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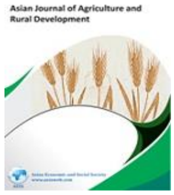

DETERMINANTS OF SYSTEM OF RICE INTENSIFICATION ADOPTION AND ITS IMPACTS ON RICE YIELD IN THE UPLAND REGION OF CENTRAL VIETNAM

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ABSTRACT
The System of Rice Intensification (SRI) is an eco-friendly approach that aims to increase rice yield, reduce required inputs, and improve rural households' income without burdening the environment. This paper investigates the factors that influence the adoption of the SRI practice in rice production and the impact of the SRI adoption on rice yields in the upland region of Central Vietnam. Utilizing the stratified random sampling method, 239 rice farmers in Quang Nam and Thua Thien Hue provinces were selected for the study. Our study employed the logit model to identify the determinants of SRI adoption and found that the age of respondents had a significant and negative effect on the adoption of SRI. In contrast, the amount of family labor, number of plots, and access to credit had significant positive effects on farmers' decision to adopt SRI. In addition, the results showed that when rice farmers adopted SRI, their yields increased by 15.1% on average. Regarding the policy implications, the results suggest a need for a coordinated policy between the Vietnamese government and farmers to support the implementation of the SRI method in mountainous areas, especially to train farmers to use the SRI technique.

Contribution/Originality: Our study makes a significant contribution to the literature by analyzing the factors influencing SRI adoption in rice production. By employing a quantitative approach, our study showed the positive impact of the adoption of the SRI method on rice yields and addressed the issue of new technology adoption in agriculture.

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1. INTRODUCTION
The adoption of new technology in agricultural production is crucial to improving rural households' income and enhancing economic development (Takahashi & Barrett, 2014). The success of the green revolution has shown that the adoption of technology in the agricultural sector has resulted in significant productivity and farm income gains. Increasing agricultural productivity, particularly rice productivity, is essential to achieve food security and enhance household income, especially in low and middle-low-income countries, where many farmers rely on rice cultivation. A new technique for paddy production – the System of Rice Intensification (SRI) – has recently attracted interest and been widely introduced in many countries, with support from Africare, the Oxford Committee for Famine Relief (OXFAM), the World Wildlife Fund (WWF), and World Bank (Barrett, Islam, Mohammad Malek, Pakrashi, & Ruthbah, 2022). The SRI practice, developed by Father Laulanié in Madagascar in the mid-1980s, is an approach to

increasing rice yield, reducing required inputs, and improving environmental friendliness (Stoop, Uphoff, & Kassam, 2002; Uphoff et al., 2002).

The SRI practice does not require using new varieties and chemical inputs, such as inorganic fertilizers, pesticides, and herbicides. Instead, this technique combines several agronomic management practices in rice farming by changing how water, plants, soil, and nutrients are managed (Dass et al., 2015; Thakur, Rath, Roychowdhury, & Uphoff, 2010). The technical components of the SRI method are based on five principles: care in transplanting young seedlings, wider spacing between the plants, soil aeration combined with weed control, decreasing irrigation water to keep the soil moist, and the application of organic fertilizer (Stoop et al., 2002; Styger et al., 2011; Varma, 2019). Some studies consider the SRI approach a "system" of techniques rather than a "technology" because it requires no specific inputs and does not apply a fixed set of principles (Barrett et al., 2022).

Rice is Vietnam's main crop; the country ranks as the second-largest rice exporter in the world (Fulton & Reynolds, 2015; Ha, Nguyen, Kompas, Che, & Trinh, 2015) with a total exported value of 2.79 billion US$ in 2020 (Trade International Center (TIC) calculations based on United Nations Comtrade and Trade International Center statistics). Rice production in upland areas of Vietnam, especially the Central region, faces many difficulties, such as poor soil, drought, weeds, diseases and pests, and high fragmentation. Since 2003, Vietnam's Plant Protection Department (PPD) has been implementing the SRI practice in North Vietnam. In 2012, the Foundation for International Development and Relief (FIDR), a Japan-based non-governmental organization (NGO), introduced SRI in three mountainous districts in Quang Nam province. This model was expanded to six districts in Quang Nam province and one district in Thua Thien Hue province (Do, Le, Cao, Otsuki, & Kano, 2020). The application of SRI has fundamentally and comprehensively changed the status of rice production by increasing rice productivity and improving food security for local people (Do et al., 2020; Varma, 2019). In addition, the SRI practice can adapt to the negative effects of climate change (Thakur & Uphoff, 2017) and is suitable for upland farming conditions.

The literature has extensively reported that the SRI practice is expected to reduce input costs, curtail water use, and improve rice yields (Barrett et al., 2022; Choudhary & Suri, 2018; Dass et al., 2015; Dobermann, 2004; Mishra, Ketelaar, Uphoff, & Whitten, 2021; Sinha & Talati, 2007; Styger et al., 2011; Thakur et al., 2010). Several empirical studies have indicated that the adoption of SRI enhances household income and increases economic returns or profits (Barrett et al., 2022; Kadigi et al., 2020; Mishra et al., 2021; Varma, 2019). However, some studies have expressed skepticism about this and indicated that SRI did not increase rice yields (Reddy, Reddy, Reddy, & Raju, 2005).

The successful SRI practice seems to bring many benefits to farmers; however, studies on the determinants of SRI adoption and its impacts on rice yields using quantitative models are still limited. Therefore, our paper attempts to address this issue in the uplands of the Central region in Vietnam. Our paper focuses on SRI adoption in the uplands for several reasons. First, most minority people are concentrated in the uplands and mountainous areas of Vietnam. Most of them are poor, vulnerable, and live in difficult situations, subject to natural disasters and extreme weather conditions (Inoue, 2019). Their main income source is agricultural activities. Improving the food security and livelihoods of ethnic people in these areas is a target of the Vietnamese government. Thus, the adoption of SRI is considered one way to enhance farm income through increased rice yields. Secondly, the rice farming practice of minority ethnicities in mountainous areas differs from that of the delta areas, and productivity is usually low. Thirdly, the adoption of SRI in upland and mountainous areas faces certain difficulties because of low education levels and long-standing farming practices. These may induce constraints on the adoption of new techniques in agricultural production in these areas. Therefore, this research investigates the adoption of SRI in the upland and mountainous areas of Vietnam. Furthermore, the contribution of our study does not only lie in showing the benefits of applying the SRI method to increase rice yields but also the benefits of its adoption in alleviating food shortage and poverty for minority people. The results could provide information for policymakers on the implementation of new practices in other mountainous areas of Vietnam.

2. CONCEPTUAL FRAMEWORK

According to Loevinsohn, Sumberg, Diagne, and Whitfield (2013), technology can be defined as a vehicle and manner of producing goods and services. Technology adoption is defined as "the integration of new technology into existing practice" (Loevinsohn et al., 2013). In agricultural production, technology adoption is not a simple yes or no decision (Varma, 2019). Farmers' decisions about whether and how to apply a new agricultural technique are influenced by the interaction between the characteristics of the technology itself and the factors related to the characteristics, conditions, and circumstances of farmers (Loevinsohn et al., 2013).

The adoption of agricultural technology is the result of the optimization of heterogeneous factors in the presence of various constraints, such as budget, lack of information, and availability of technology (Foster & Rosenzweig, 2010; Ghimire, Wen-Chi, & Shrestha, 2015; Kuswardinah, Ansori, Rachmawati, & Fajri, 2021; Mwangi & Kariuki, 2015). Thus, farmers will adopt an agricultural technology that can provide maximum utility, subject to these constraints (Varma, 2019). The discrepancy between the utility of adopting (U_{iA}) and the utility of not adopting the technology (U_{iN}) in a utility-maximizing farm household is denoted as U_i^*. According to De Janvry, Dustan, and Sadoulet (2010), Asfaw, Shiferaw, Simtowe, and Lipper (2012), and Ghimire et al. (2015), the adoption decision model can be presented in a random utility framework as in Equation 1:

$$U_i^* = X_i\beta + u_i$$
$$\text{With } U_i = \begin{cases} 1 \; if \; U_i^* > 0 \\ 0 \; otherwise \end{cases} \quad (1)$$

Where U_i^* is the latent variable representing the probability of the farmer deciding to adopt agricultural technology; X_i are explanatory variables explaining the adoption decision; β is a vector of parameters of the explanatory variables, and u_i is the error term.

There is extensive prior literature on the elements that influence farmers' technology adoption decisions in agricultural production. The decision to adopt new agricultural technology is affected by several internal and external factors (Sunny, Huang, & Karimanzira, 2018). Davies (1979) developed a threshold model that includes three elements that boost adoption decision-making, such as microeconomic behavior, heterogeneity factors, and a dynamic process affecting adoption behavior. The author indicated that the adoption decision was heterogeneous and was affected by many factors, such as knowledge, farm scale, technology information, human capital, cost, risk, and more. Some previous studies have explained that technology adoption behaviors relate to socio-economic factors, including demographical characteristics, imperfect information, risk, input availability, institutional characteristics, and infrastructure (Feder, Just, & Zilberman, 1985; Foster & Rosenzweig, 2010; Mwangi & Kariuki, 2015).

Previous studies have classified the various factors into different groups. Akudugu, Guo, and Dadzie (2012) categorized the adoption factors of new agricultural technology into three groups: economic factors, social factors, and institutional factors. Varma (2019) classified the factors affecting SRI adoption into economic factors, social factors, institutional factors, and household characteristic factors. Other recent studies have included a factor related to technical information among the categories of factors affecting technology adoption, called "technology factors." For example, Mwangi and Kariuki (2015) reviewed the factors influencing technology adoption by classifying them into four groups, namely, technological factors, economic factors, household-specific factors, and institutional factors. Udimal, Jincai, Mensah, and Caesar (2017) showed that the adoption of technology in rice farming is affected by many elements, including demographic characteristics, economic factors, and technology factors. Li, Huang, Ma, Qi, and Li (2019) developed a theoretical model of technology adoption decision-making for the farmers of Litchi based on Rogers' innovation diffusion theory. According to this study, the decision to apply new agrarian technology in agricultural production is impacted by five factors, that is, the farmer's characteristics, the farmer's family characteristics, the farmer's ability to access information, technology information accumulation, and the farmer's opinion of the technology. The research on influencing factors is contingent on the current technology being investigated and the location of the study area. Equation 2 presents the theoretical model of farmers' agricultural technology adoption.

$$D_i = f(H_i, E_i, I_i, T_i) \quad (2)$$

In the formula, D_i represents the agricultural technology adoption decision of the i-th farmer; H_i is the human capital of the farmer or the farm household characteristics; E_i represents the economic factors of the i-th farm household; I_i is the farmer's institutional factors, and T_i represents the technology factors.

The human capital of the farmer, which some studies call the household-specific factor or farm household characteristics, is believed to have a significant impact on the decision to adopt technology for agricultural production. Several studies have indicated that the human capital of farm households can be defined as household characteristics such as the farmer's age, gender, education, and farm size (Feder et al., 1985; Keelan, Thorne, Flanagan, Newman, & Mullins, 2009; Teklewold, Kassie, & Shiferaw, 2013; Uaiene, 2011). Some studies, such as Langyintuo and Mungoma (2008) and Meshram, Chobitkar, Paigwar, and Dhuware (2016), have found a positive influence of the farmer's age on adoption decisions. In contrast, other studies have indicated a negative impact of farmer age on adoption decisions (Teklewold et al., 2013), meaning that older farmers tend to have less interest in adopting new technology due to an increase in risk aversion. There is an expectation that a farm household's education level has a positive effect on their technology adoption decision (Langyintuo & Mungoma, 2008; Meshram et al., 2016). Farmers' education level could increase their ability to access and obtain new technology, their capacity to understand the information about the technology, and their capacity to evaluate the utility of the new technology (Okunlola, Oludare, & Akinwalere, 2011). Gender differences have been investigated in many studies, which have found mixed results about the differences between men and women regarding the decision to adopt new technology. According to Manda, Alene, Gardebroek, Kassie, and Tembo (2016), there was a negative relationship between the gender of households' heads and their decision to adopt improved maize varieties. Kamau, Kabuage, and Bett (2019) indicated that women heads of households were more likely to adopt new technology than male heads of households. However, Doss and Morris (2000) found no relationship between gender and the decision to adopt new technology in agricultural production. Household size is considered a measure of family labor availability. According to Teklewold et al. (2013), it is expected that the number of household members or available family labor has a positive impact on technology adoption because a larger household could relax the labor constraints when applying the new technology. Ghimire et al. (2015) investigated family labor as a factor affecting the adoption of improved rice varieties; however, they found that the number of family laborers had no impact on rice farmers' adoption. According to Sigdel, Devkota, Joshi, and Devkota (2014), farm household characteristics such as gender, age, and education are the factors that influence the adoption of SRI.

Regarding economic factors, many studies have shown the critical role of farm size in the decision to adopt new technology (Langyintuo & Mungoma, 2008; Manda et al., 2016; Meshram et al., 2016; Mwangi & Kariuki, 2015; Nyairo, Pfeiffer, & Russell, 2021). Large-scale farmers tend to adopt new technology because they can afford to spend part of their land trying out the new technology (Uaiene, 2011). A few studies have explored how the plot characteristics of farm households influence their technology adoption decision. In particular, Takahashi and Barrett (2014) found that the size of the plot had a positive effect on SRI adoption, while the number of plots that a household operates negatively affected the adoption of SRI practices.

Access to credit is believed to promote technology adoption because it reduces risk by loosening liquidity constraints (Simtowe & Zeller, 2006). This is considered an institutional factor that influences the technology adoption decision of farming households (Mwangi & Kariuki, 2015).

3. MATERIALS AND METHODS

3.1. Data and Study Area

This research was carried out in two provinces in the Central region of Vietnam, that is, Quang Nam and Thua Thien Hue provinces. Data was collected in three districts, namely, Bac Tra My and Nam Tra My in Quang Nam province, and Nam Dong district in Thua Thien Hue province (as illustrated in Figure 1). All three districts are located in the mountainous or upland areas of the Central Coast in Vietnam, which have a high proportion of ethnic minorities. Specifically, about 95% of the total population of Nam Tra My district belongs to ethnic minority groups, and these population groups account for nearly 50% and 54% of the population in the Bac Tra My and Nam Dong districts, respectively. Agriculture is the primary production sector in these districts, accounting for more than 70% of the total production value. Nevertheless, the small production scale has resulted in many poor households in these areas.

Wet-rice cultivation is the main traditional cultivation method in the study areas, with Winter-Spring and Summer-Autumn crops; of these, Winter-Spring is the main crop. Aside from the wet-rice areas, farmers cultivate rice in the uplands; however, the productivity is rather low due to drought and the traditional cultivation method. The majority of Nam Tra My district is made up of steep mountains. Consequently, most wet-rice crops are cultivated on fragmented terraced fields with inactive irrigation. The terrain of the Bac Tra My district is flatter than the Nam Tra My district, resulting in more convenient wet-rice production. With its flat terrain and active irrigation, most of the paddy land can be used to cultivate both Winter-Spring and Summer-Autumn crops in Nam Dong district, Thua Thien Hue province.

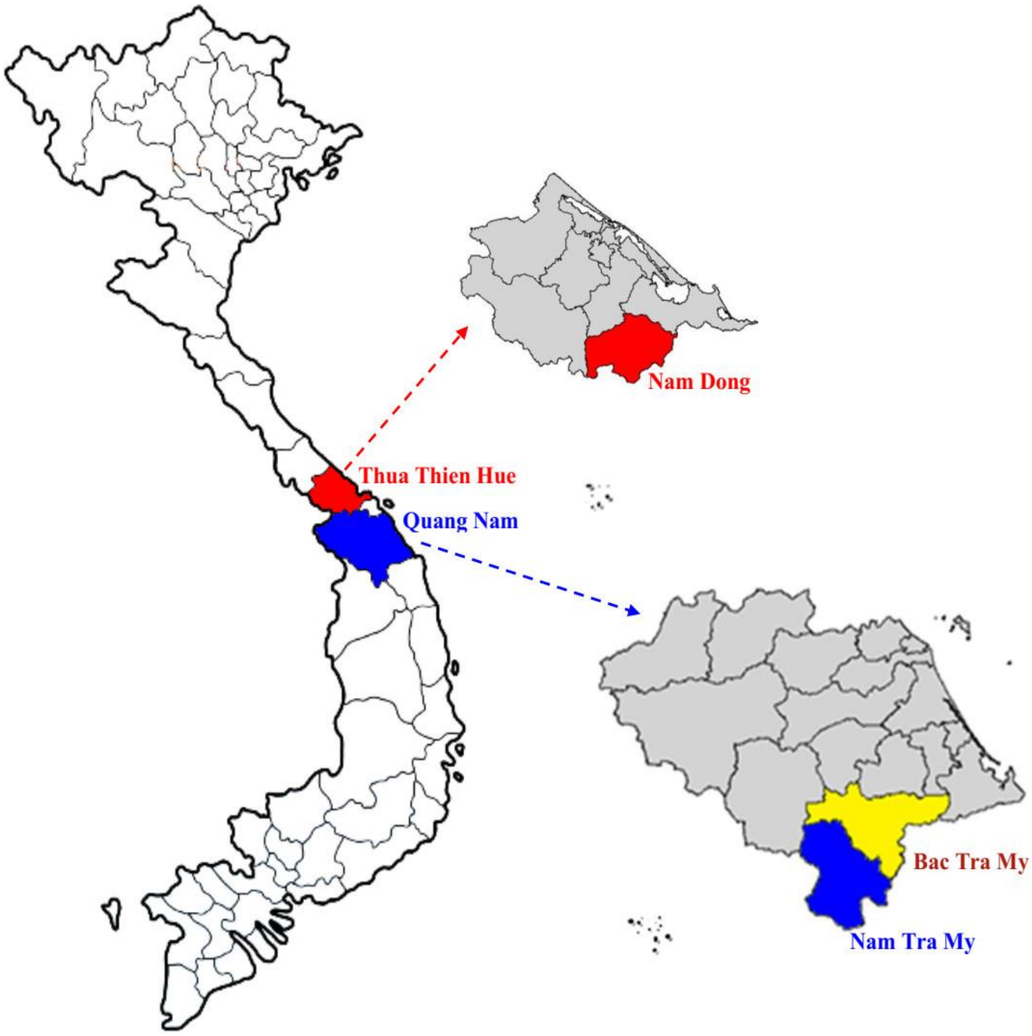

Figure 1. Map of study areas.

The farm households that took part in this study belong to the project on Food Security Improvement for Small-Scale Farmers in Central Vietnam, organized by the Foundation for International Development and Relief (FIDR), which started in Quang Nam in 2012. In 2015, this model was expanded to six districts in Quang Nam province as well as Nam Dong district in Thua Thien Hue province. The project aims to improve food security for small-scale farming households by implementing an advanced rice farming technique (SRI) in mountainous areas. Rice farmers were selected and trained to apply the SRI technique in their rice production.

A stratified random sampling technique was used to select the rice farmers for the study. The rice farmers were divided into 2 groups: SRI adoption and SRI non-adoption. In each group, farmers were randomly selected. The interviewed rice farmers were selected based on a list of households reporting SRI adoption in the Winter-Spring crop of 2020 provided by the district's staff. The farming households without SRI adoption were also selected randomly. The total number of farm households interviewed in this study was 239, including 89 households in Bac Tra My district, 67 households in Nam Tra My district, and 83 households in Nam Dong district. A proportionate sampling technique based on the wet-rice cultivation area and the area implementing SRI was applied to determine the sample size for each district. A pre-test survey was conducted with 10 rice farmers from each district to validate the accuracy of the questionnaire.

3.2. Method

3.2.1. Binary Logistic model

To investigate the factors that influence the adoption of SRI, we applied logit regression for the binary dependent variable of SRI adoption. This model was adjusted from similar studies on farmers' technology adoption decisions (Li et al., 2019; Ntshangase, Muroyiwa, & Sibanda, 2018; Udimal et al., 2017). When faced with a decision relating to the adoption of an innovation, the farmers would either adopt or reject the technology. It is well documented that farmers' adoption decisions can be analyzed using logistic regression. The dependent variable in this model was a dummy variable in which the rice farmers who were adopters of the SRI method took the value 1, and non-adopters of the SRI method took 0:

$$SRI_i = \begin{cases} 1\ if\ a\ farmer\ adopts\ SRI \\ 0\ if\ a\ farmer\ does\ not\ adopt\ SRI \end{cases}$$

The likelihood of the farmer adopting the SRI technique was predicted by the odds of ($SRI = 1$); that is, the ratio of the probability that $SRI = 1$ to the probability that $Y \neq 1$:

$$Odd\ SRI = \frac{P(SRI = 1)}{(1 - P(SRI = 1))}$$

The binary logistic regression model is represented as follows:

$$Logit\ (SRI) = \log Odds\ SRI = \ln\left(\frac{P(SRI = 1)}{(1 - P(SRI = 1))}\right)$$

Where logit (SRI) is given by the natural log of Odds.

The binary logistic regression model of the determinants affecting SRI adoption was constructed and expanded based on theories and practices:

$$Logit\ (SRI_i) = \alpha_0 + \alpha_1 \sum_{i=1}^{i} Z_i + \varepsilon_i$$

Where Z_i is a vector of the socio-economic characteristics variables of the *i-th* household and the district dummy variables.

3.2.2. Ordinary Least Squares Regression

The estimation of the effect of the adoption of SRI on rice yield was performed by applying the ordinary least squares (OLS) model, which is represented in the following equation:

$$Y_i = \beta_0 + \beta_1 \sum_{j=1}^{j} Z_{ij} + \beta_2 \sum_{k=1}^{k} X_{ik} + \xi_i \quad (3)$$

Where Y_i is the rice yield of the *i-th* farm household.

X_i is a vector of inputs used in the rice production of the *i-th* farm household.

β_1 and β_2 are the parameters of vector variables Z_i and X_i.

3.3. Descriptive Statistics of Variables

Based on the technology adoption theory and the literature, the SRI adoption model and the model describing its impact on the rice yield include several explanatory variables, which are defined in Table 1.

The descriptive statistics of the variables in the two models that influence SRI adoption and rice yield within the two groups (adopters and non-adopters) are presented in Table 2. The group of non-adopters included 99 households. The total number of SRI-adopting households was 140. An independent t-test was applied to discover the differences between the adopters' and non-adopters' characteristics. This revealed statistically significant differences between adopters and non-adopters of the SRI technique concerning certain household and farm-level characteristics, including rice yield, age of household, the amount of family labor, and the quantity of seed used.

Table 1. Variable definitions.

Variables	Definition
Rice yield	The rice yield of the Winter-Spring crop (kilogram per *Sao*)
Gender	Gender of the interviewee or head of the household
Age	Age of the interviewee or head of the household
Education	The completed years of schooling of the household's interviewee
Ethnicity	Dummy variable, = 1 if the household is of *Kinh* ethnicity (the major racial identity of Vietnamese people, = 0 for minority ethnicities
Rice land	The total rice area of the household (hectare)
Number of plots	The number of plots in rice cultivation
Family labor	The number of family members' labor available
Credit	The credit borrowed from banks by the household (million dongs)
SRI	Dummy variable, = 1 if household adopts SRI technique, and = 0 otherwise (non-adopter)
Seed	The quantity of seed used in the Winter-Spring crop (kilogram per *Sao*)
Chemical fertilizer	The quantity of chemical fertilizer used in the Winter-Spring crop (kilogram per *Sao*)
Organic fertilizer	The quantity of organic fertilizer used in the Winter-Spring crop (kilogram per *Sao*)
Rice land of Winter-Spring crop	The rice land cultivation in the Winter-Spring crop (*Sao*)
Rice labor days	The number of labor days for 1 *Sao* of rice in the Winter-Spring crop (labor days per *Sao*)
Dummy of Bac Tra My district	Dummy variable of Bac Tra My district, = 1 if household in Bac Tra My district, = 0 otherwise
Dummy of Nam Tra My district	Dummy variable of Nam Tra My district, = 1 if household in Nam Tra My district, = 0 otherwise
Dummy of Nam Dong district	Dummy variable of Nam Dong district, = 1 if household in Nam Dong district, = 0 otherwise

Note: 1 Sao = 500 m^2.

Table 2 also presents the independent t-test values of the differences between adopters and non-adopters of the SRI method. There are statistically significant differences between the household characteristics of adopters and non-adopters of the SRI technique. Specifically, the rice yield of non-adopters was 189.03 kilogram/500m^2 (approximately 3.78 tons per hectare), while adopters obtained 225.67 kilogram/500m^2 (approximately 4.51 tons per hectare). Moreover, adopters and non-adopters differed significantly in the age of the household head or interviewee, the amount of family labor, and the use of seeds in rice production. The households that adopted SRI were younger than the non-adopters. The amount of family labor was significantly higher for adopters than for non-adopters. Because the SRI technique does not use herbicides and pesticides, farmers used more labor in the cultivation practice. The use of seed inputs in rice production differed between the two groups, in that adopters used less seed than non-adopters. One of the requirements of the SRI technique is sparse planting density compared to the traditional technique (Reddy et al., 2005). Thus, this result implies rice farmers met the requirements of this specification of SRI.

Table 2. Descriptive statistics for rice yield and input variables of rice production between non-adopters of SRI and Adopters of SRI.

Variable	Non-adopters of SRI	Adopters of SRI	Total	Mean difference
Rice yield (kg/*Sao*)	189.03 (69.0)	225.67 (93.3)	210.5 (85.88)	0.001***
Age	38.52 (12.86	35.45 (10.28)	36.72 (11.49)	0042**
Rice land (hectare)	0.25 (0.35)	0.32 (0.72)	0.29 (0.60)	0.365
Number of plots	2.68 (2.01)	3.13 (2.30)	2.94 (2.19)	0.117
Family labor	2.70 (1.01)	3.24 (1.22)	3.01 (1.17)	0.000***
Credit	29.47 (22.66)	34.38 (33.68)	32.34 (29.66)	0.208
Seed (kg/*Sao*)	6.44 (3.30)	5.07 (4.39)	5.64 (4.02)	0.010***
Chemical fertilizer (kg/*Sao*)	6.64 (8.83)	5.25 (7.56)	5.83 (8.12)	0.192
Organic fertilizer (kg/*Sao*)	0.14 (0.38)	0.57 (2.36)	0.39 (1.83)	0.074
Rice land of Winter-Spring crop (hectare)	2.21 (1.21)	2.14 (1.38)	2.17 (1.31)	0.706
Rice labor days	12.42 (9.14)	13.45 (8.70)	13.02 (8.88)	0.38
Number of observations	99	140	239	

Note: 1) Standard deviations in parentheses; 2) ** and *** indicate significance at 5% and 1% levels, respectively; 3) *1 Sao* = 500m^2.

4. RESULTS AND DISCUSSION

4.1. Factors Influencing the Adoption of SRI

Table 3 presents parameter estimates of the factors that influence the adoption of the SRI method by rice farmers in the mountainous area of Central Vietnam. The influencing factors are used in the model, which is based on the conceptual framework and the characteristics of the study area. The results show that the age of farmers had a statistically significant and negative impact on the adoption of SRI. This implies that farmers who adopt the SRI method tend to be younger than non-adopters. This result is consistent with the studies of Varma (2019) in India and Teklewold et al. (2013), Akudugu et al. (2012), and Udimal et al. (2017) in Ghana. However, this result is in contrast with the study of Ntshangase et al. (2018), which found a positive impact, as well as the statistically insignificant results reported in studies such as Ghimire et al. (2015) and Takahashi and Barrett (2014).

The number of plots had a positive and statistically significant effect on the SRI adoption decision of rice farmers. This result indicates that rice farmers with more rice plots are more likely to adopt SRI. This may be because farm households with many plots find it easier to try new technology by committing only a few plots to the new method of rice production, thereby decreasing their risk. This result contradicts the finding of Takahashi and Barrett (2014) in their study on SRI adoption in Indonesia.

Another interesting outcome of our model is that an increase in the number of family laborers boosts the adoption of the SRI method. The results show a positive and statistically significant relationship between the amount of family labor available and the adoption of SRI. SRI is a labor-intensive model, requiring hands-on techniques such as soil aeration, weed control, and seedling planting rather than using machines or herbicides. Thus, this approach requires more labor days than traditional farming methods. The finding is consistent with earlier studies on SRI adoption by Teklewold et al. (2013), Takahashi and Barrett (2014), Udimal et al. (2017), Ntshangase et al. (2018), and Varma (2019). However, our finding contradicts the study of Ghimire et al. (2015), which found no impact of family labor on technology adoption decisions in farming households.

Table 3. The factors that influence the adoption of SRI.

Independent variables	Coefficient	S.E.
Gender	-0.194	0.31
Age	-0.023*	0.01
Education	0.092	0.09
Ethnicity	-0.755	0.86
Rice land	-0.016	0.28
Number of plots	0.115*	0.07
Family labor	0.500***	0.16
Credit	0.011**	0.01
Dummy of Bac Tra My district	-0.045	0.36
Dummy of Nam Tra My district	1.109**	0.43
Constant	-1.349	0.76
Number of observations	239	
P > chi2 (χ^2)	0.0038	

Note: 1) ***, **, * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.
2) The base district is Nam Dong district.
3) S.E. indicates the robust standard error.

In addition, access to credit had a positive impact on SRI adoption among rice farmers. The accessibility of credit sources could make it easier for rice farmers to adopt new techniques in agricultural production. This result is consistent with the study of Udimal et al. (2017). Regarding the dummy variables for the district, the dummy variable of Nam Tra My district had a positive and significant effect. The result indicates that the SRI adoption project was conducted more effectively in Nam Tra My district than in Nam Dong district. Indeed, this project was implemented in Quang Nam province (including Nam Tra My and Bac Tra My districts) first and was applied in Nam Dong district three years later.

4.2. The Impact of SRI Adoption on Rice Yields

Table 4 shows the estimates of the impact of SRI adoption on rice yields. From the estimation results, we can see that the parameter of the SRI adoption variable is positive and statistically significant at a significance level of 1%. This result implies that the farmers who adopted the SRI technique had a higher rice yield than non-adopters. The parameter also indicates that adopting SRI in rice cultivation could increase the rice yield of farm households by about 15.1%. This result is in line with the studies of Varma (2019), Kadigi et al. (2020), Mishra et al. (2021), and Barrett et al. (2022), who found that SRI adoption could increase rice yields through an estimated econometric model.

Regarding the other variables affecting rice yield, the results showed a positive effect on rice yield if the number of labor days used for rice production in the Winter-Spring crop was higher. The parameter of this variable indicates that if farmers spend 1% more labor days on the Winter-Spring crop, the yield will increase by 0.098%. This aligns with the fact that households applying the SRI technique need more labor for production activities than those using the conventional method. In contrast, the size of households' rice land (in the Winter-Spring crop) had a negative impact on rice yield. This result implies that rice farmers with a larger area of rice land had lower rice productivity.

Specifically, if the size of farm households' rice land increases by 1%, the rice yield will reduce by 0.185%. The coefficient of ethnicity variable is positively significant at the 1% significance level. This result means that rice farmers who are *Kinh* may produce higher rice yields than minorities. Regarding the dummy variables for districts, the estimation results showed that Bac Tra My and Nam Tra My districts have higher rice productivity than the base district (Nam Dong).

Table 4. The impact of the adoption of SRI on rice yield in the Winter-Spring crop.

Independent variables	Rice yield (log)	
	Coef.	S.E.
SRI	**0.151*****	**0.05**
Rice labor days (log)	0.098*	0.06
Seed (log)	-0.012	0.04
Chemical fertiliser (log)	0.007	0.01
Organic fertiliser (log)	0.003	0.01
Rice land Winter-Spring (log)	-0.185***	0.05
Gender	0.015	0.06
Age	0.001	0.00
Education	-0.003	0.02
Ethnicity	0.323***	0.11
Number of plots (log)	0.026	0.04
Credit	0.001	0.00
Dummy of Bac Tra My district	0.191**	0.08
Dummy of Nam Tra My district	0.180**	0.09
Constant	4.858***	0.21
Number of observations	239	
R-squared	0.236	

Note: 1) ***, **, * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.
2) S.E. indicates the robust standard error.
3) The base district is Nam Dong district.

5. CONCLUSIONS

The decision to adopt the SRI practice in rice production is a function of a farm household's age, amount of family labor available, access to credit, and number of plots. Thus, the study recommends that in mountainous areas, the local government and NGOs should focus more on young farmers, who are more willing to apply new farming practices such as SRI. In addition, a credit program for farmers needs to be implemented to increase the number of SRI adopters. The results also showed that the adoption of SRI increased the rice yield by about 15.1%. Thus, aside from improving the productivity of rice paddies, this method can enhance farm households' incomes. However, it is more difficult to increase the adoption of SRI techniques among minorities in the upland regions than among *Kinh* people because minorities tend to have lower education levels and prefer not to shift cultivation practices. Thus, the results suggest a need for a coordinated policy between the Vietnamese government and farmers to support the extension of the SRI method in mountainous areas. The expansion and development of SRI practices should also be conducted in many other regions in Vietnam, with the support of the Ministry of Agricultural and Rural Development. Furthermore, we recommend training farmers on the techniques of the SRI method, especially the five technical multi-component principles that need to be fully implemented.

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