# Asian Journal of Scientific Research

ISSN 1992-1454

OPEN ACCESS Asian Journal of Scientific Research

ISSN 1992-1454
DOI: 10.3923/ajsr.2018.480.488

# Research Article
# Comparative Analysis of the Technical Efficiency of Different Production Systems for Rice Farming in Eastern Thailand

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## Abstract

**Background and Objective:** Generally, there are three different rice farming production systems: Farming under the agriculture network, conventional organic rice farming and chemical rice farming. This study estimated the technical efficiency (TE) of different production systems for rice farming in eastern Thailand. **Materials and Methods:** Chachoengsao and Prachinburi were selected as the study areas. Farm-level data were collected during the 2016-2017 production period from 150 respondents consisting of 58 organic farmers under the Alternative Agriculture Network (AAN), 42 conventional organic rice farmers and 50 chemical rice farmers. A stochastic frontier analysis was employed to analyze the survey data. **Results:** The results indicated that the technical efficiency scores for organic rice farmers under the AAN had the highest level of efficiency compared to conventional organic rice and chemical rice farmers. The average TE of the farmers under the AAN was approximately 0.733, ranging from 0.375-0.940, while the average TE of the conventional organic rice farmers was approximately 0.669, ranging from 0.103-0.948 and the average TE of the chemical rice farmers was approximately 0.688, ranging from 0.293-0.999. The results indicate that farmers should use high-quality seeds and organic fertilizer to improve the efficiency of organic rice. **Conclusion:** The findings indicated that the technical efficiency scores for organic rice farmers under the AAN had the highest level of efficiency comparing to conventional organic rice and chemical rice farmers.

Key words: Technical efficiency, alternative agriculture network, organic rice network, rice efficiency and chemical rice farming

Received: March 23, 2018 Accepted: June 04, 2018 Published: September 15, 2018

Citation: Chanhathai Kerdsriserm, Suneeporn Suwanmaneepong and Panya Mankeb, 2018. Comparative Analysis of the Technical Efficiency of Different Production Systems for Rice Farming in Eastern Thailand. Asian J. Sci. Res., 11: 480-488.

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

## INTRODUCTION

The purchase of high-quality foods and environmentally friendly and organic products has increased due to greater awareness of environmental degradation and growing concerns about chemical-based farming and related issues[1-3]. Most consumers are more aware of the risks of pesticides used in food production. They are concerned about their health andsafety[4]. Consumers' risk perception and health awareness are the main reasons they choose to purchase and consume organic foods[5]. Previous research revealed that consumers have become increasingly aware of how their health is affected by consuming organic food instead of non-organic food[6-8]. As reported by the International Federation of Organic Agriculture Movements (IFOAM) and the Research Institute of Organic Agriculture, in 2015 the market share of organic products amounted to $81.6 billion, with $2.4 million organic producers. This indicated that the demand for organic food grew faster than the supply[9].

Similar to global trends, in Thailand consumers are increasingly seeking healthier products. In 2017, organic agriculture in Thailand expanded by 21%. Organic rice farming increased by 28% and integrated farming by 187%. Indeed, the demand for organic food, particularly organic rice, has grown rapidly. The Thai government launched an organic rice production project with the goal of increasing production areas from 300,000 rai in 2017 to 3,000,000 rai by 2021[10]. Price incentives are the main driving force for farmers transitioning from conventional farming to organic farming with the development of technology and marketing, including production standard upgrades[11]. However, organic rice growers, particularly small-scale farmers, critically need sustainable strategies. Networking is the key solution to strengthening horizontal and interdependent relationships among producers and consumers. The Alternative Agriculture Network (AAN) was established in the early 1980s to support local farmers to adopt sustainable farming practises, organize alternative marketing methods for small-scale farmers and initiate organic standards and a certification system[12]. In 2017, 1500 small-scale farmers participated in the AAN. The AAN also assists small-scale farmers with organic supply chains, for instance, helping them manage their production for market demands. Nevertheless, there are insufficient numbers of small-scale farmers under the AAN. Adding incentives to encourage new farmers to participate in the organic farming network is one strategy for increasing membership[13].

Eastern Thailand is the third largest producer of the nation's organic rice at 16%[10]. Rice is an important crop for economic development in this region. This is in line with Thailand's overall agricultural strategy: Safe agricultural products with standardized quality and farmers who can increase product value in line with competitive market demands and enjoy a good quality of life as well as robust network marketing power[14]. This study focused on organic rice production in Chachoengsao and Prachinburi because these are major organic rice production areas with different patterns of production, both under the AAN and using conventional organic rice farming. In addition, many farmers use chemicals to grow rice. Their productivity costs are high due to overproduction factors[15] but this is compensated by higher prices. The smaller farmers do not have fractal marketing. Product distribution usually involves middlemen or brokers rather than agreements on the quality of the yields or market prices. Moreover, partners do not have confidence in farmers because there is no formal organization or local group leaders. Smaller farmers should be aggregated into a farmer network[16] to promote members' knowledge and strengthen the network. One reason for the farmers' transition from conventional to organic farming is that they had robust marketing and knowledge from continuous training[17].

Organic rice farming patterns varied in the regions studied due to different production methods. The results of a study on the technical efficiency of different rice farming systems in this region may not only support the enhancement of each system's rice farming efficiency but also convince farmers to grow organic rice or participate in a network if the efficiency score is higher than that of chemical rice farming. Technical efficiency (TE) refers to how productive a business can be given the fewest inputs or resources, necessary for the job. TE is expressed (over a given time period) as the ratio of mean production (conditional on the levels of factor inputs and firm effects) to the corresponding mean production if a business most efficiently utilizes inputs[18]. The measurement of efficiency in agricultural production is indicative of the efficiency levels of farms' activities that assesses their ability to reduce production costs, improve productivity and use appropriate production factors[19-24]. A significant amount of this research dealt with technical efficiency and factors affecting rice production efficiency in different regions[25-28].

However, there was scant comparative research on the technical efficiency of rice farming using varying production systems, especially in regions where organic rice is a strategic product. Consequently, this study aimed to compare the technical efficiency of Thailand's Chachoengsao and Prachinburi provinces' three different rice farming production systems: Farming under the alternative agriculture network, conventional organic rice farming and chemical rice farming.

## MATERIALS AND METHODS

**Study areas:** Chachoengsao and Prachinburi provinces, major rice producers in eastern Thailand, were selected as the study area because they are strategic production regions and target areas for increasing organic rice cultivation. An organic network is the most successful pattern of organic rice farming in this region. Also, the Alternative Agriculture Network (AAN) for small-scale organic rice farmers is located in these areas, they account for 12.66% (190 of 1500) the AAN's total membership in Thailand. This network initiates organic agriculture development by supporting local farmers to adopt sustainable farming practises, organizing alternative marketing methods for small-scale farmers and establishing organic standards and a certification system[29].

### Population and sample sizes

**Population consisted of three categories of rice farming systems:** Organic rice farming under the AAN, conventional organic rice farming and chemical rice farming. Organic rice farming under the AAN included organic rice growers who we remembers of the AAN and employed sustainable farming practises and organized marketing methods provided by the network. Conventional organic rice farming included farmers who individually grew organic rice and were not AAN members. Chemical rice farming included farmers who grewrice using chemicals.

The sample sizes of the three rice farming systems were shown in Table 1. A purposive sampling technique was used to collect data from 58 farmers in the AAN network from 28 farmers in Chachoengsao and 30 farmers in Prachinburi. Data on 42 conventional organic rice farmers were gathered from 28 farmers in Chachoengsao and 14 farmers in Prachinburi. Data on 50 chemical rice farmers were obtained from 28 farmers in Chachoengsao and 22 farmers in Prachinburi.

**Data collection and analysis:** The data were collected using questionnaires and interviews with the selected rice farmers for farm level production periods during November 1, 2016-March 30, 2017.

A stochastic frontier analysis (SFA) was applied to estimate the technical efficiency. This method is less invasive and provides greater incentives for efficiency improvements[30]. A Cobb-Douglas form of SFA has been used in many observational studies, particularly those related to developing agriculture[18]. This method has been also often used in other studies[25,26,31-35]. In this study, variables in Cobb-Douglas Stochastic Frontier Production function were adopted from previous research on technical efficiency of rice farming namely: Tipi *et al.*[36], Kiatpathomchai *et al.*[37], Kea *et al.*[38] and Parichatnon *et al.*[39]. In addition, organic fertilizer variable was adapted and included in the function, since it is the main input for rice farming under the alternative agriculture network and conventional organic rice farming.

Therefore, the general form of the Cobb-Douglas stochastic frontier production function was employed. The model is expressed as follows:

In this study:

$$\ln Y = \ln\alpha + \sum_{i=1}^{6}\beta_i \ln X_i + v_i - u_i$$

- $\ln Y$ = Is the natural logarithm of rice output (kg)
- $\ln X_1$ = Is the natural logarithm of the farm size or area of land planted (rai)
- $\ln X_2$ = Is the natural logarithm of seed (kg)
- $\ln X_3$ = Is the natural logarithm of organic fertilizer (kg)
- $\ln X_4$ = Is the natural logarithm of fertilizer (kg)
- $\ln X_5$ = Is the natural logarithm of pesticide and herbicide (litres)
- $\ln X_6$ = is the natural logarithm of labour (h)

Table 1: Distribution of sample size in the study areas

| Areas | Organic farming under the AAN | Conventional organic rice farming | Chemical rice farming |
|---|---|---|---|
| Chachoengsao province | 28 | 28 | 28 |
| Sanam Chai Khet district | 18 | 23 | 20 |
| Tha Takiap district | 4 | - | 4 |
| Phanom Sarakham district | 2 | - | - |
| Bang Nam priao district | 4 | 5 | 4 |
| Prachinburi province | 30 | 14 | 22 |
| Prachantakham district | 11 | - | 10 |
| Kabin Buri district | 18 | 14 | 12 |
| Si Maha Pho district | 1 | - | - |
| Total | 58 | 42 | 50 |

Furthermore, $v_i$ is an error term that captures the effects of unspecified explanatory variables, while $u_i$ accounts for technical inefficiency in production and ranges between zero and one[40].

## RESULTS AND DISCUSSION

**Socio-economic characteristics of farmers:** In Table 2 the socio-economic characteristics were presented.

**Gender:** A total of 58.6% of the organic rice farmers under the AAN and 57.1% of the conventional organic rice farmers were female, while 60% of the rice farmers using chemicals were male.

**Age:** The farmers' average age was 54.11 years old, which was consistent with the average age of Thai rice farmers. The farmers' average ages varied for each growing system. Overall, 34.5% of the organic rice farmers under the AAN were between 41-50 years old, 40.5% of the conventional organic rice farmers were older than 60 and 42% of the chemical rice farmers were 51-60 years old.

**Educational levels:** Most household heads graduated from primary school, at 55.2, 71.5 and 70% for organic rice farming under the AAN, conventional organic rice farming and chemical rice farming, respectively.

**Family labour:** An average of 1.83 family members participated in rice farming. Only 1-2 family members participated in rice farming, at 87.9, 76.2 and 86% for organic rice farming under the AAN, conventional organic rice farming and chemical rice farming, respectively.

**Number of years of rice farming experience:** The rice farmers had an average of 33.71 years of experience in each system. For each production system, most had more than 20 years of farming experience: 77.6% for organic rice farming under the AAN, 90.5% for conventional organic rice farming and 74% for chemical rice farming.

**Participation in the agricultural training program:** Overall, the farmers participated in an agricultural training program an average of 7.49 times per year. Most participated 6-10 times per year, at 75.9, 35.7 and 40% for organic rice

Table 2: Socio-economic characteristics of rice farmers in different production systems

| | Organic farming under the AAN | | Conventional organic rice farming | | Chemical rice farming | |
|---|---|---|---|---|---|---|
| Characteristics | Frequency (n) | Percentage | Frequency (n) | Percentage | Frequency (n) | Percentage |
| **Gender** | | | | | | |
| Male | 24 | 41.4 | 18 | 42.9 | 30 | 60.0 |
| Female | 34 | 58.6 | 24 | 57.1 | 20 | 40.0 |
| Total | 58 | 100.0 | 42 | 100.0 | 50 | 100.0 |
| **Age (years) (Mean = 54.11 years)** | | | | | | |
| ≤40 years | 8 | 13.8 | 1 | 2.4 | 2 | 4.0 |
| 41-50 | 20 | 34.5 | 10 | 23.8 | 12 | 24.0 |
| 51-60 | 17 | 29.3 | 14 | 33.3 | 21 | 42.0 |
| Above 60 years | 13 | 22.4 | 17 | 40.5 | 15 | 30.0 |
| Total | 58 | 100.0 | 42 | 100.0 | 50 | 100.0 |
| **Educational level** | | | | | | |
| Primary education | 32 | 55.2 | 30 | 71.5 | 35 | 70.0 |
| Secondary education | 17 | 29.3 | 8 | 19.0 | 14 | 28.0 |
| Tertiary education | 9 | 15.5 | 4 | 9.5 | 1 | 2.0 |
| Total | 58 | 100.0 | 42 | 100.0 | 50 | 100.0 |
| **Family labor (persons) (Mean = 1.83 persons)** | | | | | | |
| 1-2 | 51 | 87.9 | 32 | 76.2 | 43 | 86.0 |
| 3-4 | 17 | 12.1 | 9 | 21.4 | 7 | 14.0 |
| ≥5 | - | - | 1 | 2.4 | - | - |
| Total | 58 | 100.0 | 42 | 100.0 | 50 | 100.0 |
| **Number of years of rice farming experience (Mean = 33.71 years)** | | | | | | |
| 1-10 | 5 | 8.6 | 3 | 7.1 | 8 | 16.0 |
| 11-20 | 8 | 13.8 | 1 | 2.4 | 5 | 10.0 |
| >20 | 45 | 77.6 | 38 | 90.5 | 37 | 74.0 |
| Total | 58 | 100.0 | 42 | 100.0 | 50 | 100.0 |
| **Participation in trainings (Time per Year) (Mean = 7.49 Time per Year)** | | | | | | |
| 1-5 | 14 | 24.1 | 13 | 31.0 | 13 | 26.0 |
| 6-10 | 44 | 75.9 | 15 | 35.7 | 20 | 40.0 |
| >11 | - | - | 14 | 33.3 | 17 | 34.0 |
| Total | 58 | 100.0 | 42 | 100.0 | 50 | 100.0 |

farming under the AAN, conventional organic rice farming and chemical rice farming, respectively.

**Definition, Measurement and Summary Statistics of Variables:** The data in Table 3 demonstrated the input-output variables.

For organic rice farming under the AAN, an average rice production output was 325.50 kg/rai. The average farm size was 15.97 rai. The average seed rate was 17.54 kg/rai and the average amount of organic fertilizer used was 94.41 kg/rai. The average labour for rice farming was 7.23 h/rai.

Regarding conventional organic rice farming, the average rice production output was 356.21 kg/rai. The average farm size was 14.64 rai. The average seed rate was 24.43 kg/rai and the average amount of organic fertilizer applied was 14.92 kg/rai. The mean labour employed for rice farming was 12.82 h/rai.

In terms of chemical rice farming, the average rice production output was 391.78 kg/rai, the average farm size was 23.14 rai, the average seed rate was 26.15 kg/rai, the average chemical fertilizer use was 42.87 kg/rai and the average pesticide and herbicide use was 0.26 litres/rai. The average labour for rice farming was 5.41 h/rai.

Chemical rice farming had the highest average output of rice per rai because the farmers used only chemical fertilizer. The farm size for chemical rice farming was larger than conventional rice farming and organic rice farming under the AAN. Regarding organic rice farming, conventional organic rice farming had a higher average rice output and occupied a larger land area than farming under the AAN. In regard to seeds used per rai, the organic rice farmers under the AAN used fewer seeds than the conventional farmers. In addition, organic rice farmers under the AAN applied greater amounts of organic fertilizer than conventional organic rice farmers.

**Maximum likelihood estimates:** The results of the maximum likelihood estimate (MLE) were displayed in Table 4. Farm size had a positive and significant effect on rice productivity in the study areas. This was in line with the findings of Chandio, *et al.*[41], Abdullah[42] and Tijani[43], which discovered a significantly positive relationship between farm size and rice

Table 3: Definition, measurement and summary statistics of variables (per farm)

| | | Organic farming under the AAN | | Conventional organic rice farming | | Chemical rice farming | |
|---|---|---|---|---|---|---|---|
| Input and output variables | Unit | Mean | SD | Mean | SD | Mean | SD |
| Output of rice | kg | 5,198.28 | 4358.13 | 5,214.98 | 7325.16 | 9,065.80 | 5205.52 |
| | kg/rai | 325.50 | | 356.21 | | 391.78 | |
| Farm size | rai | 15.97 | 16.35 | 14.64 | 19.80 | 23.14 | 13.33 |
| Seed | kg | 280.18 | 346.50 | 357.68 | 525.60 | 605.02 | 363.26 |
| | kg/rai | 17.54 | | 24.43 | | 26.15 | |
| Organic fertilizer | kg | 1,507.80 | 2312.51 | 218.48 | 2817.48 | - | - |
| | kg/rai | 94.41 | | 14.92 | | | |
| Chemical fertilizer | kg | - | - | - | - | 992.00 | 558.82 |
| | kg/rai | | | | | 42.87 | |
| Pesticide and herbicide | litter | - | - | - | - | 6.00 | 3.31 |
| | litter/rai | | | | | 0.26 | |
| Labor | h | 115.44 | 84.42 | 187.66 | 187.66 | 125.25 | 76.22 |
| | h/rai | 7.23 | | 12.82 | | 5.41 | |

Table 4: Maximum likelihood estimates of frontier production

| | | Organic farming under the AAN | | Conventional organic rice farming | | Chemical rice farming | |
|---|---|---|---|---|---|---|---|
| Variables | Parameters | Coefficient | T-ratio | Coefficient | T-ratio | Coefficient | T-ratio |
| **Production function** | | | | | | | |
| Constant | $\alpha_0$ | 6.675 | 15.014*** | 6.249 | 12.737*** | 7.395 | 8.803*** |
| In farm size (rai) | $\alpha_1$ | 0.972 | 9.375*** | 0.877 | 5.182** | 1.085 | 3.759** |
| In seed (kg) | $\alpha_2$ | -0.080 | -1.018 | -0.047 | -0.356 | -0.138 | -0.763 |
| In organic fertilizer (kg) | $\alpha_3$ | 0.025 | 0.822 | 0.046 | 1.068 | - | - |
| In chemical fertilizer (kg) | $\alpha_4$ | - | - | - | - | -0.063 | -0.490 |
| In pesticide and herbicide (L) | $\alpha_5$ | - | - | - | - | -0.045 | -0.736 |
| In labor (h) | $\alpha_6$ | -0.030 | -0.333 | 0.071 | 0.826 | 0.019 | 0.138 |
| **Variance parameters** | | | | | | | |
| Sigma-squared | $\alpha_2$ | 0.285 | 4.181** | 0.440 | 3.804* | 0.260 | 4.985** |
| Gamma | $\gamma$ | 0.929 | 19.113 | 0.963 | 35.080 | 0.999 | 90.879 |
| Log-likelihood | | -15.871 | | -18.698 | | -2.462 | |

***Significant at ($p \leq 0.01$), **Significant at ($p \leq 0.05$), *Significant at ($p \leq 0.10$)

yield. This result also implied that when rice farmers had enough land, their rice production improved significantly. However, seeds, organic fertilizer, chemical fertilizer, pesticide, herbicide and labour were not significant. The results underscored that the three categories of rice farming in the study areas still have considerable room for improvement under the current production methods and technology, which was consistent with the study of Koirala *et al.*[34] that found the TE level of Filipino rice production was about 79% and rice production was also affected by farm size.

For organic rice farming under the AAN, the MLE of farm size with respect to rice production was positive and highly significant with a 0.972 estimation coefficient. The results indicated that an increase in land area could yield more than 0.972 of the production of rice in the study areas. As for conventional organic farming, the MLE of farm size with respect to rice production was positive and significant with a 0.877 estimation coefficient, underscoring that an increase inland area could yield more than 0.877 of the production of organic rice. Regarding chemical rice farming, the MLE of farm size with respect to rice production was positive and significant with a 1.085 estimation coefficient, showing that an increase in land area could yield more than 1.085of rice production (Table 4).

**Estimated technical efficiency scores:** The Table 5 presented organic rice farming under the AAN had the highest level of TE (mean efficiency = 0.733) compared to conventional organic rice farming (mean efficiency = 0.669) and chemical rice farming (mean efficiency = 0.688). Organic rice farming under the AAN was more efficient due to the value of planning that included production and marketing. Farmers also chose high-quality seeds and applied organic fertilizer. This result was confirmed by Asea *et al.*[44], who noted that quality rice seeds can increase yields among smaller rice farm as well as Xu *et al.*[45], who found that organic manure could increase rice yields.

Considering the TE for each production system, organic rice farming under the AAN had an estimated TE ranging from 37.5- 94% and the efficiency scores of more than 53.5% of the farmers ranged from 61-80%, with an average TE of 73.3% and a 0.126 standard deviation. Conventional organic rice farming had an estimated TE ranging from 10.3-94.8% and the efficiency scores of more than 38.1% of the farmers ranged from 61-80%, with an average TE of 66.9% and a 0.196 standard deviation. Chemical organic rice farming had an estimated TE ranging from 29.3-99.9% and the efficiency scores of more than 36% of the farmers ranged from 61-80%. These results implied that in order to improve the technical efficiency, farmers should decrease or increase the number of farm inputs to obtain maximum rice output (Table 5).

The data in Table 6 revealed the best practice (highest TE score) for organic rice farming under the AAN within one rai of plantation area produced 600 kg of rice output using the following inputs: 20 kg of seed, 71 kg of organic fertilizer and approximately 14.2 h of labour. The worst practice (lowest TE score) within one rai of plantation areaproduced166.67 kg of rice output using inputs of 5 kg of seed, 10 kg of organic fertilizer and 3.53 h of labour. Therefore, organic rice farmers under the AAN should increase the number of inputs in order to increase the technical efficiency.

Regarding conventional organic rice farming within one rai of plantation area, the best practice (highest TE score) produced 652.17 kg of rice output using inputs of 20 kg of seed, 79 kg of organic fertilizer and approximately 6.61 h of labour. The worst practice (lowest TE score) within one rai of

Table 5: Distribution of technical efficiency scores

| | Organic farming under the AAN | | Conventional organic rice farming | | Chemical rice farming | |
|---|---|---|---|---|---|---|
| Technical efficiency scores | Frequency | Percentage | Frequency | Percentage | Frequency | Percentage |
| <0.4 | 1 | 1.7 | 4 | 9.5 | 3 | 6.0 |
| 0.41-0.60 | 8 | 13.8 | 9 | 21.4 | 15 | 30.0 |
| 0.61-0.80 | 31 | 53.5 | 16 | 38.1 | 18 | 36.0 |
| 0.81-1.00 | 18 | 31.0 | 13 | 31.0 | 14 | 28.0 |
| Total | 58 | 100.0 | 42 | 100.0 | 50 | 100.0 |
| Mean efficiency | 0.733 | 0.669 | 0.688 | | | |
| Standard deviation | 0.126 | 0.196 | 0.185 | | | |
| Minimum | 0.375 | 0.103 | 0.293 | | | |
| Maximum | 0.940 | 0.948 | 0.999 | | | |

Table 6: Output-Input of the highest-lowest technical efficiency of each rice production system

| | | Organic farming under the AAN | | Conventional organic rice farming | | Chemical rice farming | |
|---|---|---|---|---|---|---|---|
| Output-Input | Unit | Highest (TE = 0.940) | Lowest (TE = 0.3752) | Highest (TE = 0.948) | Lowest (TE = 0.103) | Highest (TE = 0.999) | Lowest (TE = 0.293) |
| Rice output | kg | 6,000 | 5,000 | 15,000 | 1,000 | 6,000 | 3,000 |
| | kg/rai | 600 | 166.67 | 652.17 | 50 | 666.67 | 166.67 |
| Farm size | rai | 10 | 30 | 23 | 20 | 9 | 18 |
| Seed | kg | 200 | 150 | 460 | 500 | 225 | 450 |
| | kg/rai | 20 | 5 | 20 | 25 | 25 | 25 |
| Organic fertilizer | kg | 710 | 300 | 1817 | 670 | - | - |
| | kg/rai | 71 | 10 | 79 | 33.5 | - | - |
| Chemical fertilizer | kg | - | - | - | - | 300 | 1,000 |
| | kg/rai | | - | | - | 33 | 55.55 |
| Pesticide and herbicide | liter | - | - | - | - | 3 | 10 |
| | liter/rai | - | - | - | - | 0.33 | 0.55 |
| Labor | h | 142 | 106 | 152 | 232 | 62 | 86 |
| | h/rai | 14.2 | 3.53 | 6.61 | 11.6 | 6.89 | 4.78 |

1 ha: 6.25 rai

plantation area produced 50 kg of rice output using the following inputs: 25 kg of seed, 33.5 kg of organic fertilizer and 11.6 h of labour. To this end, conventional organic rice farmers should reduce all inputs in order to increase the technical efficiency.

For chemical rice farming within one rai plantation area, the best practice (highest TE score) produced 666.67 kg of rice output using inputs of 25 kg of seed, 33 kg of chemical fertilizer, 0.33 litres of pesticide and herbicide and approximately 6.89 h of labour. The worst practice (lowest TE score)in one rai of plantation areaproduced166.67 kg of rice output using the following inputs: 25 kg of seed, 55.55 kg of chemical fertilizer, 0.55 L of pesticide and herbicide and 4.78 h of labour. To increase efficiency, chemical rice farmers should reduce the number of inputs, such as chemical fertilizer, pesticide and herbicide and increase labour hours in order to increase the technical efficiency.

## CONCLUSION

This study analyzed and compared the technical efficiency of organic rice farming under the AAN, conventional organic rice farming and chemical rice farming in eastern Thailand. The findings indicated that the technical efficiency scores for organic rice farmers under the AAN had the highest level of efficiency (TE = 0.733) comparing to conventional organic rice (TE = 0.669) and chemical rice farmers (TE = 0.688). The results indicated that farmers should use high-quality seeds and organic fertilizer to improve the efficiency of organic rice.

## SIGNIFICANCE STATEMENTS

The technical efficiency (TE) scores for organic rice farmers under the AAN had the highest level of efficiency (TE = 0.733) comparing to conventional organic rice (TE = 0.669) and chemical rice farmers (TE = 0.688). The results indicated output-input of the highest-lowest TE of each rice production system in order to make a recommendation on improving the technical efficiency with best practice, such as the use of high-quality seeds and applied organic fertilizer in rice farming.

## ACKNOWLEDGMENT

The authors would like to express sincere appreciation to all rice farmers in the study area for their fruitful collaboration and kind support.

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