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Vulnerability assessment of households to flash floods and landslides in the poor upland regions of Vietnam

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ABSTRACT

Increased frequency and intensity of flash floods and landslides in the Northern Mountainous Regions of Vietnam represent the most damaging hazards to the production activities and livelihoods of rural households, which are heavily reliant on agriculture. Assessing households' vulnerability therefore becomes critical and urgent to help policy-makers in Vietnam in facilitating the implementation of adaptation strategies for households living in this area. Thus, this paper employed the Household Vulnerability Index method along with the qualitative data analysis to evaluate the vulnerability level of smallholder farmers under the effect of these hazards. Data was collected from 405 households in three communes of Yen Bai province, one of the poorest provinces in the Northern Mountainous Regions of Vietnam with a high proportion of ethnic minorities who have extremely low incomes and education levels. Food and fresh water quality and security are also relatively low in this region. The empirical results indicate that ethnicity, diversified sources of income, organizational membership, health insurance, food security, land tenure documentation, water resources, and locational dimensions are the key factors affecting the vulnerability of farmers under the impacts of flash floods and landslides. Results also suggest that the livelihoods of farmers in the Dai Son commune are the most vulnerable to these natural hazards identified by the Social Network, Socio-Demographic Profile, and Water component factors. We subsequently identify and prioritize measures to ensure sustainable livelihoods for local farmers through practices, such as improving people's literacy, enhancing production systems, and strengthening natural resource management strategies.

1. Introduction

Natural hazards are considered to be one of the major drivers causing the recent increases in global prevalence of undernourishment and food insecurity, particularly in developing countries since farmers' livelihoods are more exposed and vulnerable to climate-driven disasters (FAO et al., 2018). In addition, it is acknowledged that natural hazard-induced disasters heighten the livelihood vulnerability of smallholder farmers while reducing households' capacity to resist risks, shocks, and stresses. Although climate-induced change is considered to be a global problem, its impact level is different for each region, as well as for each specific

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system, family, and community. Consequently, the vulnerability of each object is not identical (Adger et al., 2004). From such a fact, there are numerous scholars suggesting that assessing vulnerability to climate variabilities should be localized (Below et al., 2012; Deressa et al., 2009). Understanding the livelihood vulnerability of rural households, therefore, has been found as an urgent need in order to develop adaptation strategies and have proper solutions/policies in reducing climate-associated risks and improving households' resilience, especially in countries that rely heavily on agriculture.

Studying one of the most prone agricultural countries in the Asia Pacific region to natural hazards like Vietnam (IPCC, 2014; Marconi et al., 2011; World Bank, 2017) is therefore highly important given limited studies on this issue in the country and particular sub-national regions. It is estimated that over the past two decades, these natural hazards have caused significant losses in Vietnam, including more than 13,000 mortalities (World Bank, 2017) and average annual asset damage in excess of $6.4 billion that is equivalent to 1.5% of GDP (MONRE, 2017; World Bank, 2017). Of these, more than 80% of the country's population is exposed to risks from the direct impacts of natural disasters (FAO, 2012). In particular, around 59% of the country's total land area and approximately 71% of the total population are frequently affected by typhoons and floods (World Bank, 2017). This is because annually around six to ten typhoons and tropical depressions generated in the Western North Pacific Ocean hit Vietnam's coastline, resulting in heavy rains and floods over large areas, particularly in the northern and central parts of the country. Also, these typhoons often result in flash floods and landslides (FF&LS) in the mountainous regions of the country.

In this regard, FF&LS have been considered serious natural disasters[1] in the Northern Mountainous Regions (NMR) of Vietnam (Table 1), which substantially affect production levels and daily activities (FAO, 2012; Socialist Republic of Vietnam, 2012). More importantly, households in this area have relatively low income and the infrastructure is not well developed. As a result, it would take a long time and more financial resources to recover from the effects resulted from these natural disasters. The provinces such as Lao Cai, Ha Giang, Yen Bai, and Son La are among the most frequently affected provinces by FF&LS, of which Yen Bai, located along the Red River, has the highest number of landslide events in the NMR (MONRE, 2014).

Yen Bai, located between the Northeast and Northwest (see Fig. 1), is more prone to these natural hazards not only because of the increasing number of FF&LS during the past years but also due to its heavy reliance on agriculture and natural resources which are the most sensitive sectors to climate change-induced impacts (Parry et al., 2007a,2007b). Furthermore, Yen Bai is one of the top ten poorest provinces characterized by a high percentage of ethnic minorities; who are especially vulnerable to natural hazards due to their limited access to areas that are fit for safe and healthy habitation and profitable livelihood opportunities (Adger, 2003; Parry et al., 2007a,2007b). Particularly, as reported by the Ministry of Natural Resources and Environment in 2018, there were 15 natural disasters occurred in Yen Bai, killing 21 people, missing 1 person, injuring 25 people, damaging 5800 houses, and affecting nearly 4500 ha of rice and vegetable fields, along with having road, irrigation systems, and schools extremely damaged.[2] Besides, economic losses caused by natural disasters are estimated to be over 1000 billion VND (around $476 million), while annual per capita income in this area is about 1.4 million VND (around $54). In 2005, for example, this province experienced five noticeable FF&LS events, which resulted in soil erosion of 75,000 m^3 and a loss of seasonal paddy and vegetable growing areas totaling 2607 ha. Noticeably, one flash flood swept away and damaged 181 houses, while 57 other houses were entirely destroyed. In addition, 50 people died in the flash flood. Recently, the province had been witnessed three continuous events of FF&LS in 2017 that results in 32 deaths and injuries, 50 houses washed away.

Although the region and communities are highly exposed to frequent and intense FF&LS, studies on the vulnerability of the region to these natural hazards are scarce. Previous studies on the vulnerability of rural households to climate variability were only conducted at farm level in different regions in Vietnam (Duy Can et al., 2013; Huynh and Stringer, 2018). These studies, as with most other natural hazard-related studies, just explore the factors influencing farmers' vulnerability in the context of climate change in general, and mainly focus on the two Deltas (Red River Delta and Mekong River Delta) and the Central Region. Given the fact that the economic, infrastructure, population density, and natural environments are significantly different between regions in Vietnam, the impact of a particular natural hazard on the NMR is highly different from the impact in other parts of the country. In addition, this area is home to multiple minor ethnic groups with extremely low incomes and poor healthcare and fresh water services. They also often experience substantial food shortage and low food quality due to natural hazards. Furthermore, this is a highly hilly remote area with poor infrastructure, which causes significant transportation difficulties to nearby cities or centrals of main towns for shopping, attending schools, and seeking assistance or services, such as healthcare services. For these reasons, a study that focuses on the NMR is particularly important. This is because findings associated with this region would explicitly help policymakers develop appropriate strategies to support households and minor ethnic communities in the region to reduce poverty and to ensure sustainable development. In addition, as most previous studies examined general natural hazards, there is a high demand for research that focuses particularly on the most pressing hazards in the region, i.e., FF&LS. This is also the motivation and main objective of this present study which aims to explore the livelihoods of local people and disclose the factors affecting rural household vulnerability to FF&LS by developing and applying the Household Vulnerability Index (LVI), with a case study in Yen Bai province. This study also makes

[1] There were numerous FF&LS recorded in the mountainous areas of the country (MONRE, 2017). According to the Socialist Republic of Vietnam (2012), these events resulted in more than 880 dead and almost 1,500 injured people. They also destroyed more than 6,000 houses out of 120,000 flooded houses and flooded around 132,000 ha of rice and crops. It is noted that flash floods and landslides are two events that usually take place simultaneously in the research area, this study therefore bases on an assumption that these two disasters are a single event strongly affecting households livelihood (Pham et al., 2019).

[2] http://dwrm.gov.vn/index.php?language=vi&nv=news&op=Hoat-dong-cua-dia-phuong/Yen-Bai-Huong-ung-Tuan-le-Quoc-gia-ve-phong-chong-thien-tai-8125

Table 1
Common hazards and vulnerability levels in the NMR.

Disasters	The vulnerability levels by geographical regions	
	Northwest Mountainous Region	Northeast Mountainous Region
Storms	+	+ + +
Flood	+ + + +	+ + + +
Flash flood and landslide	+ + + +	+ + + +
Whirlwind	+ + + +	+ + + +
Drought	+ + +	+ + +
Inundation	–	–
Forest fire	+ + + +	+ + + +
Earth quake	+ + +	+ + +
Failure of water reservoir	+ + +	+ + +

Source: FAO (2012) and MONRE (2017).
Note: + + + +: Very severe; + + +: Severe; + +: Medium; +: Light; -: None.

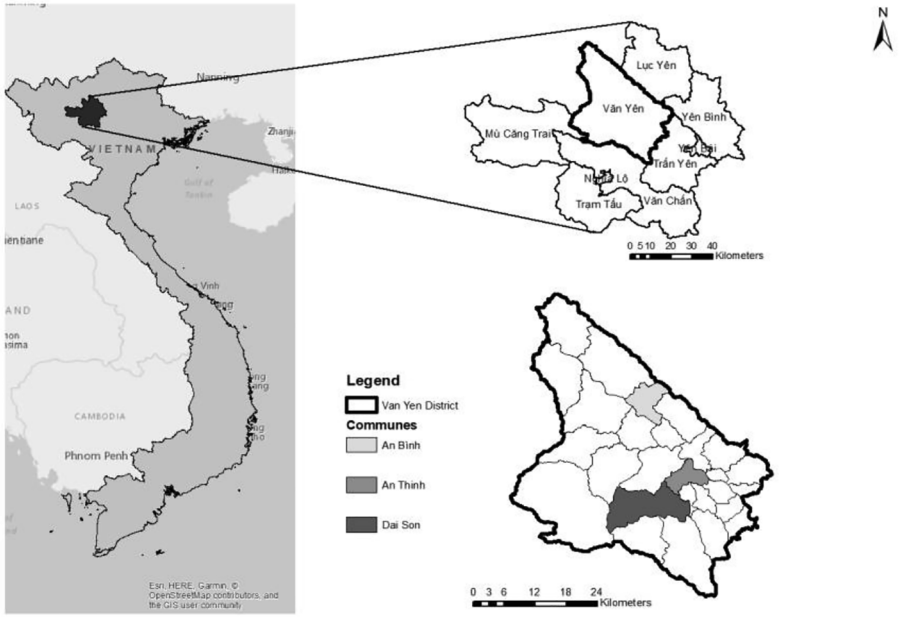

Fig. 1. Map of study areas.

major contributions to the literature, as the findings are replicable for assessing the vulnerability of smallholder farmers in other hazard-prone areas and provide good references for policymakers to have timely supporting policies to help people living in similar economic and natural regions.

The proceeding sections of this paper are organized as follows: Section 2 provides the material and methods of the research; Section 3 presents the results and analysis and in Section 4 we present the discussion, some concluding remarks and policy implications based on the findings of the research.

2. Material and methods

2.1. Study area and household surveys

The study was carried out in the Van Yen district located in the North of Yen Bai province (Fig. 1). There are 26 communes and one town in Van Yen district, of which 13 are located in the highlands, and 8 belong to the group regarded as "especially difficult communes" specified under "Program 135" by the Vietnamese Government.[3] The total natural area of the district is 1391.54 km^2, and

[3] Program 135 is 'the program for the socio-economic development of extremely difficult communes in ethnic minority and mountainous areas' and is one of the poverty reduction programs in the country implemented by the Vietnamese Government in 1998 (according to the Decision 135/QD-TTG).

it is divided into three economic regions: the rice intensification (13 communes), fruit and crop (6 communes) and cinnamon areas (8 communes).

The district has many streams, most significantly the Red River which traverses the length of the district. There are 17 communes and 9 communes on the right and the left sides of the river, respectively. As a result, these locations often experience frequent occurrences of extreme weather, such as flash floods, whirlwinds, cyclones, landslides, and inundation.

Three communes in Van Yen district, namely An Binh, An Thinh, and Dai Son (Fig. 1), were purposively chosen for the research, whereby An Binh is representative of a cassava growing area, while An Thinh and Dai Son are typical rice and cinnamon regions, correspondingly (Table A1 in Appendix A).

The survey was administered in two periods: from September to November 2015 and from February to April 2016. In the first survey, in-depth interviews with experts in different organizations, including the Departments of Irrigation and Flood Control, Meteorological Center, Statistical Departments, Agriculture Department, and the People's Committee, were conducted at both provincial and district level. The primary purpose was to get a better understanding of the research's context as well as the situation of FF&LS in the region and then to determine the specific research areas in Van Yen district (not only at commune but also at village level). In-depth interviews focus on asking questions related to livelihood activities, weather conditions, the situation of FF&LS in recent 15 years, what the main causes of FF&LS are, and which areas and who are mostly affected by these natural disasters. As a result, three study communes are chosen since they are characterized by: (1) geographical zone; (2) FF&LS situation; (3) economic pattern; (4) ethnic minority groups. Three focus group discussions (FGDs) were then organized with farmers at commune level. Each FGD included 10 to 15 people and lasted around 3 hours. The main purpose of doing FGDs was to capture the timeline of village history, main livelihood activities, cropping calendar, challenges for agricultural activities, the role of weather and other factors such as health, access to market, information and knowledge to agricultural production, the extent of flash flood and landslide impacts, and taken measures before, during, and after FF&LS. At the same time, a list of indicators related to a vulnerability assessment of these natural hazards was given to local officials and experts in the field of agriculture and climate for the expert selection of relevant indicators suited to the locality. These indicators were then revised for the household survey in the next stage of fieldwork, and are provided in Table A2 in Appendix A. A total of 405 households were interviewed in Van Yen district. Based on the size of land and population, 154 households in An Binh, 105 households in An Thinh and 146 households in Dai Son commune, were selected for the interviews. The sampling in each commune was selected based on the level of impact[4] of FF&LS on livelihood and production activities[5] of the household. Only the response of the head or main laborer of the household, in case the head was not at home, was recorded. Each interview lasted from 1 hour to 1.5 hours on average and followed a detailed questionnaire (Pham et al., 2019). A total of 35 key variables applied in calculating the Household Vulnerability Index as shown in Table A2 in Appendix A. In addition, secondary data on monthly rainfall were aggregated from the National Meteorological and Hydrological Center from 1980 to 2015.

2.2. Approaches to measuring vulnerability

The vulnerability measurement can be conducted by various ways and methods, depending on fields of specialization. For evaluating the impacts of climate change and hazards, vulnerability is often measured by constructing an index of vulnerability. Commonly, the vulnerability index of a certain system is defined as a function of three typical components: (1) Exposure (Exp), (2) Sensitivity (Sen), and (3) Adaptive Capacity (Ada.Cap) (for example, see Adger, 2006; IPCC, 2001). It is noted that the method can be used to measure the vulnerability subject to any natural hazzards. However, the object (i.e., kinds of natural hazzards) are often determined in advance through the questionaire design in the surveys targeting to particular natural hazzards. In this study, the survey was designed to study the impacts of flash floods and landslides; hence, the vulnerability index is measured as a function of exposure, sensitivity, and adaptive capacity conditional upon the flash flood and landslide events. The equation below expresses the function, while details are provided in Appendix B.

$$\text{Vulnerability} = f(\text{Exp}; \text{Sen};\ \text{Ada.Cap}) | (\text{Flash flood and Landslide})$$

The present study further employs an indicator-based vulnerability assessment method (Hahn et al., 2009), the Household Vulnerability Index (HVI_{FL}), with the rationale provided in Appendix B. This method has been used widely in different study contexts to evaluate the disparate impacts of natural hazards on a region or community (Duy Can et al., 2013; Panthi et al., 2016; Shah et al., 2013). In particular, the HVI_{FL} index, which is based on the vulnerability concept defined by the IPCC, is used in coupled with the qualitative data analysis to analyze households' vulnerability to FF&LS and to determine which factors contribute most to such vulnerability.

2.3. HVI_{FL}: a composite index

The HVI_{FL} contains eight key components that are (1) Socio-Demographic Profile (SDP), (2) Livelihood Strategies (LS), (3) Social

[4] The impact level is determined based on the extent of both human and financial damage that people experienced through flash floods and landslides in recent years as reported by commune officials.

[5] Since the scope of this research is to analyze the vulnerability of households towards flash floods and landslides, only households with livelihood activities associated with agriculture, for example growing rice, maize, cassava, cinnamon, and acacia or rearing pigs, cows, chickens, or buffalo, are selected to conduct the survey.

Network (SN), (4) Health (H), (5) Food (F), (6) Water (Wa), (7) Housing (Ho), and (8) Hazard Impacts (HIz). "Housing" (#7) is a newly introduced major component while considering previous vulnerability index studies, as it plays an important role in helping households to avoid injury and damages to property during FF&LS.

In addition, each key component is divided into specific indicators (see Table A2 in Appendix A). Based on a review of existing literature, a field survey, consultation from numerous experts and local officials, 35 indicators (in Tables A2 and A3 in Appendix A) were selected to assess the vulnerability level under the impact of FF&LS.

The HVI_{FL} is subsequently calculated by using a balanced weighted average approach.[6] This means each indicator contributes equally to the overall index although the number of indicators in each key component is different. Furthermore, as many of the indicators are measured using different units, e.g., numbers, percentages, or pre-existing indices, it is indispensable to standardize each indicator so that the index can be compiled and each indicator made comparable. In this study, this is computed by following the method used to calculate the Human Development Index (HDI) (UNDP, 1990), that is:

$$\text{Index}_{sd} = \frac{S_d - S_{min}}{S_{max} - S_{min}} \tag{1}$$

where,

$S_d$is the primary indicator for the commune; and
S_{max} and S_{min} are the upper and lower bound values, respectively.

After normalizing indicators as shown in Eq. (1), each key component (M_{di}) is computed as follows:

$$M_{di} = \frac{\sum_{j=1}^{n} \text{Index}_{sdj}}{n} \tag{2}$$

where,

M_{di} represents each key component (eight components) of the commune;
Index_{sdj} is the indexed indicator value of each key component $M_{di}$for the commune; and
n refers to the number of indicators of each key component.

Then the average value for each of the eight key components for the commune is obtained according to Eq. (3):

$$HVI_{FL\_d} = \frac{\sum_{i=1}^{8} w_{M_i} M_{di}}{\sum_{i=1}^{8} w_{M_i}} \tag{3}$$

where,

W_{M_i} is the number of indicators making up each key component for the commune; meanwhile M_{di} is the average value of each key component calculated in Eq. (2).

Hence, HVI_{FL_d} can also be expressed as shown in Eq. (4).

$$HVI_{FL\_d} = \frac{w_{SDP}SDP_d + w_{LS}LS_d + w_{SN}SN_d + w_H H_d + w_F F_d + w_{Wa}Wa_d + w_{Ho}Ho_d + w_{Hz}HIz_d}{w_{SDP} + w_{LS} + w_{SN} + w_H + w_F + w_{wa} + w_{Ho} + w_{HIz}} \tag{4}$$

These calculations (in Eqs. (1)–(3)) result in the final value for the HVI_{FL_d} and each of its dimensions in the range from 0 to 0.5. A higher end value for the HLI_{FL_d} denotes more vulnerable systems.

2.4. HVI_{FL_d} calculation based on the IPCC's method

Based on the IPCC definition of vulnerability, an alternative approach to calculate the HVI_{FL_d} index, so-called the HVI_{FL_d-IPPC}, is used in which the vulnerability is defined as a function of three distinguished components, namely exposure, sensitivity, and adaptive capacity (IPCC, 2001). Of these components, exposure includes Hazard Impacts; adaptive capacity comprises of Socio-Demographic Profile, Livelihood Strategies, and Social Network; and sensitivity consists of Health, Food, Water, and Housing. Specifically, exposure is quantified by (1) the mean standard deviation of monthly average rainfall (from 1980 to 2015), (2) the proportion of households not receiving any notices or warnings about FF&LS and (3) the percentage of households with problems, such as losing housing/property, agricultural land damaged or illness/injury/death of a family member due to FF&LS. Adaptive capacity is quantified by (1) the Socio-Demographic Profile of the community, (2) the Livelihood Strategies that households are using, and (3) the cooperation of the Social Network. Sensitivity, meanwhile, is computed by considering the recent status related to (1) Health, (2)

[6] Our main purpose of using this method is due to the fact that assigning weight for each component in the index is quite tricky since it could lead to bias problem in assessing the importance of each component in the overall index. Therefore, in the study, these components are assumed that they have an equal contribution to the overall vulnerability index. This also helps to make the interpretation process simpler and easier to understand.

Food, (3) Water, and (4) Housing in the community.

The vulnerability is defined, which includes the mentioned key components, by using a linear function explicitly represented in Eq. (5):

$$HVI_{FL_d-IPCC} = (e_d - a_d) * s_d \quad (5)$$

where:

e_d, a_d, s_d is the calculated exposure, adaptive capacity, and sensitivity score, respectively. These scores are equivalent to differently specified factors for each commune and are identified based on a so-called IPCC-defined contributing factor CF_d, as shown in equation (6):

$$CF_d = \frac{\sum_{i=1}^{n} w_{M_i} M_{di}}{\sum_{i=1}^{n} w_{M_i}} \quad (6)$$

where,

M_{di} is the average value of each key component;
w_{M_i} is the weighting factor of each key component; and
n is an integer value representing the total number of key components in each contributing factor.

The calculated values of HVI_{FL_d-IPCC} represents the vulnerability level of each commune, ranging from -1 to 1, i.e. from least to most vulnerable level.

In this research, we use the HVI_{FL_d} results calculated from these two methods to strengthen the analysis. It also helps support the validity of our survey information if HVI_{FL_d} results computed from these two methods are consistent.

3. Results and analysis

3.1. Household vulnerability index

Table A3 in the Appendix A shows the actual values and the minimum and maximum values of indicators for each commune. Table 2 shows the indexed indicators (resulting from Eq. (1)), major components (shown in Eq. (2)) and the Household Vulnerability Index (shown in Eq. (3)) for An Binh, An Thinh and Dai Son. It is noted that the HVI here is calculated by using the composite index method, while the HVI calculated by using the IPCC framework approach is provided later in Section 3.2. Overall, the results show that Dai Son has the highest HVI_{FL_d} (i.e., 0.325), indicating that this commune is the most vulnerable area to the impacts of FF&LS when compared with An Binh (0.320) and An Thinh (0.290). It is noticeable to point out from the research data that there are only minor differences in the household vulnerability indices for FF&LS in these three communes. Hence, the index is complemented with a qualitative analysis to facilitate a deeper understanding of which household attributes contribute most to the vulnerability to FF&LS in different communes.

3.1.1. Adaptive capacity

3.1.1.1. Socio-Demographic Profile. Although the percentage of households headed by females is lowest in Dai Son, this commune had the highest vulnerability on the Socio-Demographic Profile component (Dai Son: 0.353, An Binh: 0.258, An Thinh: 0.178). This is mainly because Dai Son has the highest percentage of household heads that belong to ethnic minority groups (i.e., Yao, Tay, H'Mong) (Dai Son: 0.959, An Binh: 0.520, An Thinh: 0.383). Furthermore, 47.95% of respondents in Dai Son reported that they are poor households[7] according to the government's standard, while the percentage of poor households in An Binh (18.83%) and An Thinh (16.2%) is much lower than in Dai Son. It is due to the fact that Dai Son, an ethnic minority and mountainous area, was recognized as an exceptionally difficult region since 2011 under "Program 135" of the Vietnamese Government. Data from household surveys also show that Dai Son has the largest household size at 4.38 persons/household compared to 4.28 persons/household in An Binh and 4.18 persons/household in An Thinh. In addition, with a higher proportion of the dependent members who are under 15 and over 65 years, the dependency ratio is also highest in Dai Son (0.147), followed by An Thinh (0.137) and An Binh (0.130).

3.1.1.2. Livelihood strategies. Survey results show that the greatest vulnerability on the Livelihood Strategies is in An Binh with an index value of 0.357. However, this value is not significantly different among the three communes (e.g., An Binh 0.357, An Thinh 0.342, Dai Son 0.334). The highest percentage of households that lost their jobs during the flash flood and landslide season are found in Dai Son, following by An Thinh and An Binh (i.e., 95.21%, 80.95%, and 77.92%, correspondingly). The livelihood strategies of the surveyed households in this study include growing crops, raising animals, and forestry. On average, the respondents in Dai Son report that they employ 2.80 $\pm$ 0.45 livelihood strategies, while 2.62 $\pm$ 0.60 and 2.54 $\pm$ 0.57 livelihood strategies are reported by households in An Binh and An Thinh, respectively. As a result, the average agricultural Livelihood Diversification Index (LDI) is

[7] Based on the income criteria, the Vietnamese Government defines a poor household as having an income of 700,000 VND (around $30) per person per month for rural areas and 900,000 VND (around $39) per person per month for urban areas.

Table 2
Indexed values for the indicators, key components, and overall HVI_{FLd} for An Binh, An Thinh and Dai Son.

Key components	Indicators	Units	Index Sd			Md		
			An Binh	An Thinh	Dai Son	An Binh	An Thinh	Dai Son
Socio-demographic profile	1. Proportion of dependency	Ratio	0.130	0.137	0.147	0.258	0.178	0.353
	2. Households headed by a female	Percent	0.130	0.086	0.062			
	3. Average age of households' head (only for female)	1/#years	0.361	0.205	0.370			
	4. Household heads having no education	Percent	0.481	0.276	0.452			
	5. Household heads who are ethnic minorities	Percent	0.520	0.383	0.959			
	6. Poor households	Percent	0.188	0.162	0.479			
Livelihood Strategies	7. Average diversification index of farming	1/# livelihoods	0.049	0.055	0.024	0.357	0.342	0.334
	8. Households experiencing jobless during FF&LS season	Percent	0.779	0.810	0.952			
	9. Households who exploit natural resources during FF&LS	Percent	0.039	0.029	0.007			
	10. Households whose a member working in various community	Percent	0.234	0.276	0.123			
	11. Households whose incomes mainly from forestry/agricultural activities	Percent	0.682	0.543	0.562			
Social Network	12. Households without any help/support during FF&LS	Percent	0.331	0.305	0.336	0.312	0.242	0.343
	13. Households who did not provide help to any others	Percent	0.149	0.114	0.295			
	14. Household head does not belong to any organization	Percent	0.506	0.343	0.562			
	15. The ratio of borrowing and lending money of households	Ratio	0.260	0.207	0.180			
Health	16. Average distance (house to the nearest health center (or hospital))	Km	0.102	0.153	0.373	0.277	0.348	0.272
	17. Households whose at least one member has a chronic illness	Percent	0.351	0.219	0.260			
	18. Households who do not have an insurance card	Percent	0.152	0.319	0.025			
	19. Households who are not affordable to pay off the costs of health care	Percent	0.505	0.700	0.429			
Food	20. Households experiencing insufficient food produced from their farm	Percent	0.344	0.476	0.336	0.344	0.337	0.327
	21. Households experiencing decreased production of food	Percent	0.617	0.524	0.562			
	22. Crop diversification index	1/# crops	0.194	0.194	0.283			
	23. Households not raising livestock	Percent	0.221	0.152	0.130			
Water	24. Households experiencing problems to access irrigation water	Percent	0.299	0.552	0.322	0.416	0.340	0.429
	25. Households experiencing problems to access potable water	Percent	0.208	0.067	0.089			
	26. Households using water from a natural resource	Percent	0.740	0.400	0.877			
Housing	27. Households having no Red book	Percent	0.436	0.205	0.160	0.364	0.322	0.309
	28. Households having no toilet facility	Percent	0.104	0.076	0.137			
	29. Households without stabilized houses	Percent	0.552	0.686	0.630			
Hazard impacts	30. Households experiencing house lost or property damage caused by FF&LS	Percent	0.357	0.385	0.219	0.296	0.280	0.269
	31. Households experiencing agricultural land damage caused by FF&LS	Percent	0.896	0.990	0.966			
	32. Households who did not receive FF&LS warnings	Percent	0.117	0.029	0.116			
	33. Households whose a member becomes ill or injured due to FF&LS	Percent	0.104	0.029	0.014			
	34. Households having a recent death caused by FF&LS	Percent	0.019	–	0.007			
	35. Mean standard deviation of monthly average precipitation (1980–2015)	Millimeters	0.285	0.250	0.291			
	HVI_{FLd} An Binh	0.320						
	HVI_{FLd} An Thinh	0.290						
	HVI_{FLd} Dai Son	0.325						

Source: Field survey, 2016.

highest in An Thinh (0.055) compared to the other communes (An Binh: 0.049, Dai Son: 0.024). The result also reveals that Dai Son has the lowest percentage of both households with a family member working in different communities (12.33%) and households exploiting natural resources during FF&LS (0.69%). An Binh, on the other hand, has the highest proportion of these sub-components (23.38% and 3.90%, correspondingly). Noticeably, over 50% of respondents across all research sites reported that their major source of income is from and mostly depends on agriculture.

3.1.1.3. Social Network. The Social Network component shows that the percentage of households receiving assistance is less than the proportion of households providing help to others during FF&LS across the whole research area. Labor support, money lending, spiritual encouragement, and help with seed supply are different kinds of assistance recorded in the three communes. Furthermore, the results show that high percentage of household heads have not participated in any organization in both An Thinh and An Binh (56.16% and 50.65%, correspondingly). Thanks to the lowest percentage of households that have not been a member of any organization (34.29%), An Thinh has the lowest vulnerability index regarding the social network component as explained in the following section.

3.1.1.4. Interaction between farmers' adaptive capacity and ethnicity, farming activity/occupations, and organization membership. "*There are six members in our family. However, only two of us (I and my wife) are working on our five (5) Sao (equivalent to 0.18 ha) of agricultural land and three (3) ha of hilly land. I just finished elementary school, while my wife does not know how to read and write. So we can do nothing without agriculture, and we have no interest in joining any organization*" – A Dao-ethnic and poor household in Village 3, Dai Son commune.

a. Ethnic minorities

In general, ethnic minority communities are marginalized geographically, socially, economically, and politically, not only in the surveyed communes but also generally in the NMR of Vietnam. They typically live in remote regions and their livelihoods greatly depend on natural resources, often on low productivity land (CARE, 2013). According to a farmer in Khe Rong village, An Binh commune: "*Our inter-village road is extremely poor and so difficult to travel, with more than 5 km of muddy road with high steep and too many rocks, our village is often isolated during the rainy season*". Consequently, geography, working environment, and resource difficulties result in high poverty rates among ethnic minorities, though there have been remarkable reductions in the national poverty rates in recent decades. In other words, the gap between ethnic minority groups and the ethnic majority group has expanded (Dang, 2010). Compared to Vietnam's ethnic majority, the 'Kinh' people, ethnic minority groups in the research areas are much poorer with lower levels of education and higher dropout rates from school, resulting in higher levels of illiteracy and a lack of fluency in the main language (i.e., Vietnamese), especially among elderly household heads, which hold minorities back when interacting with other people and taking advantage of outside resources (Fig. 2). An interviewee in Dai Son commune stated that: "The *commune officials often disseminate new local policies, such as loan procedures, as well as information related to agricultural production at commune meetings. Although involved, I often do not understand the full content of the meeting. If the officer distributes the material for reading, then it is also a problem for me because I am illiterate*". In addition, because of poverty the local farmers also experience numerous troubles in seeking enough financial resources to pay for their children's schooling. Furthermore, even though the Government has a policy that each family should have only one or two children, ethnic minorities tend to have more children, which results in greater dependency rates among ethnic minority families than the 'Kinh' families. Combining all of these factors, ethnic minority characteristics have been considered as some of the key elements that cause the reduce community adaptive capacity to FF&LS.

b. Diversity of source of income

Research conducted by Paavola (2008) pointed out that diversity in crops and income sources allows farmers to build a portfolio of livelihoods with diverse risk distributes so that risks, such as those posed by natural hazards or climate change, can be managed, making recovery easier and quicker. In addition, it is also assumed that a farmer who earns income from various sources has a higher adaptive capacity than one with fewer income sources (Abdul-Razak and Kruse, 2017). In this regard, the household's livelihood in the three communes mainly relies on agricultural farming. There are two main sources of income among the surveyed households, including farm and non-farm income, such as crop production (rice, maize, cassava, cinnamon), animal rearing (chicken, pig, cow, buffalo), waged labor, and trading. In general, most households in An Binh are engaged in agriculture and forestry. The commune has also exploited natural resource at most amongst the three surveyed sites. An interviewee in Khe Ly village, An Binh commune – Mr. Dao Lang Tap – acknowledged that: "*The main*

Fig. 2. Respondents using fingerprints as their signatures.

livelihoods of my family with two children and my father are rice, cassava, and cinnamon cultivation. We have no income from off-farm jobs. Hence, it is challenging for us to be able to secure our family income once affected by FF&LS".

c. Organization membership/Farmer's participation in organizations

The key factor influencing adaptive capacity is found to be social networks (McElwee et al., 2010). There are a number of organizations that support farmers in their livelihoods in these communes, for example, the Farmer's Union, Women's Union, Farmer Interest Group, and Agricultural Cooperative. Joining these groups can help farmers get useful information related to agricultural production, such as new varieties, pest and disease status, price changes, as well as information on natural disasters, such as FF&LS. At the same time, participation in these organizations also allows people to have more intimate social ties with other communities and individuals, thereby facilitating them in seeking help or assistance when they are in trouble. In the study area, people often receive in-kind assistance from local government organizations, such as rice, seeds, livestock, or financial support, such as cash. These subsidies are not much, yet also contribute somewhat to helping the households overcome the consequences of natural disasters. In addition, in the country as a whole and in the particular research areas, networks with relatives can be effective channels to gain new information and seek mutual assistance, such as sharing works in crops (Hoang et al., 2006). People also can seek help from their friends or neighbors in the communities, normally in terms of providing loans and labor (i.e., working days).

3.1.2. Sensitivity

3.1.2.1. Health. Among the three research communes, An Thinh displays the highest sensitivity in terms of Health component. The survey results indicate that in total, almost 32% of the interviewed households in An Thinh did not have a health insurance card. As a result, the commune has the highest percentage of households who could not afford health care costs (70% of surveyed households), although the proportion of households having family members with a chronic illness is lowest in An Thinh. In addition, it is important to point out that people in Dai Son have the longest distance from their houses to the hospital (14.82 km), but this commune has the lowest proportion of households without a health insurance card (2.5%). The reason behind this is that most of the respondents in Dai Son belong to ethnic minorities.[8] Therefore, they are provided ethnic health insurance entitling them free treatment at the hospital according to government policy. The survey results also show that the highest percentage of households with a family member that has a chronic illness (35.07%) is in An Binh commune, followed by Dai Son (26.03%) and An Thinh (21.09%).

3.1.2.2. Food. Although there is no significant difference between the Food component among the three communes, it is by no means identical. An Binh is the most vulnerable commune regarding the Food component (0.344). It is noted that 100% of households in these three communes use pesticide, fertilizer, and plant protection products in the production process. The highest proportion of respondents (61.69%) in An Binh reported that the actual usable size of crop yields has decreased in recent years due to the impacts of FF&LS. An Thinh, on the other hand, has the greatest percentage of households with insufficient food from the farm (47.62%) due to these natural hazards. While An Binh respondents reported they grow 2.23 $\pm$ 0.74 types of crop, An Thinh households plant fewer types of crops (2.17 $\pm$ 0.56) and the least is in Dai Son (1.79 $\pm$ 0.87). Of these, the two crops commonly grown in the field are rice and maize and are mainly produced for home consumption. There are also three major harvests per year: the first is for producing Chiem rice in Winter-Spring (from January to middle of May), the second is Mua rice in Summer-Autumn (from middle of May to September), and the third is for Maize (from October to December). In contrast with rice and maize, cassava is normally grown on hilly land, mostly in An Binh and Dai Son communes, and cassava is cultivated in February and gathered in December each year.

3.1.2.3. Water. Regarding the Water component, over 55% of households in An Thinh responded that the amount of irrigation water was not sufficient for their fields, while this rate is much lower in An Binh and Dai Son (29.87% and 31.19%, respectively). The source of irrigation water households used for their plots is primarily from canal systems, making up 57.74% of total irrigated lands. However, not all fields owned by the respondents in the region have access to irrigation canals. This is because many fields were reclaimed illegally by deforesting, which were also located in many different places across hills. The Government, therefore, did not build the canal system for these fields; hence 24.17% farmers in the study zone often use rainwater from ravines in order to irrigate their fields. Water scarcity was found in all three communes, and many farmers even have to compete to get more water for their farms. As a result, it has severe impacts on crop productivity. For example, farmers in Hoa Nam and Cau Cao villages in An Binh commune claimed that the irrigation system is very poor. Thus, they are highly dependent on the weather, and many households in these villages do not plant a winter maize crop due to lack of water. In addition, the result also indicates that An Binh has the highest percentage of households (20.78%) with a problem accessing potable water (lack of water for daily demands), while An Thinh has the lowest proportion of households that face this problem (6.67%). A majority of respondents in Dai Son reported that they are using natural water resources, such as rainwater, water from ravines or from springs or rivers to cook and drink every day, accounting for 87.67% of all respondents. Households usually build their own water tanks and divert water from ravines to these tanks through small water pipes (Fig. 3). In the rainy season, these water pipes are often blocked by rocks and soil from the top of the hills or mountains. As a result, households in these areas do not often have enough water for their daily lives. Remarkably, all these water sources are used directly by families without any treatment process, making them vulnerable to water-borne diseases, such as

[8] The three research communes are home to ethnic minority groups, such as Dao (Black Dao and White Dao), Tay, and Hoa. However, of those, most of the respondents (94%) in Dai Son are ethnic minorities, while the percentage of interviewed households belonging to ethnic minorities in An Binh and An Thinh is lower (62% and 40%, correspondingly)

Fig. 3. Irrigation canals and water pipes in the research areas.

cholera, diarrhea, and measles. Overall, when the sub-indicators are integrated, Dai Son has the greatest water vulnerability score (0.429) compared to the other communes.

3.1.2.4. Housing. In terms of Housing component, in general, there are slight differences in the three communes. For instance, An Binh has the highest vulnerability score of the Housing component (0.364). Over 43% of households in An Binh have no land certificate (called the 'Red Book' in Vietnam). This is due to the fact that in the past these land areas belonged to Yen Bai forestry farms but since 1995 people began to come and build houses without permission from the local government. Currently, if people want to have a land certificate, they need to submit the required documents to the commune, district, and provincial offices. From there, the province committee will decide whether to abolish the ownership of the forestry farms and issue a certificate of land use for households. People, however, are either afraid of doing it or already do it but have not received the certificate because of the complicated nature of the process. The other reason, as mentioned, is because of land fragmentation situation. In this regard, the certifications of land use rights were only issued for total land held by households, without certifying any individual plots. However, households in this region tend to have multiple plots allocated in different places. As a result, most of the lands inherited from parents does not hold the land certificate. Without the Red Book, local people are facing difficulties in accessing financial institutes to mortgage their lands to borrow money.

The survey results also indicated that wood and brick are the main construction materials of houses while the key materials for building floors are cement, marble tiles, and tiles. About 37% of the study households have roofs made from straw or leaves and 29% had cement panels. To define whether housing is stabilized or unstabilized, each type of wall, floor, and roof was scored. The higher the score, the stronger the house. The results show that approximately 62% of respondents owned unstabilized houses, in which An Thinh commune has the highest percentage of households with precarious houses (69% of sample households). The data from household surveys also highlight that Dai Son has the highest proportion of households without a toilet (13.70%), while this percentage is lowest in An Thinh (7.62%). In fact, households with moderately good economic life often build sanitary schemes, whereas low-income families normally have temporary hygienic schemes or nothing (Centre for Sustainable Rural Development, 2010).

3.1.2.5. Who is more sensitive?. a. Living without health insurance

Serious illness of family members is always a major concern of a family, as it affects the morale and spirit of other members, and in terms of economic perspective it has an undesirable and substantial influence on consumption and income. There are two significant financial/economic outflows due to illness: additional expenses for medical care and reductions of income due to a shortage of labor force. In low-income households, these unexpected and unpredictable costs may result in increased rates of poverty and poor health. As a result, these consequences cause households to become unrecovered during periods of major illness, especially for those who are faced with the negative impacts of natural hazards in developing countries where having health insurance is not common. According to the Ministry of Health of Vietnam & Health Partnership Group (2013), without health insurance cards, households may face significantly devastating consumptions, as well as higher impoverishment due to high expenses for health, even though they have lower out-of-pocket spending for health care. In addition, findings by Vo (2016) suggested that the need of increasing health insurance registration rate is essential for reducing the vulnerability of households. As outlined by a farmer in Goc Nu village, An Thinh commune: *"The health insurance fee is costly for us (600.000VND (or $26)/person/year); hence, we live without insurance. When there are health problems, we often do not have enough money to go to the hospital or buy drugs/medicine. Instead, we often use herbs, or our experience to heal ourselves"*. Therefore, due to a large proportion of people living without health insurance, even though An Thinh commune has the fewest households with chronic illnesses and is nearer to health facilities, this commune still had the highest vulnerability in terms of Health component.

b. Inadequate food

As pointed out by Son (2013), the income of approximately 90% of the population in upland regions depends on agriculture or

forestry activities. Also, food insecurity still remains a key issue at the household level in the NMR. Food shortage is often found in households in remote areas where natural resources are scarce and where land cultivation and climate conditions are difficult (Pham et al., 2015). In the study areas, households facing food shortages are those who have little farmland available for cultivation and poor access to the irrigation system. An interviewee in An Thinh commune stated that: *"Our farms are fragmented, and the irrigation system is extremely poor in my village, so we have insufficient food from our farm, especially in case we are affected by FF&LS"*. The survey results showed that regarding the Food component, An Thinh is highly vulnerable because almost 50% of the households have insufficient food from their farm while in both An Binh and Dai Son it is about 34%.

c. No land tenure document

According to one farmer in Khe Trang village, An Binh Commune: *"The procedure of making land certificate has taken so long time, the commune official came to my house sometimes to measure my land. We even entertained them with great meals. However, so far we still have no land tenure document. Hence, it is so difficult for us to borrow money from the banks"*. A large proportion of households (almost 44%) in An Binh commune have not been granted land tenure certificates, although they have all been cultivating land since their settlement. Owning land tenure rights is very important for the local households to ensure their livelihoods, since it is considered a means of furthering sustainable natural resource management by increasing the incentive for landowners to invest in long-term soil improvement (Jakobsen et al., 2007). Furthermore, in the research areas, ownership of land use rights is one of the most important assets to help households access credit sources. In addition, this helps households ensure food security because they have capital to invest in agricultural production. In this regard, although An Binh commune has a lower percentage of interviewed households with precarious houses and without toilet facilities, it is a leading commune in terms of households without the land certificate, which is a major factor affecting vulnerability. Consequently, An Binh displays the highest vulnerability towards the Housing component.

d. Relying upon natural water sources

The ability to access clean drinking water is one of the key factors which affects vulnerability to health problems caused by weather and/or other factors. In addition, lack of water resources is one of the most important barriers to poor people's adaptation in the NMR. However, in the study areas, it was acknowledged by most of the farmers in Dai Son commune that: *"Our village has no clean water schemes, my family as well as most of my neighbors are using water from creeks without water treatments, leading to health diseases. Furthermore, during the dry season, we do not have enough water for cooking and drinking"*. Water supply is one the most frequently mentioned needs in the commune because they still do not have access to this service. The household survey indicated that almost 90% of the households in Dai Son commune utilize natural water resources for both their daily lives and agricultural production. As a result, it leaves people in the commune more vulnerable to health-related problems due to lower levels of food and water security (because of the water shortages), and water-borne diseases associated with low water quality.

3.1.3. Exposure

3.1.3.1. Hazard impacts. Although the percentage of households who did not receive FF&LS warnings is lowest in An Thinh (2.86%), this commune has the highest proportion of households who had their house or property damaged due to FF&LS (38.46%). However, it is important to point out that most of the respondents reported that their agricultural land was damaged due to FF&LS (more or less 90%), especially in An Thinh (99%). The results also show that the greatest proportion of respondents with an illness/injury (10.39%) or a recent death (1.95%) due to FF&LS reside in An Binh. Among the three communes, Dai Son received more average rainfall between 1980 and 2015. Combining the value of the sub-elements, the overall vulnerability index of Hazard Impacts is highest in An Binh (0.296) (Fig. 4).

3.1.3.2. Household exposure – locational dimensions are closely linked with a households' damages. The physical location of a household is one critical influence in relation to the distribution of hazard effects (Few and Tran, 2010). For example, households situated

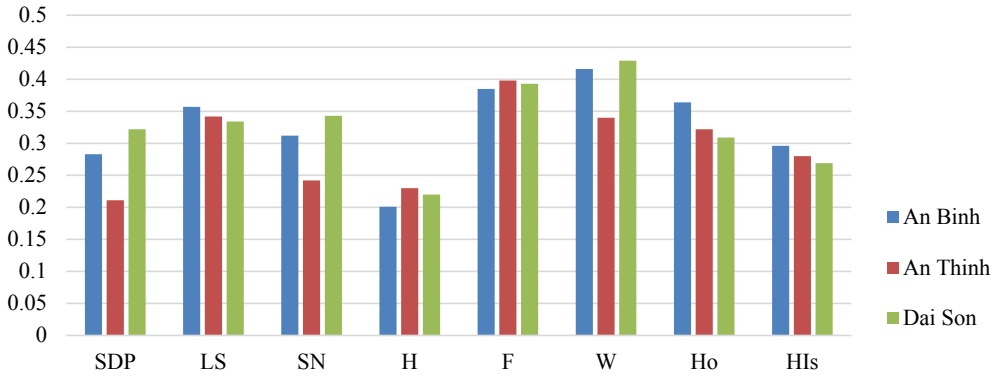

Fig. 4. Major components of the LVI for An Binh, An Thinh, and Dai Son. Note: SDP: Socio-Demographic profile; LS: Livelihood strategies; SN: Social network; H: Health; F: Food; W: Water; Ho: Housing; and HIs: Hazard Impact.

Fig. 5. Inter-village road in the research sites.

alongside the river or stream networks are considered to be more vulnerable to flash floods and bank erosion. Mr. Lich – a former village head in Goc Nu village, An Thinh commune stated that: *"The flash flood occurs every year from May to August in our village because we located alongside with the Ngoi Buc river. As a result, there are so many households in the village suffering flash floods so that their fields have been turned into streams due to flash floods"*. In An Binh commune, many households located at the foothill's edge are more vulnerable to landslide conditions. As Mr. Ly Van Sang in Khe Trang village, An Binh Commune remarked: *"My wife was passed away by the landslide in 2008 while working on the hill. A nine years old buffalo and one ton of fertilizer were swept away due to the flash flood. Also, 1 ha of our hilly land could not recover after the landslide"*. Furthermore, as pointed out by Few and Tran (2010), the location of households is also a key factor affecting their abilities to prepare for and prevent impending hazard events. In the research areas, households can get information related to warnings and risk by different channels, including the announcement by digital means, such as village speakers, television or in-person public meetings in the village. Therefore, for those who are situated at remote areas of rural villages, they may be unable to reach the audible range of loudspeakers, disconnected to the media, or uninformed of public meetings (Fig. 5). As an interviewee in An Binh indicated: *"My family has a television, but I rarely watch it. Because the signal here is not good and I often spend my whole day on the field or in the forest. Furthermore, we are not at the reach of the loudspeaker in the village because we are too far away from it"*.

3.2. HVI_{FLd}–IPCC

The result related to the HVI_{FLd} from using the HVI_{FLd} – IPCC approach is consistent with the calculated HVI_{FLd} based on the composite index method. It shows that Dai Son is the most vulnerable commune due to FF&LS (−0.0739), following by An Binh (−0.07408) and An Thinh (−0.083) (shown in Table 3). It also indicates that An Binh is more exposed to flash flood and landslide impacts (0.296) than An Thinh (0.280) and Dai Son (0.269). Furthermore, An Binh is also considered the most sensitive commune regarding Health, Food, Water, and Housing under the impacts of these climate and weather-related events among the three communes. Based on the results from the Socio-Demographic Profile, Livelihood Strategies, and Social Network components, Dai Son has the lowest adaptive capacity (0.488) compared to An Binh (0.513) and An Thinh (0.537). To summarize, although Dai Son has the least exposure to the impacts of FF&LS, due to its high sensitivity and low adaptive capacity, this commune is still the most affected area.

4. Discussion and conclusion

Flash floods and landslides (FF&LS) are serious natural hazards in the NMR in Vietnam. People living in this area are also mainly from minority ethnic groups with lower levels of education and income, and poor housing systems. This is also a highly hilly remote area with poor infrastructure, which causes significant difficulties for transport to nearby cities or centrals of main towns for shopping and seeking assistance or services, such as healthcare. In addition, households in this region are extremely poor and lack food and freshwater used for daily life and production activities. They also mainly rely on their own agricultural produce for daily meals.

Table 3
HVI_{FLd}-IPCC contributing factors in An Binh, An Thinh, and Dai Son.

Contributing factors	An Binh	An Thinh	Dai Son
Adaptive capacity	0.513	0.537	0.488
Sensitivity	0.342	0.323	0.338
Exposure	0.296	0.280	0.269
Overall HVI_{FLd}-IPCC	−0.074	−0.083	−0.073

Hence, they are highly vulnerable to the FF&LS that occur frequently in this region. This study considers this issue to determine what are the most influential factors contributing to their vulnerability so that policymakers in Vietnam can be provided with useful information to issue appropriate policies or assisting programs for the timely support of people in this region. The importance of the findings is highlighted by the fact that the research area (three communes in Van Yen district, Yen Bai province) in this study is regarded as one of the extremely difficult and poor regions specified under "Program 135" provided by the Vietnamese Government, which would need special support from the Government and public.

This research uses the HVI_{FLd} and a substitute approach (HVI_{FLd} – IPCC) in combination with in-depth qualitative data to assess rural household's vulnerability to FF&LS in three agro-ecological areas in Van Yen district. The HVI_{FLd} and HVI_{FLd} – IPCC and corresponding indicators used in this study are also replicable with necessary modifications for assessing the vulnerability of smallholder farmers in other hazard-prone regions having similar geographic. Each approach provides a detailed description of the determinants that affect the vulnerability of the household. These approaches, however, also reveal their limitations, particularly in terms of subjectivity in the selection of the sub-indicators comprising the index, as well as a lack of precise information on FF&LS. The results of this study point out which key factors affect the capacity of households to adapt to FF&LS, and identify who are likely to be more sensitive and are more exposed to these events. The overall indices show that households in Dai Son commune are the most vulnerable, although there is a slight difference among three communes. However, upon zooming in detail in each principal component, many exciting findings are found.

We particularly found that ethnicity, diversified source of income, and organization membership are the most critical factors influencing the Adaptive Capacity of smallholder rural households in the research areas. We also observed that most families in Dai Son belong to ethnic minority groups (Dao, Tay, Hoa) with a low education level and a high dependency rate. These factors impede people's ability to receive/absorb information and policies from local authorities and thus weaken their adaptive capacity. Also, their diversity of livelihood income is extremely low due to great dependence on agriculture and forestry. Ensuring income levels of households affected by FF&LS is also a great challenge, thereby leading to intensive exploitation of natural resources of local people in the region.

We also found that participating in social organizations such as the Farmer's Union, the Women's Union, Farmer Interest Group, and Agricultural Cooperative not only provides people useful information for agricultural activities but also helps them to have a close connection with the community. Obviously, non-participation in any organizations leads to inefficient social links/networks for local people in the region; for example, it is difficult to receive support from the community. There is evidence that in-kind support (e.g., rice, seeds, livestock or exchanging working day) and spiritual assistance have commonly witnessed in the study areas. In terms of Sensitivity, health insurance, food security, land tenure document, and water resources are recognized to be the key components in increasing people's sensitivity under the impacts of FF&LS. We also observed that living without insurance pushes local people to face difficulties in paying for health-related expenses. Since the majority of people in An Thinh commune are Kinh people (the only major ethnic group in Vietnam), who are not eligible for free social insurance under the Government's policy, An Thinh has the lowest percentage of households with health insurance in the research areas. Meanwhile, the inefficiencies of the irrigation system and the shortage of arable land have left rural households with insufficient food and caused them to become more sensitive to the effects of FF &LS. Abuse of fertilizers and pesticides has also been reported throughout the study area, which not only affects the reduction of soil fertility but also seriously influences people's health. Besides, water availability is also an important factor since most households are relying upon natural water resources for both daily life and production activities, leading them to become more exposed to health-related diseases and often face water shortages in the dry season (it sometimes happens during the rainy season when the water pipes are buried by rocks). Furthermore, lack of land certificate hinders local people's access to credit, which in turn leads to food insecurity, consequently increasing people's sensitivity to natural disasters. Land fragmentation was also considered to be a major obstacle in accessing land certificate. Regarding Exposure, housing location as well as arable land, including agricultural and forest land, were found to have a strong relationship in affecting households' exposure to FF&LS. The favorable location facilitates people in accessing information from a variety of sources, including through the media as well as through village meetings. To sum up, both employed approaches demonstrated that households in Dai Son commune, a highland region characterized by cinnamon growing, are the most vulnerable to the impacts of FF&LS, despite this commune being the least exposed area to these natural hazards. Thanks to its highest adaptive capacity, including the Socio-Demographic Profile, Livelihood Strategy, and Social Network components, An Thinh was found to be the least vulnerable region among the three communes.

To reduce household vulnerability in the research areas, we recommend a wide range of policies that need to be implemented/considered. Firstly, it is necessary to improve people's literacy by opening free literacy classes. At the same time, the local government should help farmers by organizing vocational classes, such as handicrafts (knitting, sewing, etc.); and by guiding them on how to process agricultural products to reduce their dependence on agricultural production. This would also have a positive impact by improving people's income, thereby helping them escape poverty. Thirdly, the government may also need to encourage people to use different measures to protect their cultivated lands, such as planting grass strips or making stone embankments alongside fields, ditches, and rivers. In addition, there is a need to improve drinking water quality by providing clean water sources, building water tanks and conducting water treatment before people use it. We also basically recommend local authorities to facilitate people in the process of issuing land use right certificate through the reduction of related paperwork. Since small and fragmented plots are mentioned as the reason hindering farmers to get the land certificate, policy interventions should also consider reducing fragmentation by promoting exchanging agricultural land plots between households. It is also important to notice that to help farmers reach updated information on FF&LS, upgrading infrastructure, such as public transportations, roads as well as media protocols, is essential. Lastly, supporting policies and considerable financial supports should also be provided to upgrade irrigation systems to ensure sufficient water during the dry season and to protect soil in the rainy season. Since our focus in this research is to find out the

livelihoods of local people and to reveal the factors affecting rural household vulnerability to FF&LS, there is a room for future research to pay attention to understanding and analyzing which livelihoods are appropriate and able to help people reduce their vulnerability to these natural disasters.

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Appendix A

Table A1
Key characteristics of the study areas.

Category	An Binh	An Thinh	Dai Son
Total area (km^2)	36.14	26.37	83.75
Location	Middle land	Low land	Highland
Number of villages	8	18	8
Major crops	Cassava	Rice	Cinnamon
Total population (person)	4142	9000	3249
Population density (person/km^2)	115	274	28
Minority ethnic groups	Dao	Tay, Dao	Dao

Source: Field survey, 2016.

Table A2
List of the key components and indicators comprising the HVI_{FL}.

Key components	Indicators	Additional explanation	Assumed functional relationship
Socio-demographic profile	1. Proportion of dependency	Proportion of people between 0 and 14 and over 65 years old to the people aged 15 to 64 years old	The higher the dependency ratio, the lower the adaptive capacity
	2. Households headed by a female		The lower the percentage of female-headed households, the higher the adaptive capacity
	3. Average age of households' head (only for female)		The older the female-headed household, the higher the adaptive capacity
	4. Household heads having no education	Proportion of families that the head of household did not go to school	Education plays a vital role in helping people be more aware and able to adjust to FF&LS
	5. Household heads who are ethnic minorities		Ethnic minority groups have less adaptive capacity than the ethnic majority group
	6. Poor households	Household who have an income of 700,000 VND (around $30) per person per month.	The wealthier the household, the higher the adaptive capacity
Livelihood Strategies	7. Average diversification index of farming	Calculated by adding together the total number of agricultural livelihood activities plus 1 and dividing by 1, e.g., if a household has three different activities such as cultivating crops, raising livestocks and exploits natural resources then the index will be: 1/(3 + 1) = 0,25	Livelihood diversification strengthens adaptive capacity
	8. Households experiencing jobless during FF&LS season		Having no job reduces people's capacity to adapt
	9. Households who exploit natural resources during FF&LS		Families who exploit natural resources have less adaptive capacity
	10. Households whose a member working in various community	Percentage of households reporting that at least one family member works outside of the community	Job diversification increases adaptive capacity
	11. Households whose incomes mainly from forestry/ agricultural activities		The more diverse the income source, the greater the adaptive capacity

(*continued on next page*)

Table A2 (*continued*)

Key components	Indicators	Additional explanation	Assumed functional relationship
Social Network	12. Households without any help/support during FF&LS		Receiving outside help increases a household's adaptive capacity
	13. Households who did not provide help to any others		Providing help to other people strengthens adaptive capacity
	14. Household head does not belong to any organization		Information and support from organizations increases adaptive capacity
	15. The ratio of borrowing and lending money of households	The ratio of household borrowing to household lending (until now). E.g. If a household borrowed money but did not lend money, the ratio would be 2:1; if a household lent money but did not borrow money, the ratio would be 1:2	The higher the ratio, the more financial stress and less capacity for adaptation
Health	16. Average distance (house to the nearest health center (or hospital))		The longer the distance, the more vulnerable
	17. Households whose at least one member has a chronic illness		Families with chronic illnesses are more sensitive
	18. Households who do not have an insurance card		Families without an insurance card are more sensitive
	19. Households who are not affordable to pay off the costs of health care	Percentage of households who reported they cannot afford the costs related to health care in case of sickness	The less capability of paying for health-related costs, the more sensitive the household
Food	20. Households experiencing insufficient food produced from their farm		Lack of food increases sensitivity
	21. Households experiencing decreased production of food	Percentage of households who reported decreasing crop yields	Reduced crop yields reflects more sensitivity
	22. Crop diversification index	The inverse of (the total number of crops + 1)	Crop diversification decreases sensitivity
	23. Households not raising livestock		Raising livestock may decrease sensitivity
Water	24. Households experiencing problems to access irrigation water		Limited access to irrigation water increases sensitivity
	25. Households experiencing problems to access potable water		The higher the percentage, the higher the sensitivity
	26. Households using water from a natural resource	Proportion of families reporting that they use water from rivers, lakes, or creeks as their primary water source	Households utilizing natural water resources are more sensitive
Housing	27. Households having no Red book	Proportion of families who reported they have no land certificate (Red book)	Land tenure certification helps a family to decrease sensitivity
	28. Households having no toilet facility		Households without a toilet facility are more sensitive
	29. Households without stabilized houses	Percentage of households that have an unsolid house, based on the main material of house's walls, floor and roof	An unstabilized house increases sensitivity
Hazard impacts	30. Households experiencing house lost or property damage caused by FF&LS	Percentage of households reporting that they lost a part of their house or property due to FF&LS	The higher the percentage, the greater the exposure
	31. Households experiencing agricultural land damage caused by FF&LS		The higher the percentage, the greater the exposure
	32. Households who did not receive FF&LS warnings		The higher the percentage, the greater the exposure
	33. Households whose a member becomes ill or injured due to FF&LS		The higher the percentage, the greater the exposure
	34. Households having a recent death caused by FF&LS		The higher the percentage, the greater the exposure
	35. Mean standard deviation of monthly average precipitation (1980–2015)	Standard deviations from the average monthly precipitation between 1980 and 2015 was averaged for each commune	

Table A3
Actual minimum and maximum indicator values for An Binh, An Thinh, and Dai Son.

Key components	Indicators	Units	An Binh	An Thinh	Dai Son	Maximum value in 3 villages	Minumum value in 3 villages
Socio-demographic profile	1. Proportion of dependency	Ratio	0.39	0.41	0.44	3.00	0
	2. Households headed by a female	Percent	12.99	8.57	6.16	100.00	0
	3. Average age of households' head (only for female)	1/#years	0.02	0.02	0.02	0.03	0.011
	4. Household heads having no education	Percent	48.05	27.62	45.21	100.00	0
	5. Household heads who are ethnic minorities	Percent	51.97	38.32	95.89	100.00	0
	6. Poor households	Percent	18.83	16.19	47.95	100.00	0
Livelihood Strategies	7. Average diversification index of farming	1/# livelihoods	0.29	0.29	0.27	1.00	0.250
	8. Households experiencing jobless during FF&LS season	Percent	77.92	80.95	95.21	100.00	0
	9. Households who exploit natural resources during FF&LS	Percent	3.90	2.86	0.68	100.00	0
	10. Households whose a member working in various community	Percent	23.38	27.62	12.33	100.00	0
	11. Households whose incomes mainly from forestry/agricultural activities	Percent	68.18	54.29	56.16	100.00	0
Social Network	12. Households without any help/support during FF&LS	Percent	33.12	30.48	33.56	100.00	0
	13. Households who did not provide help to any others	Percent	14.94	11.43	29.45	100.00	0
	14. Household head does not belong to any organization	Percent	50.65	34.29	56.16	100.00	0
	15. The ratio of borrowing and lending money of households	Ratio	0.89	0.81	0.77	2.00	0.5
Health	16. Average distance (house to the nearest health center (or hospital))	Km	4.78	6.65	14.82	38.00	1.000
	17. Households whose at least one member has a chronic illness	Percent	35.06	21.90	26.03	100.00	0
	18. Households who do not have an insurance card	Percent	15.17	31.89	2.50	100.00	0
	19. Households who are not affordable to pay off the costs of health care	Percent	50.45	70.00	42.86	100.00	0
Food	20. Households experiencing insufficient food produced from their farm	Percent	34.42	47.62	33.56	100.00	0
	21. Households experiencing decreased production of food	Percent	61.69	52.38	56.16	100.00	0
	22. Crop diversification index	1/# crops	0.33	0.33	0.40	1.00	0.167
	23. Households not raising livestock	Percent	22.08	15.24	13.01	100.00	0
Water	24. Households experiencing problems to access irrigation water	Percent	29.87	55.24	32.19	100.00	0
	25. Households experiencing problems to access potable water	Percent	20.78	6.67	8.90	100.00	0
	26. Households using water from a natural resource	Percent	74.03	40.00	87.67	100.00	0
Housing	27. Households having no Red book	Percent	43.60	20.46	16.01	100.00	0
	28. Households having no toilet facility	Percent	10.39	7.62	13.70	100.00	0
	29. Households without stabilized houses	Percent	55.19	68.57	63.01	100.00	0
Hazard impacts	30. Households experiencing house lost or property damage caused by FF&LS	Percent	35.71	38.46	21.92	100.00	0
	31. Households experiencing agricultural land damage caused by FF&LS	Percent	89.61	99.05	96.58	100.00	0
	32. Households who did not receive FF&LS warnings	Percent	11.69	2.86	11.64	100.00	0
	33. Households whose a member becomes ill or injured due to FF&LS	Percent	10.39	2.86	1.37	100.00	0
	34. Households having a recent death caused by FF&LS	Percent	1.95	–	0.68	100.00	0
	35. Mean standard deviation of monthly average precipitation (1980–2015)	Millimeters	126.94	114.39	129.07	380	25.9

Source: Field survey, 2016.

Appendix B

Regarding the function of vulnerability, Fellmann (2012) describes exposure as a relation of the nature and exposed level of a system to nontrivial climate changes. Sensitivity, on the other hand, describes the affection level (either positive or negative) caused by the reaction of human in particular environmental conditions. Meanwhile, adaptive capacity indicates the likelihood to having tools or adaptation approaches to prevent potentially adversed impacts.

There is no specific form of the relationship between vulnerability and these three independent endogenous components. However, it follows that increased expose and sensitivity is positively correlated to vulnerability while increased adaptive capacity has negative impacts on vulnerability (Ford and Smit, 2004). In other words, decreasing the system vulnerability requires weakening the sensitivity and improving the adaptive capacity of the related system (Fig. B1) (Fellmann, 2012).

On the contrary, if the system is less exposed and less sensitive, but has a robust adaptive capacity, it is understood as being less vulnerable (Smit et al., 1999; Smit and Wandel, 2006).

According to Deressa et al. (2009), indicator and econometric approaches are two common analytical methods often employed to assess the levels of household vulnerability to climate change, in which the indicator methods identify main variables that affect vulnerability. In other words, by using multiple techniques (e.g., judgment by experts, analysis of principle component, or correlation analysis with disasters happened in the past) researchers will select key indicators among numerous indicators. This approach, however, is constrained by the researchers' subjectivity when choosing indicators (Hahn et al., 2009). Regarding econometric approaches, there are often three principal methods (Hoddinott and Quisumbing, 2003): Vulnerability as Expected Poverty (VEP), Vulnerability as low Expected Utility (VEU) and Vulnerability as uninsured Exposure to Risk (VER). Of these, VEP and VEU are universal to assess individuals' vulnerability, while VER is used to examine loss of welfare because of external shocks. However, testing different econometric assumptions, such as hypotheses, standard errors and confidence intervals, are highly challenging. In addition, users often use weak or unclear assumptions related to causality which may result in biased indicator selection. As a result, the present study employs an indicator-based vulnerability assessment method, the Household Vulnerability Index (HVI_{FL}), developed by Hahn et al. (2009).

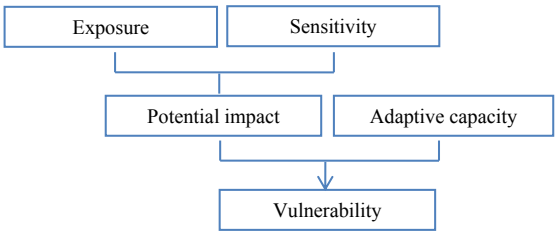

Fig. B1. Vulnerability and its components. Source: Fellmann (2012).

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