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Livelihood vulnerability to climate change in the mountains of Northern Vietnam: comparing the Hmong and the Dzao ethnic minority populations

Thinh An Nguyen[1] · Bich Thi Nguyen[2] · Hanh Van Ta[3,4] · Nhung Thi Phuong Nguyen[5] · Huong Thi Hoang[1] · Quan Phung Nguyen[6] · Luc Hens[7]

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Abstract
Livelihoods of ethnic minority populations living in the mountains of Northern Vietnam are highly vulnerable to climate-induced natural hazards. Therefore, the livelihoods of vulnerable ethnic minority populations in these areas could be improved through climate change adaptation measures. This study pursues an enhancement of three different aggregate indices such as Livelihood Vulnerability Index (LVI), Livelihood Vulnerability Index framed within the IPCC vulnerability framework (LVI-IPCC), and Livelihood Effect Index (LEI) to find out components contributing to the livelihood vulnerability of major ethnic minority populations in a case study of Mo Vang mountain (Yen Bai, Vietnam). A total of 120 Dzao and Hmong respondents from 11 villages are surveyed based on a combination of informal interviews, a questionnaire survey, and Focused Group Discussions (FGD). Twenty-nine sub-components belonging to 10 major components (socio-demographic profile, livelihood strategies, social networks, revenue, health, food, water, housing, land, and natural hazards and climate variability) are conducted to calculate LVI, LVI-IPCC, and LEI. The results show that the livelihood of Hmong populations is more vulnerable to climate change for natural conditions such as natural hazards and climate variability, housing, land, water, food, and health. However, the livelihood of Dzao populations is more vulnerable because of socio-economic conditions such as socio-demographic profile, livelihood strategies, revenue, and social networks. The results provide a scientific basis for both residents, local officials, and policy-makers prioritizing solutions to enhance livelihood capitals as well as to improve adaptive capacity to climate change in the mountains of Northern Vietnam.

Keywords Livelihood vulnerability · Climate change · LVI · LVI-IPCC · LEI · Dzao · Hmong · Mountains of northern Vietnam

✉ Thinh An Nguyen
anthinhhus@gmail.com

Extended author information available on the last page of the article

1 Introduction

Approximately 13 percent of global population lives in mountainous environment (FAO 2015). They are merely farmers, who change their traditional agricultural practices and diversify their way of life to adapt to the contemporary socio-economic context and global change. Farmers contribute to traditional rural activities such as cultivation, livestock grazing, and forestry, but also participate in new hydropower production, trading, and tourism (Beniston et al. 1996). The mountainous environment supports arable land and biodiversity as the main natural resources for local livelihood. However, mountains are prone to natural hazards and climate change due to their physical characteristics including complex topography, climatic events, seasonal contrasts, and geomorphic processes (Körner 2013). Both upland fields and forests and their services are highly climate sensitive (Kollmair and Banerjee 2011; Johnson and Hutton 2014). Mountains have warmed by 1 °C during the past 100 years (Hartmann et al. 2013). Local populations living in mountains are high vulnerable to climate change. Increasing the frequency and intensity of climate-induced natural hazards threatens the livelihoods of ethnic minorities (Ingold et al. 2010; Palomo 2017).

Livelihoods of ethnic minority populations living in mountains of Northern Vietnam are highly vulnerable to climate-induced natural hazards. Therefore, the livelihoods of vulnerable ethnic minority populations in these areas could be improved through climate change adaptation measures. Among the most common approaches that were applied to understand livelihood vulnerability, the combination of three different aggregate indices as Livelihood Vulnerability Index (LVI), Livelihood Vulnerability Index framed within the IPCC vulnerability framework (LVI-IPCC), and Livelihood Effect Index (LEI) has the advantages in that it can find out components contributing to the livelihood vulnerability at the community level (Hahn et al. 2009; Huong et al. 2018). Vulnerability to climate change is assessed using the rate of climate variability and the extent of exposure, sensitivity, and adaptation capacity of a system or a society (IPCC 2007). The livelihood vulnerability approach allows estimating the degree of vulnerability of locals to climate change according to food security, public health, livelihood, policy, natural hazards, and climate variability (Kasperson et al. 2005; Hahn et al. 2009). Livelihood vulnerability assessment can be used to establish climate change adaptation strategy, poverty reduction, and the secure livelihoods in the context of climate change (Ford and Smit 2004; O'Brien et al. 2004; Etwire et al. 2013). LVI-IPCC assesses effectively livelihood vulnerability to climate change (Hahn et al. 2009; Shah et al. 2013; Etwire et al. 2013). This approach, combined with data collection methodologies, deals with vulnerability components, sub-components, and dimensions (exposure, sensitivity, and adaptive capacity) across the case study areas and applies to developing countries. Good examples of livelihood vulnerability to climate change in Asia and Africa exist.

In Asia, the livelihood vulnerability of communities lives in the sub-basins of the Brahmaputra River in the State of Assam, India and Bhutan is assessed by a combination of LVI-IPCC and spatially explicit data from census, household surveys and earth observation (Johnson and Hutton 2014). Livelihood vulnerability of poor agro-pastoralists in Bhilwara district (India) is estimated based on stakeholders' perspectives. Climate change degrades financial and natural assets, while organizational and financial assets support climate change resilience (Singh and Nair 2014). Livelihood vulnerability between households is compared using mixed agro-livestock in the mountains, mid-hills, and lowland of Central Nepal. LVI-IPCC is calculated according to socio-demographic parameters, livelihood determinants, social networks, health, food and water security, natural hazards, and

climate variability (Panthi et al. 2016). Impacts of hazard induced land loss to livelihood vulnerability are assessed. LVI-IPCC is combined with data collected from the scientific literature, government and non-government organizations (NGOs), informal interviews, questionnaire surveys, and Focused Group Discussions (FGD). The results show that riverbank erosion affects most hazardously rural household along the Padma river in Bangladesh (Bhuiyan et al. 2017). A weighted-LVI-IPCC is used to assess livelihood vulnerability of riparian households in Bangladesh. The main drivers of vulnerability proved being livelihood strategies, food accessibility, water, and health facilities (Alam 2017). The contribution of floods, river bank erosion, lack of employment, and fiscal deficits to local livelihood vulnerabilities to climate change in Bangladesh is clarified with the combined LVI-IPCC using data from face-to-face interviews, FGDs, key informant interviews, in-depth case studies, community mapping, and participant observations (Islam 2018). The LVI-IPCC is used to investigate the determinants of local livelihood vulnerability in semi-arid districts of Pakistan. Climate change adaptation measures for agriculture, strengthening and promoting opportunities of rural household for off-farm families are proposed (Qaisrani et al. 2018).

In Africa, LVI-IPCC is used to assess the livelihood vulnerability in Ghana and its regions. The results indicate vulnerable households within resilient communities and more resilient households within vulnerable communities (Antwi-Agyei et al. 2013). The LVI-IPCC based analysis on households' perception is tested in Akwa Ibom State, Nigeria. Households were found vulnerable to climate change due to the lack of adequate finance; therefore, the support of both government and non-governmental organizations to enhance climate change resilience of households is necessary (Amos et al. 2015). The LVI-IPCC for mixed crop-livestock farming households is examined in Choke Mountain, Ethiopia. The results show that high sloping lands and low elevation steep lands have a limited adaptation capacity and high vulnerability, while more capacity and less vulnerability are found in the midlands (Simane et al. 2016). The LVI-IPCC is used to assess livelihood vulnerability in rural households in Ghana. They showed that male-headed households are more vulnerable than their female counterparts. Gender is proposed to mainstream into rural development and livelihood policies (Baffoe and Matsuda 2018).

2 Methodology

2.1 Study area

This study estimates and compares the livelihood vulnerability of the Dzao and Hmong in a case study of the Mo Vang commune (Yen Bai province). The commune has a total area of 99.7 km^2, is 500 m above sea level, and experiences a tropical monsoon climate with an average temperature between 23 and 24^0C. The mean annual moisture is about 86%, and the annual average rainfall is 1800 mm. Forests cover about 8900 hectares, among which, cinnamon covers 1270 hectares. Dzao and Hmong are two major minority populations in Mo Vang: the Dzao population accounts for 63.6%, and Hmong account for 25.9% of total population, and others are Kinh people. The crop systems of Hmong and Dzao have significant implications for the mountainous landscape and environment of study area. The life of the Dzao and the Hmong farmers depends on the cinnamon trees on the slopes for decades (Pandey et al. 2006). The Dzao started growing cinnamon on favorable land surfaces at the foothills and in lowlands, where they have villages as Khe Dam, Khe Hop,

Canh Tien 1, Canh Tien 2, Thac Ca, Khe Ngoa, Gian Dau 1, and Gian Dau 2. The Hmong migrated from neighboring areas in Van Chan and Simacai (Yen Bai province) to Mo Vang after the Vietnamese-Chinese war in 1979. They established their farms and new villages (Khe Long 2, Khe Long 3, and Goc Sau) on more difficult steep slopes (Fig. 1). The Mo Vang was selected because rural communities in this area rank among the poorest in Vietnam (Castella 2002). The villagers of the Mo Vang are increasingly exposed to heavy rain, floods, landslides, and drought. The area experienced dramatic damage of natural hazards because of its steep slopes, climate variability, socio-economic characteristics, poverty, production means, and exhausted natural resources. While the local economy depends on the cinnamon production, it is prone to possible climate-induced hazards during the rainy season. Most recently, a multiple-hazards situation combining heavy rain, floods and landslides happened in Mo Vang on August 5–6, 2017, which destroyed about 35 hectares of cinnamon (https://vov.vn/tin-24h/yen-bai-sat-lo-dat-lam-5-nguoi-thuong-vong-656000.vov, retrieved in 20 Dec 2017).

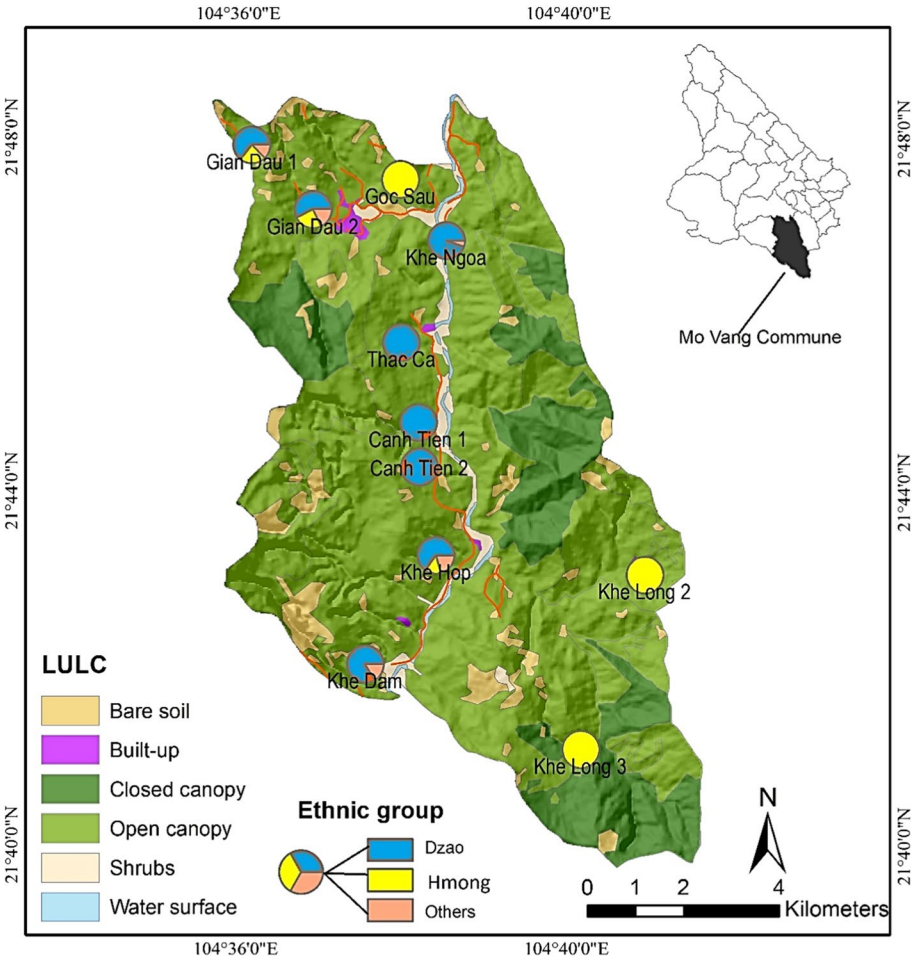

Fig. 1 Land use land cover (LULC) and population distribution in the Mo Vang (Yen Bai province, Vietnam)

2.2 Research approach

2.2.1 Livelihood vulnerability dimensions.

Vulnerability in the context of climate change is "the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity" (IPCC 2007). Exposure is defined as "the nature and degree to which a system is exposed to significant climatic variations" (IPCC 2007). The sensitivity reflects the "degree to which a system is affected, either adversely or beneficially, by climate variability or change. The effect may be direct (e.g., a change in crop yield in response to a change in the mean, range or variability of temperature) or indirect (e.g., damages caused by an increase in the frequency of coastal flooding due to sea level rise)" (IPCC 2007). Adaptive capacity is "the ability (or potential) of a system to adjust successfully to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, and/or to cope with the consequences" (IPCC 2007).

This study combines LVI, LVI-IPCC, and LEI to quantify livelihood vulnerability of selected populations. A livelihood is vulnerable in the case it is exposed and sensitive to the climate change impacts together a limited capacity to adapt. In contrast, a livelihood is less vulnerable if it has a strong adaptive capacity and be less exposed and sensitive. Figure 2 indicates the connection of three livelihood vulnerability models. Livelihood vulnerability indicators are constructed according to LVI model at the first stage. They then are distributed to two other models to consider different dimensions of climate change vulnerability (sensitivity, exposure, and adaptive capacity in LVI-IPCC model) and climate change affected local livelihood (five livelihood capitals in LEI model). Results of these models provide integrated measures for both enhancing livelihood capital and improving response capacity to climate change at local level.

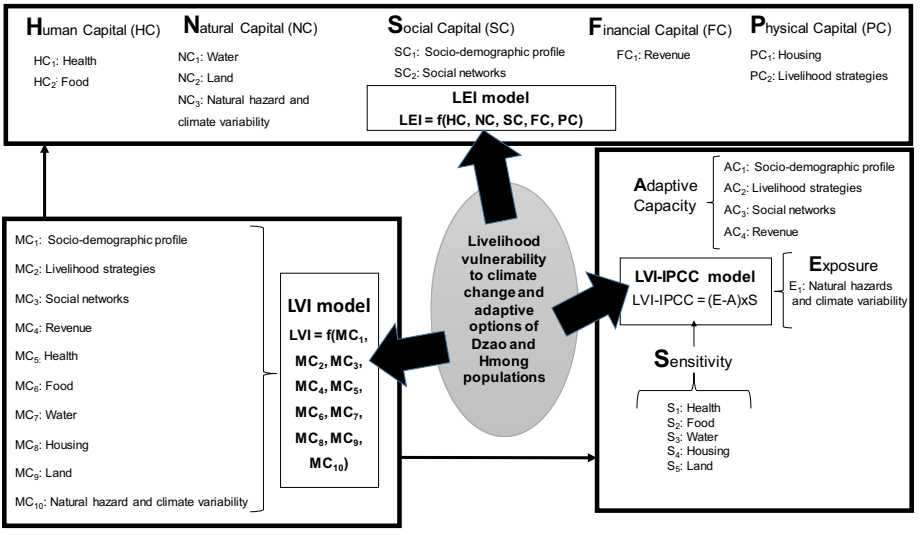

Fig. 2 Conceptual model of livelihood vulnerability dimensions

2.2.2 Livelihood Vulnerability Index (LVI)

This study uses a balanced weighted average of the Livelihood Vulnerability Index (LVI) developed by Hahn et al. (2009). Ten major components and 29 sub-components contribute equally to the overall LVI (Table 1). Major components with sub-components consist of:

(i) *Socio-demographic profile:* Dependency ratio (number of persons aged less than 15 and higher than 65 calculate the percentage of person aged 15–64 year old), female-headed households (percentage of households, of which the head is female), single-parent households (single parent is a mother or father who was never married, widowed, divorced or separated, with children under 18 years living with her/him in the same house), unschooling household-head (percentage of the heads of households who report that they did not attended school before), average household size (number of family members) (ILO 2007; Amato et al. 2015; ADB/ERCD 2018).

(ii) *Livelihood strategies:* Working in different communities (Percentage of households with family members are working outside study area), household income from agriculture (the main sources of livelihood for household in the last year: livestock rearing, crop production, fishing, and hunting), Average Agricultural Livelihood Diversification Index (the inverse of the number of agricultural activities reported by a household plus 1) (UNICEF 2006).

Table 1 Restructuring the Livelihood Vulnerability Index (LVI) for Mo Vang mountain

Major component	Sub-component
Socio-demographic profile (MC_1)	Dependency ratio (SC_{11}), female-headed households (SC_{12}), single-parent households (SC_{13}), unschooling household-head (SC_{14}), average household size (SC_{15})
Livelihood strategies (MC_2)	Working in different communities (SC_{21}), household income from agriculture (SC_{22}), Average Agricultural Livelihood Diversification Index (SC_{23})
Social networks (MC_3)	Average income: give ratio (SC_{31}), average amount borrowed: lend money (SC_{32}), assistance from officials (SC_{33})
Revenue (MC_4)	Poverty line households (SC_{41}), net income of cinnamon per year (SC_{42})
Health (MC_5)	Access to health facilities (SC_{51}), incidence of chronic illness (SC_{52})
Food (MC_6)	Average Crop Diversity (SC_{61}), no intention to save crops (SC_{62})
Water (MC_7)	Use of natural water sources (SC_{71}), public water supply system (SC_{72}), household storage tanks (SC_{73})
Housing (MC_8)	Resistant house foundation (SC_{81})
Land (MC_9)	Agricultural land patch size (SC_{91}), average cinnamon land area (SC_{92})
Natural hazards and climate variability (MC_{10})	No warning for natural hazard (SC_{101}), standard deviation of daily average maximum temperature (SC_{102}), standard deviation of daily average minimum daily temperature (SC_{103}), standard deviation of average monthly precipitation (SC_{104}), average number of yearly flood events (SC_{105}), damaged houses due to natural hazards (SC_{106})

(iii) *Social networks:* Average receive: give ratio (ratio of 'the number of types of help received by a household during the past month plus 1′ to 'the number of help given by a household to someone else in the past month plus 1′), average amount borrowed: lend money (ratio of 'number of households borrowing money' to 'number of households lending money' during the past month), assistance from officials (percentage of households reported applying assistance from the local government during the past 12 months) (WB 1997; WHO 2011; Hahn et al. 2009).

(iv) *Revenue:* Net income of cinnamon per year (annual income of locals from cinnamon as reported by officials), poverty line households (poverty lines are below 30 $US per person monthly in rural areas of Vietnam, according to Vietnamese Ministry of Labour, Invalids and Social Affairs).

(v) *Health:* Access to health facilities (average time residents need going the nearest health facility to their house), incidence of chronic illness (percentage of households reported at least one family member with a chronic illness) (WB 1997).

(vi) *Food:* Average Crop Diversity (the inverse of the number of crops grown by a household plus 1 reported by a household), no intention to save crops (percent of households reported they have no intention to save crops different purposes than food supplies) (WB 1997).

(vii) *Water:* Use of natural water sources (percentage of households reported using a creek, river, lake, pool, or hole as their primary water source), public water supply system (percentage of heads of villages who reported a public water supply system is available in their village), household storage tanks (percentage of households reported having a storage tank).

(viii) *Housing:* Resistant house foundation (percentage of houses with a higher foundation to resist natural hazards).

(ix) *Land:* Agricultural Land Patch Size (mean value of land surface reported by farming households), average cinnamon land area (mean value of cinnamon land in a village as reported by officials) (FAO and ILO 2009).

(x) *Natural hazards and climate variability:* No warning for natural hazard (percentage of households which did not receive any warning of natural hazards from their neighbors, the public or officials); standard deviation of average daily maximum temperature, standard deviation of average daily minimum daily temperature, standard deviation of average monthly precipitation (standard deviation of these indexes in the period 1961–2016); average number of yearly flood events (estimated floods events during the past 10 years, 2006–2016), damaged houses due to natural hazards (percentage of houses lost due to natural hazards during the past 4 years, 2012–2016) (MONRE 2016; WMO 2017; Arouri et al. 2015; Onuma et al. 2016).

The Livelihood Vulnerability Index (LVI) is calculated by averaging standardized scores of sub-components, to obtain the index of a major component, by using Eqs. (1–3):

$$\mathrm{LVI}(d) = \frac{1}{m}\sum_{j=1}^{m}\frac{w_j \mathrm{MC}_j}{w_j} \tag{1}$$

with

$$\mathrm{MC}_j = \frac{1}{n}\sum_{i=1}^{n}\overline{\mathrm{SC}_{ij}} \tag{2}$$

and

$$\overline{\mathrm{SC}_i} = \frac{\mathrm{SC}_{ij} - \mathrm{SC}_i(\min)}{\mathrm{SC}_j(\max) - \mathrm{SC}_j(\min)} \tag{3}$$

where d is an ethnic minority population (the Hmong or the Dzao); MC_j is estimated score of major component j; $\overline{SC_{ij}}$ is standardized score of sub-component i belonging to major component j; $\mathrm{SC}_{ij}(\max)$ and $\mathrm{SC}_{ij}(\min)$ are the maximum and minimum scores, respectively, for sub-component i belonging to major component j; n is the number of sub-components in major component j; m is number of major components.

The LVI scales range between 0 (the least vulnerable) and 1 (the most vulnerable).

2.2.3 Livelihood vulnerability index framed within the IPCC vulnerability framework (LVI-IPCC)

LVI-IPCC, a combination of exposure, sensitivity and adaptive capacity, is calculated using Eq. (4):

$$\text{LVI - IPCC}(d) = [E(d) - \mathrm{AC}(d)] \times S(d) \tag{4}$$

where E is the exposure score; AC is the adaptive capacity score; S is sensitivity score.

2.2.4 Livelihood effect index (LEI)

LEI is calculated using the sustainable livelihood framework approach (DFID 1999). We calculate LEI as the weighted mean of five livelihood capitals (human, social, natural, physical, and financial) using Eqs. (5–6):

$$\mathrm{LEI}(d) = \frac{\sum_{i=1}^{5} w_i C_i(d)}{\sum_{i=1}^{5} w_i} \tag{5}$$

with

$$C_i(d) = \frac{1}{n} \sum_{j=1}^{n} C_{ij} \tag{6}$$

where C_i is the score of livelihood capital i (Human capital = HC; Natural capital = NC; Social capital = SC; Financial capital = FC; Physical capital = PC); C_{ij} is the score of major components j for capital i; n is the number of sub-dimensions by capital i; w_i the weight of capital i decided by the number of dimensions in each indicator.

The LEI scales from 0 (the least vulnerable) to 1 (the most vulnerable).

2.3 Data collection methods and instruments

This study uses a combination of data from relevant sectorial impacts, informal interviews, a questionnaire survey, and FGDs. A total of 11 FGDs were organized over all 11 villages of Mo Vang commune to investigate both official opinions and local perceptions on the components of livelihood vulnerability. A livelihood vulnerability questionnaire was designed to collect data from local Dzao and Hmong residents. Twenty random

respondents were selected at pilot stage. Questionnaire revisions are based on the results of the pilot study. The total sample size is 60 Hmong and 60 Dzao respondents. The questionnaire finally used includes 29 questions which correspond which 29 key variables of 10 sub-components of the LVI-IPCC. Official surveys then took place during field trips from November to December 2017. It took about 30 min to complete a questionnaire survey. Climatic data are collected from the Vietnam National Hydro-Meteorological Service. Socio-economic data, and the information on the extent, intensity, and frequency of the flooding and landslides are collected from official reports and statistics by local officials. The reference climatic period is 55 years (1961–2016), while the reference socio-economic period is 8 years (2010–2017). Official reports were collected during a sectorial meeting organized at the Van Yen district government office in December 2018 under the Vietnamese national project CTDT.39.18/16–20.

3 Results

3.1 Livelihood vulnerability index between Hmong and Dzao

In the Hmong and the Dzao's habitats, deforestation, biodiversity degradation, and environmental pollution increased during the recent period. Flash floods and landslides challenge both Hmong and Dzao population's life. Because local livelihood depends on cinnamon cultivation, the most pressing constraints facing smallholders include the difficulties in accessing to credits, and the contemporary volatility in the markets for cinnamon products.

The socio-demographic profile of the Dzao population is more vulnerable than this of the Hmong. Dzao has a higher rate of dependent family members than Hmong ($SC_{11}(M) = 0.03$, $SC_{11}(D) = 0.05$). While Hmong has more household members than Dzao, they show a higher proportion of female-headed households (23.3%) comparing to Dzao (12.8%). Female-headed households are likely to be more vulnerable than male-headed households because of their limited accessibility to education and information (WHO 2011; Mendoza et al. 2014). In the Hmong population, 51.7% of household-heads never attended school. The comparable the figure of the Dzao is 23.34% reported. School educated household-heads show a better adaptation capacity to climate change, and they are more reception for new, modern agricultural technologies.

The Dzao go more frequently outside of the district to look for work than the Hmong ($SC_{21}(M) = 5\%$; $SC_{21}(D) = 8\%$). More households of the Hmong depend on income from agriculture ($SC_{22}(M) = 6.7\%$; $SC_{22}(D) = 5\%$). Both Hmong and Dzao raise their income by raising cattle, and planting cinnamon, bean, and cassava. Buffalos are major assets for Hmong, which is reflected by a higher livelihood diversification index for Hmong than this for Dzao ($SC_{23}(M) = 0.33$; $SC_{23}(D) = 0.50$). When all the three components are aggregated to livelihood strategies, Dzao show a higher vulnerability than Hmong ($MC_2(M) = 0.10$; $MC_2(D) = 0.18$).

Social networks are important for both Hmong and Dzao exchanging livelihood to help each other. Hmong show a lower vulnerability score than Dzao for social networks ($MC_3(M) = 0.63$; $MC_3(D) = 0.74$). A figure of 68.3% of the Hmong and 88.3% of the Dzao reported they visited local government for assistance during the last year. Dzao residents borrow less money and receive more assistance from family, friends, and the local government during the last month than Hmong ($SC_{31}(M) = 1.54$; $SC_{31}(D) = 1.76$; $SC_{32}(M) = 1.5$; $SC_{32}(D) = 1.38$).

For revenue aspect, over 16% of Hmong households rank below the poverty line, which means a monthly income of less than US$30 per person. Poverty and persistent inequality shape their vulnerability to climate change, while their coping capacity depends on the socio-economic development (Ribot 2010).

Both Hmong and Dzao have limited access to health care systems. Hmong have higher vulnerability than Dzao for health ($MC_5(M) = 0.16$; $MC_5(D) = 0.47$) with 21.7% of Hmong households entail members with chronic illness as compared to 28.3% of the Dzao. Hmong spend about 2 h on average to go to a health facility for each trip, while Dzao spend 1.48 h on average. Health facilities are localized about 4.5 km on average away from Hmong's settlements. Mud covered roads and moderate slopes are equally part of the explanation.

Hmong showed more vulnerability when it comes to food than Dzao ($MC_6(M) = 0.50$; $MC_6(D) = 0.33$). Agriculture by both Dzao and Hmong focuses on dry rice and maize of which only one crop per year is harvested. Most households buy food in the small market. Over 46% of the Hmong households and over 30% of the Dzao families do not store foods and save money during the flood season (from May to September). Many households need more food but only the better-off households can buy it when they experience shortage.

Dzao are less vulnerable than Hmong when it comes to water storage ($MC_7(M) = 0.64$; $MC_7(D) = 0.58$). Households collect piped fresh water from streams. Over 90% of the Dzao use natural water sources, while more than 30% of the Hmong population collects water from a public water supply system.

Hmong live up in the top of mountains with the steepest slope environment, which makes their populations more vulnerable than Dzao ($MC_8(M) = 0.53$; $MC_8(D) = 0.06$). 52.7% of the Hmong respondents reported their houses have been damaged by floods and/or landslides, whereas this rate is 19.2% for Dzao.

Hmong are more vulnerable than Dzao when it comes to land ($MC_9(M) = 0.46$; $MC_9(D) = 0.25$). Both Hmong and Dzao grow wet rice. These rice fields have a size of 936 m^2 per household for the Hmong, which is large than the Dzao field surface (532 m^2). Hmong households reclaim bare land or inherit land from their parents. Dzao have more experience than Hmong with the cinnamon production. For them, cinnamon is the most important asset. Dzao populations settled first in Mo Vang, and they have possession of the most favorable lands for cinnamon trees. Each Dzao household owns 2.58 hectares of cinnamon on average; the comparable figure is 2.3 hectares for the Hmong.

Hmong has a higher score for natural hazards and climate variability than Dzao ($MC_{10}(M) = 0.61$; $MC_{10}(D) = 0.57$). While climate conditions such as mean minimum and mean maximum daily temperatures, and mean monthly precipitation during more than 50 years are similar for both Dzao and Hmong, due to the location of habitats, Hmong face more natural hazards such as floods and landslides than Dzao. About 8.3% of Hmong and only 5% Dzao reported their house is damaged by a natural hazard during the past recent years.

The overall aggregated LVIs are 0.41 and 0.43 for Dzao and Hmong populations, respectively, which indicate that the livelihoods of the Hmong are more vulnerable to climate change (Fig. 4). Table 2 shows the result of a two-sample t-test showing the difference in mean LVI for the major components. The null hypothesis is rejected because the *t*-value (4.127) is above the level of significance (2.01) with 148 degrees of freedom. The probability value ($p < 0.05$) supports this result, which indicates disparity between the mean LVI for Hmong and Dzao populations.

Figure 3 shows the vulnerability between 0 (least vulnerable) and 0.8 (extremely vulnerable). Hmong are more vulnerable for natural hazards and climate variability, quality

Table 2 Statistical values of sub-component for Hmong and Dzao

Major component	Sub-component	Observed score (Hmong)	Observed score (Dzao)	Max	Min
Socio-demographic profile [$MC_1(M)=0.24$; $MC_1(D)=0.26$]	Dependency ratio (SC_{11})	0.03	0.05	0.070	0.017
	Female-headed households (SC_{12})	23.30	12.80	100.0	0.0
	Single-parent households (SC_{13})	8.30	6.40	100.0	0.0
	Unschooling household-head (SC_{14})	51.67	23.34	100.0	0.0
	Average household size (SC_{15})	3.00	4.00	7.00	2.00
Livelihood strategies [$MC_2(M)=0.10$; $MC_2(D)=0.18$]	Working in different communities (SC_{21})	5.00	8.33	100.0	0.0
	Household income from agriculture (SC_{22})	6.67	5.00	100.0	0.0
	Average Agricultural Livelihood Diversification Index (SC_{23})	0.33	0.50	1.0	0.17
Social networks [$MC_3(M)=0.63$; $MC_3(D)=0.74$]	Average Income: Give Ratio (SC_{31})	1.54	1.76	2.0	1.0
	Average Amount Borrowed: Lend money (SC_{32})	1.50	1.38	2.0	0.5
	Assistance from officials (SC_{33})	68.33	88.33	100.0	0.0
Revenue [$MC_4(M)=0.16$; $MC_4(D)=0.47$]	Poverty line households (SC_{41})	16.67	13.33	100.00	0.00
	Net income of cinnamon per year (SC_{42})	12,609	19,565	21,739	10,870
Health [$MC_5(M)=0.35$; $MC_5(D)=0.26$]	Access to health facilities (SC_{51})	2.0	1.48	3.0	1.0
	Incidence of chronic illness (SC_{52})	21.667	28.30	100.000	0.000
Food [$MC_6(M)=0.50$; $MC_6(D)=0.33$]	Average Crop Diversity (SC_{61})	0.571	0.43	1.00	0.10
	No intention to save crops (SC_{62})	46.67	30.00	100.0	0.0
Water [$MC_7(M)=0.64$; $MC_7(D)=0.58$]	Use of natural water sources (SC_{71})	88.30	95.00	100.0	0.0
	Public water supply system (SC_{72})	30.00	8.30	100.0	0.0
	Household storage tanks (SC_{73})	73.33	70.00	100.0	0.0
Housing [$MC_8(M)=0.53$; $MC_8(D)=0.06$]	Resistant house foundation (SC_{81})	52.70	19.23	100.0	0.0
Land [$MC_9(M)=0.46$; $MC_9(D)=0.25$]	Agricultural Land Patch Size (SC_{91})	936.00	532.80	1440.0	360.0
	Average cinnamon land area (SC_{92})	2.30	2.58	5.0	1.0

Table 2 (continued)

Major component	Sub-component	Observed score (Hmong)	Observed score (Dzao)	Max	Min
Natural hazards and climate variability [$MC_{10}(M) = 0.61$; $MC_{10}(D) = 0.57$]	No warning for natural hazard (SC_{10})	85.00	71.70	100.0	0.0
	Standard deviation of daily average maximum temperature (SC_{102})	0.55	0.55	0.7	0.0
	Standard deviation of daily average minimum daily temperature (SC_{103})	0.46	0.46	0.55	0.0
	Standard deviation of average monthly precipitation (SC_{104})	140.17	140.17	239.56	75.0
	Average number of yearly flood events (SC_{105})	3.20	3.20	4.0	1.0
	Damaged houses due to natural hazards (SC_{106})	8.30	5.00	100.0	0.0
	Overall LVI	0.43	0.41		
Two-sample t-test	Obs	60	60		
	Mean	0.369	0.290		
	Std. Deviation	0.1210	0.0834		
	Std. Err	0.0156	0.0107		
	t	4.127[a]			
	p	0.001			
	d.f	148			

[a]Indicates significance at 5% significance level

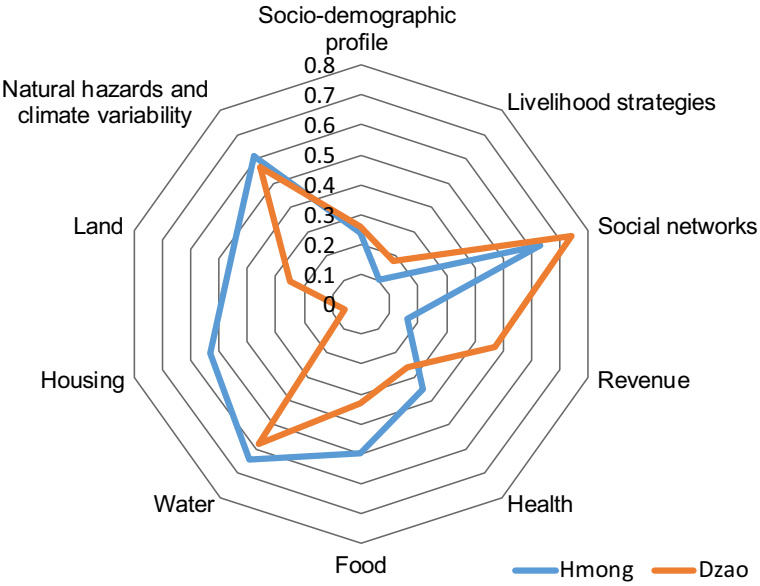

Fig. 3 Vulnerability of the major components of the LVI for Hmong and Dzao

of housing and land tenure, water, food, and health. Dzao are more vulnerable in terms of social-networks and livelihood strategies.

3.2 LVI-IPCC comparison between Hmong and Dzao

Table 3 shows the results of LVI-IPCC for Dzao and Hmong by exposure, sensitivity, and adaptation capacity. Hmong are more vulnerable to climate change impacts than Dzao ((V(M) = 0.16; V(D) = 0.07)). Hmong have a higher exposure because their habitats locate high on steepest slopes, which increases risk of natural hazards on slopes such as floods and landslides (AC(M) = 0.29; AC(D) = 0.39). While health, food, water, land, and housing situation of the Hmong are more sensitive, Dzao are more vulnerable by their socio-demographic profile, livelihood strategies, and social networks. Dzao have a lower sensitivity because they save crops better for other food supplies and experience better for health, work, water, and arable land conditions (S(M) = 0.5; S(D) = 0.35).

3.3 LEI comparison between Hmong and Dzao

The results of the LEI comparison show that Dzao have a higher livelihood effect index than Hmong (LEI(M) = 0.34; LEI(D) = 0.35) (Table 4). Human capital is most influential on the vulnerability index on the Hmong (HC(M) = 0.42; HC(D) = 0.3). The intention to save food of Hmong scores higher than those of Dzao. About 50% of Hmong depend merely on their farm or forestry wild collection for their food, as comparing to 33% of the Dzao. Dzao buy food from small markets. Although both Hmong and Dzao live in less advantaged areas, Hmong score a higher health index than Dzao. Their latter use less public health services and spend more time go the nearest health facility.

Table 3 LVI-IPCC for Hmong and Dzao

IPCC vulnerability components	LVI major component	Major component score		Number of subcomponent per major component	IPCC vulnerability component score	
		Hmong	Dzao		Hmong	Dzao
Adaptation Capacity (AC)	Socio-demographic profile (AC_1)	0.24	0.26	5	0.29	0.39
	Livelihood strategies (AC_2)	0.10	0.18	3		
	Social networks (AC_3)	0.63	0.74	3		
	Revenue (AC_4)	0.16	0.47	2		
Sensitivity (S)	Health (S_1)	0.35	0.26	2	0.50	0.35
	Food (S_2)	0.50	0.33	2		
	Water (S_3)	0.64	0.58	3		
	Housing (S_4)	0.53	0.06	1		
	Land (S_5)	0.43	0.28	2		
Exposure (E)	Natural hazards and climate variability (E_1)	0.61	0.57	6	0.61	0.57
Vulnerability (V)					0.16	0.07

Table 4 Livelihood Effect Index (LEI) for the Hmong and the Dzao

Contributing factors	Major component	Score of major component (Hmong)	Score of major component (Dzao)	Number of sub-components	LEI (Hmong)	LEI (Dzao)
Human capital (HC)	Health (HC_1)	0.35	0.26	2	0.42	0.30
	Food (HC_2)	0.50	0.33	2		
Natural capital (NC)	Water (NC_1)	0.64	0.58	3	0.59	0.52
	Land (NC_2)	0.43	0.28	2		
	Natural hazards and climate variability (NC_3)	0.61	0.57	6		
Social capital (SC)	Socio-demographic profile (SC_1)	0.19	0.30	4	0.29	0.42
	Social networks (SC_2)	0.63	0.88	1		
Financial capital (FC)	Revenue (FC_1)	0.17	0.30	2	0.17	0.30
Physical capital (PC)	Housing (PC_1)	0.53	0.19	1	0.21	0.19
	Livelihood strategies (PC_2)	0.10	0.21	3		
Livelihood Effect Index (LEI)					0.34	0.35

Hmong show more vulnerability of their natural capital than Dzao (NC(M) = 0.59; NC(D) = 0.52). They live in high areas and receive limited warning for natural hazards. During the last ten years, climate-induced hazards such as floods, landslides, and droughts influenced negatively their agriculture, especially cinnamon cultivation. Water contributes more significantly to the live and farming of Hmong than Dzao, although most of them use water from natural sources.

The Dzao population has a higher social capital vulnerability than the Hmong (SC(M) = 0.29; SC(D) = 0.42). This statement fits to both figure of social-demographic profile and social network of Dzao are higher than those of Hmong.

The financial capital makes the Dzao population more vulnerable than the Hmong (FC(M) = 0.17; FC(D) = 0.30). About 17% of Hmong population have a net monthly income of less than 30 $US per person, which more than the Dzao.

The physical capital (PC) vulnerability values for Hmong and Dzao are 0.21 and 0.19, respectively. In reality, 52.7% of the Hmong population lives in houses with low resistance materials in walls (brick, bamboo, wood), floor (dirt, concrete, bamboo), and roof (wood tiles). About 7% of the Hmong population depends on crops as their main income, which is equivalent to 5% of the Dzao.

4 Conclusion

This study extends the analytical utility of the combination of LVI, LVI-IPCC, and LEI to identify and to compare the vulnerability of the Hmong with this of the Dzao population in the mountains of Northern Vietnam. Also drivers of the livelihood vulnerability at the community level are clarified. Agriculture and rural livelihood indicators are connected to climate change vulnerability concept. Natural capital supports goods or services for agricultural production for a long-term. The decline of water and land availability could enhance climatic vulnerability by reducing crop yields. Physical capital is a factor of production, consisting here of electricity, and land value and improvements. Low quality of houses and poor livelihood strategies lead to limited access to resources and limited to cope with natural hazards, which can cause high vulnerability. Human capital refers to the farmer's health and intention, which increase labor productivity and climate change response ability. Financial capital focuses on cash income and poverty line households. This resistance to extreme environments has made farmers the focus of financial about the possible properties of improved income. Social capital, which is assessed by socio-demographic profile and social networks, is hypothesized to reduce vulnerability. They help farmers to respond effectively to climate-induced natural hazards because increased public involvement reduces costs by risks of hazards.

5 Discussion and policy implication

To the best of our knowledge, till now Mo Vang (Yen Bai) is the fourth case study on livelihood vulnerability in the mountains of Northern Vietnam. The first work by Huong et al. (2018) is on the Pa Vay Su commune (Lai Chau province), Hien Luong (Hoa Binh), and Moc Chau (Son La). The livelihood vulnerability in the villages is compared based on 12 major LVI components: health, knowledge and skills, food, livelihood strategy, natural resources, land, water, socio-demographic, social networks, financial, infrastructure, and

housing. This study compares the livelihood vulnerability of the Hmong and the Dzao populations at village level. The Hmong and Dzao live in the same climate; however, they are prone to different to natural hazard risks as a result of the different landscapes they live in combined with their different socio-economic context. Consequently, Hmong populations emerged as more vulnerable than Dzao because of more risks in natural hazards and climate variability, and their limitation in house quality, land tenure, water, food, and health. Dzao populations are more vulnerable because of their socio-demographic profile, livelihood strategies, and social networks. Overall, Hmong populations are more vulnerable than Dzao populations.

This study provides an example of introducing anthropological investigation into research of sustainable livelihood and climate change adaptation in the Northern Mountains of Vietnam. Dzao and Hmong populations experience different degrees of climate change vulnerability in the mountainous environment. These differences are explained by the livelihood indicators such as the socio-demographic profile, livelihood strategies, social networks, health, food, water, housing, land, natural hazards and climate variability. Figure 4 shows that a combination of these indicators allows understanding the differences in local livelihood of Hmong and Dzao under the pressure of climate-induced natural hazards. While Hmong populations are more vulnerable than Dzao for natural conditions such as natural hazards and climate variability, housing, land, water, food, and health; Dzao populations are more vulnerable because of socio-economic conditions such as socio-demographic profile, livelihood strategies, revenue, and social networks.

This study has several limitations. Each livelihood capital is calculated on the assumption that it can reduce the climate change vulnerability of ethnic minority populations. The composite index is used to quantify the major components, while the major components are highly dependent on a particular study area and purpose, which introduces subjectivity in selecting the indicators. A second limitation is the time scale:

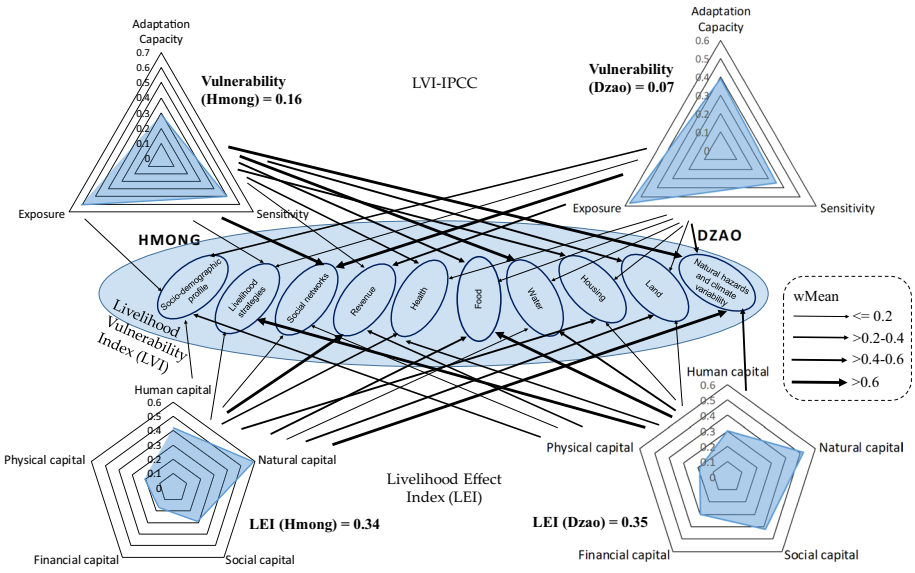

Fig. 4 Interconnection of contributing factors and major components of climate change vulnerability between the Hmong and the Dzao populations

components as health, food, water are assessed on a short term, but livelihood strategies, land tenure, and climate variability would be long-term events. Limitations of the LVI and LVI-IPCC approach deal with the subjective choice of sub-components, data collected in different years, at varying spatial scales, and for different purpose (Hahn 2009). LEI has the advantage of allowing household-level assessment. Using the averaging sub-components method to measure a set of relationships entails uncertainty. Moreover, this approach may cause risks misapprehension by policy makers who are not intimately familiar with quantitative method. Even though the LEI scores are separated by just 0.01, their component values different substantially. This situation is part of the problem with indices that collapse many components into a simple score. While the results show that the Hmong and Dzao occupy substantially different environmental settings, looking at the LEI scores of the Hmong and Dzao alone without seeing component scores or LVI or LVI-IPCC scores would lead the reader to conclude the respective situations of the Dzao and Hmong are effectively the same.

The study findings give new inputs for policy options on the promotion of sustainable livelihood and climate change adaptation in the Northern Mountains of Vietnam. The results of LVI, LVI-IPCC, and LEI provide information of both natural and socio-economic factors contributing differently to climate change vulnerability at the community levels. Therefore, the study results provide a scientific basis for local governments and policy-makers prioritizing solutions to improve livelihood capitals and to enhance the adaptive capacity of upland ethnic minorities to the risks of climate change. Improving livelihood capitals can reduce vulnerability to climate change in rural areas (DFID 1999). Each livelihood capital is able to reduce or to increase vulnerability depending on its nature (Huai 2016). Restrictions on forest land use by the local government are a bottleneck for local people. Vulnerable groups in the mountains of Northern Vietnam are ethnic minority farmers, the poor, and women to ensure equity, and they should have access to land use rights. The life of local resident depends on income from cinnamon, which is closely related access to land and forestry. Dzao own more cinnamon land than Hmong. The local government focused on a policy to develop the cinnamon value chain to improve livelihoods capitals. The Mo Vang commune has the potential to develop cinnamon products, more income depends on their access to markets. Government should improve the housing policy supporting the poor. The physical capital of the Hmong increases their vulnerability to climate change because they are poor, have a lower living standards, and lack transport on the dirty roads. Traditionally, they build woody houses. Only the higher income families would built houses in cement, bricks, and enforcing steel bars.

Also, the study results provide essential information on enabling households in vulnerable populations to take advantage of opportunities associated with socio-economic transformations and environmental changes. Households have an array of alternative livelihood options and tend to be socially well connected in Mo Vang commune. The findings show that the causes of the human capital vulnerability are related with limited education and poverty. Most education initiatives use the national Vietnamese language, which is a barrier for ethnic minorities as the Hmong and the Dzao. To sustain and enhance the livelihoods of the vulnerable population, the education for ethnic minorities should be improved. Vocational training for the adult should not just address school-age children because handicraft from cinnamon helps them escaping from poverty. Training on disaster risk and climate change adaptation for local residents also becomes more necessary.

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Affiliations

Thinh An Nguyen[1] · Bich Thi Nguyen[2] · Hanh Van Ta[3,4] · Nhung Thi Phuong Nguyen[5] · Huong Thi Hoang[1] · Quan Phung Nguyen[6] · Luc Hens[7]

1 VNU University of Economics and Business, Vietnam National University, Hanoi, Vietnam

2 Vietnam National University of Forestry (VNUF), Hanoi, Vietnam

3 Institute of Materials Sciences, Vietnam Academy of Science and Technology (VAST), Hanoi, Vietnam

4 Graduate University of Science and Technology, Vietnam Academy of Science and Technology (VAST), Hanoi, Vietnam

5 Vietnam National Productivity Institute, Hanoi, Vietnam

6 The Committee On Ethnic Minority Affairs, Hanoi, Vietnam

7 Vlaamse Instelling Voor Technologisch Onderzoek (VITO), Mol, Belgium