Farming household adoption of climate-smart agricultural technologies: evidence from North-Central Vietnam

Alice Joan G. Ferrer[1] · Le Ha Thanh[2] · Pham Hong Chuong[3] ·
Nguyen Tuan Kiet[4] · Vu Thu Trang[5] · Trinh Cong Duc[4] · Jinky C. Hopanda[6] ·
Benedict Mark Carmelita[6] · Eisen Bernard Bernardo[7]

Abstract

Vietnam recently introduced a policy to promote climate-smart agricultural technologies (CSATs) to enhance farmer resilience and adaptation to climate change. This study sought to identify factors influencing the adoption and the continuation of CSATs adoption among smallholder farmers. The study surveyed 215 farmers in My Loi Village, Ha Tinh Province in North-Central Vietnam, where CSATs have been adopted and practiced since 2014. Logistic and ordinary least square regression models were applied to analyze the data. The results showed that attendance to training on CSATs, presence of a fellow farmer as a source of information, rice cultivation, farming experience and number of crops grown significantly influenced the adoption of CSATs. Farmer adoptions of CSATs, in contrast, were negatively influenced by more working men in the family and membership in a farming organization. The continuous adoption of CSATs was promoted by training, support from agriculture extension officers, upward mobility of farmers, farm ownership and the number of crops grown. Meanwhile, families with a larger number of male workers were less likely to continuously adopt CSATs. Policy-related recommendations were proposed to encourage farmers to adopt CSATs in the region. They included: (i) raising public awareness on CSATs through provision of high-quality information and training; (ii) enhancing technical assistance through the agricultural extension staff to all farmers, especially women; (iii) considering local context and smallholder farmer socioeconomic factors when developing climate-smart actions and programs.

Keywords Climate-smart agricultural technologies · Farmers · Adoption · Central Vietnam

✉ Le Ha Thanh
  thanhlh@neu.edu.vn; lehathanhneu@gmail.com

Extended author information available on the last page of the article

🖄 Springer

1 Introduction

Climate change affects global food security through rising temperatures, changes in rainfall patterns, and the increased frequency of extreme weather phenomena (Mbow et al. 2019; FAO 2018). This in turn negatively affects agriculture through food insecurity and changes in people's livelihood; lower productivity in farming, aquaculture, and animal husbandry; and an increase in global greenhouse gas emissions (Dinesh et al. 2018; IPCC (Intergovernmental Panel on climate Change) 2014; FAO 2010).

Vietnam, while contributing significantly to global food security, is among those countries most affected by climate change (World Bank Group and the Asian Development Bank 2020; MONRE 2016; World Bank 2011). In recent decades, Vietnam has faced higher temperatures and a sharp rise in extreme weather events, such as droughts, floods, and tropical cyclones (Son et al. 2018; Trinh 2018; MONRE 2016; CCAFS-SEA (CGIAR Research Program on Climate Change, Agriculture and Food Security- Southeast Asia), 2016a; CCAFS-SEA 2016b; World Bank 2010). These have presented multiple risks to Vietnam's agricultural sector (Vu et al. 2018). Past and ongoing studies confirm the strong negative impact of climate change on Vietnam's agricultural production and efforts at poverty reduction, food security, employment, and export (Nguyen et al. 2022; Ferrer et al. 2022; Diallo et al. 2019; Huong et al. 2019; Nguyen and Nguyen 2019; Trinh 2018; Tivet and Boulakia 2017; Le et al. 2015a, 2015b; Arndt et al. 2015).

For example, saltwater intrusion during the winter–spring crop season in 2015/2016 adversely affected many agricultural zones across Vietnam (Le and Nguyen 2019; FAO 2016; UNDP 2016). Rice paddy production fell by 11.2% compared to the 2014/15 crop year (GSO (General Statistical Office) 2016). The marked changes in rainfall dynamics, with more frequent and intense precipitation events and droughts disrupting agricultural and other economic activities, presented new challenges for Vietnamese farmers. Farmers with traditional farming methods are unable to effectively respond to adverse events that threaten the economic viability of many farming communities. The situation is serious for Vietnam, whose agricultural sector is the backbone of the national economy, accounting for 24% of the country's gross domestic product (GDP) and more than 20% of exports. Agriculture is also important for employment, with 70% of the country's population depending on this sector for livelihood (Maitah et al. 2020).

Given the context, a change in agricultural practices is in order. Efforts have been made to develop, promote, and disseminate new farming systems, technologies, strategies, and measures that can help farmers, especially those in vulnerable areas, overcome climate change challenges (Bai et al 2019; Lipper and Zilberman 2018; FAO 2013, 2010).

Globally, the key response to climate change is the introduction of climate-smart agriculture (CSA). It is a systematic approach to developing technical, policy, and investment conditions that achieve sustainable agricultural development and food security under climate change (Lipper et al. 2014). The goal of CSA is

to enable the sector to move toward more climate-resilient production systems and more sustainable livelihoods in the presence of climate change stressors and climate variability. The three pillars of CSA interventions are to: (i) sustainably increase agricultural productivity and income; (ii) adapt and increase resilience to climate change impacts; and, (iii) reduce and/or remove greenhouse gas emissions to the extent possible and appropriate (Asfaw and Maggio 2016; FAO 2013, 2010).

In Vietnam, the CSA is recognized as an important tool for managing the impact of climate change and climate-responsive policies were adopted (Simelton et al. 2017; Van et al. 2017; Pham et al. 2017; Tivet and Boulakia 2017). In 2014, climate-smart agricultural technologies (CSATs) were first introduced in three villages in Vietnam, namely, Ma Village in Yen Bai Province, My Loi Village in Ha Tinh Province and Tra Hat Village in Bac Lieu Province, with the support of the CGIAR Program on Climate Change, Agriculture and Food Security in Southeast Asia (CCAFS SEA). These villages are representative of different agro-ecological regions of Red River Delta, North-Central and Mekong River Delta, respectively (Simelton et al. 2017). My Loi Village in Ha Tinh Province in the uplands of North-Central Vietnam was chosen as one of three villages for CSATs piloting in Vietnam because of its high level of exposure to multiple extreme weather events (temperature and water stress, storm and typhoon) and the potential for climate-smart solutions (Aggarwal et al. 2018; Campbell et al. 2016; Duong et al. 2016; CCAFS-SEA 2016b). Seventeen CSATs were introduced in My Loi Village to make smallholder farmers more productive and resilient to climate change impacts. One important intermediate outcome identified in My Loi Village was the adoption of certain CSATs by farmers due to their enhanced knowledge and favorable attitude (Ferrer and Bernardo 2020), and their attitudes toward climate risks (Jin et al. 2020; Nguyen and Ho 2021). Although CSA practices has been documented and well-recognized method for adjusting agricultural output to the new conditions brought on by climate change, it has been emphasized that smallholder farmers find it challenging to adopt and apply CSATs. As such, a clear understanding of the factors that influence farmers' CSATs adoption is important to support farmers to increase their resilience to climate change and to promote effective climate-smart actions in the agricultural sector.

Previous studies conducted in different developing countries provide empirical evidence on the factors influencing farmers' adoption of CSATs, such as age, gender, ethnicity, education, number of children, family agricultural labor, off-farm work, diversified crops, farm size, experience, land ownership, community meetings, credit, yield, revenue, extension, training, institutions, household resources and household dependents (Usha et al. 2022; Atta-Aidoo et al. 2022; Abegunde et al. 2020; Solomon 2020; Jin et al. 2020; Liu et al. 2018; Maguza-Tembo et al. 2017; Di Falco and Veronesi 2013; Teklewold et al. 2013; Grothmann and Patt 2005). Studies found that adoption decisions are location-specific and are influenced by different key drivers. Due to differences in culture, awareness, resource endowments, objectives, preferences and socio-economic backgrounds, and psychological factors, farmers in different countries varied in their willingness to adopt new technologies. Farmers also modified or combined the original CSATs to address specific conditions and strategies they face.

Studies conducted in Vietnam focused on the effectiveness of potential and priority CSATs (e.g., Nguyen et al. 2020; CCAFS-SEA 2016b; Nghia et al. 2015) as well as the factors that influence farmers to adopt one or a combination of CSATs (e.g., Tran et al. 2020; Luu 2020; Nguyen and Nguyen 2019; Le et al. 2014a, b). Key factors affecting farmers' adoption of CSATs were found to include socio-demographic features, risk perception, social capital, or geographical location. However, no studies have addressed the issues of the continuation (or intensity) of farmers' adoption of CSATs in Vietnam, specifically in areas, where CSATs were formally introduced and promoted for use by farmers, such as in My Loi Village. This study attempts to fill this gap and expands the definition of successful adoption by incorporating this element. The present paper contributes to the literature on household's farming CSATs adoption behavior in developing countries by analyzing data from My Loi Village using a binary logit regression model for the initial uptake and an ordinary least squares (OLS) model for the continuation of adoption of CSATs. The OLS particularly looks at the factors affecting farmers' decision to continue or suspend the use of CSATs and the number of CSATs still in use after 5 years of introduction. This research strategy was proposed to examine farmers' decisions in the long run. Adaptation to climate change is a long process that requires not only initial adoption but also maintaining the practices without discarding them in the short-to-medium run. To the best of our knowledge, this study is the first attempt to identify key determinants of continuous adoption of CSATs. Moreover, understanding the factors driving farmers' CSATs adoption is crucial for proposing timely and effective policies and interventions. The findings of this study can guide policymakers in developing plans and programs for disseminating and promoting CSATs adoption and mitigating the detrimental impacts of climate change on the agricultural sector.

The paper proceeds as follows. The next section presents an overview of the study site. Section 3 describes the methodology, including the data and regression models. Section 4 presents the analysis and discusses the results. Section 5 provides a brief summary and areas for future research. Section 6 presents the policy implications of this study.

2 The study area

My Loi Village is located in the uplands of Ky Son Commune, Ky Anh District, Ha Tinh Province on the North-Central coast of Vietnam (Fig. 1). There were 230 households in the village in 2021, each with approximately four members. The main products of the village are cassava, peanuts, and acacia. It has a total land area of 195 hectares, of which 55 hectares is farmland for such annual crops as peanuts (30 hectares), paddy rice (8.5 to 9.5 hectares), maize, green beans, and sweet potatoes. About 90% of households raise a small number of animals for household consumption. My Loi has faced a range of extreme weather events from cold spells to hot spells, droughts and floods, dry Foehn winds, tornadoes, and tropical storms and typhoons. During floods, polluted water sweeps over fields or ends up in wells.

Seventeen CSATs to increase productivity and income, enhance the resilience of livelihoods and ecosystems, and reduce or remove greenhouse gas emissions into
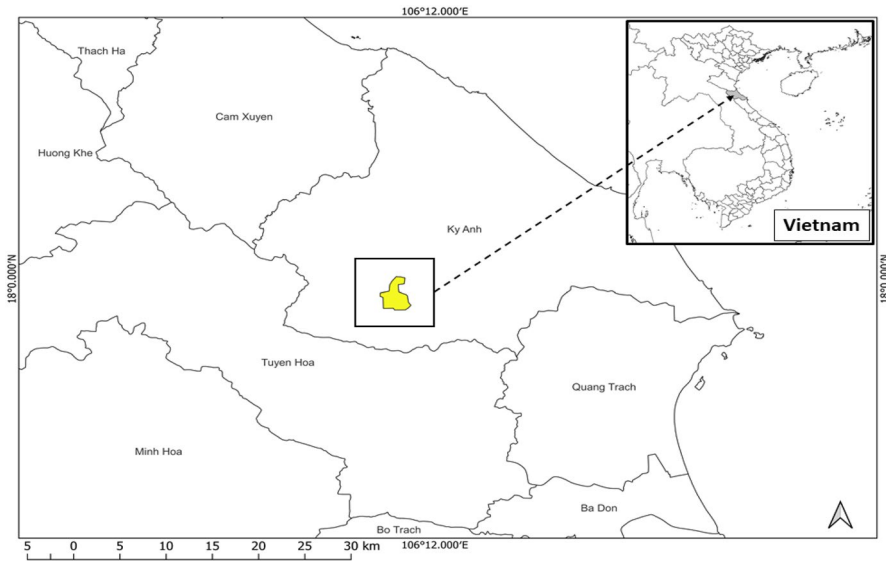
Fig.1 Location of My Loi Village

the atmosphere were designed and introduced to My Loi Village (Bonilla-Findji and Yen 2019; Simelton et al. 2017). They specifically included alley cropping (non-N-fixing trees), the production and use of compost, crop type changes, diet management, improved pigsties and animal cages, manure treatment, intercropping (non-legume), mulching, improved cooking stoves, crop rotation (alteration of legume and non-legume crops), drip irrigation, silvo pasture, multi-strata agroforestry, parklands, complex crop rotation, biogas, and biochar.

3 Methodology

3.1 The theoretical framework

The discipline of economics assumes that economic agents, when making decisions, are rational and maximize their self-interest. However, Simon (1972) challenged this classical thinking by presenting the theory of bounded rationality which states that decision-making was about 'satisficing' rather than 'optimizing'. It was argued that people were limited by their "cognition" and made decisions using limited information to produce a satisfactory result instead of using all available information needed to make rational decisions.

According to this theory, a farmer considering whether or not to adopt recommended CSATs is influenced by the information received either formally or informally as well as the cognitive level and attitude of that farmer regarding CSA. The theory of diffusion of innovation by Rogers (1962) suggests five stages through which a farmer makes a decision about CSATs: (i) the farmer becomes aware of

CSATs; (ii) the farmer forms an attitude about CSATs; (iii) the farmer decides to accept or reject CSATs; (iv) the farmer initiates the use of CSATs for testing; and, (v) the farmer continues the use of CSATs.

3.2 Empirical models

To identify the drivers of the adoption and continuation of the practices, a two-way empirical strategy was adopted. First, the drivers of initial adoption are studied using a binary logit choice model. Second, the key drivers for the continuation of the adoption are examined using OLS regression model. The two empirical models are as follows.

3.2.1 Model 1

To explore the factors affecting the adoption of CSATs, a logistic regression model was applied. The model is similar to the one developed by Di Falco and Veronesi (2013) and Bryan et al. (2013), which has become one of the common models in technology adoption research. The logistic procedure is used to capture nominal categorical responses on a set of discrete and/or continuous predictor variables allowing us to estimate the CSATs adoption probability (Wooldridge 2012). The model can also identify the main barriers and potential constraints to adoption.

There are only two choices in farmers' decisions regarding the introduced technology. The farmers were asked whether or not they had used any of the CSATs. The dependent variable in this study is a binary variable that takes the value of either 1 (adopted) or 0 (not adopted). Independent variables included personal characteristics of the farmer, family level variables, farm variables, and institutional and social variables (Table 1).

In this model, the dependent variable becomes the natural logarithm of the odds when a positive choice is made:

$$\ln \left(\frac{p_i}{1 - p_i} \right) = \beta_0 + \beta_1 x_{1i} + \beta_2 x_{2i} + ... + \beta_k x_{ki} + e_i \tag{1}$$

where p_i is the probability of ith observation in the sample of adoption; $(1-p_i)$ is the probability of ith observation in the sample of non-adoption; i is ith observation in the sample; β_0 and e_i stand for the intercept parameter and the error term, respectively; β_1, β_2 ... β_k are regression coefficients of the independent variables; k is the number of independent variables; x_{1i}, x_{2i},... x_{ki} are the independent variables or characteristics of ith farm household/ith observation in the sample.

3.2.2 Model 2

The continuation (or intensity) of the adoption is measured by the number of CSATs currently used. Because the dependent variable (DC_i) is the continued adoption of the CSATs, which is a count variable, the ordinary least squares (OLS) method was used (Wooldridge 2012). The use of OLS in this study is

Table 1 Variables in the research models

Variable	Definition
Dependent variables	
Adoption of CSATs	1 if the farmer is an adopter of any CSATs at any one time since 2014; 0 if not
Continuation of adoption (intensity)	The number of CSATs adopted and continued to be used
Independent variables	
Farmer	
Sex	1 if the farmer is a man; 0 if a woman
Age	Age in years of the farmer as of last birthday
Education	Number of years in formal schooling
Farming experience	Number of years as a farmer
Rice farmer	1 if the farmer is growing rice; 0 otherwise
Upward mobility	1 if the farmer indicates that he or she is always looking for better farming techniques; 0 otherwise
CSATs training	1 if the farmer attended training on any CSATs; 0 otherwise
Experience as a source of information	1 if the experience is a source of information for the farmer; 0 otherwise
TV as a source of information	1 if TV is a source of information for the farmer; 0 otherwise
Village information center as a source of information	1 if the village information center is a source of information for the farmer; 0 otherwise
Fellow farmer(s) as a source of information	1 if a fellow farmer(s) is a source of information for the farmer; 0 otherwise
Agricultural extension officer as a source of information	1 if an agricultural extension officer is a source of information for the farmer; 0 otherwise
Internet as a source of information	1 if the internet is a source of information for the farmer; 0 otherwise
Farmer's family	
Men in labor force	Number of male family members in labor force
Women in labor force	Number of female family members in labor force
Share of farming income	Percentage of annual farming income in total annual household income
Farm and farming	
Farm size	Farmland in hectares
Ownership	1 if the farmland is owned by family; 0 otherwise
Hired labor	1 if farm labor is composed of both family and hired labor; 0 otherwise
Ease of finding farm labor	Score on a scale of 1 to 10, where 1 is most difficult and 10 is easiest in finding farm labor
Number of crops	Number of crops grown on the farmland
Institutional	
Credit access	1 if the farmer was able to access credit during the past 10 years (2011–2021); 0 otherwise
Social	

Table 1 (continued)

Variable	Definition
Communal membership	1 if the farmer is a member of a community-based farmer organization; 0 otherwise

similar to previous studies using continuous dependent variable in conservation practice adoption or conservation program enrollment (Liu et al. 2018), agricultural technologies adoption (e.g., Chuang et al. 2020). The list of explanatory variables is shown in Table 1. The regression equation thus is

$$DC_i = \beta_0 + \beta_1 x_{1i} + \beta_2 x_{2i} + ... + \beta_k x_{ki} + e_i \qquad (2)$$

where DC_i is the number of CSATs currently adopted by a ith farmer; i is ith observation in the sample; β_0 and e_i stand for the intercept parameter and the error term, respectively; $\beta_1, \beta_2 ... \beta_k$ are regression coefficients of the independent variables; k is the number of independent variables; $x_{1i}, x_{2i}... x_{ki}$ are the independent variables or characteristics of ith farm household/ith observation in the sample.

3.2.3 Selection of independent variables

Five groups of independent variables employed in this study are personal characteristics of the farmer, family level variables, farm variables, and institutional and social variables. The selection and categorization of variables is based on the CSATs being investigated and literature review. Personal characteristics of the farmer or demographic variables (e.g., age, gender, education, farming experience, training, and information) have been discussed substantially in previous empirical studies regarding the factors influencing farmers' adaptive behaviors in response to climate change (Nguyen et al. 2022; Hoa et al. 2022; Maguza-Tembo et al. 2017; Tran et al. 2020; Trinh et al. 2018; Le et al. 2014a, b; Ozor et al. 2012; Weinstein 1989). The age of the farm household head, farming experience, education level were reported to affect the CSATs adoption decisions of farming households. The differences between the adaptive responses of farmers may be accounted for by disparities in their land ownership, off-farm job opportunities, health and welfare, education, socio-cultural context, access to credit, information and other resources. The factor-related socioeconomic and farming characteristics such as farm income, family labor force, farm size, and land tenure were found to have strong impacts on farmers' decision to adapt to climate change (Hoa et al. 2022; Nhemachena and Hassan 2007; Tran et al 2020; SeinnSeinn et al. 2015). Some institutional and social variables have been incorporated in the models, including the farm households' access to formal credit and status of participation in membership in social/agricultural groups. The two variables are all dummies and have been employed in previous studies of Maguza-Tembo et al. (2017), Teklewold et al. (2013) and Mignouna et al. (2011). Table 1 describes variables used in Eqs. 1, and 2.

3.3 Study participants

The study participants were 215 farming households in My Loi Village. During the data collection in September 2021, My Loi Village had 230 households. The 15 households under quarantine due to COVID-19 were not included in the survey. Women accounted for 73% of the study participants. The data collection period coincided with the rice farming off-season, when many men left the village to find temporary jobs elsewhere and for their wives to take care of the farm. The average female-to-male ratio in agricultural labor in Ha Tinh Province is about 65:35, but it may reach 75:25 in some places.

3.4 Data collection method and instrument

Mixed data collection methods were employed. These were key informant interviews with CSA experts of local government agencies and face-to-face interviews with farming households in My Loi Village. The selection of key informants was based on involvement in agriculture, rural development, and CSA. The key informant interviews were conducted prior to the survey to generate information necessary in designing the interview schedule used in the survey.

We collected data from the household survey as follows:

First, the interview schedule was pilot-tested with 5 households in My Loi Village to check the clarity and appropriateness of the questions, possible alternatives to the questions, the difficulty of the questions, the probability that a large number of questions would go unanswered, and the length of the interview.

Second, the interview schedule was revised and finalized to address the concerns raised by the pilot testing participants. It also became an opportunity for the data collection team to gain experience in working with the farm households and to find the best interview strategy.

Third, 2-day training was provided to the enumerators focusing on familiarization with the interview schedule, how to approach the farmers, and how to conduct the interviews to ensure reliable answers.

Finally, a team of trained data collectors conducted the survey in September 2021.

4 Results and discussion

4.1 Characteristics of the study participants

Among the 215 farmers who participated in the study, 74% (159 farmers) adopted at any one time at least one CSAT introduced since 2014 (Table 3). While most study participants were women (73%), the women-non-adopters were higher in proportion than the women-adopters (80% vs. 70%). Almost all of the participants were married (88%). On average, they were in their late 40 s but the non-adopters were

younger (41 years) than the adopters (50 years). This suggests that the adoption of new technology is more attractive to older farmers. The study participants, on average, had 8 years of formal education with the non-adopters staying a little longer in school than the adopters (9.41 years vs. 8.04 years). The majority of them (68%) studied or finished junior high school education at the minimum (Table 2).

The number of adopted CSATs varied through the years. The most commonly adopted CSATs were ally cropping (75%), compost (52%), and crop type change (49%) (Table 3). At least one-third of the adopters–farmers attempted improved pig sty or animal cage and diet management. About one-fourth of the adopter–farmers

Table 2 Profile of the farmers in My Loi Village who participated in the study

	Adopter n=159		Non-adopter n=56		All n=215	
	No	%	No	%	No	%
Sex						
Male	48	30.19	11	19.64	59	27.44
Female	111	69.81	45	80.36	156	72.56
Total	159	100	56	100	215	100
Age						
Mean	49.62		41.13		47.41	
24 below	2	1.26	0	0.00	2	0.93
25 to 35	27	16.98	26	46.43	53	24.65
36 to 45	31	19.50	14	25.00	45	20.93
46 to 55	39	24.53	5	8.93	44	20.47
56 to 60	27	16.98	4	7.14	31	14.42
Beyond 60	33	20.75	7	12.50	40	18.60
Total	159	100	56	100	215	100
Civil status						
Married	141	88.68	48	85.72	189	87.90
Single	4	2.52	0	0.00	4	1.86
Widow/er	12	7.54	8	14.28	20	9.30
Separated	1	0.63	0	0.00	1	0.47
Others	1	0.63	0	0.00	1	0.47
Total	159	100	56	100	215	100
Educational attainment						
No. of years in school (mean)	8.04		9.41		8.40	
No schooling	0	0	1	1.79	1	0.47
Primary school	15	9.43	4	7.14	19	8.83
Junior high school	117	73.58	29	51.79	146	67.91
Senior high school	14	8.81	14	25.00	28	13.02
High school	2	1.26	0	0.00	2	0.94
University/college/vocational	11	6.92	8	14.28	19	8.83
Total	159	100	56	100	215	100

Table 3 Adoption of CSATs by My Loi farmers

	CSATs	Adopters ($n = 159$)	
		No. *	%
1	Alley cropping (non-N-fixing trees)	120	75.47
2	Compost	82	51.57
3	Crop type change	78	49.06
4	Diet management	60	37.74
5	Improved pigsty or animal cage	54	33.96
6	Manure treatment	46	28.93
7	Intercropping (non-legume)	45	28.30
8	Mulching	37	23.27
9	Improved cooking stoves	29	18.24
10	Crop rotation (mixed legume/non-legume)	25	15.72
11	Drip irrigation	14	8.81
12	Silvo pasture	13	8.18
13	Multi-strata agroforestry	9	5.66
14	Parklands	4	2.52
15	Complex crop rotation	2	1.26
16	Biogas	2	1.26
17	Biochar	1	0.63

*Multiple response

practiced manure treatment, intercropping, or mulching. The least popular CSATs were multi-strata agroforestry, parklands, rotation, biogas, and biochar. At the time of the survey, the number of adopted CSATs ranged between 1 and 12 among 159 adopter–farmers with an average number of four practices. The proportion of farmers who had both heard about and actually attended at least one of the training sessions and the proportion of farmers who heard about the training sessions of almost all of the CSATs were both higher among the adopters than among the non-adopters.

4.2 Factors influencing the adoption of CSATs

The factors that significantly influence a farmer's decision to adopt at least one of seventeen CSATs were identified using a binary logit regression for initial adoption ("ever adopted") and OLS regression for the continuation (intensity) of adoption. The summary statistics for the two dependent variables and independent variables are presented in Table 4.

4.3 Factors influencing adoption at any time of any CSATs

Table 5 presents the results of the binary logit regression model that identified the factors influencing the adoption of any CSATs at any time (ever adopted) since the introduction of CSATs in 2014. The model fits the data reasonably well

Table 4 Descriptive statistics

Variables	Mean	SD	Min	Max
Dependent variables				
Adoption of CSATs	0.74	0.44	0	1
Continuation of adoption (intensity)	3.19	2.94	0	12
Independent variables				
Farmer				
Sex	0.27	0.45	0	1
Age	47.41	14.09	19	79
Education	8.40	3.19	1	20
Farming experience	29.73	14.92	0	63
Rice farmer	.80	.39	0	1
Upward mobility	0.88	0.32	0	1
CSATs training as a source of information	0.50	0.50	0	1
Experience as a source of information	0.90	0.30	0	1
TV as a source of information	0.87	0.34	0	1
Village information center as a source of information	0.89	0.32	0	1
Fellow farmer(s) as a source of information	0.92	0.28	0	1
Agricultural extension officer as a source of information	0.91	0.28	0	1
Internet as a source of information	0.42	0.50	0	1
Farmer's family				
Men in labor force	1.29	1.02	0	10
Women in labor force	1.18	0.81	0	5
Share of farming income	24.29	27.36	−15	100
Farm and farming				
Farm size	1.32	1.87	0	12
Ownership	0.90	0.30	0	1
Hired labor	0.58	0.50	0	1
Ease of finding farm labor	8.89	1.37	2	10
Number of crops	3.36	1.75	0	10
Institutional				
Credit access	0.49	0.50	0	1
Social				
Communal membership	0.71	0.46	0	1

(Prob > chi2 = 0.000) with correct prediction at 89.77%. The significant factors positively influencing the decision of a farmer to adopt or not adopt a CSAT were attendance to training on CSATs ($p < 1\%$); having a fellow farmer as a source of information ($p < 5\%$); rice cultivation, farmer's experience as a source of information, and the number of crops grown (each at $p < 10\%$). The two factors that significantly and negatively influenced adoption decision were having more working men in the family ($p < 5\%$) and membership in a farming organization ($p < 10\%$).

Table 5 Logit regression results: Adoption of CSATs (Ever adopted)

Variables	Odds ratio	$P>|z|$
Farmer		
Sex	1.497	0.502
Age	1.039	0.506
Education	0.999	0.992
Farming experience	0.966	0.537
Rice farmer	3.466	0.074*
Upward mobility	2.739	0.204
CSATs training as a source of information	40.703	0.000***
Experience as a source of information	4.098	0.093*
TV as a source of information	2.059	0.316
Village information center as a source of information	0.570	0.563
Fellow farmer(s) as a source of information	7.132	0.045**
Agricultural extension officer as a source of information	1.367	0.723
Internet as a source of information	0.466	0.189
Farmer's family		
Men in labor force	0.455	0.014**
Women in labor force	1.721	0.276
Share of farming income	0.999	0.908
Farm and farming		
Farm size	0.921	0.586
Ownership	2.769	0.259
Hired labor	1.428	0.564
Ease of finding farm labor	.8761	0.573
Number of crops	1.394	0.080*
Institutional		
Credit access	2.082	0.183
Social		
Communal membership	0.359	0.088*
Number of obs.=215	Pseudo R^2=0.5084	
LR chi^2(32)=125.39	Log likelihood=−60.617358	
Prob>chi^2=0.0000	Correctly classified 89.77	

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

Attendance to training on any CSAT was highly significant (1%) and had a strong positive impact on adoption behavior. The odds ratio indicated that the farmer's attendance of training greatly increased the likelihood of adopting any CSAT by a factor of 40.70 compared to those who did not attend. This highlights the significance of training when introducing new farming technologies and practices. This may also reflect the quality of the training provided to the farmers in this case. These results were consistent with the findings of Nguyen et al. (2022), Nguyen et al. (2020), Nguyen and Nguyen (2019), and Trinh et al. (2018) that training not only helps farmers increase their awareness of the severity of the

risks and benefit of each CSAT but also provides detailed guidance on how to practice the proposed methods, leading to a positive response to the risks. Grothmann and Patt (2005) showed that farmers will not respond to warning information if they perceive the risk to be low, with little intention of taking suggested actions.

Having a fellow farmer (or farmers) as a source of information was also significant (5%) and positively associated with adoption behavior. The odds ratio showed that the likelihood of adopting any CSAT is boosted by a factor of 7.13 than otherwise. This result was similar to those of Tran et al. (2020) and Teklewold et al. (2013), which confirmed that consultation with other farmers who are well-informed about the new ways of farming is an important strategy to scale up CSATs. Thus, the CSA roving workshops, where farmers meet other farmers to share practices as well as any other gatherings, where practices and experiences are similarly exchanged among farmers, are highly recommended. The farmer's own "experience as a source of information" was also strongly associated with adoption behavior, with an odds ratio of 4.098. This variable can be construed as a proxy for the confidence of the farmer as a farmer. This is consistent with the results of Nguyen et al. (2022), Trinh et al. (2018), Le et al. (2014a, b), Ozor et al. (2012), and Weinstein (1989), which concluded that past risk experience positively influences the self-protection behavior of farmers.

Moreover, being a rice farmer also increased the likelihood of adoption with an odds ratio of 3.466. Although a few farmers in My Loi Village have diversified their crops from rice to cash crops, fruit trees, and forest trees, still 80% of the farmers grew rice. Rice as the most important agricultural product may allow farmers to receive more relevant information and support than the growers of other crops, which may make the former relatively more open and willing to improve their practices. In addition, the odds ratio (1.394) of the variable "number of crops grown" indicated that one additional crop grown also increased the likelihood of adopting any CSAT by 39%.

On the other hand, having male family members in the labor force (odds ratio = 0.455) reduced the likelihood of adoption. This can be understood in the context of My Loi Village, where the men usually leave the village temporarily and seasonally, especially between farming seasons or more permanently to find work in other regions. Farm labor is dominated by women. In this study, 73% of the survey participants were female farmers. The mobility of men who spend much of their time outside the village may make them pay less attention to farming and more conservative about the adoption of new methods. This result corroborated the findings of Nhemachena and Hassan (2007) and Tran et al (2020) that female-headed households more willingly adopt climate change adaptation methods in farming than male-headed ones.

Adoption of CSATs was negatively affected by involvement in community organizations (odds ratio = 0.360). In My Loi Village, men were usually members of the farmer's organization, which can explain the negative influence of gender as explained above. This result, however, was contrary to what Vo et al. (2021) found, where membership in local organizations encourages farmers' adaptation to climate change. Nonetheless, the results of the current study were generally consistent with

previous findings on factors affecting the adoption of good agricultural practices (e.g., Di Falco et al. 2011; Jin et al. 2020; Tran et al. 2020; Trinh et al. 2018).

4.4 Factors influencing the continued adoption of CSATs

OLS regression was used in the second stage to identify the significant factors affecting the continuation or intensity of CSATs adoption. The dependent variable is the number of CSATs the farmer was adopting at the time of the interview. It should be noted that this measure of adoption covers the period from 2014 to 2021. It is acknowledged that counting the number of adopted practices is not a perfect representation of the frequency or duration of adoption of each CSAT. However, the measure should still be useful in studying the extent to which farmers continue to use CSATs. The model has an adjusted R-squared of 41%, showing that the independent variables can collectively explain 41%, a relatively large portion, of the variation of the dependent variable.

The factors that significantly and positively influenced the continued adoption behavior were attendance to CSATs training ($p < 1\%$); the agriculture extension officer as a source of information and TV as a source of information (at $p < 5\%$ each); and, upward mobility, farm ownership, and the number of crops grown (at $p < 10\%$ each). The factors that significantly (at $p < 10\%$) and negatively influenced this decision were having more male family members in the labor force and the ease of finding farm labor.

Attending to a CSA training course was likely to increase the number of CSATs adopted by a factor of three, which was similar to the results of the 'ever adopted' regression. It indicated a strong association between training and adoption behavior. The positive role of the agriculture extension officer on the adoption behavior of the farmers was also brought to the fore. Survey data confirmed that the agricultural extension officer was a common source of information for matters related to production inputs, such as crop variety, fertilizer, and pesticide, as well as soil and livestock management. This suggests the importance of a highly skilled agricultural extension officer who can share information and skills with the farmers. Similarly, sourcing farming information from TV increases the number of CSATs adopted by one. For farmers, TV was the main source of information on the daily weather forecast and one of the major sources of the seasonal forecast. This points to the importance of TV as a medium to disseminate better farming technologies and practices in Vietnam. The presence of popular information media perceived to be reliable by farmers, such as TV, can improve their awareness of the threats posed by the changing climate conditions (Di Falco et al. 2011). This can positively influence farmer's responses against such risks (Li et al. 2022; Le et al. 2014a, b; Di Falco et al. 2011).

In addition, the upward mobility of farmers, i.e., their positive attitude toward better ways of farming, increased CSA adoption rate. The same was true for farmers who owned their land. The positive relationship between land ownership status and CSATs intensity of adoption revealed in this study implies that farmers are more likely to manage self-owned land in a more favorable manner than rented land. Our research finding is in line with Dung et al. (2018), who found that household land

tenure status positively influences the CSATs adoption. Since 1988, Vietnam recognized farm households as autonomous economic units, freed up markets for inputs and outputs, recognized their right on land, and made allowance for long-term allocations of land to farming households. Farmers can use agricultural land for agricultural production purposes. They can also transfer, exchange, lease, inheritance and mortgage the allocated land. This policy has resulted in a boost in agricultural output and significant improvement in living standards in rural areas (World Bank 2016).

Growing one additional crop also increased the adoption of CSAT by a factor of 0.21. On the other hand, the ease of finding farm labor negatively influenced the adoption of CSATs. This may be attributable to labor mobility in My Loi Village, in particular, and the rural areas of North-Central region of Vietnam, in general. Another possible explanation could be that the available workforce in rural area in North-Central Vietnam is normally less educated and has fewer information-comprehension skills, and is, therefore, is less aware of new farming technology. As a result, local farmers are less likely to adopt CSATs that predominantly require unskilled labor. This also might mean that proactive farmers constantly look for ways to improve their farming activities by continuously seeking agricultural information and training, thus providing them with knowledge and skills. This result corresponds to the study of Kangogo et al (2021), who found that CSA adoption to be negatively associated with unskilled labor. Similarly, having more male family members in the labor force negatively influenced CSATs adoption. This result can again be attributed to the mobility of village men who migrate to other areas temporarily or permanently to find work Table 6.

5 Conclusions

The study focused on farming households' adoption and practice of CSATs in My Loi Village in the North-Central region of Vietnam. Among 215 farming households interviewed, 159 had adopted at least one CSAT since 2014. At the time of the survey (September 2021), the average number of adopted and practiced CSATs over farming households which adopt and practice at least one CSAT is around 4. Factors are identified that positively and negatively influence farmer's decision to adopt and continue to adopt CSATs.

It is proved that positive impacts are given by training on CSATs and having fellow farmers who can spread new ways of farming to others, well-informed and highly skilled agricultural extension officers, and reliable media of information for farmers including TV. More specifically, the following results for initial adoption and continued adoption are particularly noteworthy.

First, initial adoption is enhanced by attendance to any training course on CSATs, presence of a fellow farmer or farmers as a source of information, rice cultivation, farmer's own experience in farming, and number of crops grown. On the other hand, the two factors that significantly and negatively influence adoption are having more working men in the family and membership in the village farming organization.

Table 6 Regression results: Continuation of adoption of CSATs

Variables	Coefficient	$P > |z|$
Constant	−2.361	0.262
Farmer		
Sex	0.212	0.573
Age	0.021	0.506
Education	0.022	0.719
Farming experience	−0.019	0.516
Rice farmer	0.203	0.693
Upward mobility	1.135	0.051*
CSATs training as a source of information	2.588	0.000***
Experience as a source of information	0.279	0.648
TV as a source of information	1.014	0.050**
Village information center as a source of information	−0.635	0.274
Fellow farmer(s) as a source of information	0.716	0.259
Agricultural extension officer as a source of information	1.456	0.029**
Internet as a source of information	−0.244	0.530
Farmer's family		
Men in labor force	−0.320	0.092*
Women in labor force	0.0245	0.291
Share of farming income	0.003	0.698
Farm and farming		
Farm size	−0.086	0.377
Ownership	1.008	0.073*
Hired labor	0.238	0.530
Ease of finding farm labor	−0.241	0.052*
Number of crops	0.209	0.093*
Institutional		
Credit access	−0.363	0.284
Social		
Communal membership	0.524	0.162
Number of obs. = 215	$F(26, 188) = 6.730$	Prob > F = 0.000
$R^2 = 0.482$	Adj. $R^2 = 0.410$	Root MSE = 2.258

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

Second, variables that enhance the decision to continuously adopt CSATs are attendance to any CSATs training, support by an agriculture extension officer, TV as a source of farming information, upward mobility of farmers, farm ownership, and the number of crops grown. The factors that negatively influence continuous use are the large number of working men in the family and the ease of finding farm labor.

This research is not without limitation. The data for the study were collected from farmers based on recall. Future research would benefit from the examination of another research design, such as longitudinal experiments and other regression

estimation methods. In addition, the study only looked at the factors that influence CSATs adoption and intensity adoption among smallholder farmers in My Loi Village in North-Central Vietnam. Further research should be carried out in other regions of Vietnam.

6 Policy implications

The study highlights the importance of both the quality and quantity of information available to farmers and as well as easy access to it. A key policy message suggested is effective and accessible information provision. Trust-building communication among stakeholders is the area that needs more policy effort and action. While everyone needs to work to raise public awareness of CSA, the role and leadership of the government are particularly important.

More concretely, the government must provide high-quality information through appropriate training programs on CSA. This is a relatively simple and inexpensive yet highly efficient way to produce changes in the farmer's attitude and behavior toward the adoption of CSATs. Training activities on CSATs and educational opportunities should be made more accessible for female farmers. Utilizing the power of the media—including TV but also radio, posters, websites, others—to strengthen the awareness of CSA and communicate effective response strategies is crucial.

In addition, the local government leaders responsible for the agriculture sector should formulate a plan to increase staffing for agricultural extension and support services as well as staff development programs to further accelerate the adoption of CSATs. Extension activities should be widened and made more accessible to all households particularly to those with larger number of male members. The technical know-how on CSATs by the agricultural extension and support staff is significantly important in promoting new technologies and upgrading the skills of farmers, thereby speeding the adoption of CSATs.

Finally, since adaptation to climate change is a location-specific issue, understanding the features and constraints of farming households is vital and needs more attention at the policy, research, and practice levels for introducing new CSATs and designing proper incentive mechanisms to encourage local farmers to adopt them.

Declarations

Conflict of interest The authors have no competing interests to declare that are relevant to the content of this article.

References

Abegunde VO, Melusi S, Ajuruchukwu O (2020) Determinants of the adoption of climate-smart agricultural practices by small-scale farming households in King Cetshwayo District Municipality, South Africa. Sustainability 12(1):195. https://doi.org/10.3390/su12010195

Aggarwal PK, Jarvis A, Campbell BM, Zougmoré RB, Khatri-Chhetri VSJ, Loboguerrero AM, Sebastian LS, Kinyangi J, Bonilla-Findji O, Radeny M, Recha J, Martinez-Baron D, Ramirez-Villegas J, Huyer S, Thornton P, Wollenberg E, Hansen J, Alvarez-Toro P, Tan Yen B (2018) The climate-smart village approach: framework of an integrative strategy for scaling up adaptation options in agriculture. Ecol Soc 23(1):14. https://doi.org/10.5751/ES-09844-230114

Arndt C, Tarp F, Thurlow J (2015) The economic costs of climate change: a multi-sector impact assessment for Vietnam. Sustainability 7(4):4131–4145. https://doi.org/10.3390/su7044131

Asfaw S, Maggio G (2016) Gender integration into climate-smart agriculture: tools for data collection and analysis for policy and research, working paper No. 2016/1, Rome, January 2016

Atta-Aidoo J, Antwi-Agyei P, Dougill A, Ogbanje CE, Akoto-Danso EK, Eze S (2022) Adoption of climate-smart agricultural practices by smallholder farmers in rural Ghana: An application of the theory of planned behavior. PLOS Climate 1(10):e0000082. https://doi.org/10.1371/journal.pclm.0000082

Bai X, Huang Y, Ren W, Coyne M, Jacinthe P, Tao B, Hui D, Yang J, Matocha C (2019) Responses of soil carbon sequestration to climate-smart agriculture practices: a meta-analysis. Glob Change Biol 25(8):2591–2606. https://doi.org/10.1111/gcb.14658

Bonilla-Findji O, Yen BT (2019) Southeast Asia Climate-Smart Villages AR4D sites: 2017 Inventory. Wageningen, The Netherlands: CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). https://ccafs.cgiar.org/resources/publications/southeast-asia-climate-smart-villages-ar4d-sites-2017-inventory. Accessed 10 Sep 2021

Bryan E, Ringler C, Okoba B, Roncoli C, Sivestri S, Herrero M (2013) Adapting agriculture to climate change in Kenya: household strategies and determinants. J Environ Manage 114:26–35. https://doi.org/10.1016/j.jenvman.2012.10.036

Campbell BM, Vermeulen SJ, Aggarwal PK, Corner-Dolloff C, Girvetz E, Loboguerrero AM, Ramirez-Villegas J, Rosenstock T, Sebastian L, Thornton PK (2016) Reducing risks to food security from climate change. Glob Food Sec 11:34–43. https://doi.org/10.1016/j.gfs.2016.06.002

CCAFS-SEA (CGIAR Research program on Climate Change, Agriculture and Food Security- Southeast Asia) (2016a) Assessment report: The drought and salinity intrusion in the Mekong River Delta of Vietnam, Hanoi, Vietnam: CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). https://ccafs.cgiar.org/resources/publications/drought-and-salinity-intrusion-mekong-river-delta-vietnam-assessment. Accessed 26 Aug 2021

CCAFS-SEA (2016b) Climate-Smart Villages: An AR4D approach to scale up climate-smart agriculture. Copenhagen, Denmark: CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). https://ccafs.cgiar.org/resources/publications/climate-smart-villages-ar4d-approach-scale-climate-smart-agriculture. Accessed 26 Aug 2021

Chuang JH, Wang JH, Liou YC (2020) Farmers' knowledge, attitude, and adoption of smart agriculture technologie in Taiwan. Int J Environ Res Public Health 17(19):7236. https://doi.org/10.3390/ijerph17197236. (**PMID: 33022936; PMCID: PMC7579605**)

Diallo Y, March S, Espagne E (2019) Impacts of extreme events on technical efficiency in Vietnamese agriculture, Études et Documents No. 12, Centre d'Etudes et de Recherches sur le Développement International, University of Clermont-Auvergne.

Di Falco S, Veronesi M (2013) How can African agriculture adapt to climate change? A counterfactual analysis from Ethiopia. Land Econ 89(4):743–766. https://doi.org/10.3368/le.89.4.743

Di Falco S, Veronesi M, Yesuf M (2011) Does adaptation to climate change provide food security? A micro-perspective from Ethiopia. Am J Agr Econ 93(3):829–846. https://doi.org/10.1093/ajae/aar006

Dinesh D, Zougmore RB, Vervoort J, Totin E, Thornton PK, Solomon D, Shirsath PB, Pede VO, Noriega IL, Läderach P, Körner J, Hegger D, Girvetz EH, Friis AE, Driessen PPJ, Campbell BM (2018) Facilitating change for climate-smart agriculture through science-policy engagement. Sustainability 10(8):1–21. https://doi.org/10.3390/su10082616

Dung LT, Ho DP, Hiep NTK, Hoi HPT (2018) The determinants of rice farmers' adoption of sustainable agricultural technologies in the Mekong Delta, Vietnam. Appl Econ J 25(2):55–69

Duong MT, Simelton E, Le VH (2016) Participatory identification of climate-smart agriculture priorities. CCAFS Working Paper No.175. Copenhagen, Denmark: CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). https://ccafs.cgiar.org/resources/publications/participatory-identification-climate-smart-agriculture-priorities. Accessed 15 Aug 2021

FAO (2010) Climate-smart agriculture: Policies, practices and financing for food security, adaptation and mitigation. Food and Agriculture Organization (FAO), Rome, Italy

FAO (2013) Climate smart agriculture sourcebook. Food and Agriculture Organisation of the United Nations (FAO), Rome, Italy

FAO (2016) "El Nino" event in Vietnam-Agriculture, food security and livelihood needs assessment in response to drought and salt water intrusion. Italy, Rome

FAO (2018) The State of food security and nutrition in the world 2018 Building climate resilience for food security and nutrition. FAO, Rome

Ferrer AJG, Bernardo EB (2020) Outcomes of CCAFS work in Vietnam. Climate Change, Agriculture and Food Security. https://ccafs.cgiar.org/resources/publications/outcomes-ccafs-work-vietnam. Accessed 15 Aug 2021

Ferrer AJG, Thanh LH, Kiet NT, Chuong PH, Trang VT, Hopanda JC, Carmelita BM, Gummadi S, Bernardo EB (2022) The impact of an adjusted cropping calendar on the welfare of rice farming households in the Mekong River Delta, Vietnam. Econ Anal Polic 73:639–652. https://doi.org/10.1016/j.eap.2021.12.018

Grothmann T, Patt A (2005) Adaptive capacity and human cognition: the process of individual adaptation to climate change. Glob Environ Chang 15(3):199–213. https://doi.org/10.1016/j.gloenvcha.2005.01.002

GSO (General Statistics Office of Vietnam) (2016) Statistical yearbook of Vietnam. Statistical Publishing House, Hanoi

Hoa LD, Thuyen TP, Nhung THP, Nam KP (2022) Gender differentiated determinants of rice farmers' choice of strategies to adapt to salinity intrusion in the Mekong Delta, Vietnam. Environment for Development, Discussion Paper Series June 2022 (EfD DP 22–09)

Huong NTL, Bo YS, Fahad S (2019) Economic impact of climate change on agriculture using Ricardian approach: A case of northwest Vietnam. J Saudi Soc Agric Sci 18(4):449–457. https://doi.org/10.1016/j.jssas.2018.02.006

IPCC (Intergovernmental Panel on climate Change) (2014) Climate change 2014 Synthesis report. IPCC, Geneva

Jin J, Xuhong T, Wan X, He R, Kuang F, Ning J (2020) Farmers' risk aversion, loss aversion and climate change adaptation strategies in Wushen Banner, China. J Environ Plan Manag 63(14):2593–2606. https://doi.org/10.1080/09640568.2020.1742098

Kangogo D, Dentoni D, Bijman J (2021) Adoption of climate-smart agriculture among smallholder farmers: does farmer entrepreneurship matter? Land Use Policy 109. https://doi.org/10.1016/j.landusepol.2021.105666

Le HT, Nguyen QH (2019) Framework for a cost-benefit analysis of forecast-based financing. Case study of Gia Lai and Ca Mau provinces. Research report of FAO, Save the Children (SC), and project Drought forecast based financing for food security, livelihoods and WASH in Vietnam

Le DH, Li E, Nuberg I, Bruwer J (2014a) Farmers' assessments of private adaptive measures to climate change and influential factors: a study in the Mekong Delta, Vietnam. Nat Hazards 71(1):385–401. https://doi.org/10.1007/s11069-013-0931-4

Le VH, Duong MT, Do TH, Le KH, Phan H, Simelton E, Ferrer A, Bui TY (2014b) Village baseline study - Site analysis report for My Loi, Ky Anh district, Ha Tinh province - Vietnam (VN02). CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS), Copenhagen, Denmark. https://cgspace.cgiar.org/handle/10568/79896. Accessed 16 Sep 2021

Le TDP, Vu VDH, Xuan HTD (2015a) Estimating the economic impacts of climate change on crop production in the coastal provinces of the Mekong Delta, Vietnam. In EEPSEA SRG Report (Issues 2015a-SRG1). http://www.eepsea.org/index.php?option=com_k2&view=item&id=541:estimating-the-economic-impacts-of-climate-change-on-crop-production-in-the-coastal-provinces-of-the-mekong-delta-vietnam&Itemid=433. Accessed 8 Oct 2021

Le VH, Duong MT, Simelton E, Ferrer A, Yen BT, Sebastian LS (2015b) Situation Analysis and Needs Assessment Report for My Loi village and Ha Tinh province, Viet Nam (VN02) CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS), Copenhagen, Denmark. https://ccafs.cgiar.org/resources/publications/situation-analysis-and-needs-assessment-report-my-loi-village-and-ha. Accessed 17 Sep 2021

Li L, Jin J, He R, Kuang F, Zhang C, Qiu X (2022) Effects of social capital on farmers' choices of climate change adaptation behavior in Dazu District, China. Clim Dev. https://doi.org/10.1080/17565529.2022.2061403

Lipper L, Zilberman D (2018) A Short History of the Evolution of the Climate Smart Agriculture Approach and Its Links to Climate Change and Sustainable Agriculture Debates. In: McCarthy N, Zilberman D, Asfaw S, Branca G (eds) Climate Smart Agriculture. Natural Resource Management and Policy. Springer, Cham. https://doi.org/10.1007/978-3-319-61194-5_2

Lipper L, Thornton P, Campbell BM, Baedeker T, Braimoh A, Bwalya M, Caron P, Cattaneo A, Garrity D, Henry K, Hottle R, Jackson L, Jarvis A, Kossam F, Mann W, McCarthy N, Meybeck A, Neufeldt H, Remington T, Sen PT, Sessa R, Shula R, Tibu A, Torquebiau EF (2014) Climate-smart agriculture for food security. Nat Clim Chang 4(12):1068–1072. https://doi.org/10.1038/NCLIMATE2437

Liu T, Bruins R, Heberling MT (2018) Factors influencing farmers' adoption of best management practices: a review and synthesis. Sustainability 10(2):432. https://doi.org/10.3390/su10020432

Luu TD (2020) Factors influencing farmers' adoption of climate-smart agriculture in rice production in Vietnam's Mekong Delta. Asian J Agric Dev 17(1):109–124. https://doi.org/10.37801/ajad2020.17.1.7

Maguza-Tembo F, Edriss AK, Mangisoni J (2017) Determinants of climate smart agriculture technology adoption in the drought prone districts of Malawi using a multivariate probit analysis. Asian J Agric Ext, Econ Sociol 16(3):1–12. https://doi.org/10.9734/AJAEES/2017/32489

Maitah K, Smutka L, Sahatqija J, Maitah M, Anh NP (2020) Rice as a determinant of vietnamese economic sustainability. Sustainability 12(12):5123. https://doi.org/10.3390/su12125123

Mbow C, Rosenzweig C, Barioni LG, Benton TG, Herrero M, Krishnapillai M, Liwenga E, Pradhan P, Rivera-Ferre MG, Sapkota T, Tubiello FN. Xu Y (2019) Food Security. In: Shukla PR, Skea J, Calvo Buendia E, Masson-Delmotte V, Pörtner HO, Roberts DC, Zhai P, Slade R, Connors S, van Diemen R, Ferrat M, Haughey E, Luz S, Neogi S, Pathak M, Petzold J, Portugal Pereira J, Vyas P, Huntley E, Kissick K, Belkacemi M, Malley J (eds.) Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems

MONRE (2016) Scenarios for climate change and sea level rise for Vietnam. Hanoi, Vietnam

Nghia TD, Hai LT, Thu DM (2015) National prioritization of climate-smart agriculture (CSA) practices and services in Vietnam: cost benefit analysis (CBA) of selected CSA practices in Vietnam, working paper, Institute of Policy and Strategy for Agriculture and Rural Development (IPSARD), Ha Noi

Nguyen TK, Ho CHP (2021) The relationship between attitudes towards risk and income of farming households in Mekong river Delta. J Sci Trad 149–150(2):104–114

Nguyen TK, Trinh CD, Le HA (2020) Strategies to cope with risks affecting the income of farmers in the west of Hau River. J Asian Bus Econ Stud (JABES) 30(9):67–84

Nguyen KT, Ho CHP, Trinh DC (2022) Risks and risk responses of rice farmers in the Mekong Delta, Vietnam. Lett Sp Resour Sci 15(1):129–144. https://doi.org/10.1007/s12076-021-00290-5

Nguyen TK, Nguyen TP (2019) Farmers' response to risks in agricultural production in Can Tho city. J Sci Can Tho Univ 55(Economic issue):135–147

Nhemachena C, Hassan R (2007) Micro-level analysis of farmers adaption to climate change in southern Africa, working paper No. 714, International Food Policy Research Institute (IFPRI)-Centre for Environmental Economics and Policy in Africa (CEEPA), Washington, DC.

Ozor N, Madukwe MC, Enete AA, Amaechina EC, Onokala P, Eboh EC, Ujah O, Garforth C (2012) A framework for agricultural adaptation to climate change in Southern Nigeria. Int J Agric Sci 4(5):243–252. https://doi.org/10.9735/0975-3710.4.5.243-252

Pham TS, Tan Yen B, Do TH, Ngoc Quyen L, Le Dung V, Thi Thanh Hai N, Van Chinh N, Le Hoan K, Quang Thuong H, Duong CA (2017) CSA in Vietnam. CGIAR Research Program on Climate Change,

Agriculture and Food Security (CCAFS). Wageningen, The Netherlands. https://ccafs.cgiar.org/resources/publications/csa-thuc-hanh-nong-nghiep-thong-minh-voi-khi-hau-o-viet-nam. Accessed 8 Sep 2021

Rogers EM (1962) Diffusion of Innovations, 1st edn. Free Press, New York

SeinnSeinn M, Ahmad M, Thapa G, Shrestha R (2015) Farmers' adaptation to rainfall variability and salinity through agronomic practices in lower Ayeyarwady Delta, Myanmar. J Earth Sci Clim Chang 6(2):258. https://doi.org/10.4172/2157-7617.1000258

Simelton EM, Dao TT, An TN, Tam TL (2017) Scaling climate-smart agriculture in North-central Vietnam. World J Agric Res 5(4):200–211. https://doi.org/10.12691/wjar-5-4-2

Simon H (1972) Theories of bounded rationality. In: Organization D (ed) McGuire CB, Radner R. North-Holland, Amsterdam, pp 161–176

Solomon Y (2020) Adoption of improved agricultural technologies in developing countries: literature review. Int J Sci Food Agric 4(2):183–190. https://doi.org/10.26855/ijfsa.2020.06.010

Son NH, Yen BT, Sebastian L (2018) Development of climate-related risk maps and adaptation plans (Climate Smart MAP) for rice production in Vietnam's Mekong River Delta. CCAFS Working Paper. https://cgspace.cgiar.org/rest/bitstreams/148994/retrieve. Accessed 19 May 2022

Teklewold H, Kassie M, Shiferaw B (2013) Adoption of multiple sustainable agricultural practices in rural Ethiopia. J Agric Econ 64(3):597–623. https://doi.org/10.1111/1477-9552.12011

Tivet F, Boulakia S (2017) Climate smart rice cropping systems in Vietnam. State of knowledge and prospects. CIRAD: Montpellier, France. https://asie-sud-est.cirad.fr/content/download/5901/51488/version/1/file/2017-06+CS+rice+Vietnam+final.pdf. Accessed 18 May 2022

Tran NLD, Rañola RF, Ole Sander B, Reiner W, Nguyen DT, Nong NKN (2020) Determinants of adoption of climate-smart agriculture technologies in rice production in Vietnam. Int J Clim Chang Strateg Manag 12(2):238–256. https://doi.org/10.1108/IJCCSM-01-2019-0003

Trinh TA (2018) The impact of climate change on agriculture: findings from households in Vietnam. Environ Resource Econ 71(4):897–921. https://doi.org/10.1007/s10640-017-0189-5

Trinh TQ, Rañola RF, Camacho LD, Simelton E (2018) Determinants of farmers' adaptation to climate change in agricultural production in the central region of Vietnam. Land Use Policy 70:224–231. https://doi.org/10.1016/j.landusepol.2017.10.023

UNDP (2016) Vietnam drought and salwater intrusion: Transitioning from Emergency to Recovery. Analysis report and policy implications, UNDP Viet Nam. https://www.undp.org/content/dam/vietnam/docs/Publications/Recovery%20draft%20Sep%202016_final.pdf. Accessed 5 Mar 2022

Usha D, Ansaria MA, Souvik G (2022) Effectiveness and upscaling potential of climate smart agriculture interventions: Farmers participatory prioritization and livelihood indicators as its determinants. Agric Syst 203. https://doi.org/10.1016/j.agsy.2022.103515

Van HL, Tuan DM, Hoa LD, Simelton EM (2017) Climate-induced vulnerabilities: Participatory assessment for My Loi village, Ky Son commune, Ky Anh district, Ha Tinh province. https://cgspace.cgiar.org/handle/10568/89634. Accessed 15 Jan 2022

Vo HH, Mizunoya T, Nguyen CD (2021) Determinants of farmers' adaptation decisions to climate change in the central coastal region of Vietnam. Asia-Pac J Reg Sci 5:327–349. https://doi.org/10.1007/s41685-020-00181-5

Vu DT, Yamada T, Ishidaira H (2018) Assessing the impact of sea level rise due to climate change on seawater intrusion in Mekong Delta, Vietnam. Water Sci Technol 77:1632–1639. https://doi.org/10.2166/wst.2018.038

Weinstein ND (1989) Effects of personal experience on self-protective behavior. Psychol Bull 105(1):31–50. https://doi.org/10.1037/0033-2909.105.1.31

Wooldridge JM (2012) Introductory econometrics: A modern approach, Fifth edition, South-Western Cengage Learning

World Bank (2011) Vietnam: Vulnerability, risk reduction, and adaptation to climate change. The World Bank Group, Washington, DC

World Bank Group and the Asian Development Bank (2020) Climate risk country profile: Vietnam, Hanoi, Vietnam. https://climateknowledgeportal.worldbank.org/sites/default/files/2021-04/15077-Vietnam%20Country%20Profile-WEB.pdf. Accessed 25 Jan 2022

World Bank (2010) Economics of adaptation to climate change: Synthesis report. Washington, DC. https://openknowledge.worldbank.org/handle/10986/12750. Accessed 16 Dec 2021

World Bank (2016). Transforming Vietnamese agriculture: Gaining more for less. World Bank. http://hdl.handle.net/10986/24375

Authors and Affiliations

Alice Joan G. Ferrer[1] · Le Ha Thanh[2] · Pham Hong Chuong[3] · Nguyen Tuan Kiet[4] · Vu Thu Trang[5] · Trinh Cong Duc[4] · Jinky C. Hopanda[6] · Benedict Mark Carmelita[6] · Eisen Bernard Bernardo[7]

Alice Joan G. Ferrer
agferrer@upv.edu.ph

Pham Hong Chuong
chuongph@neu.edu.vn

Nguyen Tuan Kiet
ntkiet@ctu.edu.vn

Vu Thu Trang
vttrang@vdf.org.vn

Trinh Cong Duc
trinhcongduc2011@gmail.com

Jinky C. Hopanda
jinkychopanda18@gmail.com

Benedict Mark Carmelita
bmcarmelita@up.edu.ph

Eisen Bernard Bernardo
e.bernardo@irri.org

[1]   Division of Social Sciences, University of the Philippines Visayas, Miagao, Iloilo, Philippines

[2]   Department of Natural Resources and Environmental Economics, National Economics University, Hanoi, Vietnam

[3]   Faculty of Tourism and Hospitality, National Economics University, Hanoi, Vietnam

[4]   Faculty of Economics, Can Tho University, Can Tho, Vietnam

[5]   Faculty of Marketing, National Economics University, Hanoi 11600, Vietnam

[6]   University of the Philippines Visayas, Miagao, Iloilo, Philippines

[7]   CGIAR Research Program on Climate Change Agriculture and Food Security, Hanoi, Vietnam