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An Analysis on the Efficiency of Glutinous Rice Production in Different Cropping Systems: The Case of Rainfed Area in Northeast Thailand

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ABSTRACT

Productive efficiency is the index that measures production ability of a farm and determines the difference of rice production in different production environments. This study of glutinous rice production in different cropping systems measures the efficiency of glutinous rice production in three different cropping systems namely Rice monoculture (Rice-follow), Rice-sweet corn and Rice-peanut. Stochastic Frontier Production Model was applied for technical efficiency measurement. The data used were collected from farmer's grow RD6 Rice in Roi-Et province, 30 farmer households for each system, totaling 90 households. Purposive sampling is the method used in selecting the sample. The results of the estimation of Cobb-Douglas Production Function show that fertilizers and seeds are important factors affecting the change in the glutinous rice production. As for the return to scale, it is found that glutinous rice production exhibits decreasing returns to scale while the technical efficiency level analysis of three different types of farmer has not significantly difference. However, farmers who also grow rotating crops have higher agricultural net income than mono-culture rice cultivation and the income proportion of the agricultural sector affects the improvement of farm production efficiency in the rainfed area. Hence, relevant organizations should encourage rotating crop cultivation system to further improve income and living standard of farmers.

Key words: Production efficiency, technical efficiency, cropping system, rice production, glutinous rice

INTRODUCTION

Glutinous rice has been an important life crop for Thai people for a long time. Apart from consumption, glutinous rice is deeply associated with Thai culture and tradition. It is also important in terms of food security for farmer households especially small farm holders in the Northeast. The area for growing glutinous rice in Thailand is approximately 14 million Rai. Approximately 80% of the area for growing glutinous rice in Thailand is in the Northeast (Kongritti, 2009). Despite huge effort on the part of research work and the government, glutinous rice production in Thailand has not been increase according to the genetic potential of varieties. Average glutinous rice yield is much below than potential output, especially in the Northeast region. It has been found that the average glutinous rice yield is 2,012.5 kilograms per hectare while the country's is 2,293.75 kg ha^{-1} (OAE, 2011).

There are number of factors contributing to this yield gap. This is also due to problems regarding soil quality, inappropriate use of input factors and the fact that rainfall is the main factor in the cultivation. Studies have shown that Thai farmers had been producing rice below the ultimate potential output (Patmasiriwat and Isvilanonda, 1990; Sriboonchitta and Wiboonpongs, 2000, 2004; Pochatan, 2005; Songsrirod and Singhapreecha, 2007; Srisompun and Isvilanonda, 2012). The findings suggest there is scope to increase their production efficiency. Increasing average rice yield under the present technology could be achieved by improving the socio-economic characteristics and production management of farmers. In other words, technical efficiency of rice production can be increased by improvements in farmer characteristics, farm characteristics, environmental condition and agricultural practices (Songsrirod and Singhapreecha, 2007).

Monitoring crop cultivation system and rice output from the past shows that mono-culture rice cultivation or rice-rice cultivation for a long time results in inefficient use of soil especially in dry seasons as there is not enough water for crops. The system set up for growing crops during the intermediate phase between late wet season and early winter is therefore very important. This is because the moisture in the soil is enough for another type of crop to grow (Pookpakdi, 1998; Ali *et al.*, 2012). Growing rotating crops is therefore needed to increase income for farmers in rainfed area during dry season. This also shows one of the ways to optimise benefits from the land efficiently (Boonngern *et al.*, 2011; Suprama *et al.*, 2011).

From the above points, it can be seen that systemising crop cultivation is necessary in improving productive efficiency under existing resources that one or the community possesses (Bor-Ngern, 2006). Farmers can start by themselves or learn from their farmer friends who have used appropriate factors of production and production systems and have not waited for external help. Thus, this study aims to comparatively analyse the use of input factors and the efficiency of the use of such input factors in a mono-culture farm and the appropriate combination of glutinous rice growing and other economic crops systems in rainfed area. The study also includes the analysis of factors that affect the productive efficiency level of farmers in the area. In order to be able to come up with a way to develop productive efficiency and increase income for farmers, we also need to know the efficiency by comparing production environments and appropriate production systems. Results from the study are important for farmers and relevant organisations in deciding the system for growing rice and appropriate production plans which will enhance productive efficiency, improve income and establish sustainability for rice farmers.

MATERIALS AND METHODS

Study area and data collection: The study collected data from farmers who grow glutinous rice in rainfed area of Roi Et which is in the Northeast of Thailand. The data used is from January to December, 2012. The data includes that of farmers who grow glutinous rice in three different systems namely glutinous rice monoculture, rice-sweet corn and rice-peanut. All farmers grow RD6 glutinous rice which is the most popular type of glutinous rice grown in Thailand. The sample was selected through purposive sampling. Details of the selection process are as follows:

Step 1: Select the district with the largest area that grows glutinous rice in Roi Et which is Phon Thong District (Amphoe Phon Thong)

Step 2: Select the sub-district (Tambon) with areas that have at least 3 different cropping systems for glutinous rice which is Tambon Wang Samran

Step 3: Conduct purposive sampling for farmers in 3 different cropping systems for glutinous rice namely rice mono-culture, rice-sweet corn and rice-peanut. Thirty samples are selected from each system (Fig. 1)

Step 4: Collect data using questionnaires featuring details in the production process, management and the use of labour in each production activity, expenses spent in buying input factors, outputs and returns as well as production problems. Then, the data will be analysed with regards to factors that affect the productive efficiency of glutinous rice production in different cropping systems. Details are elaborated in the next section

Analytical framework: Productive efficiency measure is important in evaluating the capacity or productive efficiency of the production unit. It allows us to know the state of the production unit. If it is not healthy, we will be able to cure it. Hence productive efficiency of a production unit refers to the comparison between the actual outcome that a production unit can produce and the highest outcome estimated for production unit under certain factors of production and technology. Efficiency measure is said to be an important tool and is very beneficial in comparing capacity of a production unit whether it is relevant to producers, businesses, agencies or various organizations. Efficiency measure helps us to point out any inefficiency and correct them. Total Economic Efficiency (EE) includes two main components; Technical Efficiency (TE) which means the ability of the production unit to increase its output under the same amount of resources and Allocative Efficiency (AE) which means the ability of the production unit in using appropriate proportion of input factors under conditions of existing price levels of input factors (Farrell, 1957).

Technical Efficiency is the ability of the production unit to improve production techniques in order to increase output using the same factors of production or reduced input factors resulting in the same amount of output. It may also mean the development of productive efficiency level under existing technology using the same amount of input factors but changing the way of input factors are used. Changes may involve features and specific properties of each farmer as well as the production's management systemusing the principle of technical efficiency and farm management.

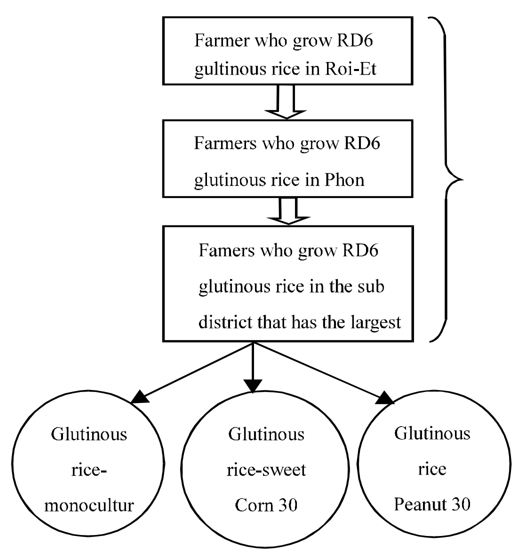

Fig. 1: Sampling technique in study area

Technical efficiency measure presented by Farrell (1957) is the comparative measure of productive efficiency for production unit through the evaluation of Frontier equation in order to calculate output using highest possible comparison of interested production units. Then results will be compared to outputs that we estimated in terms of the distance from the highest point on the boundary line. Hence this study will evaluate the technical efficiency of the use of input factors as one can tell differences between efficiencies with regards to production environments, the use of factors of production and different management production systems of farmers.

The evaluation of the efficiency regarding the use of input factors uses Stochastic Production Frontier Model (Meeusen and van den Broeck, 1977; Aigner *et al.*, 1977; Battese and Corra, 1977). Error term is distributed with half-normal distribution. This reflects the inefficiencies of farmers. Such model can be shown in Eq. 1:

$$Y_i = f(x_i, \beta) \exp\exp(V_i + U_i), i \quad = 1.2.3, ..., N \tag{1}$$

where, Y_i is output of farmers in ith order, f (.) is the appropriate production function. In this model, it is a Cobb-Douglas production function, x_i is the vector of the amount of input factors for farmer in ith order, $\boldsymbol{\beta}$ is the vector of the parameter that needs to be estimated, V_i is the error resulting from uncontrollable factors such as natural disaster and changeable climate and U_i is the value of farmers' inefficiencies.

After the model is estimated using Maximum likelihood technique, one can calculate technical inefficiency and technical efficiency of farmers in each income group. Methods used in this estimation can be further studied by Kumbhakar and Lovell (2000).

As for the equation format for Stochastic Production Frontier Model that is used in this study, Cobb-Douglas production function is selected because it is easy to estimate values. Estimation can be done by changing it into a linear equation in Logarithmic terms. Coefficients of independent variables in the Cobb-Douglas equation show the elasticity of output to each factor of production. Moreover, the sum of coefficients (elasticity) of independent variables also shows the returns to scale. This is beneficial in deciding whether to expand the production and in adjusting the proportion of the use of factors of production for the highest efficiency. Details are as in Eq. 2:

$$\text{In}Y_i = \beta_0 + \beta_1 \text{InIn}(SEED_i) + \beta_2 \text{InIn}(FERT_i) + \beta_3 \text{InIn}(LAB_i) \beta_4 \text{InIn}(MACH_i) + \beta_5 CS_{1i} + \beta_6 CS_{2i} + V_i + U_i \tag{2}$$

From Eq. 2, the dependent variable is the glutinous rice output of each farmer (Y_i: kg per Rai). Independent variables are the number of seeds ($SEED_i$: Kilograms per Rai), the amount of chemical fertilizers used ($FERT_i$: kg per Rai), labour use (LAB_i: hours per Rai), machine hours ($MACH_i$: hours per Rai) and a Dummy Variable which reflects other two cropping systems namely rice-sweet corn and rice-peanut (CS_1 and CS_2).

After Eq. 2 is estimated using Maximum likelihood technique, technical efficiency for each farmer will result. These results can be compared and calculated for average efficiency level for farmers in each cropping system.

In the last step, productive efficiency levels from Eq. 2 will be analysed in terms of factors that influence changes in the said efficiency levels through calculations of variable relations through Simple Linear Regression Model using Least Square Method. Factors considered include age of the household leader (AGE), education level of the household leader (EDU), agricultural experience of the household leader (EXP), proportion of hired labour to total labour (RLAB), proportion of machines to total labour (RMACH), rice planting technique (PTEC); PTEC = 0 for broadcasting technique and PTEC = 1 for transplanting technique, stubble burning before ploughing (STB), farm size of glutinous rice area (SIZE) and the proportion of agricultural income of a household (RFINC). Details of these are shown in Eq. 3:

$$TE_i = \beta_0 + \beta_1 AGE_i + \beta_2 EDU_i + \beta_3 EXP_i + \beta_4 RLAB_i + \beta_5 RMACH_i + \beta_6 PTEC_i + \beta_7 STB_i + \beta_8 SIZE_i + \beta_9 RFIC_i \quad (3)$$

RESULTS AND DISCUSSION

The analysis of glutinous rice production equation using Stochastic Production Frontier Model in Eq. 2 using Maximum Likelihood Technique gives the estimation as stated in Eq. 4:

$$\underset{(27.64)}{\ln Y_i = 5.5} + \underset{(2.39)}{0.13 \ln SEED^{**}} + \underset{(2.29)}{0.12 \ln FERT^{**}} + \underset{(0.27)}{0.018 \ln LAB} + \underset{(0.29)}{0.014 \ln MACH} + \underset{(1.53)}{0.13 CS_1} + \underset{(-0.45)}{0.46 CS_2} \quad (4)$$

where, **means statistical significance at the confidence level of 95%, Log likelihood = -21.71, values in parenthesis refer to t-statistic.

From Eq. 4, it has been shown that of the six estimated parameters, two were found to be statistically significant in the Cobb-Douglas Model. Seeds and chemical fertilizers are factors that affect glutinous rice output the most in this study. With regards to the dummy variable which reflects different cropping systems, it has been found that rice-sweet corn is positively correlated to output that is farmers in this type of cropping system receive higher output than that of rice-monoculture while it is quite the opposite for rice-peanut. For rice-peanut, the output is lower than that of rice-monoculture. However, as parameters of the two variables are not statistically significant, one has to consider in conjunction with technical efficiency of glutinous-rice growing technical efficiency level of glutinous rice cultivation in each cropping system which will be explained in more detail.

When considering returns to scale of rice cultivation in rainfed area, it has been found that the sum of coefficients of the estimate is 0.253. This means glutinous rice cultivation in rainfed area exhibits decreasing returns to scale. This means that the increase in factors of production by 1% results in the increase in output of 0.253% only. This conforms to the study on previous returns of glutinous rice cultivation in Thailand (Songsrirod and Singhapreecha, 2007; Pochatan, 2005; Srisompun and Isvilanonda, 2012).

Once the estimation in Eq. 4 is calculated to find technical efficiency level of glutinous rice cultivation, it is found that farmers in the studied area still have low technical efficiency. Technical efficiency level for glutinous rice cultivation equals to 0.7163 or 71.63%. This means that under the current resources and technology, farmers in the area are producing 28.37% lower than their highest potentials. Farmers can increase their productive efficiency level through an improvement in particular economic, social and productive management characteristics in the plantation. From the comparison of productive efficiencies of glutinous rice production in 3 different cropping systems, it has been found that average technical efficiency levels of farmers in each system are not very different. Average technical efficiency level for farmers in rice-monoculture cropping system is 72.25% while that for rice-sweet corn and rice-peanut systems are 71.93 and 70.79%, respectively. Even though the average output of glutinous rice in the rice-sweet corn system is the highest at 487 kg per Rai, the technical efficiency level of glutinous rice cultivation is not very different from that of farmers that grow glutinous rice in other different cropping systems. The main reason why rice cultivation efficiencies are not so different in each system is likely to be that farmers do not really consider the amount of fertilizers left in the soil in the period of dry-season crop cultivation. During such period, one should reduce the use of fertilizers in rice cultivation. Even though, farmers still use fertilisers and other factors of production just like in rice-monoculture cultivation. When farmers are divided into 3 groups according to their technical productive efficiency level which are high (more than 0.80 or 80%), medium (0.50-0.80 or 50-80%) and low (below 0.50 or 50%), it has been found that around 12% of farmers have low technical efficiency level. Of that, 5 from 11 household are farmers who grow rice in rice-monoculture system whereas most farmers of around 48% in every system have medium technical efficiency level and 40% are in high efficiency level (Table 1).

Although, the comparison of glutinous rice productive efficiencies for each system is not so different, the comparison of agricultural income of households finds that farmers who grow rice in rice-sweet corn and rice-peanut systems have higher income than those who grow rice in rice-monoculture system. The study of income of farmer households in rice-sweet corn system has found that the highest household income from agricultural sector is 48,657 baht per household per year. Coming second is the rice-peanut system with the income of 32,318 baht per household per year whereas, rice-monoculture comes last with 29,553 baht per household per year. The analysis on the difference of income from agricultural sector in rotating systems and glutinous rice-monoculture has shown that there is a statistically significant difference at the confidence level of 95%. Households that grow in rotating systems have higher income than those using a monoculture system.

The result from the estimation of Eq. 3 which studies factors that affect the change in technical efficiency level through the use of Simple Linear Regression Model using Ordinary Least Square method is as stated in Eq. 5:

$$\begin{aligned} TE = 0.43 + 0.01AGE + 0.03EDU + 0.01EXP + 0.19RLAB^{**} + 0.04RMACH + 0.09PTEC^{*} \\ + 0.05STB - 0.01SIZE^{*} + 0.09RFIC^{*} \end{aligned} \tag{5}$$

Where, *,**mean statistical significance at the confidence levels of 90 and 95%, respectively.

The first group concerns characteristics of household leaders. Normally, age reflects agricultural experience of the household leader. This is because, in Thailand, most farmers start growing rice

Table 1: Technical efficiency level and income from glutinous rice cultivation for each cropping system

Cropping system	Rice monoculture	Rice-sweet corn	Rice-peanut	Total
Low efficiency level (below 0.50 or 50%)	5	3	3	11(12 %)
Medium efficiency level (0.50-0.80 or 50-80%)	12	15	6	43 (48%)
High efficiency level (more than 0.80 or 80%)	13	12	11	36 (40%)
Total	30	30	30	90 (100%)
Average efficiency level (%)	72.25	71.93	70.79	71.63
Agricultural income (Baht per household per year)	29,553	48,657	32,318	36,843

after they are graduated from the compulsory education (Grade 4 or Grade 6). Hence older farmers have more experience in terms of rice cultivation. The result from the estimation of the correlation of the said factor and technical efficiency level shows that there is a positive correlation. This means that more rice cultivation experience results in higher technical efficiency level in terms of glutinous rice cultivation. However this has no clear proof yet as the coefficient of such variable has no statistical significance at the confidence level of 90%.

The second group concerns the physical qualities of the farm as farmers have changed their ways of rice cultivation a lot. In the past, human labour in the household formed the main part of labour work. At present, hired labour is used in almost every activity of the production. More farmers have changed their status from 'farmer' to 'rice field manager'. Hence hired labour is an important factor that influences the change in productive efficiency level of glutinous rice cultivation of farmers. This reasoning comes from the coefficient of RLAB in Eq. 5 which is the positive value of 0.19 and has the statistical significance at the confidence level of 95%. Also, nowadays, Thai farmers are entering into a society of the elderly and the average age of farmers is 54 year-old and is increasing (Butso and Isvilanonda, 2010). Young labourers are moving from agricultural sector to industrial and service sectors with high income and stability. Hence there are more hired labourers working in paddy fields than labourers from households. With regards to cultivation size, it has been found that the coefficient for farm size variable is -0.01. This means that farmers in larger cultivated area have a tendency to have lower efficiency level. This contradicts the previous study which found that farm size is not affects the change in efficiency level (Pitipunya, 1995). Some studies state that larger farms have a tendency to have higher efficiency than small farms (Srisompun and Isvilanonda, 2012). The last variable in this group is the proportion of machine labour. It has been found that the result of the analysis of the coefficient has not statistical significance. Hence the proportion of machine labour cannot explain the change of technical efficiency level of glutinous rice cultivation.

The third group concerns the variable of glutinous rice cultivation plan. In this group, glutinous rice cultivation method is the variable that can explain the change in technical efficiency level for glutinous rice cultivation. Farmers who use transplanting technique have a tendency to have higher efficiency level than farmers who use broadcasting technique and stubble burning before ploughing correlate in the same way as the change in efficiency level yet there is no statistical significance from this variable. The financial status of the farm is the variable that correlates to the change in technical efficiency level at the confidence level of 90%. It has the coefficient of 0.09. This means that the increase in the proportion of household income in the agricultural sector for 1 unit will cause the technical efficiency level of glutinous rice cultivation to increase by 0.09 units. Hence, households with higher proportion from the agricultural sector have the tendency to have higher efficiency level than other farms. Thus, there is an indirect influence which can be said that the cultivation using rotating crop system with higher income from the agricultural sector is an important factor that can result in higher technical efficiency level for farmers.

CONCLUSIONS

This study has shown that farmers who grow glutinous rice in rainfed area in Thailand still have low technical productive efficiency. This means that they can produce lower than their highest potential level. The result of the study from the production equation has found that fertilizers and seeds are important factors in the change of glutinous rice output in the studied area. Moreover the analysis of the sum of the coefficient of input factors also states that the production of glutinous rice exhibits decreasing returns to scale. The comparison of glutinous rice productive efficiency level in each system has found that the average efficiency level is 0.7163% or the inefficiency level is 28.37%. Technical efficiency level of glutinous rice cultivation for each level is not very different yet farmers who grow rice in rotating crop systems have higher net income from the agricultural sector than rice-monoculture. This conforms to the result from the correlation analysis of the proportion of income from the agricultural sector and the technical efficiency level which has found that farmers who have increasing proportion of income from agricultural sector tend to have increasing technical efficiency level in glutinous rice production. This study thus suggests that even though the rotating cropping system does not result in a difference in technical efficiency level of glutinous rice production, it results in farmers having higher net income for the farm than that of glutinous rice-monoculture. Hence rotating cropping system is crucial for the improvement of income of farmer households in rainfed area. Relevant organizations should encourage planning for rotating cropping system in order to improve income and living standard of households in the agricultural sector in the rainfed area.

Furthermore, the analyses on the correlation of technical efficiency level and farmer characteristics as well as 5 groups of production plan show that apart from the income proportion from households, factors which influence the change in efficiency level include the farm size, planting technique and the proportion of hired labour. They affect the change in technical efficiency score to the higher degree. This shows that households with higher proportion of hired labour than household labour have a tendency to have higher efficiency level than those with only household labourers. This can be used to nicely explain the state of old-age agricultural labourers and the deficiency of young labourers. This is because most household labourers are the elderly. Hence technological development that saves human labour is now needed for the rice production sector.

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