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A Nonparametric Approach to Evaluate Technical Efficiency of Rice Farms in Central Thailand

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Abstract

Rice is an important strategic crop for Thai farmers whose rice production has been increasing from the expansion of planted area and not from the average yield per acreage. This study aims to investigate technical efficiency of rice farms in Central Thailand where the highest rice output per acreage has been achieved and rice could be grown twice a year. Technical Efficiency was evaluated by using the nonparametric approach, the Data Envelopment Analysis Approach (DEA) on 400 rice farms in crop year 2009/2010. Tobit regression model employed in this study provides the results on factors affecting technical inefficiency. The results show that the average technical efficiency was 51.86 percent. The estimated technical efficiencies of the farmers ranged between 0.30 percent and 100 percent. This indicates that most farms are likely to be operating at lower level of technical efficiency. The finding reveals that there is a positive relationship between farm efficiency and family labor, extension officer's service, certified seed use and pest control on weedy rice and insect.

Keywords: Technical Efficiency, Rice Farms, Data Envelopment Analysis (DEA), Tobit Model

Introduction

Rice is an important commodity of Thai agricultural sector as it generated income worth USD 5.54 billion in 2009 while approximately 3.71 million households are involved in rice production (Office of Agricultural Economics 2010). At the same time, Thailand is the world's largest rice exporter country with 9.7 million metric ton in 2010, followed with Vietnam, United States, Pakistan and India respectively (USDA 2010).

The increment of rice production results from the acreage expansion and number of planting time per year but not from the average yield harvested per acreage. Until the last few years, the rice's planted area decreased by 0.60 percent from 11.23 million hectare in 2007 to 11.10 million hectare in 2009. The planted area for other crops such as rubber, cassava, corn and palm oil also have been increasing at 5.92, 6.43, 4.39 and 8.91 percent, respectively (Office of Agricultural Economics 2010). These have caused concerns about Thai rice production in the future. The average yield per acreage is another concern in Thai rice production. Either in each region or as a whole country, rice yield in Thailand is still lower in comparison to the capacity of each rice varieties and also to the other producing countries.

The main objective of this study is to investigate technical efficiency, and factors affecting technical inefficiency of paddy farmers in the Central region of Thailand. To measure technical efficiency scores at farm level, the DEA approach is employed whereas Tobit regression model employed in this study provides the results on determination of technical inefficiency.

This paper is divided into four parts. Following this introduction, the Theoretical framework is described. Next, data and the variables used in this analysis are presented and following with Results and discussions, and Conclusions in the end of this paper.

Theoretical Framework

The beginning of efficiency measurement started with Farrell's work (1957) in which was drawn upon the work of Debreu (1951) and Koopman (1951) to define a simple measurement of firm efficiency. Farrell demonstrated this concept by an example involving firms which produce a single output (y) with two inputs (x_1 and x_2) under the assumption of constant returns to scale.

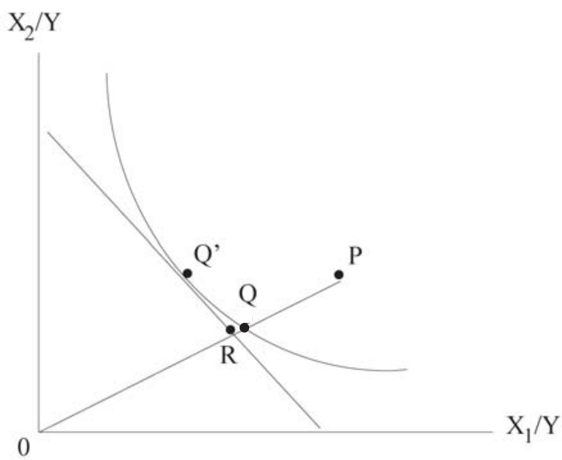
According to Farrell (1957)'s ideas, the efficiency of a firm consists of two components: *Technical efficiency* (TE) and *Allocative efficiency* (AE). These two measures are then combined to provide a measure of total *economic efficiency*. Technical efficiency reflects the ability of a firm to obtain maximal output from a given set of inputs, while allocative efficiency reflects the ability of a firm to use the inputs in optimal proportions, given their respective prices and the production

technology (Coelli, Rao and Battese 1998).
The technical efficiency (TE) of a firm is most commonly measured by the ratio of

$$TE_i = OQ/OP \qquad (0 \leq TE_i \leq 1)$$

which is equal to one minus QP/OP (Figure 1). It provides an indicator of the degree of technical inefficiency of the firm and will take a value between zero and one. A value of one indicates the firm is fully technical efficiency.

Figure 1: Technical Efficiency Measurement



Source: Coelli et al., 1998

To measure technical efficiency, there are several techniques, which can be applied namely; 1) Parametric approaches and 2) Nonparametric approaches. The most frequently used approaches are Stochastic Frontier Analysis (SFA) for Parametric approaches and Data Envelopment Analysis (DEA) for Nonparametric approaches.

Data Envelopment Analysis (DEA) involves the use of linear programming methods, which was first used by Charnes, Cooper and Rhodes (1978) under the constant returns to scale assumption (CRS). Because of limitation on this assumption in which a firm operates at an optimal scale, Banker, Charnes and Cooper (1984) proposed the alternative model; variable returns to scale (VRS) which is properly adopted when the firms face with imperfect competition or constraint in the production and cannot operate their firms at optimal scale.

The basic concept of DEA model is to measure the efficiency of a Decision Making Unit (DMU) relative to similar DMUs in order to estimate a “best practice” frontier. DMU refers to any entity that is to be evaluated in terms of its abilities to convert multiple inputs into output. Assume that there are *N* DMUs to be evaluated, each DMU consumes varying amount of *m* different inputs to produce output. The DEA model, as introduced by Charnes, Cooper and Rhodes (1978), the ratio of output to input is used to measure the relative efficiency of the $DMU_j = DMU_0$ to be evaluated relative to the ratios of all for the DMU_j; j = 1, 2, …N as following:

$$\text{Max } h_i(u,v) = \frac{\sum_{r=1}^{s}(u'y_i)}{\sum_{n=1}^{m}(v'x_i)}$$

$$\text{subject to } \frac{\sum_{r=1}^{s}(u'y_j)}{\sum_{n=1}^{m}(v'x_j)} \leq 1 \qquad j = 1, 2, \ldots N$$

$$u, v \geq 0$$

where
y = the amount of output from the i^{th} DMU
u = the weight of that output
x = the amount of input from the i^{th} DMU
v = the weight of that input
r = the number of output = 1
n = the number of inputs = 1, 2,…,N

In this study, the computer software DEAP version 2.1 by Coelli (1996) was used for technical efficiency measurement. The second step of this study is to identify the factors affecting technical inefficiency by using Tobit regression model.

Data and Variables

The data used in this study was collected by interviewing 400 farmers in the 9 provinces of Central Region of Thailand namely Bangkok, Chainat, Nonthaburi, Pathumthani, Phra Nakorn Si Ayutthaya, Lopburi, Saraburi, Singburi and Angthong for the crop year 2009/2010.

Two sets of variables were collected for this study; 1) the set of input variables for analyzing level of technical efficiency by DEA approach and 2) the set of Demographic, Socio-economic variables and farm characteristics, Agricultural Extension and Environmental variables for analyzing the factors affecting technical inefficiency as shown in Table 1.

Table 1: List of Variables Used in the Study

Variables	Description and Measurement
Production Variables	
1) Output *Y*	Total rice yield (kg/ha)
2) X_1	Total amount of seed used (kg/ha)
3) X_2	Total amount of fertilizer used (kg/ha)
4) X_3	Total amount of pesticide used (ml/ha)
5) X_4	Total amount of fuel used (liters/ha)
6) X_5	Contractors' cost (USD/ha)
Inefficiency Effect	
- *Demographic Variables and Farm Characteristics*	
1) GEND	Gender *(Male = 1, Female = 0)*
2) EDU	Educational Level of Farmers *(Primary school = 1, Otherwise = 0)*
3) EXP	Farming Experience (*year*)
4) FAMM	No. of Family Member *(person)*
5) FAML	No. of Family Labor *(person)*
6) FSIZE	Farm Size *(hectares)*
7) TENS	Land Tenure *(Rental land = 1, Otherwise = 0)*
8) FUND	Source of Fund *(Loan = 1, Otherwise = 0)*
- *Agricultural Extension Variables*	
1) AGMEM	Member of Agricultural Organization *(Yes = 1, No = 0)*
2) AGVOL	Agricultural Volunteer *(Yes = 1, No = 0)*
3) VISIT	Visit from Extension Officers *(Once a month = 1, Otherwise = 0)*
4) ATTFST	Attendance in Food Safety Training Project *(Yes = 1, No = 0)*
5) ATTIPM	Attendance in IPM Training Project *(Yes = 1, No = 0)*
6) GAP	GAP Certificate *(Yes = 1, No = 0)*
7) BPT	Farm Visit as Best Practice *(Yes = 1, No = 0)*
8) MEDIA	Communication Channels in Extension Services *(By officer = 1, Otherwise = 0)*
9) OFFVAR	Use of Certified Seed *(Yes = 1, No = 0)*
- *Environmental Variables*	
1) BURN	Burning Rice Straw *(No = 1, Otherwise = 0)*
2) SOILT	Test of Soil Condition *(Good condition = 1, Otherwise = 0)*
3) COLDW	Pre-harvest Cold Weather *(No = 1, Otherwise = 0)*
4) WDYRICE	Weedy Rice Infestation *(No = 1, Otherwise = 0)*
5) GENWD	General Weed Infestation *(No = 1, Otherwise = 0)*
6) INSECT	Insect Infestation *(No = 1, Otherwise = 0)*
7) SNAIL	Golden Apple Snail Infestation *(No = 1, Otherwise = 0)*
8) RAT	Rat Infestation *(No = 1, Otherwise = 0)*
9) LEAFB	Leaf Blast Infestation *(No = 1, Otherwise = 0)*
10) PPATH	Plant Disease Infestation *(No = 1, Otherwise = 0)*

Results and Discussions

The first step of the analysis is to measure the technical efficiency scores and then the second step is to explore the factors influencing technical inefficiency.

Demographic and Farm Characteristics

Table 2 presents the demographic and farm characteristics of sampled farmers. Age of farmers averages at 51 years old, with the maximum age at 75 years old and minimum at 26 years old. Most of farmers are less than 60 years old and only 18.70 percent of farmers are above 60 years old. They have farming experiences about 30 years. Of 49 percent, they have farming experience more than 30 years, followed by 22.70 percent of farmers having farm experience between 20-30 years, 17.30 percent of farmers having farm experience between 10-20 years and 11 percent of farmers having farm experience less than 10 years. The farm households have about 4 persons, with only 2 persons who work in their farms. About 76.70 percent are male, who graduated from primary school (74.50 percent). However, about 21.30 percent attended secondary school while 4.20 percent graduated with diploma.

Table 2: Descriptive Statistics for Demographic and Farm Characteristics of Sampled Farms

Variables	Percentage	Mean	Maximum	Minimum	Standard Deviation
Demographic Variables					
Age		50.90	75	26	9.39
Farming experience		30.40	63	1	13.47
Family member		4.42	8	1	1.26
Family labor		2.07	4	1	0.74
Gender					
1) Male	76.70%				
2) Female	23.30%				
Educational level					
1) Primary school	74.50%				
2) Secondary school	21.30%				
3) Diploma	4.20%				
Farm Characteristics					
Farm Size (*ha*)		4.76	23.68	0.80	2.77
No. of Planting time (*per year*)		1.86	3	1	0.50
Land Tenure					
1) Rental Land	74.70%				
2) Own Land	25.30%				
Source of Fund					
1) Loan	77.50%				
2) Self-finance	22.50%				

Source: From the survey data

Of the total farmers, about 64 percent of the farms are smaller than 5 hectare and farm size varied from 0.80 to 23.68 hectare. Farm sizes in the study area are small averaging about 4.76 hectare. However, farm size in Central Thailand are still quite large in comparison with the average farm size as a whole country about 2.48 hectare studied by Office of Agricultural Economic (2008). The majority of survey farms, about 69 percent, practiced double cropping. There are 74.7 percent of farmers who have to rent rice field for planting and about 77.5 percent of farmer loan money to invest on their farms.

On average, the farmers used 158 kg/ha of seed, fertilizer at 328 kg/ha, pesticide at 4.13 liter/ha, fuels at 76 liter/ha and spend their money for contractors about 224 US dollar per hectare for preparing the land, planting and spraying fertilizer and pesticide throughout the planting time and can obtain paddy yield about 4.26 ton/ha as presented in Table 3.

Table 3: Descriptive Statistics for Production Variables in Thai Rice Farms

Variables	Mean	Maximum	Minimum	Standard Deviation
Paddy Yield *(kg/ha)*	4,261.50	6,250.00	1,250.00	993.88
Seed *(kg/ha)*	158.05	312.50	62.50	23.70
Fertilizer *(kg/ha)*	328.29	937.50	87.50	116.84
Pesticide *(ml/ha)*	4,131.48	31,250.00	250.00	2,582.00
Fuel *(liter/ha)*	76.02	250.00	2.50	47.82
Contractors' cost *(USD/ha)*	224.05	282.20	100.38	33.66

Source: From the survey data

The mean paddy yield was 4,261.50 kilograms per hectare with a range of 1,250 to 6,250 kilograms per hectare. This is higher than the average yield of 3.56 ton/ha reported by Office of Agricultural Economics' report (2008). The measurement unit of trading paddy rice for planting is called "Tang" and 1 Tang contains 10 kg of paddy rice, which costs about 6 US dollar. The average seed used per hectare was about 158 kg. Therefore, seed cost was at 95 US dollar per hectare, averaging from all rice varieties. In consistent with the Office of Agricultural Economics' report (2008), found that the pre-germinated direct seedling broadcasting method applied the seed at the highest rate about 178.56 kg/ha whereas average seed used for all planting method equaled to 100.44 kg/ha for the whole country. The average fertilizer used in the study area was about 328 kg per hectare which comprised of the fertilizer formula (N-P-K) at 46-0-0 and 16-20-0 for the first and second fertilizer application, respectively. Likewise the Office of Agricultural Economics' survey (2008), indicated that in the Central Thailand applied fertilizer at the highest rate 288.81 kg/ha. The average pesticide used was at 4,131 ml. Pesticide in this study used for the herbicide, insecticide, fungicide and on their own formulation. Fuel used in this study was considered for the water pump and for fertigation and pest control. The fuel, on average, was about 76 liters per hectare. Of the total cost farmers have to pay, the contractors' cost was the most production cost which was about USD 224 with a range of USD 100.38 to 282.20. The contractors' cost covers for the 2 time of land preparation, the labor cost for planting, spraying pesticide and fertilizer, and the cost of harvesting.

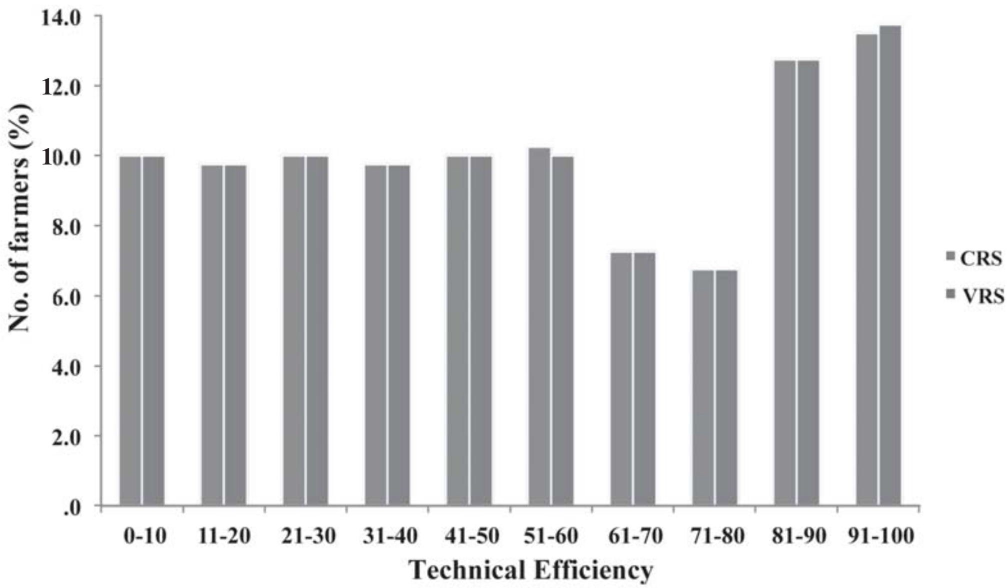
Technical Efficiency

The technical efficiency level obtained by Data Envelopment Analysis varied between 0.30 to 100 percent. The mean technical efficiency equals to 51.69 and 51.86 percent for DEA Constant Return to Scale and Variable Return to Scale, respectively while scale efficiency is equal to 99.82 percent.

From the distribution of technical efficiency in Figure 2, the estimated efficiency scores of individual farmers are considerably low. About 59 percent of total paddy farms, have technical efficiency scores less than 60 percent. This implies that there is a room for paddy farmers to increase their farm efficiency.

However, in this study will discuss only the factors affecting technical inefficiency from VRS DEA. Due to the value of scale efficiency is not equal to 1 or 100 percent, this implied that the production has not been operated at the optimal scale or Constant return to scale. Therefore, VRS DEA will be more flexible and realistic which can envelop the data tighter than CRS DEA. (Coelli et al., 1998; Krasachat 2003; Chaovanapoonphol et al., 2005)

Figure 2: Frequency Distribution of Technical Efficiency Scores by CRS and VRS



Factors Affecting Technical Inefficiency

In the second stage, Tobit regression model was applied to identify the factors affecting technical inefficiency which can explain the relationship between the variables used in this study and technical inefficiency itself. The sign of the estimated coefficient is expected to be negative, which indicates the inverse relationship to technical inefficiency. This means that the explanatory variables will contribute positively the technical efficiency.

Table 4: Determinants of Technical Inefficiency Model by Tobit Regression by VRS Assumption

Variables	Coefficient	Std. Error	z-Statistic	Prob.
C	0.352215	0.087278	4.035553	0.0001[a]
Demographic Variables and Farm Characteristics				
GEND	0.000481	0.029079	0.016558	0.9868
EDU	-0.047223	0.031337	-1.506906	0.1318
EXP	0.003487	0.001031	3.381684	0.0007[a]
FAMM	0.067254	0.010633	6.325102	0.0000[a]
FAML	-0.092225	0.018007	-5.121623	0.0000[a]
FSIZE	0.014220	0.005014	2.836065	0.0046[a]
TENS	0.063091	0.031876	1.979283	0.0478[b]
FUND	-0.049021	0.030755	-1.593926	0.1110
Agricultural Extension Variables				
AGMEM	-0.014495	0.030176	-0.480364	0.6310
AGVOL	-0.003289	0.031622	-0.104018	0.9172
VISIT	0.003966	0.027691	0.143214	0.8861
ATTFST	0.024265	0.028643	0.847166	0.3969
ATTIPM	0.127718	0.032527	3.926549	0.0001[a]
GAP	0.010327	0.036705	0.281345	0.7784
BPT	0.083601	0.039833	2.098811	0.0358[b]
MEDIA	-0.090372	0.026848	-3.366056	0.0008[a]
OFFVAR	-0.085123	0.043869	-1.940410	0.0523[c]
Environmental Variables				
BURN	-0.007180	0.030006	-0.239294	0.8109
SOILT	-0.011966	0.036587	-0.327067	0.7436
COLDW	0.052991	0.026934	1.967424	0.0491[b]
WDYRICE	-0.183149	0.030168	-6.070944	0.0000[a]
GENWD	0.051084	0.025528	2.001081	0.0454[b]
INSECT	-0.127094	0.029917	-4.248163	0.0000[a]
SNAIL	-0.029877	0.026397	-1.131845	0.2577
RAT	-0.015471	0.028077	-0.551018	0.5816
LEAFB	0.035677	0.028504	1.251628	0.2107
PPATH	-0.014576	0.028171	-0.517396	0.6049

Remark: [a] Significant at 1%, [b] Significant at 5%, [c] Significant at 10% level

The empirical finding reveals that farming experiences, family members and labors, farm size and land tenureship of Demographic and farm characteristics have statistically significant relationship on technical inefficiency, while attendance in IPM training program, farm visit as best practices, extension services by extension officers and certified seed used are the variables influencing to farms' technical inefficiency. For Environmental characteristics, facing the cold weather, infestation on weedy rice, general weed and insect are the factors affecting farm inefficiency. The remaining factors are insignificant to technical inefficiency (Table 4).

Farming experiences, family size, farm size and land tenure have positive and significant impacts on inefficiency, which opposite to prior expectations. The positive sign of estimated coefficient for these variables indicate that farmers with more experiences, larger family and farm size and rental land for planting are likely to be less efficient. In fact, the farmers who have more experienced are likely to pay less attention to find the new technology whereas the farmers, who have less experienced, open their mind and are willing to adopt the new technology and any advices. This result is similar to Ojo (2003) and Ike and Inoni (2006) which found that farmers with more years of farming experience are relative less efficient. Likewise family member and farm size, normally would exhibit economy of scale meant that larger farms are more technically efficient than smaller one as prior expectation. However, the finding indicated that the smaller farms are more efficient than the larger farms. This is due to the small-scale farmers may perform better allocative on their inputs use and resources same as in the other developing countries. In the other word, the farmers with small size of farm could concentrate on their farms more than the larger. This is consistent with Ross et al., (2009) stated that the larger farm could be considered as the extensive farming strategy which may be misallocation of time, labors and other resources. Land tenure has a significant negative effect on technical efficiency at 95 percent. This means that the farmers which cultivated lands belong to them are likely to have more technical efficiency as compared to those farmers who rented land for rice cultivation. An explanation for this result is that farmers who have their own land implied the wealth of farmers. The wealth of farmers could create the availability of inputs and resource and could provide the new technology and invest in machinery for their farming.

Family labors show the negative and significant estimated coefficient at 99 percent which implied that the farmers who have more family members work as farm labors will be more technically efficient. This is because large number of family labor exhibited intensive labor farming for rice cultivation and that would be better when family labor concentrated on farm practices. The remaining variables (gender, educational level, and source of fund) are insignificant.

For Agricultural extension characteristics, the results reveal that the extension services directly by extension officers and certified seed used are two main factors which show the negative sign of estimated coefficient on technical inefficiency. These implied that farmers who made contact directly with the officers and used the certified seed, tend to be technically efficient as compared to farmers who did not. This is the opportunity for those farmers to attain the accurate knowledge which is helpful and suitable for their farming. (Parikh and Shah 1994; O'Neill et al., 1999)

Attendance in IPM training program and farm visit as best practice, showed positive and significant coefficient on technical inefficiency. It means that farmers who attended IPM program and farms have been visited as best practice, have low level of technical efficiency. This result may be due to the measurement of variables which cannot actually capture the adoption of farmers. That is why these two variables showed the negative impact on technical efficiency. However, this result is similar to Songsrirote and Singhapreecha (2007)'s work which found that agricultural training have a negative impact on technical efficiency.

The significant estimated coefficients of Environmental characteristics are pre-harvest cold weather, weedy rice, general weed and insect infestation. The weedy rice and insect infestation have negative impact on technical inefficiency whereas pre-harvest cold weather and general weed infestation have positive impact. Although pre-harvest cold weather and no infestation on general weed would not contribute to technical efficiency, these may result from the farmers' adaptation such as using of tolerant rice varieties or choosing planting time to avoid facing cold weather. However, from these results also indicate that pest control is still important factor which can affect the rice yield and its technical efficiency. Therefore, the effective pest management should be provided for farmers to overcome the pest infestations' problem.

Conclusion

The objective of the study is to estimate technical efficiency and explore the factors affecting technical inefficiency of paddy farms in the Central Thailand by using Data Envelopment Analysis Approach (DEA) and Tobit Regression Model. It was found that most farms had technical efficiency at the mean of 51.86 percent. In addition, rice farms can enhance their production efficiency about 48 percent to be fully efficient by using farm inputs more efficiently.

As the results mentioned above, the key factors affecting technical inefficiency are family labors, extension services by extension officers, certified seed used, and weedy rice and insect infestation. Operating farms by family labors, is the way to save production cost instead of hiring contractors which will contribute to technical efficiency. The extension services link between extension officers and farmers will provide adequate knowledge which is needed to manage production problems faced by farmers. These can offer the alternative ways for rice production which is appropriate for individual farmers. Likewise, the use of certified seed will also provide the good quality of seed for enhancing farm production. The effective pest control on weedy rice and insect are the way to overcome the production problem and reduce their cost.

In conclusion, most farms in Central Thailand are still inefficient. To eliminate the technical inefficiency, better farm practices should be provided through the government and relevant agency's training program. Enhancing on efficiency level should be conducted via the agricultural extension programs on best farm practices and pest management organized by the extension officers.

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