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Choice of adaptation strategies to climate change among farm households in mountainous areas of Northeastern Vietnam

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Abstract The paper aims to identify major strategies applied by small-scale farm households to adapt to climate change and determine factors that affect their choice of adaptation strategies. A logistic regression model and a multivariate probit model were applied to a set of primary data collected from a survey of 290 farm households in two mountainous provinces of Northeastern Vietnam. Results show that farm households combined various strategies in response to the impacts of climate hazards. Changes in farm activities and livelihood diversification were the two most widely used adaptation strategies. Farm households' choice of adaptation strategies was influenced by a set of complex factors related to demographic characteristics, economic well-being, access to resources, and perception. Age and farming experience negatively affected farm households' adaptation. Meanwhile, access to resources, savings, extension services, membership of associations, access to information, and perception had a significantly positive effect on the adoption of adaptation strategies. Social-economic barriers restricted female-headed and ethnic minority households from taking up adaptation measures that required new technologies, updated knowledge, or resources. It is essential to issue policies and implement projects to enhance adaptive capacity and facilitating the adaptation process for farm households in mountainous areas, taking into account the barriers and disadvantages of female and ethnic minority farmers.

Keywords Adaptation · Agriculture · Climate change · Mountainous areas · Multivariate probit model

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Introduction

Climate change is expected to affect all sectors and regions around the world. Adger et al. (2003) argued that "nearly all human societies and activities are sensitive to climate in some way or other". However, when assessing the impacts of climate change and adaptive capacity of people, literature evidenced that the impacts of climate change are not equally distributed–"the people who will be exposed to the worst of the impacts are the ones least able to cope with the associated risks" (Adger et al., 2003). According to the Millennium Ecosystem Assessment (2005), climate change is one of the key contributing factors for the degradation of ecological services, harming many poor people globally, and these harmful effects are being borne disproportionately by the poor. In some cases, the degradation of ecological services

is the leading cause of poverty. Despite contributing the least to cause the problem, the world's poorest people are often among the most affected by climate change because of their poverty, marginalization and limited socioeconomic capacity (CARE, 2013).

Vietnam is a primary victim of global warming and climate risks such as sea level rise, salinity intrusion, flood, and increase in strengths and frequencies of extreme weather. The country has been identified as being highly vulnerable to the impacts of climate change due to its long coastline, high dependence on agriculture, and relatively low levels of development in rural areas (CARE, 2013). Agriculture is the primary source of livelihood for many people, especially the people in mountainous areas. The agricultural sector contributed 16.32% of the GDP, and the rural population (% of the total population) was reported at 65.56% in 2016 (GSO, 2017). Over the past 50 years, the annual average temperature in Vietnam increased 0.5–0.7 °C, and the sea level increased around 20 cm (Government of Vietnam, 2011). Vietnam is named among nine countries where at least 50 million people could be exposed to significant risks of rising sea levels and storm surges, assuming no adaptation or protection (IPCC, 2018).

Although Vietnam is one of the most significantly impacted countries in the world from climate change, few empirical studies have reported on the adaptation of affected communities. Some studies have been carried out to assess the impacts of climate change (Nguyen et al., 2019; Noy & Vu, 2010), analyze vulnerability, adaptation and resilience (Adger et al., 2001; Trinh et al., 2018), or investigate social vulnerability in coastal regions (Adger, 1999; Huynh & Stringer, 2018). However, most studies provided only minimal references to household-level adaptation in the mountainous areas, especially, to the determinants of the choice of adaptation strategies among mountainous farm households, one of the most vulnerable groups to climate change.

This study aims to fill this knowledge gap by identifying adaptation strategies to climate change applied by farm households in mountainous areas of Northeastern Vietnam and analyzing factors affecting their choice of adaptation strategies. This kind of information is needed to propose supportive policies and frameworks to enhance farmers' adaptation process. Moreover, in-depth knowledge on the adaptation of mountainous farm households assists targeted policies for this vulnerable group to adapt to climate change, taking into account socioeconomic disadvantages and barriers to this group.

Farmers' adaptation to climate change

Marcus and Ajaya (2004) argued that change is an inherent attribute of the human context and whether changes caused by extreme events and economic collapse or changes in environmental, technological or economic systems, people survive by adaptation. Adaptation is defined as "the adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities" (IPCC, 2007). The common aim of adaptation is to increase resilience and reduce vulnerability to climate change. Burton et al. (1993) highlighted eight types of adaptation strategies, including (i) bear the losses, (ii) share the losses, (iii) modify the events, (iv) prevent the effects, (v) change use, (vi) change location, (vii) research, and (viii) education for behavioral change. These strategies can be applied for both individual level and system or region level.

Vulnerability is presumably higher in developing countries, and people of these countries are less able to cope with climate change impacts (Adger et al., 2003); however, they are not passive victims (Elum et al., 2017). Resilience and adaptation to climate variability have been documented for smallholder farmers in developing countries such as Bangladesh, Vietnam, and Thailand (Adger et al., 2003; Boonwichai et al., 2019), those have been identified as having the least capacity to cope with climate hazards among others.

In mountainous areas, farmers face various climate hazards such as temperature extremes, drought, flash floods, hoar frost, storms, and changing rainfall patterns. In order to cope with and adapt to climate hazards, farmers choose from a range of possible adaptation strategies based on economic calculations and subjective estimations. Adaptation helps farmers reduce losses caused by extreme events and maintain farming objectives of yield, profitability, and food security (Kandlinkar & Risbey, 2000). Farmers applied various practices to increase the agricultural system's resilience and cope with the impacts of climate change. Common practices include use of new crop varieties and livestock species that are more

suitable to present climate, irrigation, crop diversification, adoption of mixed crop and livestock farming systems, change in crop calendar, and change in area for cultivation (Deressa et al., 2009; Nhemachena & Hassan, 2007; Yegbemey et al., 2014). Besides, farmers may diversify their livelihoods and incorporate non-farm components or migrate elsewhere to find work supporting their livelihoods as a way to reduce vulnerability to climate change (Adger et al., 2003; Marcus & Ajaya, 2004).

Some studies revealed that farmers' choice of adaptation strategies is influenced and restricted by many complex factors (Below et al., 2012; Deressa et al., 2009; Ojo & Baiyegunhi, 2019). Cost–benefit analysis and knowledge of hazardous events affect the adaptation decision (Thomas & Fogelman, 2013). Farmers' choice of adaptation strategies is driven by their adaptive capacity, which is a function of available resources and factors related to economic well-being, health, and education status. The determinants of adaptive capacity are also predictors of adaptation because they influence how adaptive capacity translates into adaptation (Burch & Robinson, 2007). Yohe and Tol (2002) summarized eight major determinants of adaptive capacity, including technology options, resources, institutions, human capital, social capital, access to risk-spreading processes, information management, and the public's perception of exposure. However, the study of Yohe and Tol (2002) addressed the adaptive capacity of a system, sector and region, and the eight determinants are not entirely suitable to the household level. Below et al. (2012) argued that the adaptive capacity of farm households could be determined based on five types of capital assets (human, natural, financial, social, and physical) which are identified in the livelihood framework proposed by Scoones (1998). According to these authors, the adaptive capacity of the farm household is associated with economic potential, production factors, education, gender, local infrastructure, and social and financial capital. In line with Below et al. (2012), Deressa et al. (2009) concluded that level of education, gender, age, and wealth of the head of household, access to extension and credit, information on climate, social capital, and agroecological settings all influence farmers' choice of adaptation practices. Apart from socioeconomic variables, farmers' perception of climate change is a major determinant of adaptation (Bohensky et al., 2013). Successful adaptation initially requires recognition of the necessity to adapt, and the following factors are knowledge about available adaptive strategy options, assessment capacity, and the ability to implement the adaptation strategies (Fankhauser & Tol, 1997). Adaptation is often preceded by an analysis of the perception of climate change as perception drives an individual or group to want to respond to perceived climate change or not (Elum et al., 2017). Perception is a fundamental step to shape the preparedness to take adaptive strategies in response to observed changes (Speranza, 2010). Besides, common reasons for barriers to adaptation and failures in applying adaptation strategies among the farmers include lack of credit, lack of knowledge and information, lack of technology, lack of resources, and low perception of climate change issues (Deressa et al., 2009; Nhemachena & Hassan, 2007).

Materials and methods

Study area and data

Vietnam has seven climate sub-regions, including Northwest, Northeast, Red river delta, North central coast, South central coast, Central highlands, and South region (southeast and Mekong delta). Northeast Vietnam experiences a monsoon-influenced humid subtropical climate with dry winters and is considered one of the most vulnerable regions to the impacts of climatic hazards such as an increase in temperature, flood, flash flood, and landslides. Over the past 50 years, the average temperature in winter increased 1.3–1.5 °C in this region (MONRE, 2012). Besides, other extreme events such as a large number of sunny days, long periods of low rainfall, heavy rain, extreme cold, and tornadoes have been observed over the last decades.

Northeast Vietnam consists of eight provinces, including Ha Giang, Cao Bang, Bac Kan, Phu Tho, Tuyen Quang, Thai Nguyen, Lang Son, and Bac Giang. The region covers an area of 44,624 km^2, of which 86.34% is agricultural land. In 2017, the total population of all Northeast provinces was approximately 7.6 million people, and the average population density was 170 people per km^2, being significantly lower than the national average of 283 people per km^2 (GSO, 2018). The region is characterized by cultural

diversity with the residence of approximately 20 different ethnic groups.[1] The average Gross Regional Domestic Product (GRDP) per capita was 35.35 million Vietnamese dong (VND) per year, much lower than the Gross Domestic Product (GDP) per capita of the country (50.90 million VND per year) (GSO, 2018). High incidence of poverty, poor infrastructure, and a large share of the rural population in the total population are also characteristics of the region.

The study area for this research was made up of two mountainous provinces of Northeastern Vietnam, Tuyen Quang and Bac Kan (Fig. 1). These provinces were purposively selected because they are of the most vulnerable areas to climate change impacts in Northeast Vietnam. In each province, three communes were selected randomly from the list of those affected by climate hazards. This list was defined through discussions with the local officials.

This study used household survey data collected from 290 farm households in six selected communes. 37.24% of the surveyed households belonged to the Kinh ethnic group, which accounts for the largest proportion of Vietnam's population, and 62.76% belonged to ethnic minority groups. In each commune, 45–55 farm households were randomly selected. The farm households were interviewed with a structured questionnaire including questions related to their demographic and socioeconomic characteristics, their observations of variations in climate parameters and impacts of these variations, their adaptation and coping strategies, and their perception of climate change.

Farm households in the study area may apply different strategies to cope with or adapt to climate change. The adaptation strategies (choice set) were identified through interviews with experts, including experienced farmers, extension staff, and related local leaders and group discussions. A total of two group discussions (each consisting of 7–8 household heads) in each of six communes were held making a total of 12 group discussions.

Analytical model for factors affecting households' adoption of adaptation strategies

A logistic regression model from maximum likelihood estimation (MLE) was employed to analyze factors affecting the farmers' decision to adopt adaptation strategies. The dependent variable y_i has two categories with a value of 1 if a household had applied any adaptation strategies and 0 if it had borne the losses and taken no adaptation. The empirical model is expressed as follows:

$$p = P(y_i = 1|x_i) \tag{1}$$

in which p is the probability that a household will apply adaptation strategies ($y_i = 1$). Thus, $1 - p$ is the probability that a household would bear the losses and take no adaptation ($y_i = 0$). The explanatory variables x_i comprised of socio-economic and demographic characteristics, access to information and perception of climate change of the household. These variables were selected based on reviewing existing literature and consulting with experienced farmers and local officials.

The probability that $y_i = 1$ was:

$$p_i = \frac{e^{(\alpha+\beta x_i)}}{1 + e^{(\alpha+\beta x_i)}} \tag{2}$$

in which β is the parameter to be estimated.

Analytical model for factors affecting households' choice of adaptation strategies

The primary focus of this study is to analyze factors affecting farm households' choice of adaptation strategies. The logit or probit regression model is inappropriate because it can only address the dichotomous dependent variables. Therefore, Deressa et al. (2009) used a multinomial logit (MNL) model because it can deal with multiple choices and it allows determination of choice probabilities for different categories. The MNL is used when the dependent variable falls into any one of a set of categories and it should be used in case farmers choose only one strategy from the choice set. However, it is observed from the survey that farm households in the study area

[1] Vietnam is a multi-nationality country with 54 ethnic groups. The Kinh people account for 85.37% of the country's population and mainly live in the delta areas and large cities. The other 53 ethnic minority groups (14.12 million people) mostly reside in remote mountainous areas. In 2019, the percentage of poor and near-poor ethnic minority households was 35.5% while the national rate was 8.20% (CEMA & GSO, 2020; MOLISA, 2020). Despite the government's effort to improve the living conditions of ethnic minorities, the gap between the Kinh and the ethnic minorities in the field of education, health care, and employment has been widening over time.

might simultaneously apply various adaptation strategies in response to climate hazards. Therefore, the MNL is not an appropriate approach in this case. Instead, a multivariate probit (MVP) model was used as the analytical model for this study. Some authors have also used this method to overcome similar drawbacks (GC & Yeo, 2019; Nhemachena & Hassan, 2007; Ojo & Baiyegunhi, 2019). The advantage of the MVP is that it can be used to estimate both observed and unobserved effects on choice options through various explanatory variables by permitting multiple choices to be chosen simultaneously. Besides, the MVP does not require the assumption of independence of irrelevant alternatives (IIA). It is thus possible to examine complementarity or substitutability among alternative choices.

According to Cappellari and Jenkins (2003) and Mullahy (2016), the MVP model can be expressed as follows:

$$y_{im}^{*} = \beta_m X_{im} + \varepsilon_{im}, \quad m = 1, \ldots, M \tag{3}$$

$$y_{im} = 1 \; if \; y_{im}^{*} \geq 0 \tag{4}$$

$$\varepsilon_m = [\varepsilon_1, \ldots, \varepsilon_M] \sim MVN(0, R) \tag{5}$$

$$R = \begin{bmatrix} 1 & \rho_{12} & \cdots & \rho_{1M} \\ \rho_{21} & 1 & \cdots & \rho_{2M} \\ \vdots & \cdots & \ddots & \vdots \\ \rho_{M1} & \rho_{M2} & \cdots & 1 \end{bmatrix} \tag{6}$$

$$B = [\beta_1, \ldots, \beta_M] \tag{7}$$

in which y is the dependent variable. The y_{im} denotes the binary dependent variables (m = 1, …, M), and represents the various adaptation strategy options, including share the losses, prevent the events or their effects, change use or activity, change location, diversification beyond agricultural activities, and education for behavioral change. X_{im} denotes explanatory variables that that may influence the farm households' choice of adaptation strategies, these being demographic and socioeconomic characteristics of households such as age, gender, education, farming experience, training, access to extension services, labor, savings, membership of associations, income, access to information, access to market, perception, and ethnicity. The error term, ε_m, is distributed as multivariate normal, with zero means, and variance–covariance matrix R, where R has values of 1 on the leading diagonal and correlations $\rho_{jk} = \rho_{kj}$ as off-diagonal elements. The parameters B and R were estimated by the method of simulated maximum likelihood (SML) (see Cappellari & Jenkins, 2003).

Results and discussions

Characteristics of farm households

Table 1 displays the descriptive statistics of the variables for surveyed farm households. The average age of the household heads was 48.8 years while the years of education were 7.4. Most of the household heads were male (88.8%) which is relatively popular in mountainous areas in Vietnam. The female household heads had a significantly lower education level than the male. Farm households had rather long experience in farming (29.4 years). A large share of households (75.4%) participated in training programs at least once in their lifetime; however, they did not have frequent access to agricultural extension services. Agriculture in the study area is characterized by small-scale production, with an average farmland area of approximately 1.1 hectares per household. Savings was taken as a proxy of households' financial capital instead of access to credit because formal accesses to credit (e.g. bank loan) are not popular among the small-scale farmers in the study area. On average, each household had 55.5 million VND in savings (equivalent to 2445 USD in 2016), and the standard deviations were high, suggesting a considerable variation in savings. Off-farm activities contributed roughly 46.2% of the total household income. However, it should be noted that farm activities were still the crucial source of their livelihoods. Farm households accessed information related to risks from climate change or adaptation measures mainly through mass media such as television, radio, internet or newspaper. Meanwhile, the role of formal channels (training courses and extension services) was relatively modest.

Adaptation strategies

The results in Table 2 show that the surveyed farm households in the mountainous areas of Northeastern Vietnam did not necessarily use a single strategy to counteract the impacts of climate change but

Table 1 Summary of statistics for farm households

Variable	Explanation	Mean	S.D
Age	Age of hh head in years	48.784	11.698
Gender	Gender of hh head (0 = Female; 1 = Male)	0.881	0.324
Education level	Number of years of education of hh head	7.377	3.454
	Female hh head	6.679	4.312
	Male hh head	7.471	3.323
	Male as % of female	11.858*	
Farming experience	Number of years spent farming	29.415	11.830
Training	Participation of hh head in training programs about agricultural extension (0 = No; 1 = Yes)	0.754	0.431
Access to extension services	Contacting extension agents (1 = Never; 2 = Seldom; 3 = Occasionally; 4 = Often)	1.983	0.766
Farm labor supply	Number of working adults	2.830	1.151
Farm size	Area of paddy land and sloping land in hectare	1.052	1.310
Savings	Available hh savings in millions VND	55.542	132.747
Hh income	Total hh income level in millions VND	79.693	88.692
Share of off-farm income	Percentage of off-farm income (%)	46.157	30.719
Membership of associations	Number of registered associations belonged to	2.144	0.987
Access to information	Number of sources of information related to climate change issues	1.585	1.086
Source of information	Television, radio, internet, newspaper	98.305	55.326
	Neighbors	12.288	32.900
	Training courses and extension services	37.288	64.967
Distance to market	Distance to the central market in kilometer	2.742	1.679
Perception of tendency	Perception of frequency and magnitude of weather extremes and their impacts (1 = Significantly decrease; 2 = decrease; 3 = stay the same; 4 = increase; 5 = significantly increase)	4.153	0.454
Ethnicity	Ethnicity of hh head (0 = Kinh group; 1 = Other ethnic minority groups)	0.628	0.392

Averages per household. Significance tests refer to a χ^2 test of the difference in means for binary variables: $*p < 0.10$, $**p < 0.05$, $***p < 0.01$. hh = household; S.D. = standard deviation

combined various adaptation strategies. 80.3% of the households applied at least one strategy to cope with or adapt to climate hazards. Only 19.7% of them bore the losses and took no adaptation. It should be noted that 20.0% of the households used support from the government or non-governmental organizations and individuals to cope with the impacts of climate change and this was the sole adaptation strategy applied by some households. This strategy would help the households offset threats in times of hardship due to climate hazards but could not guarantee an effective adaptation over the long-term. Formal instruments such as insurance for climate change risks might be used to share the losses, but they were not popular in studied mountainous areas. The most common strategy was change in agricultural activities such as crop mixing, crop rotation, switch to resistant crops or livestock, switch to resistant varieties of crops, adoption of new techniques in crop cultivation or livestock rearing, change in cropping calendar, etc. (72.8%). The households applied these practices mainly based on their traditional knowledge and their

Table 2 Farm households' main adaptation strategies

Variable [a]	Explanation	Percent of households
Bear the losses (BL)	Accept the losses and take no adaptation	19.655
Share the losses (SL)	Use supports from the government and non-governmental organizations and individuals	20.000
Prevent the events or their effects (PE)	Prevent or reduce the effects of events by activities such as improving irrigation system, soil conservation, reducing chemical fertilizers, and applying more manure/organic fertilizers	23.103
Change use or activity (CU)	Change the farm activities such as mixing crops, crop rotation, switch to resistant crops or livestock, switch to resistant varieties of crops, apply new techniques in crop cultivation or livestock rearing, change in cropping calendar, diversification of foods for livestock, change partially/entirely from crop cultivation to livestock rearing or vice versa	72.759
Change location (CL)	Alter the location of crop and livestock activities or settlement of humans such as wage work outside of the commune (circular migration) or permanent migration to find a wage work	45.862
Livelihood diversification (LD)	Transfer to non-farm income-generating activities (petty trade, carpentry, handicraft, etc.), collect forest products	59.655
Behavioral change (BC)	Apply water-saving, energy-saving and land-saving in farm activities	4.483

[a]Classification of adaptation strategies adapted from Burton et al. (1993)

own experience, and partly based on information sources such as agriculture training courses, neighbors, mass media, and local extension workers. A large share of the households adapted to climate change by diversifying their livelihoods beyond agricultural activities (59.7%). This adaptive strategy helped the households to overcome losses in agriculture and food production due to climate variability. However, off-farm work was not a promising option due to remoteness of the communes. Besides, collecting of forest products would not be a sustainable income source as the government has tightened its regulations of forest management and protection to reduce forest overexploitation in Vietnam. Another large share of the households (45.9%) altered the location of crop and livestock activities or migrated to find jobs elsewhere. It should be noted that the households in the study area faced difficulties developing careers outside farming due to their disadvantaged in terms of education levels, occupational skills and social status when competing for jobs with urban unemployed people. 23.1% of the households tried to prevent or reduce the effects of climate hazards by activities such as irrigation, soil conservation, and fertilizer use. These practices required knowledge and investment which became a barrier to application of such adaptation practices among poor mountainous households. Only 4.5% of the households changed their behavior such as applying water-saving, energy-saving, and land-saving in farm activities. It was observed from the survey that the majority of respondents were not aware of the importance of these practices in climate change mitigation.

Factors affecting farm households' adoption of adaptation strategies

Table 3 presents the logistic regression results for factors affecting farm households' adoption of adaptation strategies. The Hosmer–Lemeshow test was used to test the goodness of fit of the logistic regression model. Results show that the Hosmer–Lemeshow test is insignificant ($\chi^2 = 1.25$; p-value = 0.9961), indicating that the model fits reasonable. The link test was employed to detect a specification error. The _hatsq of the Linktest was insignificant (z-test value = 1.45; p-value = 0.146), which indicated that the model is properly specified. The VIF values were below 10 indicating that multicollinearity was not a severe problem in this model.

The results reveal that savings, access to extension services, membership of associations, access to

Table 3 Logistic results explaining factors affecting farm households' adoption of adaptation strategies

Explanatory variable	Coefficient	S.E.	Z	*P*-value
Age	− 0.228	0.123	− 1.85	0.064
Gender	3.262	2.487	− 1.31	0.090
Education level	0.298	0.279	1.07	0.285
Farming experience	− 0.152	0.086	− 1.77	0.077
Training	2.079	1.621	1.28	0.200
Access to extension services	8.833	3.786	2.33	0.020
Farm labor supply	0.934	0.837	1.12	0.265
Farm size	1.336	1.345	0.99	0.320
Savings	0.046	0.029	1.58	0.075
Membership of associations	2.742	1.448	1.89	0.058
Access to information	0.464	0.217	2.14	0.032
Share of off-farm income	− 0.014	0.006	− 2.44	0.115
Distance to market	− 1.188	2.221	− 0.53	0.593
Perception of tendency	1.615	0.664	2.43	0.015
Ethnicity	− 1.068	0.841	1.79	0.083
Constant	5.551	8.346	0.67	0.506
Number of observations	290			
Prob > χ^2	0.0000			
Predicted probability	71.26%			
Hosmer–Lemeshow test	χ^2 = 1.25; *p*-value = 0.9961			
Linktest (_hatsq)	z = 1.45; *p*-value = 0.146			
Minimum value/maximum value of VIF	1.05/3.12			

S.E. = Standard error

information, and perception of tendency had a significantly positive impact on the adoption of adaptation strategies, which denotes that these factors hastened farm households' adaptation. The empirical results demonstrate the importance of age and farming experience of the household head. These factors were found to significantly and negatively affect the decision to adopt adaptation strategies, meaning that older farmers and those with more years of farming experience were more likely to bear the losses. In other words, age and farming experience retarded farm households' adaptation. Female-headed households were more likely to bear the losses than the male-headed households, and ethnic minority farmers were more likely to bear the losses than the Kinh farmers. Education level, training, farm labor supply, farm size, the share of off-farm income, and distance to the market did not significantly affect farm households' decision to adopt adaptation strategies or bear the losses.

Factors affecting farm households' choice of adaptation strategies

The results of the MVP model of factors affecting farm households' choice of adaptation strategies are presented in Table 4. The likelihood ratio test of independence of error terms in the different equations was significant ($\chi^2(15) = 31.2147$, Prob > $\chi^2 = 0.0000$), which indicated that the null hypothesis for the test of independence was rejected. This result justified the use of MVP that examined different adaptation options.

Age and farming experience of the household head have been identified as critical determinants of adaptation to climate change (Deressa et al., 2009; GC & Yeo, 2019; Ojo & Baiyegunhi, 2019). However, the effect of these factors on farmers' choice of adaptation strategies is ambiguous in the empirical literature. Nhemachena and Hassan (2007) argue that farming experience increases the probability of taking up all adaptation methods because highly experienced farmers are likely to have more knowledge about

Table 4 MVP results explaining factors affecting farm households' choice of adaptation strategies

Variables	SL		PE		CU		CL		LD		BC	
	Coef.	S.E.	Coef.	S.E.	Coef.	S.E.	Coef.	S.E.	Coef.	S.E.	Coef.	S.E.
Age	0.008	0.014	− 0.002*	0.014	− 0.022	0.016	− 0.013*	0.014	− 0.002*	0.014	− 0.110*	0.065
Gender	0.122	0.342	0.507*	0.399	0.730	0.386	0.202*	0.288	0.657*	0.323	0.353*	0.954
Education level	0.065	0.034	0.022	0.034	− 0.076	0.042	− 0.071	0.030	0.002	0.029	0.039*	0.082
Farming experience	0.011	0.025	− 0.006*	0.015	− 0.002	0.016	0.022	0.034	− 0.019*	0.014	− 0.091*	0.061
Training	− 0.314	0.266	− 0.044	0.280	0.931	0.310	0.032	0.252	0.527	0.242	0.365	0.081
Access to extension services	0.047	0.164	0.381*	0.162	0.798*	0.266	0.655	0.157	0.521	0.145	0.001	0.387
Farm labor supply	0.079	0.099	0.053	0.099	0.195	0.121	0.266	0.089	− 0.042	0.081	0.647	0.318
Farm size	0.014	0.088	0.160*	0.072	0.247*	0.144	− 0.047*	0.079	− 0.002*	0.070	0.001	0.001
Savings	− 0.031	0.027	0.012*	0.011	0.021*	0.063	0.001	0.014	0.003	0.011	0.071	0.052
Membership of associations	− 0.250	0.115	0.080*	0.110	0.248*	0.148	0.199*	0.102	0.106	0.099	0.210	0.290
Access to information	− 0.227	0.154	0.295*	0.132	0.037*	0.186	0.168*	0.109	0.023*	0.111	0.021	0.256
Share of off-farm income	− 0.013	0.019	0.024	0.023	− 0.015*	0.052	0.030*	0.042	0.033*	0.018	0.034	0.117
Distance to market	0.114	0.059	− 0.141	0.068	0.092	0.087	− 0.004	0.057	0.115	0.059	− 0.054	0.157
Perception of tendency	− 0.260*	0.087	0.075*	0.088	0.158*	0.113	0.006*	0.082	0.072*	0.083	0.016*	0.229
Ethnicity	0.611*	0.363	− 1.115*	0.287	− 5.521*	1.512	− 0.279	0.261	− 0.197*	0.248	− 0.320	0.692
Constant	0.249	1.082	− 0.333	1.082	2.823	2.517	−0.887	0.990	1.995	1.004	− 1.396	2.887
Number of observations	290											

Likelihood ratio test of rho21 = rho31 = rho41 = rho51 = rho61 = rho32 = rho42 = rho52 = rho62 = rho43 = rho53 = rho63 = rho54 = rho64 = rho65 = 0: $\chi^2(15) = 31.2147$; Prob > $\chi^2 = 0.0000$

*, **, and ***denote significant at 0.1, 0.05, and 0.01 levels respectively; Coef. = Coefficient; S.E. = Standard error

climate change and farming practices. Meanwhile, a study of Ojo and Baiyegunhi (2019) shows a significantly negative effect of farming experience on the choice of varying planting and harvesting dates as an adaptation strategy. The possible reason for this observation is that young farmers often have better education and are more willing to adopt new ideas and changes (Tesema, 2006). Acquah (2011) also states that older and experienced farmers are more risk-averse and reluctant to take up new technologies. Results from the MVP model are consistent with the findings of Ojo and Baiyegunhi (2019) and Acquah (2011), showing that younger farmers and farmers with less farming experience were more likely to select strategies of *prevent the events, change location, livelihood diversification,* and *behavioral change* to adapt to climate change.

Having a female household head negatively affected the choices of strategies that required more information and knowledge such as *prevent the events, change location, livelihood diversification* and *behavioral change*. This is probably due to the fact that in rural mountainous areas in Vietnam, female-headed households have limited access to information, technologies, and other resources, and they are more risk-averse than male-headed households. During the group discussions, female heads responded that they could not migrate outside the commune to find jobs or wage work because beside their household farming work, they had other responsibilities such as taking care of family members, preparing food, and maintaining their homes. However, the result shows that the gender of the household head did not influence the choice of *change use* strategy. This result is not surprising because, in the region, females are engaged in most household agricultural activities.[2] Their decisions on farm activities and adaptation mainly derive from their own experience and indigenous knowledge rather than from knowledge transfer.

Training programs and extension services are believed to increase the probability of farmers' adoption of adaptation strategies because they provide

[2] In rural areas of Vietnam, 63% of working women engaged in agriculture compared to 57% of working men. Men spend more time than women in wage labor, while women carry out most of the household farming work (UN Vietnam, 2016).

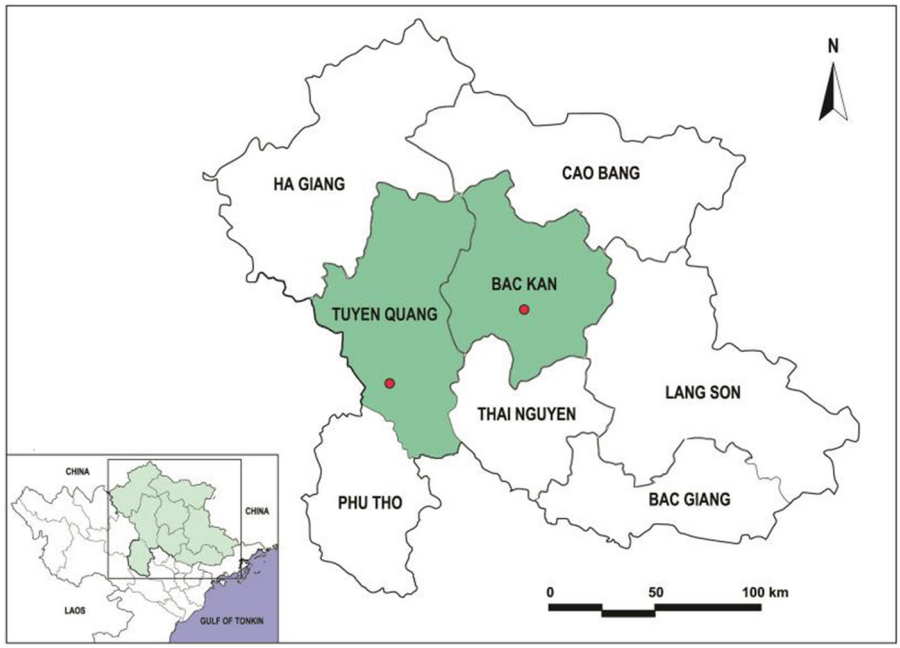

Fig. 1 Map of Northeast Vietnam showing the study area

farmers with knowledge and information on climate change as well as agricultural production and management practices. However, results from the MVP model show an insignificant relationship between participation in training programs and adoption of all adaptation strategies. Surveyed farmers responded that training programs were ineffective and infrequent. Some farmers said that the last time they participated in a training program was 7–8 years ago. Meanwhile, the frequency of contacting extension agents had a significantly positive effect on the choices of *prevent the events* and *change use* strategies. This result indicates that extension services played an essential role in farmers' adoption of adaptation strategies related to agricultural practice decision making. Regular training programs and frequent visits of extension agents are needed to improve the effectiveness of extension services.

Farm households' choice of adaptation strategies was noticeably influenced by their access to resources. The coefficient of farm size had a positive effect on the choice of *prevent the events* strategy. Households with a larger land area had more incentive to prevent or reduce the impacts of climate hazards by activities such as improving irrigation systems, soil conservation, and reducing chemical fertilizers and applying more manure/organic fertilizers than those with a smaller area of land. The results also reveal a significantly positive relationship between the coefficient of farm size and the adoption of adaptation measures related to changes in farm activities. Households with larger landholdings tended to change farm activities such as mixing crops, crop rotation, changing cropping calendar, applying new farming techniques, switching to resistant varieties of crops, etc. One possible reason could be that these households have more resources and they have a higher ability to use part of their land and bear the risks of trying new farming practices. Some previous studies also show a significantly positive relationship between farm size and adoption of adaptation strategies such as planting of improved crop varieties (Ojo & Baiyegunhi, 2019), improvement to technology (Bryan et al., 2013), or investment in farming practice and conservation technologies (Nhemachena & Hassan, 2007). However, farm size had a negative relationship with the choices of *change location* and *livelihood diversification* adaptation strategies, indicating that households with large land areas tended to invest on their land rather than to find a solution outside the farm to cope with the impacts of weather extremes.

Evidence from various sources indicates that education plays a vital role in farmers' decisions on adaptation to climate change (Deressa et al., 2009; GC

& Yeo, 2019; Maddison, 2006). Well-educated farmers often have good ability to get and use information related to climate change, adaptation, and farm management, and are more aware of the risks of climate hazards. Therefore, education increases the probability of adopting adaptation strategies. However, results of the MVP model show that education was not associated with the adaptation of farm households, except the choice of *behavioral change* strategy. This finding can be attributed to the relatively low education level of farmers in the study area. Poorly educated farmers can get information and learn new ideas and technology from neighboring farmers and the mass media such as newspapers, radio, and television (which is named non-formal education by Kalirajan & Shand, 1985).

It was surprising that farm labor supply had an insignificant effect on farmers' choice of adaptation strategies. A possible reason for this result might be found in the fact that labor exchange is typical among the farm households in this area and exchanged labor substitutes for household labor.

Savings were used to capture farm households' financial capital. Savings increased the probability of adopting adaptation strategies related to agricultural practices, including *prevent the events* and *change use*. Adaptation usually requires the availability of financial capital so that farmers can plan for and implement adaptation activities, especially those require investment such as improving irrigation system, switching to new varieties of crops, applying new techniques, etc. Thus, savings ensures to overcome any financial constraints faced by farmers during the adaptation process.

Membership of associations increased the likelihood of adopting *prevent the events, change use*, and *change location* strategies. This result supports Uddin et al. (2014). They suggested that farmers belonging to associations have a higher probability of taking up adaptation practices due to their capacity to share information, discuss problems, share ideas, and take mutual decisions.

Access to information was significantly and positively connected with the likelihood of choosing all adaptation strategies except the *share the losses* strategy. Farmers with access to information are more likely to be aware of changes in climate and related risks and measures and strategies that they can use to adapt to these changes.

Farm households with a more significant share of off-farm income tended to diversify their livelihoods by increasing non-farm income-generating activities and migrate elsewhere to find a job as a measure to cope with climate change. Discussions with the farmers suggest that when farm activities became less profitable and riskier due to climate hazards, farmers were pressed to switch to off-farm activities to reduce the climate risks and impacts. Farmers who participated intensively in off-farm activities had a higher propensity and ability to maintain and develop these activities compared to no participation or less participation. However, off-farm income had a significantly negative influence on the choice of *change use* strategy. This result suggests that those households with a larger share of off-farm income had less incentive to invest and adjust farm activities than households whose livelihoods heavily relied on agricultural activities.

The results demonstrate the positive effects of perception of tendency on the choices of all adaptation strategies, except the *share the losses* strategy. Farm households who perceived an increase in frequency and magnitude of weather extremes and their impacts were likely to adopt adaptation strategies. Maddison (2006) states that perception of climate change and awareness of its impacts is a pre-requisite to adaptation, implying that farmers must be aware and perceived of the potential impacts of climate hazards on their livelihoods before they can effectively take up adaptation strategies. Therefore, it is necessary to improve farmers' awareness and perception of change and variability in climate through appropriate communication channels such as extension services, training programs, agricultural professional organizations and farmers' associations, and mass media.

Ethnic minority farmers tended to rely on support from the government and non-government organizations and neighboring farmers in response to climate hazards. The Kinh farmers were more likely to adopt adaptation strategies of *prevent the events*, *change use*, and *livelihood diversification*. This observation can be explained by the fact that in mountainous areas of Vietnam, the Kinh have an advantage over the ethnic minority farmers in terms of knowledge, skills, and financial resources needed for taking up adaptation measures. Besides, the ethnic minorities still use traditional farming practices that have existed for a long time, making them more conservative in adopting

new technologies. Rather than taking the risk, ethnic minority farmers tend to prefer what they already know.

Conclusion

Despite living in remote mountainous areas with unfavorable socioeconomic characteristics, the surveyed farm households were not passive victims of climate hazards. They applied various strategies to cope with and adapt to the impacts of climate change. Changes in farm activities and livelihood diversification were the two most widely used adaptation strategies. Farm households' adoption of adaptation was influenced by mixture of factors related to demographic characteristics, economic well-being, access to resources, and perception. The direction of the relationship between factors and farm households' adaptation was a complex one. Some factors positively or negatively affected the adaptation while others hastened the adoption of some adaptation strategies but retarded the adoption of others. Age and farming experience negatively affected farm households' adaptation. Meanwhile, savings, extension services, membership of associations, access to information, access to resources, and perception of tendency had a positive and significant effect on the adoption of adaptation strategies. However, farm size did not necessarily influence the choices of all adaptation strategies. Instead of adopting new income-generating activities, farm households with larger landholdings tended to maintain and invest in existing farm activities,. Social-economic barriers restricted female-headed and ethnic minority households from adopting adaptation measures that required technologies, updated knowledge, or resources. Farm households with a large share of off-farm income tended to adapt to climate change by diversifying their livelihoods away from agriculture rather than investing and adjusting farm activities.

The Vietnamese government has already issued policies and implemented projects to support communities in mountainous areas to cope with and adapt to climate change. To make these policies and projects more effective, the government should consider enhancing adaptive capacity and facilitating the adaptation of farm households by improving extension service systems, providing and developing channels for disseminating information, and implementing awareness building measures. Targeted policies for female and ethnic minority farmers are needed to reduce socio-economics barriers and improve their adaptive capacity. Besides, policymakers should take into account measures and policies to train farmers on available off-farm job opportunities and create favorable conditions for farmers to diversify their livelihoods as a major method of climate change adaptation.

Author's contribution Hang Thi Minh Bui carried out the survey and wrote the manuscript. Tai Anh Do contributed to the analysis of the results. Both authors read and approved the final manuscript.

Declarations

Conflict of interest The authors declare that there is no conflict of interest.

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