Research article

Indigenous knowledge in relation to climate change: adaptation practices used by the Xo Dang people of central Vietnam

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ARTICLE INFO

ABSTRACT

Even though indigenous knowledge (IK) is considered as one of the most effective strategies in response to climate change issues, this form is not being sufficiently integrated into the climate change planning and policy at both local and national levels in Vietnam. This study investigates the role of the traditional agricultural practices of the Xo Dang ethnic minority groups in Central Vietnam and provides insights into the factors that influence farmers to adopt these practices in response to climate change. Primary data was obtained through three focus group discussions and 87 household surveys involving the Xo Dang people through face-to-face semi-structured interviews in the Tra Doc commune, Bac Tra My district, Quang Nam province, Central Vietnam. The binary logistic regression model was used to examine the factors which have influenced the choices made by this community in response to climate change. The results showed that Xo Dang people were highly aware of climate change risks and had, in response, employed their current adaptation practices. The major adaptation strategies implemented by the Xo Dang people included the use of flora and fauna indicators, native plant varieties, the adjustment of planting calendars, irrigation practices, and the application of intercropping. The results indicated that the living years, their monthly farm incomes, and farmer's perceptions of ongoing climate change effects on their environment were the factors that significantly affected farmers' adaptation decisions. Understanding indigenous knowledge plays a fundamental role in the processes of deciding the appropriate adaptation techniques more effectively and making use of human resources. Therefore, policy makers should pay much attention to indigenous knowledge to combat climate change in future national policies and projects.

1. Introduction

Climate change has become an issue of significant concern to smallholder farmers who rely primarily on agricultural activities in Vietnam (McElwee et al., 2010; Oxfam, 2008; Phuong et al., 2017; Thang et al., 2010; United Nations and Oxfam, 2009). According to Huu et al. (2007) and Thao (2017), many farmers in the Mekong River Delta reported that the increasingly negative effects of floods and saline instructions were one of the reasons of the in low annual yields and crop losses. In addition, populations and ecosystems in coastal areas are adversely affected by the changes in climate conditions (Oxfam, 2008; Schmidt-Thomé et al., 2015). In Vietnam, ethnic minorities are uniquely vulnerable to climate change because they are heavily dependent on climate-sensitive natural resources (McElwee et al., 2010). In their research, McElwee et al. (2010) empirically established an evidence of the effect of climate change in Ha Giang province, by examining the costs per household caused by droughts, flash floods, and landslides in 2008 and 2009. Climate change impacts have resulted in reduced crop yields, the decrease in number of arable land, the shortages of foods in ethnic minority groups and the increase in illness of livestock due to cold spell (Delisle and Turner, 2016; Dien et al., 2014; Son et al., 2019). Therefore, the climate change adaptation practices (APs) should be investigated in order to provide the ethnic minorities living in their indigenous landscapes with the effective solutions to adapt their farming practices and lifestyles.

Some recent studies have shown successes regarding Indigenous knowledge (IK) in climate change adaptation from scholars both in Vietnam (Dien et al., 2014; Son et al., 2019; Thao, 2017), and in other regions of the world including Africa, Asia, Australia, North America, etc. (Kangalawe et al., 2011; Kpadonou et al., 2012; Kumar, 2014; McNamara and Westoby, 2011; Nyong et al., 2007). For instance, a study by Dien et al. (2014) showed that changing from monoculture maize farming on hillsides to an inter-cropping selection of drought-tolerant ginger, medicinal plants, and bananas, was an effective method to cope with drought conditions in the Northern mountainous areas of Vietnam. These findings are consistent with the result of the study by Son et al. (2019) conducted in the Bac Kan province in which the Yao ethnic minority developed complex farming systems, cultural practices, and a knowledge base in the way that well-suited to their environments. The case study of the Great Ruaha River Catchment Area in Tanzania is also another example of the effectiveness of IK involving the planting of drought-tolerant crop varieties to cope with drought vulnerability (Kangalawe et al., 2011). Indeed, IK and APs were considered by many researchers as the best option in addressing current and future climate change events (Kangalawe et al., 2011; Kpadonou et al., 2012; Nyong et al., 2007). These practices were originally developed by local communities based on their observations of gradual changes in their natural environments over an extended period of time. The studies of Audefroy and Sánchez (2017) and Paniagua-Zambrana et al. (2014) showed that traditional knowledge of climate change was on a par with scientific knowledge. Hence, the extensive practical knowledge from indigenous groups plays a role in developing effective coping plans and strategies to curb the escalating negative effects of climate change. It is also crucial to draw attention toward the maintenance and restoration of these areas, as they represent critical balancing points within all the various interconnected ecosystems of Vietnam.

A central consideration is that most of the recent studies have focused merely on identifying the IK and APs but have not aimed at discovering which determinant factors and its influences on the local people's decisions in response to climate change (Dien et al., 2014; Kangalawe et al., 2011; Kpadonou et al., 2012; McNamara and Westoby, 2011; Nyong et al., 2007; Son et al., 2019; Thao, 2017). Second, very few studies have studied this research area in the mountainous areas of Central Vietnam (Dien et al., 2014; Son et al., 2019; Trinh et al, 2018). Finally, it was reported that some selected mountainous areas of Central Vietnam severely affected by the ongoing impact of climate change (Quang Nam PPC, 2013). Therefore, in this article, we are focusing on the IK practices of the Xo Dang ethnic minority group in Central Vietnam. We hope to provide insights into the factors that affect farmers' decisions on the employment of these practices in response to climate change, fill a gap in the growing literature on the importance of using traditional agricultural knowledge and practices to help communities adapt to climate change.

2. Methods

2.1. Study area

Tra Doc commune, Bac Tra My district, Quang Nam province, Central Vietnam, locates at 500–1000 m above sea level. This mountainous region is home to nearly 40,000 people, and over 50% of them are ethnic minority groups (Figure 1). With a population of 14,016 people, the Xo Dang people are the largest ethnic minority group living in and around the remote hills and uplands of the province (Bac Tra My Agriculture and Rural Development Office, 2018). These populations are predominantly small-scale farmers who grow rice and maize as their staple crop and cultivate acacia in the midland hills for their primary income sources. Official poverty rates were high, standing at an average of 35% in this upland region, compared to 9.8% countrywide (UNDP, 2018). Some previous reports pointed out that the ethnic minority communities in Vietnam were typically remote, and their livelihoods were significantly natural resource-dependent. In other words, their livelihoods rely heavily on weather and climate conditions for productivity (CARE Vietnam,
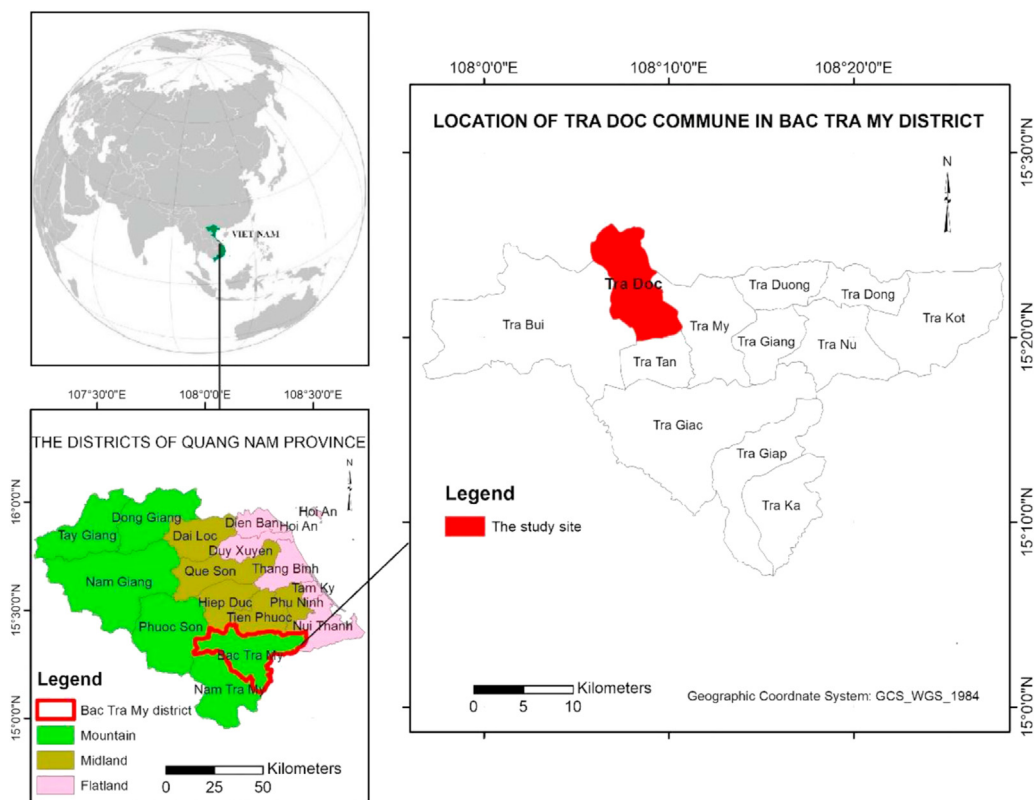

Figure 1. Map of the study area.

2013). Therefore, the communities were particularly vulnerable to natural hazards and extreme weather variability (CARE Vietnam, 2013; Delisle and Turner, 2016; Nga et al., 2019).

Subjected to the humid tropical monsoon climate, this region has a complex terrain in the upland hills (700–800 m). The area is characterized by two distinct seasons: rainy seasons (from September to January) and dry seasons (from February to August). Though this is one of the two largest rainfall regions in the province (525 mm on average), the difference in maximum and minimum rainfall amplitude has been recorded as significant, in some cases, 2,400 mm compared to 200 mm for the same area. High temperatures and humidity were also recorded at 25 °C and 89% on average, respectively. An average of two to three tropical storms hit this area yearly between September and November. Due to such complex terrain and climate, agricultural activities are frequently affected by natural disasters. The variability and intensity of local weather events, including flooding in the mid-low land areas, soil erosion, landslides in the uplands, intense cold, and drought, make it additional challenging for agricultural production.

The Xo Dang ethnic minority belongs to the Mon-Khmer, who have settled in the Annamese Cordillera (Truong Son) and Central Highlands of Vietnam (Van, 2001). Largely as a result of the remote location of the Xo Dang people and the uniqueness of their culture, the inhabitants have also faced being unfairly framed as cognitively backward concerning the more general modern societal values of the majority of Vietnam (Delisle and Turner, 2016). A report of UNDP (2018) on Multidimensional Poverty in Vietnam claimed that the Xo Dang people recognized as one of the three most vulnerable ethnic groups (together with the Hmong and Gia Rai groups). The Xo Dang people require increasing support because of high poverty rates and slow poverty reduction relative to other ethnic groups (UNDP, 2018). Furthermore, Xo Dang does not have legal rights to their lands (Chuong et al., 2020). Since moving to new areas as a provincial resettlement program in 1976, they were assigned land to cultivate and forbidden to practice shifting cultivation. These displacements often resulted in decreased incomes and food shortages. It has led the Xo Dang people into being routinely marginalized, both economically, politically, and socially, especially in relation to the neighboring Kinh people (World Bank, 2009).

2.2. Research methods

This study used both qualitative and quantitative methods. We employed some of the methodologies for a gathering of information are meetings at the district level (n = 11), focus group discussions (FGDs) (n = 3), in-depth interviews with key members of the community (n = 3), se-structured interviews (n = 87), and participant observation (Table 1).

In addition to the aforementioned research method, we gathered further information augmented by the insights, assumptions, and experiences of scientists, local social leaders, resource managers, published and unpublished literature, and other various information sources. Overall, data collection summarized in the following Figure 2.

2.2.1. Pilot trips and preparation for fieldwork

Two pilot field trips were conducted in January 2019. Each includes meetings with government offices, non-government stakeholders, and research institutions to obtain an overview of socio-economic in the Bac Tra My district. Secondary data, including various statistical and annual reports, weather data (rainfall, temperature, droughts, etc.), and socio-economic development from 2010 to 2018, was also recorded via these trips. Such empirical information subsequently enabled us to form research ideas and case studies better.

2.2.2. District meeting

A meeting was organized with 11 key local area participants at the district level. This group was comprised of the following members: one from the people's committee of Bac Tra My district, three from the Agriculture and Rural Development Office, two from the Natural Resources and Environment Office, two representatives of the Farmer's Union, and three from the Agricultural Extension Office. The main questions were used to discover vast topics related to climate-related agricultural production, vulnerable regions due to climate risks and their impact, and farmer capacities to deal with climate change. Through this meeting, the Tra Doc commune was selected as a primary study site for three main reasons: (1) the local livelihoods are firmly reliant on agriculture; (2) it is the most vulnerable commune to climate risk, especially in droughts and storms in the Bac Tra My district; (3) most local people have long experience and cooperation to each other in agricultural cultivation.

2.2.3. Focus group discussions (FGDs)

In this study, three FGDs were organized to gauge village group dynamics. They were to acquire information, cross-check information, and clarify information collected by previous sources (pilot trips, district meetings, secondary data). Each FGD was conducted with seven key informants, aged from 35 to 60 years old. Although each FGD comprised both male and female participants, their views were uniform. The participants are knowledgeable people with long-term farming experiences such as village heads, elders, patriarchs. Therefore, when being asked about issues related to their strengths, they did not hesitate to share. Furthermore, during these processes, the facilitator used the voting method to unify information among the groups to ensure that the information is accurate. The first FGD group was carried out at the community level to identify potential secondary influences within the case study in February 2019. This study included the observation of contemporary cultural norms, as well as socio-economic and environmental influences according to historical timeline events. After one month of these discussions, a second phase of the study was initiated to elicit the group's observation on similar themes. The second stage included more personal interviews. It aimed to determine individual study group members' perceptions and climate change impact on their farming systems. The final FGD took approximately two hours to determine precisely how local people apply their IK.

2.2.4. In-depth interviews

Three in-depth interviews were conducted with local representatives of various social and economic groups, especially from the Department of Agriculture and Rural Development (DARD) of Quang Nam province. These were to explore various topics related to climate-related agricultural production, weather extremes, climate change impact, and indigenous farming systems' changes to adapt to climate change. The face-to-face interviews were conducted by using a structured guide. Each interview spent about one hour.

Table 1. Description of the data collection.

No	Methods	Number of participants
1	Meetings at the district level	11
2	Focus group discussions (FGDs)	3
3	In-depth interviews with key members of the community	3
4	Semi-structured interviews	87
5	Participant observation	-

2.2.5. Semi-structured interview

After collecting and classifying information and data from the in-depth interviews, a semi-structured questionnaire was designed for household interviews. In addition to the closed-ended questions, the study also included a few open-ended questions to allow interviewees to explain their answers in greater detail, especially those related to the Xo Dang's cultural practices in agriculture, and the impact of climate change on farmer's agricultural systems. A total of 87 households were selected for the interviews at Tra Doc commune, Bac Tra My district. The interviews were carried out during August 2019. The criteria for choosing the households for the survey included being members of the Xo Dang ethnic community, having agricultural land within the area, being directly involved in, and having at least ten years of experience in agricultural production. These criteria were listed based on discussions of village heads and staff of agricultural commune officials. The sample size was calculated according to the following formula by Slovin (Asaduzzaman et al., 2017).

$$n = \frac{N}{1 + N*e^2} = \frac{695}{1 + 695*0.1^2} = 87.4 \ (87 \ households) \tag{1}$$

where n is the sample size; N is the total number of households in the study area that met three criteria, as mentioned above, and e is a margin of error (10%).

2.2.6. Participant observation

Because these tribal people are living in peripheral regions, and are habitually shy when interacting with 'outsiders', the researchers were very conscious to facilitate a respectful and amicable rapport with these respondents. This was viewed as a matter of appropriateness, which encourages the participants to share their opinions on sensitive topics, and thus to gain insights into the Xo Dang people's daily activities and their way of thinking. This conscientious approach helped the researchers to establish open communication with the study groups. As a result, helpful research insights were gained regarding the impacts of various climate hazards on their agricultural farming systems.

2.2.7. Weather data collection

Quantitative data including rainfall and temperature data for the period 1978–2018 was used to validate climate change and variability. The data was previously recorded at Tra My station and sourced from the Mid Central Hydro-Meteorological Station (MCHMS).

2.2.8. Data analysis method

In this study, a binary logistic regression (BLR) model was used to examine the factors influencing whether to apply APs in response to climate change by the Xo Dang people in the study area (Agresti, 1996; Ho, 2011). The reason for applying this model was defined as follows:

$$Ln\left[\frac{P}{1-P}\right] = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \ldots + \beta_k x_k \tag{2}$$

In this expression,

$\left[\frac{P}{1-P}\right]$ is the odds ratio.

P is the probability of Xo Dang people in applying APs based on IK.
$1 - P$ denotes the probability of not applying APs based on IK.
β_0 is the intercept.
$x_1, x_2, \ldots,$ and x_k are the independent variables.
$\beta_1, \beta_2, \ldots,$ and β_k are partial regression coefficients.

APs based on IK is the dependent variable (0 = no, 1 = yes) and we designated 11 independent variables, as seen in Table 2.

Data related to weather patterns was collected from the MCHMS, and then was analyzed in combination with local people's perceptions by using Excel (2016) software. Quantitative data collected from semi-structured interviews was processed using the computer-based software called Statistical Package for Social Sciences (SPSS). Qualitative data was interpreted and manually processed by using thematic analysis.

All of the above methods were fully ensure the ethical regulations of research. All of stages interview processing is monitored by Hue University and Village Management Board of Tra Doc commune. All of participants have consented of the interviewing and allow for using their opinions in the paper.
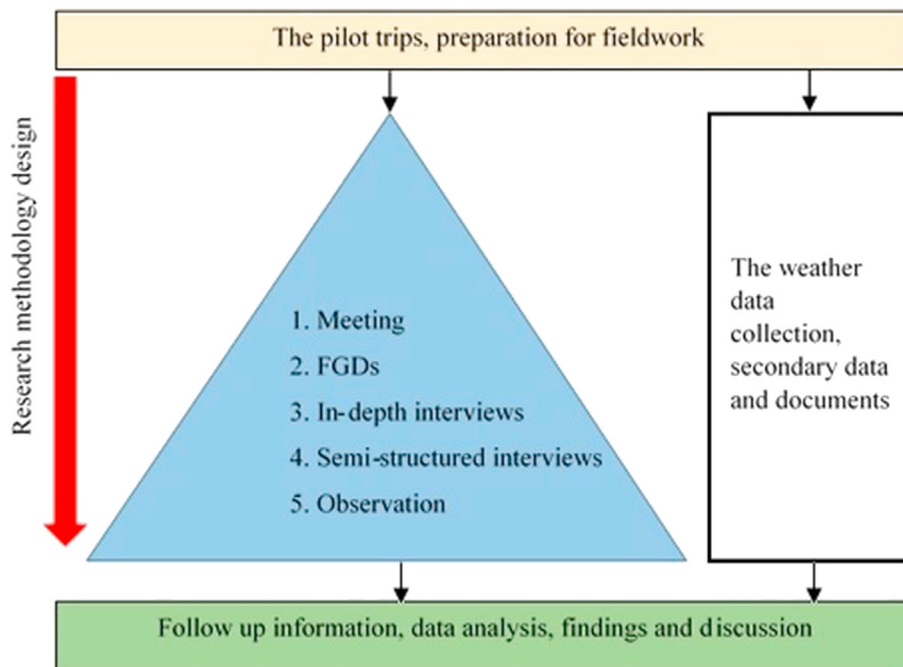

Figure 2. Diagram of applied methodology.

Table 2. Description of predictor variables for a binary logistic regression model.

Variable	Description	Expected sign
x_1	Gender of respondent (=1 if male and 0 if not)	+
x_2	Age of respondent (continuous)	+
x_3	Living years (continuous)	+
x_4	Education of respondent (=1 if literate and 0 if not)	-
x_5	Type of household's respondent (=1 if poor and 0 if not)	-
x_6	Household size (continuous)	+
x_7	Number of labors working in farming (continuous)	+
x_8	Farm-monthly income (continuous)	+
x_9	Income diversity (=1 if income diversity and 0 if not)	+
x_{10}	Land size (continuous)	+
x_{11}	Perception of climate change (=1 if perceive climate change and 0 if not)	+

3. Results

3.1. Local communities' perception of climate variability

To answer the question of their opinions on the climate change in the last years, most of the participants agreed that variability had become more extreme and more erratic within recent years (Figure 3). Nearly all farmers reported that there are three trends in seasonal climate change. While the frequency of floods, storms, rainfall, soil erosion and landslides tended to decrease, the average temperature and the number of droughts in the Tra Doc commune increased, according to respectively 63.09% and 91.42% of the respondents. The second trend showed that droughts in the area was increasing both in terms of intensity and frequency. As part of our survey involving individual households, it was demonstrated that 27.38% and 22.61% of the respondents agreed that droughts tended to increase considerably, while less than 12% of them suggested a decrease. Although the frequency of storms, floods, soil erosion, and landslides tended to decrease over the past ten years, these events were more intense when they occurred and their impact was more extreme. For example, over 60% of households reported that the floods' intensity was stronger and unpredictable than previously.

Similarly, local people often mentioned the increase in the intensity, frequency, and duration of droughts. The climatic events adversely impacted on their livelihoods and daily activities. They also reported that although floods, heavy rain, landslides, and soil erosion were greatly affecting households during the period preceding 2017, their impact had appeared slightly lessened in the last two years. It was important to note here that storms usually occurred every two years, but the intensity of these storms was being noted as becoming increasingly more robust than the previous ones. 40% of the respondents said that the storms were stronger, 20% chose normal and the rest agreed to a slight decrease. In the interviews, the farmers often cited the typhoon Wipha (called storm No.3 in Vietnamese), occurred in 2015 as an example of erratic changes in extreme weather events' distribution and nature.

Meteorological data substantiated farmers' perception that there had been an increase in temperature. According to the (The Mid Central Hydro-Meteorological Station (2019)), the Bac Tra My district did endure higher mean temperatures and an significant upward trend of recorded annual mean temperatures over the forty years from 1978 to 2018 (Figure 4). The data showed that the average annual temperatures increased by 0.46 °C during the forty years, approximately 0.12 °C per ten years, which was 0.02 °C higher than the national slope of temperature increase throughout Vietnam (MONRE, 2016). Compared to a report by IPCC (2014), the global surface temperature data showed a warming of 0.85 °C from 1880 to 2012. It means that temperatures increased by 0.06 °C per decade. The trend of increasing temperature in the area of the study was faster than the national and global averages. According to this formula, the average temperature is forecast to increase by 1 °C, and correspondingly to reach to 26 °C in the next fifty years.

The trend analysis of annual rainfall in the case study over the past forty years also indicated that the local people's perception is relatively consistent with meteorological data. Accordingly, the average annual rainfall recorded a slight increase (Figure 5a), and was high (at 4,000 mm on average), compared with the average of 1,500–2,000 mm over the whole country (GOV, 2020). Moreover, the rainfall data was seen as abnormal in terms of timing and distribution. During forty years, the highest rainfall was more than 7,300 mm in 1996, while the lowest average rainfall was recorded in 2012, at 2,421 mm. Most recently, the average rainfall significantly decreased in 2018 compared to the previous three years. More importantly, while rainfall incidence was perceived to dramatically increased in rainy seasons, rains were rarer in dry seasons (from February to August). The average annual rainfall tended to decrease significantly in May, June, and July (Figure 5b). The number of days without rain in the dry months tended to increase rapidly, especially in May and June (Figure 6). The number of non-rainy days in May increased by 14 days, from 7 days in 1978 to 21 days for forty years. There were more than 22 days without rain in February, March, June, and August of 2018.
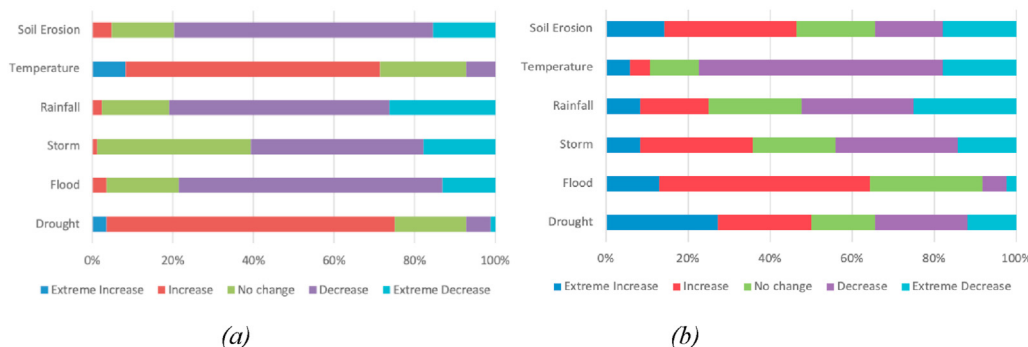

(a) *(b)*

Figure 3. The farmers' awareness of the frequency (a) and intensity (b) of climate risks during the past ten years in the Tra Doc commune.

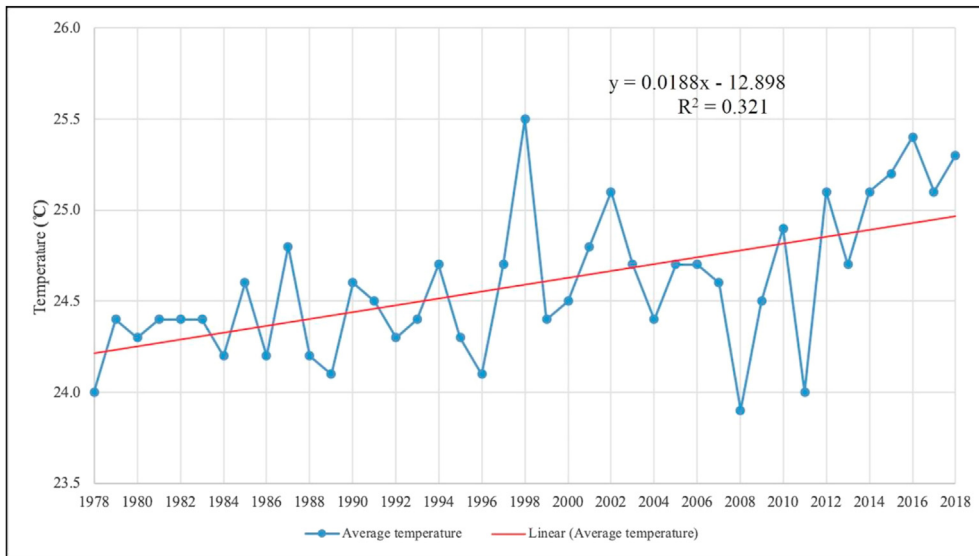**Figure 4.** Annual temperature and linear trend in Bac Tra My district during the period between 1978-2018.
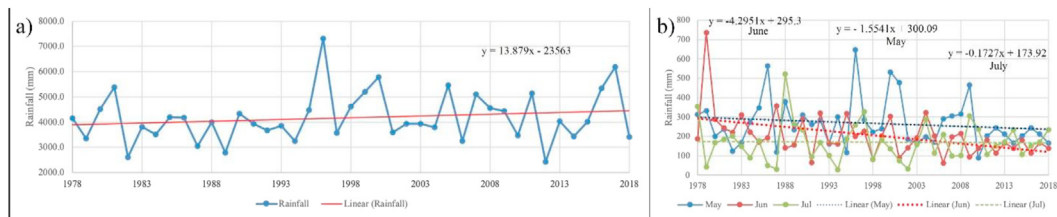

Figure 5. Annual rainfall series (a) and linear trend of rainfall during three months of dry seasons (b) in Bac Tra My district in the period of 1978–2018.
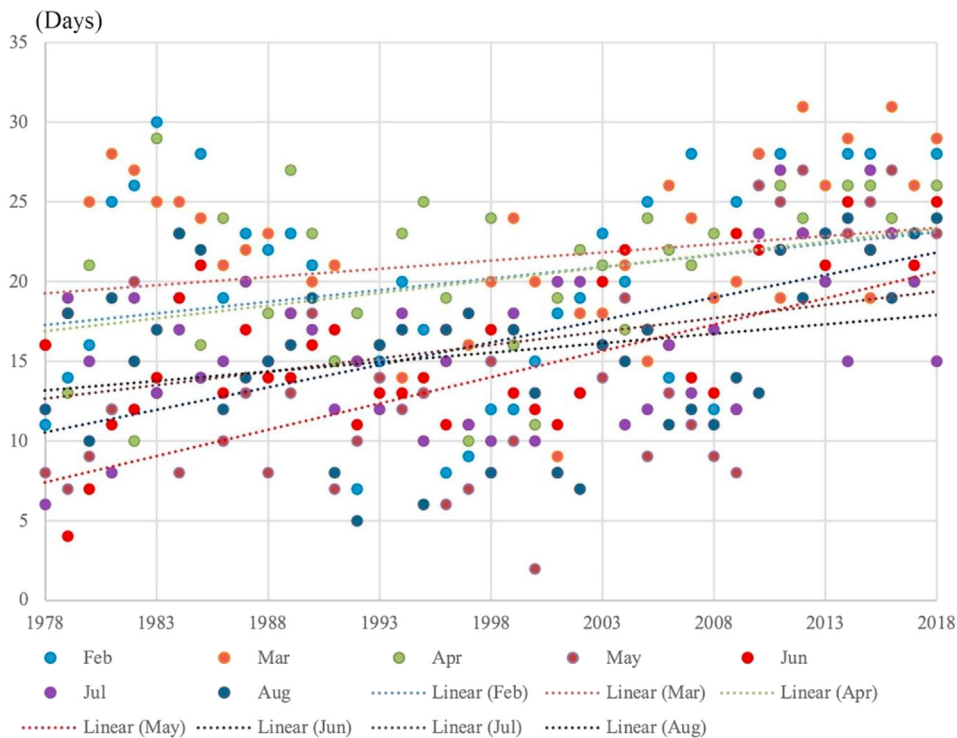

Figure 6. Total number of days without rain and linear trend in dry seasons in Bac Tra My district during the period from 1978 to 2018.

The observed scientific data reported recent changes in the incidence and pattern of temperature, rainfall, and the frequency and severity of Bac Tra My district's extreme climate events. Because heavy rain and distributed rainfall are concentrated simultaneously, flooding in the midlands and soil erosion in mountainous areas was thought to be more severe from September to December. Similarly, droughts were more extreme in dry seasons. Currently, dry seasons are also perceived to last longer than before. Particularly, the months of May and June which is the critical time of no rainfall, resulting in a lack of water resources accessible for agricultural use. The combination of low rainfall and increased amount of non-rainy days contributed to serious drought conditions in the area of the study. Such changes have been more frequent and severe, causing much damage to humans, property, and agricultural production.

3.2. The transition from awareness to APs in responding to climate change

3.2.1. Understanding local farming systems

In the distant past, rotating certain areas of crop cultivation had been their traditional agricultural modality of production. In this, farmers practiced slash and burn techniques and the processed farming areas were used for crop cultivation for a subsequent two- or three-year period. Once used in this way, these areas were then left fallow for eight to ten years to resume the tree cover and to recover the fertility of the soil. In practicing this modality, each Xo Dang household had occupied five to seven plots and utilized the custom laws to protect the trees and avoid conflicts. It was similar for other ethnic minorities (Co Tu, Pa Co, and Ta Oi) belonging to the Mon-Khmer (Mai, 2016; Minh et al., 2019).

However, after the country unified in 1975, the Vietnamese government nationalized all forestland. Therefore, it subsequently prohibited the local people from practicing their traditional techniques of crop cultivation and land rotation. At this time the forestland allocation policies also underwent similar alterations. These changes, together with the government-supported market development of pulpwood and woodchips in the two following decades, have made local people convert dry-rice fields to acacia plantations. As a result of this policy, the local people experienced a variety of negative effects on their livelihoods. However, at the same time, the land use and local agriculture systems of the Xo Dang people has also been adapted in other ways. Because of their long history in these areas in general, the Xo Dang people have accumulated a huge amount of IK on land use and crop farming measures that are suitable for

the local environment. At present, thus, agricultural systems of the Xo Dang communities are the combination between the traditional features and measures to meet the requirements of modern changes in agricultural practices (Figure 7).

3.2.1.1. Cropland areas. "Wet-rice" is the local people's main cereal. It is cultivated along the available and irrigated flat land areas such as rivers, streams, foothills, and valleys. Notably, the method of wet rice cultivation has blended into the folklore and has been considered as a treasure within the traditional cultural practices of the Xo Dang people. The local people do not use fertilizers, pesticides, or herbicides, and only apply a very basic soil preparation method for wet rice cultivation. Wet rice yields two crops per year, which ensures the self-sufficiency of the population and creates their annual reserve. They also use the techniques of intercropping including the planting of maize, beans, and vegetables around the rice paddies.

3.2.1.2. Ghost forests and residential areas. The Xo Dang's settlements are built higher up on the hillsides, and not on low-lying areas like the settlements of other ethnic groups in the region. Interspersed among the Xo Dang villages there exists small forest plots called "Rừng ma". These are also known also as ghost forests and are protected by long-standing traditional regulations. These forest plots are about two hectares and are located close to a neighboring village. The Xo Dang people have never practiced slash and burn cultivation in the ghost forests. They are associated with the customs, culture, and spiritual beliefs of the Xo Dang people. Ghost forests also have a practical role in conserving water sources for communities during drought seasons. Within the villages themselves, the Xo Dang people also cultivate personal food sources in home gardens. In these plots, they plant local cinnamon, jackfruit, areca palm, and betel leaves, among others. As well as planting fruit trees, the Xo Dang intersperse some staple food plants such as cassava and corn.

3.2.1.3. Production forest areas. Plantations within the surrounding forests is a new practice for local people, and has been formally introduced since Decision 48/2007/QD-UBND was issued by the Quang Nam Provincial People's Committee (Quang Nam PPC, 2007). Accordingly, the local people are allocated forest land to grow perennial industrial crops. The results showed that the total land-use area was large, with an average of 2.9 ha per household, 80% of which (2.34 ha) was forest planting. This

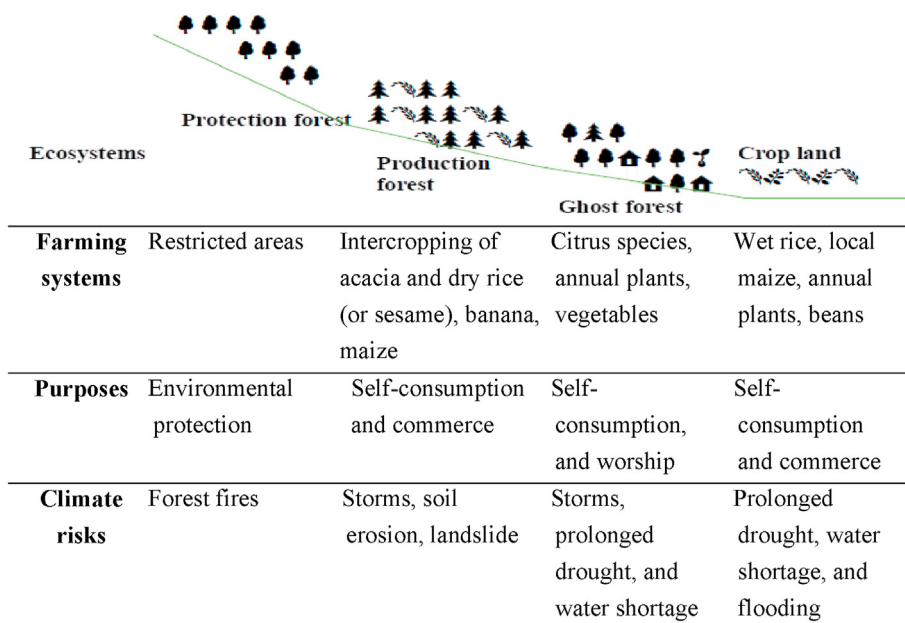|	Protection forest	Production forest	Ghost forest	Crop land
Farming systems	Restricted areas	Intercropping of acacia and dry rice (or sesame), banana, maize	Citrus species, annual plants, vegetables	Wet rice, local maize, annual plants, beans
Purposes	Environmental protection	Self-consumption and commerce	Self-consumption, and worship	Self-consumption and commerce
Climate risks	Forest fires	Storms, soil erosion, landslide	Storms, prolonged drought, and water shortage	Prolonged drought, water shortage, and flooding

Figure 7. Farming systems encompassing diverse terrains within the Tra Doc commune.

is largely applied to the plantation of Acacia. Many local people have intercropped dry rice with acacia in the first two years of acacia rotation. Near the streams, they practiced dry rice cultivation mixed with beans or sesame. It is interesting to note that the cultivation of rice is interwoven into the folklore and cultural identity of these people, including in their literature, art forms, and religion (Van, 2001). Therefore, the cultivation of dry rice is a central consideration in any agricultural practices of the Xo Dang communities. Thus, even as local people convert swidden land to acacia plantations, they have continued to intercrop dry rice for worship among the new plantations.

3.2.1.4. Protection forest. In Figure 7, the forests at a top of the watersheds are maintained as primary forests to preserve a general ecological balance within the area. According to forest classification of Directive 38/2005/CT-TTg (Prime Minister, 2005), they are considered as protection forests with the function of protecting the environment and human activities in the lower areas, and are allocated to Protection Forest Management Board. The Xo Dang people are aware that they have no right to cultivate in this area. However, some of them recognized that they have still encroached that forestland for cultivation. Also, forest fires happen as an indirect impact of climate risk due to prolonged drought.

3.2.2. Climate change adaptation strategies in agricultural cultivation

3.2.2.1. Local IK in forecasting weather. As previously mentioned, most of the Xo Dang people's settlements are in remote locations due to their cultural beliefs and the challenging variations of the terrain. The result is that their lifestyles and techniques of farming do not rely heavily on modern scientific technology. This means that they still rely significantly on their experiences based on personal physical observation of the environment. These ways of observing their natural world and harmonious ways of existing within this world has been passed along from generation to generation throughout time using an oral tradition. For weather forecasting, local people have developed personal techniques involving the keen observation of various faunal and floral movements, as well as being uniquely attuned to other physical changes in their surroundings, recorded in Table 3.

For example, if banana buds are smaller and longer than usual, it indicates the coming of windstorms. The observation of the type of wet grass from the ground also strongly indicates the coming of rain. Also, the timing of the sprouting and flowering of certain trees such as palm trees can be an indicator of a coming drought. And the abundance or lack of "Tråo" (*Cayratia japonica*) leaves might indicate the impending floods.

Moreover, the Xo Dang people can predict the occurrence of windstorms, rain, droughts, or floods by what they observe in the behavior of certain animals in their habitat. As the "Hoàng Yến" birds (*Serinus canaria*) have been observed to fly back from the sea to the mountain direction, the windstorm occurs. The croaking of frogs also signifies the coming of rain. The patterns of ants or the flight patterns of dragonflies may indicate the coming rain. The disappearance of earthworms on the ground for a long time also strongly indicates the coming of drought.

During our interviews, the people also shared the observation such as that if the beehives are situated in a low position in a given season, it is signal of a flooding upcoming. In addition to flora/fauna as an indicator, locals also rely on the personal observation of characteristics in the sky in order to determine the weather forecast. The observation is quite reliable and predictive. For instance, if the stars are not visible at night, it indicates the offset of rains. By contrast, if the stars are plentiful, it is an indication of the coming of sunny days. Dark clouds are considered to indicate heavy rainfall within a few hours.

It is worth considering that the forecasting of weather is of particular importance at the time of post-harvest. Local people often observe the sky and natural phenomena very closely in order to promptly transport staple crops back from the fields. Given the importance of successful harvest to their livelihoods, they have developed a symbiotic and responsive relationship with their natural environments as a means of necessity. The key to indigenous climate change adapting strategies lies in effective weather forecasting. It helped them to plan their activities for at least few days in advance. This observation is extremely important when the weather forecast of professional agencies is not always updated or do not accurate for each climate sub-region.

3.2.2.2. Various indigenous strategies for adapting to climate change were identified throughout the study. Integrating the IK in the farming systems. The Xo Dang people have applied four main IK APs due to changing weather patterns. These are as follows: (1) using native plant varieties, (2) adjusting planting calendars, (3) irrigation practices, and (4) intercropping (see Table 4 for details). There is a range of reasons for these adjustments. For example, farmers are required to cultivate indigenous crops and varieties that are more resistant to harsh weather conditions such as drought and soil erosion. The seeding of "Pế Tru" dry rice was recognized as a drought-tolerant variety. According to some farmers in the interviews, i.e., "Pế Tru" is easy to grow well in extreme weather, especially in drought seasons due to the crops' minimal water requirements. Other crops that work well in these conditions are bananas (*Musa sp)*, "Chuối mốc"; cassava (*Manihot esculenta)* "Canh nông", and "Tråo" (*Cayratia japonica*). In contrast, they also grow Cinnamon (*Calami similiter ducentos quinquaginta),* "Lon hớt" and Areca trees, "Lon cau" which are known for standing under heavy rain conditions. It was explained that these two types of trees have well-developed root systems that deeply extend into the soil and thus prevent erosion. 73.56% of the respondents applied native plant varieties as the APs under harsh weather conditions.

Local people have adjusted the seasonal calendar for the planting of winter-spring rice by delaying the planting season by two weeks in the rainy season to avoid future drought conditions. Given the annual fluctuations, another technique is the planting of short-term varieties of rice which can be harvested one month earlier than standard crops. Another practice the farmers employ depending on the yearly weather conditions is to plant crops earlier than usual in order to reduce the long-term effects of drought. In another way, a household cultivates one crop from November to February instead of two crops. Crops such as acacia might

Table 3. The use of flora and fauna as indicators of changes in weather.

The weather events	Flora as an indicator	Fauna as an indicator
Windstorm	Can be predicted by observance of plant manifestations such as the alternating size of banana buds, moisture content of grasses, insect, and animal behavior.	Bird flight patterns, i.e., "Hoàng Yến" flies from the sea to the direction of the mountains is an indication of a coming storm.
Rain	Humidity or fluctuation of rain patterns and intensity.	The movement patterns of ants: i.e. - ascending or descending surfaces -seeking shelter within structures Can be indicated heavy rains occur within two to three days.
Drought	If the local Palm trees (*Arecaceae*) are seen to bear more t han a typical amount of fruit, droughts over the next year are to be prevised.	If earthworms are not presented near the ground surface for an extended period, droughts can be expected.
Flood	The decreasing luster of "Tråo" (*Cayratia japonica*) leaves indicates impending floods.	If beehives are situated in a low position, it indicates heavy rains or flooding.

(Source: Household survey, 2019).

Table 4. APs used in individual farming systems.

No	APs	Percentage (%)	Description
1	Using native plant varieties	73.56	- Drought tolerance: dry rice, banana, cassava, "Trảo" and maize - Erosion adaptation: Cinnamon and areca
2	Adjusting planting calendars	19.54	- Delay planting (two-weeks) in the rainy season. - Early planting or harvesting. - Shortening growing season.
3	Irrigation practices	9.19	- Making small tanks or small-scale irrigation systems to cope with drought. - Changing the timing of irrigation.
4	Intercropping	42.53	- Dry rice is intercropped with Acacia under drought conditions. - Planting Banana and Areca surround paddy field to increase the moisture of the soil.

(Source: Household survey, 2019).

be introduced two times during the year. This is done using the "seedling method" in dry seasons, and the "transplanting method" in rainy seasons. This replaces planting one time per year as being applied in the past. Notably, 42.53% of the respondents argued that they often use inter-cropping as the best method to increase crop yields and avoid diseases. Inter-cropping between acacia and native dry rice or between bananas and annual crops are typical examples.

3.2.2.3. Factors influencing farmers' decision in using the APs. The descriptive variables of the BLR model showed that a correct prediction rate of 83.9%. This ratio was high and provided reliable proof with the overall model (Table 5). Also, the value of Nagelkerke's R^2 (0.321) means that these 11 variable factors explained 32.1 percent of the probability that farmers would apply indigenous practices.

Among the 11 independent variables, there are three significant factors that have a positive effect in relation to IK APs in responding to climate change. These factors are living years, farm-monthly income, and perception of climate change with $p = 0.094$, $p = 0.044$ and $p = 0.047$, respectively. Among these three factors, the perception of climate change has the highest significant effect on the probability that farmers apply IK in responding to climate change ($\beta = 4.037$). The second important factor is farm-monthly income ($\beta = 1.035$). It is a significant point that the households with high farm-monthly income were more likely to apply IK as compared with those who have low farm-monthly income. Similarly, the more a household is disposed to perceiving climate change, the more likely that household is inclined to apply IK as a coping strategy. Also, the longer the living yearsare, the more likely a household was to apply IK.

However, the rest of the factors did not show any significant effects on the likelihood of applying IK APs in responding to climate change.

The omnibus test showed Sig. <0.1 (90% confidence), indicating the chosen model was suitable to apply in this circumstance.

4. Discussion

4.1. Understanding farmers' APs in responding to climate change

Indigenous people are among the most vulnerable to the impact of climate change due to three main factors, such as their high dependence on climate-sensitive natural resources, their habitation within fragile ecosystems, and a long history of social, economic and political marginalization (Hiwasaki et al., 2014; Macchi et al., 2008; Oliver-Smith, 2009; McElwee et al., 2010). We found that the current trends in climate change have significant negative impact on the agricultural systems that the Xo Dang people depend on for existence. Thus, the Xo Dang farmers have taken measures to cope with their impact, mainly based on their long-standing traditional ways of observing the natural environment in which they live. Our findings showed that there were two main notable features of the Xo Dang people's farming systems including the use of indigenous species and intercropping. Although farmers were encouraged not to grow certain species according to the existing government policy guidelines due to low yields, they have continued to maintain various indigenous plants including dry rice, banana, cassava, cinnamon, and acacia. Farmers reported that these crops were varieties that are resistant to pests, diseases and highly drought-tolerant. Therefore, they possibly adapt to the local environmental characteristics and to be more

Table 5. Determinant factors influencing farmers' decision in using the APs.

No	Variables	β	SE	Wald	Significant (p)	Exp (β)
1	Gender	- 0.506	0.846	0.358	0.550	0.603
2	Age	-0.030	0.038	0.626	0.429	0.970
3	**Living years (years)**	**0.052**	**0.031**	**2.797**	**0.094***	**1.054**
4	Education (years)	0.014	0.382	0.001	0.970	1.015
5	Type of household	0.171	1.095	0.024	0.876	1.187
6	Household size	-0.286	0.308	0.863	0.353	0.751
7	Farmer members	-1.782	1.287	0.192	0.166	0,168
8	**Farm-monthly income**	**1.035**	**0.513**	**4.071**	**0.044***	**2.816**
9	Income diversity	0.434	0.853	0.259	0.611	1.544
10	Land size (hectares)	0.245	0.231	1.127	0.288	1.278
11	**Perception of climate change**	**4.037**	**2.032**	**3.948**	**0.047***	**56.661**
12	Model constant	-3.242	3.074	1.112	0.292	0.039
13	Model Nagelkerke's R^2	0.321				
14	Model correct prediction	83.9				
15	Number of households	87				

Note: The number of households is 87; β is the estimated coefficient, SE is the standard error, Wald is Wald Chi-Squared Test, p is a probability, and R is the coefficient of determinations; *p ≤ 0.1, without asterisks value are non-significant at p > 0.1.
Bold signifies significant value when p <= 0.1.
(Source: Household survey, 2019).

suitable for the culture of local people (Chuong et al., 2020; Son et al., 2019). Since the Xo Dang people are self-reliant and independent on the external sources of revenue, the farmers also maintain storage of seeds and seedlings to help local people to reduce their annual agricultural expenses. This is extremely meaningful to poor communities (Pardo-de-Santayana & Macía, 2015).

Maintaining the ghost forest of the Xo Dang people as a spiritual factor for keeping graves, but they are aware that field plots close to the ghost forest may develop better than others during the drought period. Similarly in many places, sandy forests of coastal communities in Central Vietnam have played an essential role as a place for ancestor graves of local communities and water sources in dry seasons (Mai, 2013). Sacred graves of local people groups in North-India play a vital role in water and soil conservation (Kandari et al., 2014).

It is a central observation that while Xo Dang farmers continue to use intercropping as their main adaptive farming method, other groups in the area have turned to monoculture for profit and market demands. For instance, Mai's study (2016) observed that cassava monocultures on the hillsides are cultivated by the Co Tu ethnic group in Central Vietnam. There is an intensification of maize (*Zea mays*) and cassava (*Manihot esculenta*) monoculture on steep slopes in North-western of Vietnam (Fröhlich et al., 2013; Zeller et al., 2013).

In opposition to the trend of monoculture, the Xo Dang people have noted that the diversity of crops planted in their fields helps meet their various needs in their isolated locations. Also, their practice of intercropping with a variety of complementary crops helps them to avoid the risk of crop failure due to floods or droughts and also helps them to mitigates soil depletion and landslides. Indeed, intercropping is essential in maintaining a balanced and symbiotic relationship between the varied and numerous interconnected aspects of the overall ecosystem in which they live. Moreover, the study findings showed that IK of the Xo Dang people within the Tra Doc commune of Bac Tra My district had been shaped and modified by continuous farm level experimentation over many generations. Unlike some other groups in the area, the Xo Dang people have adhered to their traditional IK in their farming systems. These systems have been developed and used over a long period of time by local people and in accordance with harmonious co-existence within their natural environments. However, it is worth noting that although their APs' are passed down through generations, some have been altered over time in order to adapt to their modern conditions. For example, the intercropping method between dry rice and acacia has only been used by farmers for the last five years. As many scholars have noted, it is important not to lose these traditional agricultural practices that have been maintained throughout generations, due to modern socio-economic conditions (Chuong et al., 2020; Mai, 2016; Son et al., 2019).

4.2. Integrating diverse knowledge to improve APs efficiency

The findings in this study showed that though the ethnic minority communities were often framed as victims and as having limited capacity, the Xo Dang people were highly aware of the recent negative climatic changes. Therefore, they are conscientious in their commitment to maintaining their IK. This is consistent with the numerous recent research papers in regard to various local communities' APs in responding to climate change. Of course, this phenomenon does not only exist within Vietnam (Hoa et al., 2014; Shaw, 2006; Son et al., 2019), but also applies to similar communities around the world (Below et al., 2010; Ifejika Speranza et al., 2010; Tolo et al., 2014). The current study attempts to understand the determinants of certain farmers' choices in coping with and adapting to significant changes in the climactic patterns of their unique locations. A better understanding of the factors that shape farmers' adaptations to climate change is critical in identifying vulnerable entities in this group and developing well-targeted strategies to counteract these changes (Smit and Wandel, 2006). The choice in the use of APs ultimately depends on specific endowments within individual households (Fagariba et al., 2018; Hoa et al., 2019; Trinh et al., 2018). In

this study, we have identified three main significant factors in motivating the use of IK, the first being living years, the second being the monthly farm income of a given household, and the final factor being each individual's perception of climate change.

Regarding the first factor, the longer a household has settled, the better they would understand their local environment. After long time resettlement in one place, the local people have been familiar with the environment and are more likely to apply their IK which is suitable for the local environment. Almas and Conway (2017) argued that residents who had lived in a specific area longer, had a greater knowledge of their environment.

Therefore, the Xo Dang people can understand and be aware change the behavior of animals and plant indicators closely relate to the abnormal change of weather. In fact, the use of fauna and flora for weather forecast have been applied by many indigenous groups or small farmers over the world, especially who have weak connection to scientific information on weather forecast. In Africa, communities of rural Tanzania or farmers, pastoralists, and indigenous experts in East Africa have observed appearances and behavior of certain animals, birds, insects and plants to forecast weather (Kijazi et al., 2013; Radeny et al., 2019; Ziervogel et al., 2010).

One other observance is that households with greater monthly farm incomes are better equipped to adapt their farming to cope with extreme weather events based on their IK. This is in accordance with studies from Esfandiari et al. (2020) who argued that the higher income of a given household, the greater the possibility that they apply adaptive options to climate variability in relation to rice production. It can be explained by the fact that farmers with higher monthly farm income have greater access to information, and to the resources required to better adapt to climate change.

Aside from economic preparedness, we also have the farmer's individual apprehension and consciousness of local changes in climate. We found that farmers' awareness, along with their personal acknowledgment of climate change, are the most important factors affecting their decisions on employing adaptation measures as in the report of Alemayehu and Bewket (2017). In this study, we have explored a positive correlation between a households' perception and the adaptive behaviors they exercise. These findings suggest the need for strengthening of collective action within the community so that the group members can further learn from each other and support each other in applying IK to climate change adaptation. For the studied community, their awareness and the action of the respondents on their climate change adaptation was independently achieved based on their own knowledge. This recommendation was also mentioned in the research of Kais and Islam (2016). They stated that "collective action and community capital shape the degree of resilience of a geographically-bounded community facing both gradual and sudden changes in climate".

Finally, most of the APs explored in this paper are autonomously implemented by smallholder farmers without support from the other sources outside the community such as local authorities or government organizations. Thus, there is a need to integrate indigenous farming methods within new governmental policies in order for these groups to maintain themselves in a more sustainable way, and to more effectively adapt to the problems of climate change. Government co-operation with the specific IK of the local people may contribute to the success of wider sustainable development goals within the region. To date, government policies such as MONRE (2019) and Quang Nam PPC (2013) have not adequately integrated IK of climate change into their current adaptation measures. Therefore, there is a serious need for financial stimulus at a governmental level to assist these ethnic groups to apply an action plan to counteract the increasing negative impacts of changing climatic patterns.

5. Conclusion

The IK of the Xo Dang people has been developed over time and focused on dealing with the particular effects of climate change within

their region. They have dealt with the negative consequences of flooding, soil erosion, fluctuating amounts of rainfall, storms, and droughts in many years. Therefore, the local people have to adapt to climate change basing on faunal and floral indicators as well as observation of characteristics in the sky in order to forecast weather events. These indigenous climate change adapting strategies have helped them to plan their activities in agriculture production more successfully. Besides, they have also been successful in mitigating climate change through an intercropping system using native species of plants and trees, the annual storing of seeds and cultivation of seedlings, as well as the annual adjustment of their planting calendars and irrigation management systems.

We also found that the three factors of the living years, household's farm-monthly income, and climate change awareness have a significant impact on the local people's options and motivation to employ adaptation solutions.

It is advisable that further studies be conducted which focus on combining IK with scientific knowledge in order to devise adaptation solutions that address newly occurring climate change concerns. This is also corroborated in similar contemporary studies such as the following (Karki and Adhikari, 2015; Makondo and Thomas, 2018; Nakashima et al., 2012). Due to the increasing extremity of certain climatic events such as droughts, there needs to be put in place some "early-warning" strategies, and ones which also take into account the long-standing cultural heritage of these peoples.

Declarations

Author contribution statement

Chuong Van Huynh, Quy Ngoc Phuong Le, Mai Thi Hong Nguyen, Phuong Thi Tran, Tan Quang Nguyen, Tung Gia Pham, Linh Hoang Khanh Nguyen, Loan Thi Dieu Nguyen, Ha Ngan Trinh: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Funding statement

This work was supported by Ministry of Education and Training of Vietnam (B2019-DHH-02).

Data availability statement

Data will be made available on request.

Declaration of interests statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

Acknowledgements

The authors want to express our thanks to all participants of the data survey who contributed to this research by sharing their knowledge and providing personal insights.

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