irrigation schemes

4. What is the total number of beneficiaries of the irrigation scheme?
5. What is the total number of trained smallholder farmers on SRI techniques in the scheme?
6. What are the criteria used in selecting farmers to participate in rice production, particularly SRI technique trainings in the irrigation scheme?
7. What is the schedule of extension agent contact with smallholder rice farmers in irrigation scheme in single cropping season?
8. What are the constraints of using SRI in irrigation scheme?

Thank you very much for your Co-operation