Factors Influencing Farmers' Adoption of Climate-Smart Agriculture in Rice Production in Vietnam's Mekong Delta

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ABSTRACT

Farmers' adoption behavior of climate-smart agriculture (CSA) is a big factor in the sustainability of agricultural growth in the areas of economic, environmental, and social development. This study explores the antecedents of adoption behavior of multiple CSA, including soil and water management, yield management, and weather risk management, among farmers in Vietnam's Mekong Delta. The study adopts a primary data sample of 350 rice farmers, using a multinomial logit model. The findings indicate that the most critical antecedents of CSA adoption among farmers include perceived climate change impact, educational level, farmland size, access to credit, social capital, access to extension, secure farmland tenure, and constraint to market. The results and policy implications are discussed and proposed.

Keywords: agriculture, environment, climate change, soil and water management, climate-smart agriculture, CSA, weather risk management, yield management, farmer perception, farmers' adoption

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INTRODUCTION

The agriculture sector and rural areas have continued playing a combined essential role in the Vietnamese economy, employing around 60 percent of the workforce, and accounting for 15 percent of the GDP (GSO 2019). Nevertheless, the substantial growth in agricultural production has come at a high environmental cost, being the second-largest source of greenhouse gas (GHG) emissions after the energy sector (World Bank 2016). Meanwhile, Vietnam is among the most vulnerable countries to climate change, ranking first among the 84 coastal developing countries profoundly affected by sea-level rise in terms of consequence to population and GDP performance, and second in terms of influence on land area and agricultural production (Van Mai and Lovell 2015; World Bank 2016). In Vietnam's Mekong Delta, the sea level in 2050 is projected to increase by 25–30 cm compared to the baseline period (2000), and salinity to rise greater than 4.0 g/L, intruding up to 50-60 km into the river. This is projected to affect rice yield in approximately 30,00 ha of the agricultural area if the sea level rises by 30 cm (Vu, Yamada, and Ishidaira 2018).

Agriculture is the second-largest source of GHG emissions after energy, contributing to about 33.0 percent of total GHG emissions in Vietnam (World Bank 2010). Within the agriculture sector, rice cultivation is responsible for significant GHG emissions, accounting for 46.3 percent (FAO 2010). Studies have revealed that climate change adaptation response, including climate-smart agriculture (CSA) participation, could play a crucial role in improving technical efficiency, economic benefits, and food security (Lipper et al. 2014; Khatri-Chhetri et al. 2016; Hasan et al. 2018; Ho and Shimada 2019; Taneja et al. 2019). In Vietnam's Mekong Delta, numerous CSA practices have been applied in rice production, which is based on soil management, water management, crop management, and risk management against natural disasters. These contribute to CSA from several vital perspectives, including productivity, adaptation through short-term risk management, adaptation through longer-term risk management, and mitigation (Chi et al. 2013; Lampayan et al. 2015; Dung et al. 2018; Ho and Shimada 2019). However, CSA has a low-to-average adoption rate in Vietnam, that is, below 30 percent (Nguyen et al. 2017).

Previous studies applied farm management models to explain decision making and technology adoption by farmers, focusing on microeconomic theory with an assumption of maximizing profit and minimizing the cost-benefit ratio (Gebrehiwot and Van Der Veen 2013; Teklewold, Kassie, and Shiferaw 2013; Tessema, Aweke, and Endris 2013; Addisu et al. 2016; Atinkut and Mebrat 2016; Ayal and Leal Filho 2017; Khatri-Chhetri et al. 2017; Asrat and Simane 2018; Dung et al. 2018; Fadina and Barjolle 2018; Wassie and Pauline 2018). Nevertheless, these models may not capture the complexity of farmers' behavior and attitudes in CSA adoption, and fail to take into account all related constraints of CSA adoption that include transaction costs, social benefits or costs, the role of social capital with collective actions, and institutional factors. Collective action regarding the management of agricultural and other resources that community livelihoods depend on plays an essential role in supporting the community's actions co-adapting to climate change, and is thus treated as a significant CSA adoption measure. Collective action involves activities carried out together, such as resource contribution, coordination, information sharing, knowledge sharing, and the formation of institutions to support them to adopt CSA more effectively. Social networks are relevant in the farmers' decision-making on CSA adoption concerning technical, moral, and financial considerations. The link between institutional factors (such as security of land tenure, and in particular, land ownership) and CSA adoption remains unclear and subject to debate in the literature.

There is little evidence from past empirical studies to establish causal relationships among these factors and CSA adoption. Indeed, dependent variables used in previous case studies focused on specific CSA practices, which cannot be generalized to make inferences about all climate change adaptation strategies. Hence, the results cannot support a proposed predictive model of farmers' behavior of CSA practices for all research cases. In Vietnam, several studies have examined variables explaining the adoption of sustainable technologies among farmers in the Mekong Delta (Heong, Escalada, and Mai 1994; Huan et al. 1999; Le Dang et al. 2014; Dung et al. 2018). However, there remains a lack of empirical studies conducted in the context of CSA practices in Vietnam's agriculture, even as Vietnam is one of the most climate change vulnerable countries in Southeast Asia. This study thus aims to help fill this gap by exploring the antecedents of farmers' adoption behavior of CSA practices in the Vietnamese Mekong Delta, including soil and water management, yield management, and weather risk management, using a multinomial regression model.

LITERATURE REVIEW

CSA improves the integration of resilience to climate risks in agricultural development. It aims to achieve food security, social, and economic goals amid the adverse effects of climate change.

CSA initiatives sustainably increase productivity, enhance resilience, and reduce net GHGs, and require action planning to address trade-offs and synergies among the three pillars of productivity, adaptation, and mitigation (FAO 2013). CSA has many approaches considered at different levels. CSA should not be considered only as a collection of production technologies or practices. CSA includes a range of processes from developing techniques and methods to modelling based on different climate change contexts, integration of information and communication technologies, insurance mechanisms to limit risks along the value chain, and through institutional arrangements and policy systems (FAO 2010). As such, CSA is not only a production technology but any combination of many interventions on production systems, landscapes, value chains, or policies that cover an area. CSA is specific in one area and may not be considered appropriate in another, and no intervention solution is climate-smart at all times or anywhere. Interventions need to consider the interactions among different factors at the landscape level, in and among ecosystems, as well as parts of the policy and institutional practice (FAO 2013).

In Vietnam, CSA in rice production aims to provide measures for yield management (e.g., the system of rice intensification, integrated pest management, improved variety for rice, change in land uses with rice-peanuts/crop rotation with rice-shrimp, changing sowing or harvesting date, reducing the number of crop plantings, changing fertilizer and chemical use, changing crop variety, and diversifying crops); soil and water management (e.g., One Must, Six Reductions;[1] Three Reductions, Three Gains;[2] Large Field Model;[3] and VietGAP[4]); and weather risk management (e.g., high-pick pear insurance) (Chi et al. 2013; Lampayan et al. 2015; Dung et al. 2018; Ho and Shimada 2019).

Various researchers have proposed theoretical frameworks to explain the behavior of individual choice. Based on these behavioral economics theories, many defining variables have been examined in studies of choice behavior toward the adoption of sustainable agricultural practices among farmers.

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1 "One Must, Six Reductions" entails the use of good quality seeds and reduction of these six: seed density, fertilizer, herbicide, water, post-harvest loss, and GHG emissions. Rice farmers reduce their input costs while maintaining or improving yields, decreasing GHG emissions and delivering other environmental co-benefits, such as reduced water pollution.

2 "Three Reductions, Three Gains" is a media campaign developed through a participatory planning process, which promotes the reduction of three inputs to bring about three benefits: increased income, lower exposure and risk due to pesticides, and an improved environment with less pollution from farm chemicals.

3 Large field model is a type of production organization, in which enterprises or cooperatives establish a cooperative relationship with farmers to apply a uniform production system by providing production inputs and buying outputs from producers.

4 VietGAP (Vietnamese Good Agricultural Practices) are production methods applied to produce clean and safe products, especially fresh fruits and vegetables.

Human Capital

The educational level of a farmer typically correlates positively with the adoption of technological innovations because of the assumed link between education and knowledge accumulation and the farmer's capacity in decision making (Gebrehiwot and Van Der Veen 2013; Teklewold, Kassie, and Shiferaw 2013; Addisu et al. 2016; Asrat and Simane 2018; Dung et al. 2018; Fadina and Barjolle 2018). Educational level may significantly affect the ability to absorb technical information and coherence in applying CSA in practice. Effect of farmer's age has also been regularly assessed on the adoption of CSA practices, with varying results: positive correlation (Atinkut and Mebrat 2016); negative association (Gebrehiwot and Van Der Veen 2013; Addisu et al. 2016; Maguza-Tembo et al. 2017; Asrat and Simane 2018); and insignificant correlation (Neill and Lee 2001). The sex of household heads has also been found to affect CSA adoption because of financial or resource constraints, access to information, extension services, and available adaptation strategies, which tend to create higher labor loads for women (Atinkut and Mebrat 2016; Jost et al. 2016; Mersha and Van Laerhoven 2016).

Farmland Size

Farmland size refers to the total land available to an individual farmer for agricultural production. Given the uncertainty and the fixed transaction and information costs associated with technologies, there may be a critical lower limit on farm size that prevents smaller farms from making CSA adoption decisions (Dung et al. 2018). Owners of massive farms are more willing to invest in CSA than those who have small farms (Teklewold, Kassie, and Shiferaw 2013; Atinkut and Mebrat 2016; Fadina and Barjolle 2018). The larger the area of productive land, the higher the motivation for farmers to learn how to apply CSA to reduce costs, labor, and care time to a minimum.

Financial Capital

The adoption of agricultural technology requires sufficient economic well-being, especially if new equipment is needed (Dung et al. 2018). Khatri-Chhetri et al. (2017) indicate that technologies and their costs of implementation influence farmers' preferences and willingness to pay. The impact of off-farm income or income and access to credit on adoption has revealed a positive correlation (Gebrehiwot and Van Der Veen 2013; Tessema, Aweke, and Endris 2013; Teklewold, Kassie, and Shiferaw 2013; Addisu et al. 2016; Asrat and Simane 2018).

Social Capital

Social capital, as defined by the World Bank (1999), refers to the institutions, relationships, and norms that shape the quality and quantity of a society's (or community's) social interactions. Social capital includes mutual trust and trust; reciprocity based on rules, exemplary behaviors, and sanctions; and unity in forming a social network that governs all human-to-human interactions and, thus, contributes to economic development (Coleman 1988; Fukuyama 1995). Social capital and networks of farmers can influence technology adoption decisions (Marenya and Barrett 2007; Kassie et al. 2013). It represents a combination of variables: membership in a farmers' association, the number of relatives inside and outside the village that a household can rely on for critical support, and the number of traders that a farmer knows inside and outside the town (Asrat and Simane 2018). Social capital, in the context of farming communities, refers to a farmer's social network, including the ability to informally access information, find jobs, access credit, insurance against unforeseen risks, exchange of information on prices, reduction of information asymmetry, and contracting in agricultural production (Maertens and Barrett 2013).

Extension Service Access

Lack of information and inadequate extension are the most critical barriers to climate change adaptation (Gebrehiwot and Van Der Veen 2013; Tessema, Aweka, and Endris 2013; Addisu et al. 2016; Atinkut and Mebrat 2016; Asrat and Simane 2018; Wassie and Pauline 2018). Information sources that positively influence adoption can include other farmers, media, meetings, and extension. The agricultural extension service is a formal source of information for producers, based on contact with extension agents and farmer groups (Tessema, Aweke, and Endris 2013).

Perceived Climate Change Impact

Farmers are changing agricultural practices due to observations of climatic and environmental changes (Jost et al. 2016; Schattman, Conner, and Méndez 2016). Farmers' perceptions on whether climate change impacts negatively on their farms have been found significantly related to the age and sex of the household head, income, knowledge of climate change, social capital, and agro-ecological settings (Deressa, Hassan, and Ringler 2011; Abrha 2015; Atinkut and Mebrat 2016; Schattman, Conner, and Mendez 2016; Ayal and Leal Filho 2017).

Farmland Tenure Status

Land tenure status is a descriptor differentiating self-owned farmland from a property that is rented from a third party (Dung et al. 2018). A farmer is more likely to manage self-owned land than rented property because of the effect of the land tenure status of the household on the adoption of CSA. The benefits of long-term practices accrue over time (Carolan 2005; Isgin et al. 2008; Teklewold, Kassie, and Shiferaw 2013). CSA is affected by the land tenure status of the farmer. This factor has been insignificant in some cases, but its impact on adoption has generally been consistent across a range of studies (Dung et al. 2018).

Access to Input and Product Markets

Access to the market is directly associated with the transaction costs that occur when households participate in input and output marketing activities (Kassie et al. 2013; Dung et al. 2018). Transaction costs on markets are barriers to participation by rice farmers and determinants of market failures in developing countries (Tessema, Aweke, and Endris 2013; Addisu et al. 2016; Atinkut and Mebrat 2016; Asrat and Simane 2018).

In the light of the empirical findings in the literature as cited, variables that have been included in the research model are shown in Table 1.

Table 1. Definition of variables in the research model

Variable	Definition	Expected Sign
Dependent variable	Categorical variable = 3 if yield management adopter; = 2 if Soil and Water management adopter; = 1 if Weather risk management adopter; = 0 if non-adopter.	
Independent variables		
Sex	Dummy variable for sex of household head: = 1if male, = 0 if female	–
Age	Continuous, age of household head (years)	–/+
Education level	Continuous, the number of formal education year of the household head	+
Farmland size	Continuous, total farmland (1 m^2)	+
Credit access	Dummy variable for access to credit of household: = 1if yes, = 0 if otherwise	+
Social capital	Continuous, number of traders/relatives that farmer trusts	+
Access to extension	Continuous, the number of agricultural knowledge sources that farmer accesses by an extension (television-radio, agricultural paper-book, smartphone, extension officer, extension-education courses, others)	+
Perceived climate change impact	Dummy variable for the perception of negative climate change impact: = 1 if yes, = 0 if otherwise	+
Farmland tenure status	Dummy variable for farmland tenure status: = 1 for self-owned land, = 0 otherwise	+
Market Constraint	Continuous, access to markets (Ristance to input/product market, km)	–

METHODOLOGY

Multinomial Logit Model

Previous studies on determinants of choice among more than two variable categories have employed quantitative models such as multivariate logit, probit, ordered logit/probit, and multinomial logit models (Deressa, Hassan, and Ringler 2011; Gebrehiwot and Van Der Veen 2013; Teklewold, Kassie, and Shiferaw 2013; Tessema, Aweke, and Endris 2013; Addisu et al. 2016; Atinkut and Mebrat 2016; Fadina and Barjolle 2018). The basic logistic regression or logit model typically adopted in behavioral choice studies is based on the theory of maximum likelihood suggested by Ben-Akiva and Lerman (1985). There are two types of logit model employed in such analyses, depending on whether the dependent variable represents a binary choice (binary logistic regression or logit model), or choice among several categorical values (multinomial logistic regression or multinomial logit model). The latter examines the probability of the dependent variable taking one of several defined categories, as influenced by multiple independent or explanatory variables. Like binary logistic regression, multinomial logistic regression uses maximum likelihood estimation to evaluate the probability of the categorized outcomes. Tabachnick, Fidell, and Osterlind (2001) discussed the advantages of the multinomial logistic regression technique over alternative regression modelling approaches.

In formulating the model employed here, farmers are assumed to implicitly maximize their expected utility or welfare (Y^*_{ij}) as they make their decision on the adoption of CSA practices. The model that describes the behavior of farmer *i* in choosing to adopt CSA practice *j* over other alternative practices is expressed in equation (1):

$$Y^*_{ij} = \beta_i X_i + \varepsilon_{ij} \quad j = 1 \ldots J \tag{1}$$

where X_i is a vector of independent variables, namely, human capital, farmland size, financial capital, social capital, extension service access, perceived climate change impact, farmland tenure status, and access to input and product factor markets; and ε_i is a random error term.

The utility to the farmer of choosing a CSA practice cannot be directly observed, but the farmer's adoption decision is observable. Let (*Y*) be an index that denotes the farmer's choice of CSA practice. Thus, the farmer will choose to adopt CSA *j* over adopting any other CSA *m* if:

$$Y = \begin{cases} 1 \text{ iff } \delta_{ij} < 0 \text{ or } Y^*_{i1} > \max\limits_{m \neq 1} (Y^*_{im}) \\ \vdots \\ j \text{ iff } \delta_{ij} < 0 \text{ or } Y^*_{ij} > \max\limits_{m \neq j} (Y^*_{im}) \end{cases} \tag{2}$$

$$\text{Since} \delta_{ij} = \max_{m \neq j}\left(Y^*_{im} - Y^*_{ij}\right) < 0$$

In Equation (2), δ_{ij} denotes a random variable representing the CSA practice chosen by any farming household. The equation indicates that farmer *i* will choose a CSA *j* to maximize expected utility and obtain greater expected utility than from any other technology $m \neq j$ (Bourguignon, Fournier, and Gurgand 2007).

The (δ_j)s are assumed to be independent and identically Gumbel distributed, following Bourguignon, Fournier, and Gurgand (2007). The probability that farmer *i* with characteristics *Xi* choosing a CSA practice *j* over other practices can be specified by a multinomial logit selection model (McFadden 1973) as follows:

$$P\left(\delta_{ij} < 0 / X_I\right) = \frac{\exp(X_i \beta_j)}{\sum_{m=1}^{J} \exp(X_i \beta_m)} \tag{3}$$

This expression shows that consistent maximum likelihood estimates of the (δ_j) can be obtained given their cumulative and density functions $G(\delta) = exp(-e^{-\delta})$ *and* $g(\delta) = exp\ (-\delta - e^{-\delta})$, respectively.

The Sample and Data Collection

A sample size requirement for the multinomial logistic regression indicates a minimum of 10 cases per independent variable (Schwab 2002).

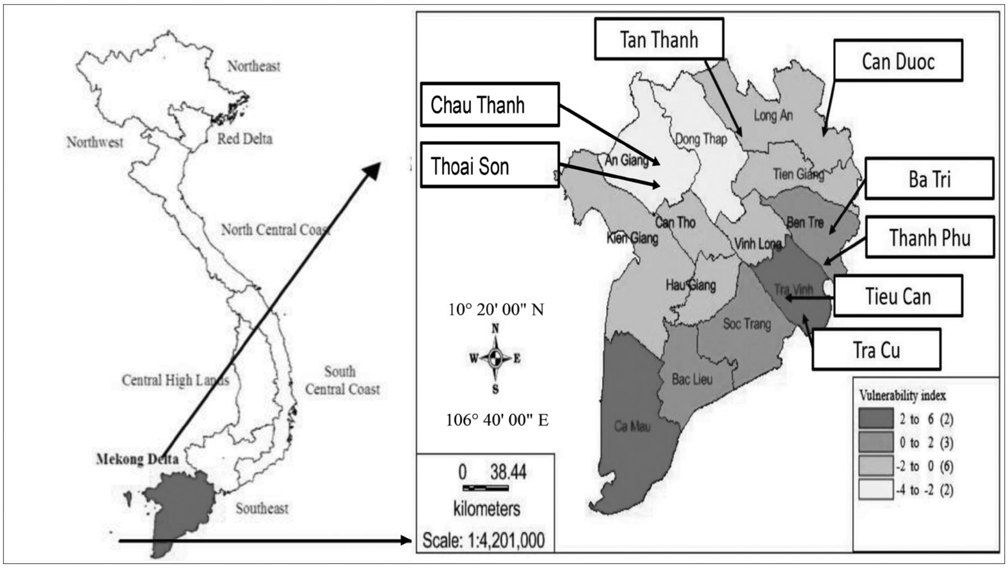
The Mekong Delta is the largest rice production area in Vietnam, located in Southwestern, Vietnam. The Delta covers 39 km^2 with about 600 km of coastline and is divided into 12 provinces (Long An, Tien Giang, Ben Tre, Tra Vinh, Vinh Long, Dong Thap, An Giang, Kien Giang, Hau Giang, Soc Trang, Bac Lieu, and Ca Mau), and one central city, Can Tho. Provinces of the delta are categorized into four groups: high vulnerability level (Tra Vinh and Ca Mau), moderate vulnerability level (Bac Lieu, Soc Trang, and Ben Tre), low vulnerability level (Long An, Tien Giang, Vinh Long, Can Tho, Kien Giang, Vinh Long, and Hau Giang), and the lowest levels of vulnerability to climate change (An Giang and Dong Thap) (Ho and Shimada 2019).

The sample areas of four provinces (An Giang, Long An, Ben Tre, and Tra Vinh), were randomly chosen from each of four groups of lowest, low, moderate, and high vulnerability levels, respectively. The sample areas also represented three major water resource zones: high flooded zone (Long Xuyen and Plain of reeds), freshwater zone (upper lands between Tien and Hau rivers), and saline intrusion zone (East Sea coastal, Ca Mau Peninsula) (Tuan, Hoanh, Miller, and Sinh 2007). Cross-sectional data across 350 households were gathered via face-to-face interviews with a structured questionnaire. A stratified random sampling procedure was adopted to select three wards of two districts in each selected province. The sample households were randomly selected based on the guidance and support of village leaders from the official households list of each commune, and household heads were interviewed. The distribution of sample households is shown in Table 2 and in Figure 1.

Table 2. Distribution of samples in the study area

Study Area	Sample Size
An Giang	
Chau Thanh	30
Thoai Son	30
Long An	
Tan Thanh	40
Can Duoc	40
Ben Tre	
Ba Tri	50
Thanh Phu	50
Tra Vinh	
Tieu Can	60
Tra Cu	50

Figure 1. Map of the study area



RESULTS

The survey results showed that 212 cases (61 percent) adopted CSA, while 138 cases (39 percent) did not adopt. Among adopters, 96 cases (27 percent of total cases) adopted weather risk management practices, 60 cases (17 percent) adopted soil and water management practices, and 56 cases (16 percent) were adopters of yield management practices. About 93 percent of the smallholder farm households, both CSA adopters and non-adopters, were male-headed. Other characteristics of the adopters and non-adopters in the sample are presented in tables 3 and 4.

The results of the F-test and Chi-square tests in Table 4 indicate that a male farmer who is the head of a household who has a higher educational level, larger farmland size, access to extension, access to market, higher social capital, access to credit, perceived climate change, and secured farmland is more likely to adopt CSA practices in general, and the different categories in particular, in comparison to non-adopters.

The estimation results of the multinomial logit model in Table 5 show the logistic coefficient, estimated marginal effects and p-levels for each independent variable for each alternative category of the dependent variable in the multinomial logit model. The chi-square results show that likelihood ratio statistics are highly significant ($p < .001$), suggesting that the model has a reliable explanatory power for behavior for farmers to

Table 3. Farmer's characteristics (all cases)

Variable	Frequency		Percentage	
Sex				
Male	326		93.1	
Female	24		6.9	
	Min	**Max**	**Mean**	**SD**
Age	20.00	63.00	39.61	11.11
Education level	0.00	16.00	8.64	4.26
Farmland size	0.50	11.00	4.35	2.22
Social capital	1.00	6.00	3.31	0.89
Access to extension	2.00	5.00	2.75	1.04
Perceived climate change	0.00	1.00	0.50	0.50
Farmland tenure	0.00	1.00	0.80	0.40
Market constraint	1.00	13.00	4.30	1.86

Table 4. Comparisons of mean of explanatory variables among categories

Variables	Non – Adopters	Adopters			P_value
		Weather risk management	Soil and water management	Yield management	
Sex	0.81	0.97***	0.99***	0.97***	0.04
Age	39.28	40.40 (–1.29; 0.82)	39.54 (1.30; 0.87)	40.16 (–1.25; 0.89)	0.65
Education level	5.41	10.00 (–4.48***)	10.19 (–5.30***)	11.47 (–6.80***)	***
Farmland size	3.04	4.08*** (–1.51***)	4.44*** (–2.44***)	5.82*** (–2.99***)	***
Access to credit	0.44	0.56***	0.66***	0.91***	***
Social capital	2.95	3.22*** (–0.24; 0.12)	3.84*** (–0.85***)	3.90*** (–0.94***)	***
Access to extension	2.28	2.87***	2.90***	2.95***	***
Perceived climate change risk	0.45	0.74***	0.77***	0.91***	***
Farmland tenure status	0.64	0.84***	0.89***	0.97***	***
Market constraint	4.97	4.45*** (–0.34; 0.028)	4.33*** (–1.06***)	3.58*** (–1.26***)	***

Note: ***$p < .001$, mean difference and p value in parentheses

Table 5. Parameter estimates and marginal effects of explanatory variables from the multinomial logit adoption model

Variables	Weather Risk Management		Soil and Water Management		Yield Management	
	Estimated coefficients	Marginal effects	Estimated coefficients	Marginal effects	Estimated coefficients	Marginal effects
Sex	–0.48 (0.71)	0.150	15.73 (0.07)	0.144	–0.98 (1.30)	–0.053
Age	0.02 (0.02)	0.005	0.009 (0.02)	–0.0004	0.03 (0.02)	0.0006
Education level	0.30*** (0.05)	0.048	0.32*** (0.07)	0.006	0.44*** (0.08)	0.012
Farmland size	0.31*** (0.12)	0.055	0.27** (0.14)	0.003	0.35** (0.15)	0.008
Financial access	0.29 (0.40)	0.014	1.02* (0.56)	0.040	1.78*** (0.71)	0.075
Social capital	0.08 (0.25)	0.027	0.69*** (0.29)	0.034	0.73*** (0.32)	0.033
Access to extension	0.11 (0.23)	0.008	0.54** (0.26)	0.025	0.52* (0.28)	0.021
Perceived climate change impact	2.21*** (0.40)	0.197	3.84*** (0.59)	0.133	4.09*** (0.66)	0.140
Land tenure status	0.15 (0.46)	0.026	1.32* (0.71)	0.050	1.18 (0.13)	0.041
Market access	–0.07 (0.11)	0.006	–0.23 (0.15)	–0.009	–0.47*** (0.16)	–0.021
Constant	–5.34 (1.37)	–	–27.02 (1.93)	–	–13.13 (2.43)	–

Number of obs = 350; LR $chi^2(30) = 363.64$; Prob > chi2 = 0.000; Log likelihood = 558.47; Pseudo Cox and Snell $R^2 = 0.646$; Pseudo Nagelkerke $R^2 = 0.696$; Pseudo McFadden $R^2 = 0.394$.

Note: *p < .05, **p < .01, ***p < .001, standard errors in parentheses, reference category: non-adopter

adopt CSA management practices. The value of Pseudo McFadden R^2 was at 0.394, Cox and Snell R^2 was at 0.646, and Pseudo Nagalkerke R^2 was at 0.696, suggesting that 39.40 percent, 64.60 percent, and 69.60 percent of the variability are explained by the set of variables used in the model, respectively.

Most of the relevant explanatory variables in the model were statistically significant at 10 percent level of significance or higher, and the signs on most variables were as expected. Sex and age of household head did not have a significant effect on the adoption of any of the categories of CSA practices. The significant determinants of farmer adoption of weather risk management practices are educational level, farmland size, and perception of climate change impact. For adoption of soil and water management practices, the significant determinants are educational level, farmland size, financial access, social capital, access to extension services, perception of climate change impact, and land tenure status. Determinants of farmer adoption of yield management practices were educational level, farmland size, financial access, social capital, access to extension services, perception of climate change impact, and market access.

The educational level of the household head was found to be positively and significantly correlated with adoption of weather risk management, soil and water management, and yield management at $p < .01$. One additional year of formal education of the farmer increases the probability of adoption of weather risk management by 4.80 percent, soil and water management by 0.60 percent, and yield management by 1.20 percent, respectively, relative to non-adopters.

Farmland size appears to be positively and significantly correlated with weather risk management, soil and water management, and yield management at $p < .01$ and $p < .05$, respectively, relative to the base category. A unit increase in 1,000 m^2 per household increases the probability of adopting weather risk management, soil and water management, and yield management by 5.50 percent, 0.30 percent, and 0.80 percent, respectively, relative to non-adopters of CSA practices.

Access to credit shows positive and significant correlations with soil and water management and yield management at $p < .10$ and $p < .05$, respectively, relative to the base category, but not with weather risk management. Farmers who have credit accessibility are more likely to adopt CSA by 4.00 percent and 7.50 percent higher, respectively, than non-adopters.

Social capital, as measured by the number of relatives or traders trusted by the farmer, is positively and significantly correlated with the household decision to adopt soil and water management and yield management at $p < 0.01$, but not with weather risk management. A unit increase in the number of relatives/traders trusted by the farmer (hence, more robust social capital) increases the probability of using the two adoption measures by 3.40 percent and 3.30 percent, respectively, relative to non-adopters.

Access to extension has a positive and significant correlation with the likelihood of choosing soil and water management and yield management at $p < .05$ and $p < .10$, respectively, relative to the base category, but not with weather risk management. A unit increase in the agricultural knowledge sources that a farmer accesses increases the probability that the farmer will adopt the two adaptation measures by 2.50 percent and 2.10 percent higher, respectively, than those households who do not practice CSA.

Household perception of climate change impact is found to be positively and significantly correlated with the choice of weather risk management, soil and water management, and yield management at $p < .01$. Farmers who have a perceived climate change impact are more likely to adopt CSA by 19.70 percent, 13.30 percent, and 14.00 percent, respectively, compared with those who do not practice CSA.

Farmland tenure has a positive and significant correlation with the likelihood of choosing soil and water management at $p < 0.1$, relative to the reference category. Having a land ownership certification can increase the probability of adopting soil and water management by five percent higher than non-CSA adopters.

Access to the market is negatively and significantly correlated with the household decision to pursue yield management practices at $p < .01$. A kilometer increase in the distance to the agricultural input/output market can decrease the probability of adopting yield management practices by 2.1 percent.

DISCUSSION

Small farmers play a crucial role in increasing production to ensure food security, but they are faced with numerous barriers to market access, knowledge, skills and technology innovations, and new value chains. To overcome these difficulties in pursuing the goal of developing sustainable agriculture requires much responsibility and effort. The participation of all stakeholders, including the government, businesses, farmers, scientists, and banks is crucial. Therefore, an understanding of factors influencing farmers' adoption of CSA could better guide the design and implementation of interventions that can overcome barriers to improved sustainability in agriculture. Hence, a vital issue requiring attention at the policy, research, and practice levels is the successful adoption and diffusion of CSA technological innovations. The findings of this study are found to align with other research results reported in the literature.

Consistent with our results, previous studies have shown that farmers with higher formal education are more likely to adopt CSA than others (Gebrehiwot and Van Der Veen 2013; Addisu et al. 2016; Asrat and Simane 2018; Fadina and Barjolle 2018). Lack of skilled labor also makes it difficult for farmers to be proactive in coping with and reducing losses due to extreme weather events, especially unseasonal rain in the Mekong Delta (Dung et al. 2018). Farmers have traditionally made use of family labor in rice cultivation. Through time, the main labor force in the household tends to decrease, while the rural labor supply, in general, is also becoming scarce as rural dwellers seek jobs in urban areas. Therefore, agricultural production methods that are less labor-intensive or more mechanized in some stages, especially in harvesting, are an urgent requirement for greater adoption of CSA by farmers.

This study found that farmland size has a significant impact on the adoption of CSA practices. The causal relationship between the two is based on the assumption of financial constraints (Khatri-Chhetri et al. 2017). That is, farmers with large production scales tend to be more financially capable and therefore have higher probability and intensity of CSA in production (Atinkut and Mebrat 2016; Fadina and Barjolle 2018). In the Mekong Delta, more than 50 percent of agricultural land has an area of less than 0.5 ha, hindering efforts to increase the application of improved technology, collaborate with enterprises, and establish concentrated production areas in the context of intensive global integration and rising climate change.

Even with farmers' access to credit, households may be inhibited from adopting improved technology, contrary to this study's findings, if legal constraints or additional investment requirements prevent small farmers from adopting CSA (Gebrehiwot and Van Der Veen 2013; Tessema, Aweke, and Endris 2013; Addisu et al. 2016; Asrat and Simane 2018). Vietnam's rural credit markets include formal, informal, and semi-formal credit (Linh et al. 2019). Even as the Vietnamese government has issued policies of rural credit access at the household level, small farmers find it difficult to access this financial resource due to procedures, timing, and needs. Farmers find great difficulty obtaining loans from commercial banks on time, nor access the needed amounts as capital for rice cultivation, or other economic and livelihood purposes. As a result, most farmers purchase inputs under informal deferred payment or credit schemes payable at the end of each rice crop, where payments end up more than twice as much as for formal credit obtained at the bank.

The effect of social capital and social networks on household choice in applying CSA, found by this study to be positive and significant, has also been assessed in past studies (Isham 2002; Bandiera and Rasul 2006; Wollni, Lee, and Thies 2010; Kassie et al. 2013). Farmers' social capital can affect the application of technological advances in many ways such as in information exchange, market access, labor exchange, capital access, as well as in coping with risks in production and market. Social capital in Vietnam is mostly in the form of group participation, including women unions, farmer unions, communist party, agricultural cooperatives, and farmer groups. Participation in local organizations with collective actions could help reduce climate change risk by knowledge sharing, mass sowing, common dike protection, water management, and group meeting of market requirements (Vo 2018).

This study also found access to agricultural extension services, which are the official source of information for farmers in agricultural production, to significantly improve the likelihood of CSA adoption by farmers. Official information about markets, advances, or technical solutions may help minimize risks, uncertainties, and asymmetric information, and thereby play a key role in increasing the choice of applications of technological advances in general and CSA measures in particular (Jansen et al. 2006; Knowler and Bradshaw 2007; Liu et al. 2011). In Vietnam, extension services provided to farmers are very comprehensive, which have played crucial roles in fostering the sustainable production of agriculture, ensuring local food, and social security (Sattaka, Pattaratuma, and Attawipakpaisan 2017).

Finally, farmers' access to input and output markets affects their transaction costs and their likelihood of CSA adoption (Neill and Lee 2001; Dimara and Skuras 2002; Pretty, Toulmin, and Williams 2011). Again, these are consistent with our study findings.

RESEARCH LIMITATIONS AND DIRECTIONS FOR FUTURE RESEARCH

The study has certain methodological limitations, including the size and nature of its sample, self-report questionnaire scale (subject to biases and limitations), and the cross-sectional nature of its data. The data sets have been collected only in the Mekong Delta from rice farmers; hence, the model may not be applicable for other regions or the whole country. Further studies can cover other areas and different types of agricultural products.

The dependent variable in the research model considered only the farmer's adoption of CSA measures. Future studies may consider other alternative dependent variables that permit measurement of the degree of adoption, rather than using only categorical variables as done in this study. For example, it may be possible to employ measures of farmers' perception and intensity in the adoption of CSA practices and efficiency of CSA measures to further enrich future analyses.

CONCLUSION AND POLICY IMPLICATIONS

Climate change adaptation practices play a crucial role in improving technical efficiency, economic benefits, and food security. Farmers play a critical role in the supply chains of the agriculture sector, and their adoption behavior of CSA determines the sustainability of agricultural development on the economic, environmental, and social spheres. Therefore, an understanding of factors that may restrict farmers' adoption of CSA is an essential question for stakeholders and policymakers and requires attention at the policy, research, and practice levels.

This study has examined several determinants of farmers' adoption of CSA, including educational level, farmland size, access to credit, social capital, access to extension, secured farmland tenure perception on climate change impact, and access to the market. Some policy recommendations that may contribute to the promotion of CSA in practice include the following:

- Promulgate a more explicit policy on farmland expansion to increase farmers' land ownership and allow area expansion to foster large-scale production and mechanization and promote agricultural modernization.
- Expand the lending network of financial institutions through the use of local socio-political associations as guarantors and grouped borrowers, which could widen access to formal credit programs and reduce transaction costs.
- Ensure that government credit policies guarantee sustainability and development in the long run, and reduce the focus on subsidized loans, and expand the activities of microfinance institutions to more effectively reach the poor and vulnerable groups.
- Improve social capital through effective operations of local organizations including farmer unions, agricultural cooperatives, farmer collaboration groups, large field models, and production-trade linkage models.
- Intensify promotion of CSA measures and widen awareness and information about climate change to enhance community participation in resource management.
- Improve farmers' awareness of fostering economic, social, and environmental effectiveness of CSA through mass media, including television, radio, printed materials, and farm-level demonstrations.
- Promote and improve vocational training for farmers on climate change and CSA through the extension service system.

- Support projects on climate change adaptation for farmers, with greater attention to quantity, level, and effective investment solutions, and tailored to peculiar characteristics of specific localities and regions.

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