Agroecology and Sustainable Food Systems

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/wjsa21

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**To cite this article:** Ho Ngoc Son , Aaron Kingsbury & Ha Thi Hoa (2020): Indigenous knowledge and the enhancement of community resilience to climate change in the Northern Mountainous Region of Vietnam, Agroecology and Sustainable Food Systems, DOI: 10.1080/21683565.2020.1829777

**To link to this article:** https://doi.org/10.1080/21683565.2020.1829777

Published online: 13 Oct 2020.

AGROECOLOGY AND SUSTAINABLE FOOD SYSTEMS
https://doi.org/10.1080/21683565.2020.1829777



# Indigenous knowledge and the enhancement of community resilience to climate change in the Northern Mountainous Region of Vietnam

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**ABSTRACT**

Over centuries, ethnic minority communities in the north of Vietnam have developed complex farming systems well-adapted to their environments. Much of this is based on indigenous knowledge concerned with adapting to locally-available resources and more recently enhancing resiliency to climatic risk. This article draws from data gathered with mixed qualitative methods in ten villages in rural Bac Kan Province in the north of the country. It documents specific examples in the production of banana and medicinal plants; maize and red peanut; taro, pachyrhizus, and maize; and green bean as systems that incorporate native crops in ways that provide resistance to drought, improve water-use efficiency, benefit the soil, minimize agrochemical use, preserve culinary traditions, support gender equality, and increase the incomes of farm families living near the poverty line. Overall, this study illustrates unique ways that indigenous knowledge and agroecological farming practices can increase social, economic, and environmental resiliency, mitigate risk, and strengthen livelihoods in marginalized communities. As communities across the Global South seek answers to ever-increasing challenges brought by changes in climate, this paper argues that policymakers should revisit, support, and promote the indigenous knowledge already present in these communities to advance more sustainable futures.

**KEYWORDS**

Climate change; intercropping; agroecological farming; indigenous knowledge; ethnic minorities; mountainous region; resilience; Vietnam

## Introduction

### *Climate change in Vietnam*

Vietnam is one of the most vulnerable countries in the world to climate change due to its geography. The country has long a coastline, which annually experiences tropical storms and typhoons. The mountainous areas are prone to landslides and flash flooding, while the lower-elevation communities along the Mekong Delta in the south are highly susceptible to rising sea levels. (Dasgupta et al. 2007; Wildcat 2013; Savo et al. 2016; Whitney et al. 2016; Belfer, Ford, and Maillet 2017). Climatic

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stresses most impact socially-marginalized and economically-disadvantaged communities, such as those in the upland areas of the Northern Mountainous Region (NMR) (Bangalore, Smith, and Veldkamp 2016; Delisle and Turner 2016; Tam et al. 2017). With a population of approximately 12 million people, it is also within these same upland areas where many of the ethnic minorities of the country reside (Vien 2003). Ethnic minority (EM) residents of the NMR comprise the majority of those living in poverty in this region (World Bank 2010). They typically reside in the more remote areas, and their limited access to markets, services, and reliable transportation networks add to their vulnerability (Author 2013). Marginalized people, including women, the poor, and the elderly, have unequal access to resources and often suffer the worst impacts of climate change (Tompkins and Adger 2004). This points to a need for immediate and sustained support for adaptation to climate change-specific threats and integrated resilience-building strategies.

### *Social-ecological resilience and adaptive capacity*

The vulnerability of communities partly depends on the sources of resilience that communities can draw on to increase adaptability in the face of change (Abel, Cumming, and Andries 2006). Resilience has emerged as 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 'social-ecological resilience' involves the intersection of factors including adaptive capacity, transformability, learning, and innovation (Folke 2006). Research on adaptation within a resilience framework was first elaborated by Holling (1973). In discussing ecological systems, Holling (1973, 9) defined resilience as "*the capacity of a system to absorb and utilize or even benefit from perturbations and changes that attain it, and so persist without a qualitative change in the system's structure*." The concept of ecological resilience has contributed to a productive exchange of ideas about assessing and understanding vulnerability both concerning global environmental change and a variety of stresses and shocks acting on and within coupled human-environment systems. In this paradigm, vulnerability is seen as a dynamic property of a system in which humans are constantly interacting with the biophysical environment (Eakin and Luers 2006).

Adaptive capacity, which is often used to refer to the set of pre-conditions that enable individuals or groups to respond to climate change (Smit and Wandel 2006), is a synonym for many characteristics of resilience (Tompkins and Adger 2004). In the context of climate change, social resilience is the ability of groups or communities to adapt in the face of external stresses and disturbances (Adger 2000). Resilient communities are those that can adapt quickly to shocks and change (Callaghan and Colton 2007). They can handle surprise, can learn from disturbance and stress, and find opportunities for renewal (Olsson 2003). In this study, resilience is defined as the capacity to deal with change and continue to develop. As such, resilient communities are those which have coping abilities to withstand, recover from stresses and surprises, and adapt to climate variability and change. This concept of resilience is consistent with many others which define resilience as the ability of a system to a) absorb shocks and retain its basic functions, b) self-organize, and c) innovate and learn in the face of disturbances (Folke et al. 2005). However, resilience cannot be equated with survival. Many communities, including indigenous communities in Vietnam, have survived for generations in difficult circumstances and might still survive well into the future in harsh environments with many hazards. However, their resilience can only support them up to a certain point, and may eventually reach a breaking point. Although communities have a long record of adapting to the impacts of weather and climate, climate change poses novel risks often outside the range of experience (IPCC 2012). This highlights the importance of building resilience to cope with future change and uncertainty (Berkes 2007; 2009).

## Agroecology

Agroecology integrates ecological science with other scientific disciplines and knowledge systems, including local and traditional knowledge, to guide the sustainable transformation of current agricultural production systems (Méndez, Bacon, and Cohen 2013). Several studies have demonstrated that agroecological farming practices have improved the adaptive capacity of agroecosystems and reduced vulnerability to natural disasters, climate change impacts, and emerging environmental and economic system stresses and shocks (e.g., Hiwasaki, Luna, and Syamsidik 2014). This resilience was accomplished through both physical and biological means including habitat and crop diversification, conservation of indigenous seed and germplasm diversity, maintenance of the species diversity of natural enemies, and improved water capture and retention. A range of sociocultural means includes the diversification of farming systems and local economies and technical, legal, and social support networks for small-scale farmers, rural communities, and indigenous peoples. Each reduces socio-economic vulnerability and strengthens adaptive knowledge processes (Clements et al. 2011; Altieri and Nicholls 2012; Jiggins 2014; Pimbert 2015). Agroecological farming recognizes the multifunctional dimensions of agriculture, as well as local and indigenous knowledge and practices. The concept positions farming as not only a food production method that provides jobs and economic well-being, but one that also creates cultural, social, and environmental benefits (Méndez, Bacon, and Cohen 2013; Pimbert 2015). For example, studies with smallholder farmers in Kenya found that many agroecological farming practices emerge as “triple wins”; that is, they support climate adaptation, greenhouse gas mitigation, and profitability goals. Integrated soil fertility management and improved livestock feeding are shown to provide multiple benefits across all agroecological zones. The results suggest that agricultural investments targeted toward these triple-win strategies would have the greatest payoff in terms of increased resilience in farming, household livelihood security, and climate change mitigation (Bryan et al. 2013).

### Traditional knowledge, local knowledge, and indigenous knowledge

In the literature, the concepts of traditional knowledge, local knowledge, and indigenous knowledge are often used similarly. According to Berkes (2009; 2012), traditional knowledge (or traditional ecological knowledge) refers to a cumulative body of knowledge, practices, and beliefs that evolve through adaptive processes, are handed down over generations through cultural transmission, and relate to the relationships between living beings and their environment. Similarly, local knowledge is the knowledge of people in a given community that has developed over time. Finally, indigenous knowledge is the local knowledge held by indigenous people or local knowledge unique to a given culture or society. In this sense, the term is used as a broader category into which traditional ecological knowledge fits. This paper focuses on indigenous knowledge and provides evidence of how agroecological practices build resilience and contribute to climate change adaptation for ethnic minority communities in NMR of Vietnam. Studies of the resilience of traditional ecological knowledge for climate change adaptation are rare within the context of indigenous communities in Vietnam, Asia, and the Global South.

## Study methods

### Study area

The NMR was selected as the focus of this study for several reasons. It is home to 31 out of 54 officially recognized ethnic groups in Vietnam, accounting for more than 50% of the total population of the area (Vien 2003). These include the Hmong, Nung, Thai, Tay, and Yao (Dien 2002; Son and Thuy 2005). Each group differs widely in ways of generating income, in kinship, and in the complexity and manifestation of social organization. This study did not attempt to cover the entire NMR, but rather provides a detailed and focused case study of the Nam Mau and Phuc Loc Communes in the Ba Be District of Bac Kan Province (Figure 1). Bac Kan Province lies in the north-eastern part of Vietnam. Approximately 87% of its 323,000 inhabitants are members of an ethnic minority, including the Tay (54%), Yao (17%), Nung (9%), Hmong (5.5%), and other groups (14.5%) (Bac Kan Province Statistic Yearbook 2018). Bac Kan is one of Vietnam's poorest provinces. In 2017, the per capita income in the province was estimated at US$1,231 (Bac Kan Province Statistic Yearbook 2018). Ba Be District covers a total area of 67,809 ha and is one of the poorest districts of Bac Kan. The population consists of about 51,000 people, who live in 15 communes and 1 town. Approximately 80% of the population belongs to an EM group, including the Tay, Yao, Hmong, and Nung (Ba Be Statistic Office 2018).

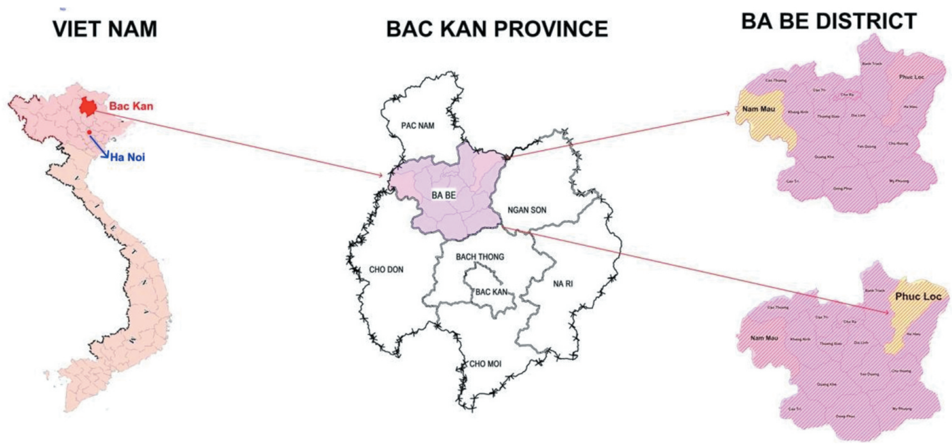


**Figure 1.** The study location of Nam Mau and Phuc Loc Communes and Ba Be District in northern Vietnam.

Within Ba Be District, ten mountain villages in Phuc Loc and Nam Mau Communes comprised the focus areas. Phuc Loc is a remote commune of 3,150 people, 50 kilometers from the center of Bac Kan Province. The commune has 19 villages. Resulting from the complex terrain, mainly upland hills, the area has several meso- and micro-climates. The agricultural fields and livestock are typically proximate to smaller streams, meaning production is often affected by natural disasters and variable extreme local weather events including floods, hail, landslides, intense cold, and frequent droughts. The Phuc Loc Commune villages of Nhat Ven, Khuoi Tra, Phieng Chi, and Na Ma were selected as the study sites. Agriculture is the main source of income in the four locations. Nam Mau is also a remote commune of 2,339 people in Ba Be District and is situated 50 kilometers from the center of Bac Kan Province. The commune has nine villages. The area also has several meso- and micro-climates and is affected by similar natural disasters and variable extreme local weather as Phuc Loc. Six villages of three ethnic groups in Nam Mau Commune were selected for this study. Pac Ngoi and Ban Cam are Tay villages. Their location on the shore of the lake and a wide alluvial plain is favorable for both agriculture and fishing but is also disadvantageous because of annual floods which often destroy food crops. Na Nghe and Na Vai are Yao villages. They lie on sloping land around terraced rice paddies. Khau Qua and Nam Dai are two Hmong villages of Nam Mau Commune. Their livelihoods derive mainly from paddy rice grown at the hill bottom, upland cultivation, cattle rearing, and the gathering of forest products. A few households earn some off-farm income from carpentry and livestock trading. Table 1 provides a socio-economic overview of the two communes in the study area.

According to data of the Center for Hydrometeorological Forecasting of Bac Kan Province, these two communes are characterized by climates typical of the hilly northern areas of the country. The regional climate can be divided into four seasons:

**Table 1.** Major socio-economic characteristics of the two communes in the study area.

| Criteria | Unit | Nam Mau | Phuc Loc |
|---|---|---|---|
| Total land area | Ha | 6,487 | 1,658 |
| Forest land | Ha | 5,230 | 558.7 |
| Cultivated land/person | $m^2$/person | 900 | 771 |
| Number of households | HH | 508 | 660 |
| Population | People | 2,450 | 3,150 |
| Ethnic groups | Group | 5 | 5 |
| Ethnic minority | % | 98 | 92 |
| Number of villages | Village | 6 | 4 |

Source: Nam Mau, Phuc Loc Commune People's Committee (2018).

spring (February to April), summer (May to July), autumn (August to October), and winter (November to January of the following year). Precipitation is highest in the summer and autumn meaning it is typically referred to as the "rainy period" (May to October). During this time, the entire mountainous region experiences heavy rains, flooding, and landslides. In contrast, precipitation is lowest in the winter and spring (November to April).

## *Research methods*

Empirically, this study collected data in Nam Mau (6 villages) and Phuc Loc (4 villages) Communes in the northern mountainous district of Ba Be in Bac Kan Province. Data was collected using household surveys, in-depth interviews, and focus group discussions. At the time of research, there were a total of 446 households in the ten villages. Of these, 384 households (i.e., 237 households in Nam Mau and 147 in Phuc Loc) were visited and contributed data for this study.

### *Household surveys*

A household survey was conducted in each of the study village communities to become better acquainted with the local people and their livelihoods. A questionnaire was used to facilitate the collection of basic household characteristics that included details on the household economy, agricultural production systems, and membership in village institutions and organizations. Initially, the households for the baseline survey were chosen randomly. Later, a sub-sample was selected based on socio-economic indicators including housing conditions and the location of the household within the village. These surveys were typically informal and time was allocated for extended conversations.

### *Interviews*

In-depth, semi-structured interviews with community members were conducted in each of the case study villages to identify the most important climate-related risks and provide insights into how these risks are experienced and managed. The language used in interviews and surveys was Vietnamese.

The interviewer was an ethnic Vietnamese (i.e., Kinh) male from the northern part of the country. Each of the Tay and Yao respondents spoke Vietnamese well, with the exception of a few elderly individuals. All the Hmong men and some of the women spoke Vietnamese well. If a respondent was not fluent in Vietnamese, the village head or head of the family being interviewed assisted with translation. The interviews were transcribed and coded according to themes. Before commencing each interview, the ethical issues and considerations were explained to the participants. The issues covered included confidentiality and privacy of the information; data recording and security protocols; and their rights as potential respondents. Consent was received before conducting any interview.

From the household survey and the interactions with the villagers, a sample of key informants was established who were interviewed in more detail. A total of 50 key informants were approached to conduct in-depth interviews. Key informants were current or former village and commune leaders and tended to be predominantly middle-aged or elderly men. An exception was the chairwomen of the Women's Union and several school teachers. These respondents were chosen as they were knowledgeable of local issues. Both village and commune leaders were either met at home or in their offices at the commune center. Semi-structured interviews were also conducted with villagers at home or in their fields. The second group of key informants comprised government officials and development experts at the district and provincial levels.

### *Focus group discussion*

Focus groups were utilized to gather information concerning climatic hazards, impacts, and adaptation practices. These focus groups were constituted from the most vulnerable groups in the communities as identified during the survey and included those who were impoverished, landless, elderly, women, young, and migratory. The focus group discussion exercise built on the information collected from the interviews. Overall, they were used to help identify problems and possible solutions based on indigenous knowledge and capacity beyond the boundaries of households or individual viewpoints.

A total of 30 of the smaller focus group discussions were conducted in the ten case study villages (three in each village). One group consisted of poor households including the landless and migrants; the second group was of better-off households; and the final group combined poor and better-off households. In addition, one larger focus group discussion was conducted in each of the ten case study villages at the end of fieldwork with 40–50 persons per session. Overall, these forums created opportunities for vulnerable community members to identify their particular climate risks and adaptation strategies.

***Data analysis.*** Since data was collected from multiple sources, several tools were employed to analyze it and then assist with theme development. The qualitative analysis involved segmenting data into relevant categories.

Writing notes in a fieldwork diary helped to prevent a loss of many relevant impressions, spontaneous ideas, evaluations, solutions, and thoughts during data collection. Following each day of fieldwork, a reflective journal was also updated to include opinions on the day's progress, the quality of the data collected, impressions of how the research is progressing, and the potential for personal biases in the research process. Data management and statistical functions in Excel were used to process primary quantitative data collected from household surveys. Counts, percentages, means, and charts were used for summarizing research results (See Authors 2019; 2020 for examples).

## Results

### *Climate change and its impacts*

#### *Evidence of climate change*

Drought, flood, and cold snaps were found to be common climate risks in the mountainous provinces. As reported by the Department of Agricultural Extension of Ba Be District (Ba Be Statistics Office 2017), droughts have increased in frequency and severity over the last fifteen years. Drought affects agricultural production, animal husbandry, and infrastructure. Severe cold impacts the livelihoods of people as it can result in a loss of livestock and the failure of crops. Tropical cyclones have a high level of impact on the whole community, damaging crops, infrastructure, and housing. In addition, the area is also affected by landslides, periods of extreme heat, and flash floods. Of particular importance has been the increase in temperature over the last fifty years (See Figure 2), as this both intensifies and expands the variety of pest and disease pressures in agriculture (Authors 2019).

#### *Impacts of climate change*

In the NMR of Vietnam, especially in areas such as Bac Kan Province, communities

are experiencing longer duration droughts, extreme and damaging cold, abnormal weather patterns, flash floods, and landslides. This combination significantly increases their vulnerability. For example, Hmong communities in Nam Mau Commune experienced drought-induced impacts on agriculture in 2009 and 2010; and cold spells in 2008 and 2011. They also experienced floods but were impacted less as they live at higher elevations and far from the major thoroughfares. Drought is becoming more common in the upland region and places considerable stresses on agricultural production. Irrigation systems in this region are largely non-existent and the dry season (i.e.,

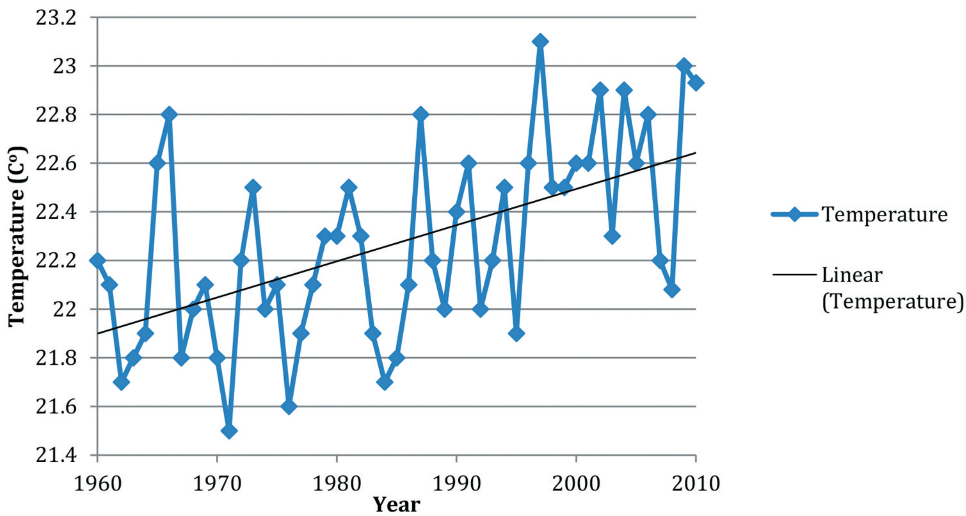


**Figure 2.** Temperature variation of Bac Kan Province over the last 50 years. (*p*-value: 2.148e-05, R-squared: 0.3107)Source: Bac Kan Meteorology and Hydrology Department (2013).

November to April) causes serious problems for Hmong farmers who live far from the centers and main roads. For example, this study found that the 2009 drought had substantial impacts on food production and local livelihoods. Drought caused rice yield declines of 50% to 100% depending on the location of the paddy. The 2009 drought negatively affected 100% of households in all Hmong villages. Importantly, the impact of drought on crop and livestock productivity was found to stress poorer households in various ways. More specifically, it not only added considerable risks of hunger but also pushed those marginal families already struggling to stay just above the poverty line back below it.

In the communities of this case study, floods in 2008 and 2009 caused minor damage to houses, including some affected by flood-triggered landslides. However, livelihood disruption is the main complication faced by local communities, especially those in poverty. As a result of their location, all Hmong villages in the case study communities annually experience some crop damage or loss. Floods destroy crops, cause landslides, overflow fish ponds, and inundate rice paddies.

Cold snaps in 2009 and 2011 caused the death of many cattle. For the poor in rural households in the NMR, cattle typically comprise one of the most valuable family assets. Households use cattle as a means of savings, and to sell when capital is required to purchase housing, pay for a child's higher education, or mitigate an economic crisis. Many households also take bank loans to purchase cattle. Cattle morbidity then represents a significant financial loss to the case study communities. One extreme cold snap in 2009 lasted for 38 consecutive days during January and February, killing 32 head in Nam Mau

Commune and 36 in Phuc Loc. The total cattle loss of Ba Be District was recorded in the district report to be 2,000 (Ba Be Office of Statistics 2009).

### *Using indigenous knowledge and agroecological farming practices to adapt to climate risks and change*

The Tay, Yao, and Hmong are the majority ethnic groups in the study area as well as in Bac Kan Province. This study found that ethnic minorities are producing many native crop varieties and animal breeds. For example, Tay people were found to be cultivating a range of crops and animals that include hilly sticky rice, green bean, white bean, yellow soybean, red peanut, persimmon, and tangerine (Author et al. 2019a). The varieties cultivated are said to be more resistant to drought and suffer less pressure from pests and disease. For many of these crops, farmers can also save seed, thereby reducing costs and beneficially allowing further genetic selection for local conditions. In addition to the cultivation of native crops, farmers were found to be using native or heritage livestock including black pig and black chicken. Many of these species have been raised in the area for over 50 years, are adaptable to the local climate, and more disease resistant.

Similarly, the Yao people in Ba Be district are using many native crops and animal breeds which are highly adapted to local environments (see also Author et al. 2019b). This crop cultivation and animal husbandry help reduce vulnerability to the impacts of climate change. For example, black chicken is a heritage breed. It suffers less from disease, is cold hardy, and produces a high quality of meat. Black pig is also a heritage breed. It too suffers less from disease, is cold hardy, is easy to raise, and also produces a high quality of meat. In addition to native or heritage animal breeds, the Yao people in Bac Kan cultivate some native crops including rice, green bean, soybean, and local maize which are highly adapted to local climate and weather conditions.

In the two surveyed communes, Hmong people were also found to be cultivating a range of native crops and animals. These include native varieties of hilly sticky rice, green bean, white bean, yellow soybean, and red peanut. Farmers were found to be using native or heritage livestock including black pig and black chicken. Many of these species have been raised in the area for over thirty years, are adaptable to the local climate, and more disease-resistant (See also Author et al. 2019a).

In addition to using native crops and animal breeds, local people also use their experience in weather forecasting and disaster preparedness. Skills of the Tay, Yao, and Hmong people in predicting the weather have evolved through observation and experience and have been transmitted to subsequent generations through oral tradition. Due to their relative isolation, limited access to the availability of scientific knowledge and information, and cultural preferences, many mountain communities in the NMR still rely largely on their experiences, traditional practices, and knowledge-based out of environmental observation.

## *Examples of indigenous knowledge use in farming systems*

The biophysical conditions of the mountainous environment have encouraged communities to adopt livelihood diversification strategies. Crop diversification is considered a feasible strategy for farmers in mountainous areas because it entails low risks of production, a higher source of income, a reduction of production costs, and improved levels of resiliency to drought. This study found that many of the farming systems have been adapted to local environmental change by combining both indigenous knowledge and technical inputs from government agencies. Furthermore, the four farming systems focused on in this study have each demonstrated resiliency to climate change in different aspects of economic, social, and environmental sustainability. These are summarized in Table 2 and expounded in the sections following.

**Table 2.** Examples of farming systems and resilience.

| Farming system | Application of indigenous knowledge | Economic resiliency | Social resiliency | Environmental resiliency |
|---|---|---|---|---|
| Banana | intercropped with medicinal plants | Medicinal plants such as ginger, *Ardisia silvestris, Alpinia*, and *Musa* are native crops with long local traditions. | The total net income of the intercropping system was valued at over US$ 3,014/ha/year. This is considerably more than growing mono-cropped maize (i.e., with a total net income of only approximately US$ 1,400/ha/year). | Increased income from the crops helped households improve their living conditions and raise above the poverty line. Furthermore, women benefitted from increased agency though decision-making on how to utilize the increased income. |
| Compared with mono-cropped agricultural systems, this | intercropping system increased land cover, reduced soil runoff and erosion, retained soil moisture, and improved water sources from streams. | | | |
| Maize | intercropped with native red peanut | The native red peanut *(Arachis hypogaea)* is highly resilient to drought and helps to limit pests, beneficially reducing the quantity of pesticide applied. | Intercropping maize and peanut generated an average income of US$2,000/ha. Profits from selling the secondary crop (i.e., red peanuts) compensated for the initial investment costs. | This cropping system generated jobs for women and reduced travel times to work by 50%. The production of peanut provided a desired source of food that contributed to the preservation of traditions and culturally important dishes. |

(*Continued*)

**Table 2.** (Continued).

| Farming system | Application of indigenous knowledge | Economic resiliency | Social resiliency | Environmental resiliency |
|---|---|---|---|---|
| The system is friendly to the | environment thanks to the use of organic fertilizers. It increased soil cover, reduced soil run-off, maintained soil moisture, enhanced fertility, and improved soil porosity. | | | |
| Intercropping of taro, | pachyrhizus, and maize | Intercropping crops with different growth periods (i.e., maize – 115 days, pachyrhizus – 180-200 days) to increase soil cover and retain moisture was common. Pachyrhizus helps to fix nitrogen in the soil to supplement maize and taro. Local people preserved taro and pachyrhizus seedlings using traditional methods. | Intercropping of maize, taro, and pachyrhizus reduced weeds and increased soil moisture, therefore saving water for irrigation. Land-use efficiency was improved thanks to the diversity of crops on a land unit at the same time. The model generated a profit of US $290/1000 $m^2$, twice as much as that of maize mono-cropping. | This farming system created jobs for local laborers, benefitting the community. |
| This farming practice used a native variety of | pachyrhizus that is highly adapted to local conditions. Its planting increases the length of time crops cover the soil, something especially important during the rainy season. Maintaining native taro and pachyrhizus varieties helped to protect natural resources and biodiversity. | | | |
| Drought resilient green bean | This native variety of *Vigna radiata (L)* is resilient to pests and longer duration drought. Farmers grow green bean in as a spring crop from late March when the bead-tree flowers blossom meaning the soil is moist enough and the weather sufficiently warm. | Growing green beans as a spring crop has increased incomes for households by approximately US $150 – 170/ 1000 $m^2$. This is a significant new income source, especially as droughts and heatwaves reduce yields from some spring rice paddies. Green bean plant stalks and leaves also reduce fertilizer costs by 20%. | This cropping system also brings social benefits by creating employment opportunities and easing the workload of women. The cultivation and consumption of native green bean also help to preserve cultural traditions. | Green bean cultivation helps to improve the soil nitrogen fixing and using the plant stalks and leaves as fertilizer. This has the added benefit of releasing the land in time for the cultivation of the next crop. It also helps to preserve *Vigna radiata (L)* for social and economic value. |

### *Banana intercropped with medicinal plants*

The intercropping of banana and ginger (*Zingiber officinale)* and other medicinal plants such as *Ardisia silvestris* and Jiaogulan *(Gynostemma pentaphyllum)* help in adapting to increasing drought in Bac Kan. Intercropping was also found to increase soil cover, reduce erosion during precipitation events, and improve water retention in the soil. This results in higher rates of adaptive capacity when compared with mono-cropping. Discussions with local people revealed that recent increases in temperature are not negatively impacting plant growth. Rather, respondents noted that the higher temperatures and extended sunny conditions prove more optimal for plant growth and the faster-ripening of fruits. Shorter and warmer winters in particular facilitate the growth of banana. This reduces the waiting time before harvest and helps to yield fruit with a better visual appearance. Banana is also barely impacted by the change in seasonal rainfall. However, the occurrence of longer and more extreme cold waves does wither the plants. Shifting cropping patterns in response to these changes in climate is vital for local socio-economic development.

The use of IK in this system is very diverse. Medicinal plants such as ginger, Jiaogulan, *Ardisia silvestris, Alpinia*, and *Musa* are native crops with long local traditions. *Gynostemma pentaphyllum* and *Ardisia silvestris* were collected and domesticated from forests based on learned experiences. Farmers preserve ginger from the previous cropping season in sand in the dark spaces under the

**Figure 3.** Banana intercropped with medicinal plants.

floor of their residences. These are then later planted out to grow in areas of fertile soil. Intercropping medicinal plants with ginger and banana produces effective results. Organic fertilizers and composted manure help to improve soil quality and prevent erosion. Based on experience, farmers often sow plants near the beginning of the rainy season to take advantage of the more available supply of water. The selection of specific times for intercropping of ginger or medicinal plants (e.g., April in the first or second year) to reduce weed pressures or erosion is also an IK technique (Figure 3).

### *Maize intercropped with native red peanut*

The native red peanut *(Arachis hypogaea)* is highly resilient to drought and helps to limit pests, beneficially reducing the quantity of pesticides required. The selection of crops which can supplement each other (e.g., native red peanut, as a legume, helps to fix nitrogen) increased soil fertility and therefore contributed to the development of the maize crop. It was also suitable for local environmental conditions such as a short growing period, which freed land in time for an autumn rice crop. The crop also quickly covers cultivation areas and resists drought and pests well. Techniques of intercropping and optimizing the planting densities of maize and peanut helped to retain moisture in the soil (for maize, the distance was 1.1–1.2 m between wide rows, 0.5 m between narrow ones, and 0.25 m between plants; peanuts were sown in between wide rows of maize with a distance of 0.35 m between rows and 0.12 m between plants). Furthermore, intercropping of the two

**Figure 4.** Maize intercropped with native red peanut.

helped to increase soil cover, benefitting moisture retention, and limiting the impact of drought.

Evidence of the use of IK in the system was found in a variety of ways. Red peanut is a native variety. It is also a food product that contributed to the preservation of the traditional cuisine of Tay and Yao ethnic groups on special occasions and holidays. Maize could be a local or hybrid variety. During serious droughts, farmers only cut weeds on the surface, leaving their roots as a means of retaining soil moisture. Local people often dry peanuts for storage and seed preservation. Maize could be preserved with the mixture of bead-tree (*Melia azedarach*) leaves, oleander leaves, and dry maize husks and stalks. The mixture would be placed in drums/buckets and then covered with a layer of ash and sealed. Farmers also used crushed bead-tree and peach leaves mixed with human urine to repel pests (Figure 4).

### *Intercropping of taro, pachyrhizus, and maize*

The combination of native crops such as taro (*Colocasia esculenta*) and the tuberous root-producing legume pachyrhizus (*Pachyrrhizus erosus*) are well-suited to the local conditions as they are highly drought tolerant. This farming system improved soil moisture retention, which helped the crops better adapt to drought. This intercropping practice also provides a solution to the high rates of soil erosion common to the uplands, increases production yields, and helps local people to adapt more effectively to climate change.

Evidence of IK use in the system includes the intercropping of pachyrhizus and taro into cultivation areas with the drought-resilient maize variety NK 4300. Intercropping crops with different growth periods (i.e., maize – 115 days, pachyrhizus – 180-200 days) to increase soil cover and retain moisture was also

**Figure 5.** Intercropping of taro, pachyrhizus, and maize.

common. Pachyrhizus also helps to bind nitrogen in the soil to supplement the maize and taro. Local people preserved taro and pachyrhizus seedlings using traditional methods, which made them less dependent on outside sources and increased the community's control of their production (Figure 5).

### *Drought resilient green bean*

Green bean *(Vigna radiata (L))* offers efficiency in strengthening adaptation capacity in agricultural production and minimizing losses caused by the adverse impacts of climate change. For example, the crop system is resilient to pests and drought by determining suitable cropping times, balancing fertilizers (increased potassium and reduced nitrogen requirements), lowering beds, constructing ditches around the field to minimize the effects of drought, and cultivating native varieties to strengthen resilience to pests. It also improves the soil as microorganisms around the roots fix nitrogen, the plant stalks and leaves become fertilizer, and the system releases land in time for the cultivation of a subsequent crop. Therefore, farmers earn additional income with the production of another crop, which increases the community's resilience to drought and significantly reduces vulnerability to climate change risks.

Evidence of IK in the system includes using a native variety of *Vigna radiata (L)* which is resilient to pests and longer-duration drought. Farmers grow a green bean in the spring cropping season from late March when the bead-tree flowers blossom (which means the soil is moist enough and the weather sufficiently warm) to avoid having to repeat sowing and help the crop develop quickly. Ash is sprinkled on leaves after the detection of insect pests and its use

**Figure 6.** Drought resilient green bean.

reduces the costs of more commercial pest prevention and control methods. Local people preserve seeds using ash and bead-tree leaves; and the dried seeds are later placed into glass jars/pots/bottles, then sprinkled with a layer of ash or bead-tree leaves and sealed. This process hinders mold growth and helps achieve higher germination rates the following year (Figure 6).

## Discussion

### *Using indigenous knowledge to build community resilience*

#### *Using local experience in adapting to climate change*

Ethnic minority people use several indicators to predict the onset of rainfall as well as changes in weather patterns. Weather forecasting by farmers was found to be largely based on interpreting the behavioral patterns of animals and birds, observing phenological changes associated with plant and tree species, examining phenomena in the troposphere and night sky, and most often some combination of these indicators learned over time. These they described as "personal experience", and are used to forecast weather and adjust their routine activities and farming practices.

Other studies in India have also shown how vital to many communities indigenous knowledge systems are in observing the environment and responding to natural disasters. These communities have collectively generated a vast body of knowledge on disaster prevention and mitigation, including early warning, preparedness and response, and post-disaster recovery (Chinlampianga 2011; Pareek and Trivedi 2011). For example, local people observe the weaver ant behavior of building a nest (especially its size, shape, numbers, and position) as a predictor of the amount of rain during the monsoon (Bagchi 2015). Others observe birds as bioindicators of weather forecasting (Sumi 2018).

#### *Adapting farming systems to build resilience to climate change*

Vietnam has 54 recognized ethnic minority groups (EM), many of whom have lived for years in the NMR and have their own cultural traditions and unique agricultural practices. Many of these mountainous communities rely largely on their experience, traditional practices, and knowledge drawn from environmental observations (Author 2013). IK plays a vital role for ethnic minorities in cropping, breed selection, and cultivation in their livelihood activities. In effect, IK helps ethnic minorities become more resilient to climate change. For example, Hmong ethnic people in Bac Kan Province believe that their black pig and chicken breeds are more resistant to cold and heat than the hybrid pig and chicken breeds typically raised in lowland areas (Author et al. 2019a). The use of indigenous plants and animals not only helps ethnic minorities become more food secure through the diversification of livelihood and income sources but also mitigates the impacts of climate change as these plants and breeds are already adapted to local conditions and cultivation practices (Author et al. 2019a; 2019b). Furthermore, using native varieties reduces the population's need for expensive agricultural inputs, as seeds from native varieties can be easily selected, saved, and then re-planted. Native vegetables, grass, banana, maize, and cassava can also be used as feed for black pigs, which reduces the cost by 80–100% when compared with purchased industrial feed, and for preventive and treatment medicines by 50% (Author et al. 2019a).

In the study area, maintaining native taro and pachyrhizus varieties helped to protect natural resources and biodiversity. This preservation of native plant varieties and animal breeds also helps sustain biodiversity and conserve natural resources. Indeed, IK comprises an integral part of the biodiversity and natural resources of Vietnam. It has been used and preserved by EM communities for multiple generations. The maintenance and development of IK are synonymous with the conservation of biodiversity, and the effective use and protection of natural resources. It also directly contributes to food security and climate change adaptation.

In this study, four farming systems of banana intercropped with medicinal plants; maize intercropped with native red peanut; intercropping of taro, pachyrhizus and maize; and drought-resilient green bean have been used to adapt to climate change. All cropping systems have demonstrated sustainability and resiliency in the context of increased climate risks in the area. For example, the selection of native crops, practicing intercropping and mixed cops have contributed to diversifying income sources, protecting soil, reducing crop loss from drought, and creating more jobs for local people, especially women. Interviews with local community members showed that using the stems and leaves of plants as micro-organic fertilizer or feed for pigs, chickens, cattle (i.e., cows and water buffalo), and fish help reduce input expenditures. The growth of maize intercropped with taro and pachyrhizus diversified income sources and created employment opportunities. A study in a rural community in southern Ethiopia also found that the importance of IK is critical to farmers' livelihoods and environmental conservation and their practices improved their livelihoods in more sustainable ways (Maru, Gebrekirstos, and Haile 2019).

Farmers in this study were able to take advantage of by-products from agricultural and livestock activities from the system to produce micro-organic fertilizer which provided humus for plants. The inter-cropping system is friendly to the environment thanks to the use of organic fertilizers, which consequently reduced risks of soil degradation. Increased soil cover, reduced soil run-off, maintained soil moisture, enhanced fertility, and improved soil porosity were also noted when peanut stem was used as an organic fertilizer. The plants in the system are stratified in planting, which helped increase soil cover time, retain moisture, and prevent erosion. The legume plant (pachyrhizus) is known to fix nitrogen, contributing to the improvement of soil fertility. Farmers composted organic fertilizer from agricultural wastes to fertilize their crops, which functioned to improve soil, retain moisture, and minimize impacts caused by drought. This showed an effective use of agricultural waste for environmental pollution reduction. "*We use green bean plant stalks and leaves to provide organic matter for the autumn rice crop, and thus reduce our fertilizer costs by over 20%*," one villager explained. Green bean cultivation helps to improve the soil by fixing nitrogen. Its stalks and leaves are also used as fertilizer, with the added benefit of releasing the land in time for the cultivation of the next crop. It also helps to preserve *Vigna radiata (L)* for cultural and economic value.

Despite the unusually long drought at the beginning of the cropping season in 2018 which negatively affected plant growth and yields, compared with maize grown as a mono-crop the inter-cropped maize had kernels of even length and no visually discernable defective cobs. This study found that intercropping a legume with a primary crop (e.g., maize) served as a basis for more stable yields. This combination also helped to diversify crops, limit pest damage, and reduce risks due to the impacts of climate change. Overall, intercropping helped to diversify livelihood activities. Increased income from the crops helped farmers leave poverty and improve their living conditions. One female respondent mentioned that "*Consumer goods like television sets, refrigerators, and motorbikes are now affordable for us, and a rise in ownership of cell-phones has increased our ability to communicate and share information*."

The intercropping of maize, taro, and pachyrhizus reduced weeds and increased soil moisture, therefore saving water. Compared with the mono-cropped agricultural systems, this intercropping system also increased land cover, reduced soil runoff and erosion, retained soil moisture, and improved water sources from streams for production. Intercropping helped to limit the growth of weeds, which consequently reduced the quantity of agrochemicals used. In turn, this contributed to the preservation of native herbal and medicinal plants and banana. Thus, indigenous knowledge offers new models for development that are both ecologically and socially sound. This is similar to the results of a study in Sri Lanka (Senanayake 2006). Polyculture or mixed cropping is the sustainable farming system that has been practiced there for centuries. It has many sustainable characteristics that include varying diets, diversifying income generation, stabilizing production, minimizing risk, lowering pest and disease incidences, promoting a more efficient use of labor, intensifying production with limited natural resources, and maximizing returns with lower levels of available technology (Senanayake 2006).

Medicinal plants grown in the system in Vietnam include ginger, *Ardisia silvestris*, and Jiaogulan. These are valuable ingredients used in many traditional medicines. For example, the Yao people slice *Ardisia silvestris* roots, dry and then let them soak with rice wine, and utilize the tincture as a blood tonic and treatment for dysentery, pharynx, and muscular pain. Viewed otherwise, medicinal plants offer alternative systems of health care, reducing costs attributed to the purchasing of medicine, and in turn increasing levels of resilience.

To adapt to climate change in agricultural production, local farmers in rural Vietnamese communities have also taken measures that combine indigenous knowledge and scientific knowledge. For example, farmers in a rural community in Central Vietnam altered the cropping calendar developed by the government (Phuong et al. 2018). In addition, they made other changes in production techniques to adapt to climate change such as altering the quantity and timing of fertilizer and pesticide applications; using more manure; changing crop density; and using additional amounts of mulch. Farmers also used more drought-tolerant, pest-tolerant, and disease-tolerant crop varieties (Phuong et al. 2018).

Another study in Central Vietnam showed that the most common adaptation measures to soil erosion are changes in cropping patterns, adjustments of planting calendars, the use of native varieties, and the addition of more intercropping (Huynh et al. 2020). These adaptation measures are influenced by the cultural observances of the local ethnic minority peoples concerning their IK. It is found that when farmers utilize IK in their farming systems, the soil erosion rate tends to decrease as compared with non-indigenous knowledge practices (Binh et al. 2008; Huynh et al. 2020). These farmers have their own methods of controlling soil erosion, revealing the relevance of an indigenous knowledge system in agricultural development. Thus, more respective attention to IK and practices are a necessary basis for effective and appropriate environmental policies, particularly within the context of the Global South (Ajibade 2008).

One finding of this study in the north of Vietnam is that agriculture development policies should not simply focus on the technical aspects of agricultural innovation, but also consider the specific social and economic dimensions intrinsic to the region. An integral part of this is to include the perceptions and experiences of smallholder farmers in the design and implementation of future agricultural projects. Indeed, the results of this study mirror that of Warren (1991), and imply that by understanding and working with indigenous knowledge and decision-making systems, rates of participation, capacity building, and sustainability can be enhanced in cost-effective ways.

### *Challenges and constraints*

The social, economic, and environmental benefits of utilizing more sustainable and agroecological farming practices to build resilience to climate change in Vietnam are clear. However, considerable barriers to their preservation and further adoption exist. First, the lack of technical and financial support for EM communities to apply these techniques comprises a major constraint. Although the national government has legislated policies aimed at strengthening the linkages between farmers, scientists, the state, and industry to promote agricultural production, results have been limited due to lack of an enabling environment. Furthermore, institutional awareness at the level of local government on the need to shift to more sustainable and agroecological farming practices remains limited. The mind-set of aiming to achieve high productivity and high yields through high inputs lingers. To this, multinational companies have introduced several new varieties into EM communities, often by making exaggerated claims of the benefits attributed to adapting the costly technology suites. Meanwhile, the government on all levels has failed to center the values of indigenous people and their knowledge in its policy agendas.

Although research on the values and role of IK in building resilience to climate change and sustaining local communities exists, this evidence remains ignored by policymakers. Indeed, within the context of Vietnam, this study found the protection and development of IK remain limited due to the lack of information and awareness by government authorities. As a result, policies on all levels pay scarce attention to the use of native plant varieties and animal breeds or the conservation of indigenous knowledge. How this might impact EM communities in the near future is a considerable concern. As argued by Huynh et al. (2020), a conscientious collaboration is essential to achieving good stewardship in building community resilience to climate change. To best achieve this, considerably more attention should be given to improving communication and cooperation between scientists, public officials, and the indigenous people of Vietnam.

## Conclusions

This article documented ways in which IK and agroecological farming practices contribute to building community resilience to climate change for ethnic minority communities in the Northern Mountainous Region of Vietnam. It documented specific practices of IK and the resulting improvements in the social, economic, and environmental livelihoods of its practitioners; the very notions of sustainability. However, this study also found the geographic diffusion of these practices remains limited due to the lack of information, awareness, and communication. For IK to become a more valuable tool to improving the livelihoods of ethnic minority people in Vietnam, a change in awareness and attitude of policymakers, community development advocates, government authorities, university educators, and local communities is required. As climate continues to change, the further promotion of the use of indigenous knowledge in agricultural production and management not only becomes essential in this Vietnamese context but also comprises a crucial component of agency and advocacy for the rights and voices of ethnic minority populations globally.

## Declaration of interest

The authors declare to have no financial interest or benefit from the direct applications of this research.

## References

Abel, N., D. H. M. Cumming, and J. M. Andries. 2006. Collapse and reorganization in social-ecological systems: Questions, some ideas, and policy implications. *Ecology and Society* 11 (1):17. doi:10.5751/ES-01593-110117.

Adger, W. N. 2000. Social and ecological resilience: Are they related? *Progress in Human Geography* 24 (3):347–64. doi:10.1191/030913200701540465.

Ajibade, L. T. 2008. Indigenous approach to the control of soil erosion among small scale farmers in Asa L.G.A., Kwara State, Nigeria. *Ethiopian Journal of Environmental Studies and Management* 1 (1):1–6. doi:10.4314/ejesm.v1i1.41564.

Altieri, M. A., and C. I. Nicholls. 2012. Agroecology scaling up for food sovereignty and resiliency. In *Sustainable agriculture reviews. Sustainable agriculture reviews*, ed. E. Lichtfouse, Vol. 11. Dordrecht: Springer.

Author. 2013. Vulnerability and resilience to climate change in the Northern Mountainous Region of Vietnam. Ph.D. Dissertation, Australian National University.

Author and et al. 2019a. Using indigenous knowledge in agroecological and climate change resilience practices. Hanoi: Agricultural Publishing House.

Author, et al. 2019b. Indigenous knowledge and climate change adaptation of ethnic minorities in the mountainous regions of Vietnam: A case study of Yao people in Bac Kan province. *Agricultural Systems* 176 (2019):102683. doi:10.1016/j.agsy.2019.102683.

Authors. 2019. Indigenous knowledge and climate change adaptation of ethnic minorities in the mountainous regions of Vietnam: A case study of Dao people in Bac kan province. *Agricultural Systems* 176: 102683.

Authors. 2020. Community adaptation and climate change in the Northern Mountainous Region of Vietnam: A case study of ethnic minority people in Bac Kan Province. *Asian Geographers* 37 (1):33–51.

Ba Be Office of Statistics. 2009. Socio-economic report of Ba Be district. unpublished.

Ba Be Office of Statistics. 2018. Socio-economic report of Ba Be district. unpublished report.

Ba Be statistics Office. 2017. Socio-economic report of Ba Be district in 2017, unpublished report.

Bac Kan Meteorology and Hydrology Department. 2013. Temperature Data of Bac Kan Meteorology and Hydrology Station.

Bac Kan Province Statistic Yearbook. 2018. Bac Kan Statistical Publishing House.

Bagchi, S. S. 2015. Weaver ants as a bioindicator for rainfall: An observation. *Archives of Applied Science Research* 7 (1):66–67.

Bangalore, M., A. Smith, and T. Veldkamp. 2016. Exposure to floods, climate change, and poverty in Vietnam. *Policy Research Working Paper No. 7765*. Washington, DC: World Bank.

Belfer, E., J. Ford, and M. Maillet. 2017. Representation of indigenous peoples in climate change reporting. *Climatic Change* 145 (1–2):57–70. doi:10.1007/s10584-017-2076-z.

Berkes, F. 2007. Understanding uncertainty and reducing resilience: Lessons from resilience thinking. *Natural Hazards* 41:283–95.

Berkes, F. 2009. Indigenous ways of knowing and the study of environmental change. *Journal of the Royal Society of New Zealand* 39 (4):151–56.

Binh, D. K. N. T., L. T. V. Phuong, I. Douglas, N. Van De, J. McMorrow, S. Lindley, T. T. Van, H. Thanh, and N. Tho. 2008. Local knowledge and economic realities affecting soil erosion in the Rach Rat catchment, Vietnam. *Geographical Research* 46 (1):17–26.

Birket, F. 2012. *Sacred ecology*. New York: Routledge.

Bryan, E., C. Ringler, B. Okoba, J. Koo, M. Herrero, and S. Silvestri. 2013. Can agriculture support climate change adaptation, greenhouse gas mitigation and rural livelihoods? Insights from Kenya. *Climatic Change* 118:151–65.

Callaghan, E. G., and J. Colton. 2007. Building sustainable & resilient communities: A balancing of community capital. *Environment, Development and Sustainability* 10 (6):931–42.

Chinlampianga, M. 2011. Traditional knowledge, weather prediction and bioindicators: A case study in Mizoram, Northeastern India. *Indian Journal of Traditional Knowledge* 10 (1):207–11.

Clements, R., J. Haggar, A. Quezada, and J. Torres. 2011. *Technologies for climate change adaptation – Agriculture sector*. Roskilde: UNEP Risø Centre. X. Zhu (Ed.).

Dasgupta, S., B. Laplante, C. Meisner, D. Wheeler, and J. Yan, 2007. The impact of Sea-level rise on developing countries: A comparative analysis. *World Bank Policy Research Working Paper 4136*. February. World Bank.

Delisle, S., and S. Turner. 2016. The weather is like the game we play': Coping and adaptation strategies for extreme weather events among ethnic minority groups in Upland Northern Vietnam. *Asia Pacific Viewpoint* 57 (3):1–14.

Dien, K. 2002. *Population and ethno-demography in Vietnam*. Chiang Mai: Silkworm Books.

Eakin, H., and A. L. Luers. 2006. Assessing the vulnerability of social-environmental systems. *Annual Review of Environment and Resources* 31:365–94.

Folke, C. 2006. Resilience: The emergence of a perspective for social-ecological systems analyses. *Global Environmental Change* 16:253–67.

Folke, C., T. Haln, P. Olsson, and J. Norberg. 2005. Adaptive governance of social- ecological systems. *Annual Review of Environment and Resources* 30:441–73.

Hiwasaki, L., E. Luna, and S. Syamsidik. 2014. Process for integrating local and indigenous knowledge with science for hydro-meteorological disaster risk reduction and climate change adaptation in coastal and small island communities. *International Journal of Disaster Risk Reduction* 10:15–27.

Holling, C. S. 1973. Resilience and stability of ecological systems. *Annual Review of Ecology and Systematic* 4:1–23.

Huynh, C. V., T. G. Pham, T. Q. Nguyen, L. H. Nguyen, P. T. Tran, Q. N. Le, and M. T. Nguyen. 2020. Understanding indigenous farming systems in response to climate change: An investigation into soil erosion in the mountainous regions of Central Vietnam. *Applied Sciences* 10:50–91.

IPCC. 2012. Managing the risks of extreme events and disasters to advance climate change adaptation: Summary for policymakers. In *A special report of Working Groups I and II of the intergovernmental panel on climate change*, C. B. Field, V. Barros, T. F. Stocker, D. Qin, D. J. Dokken, K. L. Ebi, M. D. Mastrandrea, K. J. Mach, G.-K. Plattner, S. K. Allen, et al. ed.. Cambridge: Cambridge University Press.

Jiggins, J. 2014. Agroecology: Adaptation and mitigation potential and policies for climate change. In *Global environmental change. Handbook of global environmental pollution*, ed. B. Freedman, Vol. 1. Dordrecht: Springer.

Manyena, S. B. 2006. The concept of resilience revisited. *Disasters* 30 (4):433–50.

Maru, Y., A. Gebrekirstos, and G. Haile. 2019. Farmers' indigenous knowledge of tree conservation and acidic soil amendments: The role of "baabbo" and "Mona" systems: Lessons from Gedeo community, Southern Ethiopia. *Cogent Food & Agriculture* 5 (1):1645259.

Méndez, V. E., C. M. Bacon, and R. Cohen. 2013. Agroecology as a transdisciplinary, participatory, and action-oriented approach. *Agroecology and Sustainable Food Systems* 37 (1):3–18.

Nam Mau, Phuc Loc Commune People's Committe, 2018. Socio-economic reports of the communes in the year 2018, unpublished reports

Olsson, P. 2003. Building capacity for resilience in social-ecological systems. Doctoral dissertation. Stockholm, Sweden: Department of Systems Ecology, Stockholm University.

Pareek, A., and P. C. Trivedi. 2011. Cultural values and indigenous knowledge of climate change and disaster prediction in Rajasthan, India. *Indian Journal of Traditional Knowledge* 10 (1):183–89.

Phuong, L. T., G. Biesbroek, L. T. H. Sen, and A. Wals. 2018. Understanding smallholder farmers' capacity to respond to climate change in a coastal community in Central Vietnam. *Climate and Development* 10 (8):701–16.

Pimbert, M. 2015. Agroecology as an alternative vision to conventional development and climate-smart agriculture. *Development* 58 (2–3):286–98.

Savo, V., D. Lepofsky, J. Brenner, K. Kohfeld, J. Bailey, and K. Lertzman. 2016. Observations of climate change among subsistence-oriented communities around the world. *Nature Climate Change* 6:462.

Senanayake, S. G. J. N. 2006. Indigenous knowledge as a key to sustainable development. *The Journal of Agricultural Sciences* 2 (1):87–94.

Smit, B., and J. Wandel. 2006. Adaptation, adaptive capacity and vulnerability. *Global Environmental Change* 16 (3):282–92.

Son, C. T., and T. T. T. Thuy. 2005. Nguoi H'mong (H'mong people). Nha Xuat Ban Tre. Hanoi.

Sumi, A. 2018. Birds as bioindicators of traditional weather forecasting among the Sumi Tribe of Nagaland, India. *Asian Journal of Environment & Ecology* 7 (4):1–7.

Tam, B. V., E. Iksoon, K. Hayashi, and R. Torio. 2017. Cyclones, deforestation, and production of food crops in Vietnam. *Economics of Disasters and Climate Change* 1 (3):245–62.

Tompkins, E. L., and W. N. Adger. 2004. Does adaptive management of natural resources enhance resilience to climate change? *Ecology and Society* 9 (2):10.

Vien, T. D. 2003. Culture, environment, and farming systems in Vietnam's northern mountain region. *Southeast Asia Studies* 41 (2):180–205.

Warren, D. M. 1991. Using indigenous knowledge for agricultural development. *World Bank Discussion Paper 127*. Washington, D.C.

Whitney, C. W., V. S. Min, L. H. Giang, V. Van Can, K. Barber, and T. T. Lanh. 2016. Learning with elders: Human ecology and ethnobotany explorations in Northern and Central Vietnam. *Human Organization* 75 (1):71–86. Spring.

Wildcat, D. 2013. Introduction: Climate change and indigenous peoples of the USA. *Climate Change* 120:509–15.

World Bank. 2010. The social dimensions of adaptation to climate change in Vietnam. *Discussion Paper Number 12 December 2010*. Washington, D.C: Economics of Adaptation to Climate Change.