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Factors influencing farmers' climate change adaptation in Southeast Asia: A comparative study from Vietnam, Laos, and Cambodia

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ABSTRACT

Southeast Asia is among the most climate-vulnerable regions in the world. Despite this, little is known about how climate change adaptation at the household level differs across countries in this geographic region. This cross-country study investigated factors influencing adopting three adaptation practices: growing climate-tolerant crops, intercropping, and switching to cash crops in some selected provinces in Vietnam, Laos, and Cambodia. Based on the survey data from 1017 farm households in these three countries, the paper found that surveyed households in Laos and Cambodia were less likely to adopt the three practices than those in Vietnam. Perception about the impacts of climate change and perceived usefulness of climate change adaptation consistently influenced the adoption likelihood of those practices. Information on climate change shaped farmers' decision to select climate-tolerant varieties and diversify crops. Policy implications aiming at fostering farmers' adoption of adaptation practices are discussed.

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KEYWORDS

Southeast Asia, farm households, cross-country analysis, adaptation likelihood, adaptive capacity, climate change adaptations

HIGHLIGHTS

- We focus on three adaptation practices: using climate tolerant crops, intercropping, growing cash crops.
- Surveyed farmers in Laos and Cambodia were less likely to adopt the adaptation practices.
- Perception of climate change impacts decreased the adoption likelihood of Vietnamese, Laotian, and Cambodian surveyed farmers.
- Perceived usefulness of adaptation facilitated adoption likelihood.
- Information acquisition positively influenced the decision to select climate-tolerant varieties and diversify crops.

1. INTRODUCTION

Southeast Asia is among the most climate vulnerable regions in the world (IPCC, 2022). In recent years, the regions have faced the increased frequency and intensity of extreme climate events (IPCC, 2022). Surveys conducted in this region documented that a large proportion of households have reported yield reduction due to climate change (Waibel, Pahlisch, & Völker, 2018). It is projected that increased floods and droughts, along with heat stress will negatively affect food availability and prices, resulting in increased undernourishment in the region (IPCC, 2022). Vietnam, Laos, and Cambodia, three developing countries in Southeast Asia are also vulnerable to climate change, but at varying degrees: Vietnam is the least vulnerable while Cambodia is the most vulnerable to climate change (Kuntiyawichai, Plermkamon, Jayakumar, & VanDau, 2015). At the national level, discrepancies in climate change adaptation among the three countries are well-documented (Waibel et al., 2018). However, research that compares the differences in climate change adaptation at the farm level across the three countries is limited, even though agriculture is the most climate-vulnerable sector. This leads to our incomplete understanding of farmers' adaptation at a larger scale, which is beyond the border of a single country in Southeast Asia.

Adaptation in human systems responds to climatic stimuli to reduce negative impacts or take beneficial opportunities (IPCC, 2014). Adaptations have been made at different levels, from the global to the national and farm level. In developing countries, since limited resources constrain these countries' public funding for climate change adaptation, farm-level adaptation is necessary to complement governmental efforts (Reidsma, Ewert, Lansink, & Leemans, 2010). Small-scale farmers in Southeast Asia have adopted a wide range of adaptation measures such as tolerant varieties, crop diversification, irrigation, and adjustment of seasonal calendars have been reported (Phuong, Biesbroek, Sen, & Wals, 2018; Shaffril, Krauss, & Samsuddin, 2018). However, it is worth noting that all measures above are autonomic adaptation, which is informal in its development and implementation process, reflecting the lack of relevant services (McDowell, Stephenson, & Ford, 2016).

At the farm level, adopting an adaptation practice is a result from the households' decision-making process, with multiple internal and external factors involved. Empirical studies outside Southeast Asia showed that internal factors include

knowledge and perception of climate change (Asrat & Simane, 2018), gender and other demographic characteristics (Ngigi, Mueller, & Birner, 2017), and production factors (e.g., access to land) (Gezie, 2019). External factors are agricultural and climate policies (Aryal et al., 2020), and the prevalence of broader support networks from the government and/or communities (Harmer & Rahman, 2014). Empirical evidence on the determinants of farmers' adoption of climate change adaptation practices is not lacking in Southeast Asia (Bairagi, Mishra, & Durand-Morat, 2020; Trinh, Rañola, Camacho, & Simelton, 2018). However, most of them focus on a single country, leading to a narrow view of farmers' adaptation in the region. To address this gap, the study investigates the determinants of farmers' adoption of three adaptation practices: growing tolerant-climate crops, intercropping, and growing cash crops in Laos, Cambodia, and Vietnam. We found cross-country differences in farmers' adaptation, the consistent influence of perception of climate change and perceived usefulness on the decision to implement the three practices. This way, this study contributes to existing adaptation literature and provides useful information to assist the development of adaptation policies in Southeast Asia.

2. MATERIALS AND METHODOLOGY

2.1. Farmer survey

Four provinces, including Son La (Vietnam), Xaysomboun and Vientiane (Laos), and Oddar Meanchey (Cambodia), were selected for the farmer survey. These provinces have faced extreme climate events in the past five years, including intensified cold air, cold spells, heat waves, droughts, floods, and storms. In chosen provinces above, we selected districts that are highly vulnerable to climate change. They include Yen Chau and Van Ho (Son La), Anouvong (Xaysomboun), Naxaythong (Vientiane), and Banteay Ampil (Odda Meanchey). Common cropping systems in Yen Chau and Van Ho districts are paddy rice, upland rice, maize, fruit and vegetables. In Anouvong and Naxaythong districts, popular crops include paddy rice, upland rice, vegetables, and fruits. Farmers in Banteay Ampil mainly grow upland rice, cassava, vegetables, and fruits.

We used the convenience sampling method to recruit farmers. In each chosen district, we collaborated with village leaders to send oral invitations to farm households. Only one representative of each household which agreed to participate in our survey was recruited. The survey was conducted from June 2021 to November 2021 and we received 1017 complete replies from farm household representatives (417 from Vietnam, 299 from Laos and 303 from Cambodia). The characteristics of surveyed farmers and their households are presented in Table 1. The distribution of male and female respondents is relatively equal, with 52% of the surveyed participants being men. Noticeably, respondents' education level was relatively low; about 60% of them either had no schooling or only had elementary education (result not shown). Respondents' mean age is 42; on average, their households had five to six members. 32% of surveyed households were self-reported as poor, and the agricultural land per household was about 3.1 ha on average.

2.2. Variable description and data analysis

Table 1 shows descriptive statistics of variables used in this study. Dependent variables are the adoption of three adaptation practices, including (1) using climate-tolerant varieties (e.g., drought-tolerant varieties), (2) intercropping, and (3) growing cash crops. Previous research shows that rice farmers in Vietnam and Cambodia have used climate-tolerant varieties to respond to climate change (Bairagi et al., 2020; Phuong et al., 2018). Crop diversification including intercropping has the potential to increase smallholder farmers' income while being climate resilient in Southeast Asia (Phuong et al., 2018; van Noordwijk et al., 2020). Transitions toward cash crop production that are market-oriented improve Southeast Asian farmers' income (Burra et al., 2021), and thus strengthen their adaptive capacity. Here, we define cash crops are high value crops such as coffee and tea.

Variable	Mean (Standard Deviation) or %			
	Whole sample (n=1017)	Vietnam (n=417)	Laos (n=299)	Cambodia (n=303)
Use Tolerant Crop: % of farmers using tolerant climate crops, =1 if use, =0 otherwise	44.94	91.566 ^{a}	9.365 ^{b}	16.172 ^{c}
Intercropping: % of farmers intercropping, =1 if intercrop, =0 otherwise	32.25	57.590 ^{a}	14.381^{b}	15.12 ^{bc}
Use Cash Crop: % of farmers growing cash crops, =1 if growing cash crops, =0 otherwise	33.92	65.542 ^{a}	16.388 ^{b}	7.921^{c}
Gender: % of male respondents, =1 if being male	52.02	51.807	56.856	47.525
Age	41.99 (13.11)	37.764^{a} (10.450)	41.452^{b} (13.782)	48.293^{c} (13.287)
Education: From 0 (no schooling) to 6 (Postgraduates)	1.43 (1.29)	1.627^{a} (1.237)	1.712^{ab} (1.472)	0.888^{c} (0.956)
Household Size: Number of people	5.54 (2.45)	4.928^{a} (1.565)	7.542^{b} (2.960)	4.403 ^{c} (1.547)
Income: Annual household income, USD	3252.318 (2512.361)	3529.099 ^{a} (2867.041)	2849.848^{b} (3852.145)	3270^{c} (2111.113)
AgriLand: Agricultural landholding, hectares	3.13 (5.867)	1.670^{a} (1.96)	3.276^{b} (5.770)	4.991^{c} (8.436)
Perceived Climate Impact : Perceived impact of climate change on crop production from 1 (not at all) to 5 (very much)	3.77 (1.14)	4.248^{a} (0.889)	3.184^{b} (1.131)	3.706^{c} (1.172)
Perceived Climate Change: Perceived the frequency of extreme climate events, from 1 (very low) to 5 (very high)	3.57 (1.01)	3.723^{a} (0.806)	2.993^{b} (0.909)	3.941^{c} (1.105)
AdaptationInform: Acquisition of adaptation information, from 1 (very little) to 5 (very much)	2.13 (1.34)	2.251^{a} (0.887)	2.154^{ab} (2.019)	1.954^{bc} (0.937)
UsefulnessTolerantCrop: Perceived usefulness of using tolerant crops, from 1 (very little) to 5 (very much)	2.76 (1.01)	3.161^{a} (0.762)	2.528^{b} (1.171)	2.426^{bc} (0.960)
UsefulnessIntercropping: Perceived usefulness of intercropping, from 1 (very little) to 5 (very much)	2.53 (0.99P)	2.863^{a} (0.785)	2.234^{b} (1.209)	2.367^{bc} (0.862)
UsefullnessCashCrop: Perceived usefulness of switching to cash crops, from 1 (very little) to 5 (very much)	2.66 (1.120)	3.084^{a} (0.935)	2.505^{b} (1.273)	2.241^{c} (0.976)

^{a,b,c}Note: Scores in one row with a different superscript are significantly different at $p < 0.05$ using oneway ANOVA and post hoc Tukey test.

TABLE 1. Descriptive statistic of variables

Independent variables include farmers' demographics (country, age, gender, education), farms' characteristics (household size, land area, annual income), and perception. The variable "country" (not shown in Table 1) was coded as 1, 2, or 3 for Vietnamese, Laotian, or Cambodian respondents, respectively. To measure the perception of climate change, respondents were asked to evaluate the frequency of extreme climate events, on a 5-point Likert scale ranged from 1 (very low) to 5 (very high). Perceived climate impact refers to the impact on farmers' crop production. There were three items on perceived usefulness for three corresponding adaptation practices. The responses for all perception-related items were on 5-point Likert Scale, ranging from 1 to 5, with higher scores reflecting a higher frequency, impact, or usefulness. To measure the acquisition of adaptation information, respondents were asked how well they were informed about recommended adaptation strategies at the farm level.

Since the adoption of the three adaptation practices, the dependent variable, is in the form of binary data, we used logit regression to predict the probability a farmer adopts a specific practice. Each crop production practice is associated with a separate logit model, making three regression models in total. For simplicity, for each regression model, we used pooled data, which combines data from all studied countries. The multicollinearity assumption was satisfied, as evidenced by the absence of coefficient correlations less than 0.5.

3. RESULTS AND DISCUSSION

3.1. Perception of climate change and climate change impact

There is a statistically significant difference in perception of climate change and climate change impact among surveyed farmers in Vietnam, Laos and Cambodia (oneway ANOVA and post hoc Tukey test results, Table 1). Cambodian respondents perceived the highest frequency of extreme climate events, while Vietnamese farmers also reported a high frequency but to a lesser extent, and Laotian respondents perceived the lowest. Vietnamese respondents expressed the highest impact of climate change and Laotian respondents indicated the lowest impact.

Perception of climate change might be influenced by actual extreme climate events that occurred in relatively recent time. Venkatappa, Sasaki, Han, and Abe (2021) reported that among the three countries, the relative frequency of moderate and extreme droughts was the highest in Cambodia from 2015 to 2019.Our group discussions with surveyed farmers in Cambodia also show that farmers had experienced severe drought in 2021 before our survey. Group discussions participants in Vietnam also reported a severe drought and heat waves in the surveyed area in 2021. Participants said that droughts, floods, and landslides have become more frequent in the past five years. Vientiane province (Cambodia) has often been flooded during the rainy season, while Xaysomboun province experienced a water shortage during upland rice plantations in 2021. In all surveyed districts, farmers reported decreased rice yield due to extreme climate events. In general, there was a link between farmers' perception of climate change and actual climate change, as shown by Hasan and Kumar (2019).

3.2. Factors associated with the adoption of climate change adaptation practices

Table 2 shows a number of factors associated with farmers' adoption of adaptation strategies. Surveyed Laotian and Cambodian farmers were less likely to use climate-tolerant varieties, have integrated cropping systems, and change cash crops compared to Vietnamese farmers. It is evidenced by negative and significant coefficients associated with the variable "Laos" and "Cambodia" in all regression models. Descriptive statistics also confirm this result: the percentage of surveyed farmers adopting all three practices is the highest in Vietnam (Table 1). Previous literature shows that adaptation strategies vary across countries and are context-dependent. A comparative study between Cambodia and Myanmar reported that changing new crop species were more common in Myanmar, while

changing cropping calendars was more popular in Cambodia (Shrestha, Raut, Swe, & Tieng, 2018). The differences in the adoption of studied adaptation strategies among Vietnamese, Laotian, and Cambodian surveyed farmers might be attributable to the heterogeneity in adaptive capacity across the three countries (Yusuf & Francisco, 2009). Vietnamese farmers might benefit from a higher level of economic development in Vietnam, as evidenced by their higher income level (Table 1). Therefore, they are more capable of adapting and this might explain their higher adoption rate of adaptation practices as compared to Laotian and Cambodian farmers.

Farmers' characteristics did not play an important role in influencing adoption likelihood. The effect of gender and education was non-significant in all regression models. Age is the only demographic variable that had a significant effect, but only in "growing cash crops". This means older farmers were more likely to produce cash crops. Older farmers are likely to have more farming experience (Prokopy et al., 2019) and better resources for agricultural production (Wang, Jin, Fan, Obembe, & Li, 2021). These might explain the positive association between age and the likelihood to grow cash crops.

Noticeably, regarding households' characteristics, income exerted a significant effect, but only in the "growing cash crops" model. This result suggests that shifting to cash crops might contribute to improved income. This result also implies that producing cash crops is costly, so farmers with a lower income are less interested in cash crop production. As such, limited income or resources can be seen as a barrier to cash crop production. Moreover, agricultural landholding only determined intercropping adoption. Famers with larger landholding were more likely to intercrop.

Information about recommended adaptation strategies influenced farmers' decision to use adaptive crop varieties and diversify crops. In other words, farmers, who are better informed about available adaptation measures were more likely to adopt intercropping and use drought tolerant varieties. This finding aligns with the study by Etwire, Koomson, and Martey (2022), which reported that access to information was positively associated with adaptation decisions. This result suggests that the improvement of information provision on adaptation measures, for example, via extension service, will facilitate the adoption of adaptation practices. However, the association between information and the decision to switch to cash crops was non-significant. This result implies that farmers might not consider changing to cash crops as an adaptation strategy.

The perception of climate change significantly affected the decision to grow climate-tolerant crops. Previous studies provide mixed results on the association between the perception of climate change and adaptation. For instance, Hasan and Kumar (2019) reported a positive correlation between the perception of climate change and the number of adopted adaptation practices in Bangladesh. In contrast, Marie, Yirga, Haile, and Tquabo (2020) found that climate change perception did not determine adaptation strategies in Ethiopia. Similarly, the current paper found that perception of climate change did not influence the decision to intercrop and grow cash crops. Farmers might not view these two practices as adaptation strategies and, therefore, not relate them to climate change.

Given the drastic impact of climate change in the survey provinces, farmers' high perception of climate impact is expected. However, the negative association between perception about the impact of climate change and adaption likelihood was surprising. This result can be explained in two ways. Farmers who perceive high climate change impacts might not be aware that intercropping, producing cash crops or using climate-tolerant crops are strategies to combat climate risks. As such, they would be more reluctant to adopt the three practices. There might be another way to explain this result. Farmers who have already adopted the three practices have been able to reduce the impacts of climate change and thus perceive fewer conse-

	Use Climate Tolerant Crops		Intercropping		Growing Cash Crops	
	Coefficient (SE)	Marginal effect (SE)	Coefficient (SE)	Marginal effect (SE)	Coefficient (SE)	Marginal effect (SE)
Vietnam	**Base level**		**Base level**		**Base level**	
Lao	-5.030 *** (0.375)	-0.784 *** (0.031)	-2.574 *** (0.293)	-0.385 *** (0.034)	-3.029 *** (0.305)	-0.462 *** (0.035)
Cambodia	-3.934 *** (0.293)	-0.667 *** (0.038)	-1.827 *** (0.238)	-0.306 *** (0.037)	-3.045 *** (0.294)	-0.463 *** (0.036)
Gender	-0.320 (0.228)	-0.028 (0.020)	-0.066 (0.177)	-0.009 (0.025)	-0.269 (0.189)	-0.034 (0.024)
Age	-0.003 (0.010)	-0.000 (0.001)	0.003 (0.008)	0.000 (0.001)	0.015 * (0.008)	0.002 * (0.010)
Education	0.075 (0.101)	0.006 (0.009)	0.097 (0.076)	0.014 (0.011)	0.037 (0.083)	0.005 (0.010)
Household size	0.039 (0.053)	0.003 (0.005)	0.034 (0.043)	0.005 (0.006)	0.016 (0.045)	0.002 (0.006)
Log_Income	0.062 (0.088)	0.005 (0.008)	0.023 (0.069)	0.003 (0.010)	0.232 ** (0.117)	0.029 ** (0.015)
Log_AgriLand	-0.001 (0.008)	-0.000 (0.001)	0.024 ** (0.010)	0.003 * (0.001)	0.012 (0.010)	0.001 (0.001)
Perceived ClimatChange	0.360 *** (0.121)	0.031 *** (0.010)	-0.138 (0.094)	-0.019 (0.013)	-0.057 (0.103)	-0.007 (0.013)
Perceived ClimateImpact	-0.367 *** (0.113)	-0.032 ***(0.010)	-0.395 *** (0.091)	-0.056 *** (0.012)	-0.542 *** (0.100)	-0.068 *** (0.012)
Adaptation Inform	0.362 *** (0.117)	0.031 *** (0.010)	0.257 *** (0.097)	0.036 *** (0.014)	-0.083 (0.099)	-0.010 (0.012)
Usefulness TolerantCrop	0.931 *** (0.135)	0.080 *** (0.011)				
Usefulness Intercropping			1.236 *** (0.125)	0.175 *** (0.015)		
UsefulnessCash Crop					1.196*** (0.117)	0.150*** (0.012)
Cons	-1.394 (1.029)		-2.128 *** (0.810)		-2.562** (1.009)	
Pseudo R^2	0.568		0.312		0.393	
Count R^2	0.893		0.792		0.832	

Note: Log_income, Log_Agriland denote the logarit transformation of income in USD and agricultural landholding in ha. ***, **, and * indicate significant level at 0.01, 0.05, and 0.1, respectively.

TABLE 2. **Logit regression results**

quences of climate change.

The perceived usefulness of specific adaptation practices is positively associated with adopting these practices. Previous studies indicated that adaptation strategies were used because of their perceived usefulness or benefits. Arunrat, Wang, Pumijumnong, Sereenonchai, and Cai (2017) revealed that perceived importance and usefulness positively influenced farmers' decision to apply adaptation strategies against drought and flood in Thailand. Farmers, including those not adaptation-orientated, can view the usefulness of action from diverse angles. For example, while farmers in Pakistan perceived crop diversification as an adaptive practice (Abid, Scheffran, Schneider, & Elahi, 2019), producers from Uganda viewed coffee-banana intercropping as an income-generation activity (Jassogne, vanAsten, Wanyama, & Baret, 2013).

4. CONCLUSION AND POLICY IMPLICATIONS

This paper is among the few cross-country studies in Southeast Asia investigating households' adoption of adaptation practices. Our focus practices are using climate-tolerant crops, intercropping, and growing cash crops. The paper found that surveyed households in Laos and Cambodia were less likely to adopt the three practices above than those in Vietnam. This result might reflect the weaker adaptive capacity at the farm level in Laos and Cambodia. More efforts are needed to enhance farmer adaptive capacity in these two countries.

In this study, farms' and farmers' characteristics are unimportant determinants of adaptation decisions. Age and income are the two significant predictors, but only in "growing cash crops" model. The transition to high value cash crops can boost farm income. However, our finding shows that households with a lower income level were less likely to grow cash crops. Policy instruments aiming to improve loan access are crucial to support these farmers. Moreover, agricultural landholding only influenced intercropping adoption.

Perceived impact of climate change, perceived usefulness, and information acquisition on adaptation strategies are important determinants of adaptation decisions. The negative relationship between the perception of climate change impact and the adoption likelihood of the three studied adaptation practices might be attributable to farmers' limited awareness about how these practices can enable climate change adaptation. Since perceived usefulness increased the adoption likelihood of all three concerning adaptation practices, communication that aims at improving farmers' awareness about the benefits of these practices is essential. Furthermore, because information acquisition on adaptation positively influenced intercrop adoption and the use of drought tolerant crops, providing farmers with more information on effective adaptation measures via agricultural extension programs will motivate adaption decisions.

This study has some limitations including the convenience sampling method and a non-national representative sample. Given these limitations, our research findings are unable to generalize to all geographical regions of studied countries.

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6. AUTHOR'S CREDIT STATEMENT

Thanh Mai Ha managed data collection and took the lead in writing this paper. Sayvisene and Fu Yang conducted data collection in Laos and were involved in writing the Result and Discussion sections. Pisidh Voe led data collection in Cambodia. Cong Duan Dao analyzed the data. Other remaining authors were involved in designing the survey, collecting data, and/or commenting on the manuscript.

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