VULNERABILITY, RESILIENCE AND ADAPTATION TO CLIMATE CHANGE IN THE NORTHWEST MOUNTAINOUS REGIONS OF VIETNAM

A Thesis submitted by

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ABSTRACT

Vietnam is one of the most vulnerable countries to climate change in the world. Within the country, the Northwest Mountainous Regions (NMRs) are considered some of the most vulnerable communities, due to topography and socio-economic factors. Therefore, targeted adaptation is increasingly seen as both a necessary and urgent response. However, the extent and dimensions of vulnerability need to be carefully examined in order to develop effective adaptation pathways. This research aimed to explore vulnerability, resilience, adaptation to climate change in the NMRs, particularly among ethnic communities. Specifically, we aimed to (1) identify which communities are more vulnerable to climate change, (2) identify differences in measures of farmers' household resilience among communities, and (3) investigate the major factors contributing to farmers' adaptation choices in relation to climate change. The case studies are located in the Phu Yen district of Son La province in the NMRs. Data were collected in the field from late 2018 to early 2019. Primary data is from interviews and field observations, as well as insights from local decision-makers, resource managers, scientists. Climate data, which could be compared to perceptions of climate change, was collected from the Phu Yen meteorological station and the Hydro-Meteorological Data Centre of Vietnam (HMDC) from 1961 to 2017. The resulting vulnerability assessment, based on a set of indicators quantified from respondents' self-reporting, indicates that two of the ethnic communities were, on average, more vulnerable, particularly on livelihood strategies, health, water, housing and productive land, and social networks components when compared to the other two ethnic communities. Our study also reveals that indicators of household livelihood resilience differed between ethnic communities and between genders, with ethnicity being relatively more important than gender in determining outcomes. The research identified a number of areas where changes of institutional and socio-economic factors could increase livelihood resilience scores. There is also evidence of potential benefits in targeted resilience programs. Among ethnic groups, women's responses showed, on average, a lower resilience than those of men. The study found that a high percentage of farmers had noticed changes in the frequency of particular climate attributes and climate hazards, somewhat in line with climate data. To cope with these changes, recorded adaptation strategies applied in the study region included crop management and protection (soil and plant), diversifying crop, finding off-farm jobs, and changing crop varieties. Survey respondents also identified obstacles to adaptation measures, such as lack of credit, lack of family labour, insufficient agricultural inputs, limited farm size, and difficulties in assessing updated weather information. Regression results from binary logistic models reveal that age, gender, farm size, irrigation, extension services, credit availability, level of education and updated climate information have a significant influence on farmers' preference for adaptation strategies regarding climate change and climate hazards.

CERTIFICATION OF THESIS

I, Van Thanh Tran declare that the PhD Thesis entitled "Vulnerability, Resilience and Adaptation to Climate Change in the Northwest Mountainous Regions of Vietnam" is not more than 100,000 words in length including quotes and exclusive of tables, figures, appendices, bibliography, references, and footnotes.

This Thesis is the work of Van Thanh Tran except where otherwise acknowledged, with the majority of the contribution to the papers presented as a Thesis by Publication undertaken by the Student. The work is original and has not previously been submitted for any other award, except where acknowledged.

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STATEMENT OF CONTRIBUTION

The articles produced from this study had contributions from the student and supervisory team. The details of the scientific contribution of each author in the publications are provided below:

Paper 1:
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The overall contribution of Van Thanh Tran was 60% to the concept development, formal analysis, methodology, investigation, data curation, drafting and revising the final submission; Geoff Cockfield and Duc-Anh An-Vo contributed 20% and 15% respectively, for concept development, formal analysis, editing and provided the comments on the manuscript. Shahbaz Mushtaq contributed 5% for editing and provided the comments on the manuscript.

Paper 2:
Van Thanh Tran, Duc-Anh An-Vo, Shahbaz Mushtaq, and Geoff Cockfield, 2022. "Nuanced assessment of livelihood resilience through the intersectional lens of gender and ethnicity: Evidence from small-scale farming communities in the upland regions of Vietnam". *Journal of Rural Studies, Vol. 92, pp. 68-78*. https://doi.org/10.1016/j.jrurstud.2022.03.011.

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Paper 3:
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The overall contribution of Van Thanh Tran was 60% to the concept development, formal analysis, methodology, investigation, data curation, drafting and revising the final submission; Duc-Anh An-Vo and Geoff Cockfield contributed 20 and 15% each respectively, for concept development, analysis, editing and provided the comments on the manuscript. Shahbaz Mushtaq contributed 5% each respectively for editing and provided the comments on the manuscript.

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ABBREVIATIONS

Abbreviations	Definition
NMRs	Northwest Mountainous Regions of Vietnam
USQ	The University of Southern Queensland
HMDC	Hydro-Meteorological Data Centre of Vietnam
MONRE	Ministry of Natural Resources and Environment
GoV	The Government of Vietnam
NTP	National Target Program for Climate Change
IMHEN	Vietnam Institution of Meteorology, Hydrology and Climate Change
IPCC	Intergovernmental Panel on Climate Change
SLA	Sustainable Livelihood Approach
LVI	Livelihood Vulnerability Index
LVI-IPCC	Livelihood Vulnerability Index by IPCC Framework Approach
MSD	Mean standard deviation
HLRA	Household Livelihood Resilience Approach
LRI	Livelihood Resilience Index
(KIIs)	Key Informant Interviews

CHAPTER 1: INTRODUCTION

1.1 Background and problem statement

Global concerns about climate change are increasing. According to projections issued by the IPCC in 2007, the world's climate will continue to change at unprecedented speeds. Increases in temperature, changes in precipitation patterns, and an increase in the frequency of extreme weather events such as floods and droughts are well-documented (IPCC 2007; IPCC 2012). These have the potential to threaten human welfare and security, and consequently human life quality, in profound and unprecedented ways. In fact, climate change is already having an adverse impact on nature and humans worldwide. Basically, climate change and its stressors affect humans by destabilising livelihoods, especially for poor households (Tanner et al. 2014). Climate change has impacted livelihoods, leading to an increasing vulnerability, reducing the possibilities of securing livelihoods and eradicating poverty. Variability in climate affects economies worldwide, especially in low- and middle-income countries owing to the heavy dependency on nature-sensitive sectors like agriculture and forestry. In addition, many low- and middle-income countries are experiencing higher risks from unusual changes in climate phenomena compared to high income countries because of both their location and geography (Maharjan and Joshi 2013). Social-ecological systems are under intense pressure from climate change and variability (Berkes and Jolly 2001; Adger and Barnett 2009; Bardsley and Sweeney 2010). Climate change has been and will continue to lead to comprehensive and profound changes in global development and security, particularly in water, energy, food, economy, employment, culture, and trade (IPCC 2014).

Vulnerability and low resilience have been identified as particular concerns for developing countries such as Vietnam. Vietnam is frequently and severely impacted by a changing climate through sea level rise, storms, droughts, flash floods, and landslides (Dasgupta et al. 2009; Few & Tran 2010; Eckstein et. al 2017). According to the Ministry of Natural Resources and Environment (MONRE 2016), there has been an increase of 0.26^0C per decade in annual average temperature since the 1970s, meanwhile, yearly rainfall has varied across the country with a declining trend over the Northern regions but an increasing trend over the Southern areas. Over the past two decades, climate hazards have contributed to more than 13,000 deaths and average yearly asset losses of more than US$6.4 billion (equivalent to 1.5% of Vietnam's GDP) (Bank 2017; MONRE 2017).

Unfavourable changes in climate are expected to have a wide range of effects on various sectors, particularly in agriculture because this sector is highly exposed to climatic conditions (Mestre-Sanchís & Feijóo-Bello 2009; IPCC 2013; Houser et al. 2015). Changing weather patterns have caused a significant change in rice production (Krishnan et al. 2007; Babel et al. 2011; Shrestha et al. 2013; Burney & Ramanathan 2014), yield reductions from 2% to 26% in Southeast Asia countries (Weiss 2009; Zhai & Zhuang 2012), and yield declines from 5% to 15% in a variety of staple food crops in Africa (Roudier et al. 2011; Blanc 2012; Salack et al. 2015). The natural relationships between climatic factors and the agricultural sector have been thoroughly researched (Welch et al. 2010; Desch et al. 2012; Fisher et al. 2012; Lobell et al. 2013; Roberts et al. 2013; Burke & Emerick 2016; Chen, Chen & Xu 2016). These studies have considered factors such as water resources, agriculture, fisheries, forestry, human health, infrastructures, and ecological systems, which are considered essential to livelihoods (Kohler & Maselli 2012). Poverty, rural population, and dependency on agriculture are also other factors enhancing the level of vulnerability (Asafu-Adjaye 2014).

Vietnam is highly reliant on natural resources compared to other middle-income nations in Southeast Asia (World Bank, 2010). Furthermore, the people's main livelihood is from the agricultural sector. However, agriculture's contribution to GDP has been declining over the last two decades. Agriculture contributed 38% of GDP in 1990 and employed 73% of the labour force. By 2015, agriculture's contribution to GDP had dropped to 18%, but with about 44% of the workforce employed in this industry. Therefore, climate change and its induced risks still contribute to significant sectoral and household insecurity. For instance, due to salinity intrusion and severe droughts in Mekong River Delta, rice production significantly decreased and caused losses of approximately 15,000 billion VND (about US$646 million) to the national economy. As a consequence, many farmers were forced to abandon their farms and seek employment opportunities in cities or surrounding urban areas.

Poor and marginalised groups in developing countries, such as Vietnam are most vulnerable to climate change because of the high level of poverty, lack of social safety systems, weak adaptive capacity, difficult accessibility to education programs, health care services and alternative means of production, low education, large family structure and size (Watson et al. 1996; Moser 1998; IPCC 2007; Lemos et al. 2007; Skoufias et al. 2011; Kurukulasuriya & Rosenthal 2013; Shah et al. 2013; Masud et al. 2014; Alam et al. 2018). Climate change is expected to disproportionately affect the world's poorest and most vulnerable people, who mostly live in rural areas, by adversely affecting water availability and supply, infrastructure, agricultural incomes, and food security (Beaumont et al. 2011; Lynn et al. 2011; IPCC 2014; Masud et al. 2014).

Within the agricultural sector, there may however be sub-groups with particularly high levels of vulnerability and low levels of resilience. One factor in this may be minority ethnicity, which could indicate multiple disadvantages in relation to access to resources, government influence and programs, education and so on. Vietnam has 54 recognized ethnic groups with varying lifestyles, cultures, and languages, of which 53 groups are classified as minorities. Ethnic minority groups account for more than 50% of the total poor in Vietnam, despite comprising less than 15% of the population (based on the Vietnam Household Living Standard Survey 2014).

Generally, these minorities often reside in less productive, geographically remote, or mountainous areas with poor access to infrastructure, lack of health and educational facilities, and non-farm opportunities. They have higher poverty rates than majority groups (Imai et al. 2011; Tran et al. 2015). People living in such situations also often experience substantial food shortage and low quality water due to impacts of climate hazards such as drought, floods, and storms.

Located in the North of Vietnam, the Northwest Mountainous Regions (NMRs) are highly sensitive to slight changes in the frequency and extent of natural disasters because of comparatively fragile ecosystems, unstable geology, and complex topography (UNDP 2015). In addition, these regions are also ranked the poorest and highest inequality regions of Vietnam, with 95.6% of the population being ethnic minorities (World Bank 2010; GSO 2015; Tuyen 2016). Within the study region, the level of education, especially, among ethnic minorities, is far below the national average (Ha 2007). The NMRs are hilly, remote regions without advanced infrastructure, leading to significant barriers to access to even close cities or towns for living activities such as shopping, attending schools or seeking medical assistance or services.

The Government of Vietnam (GoV) is increasingly recognizing threats from climate change, and a National Target Program for Climate Change (NTP) was adopted in December 2008. The Program document, however, has little to say about how adaptation will take place and who will be the most vulnerable populations beyond noting mountainous areas are presumed to be amongst the most vulnerable places, with sustainable agricultural productivity and livelihoods the most serious challenges (GoV, 2008). Recently, the Vietnam Institution of Meteorology, Hydrology and Climate Change (IMHEN & UNDP, 2015) also notes that, in Vietnam, vulnerability is concentrated in poor communities, and it is crucial to address the underlying causes of vulnerability in the context of climate change to achieve sustainable development goals. Given that fact, a study of climate change impacts on the livelihoods of mountainous farmers is particularly critical.

In this regard, a number of studies have been conducted to better understand the impacts of climate change on agriculture (Do 2013; Anh 2016; Benson 2017), to assess rural households' vulnerability (CARE 2013; Nguyen, Vo & Chu 2013; Huynh & Stringer 2018; Nguyen & Leisz 2021), and to investigate the factors that influence farmers' decisions to adapt to climate change (Nam 2011; Le Dang et al. 2014; Van et al. 2015; Trinh et al. 2018). However, almost all these studies focus on the two Deltas (the Red River Delta and the Mekong River Delta) and the central area. In contrast, the Northwest Mountainous Regions of Vietnam, which are particularly vulnerable to climate change, have not yet drawn much of researchers' attention, particularly in relation to ethnicity. For the above-mentioned reasons, there is a high demand for research that explores the vulnerability levels of different ethnic groups in mountainous regions, how they perceive and response to climate change and climate hazards.

Against this background, the study of *"Vulnerability, Resilience and Adaptation to Climate Change in the Northwest Mountainous Regions of Vietnam"* is conducted with the expectation for filling a fundamental knowledge gap and adding further information and insights in the existing literature in explaining the impacts of climate change on mountainous households' vulnerability, their resilience, and their decision-making behaviours. Hence, the findings of the current work will be useful for designing appropriate policy practices in order to enhance farmers' capacity and resilience toward future climate hazards not only in Vietnam but also in other countries having similar economics, social and graphical contexts.

1.2 Research Objectives

The general objective of this study is to gain a comprehensive picture of ethnic households' livelihoods, to explore the vulnerability level of farm households and their perceived resilience, and to investigate key factors influencing adaptation choices to climate change among ethnic groups in the Northwest Mountainous Regions of Vietnam.

The overall objective is divided into the following three sub-objectives:

- To assess livelihood vulnerability among groups and reveal the factors affecting their vulnerability to climate change.
- To explore differences in households' perceived livelihood resilience among members of minority groups and genders.
- To identify how farmers have adapted to climate change, and to determine major factors influencing farmers' adaptation choices.

1.3 Scope of Research

To achieve these objectives, the work was segmented into distinct tasks as follows:

- The lists of livelihood vulnerability/resilience indicators were selected from the literature and then reviewed by local experts. Questionnaires were created, pre-tested with local people, and revised before formal interviews. Household surveys were conducted by the student and one local assistant.

- The level of household livelihood vulnerability was assessed and analysed based on a livelihood vulnerability index.

- A nuanced intersectionality analysis was conducted based on household livelihood resilience approach to understand varying perceptions of livelihood resilience among groups and genders.

- Using survey data, households' perceptions of climate variables were reviewed. We also investigated adaptation practices adopted across the studied communities and their drivers using logit regression modelling.

1.4 Thesis Organisation

The study is organized into six chapters. Chapter 1 presents the research background and problem statement, research objectives, and scope of research. Chapter 2 provides the literature review the concepts of vulnerability, resilience and adaptive capacity used for the current study. In

Chapter 3, the community vulnerability level and factors influencing households' vulnerability under the impacts of climate change are analysed. This chapter was published in the journal Sustainability as a peer-review paper entitled *"Assessing Livelihood Vulnerability of Minority Ethnic Groups to Climate Change: A Case Study from the Northwest Mountainous Regions of Vietnam"*. Chapter 4 explores how perceptions of livelihood resilience differ by gender and groups and identifies the main factors contributing to better livelihood resilience. This chapter was published in the Journal of Rural Studies as a peer-review paper entitled *"Nuanced assessment of livelihood resilience through the intersectional lens of gender and ethnicity: Evidence from small-scale farming communities in the upland regions of Vietnam"*. Chapter 5 addresses the question of how farmers have responded to climate change for controlling its adverse impacts. At the time of submission, this chapter had been submitted to Weather and Climate Extremes as a peer-review article entitled *"Farmers´ perceptions and adaptation practices to climate variability risks and their associated determinants: Evidence from small-scale farming communities in the upland regions of Vietnam"*. Chapter 6 provides a general conclusion drawn from the previous chapters, expected significant contributions of the study, and some recommendations for future research.

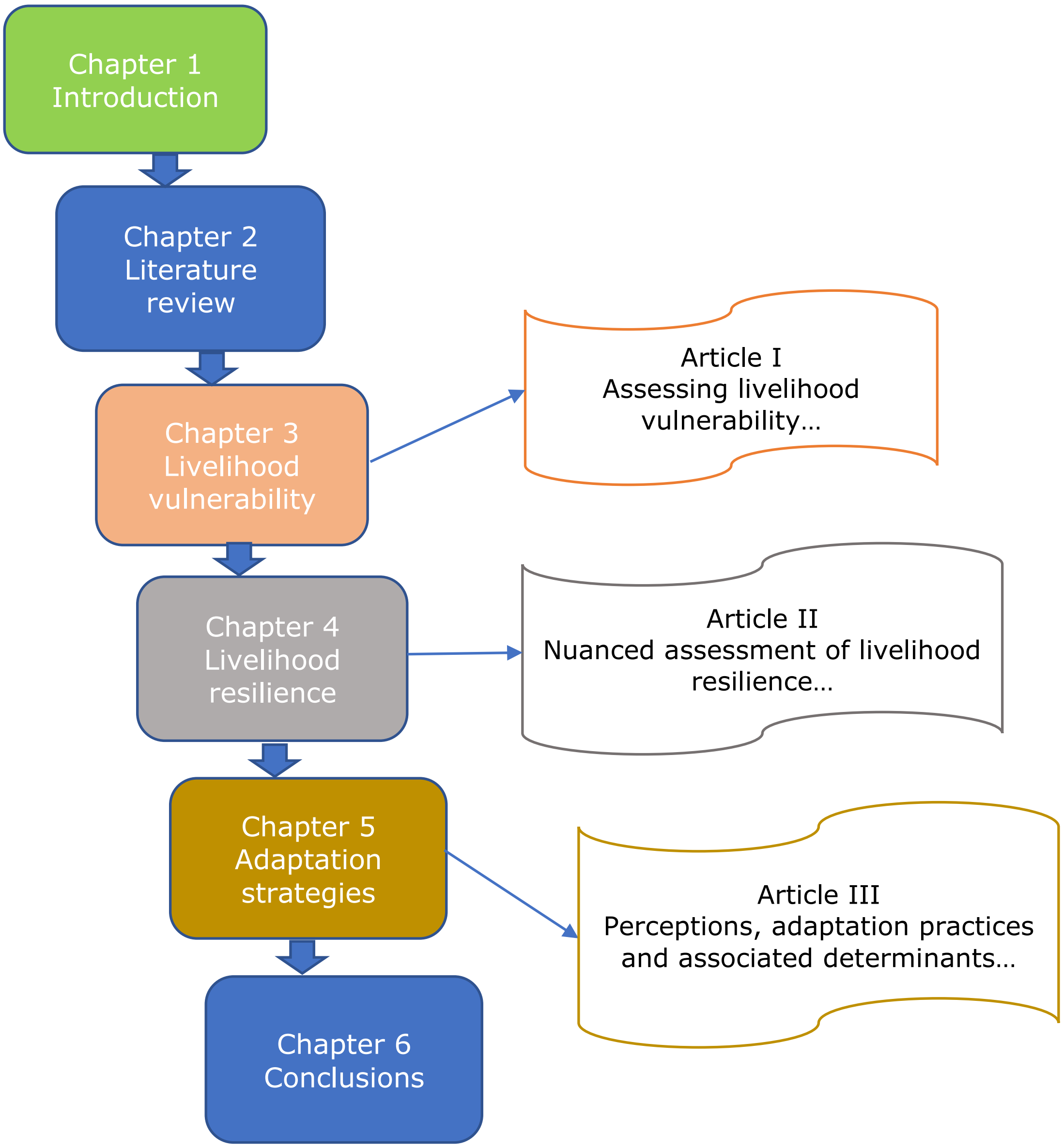

Fig. 1.1. Thesis structure.

CHAPTER 2: LITERATURE REVIEW

There are different understandings and definitions of, and linkages between, the concepts of vulnerability, resilience, and adaptive capacity. Birkmann (2006), Folke (2006), and Adger (2006) considered resilience as an integral part of adaptive capacity (Fig. 2.1A); meanwhile, Burton et al. (2002) and O'Brien (2004a) viewed adaptive capacity as a key component of vulnerability (Fig. 2.1B). In the context of climate change, vulnerability is defined as a function of three main factors: exposure, sensitivity, and adaptive capacity (Adger 2006). A third view sees them as nested concepts within an overall vulnerability structure (Fig. 2.1C) (Turner et al. 2003a; Gallopín 2006). In natural hazard research, resilience is understood as the ability to survive and cope with a disaster with minimum damage (Cutter et al. 2008). Resilience is also identified as an outcome in relation to the ability to cope with a hazard event and is embedded within vulnerability (Fig. 2.1D) (Manyena 2006). In global perspectives, scientists often embed adaptive capacity within resilience (Fig. 2.1E) (Bruneau et al. 2003; Tierney & Bruneau 2007; Paton & Johnston 2017).

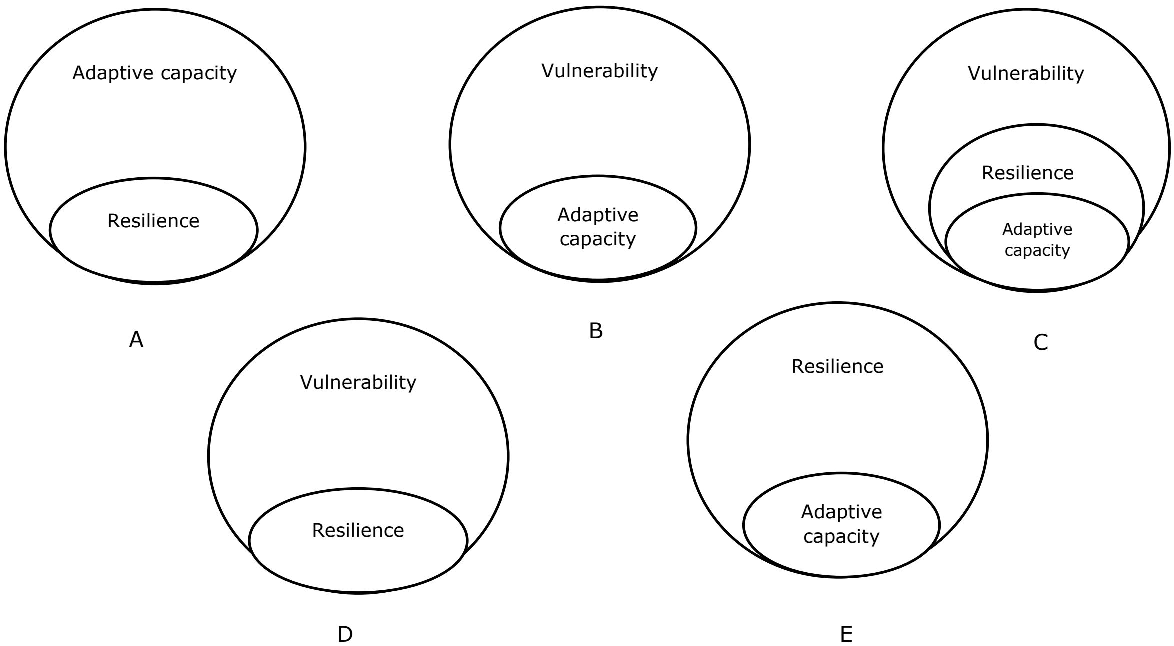

Fig. 2.1. Conceptual framework between vulnerability, resilience, and adaptive capacity (*Adapted from Cutter et al. (2008)*).

2.1 Vulnerability

The concept of vulnerability has been used in different fields of research, for example, natural hazards, food security, and political ecology (Kelly & Adger 2000; McLaughlin & Dietz 2008), yet there is little agreement on its meaning. Some researchers consider vulnerability according to factors such as exposure and sensitivity to perturbations or external stresses and the capacity to adapt (O'Brien 2004a). Other researchers look at vulnerability in relation to exposure, sensitivity, and resilience (Turner et al. 2003a, b). In other cases (Ford & Smit 2004; Smit & Wandel 2006), vulnerability is viewed as a function of exposure and adaptive capacity following the argument that exposure and sensitivity cannot be separated, and resilience is a subset of adaptive capacity (Gallopín 2006). In this conceptualisation, vulnerability, resilience, and adaptive capacity are seen as nested concepts within an overall vulnerability structure (Fig. 2.1C). However, both capacity to cope or respond and adaptive capacity are considered components of a system's resilience (Turner et al. 2003a, b). Adger (2006) reviewed existing approaches to vulnerability from social and natural sciences and concluded that three key components most commonly conceptualise vulnerability: exposure to perturbations, sensitivity to perturbation, and adaptive capacity.

In terms of climate studies, the IPCC third assessment report (IPCC 2001: 6) describes vulnerability as *"the degree to which a system is susceptible to, or unable to cope with, the adverse effects of climate change, including climate variability and extremes"*. Additionally, in the IPCC Fourth Assessment Report, Cardona et al. (2012) describes vulnerability as a function of exposure, sensitivity, and adaptive capacity, as also reflected by, for instance, Brooks (2003), O'Brien (2004a), Füssel and Klein (2006), Füssel (2007), and O'Brien et al. (2008). However, Eakin and Luers (2006) claim that the above components and their relationships are not well-defined and considered vulnerability as a dynamic property of a system in which humans are constantly interacting with the biophysical environment. It is an important task to clarify the meaning and application of the vulnerability concept in these analyses (Renaud et al. 2010). Ford and Smit (2004) conceptualised vulnerability to climate change as a function of exposure and adaptive capacity.

Exposure here reflects the susceptibility of people and communities to climatic conditions, and adaptive capacity reflects the ability or potentiality of a community to address, plan for, or adapt to exposure. In this conceptualisation, vulnerability at a local level is viewed as being conditioned by social, economic, cultural, political, and climatic conditions/processes, operating at multiple scales over time and space, which affect community exposure and adaptive capacity (Ford et al. 2008). Ford et al. (2008) argued this is broadly consistent with other approaches to vulnerability, including Turner et al. (2003a), Smit and Wandel (2006), and Eriksen, Brown and Kelly (2005). Furthermore, Füssel (2007) argued that there is no single 'correct' or 'best' conceptualization of vulnerability that would fit all assessment contexts.

A localised concept of vulnerability (Turner et al. 2003a, b; Ford & Smit 2004; Smit & Wandel 2006) is applied in this study because vulnerability and adaptation to climate change are exceedingly variable and linked to local contexts (Leichenko & O'brien 2002; O'Brien et al. 2004b). Therefore, one-size-fits-all approaches are likely to miss socio-economic and political-institutional dynamics of vulnerability and, hence, risk any assessment being ineffective, if not counterproductive (Tschakert 2007). Vulnerability at a local level is identified as being conditioned by social, economic, cultural, political, and climatic conditions/processes, operating at multiple scales over time and space, which affect community exposure, sensitivity, and adaptive capacity (Ford & Smit 2004; Ford et al. 2008). This study will assess the vulnerability at community level by the composite livelihood index (LVI) and the livelihood index (LVI-IPCC) based on IPPC's three contributing factors: exposure, sensitivity, and adaptive capacity.

2.2 Resilience

Resilience is a perspective for understanding how co-evolving societies and natural systems can cope with and develop from disturbances and change (Manyena 2006). The concept of resilience is mainly used in the study of ecosystem dynamics (Holling 1973); however, it has also been applied to social (Adger 2000) and social-ecological systems (Berkes & Folke 1998). The term resilience is often used as synonymous with the notion of 'bouncing back', from its Latin root, meaning "to jump back" (Paton 2006: 7). It implies a capability to return to a previous state. However, the concept does not necessarily capture the reality of social/socio-ecological systems experiencing perturbations. For example, changes to the physical, social, and psychological reality of social life following a disaster can present community members with a new reality which may differ in several ways from conditions pre-disaster. It is the changed reality to which people must adapt (Paton 2006).

In ecological systems, Holling (1973: 9) first defined resilience as "the capacity of a system to absorb and utilize or even benefit from perturbations and changes, and so persist without a qualitative change in the system's structure." The concept of ecological resilience was added to vulnerability discussions. It has contributed to a productive exchange of ideas on assessing and understanding vulnerability concerning global environmental change and various stresses and shocks acting on and within coupled human-environment systems. The concept of resilience has recently begun to be more widely considered in the social sciences (Folke 2006). Resilience is defined as communities' ability to withstand disturbances to maintain their social infrastructures (Adger 2000). However, resilience is a cumbersome concept for the social sciences, at least when trying to speak of resilience at the systems level (Davidson 2010; Duit et al. 2010). Duit et al. (2010) argued that the concept of social-ecological systems resilience should be used to avoid confusion.

A definition of resilience incorporating social-ecological linkages has been developed (Carpenter et al. 2001; Berkes et al. 2003). This definition includes consideration of the amount of change a system can undergo and retain essentially the same function, structure, and identity; the degree to which the system is capable of self-organisation; and the degree to which the system represents the capacity for learning and adaptation (Folke et al. 2002). Carpenter et al. (2001: 765) defines resilience as "the magnitude of disturbance that can be tolerated before a social-ecological system moves to a different state controlled by a different set of processes". A 'social-ecological system' in this sense encapsulates ecosystems and their human use by communities and institutions. For Berkes, Colding and Folke (2003), the resilience of social-ecological systems is related to sustainability.

Sustainability is defined as the adaptive capacity to deal with change and the maintenance of ecological systems' capacity to support associated social and economic systems. For Folke (2006), the concept of social-ecological resilience, meanwhile, involves the intersection of factors such as adaptive capacity, transformability, learning, and innovation. Resilience is taken to mean the capacity to deal with change and continue developing; hence, resilient communities will be those with coping abilities to withstand, recover from stresses/shocks and surprises, and, specifically, adapt to climate variability and change. They also can turn shocks/surprises into opportunities through learning. This concept of resilience is consistent with that of many others who define resilience as the ability of a system to a) absorb shocks and retain its primary function; b) self-organise; and c) innovate and learn in the face of disturbances (Carpenter et al. 2001; Folke 2006). However, Brown (2013) suggests there was not enough attention to social-ecological systems' social or political side within resilience thinking and research. A livelihood perspective concept was developed to address this criticism. For example, livelihood resilience is viewed as the accumulation of people's capacity through generations to maintain and improve their livelihood opportunities and well-being in the case of environmental, economic, social, and political instabilities (Tanner et al. 2014). Therefore, it is necessary to place people at the centre of resilience-building analysis and to emphasize the role of human organisation, rights, and capacity in preparedness and adaptation to shocks. Resilience-building programs or interventions also need to address the question of "resilience for whom?" to establish objectives (Brown 2013). In the light of this development, Constas (2014) emphasised resilience capacity as a way of looking at measurable resources and assets that may help individuals, households, or communities prepared for and respond to shocks. Another study quantified household resilience by using people's own perceptions called "subjective resilience" (Jones & Tanner 2015). Following the current focus of livelihood in both academic research and resilience-building projects, we draw from the idea of Jones and Tanner (2015) to assess the subjective livelihood resilience at the household level in the research area.

2.3 Adaptive capacity

Adaptive capacity is identified as the ability to adapt, and adaptive capacity is primarily conceptualized separately to either a vulnerability or a resilience framework. The IPCC defines adaptive capacity as *"the ability of systems, institutions, humans, and other organisation to adjust to potential damage, take advantage of chances and respond to consequences"* (Smit & Pilifosova 2003; Adger et al. 2007; IPCC 2013: 549). Adaptive capacity affects vulnerability (Section 2.1) by modulating exposure and sensitivity (Adger et al. 2007) or by addressing and reducing the vulnerability of a system under human actions affecting the system's biophysical and social factors (Eakin & Luers 2006). Figure 2.2 represents a conceptual view of adaptive capacity concerning vulnerability through moderating exposure and sensitivity. While there is an ongoing argument about definitions and boundaries between exposure, sensitivity, and adaptive capacity (Gallopín 2006; Füssel 2007), adaptive capacity is generally considered a fundamental role in a positive attribute of a system for reducing vulnerability.

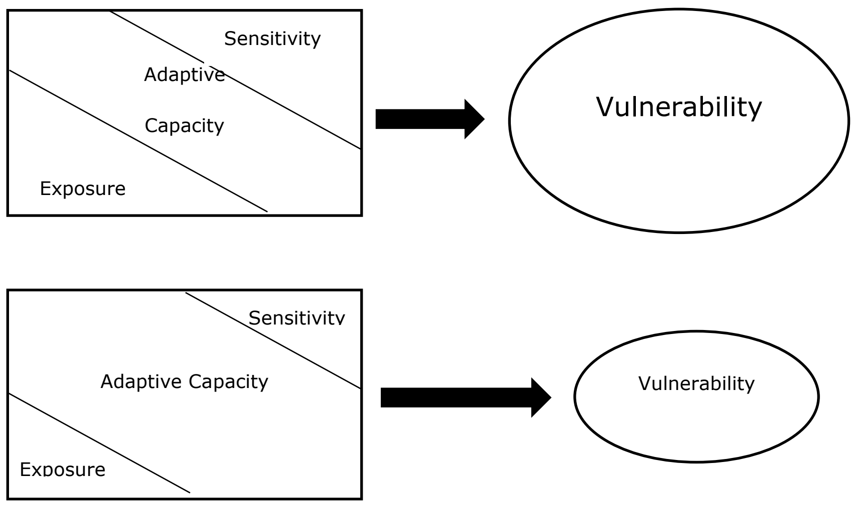

Fig. 2.2. The basic understanding of adaptive capacity's role in influencing vulnerability. Adaptive capacity influences a system's vulnerability by moderating exposure and sensitivity (*Adapted from Engle (2011)*).

In resilience literature, adaptive capacity often refers to 'adaptability', or the capacity of actors in the system to influence resilience; in social-ecological systems this amounts to humans' capacity to manage resilience (Walker et al. 2004). Human actions affect resilience through interactions between a system's human and environmental elements (Walker et al. 2006). Folke (2006) considered adaptive capacity as a property that can support people in the creation of a new system state when the existing state is somehow untenable. Adaptive capacity affects a social-ecological system by moderating between maintenance of the current situation and movement of the system to a new more 'desirable' state, where the concept of 'desirability' is based on social factors (Robards et al. 2011). Depending on how 'desirability' is negotiated/defined within a given system (i.e., system-maintaining or system-altering), more adaptive capacity increases the likelihood of achieving a desirable state (Fig. 2.2).

Resilience approaches point to governance and institutions as the two main variables affecting a socio-ecological system's adaptive capacity. For example, Lebel et al. (2006) recommend that enhancing a society's capacity to manage for resilience is essential for sustainable development- recognising that resilience enhancement might be more desirable in some situations, while transformation might be more desirable in others. Systems with higher adaptive capacity are likely to 'end up' in a desirable system state, while systems with lower adaptive capacity are likely to move to a less desirable system state (Fig. 2.3).

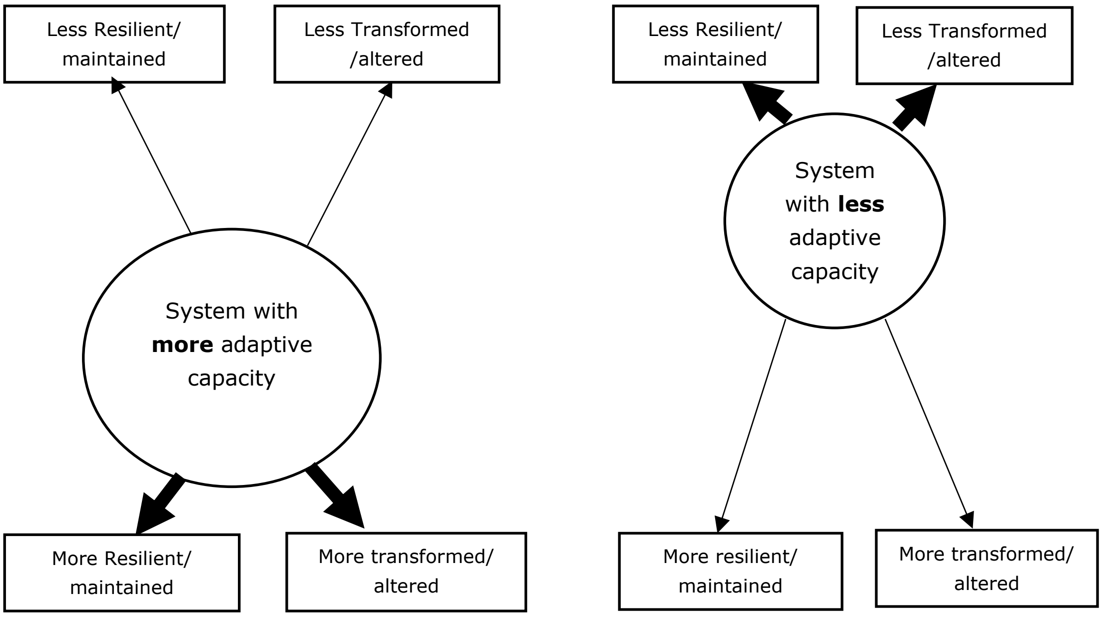

Fig. 2.3. A primary depiction of adaptive capacity's role in managing resilience (*Adapted from Engle (2011)*).

2.4 Assessing vulnerability and resilience

Socio-economic, bio-physical, and integrated assessment approaches are the three major conceptual approaches applied to analyse vulnerability to climate change (Deressa et al. 2008). Of these, the third approach combines both socio-economic and bio-physical approaches to define vulnerability. Vulnerability mapping (O'Brien et al. 2004b; Kumar & Tholkappian 2006) is a good example of this approach. Both socio-economic and bio-physical factors are systematically combined to identify vulnerability. The econometric method originated from the poverty and development literature and utilizes household-level socio-economic survey data; therefore, it can assess the level of vulnerability of different social groups (Deressa et al. 2008). The indicator method firstly selects numerous leading indicators from the whole set of potential indicators and then systematically combines these indicators chosen to estimate the levels of vulnerability (Adger & Kelly 1999; Kumar & Tholkappian 2006; Deressa et al. 2008; Moreno & Becken 2009; Nyong et al. 2009; Nelson et al. 2010; Seidl et al. 2011; Maiti et al. 2015). In the present study, the livelihood vulnerability index (LVI and LVI-IPCC) is used to understand and assess the vulnerability at community level (details in Chapter 3). Furthermore, subjective livelihood resilience at household level was measured by applying the Household Livelihood Resilience Approach (HLRA) (Quandt 2018) (details in Chapter 4). This approach uses various resilience indicators adopting from the Sustainable Livelihoods Framework (Chambers & Conway 1992), including five types of livelihood capital assets: financial, human, social, physical, and natural capital.

This chapter provided a review of the concepts of vulnerability, resilience and adaptive capacity used for the current study. Also, through literature review, our research shows the expectation for filling a fundamental knowledge gap in the field. Assessing the level of vulnerability in various minority ethnic communities in the Northwest Mountainous Regions of Vietnam can be used to address such a gap, considering particularly ethnicity (Chapter 3).

CHAPTER 3: PAPER 1 - ASSESSING LIVELIHOOD VULNERABILITY OF MINORITY ETHNIC GROUPS TO CLIMATE CHANGE: A CASE STUDY FROM THE NORTHWEST MOUNTAINOUS REGIONS OF VIETNAM

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Assessing Livelihood Vulnerability of Minority Ethnic Groups to Climate Change: A Case Study from the Northwest Mountainous Regions of Vietnam

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Abstract: Climate variability, climate change, and extreme events can compound the vulnerability of people heavily reliant on agriculture. Those with intersecting disadvantages, such as women, the poor, and ethnic minority groups, may be particularly affected. Understanding and assessing diverse vulnerabilities, especially those related to ethnicity, are therefore potentially important to the development of policies and programs aimed at enabling adaptation in such groups. This study uses a livelihood vulnerability index (LVI) method, along with qualitative data analysis, to compare the vulnerability of different smallholder farmers in Son La province, one of the poorest provinces in Vietnam. Data were collected from 240 households, representing four minority ethnic groups. The results indicated that household vulnerability is influenced by factors such as income diversity, debt, organizational membership, support from and awareness by local authorities, access to health services, water resources, and location. Results revealed that two of the ethnic groups' households were, on average, more vulnerable, particularly regarding livelihood strategies, health, water, housing and productive land, and social network items when compared to the other two ethnic groups. The study shows the need for targeted interventions to reduce the vulnerability of these and similarly placed small ethnic communities.

Keywords: livelihood vulnerability; agricultural dependency; climate change

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1. Introduction

Vietnam is ranked as one of the world's ten most vulnerable countries to climate change and climate events such as rising sea levels, storms, floods, and droughts [1–3]. Under increasing climate variability, people whose livelihoods rely mostly on agricultural activities are relatively vulnerable, particularly in developing countries [4]. Reference [5] indicates that coastal people in Vietnam have generally higher vulnerability to climate change because nearly 60% of livelihoods are based on aquaculture and agriculture, whereas the mountainous regions have unstable and complex topography with poorer economic prospects, and people in those regions are highly sensitive to slight changes in the frequency and severity of climate events [6,7]. Vulnerability and adaptation research in Vietnam has largely focused on coastal areas, especially in the Mekong River Delta, with most work focusing on assessing the direct impacts of climate change. Significant threats include increases in the frequency and intensity of droughts and sea level rise driving saline intrusion in the Mekong River Delta, causing the loss of land for rice production, which could threaten national food security [8]. There may, however, be differences in the degree of vulnerability and capacity to adapt amongst different groups, especially considering various forms of social disadvantage. To develop proper adaptation strategies and solutions/policies to reduce rural households' vulnerability and to improve their resilience, it is very important to understand the livelihood vulnerability of rural households, especially in countries depending heavily on agriculture.

Livelihood vulnerability can be a function of both physiological and social factors [9]. Physiological vulnerability is the extent to which communities are exposed to physical effects such as sea-level rise and an increase in sea temperature, and/or atmospheric temperature. Such exposure to climate change increases rural livelihood vulnerability and reduces households' ability to cope with climate risks, shocks, and stress [10]. Rural households often have limited assets and thus adaptive capacity [11]. The social vulnerability can include factors such as relative inequality, the degree of urbanisation, and the rate of economic growth [9].

Vulnerability assessments have become a core means of understanding development challenges and climate change influence in many contexts. Such assessments can encompass the numerous methods utilized to systematically consider interactions between humans and their environmental surroundings, including physical and social aspects [12]. Approaches to vulnerability assessment include historical narrative, comparative analysis, statistical analysis, indicator-based methods, and agent-based modelling. Recently, the indicator-based method has been widely used to assess vulnerability to climate change and climate-induced disasters [13,14]. Almost all the approaches use indicators to characterize and quantify the different dimensions of vulnerability, with the common practice being to combine the diverse indicators into a single composite index [12,15]. The indicator approach has been used at different scales and domains to quantify system dynamics [13,16–18]). The Sustainable Livelihood Approach (SLA) (Figure 1) has been used to understand household livelihoods and to plan community development programs. This approach considers five types of household's assets i.e., natural, social, financial, physical, and human, and uses multiple indicators to assess exposure level to natural disasters and climate change. Households' economic characteristics affect households' adaptive capacity, and the characteristics of health, food and water resources determine the household's sensitivity to climate change impacts [19]. A major work in livelihood vulnerability assessment is that of [12], who developed two approaches. They first expressed LVI as a composite index, comprising seven major components. The second approach was based on the vulnerability definition of the Intergovernmental Panel on Climate Change (IPCC), whereby they decomposed the seven components into three: based on exposure, sensitivity, and adaptive capacity. The LVI approaches consist of variables indicating the level of exposure, sensitivity, and adaptive capacity to climate-induced disasters (for example, droughts and floods, landslide, etc.) and climate change. The LVI indicates a way to understand how vulnerability varies across time and space and to identify the main factors contributing to vulnerability, highlight strategies reducing the vulnerable level, and also evaluate how efficient these strategies are in different social and ecological environments [15]. In the past decade, the LVI has become a means of assessing farmers' vulnerability to climate change and disasters around the world [4,15,20–23].

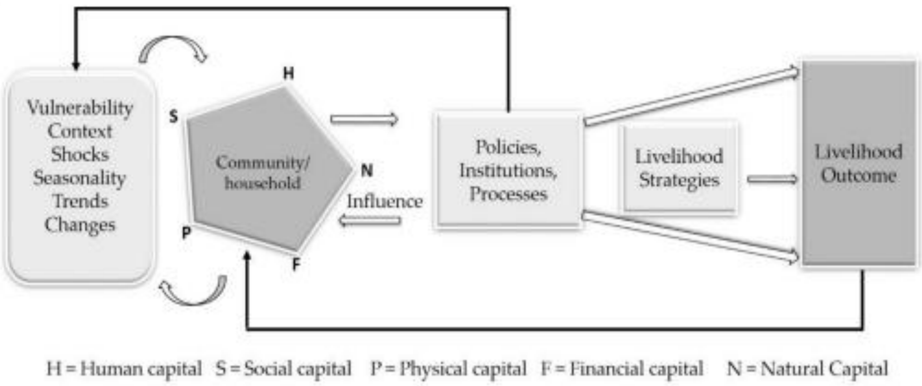

Figure 1. The asset pentagon lies at the core of sustainable livelihood approach, within the vulnerability context [24].

The Northwest mountainous region (NMR) of Vietnam is highly sensitive to slight changes in the frequency and extent of natural disasters with its fragile ecosystems, unstable geology, and complex topography [7]. The NMR is home to numerous marginalized ethnic minority groups that experience, in relative terms, extremely low-income levels and poor health care. The region is ranked the poorest and highest inequality region of Vietnam (with the overwhelming majority of the population (95.6%) being ethnic minorities) [25–27]. The level of education, especially among ethnic minorities, is far below the national average [28]. People living in this area also often experience substantial food shortage and low water quality due to climate change such as extreme weather events. Vietnam Institution of Meteorology, Hydrology and Climate Change [29] notes that, in Vietnam, vulnerability is concentrated in poor communities and it is crucial to address the underlying causes of vulnerability in the context of climate change to achieve sustainable development goals. Despite recognition of the need, there has been little attention focused on the vulnerability of communities' livelihood systems to climate change in the mountainous regions of Vietnam and specifically on the challenges faced by ethnic minority communities. Further, NMR is a hilly remote region without advanced infrastructure, leading to significant barriers to access to even close cities or towns for living activities such as shopping, attending schools or seeking medical assistance or services. For the above mentioned reasons, work focusing on the NMR is particularly necessary to develop appropriate strategies in support of reducing the poverty and vulnerability of rural households and ethnic minority groups. Importantly, previous work conducted by [23] to assess household livelihood vulnerability to climate change in the NMR did not focus on the ethnicity perspective, which remains a major gap.

This research aims to explore the livelihood vulnerability of different ethnic groups living in the Phu Yen district, Son La province in the NMR. The ethnic groups in the Phu Yen district were selected as typical of communities in the region. We consider major factors driving different assessed outcomes among the ethnic groups which could then be addressed in climate change adaptation policies and programs. We hypothesized, based on previous vulnerability studies and studies of poverty in Vietnam, that minority ethnic groups would have relatively high levels of vulnerability, generally, and therefore in relation to climate change.

We apply the LVI [12] and reference the work of [30] but have modified or added a number of new indicators relevant to the Son La province in the NRM to better understand the livelihoods of local minority people and explore the main factors affecting the vulnerability of households to climate change. This research contributes to the literature concerning the assessment of vulnerability of rural households and provides a reference for policy making aimed at helping people living in similar economic and natural regions.

More specifically, this research assists in developing targeted policy interventions aiming at improving resilience of the marginal ethnic groups in mountainous regions of Vietnam.

2. Materials and Methods

2.1. Description of the Study Area

The study was carried out in the Phu Yen district, Son La province (Figure 2). Son La is considered highly vulnerable to climate change because of its topography and geography [31]. According to the Ministry of Labour, War Invalids and Social Affairs of Vietnam (Decision 1095/QD-LDTBXH dated 8 August 2016), Son La was the province having the third-highest number of poor households in Vietnam during 2016–2020. Phu Yen is the third-largest rice-producing district of the northwest region but also one of the five poorest districts of Son La province. Phu Yen district is receiving support from the 'National Target program for Sustainable Poverty Reduction in the 2016–2020 period'. There are 27 villages in Phu Yen district, of which 14 are located in the highlands and 11 belong to the groups considered as "especially difficult communes" specified under Program 135. The total natural area of Phu Yen district is 1227 km^2 with a population of approximately 116,000 people. Agricultural production includes intensive rice, fruits and crop. Phu Yen district has four main ethnic groups: Thai, Muong, Dao, and Hmong. Among them, Thai and Muong make up the majority of the population. Some groups may have several compounding disadvantages, including isolation, social and economic exclusion, and a very high dependence on agricultural production. The Hmong and Dao people, for example, often live in high mountainous areas far from district/commune centres while the remaining ethnic groups mainly live in lowland areas (valleys) and/or near the district centre (Table 1). Thus, they are further from health and education services and labour markets. The people in the study area often experience economic loss because of natural hazards such as droughts and hot winds in the dry season, flash floods and landslides in the rainy season, and cold spells and frosts in winter [32]. In summary, the study site has known disadvantaged groups and high exposure to climatic variability, events, and change.

Figure 2. Map showing the case study. (**a**) is the map of Son La province, Vietnam; (**b**) showing the study site.

Table 1. Brief characteristic for four ethnic groups in the Phu Yen District (source: from surveys).

Characteristics	Thai	Muong	Dao	Hmong
Average age of household head (age)	49.7 ± 8.44	49.6 ± 8.66	41.3 ± 7.68	41.6 ± 10.50
Average family members (number)	4.9 ± 1.24	4.7 ± 1.00	5.05 ± 0.97	7.0 ± 2.12
Main income source (agricultural income, %)	92.5	89.7	95.4	92.9
With some non-agricultural income (%)	78.5	83.5	77.3	46.4
With outside community work (%)	61.3	60.8	45.4	42.9
Limited formal education (%)	54.8	54.6	59.1	67.9
Average distance to district centre (km)	3.36 ± 1.81	7.5 ± 5.33	15.2 ± 6.69	8.4 ± 1.85

2.2. Data Collection

The questionnaire, largely based on items used in previous studies but applied elsewhere [12,15,22,33], consisted of eight sections, including household demographic profile, livelihood strategies; social networks and finance; health; food; water supply; housing and productive land; natural disasters and climate variability. There were initial in-depth interviews with experts from organizations such as Statistical Departments, Agriculture Department, Meteorological Centre, and the People's Committee at both provincial and district level, in order to better understand the research context and to select study sites in Phu Yen district. A list of suggested components related to vulnerability assessment to climate variability and climate events was given to local officials and experts in the fields of agriculture and climate for advice on which components were relevant to the locality. These components were then revised for the household survey (see Appendix A). A survey of 240 households in the Phu Yen district was conducted from December 2018 to January 2019. Households were randomly selected from lists of all communities. As the primary purpose of this study is to focus on understanding and assessing ethnic minority vulnerability, all participants were categorised into one of four ethnic groups. Interviews were conducted by the lead author and one local assistant. Generally, interviews were conducted only with the head of the household but if he/she was not available, the main labourer was interviewed. Each interview took 1 to 1.5 h on average and was conducted in the Vietnamese language. The local people, including the various minority groups, have mostly used this language in daily communication. Surveys were conducted with the approval of the Human Research Ethics Committee of the University of Southern Queensland. Data were entered into, checked, and analysed within Excel software 2010. Secondary data on daily minimum and maximum temperatures, and daily precipitation were collected from the Phu Yen meteorological station and also obtained from the Hydro-Meteorological Data Centre of Vietnam (HMDC) from 1961 to 2017.

2.3. Data Analysis

As mentioned, this study applied the LVI and LVI-IPCC developed by [12] to calculate a composite LVI with weightings based on expert opinions and stakeholder discussions [17,34]. Calculation of LVI-IPCC is based on the IPCC definition [35], which defines livelihood vulnerability as a function of factors that contribute to exposure, sensitivity, and adaptive capacity. This then leads to proposals around adaptation. The methods for each of the vulnerability indices used in this study are provided in the following sections.

2.3.1. Composite Livelihood Vulnerability Index

We adapted the hierarchical approach [12] of constructing the LVI based on major components and associated subcomponents. In this study, the LVI has eight major components: (1) sociodemographic profile; (2) livelihood strategies; (3) social networks and finance; (4) health; (5) food; (6) water; (7) housing and productive land; and (8) natural disasters and climate variability. Compared to [12] and [30], we added a new major component—"Housing and productive land" in this research due to expected vulnerability, based on regional experience, related to injury/death as well as property damage/loss during extreme weather events. Furthermore, each major component is divided into specific sub-components (see Appendix A). Based on a review of existing literature, a field survey and consultations with numerous experts and local officials, 39 subcomponents (see Appendix A) were selected to assess the vulnerability level under the impact of climate change.

A balanced, weighted-average approach was employed to calculate the composite LVI [34]. Equal weighting of components was used in the absence of compelling evidence of a need and basis for differential weightings. Using equal weighting also makes the interpretation process simpler. This does, however, mean that while each subcomponent contributes equally to the overall vulnerability index, there is a difference in the number of subcomponents so that each major component contributes a different weighting to the overall vulnerability rating. Therefore, it is important to look closely at the subcomponent results. Data for the composite LVI are from household surveys, with the addition of regional precipitation and temperature data. The survey work was approved by the Human Research Ethics Committee of the University of Southern Queensland (approval for H18REA267).

Step 1: As many subcomponents are measured using different scales, e.g., numbers and percentages, each subcomponent needs to be standardized for comparability among them and for compiling the overall index as follows Equation (1).

$$Index_{SC_c} = \frac{SC_c - SC_{\min}}{SC_{\max} - SC_{\min}} \tag{1}$$

where SC_c is the actual value of a subcomponent for a community c; $SC_{\min}$ and $SC_{\max}$ are the minimum and maximum values of each subcomponent reflecting low and high vulnerability, respectively.

Step 2: An index for each major component of vulnerability is then created by averaging their respective standardized subcomponents given by Equation (2).

$$MC_c = \frac{\sum_{i=1}^{n} Index_{SC_{ci}}}{n} \tag{2}$$

where MC_c represents each major components (eight major components) of the commune; and $Index_{SC_c}{}^{i}$ is the indexed subcomponent value of each major component MC_c for the commune and n is the number of subcomponents in each major component.

Step 3: Once values for each of the major components for a community are calculated, they are averaged to obtain the community-level LVI, given by Equation (3).

$$LVI_c = \frac{\sum_{i=1}^{8} w_{MC_i} MC_{ci}}{\sum_{i=1}^{8} w_{MC_i}} \tag{3}$$

where LVI_c is the LVI for a community c which is the weighted average of the eight major components. The weights of each major component, w_{MCi} are determined by the number of subcomponents making up each major component and are included to ensure that all subcomponents contribute equally to the overall LVI (see Appendix B for an example of an LVI calculation). After calculating the major components and the LVI for each group, a spider diagram was also created to compare the vulnerability level in each major component among the groups. The LVI was scaled in the range from 0 to 0.7. A higher value for the LVI denotes more vulnerable systems.

2.3.2. Livelihood Vulnerability Index by IPCC Framework Approach (LVI-IPCC)

The LVI-IPCC is also calculated, with three major components: exposure, adaptive capacity, and sensitivity. This approach diverges from the composite LVI in how the eight major components of LVI are combined (Table 2). There are three steps to complete the LVI-IPCC computation (see Appendix C), including the inverse of subcomponents for adaptive capacity; the grouping of indicators; and the calculation of LVI-IPCC (detailed below).

Table 2. The contribution of the LVI eight major components to the LVI-IPCC.

LVI Major Components	IPCC Definition of Vulnerability (LVI-IPCC)
Natural disaster and climate variability	Exposure
Socio-demographic profile Livelihood strategies Social network and finance	Adaptive capacity
Health	Sensitivity
Food	
Water	
Housing and productive land	

Step 1: The same subcomponents as with the previously described approach were used. However, to fit with the IPCC's definition of vulnerability, the inverse of all subcomponents for adaptive capacity was calculated and then averaged in the relevant major components (see Appendix C for example).

Step 2: The IPCC-defined contributing factor of each category for a community c (CF_c) was calculated by Equation (4)

$$CF_c = \frac{\sum_{i=1}^{n} w_{MC_i} MC_{ci}}{\sum_{i=1}^{n} w_{MC_i}} \tag{4}$$

where w_{MCi} is the weight of each major component and MC_{ci} is the index of a major component for a community c, and n is the number of major components in each contributing factor.

Step 3: After calculating the contributing factors, the LVI-IPCC index was derived using a linear function Equation (5)

$$\text{LVI-IPCC}_c = \left(\text{CF}_{c,\text{exposure}} - \text{CF}_{c,\text{adaptive capacity}}\right) * \text{CF}_{c,\text{sensitivity}} \tag{5}$$

After calculating contributing factors and LVI-IPCC, these results were represented in vulnerability spider web diagrams for convenient visual comparison of the four groups. Each vertex of a web shows a contributing factor that can highlight differences between groups. The calculated values of the LVI-IPCC index represent the vulnerability level of each community, ranging from −1 to 1, i.e., from least to most vulnerable.

3. Results

3.1. *Overview of Sample Groups*

As expected, there were similarities and some differences between the ethnic groups as shown in Table 1. For similarities, all groups were highly dependent on their own farming for food, social network indicators were similar and more than 99% of all respondents could access information by television, radio, mobile phone, or internet. All groups were highly dependent on agriculture as the main source of income, with Muong having the lowest level of dependency. Most households reported that they had not had access to any training related to climate change preparedness. The Hmong and Dao groups are, on average, further from the district centre, younger, have larger families, are more dependent on agriculture, and have more people with very low education levels.

3.2. Differences between Groups by LVI Components

Based on the eight major components and the composite LVI, there were differences between groups (see details in Table 3, with scoring differences in components shaded). The Hmong and Dao groups had higher overall LVIs and were more vulnerable on all component scores, with those differences in scores being a function of particular but not necessarily common (between these two groups) sub-components.

Table 3. Major components and subcomponents comprising the composite LVI.

Components (Major Components in Bold)	Thai	Muong	Dao	Hmong
Dependency	0.342	0.319	0.378	0.396
Female headed household	0.247	0.175	0.182	0.107
Household heads did not attend school	0.548	0.546	0.591	0.679
Socio-Demographic Profile	**0.379**	**0.347**	**0.384**	**0.394**
Household mainly income dependent on agriculture/forestry (cultivation, livestock, aquaculture, forest products collection)	0.925	0.897	0.955	0.929
Households without family members working outside the community	0.387	0.392	0.545	0.571
Households without non-agricultural livelihood income contribution	0.215	0.165	0.227	0.536
Average agricultural livelihood diversity index	0.165	0.160	0.190	0.263
Livelihood Strategies	**0.423**	**0.403**	**0.479**	**0.575**
Household without access to information (TV/radio/telephone/internet)	0.000	0.000	0.000	0.071
Average media diversity index	0.387	0.361	0.409	0.905
Need for assistance from the local government in last 12 months	0.387	0.402	0.545	0.679
Average receive/give ratio	0.156	0.122	0.080	0.138
Average borrow/lend ratio from/to the community	0.380	0.414	0.360	0.476
Average borrow/lend ratio from/to the bank	0.545	0.612	0.818	0.810
Average distance to the district centre	0.109	0.247	0.504	0.279
Households did not receive any agricultural training	0.570	0.505	0.682	0.786
Households did not receive any climate change training course	0.957	0.979	0.955	1.000
Households without any family member being a member of a group	0.140	0.113	0.227	0.429
Social Networks and Finance	**0.363**	**0.376**	**0.458**	**0.557**
Households with a family member with chronic illness	0.118	0.124	0.000	0.000
Households with a family member had to miss work or school in the last 2 week due to illness	0.022	0.093	0.182	0.143
Household with members needing daily dependent care	0.258	0.268	0.409	0.464
Average distance to access to health center (or hospital)	0.168	0.165	0.607	0.517
Health	**0.142**	**0.162**	**0.299**	**0.281**
Households primary dependent on self-farmed food	0.925	0.959	0.955	0.964
Average number of months household struggle to find food for the family	0.066	0.062	0.114	0.070
Average Crop Diversity Index	0.187	0.138	0.209	0.207
Household without crops saving	0.022	0.010	0.318	0.250
Food	**0.300**	**0.292**	**0.399**	**0.373**
Households utilize mainly natural water resources for domestic use	0.290	0.680	1.000	1.000
Average time to main water supply resource	0.016	0.067	0.030	0.029
Households do not have enough water for domestic use for the whole year	0.355	0.392	0.545	0.643
Inverse of the average days of stored water per household	0.528	0.562	0.497	0.693
Water	**0.298**	**0.425**	**0.518**	**0.591**
Households with weak thunderstorm/hail resistant construction	0.215	0.268	0.409	0.750
Houses elevated by low ground and easily inundated by floods	0.065	0.175	0.091	0.107
Houses is located at the place prone to a landslide	0.086	0.062	0.227	0.107
Average time to get to the agricultural land	0.185	0.159	0.425	0.358
Average areas of agricultural land vulnerability to floods	0.059	0.017	0.126	0.028
Average areas of agricultural land vulnerability to droughts	0.113	0.019	0.044	0.084
Housing and Productive Land	**0.121**	**0.117**	**0.220**	**0.239**

Table 3. *Cont.*

Components (Major Components in Bold)	Thai	Muong	Dao	Hmong
Average number of natural disaster in the past 5 years	0.298	0.347	0.308	0.347
Average types of natural disasters happened in the past 5 years	0.497	0.562	0.500	0.580
Household with losses physical assets and agricultural production in the past 5 years	0.570	0.526	0.864	0.750
Household did not receive a warning about the pending natural disasters	0.226	0.278	0.409	0.643
Natural Disasters and Climate Variability	**0.426**	**0.439**	**0.475**	**0.499**
Overall LVI	**0.320**	**0.334**	**0.413**	**0.455**

The shaded cells show scoring differences amongst the groups.

3.2.1. Socio-Demographic Profile

The Hmong and Dao groups had higher dependency levels, with Hmong having the highest percentage of household heads who have not attended school, but with the percentage of young female-headed households being the lowest. Overall, the Hmong group was more vulnerable than the other three ethnic groups on the socio-demographic profile component.

3.2.2. Livelihood Strategies

Hmong and Dao groups showed greater vulnerability on the livelihood strategies, which, in this study, included growing crops, raising animals, and collecting natural resources. Hmong and Dao households employed fewer livelihood strategies. Furthermore, Thai and Muong households reported having a higher percentage of family members working outside the community than did Hmong and Dao households. Similarly, Thai, Muong, and Dao ethnic groups have more non-agricultural income sources than the Hmong ethnic group.

3.2.3. Social Networks and Finance

More than half of Hmong and Dao households reported that they approached their local government for assistance in the past 12 months, compared to one-third of Thai and Muong households. Approximately 45–50% of Thai and Muong households had attended agricultural professional training, compared to 20–30% for Hmong and Dao households. These latter two households reported that the ratio of borrowing money and lending at the local bank was higher than that of Thai and Muong households. Hmong and Muong households had a higher ratio of the frequency of borrowing to the lending of money from and to family and friends. That is, people in these two groups tended to borrow more often, relative to lending occurrences. However, the ratio of in-kind assistance from family and friends and providing assistance in the past month was quite similar in three ethnic groups, with Dao people having the lowest rate. Thai, Muong, and Dao ethnic groups reported participating in a social organization more than Hmong ethnic groups. Such organizations included Farmer's Union, the Women's Union, the Young's Union, Farmer Interest Group, and Agricultural Cooperative. However, Hmong and Dao households reported that they mostly did not attend any training related to agriculture production. While there were variations across the sub-components, the net effect was that Hmong and Dao households were more vulnerable than Thai and Muong households on the social networks and finance components.

3.2.4. Health

Hmong and Dao reported travelling, on average, much further to the nearest health facility than did Thai and Muong households, the latter two reported higher rates of chronic illness amongst family members. Hmong and Dao households had higher rates of at least one family member missing work or school due to illness in the past 2 weeks. These two groups also had higher levels of dependent family members. Overall, the Hmong and Dao groups had higher health vulnerability scores.

3.2.5. Food

On average, Dao households had the longest average periods of food shortages. Muong households reported storing more crops for the next season than Thai, Hmong, and Dao households. Therefore, food vulnerability scores for Hmong and Dao ethnic groups were higher for the other groups.

3.2.6. Water

All Hmong and Dao households reported using a natural water source such as water from ravines, springs, or rivers to cook with and consume, which is presumed to increase vulnerability due to risks associated with water supply in the rainy season and water quality. Hmong and Dao households diverted water from ravines to plastic tanks through small water pipes. So while the average time to obtain water is relatively low, in the rainy season, these pipes are often buried by rocks and soil from the top of the hills or the mountains. Consequently, households in these areas can experience a short period of water deficits for daily needs. Meanwhile, nearly 70% of Thai and Muong households reported getting water from a personal well or clean water sources. Thai and Muong households have a greater water storage capacity, and more of the associated households have enough water for daily activities. Overall, the water vulnerability score for Hmong and Dao households was much higher than that for Thai and Muong households.

3.2.7. Housing and Productive Land

The majority of residential houses were built without technical guidance or professional instruction on reinforcement to mitigate the effects of natural disasters [36] but Hmong and Dao peoples have higher vulnerability scores in the housing and productive land component. Hmong especially have a higher average rate of using materials that have a low resistance to storms and hail. These materials include bamboo or unstable wooden planks and fibre cement sheeting. In addition, the physical location of a household is one important indicator considering the distribution of climate extreme events, especially in remote and hilly areas [2]. For example, households located along the river or stream networks are considered to be more vulnerable to flash-flood and bank erosion. Additionally, households situated at foothills' edges are likely more vulnerable than others when landslides happen. There is a higher rate of Muong households with housing in areas susceptible to flooding, while Dao households are more likely to be in places prone to landslide than other groups. Most households reported their areas of agricultural land were more vulnerable to floods than droughts, except for Thai households, which were more vulnerable to droughts than floods.

3.2.8. Natural Disaster and Climate Variability

There is no difference by ethnicity in regard to opinions on the average frequency and types of natural disasters (floods, drought, landslides, and so on) that occurred in the study area over the past 5 years. As reported, there were around four types of natural hazards and an average of around 20–24 hazard events. In the study sites, all information related to warnings and risks is transmitted through different channels including the announcement by digital means (for example, television, radio, village speakers, or in-person public meetings in the village). More Hmong and Dao people reported that they did not receive any warning about the pending climate extreme events such as frost, heavy rain, thunderstorm, flash flood, or landslides. Therefore, when the above natural disasters happened, more Hmong and Dao people reported that their house/property/agriculture production was damaged than did Thai and Muong people. The variables for the period of 1961–2017 used to develop the climate change rating, included mean standard deviation (MSD) of monthly average maximum daily temperature and minimum daily temperature, MSD of monthly average rainfall, average numbers of hot days, cold days, and heavy rain days. Overall, regarding natural disasters and climate variability, the Hmong and Dao were more vulnerable than Thai and Muong households.

3.3. Comparing LVI Outcomes

As a result of the above components, Hmong and Dao ethnic groups had a higher overall LVI score than did Thai and Muong ethnic groups. The results of the major component calculations are shown in a spider web diagram (Figure 3). This diagram is based on 0.1 unit increments, from 0 (less vulnerable) at the centre of the web to 0.7 (most vulnerable) at the web edge. The diagram illustrates that overall, Hmong and Dao ethnic groups are more vulnerable than Thai and Muong to livelihood strategies, social networks and finance, health, food, water, housing, and productive land.

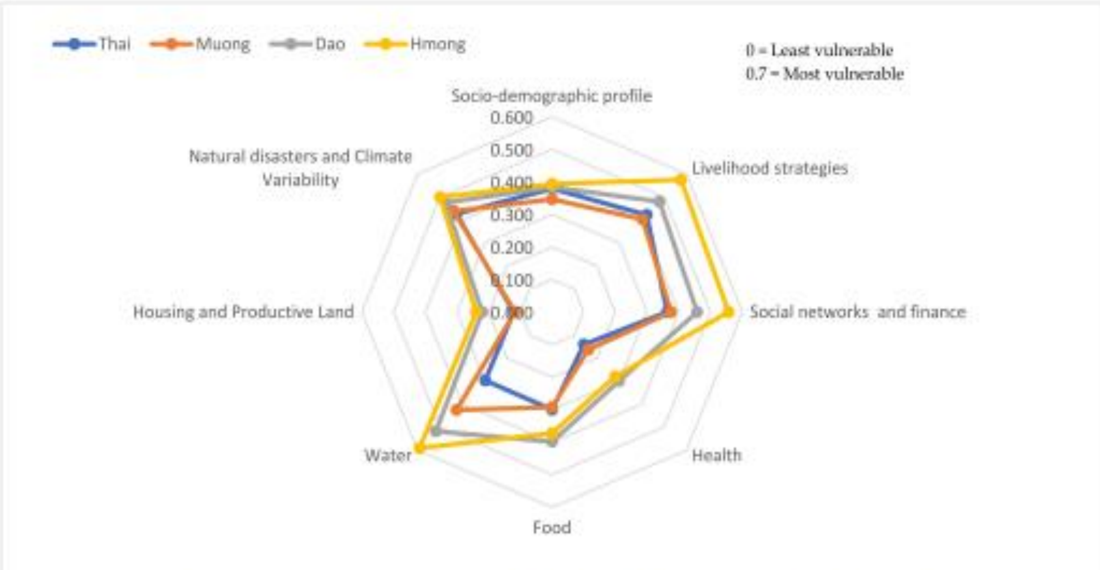

Figure 3. Vulnerability spider diagram of the major components of the composite LVI for four ethnic group.

3.4. Comparing the Groups with the LVI-IPCC Index

The LVI-IPCC estimation indicated similar rankings among the four minority ethnic groups with the IPCC vulnerability value being highest for Hmong, followed by Dao, Thai, and then Muong (Table 4). Vulnerability triangles (Figure 4) present the values of contributing factors to the overall results of the groups, including exposure, adaptive capacity, and sensitivity. In terms of exposure, Hmong and Dao groups are more vulnerable than Thai and Muong groups. Hmong and Dao ethnic groups are more sensitive to climate variability than the other two groups, driven by differences in the health, food, water, housing and productive land components, as above. Thai and Muong had a higher adaptive capacity than Hmong and Dao groups, concerning demographics, livelihoods, and social networks and finance components. The overall LVI-IPCC index suggests Hmong may be particularly vulnerable.

Table 4. LVI-IPCC contributing factors for four ethnic groups in Phu Yen district.

IPCC Contributing Factors to Vulnerability	Thai	Muong	Dao	Hmong
Adaptive capacity	0.469	0.483	0.434	0.340
Sensitivity	0.204	0.234	0.344	0.356
Exposure	0.426	0.439	0.475	0.499
LVI-IPCC	**−0.009**	**−0.010**	**0.014**	**0.057**

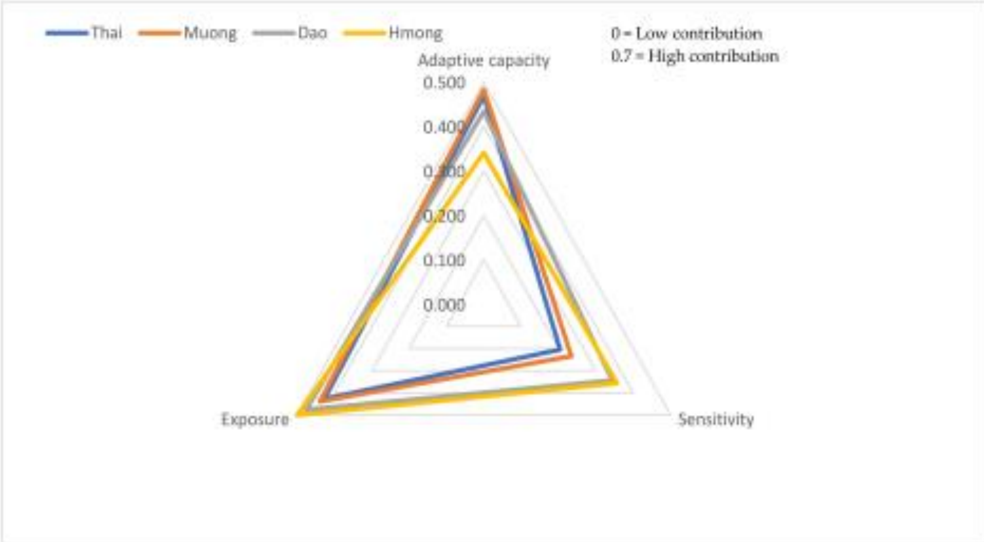

Figure 4. Vulnerability triangle diagram of the contributing factors of the LVI-IPCC for four ethnic groups.

4. Discussion

This study takes a case study approach to explore the importance of accounting for intersectionality in programs aimed at addressing vulnerability to climate risk in disadvantaged agriculturally dependent smallholder communities in the poor upland region of Vietnam. In total, we interviewed 240 households from four ethnic minority groups in the Son La Province. By using the LVI and LVI-IPCC approach, which has been successfully applied in different contexts [4,15,20,37,38], the results confirm that there are differences in vulnerability between four ethnic minority groups within the Phu Yen district, Son La province, in the NMR Vietnam, even though there is considerable disadvantage across the region and all groups. Generally, ethnic people living in the mountainous region have lower levels of education and income and poorer housing quality. This region has fragmented topography, highly remote areas, and roads in poor conditions, making transportation difficult to nearby cities or the centre of the district for shopping and to access health care services when needed, especially in the rainy season [39]. Additionally, ethnic households in this area are poor and mainly rely on their self-farmed production for daily meals. Variation in the level of vulnerability in the four studied ethnic minority groups living at different elevations indicated that livelihood vulnerability in the district is not the same and varies according to spatial distribution. This result is consistent with the work of [30] who found that livelihood vulnerability was not homogenous within the communities they studied.

In terms of adaptive capacity, differences in the index are largely driven by differences in diversity of sources of income, debt, agricultural training, and organization membership. All groups are highly dependent on agriculture, but the Hmong and Dao have a lower rate of off-farm income. That means they are most vulnerable to seasons and events that adversely affect production. Hmong and Dao peoples also rely more heavily on borrowed money, which implies a higher degree of financial hardship of the households, which potentially reduces the adaptive capacity of households in the face of adverse climatic conditions and events [40]. In order to improve households' capacity and reduce the vulnerable level in climate-changing conditions, local governments could facilitate diversification through the development of off-farm employment opportunities, value-added industries such as handicrafts, job migration schemes and small business training [41], with some of those strategies supported by concessional loans programs [40,42]. Social network ratings were found to be potentially important factors in the vulnerability of households, especially in rural and poor areas [43]. Important social organizations that provided livelihood support included the Farmer's Union, the Women's Union, the Youth Union, the Farmer Interest Group, and Agricultural Cooperative. These can provide useful information on agricultural practices/activities such as new varieties, pest and disease status, price changes, crop calendar alteration, and managing climate extreme events. These groups could also strengthen social capital.

There may also be disparities in information flows. From our survey, Thai and Muong households reported they received more advice/training on farming activities from local authorities than did Hmong and Dao households. Possible factors in this difference are relative education levels, dependency rates with consequent constraining effects on households, rate of organization membership (lower for Hmong and Dao households), and remoteness. Remoteness may also contribute to fewer training opportunities (supply-side) and difficulty in getting to those opportunities. Therefore, local government could make a priority for education/awareness programs for remote and vulnerable ethnic groups, focusing more on Hmong and Dao groups to enhance their adaptive capacity. Furthermore, improved information regarding climate impacts and mitigation strategies provided by local government/governmental organizations could increase adaptive capacity.

In terms of sensitivity, access to health services and water sources are other areas of difference and apparent disadvantage. Access to health services has previously been proposed as affecting the health status of households [12,15,22]. From the present study, Hmong and Dao peoples travelled three times longer than Thai and Muong peoples did to health services. Remote roads are often in poor condition and the lack of compounds the problem for Hmong and Dao communities [39]. In addition to road improvement, as above, the government could also reduce health vulnerability through educational programs, make greater use of visiting health professionals, and further develop water quality strategies.

Water availability is more likely to be threatened under climate variability [44]. The reliance of ethnic households on natural water sources for drinking and agricultural purposes indicates high sensitivity to climate variability and change, especially during drought or in the dry season [45]. Based on the survey data, Hmong, Dao, and Muong households could be more vulnerable to water-borne diseases, such as cholera, diarrhoea, and measles-related to low water quality, whereas Thai peoples seem to have safer water sources due to the installation of boreholes. The vulnerability of households to water availability has been observed to be affected by conflict over scarce resources [46,47], with climate change potentially exacerbating these conflicts. However, in the present work, although some Muong households reported water conflicts, especially regarding using water for agricultural production, these conflicts were generally solved peacefully.

Regarding exposure, reference [2] found that the location of households is a key factor influencing how they prepared for natural hazards events. In this regard, Hmong and Dao groups are significantly affected by climate change compared to Muong and Thai peoples. The reason for this might be that Hmong and Dao people are not necessarily within the audible range of loudspeakers for announcements, are somewhat disconnected from general media, or are too far from the sites of public meetings that provide warnings and preparedness information. Government responses could therefore include improving communication technologies and reach, as well as outreach on preparedness training. Some households are also more vulnerable due to the flimsiness of housing materials, so housing reinforcement programs could enhance living conditions and resilience, which in turn, might also help alleviate poverty [4].

Our findings and recommendations are expected to support the Vietnamese national climate change adaptation plan for 2021–2030 with a long-term vision by the year 2050 (Decision No.1055/QD-TTg, dated 20 July 2020). We suggest targeted interventions (e.g., infrastructure development for market access, education and training programs for vulnerable ethnic groups) for enhancing resilience and adaptive capacity of communities, economic sectors, and ecosystems most vulnerable to climate change and variability.

5. Conclusions

Climate variability and climate events have been increasing in frequency and intensity in the NMR of Vietnam, which affects both livelihoods and production activities of various ethnic minority groups, and those who have lower levels of education and income and poor housing systems are likely to be especially affected. This study is the first assessment of the vulnerability of Thai, Muong, Dao, and Hmong ethnic groups in this region, using the livelihood vulnerability index framework (composite LVI and LVI-IPCC). The overall indices revealed differences based on ethnicity/location, with Hmong and Dao being the most vulnerable groups. This shows the potential of the two methods to identify what might be critical factors in more or less vulnerability and adaptive capacity. We conclude that an analysis of the sub-components of LVI are critical to formulating highly targeted responses, especially where program resources are very limited.

Our findings identified education levels, diversity of income sources, agricultural training, and organizational membership as the most important factors influencing the households' adaptive capacity. The diversity of income among all groups is relatively low, with high dependence on agriculture, so there is a high exposure to climatic effects. We observed that while all four ethnic groups had relatively low education levels and high dependence ratios, Hmong and Dao were especially vulnerable on these sub-components. These then are likely constraints on people's ability to receive and understand information and policies from the local government. Becoming a member of a social or professional organization or network provides more opportunities to get information on agricultural practices/activities/natural hazards and also to strengthen the connections among communities. Access to health services and water resources could also be important, with deficits in these areas further increasing vulnerability to climate variability, change, and events. Housing location and construction also contribute to household vulnerability, especially concerning extreme weather events.

In order to reduce the vulnerable level of ethnic groups to climate change, the study provides the following recommendations which may be of interest to researchers working in other remote rural areas in other regions:

1. In national and local adaptation planning, priority should be given to support the poorer communities (in our studies case, the Hmong and Dao ethnic communities) that are more vulnerable and have a low capacity to cope with climate change.
2. It is essential to enhance literacy, especially amongst disadvantaged groups (Hmong and Dao ethnic groups in the current work). This solution is important because this would increase the effectiveness of training and education programs, especially with understanding threats to livelihood, including climate change, and better enable the transfer of technology.
3. Governments could strengthen extension, through targeted programs and appropriately designed visual aids and materials. These will help in the adaptation of farm systems and disaster preparedness.
4. Local governments could facilitate income diversification strategies, supported by training and concessional loans.
5. The government could upgrade road infrastructure to link remote communities to larger towns and centres and water systems and treatment.

Finally, we reiterate that the subjective selection and weighting sub-components for major components in the LVI models, and its influence on the vulnerability of households or communes, can be a limitation of LVI methods [4,12,45]. This research suggests that effective identification of the sub-components could improve the precision of assessment of the vulnerability of livelihoods to climate change at the local or regional level. To achieve that goal, researchers need to have a deep understanding of local situations including the natural resources, livelihoods assets, social-economic aspects, and climate conditions. The results of LVI-IPCC models in this research recommend that researchers should use caution in case the scores of LVI are negative or counterintuitive (the adaptive capacity results are greater than the exposure results). Increasing sensitivity might reduce the overall level of vulnerability. Therefore, in this case, in applying the LVI-IPCC model, caution should be taken in suggesting the adaptation options to climate change.

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Institutional Review Board Statement: The study was conducted according to the guidelines of the Declaration of Helsinki, and approved by Human Research Ethics Committee of the University of Southern Queensland (H18REA267, dated on 20 November 2018).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Data available on request due to restrictions.

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Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Table A1. Major components and subcomponents of the composite LVI and information sources.

Major Components	Subcomponents	Explanation of Sub-Component	Data Source	Explanatory Notes
Socio-demographic profile	Female household head	Percentage of households where the primary adult is female. Women are usually more vulnerable than men.	Survey	Adapted from [15,22]
	Dependency ratio	Percentage of household members who are outside employment age (under 15 and over 60 years old) as specified in Vietnam Labour Laws).	Survey	Modified from [12]. Modified the dependent age range to suit to the context of the study area
	Household heads did not attend school	Percentage of households where the head of the household reports that they have attended 0 years of school.	Survey	Adapted from [15,22]

Table A1. *Cont.*

Major Components	Subcomponents	Explanation of Sub-Component	Data Source	Explanatory Notes
Livelihood strategies	Households without family members working in a different community	Percentage of households that report no family member working outside of the community for their primary work activity.	Survey	Adapted from [12,22]
	Households income depends on agriculture/ forestry (cultivation, livestock, fishing, aquaculture, forest products collection)	Percentage of households that report only agriculture as a source of income.	Survey	Adapted from [12,33]
	Households without non-agricultural livelihood income contribution	Percentage of households that report no family member working in non-agricultural sector.	Survey	Adapted from [15]
	Average agricultural livelihood diversity index	The inverse of (the number of agricultural livelihood activities +1) reported by a household, e.g., a household that farms, raise animals, and collects natural resources will have a Livelihood Diversification Index = $1/(4+1) = 0.2$.	Survey	Adapted from [12,33]
Social networks and finance	Households without media access in the house	Percentage of households that report that they do not have any access to media information.	Survey	Adapted from [4]
	Need for assistance from the government in the last 12 months	Percentage of households that report that they have asked their local government for any assistance in the past 12 months.	Survey	Adapted from [12,22]
	Average receive/give ratio	Ratio of the number of types of help received by a household in the past month + 1) to (the number of types of help given by a household to someone else in the past month + 1).	Survey	Adapted from [12,22]
	Average distance to the district's centre (e.g., km or minutes)		Survey	Adapted from [15,48]
	Average borrow/lend money ratio (0.5–2)	Ratio of households borrowing money in the past month to a household lending money in the past month, e.g., If a household borrowed money but did not lend money, the ratio = 2:1 or 2 and if they lent money but did not borrow any, the ratio = 1:2 or 0.5.	Survey	Adapted from [12]
	Ratio of saving: saving at present (saving money in a bank + 1)/(borrowing money from a bank + 1)	Percentage of households that report that they do have not bank savings accounts.	Survey	New, added to reflect the context of study area: farmers often borrow money from a bank for agricultural production

Table A1. *Cont.*

Major Components	Subcomponents	Explanation of Sub-Component	Data Source	Explanatory Notes
	Household without family members being a member of a cooperative society (such as women union, farmer union)	Percentage of head of households that report that any family member is a member of a cooperative society.	Survey	Adapted from [48]
	Households did not receive any climate change training	Percentage of the heads of household that report that they have not participated in climate change training.	Survey	Adapted from [34,49,50]
	Households did not receive training in their main profession/s	Percentage of the head of households that report that they have not participated in professional training	Survey	Adapted from [34,50]
Health	Households with a family member having a chronic illness	Percentage of households that report at least 1 family member with chronic illness. Chronic illness was defined subjectively by the respondent.	Survey	Adapted from [12]
	Households with a family member missing work or school in the last 2 weeks due to illness	Percentage of households that report that at least 1 family member had to miss school or work due to illness in the last 2 weeks.	Survey	Adapted from [12]
	Average distance to health center (or hospital)	Average distance to the nearest health center (or hospital)	Survey	Adapted from [22,51]
	Households with members needing dependent care	Percentage of households that have at least one person needs to care for daily.	Survey	Adapted from [12,22]
Food	Households primary dependent on self-farmed food	Percentage of households that get their food primarily from their personal farms.	Survey	Adapted from [15,33]
	Average number of months households struggle to find food for the family (range: 0–12)	Average number of months households that struggle to obtain food for their family.	Survey	Adapted from [12,33]
	Average Crop Diversity Index	The inverse of (the number of crops grown by a household + 1). A household that grows pumpkin, maize, and cassava will have a Crop Diversity Index = 1/ (3 + 1) = 0.25.	Survey	Adapted from [12,33]
	Households that do not reserve crops	Percentage of households that do not save crops from each harvest.	Survey	Adapted from [12,30]
Water	Households use mainly natural water systems for domestic use	Percentage of households that report a creek, river, lake, pool, or hole as their primary water source	Survey	Adapted from [12]
	Average time to main water supply resource	Average time it takes the households to travel to their primary water source.	Survey	Adapted from [12]
	Not enough water for domestic use for the whole year	Percentage of households report that they do not have sufficient water to use for year-round activities	Survey	Adapted from [12]
	Inverse of the average days of stored water per household	The inverse of (the number of days water stored + 1)	Survey	Adapted from [12]

Table A1. *Cont.*

Major Components	Subcomponents	Explanation of Sub-Component	Data Source	Explanatory Notes
Housing and Productive Land	Households with weak thunderstorm/ hail resistant construction	Percentage of households report that their house is susceptible to extreme weather events such as thunderstorm, hail, etc.	Survey	Adapted from [15]
	Households on the low ground which is easily inundated by floods	Percentage of households that report that their house is easily inundated by flood.	Survey	Adapted from [15]
	Households located at the places being prone to a landslide	Percentage of households with a house located in landslide-prone area.	Survey	New, added to emphasize the context of mountainous area which is more vulnerable to land slides
	Average time to get to the agricultural land	Average time it takes the household to travel to their agricultural land.	Survey	New, added to address the sensitivity of production land location to climate in mountainous area. Agricultural land located farther from the household is more difficult to take care of the farm, especially in the case of extreme weather events
	Average areas of agricultural land being vulnerable to floods	Total area of household's agricultural land which is vulnerable to floods.	Survey	
	Average areas of agricultural land being vulnerable to droughts	Total area of household's agricultural land which is vulnerable to droughts.	Survey	
Natural disasters and Climate Variability	Average number of natural disaster in the past 5 years	Total number of extreme weather events that were reported by households in the past 5 years.	Survey	Adapted from [12,49]
	Average types of natural disasters happened in the past 5 years			Modified from [12,48].
	Household with losses physical assets and agricultural production in the past 5 years	Percentage of households report that they had property loss and production because of extreme weather events in the past 5 years.	Survey	Modified from [15]. Agricultural production losses would directly impact on livelihood so it was added beside physical assets
	Households with injury or death from natural disasters in the past 5 years	Percentage of households that report either an injury to or death of one of their family members as a result of the most severe flood, drought, or cyclone in the past 5 years.	Survey	Adapted from [1]
	Households did not receive a warning about the pending natural disasters	Percentage of households that did not receive a warning about the most severe flood, drought, and cyclone events in the past 5 years.	Survey	Adapted from [12]

Table A1. *Cont.*

Major Components	Subcomponents	Explanation of Sub-Component	Data Source	Explanatory Notes
	Mean standard deviation of monthly average minimum daily temperature (1961–2017)	Standard deviation of the average daily minimum temperature by month between 1961 and 2017 was averaged.	Data obtained from the Phu Yen meteorological station and HMDC	Adapted from [12]
	Mean standard deviation of monthly average maximum daily temperature (1961–2017)	Standard deviation of the average daily maximum temperature by month between 1961 and 2017 was averaged.		Adapted from [12]
	Mean standard deviation of monthly average rainfall (1961–2017)	Standard deviation of the average monthly precipitation between 1961 and 2017 was averaged.		Adapted from [12]
	Average numbers of hot days (1961–2017) (t ≥ 35 °C)	Number of hot days per year (t ≥ 35 °C) between 1961 and 2017 was averaged.		New, supported by decision 03/2020/QĐ-TTG that prescribes forecasting, warning and communication of natural disaster promulgated by the Prime Minister of Vietnam
	Average numbers of cold days (1961–2017) (t ≤ 13 °C)	Number of cold days per year (t ≤ 13 °C) between 1961 and 2017 was averaged.		
	Average number of days with heavy rain (1961–2017) (≥50mm/day)	Number of days with heavy rain per year (≥50mm/day) between 1961 and 2017 was averaged.		

Appendix B

Table A2. Calculating the livelihood strategies major component for the LVI for Thai ethnic group.

Subcomponent for Livelihood Strategies Major Component	Subcomponent Values	Max Subcomponent Value	Min Subcomponent Value	Index Value	Livelihood Strategies Major Component Value
Percentage of household mainly income dependent on agriculture (LV1)	92.47	100	0	0.925	0.423
Percentage of households without family members working outside the community (LV2)	38.71	100	0	0.387	
Percentage of households without non-agricultural livelihood income contribution (LV3)	21.50	100	0	0.215	
Average agricultural livelihood diversity index (LV4)	0.33	1	0.2	0.165	

Step 1: Calculating the index value of subcomponents (repeat for all subcomponents)

$$Index_{LV_1 Thai} = \frac{92.47 - 100}{100 - 0} = 0.93$$

Step 2: Calculating the value of livelihood strategies major component (repeat for all major components

$$Livelihood_{Thai} = \frac{\sum_{i=1}^{n} Index_{SC_{ci}}}{n} = \frac{LV_{1Thai} + LV_{2Thai} + LV_{3Thai} + LV_{4Thai}}{4} = \frac{0.925 + 0.387 + 0.215 + 0.165}{4} = 0.423$$

Step 3: Calculating LVI for Thai ethnic group

$$LVI_c = \frac{\sum_{i=1}^{8} w_{MC_i} MC_{ci}}{\sum_{i=1}^{8} w_{MC_i}} = \frac{3*0.379+4*0.423+10*0.363+4*0.142+4*0.300+4*0.298+6*0.121+10*0.426}{(3+4+10+4+4+4+6+10)} = 0.320$$

Appendix C

Table A3. Calculating the contributing factors and LVI-IPCC for Thai ethnic group.

Contributing Factors	Major Components	Major Components Value	Number of Subcomponents for Major Components	Values of Contributing Factors	LVI-IPCC Value
Exposure	Natural disaster and climate variability	0.426	10	0.426	
Adaptive Capacity	Socio-demographic profile	0.621	3		
	Livelihood strategies	0.494	4	0.469	
	Social network and finance	0.413	10		−0.009
Sensitivity	Health	0.142	4		
	Food	0.300	4		
	Water	0.298	4	0.204	
	Housing and productive land	0.121	6		

Step 1: Calculate the index value for subcomponent and major component as presented in Appendix A. However, we need to take the inverse of all subcomponents for the contributing factor adaptive capacity (Socio-demographic profile; Livelihood strategies; Social Network and finance) before doing the calculation following Appendix A. An example for taking the inverse of subcomponents for Livelihood strategies major component is given below.

Table A4. The inverse of subcomponents for Livelihood strategies major component.

Subcomponent for Livelihood Strategies Major Component (LVI Calculation)	Subcomponent Values for Thai Ethnic Group	Subcomponent for Livelihood Strategies Major Component (LVI-IPCC Calculation)	Subcomponent Values for Thai Ethnic Group
Percentage of household mainly income dependent on agriculture (LV_1)	92.47	Percentage of household with income no dependent on agriculture (LV_1)	7.53
Percentage of households without family members working outside the community (LV_2)	38.71	Percentage of households with family members working outside the community (LV_2)	61.29
Percentage of households without non-agricultural livelihood income contribution (LV_3)	21.50	Percentage of households with non-agricultural livelihood income contribution (LV_3)	78.50
Average agricultural livelihood diversity index (LV_4)	0.330	Average agricultural livelihood diversity index (LV_4)	0.504

Step 2: Calculate the adaptive capacity value for Thai ethnic group, repeat for contributing factors: Sensitivity and Exposure

$$CF_{Thai,adptivecapacity} = \frac{\sum_{i=1}^{n} w_{MC_i} MC_{ci}}{\sum_{i=1}^{n} w_{MC_i}} = \frac{3*0.621+4*0.494+10*0.413}{17} = 0.469$$

Step 3: Calculate LVI_IPCC value (repeat for all of 3 ethnic groups)

$$\text{LVI-IPCC}_{Thai} = \left(\text{CF}_{c,\text{exposure}} - \text{CF}_{c,\text{adaptive capacity}}\right) * \text{CF}_{c,\text{sensitivity}} = (0.426 - 0.469) * 0.204 = -0.009$$

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This chapter explored the livelihood vulnerability at community level. Four different typical ethnic communities in the Northwest Mountainous Regions of Vietnam were selected for assessing the level of vulnerability by using LVI approaches. The assessment revealed differences according to ethnicity and location, for example, Hmong and Dao groups are more vulnerable compared to Thai and Muong groups. Further analyses based on household surveys will be undertaken to investigate what sub-groups may be less resilient and how their resilience levels differ between both ethnic groups and gender (Chapter 4).

CHAPTER 4: PAPER 2 - NUANCED ASSESSMENT OF LIVELIHOOD RESILIENCE THROUGH THE INTERSECTIONAL LENS OF GENDER AND ETHNICITY: EVIDENCE FROM SMALL-SCALE FARMING COMMUNITIES IN THE UPLAND REGIONS OF VIETNAM

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Supplementary Table 1. Correlation between indicators of household livelihood capitals and gender.

Indicators/gender	Male	Female	Chi-Square test
Formal education	90%	78%	χ^2=21.79, *p*=0.019
Health problem	46%	77%	χ^2=16.52, *p*=0.034
Crop diversity	95%	85%	χ^2=184.88, *p*=0.000
Farm equipment ownership	46.1%	20.2%	χ^2=25.15, *p*=0.000

Supplementary Table 2. Correlation between indicators of household livelihood capitals and ethnicity.

Indicators/Ethnicity	Thai	Muong	Dao	Hmong	Chi-square test
Salaried jobs	75%	82%	45%	42%	χ^2=25.06, *p*=0.000
Bank loans	42%	32%	67%	72%	χ^2=20.08, *p*=0.018
Rent farming equipment	12%	20%	64%	62%	χ^2=43.53, *p*=0.000
Illiteracy rate	4%	20%	54%	64%	χ^2=78.77, *p*=0.000
Agricultural trainings	61%	55%	35%	32%	χ^2=8.20, *p*=0.043
Group membership	92%	93%	77%	40%	χ^2=54.77, *p*=0.000
Family size (average, people)	4.2	4.5	5.1	7.1	χ^2=14.98, *p*=0.020
Farm size (average, ha)	0.82	1.02	1.52	1.36	χ^2=29.99, *p*=0.000
No of farm crops (average)	4.52	4.46	3.59	4.39	χ^2=29.97, *p*=0.000

This chapter provided nuanced views on self-assessed livelihood resilience at the household level among ethnic communities living in the upland region of Vietnam. By using the household livelihood resilience approach, we observed that ethnicity seems to play a more important role than gender in governing differences in household livelihood resilience in the study region. The chapter also indicated the effectiveness of using the intersectional lens of gender and ethnicity in resilience assessment and resilience building. Based on these finding in the chapter, we conducted further analyses to investigate whether perceptions of climate variability and responses to climate change vary among ethnic communities in the study region. In addition, we identified some main factors contributing to adaptation choices (Chapter 5).

CHAPTER 5: PAPER 3 - FARMERS' PERCEPTIONS AND ADAPTATION PRACTICES TO CLIMATE VARIABILITY RISKS AND THEIR ASSOCIATED DETERMINANTS: EVIDENCE FROM SMALL-SCALE FARMING COMMUNITIES IN THE UPLAND REGIONS OF VIETNAM

Article III: VT Tran, D-A An-Vo, S Mushtaq, G Cockfield: Farmers' perceptions and adaptation practices to climate variability risks and their associated determinants: Evidence from small-scale farming communities in the upland regions of Vietnam. (Had been submitted Weather and Climate Extremes, 2022).

Abstract

Climate change is threatening the livelihoods and food security of low-income smallholder farmers in Vietnam, who may have little capacity or preparedness to cope with it. Adaptation at the farm level is therefore an important strategy for reducing the impacts of extreme climatic events. This study explored the perceptions of climatic attributes and their induced risks, adaptation practices, and associated determinants for small-scale farming communities in the Northwest Mountainous Regions. 240 representative farm households were interviewed in the study region. Our findings, from statistical analyses, indicated a majority of the farmers observed changes in temperature and rainfall pattern – an increase in temperature (which is consistent with the actual trend) and an increase in the rainfall (which is generally against the measured trend).

In addition, farmers reported climate-related risks – drought, flood, landslide, pests, and diseases, increasingly damaging crops. In response, farmers have adopted various strategies to respond to climate change such as changing crop varieties, crop diversification, crop management and protection (plant and soil), and finding off-farm jobs. However, there are

statistically significant differences in adoption of each adaptive strategy to climate variability risks among studied small-scale farming communities. Furthermore, a binary logistic analysis showed that farmers' socio-economic factors, farm size, and institutional characteristics significantly influence households' adaptation. Future policies (free literacy classes, concession loans, upgrading infrastructure, natural disaster warnings, etc.), therefore, should consider these main factors to facilitate appropriate interventions and holistic climate change adaptation strategies and enable sustainable farming households' livelihoods for local farmers.

1. Introduction

Climate change can have significant repercussions for agricultural production, particularly in developing nations, where small-scale farming households are disproportionately affected and increasingly exposed to natural hazards (Wheeler & Braun 2013; Altieri & Nicholls 2017; Li et al. 2017). Climate change presents in increased climate variability, which is predicted to worsen in the next decades (Pachauri et al. 2014), threatening current and future development efforts. In fact, climate change has a particularly negative influence on agricultural production in developing nations and mountain regions, especially within Southeast Asia countries (IPCC 2014; Ali & Erenstein 2017; Huong et al. 2017; Khanal et al. 2018).

Vietnam is especially prone to natural disasters and is one of the top five nations affected by climate change (Smyle & Cooke 2011). This is evident through increasing average temperatures, rising sea levels, and drier seasons. Natural hazards including cyclonic storms, flood, and droughts, have occurred more frequently and severely in Vietnam. For example, the annual average temperature has risen by 0.5^0C to 0.7^0C and sea level has increased about 20cm over the last 50 years (Government of Vietnam 2011). According to the IPCC (2018), in mountainous regions, climate hazards include flash floods, storms, temperature extremes, drought, erratic rainfall, freezes and frost. The Northwest Mountainous Regions of Vietnam is highly vulnerable to such hazards because of comparatively fragile ecosystems, complicated terrain, and unstable geology (Do 2013), meaning this region is one of the most vulnerable areas to a changing climate (PanNature 2017).

Climate change's negative effects on agriculture are likely to be unpredictable, with the potential to be disastrous (Mushtaq et al. 2020). For example, rice yields might drop anywhere from 6% to 42% by 2050, while other crop yields could drop anywhere from 3% to 47% (Smyle & Cooke 2011). Furthermore, climate change has negative impacts on soil quality, livestock, and farmer health (IPCC 2014). Given the trajectory of greenhouse gas emissions and consequent climatic effects, climate change adaptation is increasingly studied and promoted as a vital response for a vulnerable sector (Nelson et al. 2007; Barros et al. 2014; Thornton & Comberti 2017). Adaptation strategies such as diversifying crops, altering crop varieties and changes in irrigation systems and practices (Abid et al. 2016) are critical responses playing an important role in agricultural sustainability. However, smallholder farmers in mountainous regions such as those of Vietnam may have relatively low adaptive capacity (Pham et al. 2020; Tran et al. 2021) and limited capacity to learn and apply modern techniques to adapt to climate variability (Le Dang et al. 2014; Huong et al. 2017). Hence, strengthening farmers' adaptive capacity and their adaptation skills are critical for enhancing livelihood and food security (Nelson et al. 2009; Niles et al. 2015). Farmers' knowledge, views, and attitudes toward climate change are determinants of adaptation decision-making, both in approach and outcomes. In the process of climate adaptation, knowledge, perceptions, and attitudes are all interconnected and interacting (Deressa et al. 2011; Schad et al. 2012; Soubry et al. 2020). Therefore, it is critical to comprehend local perceptions of climate change and other elements that influence farmers’ awareness of the issue. Indeed, it is considered the first step of the adaptation process (Di Falco & Veronesi 2013). Research shows that improving farmers' adaptive capacity can help to mitigate climate change’s negative consequences, protect poor farmers' livelihoods, and enhance any potential benefits (Wheeler et al. 2013). Farmers' behavioural responses to natural hazards and opportunities are however heavily influenced by their perceptions (Pham et al. 2019).

While there are numerous studies on farmers' perceptions of climate change, on contributing factors and on adaptation strategies employed by affected farmers in many parts of the world (Pham et al. 2019), there has been very little research comparing farmers' perceptions and adaptation in different communities in the same mountain range to a changing climate (Schneiderbauer et al. 2021), making it difficult to examine divergent perspectives and support targeted interventions for different communities, especially if there are differences in histories and cultures on top of geographical differences. There is a lack of knowledge and understanding about how farmers prioritise and express their willingness to adapt to natural hazards. In addition, field-based research is considered critical because it may pave the way for a more accurate understanding of adaptation strategies to be applied at the local level. This work focuses on four farming communities with different predominant ethnicities, namely Thai, Muong, Dao, and Hmong, in the Northwest Mountainous Regions of Vietnam (NRMs), with all communities heavily relying on agriculture for their livelihoods. To start to address the aforementioned research gap, this paper aims to: (i) examine farmer’s perceptions and differences between them, (ii) explore the current coping practices and adaptation employed to mitigate the negative effects of climate variabilities, and (iii) determine factors influencing farmers' adaptation choices.

2. Methods

2.1 Study site

Phu Yen district (see Fig. 1) in Son La province in the NMRs was chosen as the research site because it is one of the five most impoverished districts of Son La province. The district was a target area for the Vietnam Government’s special poverty reduction program (Program 135) from 2016 to 2020 (Tran et al. 2021). This program is the socio-economic development program for remote and isolated areas, and especially for mountainous communes (Decision 135/QD-TTg dated 31st July 1998). The total area of the Phu Yen district is 1,227 km^2, with a population of approximately 116,000, the majority of which are involved in small-scale subsistence agriculture. Regional products include rice, fruits, and crops, with production systems being vulnerable to droughts and/or hot west wind in the dry season, flash floods and landslides in the rainy season, as well as cold spells, and frost in winter (Phu Yen Office of Statistics 2018). Ethnic minorities of the district distribute in three sub-regions based on elevation. The Thai and Muong groups reside at lower elevations, while Dao and Hmong groups settled, respectively, in the middle and high elevations (Dien 2002; Vien 2003).

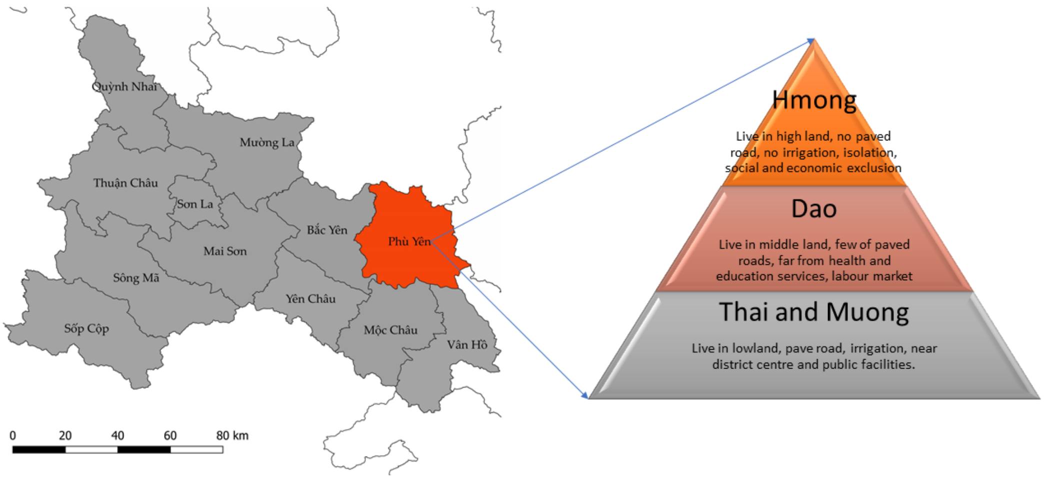


Fig. 1. Mapping the study site (Phu Yen district) in Son La province. The pyramid provided the information on ethnic groups' location and their disadvantages.

2.2 Data collection

Primary data were collected through household surveys, using structured and semi-structured question frames, and key informant interviews (KIIs). A draft questionnaire was tested with fifteen farm households and then revised for formal household interviews. A survey of 240 households was then conducted from late 2018 to early 2019. The aim of the household survey was to collect information on stressors to livelihoods, perceptions of changes in climatic attributes and climate-related hazards, climate change implications, and farmer response plans. Survey questions were developed with specialists' and local agricultural expert consultations, a literature review and field trips. Farmers' perceptions of changes in climatic attributes and climate hazards during the past decade were categorised by four responses in regard to those changes: increase, decrease, stable, and don't know (Table 2). The respondents were also asked about their adaptation and coping strategies. Household interviews were conducted by the lead author and one local assistant. Elders, head of marginalised communities, and district/commune level officers (from the disaster risk management department and the natural resources and rural development department) were key informants.

Prior to interviews at households, a consent form was read aloud, signed immediately and collected by the lead author when the interview was completed. Generally, interviews were conducted only with the head of the family but if he/she was not available, spouses or the primary labourer were interviewed. Each interview took 1.0 to 1.5 hours on average and was conducted in the Vietnamese language. The local people, including the various minority groups, have mostly used this language in daily communication. Data were entered, checked, and analysed within Excel software 2016. Data on daily minimum and maximum temperatures and daily precipitation were collected from the Phu Yen meteorological station and the Hydro-Meteorological Data Centre of Vietnam (HMDC) from 1961 to 2017.

2.3 Data analysis

Data were analysed in SPSS 27.0 to analyse and describe households' awareness of climate variability, climatic related risks, chosen adaptation options and associated determinants. In addition, data from KIIs were combined with quantitative data to compare perceptions of key informants with those of households.

A one-way analysis of variance (ANOVA) test was used to test if there were statistically significant differences in selecting adaption strategies among the studied communities. The one-way ANOVA helps to identify significant differences in means between farming communities in selecting adaptation/coping strategies. If this ANOVA analysis returns a statistically significant *p*-value (less than 0.05), the alternative hypothesis is accepted, indicating statistical differences between studied farming communities. This test only revealed an overall difference among the studied groups, not the difference between two groups. Thus, we conducted one-way ANOVA with a Tukey post-hoc test to pinpoint intergroup differences.

A binary logistic regression model was developed to quantify the determinants affecting farmers' adaptation strategies. The dependent variable in the current work is whether a farmer has 'adapted' or 'not adapted' any adaptation practices to climate change. Based on discussions with staff from the natural resources and rural development department, a literature review, and field observations, five adaptation practices were identified: changing crop varieties; crop diversification; water management; crop management (crop and plant); and finding off-farm jobs. The selection of adaptation practices was categorized by a dummy variable (0,1) indicating whether a farmer employed a specific adaptation strategy (1) or not (0). Table 1 provides descriptions of explanatory variables and their expected signs in the current work. Because dependent variables (employing an adaptation practice or not) are binary, we used binary logistic models to analyse the factors influencing farmers' decisions to adapt to climate change because this model has been used in numerous prior research (Huong et al. 2017; Trinh et al. 2018). Another reason is that results from binary logistic model are more precise than those from similar binary models (e.g., Linear Probability Model that shows a limitation regarding error term distribution abnormality and heteroscedasticity) (Khan et al., 2020). In the binary logistic model, the dependent variable becomes the logarithm of the odds as presented in Eq. (1):

$$\log_e\left[\text{odds} = \frac{P}{1-P}\right] = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 ... \beta_k X_k, \quad (1)$$

Where P is the probability of adaptation; X_i, $i \in \{1, 2, \ldots, k\}$, are the explanatory variables and β_i are regression coefficients of the explanatory variables; and β_0 is the constant term.

Table 1. Description of explanatory variables hypothetically affecting farmers' adaptation choices.

Explanatory variables	Description	Value	Expected sign
Age	Age of farmer	Years	+
Gender	Gender of the farmer	1 Male; 0 Female	±
Education level	Level of education (degree)	1 illiterate; 2 primary; 3 secondary; 4 high school and higher	+
Ethnic location	Elevation at which ethnic groups reside	1 Low (Thai & Muong); 2 Middle (Dao); 3 High (Hmong)	±
Household condition (poor household)	The condition of household	1 Yes; 0 No	+
Farm size	Number of hectares of agricultural farmland	Hectares	+
Access to credit	If the farmer has access to credit from any sources	1 Yes; 0 No	+
Access to extension	If the farmer has access to extension services	1 Yes; 0 No	+

Explanatory variables	Description	Value	Expected sign
Access to irrigation	If the farmer has access to credit	1 Yes; 0 No	+
Access to weather information	If the farmer gets information about weather, climate from any sources	1 Yes; 0 No	+
Farmers’ group membership	If the farmer is a member of a farmer’s group	1 Yes; 0 No	+

Multicollinearity significantly influences the estimation of the logit model’s parameters (Midi et al. 2010). Here, the binary logistic regression was conducted after we examined the association or correlation between explanatory variables based on the variance inflation factor (VIF) and contingency coefficient (CC) (Cama et al. 2016). The VIF was calculated for a continuous variable being related to other continuous variables, given by Eq. (2)

$$VIF(X_i) = \frac{1}{1 - R_i^2} \tag{2}$$

where, R_i^2 is squared multiple correlation coefficient between a continuous variable X_i and other continuous variables. Meanwhile, the CC was computed to explore any relationship between discrete (dummy) variables and categorical variables that could cause multicollinearity or association problems, given by Eq. (3)

$$\mathrm{CC} = \sqrt{\frac{\chi^2}{n + \chi^2}} \tag{3}$$

where χ^2 denotes the Chi-square value and *n* the sample size.

A CC value around zero means no association and a CC value of more than 0.65 means two variables are associated. A VIF value less than 10 means no multicollinearity among continuous variables and a VIF value more than 10 means there is multicollinearity among continuous variables.

3. Results

3.1 Results of testing multicollinearity between explanatory variables

The calculated values of the VIF for three continuous variables demonstrates that none of the variables have a value of 10 or higher. The contingency coefficient was also calculated to see how closely the discrete variables were related. The contingency coefficient was calculated based on the value of chi-square for one categorial variable and six discrete variables (dummy). The calculated values of CCs for the discrete (dummy) and categorical variables were low (CCs < 0.65), indicating that there was no issue with multicollinearity between the variables. Therefore, the binary logistic model accepted all dummy and categorical variables.

3.2 Farmers' perceptions on climate variability and weather extreme events

Having a better understanding of farm households' perceptions of uncertain environmental conditions is crucial for suggesting changes to their farming activities. Farmers were asked to share their observations regarding climate variability and extreme events. Table 2 presents farmers' perspectives of changes in climate variables and extreme weather events through the four categories.

Table 2. Farmers' perception of climate attributes and extreme events through four categories: Increasing, Decreasing, Stable and I don't know

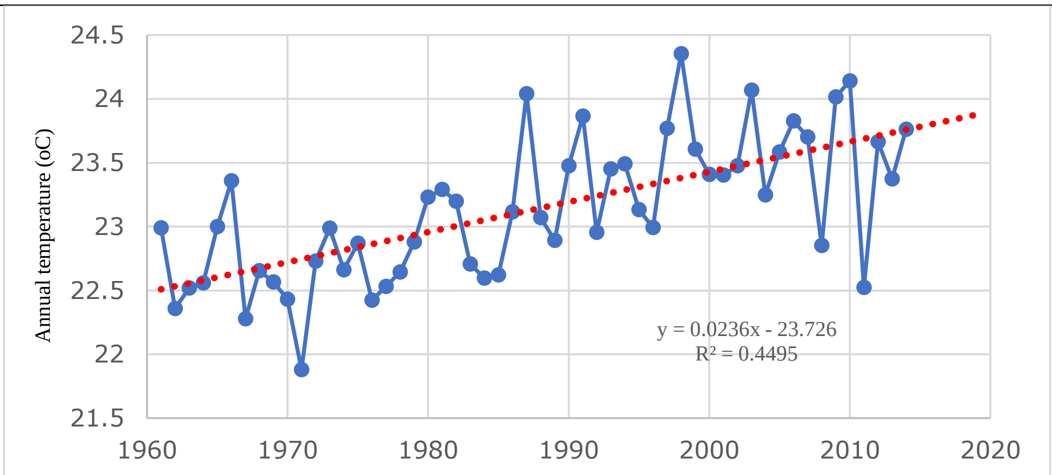
Climate Parameters	Climatic Indicators	Perceived trend	Respondents (%) agreement in farming communities *			
			Thai (n=93)	Muong (n=97)	Dao (n=22)	Hmong (n=28)
Precipitation	Overall rainfall	Increasing	84.9	85.2	83.5	81.3
		Decreasing	10.8	10.7	14.4	15.4
		Stable	4.3	5.1	2.1	3.3
		I don't know	0	0	0	0
Temperature		Increasing	83.9	81.8	78.4	64.3

	Local atmosphere temperature	Decreasing	10.8	4.5	8.2	17.9
		Stable	5.4	13.6	13.4	17.9
		I don't know	0	0	0	0
Extreme events	Frequency of flood and landslide	Increasing	81.7	81.8	83.5	82.7
		Decreasing	2.2	9.1	7.2	7.1
		Stable	11.8	9.1	8.2	6.6
		I don't know	4.3	0	1.0	3.6
	Annual damaged cold days	Increasing	15.1	22.7	32	39.3
		Decreasing	75.3	72.7	50.5	53.6
		Stable	9.7	4.5	17.5	7.1
		I don't know	0	0	0	0
	Annual extremely hot days	Increasing	82.8	81.8	69.4	64.3
		Decreasing	9.7	4.5	8.2	7.1
		Stable	7.5	13.6	22.4	21.4
		I don't know	0	0	0	7.1
	Frequency of drought	Increasing	39.8	43.6	27.8	25.5
		Decreasing	7.5	8.2	12.4	15.7
		Stable	49.5	48.2	59.8	59.3
		I don't know	4.2	0	0	0

*Due to financial resources available and time constraint for PhD study, small sample sizes used for the analysis of data for four studied ethnic groups. However, we used Slovin's formula to estimate the appropriate sample sizes for data collection. Please see Chapter 4 for more details.

Most of the respondents interviewed in various ethnic communities reported an increase in temperature. The outcome, however, differed among farming communities. Thai and Muong had a slightly higher proportion (above 81%) of farmers who thought the temperature had risen, compared to 78.4% and 64.3% of Dao and Hmong people (at medium and high altitudes), respectively. These perceptions of increasing temperatures were consistent with the actual regional trend (Fig. 2a). In contrast, there is high agreement among all studied farming communities about the trend of annual rainfall, e.g., above 81% of respondents perceived rainfall increases, which is somewhat against the observed trend of a slight decrease (Fig. 2b). Responses may have been affected by changes in the intensity of rainfall events (lower annual totals but higher falls per event). Respondents described how precipitation has been more intense and erratic. There may also have been a recency effect of heavy rain events, accompanied by flash floods that occurred in October 2017 and July 2018 in the study area, prior to the initial data collection. These flooding events greatly damaged local properties and crops and caused a few weeks of isolation and several deaths.

The frequency of extreme weather events is another important aspect of climate change. Flood, landslides, erratic rains, extreme temperatures, and droughts are the main extreme events occurring within the study region, which were reported by local farmers. A high percentage of farmers in all studied farming communities reported an increasing frequency of floods and landslides (from 81% to 84%, see Table 2). Similarly, an increase in annual extremely hot days (greater than 35°C) were reported by respondents. A higher proportion (above 81%) from Thai and Muong groups perceived that the numbers of annual extreme hot days had risen compared to 69.4% and 64.3% from Dao and Hmong groups, at the middle and high elevations. A decrease in annual damaging cold days were reported by 73% to 75% of Muong and Thai and 50% to 54% of Dao and Hmong people. The observed cold and hot day trends are in Fig. 2c and 2d. Views on drought frequency were more variable, though a majority of respondents opted for ‘stable’. There were also some perceptions of seasonal shifts, as participants mentioned (e.g., Thai and Muong groups) that rainy seasons had typically lasted from June to September, but they had become more irregular recently. In addition, water reservoirs were reported to have dried up early because of insufficient rains and high evaporation.



a)

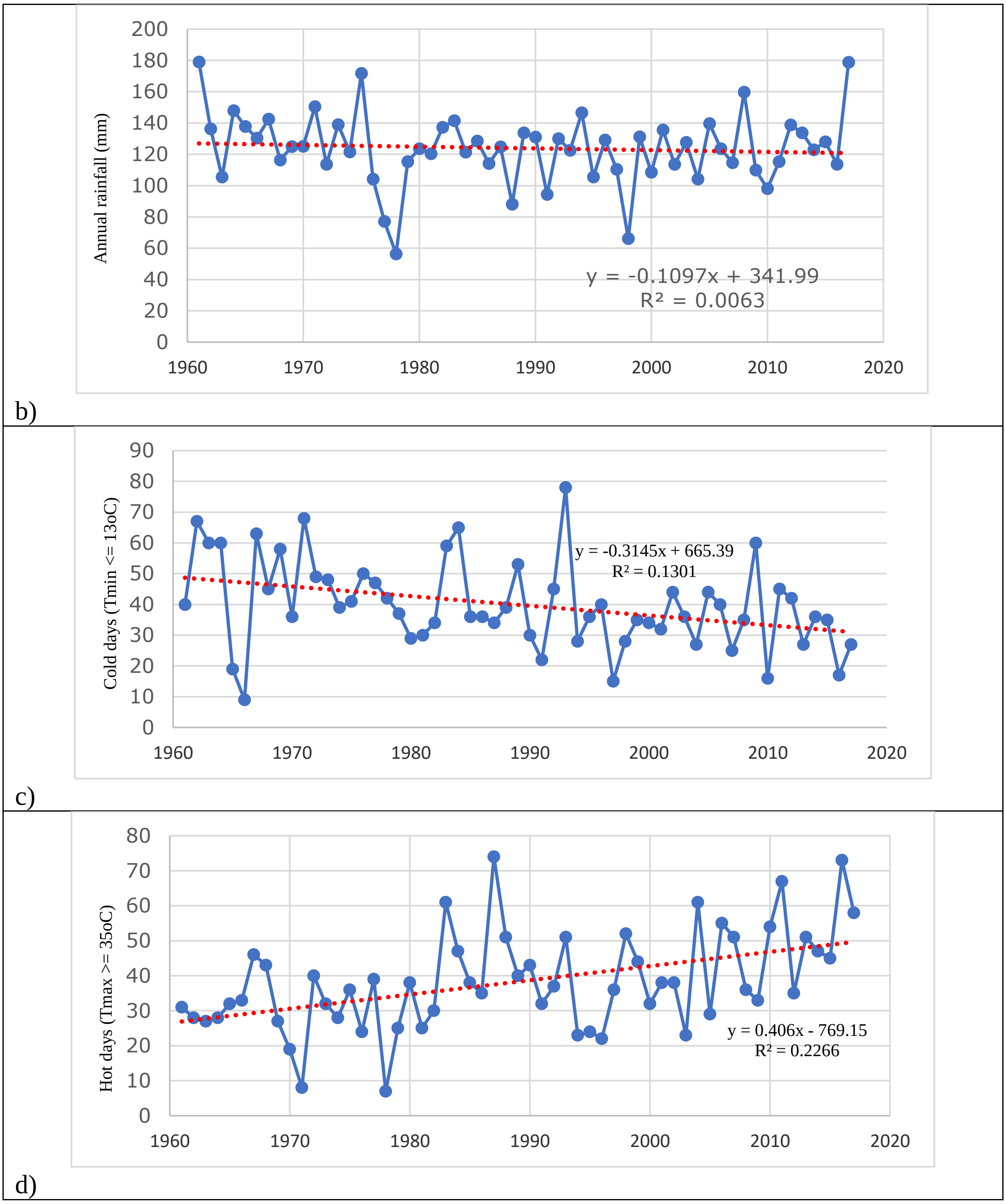


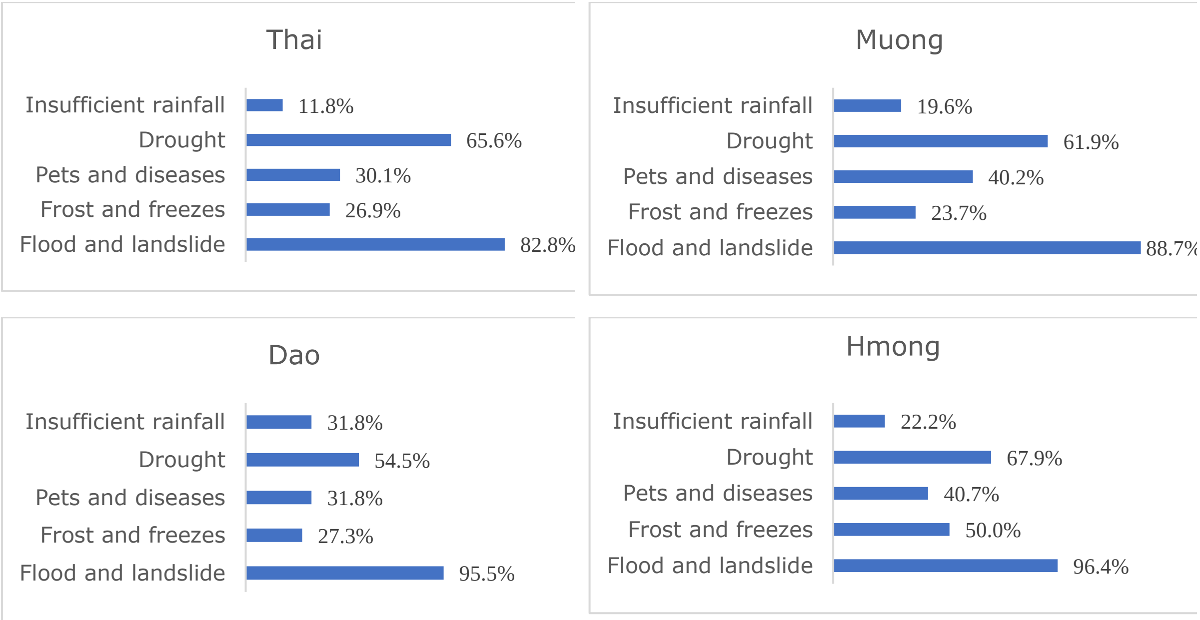
Fig. 2. The trends of a) mean temperature, b) annual rainfall, c) annual cold days and d) annual hot days in study area from 1961 to 2017.

3.3 Farmer's perception of climate and non-climate stressors

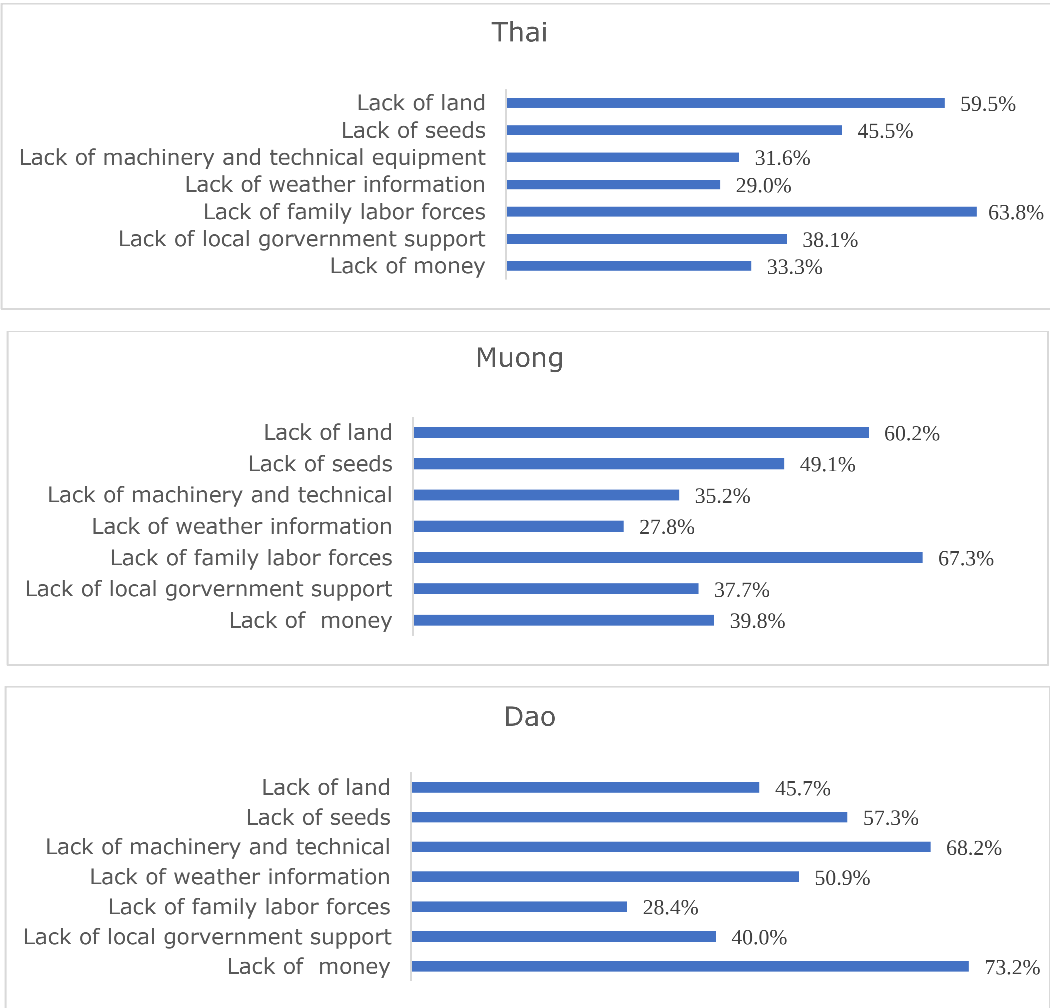
The studied farming communities have reported an emphasis on changes in frequency and severity of natural hazards. Throughout discussions with farmers in different communities, agricultural officials, and key informants, climatic and socio-economic pressures were reported to be major factors influencing agricultural activities. The socio-economic stressors include a lack of land, seeds, machinery and technical equipment, weather information, family labour, local government support, and money (detailed in Fig. 3). Flood and landslides, erratic rainfall, droughts, frost and freezes, pests, and diseases were named by respondents as the top climate-related stressors affecting crop production.

Farmers from all studied groups indicated that floods and landslides (from 82.8% to 96%), and drought (from 54.5% to 67.9%) were the two most significant climate-related stressors affecting crop production. Participants stated that they were unable to prepare their land for the following season due to the occurrence of drought. In addition, an insufficient or limited irrigation system is noted as one of the factors exacerbating farmers' vulnerability to rainfall irregularity during crop seasons. Farmers mentioned changing rainfall involves shorter duration but higher intensities. Dao and Hmong respondents mentioned that it is hard to anticipate current climatic conditions for farming activities by applying historical, indigenous knowledge due to climate change. A higher proportion of Hmong groups, who reside in the highest location, reported frost and freezes are also impacting adversely on their crops and livestock. Furthermore, erratic rainfall pattern was also a climate stressor impacting agricultural activities within the Dao community. Thai and Muong people shared that the changes in rainfall and extreme weather events lead to an increase in pets and diseases adversely impacted on crop production, especially in crop yield.

a) Farmers' perception of climate-related stress (%)



b) Farmers' perception of non-climate stress (%)



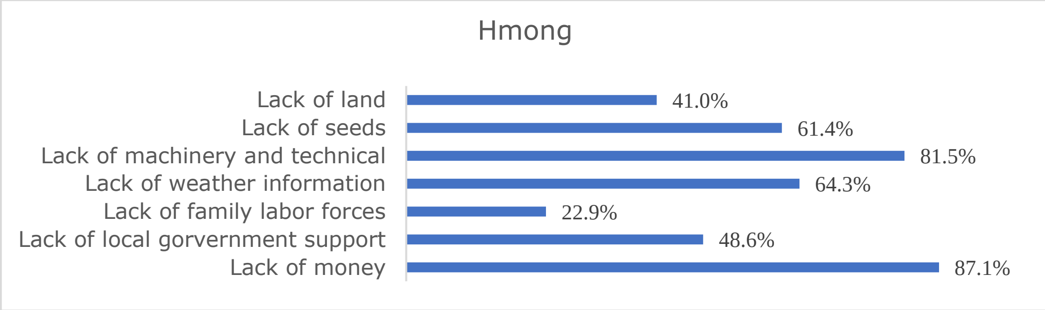


Fig. 3. Climatic and non-climatic related stress reported by percentage of farmers in the studied farming communities.

All farmers participating in current study reported lack of crop seeds is one of the top non-climatic related stressors. However, there are differences in the list of top main non-climatic stressors influencing agricultural activities identified by Thai- Muong group and Dao - Hmong group. For example, Thai and Muong farmers reported their agricultural production was affected by lack of family labour (64% and 67%) and small farming land areas (60%). Meanwhile, Dao and Hmong considered lack of money (both cash and borrowing ability, 73% and 87%), lack of farming equipment (68% and 82%) and insufficient climate information (51% and 64%) that largely impacted on their crop production, especially in a changing climate. Differences in farmers' perception of non-climate stressors might relate to different living zones and their assets and capital (such as, financial, human, and physical capitals).

3.4 Household's adaptation practices to climate variability risks

After exploring farmer's perception on climate variability and climate associated stressors, farmers were also interviewed about adaptation practices they currently employed to mitigate adverse climate impacts. The data show a variety of adaptation strategies employed to protect and improve local livelihoods under the impacts of climate change. The adaptation strategies adopted by the respondents include changing crop varieties, diversifying crops, water management, crop management and protection (soil and plant), and finding off-farm jobs. As seen from Table 3, higher percentages of Thai and Muong respondents reported practicing the above adaption measures compared to those of Dao and Hmong farmers. This might be explained from the higher financial capabilities in Thai and Muong people (Tran et al. 2022). Table 3 shows that approximately half of Muong and Thai respondents reported they grew drought-tolerant or short-duration crops whereas only about 10% to 15% of Dao and Mong's respondents used this adaptive strategy. As stated in the interviews, the cultivation of improved seed varieties would help farmers minimise their potential losses caused by climate variabilities, only a third of Dao and Mong farmers would consider this adaptation, perhaps because of the costs of the seed.

Table 3. Adaptation practices to climate variabilities among farming communities

Type of adaptation measurement	Respondents (%) in respective groups				F-*value*	*p-value*
	Thai	Muong	Dao	Hmong		
Changing crop varieties (drought, flood tolerant/short duration)	48.4	46.4	15.5	10.7	4.698	0.003
Crop diversification	79.6	72.2	35.2	30.5	9.340	0.022
Water management	9.4	8.2	6.1	5.3	2.345	0.123
Crop management and protection (Soil and plant)	86.6	87.2	36.4	32.1	14.964	0.000
Finding off-farm jobs	75.3	82.3	45.2	41.9	9.173	0.000

Diversifying crops is another adaptation method employed by 72% to 80% of Thai and Muong, and about 30% to 35% of Dao and Hmong farmers. According to a local officer, 'cultivating a single crop like rice or maize tends to increase farmers' vulnerability to a changing climate'. Diversifying crops in the same or different cultivated areas is likely to lower the risk of crop failure under a changing climate. In the past, there were two rice seasons in a year, and therefore, agricultural land was left fallow. Farmers then started planting maize or other suitable vegetables during their spare time after harvesting to reduce soil erosion caused by extreme rains or floods.

In hilly areas (e.g., in Dao and Hmong communities), farmers employed intercropping techniques for their crop production such as cassava was planted with teak trees at the early life stages of teak trees. Households also indicated that this plantation combination is one of their adaptation measures to cope with the negative impacts of increasing temperature on crop health and to improve soil structure. In addition, this practice increases plant coverage and reduces surface runoff and soil erosion during rainy season. As a result, soil fertility can be maintained and productivity per cultivated unit is improved.

Crop management and protection (soil and plant) was adopted by around 87% of both Thai and Muong farmers, followed by 36% of Dao and 32% of Hmong respondents. Flash floods and landslides were seen as the main factors causing soil degradation and out-breaks of crop pests within the study region, thus, to protect soil and plants, farmers turned more to pesticides, fertilizers, and adopted mulching techniques on their land, crops residues being left on the ground to prevent soil erosion and increase moisture retention. On the other hand, farmers tend to adopt numerous soil protection means when they have cultivated land adjacent to rivers or streams. For instance, constructing or renovating their field embankments, creating stone walls, and planting bamboo trees were commonly used to reduce or prevent potential damage from natural disasters like flash floods and landslides.

Less than 10% of respondents from different farming communities used water management measures due to natural and economic difficulties (Table 3). This was the only strategy for which no statistically significant difference were found between groups. Farmers from all farming communities stated that due to rainfall irregularities, local reservoirs do not always fill during the rainy season. Furthermore, building water tanks at the household level and pumping water from rivers with a generator is seen as expensive. The fuel generator and related supplies to pump water from streams/rivers or wells cost more than 15 million VND (about US$700).

Some water reservoirs in Thai and Muong community areas had dried up, as respondents observed during the fieldwork. Due to limited irrigation access, efficient water usage strategies such as small-scale irrigated channels and other agricultural water collection systems are not installed in Dao and Hmong communities or not working effectively within Thai and Muong farming communities. Future interventions, therefore, need to encourage farmers to use any existing water resources by offering appropriate technologies which help farmers apply water conservation measures effectively to cope with climate change.

Finding off-farm jobs is another adaptation strategy adopted by 75% to 82% of Thai and Muong households, followed by 45% of Dao and 42% of Hmong households. Farmers reported they found off-farm employment through seasonal migrating to the nearby urban centres or cities, external aid programs or new local enterprises (Table 3). Besides, farmers living near forests reported that those forests provided continuous energy sources for the household (e.g., tree leaves and wood) and collecting forest products may create an additional income source for farming communities.

To evaluate adaptation strategies adopted among studied farming communities, the current work employed ANOVA. Results from ANOVA are in Table 3. These reveal significant differences between farming communities in almost all adaptation practices, except for water management. However, the differences between intergroups for each adaption strategy were not revealed by ANOVA. This was identified by adding a Tukey post hoc test while running ANOVA analysis. We also regrouped four studied communities into three groups: group 1 (Thai and Muong), group 2 (Dao) and group 3 (Hmong) based on their living zone elevation. The results of Turkey post hoc test indicate statistically significant differences between group 1 and group 2 and group 1 and group 3 in adoption of changing crop varieties, crop diversification and finding off-farm jobs as their adaptive strategies ($p < 0.005$). However, there are only statistically significant differences between group 2 and group 3 in choosing crop management and protection (soil and plant) as an adaptive practice ($p < 0.005$).

3.5 Determinants of farmers' adaptation strategies

A logistic regression model was developed to determine the major influential factors influencing farmers' adaptation decisions. Table 4 provides the statistical results of the logistic regression of determinants influencing farmers' adaptation choices. We interpreted our findings through regression parameters such as coefficient (β), significance level (p-value), and odd ratio (Exp (β)). In the case of continuous variables (such as age, education level, and farm size, etc.), a negative coefficient indicates the likelihood of adopting a strategy decreases when continuous variables increase a unit. On the other hand, a positive coefficient indicates the likelihood of adopting a strategy increases when continuous variables increase a unit.

The regression results (Table 4) show that three explanatory variables including age, ethnic location (here referred to as elevation of their living zones) and access to extension services have a negative relationship with all four adaptation options to climate change. In contrast, four explanatory variables including gender, education level, access to irrigation, access to credit and access to climate information have a positive relationship with the four mentioned adaptation strategies. For the three remaining independent variables including household condition, farm size, and farmers' group membership have mixed effects on farmers' adaptation strategies to respond to climate variability. The details of the main determinants effecting each adaptation strategy are presented below.

3.5.1 Changing crop varieties

Four explanatory variables indicate a significant impact on adoption of changing crop varieties as a climate change adaptation practice. Specifically, farmer's education level ($p < 0.05$), household's access to irrigation ($p < 0.05$) and access to credit ($p < 0.05$) have positive significant impacts, meanwhile farmer's age has a negative significant impact on farmers' choice of changing crop varieties ($p < 0.1$). On the other hand, the remaining explanatory variables have no significant effect on households' selection of crop varieties to cope with the changing climate.

The value of Exp (β) indicates the likelihood of changing crop varieties decreases by a factor of 0.590 and 0.560, respectively, if the age of the farmer increases by one year. The finding implies that the older farmers are the less likely to adopt climate tolerant crop varieties for their farming (e.g., short duration, drought tolerant crops). The older farmers are with more experiences have the potential to increase production if they adapt. However, age may limit effectiveness in the field, while younger generations are leaving for off-farm jobs such as builders or workers at garment and shoe factories in district centres and a nearby city. Additionally, the average age of Thai and Muong household heads is almost 50 years (Table 1, page 23), which is higher than the average age of minority ethnic household heads in Thua Thien Hue province (almost 41 years) (Sen et al 2020). This aging issue is also happening for Kinh farmers in other regions such as Thua Thien Hue province (Sen et al 2020). Therefore, the old age seems to be an important stressor, especially for Thai and Muong groups in the study region. In contrast, the Exp (β) of the education variable reveals that the likelihood of adopting tolerant varieties increases by a factor of 1.297 when household head education increases by one degree. Farmers who have higher educational attainment are more likely to adapt to climate variability by using resistant seed types such as short duration or climate tolerant crop varieties. They are typically motivated by later technologies and new seeds cultivation.

Apart from farmers' education and age, institutional services such as access to irrigation and credit, showed a positive significant impact on their changing of crop varieties. Farm households with access to irrigation were 1.443 times more likely to change crop varieties than those with little or restricted access to irrigation. Likewise, the result from the logistic model indicates that households having access to credit and loan availability were 1.913 times more likely to change crop varieties than those that did not use credit services. Hence, credit availability and utilisation would improve farmers' capacity in choosing climate tolerant crop varieties for their production adapting to climatic risks.

3.5.2 Crop diversification

Four explanatory variables have significant impacts on farmers' adoption of crop diversification as their adaptive strategy. Specifically, gender ($p < 0.01$) was found having a positive significant effect in adopting crop diversification. Male household heads are more likely to select crop diversification by 2.147 times (Exp (β) = 2.147) than female-headed households. In contrast, the age of farmers ($p < 0.01$), ethnic location ($p < 0.05$), and access to extension services ($p < 0.05$) have negative significant effects on the crop diversification adoption. Farmers living in lowland areas (Thai and Muong groups) are less likely to choose this adaptation practice by a factor of 0.521 than farmers in middle and high land zones (Dao and Hmong groups). Likewise, farmers accessing extension services are less likely to choose crop diversification as an adaptation practice to climate variability. This negative relationship might reflect the local situation that farmers continue making their own farming decisions despite attending agricultural training or meetings providing information on crop diversification. Farmers suggest that the quality of current extension services is insufficient to effectively aid farmers in adaptation process because training documents are out of date (Tran et al. 2022). Some also think a high percentage of extension staffs at a young age, have insufficient experience in agricultural activities. Farmers would thus be reluctant to follow their advice to diversify their crops or other farming-related activities.

3.5.3 Crop management and protection (soil and plant)

Crop management and protection (soil and plant) is a popular strategy to cope with the currently changing climate. We found that access to climate information, farmers’ group membership, and farm size have positive significant effects ($p<0.05$, 0.1 and 0.1, respectively) while access to extension services has a negative impact in farmers’ adoption of crop management and protection.

Farmers having larger land sizes are more likely to select this adaptation practice (Exp(β)=1.788). This accords with the proposition that adaptation has a fixed cost, with the effect on average cost diminishing by increasing scale. Additionally, farmers with larger areas can more easily generate any capital needed to make changes (e.g., innovate irrigation systems). In the current study area, farmers applied more crop management and protection strategies (soil and plants) to cope with natural hazards (e.g., landslides, flood, and flash floods). Plant protection means pesticides and fertilisers. Soil conservation includes mulching techniques or reinforcing embankments, creating stone walls, and growing bamboo trees along/around farmland areas where easily vulnerable to floods and landslides. Farmers who received weather-related information through many sources (television, radio, internet, newspaper, village speaker, neighbours) were more likely by a factor of 1.754 (Exp(β)=1.754) to apply crop protection and soil management as responses to natural hazards. These responses are such as using pesticides and fertilizers, reinforcing embankments, creating stone walls, growing bamboo trees along/around farmland areas, and clearing irrigation channels before or after the occurrence of natural hazards. Similarly, being a member of farmer groups increases the probability of choosing crop management and protection (plant and soil) by a factor of 1.634.

3.5.4 Finding off-farm jobs

Finding off-farm jobs is a favourable adaptation strategy chosen by the local farmers to climate variability risks. This choice was significantly driven by ethnic location, farm size, and access to irrigation ($p < 0.05$). Access to irrigation has a positive effect while ethnic location and farm size show negative relationships in adoption of off-farm jobs. Farmers living in middle and high land zones (Dao and Hmong groups) are less likely to choose finding off-farm jobs by a factor of 0.584 than who reside in lowland areas (Thai and Muong groups). Also, households with more land decrease the probability of selecting finding off-farm jobs as an adaptation strategy to the changing climate by a factor of 0.619 per ha. On the other hand, farmers who have access to irrigation systems are 1.90 times more likely to find off-farm jobs as a response to a changing climate than farmers who do not have access to irrigation. This might be explained by the fact farmers need more income to pay for their high irrigation costs. In particular, the very water resources on which irrigation depends might be dependent on rainfall, therefore, supply constraints and rising demand might also increase irrigation costs during dry seasons.

Table 4. The binary logistic regression model predicting determinants of farmers' adaptation practices.

Variables	Changing crop varieties		Crop diversification		Crop management and protection (soil and plant)		Finding off-farm jobs	
	Coeff. (β)	Exp (β)	Coeff. (β)	Exp (β)	Coeff. (β)	Exp (β)	Coeff. (β)	Exp (β)
Age	-0.526 (0.271)	.590*	-0.580 (0.22)	0.560***	-0.210 (0.150)	0.810	-0.520 (0.21)	.594
Gender	0.270 (0.185)	1.310	0.764 (0.434)	2.147***	.0680 (0.352)	1.974	0.820 (584)	2.270
Education level	0.260 (0.102)	1.297**	0.336 (0.203)	1.399	0.248 (0.254)	1.281	0.294 (3.17)	1.342
Ethnic location	-0.772 (0. 363)	0.462	- 0.652 (0.539)	0.521**	-0.848 (0.312)	.428	-0.538 (0.312)	0.584**
Household condition	0.146 (0.188)	1.157	-0.882 (0.584)	0.414	0.608 (0.368)	1.837	0.367 (0.227)	1.443
Farm size	0.531 (0.450)	1.700	-0.329 (0.246)	0.720	0.581 (0.235)	1.788*	-0.480 (0.138)	0.619**
Access to irrigation	0.367 (0.155)	1.443**	0.601 (0.452)	1.824	0.621 (0.358)	1.861	0.642 (0.343)	1.900**
Access to extension	-0.581 (0.235)	0.560	-0.452 (0.222)	0.636**	-0.458 (0.250)	.632*	-0.572 (0.349)	0.564
Access to credit	0.649 (0.351)	1.913**	0.169 (0.083)	1.184	0.132 (0.061)	1.141	0.418 (0.288)	1.519
Access to climate information	0.362 (0.225)	1.436	0.443 (0.204)	1.557	0.562 (0.242)	1.754**	0.321 (0.156)	1.378

Variables	Changing crop varieties		Crop diversification		Crop management and protection (soil and plant)		Finding off-farm jobs	
	Coeff. (β)	Exp (β)	Coeff. (β)	Exp (β)	Coeff. (β)	Exp (β)	Coeff. (β)	Exp (β)
Farmers' group membership	-0.233 (0.197)	0.792	-0.161 (0.227)	0.851	0.491 (0.241)	1.634*	-0.320 (0.335)	.726
Model Constant	-1.612 (1.115)	0.199	1.297 (.844)	3.658	1.369 (0.932)	3.931	-1.149 (1.375)	0.317
Model chi-square	99.80***		132.38***		90.42***		91.58***	
-2Log likelihood	225.600		145.075		257.960		161.678	
Pseudo R^2	0.483		0.673		0.450		0.580	

*Note: The values in the brackets are Stand Errors; *, **, *** indicates significance level at 10%, 5%, 1%, respectively.*

4. Discussion

Comprehensive understanding of climate change and variability is crucial to determine preparedness and implementation of adaptation measures. It helps policymakers design policies and/or intervention assisting farmers for better adaptive strategies to mitigate the impacts of potential risks such as poverty and food insecurity. In line with previous studies in the Northwest Mountainous Regions of Vietnam, local farmers mostly perceived changes in temperature, rainfall, and extreme weather events (CARE 2013; UNDP, 2015; Huong et al. 2017; Nguyen et al. 2019). Increases in annual average temperature, flood and landslides, hot days and decreases in cold days are being noticed by individuals, in association with personal experiences. Increases in rainfall was reported by respondents, which may have been a recent effect of intensive rain events. This supports the idea that recent and direct experiences with extreme weather events have shaped locals' perception of climate change and variability, especially for memories of recent variability instead of long-term changes in climate (Le Dang et al. 2014).

Climate and non-climate stresses have negative impacts on livelihood sources within the study region, weakening adaptive capacity and household livelihood resilience to the changing climate (Nguyen & Leisz

2021; Pham et al. 2021). For example, labour shortages and limited farm inputs were identified as socioeconomic pressures in the studied communities for changing agricultural practices (Antwi-Agyei et al. 2018). In the present study, Thai and Muong participants shared that youth migration to cities or youth involvement in local industrial companies recently operating around their villages are main reasons for labour shortages in farming activities.

Changing crop varieties, crop diversification, water management, crop management and protection (soil and plant), and finding off-farm jobs are major adaptation strategies currently employed in the study area. The list of four mentioned adaptation strategies was also employed to adapt to climate variabilities at different locations but with a difference in the degree of adaptation practices (Bahinipati 2014; Masud et al. 2017; Fahad & Wang 2018; Harvey et al. 2018; Trinh et al. 2018; Abid et al. 2020).

The results of the binary logistic model indicate that age, ethnic location, farm size, access to irrigation, access to extension are important factors influencing farmers' decisions in adaptation to climate change and variability. Older farmers are less likely to employ adaptation measures such as changing crop varieties and diversifying crops to climate variability impacts. Abid et al. (2015), Pham et al. (2019) and Ojo and Baiyegunhi (2020) indicated that the relationship between farmers' age and their willingness to change/diversify crop varieties is negatively significant. Senior farmers are typically illiterate and cultivate based on their past farming habits. They are also risk averse (Khan et al. 2020) and thus less likely to try new crop varieties because of the risk of not achieving expected yields. Male respondents are more willing to adopt adaptive practices mitigating potential risks of climate change and variability than females, especially for crop diversification. Male headed household mostly reported greater crop diversities on their farms than female headed households (Trinh et al. 2018; Getahun et al. 2021; Bui and Do 2021; Tran et al. 2022). In the study area, men believed that they would achieve stable production and higher household incomes by diversifying their crops. On the other hand, we found that farmers having better education are more likely to employ adaptation strategies. Ashraf et al. (2014), Bahinipati (201) and Ngo (2016) indicate that education increased the likelihood of farmers adapting to climate variabilities by growing climate tolerant seeds and using irrigation systems. However, the percentage of local farmers with limited formal education ranges from 55% to 68% (Tran et al. 2021), therefore, there may be adaptation benefits in enhancing basic education levels, especially for women and disadvantaged groups. This can be done by organising free literacy classes or tutorial classes in consultation with farmers' customs.

Ethnic location is another factor affecting local farmers' decisions to cope with climate change and variability. Khanal et al. (2018) conducted a study in Bangladesh, indicating that farmers living on flat and low land are more likely to adapt to climate change impacts compared to farmers residing in hill and mountain regions. In the current work, farmers reside at low land areas (Thai and Muong groups) are more likely to employ adaptation strategies such as finding off-farm jobs and crop management and protection compared to farmers living in middle and high land (Dao and Hmong groups). Thai and Muong groups live near the district centre being more advantages to access to public facilities (health and education services) and labour markets compared to Dao and Hmong groups (Tran et al., 2021). Moreover, road systems within Dao and Mong communities have greater levels of deterioration compared to those for Thai and Muong communities (Tran et al. 2022). Local government thus needs to invest more on upgrading the road systems to facilitate communications and access to public services of remote communities (e.g., Dao and Hmong groups).

Farmers with large farmland are more likely to have relatively higher capital and other resources for climate change adaptation, employing more crop management and protection means. Piya et al. (2013), Ashraf et al.

(2014), Jin et al. (2016), Ndamani & Watanabe (2016) and Ngo (2016) found that farmers having large farmland tend to employ adaptation strategies related to their farms. This might come from the fact that large farms are likely to suffer high economic losses caused by climate change and variability compared to small farms. In contrast, farmers with small land are more likely to find off-farm jobs to increase their incomes as a response to climate change impacts. Huong et al. (2017) found that farmers with larger farm sizes had lower probability to choose off-farm jobs as an adaptation measure and therefore have more labour hours to make and manage system changes.

Access to irrigation services is another influential factor in adaptation choices such as changing crop varieties and finding off-farm jobs. Our results are consistent with those found by Khanal et al. (2018) that irrigation accessibility is one of the main factors influencing farmers' decision to use enhanced crop varieties. Accessing irrigation service is more likely to encourage farmers to find off-farm jobs, which is similar to the finding of Pham et al. (2019). In the study region, although farmers had access to constructed irrigation systems, water from irrigation systems is insufficient for their farms, particularly during the dry season (winter season) (Tran et al. 2022). Therefore, upgrading/installing irrigation system in local communities should be a priority of local interventions to increase farmers' physical capital in response to climate variability.

Access to extension services, on the other hand, was identified to have a negative impact on farmers' adaptation choices such as crop diversification, crop management and protection (soil and plant). Bui & Do (2021) and Sertse et al. (2021), however, found a positive correlation between extension services with choosing adaptation strategies. In the current study, limited agricultural staff visits, the low quality of extension staff and training documents are the main reason for ineffective extension services. Therefore, there is a need to improve the quality of agricultural officials and training materials as well as to increase communication between farmers and extension workers at their houses or at monthly meetings.

Access to credit is another important factor influencing farmers' choices to adapt to climate change impacts. The coefficient of access to credit is positive for all adaptation strategies and significant only for changing crop varieties as adaptation strategies. This finding aligns with the past studies on a positive association between access to credit and changing crop varieties (Ojo & Baiyegunhi, 2020; Sertse et al., 2021). The availability of credit services and loans will support farmers in accessing new technology and purchasing improved varieties of seeds, fertilizers, and other requisite inputs to adopt any adaptation strategies. Additionally, with greater financial support, farmers can adjust their management practices to adapt to a changing climate. Local government could support farmers' adaptation by providing concessional loans and regular meetings to guide locals how to use these credit services.

Access to climate information has positive influence on choosing adaptive strategies, especially being significant with the choice of crop management and protection (soil and plant). Van et al. (2015) and Alam et al. (2016) also found positive relationships between access to climate information and adaptation practices. Farmers who are receiving weather information and other risks warnings are more likely to adopt adaptation strategies compared to those without climate information. However, in the study region, the percentage of Dao and Hmong who did not receive on-time natural disasters warning are double the percentage of Thai and Muong due to remoteness and financial conditions (Tran et al. 2021). Hence, local government should provide a speaker louder for each village or equip a computer with internet for head of village, which can enable transmitting climate weather report and natural disaster warnings to local farmers on-time.

Famers who participate in cooperative organisations have a higher probability to employ adaptive strategies to minimize the effect of climate change. The relationship between farmer group membership and the choice of crop management and protection (soil and plant) is positive and statistically significant. The positive correlation could be traceable from the fact that membership of farmer groups can be beneficial by sharing experiences, exchanging information about any innovations, and implementing collaborative agreements (Kassie et al. 2013; Ndamani & Watanabe 2016). Therefore, membership of farmer groups improves cognitive processes through interactions among members (Bandiera & Rasul 2006). However, the relationship between farmer group membership and other three adaption practices are negative and non-significant. Hence, there is a need to investigate factors contributing to ineffectiveness of farmer groups and how to improve the quality of these groups.

5. Conclusion and implications

This study aims to investigate ethnic farm households' perceptions of climate change, climatic stressors, adaptation choices, and their determinants. The study was conducted to assist the Vietnamese governments in developing more appropriate supporting policies for farming communities by providing an improved understanding of ethnic farm households' behaviours and responses when they decided to select adaptation strategies to climate change.

We found that the local climatic conditions are changing and already have had a significant negative impact on local people's livelihood resources. Farmers from all ethnic communities reported changes in climatic conditions and natural hazards, most notably, that precipitation has changed in terms of frequency and intensity, and annual temperature has increased. Farmers also reported climatic stressors have impacted agricultural activities. Farmers, as a response to climatic risks, adopted a variety of adaptation strategies to mitigate the negative effects of climate related hazards on their agricultural activities and livelihoods. The most common adaptation strategies include changing crop varieties, diversifying crops, soil and plant management and protection, and finding off-farm jobs.

These adaptation practices were mostly practiced by Thai, Muong, and Dao farmers. There were statistically significant differences among studied farming communities when they select the above common adaptation practices. However, only water management practice does not statistically differ among ethnic farmers.

Climatic and non-climatic stressors have seriously impacted the livelihoods of local farming communities. Hence, it is critical to develop a comprehensive adaptation strategy to climate change, which considers both mentioned stressors in order to reduce vulnerability and increase farmers' adaptive capacity.

The regression analysis revealed that farm households' characteristics such as age, gender, ethnicity, and education level, have significant impacts on farmers' adaptation measure preferences. Our present study suggests more appropriate policies focusing on enhancing local farmers' knowledge and skills and investing in education systems. For example, free literacy classes and training programs related to upgraded technology promoting sustainable land use and cultivation. Additionally, providing agricultural production inputs (such as climate tolerant varieties) at reasonable prices for farmers or free seeds for the most disadvantaged ethnic group (i.e., Dao and Hmong) could improve their income, which enables better financial capital to cope with climate change impact. An-Vo et al. (2021) demonstrated that the use of those tolerant varieties with seasonal climate forecasts can return significant economic values to farmers. To encourage more farmers to plant the tolerant varieties, especially for the disadvantaged group, local authorities should reduce the price of seed varieties or provide first free seedlings, which in turn enable better farmers' crops under changing climate.

Furthermore, the current work found farm size and other institutional factors (i.e., irrigation systems and extension service connections, credit services, climate information, and farmer groups) could have a significant impact on farmers' adaptation choices. Future policy options include enhancing the quality of extension workers/training documents, building/upgrading new/existing irrigation systems, and providing media equipment other associated technology regarding receiving and transmitting climate information. Local authorities should organise free training courses (e.g., cultivation and breeding techniques) to help commune extension staff improve their knowledge and skills or send commune staff for short professional courses held at collaborative universities. Additionally, extension officers should communicate with local farmers more frequently to build up a better relationship and gradually gain their trust. Local government also should provide farmers with information on weather and climate induced risks on time, which facilitate preparedness and prevention effectively.

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This chapter provided an overview of farmers' perceptions of changes in climate variability and related extreme events, their responses to these changes and main factors affecting farmers' adaptation choices. Local farmers have observed a recent increase in temperature and extreme weather events, but a decrease in rainfall. To adapt to climate change and variability, farmers adopted several adaptation practices such as changing crop varieties, crop diversification, crop management and protection, and finding off-farm jobs. By employing the binary logistic model, we discovered that social-economic factors (especially ethnic location), farm size and institutional factors plays an important role in adopting adaptive practices to cope with climate change and variability.

CHAPTER 6: CONCLUSIONS

This study focused on the analysis of the relationship between vulnerability, resilience, and adaptation of rural farmers to climate change in Phu Yen district, Son La province, based on the data from a survey of 240 households from four ethnic communities. The picture of vulnerability at community level under the impacts of climate change was derived by applying the composite LVI and a substitute approach (LVI– IPCC), in combination with comprehensive qualitative data. In addition, an intersectional approach was deployed for a nuanced view of subjective resilience at household level based on individual's self-assessments. Finally, the study identified some of the drivers of farmers' adaptation choices. The findings of the research provide information and insights to help policy makers alleviate poverty and increase livelihood resilience, especially in disadvantaged regions, such as mountainous regions, and disadvantaged groups such as ethnic minorities. This chapter will briefly summarise and review the important results and identify the significant contributions and implications of this study. Finally, the chapter concludes by providing suggestions for policy makers and future researchers.

6.1 Summary of important findings

This study is the first assessment of the vulnerability at the community level comparing different ethnic groups in the Northwest Mountainous Regions. The groups were Thai, Muong, Dao, and Hmong ethnic groups. By applying the livelihood vulnerability index framework (composite LVI and LVI-IPCC), we identified the differences in vulnerability levels. The overall indices revealed differing vulnerabilities by ethnicity and location, with Hmong and Dao being the most vulnerable groups. These groups are more vulnerable in terms of low education levels, diversity of income sources, agricultural training, organisational membership, access to health services and water resources, and housing location.

The study then deployed a nuanced assessment of intersectionality of gender and ethnicity to explore how perception of household livelihood resilience differ among selected ethnic communities. Our analysis suggests that ethnicity was relatively more important than gender in explaining the variations, but within ethnic and locational differences there are nested gender differences. Men generally reported higher resilience scores than women did but there is significant variation in average scores across selected ethnic communities. The results also suggest a number of factors likely to contribute to better livelihood resilience self-assessment, including education, wage-paying jobs, agricultural trainings, crop diversification, social membership, roads, and irrigation systems.

In relation to climate change awareness and perceptions, the overwhelming majority of farmers had noticed changes in key variables and weather extremes events, though these differed somewhat across the groups. In response, local farmers have undertaken some adaptation measures, especially amongst those with more resources. The most recorded adaption practices are crop management and protection (soil and plant), crop diversification, finding off-farm jobs and changing crop varieties. Limitations to adaptation include financial restrictions, farming features, lack of family labour and weather information are significant impediments hindering the effectiveness of adaptation strategies. Binary logistic models were used to further examine the factors affecting farmers' choices to adapt to climate change and climate-induced hazards are analysed. The resulting adaption models suggest that age, ethnicity, farming size, access to irrigation, extension services are most important factors deciding specific adaptation choices. Other factors are levels of education, gender, credit availability, access to climate information and group membership also influence farmers' decisions to adapt to climate change and climate hazards.

6.2 Significance and scientific contribution of the study

This research aimed to be a comprehensive assessment of vulnerability at community level that could inform policies to reduce vulnerability to a changing climate. The results reveal ethnicity is the more important factor than gender in determining household livelihood capitals supporting livelihood resilience in the study regions. The research results indicate an agreement between farmers' perception on temperature with the actual trend; however, farmers' perception on rainfall are somewhat at variance with the climate data. This implies there is a gap in perceptions of climate variability among ethnic communities with the trend of the climate variables. Additionally, this study found that ethnic location, farmers' socio-economic, farming features, and institutional conditions are the main contributing factors strongly influencing their adaptation choices to climate change. These findings will support decision-making and planning by local government, crop industries, and ethnic united organisation. For example, feasible direction and policies that enhance better farmers' knowledge through investment in education systems and the quality of extension services focusing on cultivation and breeding techniques, and better communication with farmers.

This study contributed to a regional illustration of assessing vulnerability at community and perceived household livelihood resilience assessment to inform future studies across other regions and countries that can support adaptive strategies in similar communities elsewhere.

Finally, this work aligns well with other work in the climate change impacts research and will support policy makers to reduce vulnerability, enhance farmers' perceptions and strengthen households' adaptation to climate change and climate hazards.

6.3 Recommendations

6.3.1 Policy recommendations

Based on the empirical findings, this study suggests several policy interventions that could assist to reduce the household vulnerability, to enhance local farmers resilience and for better adaptation process towards climate change and climate hazards, such as:

- Enhancing farmers' literacy and organizing vocational training courses.

- Strengthening the quality of agricultural extension services (both extension staff and training documents).

- Facilitating income diversification strategies by trainings and concessional loans.

- Policy makers should consider gender and minority ethnic group as important factors in future projects regarding resilience enhancement, especially for women and amongst disadvantaged ethnic communities.

Other recommendations include improving the quality of drinking water sources, upgrading irrigation systems, providing agricultural inputs with reasonable costs, and providing timely local weather forecast, should also be emphasized, and given more attention from local governments.

6.3.2 Recommendations for future research

This current work investigates vulnerability at community level and factors affecting households' vulnerability to climate change. Future studies should consider analysing which livelihoods are suitable and able to support local people to reduce their vulnerability to climate change.

This study measures household livelihood resilience based on the quantitative survey with assuming all indicators have equal weighting to livelihood perceived resilience. The indicators may not capture essential variables, such as indigenous knowledge. Future research should involve research participants weighting the vulnerability and resilience indicators, which helps researchers better understand the importance of various indicators. Future evaluations could investigate which adaptations result in greater economic efficiency, as this will help farmers become more resilient to future climate change.

Future studies may also consider analysing farmer adaptation in a more comprehensive way, considering changes in the institutional, environmental, and economic conditions. Furthermore, the data should be collected at different times (panel data), allowing researchers to compare and examine the study areas in depth.

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