AN ECONOMIC ANALYSIS OF RICE PRODUCTION IN MWEA IRRIGATION SCHEME.

BY

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DECLARATION

This thesis is my original work and has not been presented for a degree in any other University.

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DEDICATION

To my Mum, Teresia Kuria and late father Sospeter Kuria

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LIST OF ACRONYMS

ALDEV	African Land Development Unit
CBS	Central Bureau of Statistics
FAO	Food and Agricultural Organization
GoK	Government of Kenya
ICIPE	International Centre of Insect Physiology and Ecology
IDRC	International Center for Research and Development
IWMI	International Water Management Institute
KEMRI	Kenya Medical Research Institute
LP	Linear Programming
LR	Long Rain Season
MFC	Marginal Factor Cost
MIAD	Mwea Irrigation Agricultural Development
MIS	Mwea Irrigation Scheme
MLE	Maximum Likelihood Estimate
MMRG	Mwea-Multi Purpose Rice Growers Society
MPP	Marginal Physical Product
MVP	Marginal Value Product
NCPB	National Cereals and Produce Board
NIB	National Irrigation Board
SR	Short Rain Season
UOP	Unit-Output-Profit

ABSTRACT

This study aimed at comparing the economics of rice production for two different groups of farmers in Mwea Irrigation Scheme (MIS). One group is under the management of Mwea Multi-Purpose Rice Growers (MMRG) and grows a single crop of rice in a year without rotation. The other group is composed of the sons and daughters of MMRG tenant farmers and grows a double crop of rice in a year. It is however not clear which of the two production systems is efficient or realises higher returns to farmers.

The objectives of the study were: (i) to identify major resources used by rice farmers and determine which resources significantly influenced rice output, (ii) to evaluate and compare the technical efficiency levels of both groups of farmers, (iii) to determine if both groups of farmers were allocating the identified physical resources efficiently, and (iv) to evaluate and compare the profitability of rice production in and outside the cooperative society.

A total of 106 farmers were interviewed, 61 being MMRG-dependent and 45 from non-MMRG group. Data collected was fitted to a stochastic frontier production function model of the Cobb-Douglas type. Regression coefficients and farm specific technical efficiency levels were estimated using the Maximum Likelihood Estimate (MLE) technique. Efficiency of resource use was evaluated from the ratios of MVP:MFC.

The results of the study showed that labor, mechanized tractor power, chemical fertilizer, pesticides, seeds, land and irrigation water significantly influenced rice output at 1% significance level in the MMRG farms. Labor, however, had a negative coefficient while animal draught power was not significant in explaining rice output variation even at 10% significance level. For

the non-MMRG farmers, mechanized tractor power, chemical fertilizers, pesticides, land and irrigation water were all significant at 1% level of significance while labor and animal draught power were significant at 5% level. For this group, seed quantity coefficient was not significant even at 10% significance level. Tractor power, pesticides and irrigation water had negative coefficients.

The results on technical efficiencies indicated that MMRG dependent farmers were more technically efficient than MMRG independent farmers, and there was actually a statistically significant difference in technical efficiency levels between the single-crop MMRG dependent farmers and the double-crop non-MMRG farmers. Further, an analysis of the determinants of technical efficiency indicated that farmers' specific characteristics e.g. farming experience (age) and education level as well as institutional factors like access to credit and extension facilities are important factors in determining the level of technical efficiency.

The test for allocative efficiency indicated that labor, tractor power, fertilizer, pesticides and seeds were inefficiently used and only irrigation water was efficiently used in MMRG dependent farms. For non-MMRG independent farms, these resources were inefficiently allocated though the seed input was not statistically significant in explaining rice output variability. Both groups were found either underutilizing or overutilizing the resources used in rice production.

Gross margin per hectare per year in MMRG dependent farms was Kshs. 42,695.17 and Kshs. 54,653.75 for non-MMRG farms. A test for any statistically significant difference in the two group's gross margins revealed that they were

statistically different and that rice production under cooperative society is less profitable than outside the society.

The study thus recommended: One, the Governments should facilitate the availability of credit and extension services to farmers, two, the research institutes should undertake a thorough extension exercise to advise all the Scheme farmers on the recommended input usage and application rates, three, there is need for rigorous campaign from the Government, politicians and development partners aimed at educating the young farmers on the benefits of a single rice crop in a year, and four, the Government should oversee the revision and harmonization of MMRG structure of agreement with the Scheme tenants to avoid exploitation.

CHAPTER ONE: INTRODUCTION

1.1 AGRICULTURE SECTOR IN KENYA

Agriculture is the cornerstone of Kenya's economy. The economy has experienced a sharp decline in growth over the past decade. By the end of year 2000, the economic growth rate declined from a rate of 1.4% in 1999 to negative 0.3%.

Agriculture sector, like the rest of the economy, continued to perform poorly during the last decade. For example, the sector growth declined from 4.8% in 1994 to –2.3% in year 2000. The performance of key food commodities has been poor over the same time. For example, production of maize, wheat, **rice**, milk and sugar has declined (GoK, 2000).

The decline in food production has taken place against a backdrop of growing demand for food caused by, among other factors, high population growth rate (averaging 3% per year) which has caused deficit in key food commodities like **rice**, maize, wheat and sugar. To meet the deficit, the country continues to depend on imports of key food commodities. In 1999, for example, Kenya imported 409 tonnes of maize valued at Kshs 4.7 billion for commercial and relief purposes. Similarly, large volumes of wheat and **rice** were imported to bridge the widening gap between production and consumption (Table 1-3 and 1-4). The challenge therefore is to reverse the trend, using appropriate policies to increase food production on sustainable basis as part of the strategy to achieve food security.

1.1.1 Rice Production in Kenya

Rice development in Kenya started in 1964 under the African Land Development Unit (ALDEV), which started as a broad agricultural rehabilitation programme that included irrigation. This was driven by the need to contain agitation for land occupied by the European settlers. The Unit initiated a number of irrigation schemes, including Mwea, Hola, Perkerra and Yatta, using cheap labor from Mau Mau detainees. After independence, these schemes were taken over by the Ministry of Agriculture.

Annual rice production in Kenya is about 30,000MT but production has been declining in recent years. For example, rice yield recorded a decline from 5.91 tons/ha in 1963 to 3.98 tons/ha in year 2000 as illustrated in Table 1-1.

Table 1-1: Total rice production and yield in Kenya

Year	Total Production '000' tonnes	Yields (tons/ha)
1963	13.0	5.91
1970	28.5	5.38
1975	32.1	4.28
1980	36.4	4.18
1985	39.5	3.80
1990	32.6	2.65
1995	30.6	4.08
1998	36.5	4.87
1999	48.4	4.75
2000	49.3	3.98

Source; Statistical Abstracts, National Irrigation Board, various issues.

Rice production in Kenya falls under two categories; rice from National Irrigation Board (NIB) irrigation schemes and that from rain-fed paddy fields of small-scale farmers. Most of rice production is from the irrigation schemes controlled by NIB. Mwea Irrigation Scheme (MIS) has been in the past the largest paddy producer in Kenya, supplying over 70% of domestic paddy production but production has declined. For example, a total of 21,352 tonnes of paddy were delivered during the 1997/98-crop year compared to 27,488 tonnes delivered in the 1996/97-crop year (GoK, 1999).

1.1.2 Rice Marketing in Kenya

In December 1993, the Government announced the liberalization of the rice marketing as well as that of other staple food crops. Under the market liberalization, channels for milling, distribution, storing and pricing of rice were decontrolled and diversified. The National Cereals and Produce Board (NCPB), which had hitherto controlled the rice marketing as a monopoly, was left with the role of procuring and maintaining strategic reserves of essential cereals. Marketed rice crop has declined as shown in Table 1-2

Table 1-2: Marketed Rice between 1993 to 1998

Year	Amount Marketed '000' tonnes
1993	11.4
1994	13.5
1995	14.6
1996	15.9
1997	14.4
1998	11.7

Source: Statistical Abstracts, Central Bureau of Statistics, various issues.

The Irrigation Schemes registered a marginal decrease in area cropped in hectares by 1.1% in 1999 over the previous year. Similarly the number of plot holders decreased by 4.4% in the same period. Payment to plot holders dropped drastically by 75.6% in the same period, from K£ 10,217 thousand in 1997/98 to K£ 2,496 thousand in 1998/99 Crop year (GoK, 2000).

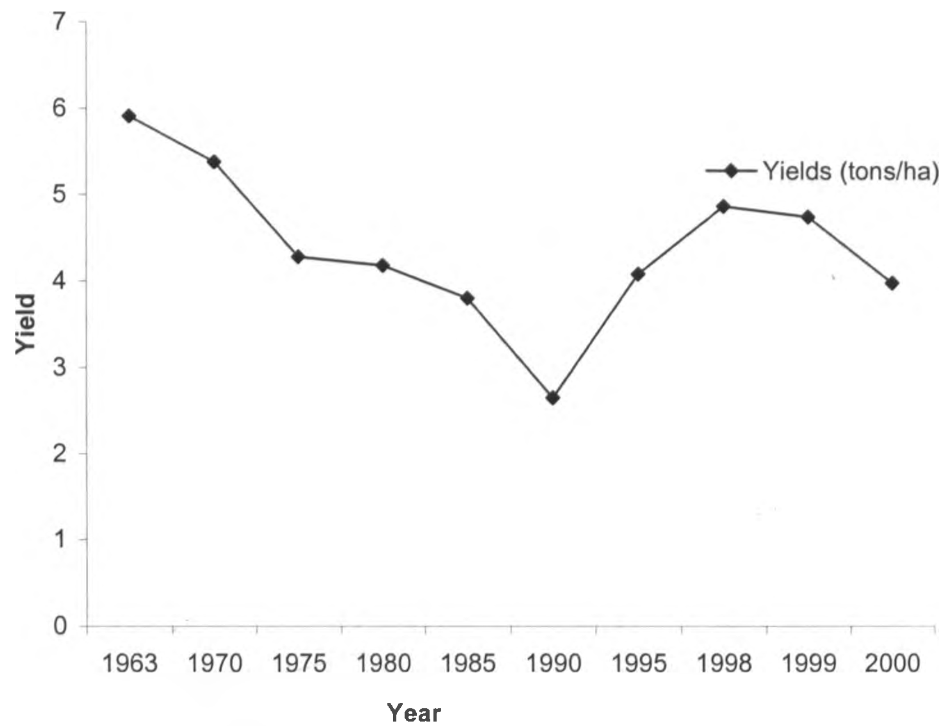
1.1.3 Rice demand in Kenya

Rice is a major food crop in Kenya. In the study of "Agriculture Towards year 2010", Food and Agricultural Organization (FAO) projected that cereal requirements in Kenya would steadily rise by 3.7% per annum, more than doubling from 3.2 million tons in 1988-90 to 6.9 million tons in the year 2010. According to FAO, **rice** deficit will register the sharpest increase, rising from 37,000 tons in 1993/94 to 161,000 tons, in the year 2010.

Whereas rice consumption in Kenya has increased, production has remained static from 1994 when rice imports stood at 93,520 tonnes against a national production of 60,000 tonnes (GOK, 1994). The rice consumption growth rate in

Kenya rose from 8% in 1992 to 12% in 1996 and by 1998 rice consumption stood at 122,700 tonnes. The area under rice cultivation has remained constant at about 10,000 hectares. Production per unit area has also continued to decline from, for example, 6 t/ha to 3.5 t/ha for Basmati 217.

Figure 1-1: Rice Yield Trend in Kenya (1963 – 2000) in tons/ha



Source: Table 1-1

Rice consumption in Kenya is always greater than supply, as shown in Table 1-3. By the year 2005, the deficit of rice supply is estimated to be 119,000 tonnes with rice self-sufficiency of only 29%. This will hit a record 156,000 tonnes by the year 2010 (FAO 2000).

Table 1-3: Rice production, imports and consumption, 1990-1995

Year	Production ('000 Mt)	Imports ('000 Mt)	Total ('000 Mt)
1990	31.2	33.8	65
1991	35.6	61.2	67.6
1992	28.8	58.9	70.7
1993	31	47	78
1994	29.5	93	122
1995	30.6	28.2	58.8

Source: Economic Survey, CBS 1996; Statistical Abstract, CBS 1997.

A recent publication by FAO showed a rice production deficit of 200 thousands tonnes which it classified as the import requirement for the year 1999/2000, as shown in Table1-4.

Table 1-4: Rice supply / demand balance for the 1999/2000 marketing year (in '000 tonnes)

Supply/Demand	Amount
Previous five years average production	53
Previous five years average imports	222
1999/ 2000 Domestic Availability	**33**
1999 production (rice in paddy terms)	50
1999 production (rice in milled terms)	33
1999/2000 Utilization	**233**
Food use	213
Non-Food use	20
1999/2000 Import Requirement	**200**
Anticipated commercial imports	200
Estimated Per Capita Consumption (kg/Year)	**7**

Source: FAO Africa Report, August 2000

As of year 1999/2000, domestic supply couldn't meet the demand, thus necessitating the imports.

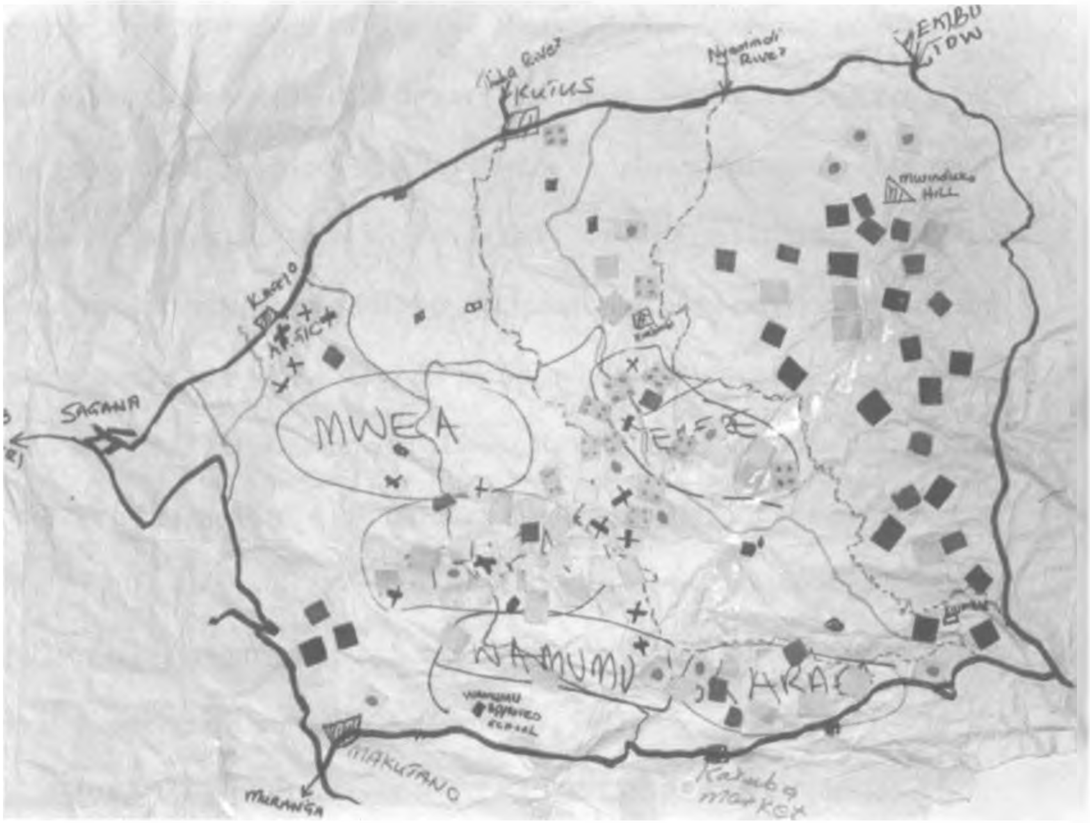
1.2 THE STUDY AREA

This study was conducted in Mwea Irrigation Scheme. The scheme is in Mwea Division of Kirinyaga District and is on the South-Eastern part of the district, about 100 kilometers North-East of Kenya's capital city, Nairobi (Figure 1-2). The scheme occupies the lower altitude zone of the district with expansive low-lying marshy areas, mainly comprising of black cotton soils. The altitude ranges from approximately 1000-2000m above sea level, with minimum and maximum temperatures of 15^0C and 30^0C . There are two rainy seasons, with long rains occurring from mid-March to May and short rains in October/November. The main agricultural activity is the rice mono cropping. Rice is grown on irrigated paddies that are flooded for about half of the year. According to 1999 national population census, Mwea division had approximately 150,000 persons.

1.3 HISTORICAL PERSPECTIVE OF MWEA IRRIGATION SCHEME

The Scheme was first established in 1953 by the British Government and handed over to the Government of Kenya in 1963 when Kenya got its independence. The Ministry of Agriculture ran the scheme until 1966 when it handed over the scheme to the National Irrigation Board provided for by the Irrigation Act passed in 1967, chapter 347 of the laws of Kenya, (GoK, 1967). NIB managed the scheme up to the end of 1998 when the rice farmers took over its management. During the previous three decades, the NIB had used powers vested on it by the Act guided by regulations,

Figure 1-2: A Sketch of Mwea Irrigation Scheme



developed in 1977 (GoK, 1977). Under NIB, Mwea expansion programme was enhanced through development of Thiba, Wamumu and Karaba sections, which by 1973 brought the total area under rice cultivation to 5,830 ha, thus making Mwea the largest rice-growing project in the country.

The scheme produces about 28,000 tonnes of paddy annually and supports 3,246 farmers' families. Farmers live in 36 villages on the settlement and each village is located as centrally as possible in relation to the farmers' holdings. Until 1998, paddy fields were flooded, rotavated and prepared with NIB tractors. Individual farmers were not allowed to carry out these operations. Paddy seeds production was entrusted with some selected farmers. NIB provided specific paddy varieties for each field block. Two paddy varieties, Basmati 217 and BW 196 were grown in the MIS.

The paddy fields in MIS were watered through gravity assisted water conveyance from two rivers, Thiba and Nyamindi. The irrigation practice was planned and managed by NIB. Each farmer is referred to as a tenant and farmed 4 to 5 acres of paddy fields. The paddy seed was sown from July and harvested in December and January. That practice was referred to as short rain (SR) season paddy cultivation. As a rule, every farmer was supposed to deliver all the paddy harvested to NIB and retain only twelve bags (75Kgs/bag) for farm family home consumption. The milled rice was finally sold and the farmer given the balance of his money after deduction of the costs. A mount and time o f fertilizer application was fixed. T he fertilizers w ere supplied by NIB, which also carried out the spraying of agricultural chemicals for pest control. Voluntary improvement of farmers' own farming and technology was limited due to all these controls and rules (Wanjogu et al., 1995)

1.4 MWEA MULTI-PURPOSE RICE GROWERS SOCIETY (MMRG)

The Mwea Multipurpose Rice Growers Society (MMRG) is a farmer association currently managing the Mwea irrigation scheme with, and on behalf of, the farmers. Its history goes back to 1964 when farmers associations started emerging. The association had a difficult time holding together as reflected in successive splits and merges. The first association was registered in 1964 as Mwea Irrigation License Tariff Cooperative Society and later changed to Mwea-Tabere Cooperative Savings and Credit Society Limited. In 1967, a sister society was formed under the name Mwea Farmers' Cooperative Society. The management and membership of these two associations remained the same until 1981 when the two split and each established its own management. In 1983, the two societies amalgamated and a banking section was formed under the name Mwea Amalgamated Rice Growers' Cooperative Society Limited. In 1993, the giant society split again to form what are currently the Mwea

Multi-purpose Rice Growers' (MMRG) cooperative society and the Mwea Rice Growers' SACCO society limited. The two operate under different sets of management.

1.5 PROBLEM STATEMENT

Seventy percent of rice production in Kenya comes from Mwea Rice Irrigation Scheme (MIS). Until 1998, the scheme has had a reputation of being the largest and most successful irrigation project in Kenya. However, paddy production has been fluctuating, e.g. a total of 21,352 tonnes of paddy were produced in 1997/98-crop year compared to 27,488 tonnes produced in 1996/97-crop year. The NIB (and currently the MMRG) production pattern in the scheme has been that of a single rice crop in a year, leaving the land idle for the rest of the year. After harvest, the practice has been that the fields are left fallow for six months. This practice has been contested by a group of young farmers, mostly the sons and daughters of the scheme tenants, as being irrational. These young farmers constitute a group of farmers, popularly referred to as *Jua Kali* farmers, who sprung up in the scheme after MMRG took over the management of the scheme from NIB and started producing two crops of rice in a year. These young farmers, though being more educated than the Scheme tenants, are limited by lack of physical production inputs as well as essential services like agricultural extension and credit facilities. Moreover, these young farmers are inexperienced in rice farming.

The emergence of these young farmers has resulted to competition for irrigation water and other rice production inputs. The outcome of this practice has been a decline in rice output and yield in the scheme. This is not withstanding the fact that until 1995, the scheme's average rice yield was still far below that of national average of other countries. For example, Tsuruuchi and Waiyaki (1995) reported an average MIS Basmati yield of 3,773kg/ha, which is far below the yield of 5,800kg/ha reported in 1989 in Egypt, and 6,100kg/ha in Japan (Herdt, 1989). Thus, unless urgent measures are put in place to contain the situation, rice production might continue to decline in the scheme.

The cause of emergence of the *Jua Kali* farmers was the growing of double instead of a single crop of rice in a year. There has also been controversy on MMRG deductions for the inputs supplied to the tenants on credit. It is alleged that MMRG supplies excess inputs to the farmers on credit and over charges the same from the tenants' rice proceeds. The result of this is reduced rice gross margins and inefficiency in resource use.

The first step towards reversing the fluctuating levels of rice output in MIS is to examine and compare the economic rationality of the two production patterns (the single rice crop and double rice crop). This is important because so far there is no factual economic evidence of the technical efficiency of the two groups of farmers, nor is it clear how the two groups of farmers allocate resources in their specific production patterns or even the returns realized from engaging in rice production. Also, Statistics and literature on rice production and marketing in the scheme has been scarce since 1998 when NIB pulled out of the scheme.

This study then will assess and compare the technical and allocative efficiency as well as profitability of rice production between the single rice crop of MMRG dependent farmers and the double rice crop of non-MMRG farmers.

1.6 OBJECTIVES OF THE STUDY

The broad objective of this study is to carry out an economic analysis of rice production in Mwea Rice Irrigation Scheme.

The specific objectives are to:

1. identify the major resources used by rice farmers and determine which resources significantly influence rice output;
2. evaluate and compare the technical efficiency levels of MMRG dependent farmers and non- MMRG farmers,
3. determine if both or either group of farmers were allocating the identified physical resources efficiently and;
4. evaluate and compare the profitability of rice production in MMRG dependent and non-MMRG farms.

1.7 HYPOTHESES TESTED

The following hypotheses were tested:

1. that each of the identified resources significantly influenced rice output;
2. that the MMRG dependent and non-MMRG farmers have equal technical efficiency levels;
3. that farmers in the study area were allocating resources efficiently and;
4. that the MMRG dependent and non-MMRG independent farmers have equal Gross Margins per hectare.

1.8 JUSTIFICATION OF THE STUDY

The role of agriculture in economic development has been recognized for years. Expected increases in agricultural demand associated with population growth and rising per-capita incomes will require continuing increases in agricultural productivity. Agricultural productivity, defined as the ratio of its output to its input, varies due to differences in production technology, the setting in which production occurs, the efficiency of the production process among other factors.

An important source of growth for agricultural sector is efficiency gain through greater technical and allocative efficiency by producers in response to better information and education. Efficiency is a very important factor of productivity growth, especially in developing agricultural economies, where resources are meager and opportunities for developing and adopting better technologies are limited.

CHAPTER TWO: LITERATURE REVIEW

This section presents a review of the relevant literature pertaining to rice production, and the concepts of technical and allocative efficiency. A theoretical background concerning the meaning of technical and allocative efficiency as used in this study and a review of a number of studies, which have tried to measure both, are given.

Rice production in Kenya occurs under small-scale type of farming and in three systems; irrigation in NIB schemes, rainfed/supplemental irrigation and smallholder water user associations. The first system of production is through irrigation in NIB schemes, namely Mwea, Ahero, West Kano and Bunyala Irrigation Schemes. These schemes are managed by NIB and have the disadvantage of requiring high investments and operational costs. In total, the schemes produce about 40,000 tonnes (85% of Kenya's rice production) from about 7,000-8,000ha of irrigated land. The yields average about 4.5t/ha for Basmati varieties and 6.5t/ha for non-aromatic varieties such as BW 196 and IR2793 (Kaluli and Gatharia, 1991).

In the schemes under NIB, farmers are provided with inputs in form of credit e.g. for such inputs as land preparation, seeds, irrigation water, fertilizers, pesticides, and tractors. They are also provided with credit for school fees and harvesting purposes. The farmers are expected to deliver paddy to NIB who in turn deducts the credit and remits the balance to the farmers. For many years, the land under NIB schemes has belonged to the Government as the licensee under landlord-tenant land tenure system.

The second system of production is under rainfed condition and/or supplement irrigation which is mainly concentrated in Nyanza, Western and coastal provinces. This is carried out by smallholder farmers mainly on marshy lands and valley bottoms which get waterlogged during the long rain season. These smallholder rainfed rice farmers operates no more than one hectare of land each and achieve paddy yield of 1,666Kg/ha. (Ogindo, 1991).

The third system is under smallholder schemes that are organized under water users associations. The schemes were initiated by the irrigation and drainage branch of the Ministry of Agriculture but have now been left to the individual associations to manage, operate and maintain.

Efficiency measurement has received considerable attention from economists. From a theoretical point of view, there have been discussions about the relative importance of the various components of farm efficiency. From an applied perspective, measuring efficiency is important because this is the first step in devising strategies for substantial resource savings. In the policy arena for example, there is a continuing controversy regarding the connection between farm size, efficiency, and the structure of production in agriculture. For individual farms, gains in efficiency are particularly important in periods of economic hardships. Efficient farms are more likely to generate higher incomes and thus stand a better chance of surviving and prospering.

The current interest in efficiency measurement finds its origin in a pioneering paper published by M. J. Farell. The approach proposed by Farell distinguishes between technical and allocative efficiency where the former refers to the ability of producing a given level of output with a minimum quantity of inputs, given technology; the latter refers to the choice of the optimal input proportions given relative prices. Economic or total efficiency is the product of technical and allocative efficiency (Farrell, 1957).

A farm is said to be more technically efficient than another if it consistently produces larger quantities of output from the same quantities of measurable inputs. Technical efficiency occurs when farms are obtaining the maximum output, given certain inputs of production (Wolgin, 1973). Differences among farms in their abilities to be technically efficient are a result of differences in resource endowments. Differences in technical efficiency are related to scores on composite modernization indices derived from factor analysis. Items included in the factor analysis scores include knowledge on new technology, knowledge of factor and product prices, knowledge of local agricultural officials and various proxies of wealth (Shapiro and Muller, 1977). A major source of technical inefficiency arises from the complexity of a given technology and the rate of change of the technology.

Several methods have been developed to empirically apply the concept of technical efficiency. One method for measuring differences in technical efficiency was developed by Mandac and Herdt who used data gathered by agronomists from experiments conducted on farmers' trial fields, to estimate a frontier or technically efficient production function. The extent of technical inefficiency of farmers can then be calculated from the difference between actual yields and the yields that technically efficient producers are estimated to get from the same levels of resources as the farmer used. This approach, however, has two shortcomings: (i) it requires both farm survey and experimental data and (ii) it's not very clear whether the experimental data does lie in the production possibility set that the farm actually faces (Mandac and Herdt, 1978).

A second method employed to estimate technical and allocative efficiency is the profit function models (Yotopoulus and Lau 1971; Yotopoulus and Lau, 1973). The method depends on the theoretical duality between production and profit functions, that is, for every production function, there is a corresponding profit function. Differences in technical efficiency between groups of farms can be observed through neutral shift parameters, i.e. terms estimating the difference between profit functions for two groups of farms. This methodology is of questionable value in multi-product situations since profit is expressed as Unit-Output-Profit (UOP), which only allows the comparison of relative technical efficiency between farm groups and can say nothing about the absolute level of technical efficiency. Additionally, it is usable only where there are differences in prices of resources and output among farmers (Pachico, 1980).

A third and the most common approach to estimating technical efficiency is by comparing the behavior of the best practice farms with other farms. This approach estimates a frontier production function of the most productive farm and the relative technical efficiency of the other farms are then determined by comparing their performance to that of the best practice farms. A major setback of this approach is the reliance on outliers for the computation of the frontier function as estimation may be highly sensitive to extreme values since it is unlikely that all the data will be utilized. Another disadvantage of this approach is that, since the estimated frontier relationships are efficient only relative to observed farms and not to any actual underlying efficient production relationship, whether any farms are truly technically efficient cannot be answered from this approach (Carlson, 1976).

A fourth approach to estimating technical efficiency is by using a stochastic frontier production function. In 1957, Farrell developed the idea of using a frontier production function to estimate technical efficiency for an industry, but it was not until 1977 that a more satisfactory means of estimating technical efficiency was created. In that year, both Aigner *et al.* (1977) and Meeusen and van den Broeck

(1977a) developed a frontier production function with a decomposed error disturbance term. This decomposed error term consists of two components: the first component is systematically distributed and accounts for events outside the farmer's control, measurement error and other 'statistical noise', and the other component is usually non-negative and represents the farm's technical inefficiency. This model was used for several years to estimate industry-wide technical efficiency, but it was not until 1982 that Jondrow *et al.* (1982) made it possible to estimate technical efficiency for each individual farm.

A farm is said to be price or allocative efficient if it maximizes profits. For optimal performance, efficient resource allocation is a necessary condition (Henderson and Quandt, 1980). Assuming competitive markets, certainty, availability of production inputs and a certain level of technology then allocative efficiency aims at correcting the disequilibria which may exist in the use of factors of production.

When efficiency in resource allocation is attained the possibilities for increasing farm incomes through resource reallocation are exhausted. Simply put, allocative (pricing) efficiency refers to the proper choice of input combination. For an economically efficient farm, the marginal value product of the variable inputs equals marginal costs of the variable inputs. Allocative efficiency is realized when the marginal value products (MVPs) of the variable factors are equated to the marginal costs of these factors (MFC). In a competitive market, this is also equal to prices of those factors. Whenever allocative inefficiency occurs, this represents resource wastage.

The ratios of MVPs to factor opportunity cost (MFCs) provide a measure of the efficiency of the prevailing resource use on average, across the population of farms relevant to the sample studied (Heady and Dillon 1961, Obwana et al., 1997). If this ratio is greater than one, it indicates that little of the particular resource is being used under the existing price conditions given the levels at which other resources are operating. This means that the use of more of such a resource would lead to an increase in profit and also output. If the ratio is less than one, a reduction of such a resource would lead to an increase in profits.

Several studies have attempted to estimate allocative efficiency and technical efficiency and are listed below. A deviation in the approach for this study is that, the cited studies have estimated either allocative efficiency or technical efficiency and not both. This study has estimated both. Moreover, most of the studies cited are concentrated in East Asian and West African countries where Agricultural activities are dominated by rice production. Thus, very few studies are cited from East African countries in general or Kenya in particular. Where cited from these countries, the focus was on competing or other enterprises and not on rice production, though the major issues were on estimating efficiency as is the case with this study. This then makes the study unique and closes the gap of lack of literature on economics of rice production in the region. The following studies are cited;

Kundu and Kato (2002) examined the productivity and resources use efficiency in High Yielding Variety (HYV) Boro rice production under deep tubewell irrigation in Bangladesh. Based on the relevant primary and secondary data collected, they performed the necessary statistical analyses and applied the Cobb-Douglas production function to examine the efficiency of various resources used in rice production. They found that there are significant levels of technical and allocative inefficiency in Bangladesh rice production and that modern variety producers are slightly more efficient than those for local variety producers. Their analysis also indicates that if the better educated younger farmers could operate the farming activities, land owners themselves could cultivate their fields, extension personnel could pay frequent visits, more family members directly worked in their fields, credit was easily available, there was less land fragmentation and size of the farm could be enlarged, then Bangladeshi rice producers' efficiency would be increased.

Sriboonchitta and Wiboonpongse (2000) studied the effects of production inputs, technical efficiency and other factors on Jasmine and Non-jasmine rice yields in Thailand. They hypothesized the variables affecting the yields of Jasmine and Non-jasmine rice production as seeds, chemical fertilizers, labor, other chemical substances, irrigation, neck blast and drought. Data on these variables was fitted in a Cobb-Douglas stochastic production frontier model for analysis. They found that crucial factors influencing Jasmine rice yield were chemical fertilizer, labor, irrigation, severe drought and neck blast, whereas those for the non-Jasmine rice are the same, except labor and neck blast. Further, they found that the factors reducing the technical inefficiency for non-Jasmine rice are male labor to total labor ratio and farming experience (reflected by age), while total labor enhanced technical inefficiency. For the Jasmine rice, only the male-labor to total labor ratio variable was found to be significant in reducing technical inefficiency. Based on these findings, they drew the following conclusions:

1. To enhance the yield of both kinds of rice, chemical fertilizers may be encouraged to be used more, for example by lowering the fertilizer price or providing more credit to buy fertilizer for farmers who are constrained by credit;
2. Drought and neck blast resistant rice variety research is recommended, or drought could be handled by providing irrigation systems to such areas;

3. To reduce the technical inefficiency for Jasmine rice production, it is recommended to use more male labor relative to the total labor;
4. For lowering the non-Jasmine rice technical inefficiency, besides increasing the male labor, experience reflected by the age variable must be added. This suggests using less labor and more capital.

Seyoum et al. (1998) investigated the technical efficiency and productivity of two samples of maize producers in Eastern Ethiopia, one involving farmers within the Sasakawa-Global 2000 project and the other involving farmers outside this program. The study used stochastic frontier production functions in which the technical inefficiency effects are assumed to be functions of the age and education of the farmers, together with the time spent by extension advisers in a ssisting farmers i n their agricultural production operations. For the cross-sectional data obtained for the 1995/96-crop year, Cobb-Douglas stochastic frontiers were found to be adequate representations of the data, given the specifications of the translog stochastic frontiers for farmers within and outside the project. The empirical results indicated that farmers within the SG 2000 project were more technically efficient than farmers outside the project, relative to their respective technologies. The mean frontier output of maize for farmers within the SG 2000 project was significantly greater than for the farmers outside the project. This current study focuses on rice production though using the same approach as Seyoum's study. Moreover, the studies are conducted in different agro-ecological zones.

Mandal et al. (1995) examined the contending proportions of size productivity relationship prevailing in DTW II project in Bangladesh. They measured and compared the per hectare cost, returns, farm size and farm productivity and their impact on employment. Empirical data was collected through a farm survey of 220 sample farmers in an area of Mymensingh district. Their study showed that medium farms obtained the highest yield and gross margin despite using least amount of inputs and that they were more technically efficient though none group was more efficient allocatively. Thus, they concluded that scope to increase the doses of fertilizer existed despite the higher prices in the recent years. Further, the study found that small farms created more employment opportunities than the other farm groups.

Coelli et al. (2002) examined the technical, allocative, cost and scale efficiencies in Bangladseh rice cultivation. They applied programming techniques to detail data for 406 rice farms in 21 villages and found that inefficiency measures differed substantially from the results of simple yield and unit cost measures. For the dry season Boro crop, mean technical efficiency was 69.4%, allocative efficiency was 81.3%, cost efficiency was 56.2% and scale efficiency was 94.9%. The wet season Aman crop had similar results but a few points lower. Their conclusion on the possible causes of allocative inefficiency was due to overuse of labour, suggesting population pressure, and of fertilizer where recommended rates may warrant revision. Their second stage regressions showed that large families are more inefficient, whereas farmers with better access to input markets, and those who do less off farm work tend to be more efficient. The information on the sources of inter-farm performance differentials could be used by the extension agents to help inefficient farmers.

Satapathy and Sudhakar (2001) analyzed the economics of borrower and non-borrower rice farmers in India. The study examined the difference in the use of inputs, costs, returns and resource use efficiencies of borrower and non-borrower rice growers during 1994/95-crop. A sample of 97-farm household was selected using a two-stage random sampling technique. The study noted that the borrowers had used higher amounts of critical inputs that enabled them to obtain higher per hectare yield as compared to non-borrowers. With regard to the optimization of resources, credit recipients could maximize profit from rice production through optimum use of credit-financed inputs. The non-borrower farmers can also allocate their resources optimally through higher investment from owned fund.

Sakurai and Palanisami (2001) conducted a theoretical inquiry and empirical analysis on the issue of institutional evolution for resource management focusing on irrigation water, a traditional local common property resource, in India. Two management schemes for irrigation water, a community managed regime (tank irrigation) and an individualized management regime (well irrigation), are compared in terms of rice production efficiency. Using farm household data collected, it is found that profit of rice production using well water only is low due to the high labour input required for well irrigation management. Then, estimation of the profit function reveals that the profit of farmers using both tank and well water is statistically significantly higher than that of farmers who use either well water or tank water only. The result, based on game theoretical inquiries, implies that (in equilibrium) tank and well irrigation can coexist. Moreover it is calculated that about 90% of farmers use wells in equilibrium considering that well users are only 37% of all farmers at present.

Mubarik (1995) studied the institutional and socio-economic constraints on the second-generation green revolution in Pakistan. The study argues that any new growth in agricultural productivity will be based on improving the institutional and socio-economic situation for the purpose of enhancing resource use efficiency. This second generation Green Revolution will not push modern inputs as a strategy but growth in productivity will depend on the efficient use of these inputs. The paper investigates the constraints on the second generation Green Revolution by quantifying the causes of resource-use inefficiency and variation in input use in agriculture. A case study is presented describing socioeconomic conditions, institutional setting and physical environment in two representative rice-growing villages Ratta Dholar and Jallan Gujranwala, the largest rice producers in Pakistan in terms of both size and production. The influence of marketing factors, access to public infrastructure, resource-based factors, and biophysical environment or variation in input level is quantified. The farm-specific resource use efficiency is estimated from a stochastic frontier production function model, and the observed differences are then related to the factors determined by the socioeconomic and institutional setting of the area. The difference in access to public infrastructure, socio-economic conditions and resource-based and biophysical factors affected production by influencing farm management practices and farmers' production related characteristics.

Rahman et al. (1993) evaluated resource use efficiency in high yielding variety (HYV) Boro paddy production in Bangladesh. The study estimated the relationship between input use efficiency and productivity of different sizes of farms producing HYV Boro rice in selected areas of Brahman Baria district using a Cobb-Douglas production function. Returns to scale efficiency in input allocation and farmer's capability to produce at the least cost level were identified. The six variables (HYV area, seedlings, fertilizers, manure, human labour, bullock power and irrigation) explain over 74% of the variation in HYV Boro production. HYV area, fertilizers and labour were the most important factors. In terms of fertilizer application, utilization by small and medium farms has been economically efficient while large farms overutilize it. Medium farms under-utilize bullock power. The present combination of most of the material inputs is higher than the least combination. Farmers need to be given better technical knowledge of crop production while extension services should promote the timing and quantity of input mixes for different crops so that farmers can choose the most efficient mix.

Dittoh (1991) examined the relative economic efficiencies of different irrigation systems in Nigeria using a profit-function approach. The study showed that small and large irrigated farms were economically efficient to the same degree, that informal irrigation systems were more economically efficient than formal irrigation systems, and that economic efficiency did not differ for small-scale and medium-scale irrigation technologies in the study area. Factor demand functions were used to test for relative price efficiencies. The analysis showed that labor was used inefficiently on large farms, while fertilizers were used inefficiently on small farms. It also indicated that labor and irrigation water were used more judiciously by informal irrigators than by formal irrigators. Absolute price efficiency tests showed that none of the farm groups maximized profits by equating the marginal value products of variable factors to their marginal factor costs (prices).

Olagoke (1990) examined the efficiency of resource use in three rice production s ystems in Ahambra state. T he s tudy s howed no statistically significant differences between the net returns from irrigated rice fields and either swamp rice fields or upland rice fields. Allocative efficiency tests were evaluated from MVP:MFC ratios and showed that all resources were underutilized on the sampled fields during the survey year. These findings are relevant to the current study as one of the objective is to test for allocative efficiency using the same approach, but on a different agro-ecological zone, thus providing a good comparison.

Kiaye (1995) carried out a study to evaluate the efficiency of resource use by small-scale wheat producers in Uasin Gishu District, with the aim of suggesting ways to increase farm productivities, rural incomes and revenue. He fitted a Cobb-Douglas production function to data collected from a cross-section sample of 50 farmers and determined the efficiency of resource use by using the student t-distribution to test whether the ratio of Marginal Value Product (MVP) and Marginal Factor Cost (MFC), i.e. (MVP:MFC ratio), differed significantly at 5% level from 1.0. His results indicated that the resources engaged in small-scale wheat production were being used inefficiently. The ratio MVP/MFC for wheat seed, Diamonium Phosphate (DAP) fertilizer, mechanized land preparation and herbicide were all significantly different from 1 .0 at 5 % l evel, s uggesting either r esource u nderutilization or overutilization. The current study uses the same approach in measuring allocative efficiency but on rice production unlike Kiaye's study, which focused on what production.

Kilungo (1999) analyzed the economics of smallholder dairy production in Kiambu District, Kenya with the aim of testing for allocative efficiency among dairy farmers and relative economic efficiency between large and small dairy farms categorized by herd size of the milking cows. He fitted a Cobb-Douglas form of production function model on 57 farms using major inputs that the dairy farmers were using. His results indicated that concentrates and hired labor were positively and statistically significant (5%) in influencing milk yields while forage was negatively and statistically significant (1%) in influencing milk yields. Operating capital positively and significantly (10%) influenced milk yields. His test for the efficiency of resource allocation showed that concentrates were being allocated inefficiently (below optimal level) while there was efficiency in the use of operating capital, hired labor, family labor and by-products. His conclusion was that substantial increases in milk yields and farm profits could be realized from increasing the levels of use of resources above the levels presently being used. This study though not focusing on rice production is relevant to the current study as it follows the same approach in estimating allocative efficiency.

Ayoo (1992) carried out a study in Hola irrigation scheme on production constraints and optimal enterprise mix in an irrigation scheme. The study concluded that the poor performance of the irrigation schemes could be attributed to how the resources were allocated between and within the various enterprises being operated. The study used Linear Programming to generate an optimal farm plan and reveal the binding agricultural production constraints. The study established that scope existed for increasing the farm incomes through a reallocation of the available resources, without necessarily adding other resources. The focus of the current study is not on enterprise mix and thus used a different model to estimate technical and allocative efficiency.

Irea (1979), Mukumbu (1987), Kamunge (1987) and Makanda (1989) carried out studies in order to examine the patterns of resource allocation in Perkerra, West Kano, Mitunguu and Kibirigwi Irrigation Schemes, respectively using Linear Programming. These studies found that through an alteration of the resource allocation patterns and enterprise combinations, it was possible to increase the farm incomes significantly. As compared to the identified optimal farm plans, the existing farm plans were found to be sub-optimal. The studies further identified the constraints to increased agricultural production to be labour and working capital. These studies utilized a Linear Programming (LP) model to assess efficiency of resource use. LP models allocate resources among the competing activities and determine the mix of efficient activities that gives the optimal plan as specified by the objective function. However, this study is not concerned with identifying the appropriate enterprise mix since Mwea Irrigation Scheme is rice-growing scheme (rice monoculture) and the issue of competing activities doesn't arise.

The majority of the studies reviewed in the foregoing discussion have concentrated on testing allocative and technical efficiency individually and at different times. This study deviated from that approach and tested both allocative and technical efficiency at the same time.

Moreover, in the studies conducted in Kenya, emphasis was on resource allocation among competing enterprises, or on enterprises other than rice. The present study, though adopting the same methodological approach in testing technical and allocative efficiency, will focus on comparing technical and allocative efficiency of two groups of farmers in Mwea Irrigation Scheme. This study also differs from past studies conducted in Mwea Irrigation Scheme as it comes at a time when a farmers' association has taken over the management from the National Irrigation Board.

CHAPTER THREE: METHODOLOGY

3.1 CONCEPTUAL FRAMEWORK

This section outlines the basic theoretical framework that underlies this study whose key interest is to examine the economic rationality of rice production in Mwea Irrigation Scheme. The focus will be on technical efficiency, allocative or resource use efficiency and gross margin analysis. A comparison will be made between the former NIB managed tenants who are now under the management of Mwea Multi-purpose Rice Growers society (MMRG) and the recently emerged non-MMRG farmers within the Scheme. This latter group of farmers is popularly referred to as *Jua Kali*[1]. The *Jua Kali* farmers operates independently of MMRG and produces two crops of rice in a year unlike the MMRG dependent farmers who grows one rice crop in a year. These *Jua Kali* group is composed of the sons and daughters of the Scheme tenants and grows two rice crops in a year though they are not in access of institutional factors as well as the physical rice production resources.

Whereas two rice crops in a year utilize the excess labor available for agricultural production, other resources like irrigation water and facilities are constrained. Moreover, the flooded rice fields throughout the year provide uninterrupted breeding of mosquitoes, thus increasing malaria prevalence in the area and this has far reaching effects on labor productivity in particular and technical efficiency in general.

A comparison will be made between a single crop and double crop of rice in terms of technical efficiency, allocative efficiency and rice production profitability. This will be important in understanding the limitations and opportunities in the two

[1] *Jua Kali* is a Kiswahili connotation for hot sun

categories in terms of such resources as labor, seeds, irrigation facilities, fertilizers, operating capital, credit, research, extension services and farming experience.

For the purpose of this study, and for comparison purposes, farmers producing a single crop and under the management of Mwea Multi-purpose Rice Growers Society will be referred to as MMRG dependent farmers while the others (two crops in a year) will be referred to as non-MMRG farmers or MMRG independent.

3.2 DATA SOURCES AND COLLECTION

Farm level field surveys were carried out to collect primary data using a questionnaire. Both quantitative and qualitative data were collected from MIS rice producers that is the single crop MMRG dependent and double rice crop non-MMRG farmers. Data gathered included rice output, production inputs like land size, labour, seeds, chemical fertilizers, pesticides, irrigation facilities, use of machinery and animal power. Data on farmer's specific characteristics like age, gender, education level, family size as well as institutional factors like availability of credit and extension services was also gathered. Other data collected were on health status and market aspects like rice output prices.

Secondary data was collected to supplement the primary data from Organizations associated with MIS. These included the National Irrigation Board (NIB), Mwea Mutli-purpose Rice Growers Society (MMRG) and Mwea Irrigation Agricultural Development (MIAD).

3.3 SAMPLING DESIGN

This study was conducted in Mwea Division of Kirinyaga district. It was part of a research project *(Agro-Ecosystem management for community based integrated Malaria control in East African Irrigation schemes)*, which was being carried out by the *International Centre for Insect Physiology and Ecology* (ICIPE) in collaboration with researchers from the *University of Nairobi*, *Kenya Medical Research Institute* (KEMRI) and the *International Water Management Institute* (IWMI).

To achieve all the objectives of the different participants in the study, a three-phase selection criterion was used to identify the study households. In the first two phases, a participatory and interactive process with the community key leaders was used to identify the study sites and the household sampling frame, based on the overall project objectives. The third phase comprised the actual collection of household data, based on individual researcher's disciplinary objectives and scope of his/her study.

For this study, households comprised the unit of sampling. Based on the list frame of households developed during phase two, proportional probability sampling was used to sample households in the two irrigated villages considered in this study. A total of 106 households were sampled, 61 growing one rice crop in a year (MMRG dependent) and 45 growing two crops (MMRG independent).

A semi-structured questionnaire was developed for households' survey data collection. Field enumerators from the local community (Mbui-Njeru and Ciagi-ini) were trained on the questionnaire administration. Before the actual data collection was initiated, a pre-test of the questionnaire was carried out in one of the MIS non-study villages. The questionnaires were finally administered to the household's heads and in their absence, to the most mature person available and over 18 years.

3.4 ANALYTICAL FRAMEWORK

The analysis of technical and allocative efficiency in rice production for the two groups of farms was derived from a production function model of the Cobb-Douglas Stochastic Frontier type. The computationally attractive characteristic of the

Cobb-Douglas production function is that it becomes linear in the logarithms of the variables (Yotopoulos and Nugent, 1976).

3.4.1 Technical Efficiency

The technical efficiencies of the two groups of farms (MMRG dependent and non-MMRG farms) were estimated by the parametric approach using a stochastic frontier production function, proposed by Battese and Coelli (1995). Since the pioneering work of Farrell in 1957, efforts have been directed towards the estimation of frontier models of a production technology and obtaining technical efficiency measures. The types of models used included nonparametric deterministic models, deterministic full frontier models, stochastic full frontier models, and stochastic frontier models.

The basic concept of a stochastic frontier production function was first proposed by Ainger et al. (1977) and Meeusen and van den Broeck (1977a). The same concept was applied in this study. Various functional forms may be specified for the stochastic frontier production function such as the Cobb-Douglas, quadratic, constant elasticity of substitution, and the translog among others. The Cobb-Douglas functional form is generally preferred because of its well-known advantages e.g. it becomes linear in logarithms of variables.

The Cobb-Douglas stochastic frontier production function is expressed as follows in this study:

$Y_i = Y(x_{ki}, \beta)\, e^{Ei} \qquad i = 1 \ldots n, k = 1 \ldots k \qquad (3\text{-}1)$

Where,

Y_i is the output of the i-th farm,

x_{ki} is a vector of k inputs of the i-th farm,

β is a vector of parameters and

E_i is a farm-specific composed error term. The stochastic frontier is called a 'composed' model because the error term consists two independent elements, namely,

$$E_i = V_i - U_i \qquad (3\text{-}2)$$

V_i are the usual two-sided error term and are assumed to be independent and identically distributed as N (0, σ^2_v), independently of U_i. They reflect the usual random effects found in any system.

U_i are one-sided error term, non-negative, technical inefficiency effects, which are assumed to be independently and identically distributed random variables. U_i measures the farm's technical inefficiency in that it measures output shortfall from the maximum possible output given by the stochastic frontier. Thus, if $U_i = 0$, then the farm lies on the production frontier and it is obtaining the maximum output, given the prices and the fixed factors. If $U_i > 0$, then the farm is inefficient and loses output due to technical inefficiencies. If the random error U_i is absent from the model, then equation (3-1) becomes the "average frontier" model used in most econometric studies and subject to criticism by Farrell. On the other hand, if the random disturbance V_i is absent from equation (3-2), the model becomes a full frontier or deterministic model, often estimated by Linear Programming (e.g. Timmer, 1971). One of the primary criticism of the deterministic estimators is that no account is taken of the possible influence of measurement errors and other noise upon the shape and positioning of the estimated frontier, since all observed deviations from the estimated frontier are assumed to be the results of technical inefficiency (Coelli 1995; Bauer 1990).

3.4.1.1 Empirical Model

The Cobb-Douglas stochastic frontier production function for rice farmers is proposed to be:

$\ln OUTPT = \beta_0 + \beta_1 \ln (LABR) + \beta_2 \ln (TRACST) + \beta_3 \ln (ADP) + \beta_4 \ln (FERT) + \beta_5 \ln (PESTCD) + \beta_6 \ln (SEED) + \beta_7 \ln (LAND) + \beta_8 \ln (IRRG) + V_i - U_i$ (3-3)

V_i are assumed to be independently distributed normal random variables with mean zero and variance σ^2_v independently distributed of U_i; U_i are non-negative technical inefficiency effects, which are assumed to be independently distributed and arise from the truncation (at zero) of the normal distribution with variance σ^2 and mean μ_i defined by:

$\mu_i = \delta_0 + \delta_1 (EDUCAT) + \delta_2 (AGE) + \delta_3 (EXTN) + \delta_4 (CREDT)$ (3-4)

Where:

Ln	Natural logarithm;
OUTPT	Total paddy output in kilograms
LABR	Total labor input in man-hours both family and hired labor
TRACST	Total operating expenses of hiring tractors in Kenya shillings
ADP	Total operating expenses of hiring ox in Kenya shillings
FERT	Amount of inorganic fertilizers applied in 50kg bags
PESTCD	Total cost of pesticides applied in Kenya shillings
SEED	Amount of seeds used in the nursery in Kilograms
LAND	Farm size under paddy measured in hectares
IRRG	Total expenses on irrigation water and facilities in Kenya shillings
EDN	Number of years of formal schooling of the primary decision maker
AGE	Age of primary decision-maker in years

EXT Access to extension services (dummy variable used, 1 if in contact and 0 if not)

CDT Access to credit facilities (dummy variable used, 1 if available and 0 if not)

β's and δ's The unknown coefficients to be estimated.

The production function defined by equation (3-3) has as explanatory variables: Labor involved in rice production, tractor power, animal draught power, fertilizer, pesticides, seeds, land and irrigation water and facilities. These variables are assumed to explain the output of rice in Mwea Irrigation Scheme. It is further assumed that the rice output is also influenced by farmers' specific characteristics and institutional factors, such as household's head education level and age, and accessibility to credit and extension services.

The technical inefficiency outlined by equation (3-4) indicates that the inefficiency effects in a stochastic frontier (3-3) are expressed in terms of the mentioned farmers' characteristics and institutional factors as explanatory variables.

The unknown coefficients β and δ are estimated together with variance parameters expressed as $\sigma^2 = \sigma^2_v + \sigma^2_u$ and $\gamma = \sigma^2_u / (\sigma^2_v + \sigma^2_u)$. The parameter γ, has a value between 0 and 1. A γ-parameter close to 1 implies that the technical inefficiency effects are significant in the stochastic frontier model and that the traditional production function, with no technical inefficiency effects is not an adequate representation of the data.

Battese and Coelli (1995) stated that the technical efficiency of production of the i^{th} farmer in the appropriate data set, given the levels of his inputs, is defined as:

$$TE_i = \exp(-U_i) \quad (3\text{-}5)$$

The technical efficiency of a farmer is between 0 and 1 and is inversely related to the level of the technical inefficiency effect. It is predicted using the conditional expectation of, exp ($-U_i$), given the composed error term in equation 3-1. In this specification, the parameters, β, δ, σ_v, σ_u and γ can be estimated by method of maximum likelihood. This was done using a computer program, FRONTIER Version 4.1 which also computes farm specific efficiency levels.

3.4.1.2 Testing of hypothesis under the Stochastic Frontier and Inefficiency Models

The test hypotheses for variables in the stochastic frontier and inefficiency models were as follows:

(i) The hypothesis that each of the physical resource identified significantly influenced rice output was tested for statistical significance for each of the β_i coefficients. The hypothesis tested took the following form:

H_0: $\beta_i = 0$

H_A: $\beta_i \neq 0$

and the t-statistic was calculated using the formula:

$$t = \beta_i / S.E\ (\beta_i) \quad (3\text{-}6)$$

(ii) The hypothesis that each of the farmer's characteristics and institutional factor identified significantly influenced the technical inefficiency in rice production was tested for statistical significance for each of the δ_i coefficients. The tests took the following form:

H_0: $\delta_i = 0$

H_A: $\delta_i \neq 0$

and the t-statistic was calculated using the formula:

$$t = \delta_i / S.E\ (\delta_i) \quad (3.7)$$

After calculating the t-value, it was then compared with the tabulated t-value at a predetermined level of significance and degrees of freedom. Given the two values of t, the null hypothesis (H_0) was accepted or rejected depending on whether the calculated t –value was less or greater than the tabulated t-values, respectively. If H_0 was accepted, this meant that the physical input under consideration did not influence rice output or the farmer's characteristic/institutional variable did not influence technical inefficiency. Conversely, its rejection indicated that the variable influenced rice output or its production technical inefficiency.

3.4.1.3 Testing Hypothesis for Technical Efficiency differences in the two groups of the farmers

The statistical significance of the difference in mean technical efficiency obtained for the two groups will be tested using the 'difference between means'.

To test for statistically significant differences in mean technical efficiencies between MMRG dependent farmers and non-MMRG farmers, i.e. the test procedure for the first hypothesis that there is no significant difference in mean technical efficiency between the two groups of farmers, is as follows:

H_0: $\mu_1 - \mu_2 = 0$

H_A: $\mu_1 - \mu_2 \neq 0$

and the t-statistic will be calculated using a formula as outlined by Ott (1988):

$$t = \frac{\mu_1 - \mu_2}{S_p \sqrt{\frac{1}{n_1} + \frac{1}{n_2}}} \qquad (3\text{-}8)$$

and

$$S_p = \sqrt{\frac{(n_1 - 1)S_1^2 + (n_2 - 1)S_2^2}{n_1 + n_2 - 2}} \qquad (3\text{-}9)$$

Where:

μ_1: Mean technical efficiency for the MMRG dependent farmers

μ_2: Mean technical efficiency for the MMRG independent farmers

n_1: Sample size, MMRG dependent farmers

n_2: Sample size, MMRG independent farmers

s_1^2: Sample variance, MMRG dependent farmers

s_2^2: Sample variance, MMRG independent farmers

s_p: An estimate of the standard deviation for the two populations and is formed by combining (pooling) information from the two samples.

After calculating the t-value, it was then compared with the tabulated t-value at a priori level of significance and degrees of freedom. Given the two values of t, the null hypothesis (H_0) was accepted or rejected depending on whether the calculated t – value was less or greater than the tabulated t-values, respectively. If H_0 was accepted, this meant that there were no statistically significant differences in mean technical efficiency between the MMRG dependent farmers and MMRG independent farmers.

3.4.2 Allocative Efficiency

The standard errors associated with the physical input's regression coefficients were used in computation of allocative efficiency. To determine the efficiency of resource use, i.e. allocative efficiency, the ratio of marginal value product (MVP[2]) to marginal factor cost (MFC[3]) was evaluated. MVPs were evaluated from Marginal Physical Products (MPP[4]) values.

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[2] Marginal Value Products (MVP) is computed by multiplying the Marginal Physical Products (MPPs) with the output prices (P_y)

[3] Marginal Factor Cost of a resource is the change in total cost for a given unit change in the employment level of the resource. Marginal factor cost simply refers to the price of the resource.

[4] The Marginal Physical Product (MPP) of an input is the addition to the physical product attributable to the last unit of input in the production process, the fixed input remaining constant.

3.4.3 Testing for Allocative Efficiency

The testing for allocative efficiency compares the MVP of a particular input with its MFC. If the factor (input) is being used efficiently, its' MVP equals the MFC and the price. However if they are significantly different, then that input is being used inefficiently. The following hypotheses were tested for efficiency in resource use (Heady and Tweeten, 1963).

H_0: $MVP_{xi} = P_{xi}$

H_A: $MVP_{xi} \neq P_{xi}$

The t-statistic is expressed as:

$$t = (MVP_{xi} - P_{xi}) / (S.E. \times MVP_{xi}) \quad (3\text{-}9)$$

Given a certain level of significance, the null hypothesis (H_0) is accepted or rejected. The level of efficiency in the use of a particular resource leads either to acceptance or rejection of H_0. A two-tailed test at 5% level was adopted and the null hypothesis was not rejected if $-t_c<t<t_c$ where t_c was critical t-value and t was calculated from equation 3-6. If, on the other hand $t>t_c$ or $t<-t_c$, the null hypothesis would be rejected in favour of the alternative hypothesis.

3.5 VARIABLES IN THE MODEL

This section presents the dependent and independent variables used in the production function model.

3.5.1 Dependent Variable

The dependent variable in the model is the total quantity of rice produced in Kilograms.

3.5.2 Independent variables

3.5.2.1 Labor

This was the total amount of labor input used in rice production activities, including both family and hired labor, in man-hours. There were adjustments in deriving the man-hour equivalents for women and children labor. These were made to take into account the effectiveness of the worker for the task at hand relative to the effectiveness of a male adult. Children were accorded a man-equivalent ratio of 0.5 while that of women was 0.65. However, in some activities, no adjustments were made since women and children were effective just like men. These were transplanting and bird scaring for children as was the case with weeding and winnowing for women. It is expected that the regression coefficient associated with the labour variable is positive.

3.5.2.2 Tractor Power

This category of input included the total cash values for tractor-mechanized activities. Total cash value was used as a proxy of physical units due to the difficult of estimating tractors service in physical terms. Thus, the variable entered into the production function model as the cost incurred to hire tractors for mechanized rotavation of flooded rice fields. It is expected that the regression coefficient associated with this variable will be positive.

3.5.2.3 Animal Draught Power

Animal power is an important input in rice production field activities. The animals mostly used in MIS are oxen for levelling the uneven paddy fields immediately after mechanized tractors rotavation. Value, rather than the physical units was used to estimate this variable due to the difficult of estimating ox service in physical terms. Thus total value of hiring oxen was used as the proxy for physical unit, and entered the production function model as total cost for hiring the oxen in Kenya shillings. The regression coefficient associated with this variable is expected to be positive.

3.5.2.4 Chemical Fertilizers

Inorganic fertilizers are an important input in rice production. The input enters the production function model as the total number of 50kg fertilizer bags used during planting and for top dressing. It is expected that the regression coefficient of this variable will be positive.

3.5.2.5 Chemical pesticides and herbicides

Farmers in MIS use various chemicals for pests and weed control. Due to the small amount used, the value of this input, rather than the physical units was used as a proxy and thus the variable entered into the model as the cost incurred in purchase of these chemicals in Kenya shillings and it's expected that the regression coefficient associated with this variable would be positive.

3.5.2.6 Rice Seed

This variable is entered into the production function model as the quantity of seed used in kilograms. It is expected that the regression coefficient of this variable will be positive.

3.5.2.7 Land

Land was measured in acres during data collection and converted into hectares during data analysis. The variable entered into the production function model as the total quantity of land under rice. The regression coefficient associated with land variable is expected to be positive.

3.5.2.8 Water charges and Irrigation facilities

Irrigation technology is important in rice production. This variable is estimated in the production function model as the value of irrigation water supply, canal maintenance charges and purchase of irrigation facilities. The cost of this is used as a proxy for irrigation physical units. This was due to the difficult of measuring this variable in physical terms. The regression coefficient for this variable is expected to be positive.

3.5.3 Sources of technical inefficiency variables

The source of efficiency differential that is observed among farmers is an issue of overriding concern. Studies on sources of technical inefficiency are concerned with the role of farm and farmers' characteristics and institutional factors. In this study, the following variables are assumed to be influencing the level of technical efficiency.

3.5.3.1 Household head's education level

This variable is measured by the number of years of formal schooling by the household head and is used as a proxy for managerial input. Increased farming experience coupled with higher education level may lead to better assessment of the importance and complexities of good farming decision, thus reducing technical inefficiency. It is expected that the regression coefficient associated with this variable will be negative indicating that more years of schooling reduces technical inefficiency.

3.5.3.2 Household head's age

Age is expressed in years and it is an indicator of farming experience. The regression coefficient associated with this variable has no expected sign, i.e. it is expected to take either sign, positive or negative. This is because, whereas the more aged farmers could be more experienced, Bravo-Ureta and Pinheiro (1993) found a threshold of a farmer's age at which the probability of failure is the lowest and beyond which it increases again. Also, it is possible that older farmers have more experience and therefore are more efficient; but it is also possible that older farmers are less concerned with optimizing the use of resources under their control, thus giving a positive coefficient.

3.5.3.3 Access to extension services

This variable entered the inefficiency model as a dummy, 1 for farmers with access to extension services and 0 otherwise. It is assumed that the involvement of extension advisers tends to reduce the technical inefficiency in farming. Thus, the regression coefficient associated with this variable is expected to be negative.

3.5.3.4 Access to credit facilities

The availability of credit reduces the constraints of production, facilitating the acquisition of farming inputs on a timely basis and hence reducing farmers' technical inefficiency. By use of a dummy, the effect of access to credit on farmers' efficiency was investigated. The regression coefficient associated with this variable is expected to be negative, meaning that farmers with access to credit facilities have lower technical inefficiency.

3.6 DESCRIPTIVE ANALYSIS

By the use of descriptive statistics, such as frequency distributions, percentages, means, range and tabulations, the results from the study were summarized. The results summarized were for inputs, output, health and socio-economic indicators, prices and marketing aspects. Analysis of the socio-economic characteristics of farmers was especially important in detecting the constraints that the farmers faced with a view to recommending possible interventions to solving the problems.

3.7 GROSS MARGIN ANALYSIS

Gross margin is the total revenue less the variable costs. The Gross Margin for rice was estimated as a proxy for profitability. That is:

$$GM_i = TR_i - VC_i$$

$$GM_i = TR_i - \sum_{J=1}^{n} C_j \qquad (3\text{-}10)$$

Where: GM_i = Gross Margin for enterprise i

TR_i = Total Revenue for enterprise i

VC_i = Variable Cost for enterprise i

C_j = Cost of input j

Gross margins per hectare per year were computed to show the profitability of rice production under single crop in a year and under double crop per year.

CHAPTER FOUR: DISCUSSION OF THE RESULTS FROM DESCRIPTIVE ANALYSIS

This chapter presents the results of descriptive analysis of the survey data.

4.1 FARMERS' SOCIO-ECONOMIC CHARACTERISTICS

The characteristics targeted here were: age of the household head (which was a proxy for farming experience) in years, education levels of the household heads, family size, sex of the household head, total farm size, land tenure status, access to credit facilities, access to extension services, farm and off-farm income and health status. In all the variables, comparison was made between the MMRG dependent and non-MMRG rice farmers.

4.1.1 Total farm size and land utilization

Reporting of farm size in this study was done in acres instead of hectares due to the small farm sizes involved. However, in the production function analysis presented in the next chapter, land variable is converted into hectares. Farm size ranged from 4.00 to 9.00 acres, with a mean of 4.74 acres (1.91ha) for MMRG dependent farms. For the non-MMRG, farm size ranged from 0.13 to 3.75 acres with a mean of 1.20 acres (0.48ha). The MMRG dependent farmers interviewed indicated that out of their 4.74 acres of land, 4.09 acres were under rice production. For the non-MMRG farmers, out of their 1.20 acres of land, 1.08 acres were under rice production (Table 4-1). This means that 86.9% and 90% of the total land area is utilized for rice production by MMRG dependent and MMRG independent farmers, respectively.

Table 4-1: Farm size and utilization

Farmer category	Mean farm size (Acres)	Range	Mean, farm size under rice	Percentage under rice
MMRG dependent (n = 61)	4.74	4.00-9.00	4.09	86.3%
MMRG independent (n = 45)	1.20	0.13-3.75	1.08	90%

Source: Author's Survey, 2002

Such a high percentage of specialization in rice production implies that very little land is devoted for production of other enterprises. For the MMRG dependent farmers, 78.7% of the respondent indicated that they did not grow any other crop, but 3.3% grew tomatoes, 9.8% grew maize, 1.6% grew beans, and 6.6% grew kales and cabbages on the remainder of the land not under rice. About 88.9% of MMRG independent farmers indicated that they did not produce any other crop, but 4.4% grew beans, while 2.2% each reported growing maize, cabbages and tomatoes (Table 4-2).

Table 4-2: Farmer's Land utilization

Farmer category	Other crop grown	Percent growing	Cumulative percentage
MMRG Dependent (n = 61)	None	78.7	78.7
	Maize	9.8	88.5
	Beans	1.6	90.1
	Tomatoes	3.3	93.4
	Kales & cabbages	6.6	100
MMRG Independent (n = 45)	None	88.9	88.9
	Maize	2.2	91.1
	Beans	4.4	95.5
	Tomatoes	2.2	97.7
	Kales & cabbages	2.2	100

Source: Author's Survey, 2002

The high percentage of farmers growing only the rice crop is due to the fact that, in the scheme, the area is almost covered by lowland paddy fields and therefore paddy cultivation has pivotal importance. Very few farmers grow upland crops, and the sizes of cropped acreage are minimal. The area thus suffers from chronic food deficits.

4.1.2 Land Tenure

Farmers in Mwea Irrigation Scheme have no land title deeds. Both MMRG dependent and MMRG independent farmers indicated that they have no land title deeds. Land in the scheme belongs to the Government and farmers are tenants. Land tenure is given in the form of user rights by the community-driven Mwea Multi-purpose Rice Growers cooperative society, which has taken over the management of the Scheme from NIB. Therefore, land tenure and ownership in the scheme is contentious.

4.1.3 Agricultural Credit

Credit is an important factor for agricultural development. Whereas the MMRG independent farmers do not get sufficient credit for purchase of yield enhancing inputs, most of the operations of the MMRG dependent farmers are financed on credit by the cooperative society. All the credit to farmers is recovered after farmers deliver their rice to MMRG for milling and marketing.

Among the sample farms, 86.9% of MMRG dependent farmers indicated that they received agricultural credit, in form of inputs, during the 2000/2001-crop season from the cooperative society. The rest (13.1%) of the MMRG respondents stated that either the credit terms were unfavorable or rice production was not profitable enough to pay back. On the other hand, only 24.4% of MMRG independent farmers indicated that they received credit in the same period from friends and relatives. None of them received credit from the cooperative society as the society extends the credit facilities to its members only. At the same time, 33.3% of the MMRG independent respondents indicated that they did not need credit, 28.9% stated that they had no source of credit while 13.3% felt that credit was available but did not have collateral.

To boost production, availability of credit is essential to ease constraints farmers face. Since 75.6% of the non-MMRG respondents did not have credit, the Government should facilitate the availability of credit to farmers.

4.1.4 Extension Services

The NIB run irrigation schemes enjoy specialized extension to the rice farmers. However, after the takeover of the MIS management by the community based MMRG cooperative society, such services as extension advice have been limited. The cooperative society lacks financial and human resources to offer such services effectively. Survey data indicated that 60.3% and 95.6% of the MMRG dependent and independent respondents, respectively, had never received agricultural extension advice during the 2000/2001-crop season. Moreover, 75.4% and 88.9% of the dependent and independent respondents, respectively, indicated that they had never attended any sort of a farming course during the same period. This is notwithstanding that 47.5% of the MMRG dependent respondents indicated that their households' head's, and in effect the farm decision makers, did not have any formal education, as shown in Table 4-3.

4.1.5 Household head: Education Level, Gender and Age

For MMRG dependent farmers, 52.5% indicated that they had attended formal schools while 98% from non-MMRG farmers had the same. For the independent farmers, only 2% of the respondents indicated that they were illiterate (Table 4-3). Post secondary level of education was, however, very low and only 1.6% and 8.9% of the dependent and independent respondents had attained that level, respectively. This scenario, coupled with the lack of farming courses and proper extension services, could lead low agricultural productivity.

Table 4-3: Household head's highest educational level

Education level	Percentage	
	MMRG dependent (n = 61)	MMRG independent (n = 45)
Illiterate	47.5	2.0
Primary	39.3	51.1
Secondary	11.5	38.0
Post secondary	1.6	8.9

Source: Author's survey, 2002

The majority of households, both MMRG dependent and MMRG independent, are managed by men (82% for the MMRG dependent and 88.9% for the non-MMRG farmers). Men were the ones involved in making the day-to-day decisions of the running of the rice production activities in the scheme. The mean age of the household heads in the dependent group is 60 years, with a range of 39-98 years, while that for the independent group is 34 years with a range of 22-67 years.

Mean size of the household is 7 for the MMRG dependent, with a range of 3-15 persons, while that for the non-MMRG is 4 with a range of 2-9 persons (Table 4-4).

Table 4-4: Household head's sex and age, and household size

Farmer category	Age of the Household head (Years)		Household family size (Persons)		Mean sex of the Household head (%)	
	Mean	Range	Mean	Range	Male	Female
MMRG dependent (n = 61)	60	39-98	7	3-15	82	18
MMRG independent (n = 45)	34	22-67	4	2-9	88.9	11.1

Source: Author's survey, 2002

The majority of MMRG independent farmers (98%) had attained primary school education and comprises of a young generation farmers, with a mean age of 34 years. This implies that proven technologies, extension and research services can be passed on to these farmers with relative ease since communication between farmers and the agents of change should present no major problems. This group of farmers would therefore be considered as more receptive than the relatively illiterate (47.5%) and older, mean of 60 years, MMRG dependent farmers.

Nearly all-household members are involved in paddy production activities. Children are mostly involved in transplanting and bird scaring, women in weeding and winnowing, and men participate in harvesting and threshing. Therefore, the average sizes of 7 and 4 persons in the MMRG dependent and MMRG independent groups imply that family labor is available to perform these activities.

4.1.6 Farm and Off-farm Incomes

Mwea irrigation scheme is predominantly agricultural and dominated by rice production. On average, farm incomes are far much larger than non-farm incomes. Farm incomes predominantly came from rice sales. Off-farm incomes were mainly from casual agricultural labor, with other sources being business activities, remittances and salaried employment.

For the MMRG dependent farmers, mean household farm income was Kshs. 166,246 per year, while off-farm income was Kshs. 11,845 per year. For MMRG independent farmers, mean household farm income was Kshs. 51,024 per year while off-farm income was Kshs. 29,130 per year.

4.2 HEALTH STATUS

Irrigation has a risk of enhancing water as well as vector borne diseases and increases the health risks from contaminated water. In Mwea Irrigation Scheme, there are incidences of water and vector borne diseases among farmers. Mean family medical expenses reported by MMRG dependent farmers were Kshs 30,178 per year (Table 4-5). They also reported that their family members were on average absent for 29 days per year seeking treatment of diseases like typhoid, malaria, cholera and bilharzia.

Table 4-5: Medical expenses and sick days

Farmer category	Mean expenditure on water and vector diseases (Kshs/yr)	Mean period household members were absent seeking treatment (Days/yr)
MMRG dependent (n = 61)	30,178	29
MMRG independent (n = 45)	9,409	12

Source: Authors survey, 2002

Though the MMRG independent farmers produce two rice crops in a year and thus are exposed to the standing water throughout the year, they still reported a lower mean medical bill of Kshs 9,409 per year compared to Kshs 30,178 per year for the one-crop MMRG dependent farmers. This was against the expectation that the MMRG independent farmers who are exposed to the stagnant water for most of the year would have a higher medical bill and be absent from active work for a longer period. An explanation for this could be the fact that the mean household size of MMRG dependent farmers is much higher (7 persons) than for the independent farmers (4 persons). Further, it can be postulated that medical expenses reflected on availability of income rather than need, as the dependent farmers had much higher mean farm income compared to the independent ones. All in all, morbidity was high and this would have negative consequences on labor availability and productivity. When the respondents were asked their views on the effects of the water and vector borne diseases on hired and family labor, as high as 53.4% of the MMRG independent respondents felt that the diseases constrained labor availability and productivity. At the same time, 41% of the MMRG dependent tenants felt that the high medical bills from the diseases drain farm incomes.

4.3 RICE PRODUCTION AND MARKETING

4.3.1 Rice Production

Agricultural production in Mwea Irrigation Scheme is dominated by rice production. For over 40 years, up to 1998 rice production was highly regulated by National Irrigation Board (NIB), which had title to the land and license for irrigation water and determined the water use schedules and the type of crops that the farmers produced.

After the takeover of the Scheme management by MMRG, there was an emergence of the independent farmers who introduced the concept of rice double crop. When the MMRG dependent respondents were asked the reason of growing one rice crop in a year, all the dependent respondents indicated that it was a requirement by the MMRG management. And asked if they would like to grow a second rice crop, 85.2% of the respondents indicated that they would like to grow a second crop.

Average rice output for the MMRG dependent farmers was 7,472 Kgs per year, with a range of 1,800-16,830 Kgs, while mean for MMRG independent farmers was 2,329 Kgs per year with a range of 90- 10,530 Kgs. MMRG dependent farmers reported a higher output in rice production per hectare as compared to MMRG independent farmers. The former reported a mean paddy yield of 4,509 Kgs/ha in the single main season while the latter reported a yield of 3,139 Kgs/ha from the two crops. Implication of this is that a single crop of rice in a year is more yielding than a double crop, all else being equal.

Various factors were given as the major constraints facing rice production in Mwea Irrigation Scheme. Unavailability and competition for water was cited as the worst problem, followed by delay in payment, competition from cheap rice imports and expensive inputs (Table 4-6).

Table 4-6: Worst problems facing rice production

Problem nature	Farmer category	
	MMRG dep (%) n = 61	Non-MMRG (%) n = 45
Competition for and unavailability of irrigation water	72.1	84.4
Delay in payment of rice delivered	23.0	0.0
Competition from cheap rice imports	3.3	8.9
Expensive inputs	1.6	6.7

Source: Author's Survey, 2002

There was a mixed response when the respondents were asked to suggest on ways of increasing rice production in the Scheme. But a notable suggestion was to have the government (in this case NIB) return on core management of the daily operations of the scheme. Farmers, especially the MMRG dependent tenants, felt that the MMRG co-operative Society had no capacity to provide essential services that were being offered by the NIB before the takeover.

There was also the suggestion that the government should manage and improve the water supply, among other suggestions as shown in table 4-7. The issue of poor management by the MMRG thus featured prominently among the farmers who to their disappointment, MMRG has failed to meet their expectations. The take-over of the Scheme by MMRG was a culmination of disagreements between farmers and the Government for alleged low price of rice, lack of serious involvement of the farmers in the management of the scheme, a land tenure system that continued to lease land to farmers although they had been in the scheme for years, and exaggeration of the input costs offered on credit basis. However, the feeling now with some farmers is that the Government is better off than MMRG in providing essential services.

Table 4-7: Suggestion by farmers on ways to increase rice production in MIS

Suggestions	MMRG Dep. (%) n = 61	MMRG Indep. (%) n = 45
Manage and improve water supply	49.1	51.1
Initiate research	23.0	17.8
Provide inputs in form of credit to farmers	16.4	20.0
Increase rice producer prices	11.5	11.1

Source: Author's Survey, 2002

4.3.2 Rice Marketing

MMRG Society which took over the Scheme management from NIB oversees the running of the scheme's rice production, processing and marketing activities. The MMRG dependent respondents reported as having being paid an average of Kshs 25.05/kg. For the MMRG independent farmers, the respondents indicated as having sold their rice at Kshs 23.30/kg. The MMRG independent farmers sell their rice output to different traders. Majority, 95.6% of the respondents, reported as having sold their rice to local middlemen, while 4.4% said they sold to the local retailers. For the MMRG dependent tenants, 73.8% of the respondents expressed their dissatisfaction with the rice-marketing channel of delivering their product to MMRG, whereas the remaining (26%) had no problem with the Society. The dissatisfied lot gave various reasons of their concern, 63.9% complained that the Grower's Society was exploitative, 6.6% said that the output prices were too low, 3.3% felt that the transport costs were exaggerated, while 26.2% could not say why they were dissatisfied with the Growers Society.

On the other hand, 68.9% of the non-MMRG respondents also recorded their dissatisfaction with their marketing channels, whereas the rest (31.1%) said that they were satisfied. The dissatisfied farmers complained of exploitation by the middlemen (33.3%), very low prices (26.7%), unstable prices (2.2%), flooded market (2.2%) and the rest (33.3%) did not give any reason for their dissatisfaction.

Whereas MMRG independent farmers are paid by their agents on cash on delivery basis, MMRG dependent farmers receive their payment after 6-12 months. Whereas 6.6% of the respondents reported that they received payment as late as six months after delivery, the rest (93.4%) said that they normally received payments twelve months after delivery. 78.7% of the MMRG dependent tenants complained that the delayed payment had reduced rice production. The rest (21.3%), however, felt that the delay had no effect on rice production.

4.4 RESOURCES USED IN RICE PRODUCTION

This section presents the resources used in rice production among the farmers in Mwea Irrigation Scheme, both the MMRG dependent tenants and the MMRG independent rice farmers. These resources were used to formulate the rice production function model for the sampled households.

4.4.1 Labor input

Labor is one of the most important resources in rice production as irrigated rice farming is labor intensive. The respondents reported to have employed a combination of both family and hired labor. All the field operations were classified into 13 categories as follows: flooding, rotavation (including puddling & levelling), nursery preparation, transplanting, fertilizer & herbicides/pesticide application, weeding, bird scaring, draining, harvesting, threshing, winnowing, packaging and transportation. Except for rotavation, puddling and levelling, all the other activities are labor intensive.

The MMRG dependent tenants reported to have used a mean family labor of 918 man-hours per hectare, and a mean hired labor of 1,104 man-hours per hectare. This was against the independent farmers' mean family labor of 1,281 man-hours per hectare and a mean hired labor of 923 man-hours per hectare (Table 4-8).

Table 4-8: Family and Hired labor used in rice production

Farmer Category	Family Labor (Man-hours/ha)	Hired Labor (Man-hours/ha)
MMRG dependent (n = 61)	918	1,104
MMRG independent (n = 45)	1,281	923

Source: Author's survey, 2002

The MMRG independent farmers had a higher involvement of family members in the rice production activities than was the case with the MMRG dependent tenants. The opposite was true for the hired labor, i.e. MMRG dependent farmers had more hired labor than the independent farmers. The reason for this was that the MMRG dependent farmers had a higher off-farm and farm incomes than the independent farmers and thus could afford to plough back some of the incomes to rice production through hiring labor. On the other hand, though the MMRG independent farmers had smaller household sizes than the dependent farmers (4 against 7), they still had higher family labor than the dependent farmers. The reason for this was that these farmers had lower incomes and could not afford to hire more labor as the dependent farmers, so that they had to put in more hours of the household members.

None of the respondents in the study, both MMRG dependent and MMRG independent, reported as having hired any permanent labor for the purpose of rice production. All the hired labor was on casual basis. The MMRG dependent farmers hired an average of 54 casual laborers per year, with a range of 10-177 casuals. The MMRG independent farmers reported hiring an average of 42 casual laborers, with a range of 0-147 casuals. The average payment to the casuals for both MMRG dependent and non-MMRG farmers was Kshs. 133.30 per person per man-day. Farmers from both group considered this as too expensive (Table 4-9).

Table 4-9: Problems farmers encounter in hiring Labor

Problem	MMRG dependent (n = 61)	MMRG independent (n = 45)
	(%)	(%)
Too expensive	44.3	33.3
Not available	27.9	22.2
Unreliable	13.1	17.8
No problem	14.8	26.7

Source: Authors survey, 2002

The views of the farmers are in line with an earlier finding that the MMRG independent farmers put in more family labor than hired labor. Thus, a high percentage (26.7%) of MMRG dependent farmers indicated that they had no problem with hired labor and a lower percentage (33.3%) indicated that labor was expensive, an indication that the independent farmers have little dealings with hired labor.

Labor requirements were high in five major field activities as reported in both groups of respondents. The activities were: Weeding, harvesting, transplanting, bird scaring and threshing. These activities required at least 100 man-hours per hectare in the crop year considered. The rest of the activities attracted less than 100 man-hours per hectare and, in most instances, accounted for less than 5% of the total labor requirement.

Least labor requirement was reported in rotavation (2.90 man-hrs/ha) among the MMRG dependent farmers, whereas for the independent farmers transportation was reported as having attracted the least labor. Explanation to this is that the dependent tenants have access to the MMRG tractors that usually carry out the mechanized rotavation of the flooded rice fields on credit basis. On the other hand, the independent farmers have no access to such facilities and further they have very little income to hire tractors so that rotavation is done by manual labor. Transportation recorded very low labor requirements in MMRG independent farms as compared to the dependent farms because the former usually sell their rice output right away in the field to the middlemen who have to transport the rice on their own.

Intensive labor requirements were recorded in five major activities (Table 4-10). In the MMRG dependent farms, 23.9% of all labor requirements was used in weeding and was the highest in the group. Bird scaring was first in the non-MMRG farms, requiring 47.2% of the total labor per hectare, while weeding came second. The reason for this high labor requirement in bird scaring for the MMRG independent farmers was that their farms are in small parcels and sparsely distributed in the Scheme so that each parcel must have somebody scaring the birds. For the MMRG dependent farms, their land holding is in one parcel of mean 1.91 hectare and one laborer is enough to do the bird scaring in the whole parcel.

Weeding is usually the most labor-intensive activity in rice production as it is very difficult to remove the weeds, which are submerged in the irrigation water. Moreover, laborers have to be very careful to uproot the weeds only leaving the rice transplants intact.

Transplanting was ranked third in both the farms (364 Man-hrs/ha for dependent and 259 man-hrs/ha for independent). Harvesting was ranked second in MMRG dependent farms (386 Man-hrs/ha) and fourth in MMRG independent farms (205 Man-hrs/ha). This was in line with the yield levels of both groups of the farms (4,509.71 kg/ha for dependent and 3,139.24 kg/ha for independent). Since the independent farms had lower yields than the dependent ones, it means that MMRG dependent farms needed higher labor per hectare to do the harvesting than the MMRG independent farms. The same was the case with threshing.

Table 4-10: Highest Labor intensive activities in MMRG dependent and independent farms.

Farm group	Activity	Man-hours/ha	% of total
MMRG dependent (n = 61)	Weeding	485	23.90
	Harvesting	386	19.09
	Transplanting	364	17.93
	Bird scaring	306	15.08
	Threshing	228	11.22
MMRG independent (n = 45)	Bird Scaring	1,040	47.20
	Weeding	286	13.08
	Transplanting	259	11.76
	Harvesting	205	9.33
	Threshing	117	5.31

Source: Authors survey, 2002

4.4.2 Seed Input

Seed rates during the 2000/01-crop year were reported as 54.1 kgs/ha and 70.4 kgs/ha for the MMRG dependent tenants and independent farms, respectively. The NIB recommended seed rate, which the Growers Society still maintained, was 52 kgs/ha. That is, each farmer receives 82 kgs of Basmati seeds for the 1.91 hectares, and 48 kgs for the BW variety. The high seed rate (70.4 kgs/ha) among the independent farmers is due to the low viability of the retained seeds.

Two rice varieties are common in the scheme; Basmati and BW (Sindano). Basmati is the main variety grown (96.7% of the MMRG dependent tenants and 95.6% of the MMRG independent respondents). The BW variety was only grown by 3.3% of the MMRG dependent tenants and 4.4% of the MMRG independent ones. There were divergent views on why the farmers preferred the Basmati variety (Table 4-11). Most of the farmers (68.9% of the independent and 49.2% of the dependent respondents) indicated that they grew Basmati because it produced better grade rice, which sells at higher producer prices. Thirty nine percent (39.3%) of the dependent tenants reported that they grew Basmati, as it was supplied by MMRG and thus readily available.

Table 4-11: Reasons for growing Basmati variety

Reason for Growing Basmati	MMRG dependent (%) n = 61	MMRG independent (%) n = 45
Was readily available	39.3	6.7
Produce better grade rice for higher pay	49.2	68.9
Matures fast	8.2	6.7
High yielding	3.3	17.7

Source: Authors survey, 2002

Whereas all the MMRG dependent farmers indicated that they obtained their rice seed from MMRG, the MMRG independent farmers reported different sources of their seed with majority of them, (55.6%), indicating that they kept their own seed from the previous harvest. Others, (40%) indicated that the bought seed from their fellow farmers and 4.4% bought from MMRG.

A high percentage of MMRG independent farmers (55.6%) indicated that they kept their own seeds and further 48.9% of them indicated that they used those seeds because it was cheaper and convenient to get. The reason for this is that by keeping their own seeds, they cut down the production costs and further they avert the risk of inconveniences of seed shortage, which arise during the planting time.

Farmers, especially the MMRG dependent tenants, complained that the supplied seed were not treated, 86.9% of them reported that they had received untreated seeds from their MMRG. On the other hand, even the MMRG independent farmers (93.3%) who retained their own seeds or bought from their fellow farmers indicated that those seeds were not treated. These untreated seeds were exposed to damage due to rotting and attack by weevils and rats. These damages resulted to lower seed viability and thus the high planting seed rate reported.

The high planting seed rate among the MMRG independent farmers can also be explained by the fact that seeds were reported to be cheaper among the fellow farmers. The mean selling price for a kilogram of rice seeds during the 2000/01-crop year was given as Kshs 23.60. This was lower compared to what the MMRG dependent farmers were paying for the seeds, a mean of Kshs 31.80 per kilogram.

The MMRG dependent respondents (77%) complained of delayed and late supply of seeds by MMRG and were of the opinion that the Government should take over the management of MIS and initiate research on better quality seeds and availed in time.

4.4.3 Tractor Power

Tractors are used for mechanized rotavation of the flooded paddy fields and also for canals clearing. MMRG offer tractor services on credit to its farmers. Tractor service charge for rotavation per hectare was reported as Kshs 5,964 in the MMRG dependent farms and Kshs 5,633 in the MMRG independent farms. Obtaining tractor services on credit terms from MMRG was thus more expensive than hiring from the free market. About 98.4% of the MMRG dependent respondents reported to have hired the tractors from MMRG Society on credit. About 86.7% of the independent respondents indicated that they hired tractor services for rotavating the fields, while, about 13.3% indicated that they used manual labor.

Demand for tractor services is usually high during the planting season. Farmers cited several problems facing them while trying to get the tractor services as shown in Table 4-12. The worst problem cited by the MMRG dependent farmers (65.6%) was the delay by MMRG Society in carrying out the rotavation activity.

Table 4-12: Problems encountered in getting tractor services

Problem	MMRG dep. (% encountering the problem) n = 61	MMRG indep. (% encountering the problem) n = 45
Delay by MMRG Society	65.6	6.6
Expensive	19.7	48.9
Do not own their tractors	3.3	20.0
No problem encountered	11.4	24.5

Source: Author's Survey, 2002

Farmers in both groups suggested that the Government should take over the responsibility of providing them with tractor services on credit basis. Farmers were unanimous that MMRG Society was unable to offer such an important input effectively due to financial constraints.

4.4.4 Animal Draught Power

Oxen power is an important resource in rice production. In MIS, ox power is used by majority of farmers (Table 4-13) for levelling the rotavated rice fields. Very few farmers, however, use the ox power in rotavation.

Table 4-13: Oxen power utilization

Kind of work	MMRG dependent (% utilizing)	MMRG independent (% utilizing)
Rotavation	1.6	2.2
Levelling	96.7	88.9
Canal clearing	2.2	0.0
None	1.6	6.7

Source: Author's survey, 2002

Oxen are mostly hired. Over 70% of respondents in both groups of farms indicated that they hired. About 70.5% of the MMRG dependent tenants reported as having hired oxen during the 2000/01-crop year, while 27.9% owned them. For the independent respondents, 75.6% hired while 20% owned them.

Oxen charges were Kshs 1,962 per hectare for the MMRG dependent farms and Kshs 2,028 per hectare for the independent farms. The high charges of the oxen per hectare in the independent farms are due to the very small farm sizes, which are often sparsely distributed.

4.4.5 Fertilizer Inputs

Four major inorganic fertilizers are applied, that is Di-Ammonium Phosphate (DAP) which is mostly used during planting, Tri-Super Phosphate (TSP) which is used if DAP is not available, Sulphate of Ammonia (SA) which is used for top dressing, and Urea which is used for top dressing if SA is not available. Di-Ammonium Phosphate (or TSP) is applied at the transplanting stage, while SA (or Urea) is applied twice for top dressing. Top-dressing is split into two parts: first application is at 14 days after transplanting, while the second application is 43 days after transplanting.

During the 2000/01-crop year, 90.2% of the MMRG dependent respondents reported to have used DAP during planting and only 6.6% used TSP. For the independent farmers, 75.6% of the respondents applied DAP during planting while 15.6% used TSP. In the same period, 70.5% of the dependent respondents applied SA for top-dressing, while 23% used Urea to top-dress. In the MMRG independent farms, SA was applied to top-dress by 75.6% of the respondents, while Urea was used by 22.2% of the respondents. Urea is not very popular with the farmers (Table 4-14) as they argued that it softens the soil, thus causing the lodging of the rice crop.

Table 4-14: Various types of organic fertilizers applied

Application Time	Type of fertilizer	MMRG dep. Farmers (% Using the fertilizer)	MMRG indep. Farmers (% Using the fertilizer)
Planting	DAP	90.2	75.6
	TSP	6.6	15.6
	Others	3.2	8.8
Top-dressing	SA	70.5	75.6
	Urea	23.0	22.2
	Others	6.5	2.2

Source: Author's survey, 2002

The application rates for DAP, SA and Urea during the 2000/01-crop year were higher in the MMRG independent farms than in the dependent farms. Prices per kilogram of DAP and SA fertilizers were lower in the MMRG independent farms than in the dependent farms. However, the price of Urea was higher in the independent farms than in the dependent farms (Table 4-15).

MMRG independent farmers purchased their fertilizers from local stockists who sold at market prices due to competition. Thus the prices were probably favorable to the independent farmers and, as a consequence, their application rate was higher than for MMRG dependent tenants. On the other hand, the dependent farmers were supplied with fertilizer inputs by MMRG Society on credit basis and that is why the price per kilogram was high. Fertilizer allocation efficiency in the two groups will be discussed in the next chapter.

Table 4-15: Fertilizer prices and application rates

	MMRG dependent (n = 61)		MMRG independent (n = 45)	
Fertilizer type	Fertilizer price (Kshs/kg)	Application Rate (Kgs/ha)	Fertilizer price (Kshs/kg)	Application Rate (Kgs/ha)
DAP	23.15	84.4	22.37	98.5
SA	23.05	100.0	20.80	108.8
UREA	21.90	16.9	24.75	23.5

Source: Author's Survey, 2002

Besides the inorganic fertilizers, both MMRG dependent (16.2%) and MMRG independent (37.4%) farmers also reported using Farmyard manure during the crop year under study. Mean manure cost per cart was reported as Kshs 400 in both groups of farms, though most farmers used manure from their own livestock.

4.4.6 Irrigation water and facilities

Mwea Irrigation Scheme draws the irrigation water from Thiba and Nyamindi rivers. The paddy fields are flooded through irrigation systems from the two rivers. Before the takeover of the management of the scheme by MMRG from NIB, irrigation schedules were well planned and managed. After the takeover, MMRG had no capacity to maintain water controls and this resulted in water shortages leading to constrained rice production.

The MMRG dependent farmers are charged by the MMRG for irrigation water distribution and for canal maintenance. The respondents indicated that the mean cost for this service during the 2000/01-crop year was Kshs 5,547 per ha. During the same period, the MMRG independent farmers indicated that they incurred a mean cost of Kshs 5,432 per ha through purchase of irrigation facilities.

Whereas the irrigation water is gravity distributed in the scheme, the independent farmers have invested heavily in small irrigation water pumps. These farmers pumps irrigation water from the main water canals in the MMRG fields into their own plots.

When farmers were asked if they had any problems in irrigating, 93.4% and 91.1% of the MMRG dependent and independent respondents, respectively, cited water competition and unavailability as major problems facing them in rice production.

4.4.7 Pesticides and herbicides

Various chemicals are used as herbicides and pesticides. The most common herbicide for weed control is propanil but in the study year, no herbicide was reported to have been used. Pesticides mostly used for pest control are Fentrothion and Furadan. During the crop season under consideration, Furadan was used for pest control in the nursery stage before transplanting. The selling price of a kilogram of Furadan was reported as Kshs 254 and Kshs 346 for MMRG dependent and Independent farmers respectively. MMRG dependent farmers reported a mean cost of Kshs 1,640 per year incurred in purchase of Furadan, while MMRG independent farmers reported a mean cost of Kshs 1,460 per year for the purchase of the same. The latter group of farmers had a very limited use of the chemicals due to lack of financial resources. MMRG on the other hand supplied the dependent farmers with the pesticides, although their usage was also minimal as farmers wanted to reduce costs.

CHAPTER FIVE: DISCUSSION OF THE RESULTS OF PRODUCTION FUNCTION ANALYSIS

This chapter presents and discusses the results of the production function analysis.

5.1 ESTIMATES OF FRONTIER PRODUCTION FUNCTION

In this section, certain factors that affect rice output are analyzed using Maximum Likelihood Estimates technique. The γ-parameter associated with the variance of the technical inefficiency effects in the stochastic frontiers are estimated to be 0.99 (Table 5-1) for both groups of farms, implying that the technical inefficiency effects are significant in the stochastic frontier model and that the traditional production function with no technical inefficiency effects is not an adequate representation of the production system.

The first objective of this study was to identify the physical inputs significantly influencing variation in rice output. To achieve this objective, the significance of the input regression coefficient was tested using the formula outlined in equation 3-6. The regression coefficients and their respective calculated t-values are given in Table 5-1.

The estimated parameters of the stochastic frontier had the a priori expected signs, except mechanized tractor services, irrigation and pesticide variables in the MMRG independent farms. Labor variable coefficient, on the other hand, had a negative sign in the MMRG dependent farms.

The model had a good fit, with seven out of eight variables in each farm group being significantly different from zero. Animal draught power variable was not statistically different from zero in the MMRG dependent farms, while seed input variable was not statistically different from zero in the MMRG independent farms.

Table 5-1: Maximum Likelihood estimates for parameters of the Cobb-Douglas Stochastic Frontier production function and inefficiency Models for MMRG dependent and independent rice farmers in MIS

Variable	Parameter	(MMRG DEPENDENT) Coefficient	t-ratio	(MMRG INDEPENDENT) coefficient	t-ratio
Stochastic frontier					
Constant	β0	3.51(0.22)	15.72	4.63(0.64)	7.17
Labor	β1	-0.02(0.007)	-2.97*	0.01(0.05)	2.26**
Tractors	β2	0.14(0.02)	5.41*	-0.09(0.03)	-3.20*
Animal Power	β3	0.05(0.05)	1.03	0.11(0.05)	2.18**
Fertilizers	β4	0.12(0.03)	4.60*	0.45(0.07)	6.52*
Pesticides	β5	0.07(0.02)	3.34*	-0.03(0.008)	-4.11*
Seeds	β6	0.36(0.03)	12.98*	0.08(0.08)	0.94
Land	β7	0.97(0.06)	15.64*	0.31(0.04)	8.05*
Irrigation	β8	0.09(0.03)	3.33*	-0.50(0.15)	-3.45*
Inefficiency model					
Constant	δ0	3.58(0.49)	7.20	0.76(0.99)	0.76
Education	δ1	-0.16(0.13)	-1.12	-1.51(0.32)	-4.72*
Age	δ2	-0.53(0.22)	-2.39**	0.43(0.29)	1.47
Extension	δ3	-0.57(0.18)	-3.06*	0.40(0.93)	0.44
Credit	δ4	-0.27(0.07)	-2.70**	0.90(0.36)	2.52**
Variance parameters					
Total Variance (σ_s^2)		0.11(0.02)	5.48*	0.62(0.15)	4.15*
Variance Ratio (γ)		0.99(4.08E-04)	2.45E+03*	0.99(1.72E-07)	5.79E+06*
Likelihood Ratio Index		64.33		52.27	
Mean Technical Efficiency		**0.81**		**0.68**	

[a] The estimated standard errors of the coefficient estimators are given in brackets behind the estimates.

[b] *Denotes significance at 1% level.

[c] **Denotes significance at 5% level

Source: Author's computation, 2002

Tractor power, chemical fertiliser, pesticides, land and irrigation variables were all significantly different from zero at 1% level of significance for both groups of farms.

Labor variable was significant at 1% in MMRG dependent farms and at 5% in MMRG independent farms. Animal Draught Power was significantly different from zero at 5% level of significance in MMRG independent farms, whereas it was insignificant in MMRG dependent farms. Seed input variable on the other hand was significant at 1% in MMRG dependent farms and insignificant in MMRG independent farms.

The empirical results from the stochastic frontier shown in Table 5-1 gives the estimated elasticities of production (β_i's). They represent the percentage change in the dependent variable as the independent variable is changed by one percent, all other inputs being held constant. The results show that, for example, if labour input is increased by one percent, rice output in MMRG dependent farms would decrease by 0.02%, holding other inputs at their current levels of use. The same increment of 1% labour input would, however, increase rice output by 0.01% in the MMRG independent farms. The rest of the elasticity coefficients can be interpreted in the same manner.

Elasticity of tractor usage is estimated to be negative (-0.09) for the MMRG independent farms and positive (0.14) for MMRG dependent farms. At the same time, the elasticity of oxen use for MMRG independent farms is estimated to be positive (0.11) and insignificant in explaining output variability in MMRG dependent farms. This is due to the small and sparsely distributed farms cultivated by the MMRG independent farmers where mechanization of field operations is difficult and hence oxen power is more compatible with the small sizes, than tractor power.

The elasticity for labor for MMRG dependent farmers is negative (-0.02) while that of the independent farmers is positive (0.01), implying that the MMRG dependent farmers are more capital intensive, while the independent farmers are more labor intensive, generally using traditional farming methods mostly manual labor.

Technology difference is also supported by the elasticity's for irrigation. Irrigation variable elasticity is positive for MMRG dependent farms and negative for independent farms. The negative estimate for the independent farms is explained by the unorganised irrigation system among these farms that usually draws irrigation water from the MMRG canals. Further, these farmers have to purchase irrigation facilities like water pumps to enable them to pump water from MMRG canals to their paddy fields.

Fertilizer usage elasticities are positive for both groups of farms. However, it is more elastic for MMRG independent farms than for the dependent farms. This can be explained by MMRG delay in supplying fertilizer to its farmers due to unavailability, and this causes late application of the fertilizers. This is not withstanding the recommended application date is 43 days after transplanting. On the other hand, with the liberalized fertilizer input markets, MMRG independent farmers purchase the fertilizers from the local dealers in time at competitive market prices, which are usually lower than what MMRG charges its farmers.

Pesticide variable had a positive coefficient (0.07) in MMRG dependent farms and negative elasticity (-0.03) in MMRG independent farms. Information on the application rate and time is given by MMRG to its farmers, unlike the independent farmers who have no access to agricultural extension services in the scheme. Thus, additional use of this input in the non-MMRG farms would reduce rice output and this is due to lack of proper information on the right application rate and time.

Elasticity for the land variable is positive for both groups of farms, but it is more elastic in MMRG dependent farms (0.97) than in MMRG independent farms (0.31). The lower elasticity of land variable in the latter is because these farmers put a double crop of rice, i.e. a rice crop in the first season followed by another rice crop in the next season. This has negative effects on soil fertility due to depletion of soil nutrients. MMRG dependent farmers grow a single crop of rice in a year and leave the land fallow in the following season, and hence there is some time for replenishing soil nutrients.

Seed coefficient is not statistically significant in explaining variation in rice output in MMRG independent farms, but is highly significant in MMRG dependent farms. The former group of farmers utilizes retained seeds from the previous harvest as a way to avert risk and minimize costs and seed rate decision is based on availability rather than rationality. Thus this input is insignificant in explaining variability in rice output among the MMRG independent farms. This observation is supported by the high seed rate reported by MMRG independent farms (70.4 kgs/ha) as compared to MMRG dependent farmers (54.1 kgs/ha). The MMRG dependent farms obtain their planting seeds from MMRG, which has a standard recommended seed rate. Thus, the variable was significant in explaining rice output variability among the dependent farms.

5.2 INEFFICIENCY MODEL RESULTS

Economic efficiency tests evaluate actual productivity relative to potential productivity and do not necessarily imply irrationality on the part of farmers who are inefficient. It may well be the case that farmers' failure to use the most efficient techniques is due to non-physical inputs, such as socio-economic and institutional factors. The estimated coefficients of these variables are presented in Table 5-1, in the technical inefficiency effects model.

The coefficient estimates for household head's education level and age, access to extension services and credit facilities had the a priori expected negative signs among the MMRG dependent farmers. Age and access to credit facilities coefficients were statistically significant in explaining variations in technical inefficiencies at 5% level of significance, while extension service coefficient was significant at 1%. However, education level was not statistically significant even at 10% level of significance.

Among the MMRG independent farmers, only education had the a priori expected negative sign. The other variables' coefficients were positive. Education coefficient is significant at 1%, credit at 5%, while age and extension were not significant in explaining the technical inefficiencies among these farmers.

Education coefficient is negative and highly significant among the MMRG independent farmers, indicating that farmers with greater years of formal schooling tend to be more technically efficient. This finding is relevant because at least 98% of the respondents in this group of farmers had reported as having formal education. Among the MMRG dependent respondents, the coefficient for education had the expected sign, albeit being weakly significant in explaining variation in technical inefficiency. The reason for this is that these farmers, though being too experienced in rice production (their mean age was given as 60 years), are not autonomous in decision making and mostly it is the MMRG which makes decisions on farming methods and inputs combination. That is, education variable was not significant in decreasing technical inefficiency in this group of farmers because most farming decisions, like management, are influenced by MMRG and not individual farmers.

Education variable is used as a proxy for managerial input. Increased farming experience coupled with higher level of educational achievement may lead to better assessment of the importance and complexities of good farming decisions, including efficient use of inputs.

Age coefficient, on the other hand, was significant and with negative coefficient among the MMRG dependent farms. For the independent farms, the age coefficient was not significant in explaining technical inefficiency variations. The variable age is used as a proxy for farming experience. Older farmers are more technically efficient in rice production due to the accumulated farming experience. From the accumulated experience, farmers learn the good crop husbandry methods and this experience enhances the technical efficiency of the farmer. The dependent farmers have been in rice production for a very long time and were thus more experienced in farming. The mean age of the primary decision maker among these farmers was reported as 60 years as compared to 34 years among the independent farmers. The non-significance of the age variable among the MMRG independent farmers suggests the complexity of estimating the various components of experience with the age variable. Experience provides management skills but the most experienced and aged farmers usually have a low education level.

Access to extension service coefficient was highly significant among the MMRG dependent farmers, but insignificant among the MMRG independent farmers. This indicates that the involvement of extension advisers from MMRG reduces the technical inefficiency among its farmers. The extension service was not available among the independent farmers, and hence this variable was not significant in reducing technical inefficiency in this group of farms.

Credit variable was used to capture the effect of access to credit facilities on the technical efficiency of farmers. Where it is available, it reduced the technical inefficiency. Hence in the inefficiency model, it was expected a priori that the variable's coefficient would be negative. The availability of credit facilitates the acquisition of inputs in time thus reducing the technical inefficiency. Among the MMRG dependent farmers, the variable coefficient was negative and significant at 5% level. This is because MMRG provide its farmers with credit in form of inputs.

Among the MMRG independent farmers, credit variable was significant at 5% level but the coefficient had unexpected positive sign. Thus, credit facilities in this group of farmers enhance technical inefficiency. These farmers had reported to have obtained credit from friends and relatives and this credit was channelled into uses other than agricultural activities.

5.3 TECHNICAL EFFICIENCY LEVELS

The technical efficiencies for MMRG dependent and MMRG independent sample farmers are less than one. The predicted technical efficiencies for the MMRG dependent farmers range from 0.28 to 0.99, with a median of 0.85, and a mode of 0.99. The mean technical efficiency for the group is estimated to be 0.81 (Table 5.2). This implies that the MMRG dependent farmers realize only 81% of the potential rice output; 19% of the rice output is not realized due to technical inefficiencies.

Table 5-2: Technical Efficiency Levels

Farm group	Technical efficiency statistic measure			
	Mean	Median	Mode	Range
MMRG dependent (n = 61)	0.81	0.85	0.99	0.28 – 0.99
MMRG independent (n = 45)	0.68	0.67	0.99/0.91	0.27 – 0.99

Source: Author's survey, 2002

For the MMRG independent farms, technical efficiencies range from 0.27 to 0.99, with a median of 0.67 and a bimodal of 0.99 and 0.91. The mean technical efficiency for the sample farmers is 0.68, implying that the MMRG independent farmers realize only 68% of the total rice output so that 32% of the output is lost due to technical inefficiencies. It can thus be concluded that MMRG dependent farmers have higher technical efficiency than MMRG independent farmers.

The second objective of this study was to compare the technical efficiency levels of MMRG dependent and independent farmers. The hypothesis test is as outlined equation 3-8.

Inserting the respective figures into the formula outlined in equation 3-8, μ_1 = 0.81, μ_2 = 0.68, S_1^2 = 0.02649, S_2^2 = 0.0476, S_p = 0.188, n_1 = 61, n_2 = 45; the calculated t-value becomes 3.51. At 1% significance level, the critical t-value for a two-tailed test with df = $n_1 + n_2 - 2$, is obtained as 1.658. Since the calculated t-value falls in the rejection region, we reject H_0 and conclude that there are significant technical efficiency differences in MMRG dependent and MMRG independent farms and thus, MMRG dependent farms are more technically efficient than the MMRG independent farms. Therefore, given a set of inputs, a single rice crop in a year gives higher output than a rice double crop.

5.4 RESOURCES ALLOC ATIVE EFFICIENCY

The third objective of this study was to examine if the farmers in MIS were using resources efficiently in rice production. A hypothesis that the resources were being used efficiently was thus tested. If resources are inefficiently used, then there occurs a possibility of reallocating the resources to enhance output. This section thus presents the allocative efficiency test and it is assumed that MIS rice farmers have an economic drive of maximising profits from rice production.

5.4.1 Testing the allocative efficiency hypothesis

To achieve the second objective of this study, the hypothesis that there were no significant differences between the marginal Value Products (MVP) and Marginal Factor Costs (MFC) of the inputs used in rice production was tested. The testing of allocative efficiency compares MVP of an input with its MFC. If the input is being used efficiently, its MVP_{xi} will be equal to the MFC and the price (MFC = P_x). If they are significantly different, then it means that the input is being used inefficiently. The testing for significance was done and the computed t-values compared with the tabulated t-values (t-critical=t_c), as outlined in equation 3-9.

The results of the calculated MPPs, MVPs, statistical tests and their interpretations are given in Table 5-3 and 5-4 for MMRG dependent and MMRG independent farmers, respectively. The interpretation of MPP, MVP and MFC results is as follows: on average, and with all other factors held constant, an increase of a unit of tractor power in MMRG dependent farms would increase rice output by 0.12 units and revenue by 2.90 units. However, this unit increase in the input would cost more (7.77 units) and thus its use is inefficient. Hence it would be desirable to reduce on the utilization of the input. Similarly, a one-unit increase of seeds in the same farms would increase rice output by 0.64 units and revenue by 16.18 units. However, the extra cost incurred by the extra unit of seed is small (3.34 units) compared to the extra revenue generated, and this implies that this input is inefficiently used as it is possible to attain higher output and revenue if more of the resource was used.

Irrigation water was used efficiently, and it implies that an increase or decrease of the usage level of the input may lead to a decrease or an increase of output and revenue and hence profits, holding other factors constant. The interpretation of

MPPs, MVPs and MFC for the rest of the inputs is similar, even in the other group of farmers.

Table 5-3: Marginal Physical Products and Marginal Value Products of the inputs used in MMRG dependent farms.

Variable	MPP	MVP	P_x=MFC	critical t-value(t_c)	calculated t-value (t)	DF	Test result	Decision	Interpretation
Tractor	0.12	2.90	7.77	-2.66	-63.2	52	-t>-tc	Rejection	Inefficient use
Fertilizers	0.11	2.89	3.21	-2.66	-3.89	52	-t>-tc	Rejection	Inefficient use
Pesticides	0.07	1.84	6.65	-2.66	-130.4	52	-t>-tc	Rejection	Inefficient use
Seeds	0.64	16.18	3.34	2.66	28.0	52	t>tc	Rejection	Inefficient use
Irrigation	0.29	7.48	7.61	-2.66	-0.57	52	-t<-tc	Non-rejection	Efficient use

P_y = Kshs 25.09

The two-tailed t-test was done at 1% level of significance and df = n-k.
Source: Author's computation, 2002

Table 5-4: Marginal Physical Products and Marginal Value Products of the inputs used in MMRG independent farms.

Variable	MPP	MVP	P_x=MFC	critical t-value(t_c)	calculated t-value (t)	df	Test result	Decision	Interpretation
Labor	0.13	2.89	4.92	- 2.74	-15.5	36	-t>-tc	Rejection	Inefficient use
ADP	0.11	2.69	5.78	-2.74	-23.5	36	-t>-tc	Rejection	Inefficient use
Fertilizers	0.42	9.66	3.15	2.74	9.73	36	t>tc	Rejection	Inefficient use

P_y = Kshs 23.20

The two-tailed t-test was done at 1% level of significance and df = n-k.
Source: Author's computation, 2002

The tested inputs for MMRG dependent farms were: Tractor power, fertilizer, pesticides, seeds and irrigation. For MMRG independent farms, only labor, animal draught power and fertilizer inputs were tested. Efficiency of resource use for inputs with negative regression coefficients was not carried out. This is because the negative coefficients implied that additional use of such inputs was decreasing output. Thus, less of such inputs needed to be employed to equate the MVPs to their corresponding

MFCs. Also not tested were inputs whose regression coefficients were not significantly different from zero.

For MMRG dependent farms, tractor power, fertilizer, and pesticide inputs were inefficiently allocated, as the computed t-values were greater than the tabulated t-values at the relevant degrees of freedom and at 1% significance level. Moreover, the ratios of their MVPs to MFCs were less than unity, implying that these resources were over utilized on the sample farms during the survey period so that under the assumptions of profit maximization objective, it is likely that rice output and net revenues would have been higher if less of these resources had been used, *ceteris paribus*. At the same time, seed input was inefficiently used and the ratio of its MVP to MFC was greater than unity, implying that the input was underused on the sample fields. It means that output and revenues would have been higher if more of the seeds were used in the MMRG dependent farms, holding all other factors constant.

The over utilization of tractors, pesticides and fertilizers by MMRG dependent farmers is because MMRG supplies these inputs to its farmers on credit basis and recovers the cost by deducting it from the farmers' rice proceeds. There are tendencies of overuse of these inputs by MMRG farmers given that they are more easily available. Irrigation water was efficiently used as this is the most constraining resource.

For MMRG independent farms, labor, animal draught power and fertilizers were inefficiently used. Labor and animal power resources were over utilized, while fertilizer was under utilized. This group of the farmers use traditional farming methods, with tendencies to over utilize manual labor and animal draught power in substitute of capital inputs.

5.5 GROSS MARGIN ANALYSIS

Gross Margin will be used to reflect on the profitability of rice production, for both MMRG dependent and MMRG independent farmers. The income generating capacity of rice production is also indicated by the analysis of its gross margin. This is arrived at by deducting variable costs of production and marketing from the gross value of the crop output, as outlined in equation 3-8. The gross value is obtained by multiplying the producer price per unit by the total output realized. The estimated Gross Margins per hectare per year for both groups of farms are presented in Table 5-5.

Table 5-5: Gross Margin calculations

	MMRG Dependent	MMRG Independent
Total Revenue	187,176.86	54,265.70
Total variable costs	105,629.09	28,031.90
Gross Margin	81,547.77	26,233.80
Gross Margin/ha/yr	**42,695.17**	**54,653.75**

Author's computation, 2002

5.5.1 Hypothesis testing for the significance of Gross Margin differences

The mean gross margins per hectare per year for MMRG dependent farmers (μ_1) and MMRG independent farmers (μ_2) were Kshs. 42,695.17 and Kshs. 54,653.75 respectively. In order to evaluate whether the difference between the two gross margins per hectare were statistically significant, the third hypothesis which stated that "no statistically significant difference in gross margins per hectare per year occur between MMRG dependent and MMRG independent farms" was tested at 1% level of significance. A null hypothesis that there was no significant difference between the two means was formulated, thus:

H_0: $\mu_1 = \mu_2$ or $\mu_1 - \mu_2 = 0$

against the alternative hypothesis that the pair of means under comparison were not equal:

H_A: $\mu_1 - \mu_2 \neq 0$

To test this hypothesis, the "difference between means methodology" was used. The statistical test used the student t- distribution calculated as shown in equation 3-8.

Inserting the respective figures into the formula: μ_1 = 42,695.17, μ_2 = 54,653.75, $S_1^2 = 1.5x10^9$, $S_2^2 = 1.5x10^9$, S_p = 38,729.83, n_1 = 61, n_2 = 45; the calculated t-value becomes -8.02. At 1% significance level, the critical t-value for a two-tailed test with df = $n_1 + n_2 - 2$ is obtained as ±1.658. Since the calculated t-value is more than the critical t-value, we reject H_0 and conclude that there are statistically significant differences in gross margins/ha/yr between MMRG dependent and non-MMRG farms. Thus, it can be concluded that rice production in MMRG independent farms is more profitable than in MMRG dependent farms. A double crop of rice in a year is thus more profitable than a single crop of rice in a year.

CHAPTER SIX: SUMMARY, CONCLUSIONS AND RECOMMEDATIONS

6.1 SUMMARY

This study aimed at comparing the economics of rice production for two different groups of farmers in Mwea Irrigation Scheme (MIS). One group comprises of tenant farmers under the management of Mwea Multi-Purpose Rice Growers (MMRG) and produces a single crop of rice in a year. The second group comprises of the sons and daughters of MMRG tenants and produce a double crop of rice in a year.

The main objectives of the study were to evaluate and compare the technical and allocative efficiency of these two groups of farmers, as well as the associated rice gross margins per hectare in a year. A total of 106 farmers were interviewed, 61 being MMRG dependent farmers and 45 non-MMRG farmers.

Data collected was fitted to a stochastic frontier production function model of the Cobb-Douglas type. Regression coefficients were estimated using the Maximum Likelihood Estimate (MLE) method.

The variables found to be significant (at 1% significance level) in explaining variations in rice output for MMRG dependent farmers were labor, mechanized tractor power, fertilizer, pesticides, seeds, land and irrigation water. Labor, however, had a negative coefficient; animal draught power was not significant in explaining rice output variation in this group of farmers.

For the MMRG independent farmers, tractor power, chemical fertilizers, pesticides, land and irrigation were all significant at 1% level of significance, while labor and animal draught power were significant at 5%. Seed input was not significant in explaining variations in rice output, even at 10% significance level. Tractor power, pesticides and irrigation water variables had negative coefficients.

The results on technical efficiencies indicated that MMRG dependent farmers were more technically efficient than MMRG independent farmers, and there was actually a statistically significant difference in estimates of technical efficiency levels of both groups of farmers.

The test for allocative efficiency indicated that labor, tractor power, fertilizer, pesticides and seeds were inefficiently used and only irrigation water was efficiently used in MMRG dependent farms. Animal draught power was not statistically significant in explaining rice output variability in this group of farms. For MMRG independent farms, all these resources were inefficiently allocated, though the seed input was not statistically significant in explaining rice output variability in these farms.

Gross margin per hectare per year in MMRG dependent farms was Kshs. 42,695.17 and Kshs. 54,653.75 for non-MMRG farms. A test for any statistically significant difference in the two group's gross margins revealed that they were statistically different.

6.2 CONCLUSIONS

This study has examined and compared technical efficiency, allocative efficiency and gross margins between farmers growing a single crop of rice in a year under Mwea-Multipurpose Rice Growers Society (MMRG) and independently operated farms, non-MMRG farmers, growing a double crop of rice in a year.

The MMRG dependent farmers had a mean technical efficiency of 81% while the non-MMRG mean technical efficiency was 68%. This implies that in MMRG farms, farmers only realise 81% of potential rice output and 19% is lost due to technical inefficiencies. Likewise, in non-MMRG farms, farmers only realize 68% of potential rice output and 32% of output is lost due to technical inefficiencies. Given that MMRG dependent farmers grows a single crop of rice in a year as opposed to the double crop of the non-MMRG, this study concludes that a single crop of rice in a year is more technically efficient than two crops. The large variation in technical efficiency between the two group of farms imply that Mwea Irrigation Scheme still has potential to promote growth by reducing the differences. The low technical efficiency scores among the non-MMRG farmers indicate that there exists potential for increasing rice output through reducing technical inefficiencies.

An analysis of the determinants of technical efficiency indicated which aspects of the physical resources, as well as farmer's characteristic and institutional factors might be targeted by public investment to improve farm technical efficiency. The observed differences in technical efficiency are related to the factors determined by the socio-economic and institutional settings. Farmer's farming experience, education, accessibility of credit and extension facilities are significant variables for improving technical efficiency. In MMRG farms, 86.9% of the respondents had received agricultural credit in the year under consideration while 24.4% of the non-MMRG had received credit. At the same time, 39.7% and 4.4% of MMRG and non-MMRG respondents indicated to be in access of agricultural extension services respectively. The inefficiency model results showed that credit was significant in reducing technical inefficiency in MMRG farms since it was available. Access to agricultural extension was significant in reducing technical inefficiency in MMRG farms as it was available but was insignificant in the non-MMRG farms as it was absent. Given the high percentages of MMRG farmers in access to credit and extension facilities as compared to non-MMRG farmers, and further given that MMRG were shown to be more technically efficient than non-MMRG farmers, then this study concludes that credit and extension service facilities are important factors in reducing technical inefficiency.

In terms of resource allocation, there appears to be no unique farm group or rice production system whose allocation is efficient over all the inputs. Both groups of farms are inefficient in the use of resources. All resources except irrigation water were inefficiently utilized in MMRG farms and this indicates that irrigation water is the most constraining resource in this group. Tractor power, chemical fertilizers and pesticides were overutilized in MMRG dependent farms. The overuse of these inputs confirms the allegation that MMRG over supplies production inputs to the tenants thus leading to inefficient use. Seed input was underutilized in this group, while labour input had a negative coefficient implying that it was reducing rice output.

For the double crop non-MMRG farms, all the resources were inefficiently allocated. Labour and Animal draught power were overutilized while chemical fertilizer was underutilized. Labour and animal power are over used in this group as their farm sizes are very small, yet these resources are readily available. Irrigation and pesticide inputs had negative coefficients showing that they were reducing rice output. Thus, there is need for extension agents to train these young farmers on the recommended input application rates.

Both groups of farmers were found either underutilizing or overutilizing the production resources considered. This implies that allocative efficiency can be attained through substitution of one resource for another or through resource re-allocation.

MMRG farmers had a mean yield of 4,509kg/ha while the non-MMRG farmer's mean yield was 3,139kg/ha. Thus, this study concludes that a single crop of rice in a year is more yielding than double cropping. However, the rice gross margins per hectare per year for the double crop of rice were higher than for the single crop. The former realized gross margins of Kshs. 54,653.75 while the latter got Kshs. 42,695.17 per hectare per year, and the difference was statistically significant. This finding further supports the assertion that MMRG over prices their inputs and other services supplied to its dependent farmers or their credit is expensive thus lowering their farmers' gross margins. Such a finding was reported by Mosoti, (1993) who compared the gross margins of contracted and non-contracted sugarcane farming in South Nyanza Sugar Project. The study concluded that sugarcane farming was more remunerative to non-contracted farmers than the contracted ones since the contractor production inputs and services were too expensive.

6.3 RECOMMENDATIONS

The findings of this study indicate that technical efficiency is affected by farmers' specific characteristics (such as age and education level) and the institutional conditions like accessibility of credit and extension facilities.

Both non-MMRG and MMRG dependent farmers were found either under or over utilising farming resources. Moreover, rice double cropping was found to be less yielding and less technically efficient than a single rice crop.

The study also revealed that MMRG was exploiting its farmers by over pricing the inputs thus making them realise lower gross margins than the lower yielding and the less technically efficient non-MMRG farmers who buys their farming inputs from the local dealers at competitive prices.

Based on these findings this study recommends,

1. That, the Governments should facilitate the availability of credit and extension services to farmers.

2. That, research institutes should undertake a thorough extension exercise to advise all the Scheme farmers on the recommended input usage and application rates.
3. That, there is need for rigorous campaign from the Government, politicians and development agencies aimed at educating the young farmers on the benefits of a single rice crop in a year.
4. That, the Government should oversee the revision and harmonisation of MMRG structure of agreement with the Scheme tenants to avoid exploitation.

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APPENDICES

Appendix 1: Field Survey Questionnaire

CONFIDENTIAL

UNIVERSITY OF NAIROBI

DEPARTMENT OF AGRICULTURAL ECONOMICS

SURVEY QUESTIONNAIRE

Topic: ***Economic Analysis of Rice Production Systems In Mwea, Kirinyaga District.***

IDENTIFYING VARIABLES:

DATE OF INTERVIEW ______________________________

ENUMERATOR ______________________________

VILLAGE ______________________________

HEAD OF HOUSEHOLD ______________________________

RESPODENT (S) ______________________________

(If not head of household)

RELATION OF THE RESPODENT TO THE HOUSEHOLD HEAD: ____________________

A. RICE OUTPUT

1. Are your farming activities under Mwea Mult-Purpose Rice Growers Society?

   Yes ________ No ______________

2. What is the total area of your farm? ____________________Acres
3. Do you have a land title deed? Yes ….. No …………. If yes when did you receive it? …………..
4. What was the total area under rice last year?

   I. First season _____________ Acres

   II. Second season ____________ Acres

5. Did you plant rice in one season or in two seasons?

   One season…………………….. Two seasons……………

6. Why did you not grow a second crop of rice? (If Q5 is one season)

   I. ……………………………………………………

   II. ……………………………………………………

   III. ……………………………………………………

7. Would you like to grow a second crop? Yes ……………… No ……………………

8. Total amount of rice produced last year:

Crop	Amount harvested (Kgs)	Amount consumed at home (Kgs)	Amount sold (Kgs)	Price per unit	Gross income
First season					
Second season					

9. What did you do with the land after harvesting the first season rice crop?

Codes

1. Planted another rice crop
2. Planted another crop other than rice

3. Planted rice in half of the plot and another crop other than rice in the other half
4. Flooded in preparation of the following year crop
5. Left it fallow
6. Grazed cattle
7. Other (specify)

10. Do you have other enterprises in your farm? List according to which you believe generates most income

Enterprise	Area (Acres)	Rank (income generated)

B. TOTAL LABOUR INPUT

11. FAMILY LABOR USED IN RICE PRODUCTION

First season

TASK	CATEGORY	HRS/DAY		DAYS/WK		MONTHS	
		1ST SEASON	2ND SEASON	1ST SEASON	2ND SEASON	1ST SEASON	2ND SEA
Flooding	• Husband						
	• Wives						
	• Children (>15 Years)						
	• Relatives living on the farm or helping						
	• Total Man-hours						
Rotavation	• Husband						
	• Wives						
	• Children (>15 Years)						
	• Relatives living on the farm or helping						
	• Total Man-hours						

TASK	CATEGORY	HRS/DAY		DAYS/WK		MONTH	
		1[ST] SEASON	2[ND] SEASON	1[ST] SEASON	2[ND] SEASON	1[ST] SEASON	SE
Nursery Preparation	• Husband						
	• Wives						
	• Children (<15 Years)						
	• Relatives living on the farm or helping						
	• Total Man-hours						
Transplanting	• Husband						
	• Wives						
	• Children (<15 Years)						
	• Relatives living on the farm or helping						
	• Total Man-hours						
Fertilizer and pesticides application both for 1st & 2nd application	• Husband						
	• Wives						
	• Children (<15 Years)						
	• Relatives living on the farm or helping						
	• Total Man-hours						
Weeding	• Husband						
	• Wives						
	• Children (<15 Years)						
	• Relatives living on the farm or helping						
	• Total Man-hours						
Bird scaring	• Husband						
	• Wives						
	• Children (<15 Years)						
	• Relatives living on the farm or helping						
	• Total Man-hours						

TASK	CATEGORY	HRS/DAY		DAYS/WK		MONTH	
		1st SEASON	2nd SEASON	1st SEASON	2nd SEASON	1st SEASON	2nd SEA
Draining	• Husband						
	• Wives						
	• Children (<15 Years)						
	• Relatives living on the farm or helping						
	• Total Man-hours						
Harvesting	• Husband						
	• Wives						
	• Children (<15 Years)						
	• Relatives living on the farm or helping						
	• Total Man-hours						
Threshing	• Husband						
	• Wives						
	• Children (<15 Years)						
	• Relatives living on the farm or helping						
	• Total Man-hours						
Winnowing	• Husband						
	• Wives						
	• Children (<15 Years)						
	• Relatives living on the farm or helping						
	• Total Man-hours						
Packaging	• Husband						
	• Wives						
	• Children (<15 Years)						
	• Relatives living on the farm or helping						
	• Total Man-hours						
Other (specify)	• Husband						
	• Wives						
	• Children (<15 Years)						
	• Relatives living on the farm or helping						
	• Total Man-hours						

12. HIRED LABOR USED IN RICE PRODUCTION

CATEGORIES: **I. Casuals II. Permanent III. Others (specify)**

KIND OF WORK: **1. Flooding 2. Nursery preparation 3. Rotavation 4. Transplanting 5. Fertilizer application (first and second applications) 6. Spraying 7. Weeding 8. Bird scarin 8. Draining 9. Harvesting 10. Threshing 11. Winnowing 12. Packaging 13. canal clearing 14. others.**

First rice crop

CATEGORY	KIND OF WORK	NUMBER		HRS/DAY		DAYS/WK		MON
		1ST SEASON	2ND SEASON	1ST SEASON	2ND SEASON	1ST SEASON	2ND SEASON	1ST SEASON
I								
II								
III								
TOTAL MAN-HOURS								

13. How much were you paying the permanent laborers per month? Kshs ....

14. How much on average did you pay your casual laborers per day? Kshs ....

15. What are the problems in hiring labor to help you in rice production?

I. Not available...........

II. Too expensive..........

III. Unreliable...............

IV. Other reasons (specify)

16. How much money did this household spend on the treatment for the following?

I. Malaria Kshs......................................

II. Bilharzia Kshs......................................

III. Typhoid Kshs..

IV. Other water and vector related ailments Kshs...................

17. For what period were the household members away from work seeking treatment for the above?

Ailments? ....Days

18. What's your opinion on the effect of the above diseases on family labor and hired labor?...

....

C: **OPERATING CAPITAL**

19. **Tractor hire and oxen**

First rice crop:

CATEGORY	TYPE	Kind of work	Hrs/Day	Days/wk	Cost/unit	TOTAL COST
TRACTOR	Hired					
	Owned					
	Other					

OXEN	Hired					
	Owned					
	Other					
OTHER	Hired					
	Owned					
	Other					

Second rice crop:

CATEGORY	TYPE	Kind of work	Hrs/Day	Days/wk	Cost/unit	TOTAL COST
TRACTOR	Hired					
	Owned					
	Other					
OXEN	Hired					
	Owned					
	Other					
OTHER	Hired					
	Owned					
	Other					

20. What problems do you have in hiring tractors?

I. Delay by management

II. Too expensive

III. No equipment of our own

21. What solutions would you suggest to these problems?

I. By the management (Cooperative Society)

II. By the farmers

III. By the Government

Fertilizers:

22. Fertilizer application rate.................................... kg/acre

First rice crop

Type of fertilizer	Time when used	Amount used (specify units)	Price per unit	Total

DAP					|	
MAP						
TSP						
SSP						
NPK						
CAN						
ASN						
UREA						
FOLIAR FEEDS						
MANURE						
HERBICIDES						
TOTAL COST						

Second rice crop

Type of fertilizer	Time when used	Amount used (specify units)	Price per unit	Tota
DAP				
MAP				
TSP				
SSP				
NPK				
CAN				
ASN				

UREA				
FOLIAR FEEDS				
MANURE				
HERBICIDES				
TOTAL COSTS				

23. What problems do you experience with fertilizers?

I. Not available

II. Too expensive

III. Demands too much to apply

IV. Others (specify)

24. What remedy would you suggest?

I. Lower prices

II. Avail them in good time

III. Others (specify)

25. What problems do you encounter in using the agro-chemicals?

I. No equipment to apply them

II. No labor to apply them

III. They are toxic

IV. They are not effective

V. They are not available when needed

VI. Others (specify)

Irrigation Facilities

26. Do you experience any problem with irrigation water? Yes .... No.................

27. If yes, which? ....
....
....
....

28. Are you charged for irrigation water? Yes .... No ....

29. If yes, how much? ....

30. What Irrigation facilities did you buy last year? ....

31. How much did they cost.........................Kshs.

32. What other related costs did you incur in irrigation facilities last year................Kshs

SEEDS

33. How much seeds did you use for the first rice crop?

	Amount (Kgs)	Price per unit	Total (Kshs)
Initial quantity planted			
Additional seeds for refilling			
Total (Kgs)			

34. How much seeds did you use for the second rice crop?

35. How much seeds did you use for the second rice crop?

	Amount (Kgs)	Price per unit	Total (Kshs)
Initial quantity planted			
Additional seeds for refilling			
Total (Kgs)			

36. Where do you get your seeds from?

I. Scheme (Cooperative society)

II. From fellow farmers

III. Kept my own

IV. Other (specify)

37. Why did you use that type of seed?

I. High yielding

II. Produce better grade rice for higher pay

III. Others were not available

IV. It is cheaper to buy

V. Germinates faster

VI. Requirement by Cooperative society

VII. Others (specify)

38. What variety did you use? ....

39. Why did you use that variety?

I. It produces better quality rice for higher pay

II. It matures faster

III. It has better yield

IV. It is a requirement by the Cooperative

V. Less susceptible to disease and pests

VI. It was the only one available

VII. Other (specify)

40. Why do you prefer to keep

I. Seed is expensive so it saves money

II. Intended for consumption but remained

III. Have better resistance to pests and diseases

IV. Better yields

V. Others (specify)

41. Are bought seeds treated? Yes/No

42. How do you keep yours treated/ not treated?

43. Treated with what

I. Copper based dusts

II. Ash

III. Mixed with bought seeds

IV. Other (specify)

44. Does keeping your own seed expose them to damages? Yes/No. If yes go to 45

45. Which ones?

I. Weevils

II. Beetles

III. Rotting

IV. Other

46. Does this result in:

I. Low yields
II. Poor germination
III. Poor resistance to pests and diseases
IV. Lodging
V. Other (specify)

47. What are the problems with the seeds?

I. Not available
II. Reliance on Cooperative management
III. Too expensive
IV. Others (specify)

48. What are your suggestions for solving these problems?

I. Cooperative to be buying for us
II. Cooperative to avail seeds in time
III. Low priced seeds
IV. Better storage methods should be devised
V. Others (specify)

EXTENSION SERVISES

49. Do you get any advisory visits from extension agents? Yes ..... No ....

50. If yes, how frequent are their visits?

51. How do you rate the advice given: Good .... Fair .... Not useful ....

52. Have you ever gone for a course about farming? Yes ...... No..........

CREDIT

53. Do you use credit for rice production?

I. Yes ....go to 54
II. No ....go to 55
III. Others (specify)

54. Which source?

I. MIS cooperative society
II. AFC
III. Relatives/friends/neighbours
IV. Organized lending groups
V. Commercial banks
VI. Others (specify)

55. Why don't you?
I. No credit available
II. Credit available but no collateral
III. I don't need it
IV. Others (specify)

56. Would you like to have credit?
I. Yes .... go to 47
II. No .... Go to 48

57. Why do you need it?
I. Inputs are expensive
II. No other source of income
III. Uncertinity in rice production
IV. Others (specify)

58. Why don't you like credit?
I. Have enough funds
II. Credit terms unfavourable
III. Rice not profitable enough to pay back
IV. Others (specify)

HOUSEHOLD INFORMATION

59. Who is the head of this household? Male....... Female.............

60. What is his/ her age? .... years

61. What is his/her highest education level ....

62. How many members does this household have? ....

FARMING INCOME

63. How much money did you get from your farming activities last year (including from rented land (For all households members)

I. Rice ....(Kshs)

II. Other crops (specify)

i) .... (Kshs)

ii) .... (Kshs)

iii) .... (Kshs)

iv) .... (Kshs)

III. Livesock ....(Kshs)

OFF-FARM INCOME

64. How much money did the household members receive from:

I. Salaried labor .... (Kshs)

II. Business activities.................................(Kshs)

III. Kibarua ....(Kshs)

IV. Remittances ....(Kshs)

MARKETING OF RICE

65. Are you satisfied with the present marketing facilities for rice available to you?

Yes .... No ....

66. If no, why not?

I. Society exploitative

II. Transport expensive

III. No suitable storage

IV. Unavailability of transport

V. Others (specify)

67. Where do you sell your rice?

I. Cooperative society

II. NIB

III. Local middlemen

IV. Local wholesalers

V. Local retailers

VI. Others (specify)

68. After how long were you paid for rice delivered to your agent last year?

.... Months.

69. Has delayed payment for rice made you reduce your rice production? Yes ..... No.....

PROBLEMS FACING THE FARMERS

70. Why do you insist on rice growing?

I. Requirement by cooperative society

II. Rice is more profitable

III. Only crop which performs well in this area

IV. Lack of labor to work on other enterprises

V. Other (specify)

71. In general, what is the most important problem facing you in rice production?

____

____

72. What improvement would you like to see in the rice industry

____

____

73. Can you suggest ways of increasing productivity of rice?

74. **ENTERPRISE COSTING**

Total farm size..Acres

Land under rice, 2001 ....Acres

A. Rice crop First Season crop from..............................to.....................

Size....................Acres Value ....Kshs.

Output................90 kg bags Value.....................Kshs

Gross value...................... Kshs.

Second season crop from..............................to.....................

Size....................Acres Value ....Kshs.

Output................90 kg bags Value.....................Kshs

Gross value...................... Kshs.

Variable Costs

TYPE	Amount Used	Cost per unit(Kshs)	Total cost (kshs)
Labor & Transport			
Tractors			
Fertilizers			
Pesticides			
Seeds			
Ox costs			
Irrigation Facilities			
Others			
TOTAL COSTS			

Soya beans

From ....to.........................Size........... Acres ....

Output: Yield ....bags value @ Kshs per bag............................

Gross value ....Kshs.

TYPE	Amount Used	Cost per unit(Kshs)	Total cost (kshs)
Labor			
Fertilizers			
Pesticides			
Seeds			
Transport			
Others			
TOTAL COSTS			

Livestock

1. State the livestock heads owned last year..............................
2. Feed costs per month (Kshs)...
3. Veterinary costs per month (kshs).......................................
4. Number of man-hours spent on livestock per day.....................
5. Average milk produced per day ....Litres
6. Average price per litre...Kshs
7. Amount consumed at home...Litres
8. Amount sold out..litres

Appendix 2: MMRG Dependent Farmers' Computer Frontier Output

```
Output from the program FRONTIER (Version 4.1c)


instruction file = terminal
data file =        MMRG DEPENDENT.txt


Tech. Eff. Effects Frontier (see B&C 1993)
The model is a production function
The dependent variable is logged


the ols estimates are :

                 coefficient     standard-error    t-ratio

  beta 0          0.13555999E+01  0.12410773E+01  0.10922768E+01
  beta 1         -0.86221373E-02  0.25629600E-01 -0.33641326E+00
  beta 2          0.27176191E+00  0.14581812E+00  0.18637046E+01
  beta 3          0.11076477E+00  0.11288153E+00  0.98124801E+00
  beta 4          0.12341483E+00  0.11098896E+00  0.11119559E+01
  beta 5          0.83674899E-01  0.11518568E+00  0.72643494E+00
  beta 6          0.44732873E+00  0.21815382E+00  0.20505198E+01
  beta 7          0.44166817E+00  0.46461498E+00  0.95061113E+00
  beta 8          0.11443517E+00  0.57304958E-01  0.19969506E+01
  sigma-squared   0.53021189E-01

log likelihood function =   0.78939116E+01

the estimates after the grid search were :

  beta 0          0.15864684E+01
  beta 1         -0.86221373E-02
  beta 2          0.27176191E+00
  beta 3          0.11076477E+00
  beta 4          0.12341483E+00
  beta 5          0.83674899E-01
  beta 6          0.44732873E+00
  beta 7          0.44166817E+00
  beta 8          0.11443517E+00
  delta 0         0.00000000E+00
  delta 1         0.00000000E+00
  delta 2         0.00000000E+00
  delta 3         0.00000000E+00
  delta 4         0.00000000E+00
  sigma-squared   0.98498657E-01
  gamma           0.85000000E+00


 iteration =       0  func evals =      19  llf =  0.12762089E+02
     0.15864684E+01-0.86221373E-02 0.27176191E+00 0.11076477E+00 0.12341483E+00
     0.83674899E-01 0.44732873E+00 0.44166817E+00 0.11443517E+00 0.00000000E+00
     0.00000000E+00 0.00000000E+00 0.00000000E+00 0.00000000E+00 0.98498657E-01
     0.85000000E+00
 gradient step
 iteration =       5  func evals =      41  llf =  0.15066441E+02
```


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*b0M

```
    0.15949646E+01-0.43568363E-02 0.25876672E+00 0.93801676E-01 0.15853089E+00
    0.70817705E-01 0.45894689E+00 0.44180352E+00 0.82104199E-01 0.15598445E-02
   -0.31272172E-01-0.23884808E-01-0.24679630E-01 0.12890415E-02 0.11700378E+00
    0.93762697E+00
 iteration =    10  func evals =     60  llf =  0.16353200E+02
    0.16753993E+01-0.13898315E-02 0.21715675E+00 0.33823516E-01 0.20433347E+00
    0.78318789E-01 0.51160595E+00 0.53959245E+00 0.88932494E-01 0.12747305E+00
   -0.19139491E+00 0.69715366E-01-0.10235099E+00 0.74550223E-01 0.10157538E+00
    0.97299878E+00
 iteration =    15  func evals =     77  llf =  0.19598223E+02
    0.23093444E+01-0.13974731E-01 0.17445890E+00 0.23280357E-01 0.20878339E+00
    0.57213943E-01 0.47693699E+00 0.87164094E+00 0.10821655E+00 0.10976357E+01
   -0.19518221E+00 0.32347572E-02-0.35853738E+00-0.75234525E-01 0.89560137E-01
    0.99846128E+00
 iteration =    20  func evals =    100  llf =  0.23553814E+02
    0.34775829E+01-0.15186066E-01 0.15319574E+00 0.29370577E-01 0.14630999E+00
    0.65398598E-01 0.35140644E+00 0.97012313E+00 0.98205633E-01 0.24880911E+01
   -0.17313052E+00-0.26073082E+00-0.52832349E+00-0.13159102E+00 0.92729000E-01
    0.99971499E+00
 iteration =    25  func evals =    141  llf =  0.26875433E+02
    0.35872033E+01-0.19152878E-01 0.14644577E+00 0.57152452E-01 0.12121129E+00
    0.59484055E-01 0.35875956E+00 0.95450169E+00 0.98606591E-01 0.35438841E+01
   -0.15264862E+00-0.51230760E+00-0.57692642E+00-0.19662823E+00 0.11577285E+00
    0.99991448E+00
 pt better than entering pt cannot be found
 iteration =    30  func evals =    182  llf =  0.27059709E+02
    0.35191236E+01-0.19714109E-01 0.14368121E+00 0.53994251E-01 0.12657883E+00
    0.66617923E-01 0.36374716E+00 0.97081512E+00 0.93922661E-01 0.35811661E+01
   -0.15555277E+00-0.52773106E+00-0.57434377E+00-0.18543606E+00 0.11908520E+00
    0.99993876E+00
```

the final mle estimates are :

	coefficient	standard-error	t-ratio
beta 0	0.35191236E+01	0.22383783E+00	0.15721756E+02
beta 1	-0.19714109E-01	0.66167063E-02	-0.29794444E+01
beta 2	0.14368121E+00	0.26516759E-01	0.54185057E+01
beta 3	0.53994251E-01	0.52018888E-01	0.10379740E+01
beta 4	0.12657883E+00	0.27495256E-01	0.46036607E+01
beta 5	0.66617923E-01	0.19951884E-01	0.33389290E+01
beta 6	0.36374716E+00	0.28008828E-01	0.12986876E+02
beta 7	0.97081512E+00	0.62073454E-01	0.15639779E+02
beta 8	0.93922661E-01	0.28156049E-01	0.33357897E+01
delta 0	0.35811661E+01	0.49732620E+00	0.72008394E+01
delta 1	-0.15555277E+00	0.13919692E+00	-0.11175015E+01
delta 2	-0.52773106E+00	0.22054384E+00	-0.23928625E+01
delta 3	-0.57434377E+00	0.18750662E+00	-0.30630586E+01
delta 4	-0.18543606E+00	0.68577004E-01	-0.27040560E+01
sigma-squared	0.11908520E+00	0.21739953E-01	0.54777119E+01
gamma	0.99993876E+00	0.40834794E-03	0.24487420E+04

log likelihood function =   -0.707059709E+01

LR test of the one-sided error = [111]0.64331595E+02
with number of restrictions = 6

[note that this statistic has a mixed chi-square distribution]

number of iterations = 30

(maximum number of iterations set at : 100)

number of cross-sections = 61

number of time periods = 1

total number of observations = 61

thus there are: 0 obsns not in the panel

covariance matrix :

```
  0.50103373E-01  0.70373016E-03 -0.32486120E-03  0.76360351E-02 -0.26431599E-02
 -0.89842093E-02 -0.50522195E-02 -0.11113435E-01  0.33752614E-02 -0.22186045E+00
  0.14408322E-02  0.29108835E-01  0.40703339E-01  0.31093524E-01 -0.85606993E-03
 -0.71700121E-04
  0.70373016E-03  0.43780802E-04  0.88561493E-04 -0.15496792E-04 -0.31233639E-03
  0.25948197E-03  0.23821697E-04 -0.71747207E-03 -0.44880925E-04  0.63917963E-02
  0.17861326E-03 -0.49558330E-03 -0.22496580E-02 -0.98098666E-03  0.92786263E-04
  0.33406799E-05
 -0.32486120E-03  0.88561493E-04  0.70313853E-03  0.62386243E-04  0.13917059E-03
 -0.60451310E-03 -0.61525753E-03 -0.58671504E-03 -0.11806382E-03 -0.66708433E-02
  0.65027228E-03  0.11330760E-02  0.90131908E-04  0.88287993E-03 -0.87896141E-04
 -0.31316347E-05
  0.76360351E-02 -0.15496792E-04  0.62386243E-04  0.27059647E-02 -0.15820724E-02
 -0.10818516E-02 -0.70073837E-03 -0 47052102E-02 -0.56702753E-03 -0.46106524E-02
  0.61302474E-03  0.75145256E-03  0.60401780E-03 -0.67150402E-03  0.31276925E-04
 -0.26719097E-05
 -0.26431599E-02 -0.31233639E-03  0.13917059E-03 -0.15820724E-02  0.75598913E-03
  0.23525528E-02  0.10534564E-02 -0.53936237E-03 -0.12235637E-03  0.48145095E-01
  0.16216441E-03 -0.47208978E-02 -0.13413666E-01 -0.69033176E-02  0.47317389E-03
  0.22710408E-04
 -0.89842093E-02  0.25948197E-03 -0.60451310E-03 -0.10818516E-02  0.23525528E-02
  0.39807767E-03  0.12575996E-03  0.59083039E-02  0.57008351E-04 -0.17652297E-01
 -0.11460606E-02 -0.21782564E-04  0.97320428E-02  0.38653775E-02 -0.37482716E-03
 -0.12846146E-04
 -0.50522195E-02  0.23821697E-04 -0.61525753E-03 -0.70073837E-03  0.10534564E-02
  0.12575996E-03  0.78449443E-03  0.32369245E-02  0.17409929E-03 -0.45789046E-02
 -0.11298555E-02 -0.39881838E-03  0.45302000E-02  0.82098862E-03 -0.21645352E-03
 -0.48719138E-05
 -0.11113435E-01 -0.71747207E-03 -0.58671504E-03 -0.47052102E-02 -0.53936237E-03
  0.59083039E-02  0.32369245E-02  0.38531137E-02  0.15924197E-04  0.10689666E+00
 -0.63981050E-03 -0.11507033E-01 -0.26533152E-01 -0.14510520E-01  0.88021248E-03
  0.48582224E-04
  0.33752614E-02 -0.44880925E-04 -0.11806382E-03 -0.56702753E-03 -0.12235637E-03
  0.57008351E-04  0.17409929E-03  0.15924197E-04  0.79276312E-03 -0.14094448E-01
 -0.55629058E-04  0.25382599E-02  0.77620361E-03  0.22718063E-02  0.38508559E-04
 -0.62806777E-06
 -0.22186045E+00  0.63917963E-02 -0.66708433E-02 -0.46106524E-02  0.48145095E-01
 -0.17652297E-01 -0.45789046E-02  0.10689666E+00 -0.14094448E-01  0.24733335E+00
 -0.23199327E-02 -0.15003814E+00  0.19161567E+00  0.62506444E-01 -0.67987426E-02
 -0.29117865E-03
```

```
 0.14408322E-02  0.17861326E-03  0.65027228E-03  0.61302474E-03  0.16216441E-03
-0.11460606E-02 -0.11298555E-02 -0.63981050E-03 -0.55629058E-04 -0.23199327E-02
 0.19375782E-01 -0.82325919E-02 -0.93877201E-04 -0.85702159E-03  0.89206446E-04
-0.95649634E-05
 0.29108835E-01 -0.49558330E-03  0.11330760E-02  0.75145256E-03 -0.47208978E-02
-0.21782564E-04 -0.39881338E-03 -0.11507033E-01  0.25382599E-02 -0.15003814E+00
-0.82325919E-02  0.48639583E-01 -0.21769559E-01 -0.60625696E-03  0.10294230E-02
 0.11792169E-04
 0.40703339E-01 -0.22496580E-02  0.90131908E-04  0.60401780E-03 -0.13413666E-01
 0.97320428E-02  0.45302000E-02 -0.26533152E-01  0.77620361E-03  0.19161567E+00
-0.93877201E-04 -0.21769559E-01  0.35158734E-01 -0.37236895E-01 -0.75287781E-03
 0.12671237E-03
 0.31023524E-01 -0.98098666E-03  0.88287993E-03 -0.67150402E-03 -0.69033176E-02
 0.38653775E-02  0.82098862E-03 -0.14510520E-01  0.22718063E-02  0.62506444E-01
-0.85702159E-03 -0.60625696E-03 -0.37236895E-01  0.47028055E-02  0.26696805E-02
 0.51754895E-04
-0.85606993E-03  0.92786263E-04 -0.87896141E-04  0.31276925E-04  0.47317389E-03
-0.37482716E-03 -0.21645352E-03  0.88021248E-03  0.38508559E-04 -0.67987426E-02
 0.89206446E-04  0.10294230E-02 -0.75287781E-03  0.26696805E-02  0.47262557E-03
-0.46480414E-05
-0.71700121E-04  0.33406799E-05 -0.31316347E-05 -0.26719097E-05  0.22710408E-04
-0.12846146E-04 -0.48719138E-05  0.48582224E-04 -0.62806777E-06 -0.29117865E-03
-0.95649634E-05  0.11792169E-04  0.12671237E-03  0.51754895E-04 -0.46480414E-05
 0.16674804E-06
```

technical efficiency estimates :

firm	year	eff.-est.
1	1	0.87347517E+00
2	1	0.72849955E+00
3	1	0.99751803E+00
4	1	0.99825509E+00
5	1	0.83997734E+00
6	1	0.98466319E+00
7	1	0.79073004E+00
8	1	0.74972945E+00
9	1	0.76144709E+00
10	1	0.97266135E+00
11	1	0.89545299E+00
12	1	0.99168695E+00
13	1	0.96465199E+00
14	1	0.57103547E+00
15	1	0.69850033E+00
16	1	0.84555875E+00
17	1	0.87359900E+00
18	1	0.88295637E+00
19	1	0.28042985E+00
20	1	0.76974798E+00
21	1	0.98801977E+00
22	1	0.85653892E+00
23	1	0.99575439E+00
24	1	0.96824801E+00
25	1	0.85355344E+00

26	1	0.90113836E+00
27	1	0.99535175E+00
28	1	0.97515887E+00
29	1	0.69418843E+00
30	1	0.96244903E+00
31	1	0.89982734E+00
32	1	0.76832986E+00
33	1	0.81512153E+00
34	1	0.57768674E+00
35	1	0.96871544E+00
36	1	0.76453179E+00
37	1	0.92358993E+00
38	1	0.99310101E+00
39	1	0.85039867E+00
40	1	0.57561614E+00
41	1	0.69143728E+00
42	1	0.69140805E+00
43	1	0.45381548E+00
44	1	0.59007223E+00
45	1	0.61372826E+00
46	1	0.86616361E+00
47	1	0.73528952E+00
48	1	0.60696751E+00
49	1	0.77172762E+00
50	1	0.43034965E+00
51	1	0.67000555E+00
52	1	0.87101965E+00
53	1	0.91152315E+00
54	1	0.93199478E+00
55	1	0.94605294E+00
56	1	0.94916194E+00
57	1	0.75336476E+00
58	1	0.68885695E+00
59	1	0.89244668E+00
60	1	0.52161733E+00
61	1	0.78630236E+00

mean efficiency = 0.80608526E+00

Appendix 3: MMRG Independent Farmers' Computer Frontier Output

```
Output from the program FRONTIER (Version 4.1c)


instruction file = terminal
data file =        MMRG INDEPENDENT.txt


Tech. Eff. Effects Frontier (see B&C 1993)
The model is a production function
The dependent variable is logged


the ols estimates are :

                 coefficient     standard-error    t-ratio

  beta 0          0.44522599E+01  0.20202818E+01  0.22037816E+01
  beta 1          0.10285542E-01  0.10164909E+00  0.10118676E+00
  beta 2          0.23278986E-01  0.18989612E+00  0.12258800E+00
  beta 3          0.16597613E+00  0.14116714E+00  0.11757420E+01
  beta 4          0.23103954E+00  0.19257705E+00  0.11997253E+01
  beta 5         -0.64962421E-01  0.28820926E-01 -0.22540018E+01
  beta 6         -0.69509597E-01  0.19004310E+00 -0.36575702E+00
  beta 7          0.71802538E+00  0.20277340E+00  0.35410235E+01
  beta 8          0.30890815E+00  0.49521867E+00  0.62378132E+00
  sigma-squared   0.26873572E+00

log likelihood function =  -0.29265899E+02

the estimates after the grid search were :

  beta 0          0.49557731E+01
  beta 1          0.10285542E-01
  beta 2          0.23278986E-01
  beta 3          0.16597613E+00
  beta 4          0.23103954E+00
  beta 5         -0.64962421E-01
  beta 6         -0.69509597E-01
  beta 7          0.71802538E+00
  beta 8          0.30890815E+00
  delta 0         0.00000000E+00
  delta 1         0.00000000E+00
  delta 2         0.00000000E+00
  delta 3         0.00000000E+00
  delta 4         0.00000000E+00
  sigma-squared   0.46851416E+00
  gamma           0.85000000E+00


 iteration =       0  func evals =      19  llf = -0.24531339E+02
     0.49557731E+01 0.10285542E-01 0.23278986E-01 0.16597613E+00 0.23103954E+00
    -0.64962421E-01-0.69509597E-01 0.71802538E+00 0.30890815E+00 0.00000000E+00
     0.00000000E+00 0.00000000E+00 0.00000000E+00 0.00000000E+00 0.46851416E+00
     0.85000000E+00
 gradient step
 iteration =       5  func evals =      45  llf = -0.18492922E+02
```

```
    0.49378178E+01 0.26922985E-01-0.58738521E-01 0.92005708E-01 0.33399083E+00
   -0.50161266E-01-0.12415350E-01 0.56711385E+00 0.15099485E+00 0.25146107E-01
   -0.53033669E+00 0.99304812E-01-0.11562985E-02 0.30225214E-01 0.56015076E+00
    0.91458479E+00
 iteration =    10   func evals =      74  llf = -0.11608866E+02
    0.48863115E+01 0.41182800E-01-0.10550712E+00 0.11026253E+00 0.44815654E+00
   -0.52450625E-01-0.20922853E-01 0.51503258E+00-0.16042389E+00 0.20379910E+00
   -0.14084458E+01 0.73430620E+00 0.29065876E-01 0.21542142E+00 0.33948822E+00
    0.94325478E+00
 iteration =    15   func evals =     169  llf = -0.80287264E+01
    0.48533113E+01 0.10837723E+00-0.11187121E+00 0.66438227E-01 0.50022449E+00
   -0.50509809E-01-0.30885400E-01 0.38311959E+00-0.34856302E+00 0.28428344E+00
   -0.13415400E+01 0.59053831E+00 0.16151484E+00 0.85242908E+00 0.39597404E+00
    0.99524000E+00
 iteration =    20   func evals =     213  llf = -0.64778224E+01
    0.47173098E+01 0.11631866E+00-0.88888540E-01 0.82000700E-01 0.48189348E+00
   -0.39827397E-01-0.42274697E-02 0.34921320E+00-0.44477238E+00 0.43026442E+00
   -0.13726685E+01 0.50861180E+00 0.10759372E+00 0.87795689E+00 0.46559675E+00
    0.99949124E+00
 iteration =    25   func evals =     237  llf = -0.55542260E+01
    0.46319619E+01 0.10681893E+00-0.81403748E-01 0.98301434E-01 0.45915238E+00
   -0.35234112E-01 0.51389776E-01 0.32319808E+00-0.47818916E+00 0.62153618E+00
   -0.14481120E+01 0.45684838E+00 0.27497575E+00 0.87695187E+00 0.56397491E+00
    0.99995841E+00
 iteration =    30   func evals =     502  llf = -0.42437155E+01
    0.46155938E+01 0.10231688E+00-0.85291063E-01 0.10558687E+00 0.45421876E+00
   -0.34700476E-01 0.78742618E-01 0.30817581E+00-0.49806636E+00 0.71973060E+00
   -0.14892060E+01 0.43825592E+00 0.38050625E+00 0.88522990E+00 0.60922241E+00
    0.99999999E+00
 iteration =    33   func evals =     524  llf = -0.41277253E+01
    0.46360468E+01 0.10170820E+00-0.85003614E-01 0.10621739E+00 0.45106873E+00
   -0.34541831E-01 0.81890845E-01 0.30693509E+00-0.50385468E+00 0.75760305E+00
   -0.15104672E+01 0.43487607E+00 0.40467547E+00 0.90098137E+00 0.62243947E+00
    0.99999999E+00
```

the final mle estimates are :

	coefficient	standard-error	t-ratio
beta 0	0.46360468E+01	0.64666261E+00	0.71691895E+01
beta 1	0.10170820E+00	0.44959420E-01	0.22622223E+01
beta 2	-0.85003614E-01	0.26556161E-01	-0.32008999E+01
beta 3	0.10621739E+00	0.48618329E-01	0.21847191E+01
beta 4	0.45106873E+00	0.69231234E-01	0.65153934E+01
beta 5	-0.34541831E-01	0.83993262E-02	-0.41124526E+01
beta 6	0.81890845E-01	0.86381010E-01	0.94801908E+00
beta 7	0.30693509E+00	0.38098825E-01	0.80562876E+01
beta 8	-0.50385468E+00	0.14602366E+00	-0.34505002E+01
delta 0	0.75760305E+00	0.99677627E+00	0.76005325E+00
delta 1	-0.15104672E+01	0.32029413E+00	-0.47158754E+01
delta 2	0.43487607E+00	0.29497373E+00	0.14742875E+01
delta 3	0.40467547E+00	0.92540005E+00	0.43729787E+00
delta 4	0.90098137E+00	0.35713377E+00	0.25228120E+01
sigma-squared	0.62243947E+00	0.15010049E+00	0.41468184E+01
gamma	0.99999999E+00	0.17264631E-06	0.57921887E+07

```
log likelihood function =  -0.41277355E+01

LR test of the one-sided error =   0.52276327E+02
with number of restrictions = 6
[note that this statistic has a mixed chi-square distribution]

number of iterations =     33

(maximum number of iterations set at :   100)

number of cross-sections =     45

number of time periods =      1

total number of observations =     45

thus there are:      0  obsns not in the panel


covariance matrix :

  0.41817253E+00 -0.80647257E-02 -0.12575619E-01 -0.20803496E-01 -0.20241920E-01
 -0.19595134E-02  0.38427591E-01  0.85263744E-02 -0.44919269E-01  0.53347349E-01
 -0.20805823E-01 -0.10890688E-01  0.89786411E-01  0.17069067E-01  0.11950719E-01
 -0.55224889E-08
 -0.80647257E-02  0.20213495E-02 -0.19362434E-03 -0.90742078E-03  0.22335168E-02
  0.67512397E-04 -0.18944486E-02 -0.80008131E-03 -0.41897665E-02 -0.28149395E-02
  0.10854350E-02  0.55168504E-03 -0.17061316E-02  0.84354938E-03 -0.45549098E-03
  0.13259095E-09
 -0.12575619E-01 -0.19362434E-03  0.70522969E-03  0.10400860E-02 -0.43966352E-03
  0.15311025E-03 -0.15545996E-03 -0.51496699E-03  0.21384832E-02  0.11798732E-02
 -0.10394818E-02 -0.19891856E-03 -0.17037599E-02  0.10527339E-02  0.84582909E-03
 -0.12882186E-09
 -0.20803496E-01 -0.90742078E-03  0.10400860E-02  0.23637419E-02 -0.67039120E-03
  0.11515559E-03 -0.82132903E-03 -0.17078444E-03  0.48378110E-02  0.16700301E-02
 -0.13871747E-02  0.37449934E-04 -0.29606218E-02  0.39058347E-03  0.77222652E-03
 -0.84829483E-10
 -0.20241920E-01  0.22335168E-02 -0.43966352E-03 -0.67039120E-03  0.47929638E-02
 -0.21033350E-03 -0.54189266E-02  0.29226378E-03 -0.17754004E-02 -0.11110145E-01
  0.57039887E-02  0.23304149E-02 -0.47628276E-02 -0.53890967E-02 -0.38347084E-02
  0.80632469E-09
 -0.19595134E-02  0.67542397E-04  0.15311025E-03  0.11515559E-03 -0.21033350E-03
  0.70548680E-04  0.20595206E-03 -0.27049002E-03  0.49627898E-04  0.62217991E-03
 -0.42759714E-03 -0.20156153E-03 -0.23453055E-03  0.60090670E-03  0.43407129E-03
 -0.34199595E-10
  0.38427591E-01 -0.18944486E-02 -0.15545996E-03 -0.82132903E-03 -0.54189266E-02
  0.20595206E-03  0.74616789E-02 -0.53592014E-03 -0.20180882E-02  0.13313299E-01
 -0.64040973E-02 -0.29166436E-02  0.44850022E-02  0.89295131E-02  0.38734716E-02
 -0.65156850E-09
  0.85263744E-02 -0.80008131E-03 -0.51496699E-03 -0.17078444E-03  0.29226378E-03
 -0.27049002E-03 -0.53592014E-03  0.14515205E-02  0.14748058E-02 -0.35115639E-02
  0.21854121E-02  0.68555163E-03  0.17160600E-02 -0.42463062E-02 -0.16736873E-02
  0.21368727E-09
 -0.44919269E-01 -0.41897665E-02  0.21384832E-02  0.48378110E-02 -0.17754004E-02
  0.49627898E-04 -0.20180882E-02  0.14748058E-02  0.21322910E-01 -0.10122536E-01
  0.61512461E-02  0.84796106E-03 -0.12206299E-01 -0.12883188E-01 -0.36697421E-02
  0.13286531E-08
```

0.53347349E-01	-0.28149395E-02	0.11798732E-02	0.16700301E-02	-0.11110145E-01
0.62217991E-03	0.13313299E-01	-0.35115639E-02	-0.10122536E-01	0.99356294E+00
-0.71702281E-01	-0.25168231E+00	0.61752293E-01	0.58762946E-02	0.29411225E-01
-0.93319098E-08				
-0.20805823E-01	0.10854350E-02	-0.10394818E-02	-0.13871747E-02	0.57039887E-02
-0.42759714E-03	-0.64040973E-02	0.21854121E-02	0.61512461E-02	-0.71702281E-01
0.10258833E+00	-0.22541278E-01	-0.40623853E-01	-0.31939106E-01	-0.28872630E-01
0.50474334E-08				
-0.10890688E-01	0.55168504E-03	-0.19891856E-03	0.37449934E-04	0.23304149E-02
-0.20156153E-03	-0.29166436E-02	0.68555163E-03	0.84796106E-03	-0.25168231E+00
-0.22541278E-01	0.87009499E-01	-0.13249158E-01	-0.57216123E-03	-0.34920529E-02
0.68763402E-09				
0.89786411E-01	-0.17061316E-02	-0.17037599E-02	-0.29606218E-02	-0.47628276E-02
-0.23453055E-03	0.44850022E-02	0.17160600E-02	-0.12206299E-01	0.61752293E-01
-0.40623853E-01	-0.13249158E-01	0.85636525E+00	-0.75813341E-01	0.11049796E-01
-0.54175612E-08				
0.17069067E-01	0.84354938E-03	0.10527339E-02	0.39058347E-03	-0.53890967E-02
0.60090670E-03	0.89295131E-02	-0.42463062E-02	-0.12883188E-01	0.58762946E-02
-0.31939106E-01	-0.57216123E-03	-0.75813341E-01	0.12754453E+00	0.19154844E-01
-0.40623684E-08				
0.11950719E-01	-0.45549098E-03	0.84582909E-03	0.77222652E-03	-0.38347084E-02
0.43407129E-03	0.38734716E-02	-0.16736873E-02	-0.36697421E-02	0.29411225E-01
-0.28872630E-01	-0.34920529E-02	0.11049796E-01	0.19154844E-01	0.22530156E-01
-0.28252771E-08				
-0.55224889E-08	0.13259095E-09	-0.12882186E-09	-0.84829483E-10	0.80632469E-09
-0.34199595E-10	-0.65156850E-09	0.21368727E-09	0.13286531E-08	-0.93319098E-08
0.50474334E-08	0.68763402E-09	-0.54175612E-08	-0.40623684E-08	-0.28252771E-08
0.29806748E-13				

technical efficiency estimates :

firm	year	eff.-est.
1	1	0.55965575E+00
2	1	0.42227415E-01
3	1	0.99915108E+00
4	1	0.48861287E+00
5	1	0.61003034E+00
6	1	0.45245400E+00
7	1	0.83297810E+00
8	1	0.96603080E+00
9	1	0.91017901E+00
10	1	0.78524856E+00
11	1	0.90809886E+00
12	1	0.89836388E+00
13	1	0.99974247E+00
14	1	0.96189961E+00
15	1	0.82335913E+00
16	1	0.65455579E+00
17	1	0.36302666E+00
18	1	0.99985663E+00
19	1	0.69218585E+00
20	1	0.66720864E+00
21	1	0.91279034E+00

22	1	0.88236775E+00
23	1	0.98339994E+00
24	1	0.87330609E+00
25	1	0.99417310E+00
26	1	0.44414899E+00
27	1	0.64507874E+00
28	1	0.65564549E+00
29	1	0.77110580E+00
30	1	0.39232146E+00
31	1	0.69205889E+00
32	1	0.47728098E+00
33	1	0.67556570E+00
34	1	0.58833686E+00
35	1	0.55468493E+00
36	1	0.91398764E+00
37	1	0.88131852E+00
38	1	0.52894447E+00
39	1	0.36673506E+00
40	1	0.26829539E+00
41	1	0.51522431E+00
42	1	0.54707917E+00
43	1	0.35465761E+00
44	1	0.41250874E+00
45	1	0.51703229E+00

mean efficiency = 0.67695364E+00