

ESTIMATING RICE PRODUCTION EFFICIENCY IN KENYA;

CASE STUDY OF MWEA IRRIGATION SCHEME

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DECLARATION

This project is my original work and has not been presented for examination to any other University.

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Supervisor's Approval

This project has been submitted for examination purposes with my approval as the University supervisor.

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List of Acronyms and Abbreviation

ASARECA	Association for Strengthening Agricultural Research in Eastern and Central Africa
ASDS	Agricultural Sector Development Support
CAADP	Comprehensive Africa Agriculture Development Programme
CARD	Coalition for African Rice Development
EAC	East Africa Community
ECARRN	Eastern and Central African Rice Research Network
ERS	Economic Recovery Strategy
FAO	Food and Agricultural Organization
FARA	Forum for Agricultural Research in Africa
GATT	General Agreement on Tariffs and Trade
MDG	Millennium Development Goals
MMRGC	Mwea Multi - Purpose Rice Growers Cooperative Society
MOA	Ministry of Agriculture
NEPAD	New Partnership for Africa's Development
NIB	National Irrigation Board
OECD	Organization for Economic Co-operation and Development
PSRP	Public Sector Reforms Programme
TICAD IV	Tokyo International Conference on Africa Development
WTO	World Trade Organization
WUA	Water Users Association

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CHAPTER ONE: INTRODUCTION

1.1 Background of the Study

The analysis of agricultural systems and how effective and competitive they are is currently influenced by new visions concerning the role played by farming in a broad societal context. The traditional crop production function is being downplayed, while there is an increasing concern with the role of farming in the stewardship of nature. Also, the ability of agriculture to sustain meaningful economic activity in low potential areas, receives considerable attention within the context of rural development policies in developing countries. Rice production is mostly in irrigated schemes. The infrastructure developed for rice farming in the schemes provides for flooded rice fields. The rice fields are of vital importance not only to food chain but also supports a wealth of biodiversity

Globally rice is one of the most important food crops. According to FAO, the total annual world production of milled rice currently stands at 400 million metric tons which compares favourably well with maize and wheat. Moreover, unlike maize and wheat that are consumed as human and livestock feed, rice remains the most favoured grain globally for human consumption (Ito, 2002). According to the World Food Summit 1996 - Millennium Development Goals (MDG), development of rice farming presents an opportunity to reduce the number of gravely food insecure people that stood at 816 million by half by the year 2015.

Many African countries have embarked on cutting down imports and focussing on local production of rice. Due to its importance, international partners and Pan-African initiatives such as FAO, NEPAD, CAADP, FARA, ECARRN, ASARECA and EAC have shown interest in research and development for benefit of the livelihoods of communities living particularly in sub Saharan Africa. In Kenya for instance, after the Tokyo International Conference on Africa Development (TICAD IV) meeting held in Tokyo, Japan in May 2008, the Coalition for African Rice Development (CARD) was formed whose aim was doubling rice production in Sub-Sahara Africa by 2018 by promoting the value chain approach.

1.1.1 Rice Production in Kenya

Rice cultivation was introduced in Kenya in 1907 from Asia. It is currently the third most important cereal crop after maize and wheat. It is grown mainly by small-scale farmers as a commercial and food crop. About 80% of the rice grown in Kenya is from irrigation schemes established by Government where Mwea irrigation scheme produces more than 60%. Only 20% is produced under rain-fed conditions. The ability of rice farmers in Kenya to adopt new agricultural technologies is affected by farmer and farm characteristics. Examples of such characteristics include age and household size of rice farmers, level of education and total number of years of schooling, total land area used for rice production, distance of farms from farmer's residence, and farmer's managerial ability or experience in rice farming. Others are off farm work, extension visits and benefit of credit facility. High illiteracy rates affect farmers' ability to adopt new agricultural practices and to effectively mobilize and apply production inputs. Rice farmers also face high input costs (fertilizer, pesticides and machine power) and they lack incentives.

It is important to note that rice forms an important diet for the majority of urban dwellers in Kenya. Its annual consumption is estimated to be increasing at a rate of 12% as compared to 4% for wheat and 1% maize, which is the main staple food (MOA). 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 2011). The deficit is met through imports which were valued at Kshs 7 billion in 2008.

Promotion of rice production is aimed at improving food security, increase smallholder farmers' income, contribute to employment creation in rural areas and reduce the rice import bill. The country has a potential of about 540,000 hectares of irrigable land and 1.0 million hectare rain fed for rice production (MOA, 2010). With improved water harvesting, storage, underground water resource utilization and innovative management technologies, the current irrigation potential can be increased by a further 800,000 ha to 1.3 million hectare (MOA, 2010).

1.1.2 Mwea Irrigation Scheme

Mwea Irrigation Scheme is situated in Kirinyaga county of Kenya. The Scheme is about 100 Km North East of Nairobi. Since in 1956, rice has been the predominant crop in the scheme. A total of 16,000 acres has been developed for paddy production in this scheme by use of irrigation water. Land tenure is on tenancy basis.

Since inception till 1998 the scheme was being run by various government agencies. In 1998, the scheme management was taken over by Mwea Multi - Purpose Rice Growers Cooperative Society (MMRGC). MMRGC lacked enough capacity to manage the scheme due to, unskilled personnel, lack of finances and lack of machinery for scheme maintenance. In 2003, the scheme reverted back the government management.

Currently, the scheme is being run by National Irrigation Board (NIB), and the farmers Organizations, mainly the Water Users Association (WUA). NIB is responsible of the entire main irrigation infrastructure while WUA is responsible of water management. Marketing of rice is open for farmers to decide where to sell.

1.2 Statement of the Research Problem

The Kenyan rice sector has recorded modest improvements in the last few years particularly in terms of yield and aggregate production, but the gap between supply and demand continues to increase. As such, rice imports continue to make up for this shortfall and account for greater proportion of Kenya's total food imports

The Ministry of Agriculture and the Agriculture Sector as a whole have been involved and affected by the various reforms and plans of the Government over the years. These reforms such as PSRP, ERS, ASDSP and now Vision 2030 are mainly geared to ensuring food security, food self sufficiency and poverty reduction among the people of Kenya. Following these reforms and in cognizance of Vision 2030, the Ministry of Agriculture developed the National Rice Development Strategy which aims to, among other things, double rice production in 10 years (from 2008 to

2018). The strategy emphasis production on irrigated and rain fed lowland ecologies where there exist suitable climatic conditions, expansion and increased productivity potential.

In a bid to address the demand/supply gap, the government has at various times come up with different policies and programmes. These policies have not been consistent but erratic reflecting the dilemma of securing cheap rice for consumers and a fair price for the producers. Thus, the fluctuations in policy and the limited capacity of the Kenyan rice sector to match domestic demand have raised a number of pertinent questions both in policy circles and among researchers. For instance, what factors explain why domestic rice production lag behind the demand for the commodity in Kenya? Central to this explanation could be the issue of efficiency of rice farmers in the use of resources.

Comprehensive and up-to-date information about the level of resource use efficiencies of rice farmers is lacking. The few available studies are mostly system based focusing primarily on the profitability of the enterprise and its competitiveness in comparison to imports but without in-depth enquiry into efficiencies of farmers and factors that determine their levels of efficiency. Thus, the main focus of this study is to examine the levels of efficiency of these farmers and explain those factors that determine their levels of efficiency.

Food production is at the heart of the Kenyan economy. Agriculture which involves 70 per cent of the workforce of the country is looked upon to provide needed food, income, employment and export earnings for the economy. However food deficits have been a perennial problem in the country necessitating imports to fill the gap. The demand for rice in the country in general is growing much faster than for any other grain, with both the rich and the urban poor relying on it as a major source of calories. Today rice has become particularly prominent in the economy and society of Kenya. Its production and consumption have generally increased over the years, from a status of mere occasional meal to being a major staple and it is widely consumed in urban and

rural areas. Against the foregoing background, this study will seek to answer the question; how is the production efficiency of rice in Kenya and more specifically the Mwea Irrigation Scheme?

1.3 Objectives of the Study

1.3.1 General Objectives

To analyze the production efficiency of rice in Kenya and more specifically the Mwea Irrigation Scheme

1.3.2 Specific Objectives

The study was governed by the following specific objectives:

- i) To investigate the factors influencing efficiency of rice production in Mwea Irrigation Scheme.
- ii) To estimate the efficiency levels in rice production in Mwea Irrigation Scheme.
- iii) To give conclusions and policy recommendation based on the observations.

1.4 Significance of the Study

The study supplements the existing literature concerning rice production in Kenya. It is also essential for the policy makers who would wish to promote rice production by promoting efficient and competitive farm practices.

The study provides valuable information on the production efficiency of rice production in Kenya. The information is beneficial to the government, development agencies and farmers working on the area related to the study.

There is no doubt that other researchers would build on the findings of the study to carry out further research to confirm, expound , improve or enrich the study findings.

1.5 The Scope of the Study

The study was limited to rice production in Mwea Irrigation Scheme. Rice production was chosen for the study since it forms an important diet for the majority of both rural and urban dwellers. Consequently the government of Kenya has focused on its production since 1998. Additionally, people in Mwea depend on rice production as income generating activities. The study utilized both primary and secondary data.

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

This chapter covers the theoretical framework and the empirical literature.

Theoretical Framework

2.2.1 Irrigation Management and Rice Production

The section discusses the irrigation management as well as the factors that affect productivity in irrigation schemes. According to Ngigi (2002) there is evidence that in the last two decades, the production from the agriculture sector has not been able to match the ever increasing population. Therefore this being the case, development of irrigation is viewed as one of the largest potential that can be embraced to address the challenge of population increase despite the high costs involved in the development of irrigation.

Several studies have revealed that production under irrigation schemes is influenced by a number of factors. Some of the notable factors are, total area used for cultivation, water availability, fertilizer use, labour and others factors such as farmers' level of education, management structures and institutions. Pandey and Suresh (2007) noted that there was a strong growth in the production as a result of increases in the area used for cultivation purposes. Thus land is thus considered as a very important factor if high production levels are to be achieved.

Todaro and Smith (2009) on the other hand observed that reasons for the higher agricultural output and the instantaneous achievement of both superior efficiency and more equity that land reform is often seen as a necessary first condition for agricultural development in many developing countries.

Availability of water was also seen to play an important role on the performance of an irrigation project in that it also indirectly has an influence on the cost associated with the project. Innocencio *et al* (2007) was able to use the annual rainfall and conjunctive use of surface water and underground water as a proxy for water availability. In their study they found out that in Sub Saharan Africa, the irrigation projects situated in areas where more water was available have a

tendency of being smaller in size and do not require storage facilities. Bardhan (2000) found out that reform in the utilization of water was important in building cooperation in community institutions. In his study of Indian's farmers, he observed that Indian farmers were able to set formal water rights which were opposed to the customary rights which in turn improved their probability of cooperation among the community. In addition to this the availability of water also influenced the types of crops farmers choose and the corresponding varieties which has an impact on the performance of any given irrigation project set up.

The way fertilizer is used is another factor that affects productivity. According to Food and Agriculture Organization after land and water, fertilizers are the other most significant inputs that can lead to increased yields as they were found to be responsible for around 55% of the expected increase in production in the developing countries in the years 1965-1976. It is further noted that efficient use of fertilizer expands most rapidly on land that is irrigated and the returns are mostly greatest as opposed to a much more slowly on rainfed land and more particularly in areas with low-rainfall (Food and Agriculture Organization, 1981).

The amount of labour that farmers hire is another important factor that influences rice productivity. Noij and Niemeijer (1988) found out that by decreasing or increasing the amount of labour hired or by optimizing the moment at which labour is hired, farmers are likely to improve on paddy yields. The critique of their observation is that as much as they consider labour amounts, they failed to take into account the relationship between the quality of labour offered and the level of yields. This is to say that the level of yield could still be improved through the upgrade of the techniques used in the cultivation of rice.

Other relevant studies argue that apart from labour, size of land and availability of water the level of education of farmers also has an effect on rice production. Pudasaini (1983) found out that the level of education of farmers contributed to agricultural production in Nepal as a result of worker and allocative effects. He further observed that although levels of education improve agricultural production through making better the ability of the farmers' decision making capability, it differs from one environment to another. On the other hand Kalirajan and Shand (1985), made a counter argument of the observation of Pudasaini by stating that even though the levels of education have an effect on productivity, the levels of schooling does not necessarily or significantly relate to the level of yield. This is so because even those farmers who are illiterate or semi-illiterate can still

understand modern production technologies and use them same way those farmers who are educated can on condition that the modern technology is properly communicated. Using a case study of rice farmers from Tamil Nadu (Kalirajan, et al 1985) assessed different types of education in relation with efficiency and competitiveness in an endeavor to determine whether farmers' levels of schooling had a superior impact on the level of yield in comparison to non-formal education among farmers. They found that educational level of the farmers had an impact on yield though it was insignificant, and a farmer's non-formal education had a significant and bigger influence on the yield thereby concluding that the farmers' level of schooling and productivity should not always be significantly related.

Another central factor that is seen to largely affect the output in large-scale irrigation schemes is management of the schemes. Uphoff (1985) supports irrigation analysts and different agencies of development who have found out irrigation management as a very significant factor that affects productivity in irrigation projects. According to them management consists of a technical infrastructure of the scheme and an institutional framework which determines the use of that infrastructure. These two are both important in the success of the irrigation system. If they are efficient and competitive there is the likelihood that they will improve on the productivity of irrigation projects. Therefore there is need to have capacity in the institutions to be able to manage all the factors affecting productivity thus ensure that schemes are able to operate to their full capacity. Ruigu (1988) observes that some degree of control and discipline in the institutions is required in an organized community such as Ahero where the well being of the tenants and of the schemes are dependent on the performance of a technically determined cycle of activities without which productivity cannot be achieved.

Institutions play a very crucial role in the formulation and operation of any economic or social policy. In irrigation schemes, the management thus sets the rules and regulations which specify the rights and obligations of both the tenants or farmers on one hand and the management team on the other. Therefore it is important to have a strong institutional capacity to bring the different factors together in order to enable the irrigation project achieve maximum results. This is consistent with the theory of management of common property resources.

2.2.2 Efficiency Model

Farrell (1957) is credited as the pioneer who introduced the frontier measures of efficiency and identified three major components in the concept of efficiency namely allocative, technical and economic which can all be gotten from the production function. According to Farrell technical efficiency is associated with the ability to produce on the frontier isoquant and allocative efficiency refers to the ability to produce at given level of output using the cost minimizing input ratios. In other words, allocative efficiency deals with the level to which farmers are able to make efficient decisions in relation to the use of inputs up to the level in which their marginal contribution to the production worth is equal to the marginal cost. Economic efficiency is the product of technical and allocative efficiency.

According to Ellis (1988), technical efficiency is the extent to which the maximum possible output is achieved from a given combination of inputs. A farmer is therefore said to be technically efficient if he/she produces along the production frontier and technically inefficient if production occurs on the interior of the production frontier.

In economic literature many alternative ways are available for measuring production efficiency. For example Lau and Yotopoulos (1971) were able to utilize a profit function. A crucial feature of the profit function analysis is that it assumes firms behave according to certain decision rules, which include the profit maximization rules, given the price regime for output and variable inputs and given quantities of their fixed factors of production. Estimates obtained by fitting the profit function are statistically consistent. Using this methodology Lau and Yotopoulos finding were small farms attain higher levels of price efficiency (i.e. optimal price behavior) and/or operate at higher levels of technical efficiency.

Aigner *et al.* (1977) and Meeusen and Van Dan Broeck (1977) on the other hand argued that the use of profit function in the measurement of productive efficiency did not provide the numerical measure of efficiency. They independently proposed stochastic frontier function to account for the presence of measurement error in production and in the specification and estimation of frontier production function. The error term is composed of two parts i.e. measurement error (statistical noise) and shocks outside the farmers control.

There have been many applications of the frontier production functions to agricultural industries. Some studies draw attention to applications that investigate relationship between technical efficiency and various social economic variables such as age, level of education of farmer, farm size, access to credit and availability of extension services. Most of the applications which seek to explain the differences in technical efficiency of farmers use a two stage approach. Ghosh *et al* (1991) and Battese and Coelli (1995) have utilized this framework. The first stage involves estimation of stochastic production function and the prediction of the farm-level technical inefficiency. In the second stage, these predicted technical inefficiency effects are related to farmer-specific factors using ordinary least-squares (OLS) regression. The use of OLS however, contradicts the assumption of identically distributing inefficiency effects in the stochastic frontier function.

2.2.3 Review of Production Frontier Models

The estimation of production frontiers has proceeded along two general paths. The first is the full frontier which expects that all observations to be on or below the frontier and hence where all deviation from the frontier is attributed to inefficiency. The second general path is the stochastic frontiers, where deviation from the frontier is decomposed into random components reflecting measurement error or statistical noise, and a component reflecting inefficiency. The estimation of full frontier could be through a non-parametric approach (Meller, 1976) or a parametric approach where a functional form is imposed on the production function and the elements of the parameter vector describing the function are estimated by programming (Aigner and Chu, 1968) or by statistical techniques (Richmond, 1974; Greene, 1980).

The notable drawback of these techniques is that they are extremely sensitive to outliers. Hence, if the outliers reflect measurement errors they will heavily distort the estimated frontier and the efficiency measures derived from it. The stochastic frontier approach, however, appears superior because it incorporates the traditional random error of regression. In this case the random error, besides capturing the effect of unimportant left out variables and errors of measurement in the

dependent variable, would also capture the effect of random breakdown on input supply channels not correlated with the error of the regression.

Measurement of efficiency started with Farrell (1957) who, following Debreu (1951) and Koopmas (1951), proposed a division of efficiency into two components: technical efficiency, which represents a firm's ability to produce a maximum level of output from a given level of inputs, and allocative efficiency, which is the ability of a firm to use inputs in optimal proportions, given their respective prices and available technology. The combination of these two measures yields the level of economic efficiency. There are several approaches to analyse the determinants of technical efficiency from stochastic production frontier functions. One set of authors followed a two- step procedure in which the frontier production function is first estimated to determine technical efficiency indicators while the indicators thus obtained are regressed against a set of explanatory variables that are usually firm-specific characteristics. Authors in this category include Pitt and Lee (1981), Kalirajan (1981), Parikh and Shah (1995), Ben-Belhassen (2000), and Ogundele (2003). While this approach is very simple to handle, the major drawback is that it violates the assumption of the error term. In the stochastic frontier model, the error term, the inefficiency effects are assumed to be identically and independently distributed (Jondrow et al., 1982). In the second step, however, the technical efficiency indicators obtained are assumed to depend on a certain number of factors specific to the firm, which implies that the inefficiency effects are not identically distributed.

This major drawback led to the development of a more consistent approach that modelled inefficiency effects as an explicit function of certain factors specific to the firm, and all the parameters are estimated in one step using maximum likelihood procedure. Authors in this category include Kumbhakar, Ghosh and McGuckin (1991), Reifschneider and Stevenson (1999), Huang and Liu (1994), and Battese and Coelli (1995), who proposed a stochastic frontier production function for panel data. Other authors in recent time include Ajibefun, Battese and Daramola (1996), Coelli and Battese (1996), Battese and Sarfraz (1998), Seyoum et al. (1998), Lyubov and Jensen (1998), Ajibefun and Abdulkadri (1999), Weir and Knight (2000), Obwona (2000), and Ajibefun and Daramola (2003).

2.2.4 Stochastic Frontier Analysis

According to Rahman (2003) in a production function concept, a farm is said to be technically inefficient, for a given set of inputs, if its output levels are below the maximum flexible output or the frontier output. As proposed by several authors the most popular approach to measure the efficiency of farms is through the use of frontier production function (Tzouvelekas *et al.*, (2001); Wadud and White, (2002); Sharif and Dar, (1996); Russell and Young, (1983)). This measurement of firm level efficiency has become commonplace with the development of frontier attributed to inefficiency, or stochastic, which is a considerable improvement, since it is possible to distinguish between random errors and differences in inefficiency.

Aigner *et al.* (1977) and Meeusen and Van den Broeck (1977) were the first to develop the stochastic production frontiers. This frontier is now widely utilized and reported in literature in relation to the measurement of farm performance (Battese and Coelli 1992, Coelli and Battese 1996, Kompas and Che 2006). In relation to this model the specification allows for a non-negative random variable denoted by μ_i , which is associated with the technical inefficiency (TE) of the i -th farm, to be generated, in addition to the normal error term, v_i , to be utilized to capture random variation in output expected as a result of factors which are beyond the control of farms. These factors include the variation in weather patterns of the regions, measurement error unexpected or any unspecified input variable in form of materials and fertilizer. The random error term can be positive or negative, and thus the frontiers vary about the deterministic part of the model, $\exp(x_i\beta)$.

The specification in the stochastic production frontier can be formally expressed by:

$$Y_i = f(X_i, \beta) e^{v_i - \mu_i}$$

As proposed by Kompas and Che ,(2006) Y denotes output, X the factor inputs, the subscript i identifies the farm. While β represents the parameters to be estimated and e is the error term reflecting both inefficiency, μ_i and noise factors, v_i . Therefore the production frontier shows the relationship between inputs in the form of labour, fertiliser, seed and outputs such as crops. The value of β on the other hand indicates the relative importance of each input to the production process.

A parametric production frontier needs to assume a functional form and two forms that are relatively easy to derive and commonly used in efficiency analysis are the Cobb-Douglas and the translog production functions.

A Cobb-Douglas stochastic frontier, using the terminology of Coelli *et al.* p.184 (1998) is defined by:

$$\ln(y_i) = x_i\beta + v_i - u_i \quad i=1,2,\dots,N$$

where

- $\ln(y_i)$ is the logarithm of the output of the i -th sample farm ($i = 1, 2, \dots, n$)
- x_i are the logarithms of the input quantities used by the i -th farm
- β is a column vector of unknown parameters to be estimated
- u_i is the technical inefficiency (TE) of the i -th farm and in this case study assumed to be an independent and identically distributed (i.i.d.) half normal random variable, and v_i is the random error term, assumed to be an i.i.d. normal random variable with mean zero and constant variance, σ_v^2 , independent of the u_i .

2.3 Empirical Studies

Rice production has been the focus of attention of a number of studies of technical inefficiency in developing country agriculture. This reflects the importance of rice in development of many developing countries. Akande (1994) carried out a study on the inter-regional competitiveness in relation with the production of food grains among them rice in Nigeria. He found out that, given what the economic environment was as well as the factor cost relationships that were present in Nigeria in the early 1990s, the country had comparative benefit in rice production. This comparative benefit is associated with traditional and enhanced production practices and animal traction systems that were embraced the Nigerian people. For example the fully-mechanized or gravity-irrigated techniques adopted which relied heavily on foreign outlays and heavy machines were found not to be competitive in any of the regions in Nigeria.

Rahman (2012) conducted a study to estimate the farm-size-specific productivity and technical efficiency of all rice crops using stochastic frontier approach in Bangladesh. The findings were that large farms exhibited the highest productivity, gross returns were highest in small farms and net returns were highest for marginal farms. The study concluded that there were significant technical inefficiency effects in the production of rice for marginal farms. In this case, production cannot be increased by increasing efficiency with the existing technology.

Khai & Yabe (2011) carried out a study to estimate technical efficiency of rice production in Vietnam and identify its determinants using stochastic frontier analysis method in the Cobb-Douglas production function. They identified intensive labour, irrigation and education as the most important factors having positive impact on technical efficiency which was calculated at 81.6%. The study findings suggest that increase in output and decrease in cost could be obtained using existing technology.

Randolph *et al.* (1994, 1996) carried out several studies targeting countries such as Sierra Leone, Niger, Burkina Faso, Mali and Senegal the main focus being on rice production efficiency. The same set of studies that were undertaken were against the backdrop of structural modification reorganization programme whose implementation was from the 1980s which had given a clear

indication that the said reforms will have a moderating effect on the economic practicality of rice production the regions under study. From their findings it is indicated that the efficiency and competitiveness of rice producing farmers was predominantly improved by the readjustment of exchange rates. This was the case because it made the imported rice less affordable to consumers in the urban setup. On the other hand the exchange rate readjustment programme had some notable shortcoming for the growth of certain types of rice production methods, chiefly the systems which relied greatly more on tradable inputs and had profited from considerable support from government in relation to investment in various important infrastructure.

Bogahawatte, (1982) also did a study for Sri Lanka which included equations for rice area irrigation, lagged rainfall, the proportion of total rice area plated to modern varieties, agricultural credit, the area under crop insurance, the lagged paddy area under production, and a ratio of the guaranteed price of paddy rice to a weighted average of the guaranteed prices of substitute food crops. Bogahawatte found out that for wet zone only the proportion of rice area planted to modern varieties was statistically significant at a 5% significance level. On the other hand for the dry zone, lagged rainfall, the proportion of rice area planted to modern varieties, the area under crop insurance, and the ratio of guaranteed prices were all statistically significant at the either the 1% or 5% level. The R^2 's were 0.559 and 0.870 for the wet and dry zones, respectively.

Equally, Mellish, (1980) carried out a study of U.S. rice acreage in five states which included Mississippi, Texas, Louisiana, Arkansas, and California where he used harvested acreage as the dependent variable. On the other hand he used the independent variables such as lagged nominal prices of rice multiplied by the ratio of allotted acreage to potential acreage, carryover stock, lagged area harvested, and technology which was represented by a time trend. He observed that the lagged price variable was insignificant for most states, except Arkansas and Louisiana, where they were significant at the 10% level. He also found out that rice stocks were significant at the 1% level in both Texas and Louisiana but significant at the 10% level in Mississippi. The study found out that the lagged area harvested was significant at the 5% level in Arkansas whereas technology was significant at the 1% significant level in Texas and Louisiana but at the 5% level in California.

Kuria et al (2003) undertook a study using stochastic frontier to investigate the technical efficiency associated with two groups of farmers producing rice in Kenya. One group was planting a single crop per year and the other group planting double crop of rice per year. They found out that farmers growing a single crop per year were more technically efficient than those growing a double crop.

Gitau et al (2010) carried out a study on trade and agricultural competitiveness with attention to wheat and rice production in Kenya by applying value chain analysis. They identified inefficiencies along the rice value chain that include high labor costs, high rates of rural-urban migration, and water borne disease. They also observed that costs of fertilizer, chemicals and seeds are high, while yields were low and that changing weather patterns have reduced the amount of water flowing to the schemes.

2.4 Over View of the Literature

Improvement in production efficiency is the best option in productivity enhancement. However review of literature reveals a near absence of empirical studies on farm level production efficiency in rice production in Kenya using the stochastic frontier models except the study by Kuria et al (2003). Theory identifies technical, allocative and economic efficiencies, yet most empirical works have analysed only technical efficiency.

Review of empirical studies show that the use of stochastic frontier model in determining efficiency in crop production has gained wide adoption in many developing countries but has limited application in Kenya. In the region, studies have focussed on other staple crops such as wheat and maize with no studies investigating the technical, allocative and economic efficiencies of rice producers using the stochastic efficiency decomposition methodology. The method certainly provides a convenient framework of measurement of efficiency in use of resources.

Review of the studies provides a strong case for the argument of using Stochastic Frontier Analytical Approach to generate vital information with a view to driving policy implications for proper policy recommendations and fill the information gap in Kenya.

CHAPTER THREE: RESEARCH METHODOLOGY

Introduction

This chapter provides the methodology applied in finding reliable study findings. It gives the analytical framework of the model adopted for the study, the model under estimation, definitions and measurement of the variables, data type and sources.

3.1 Analytical Framework

The study adopted maximum stochastic frontier model. The model is estimated after using the Econometric analysis on farm productivity and efficiency using a Cobb-Douglas production function to derive cost estimates, which are then used to calculate economic efficiency scores. The framework starts by using a general aggregate transformed production function relating output to factor inputs. The parametric model is thus specified as follows

$$\ln Y_i = \beta_0 + \beta_{ij} \ln Q_{ij} + \epsilon \dots\dots\dots (i)$$

Where the variables are previously defined as:

Y = Level of output of rice in tonnes produced per hectare.

Q = Set of quantity of inputs that goes into producing a tonne of rice per hectare.

i = Input used in producing a tonne of rice per hectare.

j = Individual farmer involved in the production of rice per hectare.

ϵ = error term that is composed of two independent elements V_i and U_i

Where $\epsilon = V_{ij} \cdot U_{ij}$

The V_s are assumed to be symmetric identically and independently distributed errors having normal distribution with mean zero and variance σ_v^2 , that is, $N(0, \sigma_v^2)$ that represent random variations in output due to factors outside the farmers as well as the effects of the measurement error in the output variable, left out explanatory variables from the model and statistical noise.

U_{it} stands for technical inefficiency and can be predicted by the following equation:

$$TE_{it} = \frac{Y_{it}}{\exp(X'_{it} \beta + V_{it})} = \frac{\exp(X'_{it} \beta + V_{it} - U_{it})}{\exp(X'_{it} \beta + V_{it})} = \exp(-U_{it}) \dots\dots\dots (ii)$$

U_{it} is measured as the ratio of observed output to the corresponding stochastic frontier output. It takes a value between zero and 1. $U_{it} = (u_i \cdot \exp(-\zeta(t-T)))$ where u_{it} is the non-negative random variables, which are assumed to account for technical inefficiency in production and are assumed to be independent and identically distributed as truncations at zero.

3.2 Model Specification

From literature review, production of rice involves use of several inputs namely: labour, chemicals, capital, seeds, fertilizer, size of the farm, water etc.

Substituting the inputs in the equation (i) above, leads us to the equation below:

$$\ln Y_t = \beta_0 + \beta_1 \ln Lab + \beta_2 \ln Chem + \beta_3 \ln Cap + \beta_4 \ln Seeds + \beta_5 \ln Fert + \epsilon \dots \dots \dots (iii)$$

Where: - in the production function

Y = Level of output of rice in tonnes produced in Mwea per hectare.

Lab = Quantity of labour used in producing a tone of rice per hectare.

Chem = Quantity of Chemicals in liters used in producing a tonnes of rice per hectare.

Cap = Amount of capital in Kenya shillings used in producing a tone of rice per hectare.

Seeds = Quantity of seeds of rice in kilograms used in planting a hectare of land.

Fert = Quantity of fertilizer in kilograms used to produce a tonne of rice per hectare.

The predicted output generated in the equation (iii) is crucial in estimating the cost function that gives the cost an individual farmer has to meet in producing a tonne of rice per hectare of land.

The study then proceeds to estimate the cost function involving the price of the quantity of inputs used in the production by starting with a general cost function as shown below:

$$\ln C_t = \alpha_0 + \ln Z_{ij} + \delta \dots \dots \dots (iv)$$

C = Total cost incurred by jth farmer to produce a tonne of rice per hectare.

Z = Set of prices of inputs that goes into producing a tonne of rice per hectare.

i = Input used in producing a tonne of rice per hectare.

j = Individual farmer involved in the production of rice per hectare.

δ = is the unexplained portion of the cost

Since the cost involved is to produce a tonne of rice, equation (iv) is then substituted in equation (iii) where y* represents the predicted values of rice output as shown.

$$\ln C_j = \alpha_0 + \alpha_1 \ln y^* + \ln Z_{ij} + \delta \dots\dots\dots (v)$$

Substituting the prices of inputs used in the cost function in five above yields the predicted cost function shown in the equation underneath.

$$\ln C_j = \alpha_0 + \alpha_1 \ln Y^x + \alpha_2 \ln pLab + \alpha_3 \ln pPest + \alpha_4 \ln pCap + \alpha_5 \ln pSeed + \alpha_6 \ln pFert \dots\dots\dots (vi)$$

Where:

Ln y* = Predicted values of output of rice per hectare.

pLab = price per unit of labour inputs used to produce a tonne of rice per hectare.

pPest = price litre of pesticides used to produce a tonne of rice per hectare.

pCap = price per unit of capital used to produce a tonne of rice per hectare.

pSeeds = price per kilogram of seeds used to produce a tonne of rice per hectare.

pFert = price per kilogram of fertilizer used to produce a tonne of rice per hectare.

Using equation (iii) and (iv) we then predict the Maximum Likelihood Stochastic Frontier equation where we will obtain the parametric estimates of the regressors used in the efficiency.

3.3 Measurement of Variables and Expected signs

Output is the dependent variable. It is expected to be positive. The independent variables are labour, pesticides, capital, seeds and fertilizers.

3.3.1 Production function

Variable	Measurement of Variable	Expected Sign
Level of Output	Measured in tones	Positive
Labour	Measured in labour units or man hours	Positive or negative
Pesticide	Measured in Litres	Negative
Capital	Measured in hours spent on one hectare	Positive or Negative
Seeds	Measured in Kilograms	Positive
Fertilizer	Measured in Kilograms	Positive

3.3.2 Cost function

Price Variable	Measurement of Variable	Expected Sign
Cost	Measured in Kenya Shillings	Positive
Labour	Measured in Kenya Shillings	Positive
Pesticide	Measured in Kenya Shillings	Positive
Capital	Measured in Kenya Shillings	Positive
Seeds	Measured in Kenya Shillings	Positive
Fertilizer	Measured in Kenya Shillings	Positive

As the prices of inputs used in production of rice increases, the cost of production is also expected to increase thus all the expected signs are positive.

3.3.3 The Efficiency Ratio

The Technical Inefficiency (TE) is expected to be positive but less 1.0.

3.4 Descriptive Statistics

Statistical properties of the model were analyzed and descriptive statistics given. Normality test of the variables was conducted. Though normality of the variables is not a basic requirement in applied econometrics, non normality of the variables could lead to non normality of the residuals which is a problem.

Test for the normality properties of the variables involved comparing the skewness and kurtosis of coefficients of the variables. For a variable to be normally distributed, its skewness should be equal to zero, kurtosis ranges between negative and positive three .In addition, we estimate the spread of data by estimating the mean and the first movement away from the mean for all variables contained in the model.

3.5 Testing for Unit Roots

The study tested the variables for unit roots to establish their order of integration. To test the level of integration of the variables employed in this study, Augmented Dickey-Fuller test (ADF) was applied. The aim was to determine whether the variables follow a non-stationary trend and are of the order 1 denoted as $I(1)$ or whether the series are stationary, that is, of the order of 0 denoted as $I(0)$.

3.6 Cointegration and Vector Error Correction Model

Most economic variables are non-stationary in their levels (integrated of order 1, $I(1)$) but stationary, $I(0)$, in their first difference. If all variables are $I(1)$ the second step is to test for cointegration. Engle and Granger (1987) introduced the concept of cointegration in which economic variables may reach a long-run equilibrium that depicts a stable relationship.

Engle and Granger (1987) established a number of new results concerning cointegration and the error correction model (ECM). This two-step procedure is carried as follows: First, a simple static OLS regression is run on the levels of each variable, and the null hypothesis of non-cointegration is tested. If rejected, the parameter estimates of the variables provide an estimate of the long-run relationship. In the second step, the dynamic specification is considered, with lagged value of the residuals from the cointegration regression appearing among the regressors.

The standard Granger test may provide invalid causal information due to the omission of error-correction terms from the tests. If the error-correction term is excluded from causality tests when the series are cointegrated, no causation may be detected when it exists, that is, when the coefficient of the error-correction term is statistically significant (Granger, 1986; 1988).

3.7 Diagnostic Tests

These tests are used as a means of indicating model inadequacy or failure. Diagnostic tests are carried out with the view of ensuring that the results are from a valid and robust econometric modeling so as to ensure they can be used for further policy analysis.

3.8 Data Type and Analysis

The study utilized both primary and secondary data. Data on factors that determine productivity and cost of a unit of production were captured by a well structured questionnaire used as a research instrument and then production and cost equations of rice estimated. The Maximum Likelihood Stochastic Frontier Model was then be estimated where the efficiency and cost effectiveness of the regressors were obtained.

CHAPTER FOUR: DATA ANALYSIS, RESULTS AND DISCUSSION

4.1 Inputs required for Production per Hectare of Land

The study findings indicate that the average hectares of land that Mwea Irrigation Scheme farmers use for rice cultivation was less than 1ha. Farmers whose land has been subdivided to less than 0.75ha were less interested in rice farming.

Table 4.1 below shows the measured variables. The study sought to find out yields per hectare of land in Mwea Irrigation Scheme. From the findings it was found out farmers harvested an average of 5.6MT per hectare. Farmers within the study area who have adopted the System of Rice Intensification (SRI) had higher yields over conventional farmer practice.

Table4.1 Summary statistics of variables

Variables	Unit	Mean	Minimum	Maximum
Yield	Kg/ha	5,650	4,220	7,230
Seed	Kg/ha	42	12	50
Fertilizer	Kg/ha	140	90	150
Labour	MD/ha	202	195	236
Pesticides	Litres/ha	7.6	1.2	12

The study was interested in establishing the amount of seed per hectare of land in the study area. Farmers in Mwea use an average 42kg/ha which compares favorably to recommendations by KARI of between 30kg/ha to 50kg/ha. Fertilizer usage was another variable measured in the study area. The findings indicate that the farmers used about 90kgs of planting fertilizer and 50kg of top dressing fertilizer in rice production making an average of 140kg/ha.

The study was interested in finding out the quantity of labour through from nursery and land preparation, transplanting, weeding to harvesting. Family labour was mostly used by Mwea farmers to carry out various farm activities. Family labour is used mostly for two reasons, first is the availability and other reason is out of the need to reduce on production cost. The study

findings indicate that on average the quantity of labour required in the production per hectare of land is 202 Man Days per hectares

The researcher sought to find out whether farmers used pesticide in the production of rice. Majority of the respondents indicated that they used pesticide in the production of rice. In relation to the quantity in litres used per hectare of land the researcher found out that on average farmers used an average of 7.6 liters of pesticide per hectare. Farmers stated that pesticide usage increased during adverse weather period.

4.2 Maximum Likelihood Estimates and Characteristics of Households

The Maximum Likelihood Estimates for the stochastic frontier model are presented in table 4.2 below. The significance of the coefficient γ (gamma) at 5% level suggests presence of error component. This means the technical inefficiency is significant. The γ variance ratio of about 51% means that 51% of the observed output and the frontier output are due to technical inefficiency. This can be interpreted to mean that the shortfall in rice production is largely due to factors that are within the farmers' control.

The study sought to find out the demographic and socioeconomic characteristics among rice farmers in Mwea irrigation scheme. About 68% of households in Mwea irrigation scheme were headed by male whereas 32% of them were headed by females. The average age of the majority of the farmers sampled for this study was 40 years and above representing 65% followed by those in the age category of 25-40 years at 25% whereas those in the average age category of less than 25 years were represented by 5%. Land holdings are very small in size, however farmers with larger farms are more likely to cultivate rice than those with smaller ones. Variations in efficiency and cost effectiveness of the rice farmers may arise from their characteristics. The study also considered socio-economic variables and estimated the model. The results are as shown in table 4.2 below:

Table 4:2 Determinants of Technical inefficiency

Variable	Parameter	Coefficient	T- ratios
Constant	β_0	0.287*	4.378**
LnLand	β_1	0.289**	2.844**
LnLabour	β_2	-0.16	-3.490
LnSeed	β_3	0.15	3.429
LnFertilizer	β_4	0.25*	2.598*
LnPesticide	B_5	-0.08*	-1.432
Inefficiency Model			
Constant	δ_0	0.658*	1.658
Age	δ_1	-1.29	-1.603
Education	δ_2	-0.17	-0.588
Household size	δ_3	0.805***	3.098
Farmer experience	δ_2	-0.364*	-2.511
Farm size	δ_4	-0.03	-5.136
Gender (head female = 1)	δ_8	0.728	0.739
Diagnostic statistics			
sigma - squared	σ^2	0.06	3.267**
Gamma	γ	0.51**	5.04**
Log likelihood		11.02	
LR Test		25.67	
Mean Technical Efficiency		0.72	

*Significant at 10% level, **Significant at 5%

Note: A negative sign of the parameters in the inefficiency function means that the associated variable has a positive effect on technical efficiency, and vice versa

The estimated elasticities of mean output with respect to land, labour, seed, fertilizer and pesticides indicate that a 10% increase in land cultivated will result about 2.9% increase in output. Result indicates the relative importance of inputs in rice production in the study area. Land, fertilizer and seed appear to be the most important inputs; an increase will result to increase in output. Labour and pesticides appear to be excessive because of the negativity of their coefficients. Increasing their use decreases rice output.

The coefficients of the inefficient variables have the expected signs. Since the dependent variable of the inefficiency function represents the mode of inefficiency a negative sign on an estimated parameter implies that the associated variable has a positive effect on efficiency and a positive sign indicates that the reverse is true. Therefore, age, education, farmer experience and farm size have positive influence on the production efficiency of the rice farmers.

The coefficient of education showed negative and insignificant which indicates that farmers with greater years of formal schooling tend to be more technically efficient indicating that the farmers with more education respond more readily in using the new technology and produce closer to the frontier output. This result is consistent with the idea that schooling increases information and together with long-term experience leads to higher production efficiency (Dey, 2000; Pagán, 2001; Basnayake and Gunaratne, 2002). With education, farmers could be able to read and understand instructions on agricultural innovation and can easily adopt them for enhanced productivity. Positive impact of education on technical efficiency and competitiveness was also observed by Admassie (1999).

The coefficient of experience is estimated to be negative as expected and statistically insignificant indicates that farmers with more experience are found technically more efficient and competitive. In other words, the older the farmers are, the more experience they have and the less the technical inefficiency is. Rahman (2012) found similar results in rice farming in Bangladesh. Therefore this reveals that farm experience enhances production efficiency.

Household size reduced inefficiency significantly. This implies that consistent availability of labour helps decrease inefficiency by mitigating the shortage of labour. This result is similar to the findings of Parikha and Shah (1994), that family size has positive and significant relationship with

production efficiency. The findings suggest that the larger the household size, the more cost efficient the household is. A possible reason for this result might be that a larger household size guarantees availability of family labor for farm operations to be accomplished in time. Also, a large household size ensures availability of a broad variety of family workforce which suggests that household heads can rationally assign farm operations to the right person.

The coefficient of farm size is found to be negatively significant in explaining farmers' inefficiency. It indicates that every unity increase in land leads to decrease in technical inefficiency. However, converse result was expected in this regard. Coelli and Battese (1996) observed the same phenomena while studying the technical efficiency and competitiveness of Indian farmers. The advantage of small farms is thus attributed to their greater technical efficiency and competitiveness. According to Admassie (1999), factors other than farm size are more important in explaining the variation in technical efficiency. By progressive increase of farm size, farm size-squared becomes positive and significant at 0.01 level indicating that as its size increases farmers may not be able to maintain the productivity of farm.

4.3 Rice Production Efficiency Analysis

Table 4.3 Distribution of farmer-specific Technical efficiency

Technical efficiency %	Percentage	Cumulative %
<25	2%	2
25-49	15%	17
50-69	40%	57
70-100	43%	100
Mean	72%	
Minimum	21%	
Maximum	98%	

Table 4.3 above shows the distribution of technical efficiency among farmers in Mwea irrigation scheme. There is great variation in the levels of efficiency. There range is from 21% to 98% within mean of 72%. The mean level of technical efficiency indicate that on average, rice output falls 28% short of the maximum possible level. Therefore in the short run, it is possible to increase rice production in the study area by an average of 28% by adopting the technology used by the best performing farmers.

CHAPTER FIVE: SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This chapter presents the summary of the finding and discussions of the study. It also covers the recommendations for further studies on related issues on the study not well covered as well as recommendations. The study finally addresses the limitations of the conclusions of this study.

5.2 Summary of Findings

This study attempted to estimate rice production efficiency in Mwea irrigation scheme and also identify the determinants of inefficiency. The calculated technical efficiency level is 72%. These results suggest that it is possible to increase production by 28% using the available technology. The results also revealed a big difference in technical efficiency among farmers with the most inefficient farmer at 21% and the most efficient recording 98%.

The study findings indicate that the average hectares of land that Mwea Irrigation Scheme farmers used for rice cultivation was less than 1 ha. It was found out that farmers harvested an average of 5.6 tons per hectare. The study findings indicate that on average 42kg of seed are used per hectare. Seed use was appreciable considering the maximum recommended by research institution was 50kgs/ha. Most farmers apply fertilizers during transplanting and for top dressing. The study findings indicate that 140kgs/ha of fertilizer are used on the average. The study findings however, indicate that farmers vary on the type of fertilizers they use based on costs and availability thereby affecting production.

The study findings show that between 1.2liters to 12liters of pesticides are used per hectare per season and the average is 7.6 liters per hectare. The big difference in pesticide use is explained by the time of planting. Early or late planting exposes farmers to adverse weather conditions especially during the cold season to increased incidence of pest and diseases. The study findings indicate that approximately the labour input per hectare of land was around 202 man days in a season.

The study examined household characteristics that may impact on efficiency. About 68% of households in the study area were headed by male whereas 32% of them were headed by females.

The average age of the majority of the farmers sampled for this study was 40 years and above representing 65% followed by those in the age category of 25-40 years at 25% whereas those in the average age category of less than 25 years were represented by 5%..

The study examined the relationship of the various farmer attributes with technical efficiency. The study findings show that age, education, farmer experience and farm size have positive influence on the production efficiency of the rice farmers

5.3 Conclusion

This study results show that rice production in Mwea can be increased with the current levels of inputs and existing technology in the short run if the less efficient farmers follow and adopt resource utilization pattern of the most efficient farmers. Thus, farmers should be encouraged to learn from experiences of themselves and their most efficient colleagues.

Extension service can also be used to popularize most efficient production methods by sharing information, knowledge and skill. Extension will need to build on traditional communication systems and involve farmers themselves in the process of extension.

Incentive systems such as availability of appropriate fertilizers, effective pesticides and herbicides should be considered in order to increase production.

5.4 Recommendations

The government should intervene in order to gain the technical efficiency of rice farmers. There is an urgent need for an appropriate policy of regulation that recognizes and encourages proper and effective use of resources. The activity of extension officers needs to be intensified in the study area so as to evenly disseminate the current production technology of System for Rice Intensification

It is also recommended that intensification of fertilizer use should be encouraged and farmers are provided with right fertilizers at the appropriate time through the government support programme.

To mitigate against the effect of adverse weather which a bearing on pesticides use, timely production is recommended.

5.5 Recommendations for Further Research

From the work done further research can be considered on: an investigation on influence of government legislation on efficiency and competitiveness of rice production, a comparative study on the determinants of efficiency and competitiveness of rice production and the impact of socio-economic factors on efficiency and competitiveness of rice production in Kenya.

5.6 Limitations of the Study

Time was a limiting factor for the researcher since he is in full time employment and therefore did not have adequate time especially in the collection of data. Further, data from Kenya Bureau of Statistics was insufficient to be used to answer the research objectives sufficiently. In addition, limited resources on the part of the researcher were another limitation. The researcher lacked adequate funding for conducting the research.

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APPENDIX 1: QUESTIONNAIRE

UNIVERSITY OF NAIROBI

QUESTIONNAIRE TO FARMERS OF MWEA IRRIGATION SCHEME

EFFICIENCY OF RICE PRODUCTION IN MWEA IRRIGATION SCHEME

I am.....a student studying Masters of Arts in Economics student at the University of Nairobi. As part of a University requirement, students are expected to carry out research in their area of choice which has necessitated this study. I have designed the following questionnaire for the study on the above topic. A copy of the findings will be sent to you on request.

I would highly appreciate if you fill this questionnaire. It will take a few minutes of your time. I expect your kind cooperation.

PART A: Background Information (Optional)

1. **Your Name**

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2. **What is your gender?**

Male Female

3. **What is your age?**

Less than 25 years (25-40) years 40 and above

PART B: PRODUCTION INPUTS REQUIRED FOR PRODUCTION PER HECTARE OF LAND (Not Optional)

4. How many kilograms of Rice do you produce per hectare of land? Please give your answer per year. (To be compared with estimates from (Kenya Bureau of Statistics).

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5. What is the quantity of Labour (persons) including family labour do you require in rice production per hectare of land?

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6. Do you use any chemicals in Production of Rice? Answer Yes or No.

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If yes, please state the quantity in litres used per hectare of land.

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7. What are the Capital (Machinery) inputs required in hours per hectare of land?

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8. What is the Quantity is of seeds (seedlings) in Kilograms do you require per hectare of land?

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9. Do you use fertilizer in Rice Production? If yes what is the quantity of Fertilizer in Kilograms do you require per hectare of land?

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PART C: COST OF INPUTS USED IN PRODUCTION OF RICE PER HECTARE OF LAND

10. What is your estimated cost for Production of Rice per Hectare of Land from the period 1990 to 2012 (Please List your answer per year).

11. What is the price in Kenya Shillings of Labour used in Producing of Rice per Hectare of Land? Please give an estimate price of family labour?

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12. What is the Price per Litre of chemicals used per hectare of Land?

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13. What is the price of Machinery used per hectare of land?

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14. Give the price of seedling per Kilogram used per hectare of Land?

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15. What is the Price per Kilogram of Fertilizer used per hectare of Land?

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PART C: EFFICIENCY AND COMPETITIVENESS OF RICE PRODUCTION (Official Use Only)

16. Production function for producing Rice per hectare of land?

17. Cost function for Production of Rice per hectare of Land?

18. Maximum Likelihood Stochastic Frontier for the Farmers

19. What are the Efficiency Scores?

THANK YOU FOR YOUR COOPERATION