Climate change impacts and adaptation strategies: A case study in Northern Vietnam

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Abstract: Climate change and its impacts have become increasingly evident in the disaster-prone country like Vietnam. This study was conducted in a mountainous province in the northern part of the country to understand impacts of climate change on the livelihoods of smallholder farmers and identify key strategies toward climate resilience. Through stakeholder surveys and interactive processes among local farmers and relevant stakeholders, a number of locally appropriate climate-resilient models and practices have been identified. In addition, an overall strategy with identified systemic interventions, through the support of a decision supporting tool, have been formulated in addressing the climate induced risks. This study provided strong rationale for policy recommendations and future research on multiple benefits of the identified climate-resilient models and practices.

Keywords: *Livelihood vulnerability; Interconnectedness; Systems approach; Climate-resilient practices; Climate change adaptation.*

1 Introduction

Climate change impacts are increasingly evident through natural disasters, posing significant challenges, especially to smallholder farmers and rural communities, exacerbating food insecurity and poverty [1]. These communities rely heavily on agriculture, which is highly vulnerable to climatic changes and extreme weather events [2, 3, 4]. Limited resources, underdeveloped infrastructure, and restricted access to alternative livelihoods hinder their capacity to recover from hazards [4, 5]. Additionally, many developing nations cannot invest in climate-resilient infrastructure and advanced weather forecasting systems [1].

Southeast Asia is one of the most climate-vulnerable regions, particularly tropical countries with high population growth and dependence on agriculture. The region saw a temperature rise of 0.1-0.3°C per decade in the latter half of the 20th century, with projections of nearly 5°C by 2100 compared to 1990. Small-scale farmers are particularly vulnerable, with crop yields predicted to decrease by 5-30% by the 2050s [7].

Like its Southeast Asian neighbors, Vietnam is severely affected by climate change due to its extensive coastline, reliance on agriculture, and low rural development levels [3, 8].

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The Northern Mountainous Region (NMR) is especially vulnerable, suffering from fragile ecosystems, poverty, deforestation, and soil degradation [3, 9].

Bac Kan province, located in the northeast of the Northern Mountainous Region (NMR), is one of the poorest in Vietnam. Its farming communities face multiple climate-related risks, including droughts, cold spells, abnormal weather, flash floods, and landslides, which increase their vulnerability, particularly among ethnic minorities in remote areas [10, 11].

This highlights the urgent need for climate adaptation measures. While government-led climate change adaptation (CCA) efforts have been well documented, local-level initiatives are less reported, both internationally and domestically [12]. In some cases, maladaptation occurs, such as overexploiting natural resources or increasing dependency on government aid, which diminishes community self-reliance [11]. Furthermore, limited research exists on decision support tools for identifying climate-resilient livelihood strategies in Vietnam, particularly in Bac Kan province.

Thus, this research aims to assess smallholder farmers' current livelihoods and vulnerabilities under climate change, identifying suitable climate-smart practices and strategies to enhance resilience and sustainable income. The study focuses on two most vulnerable districts of Bac Kan province, namely, Cho Don and Na Ri [13].

2 Methodology

Overall approach: A combination of both quantitative and qualitative approaches was employed in this study, utilizing desk studies, interviews, and focus group discussions (FGDs) with key stakeholders ranging from the provincial to the commune levels during 2020-2022. Some workshops were postponed until early 2022 due to social distancing measures implemented during the Covid-19 pandemic.

Research locations: two vulnerable districts, namely, Cho Don and Na Ri, of Bac Kan province were selected for this study.

Desk research and stakeholder survey were conducted to gather and consolidate information regarding the current state of agriculture-based livelihoods, major challenges, and the effects of climate change on livelihoods of farming households in the study areas.

Key informants included representatives from local governments (agriculture and extension networks) at the provincial to commune levels (two individuals from each organization). Additionally, leaders and agricultural staff of the selected commune (eight people across four communes), and commune civil organizations, including women's and youth unions, and farmers' associations (two individuals from each organization), were interviewed.

Farmer interviews: Cho Don and Na Ri districts were identified and chosen in the research. The survey focused on gathering information about local livelihoods, primary challenges and needs, the effects of climate change, adaptation strategies, and promising climate-smart livelihood options.

Two most susceptible communes per district were chosen for the farmer interviews, with a sample size of 40-50 household representatives in each commune. Due to limited budget for random sampling and/or a large scale survey, a stratified sampling method was therefore used to ensure the respondents were representative of various factors such as geographical location (villages most affected by climate change) and typologies of farm households and respondent. Respondents must be a decision maker and/or knowledgeable about their family's farming activities (see Table 1).

Table 1. Profl1ile of respondents in two studied districts of Bac Kan province (n = 186).

Category	Cho Don	Na Ri
Sample size by locations	100	86
Age (years old)		
Mean	44.6	42.2
S.E	*1.116*	*1.094*
Wealth groups (%)		
Above average	7.0	2.3
Average	75.0	77.9
Marginally poor	9.0	10.5
Poor	9.0	9.5
Family size		
Mean	4.7	4.85
S.E	*0.129*	*0.166*
No. of main labourers per family		
Mean	2.8	2.77
S.E	*0.103*	*0.115*
No. of family members working on farm.		
Mean	2.0	2.0
S.E	*0.128*	*0.138*
No. of family members doing off-farm work		
Mean	0.5	0.7
S.E	*0.077*	*0.115*

Workshops to identify promising livelihood models/farming practices, and strategy toward climate-resilient livelihoods:
Following the farmer survey, participants at both district and the interviewed communes, were engaged in discussion workshops (50 participants/workshop/district). Focus group and plenary discussions were held to address (1) the main challenges in their agriculture-based livelihoods, (2) the underlying causes of these challenges, and (3) potential solutions and recommendations for local governments to address these issues. Participants were then guided to define the most viable climate-smart livelihood models/farming practices. A provincial validation workshop with the participation of 70 representatives from provincial to community levels of the two districts were organized to validate information and together discuss an overall strategy toward climate resilience.

Data analysis: SPSS software (version 20) was used for statistical analysis of the surveyed data [14]. Additionally, an user-friendly Bayesian network modeling tool [15] was employed to aid decision making process during the workshops in identifying strategic actions.

3 Results and discussions

3.1. Current livelihood situation of farming households in Bac Kan province

Table 2 highlights the small-scale nature of local farmers' production. Their primary livelihoods rely on crop cultivation and livestock farming, which contribute 50.7% and 29.8%, respectively, to their total household income. These findings align with other research on the characteristics of small-scale farming households in the Northern Mountainous Region (NMR) [4, 9, 16]. Ratio of income from crop production among the households (HHs) in Cho Don district (54.3%) is significantly higher than those of Na Ri district (46.6%) ($P < 0.05$). Whereas, Na Ri has slightly higher proportions of HHs with income sources from aquaculture and forestry ($P < 0.01$).

Table 2. Characteristics of households in the research areas (n = 186).

	Bac Kan province		**Cho Don district**		**Na Ri district**		**P-value**
	Mean	**S.E**	**Mean**	**S.E**	**Mean**	**S.E**	
Income sources (%)							
Crop production	50.72	*1.569*	54.3	*2.002*	46.6	*2.407*	*
Livestock prod.	29.82	*1.231*	31.6	*1.628*	27.8	*1.860*	ns
Aquaculture	2.91	*0.484*	1.5	*0.484*	4.6	*0.851*	**
Forestry	9.13	*0.897*	6.4	*0.894*	12.3	*1.577*	**
Services	1.94	*0.569*	2.1	*0.835*	1.8	*0.762*	ns
Other sources	5.48	*0.988*	4.4	*1.328*	6.7	*1.474*	ns
Production area (m^2)							
Crop production area	4,264.4	*396.304*	3,463.3	*278.808*	5,197.4	*784.722*	*
Forestland area	8,665.4	*1,099.216*	6,507.3	*1,231.191*	11,149.7	*1,865.198*	*
Water surface area	449.9	*84.054*	224.0	*107.084*	709.9	*127.255*	**
Livestock							
Buffalo number	0.9	*0.132*	0.7	*0.172*	1.2	*0.202*	ns
Cow number	0.3	*0.103*	0.5	*0.188*	0.1	0.028	*
Pig number	6.9	*0.714*	8.7	*1.003*	4.8	*0.972*	**
Poultry number	128.1	*53.987*	142.9	*99.770*	111.0	*15.253*	ns
Other livestock	0.6	*0.328*	0.6	*0.352*	0.6	*0.582*	ns

*Note: S.E: Standard Error of Mean; ANOVA: n.s: Not significant; * P < 0.05; **P < 0.01.*

Due to the small-scale farming, local farmers tend to have limited production areas and fewer livestock. Being situated in a mountainous region, the households' forestland area is about twice the size of their agricultural crop production area. Farmers in Na Ri district have larger land size, but have smaller scale of livestock production compared to those in Cho Don district (Table 2).

3.2. Climatic condition and impacts of climate change on local households in Bac Kan

Figure 1 illustrates a rising trend in average temperatures over the 50-year span from 1960 to 2010. Data from the Bac Kan Meteorological and Hydrological Station also show a consistent increase in both mean temperature and annual rainfall between 2001 and 2019, highlighting clear signs of local climate change.

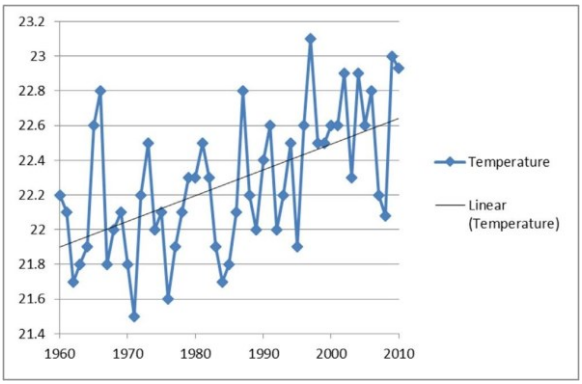

Figure 1. Temperature variation of Bac Kan Province during 1960-2010 [17]
Notes: Vertical axis: temperatures in degree C; Horizontal axis: years.

The representatives of Bac Kan DARD emphasized the increased vulnerability of the province, particularly in rural districts such as Cho Don and Na Ri. These areas are more susceptible to climate change impacts due to their relatively high population density and heavy economic dependence on agriculture, which increases their exposure to extreme weather events and environmental changes.

The centres for agricultural services of both districts also highlighted that extreme weather events such as heavy rains, floods, and cold spells have caused considerable damage to infrastructure, agriculture, and housing in Cho Don and Na Ri in the recent two decades.

Table 3. Direct impacts of climate change on local livelihoods in Bac Kan (n = 186)

#	Direct impacts on households	Average for Bac Kan	By districts		P-value
			Cho Don	Na Ri	
1	Reduced arable production land and number of crop seasons/year.	60.8%	60.0%	61.0%	ns
2	Reduced crop and/or livestock productivity	68.3%	72.0%	64.0%	ns
3	Crop losses.	49.5%	57.0%	40.7%	*
4	More frequent power cut.	18.3%	24.0%	11.6%	*
5	Changes of land use purposes or crop types.	12.9%	11.0%	15.1%	ns
6	Had to change livelihoods.	10.8%	10.0%	11.6%	ns
7	Water shortage in aquaculture.	10.2%	9.0%	11.6%	ns
8	Other.	5.4%	6.0%	4.7%	ns

Note: Pearson Chi-Square Test: n.s – not significant; *$P < 0.05$.

The surveyed results in both districts revealed significant impacts on agricultural production, including reduced crop and/or livestock productivity (68.3% of the interviewed households stated), reduced arable production land and number of crop seasons per year (60.8%), and crop losses (49.5%). In which, the farm households in Cho Don district were more affected by crop losses and power cut compared to those in Na Ri district ($P < 0.05$; Table 3). This is because, one commune of Cho Don district, namely, Nam Cuong is situated in a rather low land area with frequent impact of flooding during the summer season. Therefore, a high ratio of households reported such impacts from Nam Cuong commune. Likewise, the remaining communes of Cho Don and Na Ri districts locate in higher elevations.

It is worth noting that the ratios of households shifting their land use purposes and/or crop types were rather low (Table 3). This somehow implies limited adaptive capacities of farmers in both districts.

3.3. Potential climate resilient models/farming practices and strategy

Table 4 provides a summary of the most promising climate-smart models and farming practices derived from the findings of FGDs with participants from each district, along with insights gathered during a validation workshop at the provincial level.

Table 4. Potential climate smart models and practices in Bac Kan province

#	Potential production models/practice	Description of models and practices in both districts
1	Shifting production and/or land use purposes to adapt with water shortage and/or innundation.	**Cho Don:** Changing from crop production to aquaculture on frequently inundated land. Main reasons: Avoiding risks of crop losses due to frequent inundation. Planting potato, vegetables and maize on paddy land; and local Shan tea and seedless persimmon on hilly land. Main reasons: higher income; adapting to water shortage conditions. **Na Ri:** Planting citrus crops, legumes, potatoes, and edible canna on paddy land. Main reasons: higher income; adapting to water shortage conditions.
2	Intercropping and/or Agroforestry practices	**Cho Don**: Intercropping fruit crops and food crops (maize, cassava) with leguminous crops. Main reasons: Utilizing land for improving yields and income; Improving land cover, moisture and fertility; utilization of green manure. Intercropping and/or rotating potato with maize on alluvial land. Main reasons: Increased yields and income; reduced pests and disease thanks to crop rotation. Afforestation & planting medicinal plants under forest cover. Main reasons: Protecting ecosystems; storing water for irrigation; promoting forestry economics (particularly large timber production); utilization of non-timber forest products. **Na Ri:** Intercropping soybean and peanuts in fruit orchards. Main reasons: diversifying incomes; improving land use efficiency. Afforestation and adoption of agroforestry practices. Main reasons: improving land use efficiency and income; storing water for irrigation.
3	Use of drought resistant and short-cycle crop varieties.	**Cho Don**: Planting short-cycle crops (e.g. soybean, peanut, and potato, etc.) on paddy land to avoid the flood season during summer. Planting drought resistant, cold tolerant (Japonica rice), and short-cycle rice varieties. Main reasons: Adapting to water shortage, drought and cold conditions; Planting short-cycle varieties can avoid storms and cold spells. Planting GM maize NK4300. Main reasons: Drought & disease resistance; and wind tolerance. **Na Ri:** Growing cold tolerant rice varieties.
4	Integrated crop-livestock production models.	**Both districts:** Raising pigs combined with Biogas digester installation (and making rice wine). Main purposes: Treating animal dung to become clean organic fertilizers; Reduced air

#	Potential production models/practice	Description of models and practices in both districts
		pollution; utilizing energy (biogas) for cooking; Utilizing by-products from rice wine production to use as pig feeds. **Na Ri:** livestock production using probiotic bedding methods. Main reasons: reduce pollution and livestock diseases; making compost for crop production. Vermicompost production. Main purpose: use of vermicompost (organic fertilizer) for crop production, and redworms for livestock.
5	System of Rice Intensification (SRI) and/or 1M5R approach and Integrated Pest Management (IPM).	**Both districts**: Adopting SRI and/or "One Must Do, Five Reductions" (1M5R) approach (i.e. use of good-quality/certified seeds (the One Must Do) and reduced seed amount, pesticide use, fertilizer inputs, water use, and postharvest losses (Five Reductions) and IPM in rice production. Main reasons: Reducing water use; improving productivity; enhancing plant growth and reducing pests and diseases.
6	Alternative livelihoods for diversified & increased income.	**Cho Don:** Raising reproductive cattles and growing forage; raising indigenous pigs and blue neck fat ducks (vịt bầu cổ xanh); and making noodle from a local rice variety. **Na Ri:** raising big cattle (combining with growing forage) and poultry.
7	Soil and water conservation techniques/initiatives.	**Na Ri:** Adopting mulching techniques for fruit crops; and SALT models (Sloping Agricultural Land Technologies); Construction of ponds for harvesting rainwater.

(Source: Focus group discussion and validation workshop results).

Table 4 highlights a significant number of adaptive measures aimed at addressing climate change. These initiatives can be considered "potential germ-cell activities," serving as opportunities for continuous learning and knowledge-sharing to enhance climate resilience in local farming communities both within and beyond Bac Kan province. The adaptive strategies primarily focus on managing water scarcity, mitigating floods, and reducing climatic risks by altering cropping patterns, introducing resistant and/or adaptive crop varieties, utilizing renewable energy, reducing pollution and greenhouse gas emissions, improving water retention for irrigation, and diversifying and increasing income sources.

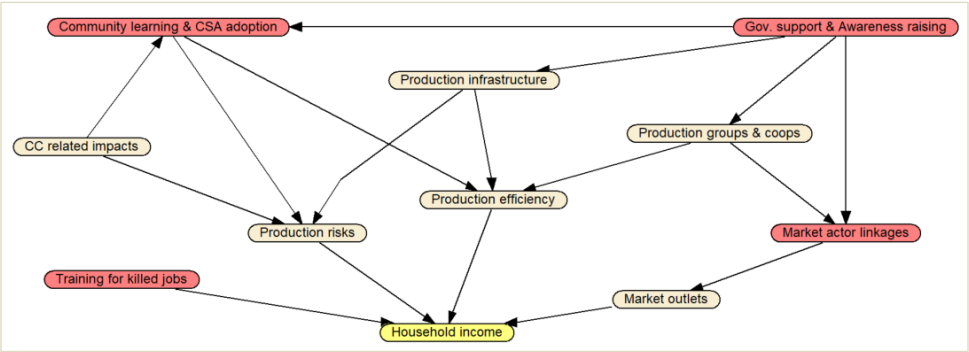

Figure 2. Bayesian network modelling for defining strategies toward improved livelihoods and income of local farmers under the context of climate change. *Note: arrows indicate causal links.*

The workshops at district and provincial levels and FGDs have helped local farmers and relevant stakeholders identify a range of interconnected factors that collectively affect the

livelihoods, particularly the income, of farming households in Bac Kan province. Rather than focusing solely on immediate solutions to the challenges posed by climate change, workshop participants were encouraged to take a broader view and/or "big picture" by examining other related factors that together influence their lives.

Through the discussions among stakeholders, "household income" (yellow variable, Figure 2) was identified as the final goal for the local smallholder farmers. Achieving this desired income increase relies on improving production efficiency, reducing production risks, enhancing market access and secure outlets, and building capacity for skilled jobs, and offering an alternative livelihood option for family members (Figure 2). It is important to note that the current trend of rural labor migration to big cities or industrial zones is merely a short-term "quick fix" or temporary solution for off-farm income. A more sustainable approach would require training for skilled jobs to secure higher and more stable alternative income [4]. The red variables (nodes) shown in Figure 2 were identified as systemic interventions necessary to achieve this goal.

Based on the analysis and inputs from participants at the validation workshop, the following strategies were developed to enhance livelihoods and income for local farmers in the context of climate change:

1) Improving production efficiency and reducing risks by promoting community learning and employing climate-smart models/practices; enhancing government support for improved production infrastructure, and building the capacity of production groups and cooperatives.
2) Enhancing access to secure market outlets by supporting capacity-building for production groups and cooperatives, while fostering stronger linkages with market actors.
3) Creating stable and well-paying off-farm employment opportunities for rural laborers through skills training and connecting them with potential employers.

The formulated strategies would be locally appropriate as they address the main concerns raised by farmers, such as production risks from climate change, insecure market outlets, and low income, while promoting the adoption of climate-smart production models/practices. In particular, community and/or social learning would be regarded effective and low-cost methods for adopting the defined climate-resilient practices [4, 18]. Furthermore, establishing or strengthening the capacity of production groups and cooperatives is essential for enhancing collective bargaining power and building stronger links with market actors [19, 20].

4 Conclusions

In summary, this research has shed light on the current livelihoods of farmers in two districts of Bac Kan province. Their livelihoods are mainly reliant on small-scale crop and livestock production, which are highly susceptible to climate change effects. Major impacts of climate change on their livelihoods included: reduced crop and/or livestock productivity, reduced arable production land and number of crop seasons per year, and crop losses. The study identified a number of promising climate-smart production models and/or farming practices, and facilitated the development of three interrelated strategies by local farmers and stakeholders to address their challenges and needs.

The developed strategies together with the identified climate-resilient models/practices would lay a solid basis for collaborative efforts among local authorities, extension networks, community-based organizations, and farmers. These joint efforts will help effectively implement the guided activities toward climate resilient farming communities in the study areas, as well as for smallholder farmers in other regions with similar contexts and conditions.

Future studies may focus on the multiple benefits of the defined climate-smart production models/practices. These could serve as "germ-cell activities" for transformative social learning and dissemination for wider adoption within and beyond the northern mountainous region of Vietnam.

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