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RESEARCH ARTICLE

Factor Affecting Rice Cultivation to Reduce Greenhouse Gas Emissions in Vietnam: An Experience from Farm Households in Thai Binh Province

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ABSTRACT

The aim of this study is to assess the current status of factors affecting greenhouse gas emission reduction in rice cultivation of farm households in Thai Binh province, Vietnam. Then, to have appropriate solutions to promote farmers to participate and expand the rice cultivation area to reduce greenhouse gas emissions in Thai Binh province. Based on data collected from 120 households cultivating emission - reduction rice and 40 households cultivating traditional rice, this study shows that the majority of surveyed farm households have knowledge of emission reduction techniques for rice cultivation. The market for selling emission-reduction rice is considered favorable by almost 42 percent of farm households. However, the production cost per "sao" of emission reduction rice is nearly 20 percent higher than production cost of traditional rice, so that many households are still considering their investment for emission reduction rice. The linear regression model shows that education level of the household head, understanding of the techniques, production cost and market favorable are factors affecting the expansion of the emission reduction rice cultivation area in Thai Binh province.

INTRODUCTION

Rice production is a major contributor to methane emissions worldwide (Nguyen Van Bo, 2016). According to 2019 statistics from General Statistics Office, the national methane emissions were 99.5 million tons, of which rice production accounted for 43% of the total emissions in Vietnam (Katherine et al, 2022). For the agricultural sector, the Vietnam Academy of Agricultural Sciences calculates the average annual greenhouse gas emissions to be 88.6 million tons of CO_2e, of which rice production contributes 75% of total methane emissions (Vietnam Academy of Agricultural Sciences, 2021). Due to methane's global warming potential is 28 times greater than that of carbon dioxide, reducing methane emissions would help curb global warming quickly and effectively (Katherine et al, 2022). Recognizing the importance of reducing greenhouse gas emissions, especially methane, the Vietnamese Government together with more than 100 countries, signed a commitment to reduce methane emissions at the COP26. To implement this commitment, reducing methane emissions from rice production is considered a focus of the action plan. With the goal of reducing methane emissions from rice production by 30%, millions of rice farming households in Vietnam will have to switch from tradition and high-emission farming methods to low-emission farming techniques (Xuan Truong, 2022). Projects and Programs supporting the conversion of rice cultivation methods towards reducing greenhouse gas emissions for millions of farming households were initially implemented in the Mekong Delta of Vietnam (Tin et al, 2012).

In summer season 2017, the first 11 farm households in Thai Binh province of the Red River Delta of Vietnam, were exposed to new rice cultivation methods to reduce greenhouse gas emission when

they participated in the project named *"Sustainable Rice Production and Greenhouse Gas Emission Reduction"*. To switch to low-emission rice cultivation techniques, farm households in Thai Binh province have received support from rice enterprises and agricultural cooperatives in training on transplanting, fertilizing, spraying pesticides and harvesting, etc. However, the number of farming households converting to new rice cultivation methods accounts for only more than 10% of the total number of rice-growing households in the whole province (Geyer et al, 2022). Several factors are said to affect the conversion of new farming techniques by farmers in Thai Binh province, such as: the age of rice farming laborers is high, new techniques are more difficult to apply than the traditional ones, and rice production is no longer the main source of households' income (Hai N. N. Thi et al, 2023). Therefore, analyzing the factors affecting rice cultivation of farm households is necessary to have appropriate solutions to promote farmers to participate and expand the rice cultivation area to reduce greenhouse gas emissions in Thai Binh province.

Based on the above-mentioned issues, this paper focuses on assessing the current status of rice cultivation and factors affecting rice cultivation to reduce greenhouse gas emissions of farm households in Thai Binh province, Vietnam. The following sections of this paper include: research methodology; results and discussion; and conclusion.

LITERATURE REVIEW

Studies on the relationship between rice production and greenhouse gas emissions have been conducted in many countries around the world, especially in rice-growing countries such as China, India, Thailand, and Vietnam since the early 2000s. The research results focus on proposed rice cultivation techniques and models to reduce greenhouse gas emissions. From a technical perspective, the study shows that techniques such as the use of decomposed organic fertilizers and alternate wet and dry irrigation significantly reduce greenhouse gas emissions into the environment (Feng et al, 2013). In other words, the authors have pointed out various feasible options that can help limit greenhouse gas emissions in rice cultivation such as water-saving irrigation, the use of organic fertilizers, and the selection of short-term rice varieties (Hussain et al 2015, Win et al 2021). From economic and environmental perspectives, studies by Datta and Chaudluary on the economic and environmental benefits of chemical fertilizer application methods concluded that reducing greenhouse gas emissions in rice cultivation while increasing rice yield is one of the important challenges for global food security and climate change. Research conducted on experimental rice fields in lowland areas of eastern India over two consecutive years showed that deep nitrogen fertilizer application not only contributed to reducing greenhouse gas emissions but also increased rice yield by 5% (Datta et al 2017, Chaudluary et al 2020). Also conducted in India, a study by Gupta et al. (2021) is a comprehensive study on the issue of greenhouse gas emissions in rice production across the country, showing that traditional wet rice farming methods using a lot of irrigation water, chemical fertilizers and burning straw have caused more greenhouse gas emissions. Changing old farming habits of farmers requires great efforts from the whole community and help from agricultural extension organizations as well as businesses (Gupta et al, 2021).

In Vietnam, some scientists affirm that rice production is the sector that emits the most greenhouse gases in agricultural production, but it also has the potential to reduce emissions through farming methods such as applying biochar techniques, combining rice - soybean and corn, combining rice - aquaculture (Mai Van Trinh et al, 2013). From a socio-economic perspective, rice development is facing huge challenges in terms of climate change, competition for land with urban agriculture and transportation, over-cultivation with intensive farming, increasing crops leading to a decline in soil productivity, environmental pollution, and increased greenhouse gas emissions. In addition, low profits from rice production, high costs, and an unstable market make farmers really insecure about rice cultivation (Nguyen Van Bo, 2016). Approaching from the perspective of farmer participation, research in Hau Giang province has shown that if farmers apply a combination of rice cultivation techniques such as alternating wet and dry irrigation, reducing the use of fertilizers according to recommended levels, and utilizing straw, 10.2 tons of CO_2eq/ha/year can be reduced (Nguyen Thi Ngoc Anh, 2019).

RESEARCH METHODOLOGY

Data collection

Thai Binh is the province with the second largest rice cultivation area in the Red River Delta of Vietnam with an area of about 145 - 150 thousand hectares per year. Farmers in Thai Binh province are always at the forefront in applying scientific and technical advances. Therefore, in recent years, the province's rice productivity has reached over 13 tons/ha/year; the annual rice output is about 1 million tons, contributing to ensuring national food security, meeting the consumption needs in the province and export (Thai Binh Statistical Year Book, 2023). In addition, Thai Binh is also the first province in the Red River Delta to deploy rice cultivation techniques to reduce greenhouse gas emissions at farm households' level (Hai N. N. Thi et al, 2023).

To assess the current status of rice cultivation and factors affecting rice cultivation to reduce greenhouse gas emissions of farm households, this research conducted a survey to interview 160 rice-cultivating households by using questionnaire in Thai Binh province. Of which, 120 households grow rice to reduce greenhouse gas emissions (hereinafter referred to as emission-reducing households) and 40 households grow rice in the usual way (hereinafter referred to as traditional households).

The survey was conducted in the 2023 summer season and the 2024 spring season. In each rice farming household, the household head was interviewed for about 1 hour. The questionnaire focused on the demographic characteristics of farm household, cultivated rice area, rice production costs and rice cultivation techniques. In addition, detailed information related to the market for reducing greenhouse gas emissions' rice was also collected. In some survey contents, to consider the household's assessment of the importance of rice cultivation to reduce emissions; and the difficulty of the market for reducing emissions' rice, the research uses a 5-level Likert scale, such as: (1) very unfavorable; (2) unfavorable; (3) neutral; (4) favorable; (5) very favorable.

In addition to 160 rice farming households, this research conducted 02 focus group discussions including: group 1 with 5 directors of Agricultural Cooperatives and group 2 with 5 local traders who buy rice from farmers. These two focus group discussions provided a deeper insight into the advantages and difficulties of farm households in the process of cultivating rice with greenhouse gas emissions reduction techniques.

Data analysis

This research uses descriptive statistical methods such as mean, frequency and T-test to compare the difference in mean values of some indicators such as rice area, rice yield and rice output between the two selected groups of farm households. Moreover, this paper applies linear regression model to quantify factors affecting rice cultivation with greenhouse gas emissions techniques.

Vietnam is a major rice producer and exporter in Southeast Asia, many studies have been conducted to find out the factors that affect farm households' application new techniques in rice cultivation. In the Mekong River delta, a study using a binary logistic model to analyze the factors that motivate farm households to apply advanced techniques in rice production concluded that education, rice area, and agricultural infrastructure are positively correlated with the decision to apply new rice farming techniques of the household (Son & Thanh, 2014). Similarly, another study in the Red River Delta showed that educational level, household's income, number of agricultural laborers, rice cultivated area, and access to agricultural extension are factors that motivate farm households to apply high technology (Nguyen Xuan Dinh & Nguyen Mau Dung, 2021). Based on the research results of the above-mentioned authors, the regression model includes the following variables (Nguyen Thi Ngoc Anh, 2019):

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_6 X_6$$

The dependent variable Y is measured by the area of rice growing with greenhouse gas emissions reduction methods ("sao"/household).

The independent variables representing the demographic characteristics of the household head include: age of the farm household head is X_1 (in years); gender of the household head is X_2 (a dummy

variable that takes the value of 0 if the household head is female and 1 if the household head is male); and education level of the household head is X_3 (in years of schooling).

Other factors that affect a farm household cultivating rice with greenhouse gas emissions reduction methods include: X_4 representing the understanding of rice cultivation techniques to reduce emissions (a dummy variable that takes the value of 0 if the household head has little knowledge and 1 if the household head knows well); X_5 is the production cost (thousand VND[1]/"sao"); X_6 represents the advantages and disadvantages of consuming rice products with greenhouse gas emissions reduction methods (a dummy variable that takes the value of 0 if difficult and 1 if favorable).

RESEARCH RESULTS

Status of rice cultivation in surveyed farm households

Rice area, rice yield, and rice output

Thai Binh is not a province with a high per capita rice land area compared to other provinces of the country (Thi, H. N., 2022). However, due to the trend of abandoning rice fields to do non-agricultural jobs with higher incomes, many farm households have rented or lent their rice fields. For that reason, it can be seen that the average rice area of a surveyed farm household is relatively high, especially the area of rice growing with emissions reduction methods is nearly 15 "sao" per household; higher 2.4 "sao" than the area of a household growing rice by traditional techniques (Table 1). Moreover, this difference is statistically significant, proving that emission-reduction households tend to expand their rice area more than traditional households.

Table 1: Rice area, rice yield, and rice output of surveyed farm households

Indicators	Unit	Traditional households (n=40)	Emission-reduction households (n=120)	T-test	P-value
Rice area	sao/household	12.5	14.9	2.452	0.025**
Yield	(100kg/sao)	2.52	2.59	0.429	0.668
Output	100kg/households/ season	31.5	38.6	3.285	0.075*

*, **, *** significant at 10%, 5%, and 1%, respectively;

In terms of yield, recently rice in Thai Binh is considered to have reached its highest yield due to the high level of intensive farming of farmers. This is reflected in the average rice yield of traditional households at 2.52 quintals/"sao", equivalent to 7 tons/ha. However, the average rice yield of the emission reduction households is higher at 2.59 quintals/"sao", equivalent to 7.2 tons/ha. This difference is not statistically significant, but it also reflects the fact that households growing rice with greenhouse gas emissions reduction methods have applied better farming techniques not only for the environment but also for improving rice productivity.

In terms of output, corresponding to the gap in rice area and rice yield, the average rice output of each farm household group also has a statistically significant difference. Each emission – reduction household has a higher rice output than a traditional household by more than 7 quintals per crop. It can be said that, along with the expansion of cultivated area, rice production using reduced emission techniques has helped increase the rice output of households; thereby partly encouraging households to continue to participate in rice cultivation using new methods.

Practicing rice cultivation techniques at surveyed farm households

According to agricultural scientists, technical steps for rice cultivation to reduce greenhouse gas emissions include new practices related to low planting density, slow-release fertilizers, limited use of nitrogen fertilizers, alternate wet and dry irrigation, and use of biological products to decompose straw instead of burning it in the field (Thi Hai Ninh Nguyen et al., 2022). In order to assess the

[1] 25,000 VND equals to 1 USD

current practice of these technical steps in rice farming households, this research compares the implementation of these steps between emission-reduction households and traditional households. The results in Table 2 show that rice farming households with emissions reduction techniques have about 7% lower planting density (equivalent to 0.1 kg of rice seeds), use fertilizer about 19% more often, and add 12% less nitrogen.

Table 2: Practicing rice cultivation techniques at surveyed farm households

Indicators	Emission-reduction techniques	Traditional households (n=40)	Emission-reduction households (n=120)	(+/-)	P-value
1. Planting density (kg/sao)	=, < 1.3 kg	1.5	1.4	- 0.1**	0.032
2. Use fertilizers as recommended by the cooperative (%)	NPK Luc Than Nong NPK Viet Nhat Con Co NPK Binh Dien	20.0	71.6	51.6***	0.000
3. Number of fertilizations (times)	>, = 3 times	2.6	3.2	0.6***	0.000
4. Nitrogen fertilizer use (kg/sao)	< 3 kg	3.1	2.5	- 0.6**	0.049
5. Number of days for the field to dry completely (days)	15-17 days	10.0	12.0	1.1	0.860
6. Using biological products to decompose straw (%)	Cooperative recommends product names by season	5.0	40.0	35.0***	0.000
7. Farmers burning straw (%)	Do not burn	55.0	45.0	- 10.0*	0.072

*, **, *** significant at 10%, 5%, and 1%, respectively;

Regarding water management, both groups of farm households depend on irrigation system controlling by agricultural cooperatives. However, the group of farm households who cultivate rice using greenhouse gas emissions reduction methods often let their fields dry for 2 days longer than the group of traditional households. This comes from the requirement for irrigation techniques to reduce greenhouse gas emissions; the rice fields are left to dry longer to limit the gas emissions generated during the process of rice being flooded. In addition, 40% of rice farm households who reduce emissions use biological products to decompose straw instead of burning it in the rice field. In contrast, the proportion of traditional households who burn straw still accounts for 55% (10% higher).

Although there are many adjustments compared to traditional rice farming techniques, it can be said that many farmers who are cultivating rice to reduce greenhouse gas emissions have not strictly followed the technical requirements of enterprises and agricultural cooperatives. Typically, many farmers have not followed the recommendation on planting density at 1.3 kg/sao. The number of days for the rice field to dry is 12 days, while the technical recommendation is 15 to 17 days.

Current status of factors affecting rice cultivation to reduce greenhouse gas emissions

Demographics of surveyed households

2.1 Table 3: Demographic information of emission-reduction households

Indicators	Unit	Number emission-reduction households (n=120)	Percentage (%)
1. Gender of household head	Persons		
Male		25	41.7
Female		35	58.3

2. Age of household head	Year		
Under 30 years old		0	0.0
From 30 to 45 years old		19	31.7
Above 45 years old		41	68.3
3. Education level of household head	Persons		
Primary school		9	15.0
Secondary school		31	51.7
High school and higher education		20	33.3
4. Number of people in household	Persons		
Under 3 persons		18	30.0
From 3 to 5 persons		37	61.7
Above 5 persons		5	8.3
5. Number of laborers in household	Laborers		
From 1-2 laborers		32	53.3
From 3-5 laborers		28	46.7
Above 5 laborers		0	0.0
6. Number of laborers for rice cultivation	Laborers/household	1.5	-
7. Rice growing experience of household head	Year	30.5	-
8. Income from rice contributes to total household income	%	22.5	-

Table 3 illustrates the demographic information of the emission-reduction households. The results show that the proportion of female household heads is 58.3%, higher than that of male. This shows that decisions related to emission-reduction rice cultivation are mostly made by women. Regarding the age and experience of the household heads, it can be seen that the majority of household heads (over 68%) are over 45 years old with over 30 years of rice growing experience. With many years of experience, traditional rice farming methods seem to have become farming practices that are difficult to change among household heads. In addition, many household heads will have difficulty changing to new techniques at older age. Another noteworthy point is that the average number of laborers participating in rice cultivation is less than 2 people per household and the income from rice currently accounts for only over 22% of the total income of each household. According to many studies, this situation is common in many rural areas of the Red River Delta nowadays (Ninh, N. T. H et al 2018). Many households abandon their rice fields to do non-farm work to earn higher incomes. They consider rice as a food crop for their consumption rather than a main income-generating crop.

Farmers' understanding of emission-reduction rice cultivation techniques

2.2 Table 4: Level of understanding of emission reduction rice cultivation techniques

Cultivation steps	**Response of household head (n=120)**		**The importance of emission reduction techniques**
	Number of correct answers	Percentage (%)	
1. Low transplanting density	28	46.7	2.9
2. Keep the rice field dry (alternately wet and dry irrigation)	33	55.0	3.1
3. Apply NPK fertilizer or slow-release fertilizer	36	60.0	3.6
4. No (limited) use of nitrogen fertilizers	32	53.3	3.1
5. Use biological products to decompose straw (do not burn straw in the rice field)	43	71.7	3.4
6. Limit the use of pesticides	48	80.0	3.8

In order to assess the understanding of emission-reduction rice cultivation techniques among households' head, this research collected correct responses and calculated their assessment about the importance of this technique for rice production and environmental protection (using a 5-level Likert scale with 1-very unimportant, 2-unimportant, 3-normal, 4-important, and 5-very important). The results in Table 4 show that after several years of applying emission - reduction techniques, farm households have gradually gained positive awareness of these new techniques.

Almost all households' head are aware that using biological products to decompose straw instead of burning straw in the rice field, and limiting the use of pesticides will contribute to reduce greenhouse gas emissions. In addition, using NPK fertilizers instead of single fertilizers, and not using nitrogen fertilizer in rice cultivation are also correctly recognized by many households' head. However, low density transplanting method is not recognized as reducing greenhouse gas emissions because many households do not have enough labor, so that they use the direct sowing method.

Regarding the importance of all technical steps, the results of farmers' assessment showed that they highly appreciated the limitation of the use of pesticides (3.8 points) and the application of slow-release fertilizers (3.6 points). These steps are good for rice plants, reduce production costs, and contribute to protecting the environment and the health of producers.

Rice production costs

2.3 Table 5: Rice production cost per "sao" of surveyed households Unit: 1000 VND

Indicators	Traditional households (n=40)	Emission-reduction households (n=120)	T-test	P-value
1. Rice seeds	39.0	23.1	3.059	0.019**
2. Fertilizer (NPK)	114.7	114.1	0.608	0.480
3. Potassium	15.0	0.0	2.885	0.037**
4. Nitrogen	13.3	0.0	2.487	0.075*
5. Pesticides	43.1	38.2	4.409	0.060*
6. Hiring labor (farm machines)	677.0	923.0	6.285	0.000***
7. Rat extermination	42.0	42.7	0.952	0.179
8. Irrigation cost	48.6	48.0	0.899	0.332
Total production cost	**1189.4**	**992.7**	**3.285**	**0.047****

*, **, *** significant at 10%, 5%, and 1%, respectively;

Table 5 reflects the average production costs per household for 1 "sao" of rice, excluding family labor. It can be clearly seen that the total production costs of the two groups of households have a statistically significant difference. The production cost of an emission – reduction household is nearly 200 thousand VND/sao higher than that of a traditional household. This difference mainly comes from the rental of harvesters, tillage machines and manual transplanting labor.

Due to the requirements of low-density transplanting technique, most emission – reduction households have to hire manual labor, which costs more than traditional households hiring transplanting machines. Regarding fertilizer costs, it can be seen that the traditional households still use single potassium and nitrogen, which are types of fertilizers that are not recommended for use in low-emission rice growing techniques in Thai Binh province. According to agricultural scientists, these fertilizers produce a lot of greenhouse gas emissions (Savci 2012, Wu et al 2024). The traditional households use these two types of fertilizers, so the cost spending on fertilizers is higher than that cost of emission-reduction households. Similarly, the pesticides' cost of emission-reduction households is also statistically significantly lower due to the fewer spraying times.

Regarding rice seeds, each emission-reduction household received 20% to 30% support for seeds from linkage enterprises through agricultural cooperatives. Additionally, the amount of rice seeds used was less due to low – density transplanting, so that the cost of buying rice seeds was significantly lower than that cost of traditional households.

Market for emission - reduction rice

2.4 Table 6: Emission-reduction rice buyers of surveyed households

Rice buyers	Percentage of households selling rice (%)	Sales structure for each buyer (%)
1. Linkage enterprises	100	65
2. Rice traders	25	20
3. Direct consumers	5	5
4. Keep for home consumption	40	10

Emission-reduction rice households have many options for their rice market, they can sell rice to enterprises that associate with agricultural cooperatives, sell to local traders, or sell directly to local consumers (they are non-rice-growing households in the community). While traditional households usually sell their rice to local traders, all emission-reduction households (100%) sell rice directly to enterprise that signed contract with agricultural with agricultural cooperative. Basically, the agricultural cooperative in each commune represents the rice farming households to sign a contract directly with the enterprise. The selling price is usually 10% higher than the market price. There are 25% of households still sell a part of their rice to local traders; and 40% of households keep a portion of rice for home consumption because they believe that emission-reduction rice is clean and safe for health.

The structure of rice selling for each target buyer is shown in Table 6. In general, the majority (65%) of the emission-reduction rice after harvest is sold directly in the rice field. The linkage enterprise purchases rice for processing to serve the domestic high-quality rice market or export. There are two large enterprises that often cooperate with agricultural cooperatives to produce and purchase emission-reduction rice from farmers, namely Thai Binh Rice Seed and An Dinh Rice. They are the large-scale enterprises doing rice business in Thai Binh province and in the northern Vietnam. However, the purchasing and processing capacity of these companies are limited by season, so that there are still 35 percent of the emission - reduction rice after harvest is dried by farm households and then sell to local traders (20%), direct local consumers (5%) and keep for home consumption (10%).

When discussing the disadvantages and advantages of the market for emission-reduction rice, 41.7 percent of surveyed farmers said that the process of selling rice was favorable and very favorable because the agricultural cooperative had signed a contract with a enterprise to purchase most of the rice output, so there was no need to worry about product backlog. The production cost of emission-reduction rice is higher than that cost of traditional rice, but the price of emission-reduction rice is only 10 percent higher than the price of regular rice, therefore emission-reduction households do not make higher profit.

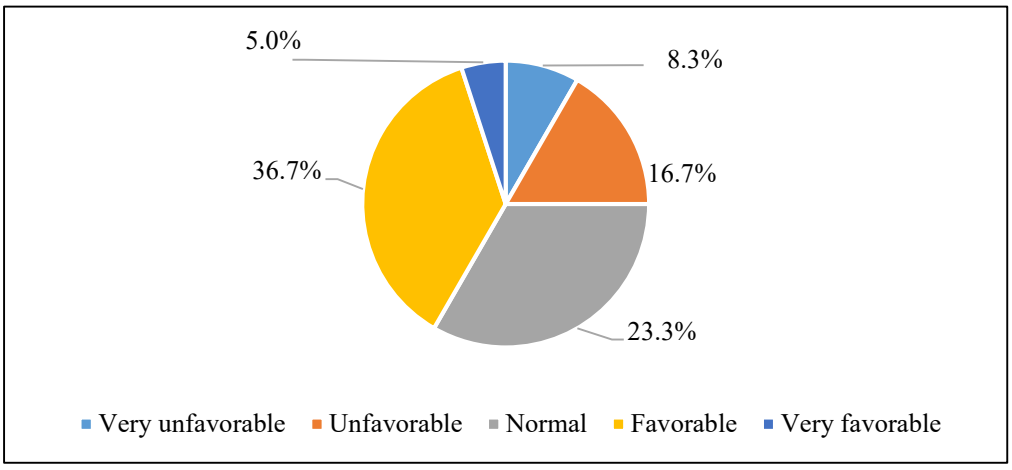

Figure 1: Disadvantages and advantages of the market for emission-reduction rice

On the contrary, some households said that when the company buys all the emission-reduction rice, it will be difficult for them to sell it to the market if the market price is higher. Moreover, the market for emission-reduction rice also has many disadvantages aspects because rice grown using these techniques has not been certified with a brand or trademark, hence local traders only buy rice with the same price as regular rice. This shows the need to promote the process of building a brand for emission-reduction rice, so that households can sell rice at a higher price, commensurate with the quality of the rice as well as the effort and cost that farm households have spent. Thereby, promoting further participation of farm households in expanding the area of emission-reduction rice.

Econometric model analyzing factors affecting rice production to reduce greenhouse gas emissions

As presented in the methodology section, a linear regression model is applied to quantify the impact of demographic and other factors on emission-reduction rice production at farm households. With the dependent variable being the emission-reduction rice area, the model considers the impact of each factor on the emission reduction rice area with the expectation that many positive factors will increase the emission reduction rice area, which means that the factor will encourage households to expand the emission reduction rice production scale.

Table 7: Linear regression model results

Variables	Coefficient ??	Standard error (Std)	t	Sig.
Constant	0.185	0.171	1.079	0.282
1. Age (X_1)	0.368	1.226	1.162	0.206
2. Gender (X_2)	0.224	0.025	0.960	0.104
3. Education (X_3)	0.264***	0.028	10.056	0.000
4.Understanding of emission-reduction rice farming techniques (X_4)	0.052*	0.024	2.169	0.061
5. Production cost (X_5)	-0.187**	0.133	3.277	0.022
6. The advantage of rice market (X_6)	0.252***	0.027	9.293	0.000

, **, * significant at 10%, 5%, and 1%, respectively;*

The results of the linear regression model show that the factors that have a statistically significant impact on emission-reduction rice cultivation of farm households include: education level and understanding of emission reduction rice cultivation techniques of households' head; production costs, and the advantages of the emission reduction rice market. The regression coefficient means that for each additional year of education, the household head tends to expand the emission reduction rice cultivation area by 0.264 "sao". In addition, the advantages of the emission-reduction rice market also makes households want to expand the rice cultivation area, and households with favorable rice consumption tend to expand the emission reduction rice cultivation area by 0.252 "sao" compared to households without favorable conditions. On the other hand, production cost is a factor that prevents households from expanding their emission-reduction rice area. The results of Table 7 show that with an additional 1,000 VND in cost, households want to reduce their area of rice cultivation by 0.187 "sao". When the project *"Sustainable rice production and greenhouse gas emission reduction"* was implemented in Thai Binh province, households growing rice with emission-reduction methods were supported with 20 % to 30% of the cost of rice seeds and fertilizers, and agricultural cooperatives coordinated with enterprises to provide all microbial products for households to treat straw on the rice field. Therefore, the cost of producing one "sao" of emission-reduction rice at that time was equivalent to the cost for one "sao" of normal rice. However, after the project has ended, the support is no longer causing households growing emission-reduction rice to incur more costs. This is the reason why households' head will consider expanding their rice area if production costs increase.

DISCUSSION

Agricultural production generates 12% greenhouse gas emissions of the world, with the majority of those emissions coming from rice production (Koblianska et al 2024, Arunrat & Pumijumnong 2017).

In Vietnam, rice production is carried out by millions of smallholder farmers (Hoang et al, 2021). Therefore, reducing greenhouse gas emissions from rice production means finding solutions to encourage rice farmers to adopt low-carbon rice farming practices.

As the research results show, the education level of household heads, understanding of emission-reduction rice cultivation techniques, production costs and the convenience of rice market are factors that motivate farm households to participate in production and expand the emission-reduction rice area in Thai Binh province of Vietnam. Regarding the education level of the household head, this research result is similar to the results found by some scholars that the higher the education level, the more likely farmers are to adopt new farming techniques, including carbon-reduction rice farming (Ramoneda & Pene 2017, Nguyen et al 2024).

Regarding farmers' understanding of new techniques for rice cultivation, the results of this study is similar to what some authors found in Vietnam that when farmers' understanding of new techniques is better, they are more willing to apply these techniques in rice cultivation (Nguyen Xuan Đinh & Nguyen Mau Dung, 2021). Regarding the rice production costs, the study of Brenda and Junnel also pointed out that the cost of rice production (especially fertilizer costs and machinery rental costs) is a factor that prevents farmers from applying emission-reduction rice cultivation techniques (Ramoneda & Pene, 2017). This result is also consistent with the study of Effendy and Yen from Vietnam (Effendy 2017, Yen & Kamoshita 2024). For the method of rice cultivation to reduce greenhouse gas emissions, farmers are recommended to use slow-release fertilizers, according to agricultural cooperative leaders the cost of slow-release fertilizer is much higher than normal fertilizers farmers used to apply. In addition, emission-reduction rice cultivation requires farmers to apply low-density transplanting with transplanting machine. So that farmers have to hire machine with the high cost (Tomita et al, 2003). In fact, applying low-density transplanting is beneficial for households in saving labor while still having high rice productivity, and at the same time reducing greenhouse gas emissions (Chen et al, 2024).

Furthermore, the study also shows that market for selling rice has an impact on emission-reduction rice cultivation of farm households. The more favorable of the market, the larger emission-reduction rice area that farm households willing to cultivate. This result also shows similarities with the study of Chau Nguyen Thi and Ahamed in Vietnam (Chau & Ahamed, 2022).

CONCLUSION

Greenhouse gas emission reduction agriculture is a trend that the world is interested in to minimize the impact of climate change. However, the greenhouse gas emission reduction rice cultivation technique is still quite new to farmers in Vietnam in general and to farmers of Thai Binh province in particular. For this reason, many farm households are still hesitant to apply these new techniques and expand their emission-reduction rice area. This study shows that the higher cost (almost 20 percent) of producing emission-reduction rice makes farm households uncertain to expand the rice area. Meanwhile, the market for greenhouse gas emission reduction rice is favorable (nearly 42 percent of farm households confirms that), households can sell rice easily, which is a factor that stimulates households to participate in growing more greenhouse gas emission reduction rice. However, this study did not find any effect of age and gender of the household head on the production of emission-reduction rice in Thai Binh province, but the education level of the household head was an important factor in promoting the production and expansion of the emission-reduction rice area.

From the above findings, this paper proposed a number of solutions to encourage farm households to expand the emission-reduction rice area in Thai Binh province namely: (i) strengthening training to further improve the understanding of farm households about emission-reduction rice cultivation techniques; (ii) agricultural cooperatives in association with enterprises to provide financial support to reduce the burden of seeds and fertilizers for farm households; (iii) agricultural cooperatives in coordination with enterprises to purchase emission-reduction rice from households at appropriate market prices; (iv) agricultural cooperatives in coordination with enterprises to build a low-emission rice brand to increase the value of rice products cultivated by this method in the market, thereby creating a stable consumption market and increasing income for farm households.

Due to limited resources and time, this research collected data on a small number of farmers in Thai Binh province, so some proposed solutions are specific at provincial level rather than for the whole country of Vietnam.

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