TECHNICAL EFFICIENCY DIFFERENTIALS BETWEEN CONVENTIONAL AND SYSTEM-OF-RICE INTENSIFICATION METHODS OF RICE PRODUCTION IN WEST KANO IRRIGATION SCHEME, KENYA

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A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN ENVIRONMENTAL STUDIES (ENVIRONMENTAL ECONOMICS), UNIVERSITY OF ELDORET, KENYA

2015

DECLARATION

Declaration by the Candidate

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DEDICATION

This work is dedicated to my wife, Noel and my daughter, Kadzo, for the support and encouragement they granted me.

ABSTRACT

Rice in the irrigation schemes of Kenya is grown under the conventional method of continuous flooding which leads to production inefficiencies. With the limited resources such as land and capital inputs there is need for a better production method that improves rice productivity. System-of-Rice Intensification method (SRI) has been proposed as a solution. However, there is need for a study to establish the differentials in technical efficiency between conventional and SRI methods of rice production for better decision-making. This study was done at West Kano rice scheme of Western Kenya, and involved a sample of 123 households and the experimental SRI method. Study results show that 89% of the households in the study area are farmers who depend on rice production for consumption and commercial purposes. Findings also indicated that the SRI system saved about 64% of water compared to the conventional paddy system. The Conventional method used 95% chemicals (inorganic fertilizers), compared to SRI method that used 5%, hence using lesser chemicals by 90%. The study also showed that SRI method had a relatively higher level of mean technical efficiency at 83% compared to the conventional method at 75%, indicating a significant difference of 8% between the two methods of rice production. These findings further show that SRI under wide crop spacing of 25cm by 25cm and younger seedlings of 8 to 12 days method is more efficient than the Conventional method with random planting at closer spacing and older seedling age in rice production. Further, results demonstrate that the method of rice production is the major significant determinant of technical efficiency. This implies that the adoption of SRI with spacing of 25cm by 25cm is critical to the achievement of efficiency in rice production in West Kano. This means farmers should be encouraged to adopt the new SRI method with wider spacing of 25cm by 25cm and transplanting young seedlings of 8 to 12 days. It is recommended that due to reduced water levels in the riverine systems, the National Irrigation Board should assist farmers understand the technical efficiency of SRI method for improved yields and better livelihoods. This can be done through promotion of Farmers Field Schools for faster adoption of the method.

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LIST OF ABBREVIATIONS

FFS	Farmers Field School
GOK	Government of Kenya
NACOSTI	National Commission of Science, Technology and Innovation
NIB	National Irrigation Board
SFA	Stochastic Frontier Analysis/ Approach
SRI	System of Rice Intensification
TE	Technical Efficiency
WKIS	West Kano Irrigation Scheme

ACKNOWLEDGEMENTS

I wish to express my sincere appreciation to the National Commission for Science, Technology and Innovation (NACOSTI) for the financial and material support towards the successful completion of this study. I equally express my gratitude to my three supervisors, Dr. Anderson Kipkoech, Eng. Prof. Emmanuel C. Kipkorir and Dr. Joel Sumukwo for the great technical/academic guidance throughout the period of the study. Gratitudes also goes to the National Irrigation Board (NIB), rice farmers in West Kano irrigation scheme for their cooperation and provision of invaluable information and to the local research assistants, especially Kennedy Sitawa, for their support in data collection. Special acknowledgements also go to my wife, Noel and my daughter, Kadzo, for their great encouragement and prayers that they accorded me. Thank you for standing-in with me in all situations towards the completion of the study. Last but not least, I appreciate my colleagues at Nature Kenya (Kapsabet office) for their encouragement during my study.

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Africa is generally a food insecure continent and studies have shown that it accounts for 50% of the 12 million children under five, who suffer chronic hunger (Donkoh *et al.*, 2013a). While hunger and poverty are found in all the regions of the world, Sub-Sahara Africa is the only region where per capita food production has failed to increase since 1980 (Donkoh *et al.,* 2013b). One of the reasons that explain this precarious situation is that the region missed out of the Green revolution. The green revolution combined seeds, inorganic fertilizers, plant protection products and irrigation, resulting in significant increases in food supply, especially in Asia (Bationo and Waswa, 2011). Among the crops that the revolution targeted was rice, which is now an important staple food globally. It is estimated that over 50% of the world population depend on rice as a staple food, especially in India, China and some other African countries (Ogundele *et al.,* 2006). While at the world level, rice supply is, at least enough to cover consumption, in Sub-Saharan Africa (Kenya being part of it), supply falls short of demand, resulting in rice import bill of about 1 billion US dollars annually in the region (Donkoh *et al.,* 2013a).

Rice production is faced with a number of problems, including water scarcity, degradation and declining soil fertility, which is caused by increasing land pressures from rapid population growth (Donkoh *et al.,* 2013a). Agronomically, it is convenient to regard the life history of rice in terms of three growth stages: vegetative, reproductive and ripening. The vegetative stage refers to a period from germination to the initiation of panicle (primordial), the reproductive stage is from panicle primordial initiation to heading; and the ripening period is from heading to maturity. A 120-day variety, when planted in a tropical environment, spends about 60 days in the vegetative stage, 30 days in the reproductive stage, and 30 days in the ripening period (Wanjogu *et al.,* 1995).

In Kenya, about 80% of the rice grown is from irrigation schemes established by the government while the remaining 20% is produced under rain-fed conditions (GOK, 2008). West Kano is one of the areas in Kenya where rice is grown through irrigation. Other regions with rice growing irrigation schemes include Mwea, Bunyala and Yala swamp. Rain-fed rice production is mostly on a small scale in Kenya but some areas are increasingly practicing this system of production. Most of the rain-fed rice is grown in Kwale, Kilifi and Tana River counties, and Bunyala and Teso districts in Western Kenya.

Rice cultivation was introduced in Kenya in 1907 from Asia and is currently the third most important cereal crop after maize and wheat (GOK, 2008) in the country, which is more than a century ago, but still the level of production is below the demand level in the country. In Kenya rice milling is carried out by small-scale milling enterprises, which are mainly privately owned (GOK, 2005). Although most Kenyans living in rural areas consume limited quantities of rice, it forms an important diet for majority of urban dwellers. The annual consumption is increasing at a rate of 12% as compared to 4% for wheat and 1% maize, which is the main staple food (Mati, 2010). This is attributed to progressive change in eating habits. The national rice consumption is estimated at 300,000 metric tonnes compared to an annual production range of 45,000 to 80,000 metric tonnes (GOK, 2008). The deficit is met through imports which were valued at KShs. 7 billion in 2008 (Mati, 2010; GOK, 2008).

Over the years, the government of Kenya has attempted to boost rice production locally. Despite these efforts, the importance and need for increased rice production even within the Nyando region, Western Kenya, comprehensive and up-to-date information about the level of resource use efficiencies of the rice farmers is still lacking. Most of the studies done in West Kano irrigation scheme by Kipkorir (2012b), Odero (1992), Ngongolo (1977) and Chandler (1979) focused either on general factors of production on the conventional method of rice production or on the profitability of the enterprise, without enquiring into efficiencies of the two methods of rice production and factors that determine their levels of efficiencies. To address this gap, this study was designed to determine the technical efficiency differentials between conventional and SRI methods of rice production at West Kano irrigation scheme in Western Kenya.

System of Rice Intensification (SRI) is the process where seedlings are raised in such a way that they can be transplanted along with the seedbed soil without disturbing the root system. This involves transplanting 8-12 days old seedlings to the main field in order to tap the maximum tillering potential. The number of tillers can increase exponentially with as many as 84 or more from a single plant (Norman, 2013). Single seedling per hill is recommended. Seedlings should be transplanted within 15-30 minutes after removing from the seedbed to avoid any kind of shock. A wider spacing of 25 cm by 25 cm or more is provided to create better micro-environment for higher number of tillers. Frequent mechanical weeding is recommended but chemical weeding is not recommended. Against the Conventional system, SRI method only alternate wetting and drying from 14 days after transplanting to end of vegetative stage and flooding similar to conventional for the remaining part of the season is followed (Mati, 2010) to create an aerobic condition at the root zone. A sub-saturated to saturated soil-water environment is preferred. This helps in channeling the energy required to create aerenchyma (air pockets) in the roots under anaerobic conditions to better productivity. This study differentiated between full SRI and partial SRI, where full SRI referred to practicing all the principles of SRI (at least 80% of all SRI principles) as indicated above, while partial SRI referred to practicing below 50% of all the SRI principles.

1.2 Statement of the Problem

Globally rice is one of the most important food crops in the fight against hunger. In addition, unlike maize and wheat that are consumed as human and livestock feed, rice remains the most favoured grain for human consumption (Ogundele *et al.*, 2006). Development of rice therefore presents an opportunity to reduce the number of gravely food insecure people that stands at 816 million by half by 2015 according to the World Food Summit 1996 - Millennium Development Goals (GOK, 2008). Rice is the third most important staple food in Kenya after maize and wheat. About 95% of the rice in Kenya is grown under irrigation in paddy schemes managed by the NIB (GOK, 2005).

Although great potential exists for rice production in Kenya, domestic demand continues to outstrip supply. The annual consumption is increasing at a rate of 12% compared to 4% for wheat and 1% for maize, which is the main staple food (GOK, 2008). This is attributed to progressive change in eating habits. Results from a study conducted in three irrigation schemes showed that over 93% of all the households Ahero, West Kano and Bunyala irrigation schemes primarily depended on rice production as the main source of income (Kipkorir, 2012a). The national rice consumption is estimated at 300,000 metric tons compared to an annual production range of 45,000 to 80,000 metric tons; the deficit is met through imports which are valued at KShs. 7 billion in 2008 (GOK, 2008; Mati, 2010) payable through tax-payers money. Among the tax payers are the rice farmers of West Kano irrigation scheme.

Rice in the irrigation schemes of Western Kenya is grown under the conventional method using continuous flooding as evidenced by the pump operated in West Kano irrigation scheme. In the three western Kenya rice irrigation schemes namely Ahero, West Kano and Bunyala, the normal method of paddy cultivation is creating demand for more water, increased cost of inputs including heavy dosage of chemical fertilizers and less returns causing negative effect on the livelihoods of the farmers (Kipkorir, 2012b). However, scarce water resources due to climate change, high electricity costs for pumping water and other competing needs has presented hurdles to sustainable rice cultivation in western Kenya irrigation schemes. The challenge has become a rallying call by scientists and policy makers, raising a number of pertinent concerns on the need to consider interventions that would aid in minimal inputs including water, energy, fertilizers, land and labour, while maintaining optimal yields per acreage.

The main issue emerging from the concerns discussed above is efficiency of the method of rice production in the use of resources. The average unit production under irrigation is 5.5 tons/ha for the aromatic variety, and 7.0 tons/ha for the non-aromatic varieties in Kenya (inclusive of West Kano irrigation scheme) (GOK, 2005) compared to Madagascar, whose average rice production was 12 tons/ha (Laulanie, 2011). SRI concepts and practices continue to evolve as they are being adapted to rain-fed (un-irrigated) conditions and with transplanting being superseded by direct-seeding sometimes (Norman, 2013). The SRI method has the potential to increase the yield, reduce demand for water and improve the livelihoods of farmers (Kipkorir, 2012b).

It can be observed that rice farmers practicing the conventional method were not getting maximum returns from the resources committed to the rice production. In order to ensure increase of rice production and to be equipped with market competitiveness, it is important to improve productivity by removing inefficiency of rice production (Kim *et al.,* 2012). Water is a natural and scarce resource, essential both for agriculture in many regions of the world and to achieve sustainability in production systems (Alvarez *et al.*, 2004; Samani *et al.*, 2005). Due to scarcity of resources such as land, water, labour, capital inputs and incomes to purchase the inputs for rice production, there is need to conduct a study to establish differentials in technical efficiency between Conventional and SRI methods of rice production at West Kano rice scheme of Western Kenya region, with a view to improving/ increasing the efficiency and quantity of rice production with less water and less chemicals dosage to alleviate poverty in households in the study area and in other rice schemes in Kenya. Improved production efficiency of rice production in Western Kenya region is important, considering its contribution to improve food security, increase smallholder rice farmers' income, contribution to employment creation in the Western, reduction of the national rice import bill and optimization of the scarce water use.

1.2 Objectives of the study

The overall objective of this study was to establish differentials in technical efficiency between Conventional and SRI methods of rice production at West Kano irrigation scheme in Western Kenya. This was with a view to improving/ increasing the efficiency and quantity of rice production with less water and less chemical dosage to subsequently alleviate poverty in households in the irrigation scheme and in other rice schemes in Kenya.

Specific objectives were to:

a) Analyze the effects of major socio-economic characteristics on rice productivity in West Kano irrigation scheme of Western Kenya.

b) Assess the economic significance of rice farming and technologies to rural households of the scheme.

c) Examine the factors that determine the level of technical efficiency of Conventional and SRI methods of rice production.

d) Determine the technical efficiency differentials between Conventional and SRI methods of rice production.

1.3 Study Hypotheses

a) There is no significant difference in the socioeconomic characteristics of rice farmers practicing conventional and SRI methods of rice production at West Kano irrigation scheme of Western Kenya.

b) There is no significant difference in the level of input use and rice yields between conventional and SRI methods of rice production at West Kano irrigation scheme of Western Kenya.

c) There is no differential in technical efficiency between conventional and SRI methods of rice production at West Kano irrigation scheme of Western Kenya.

1.4 Justification of the Study

There is an ever increasing demand for rice consumption of 12% per annum as compared with other foods such as wheat and maize that is attributed to progressive change in eating habits (GOK, 2008). Results from a study conducted in three irrigation schemes showed that over 93% of all the households, Ahero, West Kano and Bunyala irrigation schemes, primarily depended on rice production as the main source of income (Kipkorir, 2012a). This, therefore, necessitates the need to increase rice production. For improved market competitiveness, inefficiencies in production chain should be removed. However, in general, improvement of productivity of rice is possible through improvement of technological progress, which refers to development of new production technologies, and production/technical efficiency, which utilizes known technologies efficiently (Kim *et al.,* 2012). This is because a decline in efficiency is not necessarily due to diminishing returns (Verón *et al.,* 2005). Hence, the importance of conducting a study on the technical efficiency differentials between the Conventional and System-of-Rice-Intensification methods so as to determine the most efficient technology to be adopted for increasing rice production.

Due to scarcity of resources such as land, water, labour, capital inputs and incomes to purchase the inputs to support rice production, there was need to conduct a study on technical efficiencies so as to help decision-makers and rice farmers in optimal allocation of scarce resources and also to be able to give better guidance on choices to be made in terms of what species of rice crop to be grown and what rice method to be used. That therefore justifies the need to analyze input use and rice yields of the two methods of rice production. Applying fertilisers has different thresholds of efficiency that depend on a number of factors. Applying fertilisers in increasing amounts lead to lower yields that eventually reach the value 0 if fertiliser and fertiliser application costs keep constant, with a trend increasing proportionally with the fertiliser rate applied (Sala *et al.,* 2011). It's for these reasons that the study aimed at analyzing the major socio-economic characteristics of rice farmers and also examining factors that determine the level of technical efficiency of the two methods of rice production.

The communities of West Kano irrigation scheme stand to benefit from the study by gaining knowledge on the efficient method of rice production that is worth adopting to increasing rice yields and subsequently alleviate poverty. Academia will gain knowledge on factors that determine the levels of technical efficiency in rice production, scarce resource allocation and best models to use in determining technical efficiency differentials. They will also get recommendations for further research areas in relation to this study.

To the researcher, there is no known literature done on technical efficiency differentials between the two methods of rice production in Kenya. Due to this limited literature, this study attempts to bridge the knowledge gap.

1.5 Scope and Limitations of the Study

The study was limited to establishing differentials in technical efficiency between conventional and SRI methods of rice production. Geographically, the study was carried out at West Kano irrigation scheme in Western Kenya. The study collected primary data from the rice farmers in the rice scheme based on production activities for year 2011 to 2013. The findings of the study were based on first, field experiments/ trials for four experimental plots for conventional paddy system and four plots under SRI system.

Secondly, findings were also from questionnaires administered to the 123 respondents, information from 10 focused group discussions and data synthesized from secondary sources. Findings include those on household socio-economic characteristics, economic significance of rice farming to rural households, effects of rice technologies on productivity and technical efficiency estimates. Results from this study could be used to disseminating knowledge on the efficient method of rice production that is worth adopting to increasing rice yields and subsequently alleviate poverty and best models to use in determining technical efficiency differentials.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter discusses the literature related to the technical efficiency differentials between Conventional and SRI methods of rice production in West-Kano irrigation scheme, Kenya. It particularly focuses on critical review of other similar previous studies done by other researchers.

Findings from baseline survey indicated that the inhabitants of Western Kenya rice schemes have limited sources of livelihoods and most rely on rice farming. However, most of the respondents attain low yield levels which do not help in improving their living standards in terms of housing, education facilities, health facilities and infrastructure in general (Kipkorir, 2012a). As rice farming is the main source of income for the inhabitants of the study area, it is important to enhance techniques that will greatly improve rice crop production at affordable costs. This therefore is an indicator that the conventional method of rice production that the rice farmers in West Kano irrigation scheme have been using has been producing low yields.

2.2 Technical efficiency

There are three main types of efficiency identified by the economic theory. These include technical, allocative and economic efficiencies (Al-Sharafat, 2013). Economic efficiency is a broad term that implies an economic state in which every resource is optimally allocated to serve each person in the best way while minimizing waste and inefficiency (Ukpong and Idiong, 2013). When an economy is economically efficient, any changes made to assist one person would harm another. On the other hand, technical efficiency reflects the manager's capacity to minimize input utilization and to reduce waste, while the concept of allocative efficiency is based on the ability to define a cost-minimizing input mix, given the market factor prices (Erbetta and Petraglia, 2011). Technical efficiency is the ability of the farmer to produce the maximum possible output using a given quantity of inputs or set of farm resources and technologies without wastage (Kipkoech, 2008; Djokoto, 2011; Ukpong and Idiong, 2013). It is also defined as the ratio of actual output to the maximum output attainable (potential production) with given amounts of inputs (Gicheru *et al.*, 2007; Cokgezen, 2009). Technical efficiency is a form of productive efficiency and is concerned with the maximization of output for a given set of resource inputs. Measures of efficiency have been defined on the assumption that the efficient production function is known. In other words, they are methods of comparing the observed performance of a firm with some postulated standard of perfect efficiency, so that each of the measures has, in general, corresponding to each postulated standard, a different value and a different significance (Farell, 1957). In context of this study, it implies that in order to test technical efficiency of the rice production methods, the actual output per acre per rice production method should be compared to its potential output in the study area, in consideration to the cost of inputs.

Technical efficiency is associated with behavioural objectives of maximization of output (Battese and Coelli, 1995). According to Kipkoech (2008), technical efficiency is the ability of the farmer to produce the maximum possible output using a set of farm resources and technologies and noted that the technical efficiency of the i^{th} farm is the proportion of the expected output when the farmer applies X_{ij} resources to produce maize and experiences technical inefficiency of μ_i to the yield expected when the farmer uses X_{ij} but $\mu_i = 0$. This can be represented as follows: $TE = E(Y_i / \mu_i, X_{ij}) / E(Y_i^* / \mu_i = 0, X_{ij})$ where μ_i is technical efficiency coefficient, E refers to expected output. For a farm to be called technically efficient, it has to produce at the production frontier level (Kibirige, 2008). However, this is not always the case due to random factors such as bad weather, animal destruction and/or farm specific factors, which lead to producing below the expected output frontier (Battese and Coelli, 1995).

Farell (1957) reported that measures of efficiency have been defined on the assumption that the efficient production function is known. In other words, they are methods of comparing the observed performance of a firm with some postulated standard of perfect efficiency, so that each of the measures has, in general, corresponding to each postulated standard, a different value and a different significance. It is therefore necessary to consider the definition of the efficient production function before discussing the significance of the efficiency measures.

2.3 Socio-economic factors determining Technical Efficiency of farming

A number of studies have been carried out to determine the factors that influence the efficiency of farmers especially on rice (Kibirige, 2008). Some of the socio-economic factors that influence agricultural efficiency of small scale farmers include sex, age, level of education, farmers experience, farm size and farmer's contact with extension services.

Todsadee *et al.,* (2012) analyzed variations in the production and technical inefficiencies of Thailand broiler farms in the northern region, using a SFA. Results showed that feed, bird stocks, fixed cost and total variable costs were important factors contributing to broiler output in the Chiang Mai Province. Another interesting result found is that the total variable costs of production had a negative sign, which means that electricity, water and tax indirectly affect the output. However, age, education, family size, training and access to credit, were found to be technical inefficiencies of farmers' abilities to produce output in this province. This implied that socioeconomic assistance to farmers positively affects on the technical efficiency at the farm level. The mean technical efficiency was estimated at 79%. Moreover, the farmers' technical efficiency score range from 44.23% of broiler producers was the largest proportion of the farmers having technical efficiency between 0.70% and 0.80% to 9.61% of farmers having a technical efficiency score of more than 0.90%. The results suggested that, there was opportunity to improve broiler production in the region by adopting appropriate management practices.

In a study carried out on maximum likelihood estimates and determinants of technical efficiency of leafy vegetable producers in Akwa Ibom State, Nigeria, Ukpong and Idiong (2013) which determined the influence of some socioeconomic and environmental factors on technical efficiency of leafy vegetable producers. The results showed that leafy vegetable production was dominated by female. The Maximum Likelihood Estimates of the Cobb-Douglas stochastic production frontier function indicated that the age of vegetable producers had a negative and significant influence on their technical efficiency, while, educational levels, farming experience, farm size, household size and soil quality had positive and significant influence on their technical efficiency.

In a baseline survey report of rice production in irrigation schemes in western Kenya, Kipkorir (2012a) showed that over 93% of all the households in Ahero Irrigation Scheme, West Kano Irrigation Scheme- WKIS and Bunyala irrigation scheme primarily depended on rice production as the main source of income. Most farmers in Ahero Irrigation Scheme (95%) and WKIS (86%) grow rice on less than seven acres of land, most of which is allocated by NIB, and less than 8% rent land for rice production. The situation reveals a vicious cycle in which numerous factors contribute to rampant poverty. Living conditions are difficult as witnessed by low purchasing power, high rice crop production costs, low levels of education of women, overcrowded households and nature of housing. However, this study compared between the two rice production methods, with a view to comparing their technical efficiencies.

Results of a study by Odero (1992) reveled that in a socio-economic study of some performance aspects of the West Kano irrigation scheme, rice output was significantly affected by the farmers' socioeconomic attributes such as agricultural training, education level and the degree of outside exposure. Labour, especially from family sources, also exerted considerable influence on the output. Further, results indicated that the scheme output was affected by the legal framework, farm machinery problems as well as a myriad of farm-level constraints including rice diseases, water scheduling and field conditions. The cost of water was found to be lower than its real value which was viewed to be a hindrance to efficient water utilization. However, research based its rice output on farmers' socioeconomic attributes only. It did not assess the different methods of rice production to complement the performance of the irrigation scheme. Odero (1992) recommended systematic rehabilitation of the West Kano irrigation scheme, without considering that different rice production methods result to different yields of rice, which ends up affecting the socio-economic characteristics of the rice farmers. This study went beyond socioeconomic attributes.

2.4 Economic significance of rice farming and technologies

Factors such as land, labour and self-sufficiency have significant relationship with technical efficiency (Ukpong and Idiong, 2013). Applying fertilisers has different thresholds of efficiency that depend on a number of factors. Applying fertilisers in increasing amounts lead to lower yields that eventually reach the value zero (0) if fertiliser and fertiliser application costs keep constant, with a trend increasing proportionally with the fertiliser rate applied (Sala *et al.*, 2011).

Simonyan *et al.*, (2012) evaluated productivity and technical efficiency among beneficiary farmers of second national Fadama project in Kaduna state, Nigeria. The study revealed that fertilizer and pumping machine rated high among the Fadama II project facilities used by the beneficiary farmers. Evidence from the stochastic production analysis shows that farm size, fertilizer and hired labour were highly significant (1%) in determining the output of project beneficiaries, while chemical, farm size and fertilizer were significant at 1% respectively in determining the output of the non-beneficiary farmers in the study area. The mean technical efficiency of the project beneficiary was higher (92%) than the mean technical efficiency (48%) of the non-beneficiaries. Age, educational level, Fadama farming experience and access to credit were positively related to technical efficiency of project beneficiary at 1% respectively. It was recommended that these policies be aimed at improving beneficiaries' access to credit and timely distribution of productive inputs, so as to help the country be guaranteed of all year round food production and reduction of poverty levels.

Sala *et al.*, (2011) researched on elements of technical and economic efficiency with nitrogen fertilization on winter wheat in Romania. The researchers took into account the impact of the factor nitrogen on yield and on some technical and economic optimal elements in winter wheat. Using as a mathematical instrument, the monofactorial function (2^{nd} degree parabolic function) they assessed the interdependence between fertilizer rates and yield, the correlation coefficient, maximum fertilizer rate technically and economically, maximum production, and optimal production. They also assessed a few economic elements generated by the use of fertilizers, cost increase, income increase, benefit increase, as well as maximum benefit. With the technical and economic conditions in which they processed experimental data, optimal yield was 4,010.65 kg/ha that corresponded to a fertilizer rate of 151.24 kg of active substance nitrogen, while the maximum fertilizer rate was of 186.09 kg/ha of active substance nitrogen.

Ngongolo (1977), in a study on the flow measurements in West Kano rice scheme, mentioned poor performance of the pumps and attributed it to debris clogging, reduced pump capacity and pressure causing air leaks. The study noted that there was a need of a critical analysis in order to reduce the inefficient water use problem. It noted that water management in the Kano plains had been below standard resulting in inadequate irrigation, low yields, increased weed growth, and high pumping costs. However, the study did not assess other causes of low rice yields and which rice production method or principles to apply to possibly address the inadequate irrigation due to the reduced water and high pumping costs. Moreover, Mukumbu (1987) later identified problems associated with production of rice in the same area as to include high operational and maintenance expenses due to high siltation, machine and pump breakdown; high pumping and drainage costs; inefficient water management; lack of portable water and Lake Victoria’s recession. These findings are in agreement that water in the study area is a scarce resource and that if not well managed, rice production will not be sustainable.

Chandler (1979) stated that “although the appropriate water management practices are influenced by varietal differences and soil conditions, a few general principles can be widely applied: The ideal water depth in the paddy is 5 to 7 centimeters, although depths varying between 2 and 15 centimeters are not harmful. He further reported that rice grows best in soil that is continuously submerged from the time of planting until the crop approaches maturity. Any drying and rewetting of the soil not only reduces crop yield but causes losses in soil nitrogen”. However, such methods of rice production has led to high demand for water to produce rice, and yet due to changing climate, the Western region has been experiencing reduced water flows as evidenced by low water levels in the rivers and recession of Lake Victoria. This is notwithstanding the fact that the ever-growing population brings with it increased demand for rice with an equal measure of demand for water to irrigate the rice. There is therefore need to identify a rice growing approach/ method that uses water optimally and produces more rice.

2.5 Factors determining Technical Efficiency of farming

Gicheru *et al.* (2007) studied on technical efficiency of Kenya’s sugar factories, where he examined factors affecting technical efficiency by applying a stochastic production frontier approach over the period 1996 – 2005 using firm level panel data. The findings show an average efficiency for the sugar factories of 81%. Results on efficiency of individual firms show that Mumias sugar factory is technically efficient while Muhoroni has improved over time from 75% in 1996 to 83% in 2005 in efficiency.

Donkoh *et al.* (2013a) investigated the determinants of technical efficiency of rice farmers at Tono irrigation project, and used the one-step estimation methodology of the Stochastic Frontier model. Results showed that the technical efficiency estimates ranged from 0.41 to 1.00 with a mean value of 0.81. Factors that determined farmers' technical efficiency included education and the adoption of modern inputs such as seeds and chemical fertilizers. This study however, dealt with technical efficiency differentials between two methods of rice production. Djokoto (2011) studied the technical efficiency of Agriculture in Ghana, using a time series Stochastic Frontier estimation approach. A Cobb-Douglas production was fitted to time series data, 1961 to 2010 using stochastic frontier methodology. All factors of production possessed the *a priori* signs except land and seeds, whilst all except seeds variable were significant at 1% level. All the capital variables were output inelastic. Labour was elastic to output; with elasticity of 1.28. The sum of the elasticities equaled 1.74, indicative of increasing returns to Ghana's Agriculture over the period. The estimates of technical efficiency had a mean of 82% with a minimum of 59% and maximum of 96%. Efforts remain to make up for the 18% inefficiency using the current technology. With a negative relationship between land and Agriculture output, coupled with the increasing population and increasing need for non-agricultural land uses, the need to adopt land productivity enhancing practices is necessary.

Samani *et al.,* (2005) evaluated irrigation efficiencies for three crops in Southern New Mexico using the chloride technique. The chloride technique is a simple method in which the natural chloride in the irrigation water is used as a tracer to estimate the leaching fraction and the irrigation efficiency at the farm level. Soil samples were collected and analyzed for moisture and chloride content. In addition to the chloride technique, on-farm irrigation efficiencies were measured using applied water, yield and water production functions. Water production functions and yields were used to estimate total evapotranspiration while flow measurements were used to calculate the amount of applied water. The results showed that contrary to conventional belief, high on-farm irrigation efficiencies can be obtained using surface irrigation. Irrigation efficiency values ranged from 83 to 98%. Irrigation efficiencies using the chloride technique were compared with efficiencies estimated from direct flow measurements. The differences between the two methods ranged from 2 to 11.4%. Results showed that even though the chloride technique is subject to sampling errors and simplified theoretical assumptions, it can be used to estimate on-farm irrigation efficiency with considerable accuracy. These findings are in agreement with this study that measuring of applied water in a rice field can be done using water flow measurements.

Kim *et al.* (2012) estimated changes in total factor productivity of 12 Korean offshore fisheries between 1997 and 2009 through the Malmquist productivity index, which is a nonparametric method. He also analysed the cause of such changes in productivity of each fishery, more specifically by segmenting into factors for technological progress and technical efficiency. As a result of this analysis, the total factor productivity change of the entire offshore fisheries was 6.0%. Changes in the technical efficiency and technological level factors, respectively, contributed 0.2 and 6.2% to this rate of decrease in total factor productivity; that is, inactivity of technological progress led to the decrease in productivity of the offshore fisheries. In addition, technological progress and technical efficiency were found to differently influence the change in total factor productivity of each fishery.

Donkoh *et al.* (2013b) researched on estimating technical efficiency of Tomato production in Northern Ghana by applying one-step estimation of the Cobb-Douglas Stochastic Frontier model. He investigated factors influencing technical efficiency of tomato farmers at the Irrigation Company of Upper East Region of Ghana in the 2007/2008 cropping season. Findings were that the mean technical efficiency was 0.71, ranging from 0.36 and 0.99. The relatively high efficiency levels were as a result of agricultural intensification measures (such as adoption of modern inputs) that the farmers followed as well as high levels of education and long years of experience in cultivating tomatoes. The most identified effect of tomato influx into the country was that it drives farmers out of production. As a way out the farmers suggested that there should be a review of the country's cross border relations with its neighbours. In conclusion, Donkoh et al. (2013b) indicated that the farmers at the study area were technically efficient and that the main problem however, was bordering on the fierce competition they faced from their foreign counterparts.

Alam (2011) measured technical efficiency, allocative and cost efficiency of pangas fish-producing farmers of Bangladesh. Data envelopment analysis was used to measure the efficiency while Tobit regression was applied to identify the factors affecting efficiencies. The estimated mean technical efficiency, allocative efficiency and cost efficiency were

86%, 62% and 54% respectively. Pangas production is characterized by considerable technical inefficiencies and substantial allocative and cost inefficiencies. Pond size, fingerling size, culture length and use of pelleted feed are important determinants of efficiencies. It is nevertheless profitable in terms of benefit-cost ratio, break-even yield and price criteria. Proper mixing of inputs given their prices could make pangas producers profit maximizers. More fisheries extension was suggested to expand pangas culture and improve efficiency.

2.6 Determination of differentials in technical efficiencies of production methods

Ogundele *et al.*, (2006) carried out study on technical efficiency differentials between farmers planting traditional rice varieties and those planting improved varieties in Nigeria. Results from the analysis showed that significant increase recorded in output of rice in the country could be traced mainly to area expansion. The use of some critical inputs such as fertilizer and herbicides by the farmers were found to be below recommended quantity per hectare. There was also significant difference in the use of such input as labour between the two groups of farmers. Other variables that tended to be technically efficient were hired labour, herbicides and seeds. Fertilizer, the most critical input required for increased production, was found not to have contributed significantly to technical efficiency. The estimated average technical efficiencies for the two groups were correspondingly high (>0.90), which indicated that there is little opportunity for increased efficiency given the present state of technology. The test of hypothesis on the differentials in technical efficiency between the two groups of farmers showed that there was no absolute differential. Unlike the study by Ogundele *et al.,* (2006), which examined technical efficiency differentials on two groups of rice farmers planting two rice varieties, this study examined the technical efficiency differentials between two rice production methods, conventional and SRI.

Hossain *et al.* (2012), conducted a study to apply Translog Stochastic Frontier production model (SFA) and Data Envelopment Analysis (DEA) to estimate efficiencies over time and the Total Factor Productivity (TFP) growth rate for Bangladesh rice crops. Results indicated that technical efficiency was observed as higher for Boro among the three types of rice, but the overall technical efficiency of rice production was found around 50%. Although positive changes existed in TFP for the sample analyzed, the average growth rate of TFP for rice production was estimated at almost the same levels for both Translog SFA with half normal distribution and DEA.

Kipkoech (2008) carried out a study on the economics of biological control of cereal stemborers in maize fields of Kenya, where he examined benefits and costs for biological control of cereal stemborers. Results showed that the net reduction in total stemborer density within the first ten years since introduction was 33.7%, thus abating 47.3% of yield loss. The low potential zones would accumulate a net present value of US $ 183 million in economic benefits in 20 years since release of the parasitoid. The benefit-cost ratio is estimated at 19:1 with an internal rate of return of 41%. The average yields and technical efficiency of maize producers ranged from 1 – 1.2 tons/ha and 57.9 – 67.9% respectively. Farmers who relied on biological control were technically significantly more efficient compared to farmers who applied pesticides. The losses to stemborers could fall to less than 5% in ten years in the high potential areas, if pest reduction by each parasitoid grows to at least 20% on the reducing pest density by the 10th year. The internal rate of return (IRR) of the project in the high potential maize growing areas in Kenya ranges between 58.7 and 122.9%. Because of low average yields in the low potential areas, marginal productivity of pest control was low.

Ngui-Muchai and Muniu (2012) provided empirical evidence on technical efficiency differences and efficiency distribution for three Kenyan manufacturing subsectors, namely food, metal and textile, using an unbalanced panel data covering two periods. The study estimated econometric production frontiers for each subsector in each period. The results indicated variation of technical efficiency estimates of the sampled firms in each period. The technical efficiency distribution for each subsector changed not only in relation to itself, but also in relation to the other subsectors across the periods of analysis. The efficiency distribution of the firms for both food and textile (metal) subsectors improved (declined) during the study period but with the food subsector firms remaining relatively inefficient. The improvement of the technical efficiency distribution for both the textile and food subsectors is an indication of intra-plant improvement during the period of analysis. The decline of the technical efficiency distribution for the metal subsector suggests that the market orientation during the structural reform period did not promote firm efficiencies or the firms were slow in responding to the reforms.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Introduction

This chapter analyses theoretical framework, conceptual framework, inefficiency effects and socioeconomic model, detailed characteristics of SRI and conventional methods of rice production and rice production trends, field experiments and trials, sampling techniques, data collection and analysis procedures in the West Kano irrigation scheme.

This study was conducted in West Kano irrigation scheme which is one of the three rice schemes in Western Kenya, West Kano. The other two being Ahero and Bunyala. The study was not done in these schemes due to financial constraints and also because data from the one irrigation scheme was considered to be representative. The study used mainly primary data collected from the rice farmers in the rice scheme based on production activities for year 2011 to 2013. Primary data were collected using field trial plots laid in the scheme and structured questionnaires administered to households in the rice scheme. The questionnaires were pre-tested prior to their full administration. Other information on aspects such as number of farm families was collected from the NIB. For the purpose of this study, a household refers to a group of persons living together in the same house or compound and sharing the same housekeeping arrangements (Odero, 1992). A household therefore includes a family encompassing a husband, wife or wives, children and relatives as well as non-relatives living together. The study used market prices because the great attribute of market prices, with all their shortcomings, is that they provide an enormous amount of information concerning production possibilities, consumer preferences, and sometimes government objectives, which is available to the economist at a relatively low cost.

3.2 Area of Study

Rice is generally grown in hot and wet environments (Wanjogu *et al.*, 1995). The field study was conducted in West Kano irrigation scheme (Figure 3.1). West-Kano irrigation scheme is located in Nyando River basin. The scheme is located in the Kano plains between Nandi Escarpment and Nyabondo Plateau on the shores of Lake Victoria. It is in Kisumu East District in Kisumu County. The scheme has about 780 farmers with a gross area of 1780 Ha and farm size of 1-4 acres (GOK, 2013). The Nyando River basin covers an area of 3,500 km^2 of western Kenya, and has within it some of the most severe problems of agricultural stagnation, environmental degradation and deepening poverty found anywhere in Kenya. The poverty index is high, ranging from an average of 58 percent in Kericho District, to 63 percent in Nandi District and 66 percent in Nyando District. At the administrative location level, the locations of Nyando District include both those with the lowest poverty rate in the sugar belt of Muhoroni Division (36 percent) and those with the highest poverty rate in Upper Nyakach Division (80 percent) for the entire basin (GOK, 2003).

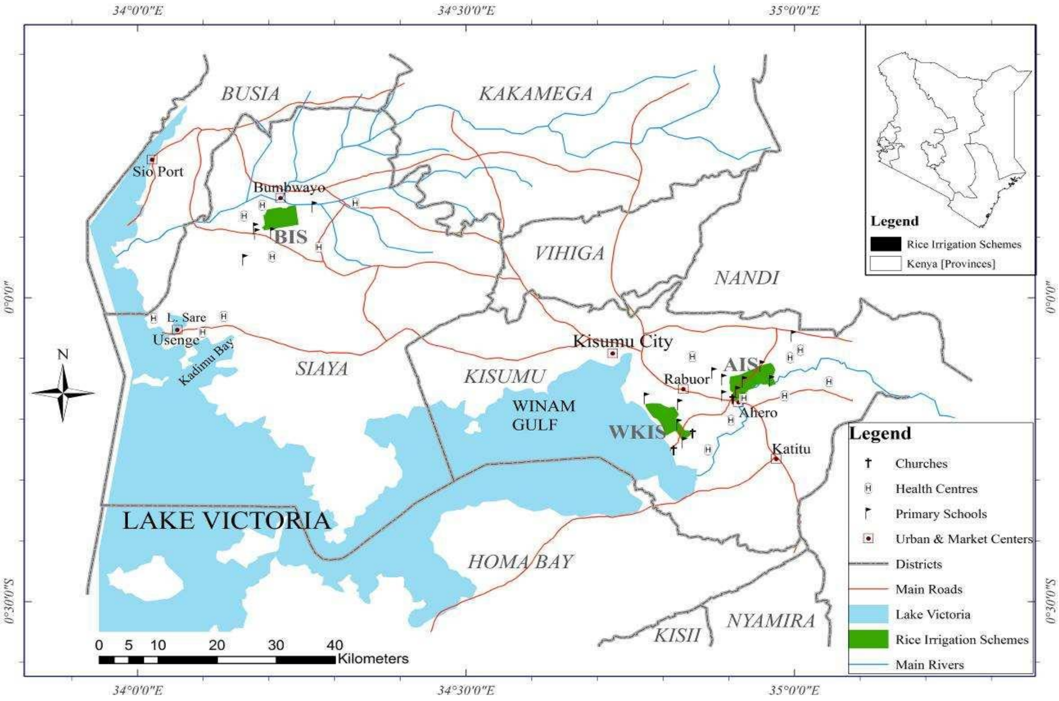

Figure 1: Location of the three irrigation schemes in Western Kenya

(Source: Adapted from Kipkorir, 2012b)

The NIB established two large irrigation projects in the Kano Plain area: the Ahero Irrigation Scheme in 1969 and the West Kano Irrigation Scheme in 1976. West Kano irrigation scheme was established in 1974 and became operational in 1976 (GOK, 2012). Land was expropriated and the scheme plots were subsequently distributed among the previous owners and smallholder farmers from neighboring areas. A total of 1.6 hectares of irrigated land were allocated per farming household. In the mid-1980s West Kano covered an area of 880 hectares, out of which 553 tenants farmed. The most current official number of tenant farmers/ households is 782 tenant farmers/ households (GOK, 2013). However, the scheme has a population dependence of about 30,000 people (GOK, 2012). The scheme irrigation water is abstracted by pumping both in the inlet and pumping out drainage water at the outlet and the drainage system is through gravity.

Besides cultivating irrigated crops, tenants also grow rain fed crops, usually on a small area around the house but also on plots outside the schemes. Substantial differences exist with respect to access to rain-fed farmland. When the schemes were first set up, all tenants were obliged to live in designated villages within the schemes. Over time, these villages have become very crowded, compounds are close to each other, and there is little space for gardens. In these circumstances, it is difficult to build extra houses and there is little room for the traditional expansion of the homestead. In fact, sons, on reaching adulthood, are no longer allowed to reside in the scheme according to scheme regulations. Tenants are not allowed to keep cattle at the schemes. The lack of space is an important obstruction and a major reason for people's desire to move outside the scheme. Later, it was tolerated for tenants to take up residence outside the scheme (where they had no restriction for keeping cows) and still retain their scheme plots.

Currently, tenants can be distinguished as either "resident tenants," who live within the schemes and have no or relatively little land outside the schemes, or "nonresident tenants," who live outside the schemes and have more sizable tracts of non-scheme land. Depending on the scheme, an estimated 30-50 percent of tenants belong to the latter category. There are also smallholder schemes in the area that were started by the farmers themselves and are controlled by farmers' committees. Participating farmers individually cultivate a plot, privately owned or rented. Plots are much smaller in size than at the NIB schemes, and farmers generally start to cultivate only when and if they have labor available, thus facing considerably lower labor costs.

As at year 2012, population size of tenant households, West Kano was 782, but the unofficial size was 2,500 households. This is because of the guiding rule in the scheme that one cannot get a Tenant number when possessing less than 2 acres.

3.3 Theoretical Framework

This study was guided by the Production theory, which is one of the Economic theories. The theory of production deals with the relationship between the factors of production and the output of goods and services (Clayton, 1995). It is also defined as the study of production, or the economic process of converting inputs into outputs (Koutsoyiannis, 2008) per given period of time.

The production of an economic good or service requires a combination of land, labour, capital, and entrepreneurship; some combinations are more technically efficient than others, and all combinations affect both output and the cost of production (Clayton, 1995). This study compares technical efficiencies of two different rice production methods (SRI and conventional). The study compares the inputs used per technology and their subsequent outputs (rice yields) within a rice growing season.

3.4 Conceptual framework

3.4.1 Inefficiency effects and socioeconomic model

Average level of technical efficiency measured by mode of truncated normal distribution (i.e., U_{it}) has been assumed to be a function of socioeconomic factors as shown in the relationship (Ogundele *et al.*, 2006):

$$U_{it} = \beta_0 + \beta_1 R_{1it} + \beta_2 R_{2it} + \beta_3 R_{3it} + \beta_4 R_{4it} \text{...} \quad (1)$$

Where:

U = Technical efficiency

R_1 = education of the farmer

R_2 = age of farmer

R_3 = years of farming experience (rice only)

R_4 = household size

$\beta_0 - \beta_4$ = parameters to be estimated

Estimation of the model was accomplished through a joint estimation of the production efficiency model as specified by Ogundele *et al.* (2006).

3.4.2 Estimation and analysis of Technical efficiency in relation to input use and rice yields

The level of technical efficiency measured by the distance a particular rice production method is derived from the production frontier (Donkoh, 2013a). Thus a method of rice production that sits on the production frontier is said to be technically efficient. Technical Efficiency (TE) is measured as a ratio of actual to potential output (Donkoh, 2013b).

A production process is said to be inefficient when there exists another feasible process that, for any given output, uses less inputs (Kipkoech, 2008). In this study, a unit isoquant is defined by describing the minimum combination of inputs needed to produce a unit of output. Every combination of inputs along the isoquant is considered technically efficient and any points above are technically inefficient (Gicheru *et al.*, 2007). It takes a value between zero (0%) and one (100%) in which case a value of one (100%) implies that a technology is fully efficient. When the value is closer to 1 (100%), it means that the rice production is operating closer to the production frontier, hence is efficient and vice versa (Kim, 2012).

There are four major approaches used to measure technical efficiency. These include the non-parametric linear programming approach (Kipkoech, 2008), the parametric programming approach, the deterministic statistical approach and the Stochastic Frontier Approach (SFA) (Djokoto, 2011; Kipkoech, 2008). The parametric approach, which imposes an *a priori* functional form to the frontier, is dominated by the SFA model, while the non-parametric approach, which does not impose *a priori* functional form to the frontier, is dominated by the Data Envelopment Analysis (DEA) model (Ngui-Muchai and Muniu, 2012). The strength of SFA is that it considers stochastic noise in data and also allows for the statistical testing of hypotheses concerning production structure and degree of inefficiency (Hossain *et al.*, 2012). In order to estimate and analyze the technical efficiency of the two methods of rice production, the SFA was used.

In measuring the technical efficiency, the study compared the technical efficiency of conventional rice production method as applied by the rice farmers in the scheme, differentiating the efficiency with that of conventional and SRI as applied by the study in the field trial plots. In this study, the Cobb-Douglas stochastic frontier model to be estimated is defined by, equation 2.

$$ln\ Y_{it}=a_0+a_1lnX_{1it}+a_2lnX_{2it}+a_3lnX_{3it}+a_4X_{4it}+a_5X_{5it}+a_6X_{6it}+a_7X_{7it}+\ a_8X_{8it}\ +\ a_9X_{9it}\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where, the subscripts *i* and *j* refer to the *i*th farmers and *j*th observations, respectively, while,

Y = Grand revenue from rice (KShs)

X_1 = cultivated land area under rice (own and leased) (in acre)

X_2 = sum of family labour (labour for puddling, nursery preparation, transplanting, weeding, birds scaring, harvesting, drying and bagging) (person days)

X_3 = sum of hired labour (labour for puddling, nursery preparation, transplanting, weeding, birds scaring, harvesting, drying and bagging) (person days)

X_4 = quantity of seeds planted (kg)

X_5 = quantity of fertilizer used (organic and inorganic) (kg)

X_6 = quantity of pesticides and herbicides used (litres)

X_7 = mechanical costs (Land ploughing, harrowing, rotavation, levelling) (KShs)

X_8 = water costs for maintenance and operations (KShs)

X_9 = age of farmers (years)

ln = the natural logarithm (i.e., to base e)

$a_0 – a_9$ = parameters to be estimated

3.4 The Stochastic Frontier Production Analysis/Approach

Stochastic Frontier Production Model (SFA) measures production efficiency with respect to the relationship between observed production and corresponding production potential (Oren and Alemdar, 2005). On the other hand, DEA does not account for random variation in the data and assumes that deviations from the frontier are due to inefficiency (Ngui-Muchai and Muniu, 2012). Comparative studies reveal that efficiency scores estimated using DEA and SFA are different, and those yielded by SFA are more plausible than those yielded by DEA. DEA ignores the effect of exogenous variables on the operation, ignores statistical errors and it does not say how to improve efficiency (Jorda *et al.*, 2012).

In order to estimate and analyze the TE of rice farmers, the best approach used is SFA (Donkoh *et al.*, 2013a). Apart from yielding plausible estimates, SFA allows for formal statistical testing of hypotheses as regards the existence of inefficiency and the structure of production technology, and for construction of confidence intervals (Ngui-Muchai and Muniu, 2012). Besides that, the input and output prices are known, hence, the SFA was adopted for the current study. The stochastic production frontier was estimated using the STATA 12 software. The study used the SFA in determining the marginal effects of the independent variables on technical efficiency of the rice methods through determination of the variance parameter.

3.5 Characteristics of SRI and Conventional Methods of Rice Cultivation

Table 3.1 highlights the characteristics that differentiate SRI and conventional methods of rice production.

Table 1: Characteristics of SRI and Conventional Methods of rice cultivation

Operation	**SRI Method**	**Traditional (Conventional) Method**
Nursery Preparation	Nursery bed should be nearer to the main field. About 5 kg/acre seed is sown in the seed bed. Chemical fertilizers are not recommended.	Nursery bed is not necessarily prepared near the main field. About 30 kg/acre or more seeds are used.
Main field preparation	Careful plowing, puddling, leveling, raking is done. Thirty cm wide channels are made at an interval of 2-meter across the field to drain excess water.	No cross drain is made as inundation is encouraged and drainage is not a priority.
Transplanting	Eight to ten day old seedlings are transplanted singly soon after they have two leaves and at least below 15 days after sowing. The seedlings must be transplanted with their roots intact while the seed sac remains attached. They must not be plunged too deep and placed at on the ground at appropriate point on the planting grid. Square pattern of planting grid is preferred to facilitate weeding. Transplanting should be done quickly after gently removing seedling from the nursery. The root should not dry. Seedlings remain green and establish early.	About 25 days old or more seedlings are transplanted. 2-3 nos. of seedlings per hill are used. Seedlings are uprooted from the nursery; the nursery bed soil is removed from the root zone before binding and transporting to the main field. Seedlings are generally not transplanted as quickly as in SRI method. Random planting is preferred. Seedlings generally turn yellow and take about a week to establish.
Spacing	Seedling should be planted precisely at a spacing of 25x25cm or more depending upon the tillering capacity of the variety. About 16 to 20 hills per M^2 is maintained	Usually 20x15cm spacing or less is maintained.

Soil Nutrient	SRI is promoted as an organic culture. This promotes proper microbial activity in the soil. Farmers who do not have sufficient organic matter may use less amount of chemical fertilizer	Farmers generally do not apply balanced nutrients to soil. Farmers are prone to use more nitrogenous fertilizers and give less emphasis on organic manures
Watering	SRI requires root zone to be kept moist, not submerged. Water application can be intermittent upto end of vegetative period then standing water established for the remaining part of the season.	Inundation is preferred. Standing water helps in weed suppression thereby eliminate weeding
Weeding	Since there is no standing water in the field, weeds tend to proliferate hence requires frequent weeding. First weeding should be done 10-12 days after transplanting. Further weedings are required at an interval of 10-12 days. Weed biomass is generally mixed with the soil with weeder (Cono weeder) which enhances organic matter in the soil	Limited weed growth and random planting does not warrant mechanical weeding. Sometimes manual weeding is done which does not churn the soil.

(Source: Adapted from Singh et al., 2007).

3.6 Environmental Dimensions of Irrigation

Irrigation schemes are not always successful in promoting production and the main problems arise due to the incorrect use of water, the use of poor quality water and the use of unsuitable soil. These problems are often interrelated and lead to serious consequences especially in arid areas (Ngugi *et al.*, 1990) like the case of West Kano irrigation scheme. Water may enter the plant root zone either by percolation from above or due to a rise in the level of the water table. The former occurs naturally with rain or irrigation. The later occurs due to over irrigation or to excessive seepage from canals and irrigation ditches.

All water, except rain water, contains dissolved chemicals or ‘salts’ and when evaporation or transpiration takes place these salts are left in the ground. If the concentration becomes too great, the soil is said to be *saline* and plant growth may be affected. Irrigation with water containing too high concentration of salts can quickly cause the soil to become saline. Similarly, a rising water table can bring dissolved salts from lower layers of the soil to the surface where they accumulate due to evaporation. A farmer who puts on too much water may cause waterlogging of the soil and poor plant growth due to lack of air.

Later, as the soil dries, plants may be affected by salinity. Once this problem has developed, it can only be solved by periodic leaching (washing out) of the salts by allowing water to soak through the root zone and out into drains which carry it off the land. The problem of salinity is most likely to occur in the arid areas where leaching by rainfall rarely takes place and the level of salts in the soil is naturally high. Another problem known as *alkalinity*, can arise due to the accumulation of excessive quantities of sodium in the soil. This is sometimes, but not always, associated with high salinity. Excessive sodium can lead to the breakdown of soil structures and the formation of an impervious layer below the surface, which makes irrigation very difficult. Whereas a saline soil can normally be improved by leaching, a soil which is alkaline usually requires the application of gypsum or sulphur which can be expensive (Ngugi *et al.*, 1990).

3.7 Rice Production Trends in West-Kano Irrigation Scheme

The rice scheme had previously not been keeping records (trends) of rice production. What was available in the records was only for the years 2011/2012 and 2012/2013. In the year 2011/2012, land size (cultivated acreage, out of the 2,230 acres), only 2,005 acres were cultivated, producing 60,000 rice 80kg bags, equivalent to 6 tones/ha (GOK, 2012). In year 2012/2013, land size (cultivated acreage, out of the 2,230 acres), only 1,720 acres were cultivated, producing 33,481 rice 80kg bags, equivalent to 4 tones/ha (GOK, 2013). The scheme grows four varieties of rice as the main crop, namely Basmati 370, IR 2793, ITA 310 and BW 196. The main varieties are Basmati 370 and IR 2793. Factors that led to the reduction in rice production in the year 2012/2013 compared to the previous year were floods and outbreak of Rice yellow mottle virus (RYMV) (GOK, 2013).

3.8 Sampling Techniques

This study focused on differentiating the technical efficiencies of conventional and SRI methods of rice production in West Kano irrigation scheme by use of field trial plots, questionnaires and focused group discussions. It therefore adapted both the experimental and comparative research designs since the two rice production methods were compared. The designs enabled the study to provide rigorous and replicable procedure for understanding the technical efficiency differences between the two methods of rice production, and which among the two methods is recommendable as the most efficient method to be promoted for adoption by rice farmers.

The study used questionnaires, interviews, focused group discussions, document analysis, observation, photography, field experiments/ trials that focused at inputs, spacing of seedlings, rice varieties, water regimes, fertilizer rates and rice yields per rice method) and secondary data. The selection of these tools was guided by the nature of data to be collected, the time available, level of education of respondents as well as by the objectives of the study. The official population size in West Kano was 782 households. The research was conducted between 2011 to 2013.

West-Kano rice irrigation scheme was chosen due to a predetermined study that was going on, funded by the National Council of Science and Technology (NCST) through the “3 Competitive Science, Technology and Innovative Grant” (Ref: NCST/5/003/3rd STI CALL/188) for the project period 01 January 2011 to 01 January 2014.

The sample size was arrived at, based on the following formulae (Sumukwo *et al.*, 2013):

$$n = \frac{NC^2}{C^2 + (N-1)e^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. (3)$$

Where:

n – sample size

N – population size

C – coefficient of variation (30%)

e – standard error (2.5% of target population)

Therefore the computed sample size, n, was 123 households.

This is due to the fact that not all the farmers were likely to be present during the data collection period especially the nonresident tenants that would be available on part time basis.

This study administered 123 questionnaires in the West Kano irrigation scheme that consisted of 782 households and 17 rice blocks, as indicated in Appendix 2. The questionnaire comprised of the following sections/ topical areas: identity of respondent (village, administrative location and name, which was optional), respondent's socio-economic characteristics (age, gender, level of education, source of income, size of household, average household income and food security) and rice production (costs of farm inputs, rice yields, technology of rice production used, rice varieties used, experience of rice farming, exposure to trainings on rice production and constraints of SRI). The last section required any other comment that would be necessary and not captured in the questionnaire.

Two enumerators, through close supervision by the researcher, were used to administer the 123 questionnaires. The enumerators had past experiences in doing the same and they were literate and conversant with households in the irrigation scheme, English and the local language, Dholuo. The questionnaires were pre-tested by the researcher together with the enumerators, and a few revisions done prior to their full administration. This assisted in capturing all the information needed with maximum clarity. The sample of questionnaire is attached in Appendix 3. In determining the households and persons to be administered with questionnaire, the study was guided by the rice blocks and population per block, where a representative sample size from each of the 17 blocks was chosen based on the formulae given in section 3.10 (see Appendix 2). The records of farmers per block were obtained from NIB Western regional office, Ahero. The target population was 782 households, and the sample size selected was 123 households. The 123 questionnaires were distributed as follows: the village to start with was determined through making a ruffle of the first 5 households, out of which household number 2 was picked. From household number 2, the administration was done, skipping 4 households to the 6th household being a respondent, through to the last household. The two enumerators were trained on the following topical areas prior to proceeding with administration of the questionnaires: purpose of the survey, roles and responsibilities of the interviewer, interviewing techniques, familiarization and filling in of the questionnaires, importance of randomness and minimizing bias of data collection. The enumerators were taken through the required sample sizes per block, the household to start with and the skip-patterns. A total of 123 questionnaires were administered. Although the local leaders and NIB management had already been informed about the survey, the enumerators reiterated the aim of the survey to the local area chief and, to village elders, who then created an enabling environment for undertaking the exercise without any suspicions and interruptions.

A total of 10 focused group discussions were held throughout the period of data collection, as from land preparation to harvesting of rice in the experimental plots. Members were 17 in total, out of who 5 were women. A rice farmer from each of the 17 rice blocks was nominated by fellow rice farmers in each rice block to participate in the discussions.

3.9 Field Experiments/ Trials

During the 2011/2012 short rains growing season IR2793 and basmati 370 rice varieties were cultivated. The field site considered is a clay soil. The scheme receives a mean annual precipitation of 1100 mm, reference evapo-transpiration of 2200 mm per annum, mean diurnal temperature of 23 ^{0}C, and a relative humidity of 68-70 % (Kipkorir, 2012b).

3.10.1 Description of experimental factors

The experimental factors considered were two irrigation water regimes, two rice varieties and two different spatial crop patterns as explained below:

(i) *Irrigation water regimes*

Two irrigation water regimes were tested in the rice field trials as follows:

(a) Conventional paddy rice system, where water layer of 5 cm was maintained in the field and drained 2 weeks before harvesting. In total 11 irrigation events were applied after accounting for the rainfall events; and

(b) Intermittent water application of water up to a depth of 2 cm at irrigation intervals ranging from five to seven days referenced to when hair sized cracks were observed on the plots (S 2). With this water regime a total of nine irrigation events were applied after accounting for the rainfall events. The intermittent irrigation regime was only applied two weeks from transplanting till tillering process was complete at flag leaf stage of growth and thereafter a constant water layer of 2 cm was maintained in the field till the final field drainage which was done two weeks before harvesting.

The applied water to a total of two blocks (of total area A=1419.3 m^2 for conventional and A=1584.8 m^2 for SRI) and each divided into four plots, under a given water regime was measured by determining the time in seconds required to fill a 20-litres bucket by water flowing through a 75 mm in diameter plastic pipe installed in a feeder canal to supply irrigation water.

(ii) *Treatment variables and factor combinations*

The field trials tested four treatment combinations under the two irrigation regimes. The main variables included the following: i) two rice varieties namely IR 2793 and basmati 370; ii) two different spatial crop patterns for conventional paddy and SRI systems. For conventional paddy, two spacing levels at 15 cm by 10 cm (C1) and 20 cm by 20 cm (C2) were considered, while the SRI system were spaced at 25 cm by 25 cm (S1) and 35 cm by 35 cm (S2). The fertilizer level used for SRI fields was a mixture of organic fertilizer (cattle manure) at the rate of 5 tons/acre plus inorganic nitrogen at the rate of 4.41 kg N/acre. The organic manure was applied before transplanting. The N application was split twice. The fertilizer level for conventional paddy system was only in the form of inorganic nitrogen at the rate of 4.41 kg N/acre also split twice. Therefore, the experiment comprised of eight experimental plots: Four plots under conventional (C1, C2, C3, C4) and four plots under SRI (S1, S2, S3, S4), as shown in the field layout in Figure 3.2.

(iii) *Experimental field layout*

Four experimental plots for conventional paddy system had each a net area in the range 298.2 to 399.3 m^2 while the four plots under SRI had each a net area in the range 305.0 to 521.5 m^2. In each plot during harvest, five quadrants were randomly selected and sample crop was harvested to compute grain yield and yield components. The fields for the two different irrigation water regimes were divided by 2.0 m wide permanent bund running south – north with very minimal uncontrolled water flows between the two adjacent blocks. The individual plots within each block were separated by 0.5 m wide bunds of 5 cm in height that either served as an irrigation or drain canal as shown in Figure 2.

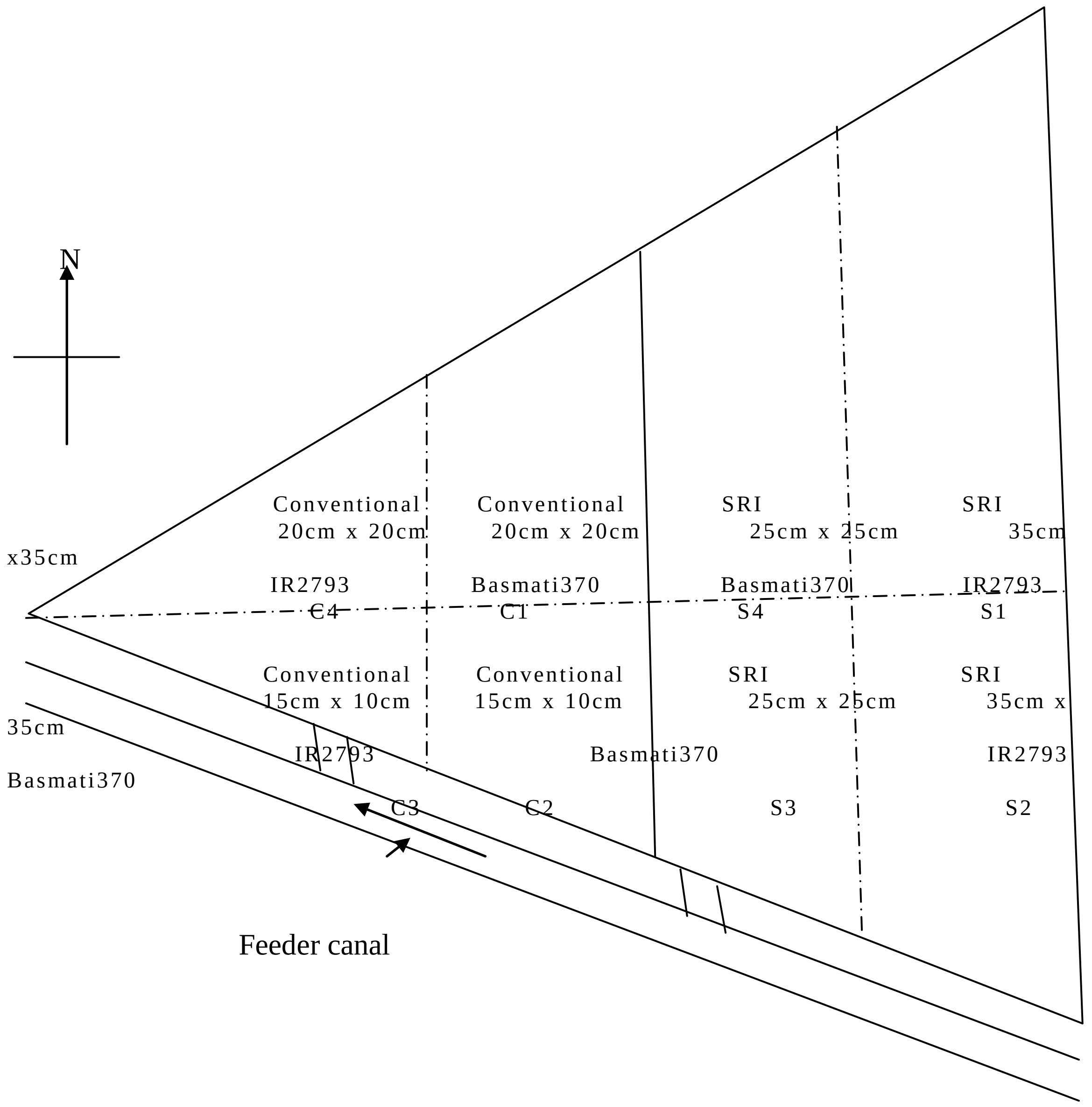

Figure 2: Experimental field layout in West Kano Irrigation site

(Source: Survey Data, 2012)

(iv) *Land preparation*

The fields were dry ploughed then soaked for four days prior to being rotavated using a tractor. Non-selective herbicide (Round-up Turbo) was applied two weeks after rotavation to reduce the problem of weeds during the early stages of rice growth. The fields were then re- rotavated just before transplanting. Leveling using tractor was done to enable water to spread uniformly in the fields. Appendix 1 illustrates some of the above activities.

(v) *Cultural management*

Hand transplanting in the trial plots for both rice varieties and for SRI and conventional system were planned to coincide on the same date. Hand sowing in the nurseries for the two varieties was done on 22nd October 2011 for conventional paddy and transplanting with 21 days old seedlings was done on 12th November 2011. While for SRI sowing in the nurseries for the two rice varieties was done on 1st November 2011 and transplanting with 12 days old seedlings was done on 12th November 2011. One seedling per hill was transplanted for the plots with SRI while 2-3 seeding according to the farmer’s practices was adopted for the conventional paddy system. Fertilizer was applied to all fields in the form of inorganic nitrogen at the rate of 4.41 kg N/acre. Inorganic fertilizer was applied in two equal splits, the first was applied 14 Days After Transplanting (DAT) and the second split was applied 35 DAT.

Weeding was done twice for conventional paddy plots by manually pulling the weeds while it was done three times for SRI plots using hand weeding machine. The maximum root depth of the crop was measured after the mid season as 0.15 m. For all the plots, water application was stopped two weeks before harvesting. The crop was cut and harvested in the field 105 DAT (conventional) and 110 DAT (SRI) for basmati 370 variety and 120 DAT (conventional) and 130 DAT (SRI) for IR 2793 variety. Yield for a plot in each treatment was determined from mean weight of field grain rice harvested from five quadrants and dried to 12.5% moisture content.

The performance of the two rice varieties tested under two water regimes (conventional paddy and SRI water regimes) and under two different spacing was assessed and further analysed.

3.10.2 Data collection

To minimize bias in the analysis, the random sampling technique was adopted. The technique involved identifying the crop area to be selected by not actually looking at the crop, but by throwing a piece of stone while facing away from the site in each plot. The area of one square meter (quadrant) was taken for sampling in the place where the stone fell. In this manner, 40 samples were collected (i.e., 5 samples from each of the 8 experimental plots) from the experiment and several crop variables were measured.

3.10.3 Variables measured

(i) Paddy hills in 1 m^2 area

A metallic 1 m^2 quadrant (Plate 3a) was placed at the randomly identified sampling point in each plot where the total number of enclosed hills was counted alongside the number of tillers in each hill.

(ii) Grains weight in 1 m^2 area

To calculate the yields for each experimental plot, samples were collected as mentioned earlier from each of the experimental plot and grains were separated from the straw and sun dried to 12.5% moisture content. The unfilled grains were removed from the good grains by winnowing. Out of the forty samples, calculations were made to get the average yield per acre area of land.

(iii) Yield per acre

From the $1m^2$ area grain yield (g/m^2) measured using electronic balance (Plate 4a), calculations were made to find out the average yield per acre area (kg/acre).

3.11 Data Analyses and Presentation

In measuring the technical efficiency, the study compared the technical efficiencies of the two rice methods (Conventional and partial SRI) as applied by the rice farmers in the scheme, differentiating them (the efficiencies) with those of the two rice methods (Conventional and full SRI) as applied by the study in the field trial plots. Statistical Programme for Social Scientists (SPSS) version 17.0 was used to determine relationships between different variables and STATA (12) computer software in assessing the technical efficiencies.

The data obtained from field survey, focused group discussions and field experiments/ trials was subjected to descriptive and inferential statistical analysis such as multiple regression; correlation analysis was used to show the degree of relationship between variables. Descriptive statistics for the data obtained in this study included frequency of occurrence, percentages of occurrence and means.

3.12 Ethical considerations

Since the research involved a study of farmers’ livelihoods and farming practices, some concerns of personal identification, personal life, individual’s values and the use of the data collected were foreseen. Permission was sought from the NIB prior to the study. Consent of the participants was also sought. All the participants engaged in the study were given the option not to include their identity during the study.

Research findings were confined to the researcher’s academic usage and the School of Environmental Studies, University of Eldoret. Any publication of the research findings will not include names of the participants and the NIB unless there is a prior discussion by all those involved who in that case will be required to append their authorization through signing against such publications.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Introduction

In this chapter, the study results are presented. The findings are based on first, field experiments/ trials for four experimental plots for conventional paddy system and four plots under SRI system. Secondly, findings from questionnaires administered to the 123 respondents, information from 10 focused group discussions and data synthesized from secondary sources. Findings include those on household socio-economic characteristics such as gender of household heads, level of education, average household income per year, size of land (owned and rented) for irrigation; economic significance of rice farming to rural households; effects of rice technologies on productivity; and technical efficiency estimates.

4.2 Socio-economic characteristics of households

4.2.1 Socio-economic characteristics of households

Table 4.1 shows findings on socioeconomic characteristics of households. The females constituted 57% of the sample while the male represented 43% of the total households. Considering that most of the farm operations in the rice cultivation, such as land clearing, tilling, weeding and harvesting, require a lot of strength and energy, the majority of the rice farmers, who were of female gender may have to hire young and energetic people to do the work, hence incur more labour costs. However, with 84% of the households comprising size of between 5 to 14 persons, the rice farmers were incurring insignificant costs on labour due to engagement of family labour. Table 4.1 below summarizes the descriptive statistics of the main socioeconomic characteristics of the households.

Table 2: Socio-economic characteristics of households sampled

Variable		**Count**	**Percent**
Gender	Female	70	57
	Male	53	43
Household size	5 – 9 persons	67	54
	10 – 14 persons	37	30
	15 – 19 persons	19	16
Age (Years)	20 – 29	10	8
	30 – 35	21	17
	36 – 40	23	19
	41 – 49	46	37
	Over 50 years	23	19
Major source of income	Fishing	1	1
	Trading	14	11
	Farming	108	88
Education	No. formal schooling	18	15
	Primary school	52	42
	Secondary school	38	31
	Technical/college	15	12
Income per annum (KShs.)	30,000 – 59,000	8	7
	60,000 – 119,000	14	11
	120,000 and above	101	82
Irrigation land allocated by NIB	2 acres	58	47
	4 acres	65	53
Rented Irrigated land from others	0 acres	109	89
	2 acres	14	11

(Source: Survey Data, 2012)

Majority of respondents (85%) had formal education and among these 42% had primary education. Education is an important instrument in new skill acquisition and technology transfer. It enhances technology adoption and the ability of farmers to plan and take risks. The fact that about 43% of the respondents had secondary education and above means that it is possible for the farmers to adopt better efficient rice technologies.

All the respondents had experience in rice growing for above 15 years. As farming involves a lot of risks and uncertainties, to be competent enough to handle all the vagaries of farming, a farmer must have stayed on the farm for quite some time. Most (88%) of the respondents indicated that their major source of income was farming, meaning that if the efficiency of rice production was improved, there would be high probability of poverty reduction.

On average, out of the 123 households surveyed, 54% of the household size in West Kano is composed of between 5 to 9 household members, 30% comprise of between 10 to 14 members while 16% comprise of 15 to 19 household members. Household size plays a significant role in subsistence farming in West Kano rice scheme where farmers rely on household members for the supply of about 80% of the farm labour requirement. This is particularly so in view of the increasing cost of hired labour and the inability of the farmers to make use of improved mechanical tools whether due to high cost or relative smallness of farm sizes. According to Kibirige (2008), the impact of household size on productivity depends on the quality and capability of the household members, rather than on the sheer magnitude of the household size.

4.2.2 Economic Significance of Rice farming to rural households

The paddy system of rice production that is cultivated in the scheme creates a high demand for irrigation water, increased cost of inputs including heavy dosage of chemical fertilizers and pesticides and less returns causing negative effect on the livelihoods of farmers. Majority of these farmers (62%) have been growing rice for about 15 years and hence are experienced. Few (1%) of the households supplement their income by fishing, while about 11% exploit wage labour opportunities and basic trading such as kiosk trade.

Therefore, these other supplementary sources contribute minimal incomes when compared with rice production. These income sources, on average, contributed over Sh.120,000 of income annually to 82% of households. Apart from the main income sources, households in the study area have invested in productive assets such as livestock keeping like cattle, goats and sheep that enable them to diversify their income options, and cushion themselves against livelihood shocks that are associated with reduced yields. About 55% of households have on average between one to nine herds of cattle, five goats, two to eight sheep and 10-14 chicken/ducks. These self-insurance strategies are important to these households as many have low incomes, and therefore constantly face income and consumption risks. As long as the percentage of those with livestock is high, then the 55% of households can afford to use organic manure in replacement of chemical fertilizers which would enhance rice production and also reduce environmental degradation through the reduced chemical inputs.

4.3 Input use and rice yields of Conventional and SRI rice production methods

4.3.1 Costs of Rice production

The costs of rice production assessed were that of field operations including nursery bed preparation, land preparation, seedlings transplanting, applying planting and top dressing fertilizers. Farmers apply more fertilizer during the planting season (average of 61 kg) than for top-dressing (48 kg) while only 2% of those interviewed use farm manure. Generally, households hire labour in transplanting seedlings (15%), threshing (8%), staking or drying (7%) and land preparation (6%). On average households spent about KShs.1,528 in purchasing fertilizers for planting (DAP) per annum and KShs. 15,437 in buying topdressing (sulphate of ammonia). Respondents indicated that they do not spend money on mulching and farm/organic manure, mainly because the opportunity costs of labour are very low due to the higher number of free family labour and easy availability of domestic manure. Majority of the farmers (83%) spend between KShs. 3,500-4,000 per annum on irrigation water fee to NIB which is mainly used to cover the operation and maintenance costs of irrigation infrastructure.

The conventional method uses 94.8% chemicals (inorganic fertilizers), compared to SRI method that uses 5.2%, using lesser chemicals by 89.7% (Figure 4.1). This is because SRI uses 5,000 kg of compost (organic manure) per acre of land instead of the inorganic fertilizers for planting and topdressing.

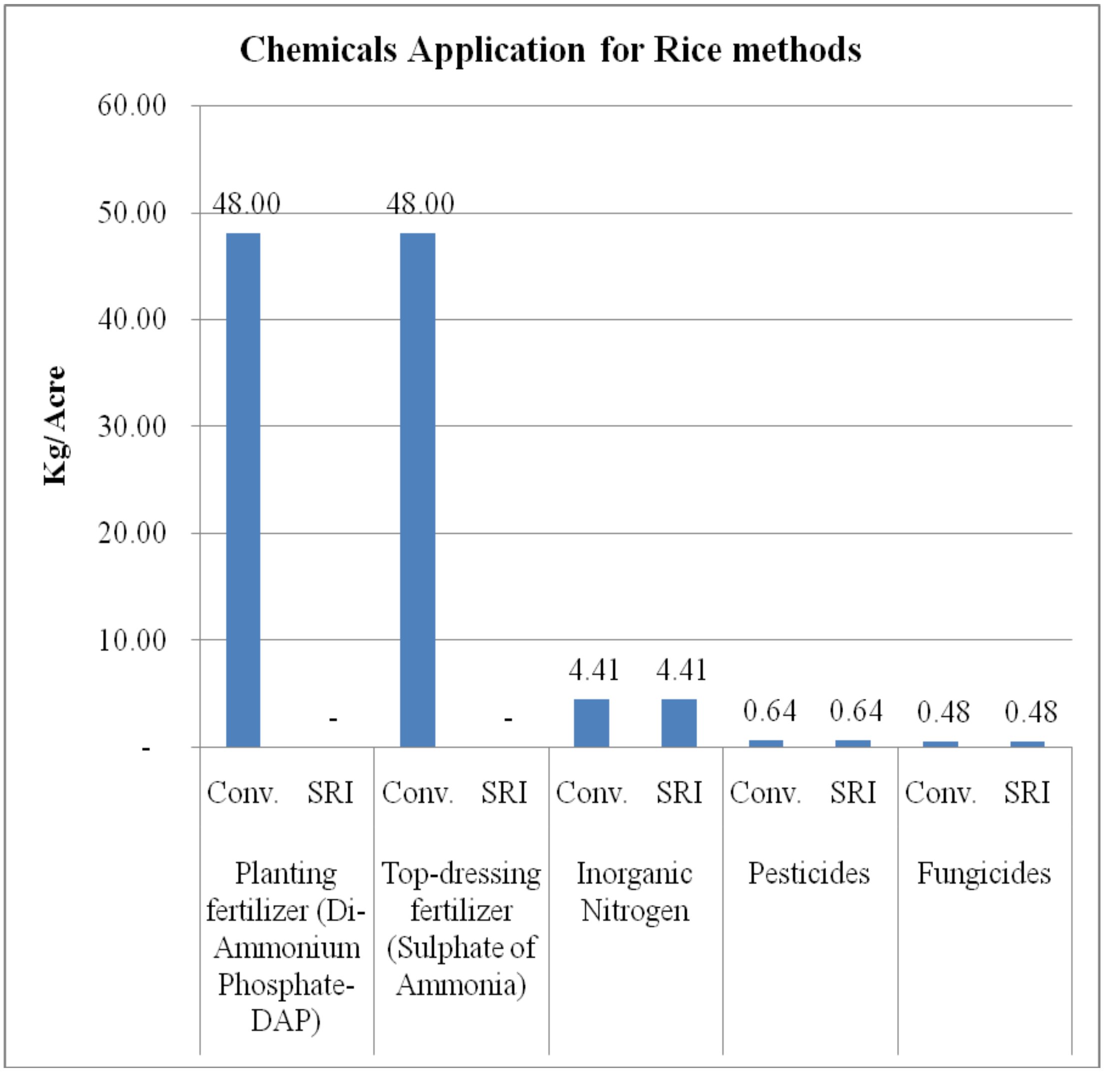

Figure 3: Chemical Application for Rice methods per Acre of Land in WKIS

A paired t-test on the relationships between various costs of rice inputs was done. Table 4.2 illustrates the findings.

Table 3: Paired Samples t-tests of Rice input costs

Paired variables	Mean (Kg)	St.dev	Std.error	t-value	Sig.
Water irrigation and fertilizers (DAP)	10427.3	5902.6	532.2	19.592	0.000
Top dressing and organic manure	15437.4	4524.1	407.9	37.844	0.000
Fungicides and pesticides	-448.78	518.73	46.77	-9.595	0.000

Source: Survey Data, 2012

Note: Paired samples test significant level at 5%; St. Dev means Standard deviation; Sig. shows Significance.

There is a significant difference between the means of costs of irrigation and costs of dia-monium phosphate (DAP) fertilizers at 5% level as indicated by the $\rho<0.000$, indicating increasing irrigation also increasing the amount of DAP fertilizers applied. This may be because the size of land irrigated would affect the amount of rice planted. Results also showed that increased costs of fungicide application reduce the costs of pesticides. The reason could be because for the aromatic rice variety, basmati 370 (where out of the 123 sampled households, 31 planted basmati 370 which is equivalent to 25%), it’s much prone to fungal disease, *blast*, hence requiring more application of fungicides and less pesticides, while the non-aromatic variety, IR2793 (where out of the 123 sampled households, 92 planted IR2793, which is equivalent to 75%), is more prone to pests, hence need for application of more of pesticides and less fungicides. The reason why most farmers (75%) planted IR2793 instead of basmati 370 is because the basmati variety is aromatic (sweet-smelling) and hence is prone to destruction by birds. These results are in concomitant with findings of Ogundele and Okoruwa (2006) where from 1954 to 2002, a total of 54 blast-resistant rice varieties were released to serve different ecologies and other specific needs in Nigeria, to help reduce costs of pesticides and fungicides.

As a major component of rice production, the cost of water irrigation is expected to affect the costs of other independent variables. The total cost of water irrigation had a positive and significant effect on the costs of hired labour in nursery bed preparation, hired labour in transplanting, hired labour in topdressing fertilizer, hired labour for cutting, transportation and spraying with correlation values of 0.517, 0.710, 0.512, 0.665, 0.512 all at 95% level). This means that when costs of water for irrigation go up the general costs of labour also increases. The reason for this is that the NIB base charges of irrigation water per unit area of land, such that as the land under irrigation is increased, the water charges are increased, and subsequently the other costs like labour costs are increased by virtue of the increased land size under rice. This is in agreement with the fact stated above that water charges are based on acreage of land. The respondents also indicated that diseases and pests, inadequate irrigation water and low prices of rice produced are the major problems facing rice farmers.

4.3.2 Rice Revenues to the Household

Farmers sell about 83% of rice harvested (on average about 3,500kg) and retain 500kg of the rice produced for domestic use. This means that most of the rice produced by the farmers is for sale. The findings also show that rice is generally a commercial crop, and the little consumed within the household indicates that rice is not a basic food for most of the respondents. Like in many parts of Kenya, maize is the basic food for domestic consumption. The price at which the farmers sell the rice varies depending on the season and outside demand. Majority of rice farmers (65%) sold 1 kg of rice at between KShs. 37-44 per kg while about 19% of farmers sold for between KShs. 45-52 per kg. The rest (4%) sold in the range of KShs. 53-60 per kg. Business process and marketing skills determines the price the household fetches in the market place. The rice farmers received on average KShs. 272,566 in sales yearly. Since the total average revenue is KShs. 283,396, it means that the rice consumed within the household is worth only KShs. 10,830. These results show that the rice is mainly consumed by people outside the local community. Hence, low rice consumption means that there is no local market to sale the rice. These findings imply that the farmers are totally dependent on outside market for their produce and therefore, the rice farmers were faced with stiff competition in the outside market on prices, which is disadvantaged by their low yields per acre and high costs of rice production.

To determine effect of various factors affecting household revenue levels, an analysis of variance (ANOVA) test was done. Results of the ANOVA test are given in table 4.3.

Table 4: Analysis of variance (ANOVA) of factors affecting household rice revenue

Grand Rice Revenue	Sum of squares	Df	Mean square	F	Significance
Total costs of Fertilizers (DAP)	7.629 2.36	35 122	2.180 1.840	1.185	0.260
Total cost of fungicides	2.710 3.435	35 122	774243.912 83371.648	9.287	0.000
Educating from rice production	262.825 265.659	35 122	7.509 0.033	230.579	0.000

(Source: Survey data, 2012)

Results in Table 4.3 above shows that the F-ratios for the variables are significant at 5% level which means that these factors act differently in their effects on household rice revenues. In other words, total costs of pesticides; and educating children using proceeds from rice production are the main factors that cause revenues to reduce or increase. The higher the F-value, the more the variable makes a greater difference (impacting) in affecting household rice revenues. However, total costs of DAP fertilizers was not really significant, implying that this factor affects rice revenues merely out of chance.

The revenues generated from rice production had a positive and significant correlation (0.628, $p<0.05$) with the improvements of children’s education. This means that the main motivation of farmers to do rice farming, and therefore generate rice revenues, thus resulting in the benefits of educating the children. Gender had negative and significant relationship (correlation of -0.434, $p<0.01$) with earned revenues, where females carried the weight of 1 and male 2, indicating that the male are the main beneficiaries of rice revenues. The reason for this may be that men, in Kenyan households generally have more say in not just investment decisions but also get the revenues of these investments. The age of the respondent did not correlated (-0.050) with rice revenues, showing that the age of the farmer does not affect the income earned from rice farming. In other words, the people of working ages can benefit from rice production when proper productivity is done. Education level of the household head had an inverse and significant (Pearson correlation of -0.300, p<0.01) effect on the amount earned from rice incomes. This means that the more the farmer is educated, the more likely he would reduce dependency on rice farming as major source of income due to price fluctuations and better access to other income opportunities.

4.3.3 Effects of Rice Technologies on Productivity

In order to understand the effects of different irrigation water regimes on rice grain yield under the SRI and conventional methods, their performance was assessed and compared based on their marginal yield means. Results in Table 4.4 show that by varying irrigation water regimes, the SRI irrigation water regime exhibited significant increase in rice yield of 2.26 tons/ha compared to conventional paddy irrespective of the rice variety and spacing used. Consequently, SRI demonstrated that it was more productive than conventional rice production method.

Table 5: Effect of different irrigation water regimes on rice grain yield (Tons/ha)

Irrigation water management technology	Mean	Std.Error	Lower Bound	Upper Bound
Conventional Paddy	6.31	0.126	6.05	6.57
SRI	8.57	0.126	8.32	8.83

Pair wise comparisons of rice grain yield for the two water regimes

Irrigation water management		Mean difference	Std. Error	Sig.^{a}	95% confidence interval	
					Lower Bound	Upper Bound
Conventional	SRI	-2.26*	0.177	0.000	-2.63	-1.90
SRI	Conventional	2.26*	0.177	0.000	1.90	2.63

*The mean difference is significant at 0.05 level.

(Source: Survey Data, 2012)

From table 4.4 it can be observed that the SRI method is more superior in yield performance compared with the conventional paddy method. To test further the other factors that influence rice productivity, the experiment had an interaction effect of rice variety, plant spacing and irrigation water regimes. Table 4.5 illustrates the findings. Further, the SRI method of rice production showed significant higher profits per growing season of between KShs. 20,000 to KShs. 50,000 per acre compared to conventional paddy method of rice production.

Table 6: Interaction effect of variety, plant spacing and irrigation water on rice yield

Plant spacing	Rice variety	Irrigation water management	Mean	Std. error	95% Confidence Interval	
					Lower Bound	Upper Bound
Conventional (15cmx10cm) or SRI (25cmx25cm	IR2798	Conventional	8.39	0.251	7.88	8.90
		SRI	11.19	0.251	10.68	11.71
	Basmati 370	Conventional	3.88	0.251	3.37	4.39
		SRI	7.12	0.251	6.61	7.63
Conventional (20cmx20cm) Or SRI (35cmx35cm)	IR2798	Conventional	9.01	0.251	8.50	9.52
		SRI	10.03	0.251	9.52	10.54
	Basmati 370	Conventional	3.96	0.251	3.45	4.47
		SRI	5.95	0.251	5.44	6.46

(Source: Survey Data, 2012)

Results of the influence of rice variety, irrigation water regime and spatial plant arrangement interactions on rice grain yield indicated that these variables had significant influence on grain yields attained as shown in table 4.5 above. Hence, the rice variety, SRI method and rice spacing affected rice yields. That is, these results indicate SRI method of irrigation water management significantly improved rice yields. The yield difference between convention system and SRI showed that when 12 days old transplanted seedlings for SRI are compared with 21 days old seedlings for conventional system, the yields for IR2793 rice variety when SRI used increased by up to 33.4 % compared to conventional. In the case of basmati 370 rice variety, SRI increased grain yield of up to 53.3 % compared to conventional.

The SRI and conventional methods of rice production also influence efficiency of irrigation water use and ultimately costs. Results indicate that SRI system saved about 64% of water compared with the conventional paddy system. Further, SRI technology had seed savings of up 75% compared to conventional method. Hence, the findings imply that the farmers who adopt the SRI system stand a better chance of increasing their production and hence their income from rice farming.

Majority (99%) of the farmers practiced conventional and partial SRI methods of rice production. Though the grand cost (input) is high for SRI method (at KShs. 91,360 for an acre) compared to KShs. 79,980 for Conventional and partial methods of rice production, the profit for SRI method surpasses that of Conventional and partial SRI by a margin of KShs. 46,895 for an acre size of land. The comparative performance of the rice technologies is illustrated in the figure 4.2 below. The figure shows that the grand revenue (which is the total revenue from the sales of rice) is higher for the SRI method than the conventional rice production. Even for the conventional method, the spacing of 20cm by 20cm of rice is better than that of 15cm by 10cm. The best spacing, however, that provides the highest revenue is that of SRI 25cm by 25cm. This gives an average income of about KShs. 188,343 per growing season compared with the best of conventional which is about KShs. 130,068 per growing season. Hence, for optimal rice yield and revenue generation, the rice method to use is SRI with spacing of 25cm by 25cm. The analysis clearly indicates that profit margin for Conventional 20cm by 20cm gives profit margin of KShs. 50,088, SRI 25cm by 25cm is KShs. 96,983 while profit through practicing SRI 35 by 35cm drops to KShs. 72,186. This was in agreement to observations made by Kipkorir (2012b) that SRI of 25cm by 25cm spacing was more profitable than SRI of 35cm by 35cm spacing.

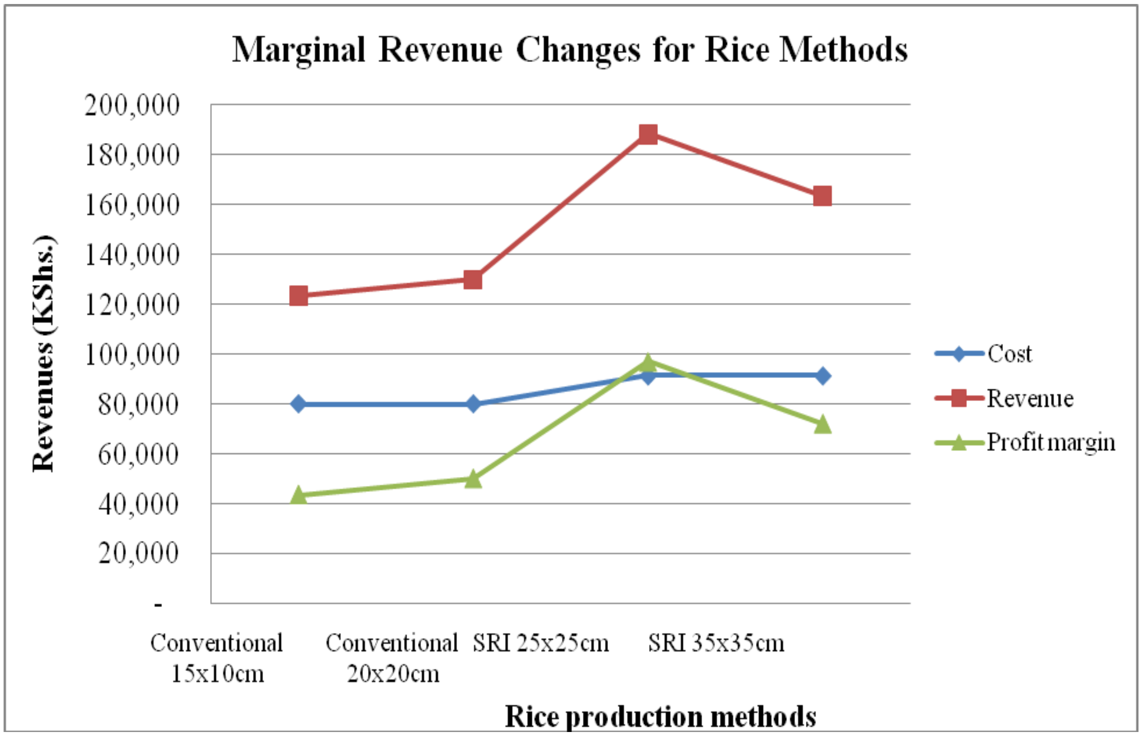

Figure 4: Marginal Revenue Changes for Rice Production methods

4.3.4 Factors affecting adoption and application of SRI

From focused group discussions (see Appendix 1), the following factors were listed and explained by the rice farmers as the constraints on adoption and application of SRI method. Pertaining to land preparation, leveling of farms was said to be very difficult. The young seedlings at age of between 8 to 12 days, as practiced in SRI, would immerse in water and would not grow if land leveling was not properly done. The other challenge was on transplanting of the rice seedlings. Farmers transplanted at different times, hence young seedlings would easily be flooded because by the time a farmer had just transplanted, the neighbor would be requiring a lot of water in his/her farm because his/her crops would for instance, be at booting stage, hence leading to flooding of the young seedlings, that would lead to drowning. This would be worsened by a scenario where an interested SRI farmer had a neighbor still practicing conventional paddy rice production method.

There was an attitude that nursery preparation for SRI was very expensive, and after doing calculations, it was realized that expenses incurred for SRI nursery preparation was cheaper than the Conventional one. For instance, while SRI only required 1m by 1m size nursery served by 5 to 8kgs of seeds only, which would serve a whole acre of transplanted rice, on the other hand, Conventional required 1/8 of acre size nursery served by 25kgs of seeds, that would serve an acre of transplanted rice. The calculations showed that SRI nursery costed KShs. 500, while Conventional nursery costed KShs. 2,500. Lack of uniformity, where some farmers were practicing SRI and some Conventional, such that if farm of SRI farmer was lower in gradient, then Conventional practicing neighbor floods his/her farm, it would end up flooding that of the SRI practicing neighbor. Inadequate knowledge on SRI was also cited as one of the constraints. The rice farmers needed more trainings and exposure tours to understand and appreciate more of SRI. These results were concordant with findings by Kipkorir, 2012b, where participants listed key challenges in adopting SRI, which included transplanting young seedlings (8 to 12 days), damage of young seedlings by birds, difficulty and high costs of leveling of rice fields, increase in number of weeding and unreliable water supply at the block level.

4.3 Determinants of Technical efficiency levels

4.4.1 Factors affecting the level of Technical Efficiency

Table 4.6 below shows the linear regression results of TE scores against explanatory variables as generated through STATA 12 computer programme. A standard error regression was done to address heteroskedasticity. The F-value indicates that the explanatory variables combined, significantly influence changes in the dependent variable; the bigger it is, the higher the significance. P-value is a measure of probabilistic level. P-value below 0.05 means the relationship between dependent and independent variable is high.

Table 7: Production function showing determinants of Technical Efficiency levels in rice production based on Experimental data

Variable	**Coefficient**	**Std. Error**	**t-value**	**P-value**	**F-value**	**Adjusted R^2**
Rice method	0.29	0.07	3.94	0.00	15.53	0.27
Constant	4.21	0.24	17.35	0.00		
Hired labour costs	3.70	0.72	5.11	0.00	26.09	0.39
Constant	-8.15	2.61	-3.13	0.00		
Rice variety	-0.51	0.10	-5.19	0.00	26.95	0.40
Constant	6.78	0.31	21.77	0.00		
Fertilizer	-0.51	0.10	-5.11	0.00	26.09	0.39
Constant	6.76	0.31	21.58	0.00		
No. of observation	40					

(Source: Survey Data, 2012)

Two (Rice method and hired labour costs) of the four mentioned significant factors were found to be positively related to and significantly affecting technical efficiency, which is in agreement with the estimation of stochastic frontier function in Table 4.8 below. Evidence being that they (in Table 4.6 above) had $P<0.05$ and high F-value.

Table 8: Production function showing determinants of Technical Efficiency levels in rice production based on Household data

Variable	Coefficient	Std. Error	t-value	P-value	F-value	Adjusted R^2
Rice method	3.43	0.54	-6.32	0.00	39.90	0.24
Constant	1.69	0.54	31.50	0.00		
Hired labour costs	1.63	0.00	339.55	0.00	0.00	0.00
Rice variety	-1.93	1.09	-1.76	0.00	3.11	0.02
Constant	1.53	0.06	27.67	0.00		
Fertilizer	-3.40	0.96	-3.55	0.00	12.63	0.09
Constant	6.19	1.33	4.66	0.00		
Household size	0.51	0.77	0.67	0.01	0.44	0.00
Constant	1.45	0.06	22.65	0.00		
Age of farmer	-2.08	0.71	-2.91	0.00	8.49	0.06
Constant	1.82	0.13	14.33	0.00		
Level of education	1.00	0.81	-1.24	0.22	1.53	0.00
Constant	1.59	0.11	15.11	0.00		
Experience of farmer	-1.05	0.64	-1.65	0.10	2.72	0.01
Constant	1.89	0.26	7.37	0.00		
Number of observation	123					

(Source: Survey data, 2012)

All the eight mentioned significant factors were found to be positively related, except level of formal education ($P>0.05$) and experience of farmer in rice production ($P>0.05$)

that had negative relationship with technical efficiency (Table 4.7), while all the eight mentioned significant factors were found to be significantly affecting technical efficiency. This means, level of formal education and experience of the farmer in rice growing did not have any significant effect on the TE. This may be attributed to the fact that as much as level of formal education is supposed to help in faster adoption of new technologies, the new SRI rice production technology was still in the process of being introduced at the time of the research, and only one farmer had adopted by the time of the survey. Most interesting is the high F-value (39.90) for rice method and F-value of 12.63 for fertilizer, which indicate that rice method and fertilizer application significantly affect TE of rice production.

Rice method ($P<0.05$) had a positive and significant effect on TE, which is in agreement with the earlier observation that SRI method had a positive effect on increased productivity, spacing of 25 by 25cm being the optimal on rice production, beyond which (as shown in Figure 4.2 at SRI 35cm by 35cm) reaches the point of diminishing returns. Age of farmer ($P<0.05$) and hired labour costs ($P<0.05$) were found to be positively and significantly affecting TE. The negative sign of t-value is associated with reduced activeness of the farmer as he/she grows old, and diminishing returns of hired labour, respectively. This is in agreement with findings of Ogundele *et al.,* (2006) that as farmer's age, there is a tendency that productivity will continue to fall owing to their declining strength, unless they hire the young in age, so that they utilize their high level of experience in guiding the youth, hence enhance production.

4.5 Technical efficiency and differentials in rice production methods

4.5.1 Estimation of Stochastic Production Frontier

A Stochastic frontier regression was conducted using the STATA 12 software. The frontier (rice method with optimal rice yields) of the various rice methods was determined as to be SRI 25cm by 25cm as shown in figure 4.2. The dependent variable of the estimated model was the grand revenue of rice out of SRI method of 25cm by 25cm spacing. This is the rice method that produced the highest rice yield from the experimental field trial plots as evidenced in figure 4.2. The independent variables are rice method, irrigation costs, hired labour costs and grand costs (herbicides costs, fertilizer costs and seeds costs).

Table 9: Estimates of the Stochastic Frontier Production Function

```
Stoc. frontier normal/half-normal model           Number of obs   =         40
                                                  Wald chi2(3)    =     188.45
Log likelihood =  127.36925                       Prob > chi2     =     0.0000

------------------------------------------------------------------------------
logofgrandrevenueinacre |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
------------------------+-----------------------------------------------------------------
logofirrigationwatercost |   .6185916   .7516988     0.82   0.411    -.8547109    2.091894
   logofhiredlabourcosts |   3.723957   .3848351     9.68   0.000     2.969694     4.47822
         logofvarieties |  -.5141337   .0526726    -9.76   0.000    -.6173701   -.4108974
                  _cons |  -2.070159   .6190349    -3.34   0.001    -3.283446   -.8568733
------------------------+-----------------------------------------------------------------
               /lnsig2v |  -9.206974   .2316158   -39.75   0.000    -9.660933   -8.753016
               /lnsig2u |   -15.5174   90.88661    -0.17   0.864    -193.6519    162.6171
------------------------+-----------------------------------------------------------------
                sigma_v |   .0100168     .00116                      .0079828    .0125692
                sigma_u |    .000427   .0194048                      8.89e-43    2.05e+35
                 sigma2 |   .0001005   .0000248                      .0000519    .0001492
                 lambda |   .0426294   .0197363                       .003947    .0813118
------------------------------------------------------------------------------
Likelihood-ratio test of sigma_u=0: chibar2(01) = 0.00   Prob>=chibar2 = 1.000
```

(Source: Survey data, 2012)

For the stochastic frontier function, results revealed that the marginal effects on technical efficiency are all positive except for rice varieties. The variance parameter, lambda, λ, for the translog function is approximately 0.0426, which implies that of the total variation captured by sigma squared, 4.26% is associated with positive effect on technical efficiency of the rice methods.

4.5.2 Estimation of Technical Efficiency

Technical efficiency (TE) was obtained using the STATA 12 Computer programme, estimated parameters of the log linear Cobb Douglas stochastic production frontier; using the SRI 25cm by 25cm as the frontier, compared to the least producer, Conventional 15cm by 10cm. TE computed for each field trial plot (for the experimental data) and for each household (for the farmers) was later disaggregated into two groups, that is, the Conventional and SRI rice methods. The following range of TE was generated as shown in tables 4.9 and 4.10 below, for experimental and household data, respectively.

Table 10: Frequency distribution of technical efficiency for rice production methods in percentages based on Experimental data

Ranges of efficiency	Conventional (n=8)	SRI (n=8)	Overall (n=16)
<20	0	0	0
20-39	0	0	0
40 – 59	35	0	17.5
60 – 79	15	20	17.5
80 – 99	50	80	65
Total	**100**	**100**	**100**

(Source: Survey Data, 2012)

On average, 65% of Conventional method are 60% and above range of efficiency while 100% of SRI method operated above the range of 60%. This may be attributed to production of high rice yield at low cost through SRI method compared to the Conventional method. On the other hand, 35% of Conventional farmers and 0% of SRI farmers were operating below 60% of technical efficiency and thus considered technically inefficient.

Table 11: Frequency distribution of technical efficiency for rice production methods based on Household data

Ranges of efficiency (%age)	Conventional (n=122) (%age)
<20	11.48
20 – 39	1.64
40 – 59	31.96
60 – 79	22.97
80 – 99	31.97
Total	**100**

N = 122

(Source: Survey data, 2012)

Results from analysis of the household data (Table 4.10) showed comparable results to that from the experiments (Table 4.9). The household data showed that 45.1% of farmers using Conventional methods to produce rice operated at levels below the average 60% range of efficiency.

4.5.3 T-Test Results of Technical Efficiency for Conventional and SRI methods

The STATA 12 computer programme was used to test and compare efficiency levels of rice methods, Conventional and SRI methods (Table 4.11).

Table 12: Differential in efficiency levels of SRI and Conventional rice production methods

```
. ttest  logsri25cmx25cm= logconv15cmx10cm

Paired t test
------------------------------------------------------------------------------
Variable |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
logsri~m |      10    .8302416    .0047043    .0148762    .8195998    .8408834
logcon~m |      10    .7463582     .023233    .0734692    .6938015    .7989149
---------+--------------------------------------------------------------------
    diff |      10    .0838834    .0194935    .0616437    .0397861    .1279806
------------------------------------------------------------------------------
     mean(diff) = mean(logsri25cmx25cm - logconv15cmx10cm)        t =   4.3032
 Ho: mean(diff) = 0                              degrees of freedom =        9

 Ha: mean(diff) < 0           Ha: mean(diff) != 0           Ha: mean(diff) > 0
 Pr(T < t) = 0.9990         Pr(|T| > |t|) = 0.0020          Pr(T > t) = 0.0010
```

A t-test was done between the profit margins of the optimal rice method, SRI 25cm by 25cm and of the lowest yielding rice method practiced by 80% of rice farmers in the scheme, Conventional 15cm by 10cm. The results show that the SRI method had a relatively higher level of mean technical efficiency (83.0%) than the Conventional method (74.6%), which is a significant difference (8.4%) between the two methods of rice production. These results indicate that SRI method is more efficient that Conventional method in rice production, which is in agreement to observations made above. This indicates that there is a big opportunity (25.4%) to increase technical efficiency for the farmers practicing the conventional method of rice production to increase the production capacity in West Kano irrigation scheme. This is unlike results obtained by Ogundele *et al.* (2006) where in Nigeria, the average technical efficiency for traditional rice varieties was 90.0% and that of improved rice varieties was 91.0% which was insignificant at 1.00% level only. This study was dealing with rice methods with a broader outlook than rice varieties alone.

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This chapter gives the conclusions as well as recommendations for policy implementations and areas that require further research. The purpose of the study was to find out the technical efficiency of rice technologies in West Kano irrigation scheme, Kenya. The stochastic frontier model (SFA) was used to estimate the efficiencies of SRI and conventional methods of rice production.

5.2 Summary of major findings

The study results showed that 89% of the households in the study area are farmers who depended on rice production for consumption and commercial purposes. Findings also indicated that the SRI system saved about 64% of water compared to the conventional paddy system. The Conventional method used 95% chemicals (inorganic fertilizers), compared to SRI method that used 5%, hence using lesser chemicals by 90%. The study also showed that SRI method had a relatively higher level of mean technical efficiency at 83% compared to the conventional method at 75%, indicating a significant difference of 8% between the two methods of rice production. These findings further show that SRI under wide crop spacing of 25cm by 25cm and younger seedlings of 8 to 12 days method is more efficient than the conventional method with random planting at closer spacing and older seedling age in rice production. Further, results demonstrate that the method of rice production is the major significant determinant of technical efficiency. This implies that the adoption of SRI with spacing of 25cm by 25cm is critical to the achievement of efficiency in rice production in West Kano.

5.3 Conclusions

The study made the following conclusions.

5.3.1 Major socioeconomic characteristics of households

The study revealed that the major socio-economic characteristics of households in West Kano irrigation scheme were age of farmer, level of education, experience of rice farming and household size. Since increase in number of years of rice farmers negatively affect efficiency, as they grow old, as much as they have advantage of being more experienced and have grown wiser, they lose energy needed to accomplish hard tasks in farming. Level of formal education and experience of farmer did not come out significantly affect technical efficiency of rice production, since it was observed that the new SRI rice production technology was still in the process of being introduced at the time of the research, and only one farmer had adopted it by the time of the survey. Enhancement of formal education to the households in West Kano will help in faster adoption of new rice technologies like SRI.

5.3.2 Economic significance of rice farming and technologies to the rural households

Study results indicated that rice is generally grown as a commercial crop, and little is consumed within the household indicating that rice is not a basic food for most of the respondents. Findings indicate that the SRI system saved about 64% of water and used lesser chemicals by 98% compared with the conventional paddy system. Further, the SRI method of rice production showed significant higher profits per growing season per acre compared to the conventional paddy method of rice production. This means that the new system of rice intensification (SRI) of spacing 25cm by 25cm, which involves intermittent wetting, drying of paddies and less chemicals, with better rice production practices is the best method to be adopted by rice farmers in West Kano irrigation scheme.

5.3.3 Determinants of Technical efficiency levels

In testing the determinants of technical efficiency in rice production, rice production method, as an independent variable, had a significant effect on efficiency. This means that the adoption of SRI is critical to the achievement of efficiency in rice production in West Kano. Hired labour costs ($P<0.05$) were found to be positively and significantly affecting TE which implies that there is diminished returns on hired labour. Therefore, there is need to introduce mechanized system that can improve effectiveness of labour inputs. Respondents indicated that diseases and pests, inadequate irrigation water and low prices of rice produced are the major problems facing rice farmers. These deterrents to productivity should be addressed by improving rice marketing strategies and better access to disease and pests control inputs.

5.3.4 Technical efficiency and differentials in rice production methods

In as much as most (89%) of the households in the study area are farmers who depend on rice production for consumption and commercial purposes, results revealed that rice farmers are not technically efficient in applying the conventional rice production method. Results showed that the SRI method had a relatively higher level of mean technical efficiency than the Conventional method. These results indicate that the SRI method is more efficient than the Conventional method of rice production.

It can be inferred that rice farmers practicing the conventional method are not getting maximum returns from resources committed to rice production. In order to ensure increase in rice production and to be equipped with market competitiveness, it is important to improve productivity by removing inefficiency in rice production. Water is a natural and scarce resource, essential both for agriculture in many regions of the world and to achieve sustainability in production systems. Improved technical efficiency of rice production in Western Kenya is important, considering its contribution to improved food security, increase smallholder rice farmers' income and poverty alleviation, contribution to employment creation in Western region, reduction of the national rice import bill and optimization of scarce water use.

5.4 Management and Policy Recommendations

Considering that 84% of the households were comprised of between 5 to 14 persons, it was recommended that as the rice farmers engage their family labour, it should be done in a manner that would not lead to low uptake of formal education among the young ones.

Most (88%) of the respondents indicated that their major source of income was farming, implying that for faster poverty reduction in the study area, rice production should be characterized with efficiency. The low rice yields by the Conventional paddy method as practiced by rice farmers in WKIS may undermine Kenya Vision 2030 social pillar (Social equity and Poverty reduction), hence need for adoption of rice production method with high yields.

Considering that water usage by the conventional paddy method, which was being practiced by 99% of the rice farmers, there was need for policy attention to be directed towards providing water-saving rice method, considering scarcity of the water resource. Water is a natural and scarce resource, essential both for agriculture in many regions of the world and to achieve sustainability in production systems, improved efficiency of rice productivity in Western Kenya is important, considering its contribution to the improved food security, increase smallholder rice farmers' income and poverty alleviation, contribution to employment creation in Western region, reduction of the national rice import bill and optimization of the scarce water resource. High dosage of chemicals by

Conventional paddy method is a great threat to water quality to the adjacent Lake Victoria, its fish and other biodiversity therein, hence need for government to develop specific policies to safeguard the Lake from eutrophication and loss of biodiversity out of the chemical dosage from rice fields. So as to facilitate faster adoption of the SRI method, the NIB should promote Farmers Field Schools (FFS) on the new technology (SRI) in West Kano rice scheme and other rice schemes in the country. There was need to introduce mechanized system that could improve effectiveness of labour inputs. Since the respondents indicated that diseases and pests, inadequate irrigation water and low prices of rice produced were the major problems facing rice farmers, these deterrents to productivity should be addressed by improving rice marketing strategies and better access to disease and pests control inputs.

In order to ensure increase of rice production and to be equipped with market competitiveness, it was important to improve productivity by removing inefficiency of rice production. Improved technical efficiency of the rice in Western Kenya was important, considering its contribution to the improved food security, increased smallholder rice farmers' income and poverty alleviation, contribution to employment creation in Western region, reduction of the national rice import bill and optimization of the scarce water use. For faster adoption of SRI method, rice farmers need training on SRI through Farmers Field Schools and exposure tours. Rice farmers needed training on SRI through Farmers Field Schools and exposure tours. There is also need of identifying SRI-method interested farmers so as to organize joint-effort leveling of their farm land.

5.5 Areas of Further Research

Provided below are the research findings out of the study.

a) Though this study found that SRI method uses less water and agricultural chemicals (inputs) to produce more rice, compared to the Conventional method, further research needs to be carried out on the environmental efficiency of the two rice methods in West Kano irrigation scheme. This will help in determining which method among the two is environmentally efficient than the other.

b) Further research should be done on allocative efficiency of the rice produced through the optimal rice production method (SRI) in order to define a cost-minimizing input mix, given market factor prices.

c) Further research should also be carried out on the valuation of irrigation water in West Kano scheme so as to help determine the correct charges on the water use; not only the operations costs as has been the practice. Charges on water will galvanize the rice farmers into efficient use of the resource.

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APPENDICES

APPENDIX I: PLATES

A) PLATES SHOWING VARIOUS LAND PREPARATION ACTIVITIES

(i) Top left – paddling

(ii) Leveling

(iii) Weeding using simple tools

(Source: Author, 2012)

B) PLATES SHOWING MEMBERS OF FOCUSED GROUP DISCUSSIONS

(i) Registered farmers for FGD, during transplanting, the researcher holding hands backwards

(ii) Right: Mid season of rice production, researcher is in black T-shirt

(Source: Author, 2012)

C) PLATES SHOWING RANDOMLY SELECTED PLOT SAMPLING POINT

(i) Metallic sampling quadrant

(ii) crop height measurement

(Source: Author, 2012)

D) PLATES SHOWING GRAIN YIELDS AND DENSITY MEASUREMENT

(i) Grain yield

(ii) Grain density measurement

(Source: Author, 2012)

APPENDIX II: PROCEDURE USED IN ADMINISTERING THE 123 QUESTIONNAIRES

Block No.	**Population (No. of tenant farmers/ Households)**	**Sample size**	**Percentage of population per block**
A	52	8	15
B1	42	7	17
B2	36	6	17
C1	40	6	15
C2	55	9	16
C3	15	2	13
C4	15	2	13
D1	60	9	15
D2	72	11	15
E1	67	11	16
E2	42	7	17
F1	62	10	16
F2	69	11	16
G1	26	4	15
G2	22	3	14
H	62	10	16
J	45	7	16
TOTAL	**782 Households**	**123 Questionnaires**	

(Source: Survey Data, 2012)

APPENDIX III: QUESTIONNAIRE FOR WEST KANO IRRIGATION SCHEME

Questionnaire No. ☐

Collaborating institutions: University of Eldoret and National Irrigation Board

I. IDENTIFICATION

1. Date: ....

2. Name of respondent (optional): ....

3. Tel No: ....

4. Irrigation scheme: ....

5. Village: ....

II. RESPONDENT'S CHARACTERISTICS

6. Household head respondent's gender: 1. ☐ Female 2. ☐ Male

7. Respondent's level of education:

1. ☐ None 2. ☐ Primary school 3. ☐ Secondary school

4. ☐ Technical/ College 5. ☐ Tertiary/ University 6. ☐ Adult literacy

7. ☐ Other (Specify)

8. Who in your family live and eat with you here? *(Multiple responses accepted)*

1. ☐ Husband 2. ☐ Wife 3. ☐ Children *(No. ....)*

4. ☐ Grand children *(No.....)* 5. ☐ Others *(who: ...., No. ....)*

9. What is the total of members of your household?

1. ☐ Between 5 to 9 persons 2. ☐ Between 10 to 14 persons

3. ☐ Between 15 to 19 persons 4. ☐ Over 19 persons

10. How long have you lived in West Kano irrigation scheme?

1. ☐ Less than 6 months 2. ☐ 6 months to 1 year 3. ☐ 1 to 2 years

4. ☐ 3 to 5 years 5. ☐ Permanent resident

11. What is the major source of income to the household? *(Multiple responses accepted)*

1. ☐ Fishing 2. ☐ Craftsman 3. ☐ Wage earning

4. ☐ Trading 5. ☐ Farming

12. What is the average household income per year?

1. ☐ Less than KShs. 30,000
2. ☐ Between KShs. 30,000 – 59,000
3. ☐ Between KShs. 60,000 – 119,000
4. ☐ Equal or more than KShs. 120,000

III. RICE PRODUCTION

13. What is the location of your rice field in the scheme: Field No...................; Block: ....

14. In relation to rice production, give the following land details:

Sr. No.	Farm input	Acres	KShs./ Acre
1.	Irrigated land allocated by National Irrigation Board		
2.	Irrigated land rented from others		
3.	Total area under rice farming (owned + rented) this season		
4.	Total land area under rice production last season/ year		
5.	Is the land under rice production currently,		
	a) 0. ☐ Owned		

	b) 1. ☐ Rented		
6.	If the land is rented for rice production, what is the rental cost per year?		
7.	Cost of irrigation water per acre in a growing season		

15. What technique of seed sowing do you use? 1. ☐ Transplanting 2. ☐ Direct sowing

16. At what age do you transplant the rice seedlings? *(Specify: .... days).*

17. When transplanting, how many seedlings do you plant in one planting spot? .... seedlings.

18. Do you space the seedlings when transplanting?

1. No ☐ 2. Yes ☐ 3. ☐ not Know/ No Response

19. If yes, what is the spacing you give between seedlings? ....

20. For each of the rice varieties that you grow, provide the following information:

Rank	Name of varieties (ranked)	Seed source	If purchased specify:		Preferred variety *(Tick one only)*
			Quantity (Kg)	Unit cost (KShs./ Kg)	
1.					

2.					
3.					
4.					
		1. Purchased (P) 2. Own (O)			

21. For a one acre irrigated paddy field, how much labour (hired + family) do you use for the following activities related to rice production and how much do you pay them?

Sr. No.	Activity	No. of people x No. of days (Hired labour only) (Man days)	Unit cost of hired labour (KShs./ 1 man day)
1	Nursery bed preparation		
2	Land preparation		
3	Transplanting		
4	Top dressing fertilizer		
5	Spraying		
6	Irrigation		
7	Weeding		
8	Cutting		
9	Heaping/ Staking/ Drying		
10	Threshing		
11	Transporting		
12	Guarding against birds destruction		
13	Other (Bagging, etc)		

22. Do you use any of the following farm inputs with rice, and if so, what is their source and unit cost per acre?

Sr. No.	Input	Yes	No	Source (Self/ Purchased)	Quantity/ acre used (units)	Unit cost (units)	Total cost/ acre (KShs.)
1	Seeds						
2	Fertilizers (Planting)						
3	Fertilizers (Top dressing)						

4	Pesticides						
5	Farm/ organic manure						
6	Compost						
7	Mulch						
8	Stakes						
9	Ties						
10	Other (specify)						

23. What is the source of the irrigation water that you use for rice growing? *(Multiple responses accepted)*

1. ☐ Borehole 2. ☐ Well 3.☐ Lake 4.☐
☐ ☐
River/ stream

5. Irrigation canal 6. Other *(Specify: ....)*

24. Do you pay for the irrigation water you use?

1. ☐ No 2. ☐ Yes 3. ☐ Do not Know/ No Response

25. If yes, how much do you pay per year? ....

26. What was the rice output for the last growing season?

1. Total harvested (..................... Kg)
2. Total sold (..................... Kg)
3. Total for domestic use (..................... Kg)
4. Rice price per unit sold (..................... KShs./ Kg)

27. How many years have you been actively involved in farming? .... years.

28. How many years have you been growing rice? .... years.

29. How many seasons do you grow rice annually? ....

30. What problems do you encounter in the rice production? *(Multiple responses accepted)*

1. ☐ Lack of quality seeds
2. ☐ High cost of fertilizers
3. ☐ Diseases/ pests
4. ☐ Inadequate irrigation water supply
5. ☐ Poor drainage
6. ☐ Inadequate grain storage facility
7. ☐ Access to loan
8. ☐ Low rice prices
9. ☐ Deterioration of soil fertility
10. Others *(Specify)*

....

11. ☐ Do not Know/ No Response

31. In the past year, how many times did you participate in a meeting or demonstration on how to grow/ manage rice? ....

32. What actions and incentives would encourage farmers to use water more efficiently? *Rank top four most important.*

0. ☐ Water scheduling equipment 1. ☐ Efficient irrigation equipment

2. ☐ Training 3. ☐ Information on the crops

4. ☐ Information on new markets 5. ☐ Water pricing

6. ☐ Encourage compliance with regulations 7. ☐ Water meters

8. ☐ Other *(specify)* ....

33. How many times do you weed the rice from transplanting up to harvesting? ....

34. What is the weeding interval (in days) after transplanting up to harvesting? .... days.

35. What is the method used in weed control?

1.☐ Mechanical 2.☐ Manual hand pulling 3.☐ Hand hoe

4.☐ Herbicides 5.☐ Other methods *(Specify)* ....

IV. FOOD SECURITY

36. What is your staple food?

1. Ugali ☐ 2. Rice ☐ 3. Githeri☐

4. Other (*specify*) ....

37. How many kg of maize flour/ rice does your family consume per day? ....Kgs.

38. How many maize/ rice bags do you produce per year? ....

39. How many maize/ rice bags did you use to produce annually, approximately 5 to 10 years ago, if by then you had already started rice production?

....

V. CONSTRAINTS TO SRI

40. Do you practice full SRI (i.e. all principles of SRI)?

1. ☐ No 2. ☐ Yes 3. ☐ Do not Know/ No Response

41. If yes, which principles of SRI do you practice? List them

....

....

42. If no, do you practice some (i.e. not all) principles of SRI?

1. ☐ No 2. ☐ Yes 3. ☐ Do not Know/ No Response

43. If yes, which principles of SRI do you practice? List them

....

....

44. If no in question 40 above, why don't you practice SRI?

....

....

....

45. Do you keep cows?

1. ☐ No 2. ☐ Yes 3. ☐ Do not Know/ No Response

46. If Yes, how many cows? (Optional)

....

47. What are the constraints that make you not to adopt SRI? List them

....

....

………

VI. EDUCATION

48. Do you have children that you have educated using proceeds from rice production?

1. Yes 2. No

49. If yes, to which level of education have they reached?

1. ☐ None 2. ☐ Primary school 3. ☐ Secondary school

4. ☐ Technical/ College 5. ☐ Tertiary/ University 6. ☐ Adult literacy

7. ☐ Other (Specify)

VII. EMPLOYMENT

50. Does rice production lead to job creation in this area?

1. Yes 2. No

51. If yes, list down the type(s) of jobs that it leads to and their respective wages/ salaries?

………

………

………

VIII. ANY OTHER COMMENT ON ISSUES OF RICE PRODUCTION IN THIS AREA

………

………