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ECONOMIC SUSTAINABILITY OF GEOGRAPHICAL INDICATION INDIGENOUS RICE: THE CASE OF KHAO SANGYOD MUANG PHATTHALUNG, THAILAND

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ABSTRACT
Khao Sangyod (Sangyod rice) is an indigenous red rice variety commonly cultivated in Southern Thailand. Its distinctive and desirable cooking quality and nutritional value made Sangyod rice in Phatthalung province Khao Sangyod Muang Phatthalung the first geographical indication (GI) rice registered in Thailand. These attributes also earned it the status of a Protected Geographical Indication (PGI) Thai rice registered in the EU. Sangyod rice cultivation can generate a good income for farmers and contribute to the conservation of indigenous varieties and genetic biodiversity. This study aims to measure farmers' net incomes (profitability), which is one important indicator of sustainable rice platform (SRP) indicators by the United Nations Environmental Programme, and to compare the profit inefficiency among farmers. The data were collected from 328 farmers in three southern provinces for the 2019/2020 cropping season. The results show that, on average, Sangyod rice farmers have a profit efficiency score of 68, implying that they can still improve their profit by 32%. Sangyod rice production in the GI area has a profit efficiency higher than that outside the area. The results from this study can inform the formulation of policies that support the sustainability of indigenous rice in Thailand.

Contribution/Originality: The profit inefficiency estimates show that GI registration, experience in Sangyod rice cultivation, and reducing vulnerability to drought can improve Sangyod rice farmers' profit efficiency. However, adhering to an organic production standard and engaging in off-farm jobs can bring down farmers' efficiency in maximizing profit.

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1. INTRODUCTION
"Khao Sangyod" or Sangyod rice is an indigenous rice variety mainly cultivated in Southern Thailand. It possesses a well-recognized and desired flavour and aroma, and given that it has a red pericarp, Sangyod rice is reputed for its high fiber content, rich nutritional value, and being the rice of choice for special occasions in the Southern culture. Although Sangyod rice is commonly produced in Southern Thailand, the main crops of the region are other high-value crops, such as palm oil, rubber, and perennial fruits. In recent years, the Southern region has begun to contend with production challenges from climate change. Compounding the production risks to this region's key crops are the market uncertainties brought about by increasing competition in the international market. This has been causing instability in prices and the market.

Although rice is not the main crop in the Southern region, it can provide a good source of income in the short run. The market for colored rice has been expanding in recent years as consumers become more aware of the benefits of a healthy diet (Napasinuwong, 2020; Office of Agricultural Economics, 2022). Adding to its popularity is the rising public awareness of *in situ* conservation of indigenous varieties as an important measure to preserve biodiversity. These have drawn increasing public attention to Sangyod rice, particularly for sustainable development.

Although Sangyod rice is widely cultivated throughout the Southern region, Sangyod rice produced in Phatthalung province has unique qualities due to the suitability of the soil, water and climate (European Commission, 2016). As a result, Phatthalung's local government assisted local farmers' groups to successfully register "Khao Sangyod Muang Phatthalung" as a geographical indication (GI) product in Thailand in 2006, and as a protected geographical indication (PGI) in the EU in 2016. GI has also been encouraged by several Asian countries to support rural agriculture development (Jena, Ngokkuen, Rahut, & Grote, 2015; Rahmah, 2017).

It grants farmers the right to protect their traditional knowledge and methods of cultivation such that the distinctive qualities of the product endows it a reputation attributable to a specific geographical origin. With "Khao Sangyod Muang Phatthalung" registered as a PGI rice from Thailand and one of the first GI rices in the country, GI certification was promoted to Phatthalung rice farmers' groups that have the control system for complying with the GI code of practice.

GI certification gives those who conform with the applicable standards the right to use the GI certification mark to prevent its use by a third party whose product does not meet the GI standards. It gives consumers the assurance that the product possesses the quality that it is reputed to have from a specific geographical origin. This, in turn, enables farmers to command a premium price. As an export product, the certification enhances access to international markets, especially the EU. Although studies have found that GI products offer significant price premiums (Napasintuwong, 2019; Török, Jantyik, Maró, & Moir, 2020) and consumers are willing to pay more for GI rice that has supreme quality associated with the source of origin (Lee, Pavasopon, Napasintuwong, & Nayga, 2020), the impact of conforming to GI standards on a farmer's income is ambiguous largely because of the cost associated with GI production (Cei, Defrancesco, & Stefani, 2018; Török et al., 2020).

Furthermore, Thailand's law on intellectual property rights does not prohibit the use of the GI name (although it does prohibit the use of the GI certification mark) for products that do not meet the GI standard (Department of Intellectual Property, 2020). This implies that uncertified Sangyod rice grown in Phatthalung province can, without the GI certification mark, use the term "Khao Sangyod Muang Phatthalung".

Understanding the elements contributing to the sustainability of Sangyod rice farming is crucial for a sustainable food system. The FAO (2018) suggested that profitability (or net income) is one of the key economic aspects of a sustainable food system as farmers' profitability is a major incentive for them to stay in farming, expand production, improve quality and raise productivity, which is the bedrock of food and nutrition security, poverty reduction and, ultimately, social and economic development. Standards, as a governance mechanism, ensure socially and environmentally responsible production, so that the product and the way it is produced and processed cause no harm to the environment, resources, or society.

More specifically, they ensure that no adverse impacts occur among stakeholders of the food supply chain. Specific to rice, the Sustainable Rice Platform (SRP) provides guidelines for sustainable rice cultivation from a set of 12 quantitative performance indicators (Sustainable Rice Platform, 2021). Among these indicators is profitability to ensure that rice cultivation is attractive among farmers. Increasing farm profitability provides incentive and improves the farmers' capacity to invest in improvements that increase efficiency, productivity and profitability. The higher income, in turn, increases household capacity to pay for food, health services and education. According to Vandecandelaere et al. (2021), GI is linked to the sustainability process and can be quantified using a variety of indicators, with economic impacts being especially crucial to the viability of GIs. However, the registration of GI does not automatically guarantee sustainable processes.

To better understand the role of GI on the sustainability of indigenous rice, we focus on the economic pillar of sustainable development, namely the profitability of farmers. Several studies have applied the profit efficiency concept to measure profit inefficiencies of farmers and identify factors contributing to the inefficiencies so that recommendations for more efficient profit-maximizing behavior can be formulated to inform policy, programs and practices (Ali & Flinn, 1989; Ali, Parikh, & Shah, 1994; Chang, Takahashi, & Yang, 2017; Ho, 2021; Nguyen, Nguyen, Jolly, & Nguelifack, 2020; Rahman, 2003; Van, Nanseki, & Chomei, 2019).

This study aims to estimate profit efficiency among farmers who cultivate Sangyod rice in the Southern region by comparing farming in Phatthalung province, the geographical area of GI rice, other non-GI areas, and on the comparison among different standards of cultivation (i.e., GI, good agricultural practice (GAP), and organic farming). The study also aims to identify factors that contribute to profit inefficiency. Because Sangyod rice is preferred in Southern cuisine and the support given to rice production has been focused on GI Sangyod rice products in Phatthalung province, it is hypothesized that farmers in Phatthalung province will benefit from GI registration and those who comply to GI standards would be more profit efficient than others.

2. MATERIALS AND METHODS

2.1. Data

A three-stage stratified sampling method was employed to collect data on Sangyod rice cultivation in Southern Thailand for the 2019/20 cropping season. In the first stage, provinces are classified in two groups, one is the geographical area eligible for GI registration (Phatthalung province) and the other is a non-GI zone. Two provinces, namely Krabi and Nakhon Sri Thammarat, out of seven provinces that cultivated Sangyod rice between 2015 and 2019

(Department of Agricultural Extension, 2020) were randomly selected for the non-GI zone. In the second stage, districts were classified into two groups based on share of suitable areas for rice production, i.e. high (at least 75%) and low (less than 75%) (Agri-Map, 2020).

In the last stage, sub-districts were selected based on certification standards, e.g., GI, GAP, organic, and none of the above. Farmers were randomly selected from farmers' groups that have at least one certification (i.e., GAP, organic or GI) and from groups that have no certification. A sample size of 357 was selected from 4,639 Sangyod rice households in three selected provinces with a 95% confidence level, 0.05 acceptable error, and a 0.5 sample proportion of the interested households (Krejcie & Morgan, 1970). The information on Sangyod rice production was based on the largest plot if farmers cultivated more than one plot. Excluding negative profit and outliers, 328 farmers are included in the estimation.

2.2. Profit Efficiency Model

Profit efficiency is an economic concept defined as the capability of a farm to achieve the highest possible profit given the prices and levels of fixed inputs of that farm (Ali & Flinn, 1989). Based on Kumbhakar & Lovell (2000), the variable profit frontier function is given as:

$$\pi(p,w,z) = pf(x,z) - \textstyle\sum_j w_j x_j = p(f(x,z) - \sum_j w_j{}^N x_j) \qquad (1)$$

where p is the nominal farm gate price of Sangyod rice, x is the variable inputs, z is the quasi-fixed inputs, such as land, $f(x,z)$ is the production function of Sangyod rice, y, and $w_j{}^N = \frac{w_j}{p}$ is the normalized price of variable input j including labor service, seed and fertilizer.

Profit efficiency (PE) can be measured as the ratio of actual variable profit to maximum variable profit. Provided that profit is > 0 and profit efficiency is ≤ 1, profit efficient farmers would achieve PE $= 1$; in other words, being on a variable profit frontier.

2.3. Stochastic Frontier Analysis

The stochastic profit function model is used to estimate farm-specific efficiency. Any errors in the production decision are assumed to translate into lower profits for farmers (Ali et al., 1994; Coelli, Rao, O'Donnell, & Battese, 2005; Kumbhakar, 1987). By assuming a single output profit maximization, a stochastic normalized variable profit frontier function (Ali et al., 1994) is given as:

$$\pi_i{}^N = \mathrm{f}(w_{ij}{}^N, z_{ij}) \cdot \exp(e_i) \qquad \mathrm{i} = 1, 2, \ldots, \mathrm{n} \qquad (2)$$

$$e_i = v_i - u_i \qquad (3)$$

where

π^{N} is the normalized variable profit function.

e_i is the error term.

v_i is a two-sided error term representing the usual random effects and is assumed to be independent and identically distributed (iid) as $N(0, \sigma_v^2)$.

$u_i > 0$ is a one-sided error term representing profit inefficiency. If $u_i = 0$, a farm is on the profit frontier and achieving the maximum profit given the prices it faces and level of quasi-fixed inputs. It is assumed that $v_i$and $u_i$are independent of each other.

Given the flexibility of the translog functional form, which allows returns to scale to be variable, the normalized variable profit frontier of Sangyod rice production is represented as follows:

$$In\pi_i{}^N = \alpha_0 + \textstyle\sum_j \beta_j\, lnw_{ij}{}^N + \mu lnz_i + \frac{1}{2}\sum_j \sum_k \theta_{jk}\, lnw_{ij}{}^N lnw_{ik}{}^N + \frac{1}{2}\sum_j \gamma_j\, lnw_{ij}{}^N lnz + \frac{1}{2}\rho lnz_i{}^2 + (v_i - u_i) \qquad (4)$$

where

$w_{service}$ = price of labor service (USD/ha) calculated as the weighted average of wage and/or labor and machinery service fees from land preparation to harvest.

w_{seed} = seed price (USD/ha). If the farmers kept seed from a previous harvest or received free seeds from support programs, seed price is estimated from the public seed price of the equivalent quality.

$w_{fertilizer}$ = price of fertilizer (USD/ha) calculated as the weighted average of all types of fertilizer.

z = Sangyod rice cultivation area (hectares).

The normalized variables in Equation 4 are with respect to the farm gate price of Sangyod rice (USD/kg).

The frontier function to identify factors associated with variations in the profit inefficiency level of the ith farm can be expressed as a linear function (Battese & Coelli, 1995) defined as:

$$u_i = \delta_0 + \textstyle\sum_m \delta_m S_{mi} + \vartheta_i \qquad (5)$$

where S_{mi} is variable m associated with profit inefficiency of the ith farm including:

S_{age} = age of farmer (years); S_{edu} = education (years of schooling); S_{HH} = number of household members (people); S_{exp} = experience in Sangyod rice production (years); S_{group} = membership in a cooperative or farmers' group (1 if yes and 0 otherwise); $S_{offfarm\ inc}$ = share of non-agricultural income (proportion of total household income obtained from non-agricultural sources); S_{ext} = agricultural extension (1 if the farmer had received training on rice production from public or private agricultural extension in the past three years and 0 otherwise); $S_{contract}$ = price arrangement (1 if the farmer agreed a price with buyers prior to production and 0 otherwise); $S_{GI\ area}$ = GI registered area (1 if the farm is located in Phatthalung province and 0 otherwise); $S_{drought}$ = experiencing recurrent drought (1 if yes and 0 otherwise); S_{GI}= GI (1 if GI certification was received and 0 otherwise); S_{GAP}= GAP (1 if GAP certification was received and 0 otherwise); S_{org} = organic (1 if organic Thailand certification was received and 0 otherwise).

A maximum likelihood method was used to estimate the unknown parameters of the stochastic frontier (Equation 4) and inefficiency function (Equation 5) simultaneously to avoid inconsistency in the assumptions regarding the independence of the inefficiency effects of the two-stage estimation.

3. RESULTS AND DISCUSSION

3.1. Summary of Sangyod Rice Farming

The summary of the survey data is provided in Table 1, showing the key variables used in the estimation models. There are 304 samples in the GI area, specifically Phatthalung province, and 28 in the non-GI area. While there are 41, 39, and 26 certified GI, GAP and organic farms, respectively, the majority of samples are uncertified farms. A test of the differences between farms in the GI and non-GI areas shows that, on average, the farm gate price of Sangyod rice in the non-GI area is higher than that in the GI area, but the variable cost of production in the non-GI area is larger than that of the GI area.

This makes the variable profit in the GI area higher than that in the non-GI area. The comparisons of price, yield, revenue, cost, and variable profit of Sangyod rice across different standards are shown in Table 2. Certified organic rice fetches a higher price and needs a cheaper fertilizer than any other type of rice, but it generates the lowest yield and highest variable cost, especially labor service cost. GI certified rice has the second highest price after organic rice, as expected. The land rent of certified GI rice is the highest, and even though this quasi-fixed cost is not included in the variable cost, certified GI rice still shows the lowest variable profit among all types of farms.

The results show that the average profit efficiency of Sangyod rice farms in the Southern region is 68%, and farms located in Phatthalung province, the GI area, have a higher average profit efficiency than those located in the non-GI area (see Table 4). Non-certified farms in Phatthalung province have the largest profit efficiency followed by certified GAP, GI and organic farms. This suggests that the standard of Sangyod rice production may contribute to farmers' profitability. The majority of Sangyod rice farms in the GI area scored a medium to high profit efficiency level (0.41–0.60 or above), while the majority of those located in the non-GI area are distributed at the low efficiency end (0.41–0.60 or lower) (see Figure 1).

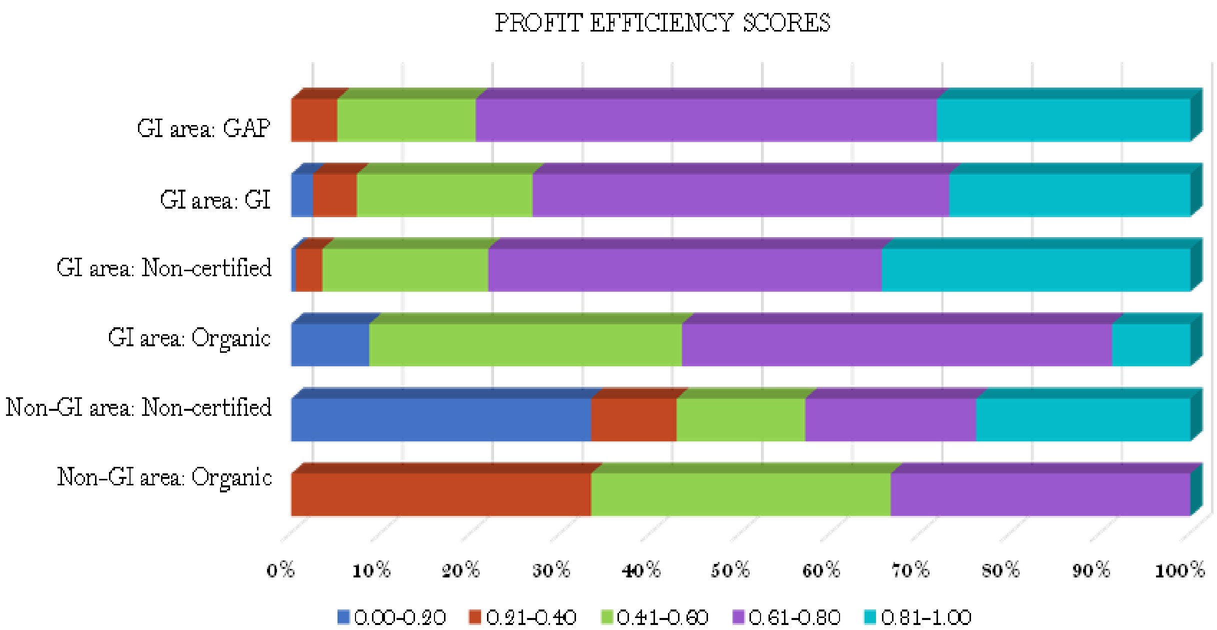

Figure 1. Profit efficiency scores of Sangyod rice production in Southern Thailand, by area and production standard, 2019/20.

Table 1. Summary statistics of Sangyod rice production in Southern Thailand, by area and standard, 2019/20.

Variable	GI area					Non-GI area			Total	T-statistic
	GI	GAP	Organic	Non-certified	Total	Organic	Non-certified	Total		GI area VS Non-GI area
Output, price, cost and profit										
Output	2,421.27	2,599.88	2,269.94	2,470.54	2,465.31	2,145.00	2,394.32	2,363.16	2,457.84	0.46
(kg/ha)	(538.49)	(513.24)	(691.29)	(544.32)	(556.28)	(1,407.35)	(1,054.90)	(1,070.97)	(606.73)	
Output price	0.51	0.49	0.55	0.50	0.51	0.81	0.56	0.59	0.51	-2.62**
(USD/kg)	(0.09)	(0.09)	(0.10)	(0.09)	(0.09)	(0.14)	(0.14)	(0.16)	(0.10)	
Labor service price	30.80	32.95	40.19	30.13	31.35	9.43	34.58	31.44	31.35	-0.02
(USD/day)	(18.00)	(17.31)	(16.98)	(16.66)	(17.08)	(3.85)	(17.64)	(18.55)	(17.16)	
Seed price	0.92	0.89	0.97	0.88	0.89	0.81	0.99	0.97	0.90	-1.62
(USD/kg)	(0.11)	(0.12)	(0.08)	(0.13)	(0.13)	(0.14)	(0.25)	(0.25)	(0.14)	
Fertilizer price	0.35	0.37	0.20	0.32	0.32	0.43	0.43	0.43	0.33	-3.60***
(USD/kg)	(0.11)	(0.14)	(0.18)	(0.15)	(0.15)	(0.10)	(0.15)	(0.14)	(0.15)	
Cultivation area	0.70	0.77	1.01	0.67	0.71	0.43	0.73	0.69	0.71	0.19
(ha)	(0.43)	(0.41)	(0.50)	(0.36)	(0.40)	(0.32)	(0.45)	(0.44)	(0.40)	
Variable Cost	508.26	543.37	519.82	457.24	479.91	861.49	769.40	780.91	501.93	-3.54***
(USD/ha)	(141.42)	(187.78)	(136.76)	(123.41)	(139.86)	(584.48)	(401.81)	(413.60)	(190.58)	
Variable Profit	789.72	809.25	790.61	823.32	814.51	887.61	601.25	637.04	801.52	2.11**
(USD/ha)	(320.15)	(385.45)	(375.30)	(345.68)	(348.50)	(298.99)	(405.68)	(400.30)	(354.89)	
Farm-specific Variable										
Age	59.83	57.97	59.74	60.90	60.29	65.00	62.90	63.17	60.50	-1.78*
(Year)	(10.63)	(10.23)	(12.45)	(11.71)	(11.44)	(9.85)	(7.06)	(7.23)	(11.20)	
Education	9.34	9.54	10.09	8.27	8.72	6.00	6.76	6.67	8.57	3.92***
(Year)	(4.05)	(3.97)	(4.19)	(3.53)	(3.75)	(0.00)	(2.49)	(2.33)	(3.70)	
Household members	3.07	3.67	3.48	3.37	3.38	3.33	4.48	4.33	3.49	-2.26**
(Person)	(1.60)	(1.66)	(1.44)	(1.66)	(1.63)	(1.53)	(2.06)	(2.01)	(1.68)	
Experience	11.56	11.59	14.22	9.86	10.64	9.00	17.43	16.38	11.06	-3.08***
(Year)	(7.21)	(7.26)	(10.23)	(9.30)	(8.93)	(1.73)	(8.89)	(8.78)	(9.03)	
Off-farm income	34.80	29.33	40.16	27.23	29.50	72.90	33.12	38.09	30.13	-1.23
(%)	(30.25)	(27.48)	(37.16)	(28.36)	(29.37)	(24.48)	(31.52)	(33.13)	(29.69)	
No. of observations	41	39	23	201	304	3	21	24	328	

Note: Exchange rate: USD 1 = 31.30 THB (Reference rate 2020 (BOT, 2021)).
Numbers in parentheses represent standard deviation. *, ** and *** denote significance at 10%, 5%, and 1%, respectively.

Table 2. Output, price, cost and returns of Sangyod rice production in Southern Thailand, by standard, 2019/20.

Variable	GI (1)	GAP (2)	Organic (3)	Non-certified (4)	F-statistic
Output	2,421.27	2,599.88	2,255.52	2,463.33	1.74
(kg/ha)	(538.49)	(531.24)	(761.99)	(607.74)	
Output price	0.51	0.49	0.58	0.50	5.46***
(USD/kg)	(0.09)	(0.09)	(0.15)	(0.10)	
Labor service price	30.80	32.95	36.65	30.55	1.11
(USD/day)	(18.00)	(17.31)	(18.85)	(16.77)	
Seed price	0.92	0.89	0.95	0.89	2.05
(USD/kg)	(0.11)	(0.12)	(0.10)	(0.15)	
Fertilizer price	0.35	0.37	0.23	0.33	5.13***
(USD/kg)	(0.11)	(0.14)	(0.18)	(0.15)	
Total revenue	1,234.08	1,287.15	1,272.53	1,226.01	0.43
(USD/ha)	(308.21)	(355.79)	(428.09)	(345.69)	
Variable cost	508.26	543.37	559.24	486.77	1.90
(USD/ha)	(141.42)	(187.78)	(237.02)	(191.77)	
- Labor service cost	306.28	323.71	368.22	308.02	1.32
(USD/ha)	(80.94)	(124.66)	(204.77)	(157.84)	
- Seed cost	66.09	67.95	64.46	70.97	0.47
(USD/ha)	(18.66)	(63.94)	(23.86)	(30.56)	
- Fertilizer cost	135.89	151.70	126.57	107.78	3.55**
(USD/ha)	(92.07)	(108.21)	(98.44)	(81.94)	
Quasi-fixed cost	141.59	106.87	94.14	94.84	6.05***
- Land rent (USD/ha)	(44.16)	(33.74)	(9.74)	(35.54)	
Variable Profit	789.72	809.25	801.80	802.31	0.02
(USD/ha)	(320.15)	(385.45)	(363.45)	(356.76)	
No. of observations	41	39	26	222	328

Note: Numbers in parentheses represent standard deviation. ** and *** denote significance at 5% and 1%, respectively.

3.2. Profit Frontier and Profit Efficiency Estimates

The coefficient estimates of the variable profit frontier are shown in Table 3. From these estimates, the profit efficiency of each individual farm is estimated. The estimates of the mean profit efficiency score by area and by standard are presented in Table 4. The distribution of profit efficiency score by area and standard is presented in Figure 1.

Table 3. Coefficient estimates of the variable profit frontier function.

Variable	Coeff.	Std. Err.	Z
Constant	0.48	0.08	6.20***
$\ln W_{service}$	-0.06	0.63	-0.09
$\ln W_{seed}$	0.39	0.19	2.08**
$\ln W_{fertilizer}$	-0.09	0.08	-1.15
$\ln Z$	0.05	0.27	0.2
$1/2\ (\ln W_{service})^2$	0.20	0.44	0.45
$1/2\ (\ln W_{seed})^2$	1.55	0.62	2.52**
$1/2\ (\ln W_{fertilizer})^2$	0.00	0.05	-0.06
$1/2\ (\ln Z)^2$	-0.11	0.53	-0.2
$\ln W_{service} \times \ln W_{seed}$	-0.66	0.38	-1.72*
$\ln W_{service} \times \ln W_{fertilizer}$	0.06	0.13	0.49
$\ln W_{service} \times \ln Z$	-0.05	0.47	-0.1
$\ln W_{seed} \times \ln W_{fertilizer}$	-0.01	0.09	-0.12
$\ln W_{seed} \times \ln Z$	0.57	0.34	1.68*
$\ln W_{fertilizer} \times \ln Z$	-0.09	0.11	-0.79
σ_v^2	0.22	0.03	
Log-likelihood	-158.42		
No. of observations	328		

Note: *, ** and *** denote significance at 10%, 5%, and 1%, respectively.

Table 4. Profit efficiency scores of Sangyod rice production in Southern Thailand, by area and standard, 2019/20.

Statistic	GI area					Non-GI area			Total	T-stat
	GI	GAP	Organic	Non-certified	Total	Organic	Non-certified	Total		GI area vs Non-GI area
Mean	0.67	0.7	0.62	0.71	0.69	0.5	0.48	0.48	0.68	-3.41***
(Std. Dev.)	(0.17)	(0.15)	(0.22)	(0.15)	(0.16)	(0.24)	(0.31)	(0.30)	(0.18)	
Min.	0.16	0.31	0.09	0.18	0.09	0.24	0.03	0.03	0.03	
Max.	0.94	0.94	0.88	0.93	0.94	0.73	0.87	0.87	0.94	
No. of obs.	41	39	23	201	304	3	21	24	328	

Note: *** denotes significance at 1%.

3.3. Profit Inefficiency Equation Estimates

The investigation of the factors associated with profit inefficiency (Equation 5) revealed that more experience in Sangyod rice production and the location of the farms in Phatthalung province reduce profit inefficiency. Also, an increase in profit inefficiency was found in farms operating to an organic standard and in farming households that have a larger share of off-farm income (see Table 5).

Table 5. Coefficient estimates of profit inefficiency function.

Variable	Coeff.	Std. Err.	Z
Constant	1.64	1.08	1.53
S_{Age}	-0.01	0.01	-0.85
S_{edu}	-0.05	0.04	-1.26
S_{HH}	0.01	0.06	0.23
S_{exp}	-0.03	0.01	-3.13***
S_{group}	0.03	0.23	0.14
$S_{off\text{-}farm\ inc}$	0.01	0	2.75***
S_{ext}	0.27	0.23	1.19
$S_{contract}$	0.27	0.22	1.25
$S_{GI\ area}$	-2.66	0.47	-5.64***
$S_{drought}$	1.35	0.76	1.78*
S_{GI}	0.3	0.43	0.69
S_{GAP}	0.14	0.28	0.49
$S_{organic}$	0.74	0.41	1.81*
No. of observation	328		

Note: * and *** denote significance at 10% and 1%, respectively.

These results imply that the registration of GI, which is confined to the geographical area comprising Phatthalung province, gives Phatthalung farmers a higher ability to generate profit, even if they are not certified GI producers. This has implications that are similar to Jena et al. (2015) and Jena & Grote (2012), which are that by adopting a GI rice variety, namely Basmati, farmers could improve their income, and that GI registration can provide benefits to farmers who grow the registered variety. Sekine (2021) also found that farmers who grow heirloom rice receive higher farm gate prices and obtain higher margins. The heirloom rice generates more benefits to their economic and livelihood security than the improved lowland varieties. Although this study does not compare profit efficiency across varieties, the results show that growing specialty rice can improve farmers' income, and this is particularly true for the GI specialty rice in the defined geographical area.

Meeting GI and GAP standards does not improve farmers' efficiency in generating profit. Adherence to an organic standard can even worsen it. A plausible explanation is that the organic rice certification decreases the ability to arrange inputs in a cost-effective manner, especially labor service. Organic rice production is more labor intensive, e.g., weeding. Thus, even if certified organic rice fetches a high price, low yield and high variable costs make it more profit inefficient (see Table 2).

Farmers with longer experience in Sangyod rice production are also more efficient in generating profit, but their age and education are not associated with their ability to maximize profit. These results are consistent with other studies, such as Ho (2021); Trong & Napasintuwong (2015); Khan, Roll, & Guttormsen (2021); Nguyen et al. (2020) and Rahman (2003), who found that farming experience improved the profit efficiency of agricultural production. Similar to this study, Chang et al. (2017); Khan et al. (2021); Oladeebo & Oluwaranti (2014) and Rahman (2003) also found that education is not associated with profit efficiency. This may be especially true in the farming of an indigenous rice variety (as per this study), which suggests that the ability to maximize profit may not be associated with formal education but with farming experience. Studies by Galawat & Yabe (2012); Hong & Yabe (2015) and Wongnaa, Awunyo-Vitor, Mensah, & Adams (2019) similarly found that age is not associated with profit efficiency. The result from this study suggests that while older farmers have more traditional knowledge of indigenous rice cultivation and are efficient in minimizing the inputs required to produce an output (technically efficient), younger farmers may have a higher ability to access price information, e.g., find cheap input sources and marketing channels so that they can more efficiently allocate their inputs in a cost-effective manner (cost efficient) and their outputs in a revenue-maximizing manner (profit efficient). Technical and price efficiency are important elements of profit efficiency and farmers of different ages may possess knowledge and skills that contribute to different efficiencies.

While farmers' groups or cooperatives can provide better input procurement and access to markets that increase profit efficiency (Hong & Yabe, 2015; Van, Nanseki, & Chomei, 2019), the finding from this study shows that being a member of a farmers' group does not improve efficiency in generating profit in Sangyod rice production. This is similar to Oladeebo & Oluwaranti (2014) and Wongnaa et al. (2019) and might be explained by the popularity of Sangyod rice and government support to conserve indigenous rice production, which gives group members no advantage over non-members in terms of the capability to maximize profit. A training program was hypothesized to improve profit efficiency, but it was found that being trained in Sangyod rice production does not have any significant contribution to farmers' ability to maximize profit, and neither does an agreement on price with buyers (i.e., informal contract). Either the training program for indigenous rice production was not effective or farmers who grow indigenous varieties do not need to be trained in production techniques to improve their ability to increase profitability. Training on marketing to improve farmers' entrepreneurial ability might improve their profit efficiency. However, no marketing training or support program were found in the technical services provided to farmers.

Off-farm income was also found to increase profit inefficiency and is consistent with the findings of Ho (2021) and Rahman (2003). This provides a good explanation for the situation in Southern Thailand; only about 20% of households derive their main income from the agricultural sector, which is the lowest among all regions (National Statistical Office, 2013). When rice farming is not the farmers' main source of income, their profit efficiency decreases. The impacts of natural disasters, such as flooding, saltwater intrusion and disease have been shown to significantly decrease economic efficiency (Nguyen et al., 2020). As the Southern region has been beset by production challenges from the impacts of climate change, our finding also confirms that recurrent drought has resulted in lower profit efficiency, conceivably from low productivity. The livelihood of rice farming, particularly of indigenous varieties, can be severely threatened without proper and effective measures to mitigate the risks from climate change.

For GI to be sustainable, economic viability is a key element, but a balance among the three pillars of sustainable development – social, economic, and environmental sustainability – is needed (FAO, 2009). This study focused on the economic aspect of sustainability. However, it suggests that the sustainability of farming indigenous rice varieties in Southern Thailand can be improved by improving profit efficiency, the economic pillar of SRP. This can then be reinforced by infusing the management of rice farming with social and environmental responsibility. Contributions and interests of various stakeholders in the social, economic, and environmental aspects of farming system should be encouraged.

4. CONCLUSIONS

The GI registration of Sangyod rice provides benefits to farmers in a GI area, but the GI certification does not. This suggests that the registration of GI Sangyod rice is beneficial to all farmers in the geographical indicated area. There is also a need to further investigate ways to improve the control system of GI certification and to implement more effective training programs, such as ones that improve entrepreneurial skills so that the economic viability of producing GI indigenous rice can be enhanced.

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