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Farmers' Awareness and Adaptation Measures to Climate Change in Lai Chau Province, Vietnam

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ABSTRACT

Climate change is a worldwide environmental threat that has an impact on all economic sectors, especially on agriculture. In Vietnam, Lai Chau province is the most vulnerable province to climate change because of its high exposure to extreme weather events as well as its limited capacity to adaptation. The objectives of this study are to explore farmers' awareness of climate change, adaptation measures, and identify the key factors affecting the farmers' adaptation decision in Lai Chau province, Vietnam. The study used survey data of 200 farmers and secondary data to explore the research objectives by using the risk matrix and a multivariate probit model. The results showed that most farmers believed the presence of climate change and the major causes are due to anthropogenic activities. In the context of climate change, 78.5% of the farmers applied adaptive measures on their farms. The farmers used seven adaptation methods and they were likely to combine simultaneously several strategies to manage climate risks. Farming experience, farm size, farmer association's membership, credit access, extension service, distance to market, and risk perception exposed significant impacts on the farmers' decision to adaptation practices. The findings of the study suggest the government should encourage farmers to expand production and promote the implementation of the land accumulation program while providing information regarding climate change scenarios, seasonal variability, and information about the impacts of climate change.

Keywords: Adaptation Strategy, Awareness of Climate Change, Lai Chau Province, Multivariate Probit Model

INTRODUCTION

General context

The effects of climate change are being felt throughout the world and it has manifested in the increased volatility of extreme weather events (David *et al.*, 2019). Changing climate is one of the most complicated challenges since it has negative impacts on various areas, including the economy, environment, human health, and livelihoods (Bruce and Thomas, 2018). Climate change is occurring on a global scale, but developing countries suffer most from its negative consequences due to their low level of adaptation (Elizabeth *et al.*, 2009; Abid *et al.*, 2015). Vietnam is a country that is highly vulnerable to climate change because of a combination of geographic and climatic factors, along with its socioeconomic structure.

Several factors contribute to the high level of vulnerability, specifically in mountain regions, including high poverty rates, limited resources to respond, complex terrain, heavy reliance on agriculture and forestry for livelihoods, and backward farming skills of the local communities who are mainly ethnic minorities (Martin 2003; Thomas *et al.*, 2010). Climate change and agriculture are indeed closely linked. Climate change's rapid pace has a far-reaching impact on the agro-ecosystem and productivity (Hatfield *et al*., 2011; Naveen 2019). The consequences of climate change are more conspicuous for smallholder farmers, whose livelihoods are heavily dependent on agriculture (Rashid and Charles, 2008).

The agricultural sector must adapt to the negative impacts of climate change to protect farmers' livelihoods (IPCC, 2008). Nicholas *et al*. (2012) argued that climate change adaptation is an effective farm-level measure that can minimize climate vulnerability by better-preparing farmers and their farming activities for the climate change's effects, preventing expected damage, and assisting themto cope with bad events. Several factors are commonly used to investigate farmers' adaptive behavior, including age, education level, household size, farm income, credit access, and information access. Farmers' awareness of climate change contributes a significant role in their decision-making regarding adaptation measures (Deressa *et al*., 2011; Fosu-Mensah *et al*., 2012; Hoa *et al*., 2013).

Literatures on the adoption of agricultural conservation methods have identified a connection between awareness of environmental change, attitudes toward climate risks, and the willingness to implement potential solutions (Linda *et al*., 2008). As emphasized by Howden *et al*. (2008), farmers are unlikely to adapt to climate change if they are unaware of its existence or do not perceive it as a threat to their livelihoods. Therefore, for better understanding of farmers' awareness to climate change and the way in which they perceive climate change, the types and extent of adaptation measures employed by farmers are crucial to promote successful adaptations in the agricultural sector (Mertz *et al*., 2009; Nicholas *et al*., 2012).

According to Anthony and Dagmar (2008), policies aimed at promoting climate change adaptation need garner cooperation from the beneficiaries. If these stakeholders disagree with policymakers and regulators, the implementation of proposed policies is likely to fail. In addition, Slovic (2000) highlights that risk awareness is subjective and varies among individuals and regions. Findings from risk awareness studies in one country may not be applicable to another due to differing cultural and economic contexts.

Vietnam is ranked sixth among the most climate change-vulnerable countries, facing highly frequent climate-related hazards such as drought, floods, and salinization (David *et al*., 2019). Lai Chau province (Figure 4) stands out as the most is the highest vulnerable province influenced by climate change in the upland areas of Vietnam (Anshory and Herminia, 2010). The ethnic community in Lai Chau comprises 20 ethnic minorities residing in remote areas, the majority of whom face poverty, possess low level of education, and depend primarily on nature resources for their livelihoods (Lai Chau Province People's Committee, 2020), and then rendering them particularly vulnerable to the impacts of climate change. Evidence found that climate change negatively impacts agricultural production of households in Vietnam (Trinh, 2018). Given that the majority of households in Lai Chau province depend on agriculture for their income, it is critical to implement adaptive practices to mitigate the negative impacts of climate change on their agricultural production. Derived from the above discussions, this study is conducted with the following objectives: (i) Clarifying awareness of climate change of the farmers in Lai Chau province; (ii) Identifying farmers' adaptation measures and determinants of farmer's adaptation decisions; and (iii) Proposing recommendations to boost successful adaptation to climate change in the future.

Climate change

According to the IPCC (2014), climate change refers to "changes in the state of the climate that can be identified by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer." The IPCC further elaborates that natural internal processes and external factors such as solar cycle modulation, volcanic eruptions, and anthropogenic changes in atmospheric composition can contribute to climate change. The primary characteristics of climate change are rises in the mean of temperature; changes in cloud cover and rainfall; melting ice caps and snow cover reduced; rises in ocean temperature and sea acidity levels; and increases in frequency of droughts, floods, and extreme weather events (UNFCCC, 2007; IPCC, 2014). Figure 1 illustrates the relationship between climate change and environmental variability. IPPC (2023) confirms a global increase in climate change attributed to human-caused consequences of greenhouse gas emission, deriving from energy consumption, land use changes, shifts in lifestyle and consumption patterns, as well as production activities. Consequently, climate change has impacted both human and natural systems, and mostly vulnerable groups, including food and water security, human health (physical and metal), infrastructure, livelihoods as well as natural resources.

The three principal components of greenhouse gases are nitrous oxide (N_2O), carbon dioxide (CO_2), and methane (CH_4). Increased levels of these gases have led to more heat being retained in the Earth's atmosphere, which would typically dissipate back into space. This extra heat trapped in the atmosphere has resulted in the greenhouse effect, contributing to subsequent climate change (UNFCCC, 2007). Edward *et al*. (2014) argued that 97% or more of climate scientists conclude that global warming is happening, primarily as the result of human activities. This assertion is supported by the US National Climate Assessment (2018), which states that observed warming since the mid-20th century is extremely likely caused by human activities. The primary sources for CO_2 emissions are fossil fuel burning, deforestation and mechanization.

Greenhouse gas emissions in Vietnam have surged since the 1990s when the country started industrialization (see Figure 1). In 2022, the total CO_2 emitted by Vietnam was estimated at 343.6 million tons, accounting for 0.92% global CO_2 emission (Hannah *et al.*, 2023). Agriculture is regarded as the primary contributor to the country's emission. Agricultural practices, particularly rice farming and livestock, release N_2O, CH_4, and H_2S into the atmosphere, contributing to global warming and climate change.

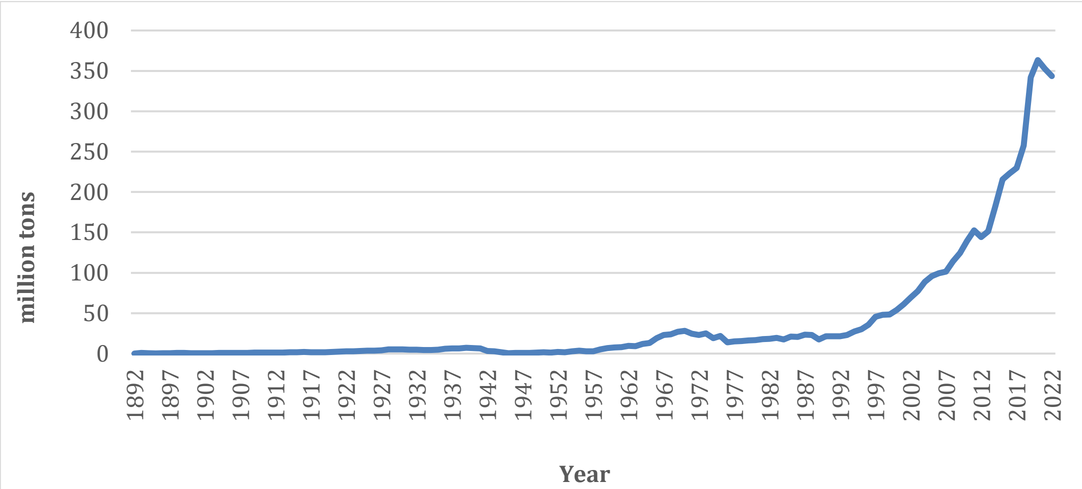

Figure 1. CO_2 emission in Vietnam from 1892-2022
Source: Hannah *et al.*, 2023

Adaptation to climate change

Adaptation to climate change entails making the necessary adjustments and changes to minimize the detrimental impact of climate change or capitalize on the positive ones (UNFCCC, 2007). In human systems, adaptation seeks to mitigate or avoid harm while seizing beneficial opportunities. Human intervention in natural systems could facilitate adaptation to anticipated climate changes and their consequences (IPCC, 2014). Therefore, adaptation refers to agricultural activities undertaken by farmers to respond to changing climatic conditions to mitigate negative impacts or exploit potential opportunities.

For farmers, adaptation involves improving the production capacity of crops and livestock in response to climate change through the application of suitable technologies. The risk of agricultural failure and reduced productivity of crops, and livestock could be reduced with adaptation and on the other hand, the resilience of crops, animals, and agricultural systems to climate change's consequences might be improved (Sen *et al*., 2015) (see Figure 2). According to Burton *et al.* (2003), the adaptation process comprises several steps, including learning about risks, evaluating response options, selecting adaptation measures, mobilizing resources, implementing adaptation measures, and adjusting strategies to suit specific circumstances. Many studies have discovered that farmers frequently employ common adaptation measures to address climate change, including crop switching, adoption of improved crop varieties, mixed cropping, crop rotation, adjustments to planting dates, modification of production techniques, implementation of soil conservation practices, utilization of irrigation, and diversification of income sources (Elizabeth *et al*., 2009; Fosu-Mensah *et al*., 2012; Hoa *et al*., 2013; Abid *et al*., 2015; Son *et al*., 2015; Marie *et al*., 2020).

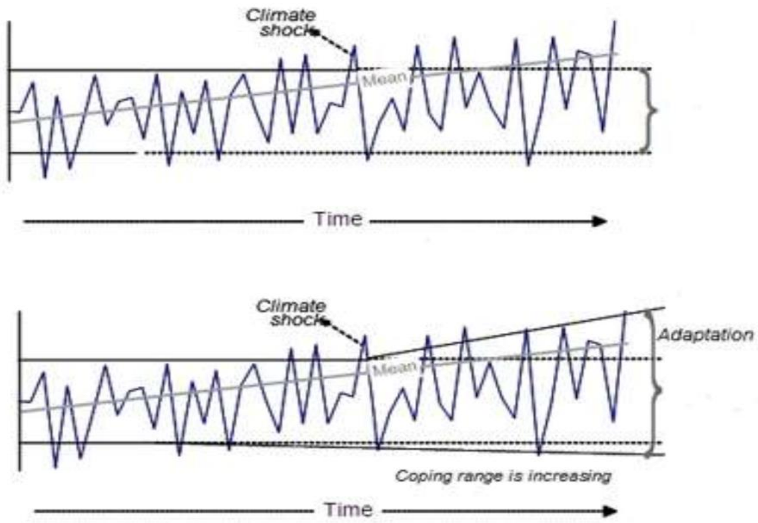

Figure 2. Illustration of increasing climate resilience of agricultural production systems with adaptation measures
Source: Sen *et al.*, 2015

Factors affecting the farmers' adaptation decision

The adoption of adaptation measures to climate change by farmers is influenced by various factors, including their awareness of climate change, demographic characteristics (such as age, education level, family size, farming experience), socio-economic attributes (such as farm size, income, proximity to markets), and institutional factors (such as credit access, extension service, membership in farmers' associations) (Elizabeth *et al*., 2009; Fosu-Mensah *et al*., 2012; Abid *et al*., 2015; Sunny and Sidana 2018; Marie *et al*., 2020). Research on key factors is summarized as follows:

Awareness of climate change: Farmers' perception of global warming attributes and perception toward risk play critical role in adaptation decision-making (Abid *et al*., 2015). Understanding the risks associated with climate change is essential for identifying the problem and selecting appropriate behaviors to address it. Appropriate risk perception is critical as it form the foundation for selecting appropriate adaptation strategies (Arbuckle *et al*., 2015). Therefore, there is a positive correlation between farmers' risk perceptions and their adaptive actions.

Farming experience: Experience in farming is indeed a significant determinant of technology adoption (Abid *et al.*, 2015). More experienced farmers typically possess better risk-bearing abilities, more information and understanding on climatic changes, and knowledge of the most effective crop and livestock management methods for adaptation (Nhemachena and Hassan, 2007). Therefore, farmers with greater experiences are more likely to employ climate change adaptation measures.

Farm size: Farm size has a positive impact on adoption of new science and technology, as larger farms are likely to adapt more quickly than smaller ones (Fosu-Mensah *et al*., 2012). Farmers with larger land holdings are more likely to have a greater capacity to experiment with and invest in methods of climate risk mitigation (Sunny and Sidana, 2018). Farm size is positively associated with crop variety change, as farmers may be more inclined to allocate a portion of their land to cultivate new types of crops.

Membership in farmers' association: Farmers' association serves as platforms to connect and exchange ideas, as well as access information on agricultural production management through training and workshops. The platform allows farmers and other stakeholders to share ideas on how to improve yields and build climate resilience (Onyeneke *et al*., 2019; Marie *et al*., 2020). Therefore, membership in farmers' association is anticipated to have a positive effect on farmers' adaptation to climate change.

Access to credit: Access to lending facilities is crucial for adapting new technology, as it enables farmers to purchase production inputs such as improved seeds and fertilizers (Fosu-Mensah *et al*., 2012). In addition, since some adaptation strategies entails high costs, having access to credit creates favorable conditions for the adoption process. Therefore, availability of credit helps farmers strengthen their financial standing, enabling them to follow new adaptation measures (Sunny and Sidana, 2018).

Access to extension service: Scholars have reported a positive association between access to agricultural extension services and climate change adaptation. Extension services serve as a valuable resource of information on new agricultural technologies. It disseminates information through implementation of innovations and improved farm management practices (Elizabeth *et al*., 2009; Fosu-Mensah *et al*., 2012).

Distance to market: Distance from the farmhouse to the market tend to hinder farmers' adoption of climate adaptation practices and technologies because adaptation measures require production inputs, which are typically purchased at the markets. As a result, the longer it takes farmers to reach the market where adaptation inputs are sold, the lower their likelihood of adapting to climate change (Nhemachena and Hassan 2007; Abid *et al*., 2015). Distance to the main market is anticipated to have a negative effect on farmers' adaptation to climate change.

Based on the preceding discussions regarding adoption behavior of the farmers towards climate change, the study proposes the conceptual framework illustrated in Figure 3.

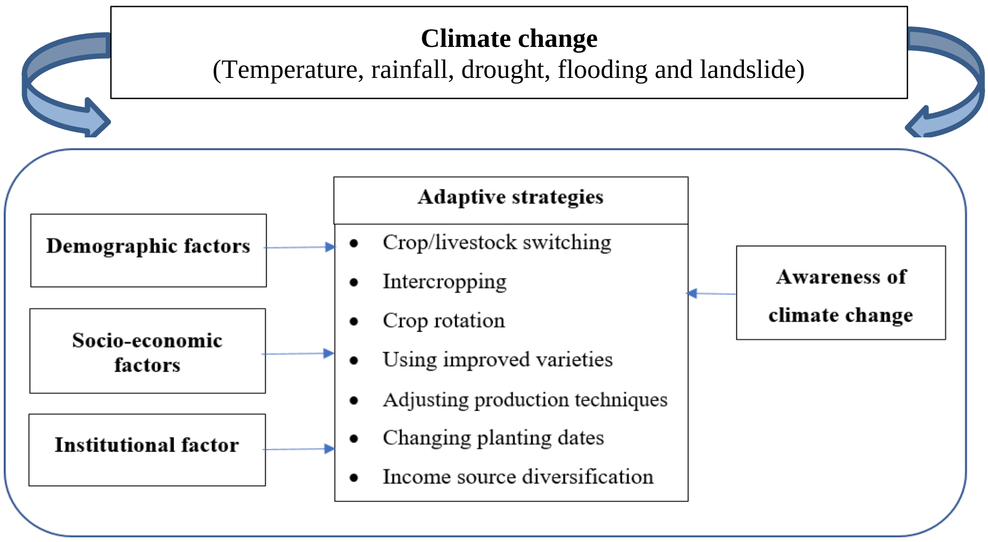

Figure 3. Conceptual framework
Source: Authors' construct

METHODOLOGY

Data collection

Primary data collection: Farm household survey questionnaire was used as the primary data method of data collection. This study purposely selected four districts, i.e., Muong Te, Phong Tho, Tan Uyen, and Than Uyen, based on their vulnerability, agricultural importance, and the severity of damage caused by climate change events (Figure 4). Random sampling was employed for the household survey. In each district, 50 households were randomly selected for interviews, resulting in a total of 200 informants in our survey. Using a structured questionnaire, the data collection mainly focuses on farmers' socio-economic characteristics, their awareness of climatic trends, the consequences of climate change, and their adaptability to climate change.

Secondary data collection: Secondary data was collected from various sources such as journal articles, books, reports, Lai Chau province's annual reports, Lai Chau Statistical Yearbook, and other related resources.

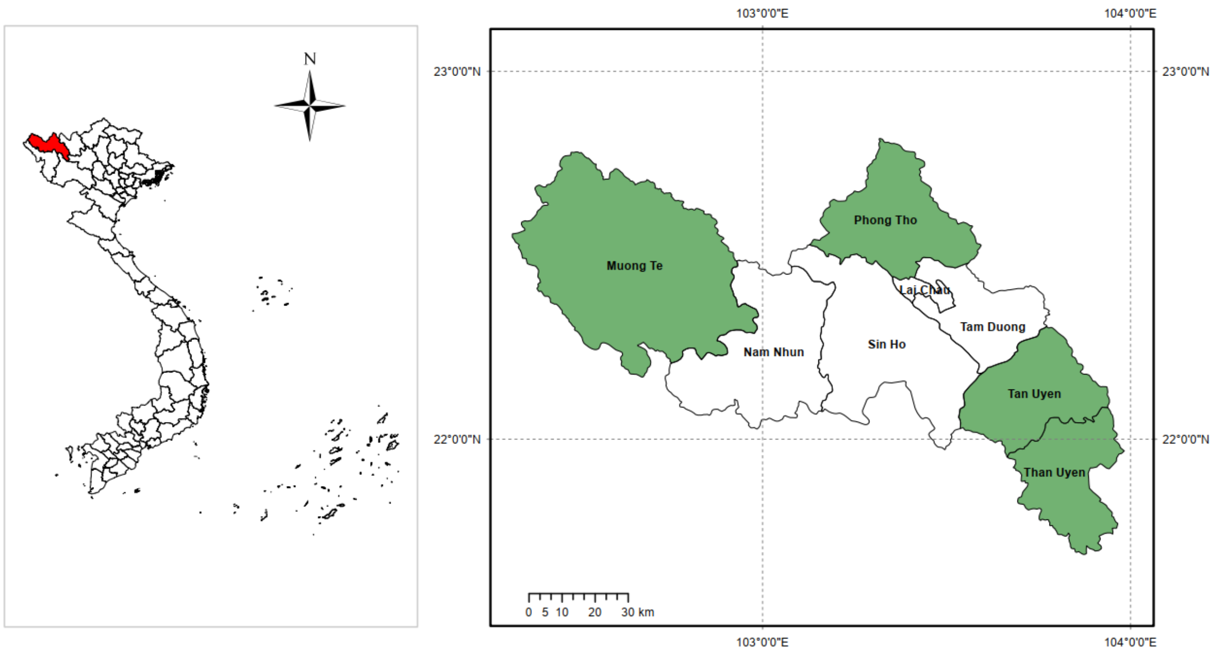

Figure 4. Map of the study area
Source: Authors' construct

Data analysis

Risk matrix method: An individual's perception of risk refers to how they assess the likelihood that a specific event will occur and its consequences. A five-point Likert scale is used to assess risk perception. This scale runs from 1 to 5, with 1 being the very low and 5 being the very high. Data was gathered for two dimensions: incidence and severity, then filled into the risk matrix to calculate risk awareness. The risk matrix method converts a farmer's response into the high risk and low risk group. It is rated low if it is between 2 and 5 and high if it is between 6 and 10 (Ogurtsov, *et al*., 2008). The perceptions of climate risk were analyzed as 1 the farmer viewed the risk as high and 0 otherwise. This study assumes a positive correlation between the level of risk and the adoption of climate change adaptation measures. This assumption is based on the notion that individuals are motivated to adapt when they believe that global warming negatively impacts their activities.

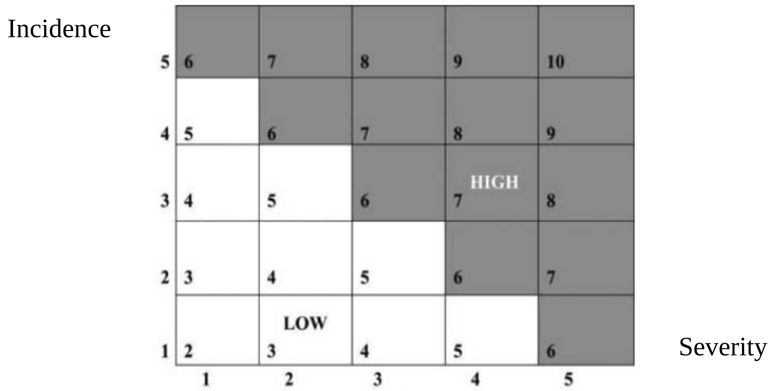

Figure 5. Risk matrix
Source: Ogurtsov, Asseldonk and Huirne (2008)

Regression model: The econometric models, notably binary probit, binary logit and multinomial probit, are employed to analyze the determinants driving farmer adaptation to climate change (Elizabeth *et al*., 2009; Abid *et al*., 2015; Son *et al*., 2015; Sunny and Sidana, 2018). The application of these econometric models provides the understanding of the factors that influence adaptation to climate change. These models however might limit our understanding by considering adaptation strategies separately and/or not considering the interdependence of farmers' adaptation measures. Through the survey, we found that farmers in Lai Chau province have numerous adaptation strategies and they tend to use simultaneously several strategies to mitigate climate risks. Thus, empirical models should consider the simultaneous adaptation decisions and therefore the authors such as Nhemachena and Hassan (2007), Mulwa *et al*. (2017), and Onyeneke *et al*. (2019) have shown that multivariate probit (MVP) model, in this case, is more suitable approach. The advantage of the MVP model is that it explicitly recognizes and controls for potential correlation among adaptation options. By contrast, the univariate tool is susceptible to biases because it ignores common factors that could be unobserved and unmeasured but affect the various adaptation measures. Thus, MVP model provides an improved estimation, or more precise estimates in other words, of the relationship between adaptation options and the determinants that explain it.

The study, therefore, used MVP model to identify the factors affecting farmers' choice of adaptation measures. The MVP model simultaneously estimates the effect of a set of independent variables on each of the different adaptation practices while permits the error terms of each adaptation strategy to be freely correlated.

In our study, there are seven climate change adaptation practices as dependent variables as following:

$Y_1,..., Y_7$ such that: $$Y_{ij} = \begin{cases} 1 & if \quad \beta iX' + \varepsilon i > 0 \\ 0 & otherwise \end{cases}$$

where Y_{ij} (j=1,…,7) represents the climate change adaptation practices adopted by the i^{th} farmer (i=1,…,200); βi is the vector of model parameters; X is the vector of explanatory variables; and εi is the error term that has a multivariate normal distribution distributed with zero mean, unitary variance and an (n × n) correlation matrix (Mulwa *et al*., 2017; Onyeneke *et al*., 2019).

Cross-sectional data in econometric analysis is usually associated with heteroskedasticity and multicollinearity problems. Multicollinearity among independent variables could lead to inaccurate parameter estimates. Therefore, this study used pair-wise correlations to examine the correlation between each pair of independent variables and determined the Variance Inflation Factor (VIF) for each of the independent variables. The result showed that all pair-wise correlation coefficients are below 0.5, the VIFs do not reach the convectional thresholds of 5. Thus, the analysis may not appear to be problematized by multicollinearity. Next, the study estimated a robust model to address the possibilities of heteroskedasticity.

RESULTS AND DISCUSSIONS

Farmers' awareness about climate variables (temperature, rainfall, drought, and flooding)

The survey findings showed that a large number of farmers believed the temperature had increased (87%). Interviewed farmers also claimed that temperature seems to decrease during the winter season and raised in the number of extremely hot days during the summer season. Because of rising high temperatures in the summer, there was an increase in drought, selection of an increase in droughts up to 80.5%. The farmers' awareness of temperature change appears in line with observed scientific data from Lai Chau province (an increasing trend in temperature, from 20.2°C in 2005 to 20.9°C in 2020). Regarding the precipitation trends, 48.5% of farmers reported an increase in rainfall, while 31.5% reported a decrease. The observed scientific data prove that farmers' perception was appropriate. Actual rainfall is unevenly distributed among districts in the study area, of which Than Uyen district tended to decrease slightly while Muong Te district tended to increase slightly. Besides, farmers claimed that the rain has become more and more complicated, intense, and unpredictable, heavy rain is concentrated in a short space of time, leading to increased flooding in the rainy season. Therefore, a wealth of the respondents (76.5%) perceived an increase in floods and landslides. Detailed statistics is presented in Figure 7.

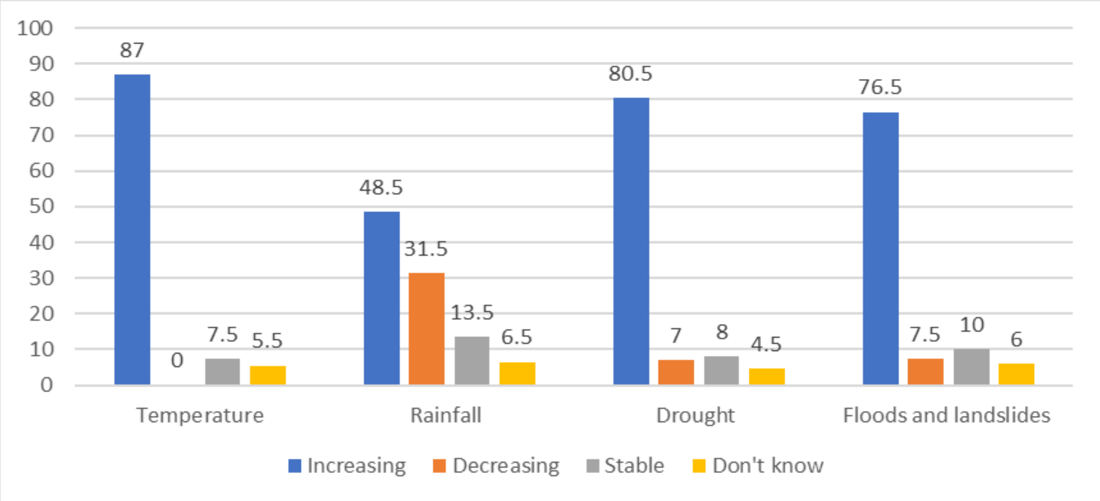

Figure 7. Farmers' awareness on climate change
Source: Authors' calculation

Farmer' awareness of causes of climate change

Table 1 shows the proportion of responses to the awareness of the causes of climate change. There is a large number of farmers (66%) attributed climate change to human-related causes such as deforestation, industrial pollution, burning fossil fuels, etc. About 68.5% of respondents believed that the appearance of many factories and industrial zones is the primary cause of climate change. Urbanization is a secondary cause (66.5%). The third cause is population growth contributes to climate change (59%). Poor management of natural resources (land, forest...) and agricultural production ranks last with only 28%. This is a point worth noting because many farmers believe that agricultural production has no effect or has little influence on climate change. Because farmers are not aware of this problem, the situation of intensive use of too much chemical fertilizers in this area is still happening, and they do not pay attention enough to sustainable farming methods.

Table 1. Awareness of causes of climate change

Unit: %

Identified cause	Strongly disagree	Disagree	Uncertain	Agree	Strongly agree	Sum
1. Climate change is happening and is mainly caused by human activities	5.00	8.00	21.00	46.50	19.50	100.00
2. The appearance of many factories and industrial zones contributes to climate change	2.00	4.50	25.00	48.50	20.00	100.00
3. Population growth contributes to climate change.	2.50	7.50	29.00	44.00	17.00	100.00
4. Urbanization contributes to climate change	3.50	5.00	25.00	50.50	16.00	100.00
5. Poor management of natural resources (land, forests...) and agricultural production contributes to climate change	10.50	30.50	31.00	16.50	11.50	100.00

Source: Authors' calculation

Note: The sum of responses *Agree* and *Strongly agree* is the rate of awareness of the causes.

Perception of farmers towards the effect of climate change on agricultural production

Heavy rains, storms, flash floods, and landslides, which caused significant agricultural losses, seriously destroy irrigation systems, and it costs a lot to overcome the consequences. Over 70% of respondents attributed the temperature and rainfall changing reduced yields, the rise in weed infestation, an increase in pests/insects, and disease outbreaks (Table 2). Motha (2011) argued that during critical growth phases, most plants and animals are sensitive and vulnerable to the direct effects of high temperatures, decreased rainfall, flooding, and freezes. Other indirect effects on crops and animals include influences on soil processes, nutrient dynamics, and pest organisms. Farmers also reported that harmful pests such as the rice-feeding ear-cutting caterpillars, fungi, black cutworms, among others, are multiplying and spreading because of increasing temperatures and shifting precipitation patterns.

Table 2. Awareness of the consequences of extreme weather events on agricultural production

Unit: %

Consequence	Strongly disagree	Disagree	Uncertain	Agree	Strongly agree	Sum
1. Flash floods, heavy rains, thunderstorms cause damage to assets.	0.00	2.50	10.00	48.00	39.50	100.00
2. Drought affects the yield of plants and animals.	0.50	3.00	8.50	53.50	34.50	100.00
3. Rising temperatures cause more diseases for plants and animals.	1.00	2.50	10.50	55.00	31.00	100.00
4. Erratic rains reduced crop yields.	0.50	1.50	12.50	57.00	28.50	100.00
5.The temperature drops too low in winter killed plants and animals.	1.50	7.50	12.00	49.00	30.00	100.00

Source: Authors' calculation

Note: The sum of responses *Agree* and *Strongly agree* is the rate of awareness of the consequences

Climate change adaptation strategies of farmers

The survey results (Table 3) show that 153 respondents (out of 200) reported having adopted climate change adaptation methods. The most commonly practiced strategies were "intercropping" (53.0%), "using improved varieties" (41.5%), "crop/livestock switching" (41.0%), and "adjusting production techniques" (40.5%). The other three strategies mentioned, namely, "crop rotation", "diversify income sources" and "changing planting date", have the lower adoption rate. Other strategies are "taking water and soil protection measures (digging ditches, planting forests)" and "manage water usage (reuse, use water sparingly)." However, only 4.5% of farmers used these strategies, therefore this study focused on seven adaptation measures from Y_1 to Y_7.

Table 3. Climate change adaptation strategies

Adaptation strategies	Frequency	Percentage
Y_1_Crop/livestock switching	82	41.00
Y_2_Intercropping	106	53.00
Y_3_Crop rotation	76	38.00
Y_4_Using improved varieties	83	41.50
Y_5_Adjusting production techniques	81	40.50
Y_6_Changing planting date	61	30.50
Y_7_Diversify income sources	72	36.00
Others	9	4.50
No adaptation	43	21.50

Source: Authors' calculation

Lai Chau farmers have utilized seven main adaptation strategies, and they are likely to use a combination of methods to manage climate risks rather than using one. Recent findings of climate change adaptation research agree that farmers often use multiple adaptation methods to reduce climate risks (Mulwa *et al*., 2017; Onyeneke *et al*., 2019). Table 4 shows that all 21 pair correlations were positive. This suggests that the adaptation methods were complementary, in other words, these measures were used at the same time. The 16 pairs of adaptation strategies had statistically significant correlation coefficients, while 5 pairs were not, and those were related mainly to method Y_7. This implies that Y_7_

Diversify income sources was often used alone. Because when farmers must choose this way, it means they will not have much time for the farm, not invest more in agriculture than at the beginning.

Table 4. Interdependencies among the adaptation strategies

Adaptation decision	Pairwise correlation coefficient
atrho21	0.401***
atrho31	0.306***
atrho41	0.292**
atrho51	0.289*
atrho61	0.326**
atrho71	0.010
atrho32	0.419***
atrho42	0.389***
atrho52	0.412***
atrho62	0.471***
atrho72	0.095
atrho43	0.525***
atrho53	0.500***
atrho63	0.382***
atrho73	0.142
atrho54	1.556***
atrho64	0.452***
atrho74	0.503***
atrho65	0.379**
atrho75	0.667
atrho76	0.058

Likelihood ratio test of rho21 = rho31 = rho41 = rho51 = rho61 = rho71 = rho32 = rho42 = rho52 = rho62 = rho72 = rho43 = rho 53 = rho63 = rho73 = rho54 = rho64 = rho74 = rho65 = rho75 = rho76 = 0

chi^2 (21) = 217.002

Prob > chi^2 = 0.0000

***, ** and * indicate statistical significance at 1%, 5% and 10% level, respectively

Source: Authors' calculation

Table 5 shows that, in general, the methods farmers used to respond to climate change are appropriate and effective. Crop/livestock switching, Adjusting production techniques, and Using improved varieties reached high efficiency with the ratings of 3.52, 3.46, and 3.43 points, respectively. The last one is Changing planting dates with only 2.89 points. It is worth noting that the level of success seems to be influenced by how deeply farmers engage with these strategies. In one group, farmers who comprehensively implement these strategies as integral parts of their short or long-term plans achieve higher efficiency. This highlights their thorough understanding of the strategies and their commitment of substantial resources to successful implementation. In contrast, another group only partially comprehends and applies these strategies, resulting in lower efficiency. This suggests that while they might have some awareness of the adaptive measures, their understanding could be limited, or they might not allocate significant resources to carry out these strategies.

Table 5. Effectiveness of adaptation measures

Adaptation strategies	Total	Partially understand and implement	Implementing as a short/long term strategy
Y_1_Crop/livestock switching	3.52	3.38	3.70
Y_2_Intercropping	3.37	3.20	3.62
Y_3_Crop rotation	3.25	3.14	3.46
Y_4_Using improved varieties	3.43	3.38	3.52
Y_5_Adjusting production techniques	3.46	3.35	3.63
Y_6_Changing planting dates	2.89	2.81	3.00
Y_7_Diversify income sources	3.15	3.03	3.30

Note: 5-point Likert scale (1= Ineffective; 2= Low effective; 3= Moderately effective; 4= Fairly effective; 5= Highly effective)
Source: Authors' calculation

Determinants of farmers' adaptation decisions

The study found that the participants had an average of 24.8 years in farming practice. The average farm size in this study area was 1.35 ha, and 38% of households were the membership of farmers association. In addition, 67% and 83% of participants had access to credit/loan and extension service, respectively. The distance from farms to market are various and the mean distance was 7.73 km. The study further shows that 67% of the participants considered the risk of climate change as high (Table 6).

Table 6. Description of independent variables

Variables	Unit	Mean		
		Total (n=200)	Adaptation Measures Adopters (n=157)	Non adopters (n=43)
X1_ Experience	Year	24.77	25.57	21.86
X2_ Farm size	Ha	1.35	1.41	1.14
X3_ Membership	%	38.00	39.00	37.00
X4_ Credit	%	67.00	69.00	56.00
X5_ Extension	%	83.00	85.00	77.00
X6_ Distance	Km	7.73	7.54	8.44
X7_ Risk perception	%	67.00	75.00	37.00

Source: Authors' calculation

An MVP model was used to analyze the determinants of farmer adaptation decisions by using seven predictors. The likelihood ratio test was used to assess the appropriateness of MVP. The result of likelihood ratio test ($Chi^2 = 206.6$, $P < 0.01$) was statistically significant. This implies that the use of MVP was appropriate and had a strong explanatory power. In addition, this study used the Akaike Information Criterion (AIC) to evaluate how well a model fits the data set. For linear regression model, statisticians estimate R^2 and for binary logit/probit or multinominal logit/probit model, they estimate Pseudo R^2 to determine the goodness-of-fit of the models. However, MVP does not have these criteria, so this study used Akaike Test to compare different possible models and identify which one is the most appropriate for the data. The model with the lowest AIC value is the preferred model. Table 7 demonstrates that the model used in this study with 7 explanatory variables, which has the smallest AIC, was the most suitable.

Table 7. Akaike Information Criterion (AIC) of model goodness-of-fit

Models	Log likelihood	AIC
Original model	-673.3196	1500.639
With education model	-668.9233	1505.847
With labor model	-670.4667	1508.933
With education, labor model	-665.9097	1513.819
Without experience model	-680.8266	1501.653
Without farm size model	-686.4402	1512.880
Without membership model	-680.9479	1501.882
Without credit model	-681.0254	1502.051
Without extension model	-680.5099	1500.914
Without distance model	-701.5095	1543.019
Without risk perception model	-682.1205	1504.241

Source: Authors' calculation

Table 8 shows the MVP model coefficients, which reveals the direction of effect of explanatory variables. The coefficient on farming experience has positively signed for all the adaptation strategies. Especially, farming experience significantly encouraged Y_4_Using improved varieties, Y_5_Adjusting production techniques, and Y_6_Changing planting dates. This finding indicates that producers with higher experiences are more likely to adapt to climate change. Farmers with greater farming experiences have more farming management skills, techniques, and better judgement on adaptation to adverse weather situations. Similarly, Nhemachena and Hassan (2007) and Abid *et al.* (2015) described that adopting climate change adaptation practices significantly correlate with farming experiences.

Except for Y_7_Diversify income sources, farm size influences the choice of all remaining strategies in a positive and statistically significant way. This means that the amount of farmland has a positive effect on farmers who are using a climatic change adaptation strategy. The result implies that large landholdings increase the probability of using adaptation methods to cope with global warming. This is consistent with some researches that reported the adoption of new technologies and the size of the farm have a beneficial link (Fosu-Mensah *et al*., 2012; Abid *et al*., 2015; Sunny and Sidana, 2018). Larger landholding farmers are more likely to invest in climate change adaptation methods.

The coefficient of farmers association participation is positively and statistically significant in influencing Y_1_Crop/livestock switching, Y_3_Crop rotation, Y_4_Using improved varieties, Y_5_Adjusting production techniques, and Y_6_Changing planting dates. This means that farmers who participate in farmers association increase the probability of adopting these adaptation measures. This may be the result of farmers' groups sharing of experiences, and ideas on how to increase yields and exchanging information about improved technology, as well as building resilience to climate risks (Onyeneke *et al*., 2019; Marie *et al*., 2020). Therefore, being a part of a farmers group can help farmers increase social learning and knowledge transfer about agriculture and climate change adaptation practices. Boansi *et al*. (2017) also found that membership of these types of groups helps to increase adopting climate risk management strategies.

Access to credit has significantly increased Y_1_Crop/livestock switching, Y_2_Intercropping, Y_5_Adjusting production techniques, and Y_7_Diversify income sources. This is because these adaptation strategies require a certain level of financial investment for implementation. Consequently, farmers with better access to credit are more inclined to utilize these strategies compared to their less affluent counterparts who face challenges in obtaining credit. This result is similar to those from Fosu-Mensah *et al*. (2012), Sunny and Sidana (2018) which also found a positive link between loan access and climate change adaptation. However, when asked more deeply, farmers said that getting a loan still faces difficulties such as procedures and collateral. These findings point to the importance of improved institutional support in encouraging adaptation practices in smallholder farming communities to relieve the negative effects of climate change.

The coefficient of access to extension is positively and statistically significantly related to several adaptation strategies. Extension increases the probability of Y_2_Intercropping, Y_3_Crop rotation, Y_4_Using improved varieties, and Y_5_Adjusting production techniques. This result suggests that these climate change adaptation methods are more likely adopted by producers who have accessed and received extension education. Agricultural extension offers knowledge and information about better farming techniques and technologies, and it could also be a valuable source related to climatic risks and climate change information. Thus, farmers with greater access to the extension services will be more able to obtain information on climate risk management, improved technology and techniques, and climate-smart practices. This corroborates the findings of Elizabeth *et al*. (2009), and Fosu-Mensah, *et al*. (2012) on determinants of climate change adaptation measures applied by farmers. Therefore, farmers' adaptability to the adverse impacts of climate change should be augmented through the provision of frequent support and timely information from extension services.

Distance to the market significantly decreased the likelihood of adopting Y_1_Crop/livestock switching, Y_3_Crop rotation, Y_4_Using improved varieties, Y_5_Adjusting production techniques. This factor determines the ability of farmers to access inputs and production materials like seeds, fertilizers, pesticides, machines, and especially for improved varieties and the materials needed to build the barn. Therefore, the further away farmers are from the market, the less likely they are to be able to obtain the supplies required for farming and climate risk management. Market access also encourages farmers to produce extra food and cash crops that can be easily transported to markets, which boosts their income and enables them to adapt to the effects of climate change. Nhemachena and Hassan (2007), and Abid *et al*. (2015) indicated that farmers face higher cost for transportation and then increase the difficulty level to buy production inputs and to market their agro-products.

The perception of risk is positively and significantly related to use all the adaptation strategies except for Y_6_Changing planting dates. People who consider climate change as a high risk are more likely to take adaptive measures than those who see it as a low risk. Communities at high risk from climate change-related hazards were identified in this study. These communities were typically located on hill land, which was also vulnerable to natural disasters (e.g., landslides, mudslides, soil loss). Azadia *et al*. (2019) argued that if farmers are not percept of the climate risks, they will not respond to them. In addition, the greater the public's understanding of the level of risk they face, the more support to relevant adaptation strategies they provide (Abid *et al*., 2015). Thus, public awareness campaigns in reaction to extreme weather events and global warming, as well as education on post-disaster actions should be offered.

Table 8. Estimates of the multivariate probit model parameters

Independent variables	Y1 Crop/livestock switching	Y2 Intercropping	Y3 Crop rotation	Y4 Using improved varieties	Y5 Adjusting production techniques	Y6 Changing planting dates	Y7 Diversify income sources
X1_ Experience	0.00271	0.0124	0.00665	0.0199**	0.0278***	0.0287***	0.0144
	(0.00956)	(0.00969)	(0.0106)	(0.00903)	(0.00928)	(0.00917)	(0.00952)
X2_ Farm size	0.201**	0.147**	0.302***	0.170***	0.157***	0.202***	0.0423
	(0.0793)	(0.0654)	(0.103)	(0.0561)	(0.061)	(0.068)	(0.0624)
X3_ Membership	0.468**	0.217	0.462*	0.465**	0.351*	0.687***	0.0872
	(0.224)	(0.221)	(0.236)	(0.22)	(0.201)	(0.23)	(0.21)
X4_ Credit	0.106*	0.494**	0.144	0.21	0.642***	0.05	0.409*
	(0.211)	(0.203)	(0.213)	(0.209)	(0.201)	(0.229)	(0.215)
X5_ Extension	0.351	0.603**	0.607**	0.551**	0.579**	0.167	0.157
	(0.291)	(0.268)	(0.272)	(0.272)	(0.241)	(0.29)	(0.274)
X6_ Distance	-0.110***	-0.0119	-0.0992***	-0.0166*	-0.0409**	-0.0438	0.00274
	(0.0218)	(0.0176)	(0.0259)	(0.0182)	(0.0175)	(0.0192)	(0.0176)
X7_ Risk perception	0.868***	0.527**	0.571**	0.584**	0.472**	0.422	0.647***
	(0.228)	(0.236)	(0.238)	(0.253)	(0.237)	(0.27)	(0.243)

Number of obs = 200
Wald chi^2 (49) = 206.67, Prob > chi^2 = 0.0000
Figures in parentheses are z-values.
***Statistically significant at 1% level, **Statistically significant at 5% level, *Statistically significant at 10% level
The number in ( ) means standard errors
Source: Authors' calculation

CONCLUSION AND POLICY IMPLICATION

This study investigates the awareness and adaptation strategies of farmers in Lai Chau province, Vietnam towards climate change, utilizing farm-level data from four districts. The results reveal that a significant number of farmers have acknowledged the adverse impacts of climate change, such as temperature increases, rainfall variations, drought, flash flooding, and landslides. While many attribute these changes to human activities, there are still individuals who believe that agricultural production has minimal or no influence on climate change. Consequently, this lack of awareness has led to excessive use of chemical fertilizers and a neglect of sustainable farming practices. To address this issue, there is a need to enhance farmers' understanding on the causes of climate change and motivate them to combat global warming, as supported by the findings of Azadia *et al*. (2019). Furthermore, a considerable proportion of farmers have experienced the detrimental effects of climate change on their agricultural production, including damage to irrigation systems, reduced productivity and income, and unfavorable working conditions resulting in crop and livestock illnesses. As a result, 78.5% of farmers in Lai Chau have implemented seven adaptation techniques to mitigate the impacts of climate change on their livelihoods, with a preference for employing a combination of strategies rather than relying solely on one approach. The most commonly reported adaptation strategies include intercropping, using improved varieties, crop/livestock switching, and adjusting production techniques. Additionally, farmers are increasingly diversifying their income sources away from agriculture. Because of a lack of qualifications (low educational attainment or a lack of specialized skills), farmers can only do hard work with low incomes, highlighting the necessity of supporting and guiding them in developing agritourism. Agritourism not only provides the additional revenue required to sustain small and mid-scale farms and rural communities but also contributes to environmental preservation (Sustainable Agriculture Research & Education Program, 2017).

Besides, this study identified the key factors influencing farmers' adaptation decision to climate change. The analysis results indicated that farm experience, farm size, farmer association membership, credit access, extension access, distance to market, and risk perception have statistically significant impact on strategies selection. Our findings reveal that an increase in farmland size positively affects farmers' adoption of adaptation measures. Therefore, it is imperative to encourage people to expand their production areas. In Vietnam, the government has identified land accumulation and concentration as playing a crucial role in the development of agriculture. However, the implementation of the "land accumulation" program in Lai Chau and other provinces still faces limitations. Consequently, it is imperative for the government to actively support the implementation of this program. By doing so, Vietnam can effectively prevent land fragmentation and abandonment, thereby ensuring the livelihoods of farmers in the face of climate change. Access to extension and membership of farmers association positively impacts climate change adaptation. This recommends that the government should encourage farmers to join social organizations, as well as farmers association. Besides, there is a need to increase the intensive capacity of trainings on adaptation measures, introduce climate-smart varieties, promote soil conservation practices, and adjust towards the extension service which may become more relevant and accessible to farmers. Another vital factor that helps farmers in adapting to climate change is access to loan facilities. Thus, supporting both formal and informal financial institutions operating to make loans available and increased institutional support to be more accessible are necessary. Distance/Time to the market reduces the uptake of climate adaptation practices of farmers. This suggests that expanding agricultural input markets, improving conditions for economic sectors to supply inputs, and developing and repairing rural roads to improve farmers' access to the market are important. Risk perception positively influences the voluntary adoption of mitigation measures. It is therefore important for the government to develop a risk communication strategy for climate change. Government agencies should provide information regarding climate change scenarios, seasonal variability, and the impacts of climate change so that farmers can make decisions instructed about the best mitigation and adaptation methods available.

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Vu Thi My Hue contributed to the design and implementation of the research. Vu Thi My Hue and Hio-Jung Shin contributed to the analysis of the results. Vu Thi My Hue, Hio-Jung Shin, and Nguyen Tien Da jointly participated in the writing of the manuscript.

COMPETING INTEREST

All the authors declare that there is no competing interest.