TECHNICAL EFFICIENCY AND PROFITABILITY OF RICE PRODUCTION: A CASE STUDY IN THAZI TOWNSHIP, MANDALAY REGION

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TECHNICAL EFFICIENCY AND PROFITABILITY OF RICE PRODUCTION: A CASE STUDY IN THAZI TOWNSHIP, MANDALAY REGION

A thesis presented by

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to

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The thesis attached here to, entitled **"TECHNICAL EFFICIENCY AND PROFITABILITY OF RICE PRODUCTION: A CASE STUDY IN THAZI TOWNSHIP, MANDALAY REGION"** was prepared and submitted by Myo Htwe under the direction of the chairperson of the candidate supervisory committee and has been approved by all members of that committee and the board of examiners as a partial fulfillment of the requirements for the degree of **MASTER OF AGRICULTURAL SCIENCE (AGRICULTURAL ECONOMICS).**

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DECLARATION OF ORIGINALITY

This thesis represents the original work of the author, except where otherwise stated. It has not been submitted previously for a degree at any other University.

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DEDICATED TO MY BELOVED PARENTS,

U TIN TUN AND DAW KHIN THAN

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ABSTRACT

Efficiency of resource use, which can be defined as the ability to derive maximum output per unit of resource, is the key to effectively addressing the challenges of achieving food security. Increasing productivity in agriculture will certainly lead to greater availability of food and reduce the real price of food. Increased food production will have to come from increased yield. Production of rice in Myanmar is mainly in the hands of smallholder farmers who in most cases use unimproved farming techniques.

A joint research program, undertaken with Oxfam GB and the Department of Agriculture was conducted to assess and compare the profitability and technical efficiency of Oxfam's beneficiary farmers and non-beneficiary farmers in 6 villages of Thazi Township in 2012. The data were collected through personal interview using a questionnaire answered by a random sample of 30 beneficiary farmers and 88 non-beneficiary farmers. An enterprise budget analysis of rice production was used to determine the profitability of different farmer groups. The stochastic frontier production function method was applied to estimate the technical efficiencies of the two farmer groups.

In the estimation of the stochastic frontier production, the elasticity of frontier production in respect to the variable 'seed rate', there is a positive and statistically significant influence on rice yields at the 5% level for all farmers sampled. If farmers use good quality seed and provide better management at the nursery stage, they can achieve better yields of rice. Introduction of better quality seeds should be a priority. The fertilizer coefficient was negatively correlated to the yield of rice and thus was statistically significant. All farmers in the study area need an efficient irrigation scheme to allow them to apply fertilizers in a timely and efficient way to enhance rice production. The mean technical efficiency was 85 percent among the sampled farms. Only 32.2 percent of all farmers had technical efficiency ratings of more than 90 percent. The mean technical efficiency of 'beneficiary farmers' and non-beneficiary farmers is, respectively, 0.93 and 0.72 of the potential (stochastic) frontier production level.

The benefit-cost ratios of rice production in 'beneficiary' and 'non-beneficiary' farmers were 1.09 and 0.98, respectively. Further analysis of benefit-cost ratios for beneficiary farmers, indicates the highest benefit-cost ratio 1.15 is in

the small beneficiary farm size group. Moreover, the ‘non-beneficiary farmer’ group was unable to generate enough income to cover the variable cost of rice production.

Both farm size and household head’s years of schooling for all sample farmers, was positively related to the inefficiency effect, while the household head’s experience in rice farming and their use of GAP practices was negatively related to the inefficiency effect. The coefficient for the farmer’s experience in rice farming was significant at the 10% level in the inefficiency model.

In this study, the major constraint faced by farmers was insufficient access to irrigation. About 85 percent of sampled farmers were confronted with insufficient irrigation supplies. Moreover, seed currently used is of low quality. The problem of labor scarcity was found in 59 percent of sampled farmers. This may be due to the relatively low labor wage rate is encouraging labor migration to other sectors.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICS

LIST OF ABBREVIATIONS

BCR	= Benefit–Cost Ratio
DAP	= Department of Agricultural Planning
DoA	= Department of Agriculture
FAO	= Food and Agriculture Organization
ha	= Hectare
kg	= Kilogram
MOAI	= Ministry of Agriculture and Irrigation
MLE	= Maximum Likelihood Estimation
MT	= Metric Ton
OLS	= Ordinary Least Square
GAP	= Good Agricultural Practices
Ks	= Kyats
l	= Liter

LIST OF CONVERTION FACTORS

1 basket of paddy	= 21 kilogram
1 ton	= 1000 kilogram
1 ton	= 2 cartloads of cow dung
1 hectare	= 2.471 acre

CHAPTER I
INTRODUCTION

The government of Myanmar is trying to reduce poverty. Agricultural sector must be developed, to fulfill its objective. In Myanmar, 61.2% of population resides in rural area and are employed in the agriculture, livestock, and fishery sector (MOAI 2010). In order to reduce poverty, farm income of rural farm households needs to increase and the livelihoods of rural people must be improved. To promote improving livelihoods, more job opportunities for rural farm households must be provided. When agricultural sector is developed, job opportunities will increase and farm income will also rise. In Myanmar, there is a rice base farming system, and most of farmers are familiar with this system. The major source of income in rural areas comes from rice production. Therefore, rice production is a major source of employment, income generation as well as nutrition for rural households, and the growth of increasing rice production is extremely important in Myanmar. Rice is by far the most economically important food crop in many developing countries, providing two third of the calorific intake of more than 3 billion people in Asia, and one third for nearly 1.5 billion people in Africa and Latin America (FAO 1995a).

Poverty alleviation has become one of the most important worldwide issues in recent years. It was listed as first on the global agenda in the Millennium Development Goals (MDGs) released by the United Nations in September 2000. The major aim is to "eradicate extreme poverty and hunger, while calling for a reduction in the proportion of people living on less than one dollar a day to half from the 1990 level by 2015". Even though the global poverty rate has fallen from 33% in 1981 to 21% in 2001, there were still 1.2 billion people living on less than one dollar a day, and about three-quarters of these live in rural areas (World Bank 2006).

Eradicating poverty is the greatest challenge for everyone concerned with development studies and development planning. Issues that related to poverty, both rural and urban, have been disused, studied and debated at local, regional, national, and global levels (Table 1.1). Although there is widespread poverty in Myanmar, a comprehensive study that would allow the development of strategies to reduce poverty at all levels is still lacking. Investigation into the nature of poverty and what extent the gender differences at both individual and household level affect poverty require field-based investigations. Therefore undertaking a poverty analysis studies in Myanmar, is more than appropriate at this point of time (Dolly Kyaw and Routray 2006).

Technical efficiency is just one component of overall economic efficiencies. However, in order to be economically efficient, a farm must be technically efficient. Profit maximization requires a farm to produce the maximum output given a level of inputs employed (i.e. be technically efficient), use the right mix of inputs in light of the relative price of each input (i.e. be input allocatively efficient) and produce the right mix of output given the set of price (i.e. be output allocatively efficient) (Kumbhaker and Lovell 2000).

Table 1.1 Indicators of agricultural productivity and food security

Country	Agricultural income per average worker ($ per year)	Poverty (% under $ 1.25 per day)	Malnutrition (% children underweight)
Malaysia	6,680	<1	13
Philippines	1,119	18	21
Indonesia	730	18	20
Thailand	706	<1	7
Bangladesh	507	43	41
Cambodia	434	23	29
Vietnam	367	17	20
Myanmar	194	26	32

Source: IHLCA 2011, World Bank Development indicators 2012 and MGD Indicators 2012

1.1 Background Information on Rice Production in Myanmar

Rice production in Myanmar is important to the food supply in Myanmar, with rice being a staple part of the Myanmar diet. The most striking feature of Myanmar agriculture is the abundance of farmland. Notwithstanding its enormous potential, Myanmar agricultural sector has underperformed over the past fifty years (Table 1.2). Agricultural productivity remains low in comparison with its international competitors and neighbors. As a result of its heavy policy focus on rice, and the generally favorable growing conditions, Myanmar has remained in the main self-sufficient in rice. Indeed, over the past decade, domestic production has permitted a small rice surplus for export (USDA 2013).

Fertilizer use on paddy fields has fluctuated significantly over the past four decades as a result of fluctuating incentives. During the 27-year period ending in 1993/94, when the government heavily subsidized fertilizer prices, per acre use on paddy increased dramatically, from less than 1 kg ac^{-1} (of NPK fertilizer) in 1966-67 to 57 kg ac^{-1} in 1993-94. Over the same time period, the share of HYV seeds used in paddy production increased from zero to just over 50%. From 1994 onwards, the government removed fertilizer subsidies on all crops except those produced by the State Economic Enterprises (SEE) operating under MOAI (Young et al. 1998).

1.2 The Role of Irrigation

Myanmar has extensive water resources available for irrigated agriculture, including for rice farming. Surface water from the Ayeyarwady and Sittoung River Basins has been developed for rice irrigation over the past century. Naing (2005) reports high potential for groundwater development in the Ayeyarwady River Basin. Optimal water management requires that rice grows in a saturated soil for most of the growing season. Surface water is not required except for its utility in suppressing weeds. In most settings in Myanmar and elsewhere in South and Southeast Asia, farmers seek to maximize water flow to their fields to reduce the yield-reducing effects of water deficit.

In irrigated rice, farmers are concerned about their access to adequate water from canals. Competition for water is common during the dry season, especially where there is limited regulation and an absence of cooperative water management. In low lying fields, there are risks of submergence and stagnant water, both of which can sharply reduce yields. Salt water intrusion affects rice in the delta, and is more serious in the summer crop season. Around 3% of the country's rice is affected by salinity.

1.3 Export Performance of Rice

Rice production is central to the economy and food security of Myanmar. Between 1900 and 1940, Myanmar exported 2 to 3 million metric tons (MT) rice annually, up to 70% of national production. In the early 1960s, annual exports were in the range 1.3 to 1.7 million MT. In recent years, exports have dropped below 1 million MT per annum, as population growth has outpaced productivity improvement (USDA). It is clear that yield has stagnated over the past 20 years, with overall production largely the function of increased harvested area. The quantity of rice export showed a dynamic fluctuated trend from year to year (Table 1.2).

1.4 Present Status of Agricultural Extension

Agricultural research, extension and education constitute key public goods driving agricultural growth over time. Currently, Myanmar operates a network of agricultural research institutions. The centerpiece of this system, the Ministry of Agriculture and Irrigation's (MOAI) Department of Agricultural Research (DAR) operates seven major research center and 17 satellite farms across Myanmar studying rice, other cereals, pulses, oilseeds and various horticultural crops. Myanmar likewise operates multiple extension services through the Department of Agriculture (DoA) and a series of specialized units serving fisheries, forestry, rural development, cotton, sugarcane and other cash crops. The largest of these, with about 75% of total MOAI extension personnel, is the DoA program focusing primarily on paddy production. Within DoA, women account for about one-third of total extension officers (Khin Mar Cho 2013).

The Department of Agriculture, under the Ministry of Agriculture and Irrigation, not only provides the high yielding varieties and proven technologies, but also organizes and diffuses these technologies to farmers. Moreover, educating and conducting training to introduce Good Agricultural Practices (GAP) is being provided to farmers by extension agents. This is done through the contact farmers and promotes the efficient application of these methods, and ways that are appropriate to local ecological conditions.

Table 1.2 Changes in rice sown area, yield and production in Myanmar

Items	1995-96	2000-01	2005-06	2008-09	2009-10	2010-11	2011-12
Sown area ('000 ha)	6138	6359	7389	8094	8067	8047	7593
Growth rate (%)		3.60	16.20	9.54	-0.33	-0.25	-5.64
Yield (MT ha^{-1})	3.08	3.38	3.75	4.03	4.06	4.07	3.83
Growth rate (%)		9.74	10.95	7.47	0.74	0.25	-5.90
Production ('000 MT)	18580	21324	27683	32573	32681	32579	29010
Growth rate (%)		14.77	29.82	17.66	0.33%	-0.31	-10.95
Export ('000 MT)	354	251.4	180	666.4	818.1	536.4	707.2
Growth rate (%)		-28.98	-28.40	270.2	22.76	-34.43	31.84

Source: Ministry of Agriculture and Irrigation 2012

1.5 Condition of Rice Production in Myanmar

From the users' point of view, current technology is still a need to develop appropriate technology. This would be significant in improving the level of resource use efficiency among the rice farmers. Rice farmers have been unable to form cooperatives, and which would have enable them to purchase modern farm inputs and hire additional labor. By introducing formal education programs for the farmers, significant steps would be made in improving their technical knowledge and hence their efficiency. An improved understanding of the rice production environment will enhance the efficacy and efficiency of planning, implementation and evaluation. This can be implemented relatively quickly and cost-effectively using a combination of new and traditional methods.

The Presidential initiative on rice, undertaken by the administration, is a new production strategy for sustained increase in rice production for national self-sufficiency, food security and export promotion. The Ministry of Agriculture and Irrigation emphasizes the rapid expansion in domestic production of rice in order to increase annual exportation of rice. However, there is still persistent low yield and output of rice, in spite of the government's efforts in ensuring the availability of improved material inputs, modern technologies and other production resources.

Efficiency of resource use, which can be defined as the ability to derive maximum output per unit of resource, is the key to effectively addressing the challenges of achieving food security. Raising productivity in agriculture will certainly lead to availability of food and reduce the real price of food. Increased food production will have to come from increased yield. Production of rice in Myanmar is mainly in the hands of small scale farmers who are still using unimproved farming techniques. Accordingly, the Ministry of Agriculture and Irrigation (MOAI) is trying to increase rice yield through various schemes such as extension of good agricultural practices, making available an increased amount of loans, encouraging the formation of rice specialization companies, and other measures. Myanmar Agricultural Development Bank increased its loan size per acre to Kyat 50,000 from 2012 monsoon agriculture season. Farmers can take out a loan for Kyat 500,000 (max) for 10 acres (MOAI) (Table.1.3).

Table 1.3 Agricultural loan for paddy production in Myanmar

Year	Sown area ('000 ha)	Loan (Kyat millions)
1995-96	6,138	6,605.71
2000-01	6,359	9,524.87
2005-06	7,389	29,292.05
2008-09	8,094	57,917.72
2009-10	8,067	76,124.72
2010-11	8,047	156,494.46
2011-12	7,593	311,530.22

Source: Department of Agricultural Planning 2012

1.6 The Study Area

The study area, Thazi Township, is located in the Central Dry zone, which has 81 village tracts. Main crops in the study are paddy, chili, cotton, chickpea, sesame, sunflower, and groundnut. Livestock and small ruminants are also raised as a partial business in the area. The agriculture sector is the major source of income. Agricultural production in Thazi Township depends heavily on rainfall. Monsoon season generally arrives in the middle of May and ends in October. There are average of 32 inches of annual rainfall, and 54 days of rain in Thazi Township. Most soils in the study area are sandy and have moderate fertility. Animal draught power and small hand tractors are generally used in agricultural production. Rural laborers, as well as work in agriculture, work as construction workers, timber workers, charcoals making, and there is also migration to other cities to find better jobs in off-farm season. Area sown, harvested area, average yield and changes in yield are shown in Table 1.4.

Table 1.4 Paddy production in Thazi Township

Year	Sown area (ha)	Harvested area (ha)	Yield (kg ha^{-1})	Yield Growth
2007-08	28356.13	28356.13	3147.07	
2008-09	24215.30	24215.30	3304.72	0.05
2009-10	14190.61	14190.61	3238.99	-0.02
2010-11	15705.38	15705.38	3240.96	0.00
2011-12	19233.51	19233.51	3171.78	-0.02

Source: Department of Agriculture, Thazi Township office 2012

1.7 Oxfam GB Project in the Study Area

Oxfam GB in Myanmar is implementing a resilient livelihoods programme in the dry zone for 3 years scheme. The project aims to assist communities to the extent that they have the capacity to develop inclusive and equitable improvements in food and livelihood security, and provide evidence of a sustainable, effective and integrated model for replication. This pilot project focuses on the improved rice production skills of women with links to the role of small holder production to economic development. It mainly aims to foster and emphasis on the comparative advantage of efficient small holder agricultural production, which benefits local producers and consumers. Moreover, it is expected that the research will demonstrate the value of low-tech improved techniques.

In Thazi Township, collaboration between Oxfam and the Department of Agriculture (DoA) is well established. Along with carrying out the pilot project, Oxfam is already implementing a study as to where irrigation schemes for rice cultivation should be considered. Thazi DoA staff provided training for women transplanters on rice transplanting skills, with this aligned to specified MOAI's Good Agricultural Practices (GAP) relevant to skilled agricultural labor (including such factors as planting depth, optimal levels for transplanting seedling and correct line and spacing specifications).

Local farmers who agreed to participate on the pilot were responsible for ensuring proper nursery practices were followed and that production of healthy seedlings at the right stage was undertaken, as well as land preparation and leveling plots. The pilot looked at direct comparisons in rates of production per participating famer. The responsibility of the Department of Agriculture (Thazi Township office) was to provide training on GAP for both selected transplanters and farmers. The DoA was also responsible for field monitoring of the project at all critical steps of production (input use) and ensuring that all data was efficiently recorded in the farm logbook. The plots were managed by farmers themselves and were cultivated with a locally adapted rice variety Manaw Thukha seeds. Fertilizers were provided by Oxfam to all beneficiary farmers.

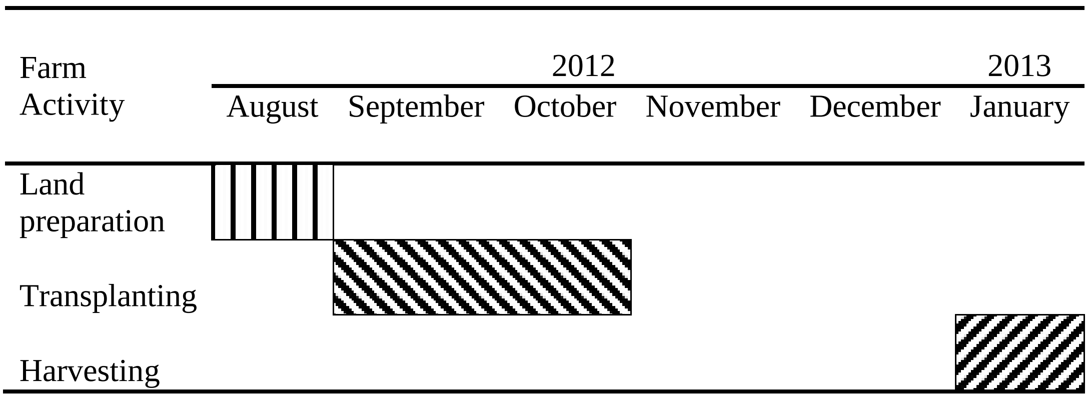
The research orientation training workshop was provided to 30 farmers and they were introduced with the application of farm record books and the concept of cost-return analysis. The joint research project carried out by Oxfam and Yezin Agricultural University (YAU) looked at profitability analysis and production efficiency. A further responsibility of YAU was to provide informed advice based on scientific research, to enhance the mutual interdependence of transplanters and farmers. The Oxfam project provided timely analysis of farm inputs and transplanting costs to beneficiary farmers in the growing season.

1.8 Provision of Oxfam project in Thazi Township

Oxfam agreed to provide Ks 105017.5 (42 transplanters x 2500Kyats per transplanter per hectare) to assist the payment of the transplanting cost for laborers. An agreement between Oxfam and DoA was signed on 25th August 2012, for joint project to provide total amount of Ks 287,624.40 that was in three payments (Table 1.5).

The first disbursement of support by Oxfam for this project was for seed and fertilizer, equal to an amount of 145,541.90 Ks ha^{-1} in August 2012. Oxfam GB also provided trained-women-transplanters for the selected farmers at the time of transplanting, with these costs amounting equals to Ks 105,017.50, paid in September 2012. The farmers were also provided cash grant of Ks 37,065 to cover harvesting cost in the last week of January, 2013. Therefore, in total, Oxfam GB subsidized seed, fertilizers (Urea, Potash and T-super), the costs of labor for transplanting and harvesting at an amount equal to 287,624.40 Ks ha^{-1}. Moreover, these 30 farm households received formal lines of credit (123,550 Ks ha^{-1}), as would normally be available, from the Myanmar Agricultural Development Bank (MADB).

Table 1.5 Payments of Oxfam project for beneficiary farmers



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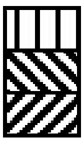


Seed, Urea, T-super, Potash supported by Oxfam
Women laborers for transplanting supported by Oxfam
Harvesting cost supported by Oxfam

1.9 Rationale for This Study

The productivity of rice cultivation in Myanmar remains low, even though there is high potential for production increases. Moreover, productivity of rice farmers in Myanmar remains low in comparison to international competitors and neighbors. The country's average yield is about 4.06 metric ton ha^{-1} while the yield of Asian countries such as China is 6.58 metric ton ha^{-1} (Table 1.6) (DAP 2012).

Among rice producing and exporting countries in Asia, Myanmar ranks number five. Although there was a little difference in the amount of rice produced in Myanmar and Thailand, and rice yield per hectare of Myanmar have generally been higher than those in Thailand, the latter exports the highest amount of rice in that region. Paddy production in Myanmar and neighboring countries (2010-11) is shown in Table 1.6.

The variation in the yield of rice reflects the uneven current application and distribution of agricultural inputs and skills. The major factors influencing increased rice productivity include the use of modern high-yielding varieties, fertilizer, agricultural chemicals, irrigation, and the improvement of access to rural institutions. Another important factor that reduces the country's rice production is the waste that occurs from production at the farm to the final consumption. This calls for substantial improvements in post-harvest processing, transportation and storage systems, and the control of pests and diseases.

The productivity of rice varies between regions, based on the different agro-ecological zones and production systems used. Actual yields of rice differ significantly from potential yields, and this has been attributed to low resource productivity. Enhancing future potential of rice production requires improvements in both productivity and distribution efficiency, not only by farmers but also all other stakeholders. It is necessary to examine resource use efficiency among rice farmers.

Efficient rice production, therefore, plays a key role in providing the population with food security and addressing poverty alleviation. Increasing food production is itself a complex process involving more intensive and extensive use of land and water, facilitation of the increased availability of basic agricultural inputs such as fertilizers, the formation of appropriate agricultural policies and rural institutions, and the strengthening agricultural research. However, if effort is made, the potential for increasing food production in every country in the world would be substantial.

Myanmar has large potential to produce more rice by improving rice yields on existing production areas, the construction of new irrigation infrastructure and the improved maintenance of existing infrastructure, the conversion of more land to rice cultivation, and including converting natural ecosystems into rice production. The adoption of modern and improved production technologies is an area of focus in current government policy, along with the expansion of irrigated areas, improved accessibility to agricultural credit, broader and intensive extension services and the improving the availability of agro-chemicals especially fertilizers, pesticides and herbicides. The productivity of rice does vary between regions within the country based on the different agro-ecological zones and production systems used.

The adoption of improved rice production and processing technologies developed through the application of science and technology has been shown to guarantee increased and sustainable production of rice. But there are several constraints that might limit the productivity including the high incidence of pests, weeds and diseases; drought and poor water control; poor seed management; poor management of soil fertility; lack of access to credit, farm inputs, farm machinery and animal traction; and shortage of labor. Rice production might face other constraints including late planting; poor post-harvest handling, including processing and marketing; poor extension services; inadequate rural infrastructures; and ineffective farmers' organizations.

There is still a large gap between the farmers' yields and those obtained by research stations, and indicate that the various limiting factors affecting rice productivity and production range from farming techniques to marketing. Limitations to rice production are closely interrelated. For instance, use of stronger seedlings from high quality seeds, will not increase yield without the use of adequate fertilizer, and furthermore a rice crop cannot respond to fertilizer application if weed infestation is intense and water supply is inadequate.

An important factor that has to be considered in rice production is the skills of women laborers. Women play a significant role in rice production from which they earn a substantial proportion of their livelihood. Pre-harvest operations that are performed predominantly by women include transplanting, removal of rice seedlings in the nursery, carting them from the nursery to the plot and then transplanting. Manual weeding is carried out by women and much of harvesting is done mostly by women using sickles.

Table 1.6 Paddy productions in Myanmar and neighboring countries (2010-11)

Country	Harvested area (mil ha)	Yield (kg ha^{-1})	Production (mil MT)	Export ('000 MT)
1.Thailand	11	2870	31	8620
2.Vietnam	7	5228	39	3411
3.India	42	3195	134	2148
4.China	30	6582	197	777
5.Myanmar	8	4067	33	536
6.Indonesia	13	4999	64	24
7.Cambodia	3	2836	8	13.2
8.Bangladesh	11	4203	48	5.2
9.Malaysia	0.6	3735	3	0.6
10.Philippines	5	3589	16	0.2
11.Lao PDR	0.8	3606	3	-

Source: Department of Agricultural Planning 2012

1.10 Objectives of This Study

This study aimed to describe the impact of the application of appropriate rice production technology, through the introduction of so called 14 points Good Agricultural Practices (GAP) into rice production systems. It examines the effectiveness of GAP as a mechanism for promoting sustainable and increased rice production levels in order to improve the lives of the farming communities. This research also looked at the importance of rice production to small-holder farmers and how production levels are linked to transplanting skill of woman laborers. The specific objectives were:

1. To observe and note the socio-economic characteristics of the selected farmers in Thazi Township.
2. To assess and compare the profitability and yield levels of two different groups of beneficiary farmers and non-beneficiary farmers.
3. To analyze how far beneficiary farmers benefited from the support of cash grants.
4. To analyze whether poor or marginalized households and laborers, especially women, benefit through this program.
5. To examine the factors affecting technical inefficiency of rice farmers.

CHAPTER II
LITERATURE REVIEW

2.1 Concepts and Measurements of Technical Efficiency

Agricultural production is important for many reasons. Among them, providing more food for people is the basic reason and efficient production of farms affects the regions' growth and competitiveness, income distribution and saving, and labor migration etc. Therefore, agricultural production can affect from micro or household level up to macro or global level. If agricultural production in less developed nations is technical inefficiency, then an increase in agricultural output could be achieved by better utilizing existing resources (Fare et al. 1985).

Tadesse and Krishnamoorthy (1997) examined the level of technical efficiency in paddy farms of the Southern Indian State of Tamil Nadu. The study showed that 90% of the variation in output among paddy (IR-20) farms in the state is due to differences in technical efficiency. Land, animal power and fertilizers had a significant influence on the level of paddy production. The results showed that, with the use of more fertilizers and land, rice production could be increased. The contribution of land in increasing production was more prominent. Farmers were overusing animal power in rice cultivation. The study further indicated that small-sized paddy farms in zone II and medium sized paddy farms in zone III are represented by ecologically based production techniques; thus achieving higher technical efficiency.

Thandar Kyi and Oppen (1999) identified an economic analysis of technical efficiency of rice farmers at delta region in Myanmar. The technical efficiencies of individual observation were estimated by the parametric approach using a stochastic frontier production function for farmers in three different farm sized groups, namely small, medium and large. The empirical results pointed out that urea fertilizer application was the most important explanatory variable in estimating the production frontier.

Mwakalobo (2000) estimated coffee production levels of different farmers and their efficiency in resource use. The results showed that the farmers displayed inefficient use of available resources and were using adequate capital-incentive input levels in order to maximize their output. The result showed that the coffee farmers need to improve their resource use efficiency and productivity. This was shown by using a Cobb-Douglas production function, using Ordinary Least Square techniques.

The technical efficiency and profitability of different farm sizes and different yield levels of rice farmers in Pyinmana Township were estimated by Theingi Myint (2001). The stochastic frontier production function was applied with the FRONTIER 4.1 computer program in the study. The most important constraints to get the highest yield were the high price of fertilizer, the shortage of irrigated water, the limited capital, the poor technical knowledge on plant protection and the availability of information for obtaining the high yield variety seeds. The results stated that small farm size group was the most financially attractive enterprise among the different farm size groups.

Wiboonpogse and Sriboonchitta (2001) analyzed the factor affecting technical efficiency jointly with production frontiers estimated using maximum likelihood method by Frontier 4.1. They stated that the technical inefficiency in jasmine rice and in the non- jasmine rice could be significantly improved. To enhance the yield per rai of jasmine and non-jasmine rice, increased use of chemical fertilizer could be achieved by lowering the fertilizer price or providing more credit. They recommended using more male labor relative to the total labor to reduce the technical inefficiencies for jasmine rice production. However, to reduce the jasmine and non-jasmine rice technical inefficiencies, besides increasing the male labor, technical training to enhance experience in place of age and education must be added for the short-run. They found that the average technical efficiencies (70%) in both kinds of rice imply substantial gaps for the rice yields improvement by increasing their technical efficiencies.

Aye Aye Khin (2002) analyzed the farm-specified technical, allocative and economic efficiencies of the sample sugar farmers in Pyinmana, Tatkone and Yedashe Townships. The application of urea fertilizer, the total labor and draft power used by farm from land preparation to transportation and the farmers' experience in sugarcane cultivation were the most important explanatory variables in frontier estimate. All sample farmers were not fully economically efficient in sugarcane production. About 40-70% of the sample farmers achieved moderate economic efficiency in sugarcane production. Therefore, the results pointed out the encouragement for reaching optimal allocation of resources in their farms was necessary to improve their income and welfare.

Rahman (2003) analyzed the profit efficiency by its three components_ technical, allocative and scale efficiency. He provided the direct measure of the efficiency of Bangladesh rice farmers using a stochastic profit frontier and inefficiency effects model. The results indicated that these rice farmers have more experience in growing modern varieties, had better access to input markets which is located in fertile regions and rice farmers who have less off-farm work tend to be more efficient. The results showed that the average profit efficiency score is 0.77 implying that the average farm producing modern rice could increase profits by about 30% by improving their technical, allocative and scale efficiency.

Production efficiency of high-income and low-income pre-monsoon cotton farmers in Kyaukse and Meikhtila Townships was estimated by Tun Win (2004) through technical efficiency measurement to find out factors affecting the production of cotton. Indicating the mean efficiency of pre-monsoon cotton farmers was 0.67, the result implied that in the short run, there was a scope for increasing cotton production by 33% by adopting the technology and techniques used by the best practice of the cotton farms.

The profitability and technical efficiency of sugarcane farmers in private sectors of Katha, Hteegyaint and Thabeikkyin Townships was examined by War War Shein (2004). The empirical result stated that Thabeikkyin Township was more financially attractive than other Townships for both new plant and ratoon. All ratoon farms were more financially attractive than all of new plant farms. The technical efficiency estimates varied from 56% to 100% with a mean value of 77% for new plant farms and from 52% to 94% with an average of 69% for ratoon farms. There was a scope for increasing syrup production by 23% for new plant, and 31% for ratoon farms with the present technology. The study concluded that improvement in technical efficiency was still possible in the private sector. This kind of syrup cottage industry would assist the raw material for syrup-based industry and generate the income of private sugarcane farmers.

Soe Soe Win (2008) focused on technical efficiency of groundnut production in main production areas of Myanmar. The results of the maximum likelihood parameter estimates of the stochastic production frontier from Cobb-Douglas frontier functions for both Mandalay and Magway Region indicated that the quality of soil was significant factor that affected the yield per hectare in both regions. The average technical efficiency level was 89% with the range from 45% to 97% in Mandalay and was 73% with the range from 16% to 94% in Magway Division. These results indicated that under existing resources and technology, farmers could increase their technical efficiency or output by11% for Mandalay and 27% for Magway through the better use of available resources.

May Yee Kay Khine Sein (2008) investigated the production efficiency and profitability of soybean farmers in the selected areas. The Cobb-Douglas stochastic production frontier using FRONTIER 4.1 was applied to know the factors affecting the yield of soybean and resource use efficiency in two locations and two income groups. The mean technical efficiency in Kyaukme was 0.49 for all farmers while it was 0.73 for low income group 0.79 for high income group. The mean technical efficiency for all farmers was lower than that of the two income groups. Mean technical efficiencies of all sample farmers were found to be 0.83 in Taunggyi. For low income group, human labor used was negatively significant. For high income group, seed rate and animal labor used showed positive effect while human labor used, bio-super foliar application, farm size and annual income indicated negative impact on yield.

Khai and Yabe (2011) measured the technical efficiency of rice production and identified some determinants of technical efficiency of rice farmers in Vietnam. By using stochastic frontier analysis method in the Cobb-Douglas production function. The calculated average efficiency in the study was around 81.6 %. This study demonstrated that the most important factors having positive impacts on technical efficiency levels are intensive labor in rice cultivation, irrigation and education. These play the important role in terms of efficiency score change, while agricultural policies did not help farmers cultivate rice efficiency.

The production and economic efficiency of farmers and millers in Myanmar rice industry was examined by Nay Myo Aung (2012). The empirical result state that the average inefficiency indexes are 10.42 and 22.11 in Hmawbi and Waw Townships, respectively. The inefficiency index suggests that, on average, about 10 % of potential maximum profit is lost in Hmawbi, and about 22 % is lost in Waw for the rice production. This corresponds to a mean profit loss of 42573 Ks ha^{-1} in Hmawbi, and 79246 Ks ha^{-1} in Waw. This discrepancy between observed profit and the frontier profit is due to both technical and allocative inefficiency.

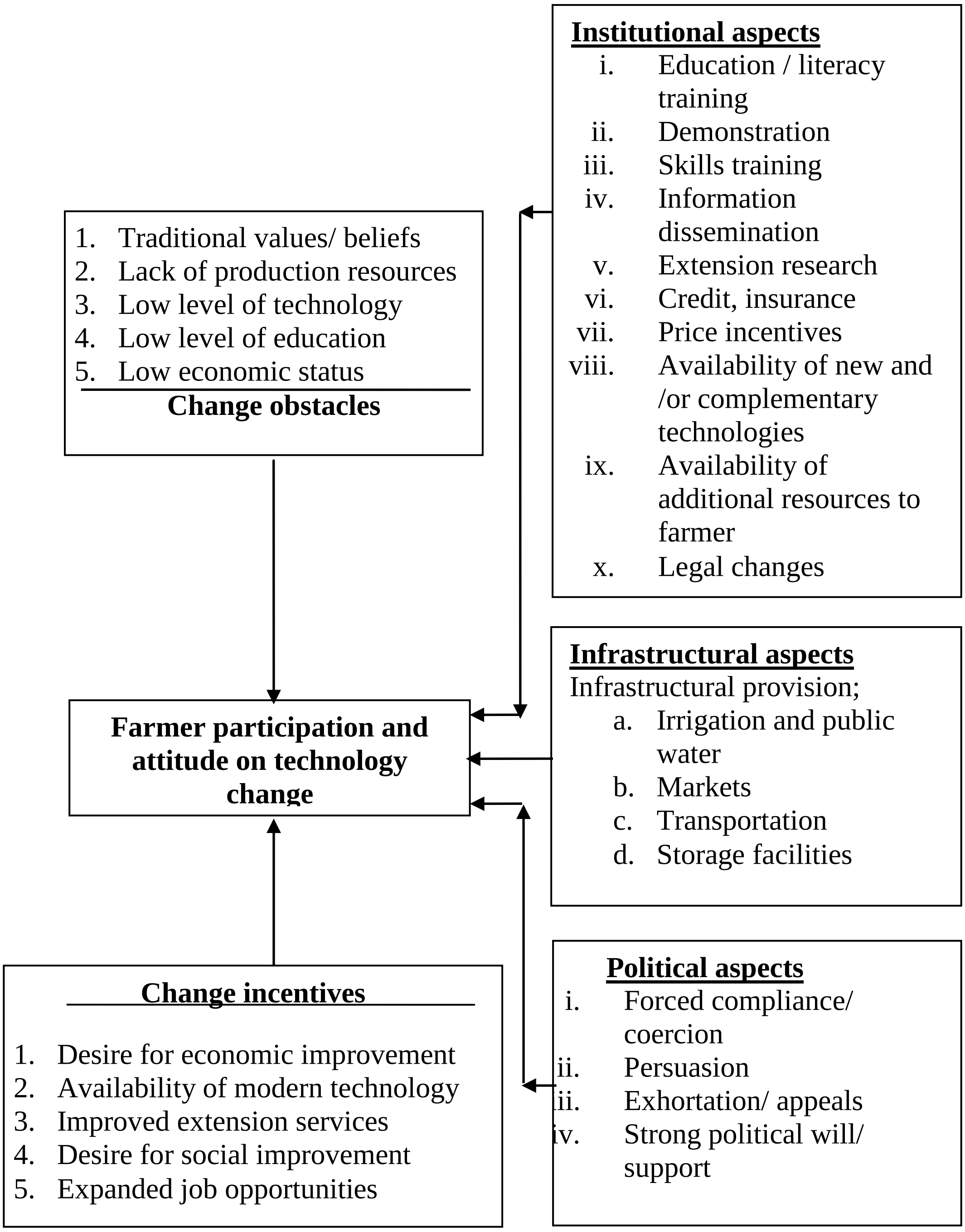


Figure 2.1 Illustration of obstacles and incentives affecting farmer behavior in developing nations

(Source: Sofranko 1984)

2.2 Theoretical Framework for Technical Efficiency

2.2.1 Definitions of efficiency

Technical efficiency, as stated in the study, is defined as the capacity of producers or farmers to maximize output from a given set of inputs (Chaudhry 1979 and Moock 1981). Allocative and economic efficiencies can be defined as the ability to produce a given level of output at a lowest cost. In theory, a firm's efficiency is usually judged by comparing the observed situation with some well-behaved efficiency norm (Pothisuwan 1997).

2.2.2 The Stochastic frontier production function

Aigner and Chu (1968) considered the estimation of a parametric frontier production function of Cobb-Douglas form, using data on a sample of N firms. The model is defined by

$$Ln(y_i) = x_i\beta - u_i \text{ ,} i=1,2,\ldots,N \qquad (2.2.1)$$

where $Ln(y_i)$ is the logarithm of the output for the i^{th} firm; x_i is a (K+1)-row vector, whose first element is "i" and the remaining elements are the logarithms of the K-input quantities used by the i^{th} firm; $\beta = (\beta_0, \beta_1, \ldots, \beta_k)$ is a (K+1) - column vector of unknown parameters to be estimated; and u_i is non-negative random variable associated with technical inefficiency in production of firms in the industry involved.The ratio of the observed output for the i^{th} firm, relative to the potential output, defined by the frontier function, given the input vector, x_i, is used to define the technical efficiency of the i^{th} firm:

$$TE = \frac{y_i}{exp\,(x_{i\beta})} = \frac{exp\left(x_{i\beta} - u_i\right)}{exp\,(x_{i\beta})} = \left(exp(-u)\right) \qquad (2.2.2)$$

This measure is an output oriented measure of technical efficiency, which takes a value between zero and one. It indicates the magnitude of the output of the i^{th} firm relative to the output that could be produced by a fully-efficient firm using the same input vector.

Aigner (1977), and Meeusen and Broeck (1977) independently proposed the stochastic frontier production function, in which an additional random error, v_i, is added to the non-negative random variable, u_i in the equation (2.2.1) to provide:

$$Ln(y_i) = x_i\,\beta + v_i - u_i,\ i = 1,2,\ldots, N \qquad (2.2.3)$$

The random error, v_i, accounts for measurement error and other random factors, such as the effects of weather, strikes, luck, etc., on the value of output variable, together with the combined effects of unspecified input variables in the production function. Aigner, et al. (1977) assumed that the v_is were independent and identically distributed (i.i.d.) normal random variables with mean zero and constant variance σ^2_v, independent of the u_i, which were assumed to be i.i.d. exponential or half-normal random variables.

The model defined by the equation 2.2.3 is called the stochastic frontier function because the output values are bounded by the stochastic (random) variable, exp (x_i β + v). The random error, v_i, can be positive or negative and so the stochastic frontier outputs vary with the deterministic part of the frontier model, exp (x_i β).

2.2.3 Maximum-Likelihood estimation

The parameters of the stochastic frontier production function, defined by equation 2.1.5, can be estimated using either maximum-likelihood (ML) method or using a variant of the OLS method. The OLS approach is not as computationally demanding as the ML method, which requires numerical maximization of the likelihood function. FRONTIER program (Coelli 1992, 1996a) automates the ML method for estimation of the parameters of stochastic frontier models.

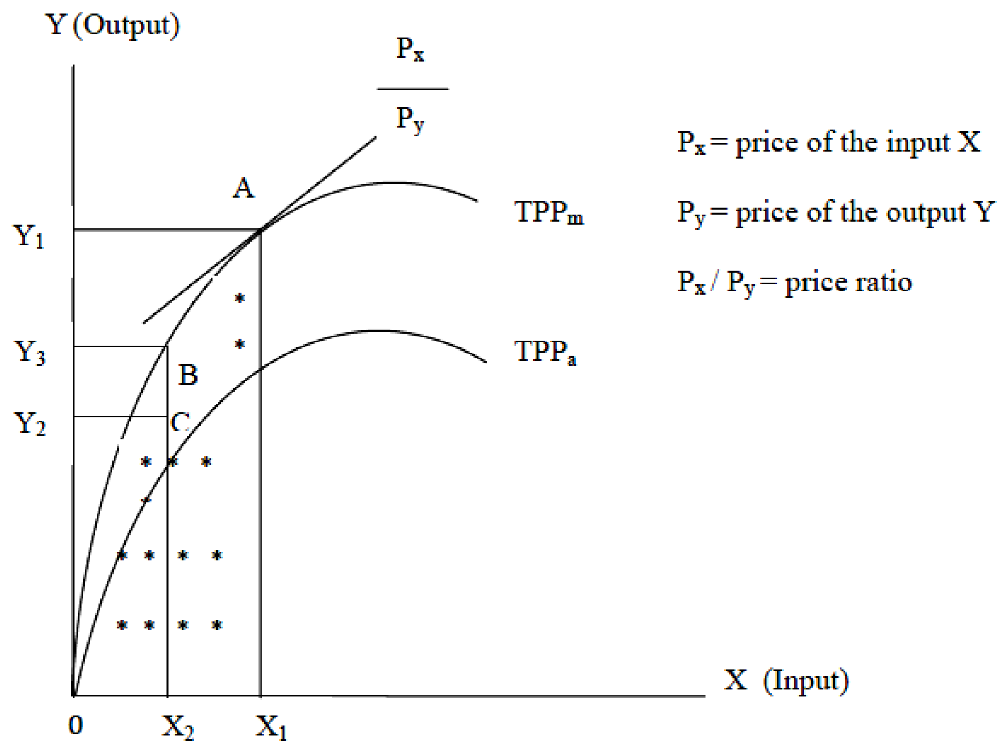
The ML estimator is asymptotically more efficient than the OLS estimator. ML estimator was found to be significantly better than the OLS estimator when the contribution of the technical inefficiency effects on the total variance term is large. Aigner, et al. (1977) derived the log-likelihood function for the model, defined by the equation 2.2.3, in which the u_is are assumed to be i.i.d. truncations (at zero) of a N(0, σ^2) random variable, independent of the v_is which are assumed to be i.i.d. N(0,σ_V). Aigner, Lovell and Schmidt (1977) expressed the likelihood function in terms of the two variance parameters, $\sigma^2_s = \sigma^2 + \sigma^2_v$ and $\lambda = \sigma / \sigma_v$. Battese and Corra (1977) suggested that the parameter, ($\gamma = \sigma^2 / \sigma^2_s$), be used because it has a value between zero and one. The ML estimates of β, σ^2_s and γ are obtained by finding the maximum of the log-likelihood function.

2.2.4 Productivity and frontier function

Ali and Chaudhry (1990) used to measure the technical, allocative and economic efficiencies in terms of input-output space presented in Figure 2.2. The curve TPP_a (total physical productivity) represents the average function that is usually estimated by using OLS, while the curve TPP_m represents the maximum possible total output as input X is increased. This is known as the frontier production function. All firms that produce below TPP_m are considered technically inefficient because of giving less output at a given level of input. The profit maximization criterion suggests that producers will utilize input level at X_1 (where the marginal value product of X is equal to its price, P_x) and will produce the technically and allocatively efficient output at Y_1. The firm which uses X_2 and produces Y_2 (represented by point C) is technically and allocatively inefficient. Technical efficiency is defined as the ratio of a firm's actual output to the technically maximum possible output at a given level of input and can be written as:

$$TE = Y_2 / Y_3$$

The frontier function is the maximum output obtainable from various input vectors at a certain level of technology. There are various approaches measuring and estimating efficiency. In this study, stochastic production frontier will be applied using Maximum-Likelihood Estimation to estimate the technical efficiency of the sesame farmers in the selected Township.



TE = Y_2 / Y_3 AE = Y_3 / Y_1 EE = $(Y_2 / Y_3)(Y_3 / Y_1) = Y_2 / Y_1$

Figure 2.2 Technical, allocative and economic efficiencies in terms of input-output space

(Source: Ali and Chaudhry 1990)

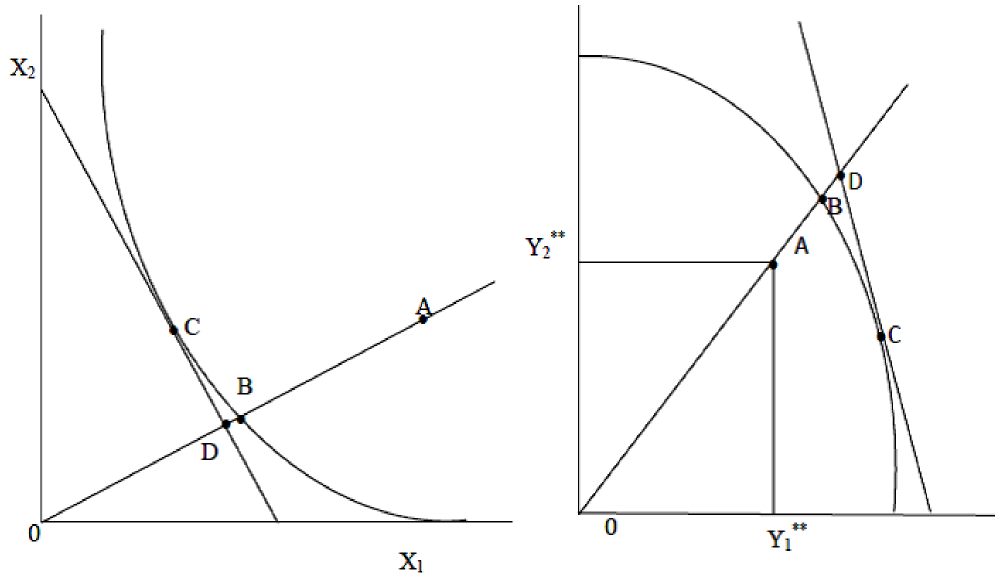
2.2.5 Technical efficiency measurement

Production is the process of transforming inputs such as land, labor and capital into output such as goods and services. These production resources can be organized into a farm-firm or producing unit whose ultimate objectives may be profit or revenue maximization, physical output maximization, cost minimization or utility maximization or a combination of the four. In this production possibilities process, the manager or entrepreneur or the firm as the case may be concerned with efficiency in the use of production resources to achieve his goal i.e. the technological and economic efficiency.

Technical efficiency is just one component of overall economic efficiencies. However, in order to be economically efficient, a farm must be technically efficient. Profit maximization requires a farm to produce the maximum output given a level of inputs employed (i.e. be technically efficient), use the right mix of inputs in light of the relative price of each input (i.e. be input allocatively efficient) and produce the right mix of output given the set of price (i.e. be output allocatively efficient) (Kumbhaker and Lovell 2000).

These concepts can be illustrated graphically using a simple example of a set of two inputs (X_1, X_2), and a set of two outputs (Y_1, Y_2) in the production process (Figure 2.3). Efficiency can be considered in terms of the optimal combination of inputs to achieve a given level of output (an input orientation), or the optimal output that could be produced in the given set of inputs (an output orientation). In Figure 2.3(a), the farm is producing a given level of output by using an input combination defined by point A. The same level of output could have been produced by contracting the use of both inputs back to point B, which lies on the iso-quant associated with the minimum level of inputs required to produce such output. The input-oriented level of technical efficiency TE is defined by OB/OA. However, the least cost combination of inputs that produces the same level of output is given by point C where the marginal rate of technical substitution is equal to the input price ratio. To achieve the same level of cost, the input would need to be further contracted to point D. The cost efficiency (CE) is therefore defined by OD/OA. The input allocative efficiency (AE) is given by CE/TE or OD/OB (Kumbhaker and Lovell 2000).

Figure 2.3(b) illustrates the production possibility frontier for a given set of inputs. If the input employed by the farm were used efficiently, the output of the firm can be expanded to point B instead of point A as present. Here, the output oriented measure of technical efficiency can be illustrated by OA/OB. Although point B lying in the production possibility frontier indicates the technical efficiency, higher revenue could be achieved by producing at point C where the marginal rate of transformation is equal to the price ratio. In this case, more of Y_1 should be introduced and less of Y_2 in order to maximize revenue. To achieve the same level of revenue at point C while maintaining the same input and output combination, output of the farm would need to be expanded to point D. Hence, the revenue efficiency (RE) is given by OA/OD. Output allocative efficiency (AE) is given by RE/TE or OB/OD (Kumbhaker and Lovell 2000).



(a) Input oriented efficiency measurement

(b) Output oriented efficiency measurement

Figure 2.3 Input and output oriented efficiency measurement

(Source: Kumbhaker and Lovell 2000)

CHAPTER III
RESEARCH METHODOLOGY

3.1 Study Area

Thazi Township in Mandalay Region was chosen as a respresentative region as villages in the western plain of Thazi Township fall into two different livelihood zones, depending on access to formal irrigation schemes for rice growing. Min Hla Lake provides formal irrigation scheme to south-west part of this township. Participatory assessment with farmers through individual interviews and group discussions with a first orientation conducted from 24^{th} to 25^{st} August, 2012. Personal interviews with staff of DoA were conducted during the second visit and key informants who provided information through a structured questionnaire (including women transplanters) were surveyed between 19^{th} and 21^{st} January 2013. Field assessment was conducted in November 2012.

The most vulnerable farmers, identified by DoA and Oxfam and whose farms are located in Min Hla Lake irrigated area, were chosen from six villages as "beneficiaries farmers'. These farmers were also trained in the recommended cultivation practices, and the keeping and use of a daily farm record, and were provided with fertilizers and seeds. They did not pay for transplanting cost with the trained women transplanters directly employed by Oxfam. Harvesting costs were also provided to the farmers in cash. Each of the selected farmers was obliged to provide a demonstration plot for rice production. From these, DoA and Oxfam expected that methods would be disseminated to non-beneficiary farmers through a spillover effect. DoA personnel made visits to the selected farms regularly to give technical assistance.

Farm size is divided into three groups; the small farmer group cultivated farms ranging in size from 0.40 hectare to 1.22 hectare, the medium group ranges from 1.23 hectare to 2.24 hectare, and large farmer group ranges from 2.25 hectare to 6.07 hectare. There is a maximum area of farm size of 6.07 hectare and minimum area of o.41 hectare.

The study area, Thazi Township located in Mandalay Region in the eastern part of the central Dry Zone of Myanmar. The Yangon-Mandalay railway passes through the zone, as does the Meiktila to Taunggyi highway, which is the main road to Shan State (Appendix 1). The main crops grown in the study area are paddy, chili, chickpeas and sesame. Small quantities of sunflower and groundnuts are also grown. In terms of staple food crop (rice) production, this is a food deficit zone.

3.2 Data Collection and Sampling Method

Cross-sectional data were collected from Thazi Township in Mandalay Region. The survey was done in January and February 2013 to study the technical efficiency of rice production in the selected areas. Thirty beneficiary farmers and 88 'non-beneficiary' farmers from 6 villages of Thazi Township were selected and the total of 118 farmers was surveyed for their rice production. A comprehensive review was executed from Department of Agriculture (DoA).

The primary data included-

(1) the social characteristics of the sample farmers such as age, education level, household's experience in rice production, family size, family labor;

(2) farming practices such as land owned, rice area, methods of sowing, availability of water, use of varieties, seed rate per acre, use of fertilizer, pesticide and manure, labor availability and yield obtained;

(3) the constraints of rice production;

(4) value of rice production of sample farmers.

The secondary data on rice production such as yield, sown area and input was obtained from Settlement and Land Records Department, Department of Agricultural Planning (DAP), Department of Agriculture (DoA) and other relevant sources.

3.3 Data Analysis Methods

3.3.1 Descriptive analysis

Descriptive analysis was applied to describe and compare the socio-economic conditions, input use, yield, existing farming practices and income of rice farmers and so forth.

3.3.2 Economic analysis

The concept of enterprise budget (Olson 2009) was used to evaluate the profitability of rice production. In this analysis, variable costs were taken into account;

(1) Material input cost,

(2) Hired labor cost,

(3) Family labor cost, and

(4) Interest on cash cost.

The interest was normally charged on cash expense for early in the growing season. The applied interest rate was 2 % per month for six months.

The first measurement was the difference between the total gross benefits or total returns and total variable cash costs, excluding opportunity costs. This value was referred to as “return above variable cash cost”.

The second measurement was the deduction of the opportunity cost and total variable cash costs from gross benefit. This return was referred to as “return above variable costs” or “gross margin”.

The “return per unit of capital invested” could be calculated by gross benefits per total variable costs. The “return per unit of cash cost” could be calculated by gross benefits per total cash costs. These measurements could be expressed with equations as:

Measurement (1)

Return above variable cash cost = Total gross benefit – total variable cash cost

Measurement (2)

Return above variable cost (Gross margin) = Total gross benefit – total variable cost

Measurement (3)

$$\text{Return per unit of capital invested} = \frac{\text{Total gross benefit}}{\text{Total variable cost}}$$

Measurement (4)

$$\text{Return per unit cash cost} = \frac{\text{Total gross benefit}}{\text{Total cash cost}}$$

3.3.3 Empirical model of stochastic frontier

In order to estimate the Cobb-Douglas Stochastic frontier production function, the software_ FRONTIER 4.1 (Aigner *et al.* 1977) was used. The maximum likelihood estimate of the parameters of the frontier model was estimated. The stochastic frontier model for rice farmers in the study areas was explained by using the equation (1) and (2).

$$\mathbf{LnY_i = \beta_0 + \beta_1 LnX_{1i} + \beta_2 LnX_{2i} + \beta_3 LnX_{3i} + \beta_4 LnX_{4i} + \beta_5 LnX_{5i} + e_i} \quad .....(1)$$

Where:

Ln = natural logarithm

i = i^{th} farm in the sample

Y = Yield of rice (kg ha^{-1})

X_1 = Seed rate used (kg ha^{-1})

X_2 = Manure (FYM) used (ton ha^{-1})

X_3 = Fertilizer used (kg ha^{-1})

X_4 = Human transplanter used(man day ha^{-1})

X_5 = Animal labor used (animal day ha^{-1})

β_0 = Constant

β_i = Estimated coefficients, i = 1,2,3, … etc.

e_i = $\nu_i - \mu_i$ ($\mu_i \geq 0$)

ν_i = independent and identically distributed random errors

μ_i = technical inefficiency effects

The technical efficiency of production for the i^{th} farm is defined as the ratio of observed output to the corresponding maximum feasible output associated with no technical inefficiency as expressed in previous section and is described by the following equation:

$$TE_i = \exp(-U_i) = \frac{\text{Observed output}}{\text{Maximum feasible output}}$$

After obtaining farm specific technical efficiency, the sources of the inefficiency were identified by making appropriate analysis. Moreover, investigating the sources of technical inefficiency were particular interests of researchers who analyzed the technical efficiency of crop production.

The literature of the previous studies indicates that socio-economic and demographic characteristics of farmers such as age and education of farmers, farming experiences, credit and extension assets, etc. and farm characteristics such as land size and soil fertility, etc. would also determine the technical efficiency or inefficiency.

$$\mu_i = \delta_0 + \delta_1 Z_1 + \delta_2 Z_2 + \delta_3 Z_3 + \delta_4 D \text{...} (2)$$

μ_i = Technical inefficiency effect predicted by the model itself

δ_0 = Constant

δ_i = Parameters to be estimated, i = 1,2,3

Z_1 = Farm size (hectare)

Z_2 = Education level of farmer (year of schooling)

Z_3 = Household head’s experience in rice farming (year)

D = Dummy variable, where 1 denotes farmers who use good Agricultural Practices (GAP) and 0 otherwise

In this study, following Battese and Coelli (1995), the parameters of the stochastic production frontier and inefficiency effect models are jointly estimated in a single stage by using the maximum likelihood estimation method. They criticized about a two-stage analysis_ the first stage involves the specification and estimation of the stochastic frontier production function and the prediction of the technical inefficiency effects under the assumption that these effects are identically distributed; the second stage involves the specification of a regression model for the predicted technical inefficiency effects, which contradicts the assumption of identically distributed inefficiency effects in the stochastic frontier. Coelli and Battese (1996) and Rahman and Rahman (2008) also used the single-stage approach in their stochastic frontier analysis. Some of the main researchers who have utilized the stochastic frontier analysis are: Aigner *et al.* (1977), Battese and Coelli (1995), Coelli and Battese (1996), Battese *et al.*, (1996) and Bravo-Ureta and Pinheiro, (1997). Several studies have been carried out on technical efficiency analysis in global, especially in developing countries, as well as in Myanmar.

CHAPTER IV
RESULTS AND DISCUSSION

4.1 Information on Sample Population from Thazi Township

The sample population consisted of local farmers (118) and these were divided into two groups; beneficiary farmers (30) and non-beneficiary farmers (88). Beneficiary farmers were those who have received aid from Oxfam project. In this study, as shown in Table 4.1, the average farm size owned by beneficiary farmers was 2.02 hectares, with areas within the range of 0.40 to 6.07 hectares and the average of that of the non-beneficiary farmers was 1.78 hectares, within the range of 0.40 to 5.670hectares. The average owned farm size of all farm households was 1.85 hectares, with areas range from 0.40 to 6.07 hectares. The majority of farmers sampled owned less than 2 hectares. The t-test shows that there is no significant difference in the area of farm size owned, between these two groups.

The socio-demographic characteristics, such as age, year of schooling, family size, farm worker and farming experience, of the sample population are presented in Table 4.2. The average age of the beneficiary farm households' heads was 50.17 years. The average age of the non-beneficiary farm household heads was 51.53 years. The average age of households' heads for all samples was 51.19 years. The F-test shows that there is no significant difference in the average age of these two groups.

To measure education level of households' heads, 5 categories are used. These are education to; monastery level, primary level, secondary level, high school level or university level. The average year of schooling for beneficiary farm household's heads was 7.90 years and that of non-beneficiary farm household's heads was 7.66 years. The average years of schooling for household heads for all farm households was 7.72 years. The F-test shows that there is no significant difference between the average years of schooling of households' heads in the two groups. The highest education level of any farm household head was at graduated level. The number of farm households' head in the study area who have graduated, was 2 in beneficiary farmer group, and 5 in non-beneficiary group.

The average family size of the beneficiary farm households was 5.50 and 5.60 people for the non-beneficiary farm households. The average number of family members for all the farm households was 5.58. The F-test shows that family size is not significantly different between these two types of farm households. The average number of family worker for the beneficiary farm households was 2.20 and that of the non-beneficiary household was 2.67. The F-test shows that there is a significant difference in the average numbers of farm workers between these two groups.

The majority of farmers in the sample population have worked as farmer for their livelihoods. In this case, the beneficiary farm households' heads experience in agriculture averages 23.70 year while the farming experience of non-beneficiary farm households' heads was 24.17. For all sampled farm households' heads, there was an average of 24.05 years in farming experience. The F-test shows that there is no significant difference between these two groups for years of farming experience.

Table 4.1 Distribution of farm size

Own farm (ha) range	Farm household					
	Beneficiary		Non-beneficiary		All	
	frequency	%	frequency	%	frequency	%
0.39-0.96	6	20.00	25	28.41	31	26.27
0.97-1.54	10	33.33	17	19.32	27	22.88
1.55-2.12	4	13.33	23	26.14	27	22.88
2.13-2.70	1	3.33	8	9.09	9	7.63
2.71-3.28	2	6.67	6	6.82	8	6.78
3.29-3.86	2	6.67	3	3.41	5	4.24
3.87-4.44	4	13.33	3	3.41	7	5.93
4.45-5.02	0	0.00	2	2.27	2	1.69
5.03-5.60	0	0.00	1	1.14	1	0.85
5.61-6.18	1	3.33	0	0	1	0.85
Total	30	100	88	100	118	100
Mean farm size	2.02		1.78		1.85	
t-test	$t_{(0.05)} = 0.94^{ns}$					
Maximum farm size	6.07		5.60		6.07	
Minimum farm size	0.40		0.40		0.40	

Note: ns is not significant.

Table 4.2 Socio-demographic characteristics of sample farm households

Item	Unit	Farm household			F-test
		Beneficiary (n=30)	Non-beneficiary (n=88)	Total (n=118)	
1. Average age of household head	Year	50.17	51.53	51.19	0.26^{ns}
2. Average household head's years of schooling	Year	7.90	7.66	7.72	0.09^{ns}
Monastery level	Number	3	8	11	
Primary level	Number	4	9	13	
Secondary level	Number	12	44	56	
High school level	Number	8	16	24	
University level	Number	1	6	7	
Graduate level	Number	2	5	7	
3. Average family size	Number	5.50	5.60	5.58	0.07^{ns}
4. Average farm workers	Number	2.20	2.67	2.55	3.68**
5. Average household head's farming experience	Year	23.70	24.17	24.05	0.02^{ns}

Note: ** is significant at 5% level and ns = not significant.

4.1.1 Possession of farming assets in sample population

The majority of farmers making up the sample population in study area possess a range of farming implements and productive equipments. The beneficiary farm households have ploughs, harrows, cattle, sprayers and power tillers at approximately 96.7 percent, 93.3 percent, 76.7 percent, 50.0 percent and 13.3 percent respectively. While the non-beneficiary household possess ploughs, harrows, cattle, sprayers and power tillers at the following levels; 96.6 percent, 100 percent, 81.8 percent, 79.5 percent and 10.2 percent, respectively. The beneficiary farm households possess fewer cattle and sprayer than the non-beneficiary farm households. However, there are significant differences in ownership of farming assets between the two sample farm household group, only for the ownership of harrows and sprayers. The data for ownership of farming assets for the sample farm households is shown in Table 4.3.

4.1.2 Rice seed variety and seed rate used

The volumes of rice seed used by two groups of farmers in the sample, is provided in Table 4.4. Oxfam and Department of agriculture (DoA) paid for guidance in seed management and nursery preparation for the beneficiary farmers. The Oxfam project provided Manawthuka rice seed to beneficiary farmers at an average amount of 51.89 kg ha^{-1}. However, some beneficiary farmers used a greater amount of seed to prevent seedling loss in nursery stage. Some of the 'non-beneficiary farmers' also used Manawthuka variety and followed Oxfam and DoA's recommended seeding rate. Beneficiary farmers applied an approximate average of 110.70 kilogram of rice seed per hectare. Similarly, the average seed rate of the 'non-beneficiary farmers' was 110.17 kg ha^{-1}. The maximum seed rate of all sampled farmers was 207.56 kg ha^{-1} and minimum seed rate was 51.89 kg ha^{-1} for all sampled farmers. The F-test shows that there is no significant difference between two different farmer groups in the amount of rice seed used.

Table 4.3 Comparison of farming assets of sample farm households

Farm Assets	Farm household			χ^2 (p-value)
	Beneficiary (n=30)	Non-beneficiary (n=88)	Total (n=118)	
Plough	29(96.7)	85(96.6)	114(96.6)	0.98^{ns}
Harrow	28(93.3)	88(100)	116(98.3)	0.01^{***}
Cattle	23(76.7)	72(81.8)	95(80.5)	0.54^{ns}
Bullock cart	18(60.0)	57(64.8)	75(63.6)	0.64^{ns}
Sprayer	15(50.0)	70(79.5)	85(72.0)	0.00^{***}
Power tiller	4(13.3)	9(10.2)	13(11.0)	0.64^{ns}

Note: Figures in the parentheses represent percentage.

*** is significant at 1% level and ns= not significant.

Table 4.4 Amount of rice seed used by two different farmer groups

Item	Rice seed (kg ha^{-1})		
	Beneficiary farmers (n=30)	Non-beneficiary farmers (n=88)	All farmers (n=118)
Mean	110.70	107.17	108.06
Minimum	51.89	51.89	51.89
Maximum	207.56	207.56	207.56
F-test	$F = 0.126^{ns}$		

Note: ns = not significant

4.1.3 Fertilizer application in rice production

Table 4.5 shows the different rate of fertilizer used by the farmer group. It can be seen that majority of farmers applied organic and chemical fertilizer for their rice production. Farm-yard manure, especially cow dung, which was collected from their own and other animals, was used as the organic fertilizer, and urea, compound, T-super and potash fertilizer were also used for basal and side dressing. There is a significant difference in T-super application between the two sample groups.

As farmyard manure (FYM) is easily available in the study area, the average rate of FYM application by the beneficiary farmers was 6.30 ton ha^{-1}, with 6.73 ton ha^{-1} used by the 'non-beneficiary farmers'. For all farms sampled, the minimum rate of FYM application was 0, and the maximum rate was 18.53 ton ha^{-1}. The average rate of use of urea fertilizer by the beneficiary was 103 kg ha^{-1} (which was higher than the amount provided in the Oxfam project), while that of non-beneficiary farmers was 110 kg ha^{-1}. The F-test shows that there is no significant difference in the level of urea fertilizer application between two different farmer groups. For all farmers sampled, the minimum rate and maximum rate of urea fertilizer use was 0 and 250 kg ha^{-1} respectively. The majority of 'non-beneficiary farmers' used more urea fertilizer than the beneficiary farmers, as beneficiary farmers had been selected in accordance with 'marginal player' who own the small farm size and produce rice for family consumption and for marketing the marginal surplus. They have shown that they can intelligently respond to the market stimulus as well as to opportunities offered by new technologies. The average rate of T-super fertilizer used by the beneficiary was 14.41 kg ha^{-1} and that by 'non-beneficiary farmers' was 38.44 kg ha^{-1}. The F-test shows that there is a highly significant difference in T-super fertilizer application between two farmer groups. For all farmers sampled, the maximum rate and minimum rate of T-super fertilizer was 185.33 and 0 kg ha^{-1}. The average rate of compound fertilizer was 44.48 kg ha^{-1} by the 'beneficiary farmers' and 31.38 kg ha^{-1} by the 'non-beneficiary farmers'. The F-test indicates that there is no significant difference in the use of compound fertilizer between the two groups sampled. The maximum amount of compound fertilizer was 185.33 kg ha^{-1}. In regard to the use of potash fertilizer, beneficiary farmers applied average rate of 16.5 kg ha^{-1} and 'non-beneficiary farmers' used 22.25 kg ha^{-1}. The maximum potash fertilizer rate was 61.78 kg ha^{-1}. There is no significant difference in the use of potash fertilizer between the two farmer groups.

Table 4.5 Use of FYM and different fertilizers in rice production

Item	Unit	Farm household			F-test
		Beneficiary (n=30)	Non-beneficiary (n=88)	All (n=118)	
1. FYM	ton ha^{-1}	6.30	6.73	6.62	0.29^{ns}
Range		0-18.53	0-14.83	0-18.53	
2. Urea	kg ha^{-1}	103	110	108	1.00^{ns}
Range		50-200	0-250	0-250	
3. T-super	kg ha^{-1}	14.41	38.44	32.33	8.99^{***}
Range		0-61.78	0-185.33	0-185.33	
4. Compound	kg ha^{-1}	44.48	31.38	34.71	1.60^{ns}
Range		0-123.55	0-185.33	0-185.33	
5. Potash	kg ha^{-1}	16.47	22.25	20.78	0.95^{ns}
Range		0-61.78	0-61.78	0-61.78	

Source: Field survey 2013

Note: *** is significant at 1% level and ns=not significant

4.1.4 Pesticide and fungicide application in rice production

The use of pesticides and fungicides in the sample population is presented in Table 4.6. The majority of all farmers used pest and disease control measure. Under the supervision of DoA personnel, farmers surveyed commonly used a rage of different pesticides and fungicides available in the local market. Generally, incidences of pest and disease infestation of rice fields were not serious problems in the study area. The most commonly used insecticides and pesticides applied in rice production areas were Force 10, Dinerdin and Acephate.

The average amount of pesticide used was 0.99 liter per hectare and 0.79 liter per hectare by the ‘beneficiary’ and ‘non-beneficiary farmers’, respectively. The maximum amount of pesticide use was 2.47 liter per hectare. The F-test shows that there is a significant difference in the use of liquid form of pesticide between these two different farmer groups. The average amount of fungicide used was 0.12 liter per hectare, and 0.32 liter per hectare by ‘beneficiary’ and ‘non-beneficiary farmers’, respectively. The maximum amount of fungicide used was 3.71 liter per hectare. The F-test shows that there is a significant difference in the use of liquid form of fungicide between these two different farmer groups (Table 4.6).

A liquid form of pesticide was applied by 90 percent of ‘beneficiary farmers’ and 87 percent of ‘non-beneficiary farmers’. The liquid form of fungicide was applied by 13 percent of ‘beneficiary farmers’ and at a range of 35 percent by ‘non-beneficiary farmers’. The use of pesticide and fungicide, both numerically and in percentage terms, is shown in Table 4.7.

Table 4.6 Use of pesticides and fungicides in rice production

Item	Unit	Farmer groups			F-test
		Beneficiary (n=30)	Non-beneficiary (n=88)	Total (n=118)	
Pesticide	$l\ ha^{-1}$	0.99	0.79	0.84	2.92^{**}
Range		0-2.47	0-2.47	0-2.47	
Fungicide	$l\ ha^{-1}$	0.12	0.32	0.27	2.85^{**}
Range		0-1.24	0-3.71	0-3.71	

Note: Figures in the parentheses present percentage.
** is significant at 5% level.

Table 4.7 Numbers of farmer using pesticide and fungicide

Item	Farmers groups			χ^2 (p-value)
	Beneficiary (n=30)	Non-beneficiary (n=88)	Total (n=118)	
Pesticide (liquid)	27 (90.00)	77 (87.50)	104 (88.10)	0.55^{ns}
Fungicide (liquid)	4 (13.33)	31 (35.23)	35 (29.66)	0.59^{ns}

Note: Figures in the parentheses present percentage.
ns is not significant.

4.1.5 Analysis of cost and returns for rice production of beneficiary and non-beneficiary farmers

The profitability of farmers' input level needs to be examined for two different farmer groups as the maximum yield, in some cases, does not lead to maximum profit. The yield and price received by the 'beneficiary' and 'non-beneficiary farmers' is shown in Table 4.8 and Table 4.9. The average yield of the 'beneficiary farmer' group was 3,308.9 kg ha^{-1} and that of the 'non-beneficiary farmer' group, 3,059.20 kg ha^{-1}. The respective prices received by 'beneficiary' and 'non-beneficiary farmers' were 184.76 Ks kg^{-1} and 183.87 Ks kg^{-1}.

The data concerned with enterprise budgets, for the two different farmer groups is presented in Table 4.10. It was found that the 'beneficiary farmer' group incurred a relatively lower total variable cost (558,802 Ks ha^{-1}) than that of the 'non-beneficiary farmer' group (573,803 Ks ha^{-1}). The average gross benefit obtained by the 'beneficiary farmer' group was 608,810 Ks ha^{-1}, whereas the gross benefit obtained by non-beneficiary farmer group was 563,630 Ks ha^{-1}.

In regard to expenditure on material cost, 'beneficiary farmers' expended a total of 192,963 Ks ha^{-1} while the 'non-beneficiary farmers' had the relatively higher expense of 204,484 Ks ha^{-1}. The 'beneficiary farmer' group had a total family labor cost of 110,913 Ks ha^{-1} while the 'non-beneficiary farmer' group had 99,124 Ks ha^{-1} for this category. The total family labor cost to the 'beneficiary farmers' was relatively higher than that of the 'non-beneficiary farmer' group. The beneficiary farmer group expended an average of 246,144 Ks ha^{-1} for hired labor cost, while the 'non-beneficiary farmer' group expended 260,887 Ks ha^{-1}. In regards to the total interest cost of cash invested, there was very little difference, on a cost per hectare base, between the 'beneficiary' and 'non-beneficiary farmer' group.

The return above variable cash cost was 160,921 Ks ha^{-1} for the 'beneficiary farmer' group and 88,951 Ks ha^{-1} for the 'non-beneficiary farmer' group. The return above variable cost for the 'beneficiary farmer' group and 'non-beneficiary farmer' group were 50,008 and (-) 10,173 Ks ha^{-1} respectively. The 'non-beneficiary farmer' group could not cover the variables costs for that year of rice production. It can be seen, that the 'beneficiary farmers' group had a better yield and higher return with less variable cost. Consequently, the benefit-cost ratios were 1.09 and 0.98 for the 'beneficiary' and 'non-beneficiary farmer' groups, respectively. The t-test shows that there is no significant difference in received benefit-cost ratios between these two different groups. Therefore, it can be concluded that there was no difference statistically in the profitability of growing a rice crop for either of the two groups in the study area. Nay (2012) found that, according to inefficiency index, on average, about 10 % of potential maximum profit is lost in Hmawbi, and about 22 % is lost in Waw Township for the rice production. This corresponds to a mean profit loss of 42573 Ks ha^{-1} in Hmawbi, and 79246 Ks ha^{-1} in Waw. This discrepancy between observed profit and the frontier profit is due to both technical and allocative inefficiency.

Table 4.8 Yield and price of rice received by different farmer groups

Item	Unit	Farmer group			F-test
		Beneficiary (n=30)	Non-beneficiary (n=88)	All (n=118)	
Yield	kg ha^{-1}				
Mean		3308.90	3059.20	3122.60	2.043**
Minimum		2075.60	778.36	778.36	
Maximum		5189.10	4670.20	5189.10	
Price	Ks kg^{-1}				
Mean		184.76	183.87	184.10	0.042^{ns}
Minimum		142.86	142.86	142.86	
Maximum		214.29	214.29	214.29	

Note: ** is significant at 5% and, ns= not significant.

Table 4.9 Distribution of yield per hectare

Yield (kg ha^{-1}) range	Farmer group					
	Beneficiary		Non-beneficiary		All	
	frequency	%	frequency	%	frequency	%
770-1219	0	0.00	1	1.14	1	0.85
1220-1660	0	0.00	5	5.68	5	4.24
1661-2101	1	3.33	9	10.23	10	8.47
2102-2542	2	6.67	4	4.55	6	5.08
2543-2983	5	16.67	22	25.00	27	22.88
2984-3424	12	40.00	16	18.18	28	23.73
3425-3865	3	10.00	14	15.91	17	14.41
3866-4306	5	16.67	11	12.50	16	13.56
4307-4747	0	0.00	6	6.82	6	5.08
4748-5190	2	6.67	0	0.00	2	1.69
Total	30	100.00	88	100.00	118	100.00

Table 4.10 Enterprise budget for rice production of beneficiary and non-beneficiary farmers

(Ks ha^{-1})

Item	Farm household	
	Beneficiary (n=30)	Non-beneficiary (n=88)
1.Gross Benefit		
Total gross benefit	**608,810**	**563,630**
2.Variable Cost		
(a) Material Cost		
Seed	31,793	34,132
FYM	39,536	37,760
Urea	59,612	65,751
T-super	18,864	17,715
Compound	15,276	22,939
Potash	13,483	12,527
Insecticide	14,399	13,660
Total Material Cost	**192,963**	**204,484**
(b) Hired labor cost		
Land preparation	22,930	31,624
Seeding & Up rooting	20,069	21,156
Transplanting	84,607	80,922
Weeding & Irrigation	9,513	11,400
Fertilizer & insecticide	3,295	6,116
Harvesting & Threshing	97,534	101,070
Drying & Transportation	8,196	8,599
Total Hired labor cost	**246,144**	**260,887**
(c) Family labor cost		
Land preparation	53,999	48,762
Seeding & Up rooting	5,881	6,253
Weeding & Irrigation	10,600	10,830
Fertilizer & Insecticide	11,410	9,659
Harvesting & Threshing	12,013	8,130
Drying & Transportation	17,010	15,490
Total Family Labor Cost	**110,913**	**99,124**
(d) Interest on cash cost		
Material cost	3,859	4,090
Hired labor cost	4,923	5,218
Interest on cash cost	**8,782**	**9,308**
Total variable cost	**558,802**	**573,803**
Return above cash cost	**160,921**	**88,951**
Return above variable cost	**50,008**	**-10,173**
Benefit-cost ratio	**1.09**	**0.98**
t-test		$t_{(0.05)} = 0.13^{ns}$

Note: ns = not significant.

4.1.6 Cost and return on rice cultivation by different beneficiary farmer groups

Farm size was divided into three groups; the small farmer group cultivated farms ranging in size from 0.40 hectare to 1.22 hectare, the medium group ranges from 1.23 hectare to 2.24 hectare, and large farmer group ranges from 2.25 hectare to 6.07 hectare. There was a maximum area of farm size of 6.07 hectare and minimum area of 0.40 hectare. It can be seen that of the 30 beneficiary farm households, there are 12 small farmers, 9 medium farmers and 9 large farmers (Table 4.11).

The yield obtained in the monsoon season of rice production by the three beneficiary farm groups is shown in Table 4.11. Average paddy yield of beneficiary farmers in the study was 3308.9 kg ha^{-1}, within a range of 2075.6 kg ha^{-1} to 5189.1 kg ha^{-1}. In looking at the average for the groups, the average yield of the small beneficiary farmer group was 3567.5 kg ha^{-1}, with yields ranging from 2594.6 to 5189.1 kg ha^{-1}. The average yield of medium beneficiary farmer group was 3101.3 kg ha^{-1} and the large beneficiary farmer group achieved an average yield 3171.1 kg ha^{-1}. Therefore, the highest average yield was obtained by the small farmer group while the medium farmer group got the lowest average yield (Table 4.11).

The detail enterprise budgets of paddy cultivation by small, medium and large beneficiary farmer groups are presented in Table 4.12, Table 4.13 and Table 4.14 respectively. Gross benefit, total variable cost and net benefit (the return above variable cost) of rice production for the different farm size groups are displayed in Figure 4.1. The highest variable cost (585,900 Ks ha^{-1}) appears for the small farmer group and the minimum variable cost (558,060 Ks ha^{-1}) was found in the large farmer group. According to the yield level, gross benefit of small farmer group was the highest (664,180 Ks ha^{-1}) and the gross benefit of the medium farmer group was the lowest (564,190 Ks ha^{-1}) amongst the three groups. Therefore, the highest net benefit (78,280 Ks ha^{-1}) was obtained by the small farmer group and the lowest net benefit (3,220 Ks ha^{-1}) was received by the medium farmer group.

The contribution of Oxfam GB support to the total variable cost of rice cultivation in the 2012 monsoon season for the different groups is shown in Table 4.15. Total variable costs of farmers ranged from 558,060 Ks ha^{-1} to 585,900 Ks ha^{-1} for the three different groups. The Oxfam cash grant (total 28,7624.40 Ks ha^{-1}) covered 49.09 % to 51.57 % of the total variable costs of the farmers. From the farmer responses, cash grants by Oxfam were a major contribution, as they saved on the need to pay interest to money lenders, who they would borrow from for the costs of land preparation. These benefits varied among the small, medium and large farmers.

The benefit cost ratio (BCR) of different farm size groups is illustrated in Figure 4.2. The benefit cost ratio of rice cultivation is calculated by dividing gross benefit by total variable costs for paddy production. The highest benefit cost ratio 1.15 was received by the small farmer group; they got 15% of net return from their investment capital in rice production. The large farm size group obtained a BCR of 1.08, which means they have 8% return on capital investment. The medium farmers received a benefit of 1 %, equal to a BCR of 1.01 of capital investment in rice production. The small farm size group was the most financially attractive enterprise among the different farm size groups (Theingi Myint 2001).

The breakeven yields of rice production are estimated by dividing total variable costs by the current market price. The lowest break-even yield was observed in rice production by the large farm size group. With the market price of this rice variety, currently at the time of their sale, the breakeven yield becomes 3,001.45 kg ha^{-1}, that is the yield that will just cover the total variable cost of rice cultivation. If farmers achieve a higher yield than breakeven yield, then a profit will be received. In contrast, for the small famer group, the breakeven yield must be at least 3,146.95 kg ha^{-1} to cover the total variable costs at the then current market price. A break even yield of 3,083.6 kg ha^{-1} was calculated for the medium farmer group's paddy production (Figure 4.3). All beneficiary farmer groups achieve higher yields than the specific breakeven yields for their respective groups, for monsoon paddy production. The lowest break even yield is the most economically attractive for the farmers. Therefore, the large farmer group had the preferable breakeven yield. This was due to them having the lowest total variable costs at current market prices for paddy, among three farm size groups.

The breakeven price is calculated as total variable cost by current effective yield of paddy. The lowest breakeven price to cover the given variable cost of paddy production is most preferable. Based on the yield of paddy and the cost structures, among three groups of target beneficiary farm households, rice cultivation of the small farmer group had the lowest breakeven price (164.23 Ks kg^{-1}). Total variable costs of paddy were covered, if the rice price is at least 175.98 Ks kg^{-1} for large farm size group.

According to the given current cost structure and given current yield level, if the market price of rice is higher than the breakeven price, farmers will receive a profit. For medium sized farmers, the lowest market price of rice to cover the cost of paddy production at the current yield level is 180.88 Ks kg^{-1}. If the market price is higher than 180.88 Ks kg^{-1}, the medium sized farmer group will achieve a profit at current paddy yield (Figure 4.4).

Table 4.11 Grouping of 30 beneficiary farm households according to their farm size

Group of Farmers	Range of Farm Size (ha)	No. of Farmers	Yield ($kg\ ha^{-1}$)			Price ($Ks\ kg^{-1}$)
			Avg.	Max	Min	
1. Small	0.40-1.22	12	3567.5	5189.1	2594.6	186.18
2. Medium	1.23-2.24	9	3101.3	4151.3	2335.1	181.92
3. Large	2.25-6.07	9	3171.1	4151.3	2075.6	185.93
Total	0.40-6.07	30	3308.9	5189.1	2075.6	184.68

Source: Field Survey 2013

Table 4.12 Enterprise budget for rice production of small beneficiary farmer group

(Ks ha^{-1})

Item	Small beneficiary group (n=12)
1.Gross Benefit	
Total gross benefit	**664,180**
2.Variable Cost	
(a) Material Cost	
Seed	33,700
FYM	44,700
Urea	59,495
T-super	20,915
Compound	24,069
Potash	8,761
Insecticide	12,710
Total Material Cost	**204,350**
(b) Hired labor cost	
Land preparation	35,896
Seeding & Up rooting	18,240
Transplanting	85,586
Weeding	4,717
Fertilizer & insecticide application	3,145
Harvesting & Threshing	104,300
Drying & Transportation	8,766
Total Hired Labor cost	**260,650**
(c) Family labor cost	
Land preparation	53,037
Seeding	4,133
Uprooting	3,763
Weeding & Irrigation	9,165
Fertilizer & Insecticide application	15,700
Harvesting & Threshing	8,620
Drying & Transportation	17,180
Total Family Labor Cost	**111,600**
(d)Interest on cash cost	
Material cost	4,087
Hired labor cost	5,213
Interest on cash cost	**9,300**
Total variable cost (TVC)	**585,900**
Return above cash cost	**189,880**
Return above variable cost (Net benefit)	**78,280**
Benefit-cost ratio	**1.15**

Break-even yield = (TVC/ effective price) = (585900/ 186.18) = 3146.95 kg ha^{-1}

Break-even price = (TVC / effective yield) = (585900/3567.5) = 164.23 Ks kg^{-1}

Table 4.13 Enterprise budget for rice production of medium beneficiary farmer group

(Ks ha^{-1})

Item	Medium beneficiary group (n=9)
1.Gross Benefit	
Total gross benefit	**564,190**
2.Variable Cost	
(a) Material Cost	
Seed	31,000
FYM	39,400
Urea	58,625
T-super	18,875
Compound	9,846
Potash	19,356
Insecticide	11,998
Total Material Cost	**189,100**
(b) Hired labor cost	
Land preparation	14,496
Up rooting	19,877
Transplanting	87,226
Weeding	11,120
Fertilizer & insecticide application	3,746
Harvesting & Threshing	87,528
Drying & Transportation	8,237
Total Hired Labor cost	**232,190**
(c) Family labor cost	
Land preparation	50,518
Seeding	6,820
Uprooting	1,883
Weeding & Irrigation	14,311
Fertilizer & Insecticide application	9,198
Harvesting & Threshing	29,562
Drying & Transportation	18,940
Total Family Labor Cost	**131,233**
(d)Interest on cash cost	
Material cost	3,782
Hired labor cost	4,643
Interest on cash cost	**8,425**
Total variable cost	**560,970**
Return above cash cost	**134,453**
Return above variable cost (Net benefit)	**3,220**
Benefit-cost ratio	**1.01**

Break-even yield = (TVC/ effective price) = (560970/ 181.92) = 3083.6 kg ha^{-1}

Break-even price = (TVC / effective yield) = (560970/3101.3) = 180.88 Ks kg^{-1}

Table 4.14 Enterprise budget for rice production of large beneficiary farmer group

(Ks ha^{-1})

Item	Large beneficiary group (n=9)
1.Gross Benefit	
Total gross benefit	**589,600**
2.Variable Cost	
(a) Material Cost	
Seed	31,000
FYM	34,460
Urea	61,912
T-super	14,592
Compound	11,668
Potash	10,762
Insecticide	19,326
Total Material Cost	**183,720**
(b) Hired labor cost	
Land preparation	11,146
Up rooting	22,252
Transplanting	77,356
Weeding	14,830
Fertilizer & insecticide application	3,432
Harvesting & Threshing	99,736
Drying & Transportation	6,178
Total Hired Labor cost	**234,930**
(c) Family labor cost	
Land preparation	67,100
Seeding	8,981
Uprooting	3,490
Weeding & Irrigation	12,991
Fertilizer & Insecticide application	11,260
Harvesting & Threshing	10,015
Drying & Transportation	16,200
Total Family Labor Cost	**131,037**
(d)Interest on cash cost	
Material cost	3,674
Hired labor cost	4,699
Interest on cash cost	**8,373**
Total variable cost	**558,060**
Return above cash cost	**162,577**
Return above variable cost (Net benefit)	**31,450**
Benefit-cost ratio	**1.08**

Break-even yield = (TVC/ effective price) = (558060/ 185.93) = 3001.45 kg ha^{-1}

Break-even price = (TVC / effective yield) = (558060/3171.1) = 175.98 Ks kg^{-1}

Table 4.15 Contribution of Oxfam GB support to variable cost of farmers

Item	Beneficiary farmer group		
	Small	Medium	Large
Total Variable Cost (Kyat)	585,900	560,970	558,060
Oxfam contribution (Kyat)	28,7624.40	28,7624.40	28,7624.40
Ratio of Oxfam GB contribution (%)	49.09	51.27	51.54

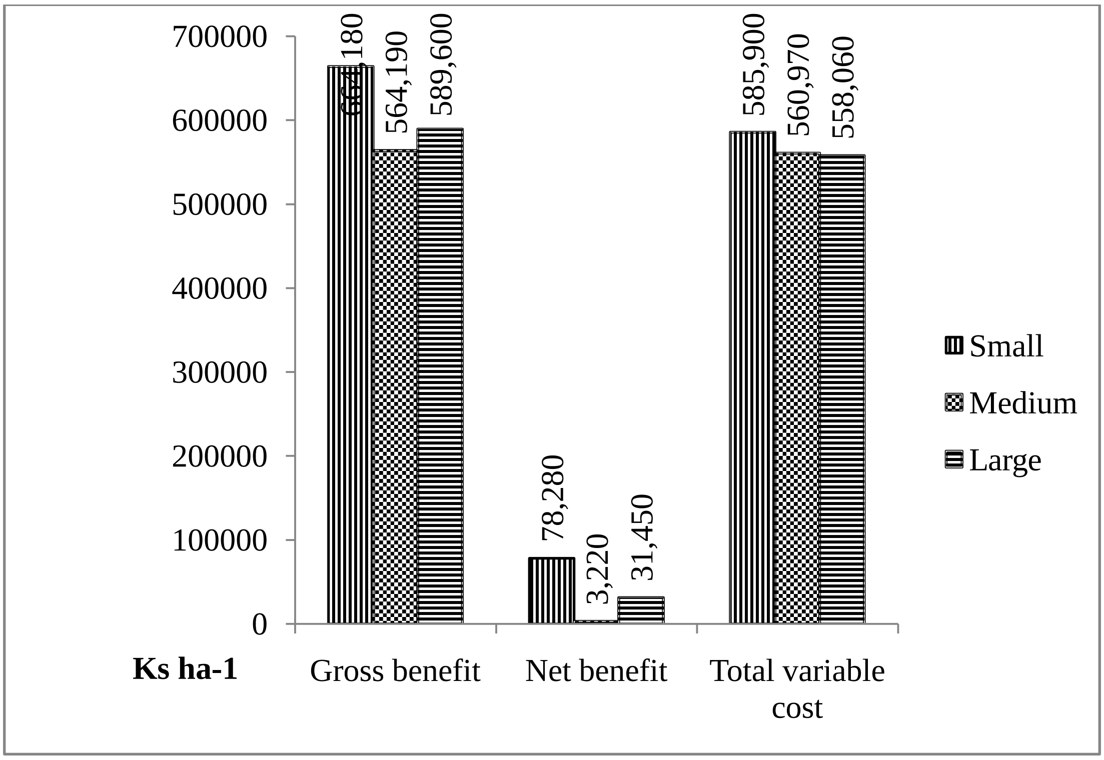


Figure 4.1 Net benefit, total variable cost and gross benefit of three beneficiary farmer groups

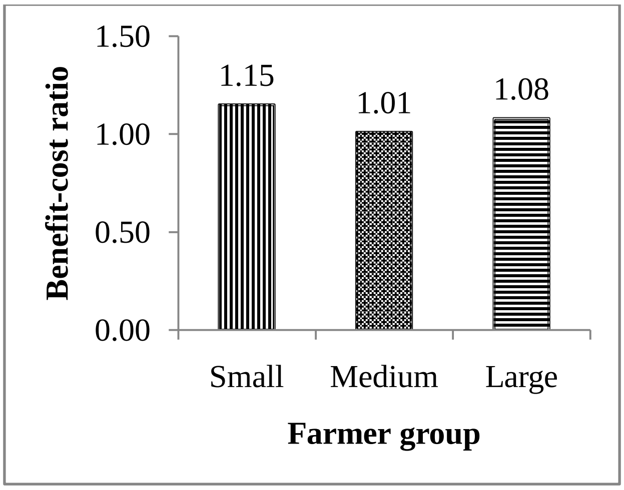


Figure 4.2 Benefit- cost ratio of three beneficiary farmer groups

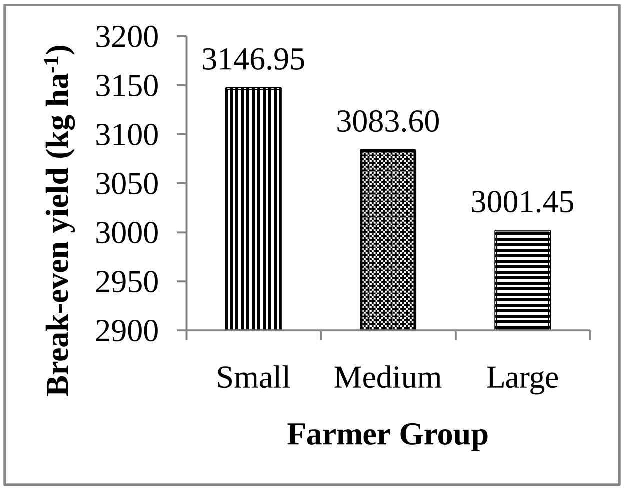


Figure 4.3 Break-even yields of three beneficiary farmer groups

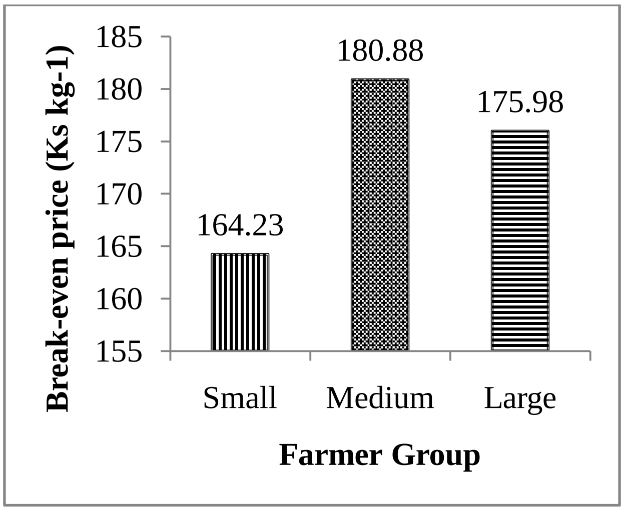


Figure 4.4 Break-even prices of three beneficiary farmer groups

4.1.7 Process for disbursement of the cash to beneficiary farmers and the inclusion of women in the decision making process

The financial support for rice cultivation provided by Oxfam GB introduced a strong motivation for the farmers to adopt the GAP practices in paddy cultivation. The management of these cash grants was mainly by the women in the farm households. For most of the farm households 53.3 % in the target groups, the decisions in regard to crop production were taken by the household head (men), while a further 20 % of total households made joint decision and in only 26.7 % of the households were the decisions regarding rice cultivation taken by women in the family. With the system set up in this study, men remained the key decision makers in matters regarding rice crop cultivation, while woman took on the responsibility of making decisions about the distribution of cash form grants for the family.

Rural women in Thazi Township play an important role in the agricultural production. Those women are mostly involved in farm duties such as seed cleaning, weeding, planting, harvesting and threshing (Figure 4.5). Their farm wage rate is usually set by the farm owner, and it is lower than that of male laborers. A significant increase in income was provided by the Oxfam grants. In 2011 women laborers received an average of Ks 1,200 per day as wages, while those in Oxfam pilot of 2012 received Ks 2,500 per day. In respond to this, the average market rate of wages in general, increased from Ks 1,200 to Ks 2,000. From the farmer's point of view, a higher wages for the trained transplanters was not seen as a burden as changed seedling transplanting methods introduced by DoA increased the intensity of seeding per hectare. Farmers could see that the extra costs of a daily wage rate of Ks 2,500 for women transplanters was covered by increased returns. Farm income of women transplanters ranges from Ks 75,000 to Ks 140,000 per season (Table 4.16).

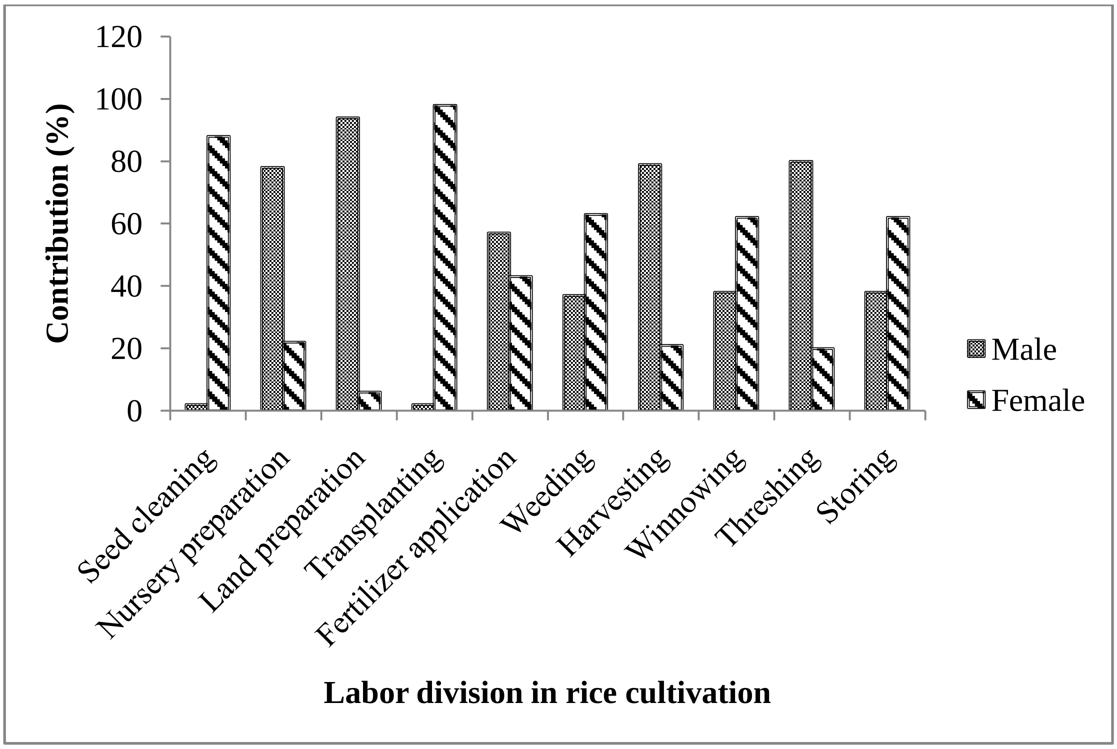


Figure 4.5 Role of gender in rice cultivation of beneficiary farmers

Table 4.16 Age, income and experience of selected women transplanters in Thazi Township

Transplanter	Max	Min	Avg
Age (year)	58	17	31
Income from transplant(Ks per season)	140,000	75,000	86,359.80
Experience(year)	45	1	11.1

4.2 Measurement of Technical Efficiency for Rice Production

4.2.1 Summary statistics of the variables for 'beneficiary' farmers and 'non-beneficiary' farmers

Detailed summaries of the variables involved in the frontier production function of the rice growing farmers, both 'beneficiary' and 'non-beneficiary farmer' are described in Table 4.17 and Table 4.18. Based on the survey data, the average yield of rice for beneficiary farmers was 3308.90 kg ha^{-1} and for non-beneficiary farmers, 3059.20 kg ha^{-1}. The overall average yield of rice was 3122.60 kg ha^{-1}, with yields ranging from 778.36 to 5189.10 kg ha^{-1}. Beneficiary farmers applied seed rate at an average of 110.70 kg ha^{-1} and 'non-beneficiary farmers', at 107.17 kg ha^{-1}. For all farmers, the average seed rate was 108.00 kg ha^{-1}, with this ranging from 51.89 to 207.56 kg ha^{-1}.

The average amount of FYM used in rice growing, was 6.3 ton ha^{-1} by 'beneficiary farmers' and 6.73 ton ha^{-1} by 'non-beneficiary farmers'. The average amount of FYM for all farmers was 6.62 ton ha^{-1} with application ranging from 0 to 18.53 ton ha^{-1}. The average of total amount of fertilizers used by 'beneficiary farmers', was 220.86 kg ha^{-1}. For the 'non-beneficiary farmers' the average was 222.10 kg ha^{-1}. The average of total amount of fertilizers used by all farmers was 221.79 kg ha^{-1} with this use ranging from 49.42 to 469.49 kg ha^{-1}. For human labor, 'beneficiary farmers' used an average of 39.37 man days per hectare in transplanting, and the 'non-beneficiary farmers' group was 37.59 man days per hectare. Overall, an average of 38.05 man days for transplanting was used, with a range from 27.18 to 42 man days per hectare.

The average animal labor used in rice farming, including hired animals and family owned beasts, was 17.75 animal days per hectare for 'beneficiary farmers' and 18.11 animal days per hectare for 'non-beneficiary farmers'. For all farmers in the study area, there was an average of 18.02 animal days per hectare used during rice production.

The average farm size for all farm households was 1.84 hectares, and ranges from 0.40 hectares to 6.07 hectares. The average farm sizes of the 'beneficiary' and 'non-beneficiary farm' households were 2.02 hectares and 1.78 hectares respectively. The average years of schooling for all farm households was 7.72 years, with a range from 1 year (monastery level) to 16 years (graduate level). The average number of years of school for the ‘beneficiary farmers’ was approximately 7.90 years, while the average number of years at school for the ‘non-beneficiary farmers’ was 7.66 years.

The mean value for a household’s ‘experience in rice farming’ was 24.05 years, with a range from 1 year to 42 years of experience. The average farming experience of the ‘beneficiary’ and ‘non-beneficiary farmers’ was 23.70 years and 24.17 years, respectively. For this variable, there was a large variation amongst farmers surveyed.

Table 4.17 Summary statistics of variables of beneficiary farmers and non-beneficiary farmers

Variables (unit)	Farmer group	
	Beneficiary (n=30)	Non-beneficiary (n=88)
Output variable		
Yield (kg ha^{-1})	3308.90(762.60)	3059.20(84.66)
Input variables		
Seed rate (kg ha^{-1})	110.70(47.17)	107.17(46.85)
FYM (ton ha^{-1})	6.30(4.39)	6.73(3.48)
Fertilizer (kg ha^{-1})	220.86(70.82)	222.10(79.74)
Human labor for transplanting (manday ha^{-1})	39.37(4.04)	37.59(4.06)
Animal labor (animal day ha^{-1})	17.75(7.63)	18.11(6.37)
Variables for inefficiency effect		
Farm size (ha)	2.02(1.45)	1.78(1.11)
Education level (years of schooling)	7.90(3.88)	7.66(3.58)
Farming experience (year)	23.70(13.39)	24.17(14.70)

Note: Figures in the parentheses are standard deviation.

Table 4.18 Summary statistics of variables

Variables(unit)	Total farm households (n=118)
Output variable	
Yield (kg ha^{-1})	3122.60(830.1)
Input variables	
Seed rate (kg ha^{-1})	108.00(46.76)
FYM (ton ha^{-1})	6.62(3.72)
Fertilizer (kg ha^{-1})	221.79(78.68)
Transplanting labor (man day ha^{-1})	38.05(4.11)
Animal labor (animal day ha^{-1})	18.02(6.68)
Variables for inefficiency effect	
Farm size (ha)	1.844(1.21)
Education level (years of schooling)	7.72(3.65)
Farming experience (year)	24.05 (14.33)
Good Agricultural Practices use (dummy)	0.25(0.44)

Note: Figures in the parentheses are standard deviation.

4.2.2 Estimation of production frontier and technical efficiency for all sampled farmers

To estimate parameters of frontier production, FRONTIER 4.1 (Coelli, 1996) was applied for all of the 118 sampled farmers. The Cobb–Douglas production function in this estimating was expected to have a significant influence on output. The normally distributed random error (v_i) and the half normal error term (μ_i) associated with technical inefficiency, were included in this function. The parameter estimates of Ordinary Least Square (OLS) and Maximum Likelihood Estimation (MLE) for all sample farmers are indicated in Table 4.19.

The values of σ_s^2 and γ were statistically significant at the $\alpha = 0.01$ level. The γ value of 0.92 implied that the inefficiency effects are highly deterministic of the variability of rice yield. Therefore, 8% of difference between observed yield and maximum possible yield, was due to factors under the farmer's management. The stochastic frontier analysis had further shown that 92% of observed inefficiency is due to the farmer's inefficiency in decision-making, and that only 8% of it was due to random factors outside their control, and this is the case for all farms. The value of likelihood ratio test of one-sided error was 29.58 with significance at the $\alpha = 0.01$ level indicating that the goodness of fit of the model.

The determinants of output included in the stochastic frontier model are seed rate, manure (FYM), fertilizer, human labor in transplanting, animal labor, farm size, farmer's years of schooling, rice farming experience and the receipt of cash grants and technology in rice production.

For Cobb-Douglas model, the coefficients of the input variables in the production function demonstrated an elasticity with respect to mean output for different inputs, as defined by equation (1) and (2). Table 4.19 includes results of the estimation of the frontier production functions (OLS) and (MLE) for the rice production of all farmers sampled. Though this analysis, the elasticity of frontier (best practice) production for seed rate was estimated to be positively related to the yield of rice and this was statistically significant at the 5% level in both estimates. It indicates that if farmers in selected area used good quality seed and gave optimum care management in the nursery, they would achieve a better rice yield. For high income group, seed rate used showed positive effect on yield (May Yee Kay Khine Sein 2008).

The estimated coefficient for manure (FYM) showed a negative relation to rice yields, and it was not significant in either the OLS or MLE estimates. However, given this negative relationship it can be concluded that the farmers' use of FYM in rice production is inefficient. The estimates for fertilizer use showed a negative relation to rice yield and its coefficient was significant at the 10% level in the MLE estimate. According to this result it can be concluded that if the farmers applied fertilizers efficiently and in timely manner, rice yields would be increased. Tadesse and Krishnamoorthy (1997) found that, with the use of more fertilizers and land, rice production could be increased.

The estimated coefficient for human labor in transplanting indicated a negative relationship to rice yield, but it was not significant in either estimate. The negative relationship indicates, that if all farmers continue to use this amount of human labor for transplanting, rice yield will not respond to increase in labor input and indicates farmers may be weak in labor management. In relation to this point, the Oxfam project provided 42 trained transplanters to the 'beneficiary farmers' for a hectare transplanting and transplanting team claimed 42 members to be set up for a hectare to the non-beneficiary farmer group in labor peak period. The estimates for animal labor displayed a negative relationship to rice yield in the MLE estimation, but this coefficient was not significant. That negative relation may indicate that all farmers in the study overused or inefficiently used their animal labor. Moreover, this input was frequently used in land preparation as there was the irregular rainfall pattern and access to irrigation. May Yee Kay Khine Sein (2008) found, that for low income group, human labor used was negatively significant on yield, and for high income group, animal labor used showed positive effect on yield.

According to the inefficiency model, both farm size and household head's year of schooling for all sample farmers, was positively related to the inefficiency effect, and the household head's experience in rice farming and use of GAP practices was negatively related to the inefficiency effect. The coefficient for the farmer's experience in rice farming was significant at the 10% level in the inefficiency model. It can be implied that the farmers who have more experience in rice farming appear to be more technically efficient. The negative coefficient for household head's 'experience in rice farming' and 'use of GAP practices for rice farming, indicates that farmers who have more rice farming experience and those who thoroughly applied GAP practices, were more efficient in rice production. The rice farmers have more experience in growing modern varieties, had better access to input markets which is located in fertile regions and rice farmers who have less off-farm work tend to be more efficient (Rahman 2003).

Farm size is positively related to the inefficiency effect, as beneficiary farmers were provided farm inputs only for hectare cultivation. In this situation, there might be provided farm inputs were allocated to all their own farms and they were weak in thoroughly manage in farm tasks on their own farms. The small-sized paddy farms in zone II and medium sized paddy farms in zone III are represented by ecologically based production techniques; thus achieving higher technical efficiency (Tadesse and Krishnamoorthy 1997).

Table 4.19 Parameters of OLS and MLE in stochastic frontier production function for all farm households (n=118)

Variables	Parameters	OLS	MLE
Stochastic frontier			
Constant		8.87^{***} (9.17)	8.87^{***} (11.98)
Seed rate	β_1	0.12^{**} (2.13)	0.10^{**} (2.21)
FYM	β_2	$- 0.07^{ns}$ (0.79)	-0.01^{ns} (0.28)
Fertilizer	β_3	-0.07^{ns} (1.01)	-0.88^{*} (1.7)
human labor for transplanting	β_4	-0.28^{ns} (1.25)	-0.16^{ns} (0.82)
Animal labor	β_5	0.06^{ns} (0.17)	-0.03^{ns} (0.96)
Inefficiency model			
Constant	δ_0		0.50^{ns}(1.44)
Farm size	δ_1		0.16^{ns} (1.28)
Schooling year	δ_2		0.007^{ns} (0.06)
Experience	δ_3		-0.84^{*} (1.89)
Receiving cash grant and technology	δ_4		-2.49^{ns}(1.49)
Variance parameters			
$\sigma_s^2 = \sigma_v^2 + \sigma_u^2$		0.09	0.47^{***} (3.06)
$\gamma = \sigma_u^2 / \sigma_s^2$			0.92^{***} (33.59)
LR test			29.58^{***}
γ^2 (0.05) (mixed Chi square distribution)			
Mean technical efficiency			0.85

Note: Figures in parenthesis are t values for the corresponding data.

***, ** and * are significant at 1%, 5% and 10% level respectively.

4.2.3 Estimation of production frontier and technical efficiency for beneficiary rice farmers and non-beneficiary rice farmers

The parameter estimates of OLS and MLE for 'beneficiary' and 'non-beneficiary' rice growing farmers, are indicated in Table 4.20 and Table 4.21 respectively. For 'beneficiary farmers', the value of likelihood ratio (LR) test of one-sided error was 1.85 and so is not significant and these details are shown in Table 4.20. The values of σ_s^2 was statistically significant at the $\alpha = 0.01$ level. The 0.38 of γ value implies that the inefficiency effects may determine to a small degree, the variability of rice yield. This is a reason why beneficiary farmers were provided with the same level of cash grants, farm inputs and technology through the Oxfam project.

For the 'non-beneficiary farmers', the value of likelihood ratio (LR) test of one-sided error was 24.58 and was significant at the $\alpha = 0.01$ level. These details can be seen in Table 4.21. This is indicative of the goodness of fit of the model. The values of σ_s^2 were statistically significant at the $\alpha = 0.05$ level. The 0.98 of γ value implied that the inefficiency effects are highly deterministic in the variability of rice yield.

The determinants of output taken into account in the stochastic frontier model for 'beneficiary' and 'non-beneficiary ' farmers' rice production, are rice yield, seed rate, manure (FYM), fertilizers, human labor for transplanting, animal labor, farm size, farmer's years of schooling and experience in rice farming.

In Table 4.20, the results of the estimation of the frontier production functions (OLS) and (MLE), for the 'beneficiary farmers' are presented. The estimate of seed rate is positively related to the rice yield but not significant in both results. The positive relation could imply that either rice seed applied or recommended seed rate was incompatibility for GAP practices in selected area. The estimated coefficient for manure shows a positive relationship to rice yield for 'beneficiary farmers' and likewise is not significant in both results. However, this positive relationship could indicate that if farmers applied manure more sufficiently, the yield of rice could be increased.

The estimated coefficient for fertilizers indicates a negative relationship to rice yield for 'beneficiary farmers' and these results are only statistically significant for the MLE calculation. It indicates, that if they used all of the fertilizers provided in the contract farm only, the 'beneficiary farmers' need to use fertilizers in a timely and efficient manner. The estimated coefficient of human labor for transplanting shows a positive relation to rice yield, but it is not statistically significant for both measures. This demonstrates that the role of transplanting system of GAP practices would give an additional rice yield to certain level. The estimated coefficient of animal labor has a negative relationship to rice yield and it was not statistically significant in both estimates.

For ‘beneficiary farmers’, in the inefficiency model, farm size and household head’s years of schooling are negatively related to the inefficiency effect. It indicates that with the same support, large land holders make use of this opportunity. The perception of the benefits of technological innovation depended partially on education. The beneficiary farmers’ level of experience in rice farming correlates positively to the inefficiency effect, but not at a significant level. This indicates that the farmers, who have longer term experience in rice farming, are less likely to adopt technology innovations introduced by the GAP practices.

Results of the estimation of the frontier production functions (OLS) and (MLE) for non-beneficiary farmers are presented in Table 4.21. The coefficients of seed rate and manure, although positively related to yield in MLE estimation, are not statistically significant. The application of the quality seed, and recommended amount of rice seed and manure, may have contributed to yield increases. The coefficient of fertilizer showed a negative relationship to rice yield for the ‘non-beneficiary farmers’ group in the MLE estimates and this is statistically significant at the 5% level. It strongly indicates that beneficiary farmers should use fertilizers in a timely and efficient manner. The estimated coefficient for human labor for transplanting is positively related to rice yield for the ‘non-beneficiary farmers’ in the MLE model, this relationship is not significant. This demonstrates that the role of transplanting system would give an additional rice yield to certain level. The estimated coefficient for animal labor is negatively related to rice yield for the ‘non-beneficiary farmers’ in the MLE model, this relationship is not significant. The negative relationship indicates that the ‘non-beneficiary farmers’ group overused and/ or inefficiently used their animal labor. This may be a result of the irregular rainfall patterns and the unavailability of irrigation during the study period, which in turn meant farmers needed to prepare land for planting more often.

In the inefficiency model for the ‘non-beneficiary farmers’, the variable farmer’s years of schooling is positively related to the inefficient effect. It may be concluded that the farmers who have lower education levels are more efficient in rice farming. Although these farmers may have poor formal education, they have integrated farm tasks for possibly a longer time into their lives. The coefficient of farm size is positively correlated on the inefficiency effect. Farm size positively related to the inefficiency effect indicating that farmers who have small farm size are more able to manage their farms efficiently. The coefficient of the household head's experience in rice farming is negatively correlated on the inefficiency effect. The non-beneficiary farmers' level of experience in rice farming correlates negatively to the inefficiency effect, and this is statistically significant at 10% level. It can be implied that the farmers who have more experience in rice farming appear to be more technically efficient.

Table 4.20 Parameters of OLS and MLE in stochastic frontier production function for beneficiary farmers

Variables	Parameters	Beneficiary farm households (n=30)	
		OLS	MLE
Stochastic frontier			
Constant	β_0	8.30^{***} (4.44)	8.76^{***} (6.47)
Seed rate	β_1	0.04^{ns} (0.39)	0.05^{ns} (0.56)
Manure	β_2	0.01^{ns} (0.13)	0.01^{ns} (0.28)
Fertilizer	β_3	-0.19^{ns} (1.07)	-0.32^{*} (1.70)
Human labor for transplanting	β_4	0.19^{ns} (0.46)	0.25^{ns} (0.63)
Animal labor	β_5	-0.03^{ns} (0.39)	-0.01^{ns} (0.16)
Inefficiency model			
Constant	δ_0		-0.88^{ns} (0.72)
Farm size	δ_1		-0.11^{ns} (0.82)
Year of schooling	δ_2		-0.10^{ns} (0.64)
Experience	δ_3		0.55^{ns} (0.93)
Variance parameters			
$\sigma_s^2 = \sigma_v^2 + \sigma_u^2$		0.05	0.06^{***} (3.31)
$\gamma = \sigma_u^2 / \sigma_s^2$			**0.38^{ns}(1.29)**
LR test			**1.85^{ns}**
χ^2 (0.05) (mixed Chi square distribution)			
Mean technical efficiency			**0.93**

Note: Figures in parenthesis are t values for the corresponding data.

***, ** and *are significant at 1%, 5% and 10% level respectively and ns is not significant.

Table 4.21 Parameters of OLS and MLE in stochastic frontier production function for non-beneficiary farmers

Variables	Parameters	Non-beneficiary farmers (n=88)	
		OLS	MLE
Stochastic frontier			
Constant	β_0	9.67^{***} (8.17)	8.61^{***} (6.55)
Seed rate	β_1	0.12^{*} (1.75)	0.07^{ns} (1.45)
Manure	β_2	-0.51^{ns} (0.94)	0.02^{ns} (0.48)
Fertilizer	β_3	-0.08^{ns} (1.02)	-0.11^{**} (2.34)
Human labor for transplanting	β_4	-0.49^{ns} (1.62)	0.03^{ns} (0.07)
Animal labor	β_5	0.01^{ns} (0.29)	-0.04^{ns} (1.47)
Inefficiency model			
Constant	δ_0		0.55^{ns} (1.28)
Farm size	δ_1		0.12^{ns} (0.71)
Year of schooling	δ_2		0.03^{ns} (0.01)
Experience	δ_3		-0.25^{*} (1.71)
Variance parameters			
$\sigma_s^2 = \sigma_v^2 + \sigma_u^2$		0.09	0.27^{*} (1.83)
$\gamma = \sigma_u^2 / \sigma_s^2$			**0.98***** (57.73)
LR test			**24.58*****
χ^2 (0.05) (mixed Chi square distribution)			
Mean technical efficiency			**0.72**

Note: Figures in parenthesis are t values for the corresponding data.

***, ** and * are significant at 1%, 5% and 10% level respectively and ns is not significant.

4.2.4 Comparison of technical efficiency between beneficiary and non-beneficiary rice growing farmers

By using the stochastic frontier model, the specific-farm technical efficiency of selected farmers was obtained. The percent distribution of the efficiency estimates obtained from the stochastic frontier model was presented in Table 4.22 and in Figure 4.6. In Appendix 2, Appendix 3 and Appendix 4, the detailed technical efficiency indices for all sample farmers, beneficiary farmers and non-beneficiary farmers were shown respectively and output from the FRONTIER (version 4.1) program for all sample farmers is shown in Appendix 5.

The technical efficiency of all sample farmers, which ranges from 0.11 to 1.00, is presented in Table 4.22. The average technical efficiency of all the sampled farmers was 0.85, that is, all farmers were able to obtain an 85 percent of the potential (stochastic) frontier production level, given the level of inputs and technology currently used. The mean technical efficiencies of 'beneficiary' and 'non-beneficiary' farmers were 0.93 and 0.72 respectively. This implies that, on average, 'beneficiary' farmers and 'non-beneficiary' farmers were able to obtain 93 percent and 72 percent, respectively, of the potential (stochastic) frontier production level, given the levels of the allocated resources and the existing practices. This measure of mean technical efficiency indicates 'beneficiary' farmers were more technically efficient than 'non-beneficiary' farmers. This strongly suggests the influence of the farm inputs and aid with technology, beneficiary farmers were getting from the Oxfam project office and Department of Agriculture, Thazi Township office. Wiboonpogse and Sriboonchitta (2001) found that the average technical efficiencies (70%) in both jasmine rice and non- jasmine rice imply substantial gaps for the rice yields improvement by increasing their technical efficiencies.

About 2.54 percent of all sample farmers had a technical efficiency index less than, or equal to, 0.50 (50 percent). In considering this aggregated sample, 16.95 percent of all farmers had a technical efficiency between 0.51 (51 percent) and 0.80 (80 percent), the rest of all farmers had a technical efficiency more than 0.80 (80 percent) as shown in Table 4.22 and in Figure 4.6. There are significant differences in technical efficiency between the two farmer groups.

For 'beneficiary' farmers, the mean technical efficiency index was 0.93 within the range of 0.71 to 1.00. From the results, 33.33 (percent) of 'beneficiary' farmers had a technical efficiency between 0.71 (71 percent) and 0.90 (90 percent), and 66.67

percent of beneficiary farmers had a technical efficiency of more than 0.90 (90 percent) as shown in Table 4.22 and in Figure 4.6**.** The mean technical efficiency index for non-beneficiary farmers was 0.72 within the range of 0.21 to 1.00. There were 3.41 percent of the 'non-beneficiary' farmers who have a technical efficiency less than, or equal to, 50 percent and 76.14 percent of 'non-beneficiary' farmers have a technical efficiency between 51 percent and 90 percent. Only 20.45 percent of 'non-beneficiary' farmers have a technical efficiency index greater than 0.90. Therefore, the percentage of 'beneficiary' farmers above technical efficiency rate of 90 percent is higher than that of the 'non-beneficiary' farmers, indicating that 'beneficiary' farmers were more efficient in rice production than 'non-beneficiary' farmers. The t-test shows there is a significant difference in mean technical efficiency between 'beneficiary' farmers and 'non-beneficiary' farmers.

The percentage distribution of sampled farmers above and below the mean, for technical efficiency is presented in Table 4.23. For 'non-beneficiary' farmers, 40.90 percent have a technical efficiency below 0.85 which indicates these farmers would obtain benefits from operating more efficiently and with better application of technology and resources in their rice farming. About 4.55 percent of 'non-beneficiary' farmers have mean technical efficiency of the sampled population. About 54.55 percent of 'non-beneficiary' farmers had technical efficiency above 0.85 which implies that their production efficiency can be increased by accepting present technology and good agricultural practices. About 3.33 percent of 'beneficiary' farmers had a technical efficiency below the mean technical efficiency of 0.85, even though they had Oxfam support, indicating that these farmers may have a low capacity in accepting technology. About 96.67 percent of 'beneficiary' farmers have a technical efficiency above 0.85.

Table 4.22 Percent distribution of sampled farmers in technical efficiency

Technical Efficiency range	Farmer group					
	Beneficiary		Non-beneficiary		All	
	frequency	%	frequency	%	frequency	%
0.11-0.20	0	0.00	0	0.00	0	0.00
0.21-0.30	0	0.00	1	1.14	1	0.85
0.31-0.40	0	0.00	0	0.00	0	0.00
0.41-0.50	0	0.00	2	2.27	2	1.69
0.51-0.60	0	0.00	2	2.27	2	1.69
0.61-0.70	0	0.00	5	5.68	5	4.24
0.71-0.80	1	3.33	12	13.64	13	11.02
0.81-0.90	9	30.00	48	54.55	57	48.31
0.91-1.00	20	66.67	18	20.45	38	32.20
Total	30	100.00	88	100.00	118	100.00
Mean TE	0.93		0.72		0.85	
t-test	$t_{(0.05)}=3.86^{***}$					
Maximum TE	0.96		0.94		0.96	

Note: *** is significant at 1% level.

Table 4.23 Percent distribution of sampled farmers above and below the mean technical efficiency

Technical efficiency range	Beneficiary farmers		Technical efficiency range	Non-beneficiary farmers	
	Frequency	%		Frequency	%
Below 0.85	1	3.33	Below 0.85	36	40.90
0.85	0	0.00	0.85	4	4.55
Above 0.85	29	96.67	Above 0.85	48	54.55
Total	30	100.00	Total	88	100.00

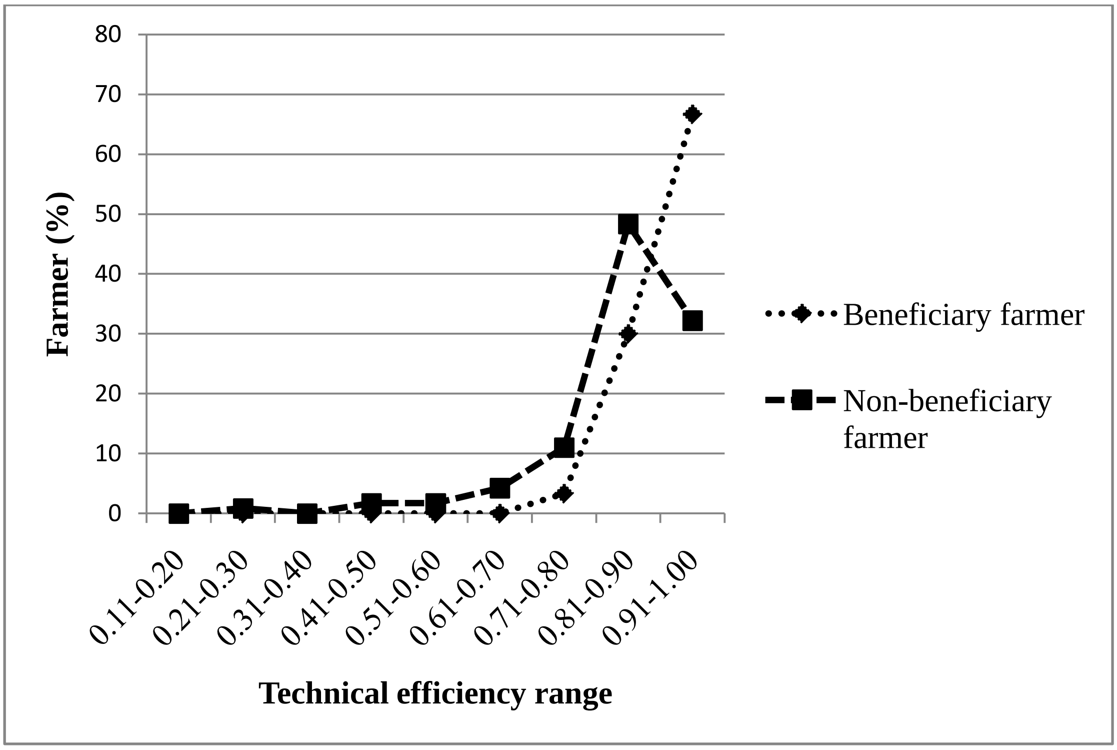


Figure 4.6 Percent distribution of sampled farmers in farm-specific technical efficiency

4.3 Constraints and Problems in Rice Production

Agricultural production is affected by biotic and abiotic factors, at different levels of influence. Abiotic factors can be partially controlled by improving physical infrastructure such as soil, climate and location of field. Biotic factors such as crop, other plants and animals are controlled by applied biology domains. This study examined there were some problems and constraints in rice production in Thazi Township. The farmers were surveyed on a qualitative basis about the constraints and problems they face in rice production, and their responses are provided in Table 4.24. There were a number of questions, including the topics of constraints due to insufficient water, inadequate credit, unmet capital requirements, labor scarcity, inadequate fertilizer, infestation of pest and disease, poor seed quality and contact with extension programs. Of these issues, the problem of insufficient water was faced by 80.5 percent of all sample farmers. Farmers in the study area could not apply fertilizers and grow rice at the most opportune time.

About 28.8 percent of the farmers sampled, responded that they wanted to receive extension services to learn of better rice growing methods. In particularly, most of the farmers do not have access to sufficient water from irrigation schemes, a crucial factor as this township is located in the Central Dry Zone. This may lead to large variations in yield variation and represents a major constraint faced by farmers in the study area. About 69.5 percent of the sampled farmers responded that they wanted to have access to sufficient amounts of credit amount with reasonable interest rates to finance rice production. In addition to this, about 63.6 percent of the sample responded that they still required capital investment for rice production. The problem of labor scarcity was mentioned by 59.3 percent of the farmers sampled. Labor wage rate in rice production were relatively low and labors migrates to proximal businesses. Issues with inadequate fertilizer, infestation of pest and disease and seed impurity were faced, respectively, by 51.7, 44.1 and 33.9 % of the sampled population.

The constraints and problems were not significantly different between two groups except seed impurity, insufficient irrigation water and labor scarcity. Significant larger percentage of the non-beneficiary farmers pointed out the problem of seed impurity. Only labor scarcity was their serious problem for the beneficiary farmers. Inadequate credit and capital requirement problems were more serious in the non-beneficiary farmers.

Table 4.24 Constraints and problems in rice production faced by the sample farmers

Indicator	Farm household			χ^2 (p-value)
	Beneficiary (n=30)	Non-beneficiary (n=88)	Total (n=118)	
1. Insufficient water	21(70.0)	74 (84.1)	95(80.5)	0.09^{*}
2. Inadequate credit	19(63.3)	63 (71.6)	82(69.5)	0.39^{ns}
3. Capital requirement	16(53.3)	59 (67.0)	75(63.6)	1.78^{ns}
4. Labor scarcity	22(73.3)	48(54.5)	70(59.3)	0.07^{*}
5. Inadequate fertilizer	16(53.3)	45 (51.1)	61(51.7)	0.84^{ns}
6. Infestation of pest and disease	12(40.0)	40 (45.5)	52(44.1)	0.60^{ns}
7. Seed impurity	4(13.3)	36(40.9)	40(33.9)	0.00^{***}
8. Need extension services	11(36.7)	23(26.1)	34(28.8)	0.27^{ns}

Note: Figures in the parentheses represent percentage.

*** and * are significant at 1% and 10% level respectively and ns is not significant.

CHAPTER V
CONCLUSION AND POLICY IMPLICATION

5.1 Conclusion

Average age and average farm experience of ‘non-beneficiary’ farm household heads was higher than that of ‘beneficiary farm’ household heads. The average education level of ‘beneficiary farm’ household heads was higher than that of ‘non-beneficiary farm’ household heads. The use of T-super fertilizer by ‘non-beneficiary farm’ households in rice production, was higher than that of ‘beneficiary farm’ households. Likewise, the ‘non-beneficiary farm’ household used higher amount of farm-yard manure. The average yield obtained by ‘beneficiary farmers’ was higher than that of the ‘non-beneficiary farmers’ group, and in addition, the highest rice yield among sampled farmers was gained in the ‘beneficiary farmer’ group. Among the beneficiary farmers, average yield of rice obtained by the small farm size group was relatively higher than that of other beneficiary farm size groups. The ‘non-beneficiary farmers’ also used the greater amount of fungicide in rice production.

According to the results of enterprise budget, which is used to compare the cost and returns of the two rice growing farmer groups, the benefit-cost ratios of rice production in ‘beneficiary’ and ‘non-beneficiary’ farmers were 1.09 and 0.98, respectively. Further analysis of benefit-cost ratio for beneficiary farmers, the highest benefit-cost ratio 1.15 is in the small beneficiary farm size group. Interpreting results through cost and return analysis, the ‘beneficiary farmers’ received a better yield and a higher return with less variable costs, even though there was less of a difference in received price for rice. Moreover, the ‘non-beneficiary farmer’ group could not generate enough income to cover the variable cost of rice production.

In this study, the technical efficiency index was measured by using FRONTIER 4.1. Frontier efficiency has been used extensively in measuring the level of technical efficiency, an important issue in evaluating the ability to obtain a higher level of output from a given set of inputs. Yield per hectare of rice was used as the dependent variable and seed rate, manure, fertilizer, transplanting labor and animal labor were used as independent variables for production frontier. Farm size, the household head’s year of schooling and farmer’s experience in rice farming were used as explanatory variables associated with technical inefficiency.

According to the results of production frontier analysis, the elasticity of frontier (best practice) production in respect to the variable ‘seed rate’ there is a positive and statistically influenced on rice yields at the 5% level for all farmers sampled. It indicates that if farmers use good quality seed and provided better management at the nursery stage, they could get better yield of rice. Farmers perceived that;

(a) a higher seed rate lead to greater yields,

(b) impurity of seeds may lead to lower yields and,

(c) insufficient water at nursery/seedling stage requires farmers to use more seeds.

Fertilizers coefficient was negatively correlated to yield of rice and statistically significant. This might be attributed to;

(a) farmers lack of knowledge regarding the right time for fertilizer application, or that

(b) though farmers know the right time for fertilizer application, fertilizer effect cannot be seen, probably due to unavailable irrigation water at that time.

All farmers in the study area needed efficient irrigation scheme to apply fertilizers timely and efficiently in rice production. A mean technical efficiency of 85 percent among the sampled farms, which indicates that on average, in the study area, the realized output can be raised by 85 percent, even without other additional resources. By proper management and proper allocation of the existing resources and technology, sufficient potential exists to improve the productivity of rice growing. Only 32.2 percent of all farmers had technical efficiency rating more than 90 percent. The mean technical efficiency of ‘beneficiary farmers’ and non-beneficiary farmers is, respectively, 0.93 and 0.72 of the potential (stochastic) frontier production level.

In the inefficiency model the ‘beneficiary farmers’, provide a negative coefficient for the household head’s years of schooling and farm size. This seems to indicate that the small land-holder included in Oxfam project obtained valuable assistance through the support of Oxfam project, and perception of the benefits of technology depends partially on education.

The estimated coefficient for fertilizer is negatively and statistically significant in relation to the technical efficiency of 'non-beneficiary farmers'. The result indicates that the use of fertilizer should be timely and efficient to get effect of fertilizer in rice production. The coefficient of farm experience has a negative and significant influence on the rice yield of 'non-beneficiary farmers', indicating that the farmers who have longer term experience in rice farming were more efficient in rice production. A technical efficiency rating of above 90 percent was achieved by 66.67 percent of the 'beneficiary farmers', whereas only about 20.45 percent of the 'non-beneficiary farmers' achieved this technical efficiency rating of above 90 percent. Therefore, 'beneficiary farmers' are more efficient in rice production than 'non-beneficiary farmers', which appears to be due to the project support through the Oxfam project and cooperation of Department of Agriculture, Thazi Township office.

There is considerable variation in agricultural productivity, which in turn is affected by biotic and abiotic factors. The major constraint faced by farmers in the study area is insufficient irrigation. About 85 percent of sampled farmers were confronted with insufficient irrigation supplies. Moreover, seed currently used is of low quality. The problem of labor scarcity was found in 59 percent of sampled farmers as labor wage rate is relatively low, including labor migration to other sectors.

5.2 Policy Implication

Encouragement to use GAP in Paddy production has being promoted by the Ministry of Agriculture and Irrigation (MOAI) since 2010-11. The MOAI presents the best organizational focus to disseminate these practices. The Oxfam GB financial support for rice cultivation provides a highly attractive motivation for farmers to adopt GAP's 14 points. According to the responses received from farmers, they were very pleased with Oxfam GB's support. The farmers targeted in the trial did not have to make any refunds to Oxfam (287624.40 Ks ha^{-1}) even after their paddy was sold. All farmers were satisfied with the amount of support (287624.40 Ks ha^{-1}) and the timeliness of distribution of these funds by Oxfam.

Farmers stated that the Oxfam support was sufficient and they were pleased they received support with supply of seed, fertilizer, and the costs of laborers transplanting and harvesting. Household heads were pleased to be able to bypass money lenders and the relatively high interest repayments the demand. This allows for more household income and savings. This releases a huge burden on women in Myanmar farming families, who in general have the responsibility to solve problems with emergency cash requirements. Participants said that the Oxfam support provides a key contribution, not only in area of crop production, but also for household concerns. When farmers receive sufficient financial support, they will hire trained transplanters at higher wage rates. If trained women transplanters receive a higher wage rate then their income will be increased. Therefore, it is a backward signal for marginalized players especially women transplanters in the production chain.

According to the results of frontier production function, the mean technical efficiency of the ‘non-beneficiary farmers’ is low. The mean technical efficiency of the ‘non-beneficiary farmers’ group could be increased by providing farm inputs similar to those the Oxfam ‘beneficiary farmers’ receive. As it had been found that experience in farming is the major determinant on accepting new practices, with a significant influence on technical efficiency, extension services’ efforts should be strengthened and promote both formal and informal trainings and demonstration programs concerned with GAP in the farming community.

From this study it can be seen that, not only socioeconomic factors are improved but also the environment for rice production is fostered. Farmers should use crucial farming inputs at right time and at the recommended rate. Although they follow recommendations made by DoA, low yields persist due to environmental factors such as insufficient irrigation, incidence of pests and disease and weed infestation. An appreciation of the interconnectivity among these factors of rice production needs to be further developed. From the study it can be concluded that even with good management of this interconnectivity, rice productivity among farmers is not increased evenly, indicating that other factors outside of those supported by the Oxfam GB program, also influenced in rice production. To increase yield, not only socioeconomic factors but also biotic and abiotic factors need to be considered.

The introduction of the better quality seeds should be a priority. Among the various factors of production good quality seed is a crucial input to obtain yield improvement in rice production. Up to now, all stakeholders have shown a preference for marketable varieties with these having economies of scale. Seeds that are used are collected by farmers from their farms, a process devoid of selection and improvement activity. This has lead to a decline in the quality of crops produced, and consequently affects the profitability of the rice farmers. In the long run, it is vital to develop seed industry, possibly through public private partnership, to meet with local conditions and market preferences.

High variability in agricultural production and prices emerges as a result of poor water control with increasingly irregular rainfall patterns, high transport costs, poor rural communications and a lack of diversification in export markets. The constraint analysis indicates that it is an effective irrigation scheme which rice farmers in the study area are in most need off. Planning and implementation of a ground water scheme should be considered to increase the profitability and technical efficiency of rice production in this study area.

Numerous strategies can be adopted to promote rice production in smallholder cropping systems. These may focus on, for example, access to credit and restoration of input subsidies; improving labor availability; improving crop production and post-harvest technologies; improving extension services and research; strengthening of farmers' organizations; advertisement of local rice; and collaboration among stakeholders. The Government must develop appropriate national rice policies which play a positive role in sustainable rice production. National rice policies should provide the framework for eliminating or reducing production constraints associated with technical, socio-economic and macro-economic issues, including credit and farm infrastructures, post-harvest technologies (especially concerned with laborers) and support for research and extension services. Access to credits is vital to rice farmers who require capital for hiring of farming equipment; purchasing pesticides, high quality seed, fertilizer and small-scale irrigation equipment; and farmers' organizations have a crucial role to play in rice promotion. Rice farmer associations should be formed to be better able to access market information and disseminate this information to farmer groups and organizations providing greater transparency and access to local rice markets. The Government, NGOs and aid agencies need to continue to provide technical and financial support to farmers' organizations.

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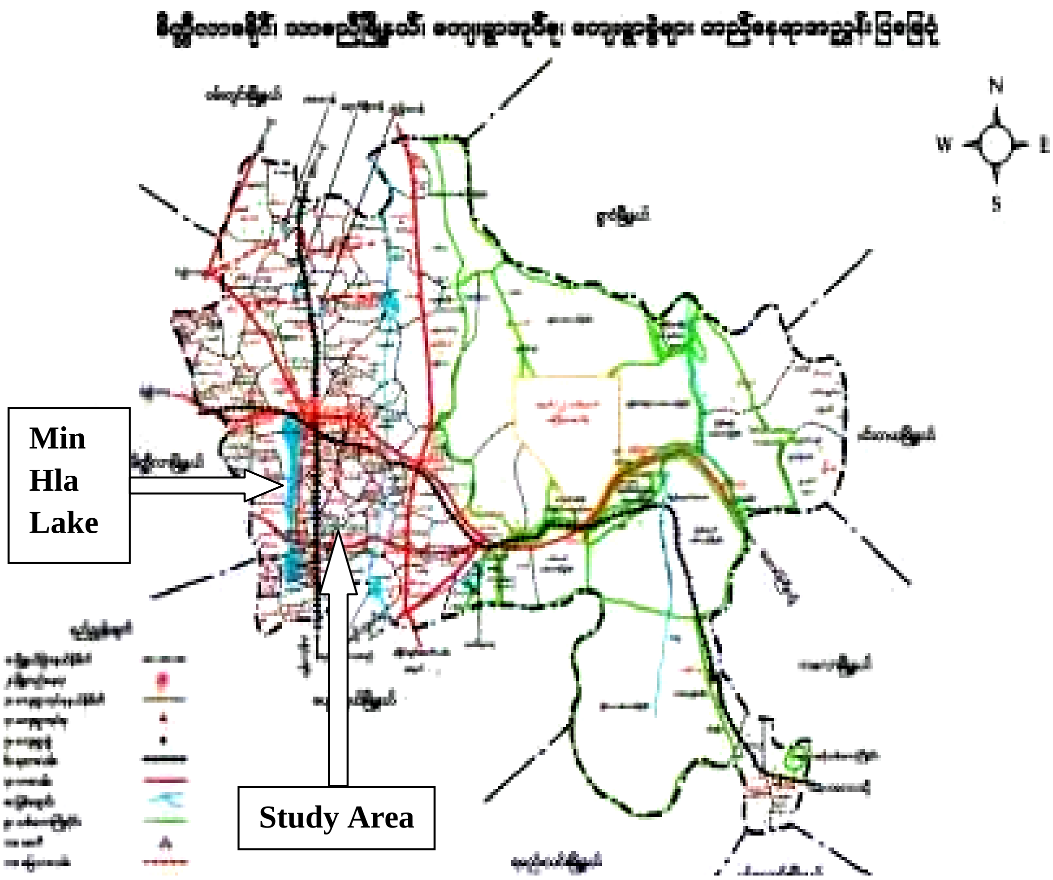
Appendix 1 Map of Thazi Township



Appendix 2 Technical efficiency indices of all sampled farmers

Farmer No.	TE Index	Farmer No.	TE Index	Farmer No.	TE Index	Farmer No.	TE Index
1	0.91	31	0.94	61	0.93	91	0.91
2	0.82	32	0.86	62	0.92	92	0.93
3	0.93	33	0.62	63	0.87	93	0.57
4	0.82	34	0.79	64	0.81	94	0.93
5	0.84	35	0.58	65	0.90	95	0.87
6	0.92	36	0.79	66	0.88	96	0.77
7	0.94	37	0.84	67	0.50	97	0.86
8	0.77	38	0.62	68	0.89	98	0.87
9	0.82	39	0.69	69	0.83	99	0.91
10	0.85	40	0.93	70	0.87	100	0.93
11	0.85	41	0.76	71	0.92	101	0.77
12	0.82	42	0.89	72	0.93	102	0.89
13	0.93	43	0.95	73	0.92	103	0.86
14	0.89	44	0.92	74	0.95	104	0.94
15	0.82	45	0.90	75	0.96	105	0.93
16	0.92	46	0.81	76	0.92	106	0.24
17	0.95	47	0.74	77	0.92	107	0.85
18	0.90	48	0.64	78	0.73	108	0.89
19	0.90	49	0.91	79	0.76	109	0.91
20	0.90	50	0.91	80	0.81	110	0.91
21	0.91	51	0.84	81	0.89	111	0.93
22	0.90	52	0.90	82	0.70	112	0.82
23	0.92	53	0.92	83	0.46	113	0.92
24	0.88	54	0.74	84	0.89	114	0.88
25	0.87	55	0.73	85	0.91	115	0.93
26	0.93	56	0.90	86	0.84	116	0.92
27	0.90	57	0.95	87	0.89	117	0.85
28	0.88	58	0.92	88	0.81	118	0.91
29	0.82	59	0.92	89	0.89		
30	0.90	60	0.94	90	0.88		

Appendix 3 Technical efficiency indices of beneficiary farmers

Farmers' No.	TE Index	Farmers' No.	TE Index
6	0.92	75	0.96
13	0.93	81	0.89
17	0.95	84	0.89
31	0.94	87	0.89
40	0.93	88	0.81
43	0.95	89	0.89
57	0.95	91	0.91
59	0.92	92	0.93
60	0.94	94	0.93
66	0.88	97	0.86
70	0.87	102	0.89
71	0.92	104	0.94
72	0.93	105	0.93
73	0.92	113	0.92
74	0.95	116	0.92

Appendix 4 Technical efficiency indices of non-beneficiary farmers

Farmers' No.	TE Index	Farmers' No.	TE Index
1	0.91	51	0.84
2	0.82	52	0.90
3	0.93	53	0.92
4	0.82	54	0.74
5	0.84	55	0.73
7	0.94	56	0.90
8	0.77	58	0.92
9	0.82	61	0.93
10	0.85	62	0.92
11	0.85	63	0.87
12	0.82	64	0.81
14	0.89	65	0.90
15	0.82	67	0.50
16	0.92	68	0.89
18	0.90	69	0.83
19	0.90	76	0.92
20	0.90	77	0.92
21	0.91	78	0.73
22	0.90	79	0.76
23	0.92	80	0.81
24	0.88	82	0.70
25	0.87	83	0.46
26	0.93	85	0.91
27	0.90	86	0.84
28	0.88	90	0.88
29	0.82	93	0.57
30	0.90	95	0.87
32	0.86	96	0.77
33	0.62	98	0.87
34	0.79	99	0.91
35	0.58	100	0.93
36	0.79	101	0.77
37	0.84	103	0.86
38	0.62	106	0.24
39	0.69	107	0.85
41	0.76	108	0.89
42	0.89	109	0.91
44	0.92	110	0.91
45	0.90	111	0.93
46	0.81	112	0.82
47	0.74	114	0.88
48	0.64	115	0.93
49	0.91	117	0.85
50	0.91	118	0.91

Appendix 5 Output from the program FRONTIER (Version 4.1) for all sampled rice farmers

```
Output from the program FRONTIER (Version 4.1c)
instruction file = god-ins.txt
data file =       god7.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        0.88779233E+01  0.96831687E+00  0.91684072E+01
  beta 1        0.12111055E+00  0.56650025E-01  0.21378729E+01
  beta 2       -0.32203632E-01  0.40284896E-01 -0.79939718E+00
  beta 3       -0.71069307E-01  0.69875252E-01 -0.10170884E+01
  beta 4       -0.27827700E+00  0.24737405E+00 -0.11249240E+01
  beta 5        0.69914056E-02  0.41402021E-01  0.16886629E+00
  sigma-squared 0.86281891E-01
log likelihood function =  -0.19797788E+02
the estimates after the grid search were :
  beta 0        0.92181742E+01
  beta 1        0.12111055E+00
  beta 2       -0.32203632E-01
  beta 3       -0.71069307E-01
  beta 4       -0.27827700E+00
  beta 5        0.69914056E-02
  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  0.19766532E+00
  gamma         0.92000000E+00
 iteration =     0  func evals =     20  llf = -0.12774636E+02
    0.92181742E+01 0.12111055E+00-0.32203632E-01-0.71069307E-01-0.27827700E+00
    0.69914056E-02 0.00000000E+00 0.00000000E+00 0.00000000E+00 0.00000000E+00
    0.00000000E+00 0.19766532E+00 0.92000000E+00
 gradient step
 iteration =     5  func evals =     47  llf = -0.86256117E+01
    0.92205641E+01 0.96888172E-01-0.25170368E-02-0.98173898E-01-0.22630182E+00
   -0.12691839E-01 0.27678023E-01 0.27718387E-01 0.81156651E-01-0.16414419E+00
   -0.12775572E+00 0.24532287E+00 0.92145997E+00
 iteration =    10  func evals =     71  llf = -0.67178847E+01
    0.91511002E+01 0.94669206E-01-0.58431527E-02-0.10756056E+00-0.17456888E+00
   -0.20003172E-01 0.42494018E+00 0.27797438E-01 0.55871866E-01-0.17752656E+00
```

```
  -0.43729040E+00 0.18345319E+00 0.91246999E+00
 iteration =    15  func evals =    128  llf = -0.59236776E+01
   0.91430819E+01 0.98271829E-01-0.55136971E-02-0.96836135E-01-0.20440236E+00
  -0.27563678E-01 0.41923560E+00 0.88186725E-01 0.44826087E-01-0.36502961E+00
  -0.84242468E+00 0.29939446E+00 0.91087851E+00
 iteration =    20  func evals =    241  llf = -0.51599160E+01
   0.89955670E+01 0.99025470E-01-0.48934922E-02-0.94379122E-01-0.17636706E+00
  -0.35104814E-01 0.48909518E+00 0.14704039E+00 0.12856644E-01-0.70966834E+00
  -0.20179385E+01 0.43616650E+00 0.92289932E+00
 iteration =    25  func evals =    388  llf = -0.50053802E+01
   0.88727325E+01 0.10204444E+00-0.79156781E-02-0.88526237E-01-0.16349640E+00
  -0.28477941E-01 0.49682539E+00 0.16253519E+00 0.72494061E-02-0.83667723E+00
  -0.24966656E+01 0.47114477E+00 0.91821176E+00
 iteration =    29  func evals =    459  llf = -0.50051855E+01
   0.88727045E+01 0.10204916E+00-0.79183814E-02-0.88521235E-01-0.16350554E+00
  -0.28475184E-01 0.49683576E+00 0.16254621E+00 0.72441849E-02-0.83682329E+00
  -0.24972516E+01 0.47118454E+00 0.91821199E+00
the final mle estimates are :
              coefficient     standard-error    t-ratio
  beta 0         0.88727045E+01  0.74032864E+00  0.11984819E+02
  beta 1         0.10204916E+00  0.46253142E-01  0.22063186E+01
  beta 2        -0.79183814E-02  0.28064512E-01 -0.28214926E+00
  beta 3        -0.88521235E-01  0.51895824E-01 -0.17057487E+01
  beta 4        -0.16350554E+00  0.20007213E+00 -0.81723298E+00
  beta 5        -0.28475184E-01  0.29483980E-01 -0.96578495E+00
  delta 0        0.49683576E+00  0.34407057E+00  0.14439938E+01
  delta 1        0.16254621E+00  0.12685011E+00  0.12814037E+01
  delta 2        0.72441849E-02  0.12502707E+00  0.57940933E-01
  delta 3       -0.83682329E+00  0.44141257E+00 -0.18957849E+01
  delta 4       -0.24972516E+01  0.16731397E+01 -0.14925541E+01
  sigma-squared  0.47118454E+00  0.15386378E+00  0.30623486E+01
  gamma          0.91821199E+00  0.27332706E-01  0.33593893E+02
log likelihood function =  -0.50051856E+01
LR test of the one-sided error =   0.29585204E+02
with number of restrictions = 6
 [note that this statistic has a mixed chi-square distribution]
number of iterations =     29
(maximum number of iterations set at :   100)
number of cross-sections =    118
number of time periods =      1
total number of observations =    118
thus there are:      0  obsns not in the panel
covariance matrix :
  0.54808650E+00 -0.45320318E-02 -0.64159025E-02 -0.10135135E-01 -0.12630190E+00
 -0.27358996E-02 -0.64125765E-02  0.84294722E-03 -0.53387226E-02 -0.33770019E-04
```

-0.21301219E-01 0.40755417E-02 -0.29258186E-02
-0.45320318E-02 0.21393531E-02 -0.82676859E-05 0.43670878E-03 -0.21107420E-02
-0.10044716E-03 0.31820620E-03 -0.58543001E-03 -0.28823291E-03 -0.38471183E-02
-0.15630114E-01 0.14815436E-02 0.11374143E-03 -0.64159025E-02 -0.82676859E-05
0.78761684E-03 0.18805789E-03 0.11600523E-02
-0.11519817E-04 0.72249364E-03 -0.22796989E-03 -0.84790436E-04 0.15633817E-02
0.59757116E-02 -0.64395597E-03 -0.10066670E-03
-0.10135135E-01 0.43670878E-03 0.18805789E-03 0.26931766E-02 -0.18775826E-02
0.61421060E-04 0.35321791E-03 -0.23501506E-03 -0.18772260E-05 -0.26304836E-02
-0.86678599E-02 0.88293598E-03 0.15849779E-03
-0.12630190E+00 -0.21107420E-02 0.11600523E-02 -0.18775826E-02 0.40028858E-01
0.20202086E-03 0.96286793E-03 0.73763019E-03 0.18463869E-02 0.11906704E-01
0.51502845E-01 -0.52259383E-02 0.25162707E-03
-0.27358996E-02 -0.10044716E-03 -0.11519817E-04 0.61421060E-04 0.20202086E-03
0.86930510E-03 -0.11680748E-02 -0.28333272E-03 0.33103466E-03 0.54240118E-03
0.51264074E-03 -0.15405131E-03 0.16024126E-03
-0.64125765E-02 0.31820620E-03 0.72249364E-03 0.35321791E-03 0.96286793E-03
-0.11680748E-02 0.11838456E+00 0.22435603E-03 -0.27255790E-01 -0.36603123E-01
-0.75554401E-01 0.39395669E-02 -0.94159894E-03
0.84294722E-03 -0.58543001E-03 -0.22796989E-03 -0.23501506E-03 0.73763019E-03
-0.28333272E-03 0.22435603E-03 0.16090952E-01 -0.18887697E-02 -0.20299707E-01
-0.74767557E-01 0.70389271E-02 0.99428040E-03
-0.53387226E-02 -0.28823291E-03 -0.84790436E-04 -0.18772260E-05 0.18463869E-02
0.33103466E-03 -0.27255790E-01 -0.18887697E-02 0.15631767E-01 0.92345952E-02
0.40242742E-01 -0.37777399E-02 -0.37979736E-03
-0.33770019E-04 -0.38471183E-02 0.15633817E-02 -0.26304836E-02 0.11906704E-01
0.54240118E-03 -0.36603123E-01 -0.20299707E-01 0.92345952E-02 0.19484506E+00
0.71389771E+00 -0.62657350E-01 -0.59128699E-02
-0.21301219E-01 -0.15630114E-01 0.59757116E-02 -0.86678599E-02 0.51502845E-01
0.51264074E-03 -0.75554401E-01 -0.74767557E-01 0.40242742E-01 0.71389771E+00
0.27993965E+01 -0.23518490E+00 -0.21331918E-01
0.40755417E-02 0.14815436E-02 -0.64395597E-03 0.88293598E-03 -0.52259383E-02
-0.15405131E-03 0.39395669E-02 0.70389271E-02 -0.37777399E-02 -0.62657350E-01
-0.23518490E+00 0.23674064E-01 0.30596603E-02
-0.29258186E-02 0.11374143E-03 -0.10066670E-03 0.15849779E-03 0.25162707E-03
0.16024126E-03 -0.94159894E-03 0.99428040E-03 -0.37979736E-03 -0.59128699E-02
-0.21331918E-01 0.30596603E-02 0.74707681E-03

technical efficiency estimates :

firm	year	eff.-est.
1	1	0.90771387E+00
2	1	0.81752571E+00
3	1	0.93458008E+00
4	1	0.82445946E+00
5	1	0.83530071E+00

6	1	0.92021044E+00
7	1	0.94386408E+00
8	1	0.76521725E+00
9	1	0.81706911E+00
10	1	0.85252669E+00
11	1	0.84716671E+00
12	1	0.81897444E+00
13	1	0.93378923E+00
14	1	0.88715443E+00
15	1	0.81617203E+00
16	1	0.91621900E+00
17	1	0.95259090E+00
18	1	0.89731797E+00
19	1	0.90327533E+00
20	1	0.89562399E+00
21	1	0.90934874E+00
22	1	0.89557420E+00
23	1	0.91856057E+00
24	1	0.88384710E+00
25	1	0.86817617E+00
26	1	0.92715400E+00
27	1	0.90278887E+00
28	1	0.87537229E+00
29	1	0.81679817E+00
30	1	0.89776778E+00
31	1	0.93708672E+00
32	1	0.86182448E+00
33	1	0.62449623E+00
34	1	0.78524512E+00
35	1	0.57823031E+00
36	1	0.78510606E+00
37	1	0.84296638E+00
38	1	0.61529259E+00
39	1	0.68570524E+00
40	1	0.93182546E+00
41	1	0.76302413E+00
42	1	0.89015849E+00
43	1	0.94773619E+00
44	1	0.92416327E+00
45	1	0.90483691E+00
46	1	0.81104315E+00
47	1	0.74465762E+00
48	1	0.64121324E+00
49	1	0.90842373E+00
50	1	0.90636318E+00

51	1	0.83653890E+00
52	1	0.90020538E+00
53	1	0.91912083E+00
54	1	0.73818977E+00
55	1	0.72894548E+00
56	1	0.90036230E+00
57	1	0.94661799E+00
58	1	0.91596224E+00
59	1	0.91765854E+00
60	1	0.93927786E+00
61	1	0.92915163E+00
62	1	0.91837321E+00
63	1	0.86754712E+00
64	1	0.80593785E+00
65	1	0.90083127E+00
66	1	0.87962885E+00
67	1	0.49532720E+00
68	1	0.89014474E+00
69	1	0.83079757E+00
70	1	0.86880653E+00
71	1	0.92158609E+00
72	1	0.92776791E+00
73	1	0.91823814E+00
74	1	0.94509034E+00
75	1	0.95795541E+00
76	1	0.91590648E+00
77	1	0.92213990E+00
78	1	0.73301539E+00
79	1	0.75917884E+00
80	1	0.81409009E+00
81	1	0.88846757E+00
82	1	0.69703909E+00
83	1	0.45619586E+00
84	1	0.89001302E+00
85	1	0.90531290E+00
86	1	0.84085881E+00
87	1	0.88823500E+00
88	1	0.80652726E+00
89	1	0.89326991E+00
90	1	0.87867130E+00
91	1	0.90704612E+00
92	1	0.93278033E+00
93	1	0.57097689E+00
94	1	0.92739964E+00
95	1	0.87057110E+00

96	1	0.77123546E+00
97	1	0.86306116E+00
98	1	0.86604282E+00
99	1	0.90501923E+00
100	1	0.93081598E+00
101	1	0.76862653E+00
102	1	0.88888373E+00
103	1	0.85588533E+00
104	1	0.93638847E+00
105	1	0.92915025E+00
106	1	0.23589971E+00
107	1	0.84659590E+00
108	1	0.89074952E+00
109	1	0.91057260E+00
110	1	0.91421507E+00
111	1	0.93275470E+00
112	1	0.82214175E+00
113	1	0.92476883E+00
114	1	0.87892153E+00
115	1	0.92599797E+00
116	1	0.92485334E+00
117	1	0.84756755E+00
118	1	0.91309708E+00

mean efficiency = 0.85129272E+00

Appendix 6 Output from the program FRONTIER (Version 4.1) for beneficiary farmers

```
Output from the program FRONTIER (Version 4.1c)
instruction file = god-ins.txt
data file =       god4.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        0.83048715E+01  0.18696394E+01  0.44419644E+01
  beta 1        0.41747937E-01  0.10671061E+00  0.39122572E+00
  beta 2        0.74034401E-02  0.55260776E-01  0.13397278E+00
  beta 3       -0.19644136E+00  0.18347168E+00 -0.10706904E+01
  beta 4        0.19912712E+00  0.42888083E+00  0.46429476E+00
  beta 5       -0.31228165E-01  0.79549361E-01 -0.39256336E+00
  sigma-squared  0.54644606E-01
log likelihood function =   0.43825695E+01
the estimates after the grid search were :
  beta 0        0.83427827E+01
  beta 1        0.41747937E-01
  beta 2        0.74034401E-02
  beta 3       -0.19644136E+00
  beta 4        0.19912712E+00
  beta 5       -0.31228165E-01
  delta 0       0.00000000E+00
  delta 1       0.00000000E+00
  delta 2       0.00000000E+00
  delta 3       0.00000000E+00
  sigma-squared  0.45152948E-01
  gamma         0.50000000E-01
iteration =     0  func evals =     20  llf =  0.43805707E+01
    0.83427827E+01 0.41747937E-01 0.74034401E-02-0.19644136E+00 0.19912712E+00
   -0.31228165E-01 0.00000000E+00 0.00000000E+00 0.00000000E+00 0.00000000E+00
    0.45152948E-01 0.50000000E-01
 gradient step
 iteration =     5  func evals =     47  llf =  0.45021670E+01
    0.83426497E+01 0.47359106E-01 0.83854849E-02-0.20039068E+00 0.19958699E+00
   -0.29541002E-01-0.45883193E-01-0.31359058E-01 0.26305819E-01 0.22221917E-01
    0.44969787E-01 0.56967356E-01
 iteration =    10  func evals =     64  llf =  0.46927776E+01
    0.83393777E+01 0.44803244E-01 0.20000883E-01-0.20196094E+00 0.20751349E+00
   -0.14187663E-01-0.24758291E+00-0.46191418E-02 0.36536812E-03 0.10983773E+00
    0.47043843E-01 0.22139578E+00
```

iteration = 15 func evals = 137 llf = 0.48568198E+01
0.86499228E+01 0.52954897E-01 0.10858829E-01-0.26038286E+00 0.19690442E+00
-0.15974499E-01-0.44901385E+00-0.77763025E-01-0.28741077E-01 0.16685134E+00
0.52223676E-01 0.27908938E+00
iteration = 20 func evals = 257 llf = 0.52714545E+01
0.90168491E+01 0.41889372E-01 0.12065951E-01-0.34941656E+00 0.23869759E+00
-0.16010613E-01-0.19237978E+01-0.10185016E+00-0.10744113E+00 0.60328543E+00
0.63318947E-01 0.39669710E+00
iteration = 22 func evals = 278 llf = 0.52734026E+01
0.90152262E+01 0.41752535E-01 0.12071803E-01-0.34976625E+00 0.23978282E+00
-0.15922078E-01-0.19292676E+01-0.10146231E+00-0.10757881E+00 0.60489073E+00
0.63323613E-01 0.39631013E+00
the final mle estimates are :

	coefficient	standard-error	t-ratio
beta 0	0.90152262E+01	0.11979504E+01	0.75255423E+01
beta 1	0.41752535E-01	0.10104615E+00	0.41320265E+00
beta 2	0.12071803E-01	0.47911417E-01	0.25196088E+00
beta 3	-0.34976625E+00	0.18478069E+00	-0.18928723E+01
beta 4	0.23978282E+00	0.37591357E+00	0.63786689E+00
beta 5	-0.15922078E-01	0.64093987E-01	-0.24841765E+00
delta 0	-0.19292676E+01	0.17655207E+01	-0.10927471E+01
delta 1	-0.10146231E+00	0.12579117E+00	-0.80659330E+00
delta 2	-0.10757881E+00	0.11737706E+00	-0.91652331E+00
delta 3	0.60489073E+00	0.52345261E+00	0.11555788E+01
sigma-squared	0.63323613E-01	0.16727175E-01	0.37856728E+01
gamma	0.39631013E+00	0.22785049E+00	0.17393429E+01

log likelihood function = 0.52734008E+01
LR test of the one-sided error = 0.17816625E+01
with number of restrictions = 5
[note that this statistic has a mixed chi-square distribution]
number of iterations = 22
(maximum number of iterations set at : 100)
number of cross-sections = 30
number of time periods = 1
total number of observations = 30
thus there are: 0 obsns not in the panel
covariance matrix :
0.14350851E+01 -0.16447624E-01 -0.12475908E-01 -0.84901319E-01 -0.21522379E+00
-0.32873946E-01 -0.34438373E+00 -0.42171932E-01 -0.49575301E-01 0.10951703E+00
0.84798683E-02 0.10007668E+00
-0.16447624E-01 0.10210324E-01 -0.64054187E-04 0.65300424E-02 -0.19385568E-01
0.20358460E-02 0.37460876E-01 -0.34462454E-02 0.26322858E-02 -0.11392474E-01
0.17209838E-04 0.42357607E-02
-0.12475908E-01 -0.64054187E-04 0.22955038E-02 0.86852849E-03 0.82382582E-03
0.78651668E-03 -0.45588087E-02 0.44464097E-03 -0.51121849E-03 0.18333954E-02

0.68168747E-04 0.27656573E-02
-0.84901319E-01 0.65300424E-02 0.86852849E-03 0.34143904E-01 -0.38553613E-01
0.34903710E-02 0.18436208E+00 -0.17711832E-02 0.12595538E-01 -0.56856275E-01
-0.66627609E-03 -0.25346668E-03
-0.21522379E+00 -0.19385568E-01 0.82382582E-03 -0.38553613E-01 0.14131101E+00
-0.21531767E-02 -0.21289826E+00 0.17246981E-01 -0.80635581E-02 0.64660342E-01
-0.12691993E-02 -0.32182976E-01
-0.32873946E-01 0.20358460E-02 0.78651668E-03 0.34903710E-02 -0.21531767E-02
0.41080392E-02 -0.14315953E-01 0.16639198E-02 -0.16185215E-03 0.43646668E-02
-0.21677933E-03 -0.66941241E-03
-0.34438373E+00 0.37460876E-01 -0.45588087E-02 0.18436208E+00 -0.21289826E+00
-0.14315953E-01 0.31170633E+01 -0.12000519E-01 0.13706828E+00 -0.91910384E+00
-0.18249619E-01 -0.13789973E+00
-0.42171932E-01 -0.34462454E-02 0.44464097E-03 -0.17711832E-02 0.17246981E-01
0.16639198E-02 -0.12000519E-01 0.15823418E-01 0.38574665E-03 0.32293087E-02
-0.84882740E-03 -0.14019451E-01
-0.49575301E-01 0.26322858E-02 -0.51121849E-03 0.12595538E-01 -0.80635581E-02
-0.16185215E-03 0.13706828E+00 0.38574665E-03 0.13777375E-01 -0.44137778E-01
-0.10446743E-02 -0.12123596E-01
0.10951703E+00 -0.11392474E-01 0.18333954E-02 -0.56856275E-01 0.64660342E-01
0.43646668E-02 -0.91910384E+00 0.32293087E-02 -0.44137778E-01 0.27400264E+00
0.52675997E-02 0.42595107E-01
0.84798683E-02 0.17209838E-04 0.68168747E-04 -0.66627609E-03 -0.12691993E-02
-0.21677933E-03 -0.18249619E-01 -0.84882740E-03 -0.10446743E-02 0.52675997E-02
0.27979839E-03 0.18882563E-02
0.10007668E+00 0.42357607E-02 0.27656573E-02 -0.25346668E-03 -0.32182976E-01
-0.66941241E-03 -0.13789973E+00 -0.14019451E-01 -0.12123596E-01 0.42595107E-01
0.18882563E-02 0.51915848E-01

technical efficiency estimates :

firm	year	eff.-est.
1	1	0.97630477E+00
2	1	0.92062528E+00
3	1	0.97736561E+00
4	1	0.98154854E+00
5	1	0.92646219E+00
6	1	0.95041815E+00
7	1	0.95996999E+00
8	1	0.97423209E+00
9	1	0.95865747E+00
10	1	0.67585507E+00
11	1	0.96077656E+00
12	1	0.94632930E+00
13	1	0.89340781E+00
14	1	0.94048356E+00
15	1	0.92109844E+00

16	1	0.95102715E+00
17	1	0.93396903E+00
18	1	0.95738130E+00
19	1	0.98059107E+00
20	1	0.91758657E+00
21	1	0.82852038E+00
22	1	0.97417068E+00
23	1	0.94303787E+00
24	1	0.95746973E+00
25	1	0.96334208E+00
26	1	0.92180922E+00
27	1	0.88885408E+00
28	1	0.76905381E+00
29	1	0.96470873E+00
30	1	0.93029522E+00

mean efficiency = 0.92817839E+00

Appendix 7 Output from the program FRONTIER (Version 4.1) for non-beneficiary farmers

```
Output from the program FRONTIER (Version 4.1c)
instruction file = god-ins.txt
data file =       god5.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        0.96678162E+01  0.11833943E+01  0.81695644E+01
  beta 1        0.12043130E+00  0.68943619E-01  0.17468085E+01
  beta 2       -0.50870762E-01  0.54167820E-01 -0.93913253E+00
  beta 3       -0.80616023E-01  0.79385641E-01 -0.10154988E+01
  beta 4       -0.48650657E+00  0.30087887E+00 -0.16169516E+01
  beta 5        0.14662451E-01  0.50300635E-01  0.29149634E+00
  sigma-squared  0.96049694E-01
log likelihood function =  -0.18672275E+02
the estimates after the grid search were :
  beta 0        0.10033018E+02
  beta 1        0.12043130E+00
  beta 2       -0.50870762E-01
  beta 3       -0.80616023E-01
  beta 4       -0.48650657E+00
  beta 5        0.14662451E-01
  delta 0       0.00000000E+00
  delta 1       0.00000000E+00
  delta 2       0.00000000E+00
  delta 3       0.00000000E+00
  sigma-squared  0.22287324E+00
  gamma         0.94000000E+00
iteration =     0  func evals =     20  llf = -0.13171320E+02
    0.10033018E+02 0.12043130E+00-0.50870762E-01-0.80616023E-01-0.48650657E+00
    0.14662451E-01 0.00000000E+00 0.00000000E+00 0.00000000E+00 0.00000000E+00
    0.22287324E+00 0.94000000E+00
 gradient step
 iteration =     5  func evals =     57  llf = -0.88649525E+01
    0.10041865E+02 0.85606983E-01 0.10932202E-01-0.10175277E+00-0.41313356E+00
   -0.40429207E-01 0.27137999E-01 0.34742412E-01 0.66167909E-01-0.14442086E+00
    0.28271136E+00 0.96330554E+00
 iteration =    10  func evals =     80  llf = -0.73928420E+01
    0.98580179E+01 0.62046566E-01 0.39903823E-03-0.11131914E+00-0.30201668E+00
   -0.44608639E-01 0.47326182E+00 0.18823620E+00 0.29169661E-01-0.23298381E+00
    0.23244434E+00 0.97081894E+00
```

```
 iteration =    15  func evals =    148  llf = -0.63840621E+01
    0.86005589E+01 0.70529607E-01 0.19174293E-01-0.11322343E+00 0.30184535E-01
   -0.39155229E-01 0.55492216E+00 0.11525796E+00 0.33482459E-02-0.24799611E+00
    0.26668958E+00 0.98672050E+00
 iteration =    20  func evals =    233  llf = -0.63821378E+01
    0.86126363E+01 0.70735121E-01 0.19485270E-01-0.11340421E+00 0.27153547E-01
   -0.39821137E-01 0.55396109E+00 0.11676489E+00 0.25059053E-02-0.25370736E+00
    0.27308607E+00 0.98690938E+00
 iteration =    22  func evals =    258  llf = -0.63821378E+01
    0.86127168E+01 0.70729557E-01 0.19482499E-01-0.11340352E+00 0.27138507E-01
   -0.39822040E-01 0.55396369E+00 0.11676844E+00 0.25121532E-02-0.25371039E+00
    0.27307299E+00 0.98690681E+00
the final mle estimates are :
                 coefficient     standard-error    t-ratio
  beta 0         0.86127168E+01  0.13149336E+01  0.65499251E+01
  beta 1         0.70729557E-01  0.48788178E-01  0.14497274E+01
  beta 2         0.19482499E-01  0.40576069E-01  0.48014751E+00
  beta 3        -0.11340352E+00  0.48381116E-01 -0.23439624E+01
  beta 4         0.27138507E-01  0.35302264E+00  0.76874693E-01
  beta 5        -0.39822040E-01  0.27512976E-01 -0.14473912E+01
  delta 0        0.55396369E+00  0.43117052E+00  0.12847903E+01
  delta 1        0.11676844E+00  0.16301879E+00  0.71628825E+00
  delta 2        0.25121532E-02  0.15610139E+00  0.16093087E-01
  delta 3       -0.25371039E+00  0.14754928E+00 -0.17194959E+01
  sigma-squared  0.27307299E+00  0.14956266E+00  0.18258099E+01
  gamma          0.98690681E+00  0.17095205E-01  0.57730037E+02
log likelihood function =  -0.63821378E+01
LR test of the one-sided error =   0.24580274E+02
with number of restrictions = 5
 [note that this statistic has a mixed chi-square distribution]
number of iterations =     22
(maximum number of iterations set at :   100)
number of cross-sections =     88
number of time periods =      1
total number of observations =     88
thus there are:      0  obsns not in the panel
covariance matrix :
  0.17290505E+01 -0.20131983E-01 -0.36377611E-01 -0.53945160E-02 -0.44259939E+00
  0.44541476E-02 -0.20911786E+00  0.28474434E-01  0.32680578E-01 -0.36808172E-01
  0.44366713E-01 -0.16184652E-01
 -0.20131983E-01  0.23802863E-02  0.36810435E-03  0.64680275E-03  0.18361938E-02
 -0.40581913E-03  0.25183432E-02 -0.16513422E-02 -0.61468647E-03  0.72432331E-03
 -0.72317031E-03  0.85956274E-04
 -0.36377611E-01  0.36810435E-03  0.16464174E-02 -0.49089186E-05  0.93090780E-02
 -0.22171435E-03  0.52742336E-02 -0.95222588E-03 -0.56248591E-03  0.10320181E-02
```

-0.12390791E-02 0.43759474E-03
-0.53945160E-02 0.64680275E-03 -0.49089186E-05 0.23407324E-02 -0.30299640E-02
 0.29304250E-03 -0.41142630E-03 -0.76810803E-03 0.51214510E-03 -0.16899663E-03
-0.17311281E-03 -0.13832834E-03
-0.44259939E+00 0.18361938E-02 0.93090780E-02 -0.30299640E-02 0.12462498E+00
-0.16734932E-02 0.56546244E-01 -0.46826270E-02 -0.95155523E-02 0.98861770E-02
-0.11441461E-01 0.45903920E-02
 0.44541476E-02 -0.40581913E-03 -0.22171435E-03 0.29304250E-03 -0.16734932E-02
 0.75696387E-03 -0.19767059E-02 0.14785714E-04 0.76666795E-03 -0.27317674E-04
 0.74812192E-05 -0.96238482E-04
-0.20911786E+00 0.25183432E-02 0.52742336E-02 -0.41142630E-03 0.56546244E-01
-0.19767059E-02 0.18590802E+00 -0.88738113E-02 -0.41726973E-01 -0.57456326E-02
-0.23828704E-01 0.16485292E-02
 0.28474434E-01 -0.16513422E-02 -0.95222588E-03 -0.76810803E-03 -0.46826270E-02
 0.14785714E-04 -0.88738113E-02 0.26575125E-01 -0.34677291E-02 -0.72778901E-02
 0.78478424E-02 -0.34713568E-04
 0.32680578E-01 -0.61468647E-03 -0.56248591E-03 0.51214510E-03 -0.95155523E-02
 0.76666795E-03 -0.41726973E-01 -0.34677291E-02 0.24367644E-01 -0.19874927E-02
 0.61681187E-03 -0.30449776E-03
-0.36808172E-01 0.72432331E-03 0.10320181E-02 -0.16899663E-03 0.98861770E-02
-0.27317674E-04 -0.57456326E-02 -0.72778901E-02 -0.19874927E-02 0.21770791E-01
-0.15790611E-01 0.39624199E-04
 0.44366713E-01 -0.72317031E-03 -0.12390791E-02 -0.17311281E-03 -0.11441461E-01
 0.74812192E-05 -0.23828704E-01 0.78478424E-02 0.61681187E-03 -0.15790611E-01
 0.22368989E-01 0.22669134E-03
-0.16184652E-01 0.85956274E-04 0.43759474E-03 -0.13832834E-03 0.45903920E-02
-0.96238482E-04 0.16485292E-02 -0.34713568E-04 -0.30449776E-03 0.39624199E-04
 0.22669134E-03 0.29224602E-03

technical efficiency estimates :

firm	year	eff.-est.
1	1	0.89573556E+00
2	1	0.59148995E+00
3	1	0.96499124E+00
4	1	0.59859569E+00
5	1	0.62880127E+00
6	1	0.97518665E+00
7	1	0.54245239E+00
8	1	0.59727482E+00
9	1	0.69876885E+00
10	1	0.61378919E+00
11	1	0.58689338E+00
12	1	0.76346053E+00
13	1	0.63399612E+00
14	1	0.92629452E+00
15	1	0.90447833E+00

16	1	0.82729874E+00
17	1	0.84130869E+00
18	1	0.88322033E+00
19	1	0.86121194E+00
20	1	0.92097411E+00
21	1	0.74545927E+00
22	1	0.69123858E+00
23	1	0.93213763E+00
24	1	0.86558097E+00
25	1	0.71347078E+00
26	1	0.60107915E+00
27	1	0.78434357E+00
28	1	0.72578901E+00
29	1	0.38689566E+00
30	1	0.57907474E+00
31	1	0.38312929E+00
32	1	0.60946509E+00
33	1	0.69190525E+00
34	1	0.39881542E+00
35	1	0.48049427E+00
36	1	0.51778470E+00
37	1	0.79843580E+00
38	1	0.94841354E+00
39	1	0.85161388E+00
40	1	0.57106353E+00
41	1	0.61511651E+00
42	1	0.49164108E+00
43	1	0.84919301E+00
44	1	0.91846614E+00
45	1	0.63675722E+00
46	1	0.88824792E+00
47	1	0.90784485E+00
48	1	0.50644669E+00
49	1	0.52074127E+00
50	1	0.87621820E+00
51	1	0.94801988E+00
52	1	0.95015220E+00
53	1	0.90442108E+00
54	1	0.64978485E+00
55	1	0.57043507E+00
56	1	0.81342079E+00
57	1	0.35648516E+00
58	1	0.86261419E+00
59	1	0.67505989E+00
60	1	0.86943813E+00

61	1	0.88885740E+00
62	1	0.53039087E+00
63	1	0.53204472E+00
64	1	0.61964069E+00
65	1	0.47980714E+00
66	1	0.38166240E+00
67	1	0.89231454E+00
68	1	0.69190340E+00
69	1	0.74772605E+00
70	1	0.38272540E+00
71	1	0.81589049E+00
72	1	0.51800582E+00
73	1	0.66049942E+00
74	1	0.88498636E+00
75	1	0.95454378E+00
76	1	0.60263982E+00
77	1	0.65491860E+00
78	1	0.17515255E+00
79	1	0.66534924E+00
80	1	0.85811659E+00
81	1	0.85752537E+00
82	1	0.94047872E+00
83	1	0.96269710E+00
84	1	0.58655494E+00
85	1	0.76915870E+00
86	1	0.93945210E+00
87	1	0.68464028E+00
88	1	0.85596044E+00

mean efficiency = 0.71450636E+00

Appendix 8 Steps for Frontier Calculation

Step-1 to create excel file and change log for each variable

to save this file in the form of text file (Text-MS-DOS)

Step-2 to create output file

save as – change file name and delete the output result and save this file

Step-3 to create instruction file (don’t forget to change excel file name and output file name) and save this file

Step-4 to run the data

to type – (1) frontier__ enter

(2) instruction file name __enter and to open output file

The End

Appendix 9 Good Agricultural Practices for producing over 100 baskets per acre (over 5 ton ha^{-1}) of Paddy

1. Raising healthy rice seedling with raised bed

2. Practice of sparse seedling

3. Covering pre-germinated seeds with well decomposed manure to protect from rain splash

4. Providing systematic care in the nursery

5. Transplant the seedling immediately after removal from nursery

6. Plant seedling no deeper than one and half inches

7. Plant 1 to 2 seedling per hill

8. Ensuring maximum effective number of tillers through alternate wetting and drying

9. Ensuring population density of 120,000 to 150,000 hills per acre

10. Continuous supply of irrigation water

11. Application of balanced inputs

12. Controlling weeds and non-effective tillers by submerging in irrigation water

13. Timely drainage for the ease of harvesting by manual labor or combine harvester

14. Minimizing crop losses at the time of harvest