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TECHNICAL EFFICIENCY OF ORGANIC RICE FARMING UNDER CONTRACT ARRANGEMENT IN PREAH VIHEAR PROVINCE, CAMBODIA

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ABSTRACT

Organic rice contract farming is considered an important livelihood to secure farmers' income in Cambodia. Although farmers have increased their income through contract farming, their productivity remains low. This study aims to determine the factors influencing productivity and measure the technical efficiency of organic rice farming under contract arrangement in the Preah Vihear province of Cambodia. A series of field surveys were conducted in February 2021. Using the data of 50 organic rice farmers, the Stochastic Frontier Analysis model revealed that planted area, cow manure inputs, share of land harvested using combine harvester to total cultivated land, and level of comprehension and adaption of training contents significantly increased productivity. In contrast, disasters, the number of plots per ha, and unskilled laborers are the factors that led to decreased productivity. In addition, the average level of technical efficiency in the study area is 83%, indicating that the current production inputs and technology levels have the potential for productivity improvement. For further study, long-term studies on organic rice farming efficiency are recommended, specifically those that will examine factors such as level of risk-taking, the training content, and the training methods.

Key words: organic rice, productivity, stochastic frontier analysis, technical efficiency

INTRODUCTION

About 75% of the Cambodian population lives in rural areas (World Bank 2021), and they rely directly or indirectly on agriculture for their livelihood. Agriculture has reduced poverty from 47.8% in 2007 to 9.5% in 2019. However, the agriculture value-added showed slowly growth from 2013 (ADB 2021). In addition, limited farming techniques, inefficient agriculture input utilization, inefficient mechanization, and lower human capital are the challenges, resulting in low productivity and insufficient income (Lao 2019). Moreover, the continuous decline in the agricultural labor force is also a vital issue as promising additional income opportunities in the industrial and services sectors have been attracting farmers to engage in off-farm activities, especially for the past two decades (Fig. 1).

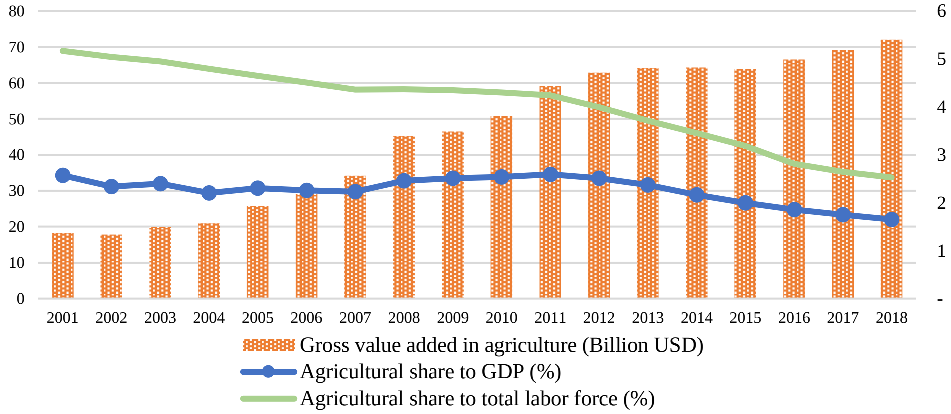

Fig. 1. Agricultural contribution to GDP and labor force, 2001-2018
Source: MAFF Cambodia, 2020

To address these challenges, the Cambodian government has been promoting two development strategies: organic and energy crop production since 2011 (Setboonsarng and Markandya 2015). Organic farming is mainly promoted through contract farming to provide appropriate training, access to proper markets, and opportunities for sustainable income (MAFF Cambodia 2011). Despite the government and private initiatives, the share of organic farming land is still limited to 0.6% (Willer et al. 2021). Moreover, only a few research studies are conducted on organic rice and contract farming. Based on the study conducted in Preah Vihear province, there was an increasing trend of small-scale farmers engaging in contract farming (Sok 2019). Some farmers even expanded their farmland due to the lucrative premium price. Contract farming entities also regularly provided technical training to farmers. However, these farmers still experienced low yields and labor shortages (Sok 2020).

Agricultural productivity and efficiency studies, including rice production efficiency studies, appear to be scarce in Cambodia, especially in organic rice production. Since there is limited research conducted on efficiency of rice production in Cambodia, it is essential to estimate the technical efficiency and inefficiency of organic rice production and clarify the factors increasing organic rice productivity.

This study attempted to determine the factors influencing the productivity of organic rice under contract farming in the Preah Vihear province, Cambodia. Specifically, this study aimed to clarify the support mechanism of organic rice contract farming, describe the characteristics of organic rice farmers under contract farming, and determine the influencing factors of the technical efficiency of organic rice farming and the distribution of technical efficiency.

MATERIALS AND METHODS

Study area. Preah Vihear province is located in the northern Cambodia about 400 km from Phnom Penh (Fig. 2). This province has the second largest arable area for agriculture production, and the largest organic granary under contract farming. It is in the plateau mountain area, which covers 14,031 km^2 with a population of 254,827 people (NIS 2019). Since the province is remote and the least populated area, about 85% of the province's population depends on agriculture. However, only 6% of the land was used for rice farming, 2.5% for other crop farming, and 0.8% for fruit farming. Hence, farmers are the main actors of this rural economy, but most farmers have low educational attainment and organic rice farming is done once a year due to rainfed farmland. Thus, adopting new technologies and improving productivity are their challenges. (Preah Vihear Provincial Department of Agriculture 2020).

Fig. 2. Map of Preah Vihear Province, Cambodia
Source: Google map, 2022

Sample selection. Preah Vihear province has a total of 6,099 organic rice farm households. During the field survey in February 2021, a combination of purposive, cluster, and random sampling methods was utilized based on previous studies (Asravor 2022; Muluneh et al. 2022; Saputra et al. 2022). The study area was then divided into seven groups (districts). Of the seven districts, three districts, namely Cheysen (1,446 HH), Rorvieng (1,191 HH), and Koulen (825 HH), were selected as the top three districts with the most organic rice contract farming households. Only 50 respondents were randomly selected from these three districts due to time constraints and Covid-19 pandemic restrictions on mobility and social contact. Face-to-face interviews were conducted with the guidance of a structured questionnaire. Since almost all farmers only had limited educational attainment, more time and effort were required to conduct the interviews.

Data analysis. In order to clarify the support mechanism of organic rice contract farming and describe the characteristics of organic rice farmers under contract farming, descriptive analysis was utilized. Support mechanism of organic rice contract farming were clarified using a combination of information collected from the field survey 2021, key-informant interview, previous literature reviews and secondary data. The field survey in 2021 collected 2020 observed data on the yield, number of farming household, agricultural cooperative in contract farming, and other information such as regulation and supports. The technical, regulation, standards support, yield, and other information from 2013 to 2019 were collected from previous literature reviews and secondary data such as the provincial department of agriculture reports.

The Stochastic Frontier Analysis (SFA) measured productivity and technical efficiencies. Typically, the concept of productivity refers to the volume of output produced with given inputs. Productivity rises when more output is produced with the same amount of input. Input and output are difficult to measure, both theoretically and empirically. Productivity measurement factors, including labor productivity and land productivity which scholars commonly apply, are referred to as partial measures of productivity. These partial measures of productivity cannot wholistically determine the inefficiency of productivity (Coelli et al. 2005). To clarify the mechanism of productivity, SFA is an efficient method applied by scholars. SFA is adopted mainly for farm management analysis with the benefit of statistical tests on the production structure and the inefficiency level (Coelli 1995b). SFA can also be used in most farming conditions and types, such as rice and vegetable farming Coelli et al.

(2005). In addition, this method also has the benefit of letting statistical tests be done on the levels of efficiency and inefficiency by figuring out why farms are not working well while separating random noise from efficiency. SFA was therefore used instead of the data envelopment analysis (DEA) method since DEA incorporates noise as part of the efficiency. In addition, the estimation methods of SFA for efficiency by using Frontier 4.1 software enable the separation of noise effects from inefficiency components and produce accurate outcomes for a single output and multiple inputs (Kebede 2001).

SFA has been used in the various fields, including agricultural research. Technical inefficiency affects rice production in a Tidal wetland in south Kalimantan, Indonesia. This study revealed that planting area, inorganic fertilizers, and pesticides were significant determinants. At the same time, the number of household members and frequency of field expansion were influential factors in the technical inefficiency of rice farming (Azis et al. 2018).
In the case of northwest Cambodia, increasing harvested land, fertilizer usage, and pesticide use significantly affected rice production, while overuse of labor in rice fields was the inefficiency factor of rice farming. Moreover, factors in the technical inefficiency model also showed that disasters (droughts, floods, and insects), household head education, family size, and cultivated area for other crops decreased the technical efficiency of household rice production. On the other hand, irrigated area, plot area, and household head gender increased technical efficiency (Kea et al. 2016).

SFA was also applied to crops (e.g., potato and rice) integrated with other crops (Nahraeni et al. 2012; Suharyanto et al. 2013). Using the Frontier 4.1 software, according to the research conducted by Nahraeni et al. (2012) on the technical efficiency of highland potato farming in Indonesia, production was highly sensitive to total land, seed, and organic fertilizer. In addition, the land slope and contour-aligned cultivation system increased efficiency, with a mean technical effectiveness of 0.84. For rice production with other crops, another research was conducted in Bali province on the technical efficiency of rice integrated crop management (ICM) (Suharyanto et al. 2013). This study used the frontier production function with the Maximum likelihood estimates method to measure the level of technical efficiency in rice with the ICM approach. As a result, the level of technical efficiency ranged from 0.71 to 0.99, with an average of 0.88. The rice yield was affected by the usage and volume of various inputs (seeds planted, active nitrogen, organic fertilizer, pesticide) and precipitation amount. The farmers' age, level of education, farm experience, and the number of owned plots per ha significantly affected their technical inefficiency.

The Stochastic frontier model was applied, which was first suggested by Aigner et al. (1977) and Meeusen and Van de Broeck (1977). The SFA model's general form is shown below:

$$Ln\ y_{it} = Ln\ f\ (x_{it}; \beta) + v_{it} - u_{it} \quad (1)$$

Where Ln represents the form of natural logarithm function, y_{it} and x_{it}denotes rice yield and inputs per ha during the time period *t*, respectively. Whereas β represents correlation coefficients; v_{it} is randoms error, assumed to be the normal distribution; u_{it} forecasts technical inefficiency, assumed to be truncated distribution; v_{it} and u_{it} are considered to be independent (Aigner et al. 1977; Ali et al. 2019; Kea et al. 2016). These technical inefficiency factors can be described in general terms as follows:

$$u_{it=\delta_0+\sum_{k=1}^{n}\delta_k z_{kit}+\omega_{kit}} \quad (2)$$

Where ω_{kit} is the stochastic noises; z_{kit} indicates external variables that are factors affecting organic rice technical efficiency; δ_0 and δ_k are estimated coefficients; if δ_k is negative, it indicates a positive correlation among affecting factor variables and technical efficiency of rice farming. Contrarily, if δ_k is positive, it shows a negative correlation between technical efficiency and determining factors. Following equations (1) and (2), the estimation SFA model parameters can use the maximum likelihood method, which estimates the likelihood function based on two variance parameters (Coelli and Battese1996；Kea et al. 2016).

$$\gamma = \frac{\sigma_u^2}{\sigma_s^2};\ \sigma_s^2 = \sigma_v^2 + \sigma_u^2 \quad (3)$$

In equation (3), gamma parameter (γ) has values ranging from zero to one ($0 \leq \gamma \leq 1$) and represents validity of the random disturbances (u_i , v_{it}). If γ is closer to zero, it indicates that the difference in actual output and the maximum possible output primarily caused by other uncontrolled random factors. This result makes the use of stochastic frontier model useless. In contrast, if γ is closer to one, it indicates that the gap is primarily caused by z_{ki} the effects of one or more external and personal characteristic variables, and it indicates that using stochastic frontier model is more relevant (Coelli and Battese 1996; Kea et al. 2016).

Application call “FRONTIER 4.1 (free download from University of Queensland, Australia)” was the package most often used to estimate the SFA model. FRONTIER 4.1 is a one-step program for the estimation of stochastic frontiers, and technical efficiency and inefficiency models (Coelli 1995a). FRONTIER 4.1 is frequently used to calculate the stochastic frontiers as mentioned in the literature review above. Moreover, it has been used in numerous rice production studies (Mayston 2015; Kea et al. 2016; Yekti et al. 2015). In this study, maximum likelihood was applied to estimate the parameters of the stochastic frontier model by using the Frontier 4.1 software.

There are 14 variables in which Y (rice yield) is a dependent variable, and independent variables are divided into two parts (Table 1). First, the efficiency included efficiency factors: planted area, amount of seeds used, amount of fertilizer used (cow manure), family labor, hired labor, exchange labor, and share of land harvested using combine harvester to total cultivated land. It should be noted that share of land harvested using combine harvester to total cultivated land is considered as one independent variable because a combined harvester can significantly reduce grain loss compared to manual harvesting methods. Combine harvester usage can save on the average of 4.9% grain losses compared to manual harvesting methods (Jones et al. 2019). Second, the inefficiency factors included age of head household, year of attended school, the number of the plot per hectare area, attended training times per year, level of comprehension and adaption of training in percentage, and percentage of cultivated land affected by disaster. Lastly, natural disasters in the study area were mostly drought, flood, and infestation of insects.

Table 1. Description and measurement of parameters of Stochastic Frontier Analysis model

Variable	Efficiency Parameters
Y	Total rice yield (ton/ha)
X_1	Total planted area (ha)
X_2	Total amount of seed used (ton/ha)
X_3	Total amount of cow manure(ton/ha)
X_4	Total family labor (man-day/ha)
X_5	Total hired labor (man-day/ha)
X_6	Total exchange labor(man-day/ha)
X_7	Share of land harvested using combine harvester to total cultivated land (%)
	Inefficiency Parameters
Z_1	Age (years)
Z_2	Education (years)
Z_3	Number of plots per ha (number)
Z_4	Frequency of training attendance per year (times)
Z_5	Level of comprehension and adaption of training (percentages)

Variable	Inefficiency Parameters
Z_6	Share of cultivated land affected by disaster (percentages)

Source: Author's compilation based on field survey and literature review, 2021

RESULTS AND DISCUSSION

Characteristics of farmer respondents. Table 2 shows that almost three out of four family members engage in farming. The average age of the farmer-respondents is 47.4 years old. Most of these respondents have had formal education for only five years, indicating that most farmers cannot read and write properly. Thus, reading comprehension of technical documents or learning to use new machineries are expected to be complex tasks for them.

The average cultivated area for organic rice per household in the study area is 4.24 ha, and total holding land is around 6.79 ha which is larger than national average total landholding of 1.3 ha (ADB 2021). It should be noted that the study area is remotely located, thus more farmlands are available for a small population. Since organic rice is only planted in single cropping as a seasonal activity, farmers also need to cultivate other crops such as cashew nuts and cassava to earn additional income. There is approximately 1.9 ha of other crop farming land per household.

Table 2. General characteristics of farmer and organic rice farming in 2020 (N=50)

Items	Mean	SD
Family member (persons)	4.02	1.30
Members engage in agriculture (persons)	2.90	1.21
Educational attainment (years)	5.60	3.18
Age (years)	47.40	12.22
Organic rice yield (tons/ ha)	1.84	0.25
Organic rice cultivated area (ha)	4.24	2.45
Other crop cultivated area (ha)	1.90	1.41
Fallow land (ha)	0.56	0.78
Total owned land (ha)	6.79	4.78

Source: Field survey, 2021

Support mechanism for organic farmers in Preah Vihear Province. Organic rice in Preah Vihear province has been supported by the Support to the Commercialization of Cambodian Rice Project in partnership with the Cambodia Organic Agriculture Association (COrAA) since 2013 (Table 3). For the first year, the project supported agriculture cooperatives to produce organic paddy in compliance with COrAA private organic standards expected to be sold directly to rice millers or exporters who had expressed interest. However, the commercialization of organic paddy was not yet satisfactory due to inefficient logistics and coordination at harvest time.

To address this logistics issue and secure the marketing channel of organic paddy, the approach was changed from a direct selling model to a contract farming approach in 2014. Changes in organic rice standards from Cambodian Organic Agriculture Association (COrAA) standards to European Organic Standard (EOS) and National Organic Program (NOP) standards were apparent, requiring external certification by an international certification body (e.g., Ecocert). Since then, contractors, government extension workers, and NGOs have worked together and provided training on organic rice standards and technical support to farmers to meet international certification requirements. Meang and

Jean-Marie (2018) found that the government or contractors only provided training, and farmers did not receive any subsidy.

Farmers commonly practice growing fragrant and non-fragrant rice in the study area because it is suitable for the wet season and land conditions. Farmers commonly start land preparation in May and do harvesting between late November and early December. Most of them followed their cultivation practice even though they received some training from extension workers, contractors, and NGOs. From the interview, even though combine harvester was used in the study area, some farmers still harvested by hand and sun-dried rice paddy in the field due to limited services, difficult land conditions, and farm location. In line with Sok's (2020) study, farmers have still faced the challenges of low yields, despite receiving technical supports and training from contractors and extension workers since 2014 (Table 2). On the other hand, contract farming enables organic rice farmers to sell harvested rice at a premium price but seems unable to improve their productivity. Although farmers have tried expanding their planted area to increase their production, it resulted in severe labor shortages. Moreover, organic rice farmers could not adapt to new machinery, and access to machinery services is very limited due to the farm location and few service providers.

Yield. The average yield of organic rice in 2020 was approximately 1.84 tons per ha (Table 4), which is still lower than average rice yield of 2.79 tons per ha (Preah Vihear Provincial Department of Agriculture 2020). Thus, farmers still seemed to underestimate their potential income.

Table 4. Mean of organic rice farming parameter per hectare of SFA model (N=50)

Variable	Mean	SD
Efficiency Parameters		
Yield (ton/ha)	1.84	0.25
Planted area (ha)	4.24	2.45
Seed (ton/ha)	0.10	0.04
Fertilizer (ton/ha)	0.09	0.14
Hire labor (pp-day/ha)	9.58	6.06
Family labor (pp-day/ha)	11.44	5.56
Exchange labor (pp-day/ha)	16.78	10.81
Share of land harvested using combine harvester to total cultivated land (%)	0.21	0.30
Inefficiency Parameters		
Age (years)	47.38	12.22
Educational attainment (years)	5.54	3.18
Number of plots (plots/ha)	39.27	8.66
Frequency of training attendance per year	5.56	1.66
Level of comprehension and adaption of training (%)	0.52	0.11
Share of cultivated land affected by disaster (%)	0.47	0.21

Source: Field survey, 2021

Table 3. Support mechanism for organic rice farmers in Preah Vihear province

Activities	2013	2014	2015	2016	2017	2018	2019	2020
Technical support	Agricultural Cooperatives (ACs) producing organic rice through **Goverment and NGOs led project**							
	Training on livestock and crop production organized by **Goverment, NGOs**							
		Training on international standards organized by **Contractors, NGOs**						
Regulatory support		Promotion and implementation of contract farming organized by **Goverment, Contractors**						
		Establishment of internal control system supported by **Goverment, Contractors, NGOs**						
				AC union establishment supported by **Goverment, Contractors, NGOs**				
Certification and standards	local OR standards by COrAA	Organic rice certification by ECOCERT with support from **Contractors, NGOs**						
						start of fair trade led by **Contrators**		
Market access	Direct purchase from buyers		Contract agreement between ACs and contractors; start of organic rice purchasing					
				Contract agreement between AC (with union support) and contractors				
Number of Agricultural Cooperatives	5	8	12	25	32	34	38	38
Number of households under contract farming	n/a	891	1,669	3,151	5,162	5,053	5,341	6,099
Yield(tons/ha)	n/a	n/a	1.96	2.15	2.07	1.81	2.01	1.84

Source: Author's compilation based on Meang et al. (2018); Provincial Department of Agriculture (2020); Sok (2020); and Field survey (2021)

Organic rice farming characteristics per hectare

Planted area. Total organic rice planted area is about 4.24 ha per household. Compared to the study of Sok (2020) that reported about 3.82 hectare per household, farmers seemed to increase cultivated land for rice farming to increase production.

Seeds. In 2020, farmers used about 100kg of seeds per ha. Since farmers conducted seed selection a season earlier for the upcoming growing season, contract companies do not conduct any rice genetic background prior to seed selection. The physical characteristics of the rice plant, specifically its thickness and heaviness of seed, are common key factors considered during the selection process. Before seeding, farmers need to separate unfit grains from the healthy seeds by soaking the seeds in water containing salt, and the floaters are separated from the sinkers.

Fertilizer. Farmers commonly use a small amount of fertilizer (cow manure) with an average of 90 kg per ha. Moreover, farmers tend to apply cow manure more after cultivating their land for more than five years to improve soil fertility. Because farmers collect cow manure from their cows, as the number of owned livestock increases, their supply of cow manure is also expected to increase, especially those farmers with matured cows.

Labor input. Most southeast Asian countries that cultivate rice rely heavily on family, exchange, and hired labor (Morooka et al. 1991). In line with field observations, this study found the same categories. Exchange labor refers to the labor inputs which farmers do not need to pay. Instead, they must return the labor input received by working in other farmers' paddy fields. Exchange and hired labors are commonly used in the study area during transplanting and harvesting. Annual exchange labor input was about 17 man-days per ha, considered the highest among labor inputs. In addition, family labor was the primary labor involved in all stages of cultivation. However, there is a shift to family labor as primary labor source when there is a lack of hired labor, especially during the high availability of off-farm activities.

Combine harvester services. During harvesting time, recently, farmers started to use combine harvester services. Most farmers use rental services because owning a combine harvester requires a high cost (Table 3). The average rental cost for combine harvester services ranges from KHR 350,000 to KHR 500,000 per ha or about USD 87 to USD 125 per ha. Currently, there are limited opportunities for farmers to lease combine harvesters depending on the availability of rental services. Some rice fields also do not have suitable field conditions to use combine harvesters. Therefore, the harvesting process still requires laborers to proceed manually.

Inefficiency parameters. The average age, family size, and education level of head household farmers are explained in Table 1. The average number of plots per ha refers to the number of plots for growing organic rice per ha. Frequency of training is defined as how many times farmers attend training per year. Level of comprehension and adaption of training are subjectively defined as how many percentages they understood and practiced after attending the training, in here, farmers defined the percentage by themselves. Finally, disasters are defined in percentages of rice cultivation areas affected by floods cause from excessive rainfall, droughts, or pests within the study period, and farmers answered in percentage by farmers themselves. About 47% of organic rice cultivation have been reported to be affected by rainfalls at the end of season. While the average rainfall in 2020 was 1,551.36 mm (Preah Vihear provincial department of Agriculture, 2020).

Technical efficiency of organic rice farming. The maximum likelihood estimation reveals that the random error variation (v_{it}) was less than 3%, and gamma (γ) was 0.970 and significance at 1% (Table 5). These results show that the variation of the composite error term came mostly from the technical efficiency (u_i).

Table 5. Parameters of stochastic frontier analysis model

Variable	Coefficient	Std. Error	t-ratio	
Constant	0.704	0.135	5.198	***
Planted area	0.042	0.021	1.967	*
Seed	-0.012	0.035	-0.354	
Organic fertilizer (cow manure)	0.040	0.002	1.704	*
Family labor	-0.006	0.031	-1.600	
Hired labor	0.015	0.008	1.846	*
Exchange labor	0.019	0.010	1.949	*
Share of combine harvester usage	0.013	0.003	1.722	*
Gamma	0.970	0.004	282.872	***
Sigma-squared	0.009	0.003	2.679	***
log likelihood function OLS	37.256			
log likelihood function MLE	58.964			
LR test of the one-sided error	43.416> chi square value 23.551			

Source: Field survey (2021)

Notes: Estimation was conducted using FRONTIER 4.1

*Significant levels are shown as follows: *** p < 0.01, ** p < 0.05, * p <0.1*

SFA revealed that most of the estimated coefficients had expected positive signs except for seed inputs and family labor. Specifically, yield increased for every increase in total planted area, input cow manure, labor hired, exchange labor used, and combine harvester in the study area. Regarding planted area, the findings suggested that the more farmers expand their cultivated land, the greater the potential for increased productivity. This finding is also consistent with previous findings that showed a positive and statistically significant correlation between the size of a rice farm and its yield (Chandio et al. 2019; Tijani 2006). More cow manure could increase organic rice yield with an elasticity of 0.04, indicating that a 1% increase in cow manure input could increase in 4% yield. Similar results from previous studies showed that a 1% increase in fertilizer input could increase rice yield by 9% and potato yield by 10% increase (Kea et al. 2016; Nahraeni et al. 2012).

In addition, hired labor and exchange labor are significant factors in increasing the yield, indicating that both seemed more skillful than family labor (Table 5). This is consistent with previous findings on rice farming efficiency that indicated an increase in hired labor positively increased rice yield in Vietnam (Khai and Yabe 2011). Combine harvesters is also a significant factor in increasing yield because these machines could reduce the harvest losses compared to manual harvesting. Despite the benefits from these agricultural machines, many farmers still use hired labor and exchange labor during transplanting and harvesting, because of the limited availability of combine harvester in the study area. Therefore, even though seed and family labor were not statistically significant with negative signs, these convey that farmers tend to use unskilled family labor and seed excessively and inefficiently.

Technical inefficiency of organic rice farming. Table 6 shows the technical inefficiency of organic rice farming. This model explains inefficiency with a negative sign on a parameter which explains the positive effect of the variables on improving technical efficiency. In contrast, a positive sign indicates inefficiency. Significant technical inefficiency factors include disaster, number of plots per ha, and training comprehension and application. A 1% increase in land area affected by disaster and the number of plots per ha decreases technical efficiency by 25% and 5%, respectively. Farmers try to make many small plots per ha to control water but the result cause decreasing the efficiency. Therefore, if farmers could reduce plot numbers per ha and maintain the good level of water, this may increase the efficiency. This is consistent with findings by Kawasaki (2010) wherein land partition was found to reduce rice production efficiency. A study on northwest Cambodian conventional rice farming revealed that for every 1% increase in disaster-affected rice field, the rice technical efficiency decreased by 27% (Kea et al. 2016). Since the studied farms are in the plateau mountain area, the number of plots per ha is significant, conveying that there is a need to decrease the number of plots to improve technical efficiency.

Table 6. Organic rice farming technical inefficiency model parameters estimation.

Inefficiency Model	Coefficient	Std. Error	t-ratio	
Age	0.039	0.074	0.527	
Education	0.021	0.047	0.438	
Number of plots per ha	0.046	0.013	2.099	*
Frequency of training attendance per year	0.079	0.097	0.818	
Training comprehension and adaption of training	-0.438	0.120	-4.500	***
Share of cultivated area affected by disaster	0.255	0.060	2.715	***

Source: Field Survey (2021)
Notes: Estimation was conducted using FRONTIER 4.1
*Significant levels are shown as follows: *** p < 0.01, ** p < 0.05, * p <0.1*

The frequency of training attendance showed no relationship to the output. However, training comprehension and application had a negative coefficient and was a significant factor at 1%, conveying that their level of understanding and application positively impacted the technical efficiency of organic rice farming in the study area. Thus, if farmers could increase the level of comprehension and application by 1%, technical efficiency could be increased by 44%. Moreover, farmers could only understand and practice less than 50% of the training contents. From the interviews, it was confirmed that some farmers could not apply or understand well the training contents. At times, they were also not the first-hand receiver of training since their children or spouse attended the training on their behalf. From observation, farmers have difficulty adapting because some technical practices (e.g., transplanting, picking good seeds) from training require more time and labor. Therefore, the training contents and method need to be improved for better comprehension and field application and to encourage farmers to join the training.

Technical efficiency distribution of organic rice farmers. Figure 3 illustrates the technical efficiency level distribution of organic rice farming in the study area. Frontier 4.1 revealed that an individual household's production technical efficiency per hectare ranges from 52% to 99%, with a mean of 0.83, indicating that organic rice farmers attained 83% of rice production at the current production inputs and technology level. By comparing the average efficiency level of farmers (83%) to the highest efficiency of farmers (99%), with the same level of inputs, rice yield could have been increased further by 16% if farmers had been technically efficient. These results also revealed a significant gap among organic rice farmers and room for organic rice productivity improvement in the study area.

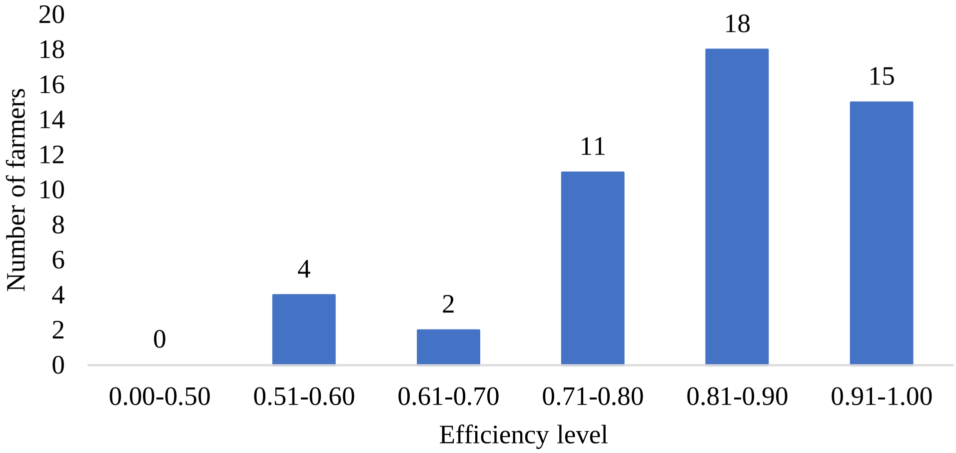

Fig. 3. Technical efficiency distribution of organic rice farmers in Preah Vihear province, Cambodia

Source: Field Survey, 2021

Note: Estimation was conducted using FRONTIER 4.1

CONCLUSION

Organic rice contract farming is considered an important livelihood to secure farmers' income in Cambodia. In Preah Vihear province, organic rice and contract farming have been promoted since 2013 and 2014, respectively. Although the income of organic rice farmers has increased through these initiatives, farmers continue to experience low yields. Thus, this study attempted to review the support mechanisms to organic rice farmers, characterize organic rice farmers under contract farming, and identify influencing factors of technical efficiency.

The review of support mechanisms confirmed that public and private institutions have been extending various support services related to certification, market access, production, and regulation since 2013. Farmers also received a premium price, which is one of their reasons for engaging in organic rice farming under contract agreement. However, farmers had low educational attainment, which led to challenges in understanding training and adapting new agricultural technologies.

SFA revealed that an increase in technical efficiency could be attributed to land expansion, increased usage of cow manure, and increased harvested land using combined harvesters. On the other hand, the share of disaster-affected land and the number of plots seemed to decrease technical efficiency. Therefore, there is a need to promote proper land preparation and minimize the number of plots. Moreover, the provincial government may consider constructing irrigation facilities to improve productivity and address flood and drought related issues. Moreover, SFA showed that understanding and application of training contents significantly and positively impacted technical efficiency, despite the frequency of attending training's insignificant impact on technical efficiency. Thus, there is a need for customized training and other support services for farmers and their family members in line with their needs and capabilities.

For further research, long-term study on organic rice farming efficiency is vital. Inclusion of factors such as level of taking risks, training contents, and training methods are suggested.

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