Assessment of Natural Disasters in Vietnam's Northern Mountains

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Assessment of Natural Disaster Risks in Vietnam's Northern Mountains

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Abstract

This study presents risk assessment of natural disasters in the poor provinces in Northern Mountain of Vietnam. We construct an Aggregate Risk Index that is a composite index comprising of three separate components: the Hazard Potential Index, Hazard Exposure Index and Coping Capacity Index. Using this index, we can rank the natural risk level of communes and districts in Northern Mountains. In addition, using qualitative method, we find that extreme and prolonged cold, drought, storm, and flash flood are seen as the most common extreme weather events that have threatened public infrastructure, household properties and especially agricultural production in particular. Among the most common extreme weather events, extreme and prolonged cold is seen as the most damaging event to for rice, other food crops, and husbandry activities since extreme and prolong cold directly affects productivity of main crops and usually causes deathly diseases in animals. Landslide caused by heavy rain, flood and flash flood results in severe damages to local infrastructure, especially traffic roads and irrigation systems located by near high mountains, hills or rivers, ponds and streams.

Key words: risk index, natural disaster, livelihood, climate change, Vietnam.

JEL classification: O12, Q54, D12

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1. Introduction

The World Bank has named Vietnam among the list of 12 countries most vulnerable to climate change[1], which is widely believed as the explanation for the growing number of severe and erratic weather occurrences in recent years. The increasing severity and incidence as well as the rising unpredictability of extreme weather events affect both individuals and communities, and leave serious social, economic, as well as environmental consequences. The immediate impacts of extreme weather events include loss of human life, damage to property and infrastructure, destruction of crops and loss of livestock.

The Northern mountain region is more prone to climate change not only because of the growing number of extreme weather events during the past years but also of its heavy reliance on agricultural livelihoods which are highly susceptible to changes in weather. This is one of the major reasons why the region has the highest poverty incidence throughout the country[2]. In such context, the second phase of Northern Mountains Poverty Reduction Project (NMPRP-2) aims to contribute to poverty alleviation and the eradication of hunger in the North-western Mountains region to align with the Vietnamese Government's Socio-Economic Development Plan (SEDP) for 2010–2015. The NMPRP-II targets the poorest areas in Northern Mountain region of Vietnam covering the most remote and difficult-to-reach communes, where the majority of project beneficiaries are ethnic minorities. The project is operated in 2,366 villages of 230 communes in 27 districts of the 6 provinces including Lao Cai, Yen Bai, Son La, Hoa Binh, Dien Bien, and Lai Chau. All villages in selected communes are eligible to benefit from project support activities within project components[3].

The development objective of the NMPRP-II is to enhance the living standards of the beneficiaries through improvements in their access to productive infrastructure, productive and institutional capacity of local governments and communities, and market linkages and business innovations. Achievements of the project development objective will be evaluated on two outcome indicators:

- At least 60 percent of the project beneficiaries report satisfaction on the selection, design, and implementation of project activities.

[1] The World Bank in Climate adaptation and Development report (2008) identified 5 most serious hazards caused by climate change: drought, flood, storm, rising sea level and agricultural loss. Vietnam was listed among 12 most affected countries. It is estimated that nearly 16% of the country's area, 35% population and 35% GDP would be damaged if the sea level rises by 5m.
[2] World Bank Vietnam (2010). "Second Northern Mountain Poverty Reduction Project - Project Appraisal Document ": 27.
[3] ibid

- The project beneficiaries report an improvement in on-farm and off- farm income of at least 10 percent over the life of the project[4].

To achieve the foremost objective of the project, it is crucial to gain an insight into project communes' vulnerability to extreme weather events through the identification, analysis and evaluation of natural disaster risks faced by these areas. Based on findings on natural disaster risk exposure of the region, an evaluation of the region's adaptability can also be developed, which would significantly contribute to recommendations on enhancing its resilience through appropriate coping measures. Within the project's subcomponent 3.5 – *Safeguarding assets of communities and households*, this vulnerability assessment report is developed with an aim to support the NMPRP-II in building the knowledge of beneficiary communities on and capacity of understanding and mitigating natural disaster risks as well as in promoting their efforts to address natural disaster hazards in order to reduce the vulnerability of 6 project provinces.

The report comprises five sections. The second section provides background information on six project provinces with regard to their geography, topography, climate pattern as well as demography. An overview of the poverty status of major ethnic minorities in the project area is examined in part two while part three goes to discuss the general context of climate change in the region. The third section presents the methodology to construct risk index of natural disasters. The fourth sections presents assessment of the vulnerability of project communes to natural disaster risks. Finally, the fifth section concludes.

2. Economic background and natural disasters

2.1. Background

Northern Mountain region is characterized by high variation in terms of topography, climate and biodiversity. The region can be relatively and conventionally divided into three different altitudinal zones: (i) high mountain (upland) zone, (ii) the mid-elevation zone and (iii) low mountain (lowland) zone. The high mountain zone, which is normally above 800m from sea level, is comprised of the highest and most

[4] ibid

inaccessible areas where water scarcity is a frequent phenomenon and the temperature is usually low. This is often the most remote and economically least- or under-developed area. The mid-elevation mountain zone is found between the high and low zones with more temperate climate. Meanwhile, most low mountain zones are better watered and the average temperature is relatively warmer. Their access to markets, services and major transportation routes is in general better than that in the other zones (Tran, D.T, 2003). There are two distinct seasons in the region. The dry season characterized by cold climate usually starts from October to March while rainy season lasts from April to October. This part provides an overview of 6 project provinces in term of their geographical, typographical, climatic as well as demographic characteristics.

Yen Bai

Yen Bai province spreads over a total land area of 6,899.5 square kilometers. Yen Bai is located between North East and North West region. The province borders the provinces of Lao Cai Phu Tho, Ha Giang, Tuyen Quang and Son La. The province is divided in nine administrative units including one municipal city, one provincial town and seven districts with 180 communes among them 70 are upland communes and 62 extremely difficult communes among which 40 communes in 5 districts of the province are selected for the NMPRP-II(Yen Bai Government, 2013).

Yen Bai experiences tropical monsoon climate. The mean temperature ranges from 18^0C to 20^0C. The highest temperature during summer can climb up to 39^0C while during winter, it can fall as low as 2^0C to 4^0C. Annual rainfall is from 1,500 mm to 2,200 mm and the mean humidity is in the range of 83% to 87%. Frost often occurs in the locality which is higher than 600 meters while in lower land alongside the Red River, the phenomenon is not common. At the end of spring or early summer, the province sometimes experiences hailstorm, especially in high mountain area. Snowing condition, despite its rarity, can occur in area which is above 1,000 meters above the sea level by winter-end (Yen Bai Government, 2013).

By 2012, the population of Yen Bai province is estimated at 765,109 with a density of 111 people per square kilometer. The population mainly concentrates in urban areas such as Yen Bai city, Nghia Lo town and other district towns. The province is home to 30 ethnic groups in which Kinh makes up nearly half of the population (49%) whereas Tay, Dao, H'mong and Thai account for 18.58%, 10.31% 8.9% and 6.7% respectively(Yen Bai Government, 2013).

Lao Cai

Lao Cai province has a total area of 6,283.9 km^2 and is bordered with Ha Giang province, Yen Bai province, and Lai Chau province. Lao Cai shares 203 kilometer border line with the province of Yunnam, China. The province of Lao Cai comprises Lao Cai city and 8 districts: Muong Khuong, Bat Xat, Bac Ha, Bao Thang, Sapa, Bao Yen, Van Ban, Si Ma Cai (Lao Cai Government, 2013). The province has 45 communes in 4 districts selected for the NMPRP-II.

Lao Cai has complex topography which results in different climatic zones. Most of the areas within the province are 300 meters to 1,000 meters above the sea level. Cities along the Red River and Chay river including Lao Cai city, Cam Duong, Bao Thang, Bao Yen and the east side of Van Ban district are located at lower heights with less difficult topography granting more convenient access to transport, production activities and services. As the province is mostly mountainous, it experiences the tropical monsoon climate with a dry cold season from October to March and rainy season lasting from April to September. The annual average temperature for lowland area ranges from 23°C to 29^{o}C while that for upland area is around 15^{0}C. In some part of the province such as Sapa, the temperature hardly goes above 20^{0}C temperature and possibly drops to less than 0 °C with snowing conditions during winter. Fog and frost are a common phenomenon in the province, especially during extreme cold period. Annual average rainfall is in the range of 1,800 mm to 2,000 mm for upland and 1,400 mm to 1,700 mm for lowland area(Lao Cai Government, 2013).

Statistics by the General Statistics Office (GSO) by the end of 2010 shows that Lao Cai has a population of 637,500 with a density of 100 people per square kilometre (GSO, 2011). Lao Cai has 25 different ethnic groups. Ethnic minorities account for more than 64% of the whole population. The distribution of the ethnic minorities is consisted by 35,9% Kinh, 22,21% H'mong, 15,84% Tay, 14,05% Dao, 4,7% Day, 4,4% Nung, and other groups including Phu La, San Chay, Ha Nhi, La Chi, etc(Lao Cai Government, 2013).

Son La

Son La province spreads over a total land area of 14,055 km^2 and borders the provinces of Yen Bai, Lao Cai, Hoa Binh, Phu Tho, Lai Chau, Dien Bien, and Thanh Hoa. It also has 250 kilometers of border line with Laos in the north east. The province is roughly around 600 to 700 meters above the sea level and segregated into three different ecological zones. The province has one municipal city along with 11 districts with a total number of 204 commune-level units: 7 wards, 9 towns and 188 communes(Son La Government, 2013). Under the NMPRP-II, the province has 37 communes in 5 districts.

Son La experiences dry cold season from October to March and hot humid season from April to September. The mean temperature of the province ranges from 16°C to 27°C. Average annual rainfall is in the range of 1,200 mm to 1,600 mm and the average humidity is around 81%. Na San and Moc Chau which are higher than 800 meters above the sea level are the largest plateaus with distinct typographic characteristics. Temperate climate in these areas with mean temperature below 18°C and availability of fertile land give favourable conditions for these areas to grow industrial crops, fruit crops, raise livestock and develop co-tourism(Lao Cai Government, 2013).

By 2011, the population of Son La is estimated at 1,119,400 people with a density of 79 people per square kilometre (GSO, 2011). The composition of ethnic groups in Son La is very diverse. Son La inhabitants come from multiple groups. Some notable ethnicities include Xinh-Mun, Muong, La Ha, Thai, H'Mong, Kinh, and Dao.

Hoa Binh

Situated at the crossroad of the North-western mountain region, Hoa Binh province is 76 kilometers away from Hanoi with direct route leading to provinces of Phu Tho, Ha Tay, Ha Nam, Ninh Binh. Hoa Binh also borders with provinces of Thanh Hoa and Son La. With a total land area of 4,662 km^2, Hoa Binh has 37% forest land, and 15% agricultural land. Hoa Binh has 10 districts and towns which are Da Bac, Tan Lac, Kim Boi, Luong Son, Lac Thuy, Yen Thuy, Ky Son and the town of Hoa Binh(Vietnamese Government Portal, 2013). Among 230 NMPRP-II communes, Hoa Binh has 42 communes of 5 districts.

Hoa Binh topography is separated into two zones: upland and lowland. The upland region which is around 600 to 700 meters above the sea level lies in the North-western of the province making up nearly 45% of the total area while the South-eastern lowland region accounts for 55% of the total area with a height of less than 200 meters. The upland region covers remote and difficult areas of the province with complex and steep topography(Vietnamese Government Portal, 2013).

Hoa Binh's climate is representative for tropical monsoon with a cold dry season and a hot humid season. The mean temperature is around 23°C going from 27°C to 29°C during summer and 15.5°C to 16.5°C in winter (Vietnamese Government Portal, 2013).

The population of the province by 2011 is estimated at 799,800 people. With a density of 174 people per square kilometer, it is among five most densely populated provinces in the Northern mountain region (GSO, 2011). Muong people are the largest ethnic group in Hoa Binh accounting for more than 60% of the province's population. Other ethnic groups include Kinh, Thai, Tay, and Dao(Vietnamese Government Portal, 2013).

Lai Chau

The province of Lai Chau is 450 kilometers South East of Hanoi and borders with Chinese province of Yunnan in the North and North West. It also borders Dien Bien, Lao Cai, Yen Bai and Son La. Sharing a border line of nearly 270 kilometers with China, Lai Chau has held a strategic role in ensuring national security. Covering a total area of 9,068.78 km^2, Lai Chau province comprises 8 administrative units. It has 7 districts with 96 communes, 5 wards and 7 towns (Lai Chau Government, 2013). Under the NMPRP-II, Lai Chau has 30 communes in 4 districts.

With numerous steep hills and mountains as well as deep and narrow valleys and rivers, streams and ponds, Lai Chau is endowed with huge potentials for hydropower development. Forest land area still accounts for as high as 35% of the province's total land area with wide varieties of fauna and flora species. 9.28% total land is used for agricultural production purposes (approximately 84,209.3 ha) (Lai Chau Government, 2013).

There are two distinct seasons in Lai Chau: rainy season from May to September with high humidity and precipitation; and dry season from November to March with low temperature and precipitation. The annual average rainfall approximates 2,500 mm to 2,700 mm whereas the mean temperature of the province ranges from 21ºC to 23ºC (Lai Chau Government, 2013).

By the end of 2011, Lai Chau's population is estimated at 391,200 people and has the lowest density in the region (43 people per square kilometer) (GSO, 2011). Lai Chau accommodates 20 different ethnic groups whereby Thai and H'Mong hold the highest proportion of the population (34% and 22.3% respectively). Kinh and Dao people also account for more than 10% population. Lai Chau is also home to such ethnic minorities as Ha Nhi, Giay, Kho Mu, La Hu, and Lu, etc (Lai Chau Government, 2013).

Dien Bien

Dien Bien is a newly established province separated from Lai Chau province with a total area of 9,554.11 km^2. It borders the provinces of Lai Chau, Son La, Laos and

Yunnam province (China). The province comprises Dien Bien Phu city, Muong Lay town and 7 districts: Muong Nhe, Muong Cha, Dien Bien, Dien Bien Dong, Tuan Giao, Muong Ang, and Tua Chua (Dien Bien Government, 2013). Dien Bien has 36 communes in 4 districts among 230 NMPRP-II communes.

The topography of the province is characterized by many mountains rising from south to north and of various heights ranging from 200 meters to nearly 2,000 meters. Highest regions can be found in the north. There are valleys, narrow rivers and streams between high peaks. Most notably, Muong Thanh valley with an area of more than 150 km^2 is the largest and most well-known paddy field of the province and the North-western region (Lai Chau Government, 2013).

Like other provinces in the region, Dien Bien experiences two different seasons: dry cold season and hot humid season. Mean temperature goes from 21^oC to 23^oC. December is usually the month when temperature falls to the lowest level. The annual rainfall ranges from 1,300 mm to 2,000 mm and mostly concentrates during May to September. Average humidity is usually from 76% to 84% (Lai Chau Government, 2013).

The population of Dien Bien by 2011 is 512,300 people with a density of 54 people per square kilometre (GSO, 2011). Dien Bien is home to 21 ethnic groups including Thai, H'Mong, Kinh, Kho Mu, Dao, Ha Nhi, Hoa, Khang, La Hu, etc. Thai people are the main population group in the province making up more than 42% of the province's population. H'Mong is the second largest group comprising 27.2% while Kinh people account for nearly 20% of the province's total population (Lai Chau Government, 2013).

2.2 Poverty profile of ethnic minorities in the project area

Ethnic minority groups hold a significant proportion of the population in six provinces. There are a substantial number of project communes where more than 90% of the inhabitants are minorities. NMPRP-II is expected to benefit up to 134,000 poor ethnic minorities households in 230 project communes (World Bank Vietnam, 2010). The composition of ethnic minorities in each province is displayed in Table 1.

Table 1: Ethnic minority composition in six project provinces

Province	Proportion of minorities (%)
Lai Chau	97.6
Son La	82.0
Dien Bien	81.0
Hoa Binh	73.0
Lao Cai	64.9
Yen Bai	81.4

Source: Provincial Feasibility Report as cited in the Project Appraisal Document

As the NMPRP-II aims to improve the living standards and reduce poverty among project beneficiaries, it is essential to gain an overview of the poverty situation of different ethnic groups in project communes. The Baseline NMPRP-II 2010 provides an insight into income poverty and inequality in the NMPRP-II area. Accordingly, the average income per capita per month of the NMPRP-II group is three times lower than the national average income in 2008. For ethnic majority (Kinh and Hoa group), the average income in NMPRP-II is roughly 50 percent lower than that of the national average income in 2008 whereas the income discrepancy between that of NMPRP-II and the national average is less apparent for minority groups (IRC, 2011a).

Regarding the poverty incidence of different ethnic groups, the poverty rate of project communes is approximately five times higher than the national poverty rate in 2008 (69.4% compared to 13.6%). Remarkable inequality in income poverty between minority and majority is also shown whereby Kinh and Hoa, the majority group experience 20.7 percent of poverty rate, which is notably lower than the remaining minority groups. Highest poverty rate of 81.4% and 68.7% are recorded for H'Mong and Dao group. Meanwhile, Muong group witnesses the lowest income poverty incidence (IRC, 2011a). .

H'Mong and Dao are also the most advantaged groups considering non-income indicators. These two groups are characterized by not only relatively lower income but also lower level of education, limited access to health care and to basic infrastructure. The groups of Muong and Tay people are considerably better-off than other minority groups and experience living standards which are quite close to those of majority groups like Kinh and Hoa people. However, overall, there exists substantial difference between the situation of the ethnic minorities and the ethnic majority in the project area and between project area and national average regarding both income and non-income standards (IRC, 2011a).

2.3 Climate change context of the project area

Though Northern Mountain region does not suffer from rising sea level, it has witnessed increasingly evident impacts of climate change due to its topography, climate and social-economic characteristics. Climate change impact on the area is reflected through changes in the mean temperature, annual rainfall as well as the rising occurrence of extreme weather events. The average temperature in Vietnam rose from 0.5 to 0.7 degree Celsius in a period of 50 years from 1958 to 2007. The growth rate of average temperature in the winter is higher than that in the summer and the average temperature in the North is higher than that in the South. Following the same trend, North-western mountainous area's mean temperature has been continuously on the rise during the past period (MONRE, 2009).

The pattern of changes in average rainfall differs among different regions in Vietnam. While the average rainfall went up in the South, it went down in the North during the 1958-2007 period. The same pattern is recorded in the Northern Mountain region where the annual average rainfall tends to decrease gradually, which results in more serious and prolonged droughts (MONRE, 2009). Drought is a common hazard and tends to occurs more frequent in the Northern Mountain region. Dry season is recorded to last longer while the rainy season arrives later during the past years resulting in more severe shortage of water for irrigation and domestic consumption (Care International in Vietnam, 2013).

Over the last two decades, the number of cold spells affecting Vietnam has dropped significantly. However, the rising concern is that unusual extreme and prolonged cold spells happen more frequently in the North, especially in the mountainous region. The occurrence of storms is also very unpredictable and leads to increasingly serious impacts. In recent years, there are an increasing number of tropical storms. The storm season tends to end later with more complex movements. Storms have an immediate impact on the weather in Northern Mountain region, resulting in heavy rains, flash floods and landslides. Storm seasons in recent years often end later and it is increasingly difficult to forecast their development (Care International in Vietnam, 2013).

As the country's poorest communities, Northern Mountain region is already affected by climate change phenomenon because of their poverty, marginalization and limited access to information, production means and resources. Agriculture remains the major source of income for households in the project areas. The income structure of NMPRP-II households is not as diversified as the national income structure. Around 80% of the income of beneficial households comes from agricultural, forestry and fishery production activities while only about 10% of the income comes from wages/salaries and less than 3% of the income is from non-agricultural activities (IRC, 2011a). Most agricultural production activities are operated on a 'family farming system' whereby production is mainly based on family and animals' labour with limited role of modern farming equipment and traditional farming practices are widely in implementation (Tran, D.T, 2003). Given the region's heavy reliance on agriculture and natural resources with poor production techniques, any changes in climatic conditions will give acceleration to the existing cycle of food insecurity, decreasing the local households' resilience, weakening community health as well as constraining the inhabitants' opportunities that could be available to them to adapt to climate change (Care International in Vietnam, 2013).

Despite the region's high exposure to climatic hazards and rising susceptibility of the local communities to extreme weather events which have recently increased in frequency and intensity, research on the areas' vulnerability to climate and weather extremes is largely missing. This situation imposes great challenges and hindrance to efforts in improving the resilience and sustainability of main livelihoods of poor households in Northern Mountain region. Therefore, a vital task brought forward is to acquire understanding of the pattern of climate and weather events of different geographical areas, and more importantly, on the dynamics of the project communities' vulnerability to extreme weather events occurring as a consequence of the recent climate change phenomenon.

3. Methodology of risk index

This part elaborates on the methodology which has been utilized to assess the risks and vulnerability to natural disasters and climate change of communes targeted under the NMPRP-II. The research has employed both quantitative and qualitative approach to address the objectives of the assignment. While the task of developing risk index and an approximate risk ranking is mainly based on quantitative methods, the analysis of the damages caused by natural disasters on major livelihood activities as well as critical elements exposed to climate-related disasters requires the deployment of qualitative study through semi-structured interviews and participatory approach. In addition to available secondary dataset, the assessment would also utilize primary data directly collected from project communes through the conduction of the quick survey, screen survey and the in-depth study.

A quick survey is carried out by sending out quantitative questionnaires to 27 project districts in order to obtain general information on most common natural disaster conditions as well as livelihood activities of the locality. Following major findings from the quick survey, 60 out of 230 project communes (10 communes per province) have been selected for the screen survey[5]. The selection of 60 communes for the screen survey follows principles that ensure geographical, climatic hazards and livelihood specific representativeness for the project area. A comprehensive semi-structured questionnaire covering various aspects such as natural disasters occurrence and impacts, key livelihood activities, availability of natural disaster hazard management plans as well as local training needs which were not covered in available secondary data set is sent to these communes. Subsequent to the screen survey, an in-depth study is undertaken in 12 communes of 12 districts in all six project provinces. The in-depth study involves a total of 36 in-depth interviews at district level, 36 interviews with commune staffs along with 12 focus group discussions involving 110 village inhabitants. These discussions are organized to ensure the active participation of village heads and Common Interest Group (CIG) members in selected communes.

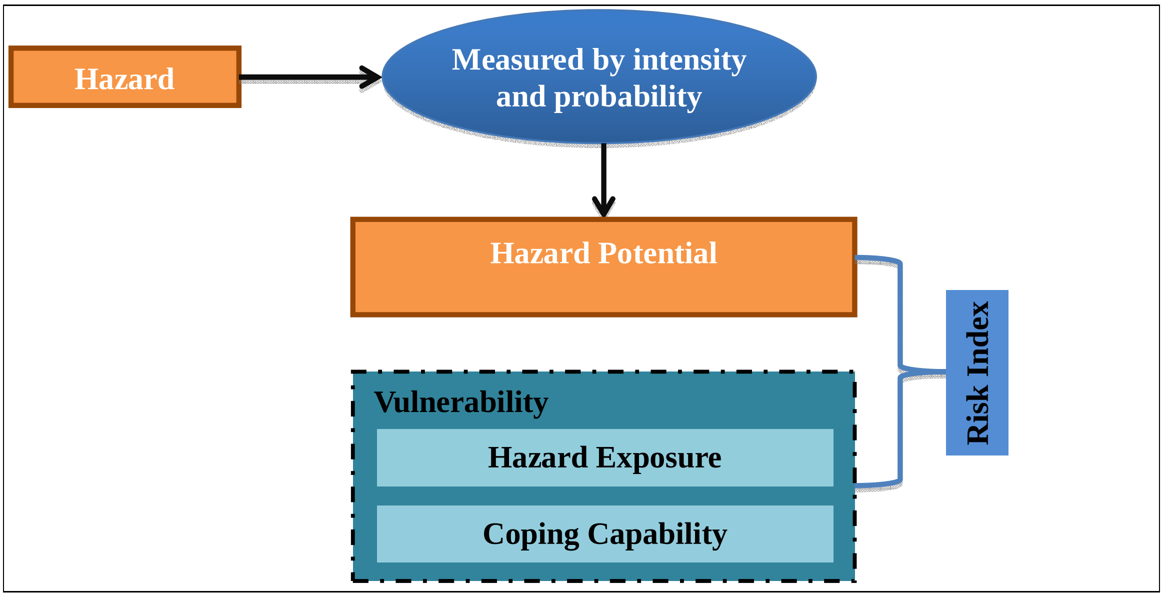
3.1. Construction of the Aggregate Risk Index

This part explains the construction of an aggregate risk index which can be used to assess the probability of natural disasters happening to communes and vulnerability of the communes to the natural disasters. The development of the risk index requires full information coverage of 230 communes through various dimensions that will be discussed below. The risk index construction follows the method of Greiving (2006) and Greiving et al. (2006). This method has been applied in Indochina Research and Consulting (IRC) in an assignment to indentify *6,000 vulnerable communes for the*

[5] List of communes selected for the screen survey and in-depth study is provided in the Annex C and D.

Government of Vietnam's Community-based Disaster Risk Management (CBDRM) programme in 2011. This methodology is similar to what has been adopted by The Inter-governmental Panel on Climate Change (IPCC) to assess the vulnerability to natural disasters and climate change at global scale (IPPC, 2007). It has proven highly relevant for the case of Vietnam. The methodology for development of the risk index is described in Figure 1 as follows.

Figure 1: Natural Disaster Risk Index



Source: Greiving (2006) and Greiving et al. (2006)

The Risk Index is a composite index constructed from three separate components: *(i) Hazard Potential Index, (ii) Hazard Exposure Index and (iii) Coping Capacity Index*. The Hazard Potential Index is a measurement of the probability of natural disasters. Meanwhile, the Hazard Exposure Index and Coping Capacity Index are used to measure the vulnerability of communes to the natural disasters[6]. Detailed explanation on the construction of component indexes will be provided in the subsequent part.

After Hazard Potential Index, Hazard Exposure Index and Coping Capacity Index are computed, the Aggregate Risk Index is estimated as the weighted average[7]:

*Risk Index = 0.5*Hazard Potential + 0.25*Hazard Exposure + 0.25*Coping Capacity*

Communes with the high value of the Aggregate Risk Index are more likely to be affected by natural disasters. Natural disasters are more likely to happen in these

[6] Greiving (2006) and Greiving et al. (2006),
[7] ibid

communes, and the damages caused by natural disasters tend to be higher in these communes because of their high vulnerability.

3.2. Construction of the Component Indexes

In order to estimate the Aggregate Risk Index, it is necessary to estimate the Hazard Potential Index, Hazard Exposure Index and Coping Capacity Index. These indexes are also aggregate indexes which are computed from several sub-indexes.

Hazard Potential Index

The Hazard Potential Index is called as the Hazard Map Index in Greiving (2006). It is constructed from four hazard components: *storms, rainfall flood, rainfall drought and other hazards* (such as hails, flash flood, land collapse, and whirlwind).

Data on storms

Data from storm archives will be used to estimate the probability of commune being affected by a storm. We use data on all the tropical storms and cyclones that hit Vietnam's areas from 1955 until present. The data on storm are maintained by international cyclone agencies including the U.S Navy's Joint Typhoon Warning Center[8] and the Typhoon Warning Center of Japan Meteorological Agency[9]. In this study, we will identify the geo-referenced affected areas in which the wind speed is at least 35 knot. This threshold of wind speed is used to classify storms. We follow the method used by (Mouton and Nordbeck, 2005) to construct the trail of affected areas for each of all the storms hitting the communes between 1955 and 2010. Using this data set, we are able to compute the probability of being hit by a storm within a year.

Data on rainfall

Data on rainfall are used to estimate the rain flood and rain drought. We rely on daily observations from active weather stations to estimate total daily rainfall for all the communes. We have access to the daily rainfall data from 1975-2006 from 172 weather stations throughout the country. The data have been maintained by Hydrometeorology Data Center[10], an institution under the Ministry of Natural Resources and Environment of Vietnam. The dataset on rainfall is available at

[8] http://www.usno.navy.mil/NOOC/nmfc-ph/RSS/jtwc/best_tracks/
[9] http://www.jma.go.jp/jma/jma-eng/jma-center/rsmc-hp-pub-eg/trackarchives.html
[10] http://www.hymetdata.gov.vn/

commune level. We estimate the probability of flood and drought using rainfall data as follows:

- Interpolate daily rainfall for all the communes in the project areas.
- Calculate weekly total rainfall for rainfall flood shocks.
- Compute the probability of rainfall flood shocks (having daily rainfall above 51mm).
- Calculate monthly total rainfall for rainfall drought shocks (having daily rainfall below 30mm).
- Compute the probability of rainfall drought shocks.

Other disasters

Other disasters in Vietnam mainly include flash flood, whirlwind, saltwater intrusion and land collapse. The Central Committee for Flood and Storm Control (CCFSC) of the Ministry of Agriculture and Rural Development (MARD) of Vietnam collected data on disasters during 1995-2010 in Vietnam. The database includes records of seven types of natural disasters, namely cold wave; flash flood; flood; land collapse; typhoon; water rising and whirlwind. The records include a number of important indicators such as the time of disaster events, locations of affected areas, number of human deaths, people injured and other losses. The data is only representative at the provincial level. Communes in the same province have the same data on other disasters.

The Hazard Potential Index is the weighted average of the probability of storms, the probability of rainfall flood, the probability of rainfall drought and the probability of other hazards. We use the weights for each hazard type from the IRC[11]. For comparison with other indexes, the Hazard Potential Index will be standardized into measurement scale from 1 to 100. Specifically, the standardised score of HP_j of commune i on 1 to 100 range is calculated as:

$$HP_i^{100} = 99\left(\frac{HP_i - HP_{\min}}{HP_{\max} - HP_{\min}}\right) + 1. \qquad (1)$$

where $HP_{\min}$, $HP_{\max}$ are the minimum and maximum value of the original *variable* in the sample, respectively. The higher value of the Hazard Potential Index means the high probability that a disaster will happen.

[11] IRC (2011)

Hazard Exposure Index

Once the disasters happen in an area, a major concern is to what extent an area can be affected by the disasters. The extent of damages depends on the area's exposure to and ability in coping with the disasters. The disasters can cause damages to both human and physical capitals. According to Greiving (2006) and Greiving et al. (2006), the exposure level depends on the GDP per capita of the areas, the population density, and the fragmentation of natural areas. The GDP per capita of the areas reflects the economic level while the population density measures the human capital. Other things being equal, the damages caused by a disaster will be higher for an area with high economic level and population density than an area with low economic level and population density. The fragmentation of natural areas is used as an indicator for possible impacts on the ecosystem, since they are likely to be totally destroyed if a hazard strikes. In this study, we include into the fragmentation index not only the land variables but also livestock variables as raising livestock is an important livelihood for households, especially poor households in Northern Mountain. Activities of raising livestock are also very vulnerable to the occurrence of natural disasters.

GDP per capita of communes

While the population density of commune is easily computed by the *Vietnam Rural, Agriculture and Fisher Census 2011* (RAFC)[12], there remains a great challenge in estimating the per capita GDP at the commune level since there is no available data of GDP at small areas such as districts and communes in Vietnam. To overcome this challenge, we combine the RAFC 2011 and the Vietnam Household Living Standard Surveys (VHLSS) 2010 to estimate the per capita income of communes using the small area estimation methods (Elbers et al., 2002; and 2003). The small area estimation is often applied to predict poverty and inequality measures at the small areas[13]. In Vietnam, it has been widely applied to construct the poverty maps (Nguyen et al., 2010; Nguyen, 2011; Lanjouw et al., 2013 for instance). However, these estimates are only available at district level. Combining the RAFC 2011 and the VHLSS 2010 allow us to estimate the per capita income at the commune level. We refer to Nguyen (2013) for detailed presentation of the estimation.

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[12] *The Rural Agriculture and Fishery Census (RAFC) in 2011*: The RAFC was carried out by the GSO in 2011. The census covered all households in rural areas. The censuses contain data on individuals and households including basic demography, employment and housing, and agricultural activities. There are also comune-level data on socio-economic conditions, agricultural production, infrastructure and transportation, education, health, and social affairs of all the rural communes throughout the country.

[13] See Annex A for explanation of this method.

The fragmentation index

As mentioned, the fragmentation index includes information on not only lands but also livestock of households. The fragmentation index is the weighted average of a land index and a livestock livelihood index with an equal weight of 50%. Using the RAFC 2011, we compute the sub-indexes of the land index and the livestock livelihood index as follows.

The crop land index is constructed by the three following sub-indicators: (i) *Rice crop*: measured by average of per-capita planted rice area of commune in square meter; (ii) *Corn crop*: measured by average per-capita planted corn area of commune in square meter; and (iii) *Cassava crop*: measured by average per-capita planted cassava area of commune in square meter. The three sub-indicators are converted to the 100-point scale. The crop livelihood index is the weighted average of the three sub-indicators. The rice crop indicator has a weight of 40% which is higher than corn crop indicator (30%) and cassava crop indicator (30%). This is because contribution of rice cultivation to crop household income is higher than other crops.

The livestock index is comprised of the four following sub-indicators: (i) *Household ownership of buffalos*: measured by commune average number of buffalos per household; (ii) *Household ownership of cows*: measured by commune average number of cow per household; (iii) *Household ownership of goats*: measured by commune average number of goats per household; and (iv) *Household ownership of goats*: measured by commune average number of goats per household. These four sub-indicators are also converted to the 100-point scale. The livestock livelihood index is the weighted average of the four sub-indicators with the equal weight of 25%.

The Hazard Exposure Index will be the weighted average of the per capita income, the population density, and the fragmentation index of communes with equal weights. The per capita income and the population density are also converted to the 100-point scale. Thus the Hazard Exposure Index is also in the range of 1 to 100. Higher values indicate communes' higher levels of exposure to hazards.

Coping Capacity

Coping Capacity Index reflects the response potential of an area's population. In Greiving (2006) and Greiving et al. (2006), the coping capacity is measured by the regional GDP per capita. The coping capacity of an area is defined by its population density and the financial, socio-cultural and institutional capacity to cope with a disaster. Coping capacity is related to the resilience which is defined as capacity of households to absorb and mitigate damage or loss caused by natural disasters (Holling, 1973; Perrings, 2001). The resilience refers to the ability to recover from disasters and the ability to withstand disasters (Rose, 2004; Briguglio et al., 2009). According to Rose (2004), resilience can take place at the three levels: micro level such as households and individual firms, medium level such as sectors and groups, and macro level with all individual units. In this study, we will measure the Coping Capacity Index by the four sub-indexes: (i) *the index of per capita income of provinces and districts; (ii) the non-farm index, (iii) the commune infrastructure index, and (iv) the household asset indexes.*

Per capita income of provinces and districts

Per capita income of provinces and districts reflect the economic capacity of the provinces and districts in supporting communes if the communes are affected by disasters. Similar to the per capita income of communes, the per capita income is estimated from the small area estimation method.

The non-farm index

In the project areas, agricultural production is mainly affected by disasters whereas non-farm production is less likely to be affected. We measure the non-farm activities of communes by the share of people working for wage, the share of people working in industrial sectors, and the share of people working in service sectors. These variables are computed from the RAFC 2011, and standardised into indexes with the 1 to 100 point scale. The non-farm index is the weighted average of these indexed with equal weights.

It should be noted that all the coping sub-indexes are standardised in scale from 1 to 100 with the higher values suggesting lower coping capacity. Thus the sub-indexes are standardised as follows (unlike equation (1)):

$$I_i^{100} = 99\left(\frac{I_{\max} - I_i}{I_{\max} - I_{\min}}\right) + 1. \tag{2}$$

where I_i^{100} and I_i are the standardised index and the original variable of commune i, respectively. $I_{\min}$, $I_{\max}$ are the minimum and maximum value of the variable in the sample, respectively.

The infrastructure index

Communes with improved infrastructure are more likely to cope with hazards. In this study, the infrastructure index is the weighted average of the following sub-indexes: (*i) communes have good road passable through the year, (ii) communes have post office, (iii) communes have irrigation system; (iii) communes have agricultural extension center; (iv) communes have market; (v) communes have solid health center; and (vi) distance to the nearest town*. These variables are computed from the RAFC 2011 for all the communes in the project area. These variables are also standardised into indexes with the 1 to 100 point scale.

The asset index

Assets hold an important role for households in improving their well-being and contribute to reducing credit constraints. We compute the aggregate asset index using data on housing conditions and durables of households in the 2011 RAFC. More specifically, the asset index is the weighted average of the following variables: *(i) proportion of households with tap water, (ii) proportion of households with flush toilet, (iii) proportion of households with motorbike; (iv) proportion of households with colour television; (v) proportion of households with telephone; and (vi) proportion of households with electric fan*. These variables are computed from the RAFC 2011 for all communes in the project area. These variables are also standardised into indexes with the 1 to 100 point scale.

4. Risk assessment

4.1. Main extreme weather events in the project area

The Hazard Potential Index reflects the probabilities of extreme weather events occurring in the project area. The index is the weighted average of the probabilities of storm, flood, drought and other hazards. Table 4.1 presents the estimates of the probability of different hazards. Overall, by provinces, communes in Hoa Binh have the highest probability of being hit by a storm within a year, at 0.316. Meanwhile, Dien Bien, Lao Cai and Lai Chau are the provinces where communes are found with lower probability of storm.

The probability of floods is small in Northern mountainous region. Hoa Binh and Lai Chau are the provinces with the highest frequency of floods, while Lao Cai and Son La are the provinces tend to have lower flood frequency. Drought is more likely to happen than flood but less likely than storm. Communes in Son La have the highest probability of drought, followed by communes in Hoa Binh. Lai Chau and Lao Cai have communes with the lowest probability of drought. For other hazards, the frequency is higher since it includes several different types. Lao Cai Lai Chau and Yen Bai tend to have higher probability of other hazards than the remaining provinces.

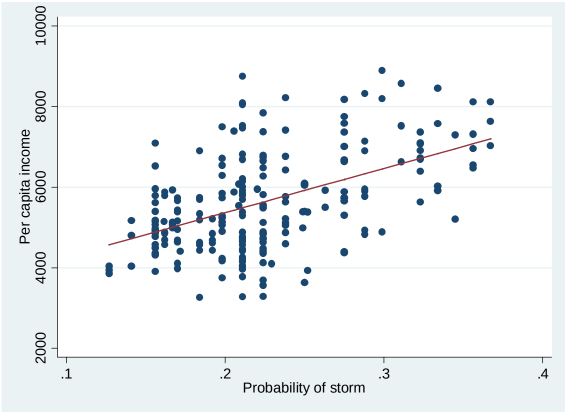
Table 4. 1: The estimates of probability of natural hazards by provinces

Provinces	Probability of storm	Probability of flood	Probability of drought	Probability of other hazards
Điện Biên	0.177	0.046	0.188	0.215
Hòa Bình	0.316	0.073	0.207	0.364
Lai Châu	0.191	0.056	0.164	0.451
Lào Cai	0.198	0.033	0.164	0.542
Sơn La	0.236	0.043	0.210	0.445
Yên Bái	0.201	0.051	0.170	0.455
Total	0.222	0.050	0.184	0.416

Figures 4.1 and 4.2 present the correlation between the per capita income and the probability of different hazards to explore whether there is correlation between disasters and welfare level. A fitted line of regression of per capita income on probability of hazards has also been added. Communes with higher per capita income tend to have higher probability of storms, floods and droughts. For other hazards, there is no clear correlation between the per capita income and the probability of other hazards. This can be due to the limited data on other hazards as there are only province-level data on other hazards.

Figure 4. 1: Correlation between per capita income and probability of storm and flood

Correlation between per capita income and probability of storm



Correlation between per capita income and probability of flood

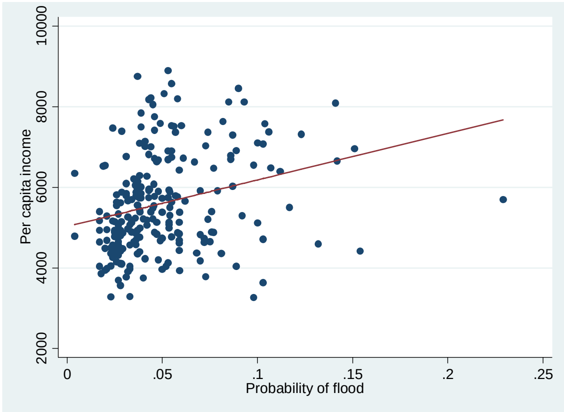
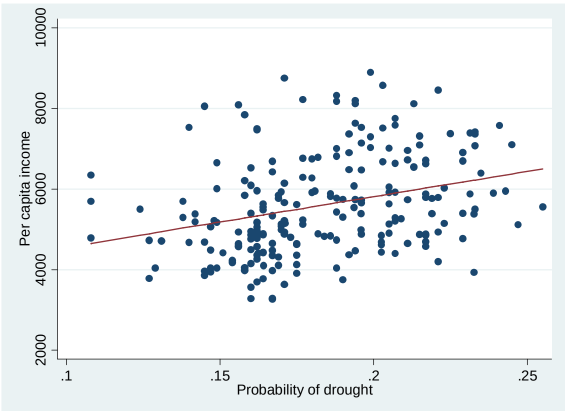
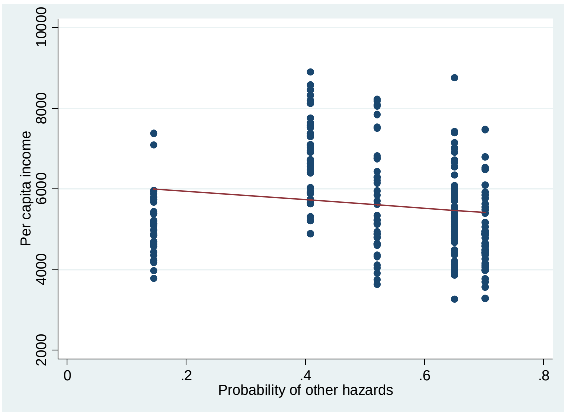


Figure 4. 2: Correlation between per capita income and probability of drought and other hazards

Correlation between per capita income and probability of drought



Correlation between per capita income and probability of other hazards



Figures 4.3 through Figure 4.6 present the geographic variation in the probability of different hazards among communes in the project areas. Figure 4.8 presents the map of the probability of storms[14] at the commune level in the project areas. In the project provinces, districts in Hoa Binh province tend to have high probability of storms.

[14] Data from storm archives will be used to estimate the probability of commune being affected by a storm. Those are data on all the tropical storms and cyclones that hit Vietnam's areas from 1955 until present.

Figure 4. 3: Map of probability of storms

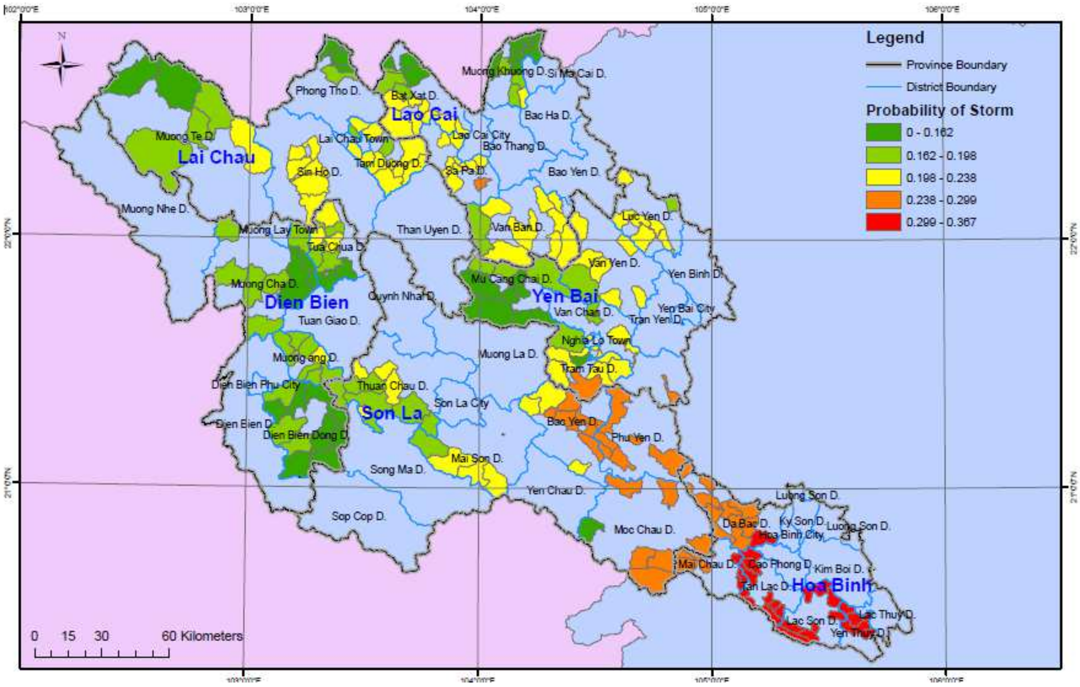


Figure 4. 4: Map of probability of flood

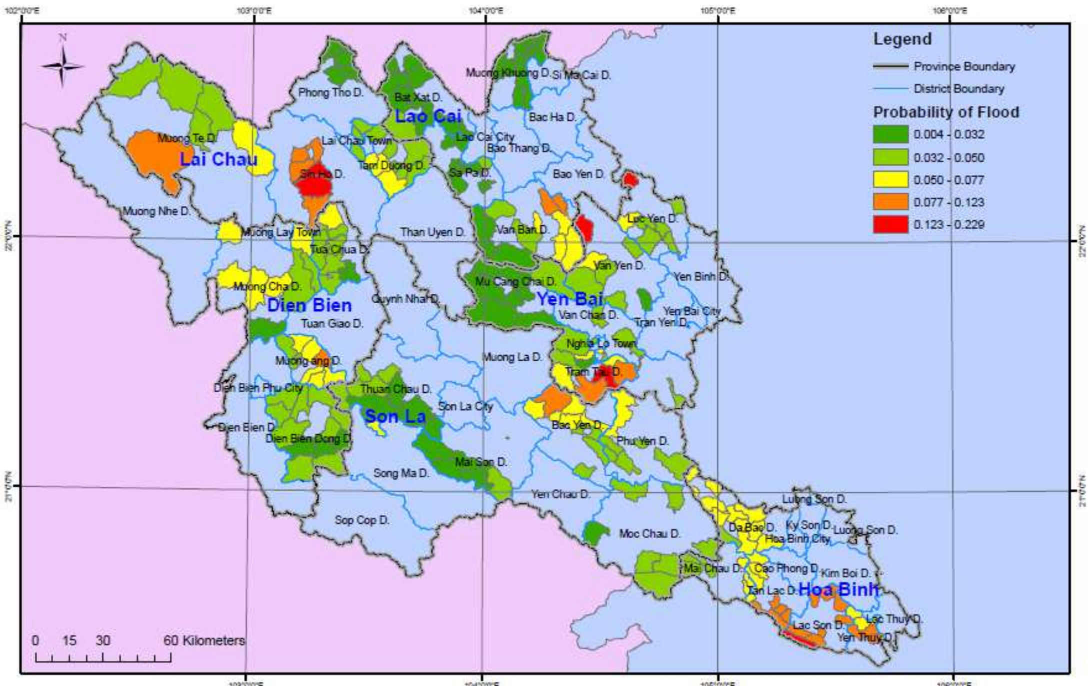
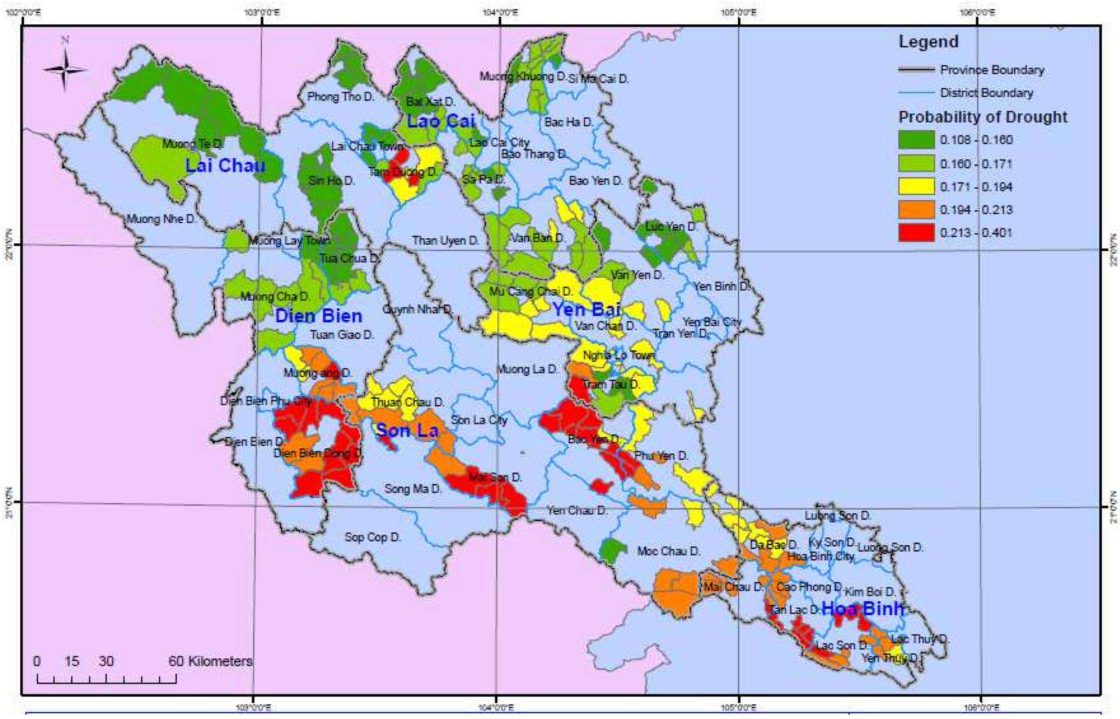


Figure 4.4 presents the map of probability of flood of the project communes. Several communes have high probability of floods are Tan Phuong (the Lac Yen district, Yen Bai province), Ta Ngao (Sin Ho district, Lai Chau province), and Tu Do (Lac Son district, Hoa Binh province)..

In Figure 4.5, the probability of drought is highest in Ban Hon commune in Lai Chau province, Phieng Pan and the Hang Chu commune in the Son La province and Ngo Luong and Nam Som communes in Hoa Binh.

Figure 4. 5: Map of probability of drought



Extreme cold is common weather event occurring almost every year in the Northern Mountains. Figure 4.7 presents the number of extreme colds happened in a commune in 2011 in the left panel, and the probability of extreme cold happing in a year in the right panel. Yen Bai, Lao Cai, Hoa inh and Dien Bien are the provinces with high frequency of extreme colds, while Son La and Lai Chau have lower frequency of extreme cold.

Figure 4. 6: Map of probability of other hazards

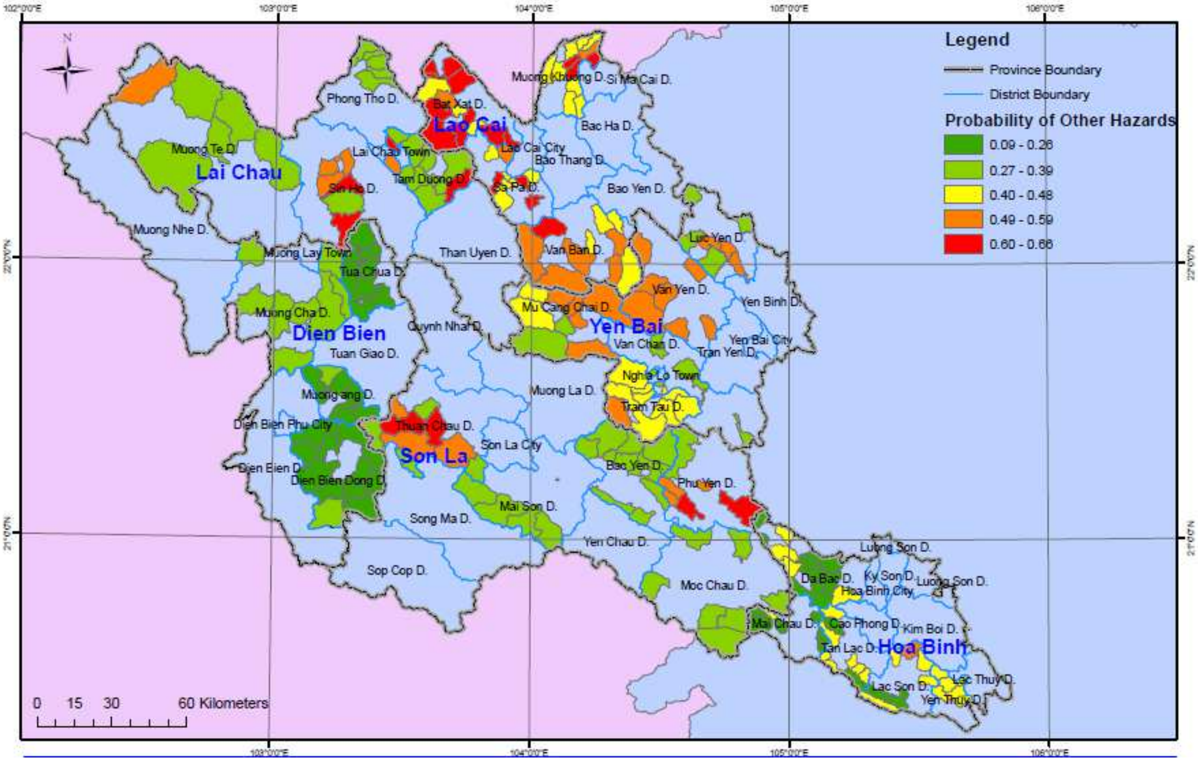
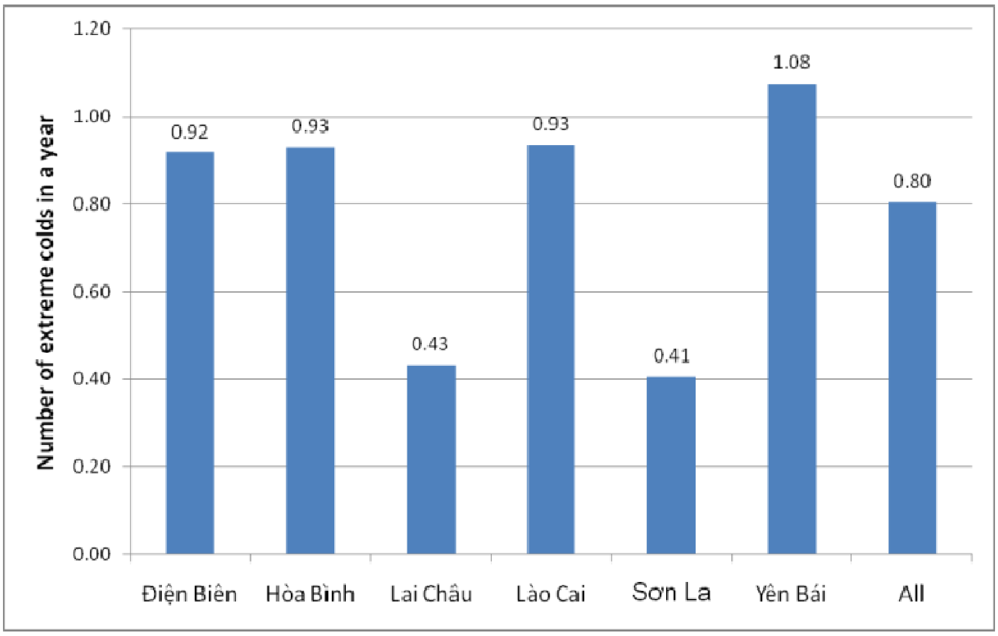


Figure 4. 7: The probability of extreme cold in a year

(a) The number of extreme colds happening in commune in a year.



(b) The probability of extreme colds happening in commune in a year.

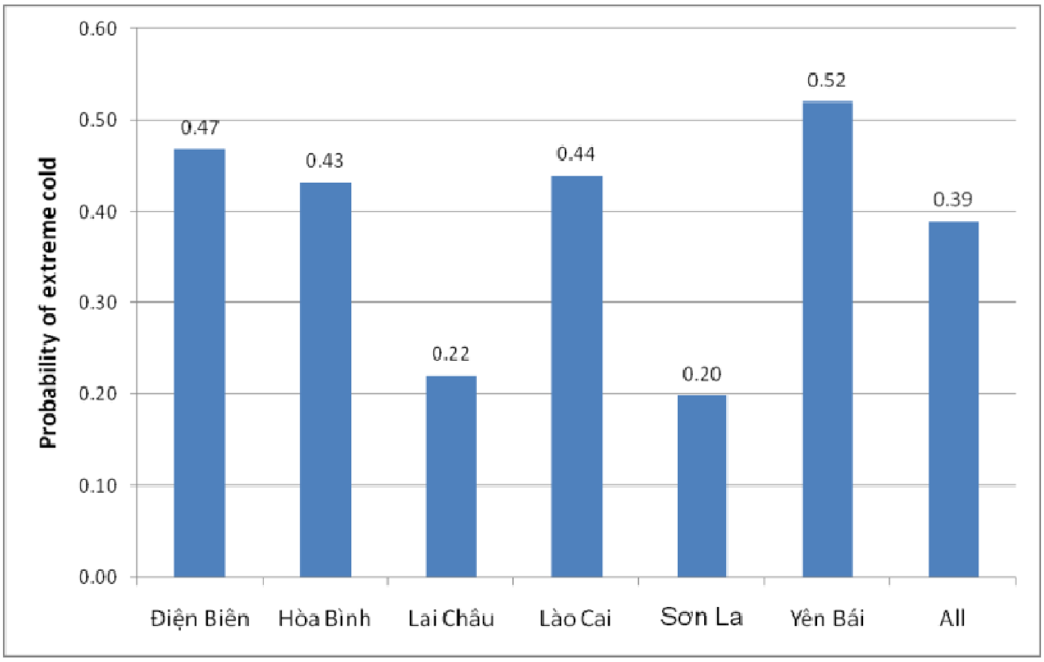
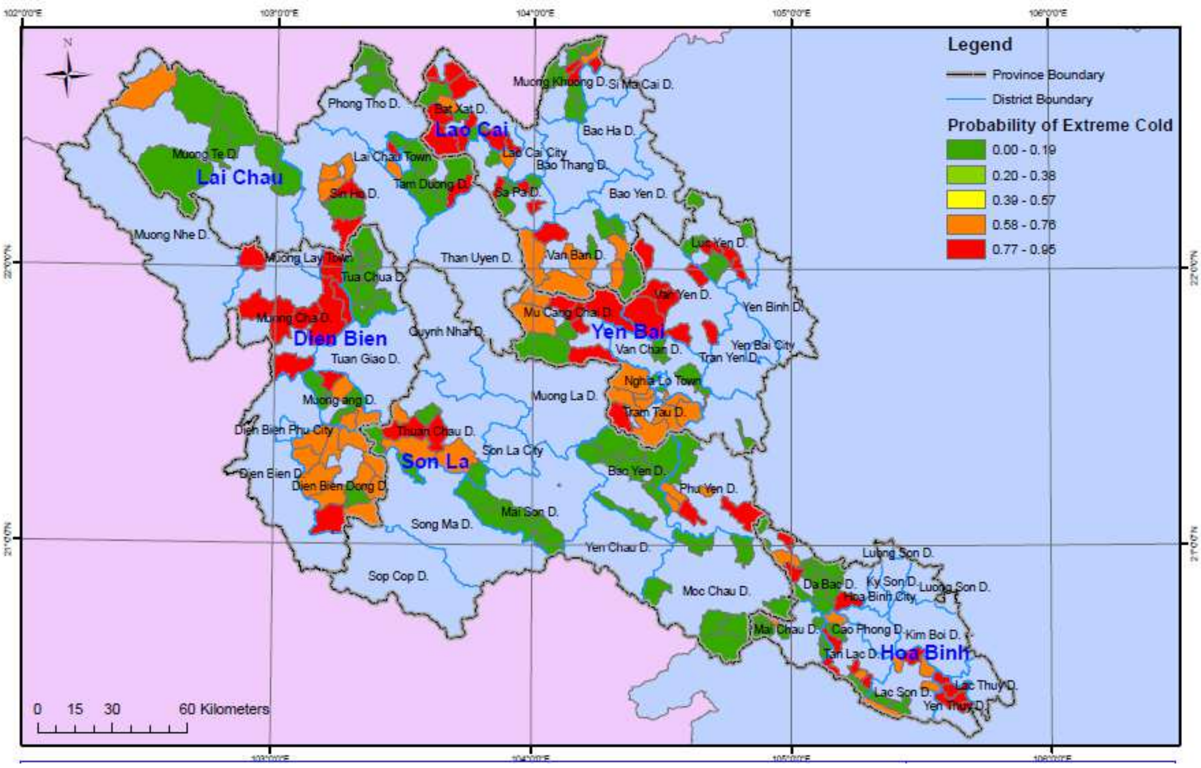


Figure 4. 8: Map of probability of extreme colds



Based on the probability of hazards, the aggregated probability is computed which is equal to the weighted average of the probabilities of the four hazards with the weights used in IRC (2011b). The Hazard Potential Index is computed by re-scaling the aggregated probability into the 1 to 100 scale so that it can be comparable with the Hazard Exposure Index and the Coping Capacity Index.

Figure 4.8 presents the Hazard Potential Index. Accordingly, overall, the communes in Son La have the highest Hazard Potential Index, followed by Lai Chau and Hoa Binh. The communes in Yen Bai and Lao Cai have the lowest frequency of hazards.

Figure 4.9: Hazard Potential Index of communes by provinces

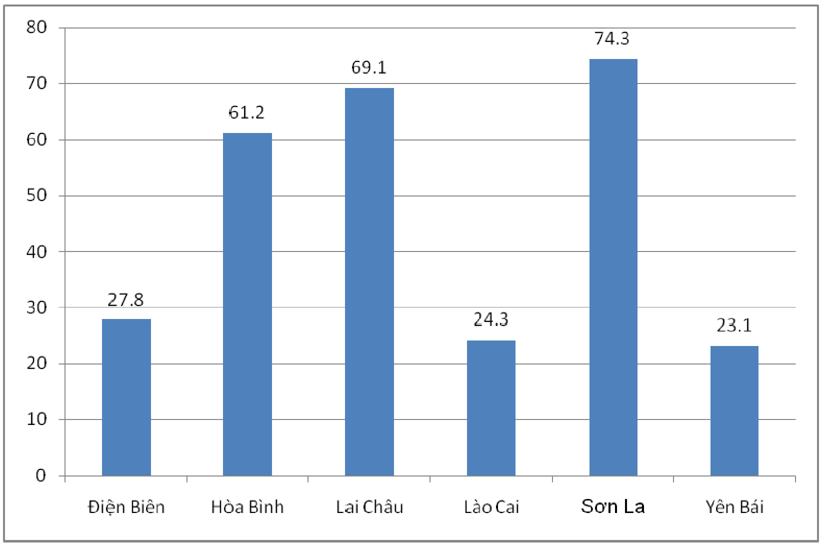
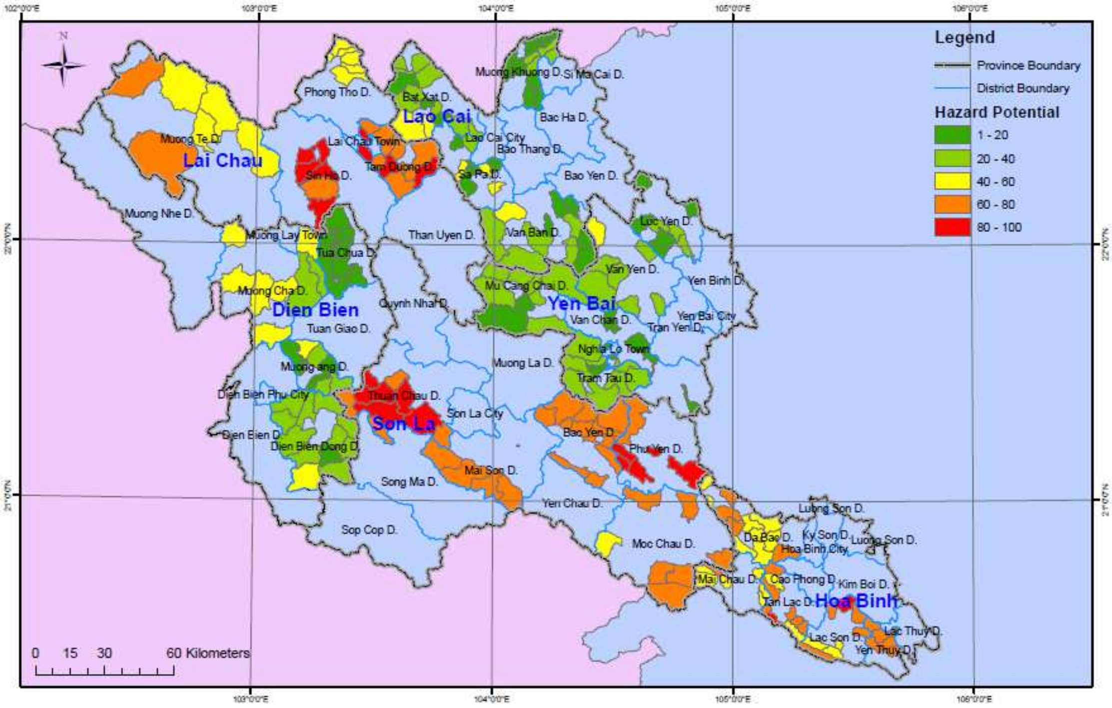


Figure 4. 10: Map of Hazard Potential Index



Similarly, tailored surveys and in-depth studies reveal that storm, flood and drought were also listed by selected communes as most common extreme weather events affecting their localities. Additionally, extreme cold and prolonged cold which is covered in the other hazards calculation has also been referred to as a frequent event which significantly impacts inhabitants' lives and agricultural production activities. Regarding the natural disasters' frequency in 2012, results from the screen survey reveal that, storm, drought, extreme cold and flash flood were recorded to happen once to three times in 70% of communes. Around 22% communes suffered from storm or extreme cold more than three times that year while up to 26% communes experienced extreme heat at least four times[15].

4.2. Assessment of vulnerability

4.2.1 The Hazard Exposure

According to Greiving (2006) and Greiving et al. (2006), the vulnerability of communes to disasters consists of the hazard exposure and coping capacity of communes. The hazard exposure depends on per capita income of communes,

[15] See Annex II for detailed results on the frequency of extreme weather events.

population density, and crop land and livestock of communes. According to the framework of Greiving (2006) and Greiving et al. (2006), holding other factors constant, communes with high economic level and population density are more likely to be damaged if the disasters happened. Table 4.2 shows that communes in Hoa Binh have the highest per capita income, while communes in communes in Lao Cai have the lowest per capita income. Lao Cai and Lai Chau have high population density, while Dien Bien and Son La have low population density.

Table 4. 2: Income and population density of communes by provinces

Provinces	Per capita income (thousand VND)	Population density (people/km2)
Điện Biên	5145	86
Hòa Bình	7069	126
Lai Châu	5105	135
Lào Cai	4868	151
Sơn La	5634	89
Yên Bái	5677	108
Total	5608	117

Table 4.3 presents the land of different crops and livestock of project communes by provinces. Son La and Dien Bien tend to depend largely on agricultural production including both crops and livestock.

Table 4. 3: Cropland and livestock of communes by provinces

Provinces	Rice area per capita (m2)	Corn area per capita (m2)	Cassava area per capita (m2)	Number of buffalos per household	Number of cows per household	Number of goats per household	Number of pigs per household
Điện Biên	1083.9	871.9	139.9	2.55	0.86	1.14	6.85
Hòa Bình	456.9	963.3	290.4	1.46	0.95	0.23	2.47
Lai Châu	903.8	451.3	131.0	1.73	0.21	0.25	2.88
Lào Cai	686.7	808.9	164.1	1.81	0.27	0.31	3.52
Sơn La	1187.0	1987.1	467.0	1.58	2.15	1.45	3.20
Yên Bái	836.1	377.5	405.6	1.65	0.47	0.30	3.53
Total	841.7	914.8	269.8	1.78	0.82	0.60	3.72

Figure 4.11 presents the estimates of the Hazard Exposure Index of communes by provinces whereby Hoa Binh and Son La are more exposed to the disasters. This implies that the economic and human losses would be larger in case a hazard occurs given other factors fixed. On the contrary, Lai Chau and Son La are less likely to be exposed to hazards.

To visualize the results at the commune level, Figure 4.12 displays the Map of Hazard Exposure Index of communes in the project areas. Commune Hua Bun in Lai Chau province communes Hanh Son and Thach Luong in the Yen Bai province are those having high hazard exposure index.

Figure 4.11: The Hazard Exposure Index of communes by provinces

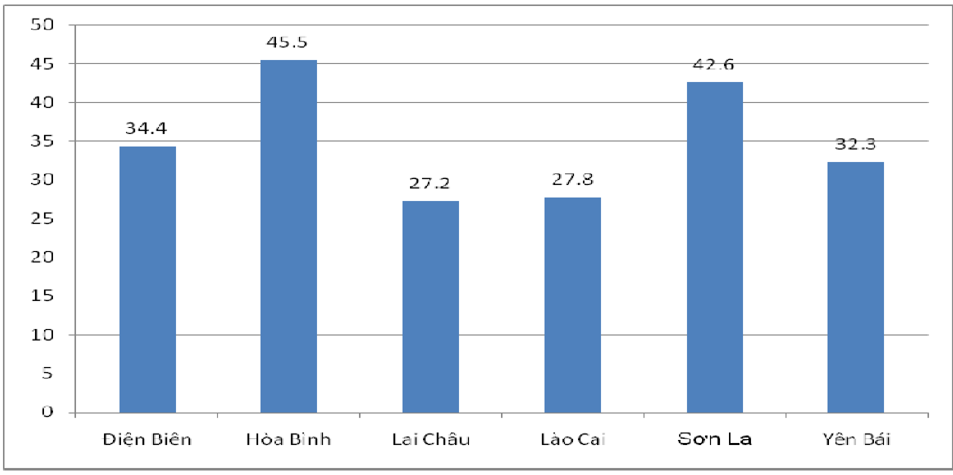


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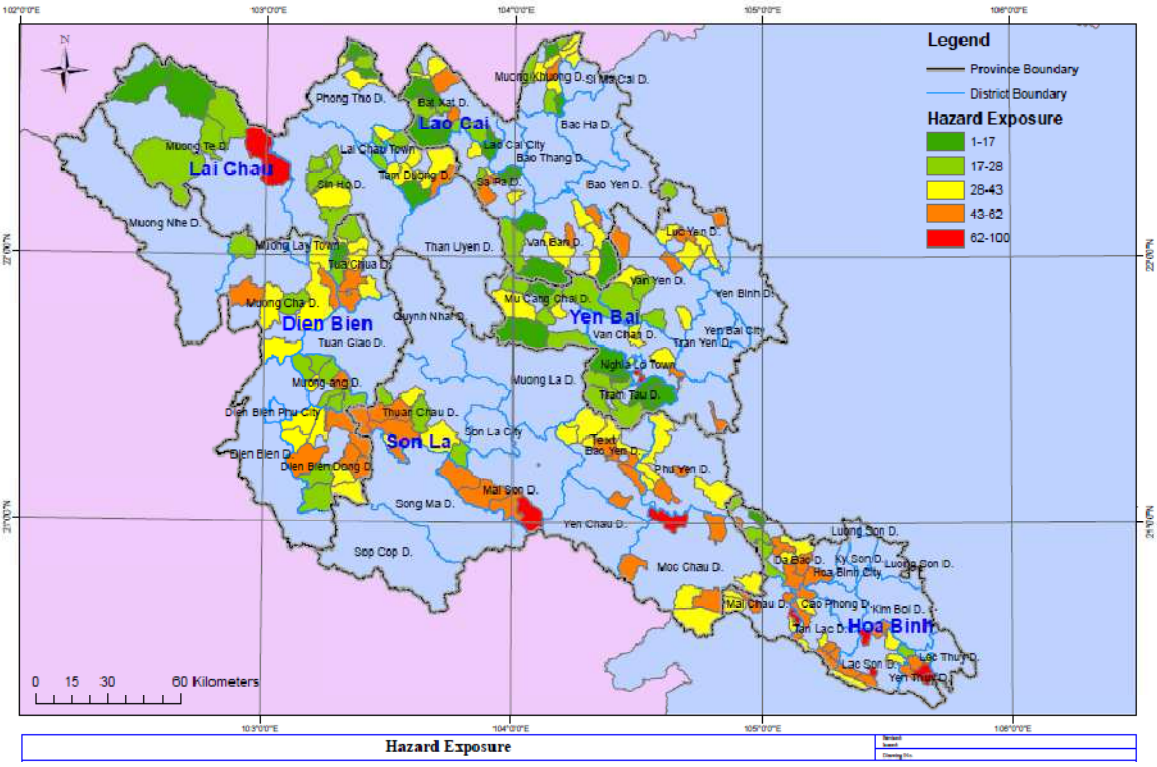
Figure 4.12: Map of Hazard Exposure Index



Impacts of extreme weather events on major livelihood activities and infrastructure

Climate change impacts are not evenly distributed. The poorest countries and people will be those who suffer the earliest and the most since the poorest heavily rely on agriculture, the most climate-sensitive of all economic sectors while their low income and vulnerability make climate change adaptation significantly more difficult. Disrupted rainfall pattern and changing agricultural cycles as the effect of climate change will affect the poorest billion people, 75 percent of whom live in rural areas and rely on agriculture for their livelihood (Stern, 2006 as cited in Gupta, 2013). It is estimated that in the North-western region, rice yield would decline by 11.1% while the yields of other crops would decline by 23.5% as the potential impacts of climate change without adaptation (World Bank, 2010). Climate change's impacts on three major crops: rice, maize and soybean are predicted using MONRE's medium emission scenarios. Accordingly, yields of summer-rice and summer-autumn rice are likely to fall by 7.9% and 8.4% by 2030 and 14.0% and 16.7% by 2050 respectively. Meanwhile, reductions in the yields of maize and soybean are forecasted to be 18.7% and 3.5% by 2030 and 32.9% and 9% by 2050 respectively (Nguyen, 2011 as cited in IFAD, 2011). Yields are also likely to decline for cassava, sugarcane, coffee and vegetables. The growth and reproduction of livestock are also threatened by climate change as the phenomenon increases the incidence and spread of diseases (IFAD, 2011).

Understanding the impacts of climate change through analyzing how specific e xtreme weather events affect grassroots level in the project area will be vital, especially in investigating the damage extent these communities suffer based on which recommendations to enhance their adaptability can be developed. Therefore, quick survey, screen survey and in-depth study including in-depth interviews with district, commune, village staffs and focus group discussions targeted local people were organized. The objectives of these activities are to provide a more thorough insight into the impacts of climate change phenomenon, the characteristics and pattern of extreme weather events caused by climate change. During the quick survey and screen survey, key production activities and infrastructure affected by extreme weather events were identified. The findings were later incorporated in in-depth interview with local staffs and especially served as the important inputs for developing the content of the focus group discussions with villagers. In 12 focus group discussions participants were asked to specify stages of their main production activities. For each stage they identified weather events which tend to affect the quality of crops/animals and respective impacts of each event. Existing coping strategies to mitigate the negative impacts of extreme weather events as well as the availability of support, for instance, extension support in term of pest management or technical assistance were also examined[16].

Overall, most households in studied areas reported the weather pattern was already erratic during the past years. There has been significant change in the local climate as the dry season is longer whereas the rainy season is shortened. Villagers participating shared that the daily temperature is also changing with wider variation between day and night temperature. In addition, the occurrence of severe and extreme weather increases in both frequency and intensity. The findings are consistent with previous findings found in recent research on this region (MONRE, 2009; McElwee, 2010; and CARE International in Vietnam, 2013).

Drought

The drought season in the Northern mountain region usually starts from October to April affecting most areas in the study and becomes more severe during March to April leading to shortage of water for both domestic and production use. Water stress has long been a top concern in the whole region. However, it is getting more severe when the drought season tends to last longer, especially in rocky mountains. Drought considerably affects the production of maize as the most severe shortage period often takes place in April corresponding with the starting stage of maize cultivation. To cope with drought, farmers are likely to switch their crops to later time. However, in some cases, drought occurs several weeks after seedlings have already been cultivated, which causes plants to be wilted and eventually leads to low productivity or even crop loss. Given low rate of irrigated agricultural land area in the region (according to IRC (2011a), 30.1% as compared to the national level of 82.9%) and that land is typically far from water source suggesting increased vulnerability of those landowners to weather related hazards, rising severe drought in recent years has created bigger burden for households and threatens local food security. Disadvantaged households are put in far more difficult situations as they cannot afford buy pumps or to pay for fuel to pump water to their fields.

[16] An example of material used in focus group discussions with regard to growing rice and raising cow is provided in Table IV.7 (Annex IV).

Box 1: The shortage of drinking water and water for agriculture activities
Ms. Ha Thi Nga (Xuan Nha commune, Moc Chau district, Son La province) reported that water source was the top concern of her family and others in the village when the dry season arrived. In recent years, the dry season often lasts longer and the rainy season comes later and is often accompanied with more frequent occurrence of flash floods, which leads to severe water shortage or water impurity or pollution. To get water for everyday life, she often shoulders water buckets and carries them from the spring to home for several hours each day.
Source: Findings from group discussions with households in Xuan Nha commune, Moc Chau district, Son La province

Box 2: Solutions to cope with drought
Mr. Ca Van Kiem (staff from Chieng Bom commune, Thuan Chau district, Son La province) suggested crop structure shift as a measure to deal with drought such as shifting from rice to growing peanut or soy-bean. If they have sufficient funds, households can use rubber pipes (black ones with the diameter of around 2cm) to transport water from the water puddles to the fields in order for rice to survive the drought. Three or four adjacent households can share one pipeline in order to reduce the cost.
Source: Findings from in-depth interview with commune staffs in Chieng Bom commune, Thuan Chau district, Son La province

Flood and landslide

The occurrence of flood in surveyed communes is reported to be mainly around July and August in project area and usually incites serious damage to human life, property, infrastructure and major crops. Following heavy rainfall, flood is associated with mud and rocks and often leads to landslide. Most focus group discussion attendants shared that the events of flood and landslide are usually accompanied by severe impacts on productive land availability. The situation worsens arable land scarcity in the areas due to its steep terrain and population pressures (CARE International in Vietnam, 2013). Some areas such as communes in Muong Ang district (Dien Bien province), Phong Tho district and Sin Ho district (Lai Chau province) and Van Ban district (Lao Cai province) suffer a higher level of impact from flash flood. As most flash floods generate quickly and show little warning signal, residents in affected areas do not have ample time to prepare and evacuate making it more dangerous and detrimental. At surveyed communes, authorities' support is only available for immediate relief for crop loss as a consequence of flood and landslide while that for recovery of productive land is missing. Some necessary interventions such as planting trees to strengthen riverbank and avoid land erosion remain uncommon. The lack of support from the local governments combined with constrained access to resources causes great difficulties for poor households as they only own limited area of land for cultivation.

Landslide following flood is an extreme event which usually devastates the quality of local infrastructure, especially traffic roads and paths in uplands and those located by hills, mountains or streams and ponds. After heavy rainfall, particularly during June and August, most between-commune, between-village and village-to-commune roads, due to low concretization level and the absence of adequate drainage system, are left inaccessible causing huge difficulties for commuters. In some cases, transporting activities are completely blocked and some villages can be isolated. Impacts of flash flood and landslide on local irrigation systems are also severe whereby notable damages to channel and dam foundation are witnessed since most of these systems at project communes are at small-scaled and the ratio of concretized works remains inadequate. Even in light rain, irrigation systems are still affected as stones, rocks and leaves fall down and easily block the water flows.

As for impacts on agricultural production, heavy rain and flood have adverse effects on summer-autumn rice crop. The rainy season often occurs when the tillering stage and booting stage begin. Consequently, the crop has high risk of being swept away. The local people cannot re-transplant new seedlings as the remaining time is insufficient for the rice to grow. Upland maize and summer maize crop also suffered from heavy rain and flash flood when maize's silk producing period is the most affected. Moreover, at the advent of severe flash flood and landslide, maize crop, like rice crop can be totally destroyed.

Box 3: Inadequate support for land restoration after natural disaster
According to Mr. Vu Khai (staff from Agriculture Department, Muong Ang district, Dien Bien province), the province and district government often support immediately after the occurrence of landslide or flash flood. However, support for farmers to restore damaged farming land has not been paid enough attention. Damaged land area becomes infertile, which obstructs cultivating activities for a long period of time and causes a lot of difficulties for people, particularly poor farmers with limited agricultural land area or those who grow only one crops a year.
Source: Results from in-depth interviews with staffs from Agriculture Department of Muong Ang, Dien Bien Province

Box 4: Heavy reliance of planting on weather conditions
Ms. Lo Thi Suong (Long He commune, Thuan Chau district, Son La province) reported that her family had a rice field of 1,080 m2. The village has no irrigation system. Therefore, when there is sufficient precipitation, her family grows two rice crops rice. However, her family can often produce only one rice crop. If there is no rain for a long time, the land will become hard and cracked. Her family can't cultivate in this land area, even planting corn is impossible. Only richer households can afford renting water pumps to water their fields.
Most of the households like her family solely rely on nature. The heavy rain which came around September of 2011 followed by flash flood destroyed her paddy field entirely. The field was filled with rocks and dirt and it took her family days to clean it up.

Source: Findings from group discussions with households in Long He commune, Thuan Chau district, Son La province

Extreme and prolonged cold

Extreme cold and prolonged cold are reported to occur in selected communes during the period from November and February and possibly lasts up to 30 or 40 days. All communes in the field study cited that their localities are affected by extreme and prolonged cold every year. The long winter cold spell in 2008 was strongly remembered among local staffs and villagers which killed thousands of livestock in surveyed districts. During winter, for communes situated in upper land, the temperature can fall as low as 5 degrees Celsius, mostly in mid-December to late January or early February. Low temperature remarkably affects households' major livelihoods especially cropping and husbandry. In recent years, some upper parts, especially in the Lao Cai province, the Son La province and the Lai Chau province, severe cold is often accompanied by ice and dense fog, which deteriorates rice and other staples 'production and is also harmful for normal growth of both the poultry and livestock as they are easily prone to various cold-related diseases.

With regards to wet rice cultivation, extreme cold weather severely affects the rice seedling transplanting stage of spring crops. It slows down crop growth and it can completely ruin transplanted seedlings. As for maize (corn) production, extreme cold weather has adverse effects on the period of flowering. Especially when dense fog follows, the light time essential for pollination period is substantially decreased, which results in lower maize productivity.

Main livestock such as buffalo, cow, and goat, and poultry such as chicken and duck are susceptible to low temperature. A notable number of livestock deaths are recorded every year during winter. A common reason is the rise of some common diseases (like Pasteurellosis and Foot and Mouth Disease among livestock and some avian flu types among poultry) when temperature falls. According to local staffs, the custom of grazing livestock in the forest and the ignorance of local authorities' warnings were the main reasons for the increased death toll during cold days in the region. On the other hand, as extreme cold weather reduces the growth of grass fields while many households have yet get accustomed to restoring sufficient straws for their livestock herds during winter, food shortage is also found as a prevalent death cause.

During field study, it was found out that several local seed and animal varieties tend to better cope with cold weathers than those brought from other localities. For instance, local pig breeds (also known as black pig), show their high adaptability to extreme cold weather. Only a small number of deaths are reported among local pigs in surveyed communes.

Box 5: Damage by extreme cold and prolonged cold on rice and livestock
In Muong Ang district in the Dien Bien province, 20-25% of transplanted rice seedlings were ruined in 2011-2012 and in Tram Tau district (Yen Bai province) about 15% of rice seedling had to be replanted. Meanwhile, the province of Yen Bai witnessed the death of 1,129 buffalos and cows in Tram Trau district and another 1,292 in Mu Cang Chai district.
Source: Results from in-depth interviews with staffs from Agriculture Department of Muong Ang, Dien Bien province and Mu Cang Chai and Tram Tau district, Yen Bai province

Box 6: Hypothermia among livestock due to freely grazing practices
On average, each household in the commune has three to five buffalos and two cows. In 2011, buffalos and cows froze to death during the extreme cold – prolonged cold spell because most of the households still freely grazed the livestock. In the winter, small livestock often froze to death due to the lack of resilience. Households are also short of foods to feed the livestock in the cold seasons as natural grass and forest leaves, their major food, can't grow well because of the lack of water.
Source: Findings from group discussions with households in Ban Mu commune, Tram Trau district, Yen Bai province
Ms. Bui Thi Que (Quy Hoa commune, Lac Son district, Hoa Binh province) reported that in the winter of 2010, two out of five cows of her family died. The reason was that she often grazed the cows and could not take them back to the cow shed when the temperature fell. Two cows died when searching for grass on the mountain.

Other extreme weather events

Hailstorm is not a common phenomenon in most project regions but quite permanent in the provinces of Lao Cai and Son La. Hailstorm which is usually seen in March to early April appears as a worrying extreme event as once it happens; it tends to show high frequency over a short period of time and exerts detrimental impacts.

Cyclone, despite its low frequency, is also a worrying event for households in the Northern Mountains. Like hailstorm, cyclone often occurs in late March and can cause severe damages to housing and properties of households in affected areas. Since forecast capacity on cyclone and hailstorm of related departments remains largely missing or limited, local authorities and households do not receive sufficient warnings and thus, fail to make adequate preparations to mitigate the impacts. Loss, as a consequence, tends to become more severe.

Box 7: Serious damages by unusual hailstorm in Lao Cai
The most recent hailstorm hit Lao Cai province by late March 2013 coupled with hailstones exceeding six centimeters in diameter causing substantial damage to property and crops. In the aftermath of the hailstorm, approximately 12,000 houses need to be repaired. The total damage is estimated at 70 billion VNDs. Muong Khuong district was the most affected where local offices, schools and nearly 7,000 houses were destroyed. The number of injuries was reported at 30.
Source: Saigon Giai phong, according to Lao Cai Steering Committee for Flood and Storm Prevention

4.2.2 The Coping Capacity

According to Greiving (2006) and Greiving et al. (2006), coping capacity depends on the economic level of high-level areas, that is, districts and provinces. In this study, we assume that the coping capacity also depends on non-farm opportunities, infrastructure and household assets of communes. Table 4.4 presents the estimate of per capita income of districts and provinces, and the non-farm employment of project communes by provinces. Non-farm employment is very low in project areas, and there is a low variation between the provinces, which implies poor coping capacity of project communes to shocks and risks. Hoa Binh is the province with the highest non-farm employment share, while Son La is the province with the lowest non-farm employment share (Table 4.4).

Table 4. 4: Per capita income and non-farm employment

Provinces	Per capita income of district (thousand VND)	Per capita income of province (thousand VND)	% working people with wages in commune	% working people in industrial sectors in commune	% working people in service sectors in commune
Điện Biên	5415	7172	3.5	4.5	3.2
Hòa Bình	9027	10408	6.0	7.5	4.9
Lai Châu	6028	6095	4.6	5.5	3.8
Lào Cai	6179	7557	3.2	4.8	3.3
Sơn La	7287	7931	3.2	3.8	3.1
Yên Bái	6926	9343	5.4	6.4	3.5
Total	6868	8197	4.3	5.5	3.6

Table 4.5 presents several variables of commune infrastructure and household assets. Communes in Hoa Binh, Lai Chau and Yen Bai are more likely to have a good road to

commune center than communes in other provinces. Lao Cai tends to have solid health center and irrigation. Regarding household housing conditions, tap water and flush toilet are very limited in this project area. Motorbikes and televisions are more popular, but the proportion of these durables varies remarkably across the provinces. Households in Hoa Binh are more likely to have durables, while households in Lai Chau are less likely to have durables.

Table 4. 5: Cropland and livestock of communes by provinces

Provinces	Commune infrastructure: % communes with:				Household assets: % of households in communes with:			
	Good road (passable all the time)	Solid health center	Irrigation system	Market	With piped water	Flush latrine	Motorbike	Color television
Điện Biên	38.89	66.67	33.33	11.11	0.04	0.48	68.02	44.60
Hòa Bình	69.05	71.43	42.86	33.33	0.28	1.27	70.62	78.78
Lai Châu	70.00	53.33	66.67	13.33	0.02	0.60	47.86	45.44
Lào Cai	46.67	82.22	86.67	20.00	0.06	1.52	69.04	52.47
Sơn La	32.43	54.05	48.65	24.32	0.39	0.46	74.58	46.58
Yên Bái	72.50	75.00	70.00	22.50	0.79	2.33	71.14	56.20
Total	54.78	68.26	58.70	21.30	0.27	1.16	67.66	54.83

Figure 4.13: The Coping Capacity Index of communes by provinces

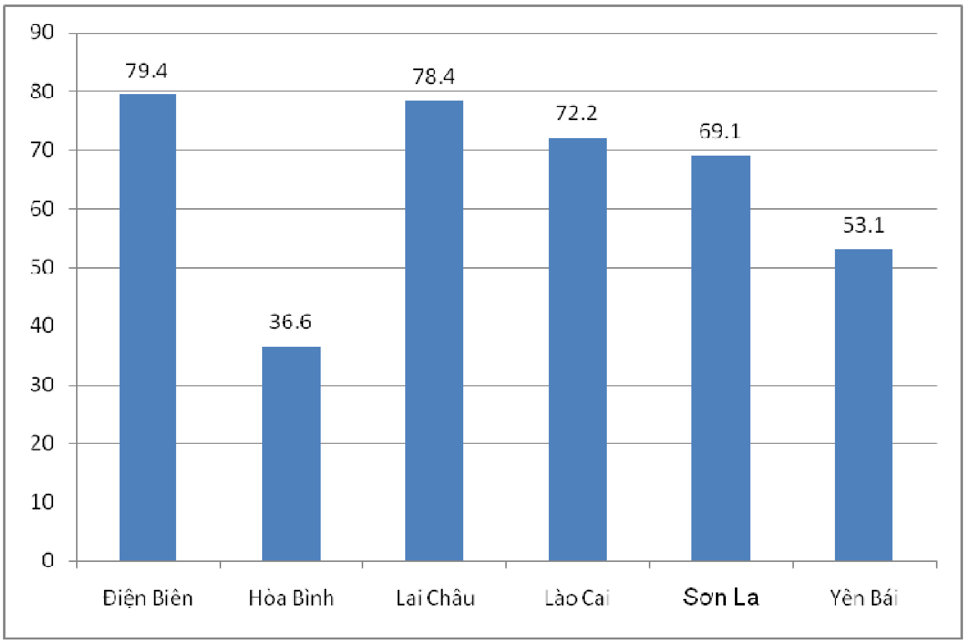


Figure 4.13 presents the Coping Capacity Index of communes by provinces. It should be noted that the higher value of the Coping Capacity Index suggests the lower

capacity to cope with and recover from the natural hazards. Lai Chau and Dien Bien are provinces with the lowest capacity to cope with hazards. Hoa Binh and Yen Bai have the highest coping capacity.

Figure 4.14: Map of the Coping Capacity Index

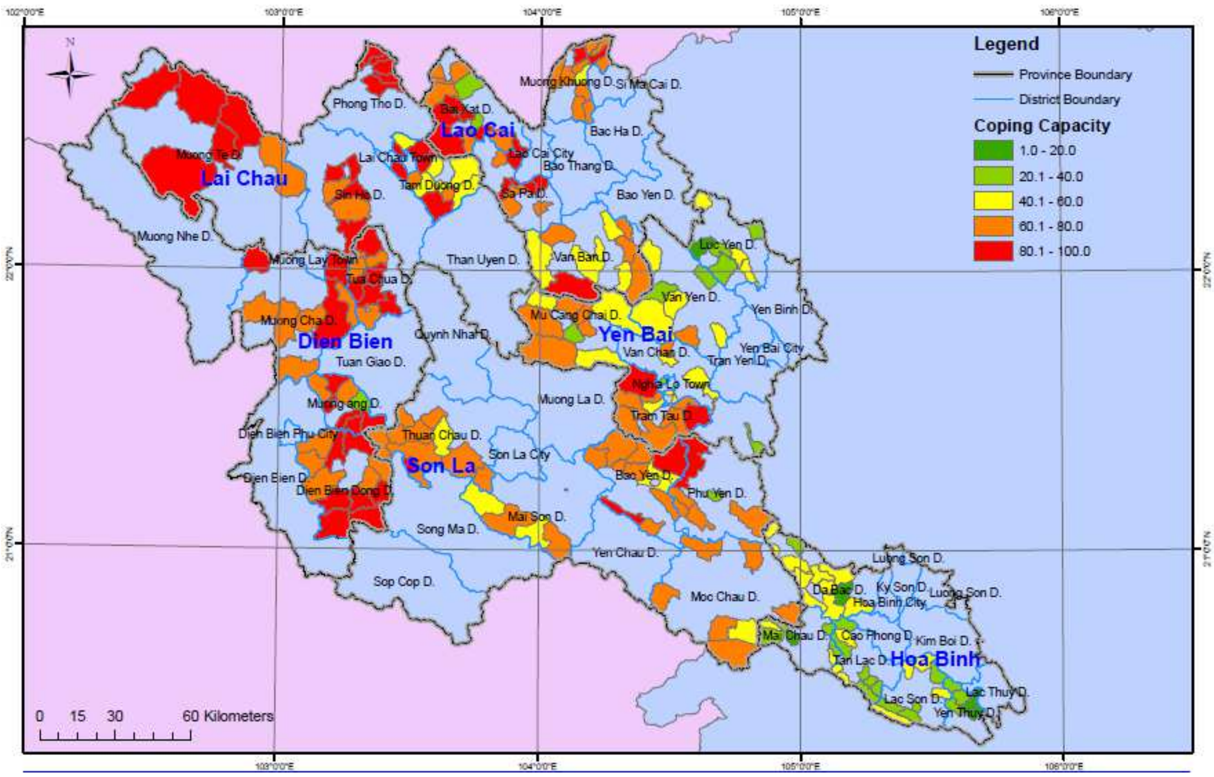


Figure 4.14 presents the Map of Coping Capacity Index of communes in the project areas. Thanh Kim commune in Lao Cai province, and the Bun To commune in the Lai Chau province, Tua Sin Chai commune in the Lai Chau province, and the Xin Chai commune in the Dien Bien province are those with the highest value of the Coping Capacity Index. These communes have the lowest capacity to cope with hazards in the project areas.

Institutional capacity

As different disadvantaged social groups are affected by climate change at different extent, and local institutions play a central role in influencing how different groups mobilize assets and resources, adaptation to climate change is local and institutions significantly impacts climate change vulnerability as well as adaptive capacity (Agrawal, 2008). It is, therefore, critical to understand the role of local officers and their interaction with community when it comes to natural disaster risk adaptation and mitigation. While the construction of the Coping Capacity Index has already taken into account the education level of local residents over 15 years of age as well as of president and vice president of People's Committee, the analysis would be incomprehensive without examining other important aspects such as the organization of risk management institution at local levels and the knowledge of key personnel as regards climate change phenomenon and adaptation. Under this circumstance, the field study has serves as supplement to the quantitative study. In this part, the capacity of district and commune officers in areas related to reducing natural hazards and adapting to climate change, and officers' knowledge gaps will be analyzed based on findings from our tailored studies.

Structure of natural disaster risk management agencies

District Committee for Flood and Storm Control and Search and Rescue (briefly called as District Committee for Flood and Storm Control) is the highest agency holding accountable for implementing prevention and mitigation measures to cope with flood and storm as well as other extreme weather events such as drought, extreme cold, and cyclone. The Committee is chaired by Vice President[17] of the District People's Committee while the Head of District Department of Agriculture and Rural Development is the standing vice chair of the committee. In all 12 districts where the field study was undertaken, the positions of the standing vice chair are held by men. The major responsibilities of the District Committee for Flood and Storm Control include: (i) develop and implement flood and storm control and evacuation plans for the whole district, (ii) monitor natural disaster control actions as well as mobilize resources to cope with natural disaster risks, (iii) implement thematic national, provincial and district guidelines on controlling flood and storm, and mitigating natural disaster, and (iv) give directions for communes in completing respective commune committee organization, developing flood and storm controlling plans as well as monitor communes to assure district guidelines are effectively complied.

There is wide availability of documents regulating the operation and responsibilities of District Committee for Flood and Storm and its members in 12 districts of the in-

[17] In some districts, the committee is chaired by the President of the District People's Committee

depth study. Collaboration mechanism between the Committee and other departments and agencies within the districts is also stipulated in such documents. For instance, documents developed by Thuan Chau district (Son La province) and Tan Lac district (Hoa Binh province) are quite comprehensive covering wide and detailed responsibilities of respective district agencies and members of their committee including stages from communication to resource mobilization. In addition, those documents also set out list of communes designated for each official member of the District Committee to be in charge of. Every year, before the beginning of the raining season (normally at the end of March or early April), the committee organizes with presence of all committee members who are in charge of monitoring respective communes' preparation stage, identifying most critical points and vulnerable issues of their in-charge communes and subsequently reporting to the committee for developing appropriate coping and evacuation measures.

At the commune level, the Commune Flood and Storm Control Committee is led by Chairperson of the Commune People's Committee and comprised of members from communal detachment, communal security head and village heads. In most communes, heads of villages are appointed as members of the Commune Flood and Storm Control Committee and mainly responsible for planning disaster preparedness and disseminating warnings on natural disaster hazards to their residents. Every year, these Committees receive guidelines on developing flood and storm control and mitigation plan based on the general plan developed by District Flood and Storm Control Committee. However, according to some communes such as Hua Ngai and Ngoi Cay in Dien Bien province, Quy Hoa, Lac Son in Hoa Binh province, and Ban Mu, Tram Tau in Yen Bai province, the development of these plans are rarely supervised and examined by in-charge district officers though all 12 communes in the in-depth study recorded that the all 12 visited communes have their storm and flood control plans prepared prior to the raining season (normally in April).

Capacity in understanding and identifying natural disasters/extreme weather events and coping strategies

Knowledge on climate change phenomenon and its underlying causes is crucial for the development of mitigating measures. It is indicated through in-depth interviews during the field study that most local officers are familiar with the 'climate change' term. Accordingly, the majority of respondents could give some examples of climate change effects such as increase in average temperature, rising sea levels and growing number and severity of extreme weather events. There are many cases where local officers supposed that climate change is interchangeable with the occurrence of extreme climatic events such as drought, storm, extreme and prolonged cold, landslide, and flash flood. With regard to reasons fueling this global phenomenon, industrialization and deforestation were cited as the most common causes of climate change. However, the number of people who are able to understand the nature of climate change and especially the human impacts leading to climate change is notably low (less than 50% of respondents). The importance of building up and enhancing climate-adaptive livelihoods while begins to be highlighted, still remains unfamiliar to most localities. The notion of integrating climate change in local development strategies or plans remains unknown to most respondents in the in-depth interviews. In some cases, local staff reveals their unwillingness to incorporate climate change issue in local planning since they are concerned about incurred potential costs for future management and about lengthened and complicated the planning process.

Box 8: Climate change is not unfamiliar

It is not until now that we first heard about climate change. Climate and weather change every year. For many years local people in our communities have been aware of the occurrence and damages of uncommon weather events. There have been already many coping strategies in place.

Source: in-depth interview with vice leader of Agricultural Department, Muong Cha district, Dien Bien province

Timely and accurate forecast of the occurrence and intensity of natural climate risks plays an important role in disaster prevention and preparedness, enabling local authorities to deliver warning messages to their people and making adequate preparations as well as being ready for evacuation plans when needed. With regard to major source of information on natural disaster hazards, all districts involved in the in-depth study responded that they mostly obtain weather forecast information from the National Center for Hydro-Meteorological Forecasting broadcast on national and local television channels. When there are forecasts of extreme weather events happening in the locality, information disseminating procedure follows a vertical order: from province to respective districts and from districts to communes. The transferring process is firstly undertaken via telephones to make sure that localities take immediate and proper coping action. Simultaneously, the issuance of written guidelines/directions on implementing appropriate preventing and mitigating measures from upper agencies to lower units is undertaken.

Box 9: Mobile phones facilitates information dissemination

Now most village heads in our communes have mobile phones. Therefore, whenever there is news regarding the movement of an extreme weather event from district or broadcast on TV, our in-charge officers only have to inform all village heads via telephones. These heads would share information with households in their village and make preparations accordingly. In case of emergency (in case of severe flash flood or landslide that requires immediate evacuation), we would use *'gong'* (a traditional equipment of ethnic minorities) to send alerts to all households.

Source: in-depth interview with Chairman of Commune People's Committee in Chieng Ken commune, Lao Cai province

The results from the assessment show that most of the local officers (more than 90% of interviewed commune and district staff) indicate high awareness of climatic risks and the damage extent caused by extreme weather events. In-depth interviews with staff from District Department of Agriculture and chairmen of the Commune People's Committees in surveyed districts show that these officers possess sound knowledge of the pattern of extreme weather events in their localities as well as the impacts on main agricultural livelihoods. Especially in Lac Son district (Hoa Binh province), Moc Chau district (Son La province), Van Ban district (Lao Cai province) and Sin Ho district (Lai Chau province), respondents from the Agriculture Department could provide insightful assessment on the history of extreme weather events during the past three years, their damages on human lives, housing, infrastructure, and farm as well as non-farm activities such as the number of destroyed houses, damaged rice area, and number of livestock deaths. In addition to regular climatic disasters, the majority of local staffs also show a reasonable understanding of irregular but devastating weather events like hails and cyclone. Likewise, up to 85% of Commune Facilitators reveal good knowledge on extreme weather events occurring at their working area during the past year with regard to the commune's topography, type of disasters, damages on main plants and livestock, as well as most affected points. There are, however, some communes where new facilitators have recently been appointed with poor understanding of natural disaster history in the locality. More training in which disaster risk identification and management should be developed and integrated with core training sessions for those staff.

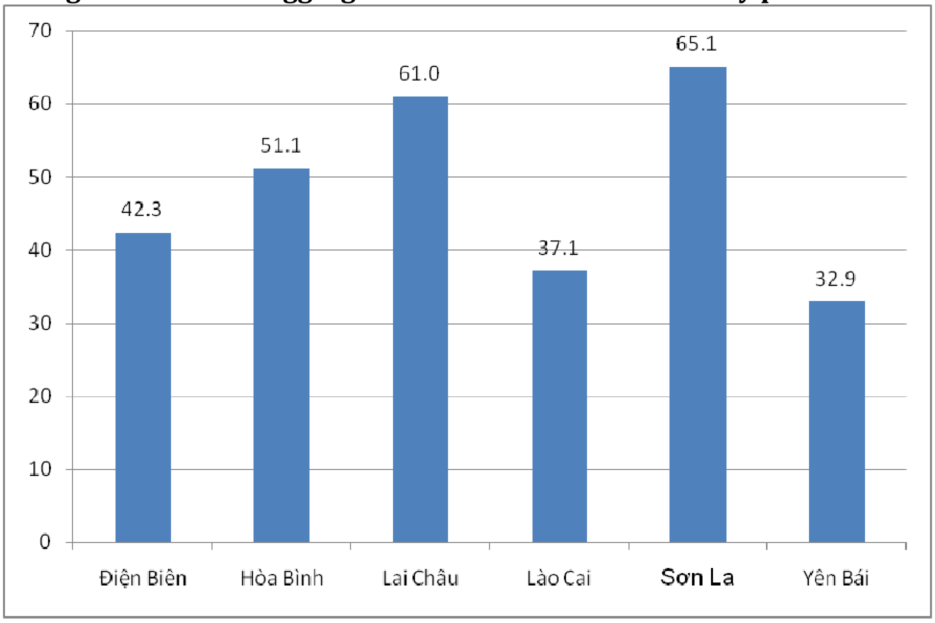
With regard to local resources to adapt to natural disaster events, annual reports on flood and storm control and mitigation in 12 districts suggest that 11 in-charge departments at district level have been well-prepared ‘four resources’ in place: (i) human resource, (ii) logistic support, (iii) material and equipment, and (iv) leadership. 10 out of 12 districts reported that they have a warehouse to store necessary equipment for managing flood and evacuating their residents in case of severe storm, landslide or other emergent events. However, resources ready for disaster mitigation and prevention remain quite poor and limited to basic items such as life vests, steel cages, shovels, and tents. At commune level, no warehouse is in place and most resources are subject to the district supply or commune people’s contribution.

These annual reports also give an evaluation of in-charge officers at district and commune level with regard to their skills and experiences in coping with flood and storm as well as other natural disasters. Accordingly, supervising and monitoring activities at most critical infrastructure and irrigation works prior to raining season are well performed in most districts, which allows timely interventions from in-charge authorities. In-charge staff of the visited communes also indicated ability in communicating with their local people and flexibility in making use of resources available within their commune during and after the occurrence of storm and flood. Nevertheless, there remain some shortcomings at commune level (in Moc Chau district, Son La province for instance) where staff show poor skills in preparing for and coping with other devastating weather events, especially hailstorm and landslides. Many communes, partly due to shortage of specialized equipment, fail to pay adequate attention to assigning staff on duty in raining season, particularly during night, which hinders timely coping efforts. Reporting capacity of commune staff is also weak leading to inaccurate dissemination of information to upper levels.

Meanwhile, at village level, in-depth interviews and focus group discussions with the involvement of village heads show that these people are quite experienced in predicting natural disaster pattern in their locality. This situation can be attributed to a fact that village heads are mostly elders who have resided in the commune for a long time and thus, gain an enriching account of extreme weather event history in their area. Village heads are also capable of connecting people in emergent cases. However, their hazard management skills are comparably low and heavily subject to guidance from commune level.

4.3. Assessment of Aggregate Risk

Figure 4. 15: The aggregate risk index of communes by provinces



The Aggregate Risk Index is computed by the weighted average of the Hazard Potential Index, Hazard Exposure Index, and Coping Capacity Index. The Aggregate Risk Index of communes by provinces is presented in Figure 4.15[18]. Son La and Lai Chau are the provinces with the highest Aggregate Risk Index, while Yen Bai and Lao Cai are the provinces with the lowest Aggregate Risk Index. The Aggregate Risk Index varies substantially across provinces. Within a province, the Aggregate Risk Index also differs but with a lower magnitude. Table3.6 and Table 4.7 present the estimates of the four indexes of communes by provinces and districts.

Table 4. 6: The estimates of the risk indexes by provinces

Provinces	Hazard potential index	Hazard exposure index	Coping capacity index	Aggregate risk index
Điện Biên	27.8	34.4	79.4	42.3
Hòa Bình	61.2	45.5	36.6	51.1
Lai Châu	69.1	27.2	78.4	61.0
Lào Cai	24.3	27.8	72.2	37.1
Sơn La	74.3	42.6	69.1	65.1
Yên Bái	23.1	32.3	53.1	32.9
Total	45.3	35.1	63.8	47.4

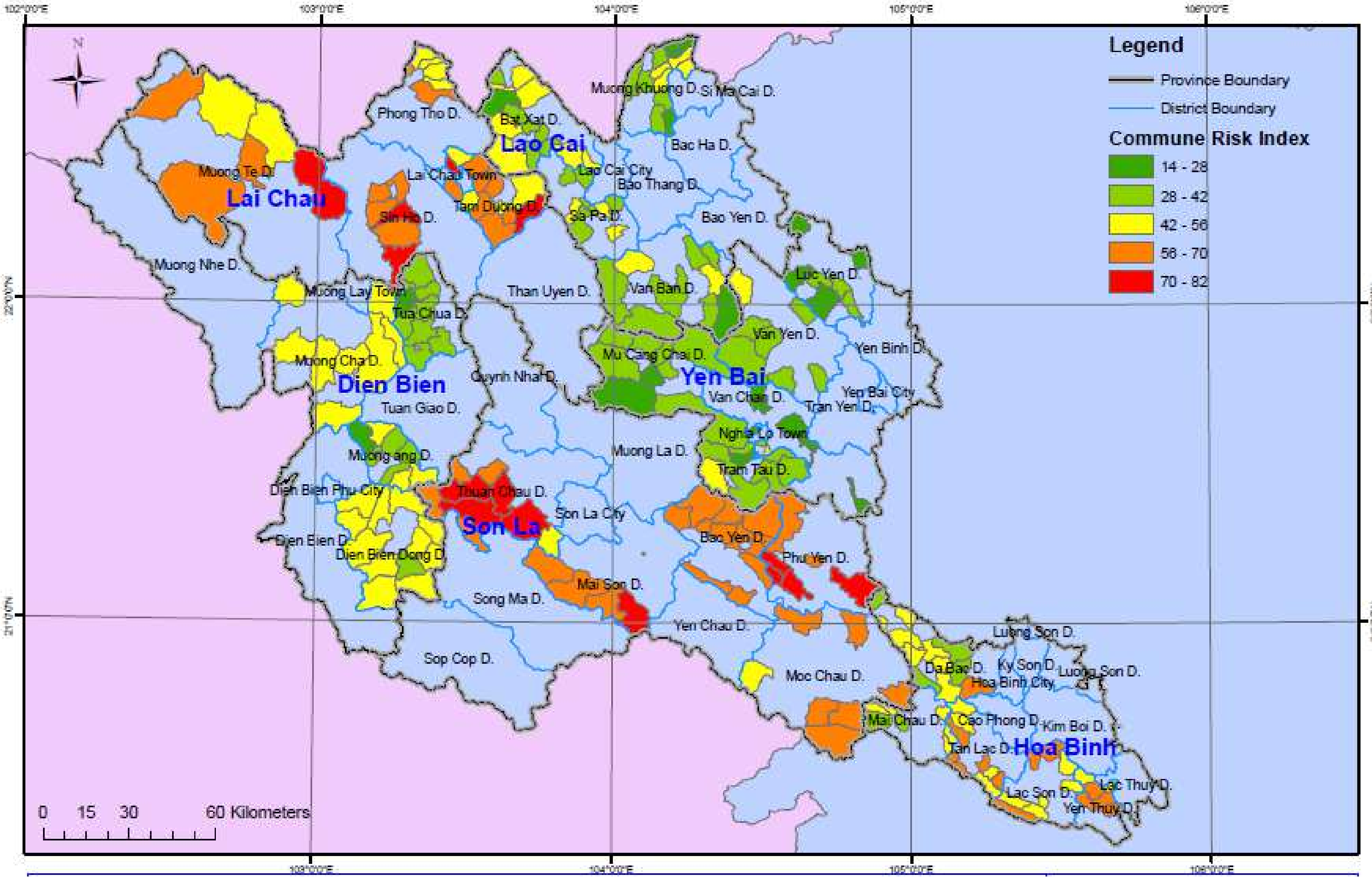
[18] The detailed maps of the Aggregate Risk Index for each project province are presented in Annex III.

By districts, Phu Yen and Thuan Chau districts in the Son La province, Sin Ho district in the Lai Chau province are those having the highest values on the Aggregate Risk Index. By communes, the commune of Kim Bon, Long He and Muong Bam in the Son La province tend to have high value of the Aggregate Risk Index. The ranking of the communes by the Aggregate Risk Index is presented in Annex III. We classify the communes in each province into 5 groups by the vulnerability to extreme weather events: (i) Highest vulnerability, (ii) Near highest vulnerability, (iii) Medium, (iv) Near lowest vulnerability, and (v) Lowest vulnerability.

Table 4. 7: The estimates of Risk Indexes by districts

Districts	Hazard potential index	Hazard exposure index	Coping capacity index	Aggregate risk index
Điện Biên				
Điện Biên Đông	34.4	37.9	82.0	47.2
Mường Ảng	25.8	27.8	73.1	38.1
Mường Chà	40.0	36.4	79.5	49.0
Tủa Chùa	7.5	33.5	81.8	32.6
Hòa Bình				
Đà Bắc	53.2	38.5	43.1	47.0
Lạc Sơn	64.0	49.5	40.7	54.6
Mai Châu	46.9	45.4	35.1	43.5
Tân Lạc	70.1	46.4	39.5	56.5
Yên Thủy	77.6	51.7	17.2	56.1
Lai Châu				
Mường Tè	62.4	31.2	86.5	60.6
Phong Thổ	56.9	19.9	85.7	54.9
Sìn Hồ	82.5	24.3	82.6	68.0
Tam Đường	71.9	30.4	68.5	60.7
Lào Cai				
Bát Xát	31.2	25.5	72.3	40.0
Mường Khương	16.2	28.5	74.4	33.9
Sa Pa	22.1	26.6	81.7	38.1
Văn Bàn	26.2	31.0	60.9	36.1
Sơn La				
Bắc Yên	70.5	39.5	71.4	63.0
Mộc Châu	64.2	48.0	67.6	61.0
Mai Sơn	68.3	56.1	61.8	63.6
Phù Yên	89.8	39.6	66.3	71.4
Thuận Châu	78.4	38.3	72.3	66.8
Yên Bái				
Lục Yên	19.1	41.3	35.2	28.7
Mù Cang Chải	23.4	21.6	60.4	32.2
Trạm Tấu	29.1	16.2	72.7	36.7
Văn Chấn	7.7	52.9	45.6	28.5
Văn Yên	36.8	34.1	44.9	38.2

Figure 4. 16: Map of the Aggregate Risk Index



5. Conclusion

The risk assessment index follows the method of Greiving (2006) and Greiving et al. (2006) to construct the aggregate risk index which is used to assess and rank the risk of project communes. The Aggregate Risk Index is a composite index comprising three separate components: Hazard Potential Index, Hazard Exposure Index and Coping Capacity Index. The Hazard Potential Index is a measurement of the probability of natural disasters. Meanwhile, the Hazard Exposure Index and Coping Capacity Index are used to measure the vulnerability of communes to the natural disasters.

Our findings show that communes in Son La, Lai Chau and Hoa Binh tend to have higher Hazard Potential Index than other provinces. Regarding the hazard exposure, communes by provinces whereby Hoa Binh and Son La are more exposed to the disasters. This implies that the economic and human losses would be larger in case a hazard occurs in Hoa Binh given other factors fixed. On the contrary, Lai Chau and Son La are less likely to be exposed to hazards. The Coping Capacity Index measures the coping capacity with higher value indicating the lower capacity to cope with hazards. Lai Chau and Dien Bien are the provinces with the lowest capacity to cope with climate hazards meanwhile Hoa Binh and Yen Bai has the highest coping capacity.

In addition to the construction of the indexes, the research has also employed tailored surveys and in-depth study during the field study to have a more profound analysis in the vulnerability level of local communities. Main findings from these studies indicate that extreme and prolonged cold, drought, storm, and flash flood are seen as the most common types of extreme weather events happening in this area, threatening communes' infrastructure, properties and especially agricultural production. Extreme cold and prolonged cold is seen as the most damaging event for rice and other food crops, livestock and poultry raising since it directly affects the growth and productivity of main crops and usually leads to deathly diseases among households' animals. Meanwhile, landslide caused by heavy rain, flood and flash flood is the most devastating to local infrastructure, especially traffic roads and irrigation systems located by high mountains, hills or rivers, ponds and streams.

The field study also contributes to a greater understanding of the strengths and weaknesses of commune staff and facilitators in identifying and adapting to extreme weather events. Most local officers show a good understanding of appropriate measures to mitigate negative effects caused by extreme weather events. However, forecasting capacity of these officers remains weak and limited. The capacity to proactively mobilize multiple resources in the locality is still missing. Village staff, despite sound familiarity with their area in term of natural disaster history, is in critical need of more systematic training in identifying natural disaster risks which is conducive to building their ability to take initiatives in developing coping measures for the local people. To address the situation, a development of a training program follows in Chapter 5.

Overall, the Aggregate Risk Index is computed as the weighted average of the Hazard Potential Index, the Hazard Exposure Index, and the Coping Capacity Index. Son La and Lai Chau are the provinces with the highest Aggregate Risk Index, while Yen Bai and Lao Cai are the provinces with the lowest Aggregate Risk Index. By districts, Phu Yen and Thuan Chau districts in the Son La province, Sin Ho district in the Lai Chau province are those having the highest values on the Aggregate Risk Index.

The risk ranking holds a crucial role in identifying most vulnerable areas in each province which need prioritized support for establishing coping measures. Meanwhile, knowledge about the characteristics of frequent natural hazards along with their impacts on main production activities plays an important role in targeting most vulnerable livelihoods and accordingly, developing appropriate interventions to promote the climate-resilient models.

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Annex: Commune Risk Ranking

Table A.1. Commune Risk Ranking of Yen Bai province

Commune	District	Hazard Potential	Hazard Exposure	Coping Capacity	Aggregate Risk Index
Xã Thạch Lương	Văn Chấn	27,0	86,6	53,1	48,4
Xã Châu Quế Thượng	Văn Yên	43,9	55,9	44,0	47,0
Xã Bản Công	Trạm Tấu	39,3	20,1	71,9	42,6
Xã Tà Si Láng	Trạm Tấu	30,4	15,0	85,6	40,4
Xã La Pán Tẩn	Mù Căng Chải	31,7	32,9	63,2	39,9
Xã Bản Mù	Trạm Tấu	33,2	17,1	75,3	39,7
Xã Quang Minh	Văn Yên	35,1	54,4	32,5	39,3
Xã Tân Lập	Lục Yên	34,6	38,2	48,4	38,9
Xã Lao Chải	Mù Căng Chải	22,9	33,3	76,1	38,8
Xã Hạnh Sơn	Văn Chấn	6,0	95,1	46,8	38,5
Xã Làng Nhì	Trạm Tấu	35,0	15,8	67,5	38,3
Xã Động Quan	Lục Yên	34,7	61,3	21,5	38,1
Xã Mồ Dề	Mù Căng Chải	32,5	11,4	75,2	37,9
Xã Nà Hẩu	Văn Yên	35,4	19,7	61,0	37,9
Xã Viễn Sơn	Văn Yên	35,5	33,1	46,8	37,8
Xã Nậm Có	Mù Căng Chải	33,3	24,7	59,6	37,7
Xã Phình Hồ	Trạm Tấu	29,6	16,0	75,0	37,6
Xã Nậm Khắt	Mù Căng Chải	32,3	27,8	56,7	37,3
Xã Chế Cu Nha	Mù Căng Chải	32,2	19,4	61,8	36,4
Xã Phong Dụ Thượng	Văn Yên	33,9	20,1	55,2	35,8
Xã Xà Hồ	Trạm Tấu	27,4	24,4	63,8	35,7
Xã Phan Thanh	Lục Yên	34,9	29,6	42,9	35,6
Xã Xuân Tầm	Văn Yên	36,2	22,2	45,1	34,9
Xã Túc Đán	Trạm Tấu	26,2	3,0	83,7	34,8
Xã Phong Dụ Hạ	Văn Yên	37,8	33,2	29,4	34,5
Xã Pá Lau	Trạm Tấu	27,7	8,0	72,1	33,9
Xã Khao Mang	Mù Căng Chải	23,7	25,5	49,2	30,5
Xã Nậm Mười	Văn Chấn	3,2	34,1	70,9	27,9
Xã Tân Phượng	Lục Yên	19,0	22,4	50,6	27,8
Xã Trạm Tấu	Trạm Tấu	12,8	26,3	59,1	27,8
Xã Suối Bu	Văn Chấn	5,3	45,9	42,1	24,7
Xã Suối Giàng	Văn Chấn	4,8	35,9	49,9	23,9
Xã Minh An	Văn Chấn	7,1	46,4	31,3	23,0
Xã Mường Lai	Lục Yên	3,1	57,7	27,2	22,8
Xã Sơn Lương	Văn Chấn	3,4	37,5	42,8	21,8
Xã Phúc Lợi	Lục Yên	2,9	38,5	35,9	20,1
Xã Nghĩa Sơn	Văn Chấn	4,7	41,9	28,1	19,8
Xã Khánh Hoà	Lục Yên	4,7	41,2	19,5	17,5
Xã Chế Tạo	Mù Căng Chải	1,3	1,0	63,4	16,7
Xã Dế Su Phình	Mù Căng Chải	1,0	18,8	38,5	14,8

Table A.2. Commune Risk Ranking of Son La province

Commune	District	Hazard Potential	Hazard Exposure	Coping Capacity	Aggregate Risk Index
Xã Kim Bon	Phù Yên	99,5	52,2	77,9	82,3
Xã Long Hẹ	Thuận Châu	95,6	49,9	66,5	76,9
Xã Mường Bang	Phù Yên	98,2	39,6	70,0	76,5
Xã Co Mạ	Thuận Châu	87,7	48,4	77,1	75,2
Xã Sập Xa	Phù Yên	92,1	37,6	77,4	74,8
Xã Suối Bau	Phù Yên	92,2	32,3	70,8	71,9
Xã Nậm Lầu	Thuận Châu	87,1	42,8	69,3	71,6
Xã Chiềng Bôm	Thuận Châu	100,0	24,8	56,9	70,4
Xã Phiêng Pằn	Mai Sơn	71,3	69,2	68,4	70,1
Xã Hua Nhàn	Bắc Yên	70,5	44,1	88,9	68,5
Xã Tân Hợp	Mộc Châu	67,0	69,9	67,3	67,8
Xã Phiêng Kôn	Bắc Yên	69,7	52,1	76,4	67,0
Xã Hồng Ngài	Bắc Yên	72,5	45,4	73,6	66,0
Xã é Tòng	Thuận Châu	86,9	19,9	69,2	65,7
Xã Pá Lông	Thuận Châu	67,6	48,8	76,7	65,2
Xã Mường Bám	Thuận Châu	65,5	47,8	78,9	64,4
Xã Co Tòng	Thuận Châu	63,9	42,5	87,2	64,4
Xã Làng Chếu	Bắc Yên	70,8	43,3	67,9	63,2
Xã Hang Chú	Bắc Yên	72,5	38,4	67,7	62,7
Xã Phiêng Cằm	Mai Sơn	68,0	47,2	66,7	62,5
Xã Xuân Nha	Mộc Châu	68,1	58,9	54,7	62,5
Xã Hưy Tường	Phù Yên	89,8	47,3	21,5	62,1
Xã Xín Vàng	Bắc Yên	70,5	35,9	71,4	62,1
Xã Suối Bàng	Mộc Châu	66,3	53,9	60,6	61,8
Xã Háng Đồng	Bắc Yên	70,5	13,8	92,0	61,7
Xã Bắc Ngà	Bắc Yên	68,7	36,6	72,3	61,6
Xã Nà Ơt	Mai Sơn	68,0	54,7	55,6	61,6
Xã Chiềng Yên	Mộc Châu	67,9	42,1	68,2	61,6
Xã Phiêng Ban	Bắc Yên	72,1	50,3	49,6	61,0
Xã Chiềng Xuân	Mộc Châu	66,1	38,2	72,6	60,8
Xã Suối Tọ	Phù Yên	67,0	28,8	80,2	60,7
Xã Chiềng Nơi	Mai Sơn	65,7	53,3	56,5	60,3
Xã Phỏng Lập	Thuận Châu	64,4	31,1	79,6	59,9
Xã Tân Xuân	Mộc Châu	66,1	29,1	77,9	59,8
Xã Tà Xùa	Bắc Yên	67,4	35,1	54,6	56,1
Xã Bản Lầm	Thuận Châu	65,0	26,9	61,2	54,5
Xã Chiềng Khừa	Mộc Châu	47,6	43,8	71,7	52,7

Table A.3. Commune Risk Ranking of Lao Cai province

Commune	District	Hazard Potential	Hazard Exposure	Coping Capacity	Aggregate Risk Index
Xã Thanh Kim	Sapa	40,2	10,4	100,0	47,7
Xã Lao Chải	Sapa	40,1	21,2	84,6	46,5
Xã Sàng Ma Sáo	Bát Xát	39,1	21,3	85,5	46,3
Xã Tả Gia Khâu	Mường Khương	37,8	29,4	79,0	46,0
Xã Lùng Khấu Nhin	Mường Khương	37,5	50,3	58,4	45,9
Xã Nấm Lư	Mường Khương	37,5	35,4	73,0	45,9
Xã Dìn Chin	Mường Khương	28,5	36,4	88,9	45,6
Xã Ngải Thầu	Bát Xát	37,2	35,8	72,1	45,5
Xã Tòng Sành	Bát Xát	39,4	15,0	86,6	45,1
Xã Phìn Ngan	Bát Xát	39,4	23,3	78,2	45,1
Xã Nậm Sài	Sapa	41,5	30,6	64,7	44,6
Xã Chiềng Ken	Văn Bàn	35,4	35,9	71,1	44,5
Xã Trung Lèng Hồ	Bát Xát	40,9	13,1	82,8	44,4
Xã Nậm Chạc	Bát Xát	36,7	39,9	63,5	44,2
Xã Nậm Chầy	Văn Bàn	40,4	12,9	78,1	43,0
Xã Trịnh Tường	Bát Xát	36,8	56,3	38,9	42,2
Xã Nậm Pung	Bát Xát	40,6	13,0	72,2	41,6
Xã A Lù	Bát Xát	36,5	23,4	68,7	41,3
Xã Bản Xèo	Bát Xát	39,4	45,1	36,9	40,2
Xã Trung Chải	Sapa	31,4	15,0	81,7	39,9
Xã Dương Quỳ	Văn Bàn	32,7	36,6	55,2	39,3
Xã Dền Sáng	Bát Xát	28,5	15,8	81,7	38,6
Xã Liêm Phú	Văn Bàn	34,5	30,5	54,5	38,5
Xã Nậm Xây	Văn Bàn	30,8	11,4	80,9	38,4
Xã Tả Van	Sapa	9,2	50,7	79,5	37,1
Xã Tân Thượng	Văn Bàn	14,8	57,9	60,0	36,9
Xã Sử Pán	Sapa	9,4	43,5	76,9	34,8
Xã Hầu Thào	Sapa	8,9	31,1	84,2	33,3
Xã Làng Giàng	Văn Bàn	12,7	50,3	56,0	32,9
Xã Dền Thàng	Bát Xát	7,9	21,0	92,3	32,3
Xã Nậm Xé	Văn Bàn	30,6	19,6	41,6	30,6
Xã Bản Phùng	Sapa	9,5	7,7	94,8	30,4
Xã Pa Cheo	Bát Xát	8,1	20,2	82,2	29,6
Xã Sơn Thuỷ	Văn Bàn	17,1	39,5	44,6	29,6
Xã La Pan Tẩn	Mường Khương	6,8	24,2	78,7	29,1
Xã Tả Phìn	Sapa	8,7	29,3	68,6	28,8
Xã Nậm Chảy	Mường Khương	6,0	21,5	79,6	28,3
Xã Thanh Bình	Mường Khương	6,6	33,9	65,6	28,2
Xã Cao Sơn	Mường Khương	7,4	29,0	68,7	28,1
Xã Tung Chung Phố	Mường Khương	6,0	13,7	86,4	28,0
Xã Tả Ngải Chồ	Mường Khương	6,1	25,3	72,4	27,5
Xã Tả Thàng	Mường Khương	8,7	13,3	77,4	27,0
Xã Nậm Tha	Văn Bàn	12,9	15,4	66,4	26,9
Xã Pha Long	Mường Khương	6,1	30,1	65,0	26,9
Xã Y Tý	Bát Xát	6,1	13,8	70,7	24,2

Table A.4. Commune Risk Ranking of Lai Chau province

Commune	District	Hazard Potential	Hazard Exposure	Coping Capacity	Aggregate Risk Index
Xã Tủa Sín Chải	Sìn Hồ	90,6	21,5	98,0	75,2
Xã Bản Bo	Tam Đường	93,6	58,5	48,0	73,4
Xã Tả Ngảo	Sìn Hồ	94,8	19,3	82,7	72,9
Xã Sùng Phài	Tam Đường	90,7	20,5	88,2	72,5
Xã Hua Bun	Mường Tè	58,6	100,0	72,1	72,3
Xã Phăng Sô Lin	Sìn Hồ	82,4	24,9	84,3	68,5
Xã Tả Phìn	Sìn Hồ	82,4	18,8	83,6	66,8
Xã Nùng Nàng	Tam Đường	81,6	22,1	80,1	66,4
Xã Sà Dề Phìn	Sìn Hồ	82,1	24,2	71,7	65,0
Xã Bản Hon	Tam Đường	86,3	28,4	56,8	64,5
Xã Giang Ma	Tam Đường	64,7	32,7	83,9	61,5
Xã Tà Tổng	Mường Tè	62,3	27,3	91,7	60,9
Xã Kă Lang	Mường Tè	79,5	3,4	80,8	60,8
Xã Nà Tăm	Tam Đường	67,6	29,3	74,8	59,8
Xã Ma Li Chải	Phong Thổ	56,5	30,2	95,3	59,6
Xã Làng Mô	Sìn Hồ	62,9	37,4	75,1	59,6
Xã Bun Tở	Mường Tè	58,4	20,1	99,4	59,1
Xã Dào San	Phong Thổ	57,8	30,9	87,7	58,5
Xã Khun Há	Tam Đường	63,6	14,7	85,8	56,9
Xã Hồ Thầu	Tam Đường	66,8	39,6	52,6	56,4
Xã Tả Lèng	Tam Đường	61,2	19,4	83,8	56,4
Xã Pa Vệ Sử	Mường Tè	57,8	20,8	86,9	55,8
Xã Bản Giang	Tam Đường	62,1	37,4	61,3	55,7
Xã Pa Vây Sử	Phong Thổ	57,1	22,3	85,0	55,4
Xã Pa ủ	Mường Tè	57,8	15,7	88,3	54,9
Xã Sơn Bình	Tam Đường	64,7	29,3	54,8	53,4
Xã Mồ Sì San	Phong Thổ	56,6	13,9	85,9	53,2
Xã Sì Lờ Lầu	Phong Thổ	56,2	15,5	80,6	52,1
Xã Thèn Sin	Tam Đường	60,0	32,4	52,1	51,1
Xã Tông Qua Lìn	Phong Thổ	57,4	6,7	80,0	50,4

Table A.5. Commune Risk Ranking of Hoa Binh province

Commune	District	Hazard Potential	Hazard Exposure	Coping Capacity	Aggregate Risk Index
Xã Miền Đồi	Lạc Sơn	71,4	69,4	56,7	67,2
Xã Quý Hòa	Lạc Sơn	85,3	47,5	46,7	66,2
Xã Gia Mô	Tân Lạc	79,4	61,6	31,0	62,9
Xã Phú Cường	Tân Lạc	77,3	60,0	34,1	62,2
Xã Bắc Sơn	Tân Lạc	79,9	44,3	44,6	62,2
Xã Nam Sơn	Tân Lạc	81,7	39,5	41,9	61,2
Xã Đa Phúc	Yên Thủy	77,3	61,3	23,8	59,9
Xã Vầy Nưa	Đà Bắc	75,2	44,2	44,3	59,7
Xã Do Nhân	Tân Lạc	79,8	39,3	37,2	59,0
Xã Hữu Lợi	Yên Thủy	77,7	65,8	14,4	58,9
Xã Tự Do	Lạc Sơn	71,4	36,1	52,2	57,8
Xã Lạc Lương	Yên Thủy	77,3	53,1	21,0	57,2
Xã Bảo Hiệu	Yên Thủy	77,7	72,3	1,0	57,2
Xã Lỗ Sơn	Tân Lạc	70,6	48,7	31,1	55,3
Xã Đồng Ruộng	Đà Bắc	73,3	24,4	49,2	55,1
Xã Pà Cò	Mai Châu	65,8	54,9	32,9	54,8
Xã Ngòi Hoa	Tân Lạc	66,7	45,4	39,9	54,7
Xã Bình Hẻm	Lạc Sơn	68,4	35,4	44,3	54,1
Xã Mỹ Thành	Lạc Sơn	70,5	38,2	36,8	54,0
Xã Hương Nhượng	Lạc Sơn	48,1	78,6	35,5	52,6
Xã Lạc Sỹ	Yên Thủy	78,0	18,2	34,2	52,1
Xã Lạc Hưng	Yên Thủy	77,8	39,7	8,8	51,0
Xã Đồng Chum	Đà Bắc	64,2	23,3	48,5	50,0
Xã Tiền Phong	Đà Bắc	43,6	60,1	49,5	49,2
Xã Thung Khe	Mai Châu	45,5	85,1	20,5	49,2
Xã Đoàn Kết	Đà Bắc	42,3	60,6	50,0	48,8
Xã Giáp Đắt	Đà Bắc	73,8	14,9	27,6	47,5
Xã Ngổ Luông	Tân Lạc	50,5	47,4	38,9	46,8
Xã Mường Tuổng	Đà Bắc	42,1	54,9	43,8	45,7
Xã Phú Vinh	Tân Lạc	45,2	31,6	56,5	44,6
Xã Ba Khan	Mai Châu	44,5	46,5	38,6	43,5
Xã Hang Kia	Mai Châu	43,1	36,6	50,4	43,3
Xã Nong Luông	Mai Châu	46,3	33,8	44,5	42,7
Xã Ngọc Lâu	Lạc Sơn	48,2	44,4	28,8	42,4
Xã Ngọc Sơn	Lạc Sơn	49,1	46,7	24,6	42,4
Xã Trung Thành	Đà Bắc	42,6	36,9	46,2	42,1
Xã Tân Dân	Mai Châu	42,6	26,6	54,9	41,7
Xã Tân Minh	Đà Bắc	42,8	32,4	47,6	41,4
Xã Caơ Son	Đà Bắc	43,4	49,2	19,6	38,9
Xã Cun Pheo	Mai Châu	43,6	31,2	36,1	38,6
Xã Đồng Nghê	Đà Bắc	41,5	23,1	47,7	38,4
Xã Bao La	Mai Châu	43,6	48,3	2,7	34,5

Table A.6. Commune Risk Ranking of Dien Bien province

Commune	District	Hazard Potential	Hazard Exposure	Coping Capacity	Aggregate Risk Index
Xã Pa Ham	Mường Chà	38,8	53,6	78,4	52,4
Xã Xa Dung	Điện Biên Đông	35,5	43,7	90,4	51,3
Xã Phìn Hồ	Mường Chà	40,4	46,0	77,6	51,1
Xã Mường Luân	Điện Biên Đông	35,1	58,4	74,5	50,8
Xã Pú Hồng	Điện Biên Đông	44,7	25,7	87,9	50,7
Xã Hừa Ngài	Mường Chà	39,3	34,0	88,9	50,4
Xã Luân Giới	Điện Biên Đông	35,6	44,9	82,0	49,5
Xã Keo Lôm	Điện Biên Đông	35,3	48,7	78,9	49,5
Xã Ngối Cáy	Mường Ảng	44,8	25,2	83,2	49,5
Xã Na Son	Điện Biên Đông	35,5	37,4	88,1	49,2
Xã Xá Tổng	Mường Chà	40,2	30,1	82,5	48,3
Xã Mường Mươn	Mường Chà	40,1	35,8	76,2	48,1
Xã Nậm Khăn	Mường Chà	40,4	25,1	85,9	48,0
Xã Ma Thì Hồ	Mường Chà	40,4	38,6	71,8	47,8
Xã Chiềng Sơ	Điện Biên Đông	35,5	46,0	71,7	47,2
Xã Phình Giàng	Điện Biên Đông	35,0	27,0	89,2	46,5
Xã Tìa Dình	Điện Biên Đông	35,5	29,0	85,5	46,4
Xã Sa Lông	Mường Chà	40,4	27,5	75,0	45,8
Xã Xuân Lao	Mường Ảng	35,7	24,3	83,9	44,9
Xã Mường Lạn	Mường Ảng	35,7	23,2	82,4	44,2
Xã Pú Nhi	Điện Biên Đông	36,2	30,5	69,5	43,1
Xã Nong U	Điện Biên Đông	35,5	29,3	72,0	43,1
Xã ẳng Tở	Mường Ảng	36,1	24,4	62,0	39,6
Xã Sính Phình	Tủa Chùa	7,7	54,5	86,4	39,1
Xã Háng Lìa	Điện Biên Đông	13,4	34,8	93,8	38,9
Xã Nặm Lịch	Mường Ảng	13,5	20,4	93,5	35,2
Xã Sáng Nhè	Tủa Chùa	7,4	42,8	82,1	34,9
Xã Mường Báng	Tủa Chùa	7,4	50,7	73,0	34,6
Xã Tả Phìn	Tủa Chùa	7,7	32,4	89,8	34,4
Xã ẳng Nưa	Mường Ảng	11,9	32,5	80,6	34,2
Xã Xín Chải	Tủa Chùa	6,6	20,2	96,1	32,4
Xã Tả Sìn Thàng	Tủa Chùa	7,5	34,2	72,7	30,5
Xã Búng Lao	Mường Ảng	18,1	47,5	34,5	29,5
Xã Trung Thu	Tủa Chùa	8,1	19,1	80,6	29,0
Xã Mường Đăng	Mường Ảng	10,6	24,7	64,5	27,6
Xã Lao Xả Phình	Tủa Chùa	7,9	14,5	73,9	26,0