Indian Journal of Traditional Knowledge
Vol 20(2), April 2021, pp 459-472

The role of Tay indigenous knowledge in climate change adaptation in the Northern Mountainous Region of Vietnam

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Received 17 June 2019; revised 10 January 2021

Through generations of observation and experimentation, the Tay people of Bac Kan Province in the Northern Mountainous Region of Vietnam have developed complex farming systems, cultural practices and an indigenous knowledge base well-suited to their environments. Drawing on data collected through surveys, interviews and focus group discussions, this article first documents some of this knowledge and its role in supporting agricultural production. However, this research also uncovered that contemporary climate change is occurring at rates faster than that knowledge base can meaningfully adjust and adapt. Agricultural productivity was found to be greatly reduced, with men seeking off-farm employment to supplement the loss in income. Agrochemical use has soared and resulted in declines in the health of the local population. Village gender dynamics have also shifted and women have taken on the extra burden of farming. This paper posits that if indigenous knowledge was better integrated into adaptation planning and policies, its conservation and application would enhance resiliency to climate change in indigenous communities and beyond. Simultaneously, it also adds that as the nature, speed and severity of climate change in many marginal areas occur at rates faster than indigenous knowledge can adapt, blended forms of knowledge may offer practical solutions.

Keywords: Climate adaptation, Ethnic minority, Indigenous knowledge, Tay, Vietnam

IPC Code: Int Cl.[21]: A23L 33/00, A61K 36/00, E04H 9/16

Indigenous knowledge (IK) refers to the unique know-how of a culture and encompasses the cultural traditions, values, beliefs and worldviews of local people[1]. Thus, it is integral to the existence of the historic and cultural heritage of a particular group as it forms the "*backbone of social, economic, scientific and technological identity*"[2]. Recently, indigenous populations have been increasingly recognized as living in ways more sustainable to their environment. Scholars have researched the potential roles and implications of IK in fields such as ecology, biodiversity conservation, environmental protection, land, natural resources and wildlife management, health and education[1,3,4]. Research has also centered on how IK is and can be made further applicable to adaptation and mitigation strategies that combat climate change and the resulting environmental hazards[5-7]. Notably, as indicated by Rautela & Karki[8], the integration of IK in disaster risk reduction significantly contributes to the preparation, response and post-natural disaster recovery processes.

In Vietnam, IK refers to the activities of the country's many ethnic minority communities. Transmitted orally across generations, IK is formed and perfected through the production processes of entire communities[9]. Recent studies on IK in Vietnam have centered on, for example, forest management[10,11]; agricultural production[12-14]; medicinal plants[15,16] and flood adaptation[17]. Nonetheless, with exceptions such as Son[18], Turner *et al*.[19] and Delisle & Turner[20], most of this research has focused on communities living in the central and coastal regions of the country. This study more generally explores the role of IK of Tay people in adapting to climate change in the Northern Mountainous Region of Vietnam. More specifically, it (1) explores the impact of climate change on agricultural production; (2) documents the IK of the Tay people as used in that production; (3) investigates how IK is employed by

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the Tay people in adapting to climate change risks and (4) assesses the nature of local adaptation to climate change.

This study focuses on the IK of the Tay people in four communes in Bac Kan Province in the north of Vietnam. It provides insights into how this IK is used to adapt to climate change. More specially, this study explores Tay choices for crops and animal breeds, their weather forecasting, and their cultivation practices. In doing so, it seeks further integration of IK into climate change strategies on the local, regional and national, and international scales.

Materials and Methods

Description of the study areas

Bac Kan Province is in the Northern Mountainous Region of Vietnam. Almost 90% of Bac Kan's nearly 350,000 residents are ethnic minorities, with around one-half being Tay[21]. With a per capita income in 2017 of approximately US $1,200, it is one of the poorest regions in the country. Within the province, generally the more remote the population, the higher is the poverty rate[21]. It is within these more remote areas where ethnic minority populations typically reside.

With a population of 1.7 million people or 2% of the total population of Vietnam, the Tay people comprise the second-largest ethnic group[22]. They largely reside in the mountainous areas or at the higher elevations of the northern and northwestern provinces of Cao Bang, Lang Son, Bac Kan, Thai Nguyen, Quang Ninh, and Ha Giang. Although largely dependent on wet rice cultivation, many plants, upland rice and other food crops including fruits are also cultivated. Free-range systems of animal husbandry and poultry are also common livelihood sources.

In terms of study sites, the Thanh Van and Mai Lap Communes of Cho Moi District were chosen to represent the central areas of lower elevation and the Van Minh and Lang San Communes of Na Ri District to represent conditions in the eastern and northeastern regions (Fig. 1). Thanh Van, Mai Lap, Van Minh and Lang San are the most economically disadvantaged communes in the districts of Cho Moi and Na Ri. All four communes are situated on hilly, heavily sloped terrains with poor soil. As a result, communities are more prone to natural disasters such as landslides and flash flooding. Each is inhabited by a population

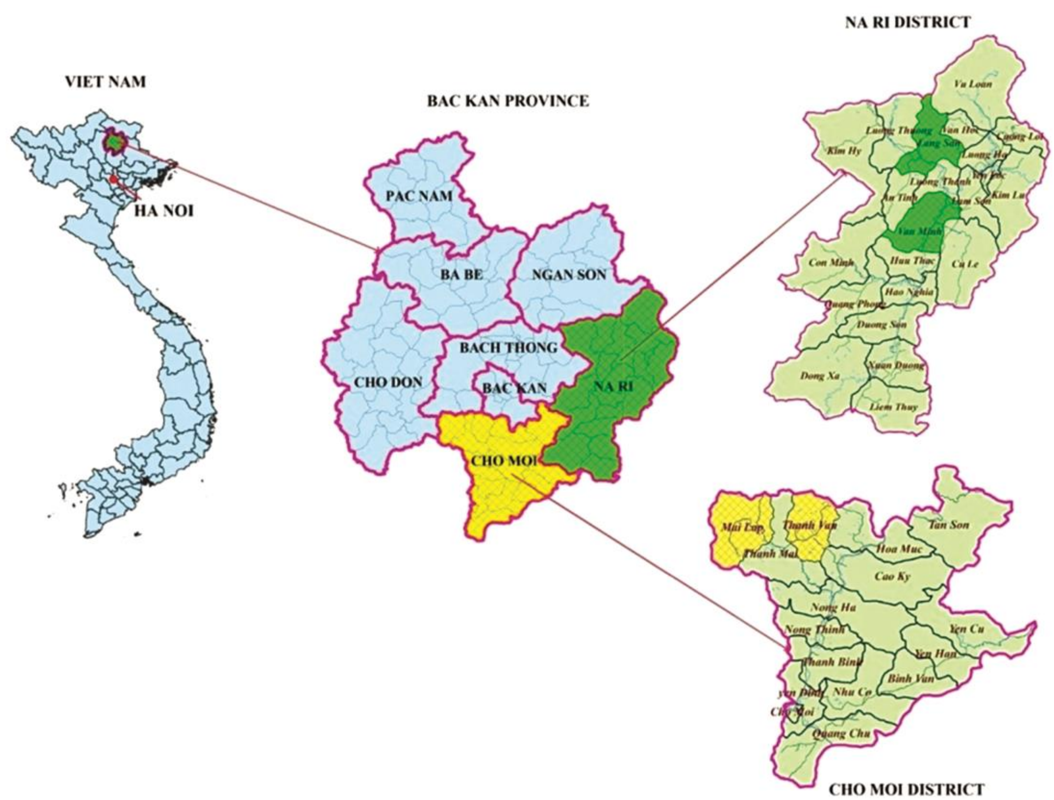

Fig. 1 — Map of the Study Areas

predominantly comprised of members of the Tay ethnic minority. Table 1 provides an overview of these four communes.

Methodology

This study combined field observations, household surveys, interviews and focus group discussions. A complete literature review of academic, policy and popular press publications was conducted. This focused on studies of the IK of the Tay people and their use in adaptation to climate change. Field observation was used in the communities throughout the research process to observe and document the daily lives of villagers and their responses to changes in climate. A survey comprised of both open- and closed-ended questions was completed by 120 residents in the villages: 60 from Van Minh and Lang San Communes and 60 from Mai Lap and Thanh Van Communes. Particularly notable was that most respondents lacked a secondary education and were of low household economic status. Interviews with community members in each of the study villages were conducted to identify climate-related risks that affect people and to provide insights into how these risks are experienced and managed. Key informants from the household surveys and agricultural experts were contacted for further in-depth interviews. In each community, 10 farmers with considerable professional experience were interviewed. Two members of the Department of Agricultural Extension of Na Ri District and Cho Moi District and one extension staff member from each community were also interviewed. Focus group discussions with community leaders, elders and experienced farmers were conducted to explore IK practices concerning climate adaptation**.** In each study area (i.e., district), three focus group discussions were also organized including 1 group of all men, 1 group of all women and 1 mixed gender group comprised of knowledgeable elderly. Each of the focus groups had 5 participants. Opinions expressed helped to inform the conclusions of this article.

Data analysis

The data collected in this study were analyzed through a variety of methods. Questionnaire data were organized using percentages, mean values and frequency tables. Information obtained through field observations, focus group discussions and interviews were analyzed on narrative content.

Results and Discussion

Evidence of climate change in the study areas

According to data from the Bac Kan Meteorology and Hydrology Department, between 1960 and 2010 the average annual temperature in Bac Kan Province rose sharply (Fig. 2). In addition, climate change is projected to increase in the future. The Ministry of Natural Resource and Environment (MONRE)[23] predicts that the annual average temperature will increase by 2.5ºC in the latter half of the 21st century. Furthermore, the annual average temperatures in the

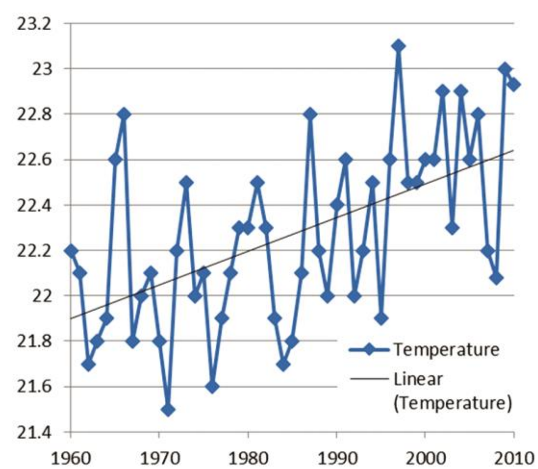

Fig. 2 — Variation in Temperature in Bac Kan Province (1960-2010)

Table 1 — Socio-economic characteristics of the four communes in the study areas

Criteria	Unit	Mai Lap	Thanh Van	Van Minh	Lang San
Total land area	Ha	4,310	2,980	3,800	3,488
Forest land	Ha	3,692	2,313	2	2,318
Cultivated land/person	m^2/person	2,858	2,365	-	2581
Number of Households (HH)	HH	396	562	294	591
Population	People	1,552	2,267	1,193	2,458
Ethnic groups	Group	Tay, Hmong, Dao, Nung and Kinh	Tay, Dao, Nung and Kinh	Tay, Dao, Nung and Kinh	Tay, Dao, Nung and Kinh
Ethnic minority	%	92.50	94.78	95.5	91.70
Poverty and near poverty rate	%	56.3	57.63	66.88	49.84

[Source: Thanh Van, Mai Lap, Van Minh and Lang San Commune People's Committee (2018)]

North-Eastern, North Central and Tay Nguyen regions will increase at more rapid rates than other areas. The trend is that colder than average winters will occur at higher rates, and summers will be increasingly drier and hotter. Furthermore, temperature increases intensify the frequency, manifestation, spatial extent and duration of extreme weather and climate events[24]. These events will impact the lifestyles, food production, economic activities and residential and migration patterns of people[25].

Importantly, these figures are generalized for the larger geographic regions and do not identify extreme weather events and the manifestation of climate change in particular localities. In areas with rugged terrain made further complicated by their locations within regions of varying topography, generalizations on larger areas fail to adequately capture the realities of local climatic change. Therefore, to identify clear examples of extreme weather events at the local level, a combination of focus group discussions and interviews with knowledgeable people (including experienced farmers and official staff) were conducted. These are summarized in Table 2.

Respondents from the four communities in Cho Moi and Na Ri districts noted that extensive droughts, extreme cold and abnormal weather patterns are the obvious manifestations of climate change in their localities. Drought has also increased in both intensity and duration. Furthermore, respondents noted that the dry period now extends into late April and even May. The opinions on the locally changing climate of most respondents match the statistics. Climate change is clearly affecting both residents and the environment of the study sites. Typically, it is manifested as a gradually increasing duration and intensity of drought, more extreme and longer duration periods of cold and a higher frequency of abnormal weather.

The use of IK in climate change adaptation

According to Agrawal[1], in the context of more sustainable resource use and balanced development, IK is seen as an integral factor. IK is therefore considered as an effective and appropriate strategy for mitigating and adapting to climate change. IK and practical experience are the basis for decision-making on the local level in many rural communities[26].

In Bac Kan Province, Tay people were found vulnerable to the impacts of climate change and with low adaptive capacity. However, through daily engagement with that natural environment, local Tay communities have also accumulated bodies of knowledge regarding its variability. This knowledge is particularly beneficial, as it provides important insights into the processes of climate variability and adaptation. The Tay communities in the study areas have developed different strategies and a wide variety of applicable responses that comprise the basis of their resilience.

Table 2 — Observations and perceptions of local people on the extreme weather events at their locality over the last 20 years

Extreme weather events and bad weather patterns	Changes in frequency *(+= increase-= decrease)*	Changes in intensity *(+= increase-= decrease)*	Changein duration *(+= increase -= decrease)*	When	Impact rank *(1 is the highest, 7 is the lowest)*
High temperatures, lack of rain and longer duration drought	++	+++	+++	2000, 2011, 2016	1
Extreme cold	+++	+++	+++	2006, 2007, 2008, 2013, 2015	2
Flash flooding and landslides	-	+++	-	2006-2007, 2017	3
Abnormal weather patterns	++	++	+++	2007-2008, 2018	4
Tornado	-	++	-	2007, 2018	5
Hail		+++		2008, 2018	6
Lighting/thunder - no rain	-	++	-	2010	7

(Source: Field Survey, 2018)

This research found that the Tay communities have different indigenous strategies including those focused on the management of resources related to water, land, crop, livestock, fisheries and other off-farm sources (e.g., foraging in forests). For example, Tay communities were found to use small reservoirs and ponds and created dams to hold water on smaller streams. Almost 75% of respondents noted they used combinations of these measures, often simultaneously. In the case of land management, strategies including manuring (9.17%), mulching (8.33%), ploughing in crop-residues (6.67%), and fallowing (5.83%). Again, nearly 70% of respondents noted the simultaneous use of each of these methods. In crop management, strategies included planting native varieties (14.17%), timing of planting (11.67%), crop diversification (10%) and crop rotation (9.17%). Also, 55% of respondents said that they used all these measures simultaneously. These strategies are summarized in Table 3. The results of this study mirror those of Kumar[27] as they indicate that traditional forms of IK are used to cope with climate change. Within this set of traditional skills, those related to water conservation were found to be of utmost importance. As with Kumar's study of North-western India, if the traditional knowledge of Tay people in Vietnam were intentionally and logically intertwined with more modern technologies, the opportunity to better protect livelihoods and play more pivotal roles in mitigating the vulnerabilities of climate change could be achieved.

In terms of livestock management, raising heritage or native breeds (47.50%), increasing livestock diversification (40.83%) and timed reductions in herd size (e.g., selling weak and elderly animals before the winter season) (11.67%) were all common. Fish management strategies include the collection of eggs of wild native fish species from smaller rivers and streams to grow out in their ponds.

Finally, in addition to the application of IK, respondents often sought off-farm employment to generate extra income to compensate for declines in agricultural productivity and the loss from natural disasters. 10.0%, 16.76% and 30.0% of respondents said they were involved in small trading, day labour jobs and working in companies respectively as adapting mechanisms. Further, 43.33% of respondents also explained that they changed their livelihoods by

Table 3 — Strategies used in water, land and crop management

Water management strategies	Percentage	Land management strategies	Percentage	Crop management strategies	Percentage
Use of small reservoirs and ponds	14.17	Manuring, use of micro-organic fertilizers	9.17	Crop diversification	10.00
Use dams on small streams	8.33	Mulching	8.33	Use of native varieties	14.17
Holding water in ravines	1.67	Fallowing	5.83	Crop rotation	9.17
		Ploughing in crop residue	6.67	Timing of planting	11.67
All	75.83		70.00		55.00
Total	100 (120)		100 (120)		100 (120)

(Source: Fieldwork, 2018)

Table 4 — Strategies used in animal husbandry, fish management, and off-farm activities to overcome impacts of climate change

Livestock management strategies	Percentage	Fish management strategies	Percentage	Off-farm activities	Percentage
Increase livestock diversification	40.83	Use native species by collecting eggs to raise in ponds	25.00	Petty trading	10.00
Use heirloom and native breeds	47.50			Day labourer	16.67
Timely reduction of herd size (e.g., selling of weak and elderly animals before the winter season)	11.67			Work in a company	30.00
				Increase in the collection of forest products	43.33
Total	100 (120)		100 (120)		100 (120)

(Source: Fieldwork, 2018)

increasing the collection of local forest products including wild honey, mushrooms, bamboo shoots, rattan and medicinal plants. These are summarized in Table 4.

Native crops, livestock, and fish breeds as strategies to adapt to climate change

In the surveyed communes, numerous native crops and animals are cultivated. These include hilly sticky rice, green bean, white bean, yellow soybean, red peanut, persimmon and tangerine. The varieties cultivated are understood to be more resistant to drought and suffer less from pest and disease pressures. Farmers also save seed, which reduces costs and permits the selection of plants more productive under local conditions. In addition to the cultivation of native crops, farmers were found to be using native or heirloom livestock and fish breeds including black pig, mudfish and barbel chub. Produced in the area for over fifty years, many are better adapted to the local environmental conditions and diseases. A summary of native crops, livestock and fish with characteristics used at the study sites is found in Table 5. These results are in accordance with Son *et al.*,[28] who similarly reported that the Yao people in the Northern Mountainous Region of Vietnam utilize numerous indigenous crop varieties to adapt to evolving local environments and climate change. Singh *et al.*[29] researching in the Rajasthan region of India, also indicated that diversified

Table 5 — Native crops, livestock, and fish used by Tay people in Bac Kan Province

Local name inTày	English name	Scientific name	Characteristics as mentioned by respondents
Khẩu nua nương	Hilly sticky rice	*Oryza sativa* var. *glutinosa*	-Planting is in June and harvest in October. -High quality, but low yield (40 kg/100 m^2). -High market price. -Drought tolerant. -Disease tolerant. -First cultivated locally in the 1950s.
Thua kheo móoc	Green bean	*Vigna radiata* (L.) R. Wilczek	-Has a short growing period of 2.5 months. -Planting is in the spring and harvest in early summer. -The green bean seeds are smaller and dark green than hybrids -Low yield of only 800- 1,100 kg / ha. - Good quality of seeds. - Good drought tolerance, high resistance to pests and diseases. - Appropriate for drier areas unsuitable for paddy rice -Plant residue can be used as protein-rich fertilizers for other crops. This reduces the overall amount of chemical fertilizers. -First cultivated locally in the 1980s.
Thua khao	White bean		-Has a short growing period between 50 and 90 days. - Planted in the middle of May in the Lunar calendar and harvested from the middle of July to August. -The seeds are white in color. -Low productivity with 0.8-1.1 ton/ha: 30 kg/100 m. -Drought tolerant. -First cultivated locally in 1970.
Thua tương lương	Yellow soybean		- Seed shape and size are similar to the hybrid varieties commonly grown in Vietnam. - Average yield, but high quality. - Planted in the middle of May in the Lunar calendar and harvested in autumn. -The seeds are yellow in colour. -Drought tolerant so suitable for areas with water shortages, more resistant to local pest pressures. -Grown locally for over 30 years.

(*Contd*.)

Table 5 — Native crops, livestock, and fish used by Tay people in Bac Kan Province (*Contd.*)

Local name inTày	English name	Scientific name	Characteristics as mentioned by respondents
Mằn ón	Native arrowroot		- The foliage is smaller than that of newer hybrids. - One-third lower yield than newer hybrids. - The planting seasons are in February and March and harvest seasons are in November and December
Thúa đin đeng	Red peanut	*Arachis hypogea* Linn	-Planting seasons are in February and May. -Harvest seasons are in July and November. -The average yield is about 1.6 ton/ha. -Good quality and high market price. -Drought tolerance is better than with white peanut varieties. -Red peanut is a potential crop to replace other cultivars on a one-season drought land. -Suitable for intercropping with maize. -Cultivated locally since 1970.
Mác hồng	Native persimmon	*Diospyros kaki*	-Harvest season is from August to September. -This regional specialty has a small fruit size, fewer seeds, and a marketable geographic indicator. -Existed in the community for more than 80 years.
Mắc pén	Native tangerine	*Citrus reticulate*	-Harvest seasons are in October and December. -This regional specialty has a medium fruit size, more seeds, a sweet taste, soothing aroma, and a marketable geographic indicator. -Existed in the community for more than 80 years.
Mắc mặn	Plum	*Prunus domestica*	-Harvest seasons are in April and June. -Local plum has a small-sized fruit and slightly sour taste. -Existed in the community for more than 80 years.
Mu đăm	Black pig		-Has a black coat, a long muzzle, and reaches a weight of around 50 kilograms. -It is cold tolerant and heat resistant, easy to raise, and less susceptible to disease. -Good quality of meat. -Have been raised locally for over 50 years.
Cá chày: Pya tất	Barbel chub	*Squaliobarbus curriculus*	-Caught in local rivers and streams, the Tay people move them to ponds to raise them. -High quality of meat. -Unknown when first appeared in community.
Cá nheo: Pya còng	Mudfish		-Live in small rivers and streams. -Easy to raise and less sick. -The quality of meat is good -Unknown when first appeared in community.

(Source: Fieldwork, 2018)

indigenous crops and technologies that are suitable to local contexts merit expansion to reduce climate-induced vulnerability.

Indigenous knowledge in forecasting weather, climate and seasonal crops

The Tay people have valuable experience in predicting rainfall, the change in weather patterns and the onset of drought in their community. Almost all experiences are based on monitoring and observing the stages in the life cycle of the plant and the behaviours of animals. These are summarized in Table 6.

The Tay people also have experience in forecasting seasonal calendars to schedule specific events in the planting of crops, agroforestry and animal husbandry. These are generalized in Table 6.

Climate vulnerability and impacts on the study areas

Climate vulnerability is determined through degrees of exposure, sensitivity and adaptive capacity. High exposure or sensitivity and low adaptive

Table 6 — IK in forecasting weather, climate and seasonal crops based on flora characteristics and fauna behaviours

Prediction and meaning	Flora characteristics	Fauna behaviours
Rain	When one of the local wildflowers (local name in Tày: *biyooc khao*) in the forest is blooming with a nice aroma, it is going to rain (This flower usually blooms for two days). If the Bo De's leaves (local name: *Bo De*) are observed to be turned upside down with white color, then it will rain one to three hours later. If the longan has more fruit than usual, it is expected that there will be heavy rain and floods that year.	If termites (local name: *tua puốc*) fly into light bulbs and into the house during the evening, it is going to rain in the next two days. If the sound of bullfrog can be heard at noon, heavy rain will appear. If ants (local name: *tua một*) are seen ascending or crawling on the pillars of the house, rain is predicted. If ants are seen crossing the road or moving into houses, heavy rain will appear in around three days. If hawks (local name: *tu khuyển*) are on the branch of the tree and calling, it will rain.
Sunny weather		If you see black magpie-robins (local name*: tu ca*) flying up high and singing when stop rain, it means the rain has ended and it will be sunny.
Drought	If the "tu hu" tree (ie an indigenous litchi variety) has more fruit than usual, drought is likely to occur next year.	
Flood	Observing moss (local name: *tòng quẩy*) in local streams and ponds. If moss is floating on the water in the stream, flooding may occur in the next few days. If the surface of a pond has yellow moss, rain will occur within 36 h.	If crabs (local name: *tua pu*)) from small streams are crawling on the road, flooding is expected in the few day.
It is time to grow corn and beans to obtain high yields. (During the January – February period in the Lunar year, the weather is warmer and wetter).	When "Po" trees (local name: *co riển*) have buds and flowers.	
It is time to transplant the spring rice crop. According to respondents, when the flowers are blooming, the warmer and wetter weather is possible to transplant rice without fear of crop loss. People base on this time of flowering to determine the optimal time of rice transplanting. In many cases, they do not follow the government's guidelines/ instructions for sowing times with upland rice.	When forest peach flowers (local name: *mac tào*) are blooming.	
It is a good time for sowing rice. When the skin of this fruit becomes darker, it is a suitable time for transplanting.	In the forest, if the fruit size of the Burmese grape tree (local name: *co mác vầy*) is as big as a finger.	

(*Contd.*)

Table 6 — IK in forecasting weather, climate and seasonal crops based on flora characteristics and fauna behaviours (*Contd.*)

Prediction and meaning	Flora characteristics	Fauna behaviours
This means that raising rice, beans, and corn in the highlands in the middle of May and growing local rice (local name: *bao thai*) in the lowlands in the middle of June will result in the highest yields. Respondents explained there were sufficient precipitation and humidity at these times for crop development.	The Tay folklore expression: "Rẫy chang há, Nà chang sốc"	

(Source: Field Survey, 2018)

capacity induce higher levels of vulnerability[30]. According to Tuan *et al.*,[31] ethnic minorities in Vietnam are particularly vulnerable groups to climate change as their livelihoods often depend on climate-sensitive resources and the intrinsic poverty common in many of their communities limits adaptive capacity. In the Northern Mountainous Region, especially areas such as Bac Kan Province, this is certainly the case. Local communities largely comprised of impoverished ethnic minority populations are experiencing extended periods of drought, extreme cold, irregular weather, flash flooding and landslides. This significantly increases their vulnerability.

This study explores drought, flood and cold snaps to assess the impacts of climate change in Tay communities. Each impact households differently and elicit unique responses. This permits the investigation of local responses to climate change-derived stress events and uncovering what factors contribute to their vulnerability and determine their adaptation responses.

The impacts of climate change on agricultural production

Most respondents who participated in group discussions and interviews at the four communes clearly recognized the impacts of the extreme weather and climatic events on their lives. In agriculture, the greatest impact was agreed to be the result of prolonged droughts, extreme cold spells and abnormal weather patterns. Each of these in isolation or in combination hinders agricultural production by increasing pest and disease pressures, which in turn reduces crop productivity. In efforts to mitigate these issues, investment is increased, which only decreases profits.

Based on the area of land under cultivation, rice is the most important crop in the study areas. Longer duration periods of hot weather combined with low precipitation were said to result in the poor development of the crop and increase pest and disease pressures. Over the last decade in each of the four communes, this has included increased pressure from blight and from pests such as brown plant hoppers (*Nilaparvata lugens*) and rice leaf folders (*Cnaphalocrocis medinalis*). New pressures from rice black-streaked dwarf virus (*Reoviridae*), yellow spiders (*Steneostarsonemus spinki* Smiley) and black bug (*Scotinophara spp*) have also greatly reduced overall yield. In 2010, the four communes lost 100% of the hilly sticky rice crop due to damage caused by black bug (*Scotinophara spp*).

Furthermore, drought has resulted in the degradation of the soil. In dry soils, the activity of microorganisms declines, reducing soil fertility. This in turn lowers crop production and yields. According to members of the focus discussion groups, drought resulted in 30-50% yield reductions in rice during the spring season in 2010, 2011 and 2015 in the study areas. Longer duration periods of drought have also created favourable conditions for added disease and pest pressure in other crops such as maize. Increased pressures from corn root aphids (*Anuraphis maidi radicis*) and borers (*Ostrinia furnacalis*) reduce maize yield and productivity. Additionally, if flowering occurs during a period of drought, kernel formation rates suffer. In 2010 for example, over 80% of the plants in the study areas were without acceptable kernel formation. As a result, respondents noted that they simply are cultivating less maize. In 2015, the area of maize cultivated at the four communes was almost 40% of that 5 to 7 years ago. Beans of different varieties were also found susceptible to drought, especially as plants in poor health were more prone to the dark blue bug (*Aphis gossypii*) and bean blister beetles (*Epicauta gorhami* Marseul). Heavy rains also were noted to damage flowers and reduce the overall amount of harvestable fruit.

Peanuts and potatoes are also susceptible to drought. Respondents often noted that during periods of lower-than-average precipitation, ants damage the tubers of potatoes. Drought then not only affects the development of the crop, but by association, its overall productivity. Additionally, while the potato is known to have good resistance to some level of cold, temperatures below freezing negatively affect its growth and may lead to leaf curl. Over the last 5 years, over 80% of households surveyed have drastically decreased the amount of potatoes cultivated.

Tangerine and persimmon are also main crops in the four communities. Both are integral fruits in the agricultural production of the province and with newer geographic indication marketing schemes, are known for being profitable. However, both were also found to be adversely affected by the impact of climate change. Respondents noted that drought affected plant development, including during flowering season, reducing the overall harvestable amount of fruit. Abnormal weather patterns also induce fruit drop and increase susceptibility to diseases including root rot and powdery mildew.

Freezes and colder winter conditions are also more frequently killing water buffalo and cattle. In 2008, 32 buffalo perished in Mai Lap and 46 in Thanh Van and the figures were 43 and 39 in 2011. Increased buffalo morbidity not only affects the immediate economic situation of a household, but also reduces their ability to prepare fields for subsequent crop production. The resulting higher associated risks have resulted in a significant reduction in their production locally. Finally, fish farming is also being negatively affected. With freezing temperatures recorded in 2008, 2011 and 2015, most of the smaller fish in more than 20 ha of managed water perished.

Likely as these four communes share similar terrains, the impacts of climate change on crops and animals were found to be uniform. These are summarized in Table 7.

The impacts of climate change on livelihoods

As indicated in Table 8, the Tay people faced a unique set of challenges to their livelihoods resulting from climate change. Nearly half of the respondents mentioned crop yield reduction, increased rates of disease and mortality in livestock and fish, flash flooding, landslides, and drought as being the major challenges of climate change. Based on the focus group discussions, because of the now highly variable weather, the yields of crops such as corn, rice and beans have been greatly reduced or even regularly fail. Investment into agrochemicals has doubled and considerably more is spent on gasoline to operate irrigation machines. Despite this, productivity remains unstable.

Respondents also clarified that changes in the productivity of agriculture have pushed some to find other sources of income. Typically, this contributes to more overarching patterns of rural to urban migration of the male village population in search of non-farm wage labour. 40% of local people in the study areas now work in companies or petty trading. Additionally, almost 50% of respondents noted a marked increase in the amount of materials collected from local forests as a means of supplementing for lost income.

Increase in economic pressure on local communities has also altered more traditional gender roles in the surveyed communities. In many cases, in addition to caring for the children, women now provide most of the labour in agricultural production. Women in the focus group discussions also noted that this situation is further exasperated by local Tay customs. Paraphrasing their words, women tend to work more, while local men tend to spend more time-consuming alcohol. Indeed, one interesting finding of this study is that the burden of climate change in these communities is largely being carried by Tay women. Many of the overarching and interconnected issues of the previous sections are captured in the personal story of one respondent, a woman in her early 60s who lives in a village at one of the study sites. Her story is shown in the quote below.

"There are four people in my family, but only two are capable of working. My husband and son are both ill. Our income is mainly from rice, maize and the gathering of firewood. We farm 5,500 m^2 of rice which is considered a lot. 400 m^2 of this rice is single cropped. In the past, making a living from farming was easier and we cultivated several different fields. Today, the opposite is true. The more you farm, the more money you will likely lose. Anyone in good health tends to migrate away for wage jobs. If we work hard farming for seven months, we harvest around 800 kg of rice, which is worth roughly the same as the income you can make in one month of off-farm labor. My husband's health is also not good and he is largely inactive. I must do everything now.

Table 7 — Impacts of climate change on major crops and animals in the study areas

Crops/ animals	Extreme weather events/poor weather patterns	Impacts
Rice	Longer duration drought	- Increase in pest and pathogen pressures. - Black bugs (*Scotinophara spp*), a new phenomenon, appear across the entire commune on native and hybrid rice varieties and especially in areas with low levels of sunlight. - Prolonged drought increases the damage of blast. -Yellow spiders: Although causing little damage, prolonged drought caused the emergence of yellow spiders (*Steneotarsonemus spinki*), which had never appeared before. - Rice stem borers (*Scirpophaga incertulas*) developed causing higher rates of crop damage. - Increased production costs for additional fertilizers, pesticides, and gasoline to pump 2 to 3 times more irrigation water than before.
	Cold	- Appearances of root rot (caused by several fungi, including *Pythium* spp., *P. dissotocum*, *P. spinosum*, and other fungi) results in stunted growth and delayed cultivation.
	Abnormal weather pattern	- Blast (*Pyricularia oryzae*). Immediately before flowering, the plant rots and dies. - Appearance of rice grassy stunt (*Tenuivirus*) is seen for the first time in the study areas.
Maize	Longer duration drought	- Corn ears with fewer or without kernels due to a lack of water during the flowering period.
	Cold	- Flowering stage and formation of ears is delayed. - Fewer kernels.
	Abnormal weather pattern	- Before the flowering stage, corn rotted and died. This had never happened before.
Green bean and soybean	Drought	-Increased pressure in May and June from the dark blue bug (*Aphis gossypii*) leads to plant death. - Increases in pressure from bean blister beetles (*Epicauta gorhami* Marseul) which consume flowers and lower productivity.
	Abnormal weather pattern, with heavy rains in February and April	- Flowers damaged during heavy rains. - Leaves and tillers develop without or with reduced amounts of fruit.
Peanut	Drought	- Heretofore rarely seen ants are found eating seeds.
	Cold	- Crop does not sprout.
Potato	Drought	- Red fire ants (*Solenopsis invicta*) damage tubers. -Lack of humidity affects plant development and growth. - Increased incidence of leaf curl.
Persimmon	Drought	- The lack of humidity adversely affects the development and growth of fruit. - Longer duration drought in the flowering season results in less fruit being formed.
	Abnormal weather pattern	- Fruits drop. - Powdery mildew appears on leaves.
	Longer duration of freezing cold	-Stems die.

(*Contd*.)

Table 7 — Impacts of climate change on major crops and animals in the study areas (*Contd.*)

Crops/ animals	Extreme weather events/ poor weather patterns	Impacts
Tangerine	Drought	-Lack of humidity affects the development and growth of fruits, leaves, roots and stems.
	Abnormal weather pattern	-Higher rates of root rot and premature fruit drop.
Pig	Abnormal weather pattern	-Increased incidents of foot rot, staphylococcus and foot-and-mouth disease.
Goat, Buffalo and Cattle	Abnormal weather pattern	-Increased incidents of foot-and-mouth disease.
	Freezing cold	-Cattle mortality rates increase.
Fish	Freezing cold	-Fish mortality rates increase.
	Drought	-Increased incidents of viral infections and bacterial diseases such as red spot and enteritis (*Aphanomyces invadans*).

(Source: Field Survey, 2018)

Table 8 — Major challenges of climate change in the study areas

Major challenges	Frequency	Percentage (%) of people mentioned
Cold spells	3	2.5
Reduction in crop yields	27	22.5
Loss of livestock	5	4.17
Loss of fish	6	5.00
Flash floods	7	5.83
Drought	9	7.50
Landslides	3	2.50
Respondents that mentioned each of the above challenges	60	50
Total	120	100

(Source: Field Survey, 2018)

I prepare the land, carry and apply the agrochemicals and pump irrigation water. The practical side of farming has also gotten tougher. To grow healthy and disease-free rice, we have doubled the amount of chemicals we use. This is a considerable financial burden to bear. In the past, we also planted maize. But with the changing weather and droughts during the flowering period, the kernels just do not form. Consequently, our maize fields were a complete loss for many continuous years. Farming today is comparable to gambling, everything depends on good fortune. In recent years, every 10 times we cultivated maize, 8-9 of those times we faced a complete loss".

Conclusions

The Tay IK system of production was found to be incredibly diverse. Based on the use of native plants and animals, it supports maintaining the natural ecosystem and increasing the resilience to climate change. In turn, this reduces vulnerability in the community. Our study also documented that Tay communities in the Northern mountainous region of Vietnam have valuable experience in predicting the onset of rainfall, the change in weather patterns, as well as the onset of drought. Their experiences are based on looking over the specific stages in the life cycle of plants and the specific nuisances of animal behavior. These forecasting methods guided farmer decision-making in preparation for and during the cropping season.

In this study, the local communities faced considerable declines in agricultural productivity and animal husbandry. As a result, more men were found migrating to urban environments to earn income from non-farming sources. In turn, women have had to substantially increase their efforts to sustain both agricultural production and the family. Indeed, the burden of climate change was largely being shouldered by women. With added pressures from pests and pathogens, lower productivity and yields have also resulted in increasing the dosages and rates of agrochemical applications. The negative consequences of these extra and more intense applications to the health and financial welfare of these women and their communities were often mentioned by respondents. The need for further education on the safer handling and application of such chemicals is both obvious and considerable.

Finally, as a source of supplemental income and sustenance, the communities of the study have greatly increased the quantity of materials they are removing from local forests. While this provides some level of shorter-term relief, the sustainability of this practice in the longer-term is highly questionable.

Importantly, this study found that IK alone was not sufficient in maintaining the sustainability of these communities. While accepting the considerable merit IK has, a combination with new technologies and scientific knowledge to reduce the negative impacts of climate change is recommended. For example, some information provided by the government, such as weather forecasts via television, could be combined with people's observations of animal behaviors and the change in flora for more accurate weather prediction and in accordance with local conditions. A combination of these approaches can contribute to making communities more resilient to the current changes in climate. Indeed, actively supporting and supplementing that knowledge provides opportunities for improving the adaptive capacities of local people in ways more culturally and economically sustainable.

Acknowledgments

The research for this paper is part of the program of the Agriculture and Forestry Research & Development Centre for Mountainous Region (ADC) at the Thai Nguyen University of Agriculture and Forestry in Thai Nguyen City, Vietnam. This research was supported financially through funding from the Asia Pacific Network for Global Change Research through a project to Ho Ngoc Son (CBA 2017-01MY-Ho).

Conflict of Interest

The authors declare no conflict of interest.

Author Contribution Statement

Hoa H T developed the research proposal; Hoa H T, Chi D T L and Phan D V conducted the field research; Tam N V analyzed the research data; Hoa H T, Son H N, and Kingsbury A wrote the manuscript; and all the authors provided feedback on article drafts and revisions.

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