ASSESSMENT OF THE SUSTAINABILITY OF RICE CULTIVATION PRACTICE OF FARMERS IN THREE CERTIFIED PROGRAMS COMPARED WITH CONVENTIONAL FARMERS IN UBON RATCHATHANI PROVINCE, THAILAND

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ABSTRACT

The sustainability of four types of rice cultivation practiced by farmers and the factors contributing to increased sustainability were assessed. The four types of rice cultivation consisted of organic rice production, Good Agricultural Practices (GAP), Sustainable Rice Platform (SRP), and conventional production. A total of 85 farmers were requested to respond to the questionnaires on farmer and farm characteristics, and farmer descriptions of 123 rice cultivation practices were assessed using SRP sustainability standards during September – October 2018. Four types of farmers were not significantly different for age, education, farming experience, level of farm integration and total income but they were significantly different for rice yield and labor size. Organic and conventional farming were highest for rice yield, whereas conventional farming system was highest for labor use. None of farming systems achieved an overall SRP score that enabled to claim as sustainable rice farm, but organic, GAP, and SRP farmers had significantly higher overall SRP scores and higher scores for farm management and pre-planting practice. The regression analysis showed that the factors promoting high SRP score were the SRP and GAP programs, and the characteristics which facilitated joining the program were the farm size, farm experience and rice yield.

Key words: organic, sustainable rice platform, good agricultural practice, certification

INTRODUCTION

Thailand is one of the world's top three rice exporting countries. In 2021, the area planted with rice was estimated at 9.12 million ha, and rice production was reported at 45.29 million tons (DFT 2021; OAE 2021). Most paddy fields are managed by family farmers. For decades, Thai government has played an encouraging role to increase productivity and raise farmers' income level by promoting intensive, chemically based agricultural systems. Nevertheless, 40% of Thai farmers are still poor (Chantatarat 2018). Rice production cost in Thailand was higher than those in other rice exporting countries (Poapongsakorn 2013; Pongsrihadulchai 2017). Yield loss is frequently affected by natural disasters including drought, flooding and high temperature, causing rice yields to vary considerably from year to year. Moreover, paddy fields are one cause of climate change due to emission of methane (Kawasaki 2010). Rice fields are responsible for 11% of global agricultural nitrous oxide (N_2O) emissions (US-EPA 2020). Thailand is also ranked 20th in the world in terms of agricultural CO_2 emissions (FAO 2018).

In 2018, the Thai government established a "20-year National Strategy Plan" that includes a 20-year agricultural strategy (2018-2037) (NSSO 2017). The principal objectives of this plan are to

expand the area in high standard agriculture and increase the number of high-performance farmers, especially organic and sustainable rice farmers. The rice department of the Thai Ministry of Agricultural and Cooperatives is collaborating with GIZ (German International Co-operation) and Olam (Thailand) in implementing a sustainable rice project called "Market-Oriented Smallholder Value Chain (MSVC)". The objectives of MSVC were to promote and develop farmers' knowledge and use of Sustainable Rice Platforms (SRP) to reduce production costs, make appropriate use of local labor, stop the burning of paddy stubble, and use production practices that mitigate greenhouse gas (GHG) emissions from rice cultivation, promote climate-resilient rice production systems, and enhance the livelihoods of smallholders (Vichitlekarn 2018). The MSVC project established SRP Standards to enable farmers to assess the current level of sustainability of their rice production practices and, thereby, stimulate farmers' awareness and provide concrete improvement targets. The SRP project has first been implemented in Ubon Ratchathani province as a pilot area and will be expanded to other areas soon.

At present, not all farmers in Ubon Ratchathani participate in the SRP program. Some farmers produce organic rice based on Participatory Guaranteed System (PGS) that is promoted by the government and certified as organic rice. Other farmers follow Good Agricultural Practices (GAP) standards, a certification program for export. Farmers who do not participate in any certification program use conventional, chemical-based practices.

To determine the best way to increase the level of sustainability of rice production practices and overall farm sustainability in the future, data on rice production practices used on all types of farms are needed. For this purpose, the following two objectives were established for this study in the SRP project area:

1. To assess the sustainability of rice cultivation based on SRP standards for 4 types of rice practices: Conventional rice practices, organic rice practices (PGS standard), GAP rice practices, and SRP rice practices.
2. To identify the characteristics of rice farmers, farm management, and rice production practices that contribute to increased sustainability based on SRP standards of rice production practices.

METHODOLOGY

Description of study location and sample size determination. Det Udom district is part of Ubon Ratchathani province located in the northeastern part of Thailand near Laos and Cambodia (Fig.1). This is an area of rainfed agriculture, and the main crop is rice. Thai rice department selected Bua Ngam and Klang subdistricts as the pilot-testing area of the SRP sustainable rice project in 2016. Stratified random sampling was used to select farmers from each of four types, SRP, organic, GAP and conventional. Lists of farmers in each type were obtained from the Extension Service Center of Det Udom district. The resulting sample consisted of 22 SRP farmers from 30 active SRP farmers (73%), 22 GAP farmers from 300 GAP farmers (7%), 19 organic farmers from 60 PGS organic farmers (32%), and 22 conventional farmers from 400 farmers who did not belong to any certified program of the government (6%). The total sample size of 85 farmers was 11% of the farmers in the lists (790 farmers in total).

Data collection and analysis. We collected both quantitative and qualitative data from the 85 sample farmers during September – October 2018. We used questionnaires to obtain data on farmer and farm characteristics. Farmers gave their descriptions of 123 rice cultivation practices, which we assessed based on SRP sustainability standards as described below.

The SRP standards contain 8 themes, each with multiple requirements, for a total of 46 types of requirements for sustainable rice production. These requirements have environmental agronomic, economic, and social impacts (Table 1). This reflects a holistic conception of sustainability that not only limited to environment but also aspects of farmer's life

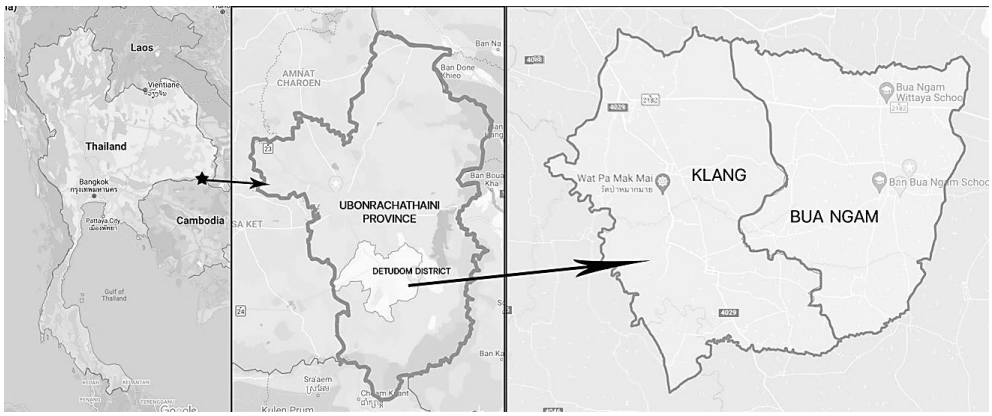

Fig. 1. Research location in Klang and Bua Ngam subdistricts in Det Udom district, Ubon Ratchathaini province, Thailand

Table 1. The SRP theme requirements and impacts (version 1.0)

Theme	Requirement
Farm management	1) Crop calendar 2) Record keeping 3) Training Impact to: Profitability, yield
Pre-planting	1) Heavy metal 2) Salinity 3) Land conversion 4) Invasive species 5) Leveling 6) Seed variety Impact to: Food safety, profitability, yield, water, GHG, biodiversity
Water use	1) Water management 2) Irrigation system 3) Inbound water quality 4) Water extraction 5) Drainage Impact to: Profitability, yield, water, GHG
Nutrient management	1) Nutrient management 2) Organic fertilizer 3) Inorganic fertilizer choices 4) Inorganic fertilizer use Impact to: Profitability, yield, nutrients, GHG, biodiversity
Pest management	1) IPM (Integrated pest management) – weed management / Insect management / Disease management / Mollusk management / Rodent management / Bird management 2) Pesticide selection 3) Targeted application 4) Label instruction 5) Calibration Impact to: Profitability, yield, food safety, pesticides, biodiversity, health and safety, community
Harvest and postharvest	1) Timing of harvest 2) Harvest equipment 3) Drying time 4) Drying technique 5) Rice storage 6) Rice stubble 7) Rice straw Impact to: Profitability, yield, food safety, nutrients, GHG, community
Health and safety	1) Safety instruction 2) Tools and equipment 3) Training of pesticide applicators 4) Personal protective equipment (PPE) 5) Washing and changing 6) Applicator's restrictions 7) Re-entry time 8) Pesticide storage 9) Pesticide disposal Impact to: Pesticides, food safety, health and safety
Labor rights	1) Child labor 2) Hazardous works 3) Education 4) Forced labor 5) Discrimination 6) Freedom of association 7) Wages Impact to: Child labor, Labor rights

Farmers, who joined the program, received training and were expected to develop their farm activities following the SRP standards. Within each requirement, the level of sustainability of each type of practice is shown by a score. The highest performance level for each requirement was indicated by a score of 3 points. Other practices with intermediate sustainability were indicated by scores of 1 or 2 points. Unsustainable practices were indicated by a score of 0 point. Scores were collected and assigned by the inspectors based on the guidelines of the first public version of the SRP standards (Ellis 2015).

Next, we calculated weighted scores for each requirement and average scores per theme and per farmer to obtain values on a common scale across themes with different numbers of requirements and unequal numbers of farmers in each type. Weighed scores for each requirement were calculated as a fraction of the maximum score of 3

Weighted score per requirement = Score of the requirement / maximum score.

The average score per theme was calculated relative to the number of requirements in the theme

Average score per theme = sum of weighted scores per requirement / no. of requirements

Average scores per farmer were calculated as the sum of all scores / maximum total score, where the maximum total score was 138 (46 requirements x 3, the maximum score per requirement).

All scores are shown as percentages. Scores for each requirement and theme were assigned to one of three levels by SRP:

1. Entry level : 10-67
2. Essential level : 68-90
3. Sustainable level : 91-100

Due to the complexity of comparing four rice programs, SRP themes were utilized to illustrate similarities and differences in the requirements of the four rice programs based on their objectives.

The information on (Table 2) showed the strictness of 4 rice programs according to SRP theme. The organic program did not allow chemical use on farm and focused on clean sources of water and natural system of soil. This program was the only one type that require farmer to pass the transition period. The SRP program was the only one program that mentioned about child labor, and other requirements were similar to those for organic program but still allowed chemicals on farms. The GAP program allowed farmers to use agricultural chemicals. For the conventional farm, there was no requirement to force the farmers to attain. However, the activities that farmers did on their farm would reflect the sustainable scores.

Table 2. The similarities and differences between the 4 rice programs

Program	**ORGANIC**	**SRP**	**GAP**	**CONVENTIONAL**
Requirement	Transition period 3 years after training	Transition period n/a	Transition period n/a	Transition period n/a
Farm management	Record keeping on seed variety, production sources, fertilizer use, cost, pest management and other operation on farm	Record keeping on seed variety, production sources, fertilizer use, cost, pest management and other operation on farm	Record keeping on seed variety, production sources, fertilizer use, cost, pest management and	N/A

Program	ORGANIC	SRP	GAP	CONVENTIONAL
			other operation on farm	
Pre planting	Farm not located in contaminated area, Not located in primary forest, Buffer zone needed, Document proof for heavy metals safe 100%, Organic seeds only from trustworthy sources, No GMO seed	Farm not located in contaminated area, Not located in primary forest, Cultivated on flat land or on terrace, Document proof for heavy metals safe and no risk of soil salinity, Use pure seed from trustworthy sources	Farm not located in contaminated area, Document proof for heavy metals safe and no risk of soil salinity, Use pure seed from trustworthy sources	N/A
Water use	Clean sources free from biological, saline and heavy metal and chemical substance	Clean sources free from biological, saline and heavy metal	Clean sources free from biological, saline and heavy metal	N/A
Nutrient management	Focus on natural system of soil fertilizer enhancement, Organic fertilizer only	Focus on natural system of soil fertilizer enhancement, Chemical fertilizer can be use from trustworthy source	Chemical fertilizer can be use from trustworthy source	N/A
Pest management	No chemical	IPM, Allowed chemical at safe level, avoid killing insects and pest animals	Allowed chemical at safe level	N/A
Harvest and Postharvest	Harvest at appropriate time, Clean harvest equipment, Separated milling to prevent contamination, Appropriate drying, Cleaned and separated store away from hazardous substance and pest damage, Not burning rice stubble	Harvest at appropriate time, Clean harvest equipment, Separated milling to prevent contamination, Appropriate drying, Cleaned and separated store away from hazardous substance and pest damage Not burning rice stubble	Harvest at appropriate time, Clean harvest equipment, Appropriate drying, Cleaned and separated store away from hazardous substance and pest damage	N/A
Health and Safety	Calibration, maintenance and cleaning tools,	Workers receive regular safety instructions,	Calibration, maintenance and cleaning tools,	N/A

Program	ORGANIC	SRP	GAP	CONVENTIONAL
	No chemical pesticide[1]	Calibration, maintenance and cleaning tools, Use personal protective equipment, Pesticide storage in safe place	Use personal protective equipment, Pesticide storage in safe place	
Labor right	N/A	No child labor, forced labor in hazardous work, workers free to join worker's organization	N/A	N/A

Source: As researched by the author (2018)

To ascertain the sustainability of the four programs, statistical analysis was performed using SPSS version 23 (2015). ANOVA and Tukey method was applied, significance was defined as p-value > 0.05. Data were represented as means and one standard deviation. Two regression models are used to determine the factors affecting SRP scores, and the characteristics of rice farmers that encourage higher sustainability based on SRP standards of rice production practices.

1) To identify the factors that contributed to the SRP score, multiple linear regression was used to analyze the correlation between the SRP score and selected factors. The use of organic program, use of GAP program and use of SRP program were applied as a dummy variable. The following independent variables hypothesized to contribute to variation in the dependent variable Y: overall SRP scores, were initially entered into a full model:

$$Y = \beta_0 + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \beta_4X_4 + \beta_5X_5 + \beta_6X_6 + \beta_7X_7 + \beta_8X_8 + \beta_9X_9 + \beta_{10}X_{10}$$

Where:

Y : SRP score (sustainable rice cultivation score)
X_1 : Use of organic program (dummy: use of the program = 1)
X_2 : Use of SRP program (dummy: use of the program = 1)
X_3 : Use of GAP program (dummy: use of the program = 1)
X_4 : Years of education
X_5 : Level of integration (no component, one-component, 2 and more components)
X_6 : Source of income (dummy: both on-farm and off-farm)
X_7 : Number of on farm laborers
X_8 : Yield (kg/ha)
X_9 : Farm size (ha)
X_{10} : Total income (baht)

2) To identify the characteristics of rice farmers that encourage positive sustainability. The correlation between significant factors identified from the multiple linear regression model were examined by using logistic regression and the wald test. The full equation is expressed below:

$$Z = \beta_0 + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \beta_4X_4 + \beta_5X_5 + \beta_6X_6 + \beta_7X_7 + \beta_8X_8$$

[1] Only insecticides made from natural extracts are allowed to be used. The following substances are permitted: Siamese neem extract, lemongrass extract, holy basil extract, and wood vinegar.

Where:

Z : A significant variable that influences boosting the sustainability scores
X_1 : Sex
X_2 : Age
X_3 : Years of education
X_4 : Number of on farm laborers
X_5 : Farm size
X_6 : Total income
X_7 : Experience on rice farm
X_8 : Yield (kg/ha)

RESULTS AND DISCUSSION

Socioeconomic characteristics of the farmers and farms. Most farmers are farmer descendants (98%) with inherited land (96%). The farmers' ages was between 40 and 59 years. Half of them (51%) completed their elementary schools and 28% of farmers graduated from high schools. The majority (88%) of farmers were full-time farmers with more than 10 years' experience. Half of the farmers (53%) never had the experience in another career, and learned rice cultivation techniques from their parents since they were young. The common agricultural system in this area was integrated farming system. Most grew vegetables and raised cows, some grew peppers and bananas, and others raised fish. Farmer's families in this study planted a variety of food crops on their farms such as weed grass, holy basil, chili, banana and other vegetables and raised some chickens or cows. Some of them obtained free chicken and cows from the extension agent by participating in a government project. Fifty five percent of the conventional farmers used 2 component integrations, whereas 42% of the organic farmers used mono crop rice system. The SRP farmers had the highest number of farmers (59%) who achieved 2 sources of income, whereas 72% of the GAP farmers relied on agricultural income. However, 4 groups of farmers were not significantly different for age, education period, farming experience, source of income and farm integration.

There were statistical differences in the number of laborers in the farms and yield (Table 3). The conventional rice farms used more labor than other farms and there was significant difference between the conventional farmer group and GAP farmer group (Table 4). According to the interviews conducted, conventional farmers did not use two-wheel tractors, whereas other types of farmers did.

Table 3. Farm size, farm labor, yield (kg/rai) and income per year (baht) by farm type.

	FARM TYPE				F	P value
	Conventional (n=22)	**Organic (n=19)**	**SRP (n=22)**	**GAP (n=22)**		
Farm size	4.32 ±1.76	3.68 ±2.24	4.16 ±2.56	4.8 ±3.52	0.65	0.58
Labor on farm	3 ±1	2 ±1	2 ±1	2 ±1	2.74	0.04*
Yield	363 ±24	366 ±33	348 ±28	335 ±26	5.60	0.00**
Agri income	89,795 ±84,872	101,210 ±125,936	124,372 ±209,223	54,318 ±37,234	1.09	0.35
Non-agri income	27,781 ±87,900	44,210 ±110,167	31,590 ±48,682	2,409 ±5,188	1.20	0.31
Total income	117,486 ±124,683	124,421 ±167,300	155,963 ±243,029	56,727 ±36,776	1.65	0.18

Source: Survey by the author (2018)

Note: The scores show the average scores per theme ± standard deviation

Note: * *p-value* > 0.05 / ** *p-value* > 0.01

Table 4. The comparison of farm labor and yield (kg/rai) between farm type.

	Mean difference	Std	P value	Confidence Interval (CI)	
				Lower	Upper
Labor on farm					
Conventional farm / GAP farm	0.68	0.26	0.05*	0.00	1.37
Yield					
Conventional farm / GAP farm	27.27	8.29	0.00**	5.51	49.04
Organic farm / GAP farm	30.86	8.61	0.00**	8.25	53.47

Source: Survey by the author (2018)
Note: * *p-value* > 0.05 / ** *p-value* > 0.01

Conventional farms and GAP farms were significantly difference for rice yield, and organic farms and GAP farms were also significantly different for this parameter (Table 4). While GAP farms had the lowest yields, the conventional, organic, and SRP farms had the rice yields exceeding the average yield of Ubon Ratchathani province (330 kg) (OAE 2020). However, SRP rice farms in this research still had the lower yield than the expectation of the program which was expected to obtain more than 400 kilograms per Rai.

GAP farmers had the lowest income among all farmers. GAP farmers did not receive any assistance from government special programs. Farmers, who participated in the SRP program, could sell their rice at a guaranteed price. Organic farmers also received a higher price from the government subsidy. While conventional farmers achieved higher yields based on the amount of fertilizer used, some of them used fertilizer three times per crop, which was more frequent than that used by GAP farmers. There was no difference in selling prices between conventional and GAP farmers. Therefore, the farmers, who produced and sold larger amount of paddy, earned higher income.

Sustainable rice cultivation score between 4 rice practice. The sustainable score from SRP depended on the activities in the rice farm. Means of percentage scores, standard deviation and the evaluation of scores were used to express the sustainability of farms on 8 themes of SRP as show in Table 5.

Table 5. The average percentage of SRP scores between 4 farm type.

	FARM TYPE				F	P value
	Conventional (n=22)	Organic (n=19)	SRP (n=22)	GAP (n=22)		
Farm management	71.71 ±22.14	83.04 ±21.07	86.86 ±13.55	92.92 ±11.13	5.73	0.00**
Pre-planting management	56.56 ±16.67	69.29 ±19.89	78.78 ±21.32	83.08 ±14.89	9.03	0.00**
Water use management	90.90 ±15.19	84.21 ±20.39	90.90 ±15.19	85.60 ±18.03	0.86	0.46
Nutrient management	70.60 ±19.04	73.68 ±21.59	76.06 ±20.84	68.48 ±25.79	0.50	0.68
Pest management	83.63 ±11.76	84.56 ±15.40	84.84 ±10.72	80 ±13.95	0.64	0.59
Harvest and post-harvest management	76.40 ±13.42	81.45 ±22.15	83.33 ±13.44	83.54 ±11.82	1.01	0.39
Health and safety	73.48 ±9.22	79.82 ±18.81	80.55 ±9.03	82.57 ±9.11	2.36	0.07

	FARM TYPE				F	P value
	Conventional (n=22)	**Organic (n=19)**	**SRP (n=22)**	**GAP (n=22)**		
Labor right	99.78 ±1.01	95.23 ±19.63	100	99.35 ±2.22	1.14	0.33
Total SRP scores	77.86 ±11.65	80.99 ±6.12	86.81 ±6.47	84.15 ±4.47	5.50	0.00**

Source: Investigation by the author (2018)
Note: The scores show the average scores per theme ± standard deviation
Note: * *p-value* > 0.05 / ** *p-value* > 0.01
Note: Entry level (10-67 points) / Essential level (68-90 points) / Sustainable level (91-100 points)

Four types of farmers were significantly different for sum of SRP scores and 2 themes including farm management and pre-planting. Other 6 theme scores among 4 rice practices were not statistically different. All farmer types did not achieve the level of sustainable rice cultivation, but they attained the essential level, "working toward sustainable rice cultivation". Among the four types, the SRP farmers achieved the highest overall scores. The lowest percentage scores were farmers using conventional rice practice.

Four types of farmers were compared for farm management including crop calendar throughout the production period, attending the training or regular receiving professional advice and farm record such as seed source, yield, pesticide, fertilizer, water use and machinery operation. Four types of farmers were significantly different for two requirements including crop calendar and the training. In the study area, farmers who joined in the certified rice standard programs (Organic, SRP and GAP) must keep records their farm accounting and daily tasks. Because these are the forms of data which are required for standard certification by the audits. From the interviews with conventional farmer's group, the conventional farmers made the crop calendar and recorded some data. On the other hand, some farmers recorded only their cost because it was not necessary for them to show the detail of their activities to the audit. In their opinion, they preferred to working freely, they did not want to write down a lot of information in complicated forms (Table 6). As the use of crop calendar is time-consuming for the farmers, extension personnel should first review the methods of crop calendar use of the 3 certified programs. Extension personnel might organize a workshop with key farmers from each program to compare the methods used in each program, discuss their advantages and disadvantages, and design a farmer-to-farmer methodology program. This approach has been effectively used in the Northeast of Thailand for farmer-to-farmer technology development (Sukchan et al. 2010; Taweekul et al. 2009).

In pre-planting, this theme expected farmers to check the heavy metals, salinity, invasive species, seed source, land conversion and land leveling prior to planting the crop. These requirements affected profitability, yield, biodiversity and greenhouse gas emission (GHG). Farmers in this study did not invade the forest area or planted rice in primary or secondary forest, and they did not use invasive species. The organic, GAP and SRP farmers planted their rice on flat land or terraces, especially SRP farmers, and they were financially supported by the program for soil leveling. The conventional farmers leveled their land for more than 3 years and some of them planted rice on sloping lands, but they used the conservation technique such as erosion barriers and cover crops. Four types of farmers were significantly different for heavy metal check, salinity and seed variety requirement (Table 5). Conventional farmers had the lowest scores for heavy metals and salinity (Table 6), reflecting that they did not have documents to prove the safety of soil from heavy metal such as arsenic, cadmium, chromium, mercury, lead and the document to proof that the soil salinity was in acceptable level. For seed source (or seed variety), some conventional farmers purchased seed from regional rice seed centers and rice research centers, but most of them used self-saved seeds for more than three crop cycles. Low

scores in these activities brought conventional farmer's score down to the entry level, whereas farmers using the other 3 types of rice production practices attained the essential level (Table 5).

Table 6. The score on farm management and pre-planting themes between 4 farm type.

	Farm Type				F	P value
	Conventional (n=22)	**Organic (n=19)**	**SRP (n=22)**	**GAP (n=22)**		
Farm management						
Crop calendar	2.3±0.7	2.8±1	2.7±0.6	2.9±0.5	4.33	0.00**
Training	2.2±1	2.3±1	3	2.9±0.3	6.45	0.00**
Pre-planting						
Heavy metal check	0.50±1	1.5±1.	1.8±1	2.2±1	6.78	0.00**
Salinity check	0.6±1	1.6±1	1.6±1.5	2.2±1	6.35	0.00**
Seed variety	2.3±1	2.8±0.3	2.8±0.5	2.3±0.5	4.43	0.00**

Source: Survey by the author (2018)
Note: The scores show the average raw scores per requirement ± standard deviation, range of scores: 0-3
Note: * *p-value* > 0.05 / ** *p-value* > 0.01

The conventional farmers always attend the training program which was organized by the extension agent even the number of trainings is lower than other farmers and this led to the significantly difference scores between conventional farmers and other farm types (Table 6, 7). In this area, some of the conventional farmers desired to switch to the organic rice farm in the future. There is also has the significantly difference between SRP farmers and GAP farmers in training (Table 7). As a pioneer group, SRP farmers worked closer with government audits more than GAP farmers. The program required SRP farmers to join the training program, record their farm activities and submit documents to the audits to pass the certified SRP farming.

Table 7. The comparison of significant different scores on farm management, pre planting and total SRP scores between farm type.

	Mean			Confidence Interval	
Farm management	**difference**	**Std**	**P-value**	**Lower**	**Upper**
Crop calendar					
Conventional farm / GAP farm	-0.59	0.17	0.006**	-1.05	-0.13
Training					
Conventional farm / SRP farm	-0.77	0.21	0.003**	-1.33	-0.22
Conventional farm / GAP farm	-0.68	0.21	0.010**	-1.24	-0.13
Organic farm / SRP farm	-0.63	0.22	0.02*	-1.21	-0.05
Pre planting					
Heavy metal check					
Conventional farm / SRP farm	-1.27	0.40	0.01**	-2.34	-0.21
Conventional farm / GAP farm	-1.77	0.40	0.00**	-2.84	-0.71
Salinity check					
Conventional / SRP	-1.09	0.41	0.04*	-2.17	-0.02
Conventional /GAP	-1.72	0.41	0.00**	-2.80	-0.65
Seed variety					
Conventional / Organic	-0.52	0.18	0.02*	-1.01	-0.04
Total SRP score					
Conventional / SRP	-8.94	2.32	0.00**	-15.04	-2.84
Conventional /GAP	-6.28	2.32	0.04*	-12.39	-0.18

Source: Survey by the author (2018)
Note: * *p-value* > 0.05 / ** *p-value* > 0.01

Considering the water use theme, rice crop was planted at appropriate times resulted from an understanding on seasons and local climate of the farmers. The farmers also prepared strong rice bunds to collected rainwater. Most of the farmers in this study (94%) did not use the agrochemicals in their farms, and there was no negative impact to biodiversity.

Under the nutrient management theme, SRP focused on the use of organic and inorganic fertilizers by farmers. These activities affected nutrient management, yield, greenhouse gas emission and profitability of farmers. Most of farmers (77%) used many soil fertility enhancement methods such as crop rotation, green manure, animal manure that are available for their farms. 67% of farmers used only organic fertilizers. Inorganic fertilizers were used by conventional farmers and GAP farmers in the lowest volume by economic reason. All of fertilizers came from registered and trustworthy companies. Most of farmers in this study (82%) applied fertilizers 2 times per crop at sowing and at 55-60 days after sowing (DAS). The method of fertilizer application by farmers was different from that suggested by the agricultural extension agents, who recommend farmers to apply fertilizer 3 times per crop at sowing, at 30-45 DAS and at 55-60 DAS (Table 8).

Table 8. Fertilizer usage between farm type

	FARM TYPE				
	Conventional (n=22)	**Organic (n=19)**	**SRP (n=22)**	**GAP (n=22)**	**Percentage of all farmers**
	%	%	%	%	%
Type of fertilizer					
Organic only	86	100	50	36	67
Inorganic only	14	0	0	9	6
Mix	0	0	50	55	27
Time					
1 time/crop	14	21	9	5	12
2 times/crop	77	79	77	95	82
3 times/crop	9	0	14	0	6

Source: Survey by the author (2018)

For the pest management theme, SRP requires farmer to use integrated pest management (IPM) techniques rather than simply applying pesticides to control insects, rodents, birds and mollusk. In case of emergency, the application of pesticides was allowed but the farmers had to strictly follow the government recommendations and label instructions and not apply on non-target areas. The farmers participating in the certified programs (organic, SRP and GAP) never used the chemical substances for pest management in their farms. All farmer types found weed problem that affected crop yields especially the SRP farmers who had this problem since 2017 (Atthawit 2017). Land preparation and manual weeding were used to solve the problem, but the process was ineffective. Conventional farmers used herbicides with limited amount for weed control. They followed the suggestions from other farmers and the agrochemical shops in the area and worried about their personal health problem.

For harvest and postharvest management theme, most of farmers (71%) sold their paddy as rough rice (unhusked rice). They did not need the drying technique or the storage except the organic rice farmers who need the highly clean equipment and the specific rice mills that prevented the contamination in yield. After harvest, the organic rice farmers used sun drying method with shelters and stored their paddy in clean and safe storage. Most of farmers (79%) incorporated rice stubble and rice straw into the soil to allow the aerobic decomposition before the beginning of next rice crop.

For health and safety theme, the objective of this theme is to protect the labors in dangerous farm activities. Most of the farmers (99%) in this study did not use the herbicide or pesticide, which made them to receive the high score on this theme. However, four types of farmers were significantly different for two requirements including safety instruction and tools and equipment (Table 5). The conventional farmers did not frequently calibrate and maintain their farm equipment. Moreover, some rice farms did not have first aid supplies available on farms.

Lastly, for the labor right theme, SRP standard paid attention to the child labor, forced labor, discrimination, freedom of association and labor wages. Four farmer types had high scores for this theme that achieved sustainable level (over 91 points) (Table 5). From these scores, it may not imply that these farmer types had the good management in labor rights theme because all laborers were family members and there was no child laborer (Table 2). The results were in agreement with those reported in 2017. Labor rights and child labor were not an issue of concern in Thailand (Watcharapongchai 2017).

Although four farmer types had similarly score on 6 themes, but their overall SRP scores are different. In general, farmers' agronomic techniques will have an impact on the sustainable scores and refer to rice farm's sustainability. However, development or change in agronomic practices of the farmers could not be carried out immediately, and this should be carried our gradually point by point. The similar results were also reported for mountain potato production in Japan (Caldwell and Ueda 2016). Programs designed to increase the motivation of farmers based on their own self-determination have proved to be effective in various countries (Sayanagi et al. 2016). Moreover, the results obtained in this section can be used as basic information for developing an integrated collaborative approach which combines agricultural extension, the three sustainability programs, and agricultural researchers working in collaboration with farmers and other stakeholders (Inaizumi 2017)

The factors that contribute to the development of sustainable rice farm.

Backwards elimination retained X_2 ,use of SRP program and X_3 ,use of GAP program as the only variables contributing significantly to variation in overall SRP scores. All other independent variables did not contribute significantly. as shown in the following equation (Eq 1.).

$$Y = 72.466 + 9.838\ (X_2) + 6.999\ (X_3)$$

$$(3.923)^* \quad (2.674)^*$$

$R^2=0.237$, Adjust $R^2=0.134$ $F=2.29$

The regression formula is significant at 5% (F-test) (Eq.1)

The use of SRP (X_2) and GAP program (X_3) had a significant effect on SRP scores. In this study, organic farmers had lower scores on the pre-planting and health and safety themes (Table 5, 7). These factors had an impact on overall scores and made the organic program significantly different from other types of practices although it was the most complex practice among the four rice programs. However, without the SRP and GAP programs, farmers would avoid keeping record of their farm finances, planning their crop calendars, participating training programs to strengthen their skill and checking their soil quality. These activities were important to develop a good farm management plan that directly affected their farm's financial situation and could cause the difference in their sustainability of their rice production.

The use of SRP and GAP programs were the factors contributing to the development of a sustainable rice farm. Logistic regression was applied to investigate the factors influencing the use of

SRP and GAP programs. No variable in this model had a significant effect on SRP farmer adoption. For GAP farmers, the enter model showed the Cox and Snell R^2 of 0.41 and Nagellerle R^2 of 0.61. The results of logistic regression and Wald test are shown in Table 8 and the logistic regression model obtained in this research is shown in (Eq 2).

$$Z = -75.292 + 0.09(X_5) - 0.03(X_8) \quad \text{(Eq.2)}$$

Cox and Snell $R^2 = 0.41$ and Nagellerle $R^2 = 0.61$

Table 8. Logistic regression result and wald test of GAP farmer

Variable	B	S.E	Wald test	p-value	EXP (B)
Sex (X_1)	1.13	0.86	1.73	0.18	3.12
Age (X_2)	-2.49	1.08	5.30	0.21	0.08
Years of education (X_3)	0.07	0.10	0.62	0.42	1.08
Number of on farm labors (X_4)	-0.02	0.43	0.00	0.96	0.97
Farm size (X_5)	0.09	0.03	5.68	0.01	1.09
Total income (X_6)	0.00	0.00	3.91	0.48	1.00
Experience on rice farm (X_7)	22.98	8530.18	0.07	0.98	9.58
Yield (X_8)	-0.03	0.01	5.05	0.02	0.96
Constant	-75.29	34120.74	0.00	0.99	0.00

Source: Survey by the author (2018)
Note: The prediction performance's correct percentage is 72.7% (use of GAP:1) and 88.9% (use of other practice: 0)
Note: * *p-value* > 0.05 / ** *p-value* > 0.01

The significant factors that influenced a farmer's decision to adopt GAP rice program were 1) farm size and 2) yield. Farmers with larger farm sizes were more likely to practice GAP than others. Larger farm sizes allowed larger space for GAP-compliant activities such as fertilizer and chemical storage as well as a drying yard. Farmers with limited farmland may be concerned about this topic because the smaller the farmland, the lower the growing area available for rice production. For yield, farmers with lower yields were more interested in the GAP program than farmers with higher yields. Farmers, who had problems with their cultivation, were willing to try new methods to improve their rice production. In Thailand, GAP practice is widely promoted by extension agents, and it is a good choice for farmers who cannot adopt the organic program.

According to the complexity of rice programs, the organic program was most difficult to implement due to the requirements, especially the transition period of the program (Table 2). Although the use of the organic program did not show a significant difference in (Eq 1), we were still curious about the factors that led farmers to adopt this rice program. Table 9 and (Eq 3) below show the logistic regression and Wald test.

According to (Eq 3), the factors that effected the adaptation of the organic program were experience on rice farm (X_7) and yield (X_8). The new farmers or the less experienced farmers (regardless of age) would be eager to try new things and would be more likely to adopt complex rice practices such as the organic rice program than other farmers. According to the interviews, farmers with a lot of experience are doubtful of the new rice standard, as well as any government enterprise. Because they frequently have mistrust towards the government officers. Many government projects that are directed at farmers had problems in the past and the government officers frequently abandon farmers to their own problems. Farmers who have worked with government authorities for a long period have a negative

attitude of government-led projects. In addition, farmers who had a high yield, appeared to be more interested in the organic rice program than others. Some organic farmers explained that farming is risky because farmers must invest their money without knowing if they will get it back. Choosing a new technique puts farmers under more stress than it provides them confidence. So, if they had a large number of rice plots and already had high yield, they would implement the organic program by dividing their farm plot and utilizing various rice practices. They were already aware that the beginning state of the organic rice program would have an impact on yield. They would adopt the organic program if they had other farm plots with higher yields that could help stabilize their income.

Table 9. Logistic regression result and Wald test of Organic farmer

Variable	B	S.E	Wald	p-value	EXP(B)
Sex (X_1)	-0.41	0.65	0.39	0.52	0.66
Age (X_2)	0.63	0.55	1.28	0.25	1.88
Years of education (X_3)	-0.08	0.08	1.16	0.28	0.91
Number of on farm labor (X_4)	-0.21	0.35	0.35	0.55	0.80
Farm size (X_5)	-0.02	0.02	1.14	0.28	0.97
Total income (X_6)	0.00	0.00	1.68	0.19	1.00
Experience on rice farm (X_7)	-1.38	0.62	4.89	0.02	0.25
Yield (X_8)	0.02	0.01	4.13	0.04	1.02
Constant	-3.80	4.57	0.69	0.40	0.02

Source: Survey by the author (2018)
Note: The prediction performance's correct percentage is 36.8% (use of organic:1) and 98.5% (use of other practice: 0)
Note: * *p-value* > 0.05 / ** *p-value* > 0.01

$$Z = -3.80 - 1.38(X_7) + 0.02(X_8) \quad \text{(Eq.3)}$$

Cox and Snell $R^2 = 0.17$ and Nagellerle $R^2 = 0.27$

CONCLUSIONS

The farmers who joined any of the three rice programs with certification were more likely to achieve a higher SRP score and reach a higher level of sustainability of rice cultivation. The significantly different activities among farmers were: 1) crop calendar 2) training 3) documents prove the heavy metal check and 4) documents that prove the salinity check on their rice farm. The factors that affected to increase the sustainability on rice farm were 1) use of GAP rice program and 2) use of Organic rice program. However, at present, half of the farmers in this study area did not participate in any of these programs.

To adopt GAP, farmers with larger farms and lower yield were more likely to use GAP rather than others. To adopt Organic, farmers with higher yield and less experience would be more willing to become organic farmers. Further research on the farmer's motivation to overcome the physical farm constraints and the studies on the sustainable marketing channel of rice farmers are necessary. These researches might provide valuable data that extension agents and other stakeholders can use to create a support systems or training programs for sustainable rice farmer development in the near future.

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