Livelihood Vulnerability Index: Measuring Climate Change vulnerability of rural communities in Northern Laos.

By
Souliyaphon Kommadam
Student ID: 2235275
Supervisor: Prof. Udoy Saikia

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DECLARATION

I certify that this thesis:

1. does not incorporate without acknowledgment any material previously submitted for a degree or diploma in any university
2. and the research within will not be submitted for any other future degree or diploma without the permission of Flinders University; and
3. to the best of my knowledge and belief, does not contain any material previously published or written by another person except where due reference is made in the text.

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Date: 30 October 2023

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ABSTRACT

Oudomxay Province, with its unique mountainous scenery, is at significant risk of being impacted by natural disasters caused by climate change every year. Beng district is one of seven districts in Oudomxay province that has been affected by natural disasters like drought and flash floods. Furthermore, because the villagers' main occupation is strongly reliant on the natural environment as a key source of living, villagers in the district are exposed to the influence of climate change. Therefore, the primary object of this study was to measure the level of livelihood vulnerability in 15 villages in Beng district, using the vulnerability assessment methodology developed by Hahn, Riederer, and Foster (2009).

The study used seven primary indicators and twenty sub-indicators by primarily using Microsoft Excel to compute the vulnerability assessment in terms of livelihood vulnerability. Furthermore, the SPSS program was used for a crosstab analysis to determine the difference in vulnerability across genders in relation to different aspects. The data for this study came from a household survey conducted by the Mekong Sentinel Landscape team in 2016. All data required for the study and calculation of livelihood vulnerability were retrieved directly from the household survey in 15 villages, with a total of 450 household samples.

The study found that Mang village had the highest overall vulnerability index (0.476) rating in relation to seven primary variables and twenty-two sub-indicators. Similarly, the findings from using the IPCC contributing factors, namely Adaptive Capacity, Sensitivity, and Exposure, to calculate the Livelihood Vulnerability Index, also indicated that Mang village exhibited the highest level of vulnerability, with a value of 0.033. However, the degree of livelihood vulnerability of each village varied in seven main indicators. As well, the result of crosstab analysis indicated that households led by females tend to be more vulnerable than male-headed households due to difficulties faced in several aspects. Therefore, the result of this study provides crucial information that can inform policy making for assisting in targeting the vulnerable communities in order to effectively manage natural disasters and in climate change mitigation and adaption.

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ADB	Asian Development Bank
DFID	Department for International Development
GoL	Government of Laos
IPCC	Intergovernmental Panel on Climate Change
IFRCS	International Federation of Red Cross and Red Crescent Societies
LVI	Livelihood Vulnerability Index
LVI-IPCC	Livelihood Vulnerability Index by using Intergovernmental Panel on Climate Change contributing factors
MoNRE	Ministry of Natural Resources and Environment

1. INTRODUCTION

1.1 Background

According to the Intergovernmental Panel on Climate Change, Climate change refers to modifications in the characteristics of the climate that can be detected through scientific investigations. These changes persist for periods typically spanning decades or even longer (IPCC 2012). Consequently, climate change has increasingly caused consequences for both communities and natural ecosystems. Furthermore, livelihoods and overall quality of life have been adversely affected by these changes (IPCC 2022a).

The United Nations (2022) emphasized that the primary driver of climate change has been the burning of fuels like coal, oil and gas. In some instances, humanitarian crises can be attributed to climate change when increased vulnerability coincides with hazards. Additionally, it is important to note that extreme weather events and conditions are increasingly influencing migration patterns across regions. Notably, small island nations bear a burden of these phenomena impacts (IPCC 2022a). According to the definition given by the IPCC, vulnerability is 'The degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes' (IPCC 2007, p.6). In other words, vulnerability refers to people's susceptibility to the potentially disastrous effects of climate unpredictability and extreme weather. In Southeast Asia specifically, many countries are considered vulnerable to climate change (Beirne et al., 2021; Yusuf & Francisco 2009). Moreover, due to its coastlines and populated regions at lower elevations, over 640 million individuals reside in an area that is highly susceptible to severe weather events and the rising sea levels stemming from global warming (Prakash 2018). Moreover, regions with vulnerable ecosystems face risks to crop yields, food security and livelihoods due to the impacts of floods, droughts and shifts in seasonal rainfall patterns (Douglas 2009; Kelkar et al. 2008).

The population of Lao People's Democratic Republic (PDR) is close to 7.3 million, and Laos is one of the nations being severely impacted by climate change. Unquestionably, Lao PDR is one of the countries vulnerable to predicted climate changes due to poverty, hunger, and the heightened susceptibility of marginalized people (ADB 2021). Additionally, the country's mountainous terrain gives it a special geographical character. Consequently, around 60 percent of Lao people continue to rely on subsistence agriculture activities such as upland and lowland

rice cultivation as their primary source of income (World Bank 2022). However, the poverty rate in Laos has seen a decline from 24.6 percent in 2013 to 18.3 percent in 2019 (World Bank 2020). As per the Lao Statistics Bureau's report for 2020, nearly 39 thousand families were affected by disasters (Lao Statistics Bureau 2021). Oudomxay Province in Laos is one of six provinces that have faced unexpected natural calamities like flash floods in recent years. According to the Lao disaster information website, Oudomxay has been struck by hazards such as floods, droughts, excessive rain, and forest fires more than 326 times, which directly affected more than 28,024 people (Laodi 2023). Recently, flash floods hit four districts in Oudomxay, impacting around 2,324 homes while causing destruction across more than 270 hectares of agricultural land (Laotian Times 2022). Moreover, the floods have inflicted damage on the villagers' farmland which serves as their primary source of income.

In order to adequately address the difficulties brought on by climate change and unexpected climate-related threats, it is imperative to acquire a comprehensive understanding of the vulnerabilities faced by communities. This research project aimed to investigate the vulnerability of livelihoods to climate variability within the Beng area of Oudomxay province using the well-known Hahn Riederer Foster (2009) approach.

1.2 Problem statement

In the climate risk reports of 2021, it was highlighted that many families in Laos were at risk of falling into poverty due to their vulnerability to climate hazards such as floods and droughts (World Bank & ADB 2021). The Ministry of Environment and Natural Resources (MoNRE) has been actively involved in addressing the disasters caused by climate change. Their focus is on implementing strategies for both adapting to and mitigating the effects of these hazards. In 2019 the Lao government introduced a decree specifically aimed at addressing climate related impacts, managing risks and safeguarding both lives and ecosystems (GoL 2019). To formulate strategies, programs and initiatives for dealing with climate change in Laos, the National Steering Committee on Climate Change Strategy was established in 2008 under the leadership of the Deputy Prime Minister (MoNRE 2009). Additionally, as per the approved 2010 National Climate Change Strategy, Laos aims to be well prepared to face challenges posed by climate change through efforts focused on adaptation and mitigation. To achieve this, Laos aims to reduce poverty, promote sustainability and improve the wellbeing of its population and the environment. This underscores the dedication of Laos to confronting and adjusting to the

difficulties presented by climate change. However, according to the Nationally Determined Contribution, there is a lack of data and understanding regarding the impacts of climate change on businesses, including downscaled scenarios and the technical expertise needed in these sectors (GoL 2021a). Additionally, the National Socio-Economic Development Plan includes measures for both mitigating and adapting to climate change. It emphasizes the importance of building capacity in all districts and provinces to effectively prevent and recover from disasters (GoL 2021b). Furthermore, according to preliminary data from the UN Habitats (2019) reports, 46% of communities have been impacted by climate change-related disasters such as droughts, floods, storms, landslides, and earthquakes. This exemplifies efforts to determine how susceptible a population is to the impacts of climate change.

Therefore, the findings from this study will provide insights for policymakers and the Lao government to address climate related challenges in regions. This will facilitate the formulation of a strategy aimed at mitigating the consequences of climate change and providing assistance for adaptation initiatives, with a specific emphasis on the populations that are most susceptible to its effects. This highlights the importance of conducting research on the impacts of climate change and evaluating the vulnerability of various regions throughout the nation. This research followed Hahn, Riederer and Foster's methodologies to evaluate how climate change affects people living in the Beng area. Additionally, it identified the group whose livelihoods are most endangered by climate change and natural disasters.

1.3 Rationale for study

Laos currently faces a dearth of information and data and adequate analysis pertaining to the extent of vulnerability within its unique population, hindering the effective management of natural disasters and the ability to respond to climate change dynamics. Furthermore, it is crucial to identify the group that exhibits the highest degree of vulnerability in order to effectively address and respond to natural disasters and climate change. The assessment of communities' vulnerability in terms of their livelihood status has emerged as a crucial factor in effectively identifying and providing assistance to the most vulnerable populations in relation to adaptation and mitigation efforts. Consequently, this study aimed to enhance the current approach to vulnerability assessment by creating a livelihood vulnerability index for communities located in Beng district, Oudomxay province.

1.4 Research question

The following research questions aided and guided the research:

a) How vulnerable are local villagers to climate variability?
b) What are aspects which make a local community most vulnerable to climate change and natural disaster?

1.4 Research objective

The primary objective of this research endeavour was to investigate the susceptibility of livelihoods in Beng district to the impacts of climate change. The study's particular objectives were:

a) To adapt the Livelihood Vulnerability Index (LVI) developed by Hahn, Riederer, and Foster (2009) to generate a localized vulnerability index.

b) To determine the level of livelihood vulnerability of local communities.

2. LITERATURE REVIEW

This chapter examines previous vulnerability assessments carried out in the study area in particular, in an effort to provide a thorough review of the literature concerning livelihood vulnerability assessment. Moreover, an analysis of the pertinent frameworks and concepts linked with vulnerability in relation to climate change are presented in this chapter, which also encompasses a historical background of vulnerability assessment.

2.1 The impact of climate change

The changing of climate is a phenomenal event that creates an enormous challenge to the environment, society and the economy all around the world. The literature shows the impact of climate change on different sectors and regions. This section reviews the impacts of the climate change on the global level. The Intergovernmental Panel on Climate Change, known as IPCC, provides a significant source of scientific literature on climate change and its impact. The IPCC's report has provided extensive information on the environment's condition, especially the science of climate change, which illustrates the observed impact and predicted impact of the climate change. The IPCC report has also emphasized that global warming is considered to be human-induced, derived from the burning of fossil fuels and deforestation (Pachauri et al. 2014). As a consequence, the impact of climate change is demonstrated in many sectors. In the agricultural sector, the changes in temperature and precipitation patterns, as well as the extreme weather events, have affected crop production, livestock and food security (Lobell et al. 2013; Rosenzweig et al. 2014). In addition, the rising of sea levels and the increasing acidity of the ocean directly affects the coast, including coastal erosion, floods and loss of habitats (Hoegh-Guldberg & Poloczanska 2017; Nicholls & Cazenave 2010). In addition, the changing climate, especially the extreme heat, also creates a threat for both the physical and mental health of the people (Haines et al. 2006; Watts et al. 2018). In the economic sector, climate change also creates damages and leads to significant cost. Stern's study indicated that the impact of climate change on the economy sector cannot be ignored and left for a long time because it will pose a more severe impact on the economy in the future (Stern 2006). The impact includes the increasing costs for improving the infrastructure, the loss of agriculture products, more budget being spent on health services, and the damages from extreme events (Hsiang et al. 2017; Pachauri et al. 2014). In addition, the most recent IPCC

report demonstrates that climate change continues to pose an adverse impact to many sectors, such as the well-being of people, biodiversity and food security (IPCC 2022b).

On the other hand, the changing climate also poses a challenge to society and the environment which includes the loss of biodiversity and disruption of ecosystems and natural resources (Pachauri et al. 2014). Due to their lower socioeconomic status, lower adaptation ability, and greater susceptibility to climate change-related risks, low-income communities, indigenous peoples, and other groups bear a disproportionate share of the costs of climate change (Adger, Arnell & Tompkins 2005; Pachauri et al. 2014). Therefore, mitigation and adaptation strategies are essential for responding to climate change globally. The focus of mitigation methods is centered on the reduction of greenhouse gas emissions as a means to attain climate stabilization. Conversely, adaptation measures seek to bolster resilience and adaptive capabilities to effectively manage the impacts of existing climate changes (Pachauri et al. 2014). The body of literature concerning the consequences of climate change unequivocally illustrates the critical nature of addressing this phenomenon. Furthermore, it exemplifies the far-reaching consequences of climate change across multiple sectors, including agriculture, health, the economy, and livelihoods. Additionally, the impact on vulnerable populations and the interdependence of social, environmental, and economic systems have been underscored. In order to foster a more resilient and sustainable future and mitigate the negative effects of climate change, the implementation of appropriate adaptation and mitigation techniques is of the highest priority.

2.3 The impact of climate change on livelihoods

As previously mentioned, climate change presents detrimental consequences for various sectors across different regions. This section will concentrate on the effects of climate change on livelihoods in particular. It is indisputable that the escalating global temperatures and the expanding unpredictability of weather patterns pose significant obstacles for various sectors and communities, threatening their ability to sustain their livelihoods. According to the IPPC report, the alterations in precipitation patterns, the escalation in temperatures, and the heightened occurrence of specific severe events collectively indicate that climate change is currently affecting food security. Furthermore, it has been observed that climate change has adversely affected the productivity of certain crops (e.g., maize and wheat) in numerous low-latitude areas. Conversely, studies that separate the impacts of climate change from those of

other factors influencing crop yields indicate that in numerous high-latitude regions, crop yields have increased in recent decades (IPCC 2022b). On the other hand, the changing pattern of rainfall and precipitation directly affects the availability of fresh water in many regions (IPCC 2022c). For instance, temporary water shortages throughout Europe have resulted from shifting snow and glacier dynamics and rainfall patterns (EU 2023). Similarly, climate change has also contributed to wildfires, deforestation and forest degradation which affect the communities who heavily rely on the forests. Nigatu (2019) highlights that the pace at which plants photosynthesis and respire is affected directly by rising temperatures, and indirectly by the likelihood of infection. Moreover, numerous comprehensive investigations and study endeavors have been conducted to examine the influences of climate change on a livelihood and well-being of individuals worldwide (Badjeck et al. 2010; Dev 2011; Dube & Phiri 2013; Garai 2014; Saadat & Islam 2011).

More importantly, the difficulties derived from climate change cause people who are not able to respond to the climate to be classed as vulnerable people. The IPCC defined vulnerability as 'the propensity or predisposition to be adversely affected and encompasses a variety of concepts and elements, including sensitivity or susceptibility to harm and lack of capacity to cope and adapt' (IPCC 2014, p.5) Moreover, based on the findings of the sixth assessment report published by the Intergovernmental Panel on Climate Change (IPCC) in 2022, a considerable proportion of the global population, estimated to be between 3.3 and 3.6 billion, lives in areas designated as "hotspots" due to their elevated vulnerability to the consequences of climate change. This demonstrates how climate change threatens the livelihoods of billions of people around the globe. In the context of Laos, the preliminary assessment report in 2019 reported that approximately 50% of the communities have encountered risks associated with climate change. This figure corresponds to a total of approximately three million individuals. Approximately 47% of the nation's rural settlements have encountered destruction caused by natural calamities such as earthquakes. Hence, it is crucial to assess the degree of vulnerability to livelihoods in order to effectively tackle the issue of climate change. This will provide additional evidence to bolster the implementation of mitigation and adaptation measures, with a particular focus on effectively addressing the needs of the most vulnerable populations impacted by climate change.

2.4 The concept of vulnerability to climate change

2.4.1 Vulnerability

The concept of vulnerability varies in different fields of study, namely sociology, ecology and natural disaster. This section will define the concept of vulnerability in various fields in general and then define the vulnerability of livelihood to climate change.

2.4.2 Definition of vulnerability

The definition of vulnerability has been examined in various field of studies which means it has also been defined with different meanings. Adger (2006) defined Vulnerability as 'the state of susceptibility to harm from exposure to stresses associated with environmental and social change and from the absence of capacity to adapt'. Sociologists define it differently, preferring instead to an individual's likelihood of experiencing disadvantages or even exploitation due to systemic issues such as culture or institutional structures (Cutter 1996; Leichenko & O'Brien 2008; Wisner et al. 2004). Moreover, McDonald & Forte (2022) highlight that vulnerable individuals are characterized as those who possess intersectional characteristics or circumstances such as race, class, gender or sexual identity, religion, among others, rendering them more susceptible to privacy violations that may lead to emotional, financial, or physical harm or neglect. Furthermore, the study of sociology also highlights that social vulnerability is typically defined by personal characteristics such as age, ethnicity, health status, income level, housing type, and employment status (Cutter 1996; Boruff & Shirley 2003). The notion of social vulnerability pertains to the attributes of a given population that impact the community's ability to effectively plan for, react to, and recuperate from catastrophic events (Cannon 1994). On the other hand, when discussing ecological systems, species, or habitats, the term "vulnerability" is used to describe how easily these entities may be damaged or degraded by a number of stressors or perturbations in the surrounding environment (Field & Barros 2014; Parmesan & Yohe 2003).

As vulnerability is defined differently in various disciplines, this illustrates that there is no collective definition of it. In the field of natural disaster, the concept of vulnerability varies from one person to the next and from one place to another, since it is both differential and dynamic (Hilhorst & de Man 2008). The degree of vulnerability to hazards is a metric of the likelihood of experiencing harm and is a multifaceted interplay between peril, alleviation, and the societal framework of a given location (Schmidlin 2009). In addition, Birkmann and Pelling

(2006) argue that the vulnerability of communities to both natural and anthropogenic hazards is analyzed through a multidimensional lens that considers environmental, social, and economic factors. This approach considers various features, including but not limited to susceptibility, exposure, and coping capacities. However, the notion of vulnerability constitutes a constituent element of the risk equation and represents a multifaceted concept (Birkmann & Pelling 2006; Roberts, Nadim & Kalsnes 2009), which illustrates that the notion of vulnerability is derived from different outcomes and disciplines, also demonstrating that there is no single meaning for vulnerability. However, in the context of climate change, many scholars have also defined vulnerability by the degree of exposure and sensitivity and resilience (Cutter et al. 2008; Gallopín 2006; Smit & Wandel 2006; Turner et al. 2003). On the other hand, due to the changing of climate and adverse impacts from climate change, the Intergovernmental Panel on Climate change explained the notion of vulnerability in its first assessment report since 1990. In 2007, the IPCC deepened the definition of vulnerability in the context of climate change as 'the degree to which a system is vulnerable to, or unable to cope with, adverse effects of climate change, including climate variability and extremes' (IPCC 2007, p.6). In other words, the vulnerability of any system to the variability of climate and extreme events refers to the level of sensitivity and level of capability to respond. Unquestionably, in recent years, vulnerability has become an important discussion point in climate change science, hazard and catastrophe risk studies, and development geography (Blaikie, Cannon & Wisner 1994; Füssel 2007; Füssel & Klein 2006; Kikstra et al. 2022).

2.5 Definition of livelihood vulnerability

As mentioned earlier in the section, the notion of vulnerability has been defined in an assortment of academic fields. Within the framework of climate change, individuals' livelihoods are directly impacted by their level of vulnerability. Therefore, it is crucial to understand the concept of livelihood. With the livelihood vulnerability's definition, many authors have defined it differently due to their different objectives and frameworks, therefore this section will define the meaning of livelihood vulnerability in general and particularly focus on climate change.

In 1998, Scoones proposed a framework to analyze sustainable rural livelihoods (Scoones 1998). While Scoones (1998) also noted that the term "livelihood" should be broken into a series of indicators such as natural, economic, human and social capital. Similarly, natural,

physical, human, financial, and social capital, together with the accompanying activities and the means of accessing them, are all included in the idea of livelihood, which is shaped by institutions and social connections (Ellis 2000). In other words, from the definition mentioned previously, livelihoods are complex constructs that encompass a variety of resources, activities, and The acquisition of abilities essential for individuals and groups to attain a sustainable means of living, while simultaneously safeguarding their holistic welfare for an extended duration.

In the context of climate change, many scholars highlight that livelihood vulnerability refers to the vulnerable communities and individuals which are adversely affected in their incomes and well-being as a result of climate change (Adger 2006; Eriksen, Brown & Kelly 2005; O'Brien et al. 2004; Smit & Wandel 2006). The necessity of understanding what makes people vulnerable so that indicators of that vulnerability may be developed to aid in policymaking effectively was emphasized by Eriksen & Kelly (2007), as the vulnerability from climate change has been influenced by different factors such as socio-economic status, resources access, and adaptive capacity (Smit & Wandel 2006). Moreover, the manifestation of vulnerability, which is determined by socio-economic and biophysical processes, occurs across various levels ranging from local to global. However, the condition of being vulnerable is especially linked to a specific demographic (Adger & Kelly 1999). Therefore, to comprehend the behavior of individuals in reaction to such situations, it could be feasible to formulate adaptation tactics that can attain greater adoption across a larger population (Reed et al. 2013). Furthermore, increasing the livelihood capabilities can effectively address the impact which is posed by the changing of climate (Tanner et al. 2015)

2.6 Assessment of vulnerability to climate change

The concept of vulnerability was explored in the previous section, encompassing various fields of study, with a specific emphasis on its implications for climate change. This illustration showcased the vulnerability of individuals to climate change and extreme events, both of which are impacted by a multitude factors. Hence, it is critical to grasp the notion of subsistence vulnerability in relation to climate change so that the degree of susceptibility of communities can be assessed. Numerous researchers and academics have implemented vulnerability assessment in a variety of ways. Therefore, this section contains a literature review on vulnerability assessment frameworks of this form.

2.6.1 The evolution of climate change vulnerability assessment

In order to better comprehend and address the vulnerabilities brought on by climate change, the notion of vulnerability assessment has been established and integrated with a number of indicators. Adger and Kelly (1999) studied the factors that made a particular district in Vietnam's north so vulnerable. Their research focused on indicators of vulnerability at both the individual and societal levels. However, Cutter (1996) highlighted that the study of vulnerability in the past had a greater tendency to prioritize only one single factor by neglecting other factors like economic and political factors of vulnerability. This idea was also supported by Kasperson & Kasperson (2012) who highlighted the common practice of conducting risk assessments with a narrow focus on biophysical elements like temperature or sea level rise without also taking into account the socioeconomic vulnerabilities that affect vulnerability outcomes. Nevertheless, Kelly & Adger (2000) highlighted how the assessment of vulnerability required an analysis of both biophysical and socio-economic factors which is imperative for the effective facilitation of adaptation. Similarly, the need for a vulnerability assessment which includes several factors and dimensions such as social, ecological and economic aspects, was also highlighted by Liverman (1990).

The IPCC stated that understanding how susceptible specific industries, regions, and people are to climate change consequences is the major goal of vulnerability assessments (McCarthy et al., 2001). Therefore, it is imperative to employ appropriate methodologies and metrics for evaluating the degree of vulnerability in various situations. As a consequence, it is essential to develop indicators in terms of measuring the vulnerability to the climate which can be used to effectively reduce the risk to the societies (Birkmann & Pelling 2006; Eriksen & Kelly 2007). The different experiences of such vulnerability, adaptive capacity and adaptation illustrate the need for vulnerability assessments at local and national scales (Brooks, Adger & Kelly 2005; Smit & Wandel 2006). Moreover, the impact of climate and economic globalization also highlighted the integration of vulnerability assessment toward the sustainable pathways (O'Brien & Leichenko 2000). Conversely, the enhancement of the vulnerability assessment framework has shown its advantageous implications in the field of climate change research (Füssel 2007). This is in line with the progress made in indicators and risk assessment methods, which have made a big difference in the scientific policies that aim to make communities more resilient in the face of disasters (Birkmann & Pelling 2006; Hinkel 2011). Hence, the development of the vulnerability framework has made a substantial contribution towards

enhancing the comprehension of vulnerability, while also furnishing crucial insights for policymakers in mitigating the consequences of climate change.

Nevertheless, the assessment of livelihood vulnerability is a crucial factor in identifying the extent of susceptibility to climate change. The livelihood vulnerability assessment plays a crucial role in identifying populations that are susceptible to adverse conditions and enables the formulation of targeted adaptive measures. These strategies are designed to address the specific needs of different communities, with a particular emphasis on enhancing food security, income generation, and general well-being. (Hahn, Riederer & Foster 2009; Kelly & Adger 2000; Vogel et al. 2007; Wisner et al. 2004). The next section will review the different framework to assess the livelihood vulnerability.

2.6.2 Sustainable livelihood framework

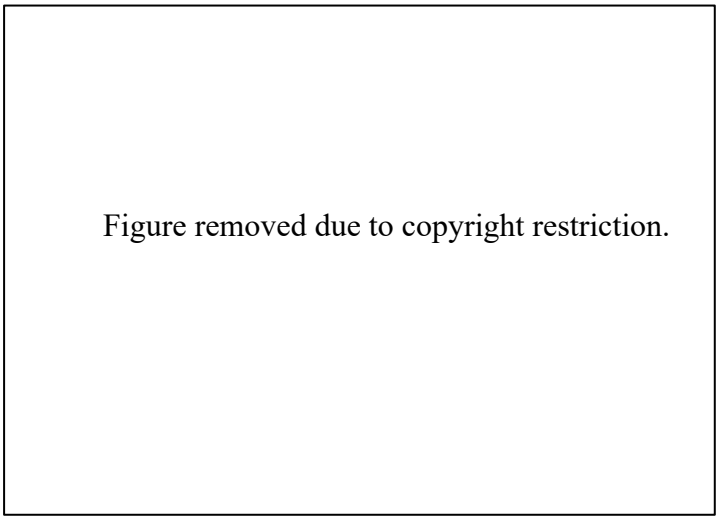
In order to better comprehend livelihood and the interplay between socioeconomic and environmental factors, the sustainable livelihood framework has evolved through time. In the early 1990s, Chambers & Conway (1992) proposed a framework for livelihood that highlighted the significance of a comprehensive strategy for sustainable development and poverty alleviation. Since then, many scholars have developed and refined the livelihood framework. Scoones (1998) highlighted a framework for analyzing sustainable livelihood which included five factors. Moreover, the sustainable livelihood framework has evolved and integrated with new perspectives such as resilience and adaptive capacity in order to comprehend how a community responds to stress and shock (Adger 2000; Scoones 2009). Furthermore, the framework also has been applied in different disciplines and sectors such as tourism, agriculture and fisheries (Bebbington 1999; Carney 2003; Ellis 2000). The significance of power dynamics, gender relations, and social equity in the sustainable livelihood framework has also increasingly gained recognition (Cornwall & Brock 2005; Moser 1998). This development has emphasized the need to investigate how social structures and disparities influence the availability of resources and possibilities for making a living. The Department for International Development (DFID) has highlighted the multidimensional approach of the sustainable livelihood framework which aims to eliminate poverty (DFID 1999).

In general, the sustainable livelihood framework has undergone a process of refinement and development over time, as evidenced by its evolution. Therefore, each framework has been modified and has incorporated distinct elements based on its respective goals. To enhance comprehension of the distinctions among various frameworks, the following section will provide a review of three pivotal sustainable livelihood frameworks such as Chambers & Conway (1992), Scoones (1998), and DFID (1999)

2.6.3 Sustainable livelihood framework of Chambers and Conway 1992

According to Chambers and Conway (1992), the concept of a sustainable livelihood framework entails the ability to effectively rebound from various stresses and shocks, while simultaneously preserving or enhancing its capacities and resources. Moreover, it aims to generate prospects for future generations to lead sustainable lives, and to yield positive outcomes for other livelihoods at local, national, and global levels. Figure 1 illustrates that a livelihood capability comprised and required both tangible and intangible assets for making a living. Within this framework, Stores and Resources are 'tangible assets commanded by a household. Stores include food stocks, stores of value such as gold, jewelry and woven textiles, and cash savings in banks of thrift and credit schemes', while Claims and Access are 'intangible assets of a household. Claims are demands and appeals which can be made for material, moral or other practical support or access' Chambers & Conway (1992, pp.7-8).

Figure 2.1: Component and Flow in livelihood



(Sources: Chambers & Conway 1992, p.7)

2.6.4 Sustainable livelihood framework of Scoones 1998

The sustainable rural livelihood analysis framework was introduced by Scoones in 1998. The framework emphasized the fundamental constituents of sustainable livelihoods, which encompass assets, livelihood strategies, institutions, vulnerability context, and outcomes. Furthermore, Scoones underscored the significance of these components in shaping sustainable livelihoods. The framework highlights the significance of diverse assets, including natural, human, social, and financial, which are regarded as the foundational components of a sustainable livelihood. Livelihood strategies refer to the means by which individuals and households transform their assets into desired livelihood outcomes. An analysis is conducted on institutions and policies to determine their impact on the formation of livelihood opportunities and outcomes, encompassing concerns regarding accessibility, authority, and administration. Scoones emphasized the significance of the vulnerability context, which centers on external factors such as natural disasters that could potentially impact the sustainability of livelihoods. The framework in question has placed significant emphasis on a multidimensional approach to the analysis of sustainable livelihoods. This approach incorporates socio-economic and environmental factors, thereby enabling a comprehensive understanding of the complexities inherent in rural livelihoods.

Figure 2.2: Sustainable rural livelihood: a framework for analysis

Figure removed due to copyright restriction.

(Source: Scoones 1998, p. 4)

2.6.5 Sustainable livelihood framework by DFIP 1999

The Department for International Development (1999) introduced the sustainable livelihood framework which aimed to analyze and promote the development of sustainable livelihoods. This framework emphasized the importance of the interaction between factors and key components such as assets, vulnerability context, institutions, livelihood strategies and livelihood outcomes (DFID 1999). Within this framework, the livelihood assets, which comprise human capital, financial capital, social capital, natural capital and physical capital, make up the key component that indicates the well-being of the people. In addition, the livelihood's strategies refer to various activities that respond to the need of people. However, the accessibility of resources, markets and decision making are influenced by the institutions (Carney 1999). In the vulnerability context, the livelihood is also influenced by the external shocks and stresses such as market movement and climate change (DFID 1999). On the other hand, this framework also highlights that a need for livelihood improvement is represented by the livelihood outcome which includes income, education, health, welfare and environmental sustainability. Therefore, the sustainable livelihood framework of DFIP (1999) considers these components and provides a systemic way to comprehend the complexity of livelihood for a sustainable development.

Figure 2.3: Sustainable livelihood framework

Figure removed due to copyright restriction.

(Source: DFID 1999, p.2)

As illustrated by the three different sustainable livelihood frameworks, it is clear that livelihood requires assets (human capital, natural capital, financial capital, social capital and physical capital) and strategies in order to cope with external shocks and stresses, particularly climate change. Therefore, measuring the livelihood vulnerability is essential for individuals and communities who are at risk and provides targets for intervention (Adger & Agnew 2004). Moreover, the measurement of livelihood vulnerability is an enabler to understanding the drivers of vulnerability such as poverty, inequality and social exclusion (Füssel & Klein 2006). In the climate change context, quantifying the livelihood vulnerability assists the design of mitigation measures that enhance resilience and reduce the impact of climate change (Eriksen, Brown & Kelly 2005). More importantly, livelihood vulnerability assessment is able to prioritize the resources and allocate the support for the most vulnerable individuals or communities (Hallegatte 2009). The IPCC also emphasizes that the vulnerability assessment is essential for monitoring and evaluating adaptive capacity, further improving the effectiveness of assessment and identifying areas for development (IPCC 2014).

However, while measuring the livelihood vulnerability to climate change promotes equitable and inclusive decision-making processes, Tschakert and Dietrich (2010) argued that it also establishes a foundation for effectively involving local communities in the development and execution of adaptation strategies by facilitating engagement, comprehension of their knowledge and experiences, and incorporation of their perspectives. Therefore, the implementation of a participatory approach guarantees the inclusion of the perspectives and requirements of marginalized populations, resulting in outcomes that are both efficacious and enduring (Adger, Arnell & Tompkins 2005). As a consequence, the literature on measuring livelihood vulnerability emphasizes the importance of adopting various indicators and multidimensional approaches for an effective assessment of livelihood vulnerability. Birkmann et al. (2013) highlight the need for intergrade vulnerability assessment in order to assess the sensitivity, vulnerability and adaptive capacity in the context of natural hazard and climate change. Moreover, the significance of applying both qualitative and quantitative means for measuring the complexity of livelihood vulnerability has been emphasized (Kelly & Adger 2000)

2.7Livelihood vulnerability index

The purpose of the livelihood vulnerability index (LVI) is to assess and quantify the susceptibility of individuals and communities to risks that jeopardize their means of subsistence. The LVI offers a comprehensive framework for assessing vulnerability levels through the incorporation of several aspects, including economic, social, and environmental dimensions (Hahn, Riederer & Foster 2009). Moreover, the objective of the LVI framework is to ascertain the factors and attributes that contribute to the vulnerability of livelihood systems in response to external stressors, including but not limited to natural disasters, economic fluctuations, and social disruptions. In recent years, the LVI has been widely used in the research and practical fields for assessing the vulnerability of people in different circumstances. For instance, Adu et al. (2017) investigated the susceptibility of smallholder maize farming households in the Brong-Ahafo region of Ghana to the impacts of climate change. The Livelihood Vulnerability Index was utilized as a tool to assess vulnerability, with a specific focus on the accessibility and utilization of water resources. Another study by Adger & Agnew (2004) utilized the LVI for assessing the vulnerability of communities who live along the coastline to the climate change. The study assessed multiple facets of vulnerability, such as susceptibility to environmental change, vulnerability to hazards, and adaptive capacity. Research has identified that communities with limited access to education and health services, which consequently diminishes their adaptive capacity, are more susceptible to the detrimental impacts of climate change.

On the other hand, Madhuri, Tewari and Bhowmick (2014) adapted the LVI to measure the extent to which vulnerable households varied, with the goal of identifying the specific causes and manifestations of vulnerability in order to design effective mitigation strategies. The LVI also has been utilized in planning and policy for intervening and prioritizing natural resources for the most vulnerable people. For example, Hahn, Riederer & Foster (2009) utilized the LVI to measure livelihood vulnerability in remote areas. The indices result was intended to assist the policy maker to determine the vulnerable groups which in turn would effectively enable targeted interventions and the allocation of resources to enhance resilience and livelihood sustainability. More importantly, in Asia, the LVI is also being widely used for assessing the level of livelihood vulnerability through case studies in Nepal, Vietnam and Bangladesh (Chi 2018; Hoque et al. 2019; Sujakhu et al. 2019). This illustrates how the LVI has been strongly used in many fields of research for measuring livelihood vulnerability, especially in the climate

change context. However, in the context of climate change, the number of studies conducted in Laos that have directly addressed the vulnerability of livelihoods is seen to be minimal. Nonetheless, a number of academics have studied aspects of vulnerability assessment, including Junquera & Grêt-Regamey (2020), Raphaël et al. (2015) , and Stout et al. (2020). The next section will describe and review the past vulnerability assessments from Laos in various contexts.

In summary, the LVI has been widely used in many countries to assess and address livelihood vulnerability. Its multifaceted method sheds light on the interplay between economic, social, and environmental elements in determining susceptibility. Evidence-based decision-making and the creation of tailored interventions to strengthen livelihood resilience in Asia are both aided by the LVI's capacity to pinpoint particular areas of vulnerability.

2.8 Vulnerability assessment in Laos

Many scholars have conducted research related to vulnerability assessment in Laos in the past years. However, the assessment of vulnerability might not directly assess livelihood vulnerability. For example, Hearn & Pongpanya (2021) developed a landslide vulnerability assessment in Laos. In this study, a composite output was generated by combining a basic vulnerability index with engineering geological observations, resulting in the production of tabular data and maps. This composite output also included comprehensive recommendations for risk assessment and engineering management. In addition, the power sector in the Lao People's Democratic Republic (PDR) has been assessed for vulnerability to natural, human-induced, and technological hazards (Stout et al. 2020). Moreover, the vulnerability assessment was also used in the forest sector in Lao PDR, as Cleetus (2005) conducted research using the strategic environmental vulnerability assessment which aims to evaluate the threats from the Mekong Sub region development plan to the forest and people in Laos. Such studies demonstrate how the vulnerability assessment has been incorporated with various sectors in Laos, namely land use planning, power, and forestry. Nevertheless, a recent study from Junquera & Grêt-Regamey (2020) applied the Bayesian network for assessing the livelihood vulnerability. In this study, the researchers suggested using a Bayesian network (BN) to compute the distribution of income using factors at the individual, family, and neighborhood levels. For explicit transmission of variability and uncertainty, a BN models interdependencies between variables and portrays them as probability distributions.

Laos has frequently conducted vulnerability assessments on climate change at both the local and national levels with the assistance of non-governmental organizations (NGOs) such as the International Union for Conservation of Nature (IUCN), Asian Development Bank (ADB), and World Bank Group (ADB 2016; Scott et al. 2018). In 2017, a total of 189 villages across 8 districts in Sekong, Saravane, and Attapeu provinces were subjected to multi-scalar risk assessments which were carried out by the UN-Habitats in a collaboration with the Ministry of Natural Resources and Environment (UN-Habitats 2019). The assessment methodology was developed with the intention of acquiring prompt, dependable, and current information by means of quantitative data analysis. The Ministry of Natural Resources and Environment provided secondary data, including annual rainfall, average temperatures, and updated shapefiles of infrastructure and services. Furthermore, the utilization of participatory data collection techniques facilitated the acquisition of primary data at the village level, facilitated by the Natural Resources and Environment Offices at the provincial and district levels. This approach proved instrumental in capturing the only primary obstacles encountered by local communities, as the previous research and the vulnerability assessment were carried out by using different methods in various sectors. Therefore, Laos needs a more extensive study of livelihood vulnerability to support the National Adaptation Plan to Climate Change. In order to make well-informed decisions about how to react to climate change, it is undeniably crucial to understand the degree to which the livelihoods of different groups and communities are vulnerable to the effects of climate change. This study, then, used a technique for calculating the livelihood vulnerability index of communities in Beng district, which is in the province of Oudomxay in northern Laos.

2.9 Conclusion to literature review

The existing body of literature has shown that scholars have adopted varying approaches in assessing vulnerability to climate change, which can be attributed to the specific circumstances and conditions under consideration. Nevertheless, the diverse range of concepts and frameworks utilized in assessing vulnerability levels share a common objective: mitigating risks faced by both communities and individuals. Furthermore, the literature has also emphasized the importance of recognizing the vulnerability of livelihoods as a crucial factor in addressing climate change in various regions. Hence, this research aimed to modify the widely used Livelihood Vulnerability Index (LVI) created by Hahn, Riederer, and Foster (2009) to provide an indicator of vulnerability that is more applicable to the context of the Oudomxay province. Significantly, this study will contribute to the limited body of research that specifically examines the assessment of livelihood vulnerability among local villagers. The findings of this study will enhance comprehension of livelihood vulnerability and make valuable contributions to mitigation and adaptation strategies at both the provincial and national levels.

3. METHODOLOGY

According to the literature, the Livelihood Vulnerability Index designed for measuring livelihood vulnerability has been extensively employed across diverse disciplines to evaluate the vulnerability of communities and individuals. In this study, I employed the methodology outlined by Hahn, Riederer, and Foster (2009) to investigate the susceptibility of livelihoods to the impacts of climate change. Two distinct models were employed for this analysis: the Livelihood Vulnerability Index (LVI) and the Livelihood Vulnerability Index adapted from the Intergovernmental Panel on Climate Change (LVI-IPCC). The chapter explicates the research methodology employed in this study, encompassing the scope of study, data sampling approaches, and data analysis processes.

3.1 Data source

The study utilized data from the *Mekong Sentinel Landscape Project*, which was conducted by the World Agroforestry Centre. Permission to access this data was obtained from the Mekong household baseline, with the explicit permission of the project leader. The Mekong Sentinel Landscape Project was initiated in response to the swift economic development observed in the Mekong region, which has resulted in significant alterations to forest cover, land use patterns, and regional ecosystem services (CIFOR n.d.). The Mekong Household Baseline study was conducted to gather data on households in three countries: China, Thailand, and Laos. The study spanned 2014 to 2016 and included a total of 1982 households. For this study, a total of 450 households were selected as the sample for quantitative analysis from a household survey that was administered in the year 2016. The data were extracted and recorded in an Excel file, utilizing a household survey questionnaire as a guide. From this extracted data, this study utilized 22 subsections from the original questionnaire which were relevant to the study. Appendix 1 provides further detail on the data extraction process.

The dataset was derived from a household survey comprising 450 households from 15 villages situated in Beng district, Oudomxay province. The 15 villages are Ban Huaylor, Ban Lai Gna, Ban Mang, Ban Muangho, Ban Nalai, Ban Namet, Ban Namtouy, Ban Nangoua, Ban Napa, Ban Pangtho, Ban Phiahua, Ban Phonsa, Ban Siengle, Ban Tharmun, and Ban Yor. The focus of this research was on the selected villages, which served as the study area. The principal aim of this research was to evaluate the susceptibility of households to climate change-related threats to their means of subsistence. The study area's location is depicted in Figure 3.1.

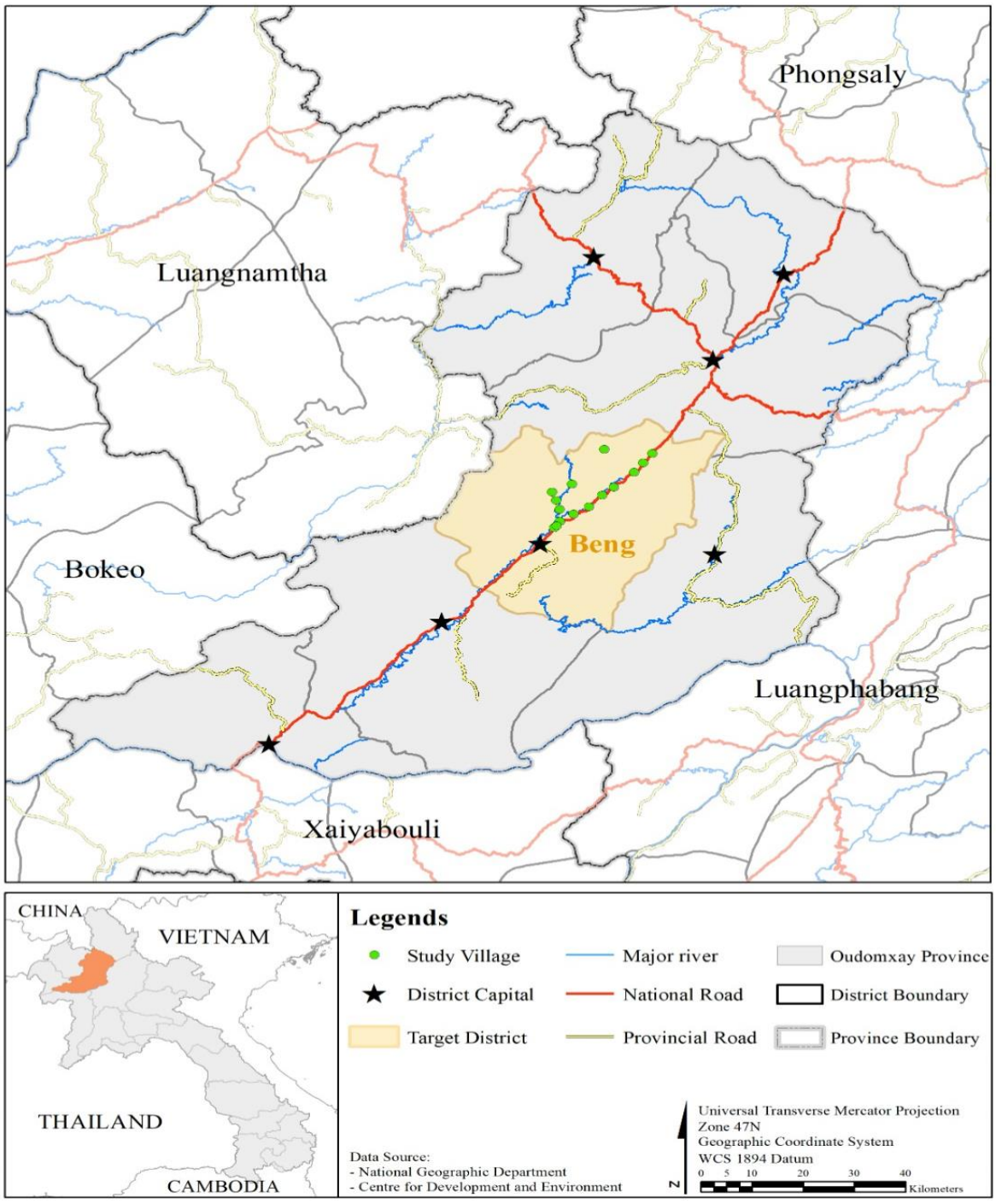


Figure 3.1: Map of study area

3.2 Description of study area

The area of this study was located in Beng district, Oudomxay province, in the northern part of Laos. This section provides information on the province in detail, including the socio-economic, climate characteristics and the information of risk assessment in Beng district.

- **Socio-economic profile of Oudomxay province**

The province of Oudomxay is situated in the northern region of Laos, sharing borders with China as well as five other provinces. The province comprises seven districts and 471 settlements, encompassing a total land area of 15,370 square kilometers. The region has a distinctive topography characterized by elevated mountains, ranging from 300 to 1,800 metres in altitude, encompassing approximately 85 per cent of the total land area. The Beng River serves as the primary watercourse in the province of Oudomxay, functioning as a tributary of the Mekong River that ultimately travels to the south. Furthermore, Oudomxay province in Laos is renowned for its significant capacity for hydropower construction, with a network of around 60 rivers. The Pak Beng Hydropower Project which located in the province is the initial in a series of hydropower initiatives along the Lower Mekong River's primary course (MRC 2017). Moreover, The Pak Beng hydroelectric project is among several hydroelectric projects in Laos that have generated considerable amount of revenue for the country. Given its significant contribution to the Lao economy, the hydropower industry is often regarded as a critical and the primary source of national income. In relation to Oduomxay's natural resources, the province encompasses around 12% of primary forests, while secondary forests constitute approximately 48% of the whole forested area.

Furthermore, Oudomxay province is recognized for its rich biodiversity as it offers a suitable habitat for several species including wild elephants, tigers, and deer. Furthermore, it has been documented that the region also serves as a habitat for the Muntjac deer, an endangered species native to South-east Asia. Oudomxay possesses a significant abundance of forest resources, including a diverse array of plant species and non-timber forest products. Notable examples include Hopea, Debrenasia hyolecuca, and wild orchids. Additionally, the region's forest encompasses wild bamboo, which serves as a valuable source of sustenance for local populations. Sources: (Investment and Promotion Department, Ministry of Planning and Investment n.d.; The World Bank Group 2017)

Table 3.1: General overview of Oudomxay province

Area	15,370 km^2
Number of districts	7 districts
Population	308,000
Area of Agriculture	15,282 Hectares
Main livelihood	Agriculture activities
Poverty rate	8.7
Geographic location	Mountainous

Source: (Lao Statical Bureau 2016)

- **Climate profile of Oudomxay province**

Oudomxay is one of seven provinces in the north that has a warm temperate climate. The months of November through February make up the dry season, whereas the months of May through October make up the rainy season. The average minimum temperate was 16.9 degree Celsius and was 25.5 degree Celsius for the average maximum temperature in 2016 (Lao Statistics Bureau 2016). Nevertheless, the annual temperature averages range from 17.7 degrees Celsius to 29.1 degrees Celsius, with the lowest temperature of around 11.3 degrees Celsius seen in January and the highest temperatures of 22.4 degrees Celsius recorded in August (Lao Statistics Bureau 2016).

The existence of climate fluctuation has considerable consequences for rural livelihoods and agricultural methodologies. The table in Appendix 2 presents data depicting the fluctuations in yearly precipitation levels for Oudomxay province throughout the period from 2003 to 2013. The data indicate that the most arid period occurred between late 2006 and early 2007, as well as in early 2009, during which there was a reported absence of rainfall with a recorded precipitation level of 0 mm. The year 2008 had the greatest average annual rainfall of 2,004 mm, as seen in the table. An analysis of climatic trends in the period from November to February of year 2013 revealed significant variability, particularly during what is traditionally considered the dry season. The table presents empirical evidence of substantial precipitation during this specific timeframe, hence indicating a discernible shift in the climatic conditions of Oudomxay province. Based on an analysis of the available climatic data, it is evident that the province has experienced the effects of climate change in previous years.

According to the preliminary assessment result in 2019, the people of Oudomxay have experienced numbers of natural disasters from the past until the present. For instance, 20,320 people have been affected by storms and 22,572 people experienced in floods (UN-Habitat 2019) as demonstrated in Table 3.2. More importantly, in 2016, Oudomxay reported quite severe flash floods in many districts such as Houn, La, Namor, Beng and ParkBeng. Within the affected districts, Beng district was reported to have the most affected families from this hazardous event which accounted for 1,944 families as demonstrated in Tables 3.3.

Table 3.2: People affected by natural disaster in Oudomxay province

Disaster activity	Population affected
Floods	22,572
Drought	168,963
Landslide	14,495
Storms	20,320

Source: (UN-Habitat 2019)

Table 3.3: 2016 Flash floods statistic in Oudomxay

District	No. of affected villages	No. of families affected	No. of affected people		
			Female	Male	Total
Beng	**45**	**1,944**	**4,891**	**5,074**	**9,965**
Houn	42	4,342	5,299	3,494	8,793
La	4	50	198	101	299
Namor	3	7	18	13	31
ParkBeng	1	20	81	73	154
Total	**95**	**6,363**	**10,487**	**8,755**	**19,242**

Source: (The International Federation of Red Cross and Red Crescent Societies 2016)

3.3 Data sampling at village level

Table 3.4: Number of sampled households

No.	Name of village	Number of Sample Households
1	Huaylor	30
2	Lai Gna	30
3	Mang	30
4	Muangho	30
5	Nalai	30
6	Namet	30
7	Namtouy	30
8	Nangoua	30
9	Napa	30
10	Pangtho	30
11	Phiahua	30
12	Phonsa	30
13	Siengle	30
14	Tharmun	30
15	Yor	30
Total		450

Using the survey data, seven indicators and the sub-indicators which were initially formulated by Hahn, Riederer, and Foster (2009) were used to evaluate the vulnerability of different livelihoods to the effects of climate change. However, the sub-indicators utilized in the computation of the livelihood vulnerability index were modified and updated for this study taking into consideration the data that was acquired from the household baseline survey as well as the particular features of the study region. A total of 22 sub-indicators were developed to assess the vulnerability of household livelihoods to climate variability for this study. These indicators are presented in detail in Table 3.6. The data obtained from the survey was entered into a new Excel spreadsheet, and the livelihood vulnerability index formula was applied using both Microsoft Excel and SPSS software for calculation purposes. Table 3.6 also provides a description of the 22 sub-indicators that were recorded and quantified from the Sentinel Landscape Household Module (SLHM) under the Mekong Sentinel Landscape project.

3.4 Data analysis

According to Hahn, Riederer, and Foster (2009), seven main indicators were extracted for calculating the LV: socio-demographic profile, livelihood strategies, health status, social networks, food security, water access, natural disasters and climate variability. Below is the equation for calculating the LVI and LVI-IPCC for each village, adapted from Hahn, Riederer, and Foster (2009).

3.4.1 LVI: composite index approach

Equation (1) $index\ s_v = \frac{sv - s_{min}}{s_{max} - s_{min}}$

s_v is the actual values of the sub indicators from each village

s_{min} is the minimum values of the sub indicators from each village

s_{max} is the maximum values of the sub indicators from each village

Equation (2) $M_v = \frac{\sum_{i=1}^{n} index_{svi}}{n}$

M_v represents each village's seven indicators (including socio-demographic profile, livelihood strategies, health status, social networks, food security, water access, and natural disasters and climate variability)

$index_{svi}$ represents the sub-indicators, indexed by i, that make up each of the seven main indicators

n is the number of sub-indicators in each of the seven main indicators

Equation (3) $LVI_v = \frac{\sum_{i=1}^{7} W_{Mi} M_{vi}}{\sum_{i=1}^{7} W_{Mi}}$

LVI_v is the Livelihood Vulnerability Index for a village

W_{Mi} is the number of sub-indicators

M_{vi} is the quantity of sub-components comprising each primary component, and is included to guarantee equitable contribution of all sub-components to the total LVI

In this study, LVI was scaled from 0 (least vulnerable) to 0.5 (most vulnerable). See Appendix 3 for an example of how to compute a vulnerability index.

3.4.2 LVI-IPCC: IPCC framework approach

According to Hahn, Riederer, and Foster (2009), the IPCC vulnerability concept was included for calculating the LVI. Based on the definition of the IPCC, vulnerability is 'the degree to which a system is vulnerable to, or unable to cope with, adverse effects of climate change, including climate variability and extreme' (IPCC 2007, p.6). The three components that contribute to the vulnerability of each village (exposure, sensitivity, and adaptive capability) were measured using a total of seven key indicators, as shown in Table 3.5. Below, I elaborate on the three procedures that this study used to derive the LVI-IPCC.

Table 3.5: IPCC contributing factors to its vulnerability main indicators

The IPCC's (Intergovernmental Panel on Climate Change) vulnerability definition is separated into its main components and contributing components in order to calculate the LVI-IPCC.

IPCC contributing factors to its vulnerability main indicators	
Exposure	Natural disasters and climate variability
Adaptive capacity	Socio-demographic profile
	Livelihood strategies
	Social networks
Sensitivity	Health
	Food
	Water

Source: adapted from Hahn, Riederer & Foster (2009)

In order to measuring the level of vulnerability of each village based on the IPCC's definition, the study applied three steps as below.

Step 1: In terms of calculating the LVI-IPCC, this model made use of the same underlying indicators (Table 3.5). However, to conform to the LVI-IPCC framework, adaptive capacity requires inverting all its sub-indicators before averaging them into their corresponding major indicators, for instance, changing the percent of household for which the income is derived only from agriculture activities to percent of households for which the income is derived not from agriculture activities.

Step 2: Using equation 4, the main indications were divided into three groups: exposure, adaptive capability, and sensitivity.

Equation (4) $CF_v = \frac{\sum_{i=1}^{n} W_{Mi} M_{vi}}{\sum_{i=1}^{n} W_{Mi}}$

CF_v is an IPCC-defined contributing factor (exposure, sensitivity, or adaptive capacity) for a village

W_{Mi} represents the weight of each major sub-indicator

M_{vi} is the main component for village v which is indexed by i

n is the number of primary indicators in each contributing factor.

Step 3: Once exposure, sensitivity, and adaptive capacity were calculated, the three contributing factors were combined using the following equation:

$$LVI - IPCC_v = (E_v - A_v) * S_v$$

$LVI - IPCC_v$ is the LVI value for village v

E_v is the calculated exposure value for v

A_v is the calculated adaptive capacity value for village v

S_v is the calculated sensitivity value for village v

The vulnerability index for a certain village, indicated as "v," is determined under the framework provided by the Intergovernmental Panel on Climate Change (IPCC), as stated by the LVI-IPCC. The exposure score E which is assigned to village v, demonstrates the primary element linked to Natural Disasters and Climate Variability. The adaptive capacity score A assigned to village v, is determined by computing the weighted average of the key components pertaining to Socio-Demographic factors, Livelihood Strategies, and Social Networks. The sensitivity score (S) for a certain village (v) is determined by calculating the average of the relative relevance of the health, food security, and water variables associated with that village. Consequently, within the scope of this investigation, the LVI-IPCC was allocated a numerical rating ranging from -1 (indicating the lowest level of vulnerability) to 1 (representing the highest degree of vulnerability). Appendix 4 has an illustrative example that demonstrates the calculation of the contributing components of the LVI-IPCC for a particular village in the Beng district.

3.5 Crosstab analysis

The study used the same dataset after computing the Livelihood Vulnerability Index (LVI) to do the crosstab analysis using the SPSS program. Importantly, this crosstab analysis further supported the Livelihood Vulnerability Index which allowed the study to determine the level of vulnerability from the gender perspective (see Appendix 5 for an example of computing the crosstab analysis). Therefore, the result of the crosstab analysis could be used to further support the objective of this study which aimed to measure the level of livelihood vulnerability to the variability of climate change.

3.6 Summary

This chapter has presented the research methodology used in the study, including the many procedures implemented to collect and analyze the data essential for the development of the Livelihood Vulnerability Index tailored to the particular geographic area under investigation. The data derived from the Mekong Household Baseline study were used to employ two methodologies for computing the Livelihood Vulnerability Index (LVI) as suggested by Hahn, Riederer, and Foster (2009). Moreover, the same information was used to conduct a crosstab analysis using the SPSS program, aiming to examine the differences in numerical values between males and females across several factors. Consequently, the purpose of this research was to evaluate the degree of vulnerability in terms of livelihoods among 15 villages located in the Beng district of Oudomxay province. This will be further elaborated in the next Chapter.

Table 3.6: Primary indicators and sub-indicator of livelihood vulnerability index.

Primary Indicators	No. of Sub-Indicators	Sub-Indicators	Assumed explanation to the LVI reflection
Socio-demographic profile	**1.1**	Percent of household that have members who are under 15 and over 60 years old	High dependency in old people and teenagers illustrates less ability to cope with the climate change (Bryant et al. 2022; UEPA 2022a; Watts et al. 2018)
	1.2	Percent of household where the head of household is female	Women are more likely vulnerable than men (Brody, Demetriades & Esplen 2008; Rahman 2013; Adeagbo et al. 2016; Habtezion 2016; UNFCC 2019)
	1.3	Percent of household where head of household did not attend school	Having an education background can imply household could have a strategy to manage natural disasters (Muttarak & Lutz 2014; Hoffmann & Blecha 2020)
Livelihood strategies	**2.1**	Percent of household which has other members in the family that do not live in your household but help the family with money or other contributions	Receiving money assistance or other contributions from others implies the household may not be able to be sufficiently nourished or may be faced financial stress, therefore, less capacity to cope with the changes (Shaw & Team 2009)
	2.2	Percent of household in which the income is derived from the agriculture activities	Household is more vulnerable when they heavily depend on the natural resources (Abeygunawardena et al. 2009; De Silva & Kawasaki 2018)
	2.3	Percent of unemployed members in household	High rate of unemployment in household implies household lack of income. As a result, household would rely more on the natural resources for consumption. Hence, Household is more vulnerable when they heavily depend on the natural resources (Abeygunawardena et al. 2009; De Silva & Kawasaki 2018)
Health	**3.1**	Percent of severe illness of household member	Households with illness member are likely more vulnerable (Steffen, Hughes & Pearce 2015; CDCP 2020; UEPA 2022b)

	3.2	Average distance from village to district health care	People who live far from the health care are more vulnerable (Adu et al. 2018)
Social Network	**4.1**	Percent of household that receive any money, food or any type of assistance from relatives	Receiving money assistance or other contribution from others implies the household may not be able to be sufficiently nourished or may be faced with financial stress, therefore less capacity to cope with the changes (Shaw & Team 2009)
	4.2	Percent of household that receive any money, food or any type of assistance from the government	Receiving money assistance or other contribution from government implies the household may not be able to be sufficiently nourished or may be faced with financial stress, therefore less capacity to cope with the changes (Shaw & Team 2009)
	4.3	Percent of household members borrowing money from an institution	Borrowing money from an institution such as microfinance implies household has experienced financial stress therefore has less capacity to cope with the changes (Shaw & Team 2009)
Food Security	**5.1**	Percent of household using firewood for cooking	Higher percentage of firewood using for cooking implies more vulnerable due to household heavily relying on the firewood from natural sources
	5.2	Percent of household that buy seed for agriculture purposes	Buying seed for agriculture indicates household needs more budget for their agriculture activities. Lower percentage implies more adaptive capacity to disasters and climate change impacts
	5.3	Percent of household that does not have enough money to buy food	Insufficient money to buy food indicates the financial stress, therefore less capacity to cope with the changes (Shaw & Team 2009). Furthermore, household faced with food shortage will be more vulnerable when faced with natural disaster (Parvez, Islam & Dey 2022)
Water Access	**6.1**	Percent of households who do not have tap water inside house.	Not having access to the tap water inside the house means household relies only on the public or natural sources

	6.2	Percent of households who used natural source of water (River, stream, creek)	Higher percentage implies higher sensitivity.
	6.3	Percent of households experiencing severe water shortage	Higher percentage of water shortage implies more vulnerability when face with natural disaster
Natural disasters and climate variability	**7.1**	Percent of households that lost crops due to drought	A higher percentage indicates a greater level of vulnerability to the impacts of climate change
	7.2	Percent of households that lost crops due to floods	A higher percentage indicates a greater level of vulnerability to the impacts of climate change
	7.3	Percent of households that experienced crop disease or crop pests	Having crop disease and crop pests implies household not able to generate income, thereby not having enough to buy food for the family, which will increase the sensitivity when facing natural disaster
	7.4	Percent of households who did not have any plan for applying mitigation/prevention strategies for drought	Able to apply strategies when facing natural disaster can reduce the vulnerability
	7.5	Percent of households who did not have any plan for applying mitigation/prevention strategies for flood	Able to apply strategies when facing natural disaster can reduce the vulnerability

4. FINDINGS

This chapter presents findings from analysing the Livelihood Vulnerability Index (LVI) as well as the results of crosstab analysis. It includes the results of LVI based on the seven primary indicators: socio-demographic profile, livelihood strategies, health status, social networks, food security, water access, and natural disasters and climate variability. Furthermore, the overall results of LVI are ranked in this chapter. In addition, the result of LVI based on the Intergovernmental Panel on Climate Change (IPCC) as well as the inverse sub-indicators for LVI-IPCC are also presented. This includes grouping all the sub-indicators into three different categories: adaptive capacity, sensitivity, and exposure, based on the IPCC's definitions.

Table 4.1 illustrates the original value of each sub-indicator which was derived from the household survey for 15 different villages: Ban Huaylor, Ban Lai Gna, Ban Mang, Ban Muangho, Ban Nalai, Ban Namet, Ban Namtouy, Ban Nangoua, Ban Napa, Ban Pangtho, Ban Phiahua, Ban Phonsa, Ban Siengle, Ban Tharmun, and Ban Yor. In addition, it shows the maximum value and minimum value for each sub-indicator. All the original values of sub-indicators were configured as a percentage unit according to the methodology. Hence, only one single sub-indicator is illustrated as Kilometers unit, which is the average distance of the village from the health district center as illustrated under the health main indicators in Table 4.1. Furthermore, all sub-indicators which are presented in this chapter were standardized, as illustrated in Table 4.2.

Table 4.1: Original Value of Sub-indicator of Livelihood Vulnerability Index for 15 villages

Primary indicators	1.Socio-demographic profile			2.Livelihood strategies			3.Health		4.Social Network			5.Food Security			6.Water Access			7.Natural disasters and climate variability				
Sub-Indicators	**1.1**	**1.2**	**1.3**	**2.1**	**2.2**	**2.3**	**3.1**	**3.2**	**4.1**	**4.2**	**4.3**	**5.1**	**5.2**	**5.3**	**6.1**	**6.2**	**6.3**	**7.1**	**7.2**	**7.3**	**7.4**	**7.5**
Huaylor	70	63.33	3.33	100	93.33	100	0	13	90	53.33	6.67	100	20	40	36.67	40	0	30	16.67	73.33	53.33	13.33
Lai Gnai	70	16.67	13.33	0	100	100	6.67	19	86.67	46.67	3.33	100	33.33	70	3.33	3.33	3.33	46.67	0	96.67	56.66	6.66
Mang	93.33	63.33	96.67	96.67	13.33	100	0	17	90	23.33	16.67	100	23.33	66.67	0	0	0	50	3.33	83.33	63.33	30
Muanghom	76.67	10	13.33	3.33	100	100	0	35	90	26.67	10	96.67	10	63.33	0	0	0	56.67	0	100	50	43.33
Nalai	63.33	16.67	0	3.33	70	100	3.33	7.5	96.67	70	0	100	23.33	23.33	26.67	26.67	0	73.33	0	90	43.33	26.66
Namet	76.67	60	16.67	3.33	80	80	0	25	96.67	53.33	3.33	100	23.33	26.67	73.33	3.33	3.33	26.67	3.33	83.33	60	23.33
Namtouy	53.33	10	3.33	6.67	93.33	3.33	3.33	13	73.33	56.67	10	100	13.33	53.33	10	10	0	50	0	100	36.67	13.33
Nangoua	70	16.67	3.33	0	73.33	96.67	0	15	90	30	6.67	100	16.67	30	13.33	13.33	0	60	13.33	96.67	40	13.33
Napa	76.67	63.33	6.67	16.67	86.67	90	3.33	30	80	30	16.67	100	30	46.67	46.67	46.67	3.33	16.67	13.33	46.67	53.33	30
Pangthong	63.33	80	0	10	73.33	80	0	17	100	36.67	3.33	100	16.67	16.67	40	40	6.67	40	3.33	56.67	46.67	33.33
Phiahuanam	80	33.33	6.67	3.33	96.67	80	13.33	17	80	26.67	30	100	43.33	70	3.33	3.33	0	23.33	13.33	56.67	40	40
Phonsa At	56.67	13.33	10	0	100	100	3.33	17	86.67	43.33	13.33	100	46.67	66.67	6.67	6.67	0	26.67	6.67	76.67	50	46.67
Sienglea	36.67	46.67	0	3.33	90	93.33	0	9.5	60	53.33	23.33	100	50	36.67	3.33	3.33	3.33	23.33	30	50	40	46.67
Thamun	63.33	26.67	10	23.33	100	93.33	6.67	21	100	40	13.33	100	36.67	30	53.33	53.33	0	20	0	70	56.67	30
Yor	66.67	36.67	0	6.67	76.67	83.33	0	8	80	23.33	0	96.67	16.67	10	33.33	33.33	0	26.67	0	90	43.33	33.33
Unit	%	%	%	%	%	%	%	KM	%	%	%	%	%	%	%	%	%	%	%	%	%	%
Maximum value	100	100	100	100	100	100	100	35	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Minimum value	0	0	0	0	0	0	0	7.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 4.2: Standardized value of sub-indicators for 15 villages

Primary indicators	1.Socio-demographic profile			2.Livelihood strategies			3.Health		4.Social Network			5.Food Security			6.Water Access			7.Natural disasters and climate variability				
Sub-Indicators	**1.1**	**1.2**	**1.3**	**2.1**	**2.2**	**2.3**	**3.1**	**3.2**	**4.1**	**4.2**	**4.3**	**5.1**	**5.2**	**5.3**	**6.1**	**6.2**	**6.3**	**7.1**	**7.2**	**7.3**	**7.4**	**7.5**
Huaylor	0.700	0.633	0.033	1.000	0.933	1.000	0.000	0.200	0.900	0.533	0.067	1.000	0.200	0.400	0.367	0.400	0.000	0.300	0.170	0.730	0.530	0.130
Lai Gnai	0.700	0.167	0.133	0.000	1.000	1.000	0.067	0.418	0.867	0.467	0.033	1.000	0.333	0.700	0.033	0.033	0.033	0.470	0.000	0.970	0.570	0.070
Mang	0.933	0.633	0.967	0.967	0.133	1.000	0.000	0.345	0.900	0.233	0.167	1.000	0.233	0.667	0.000	0.000	0.000	0.500	0.030	0.830	0.630	0.300
Muanghom	0.767	0.100	0.133	0.033	1.000	1.000	0.000	1.000	0.900	0.267	0.100	0.967	0.100	0.633	0.000	0.000	0.000	0.570	0.000	1.000	0.500	0.430
Nalai	0.633	0.167	0.000	0.033	0.700	1.000	0.033	0.000	0.967	0.700	0.000	1.000	0.233	0.233	0.267	0.267	0.000	0.730	0.000	0.900	0.430	0.270
Namet	0.767	0.600	0.167	0.033	0.800	0.800	0.000	0.636	0.967	0.533	0.033	1.000	0.233	0.267	0.733	0.033	0.033	0.270	0.030	0.830	0.600	0.230
Namtouy	0.533	0.100	0.033	0.067	0.933	0.033	0.033	0.200	0.733	0.567	0.100	1.000	0.133	0.533	0.100	0.100	0.000	0.500	0.000	1.000	0.370	0.130
Nangoua	0.700	0.167	0.033	0.000	0.733	0.967	0.000	0.273	0.900	0.300	0.067	1.000	0.167	0.300	0.133	0.133	0.000	0.600	0.130	0.970	0.400	0.130
Napa	0.767	0.633	0.067	0.167	0.867	0.900	0.033	0.818	0.800	0.300	0.167	1.000	0.300	0.467	0.467	0.467	0.033	0.170	0.130	0.470	0.530	0.300
Pangthong	0.633	0.800	0.000	0.100	0.733	0.800	0.000	0.345	1.000	0.367	0.033	1.000	0.167	0.167	0.400	0.400	0.067	0.400	0.030	0.570	0.470	0.330
Phiahuanam	0.800	0.333	0.067	0.033	0.967	0.800	0.133	0.345	0.800	0.267	0.300	1.000	0.433	0.700	0.033	0.033	0.000	0.230	0.130	0.570	0.400	0.400
Phonsa At	0.567	0.133	0.100	0.000	1.000	1.000	0.033	0.345	0.867	0.433	0.133	1.000	0.467	0.667	0.067	0.067	0.000	0.270	0.070	0.770	0.500	0.470
Sienglea	0.367	0.467	0.000	0.033	0.900	0.933	0.000	0.073	0.600	0.533	0.233	1.000	0.500	0.367	0.033	0.033	0.033	0.230	0.300	0.500	0.400	0.470
Thamun	0.633	0.267	0.100	0.233	1.000	0.933	0.067	0.491	1.000	0.400	0.133	1.000	0.367	0.300	0.533	0.533	0.000	0.200	0.000	0.700	0.570	0.300
Yor	0.667	0.367	0.000	0.067	0.767	0.833	0.000	0.018	0.800	0.233	0.000	0.967	0.167	0.100	0.333	0.333	0.000	0.270	0.000	0.900	0.430	0.330

Table 4.3: Primary indicators values and overall Livelihood Vulnerability Index for 15 villages

Primary Indicators Villages	Socio-demographic profile	Livelihood strategies	Health	Social Network	Food Security	Water Access	Natural disasters and climate variability	Overall LVI
Huaylor	0.455	0.978	0.100	0.500	0.533	0.256	0.373	0.465
Lai Gnai	0.333	0.667	0.242	0.456	0.678	0.033	0.413	0.411
Mang	0.845	0.700	0.173	0.433	0.633	0.000	0.460	0.476
Muanghom	0.333	0.678	0.500	0.422	0.567	0.000	0.500	0.432
Nalai	0.267	0.578	0.017	0.556	0.489	0.178	0.467	0.389
Namet	0.511	0.544	0.318	0.511	0.500	0.267	0.393	0.437
Namtouy	0.222	0.344	0.117	0.467	0.556	0.067	0.400	0.327
Nangoua	0.300	0.567	0.136	0.422	0.489	0.089	0.447	0.368
Napa	0.489	0.644	0.426	0.422	0.589	0.322	0.320	0.448
Pangthong	0.478	0.544	0.173	0.467	0.444	0.289	0.360	0.401
Phiahuanam	0.400	0.600	0.239	0.456	0.711	0.022	0.347	0.399
Phonsa At	0.267	0.667	0.189	0.478	0.711	0.044	0.413	0.407
Sienglea	0.278	0.622	0.036	0.456	0.622	0.033	0.380	0.364
Thamun	0.333	0.722	0.279	0.511	0.556	0.356	0.353	0.444
Yor	0.344	0.556	0.009	0.344	0.411	0.222	0.387	0.345

4.1 Livelihood Vulnerability Index (LVI) results

This section presents the findings pertaining to the Livelihood Vulnerability Index (LVI), which was derived from the seven main indicators and twenty-two sub-indicators outlined in the methodology chapter. The results of all primary indicators of the LVI are presented individually in the subsequent sections, as illustrated in Table 4.3. Additionally, the original values of each sub-indicator are presented, indicating the percentage of households corresponding to each sub-indicator in all areas studied, as derived from Table 4.1.

4.1.1 Vulnerability in Socio-demographic profile

In relation to the socio-demographic profile, the findings indicate that Mang village exhibited the highest vulnerability score of 0.845 among the 15 villages, as shown in Table 4.3. On the other hand, Namtouy had the most minimal degree of vulnerability in terms of socio-demographic characteristics, with a value of 0.222.

Percentage of households including an individual who is below the age of 15 and over the age of 60.

Mang and Phiahuanam villages had the highest proportions of members under 15 and over 60 years old, with 93 percent and 80 respectively, as shown in Table 4.1. In contrast, Namtouy and Singlea had the lowest percentages, which were 63.33 and 36.67 respectively. In addition, numerous villages such as Huaylor, Lai Gnai, and Nangoua, were discovered to have a significant proportion of households which contained a member who was below 15 or older than 60 years of age.

Percentage of households in which the head of the household is female.

According to the results shown in Table 4.1, Pangthong village had the highest proportion of female-headed households, accounting for 80 percent of the total. In contrast, it was observed that both Muanghom and Namtouy villages exhibited the lowest proportion of households with female heads of household, amounting to 10 percent for each village. However, it was observed that certain villages had a significant proportion of households with female heads, including Huyalor, Namet, and Napa, with percentages of 63.33, 60, and 63.33, respectively.

Percentage of households where head of household did not attend school.

The results show that Mang village was found to have the highest percentage of households where the head of household did not attend school, at 96.67 percent, while many villages were found not to have any heads of households in the villages who did not attend school, that is, Nalai, Pangthong, Sienglea and Yor. However, the result shows many villages were found to have a slightly greater number of households where the head of household did not attend school, such as Lai Gnai, Namet and Phonsa At, which had a percentage of 13.33, 16.67 and 10 respectively.

4.1.2 Livelihood strategies

The village that was found to have the highest index of vulnerability on the livelihood strategies aspect was Huaylor village which had an index of 0.978 as illustrated in Table 4.3, while Namtouy was 0.344 which was the lowest vulnerability index for the livelihood strategies. However, many villages were found to have significant vulnerability scores in this aspect, such Lai Gnai, Mang, Muanghom and Phonsa At, which had indexes of 0.667, 0.7, 0.678 and 0.677 respectively.

Percent of household which has other members in the family that do not live in household but help family with money or other contributions.

Mang village was found to have the highest percentage of households that received money or other contributions from members of the family that did not live in the household, which accounted for 96.67 percent of the total households from the samples. On the other hand, three villages, namely Lai Gnai, Nangoua and Phonsa At, were found not to have any households that received money or other contributions from family members that did not live in the household.

Percent of household in which the income is derived from the agriculture activities.

The results show that the majority of villages had a large percentage of families whose income was generated from agricultural activities. As shown in Table 4.1, all households in Lai Gnai, Muanghom, Phonsa At, and Thamun had revenue generated from agricultural activities, accounting for 100 percent of household income. Mang was the only village with a low proportion of families earning a living from agricultural activities (13.33 percent). Nonetheless, the majority of the villages, such as Huaylor, Namet, Namtouy, Napa, and Sienglea, were discovered to have a

substantial percentage of families with an income generated from agricultural activities, 93.33, 80, 93.33, 96.67, and 90 percent, as shown in Table 4.1.

Percent of unemployed members in household

The results indicate that the majority of villages were composed of households with unemployed members. Six villages, namely Huaylor, Lai Gmai, Mang, Muaghom, Nalai, and Phonsa At, were found to have every household composed entirely of unemployed individuals. In addition, many villages had a high proportion of unemployed household members, as shown in Table 4.1 for Namet, Nangoua, Napa, Pangthong, and Phiahuanam, where the respective percentages were 80, 96.67, 90, and 80. Namtouy was the only village with a low percentage of unemployed household members, accounting for only 3.33 percent of the total number of households.

4.1.3 Health

Muanghom was found to have the highest index of vulnerability in terms of a health indicator, with an index of 0.500 as illustrated in Table 4.3, while the lowest vulnerability index on the health aspect was Yor village which had 0.009.

Percent of severe illness of household members

Phiahuanam was found to have the highest percentage of households which had members with severe illness, at 13.33 percent of total households, while eight villages were found not have any severely ill members in the household, namely Huaylor, Mang, Muanghom, Namet, Nangoua, Panthong, Sienglea and Yor village.

Average distance from village to district health

The results showed that Muanghom village had the longest distance to travel to the district health center at 35 kilometers, while Nalai was the only village that was located closest to the district health center, at about 7.5 kilometers.

4.1.4 Social Network

In terms of the vulnerability index on the social network indicator, Nalai village was found to have the highest vulnerability, which was 0.556 as illustrated in Table 4.3, while the three villages of

Muanghom, Nangoua and Napa were found to have the lowest vulnerability with a score of 0.422 for the three villages.

Households that receive any money, food or any type of assistance from relatives.

As shown in Table 4.1, Namet and Nalai villages had the largest proportion of households that got any money, food, or other sort of aid from relatives, with 96.67 percent of the total households for both villages. Furthermore, the remainder of the villages were discovered to have a substantial number of households that got money, food, or other forms of support from relatives, such as Huaylor, Lai Gnai, Mang, and Muanghom, which had 90, 86.67, 90, and 90 percent of the total households, respectively.

Household members borrowing money from an institution.

Table 4.1 illustrates that Namet had the highest percentage of households that borrowed money from an institution, which accounted for 70 percent amongst 15 villages. This was followed by Nangoua village which had 56.67 percent. Moreover, many villages were found to have a significant number of households that borrowed money from institutions, such as Huaylor, Namtouy and Sienglea which had 53.33 percent for all three villages. However, Mang and Yor were found to have the lowest percentage of households that borrowed money from an institution, with 23.33 percent for both villages.

Households that receive any money, food or any type of assistance from the government.

In this sub-indicator, Phiahuanam was found to have the highest percentage of households which received money, food or any type of assistance from the government, accounting for 30 percent. This was followed by Mang and Napa villages which had 16.67 percent for both villages. Nalai and Yor were found not to be receiving any assistance from the government.

4.1.5 Food security

In terms of food security, Phiahuanam and Phonsa At had the highest vulnerability which was 0.711 for both villages as illustrated in Table 4.3. In contrast, Yor village had a vulnerability index of only 0.411.

Households using firewood for cooking.

All of the villages were found to use firewood as the only main source of energy for cooking except for Maunghom and Yor which had 96.67 percent of total households. However, this is still considered as being a significant number of households that used firewood for cooking.

Households that buy seed for agriculture purposes.

In this sub-indicator, Sienglea was found to have the highest number of households that bought seed for agriculture purposes, with 50 percent of the total households in the village, while Namtouyhad had the lowest number of households that bought seed at 13.33 percent.

Households that do not have enough money to buy food.

Table 4.1 shows that Lai Gnai and Phiahunam had the highest percentage of households that did not have enough money to buy food, which accounted for 70 percent for both villages. This was followed by Mang village which had 66.67 percent of total households. In addition, many villages were found to have a significant number of households that did not have enough money to buy food, namely Huaylor, Muanghom, Namtouy and Phonsa At, which had 40, 63.33, 53.33 and 66.67 percent respectively.

4.1.6 Water access

In terms of water access, Thamun had the highest vulnerability index which was 0.356 as illustrated in Table 4.3. This was followed by Napa, Panthong and Huaylor which had 0.322, 0.289 and 0.256 respectively.

Households which do not have tap water inside house.

Namet had the greatest percentage of households that did not have running water, accounting for 73.33 percent. Furthermore, numerous villages were discovered to have a high percentage of households that did not have access to running water, such as Thamun, Phiahuanam, and Huaylor which had 53.33, 46.67, and 36.67 percent, respectively. Mang and Muanghom villages, on the other hand, were discovered to have 100 percent of their households with tap water.

Households who use natural source of water.

Table 4.1 illustrates that Thamun village had the highest number of households that used a natural source of water which accounted for 53.33 percent of total households. This was followed by Napa,

huaylor and Pangthong which had 46.67, 40 and 40 percent respectively. Mang village was the only one that did not have any households that used natural sources of water. This also can imply that this village had full access to tap water for all households.

Households experiencing severe water shortage

For this particular sub-indicator, it was observed that Pangthong had the highest proportion of households, accounting for 6.67 percent of the total, that encountered severe water shortage. This information is depicted in Table 4.1. On the other hand, Lai Gnai, Napa, and Sienglea had a lower percentage of households, specifically 3.33 percent, that experienced severe water shortage. Furthermore, the findings presented in Table 4.1 indicate that a limited number of homes throughout the 15 villages had significant water scarcity issues. Nevertheless, families may encounter some challenges pertaining to water scarcity in relation to their agricultural activities, but not to the same extent or severity.

4.1.7 Natural disasters and climate variability

In terms of natural disasters and climate variability, the results showed Muanghom village had the highest vulnerability index, which was 0.500 compared to other villages as illustrated in Table 4.3. It was followed by Nalai and Lai Gnai which had 0.467 and 0.460 respectively. In contrast, Napa village was found to have the least vulnerability index at 0.320.

Households that had lost crops due to drought

Table 4.1 shows Nalai village had the highest number of households that lost crops due to the drought, accounting for 73.33 percent. Moreover, many villages were also found to have a significant number of households that experienced losing crops due to drought, namely Napa, Muanghom and Mang which accounted for 60, 56.67 and 50 percent respectively.

Households that had lost crops due to floods

In this sub-indicator, Sienglea village was found to have the highest number of households that experienced losing crops due to flood, which accounted for 30 percent. This was followed by Huaylor, Napa and Pangthong which had 16.67, 13.33 and 3.33 percent respectively. However, many villages had no experience regarding losing crops due to drought, such as Namtouy, Thamun and Yor.

Percent of households that had experienced crop disease or crop pests

Muanghom and Namtouy were discovered to have the greatest number of homes that had experienced crop disease or agricultural pests, accounting for 100 percent of the households, as shown in Table 4.1. Furthermore, most villages, including Lai Gnai, Yor, Mang, Muanghom, and Namet, had a substantial number of families affected by crop disease or crop pests, accounting for 96.67, 90, 83.33, and 83.33 percent of total households, respectively. Napa, on the other hand, was the only hamlet with the lowest number of households with agricultural pest or crop disease experience.

Households who did not have any plan for applying mitigation/prevention strategies for drought

According to Table 4.1, Mang village had the greatest proportion of households who had no strategy for implementing drought mitigation methods, accounting for 63.33 percent. This was followed by Namet, Thamun, and Panthong, who had 63.33, 60, and 56.67 percent, respectively. Overall, numerous villages were discovered to have a substantial number of households who did not have any drought mitigation and preventive techniques, including Yor, Nalai, and Phiahuanam, which had 43.33, 43.33, and 40 percent, respectively.

Households who did not have any plan for applying mitigation/prevention strategies for flood

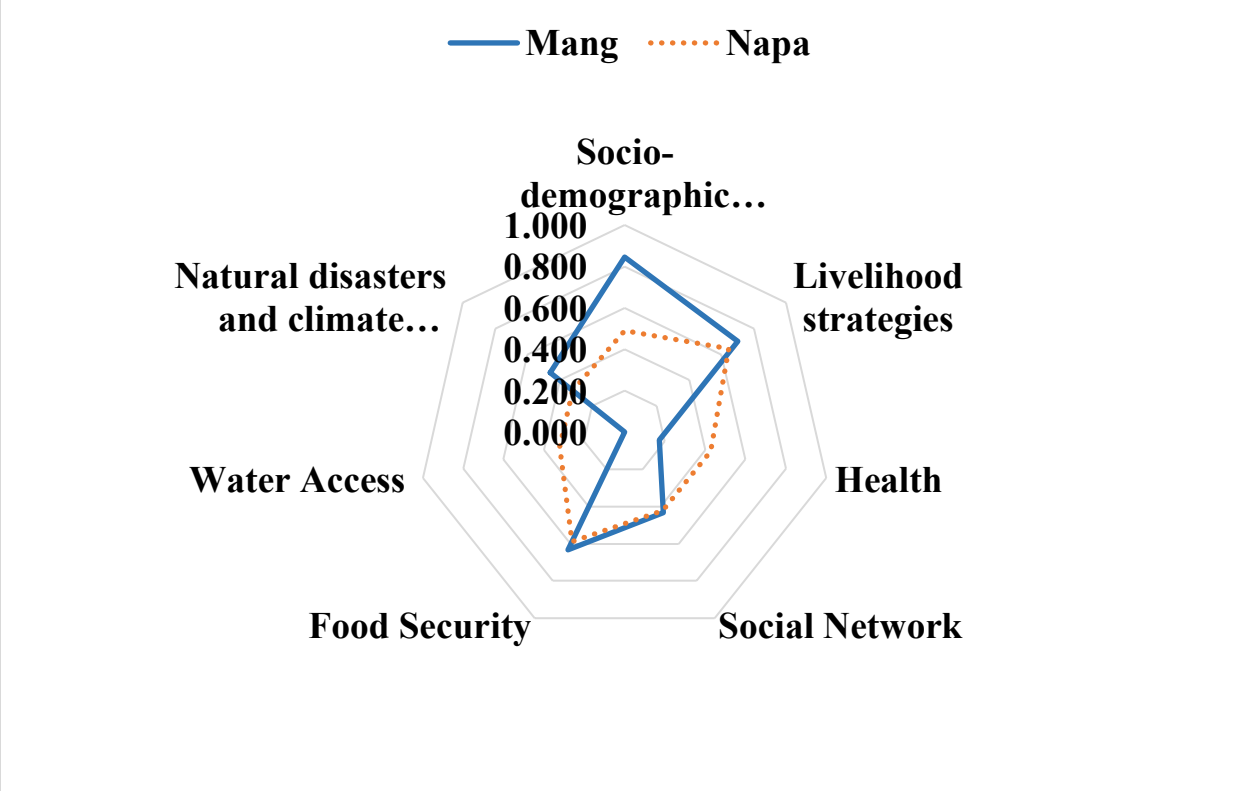
Phonsa At and Sienglea had the greatest proportion of households that did not have any flood mitigation or preventive techniques, accounting for 46.67 percent in both villages. Muanghom, Phiahuanam, and Yor were next with 43.33, 40, and 33.33 percent, respectively, while Huaylor, Namtouy, and Nangoua had the lowest proportion of households without flood mitigation and preventive techniques, accounting for 13.33 percent among all three villages.

4.2 Overall Livelihood Vulnerability Index

In relation to the computation of the Livelihood Vulnerability Index (LVI) based on seven primary indicators and twenty-two sub-indicators, the overall LVI outcome indicates that Mang village exhibited the highest vulnerability index, measuring 0.476 as depicted in Table 4.3. Following closely, Huaylor village ranked second with a livelihood vulnerability index of 0.465. The subsequent locations, namely Napa, Thamun, Namet, Muanghom, Lai Gnai, and Nalai, had values of 0.448, 0.444, 0.437, 0.432, 0.411, and 0.389 respectively, as shown in Table 4.3. Nmatouy village had the lowest level of livelihood vulnerability, as shown by its index value of 0.327.

The following diagram shows the outcome of the Livelihood Vulnerability Index for each community on a spider diagram.

Figure 4.1: Vulnerability spider diagram of major indicators of livelihood vulnerability for highest and lowest vulnerable villages



In relation to the computation of the livelihood vulnerability index, it is seen that Mang village had the highest vulnerability in terms of its socio-demographic profile, as shown by Table 4.3, while Huaylor village had the greatest degree of vulnerability in relation to its livelihood strategies. Moreover, it can be seen that Muanghom village exhibited the greatest degree of vulnerability with regard to health conditions. The village of Nalai demonstrated the highest level of vulnerability with regard to its social network. In relation to food security, it was evident that Phiahuanam and Phonsa At exhibited the most pronounced degrees of susceptibility. Based on the data provided in the table, Thamun village exhibited the most significant degree of vulnerability with regard to water accessibility, while Munaghom village had the highest level of vulnerability in relation to natural disaster and climate variability.

4.3 Livelihood Vulnerability Index – Intergovernmental Panel for Climate Change (LVI-IPCC)

As mentioned in the methodology chapter, calculating the LVI-IPCC was done by grouping all primary indicators into three different contributing factors, namely adaptive capacity, sensitivity and exposure. However, based on the Intergovernmental Panel for Climate Change, the sub-indicator for adaptive capacity needed to be changed, as illustrated by Tables 4.4 and 4.5. This section presents the results of calculating the livelihood vulnerability index based on the Intergovernmental Panel for Climate Change, exhibited in Table 4.5.

Table 4.4: Change sub-indicator for LVI-IPCC

Primary indicators	Sub-indicators for LVI calculation	Change sub-indicator for LVI-IPCC calculation
Socio-demographic profile	Percent of households that had a member who was under 15 or over 60 years of age	Inverse (Percent of households that have a member who was under 15 or over 60 years of age)
	Percent of household where the head of household is female	Percent of household where the head of household is male
	Percent of households where head of household had attended school	Percent of households where head of household had not attended school

Livelihood strategies	Percent of households with other members in family that do not live in household but help the family with money or other contributions	Percent of households with other members in family that do not live in your household but do not help the family with money or other contributions
	Percent of households in which the income is derived from the agriculture activities	Percent of households in which the income is derived not only from the agriculture activities
	Percent of households that have an unemployed member	Percent of households that do not have an unemployed member
Social Network	Percent of households that receive any money, food or any type of assistance from relatives	Percent of households that do not receive any money, food or any type of assistance from relatives
	Percent of households wheremembers borrow money from an institution	Percent of households where members do not borrow money from an institution

Table 4.5: Result of Inverse all sub-indicators for adaptive capacity

Name of village	Adaptive capacity		
	Socio-demographic profile	Livelihood strategies	Social Network
Huaylor	0.545	0.022	0.500
Lai Gnai	0.667	0.333	0.544
Mang	0.156	0.300	0.567
Muanghom	0.667	0.322	0.578
Nalai	0.733	0.422	0.444
Namet	0.489	0.456	0.489
Namtouy	0.778	0.656	0.533
Nangoua	0.700	0.433	0.578
Napa	0.511	0.355	0.578
Pangthong	0.522	0.456	0.533
Phiahuanam	0.600	0.400	0.544
Phonsa At	0.733	0.333	0.522
Sienglea	0.722	0.378	0.545
Thamun	0.667	0.278	0.489
Yor	0.655	0.444	0.656

Table 4.6: Result of LVI-IPCC

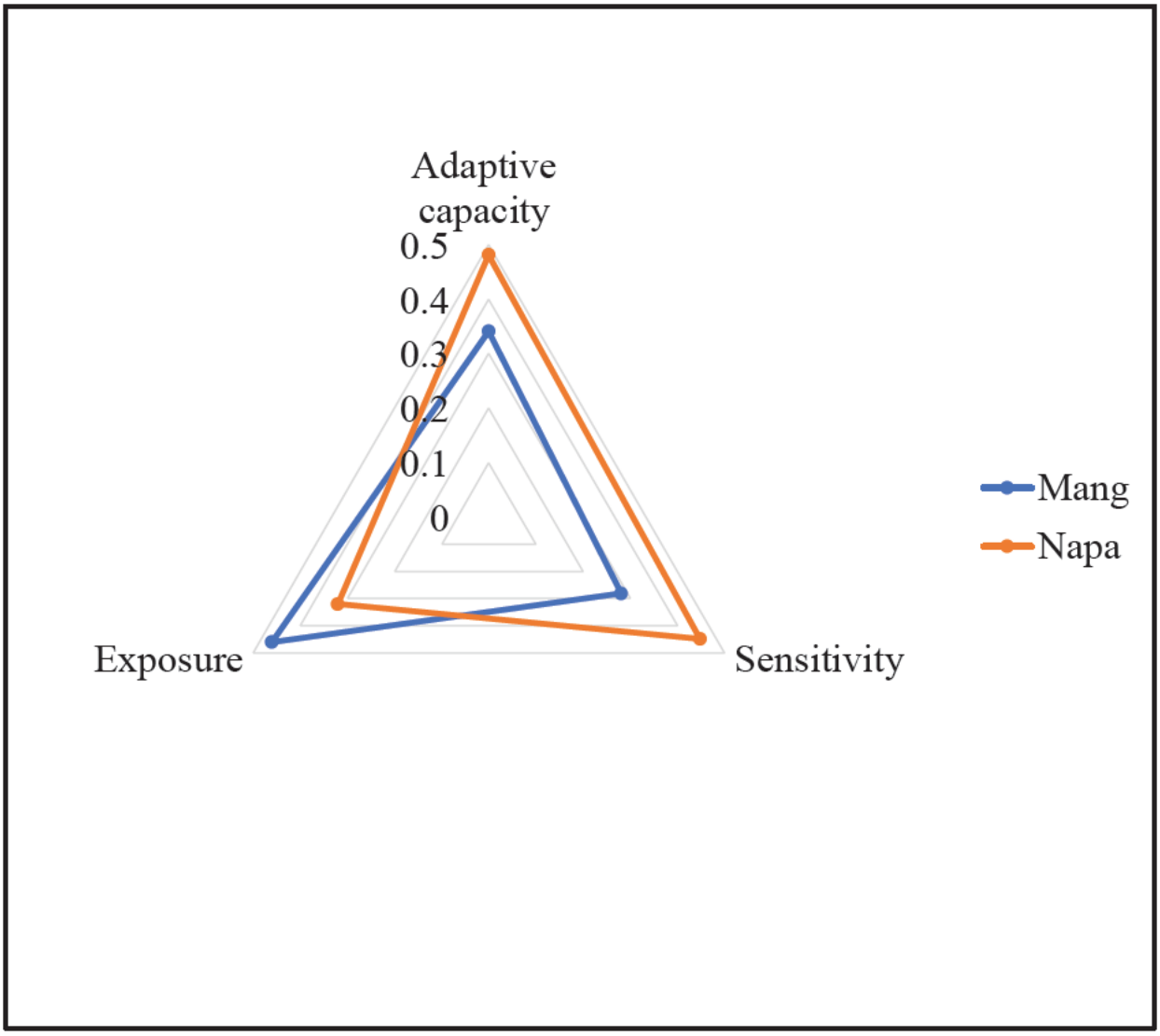
LVI-IPCC vulnerability scale: -1 (least vulnerability) to 1 (most vulnerability)

Names of villages	Adaptive capacity (A)			Sensitivity (S)			Exposure (E)	LVI-IPCC: $LVI - IPCC_v = (E_v - A_v) * S_v$
	Socio-demographic profile	Livelihood strategies	Social Network	Health	Water access	Food security	Natural disasters and climate variability	
Huaylor	0.356			0.321			0.373	0.006
Lai Gnai	0.515			0.327			0.413	-0.033
Mang	0.341			0.281			0.460	0.033
Muanghom	0.522			0.338			0.500	-0.008
Nalai	0.533			0.254			0.467	-0.017
Namet	0.478			0.367			0.393	-0.031
Namtouy	0.656			0.263			0.400	-0.067
Nangoua	0.570			0.251			0.447	-0.031
Napa	0.481			0.448			0.320	-0.072
Pangthong	0.504			0.318			0.360	-0.046
Phiahuanam	0.515			0.335			0.347	-0.056
Phonsa At	0.530			0.331			0.413	-0.039
Sienglea	0.548			0.255			0.380	-0.043
Thamun	0.478			0.412			0.353	-0.051
Yor	0.585			0.240			0.387	-0.047

According to the calculation of vulnerability based on the Intergovernmental Panel for Climate Change (IPCC), contributing factors (Adaptive capacity, Sensitivity and Exposure: Table 4.6 and Figure 4.2) show that Mang village had the highest vulnerability level at 0.033 and Huaylor village came in second with the vulnerability level of 0.006. while the village that had the lowest level of vulnerability was Napa which was -0.072. The values of vulnerability for the rest of the villages are exhibited in Table 4.6.

The following triangle diagram presents the highest and lowest vulnerability.

Figure 4.2: Vulnerability triangle diagram of the contributing factors to the Livelihood Vulnerability Index-IPCC for highest and lowest vulnerable villages



4. 4 Result of crosstab analysis

This section presents the results of the crosstab analysis with regards to the gender of the heads of 450 households intersected with different aspects as illustrated in Table 4.7 to Table 4.12.

Table 4.7 demonstrates that 26.1 percent of female-headed households had experienced food shortages in the previous 12 months while male-headed households accounted for 16.2 percent. In other words, the female household heads might have found it difficult to be sufficiently nourished due to the lack of income and inadequate agriculture production. According to Table 4.8, 12.4 percent of the female heads were getting assistance from the government while only 7.2 percent of male heads received similar kinds of assistance. Moreover, the number of female-headed households which borrowed money from micro finance institutions was found to be more than for the male-headed households. Table 4.9 illustrates that 42 percent, or 119 female-headed households, borrowed money from a micro finance institution, while there were only 65 male-headed households that borrowed money. The number of female heads who bought seed for agriculture activities was more than for male head households. As Table 4.10 illustrates, there were 32.2 percent or 91 female-headed households that bought seed, compared with male heads with only 30 households. Moreover, the female heads experienced rising food prices more than male heads. This appears to be because the male-headed households were able to find enough food by not buying from the market while female-headed households more heavily depended on the food at the market. Table 4.11 demonstrates that 18 percent of female heads were faced with rising food prices while there were only 4.8 percent of male heads who experienced rising food prices. In terms of natural disasters, the crosstab analysis also found that female heads lost their crops due to drought more often than did male heads of households, as there were 43.5 percent of 123 female heads households who lost crops due to drought, while there were 48 male heads of households who lost crops as illustrated in Table 4.12. In summary, the findings obtained from the crosstab analysis indicate that households led by females encounter a greater degree of challenges compared to households led by males. It may be inferred that female heads of households may have more challenges or exhibit increased vulnerability compared to males when confronted with natural disasters and climatic variability.

Table 4.7: Household experience of food shortage

Sex of head of household	Households that experienced a shortage of food to eat	Households that did not experience a shortage of food to eat
Male	16.29	83.8
Female	26.1	73.9
Total	100	100

Table 4.8: Household that received money, food or any type of assistance from the government

Sex of head of household	Households that received money, food or any type of assistance from the government	Households that did not receive money, food or any type of assistance from the government
Male	7.2	92.8
Female	12.4	86.7
Total	100	100

Table 4.9: Household borrowed money from Micro-finance institution.

Sex of head of household	Households that borrowed money from Micro-finance institution	Households that did not borrow money from Micro-finance institution
Male	38.9	61.1
Female	42	58
Total	100	100

Table 4.10: Households that bought seed for agriculture purposes

Sex of head of household	Households that bought seed for agriculture purposes	Households that did not buy seed for agriculture purposes
Male	18	82
Female	32.2	67.8
Total	100	100

Table 4.11: Households faced with rising price of food

Sex of head of household	Households faced with rising price of food	Households not faced with rising price of food
Male	4.8	95.2
Female	18.8	81.2
Total	100	100

Table 4.12: Households that lost crops due to drought

Sex of head of household	Households that lost crops due to drought	Households that did not lose crops due to drought
Male	28.7	71.3
Female	43.5	56.5
Total	100	100

4.7 Conclusion of findings

The findings clearly illustrate that the livelihood vulnerability of communities varied depending on different aspects. According to the livelihood vulnerability results, Mang village exhibited the highest vulnerability value (0.845) in regard to the socio-demographic indicator. On the other hand, Huaylor village had the highest vulnerability value (0.978) in terms of livelihood strategies. The village that had the highest value of vulnerability on the health indicator was Muanghom village (0.500). In addition, Muanghom also had the highest vulnerability (0.500) on natural disaster and climate variability, while Nalai village exhibited the highest vulnerability (0.556) in social networks. In terms of food security, there were two village that had the highest vulnerability (0.711), Phiahuanam and Phonsa At. In regard to the water access aspect, Thamun was found to have the highest vulnerability (0.356) amongst 15 villages. Comparing 15 villages, Mang village was found to have the highest overall vulnerability index (0.476) with regard to the seven main indicators. Similarly, the result of calculating the livelihood vulnerability index by using the IPCC contributing factors (Adaptive capacity, Sensitivity and Exposure) also showed that Mang village had the highest vulnerability (0.033). As well, the result of the crosstab analysis emphasized that the degree of female vulnerability was higher than for males.

5. DISCUSSION

This chapter provides an in-depth discussion on the findings presented in the preceding chapter, specifically focusing on the Livelihood Vulnerability Index and the results of the crosstab analysis.

5.1 Livelihood Vulnerability Index amongst 15 villages

This section discusses the difference in each main indicator and provides the reasons these indicators have contributed significantly to the level of livelihood vulnerability of communities in the villages.

Social-demographic profile

The results confirm that the number of old and young members in a household and the education level of the head of a household play significant roles in the level of vulnerability of the village. As Bryant et al. (2022) highlighted, old people might have chronic illnesses which reduce the capacity to cope with climate change. This demonstrates the level of vulnerability of a village when facing a natural hazard event or climate change. Unquestionably, individuals with chronic medical problems face an elevated susceptibility to sickness and mortality in the face of climate change-induced consequences, namely heightened vulnerability to heat, severe weather events, waterborne diseases, and compromised air quality (UEPA 2022a). More importantly, having an education background is vital for responding to the change of climate. Hoffman and Blecha (2020) stated that education and learning directly equip people with the information, skills, and perspectives to prepare for and recover from catastrophic shocks, as well as indirectly providing material, informational and social resources to people and families, lessening catastrophe susceptibility. Furthermore, there are direct and indirect ways in which education may help mitigate the effects of severe weather (Muttarak and Lutz 2014). This means individuals' adaptive ability may be influenced by their knowledge, skills, and competences, and formal education is often seen as the major means through which these might be acquired. In this research, Mang village was found to have the highest vulnerability value in terms of social-demographic profile. In addition, the village was also found to have the highest percentage of households where the

head of household did not attend school, which accounted for 96.67 percent of total households in the village. Therefore, the reuslts of having a high percentage of old people and teenagers reflects the capability to respond to changes, as well as having an uneducated head of household which increases the livelihood vulnerabiity.

On the other hand, the households headed by females were found to be more vulnerable to natural hazard events compared to male-headed households. The specific vulnerability experienced by women and girls may be attributed to a variety of circumstances. One contributing aspect is the differential socialisation of females, which results in a lack of exposure to certain abilities such as swimming and tree climbing that are often acquired by their male counterparts (Brody, Demetriades & Esplen 2008). Habtezion (2016) also highlighted that women often experience an excessive weight of domestic responsibilities, including home chores and the care of children, the ill, and the elderly. This illustrates that women who are taking care of the family and are also resposible for the household have a higher potential of being more vulnerable than does a male-headed household. This was also emphasised by the previous study about the effect of climate change amongst different genders, for instance in Banglasdesh, the adverse impacts of climate change-induced environmental degradation and natural catastrophes disproportionately harm impoverished women when compared to males (Rahman 2013). The results indicate that Pangthong village has 80 percent of its households led by women. While several other villages including Huaylor, Namet, and Napa, also have a notable number of households headed by women. However, there are several variables that contribute to the prevalence of female-headed families over male-headed households, including migration, traditional practices, social dynamics, and economic considerations. According to the (2020) report by the International Organization for Migration (IOM), Oudomxay was among the top six province in Laos from which people (mainly male members) migrated internally to Vientiane Capital. Therefore, migration to the capital city can be attributed to several factors, with employment opportunities being a significant cause.

Livelihood strategies

The results in Table 4.1 illustrate that all households in 15 villages were found to have income generated from agriculture activities. This indicates that most of the households in Beng district are heavily reliant on agricultural subsistence and natural resources. The lives of a significant majority of the population in Laos are heavily reliant on the agricultural sector and the use of natural forest resources, with over 80 percent of individuals depending on these sectors (Lao PDR 2013). The research from De Silva and Kawasaki (2018) also demonstrates that families rely significantly on natural resources for their sustenance, and it is seen that families with lower income have more pronounced adverse effects from floods and droughts compared to homes with higher income levels. This means households that heavily rely on natural resources will be more vulnerable when facing natural disasters. More importantly, facing natural disasters such as drought and flood can directly affect the agriculture activities. This makes the villages more vulnerable when facing such natural disasters particularly in developing countries. Abeygunawardena et al. (2009) emphasized that the impact of temperature fluctuations, changes in precipitation patterns, and the occurrence of severe climatic events would exacerbate the strain on agricultural resources in many parts of developing countries, therefore diminishing the suitability of land areas for agricultural purposes. Additionally, agriculture, being heavily reliant on the consistency of monsoonal rainfall, is among the primary sectors affected by changes in the hydrological regime (Vinke et al. 2017). On the other hand, for households that contained an unemployed member, that factor indicated the household could depend more on natural resources in order to be sufficiently nourished. In this study, the result showed six villages were found to have all households containing at least one unemployed member, namely Huaylor, Lai Gmai, Mang, Muaghom, Nalai and Phonsa At, as exhibited in Table 4.1.

It has been shown that families experiencing financial stress tend to have a reduced ability to effectively manage the challenges posed by climate change (Shaw & Team 2009). Undoubtedly, the presence of financial stress within a family is indicative of the amount of sensitivity experienced when confronted with the impacts of climate change. The findings demonstrate that Mang village had the largest proportion of households receiving financial support or other contributions from family members who did not reside in the same home. This accounted for 96.67 percent of all households, as seen in Table 4.1. In addition, the head count poverty rate in

Oudomxay province was 29.2 percent, as stated in the report published by the World Bank in the year 2020. This demonstrates that Oudomxay province consists of a significant population that still lives in poor conditions and is sensitive to the effects of climate change because of their socioeconomic circumstances. As a consequence of this, the investigation found that Huaylor village had the highest value on the vulnerability index when compared to the three separate sub-indicators that are shown in Table 4.3.

Social Network

According to the literature, the vulnerability varies among individuals and communities depending on different social circumstances. Societal vulnerability refers to characteristics of a population that weaken its capacity to prepare for, respond to, and recover from disasters (Cannon 1994). For this main indicator, the research found that Namet village contained the highest percentage of households that borrowed money from an institution, accounting for 70 percent as illustrated in Table 4.1. This is because Oudomxay still comprised households with a significant poverty head count rate who lived in poor conditions as discussed for the previous indicator. The high percentage of households borrowing money could illustrate a household's difficulties in terms of generating income and therefore finding it harder to be sufficiently nourished. As a result, having financials stress or difficulties in generating an income will increase the vulnerability of communities in terms of responding to and recovering from natural disaster (Cannon 1994; Shaw & Team 2009).

Nonetheless, receiving assistance from relatives in terms of money or other contributions, especially from the government, can reduce the vulnerability of households when facing natural disasters. For instance, the mitigation of sufferings may be achieved by the government via the implementation of measures such as the creation of job possibilities for those affected by drought and the provision of financial support to alleviate their circumstances (Miyan 2015). As the result in Table 4.1 illustrated, only a small percentage of households in each village received assistance from the government amongst the 15 villages, while some villages did not have any assistance from the government at all, such as Nalai and Yor. However, in Laos the National Disaster Management Committee has been responsible for the coordination of early warnings, preparation, disaster response, and recovery efforts since 1999 (PDR 2021). This coordination is carried out

under the guidance of the Ministry of Labor and Social Welfare, with focal points established at the province and district levels.

On the other hand, receiving assistance from a relative can also help households increase their capability in order to recover from and respond to natural shocks such as drought and floods. Unquestionably, the use of social networks, namely via borrowing and getting support from friends and family, has been recognized as a significant coping mechanism in response to health-related adversities (Nguyen, Nguyen & Grote 2020). For instance, many scholars have argued that remittances are indicative of an enhanced ability to address calamities, mitigate susceptibility, and expedite the process of recuperation (Mohapatra, Joseph & Ratha 2012; Savage & Harvey 2007). In this study, the result showed that Namet and Nalai village were found to have the highest percentage of households that received money, food or any type of assistance from relatives, which accounted for 96.67 percent for both villages. Moreover, many villages were also observed to have a high percentage of households that received assistance from relatives. However, receiving assistance from another can also indicate the hardship status of receivers who might not be able to respond to the shocks, particularly the natural disasters. This, therefore, indicates the vulnerability especially when facing a natural hazard event.

Health

The accessibility of healthcare has played a crucial role in enhancing the ability of households to effectively react to natural disasters and meet healthcare standards. According to the Asian Development Bank (ADB, 2019), there is a significant need for development in the healthcare standards, clinical processes, and health workforce in Laos. Significantly, the findings indicate that there exists a considerable distance between the research region and the healthcare facilities. As shown in Table 4.1, Muanghom village was situated at a distance of 35 km from the district health centers. According to the study conducted by Adu et al. (2018), individuals residing at a considerable distance from healthcare facilities have a heightened susceptibility. This finding demonstrates that those residing outside district areas are at a higher risk of vulnerability compared to those residing in close proximity to the district centre. Furthermore, given the hilly topography of Oudomxay province, the provision of adequate transportation infrastructure is necessary to facilitate access to the district regions for the local population. The limited availability of

transportation is a substantial barrier to healthcare accessibility, particularly for those with small financial means, according to Syed, Gerber, and Sharp (2013). Hence, the impact of climate change will disproportionately affect those with limited access to healthcare services (Costello et al. 2009).

Additionally, according to UEPA (2022b), households that have at least one member who is unwell or has a medical problem have a greater propensity to be more susceptible. This means having one sick member in the household could cause households to experience difficulties when facing natural disasters. Interestingly, the data indicate that just a small percentage of households in all villages had a sick member in their household. For instance, the village of Phiahuanam had the largest proportion of households that consisted of unwell members, accounting for just 13.33 percent of the total. Even if the likelihood of having a sick family member is low, as shown in Table 4.1, the accessibility to medical treatment in many communities was nevertheless restricted due to the great distances that separated them from the primary medical facility serving the region. Because of this, the village of Muanghom had the greatest vulnerability rating with respect to the health indicator.

Food security

Based on the literature above, crops, livestock, and food security have all been impacted by shifts in temperature, precipitation patterns, and severe weather events (Lobell et al. 2013; Rosenzweig et al. 2014). More importantly, the phenomenon of climate change has had a significant impact on the production of food, thereby influencing its overall availability (Gitz et al. 2016). This exemplifies how the constraint of food might render households susceptible to the ramifications of climate change (Parvez, Islam & Dey, 2022). The research results indicate that a significant proportion of families in the villages, namely Lai Gnai and Phiahuanam, had challenges in accessing sufficient food: 70 percent of the households in these two villages did not have enough money to purchase sustenance. Moreover, a significant majority of the numerous households lacked sufficient funds to purchase food for sustenance according to Table 4.1. This further indicates that the majority of the households in the sample are still experiencing food insecurity. However, this also signifies the economic condition of the community. According to the Intergovernmental Panel on Climate Change (IPCC) and Birkmann et al. (2022), it is evident that impoverished communities exhibit lower levels of resilience when confronted with the

multifaceted consequences of climate change. Furthermore, the research results indicate that a significant proportion of families engaged in the purchase of seeds for agricultural reasons. For instance, Sienglea exhibited the greatest prevalence of seed purchasing, accounting for 50 percent of the total households, as shown in Table 4.1. The act of purchasing seeds for agricultural purposes indicates that families are in need of supplementary revenue to support their agricultural operations. In the context of an economically disadvantaged community, a rise in daily expenses might heighten susceptibility to natural hazards such as droughts and floods.

Furthermore, the results indicate that firewood was used as the primary energy source for cooking in all households throughout the 15 villages, as shown in Table 4.1. Based on the findings from the household survey data, it was observed that firewood served as the primary fuel source for cooking in around 80 percent of households in Laos (Pasanen et al., 2017). This suggests that the majority of communities in rural areas continue to depend on natural resources as their primary means of sustenance. Additionally, Vatthanatham et al. (2018) underscored the significant reliance of individuals living in rural regions on non-timber forest products (NTFPs) and other resources derived from nature. As previously stated in the literature, climate change continues to have a detrimental influence on several sectors, particularly biodiversity. Hence, the heavy dependence on natural resources, namely forests, as the primary means of sustenance highlights the susceptibility of different groups to the effects of climate change.

Water access

Given the significant reliance of the nation on the Mekong River and its associated Mekong River Basin (MRB), the impact of climate change on this prominent watercourse is expected to be substantial (Pink 2016). The literature has emphasized the assessment report from the intergovernmental panel on climate change (IPCC) that shifting rainfall and precipitation directly affect the availability of fresh water. However, the findings of this study illustrate that most of the villages consisted of a low percentage of households that experienced severe water shortage. For instance, Pangthong village had 6.67 percent of the total households that were facing severe water shortage and the rest of the villages were found to have only a few households in the village that experienced water issues, as illustrated in Table 4.1. Nevertheless, according to the UN-habitats (2019), Oudomxay is significantly vulnerable to climate change threats since a substantial portion

of its population has apparently been affected by drought events. Table 3.4 shows that around 168,963 people were affected by drought events. This demonstrates the high vulnerability of people who live in Oudomxay province, particularly the Beang district, even though the result reveals a low percentage of households that experienced severe water shortage.

Furthermore, relying on natural sources of water could make the villages vulnerable due to the impact of climate change as the climate change will directly affect the availability of water as discussed in the literature. In this study, the result showed that many villages consisted of a significant number of households that utilized water from natural sources, such as Thamun village which had about 53 percentage of the total households in the village that still used water from natural sources, as illustrated in Table 4.1. This indication illustrates that the more dependence there is on natural sources of water, the greater will be the sensitivity when facing natural shock events, especially drought and heat waves. More importantly, as a nation characterized by its abundance of watersheds and water catchments, Laos is inherently susceptible to climatic fluctuation and change (Lao PDR 2010; World Bank 2021). On the other hand, there are certain communities that are made up of many different houses that each have their own source of potable water inside the home. For instance, according to the data shown in Table 4.1, Namet had a ratio of 73 percent of the total households in the village that had their own drinking water supply from the tap. However, the fact that a higher number of households had water available via their taps within the home does not indicate that the communities have a lower degree of risk, as water resources are one of several sectors that will be severely impacted by the effects of climate change in the future (PDR 2009).

Natural disaster and climate variability

The natural disasters statistics in Table 3.4 show that Odoumxay province has experienced natural hazard events caused by climate change such as drought, floods and storms. Particularly in 2016, the province was faced with an unexpected flash flood which resulted in more than 10,000 people being affected. More importantly, there were 45 villages and 1,994 people located in the Beng district who were directly affected by this flash flood, as illustrated in Table 3.5 (IFRC 2016). In this study, the result also showed that there was a significant proportion of households in each village that experienced losing their cash crops due to drought and flood. Nalai village had 73.33

percent of the total households in the village that were faced with losing crops due to drought, as illustrated in Table 4.1. Moreover, the result also showed that Sineglea village's experience in losing crops due to flood accounted for 30 percent of households as illustrated in Table 4.1. This indicates this community was highly exposed to the impact of natural disaster. The same as many areas in Laos, the agricultural sector experiences significant repercussions from floods since they inflict extensive harm to farmlands and crops (Anh 2016; Soulibouth, Hwang & Shin 2021). Consequently, this leads to restricted food accessibility, so impacting both the availability and security of food within the nation. Furthermore, the findings indicate that a majority of the 15 villages examined exhibited instances of agricultural pests and crop diseases. For example, both Muanghom and Namtouy villages reported that all families saw instances of agricultural disease or crop pests. The impact of crop pests and diseases on agricultural productivity and revenue has been studied previously, highlighting the significant dependence of the village's overall income on agricultural operations. Douangboupha et al. (2009) highlighted that the primary rodent species of concern in the upland farming system of Lao PDR is *Rattus rattus* which responds to variations in the availability of food resources that are provided by the upland crops. This highlights the villages' significant susceptibility to the consequences of natural disasters, as well as their exposure to associated risks such as agricultural diseases and pests. Consequently, these villages exhibit a high level of sensitivity in terms of this particular indicator.

Nevertheless, knowing how to cope with natural disasters and climate variability with strategies and a mitigation plan could reduce the vulnerability of communities to natural hazard events. Smit and Pilifosova)2003) argued that the implementation of strategic and proactive measures has the capacity to mitigate susceptibility and capitalize on advantageous circumstances linked to the impacts and risks posed by climate change. Undoubtedly, enhancing preparation measures and fostering community empowerment have the potential to ameliorate the circumstances faced by vulnerable populations impacted by disasters (Makwana 2019).

This study reveals that the majority of villages contain a significant number of households that are unprepared for natural disasters such as floods and droughts. In Phonsa At, as shown in Table 4.1, 47 percent of the households in the village lacked any flood prevention strategies or contingency plans. As also shown in Table 4.1, 63 percent of households in the village of Mang lacked any

mitigation or prevention strategies for dealing with drought. This shows the preparedness of villages is still low and requires more understanding of the mitigation and adaption strategies needed to respond to natural disasters. The level of awareness and understanding of climate change among the local population in Laos is limited and relatively low (Lao PDR 2000; WHO 2019). Therefore, in order to effectively address the challenges posed by climate change, it is necessary to possess a comprehensive understanding of both mitigation measures and adaptation techniques (Ratinen 2021; Surminski & Oramas-Dorta 2014).

5.2 Livelihood Vulnerability Index by using Intergovernmental Panel on Climate change contributing factors: Adaptive capacity, Sensitivity, Exposure

According to the IPCC, adaptive capacity is one of three factors contributing to the level of vulnerability of communities or individuals. Table 4.6 illustrates that Huaylor village had the highest adaptative capacity value of 0.356, while Namtouy village had the lowest adaptative capacity value of 0.655. This demonstrates that Huaylor village had the lowest level of adaptative capacity regarding the three different sub-categories of socio-demographic, livelihood strategies and social networks. In contrast, Namtouy village stood out as the village that had the highest level of adaptive capacity as shown in Table 4.6. Moreover, many villages observed had moderate adaptive capacity scores, such as Thamun, Napa, Namet and Mang. Brooks (2003) highlighted that the future vulnerability of a system is influenced by its present vulnerability, which is decided by previous adaptations and the existing range of coping alternatives. This current vulnerability serves as a foundation from which the system's future vulnerability will develop. Therefore, having an effective adaptation plan is vital for reducing the vulnerability of people. In Laos, the first National Adaptation Program of Action to climate change was submitted to the United Nation Framework on climate change in 2009 (UNDP 2012). However, one of the primary limitations hindering the execution of the National Adaptation Program of Action (NAPA) is the need for enhanced coordination and collaboration among the relevant sectors (Lao PDR 2009). Therefore, this could be a challenge that reduces the level of adaptability for villages in Laos especially for villages that have experience in natural hazard events as illustrated in Table 4.6.

The primary sub-categories identified were health, water access, and food security, according to their sensitivity. This research reveals that Napa village had the highest values of 0.448 among the 15 villages, as shown in Table 4.6. Several villages, including Huaylor, Lai Gnai, Mang, and Phonsa, were found to have a moderate sensitivity score. The values of 0.32, 0.327, 0.281, and 0.331 were observed for the corresponding variables, as shown in Table 4.6. In contrast, it was observed that Muanghom village exhibited the greatest level of exposure to natural disasters and climatic variability, with a value of 0.500, as shown in Table 4.6. Furthermore, it was observed that 15 villages had moderate levels of exposure, as shown in Table 4.6. Nevertheless, as elucidated in the preceding section, Oudomxay is situated in topographically elevated regions and has seen several occurrences of natural hazards, notably in the year 2016. This highlights the vulnerability of populations located in rural areas. The findings of the livelihood vulnerability index, which takes into account many contributing elements identified by the Intergovernmental Panel on Climate Change (IPCC), indicate that Mang village had the greatest vulnerability values, while Huaylor showed the lowest vulnerability values. This information is visually shown in Table 4.6.

5.3 The difference in vulnerability between genders

As discussed previously, villages in the study area were vulnerable with regard to different aspects or based on the sub-indicators, namely household reliance on firewood for cooking, households that did not have enough money to buy food, households that lost crops due to drought, and households where the head of household was female. The result of crosstabulation analysis has clearly demonstrated that female headed households experienced difficulties in several aspects such as shortage of food, experience of rising food prices, and losing crops due to drought more than did male headed households. In the context of vulnerability to climate change, experiencing these difficulties more significantly will make the female-headed households more vulnerable than the male-headed households when facing extreme weather events like droughts and floods (Adeagbo et al. 2016;Rahman 2013). In addition, these difficulties are the fundamental factors that can cause people to be vulnerable if faced with the changing of climate. As the literature above stated, the ability to cope with and respond refers to the level of vulnerability (McCarthy et al. 2001).Therefore, this demonstrates that the female heads within the 450 households of this research were more vulnerable than the male-headed households.

5.4 Limitation of research

In this study, the calculation of the livelihood vulnerability index was based on the existing dataset which derived from the household survey. As a result, choosing the indicators need to adapted according to the availability of data. In addition, each sub-indicator was modified and adapted in regard to the availability of data. Hence, the results cannot be used to make a comparison to other studies due to the different use of some of the sub-indicators which directly influenced the results of the calculations. Moreover, these datasets were collected by the Mekong Sentinel Landscape, which meant some of the information did not fulfill the study's requirement. As Hahn, Riederer & Foster (2009) also noted that due to the omission of data collection from residences that were unoccupied during the field team's visit, I was unable to provide an assessment about the possible extent of the selection bias that may be linked with this circumstance. For instance, it is plausible that a significant proportion of the households interviewed consisted of two adults, with one adult engaged in employment outside the residence. Conversely, the vacant houses were mostly single-adult dwellings, with the resident perhaps being absent due to job commitments throughout the interview timeframe. Therefore, this limitation directly affected or influenced the effectiveness in terms of measuring the livelihood vulnerability of the distinct communities.

6. CONCLUSION

This study used data extracted from the household survey by the Mekong Sentinel Landscape, and adapted Hahn, Riederer, and Foster's (2009) methodology in order to measure the livelihood vulnerability index of 15 villages in Beng district, Oudomxay province, Laos. The same dataset was utilized in two different models, namely LVI and LVI-IPCC by using seven main indicators and twenty-two sub-indicators. Below is the summary of the findings of this study:

- The result of livelihood vulnerability calculations in Table 4.3 shows that Mang village had the highest degree of susceptibility (0.845) in terms of its socio-demographic profile, while Huaylor village had the highest degree of vulnerability (0.978) in terms of its livelihood. In addition to this, it can be noted that the village of Muanghom had the highest degree of vulnerability (0.500) with regards to the health indicator. Moreover, regarding the social network indicator, the village of Nalai had the greatest degree of vulnerability (0.556) among all the other villages. In terms of food security indicators, the results show that Phiahuanam and Phonsa At had the highest levels of vulnerability (0.711). Regarding water accessibility, Thamun village was found to have the highest vulnerability (0.365), while the village of Munaghom exhibited the greatest degree of vulnerability (0.500) in regard to natural disasters and climate variability. Overall, Mang village stood out as having the highest livelihood vulnerability value among the 15 villages regarding the seven main indicators and twenty-two sub-indicators.

- Calculating the livelihood vulnerability by IPCC model, the result also illustrated that Mang village had the greatest vulnerability index (0.033) in terms of adaptive capacity, sensitivity, and exposure, as illustrated in Table 4.6. In contrast, Napa was found to have lowest vulnerability (-0.072).

- Additionally, the findings of the crosstab analysis have shown the extent of vulnerability experienced by both male and female heads of household in 450 households. Tables 4.7 to 4.12 provide evidence indicating that households led by females have more challenges, such as crop loss resulting from drought, experiencing food shortages, and facing rising food prices. This means households led by women could experience difficulties during natural disasters. In addition, the result of the crosstab analysis emphasized the difference

in gender vulnerability in households. Therefore, female-headed households exhibited a higher degree of vulnerability compared to their male-headed households.

APPENDICES

Appendix 1: The subsection questionnaire and name of file.

Subsection	questionnaire	File
D	Could you list all members of your household?	Demography
D	Could you list all members of your household?	Demography
D	Could you list all members of your household? Attended School?	Demography
J	Are there any other members of your family that do not live in your household but help the family with money or other contributions	Remittance
I	During the last 12 month did any cash come to the household through any of the following means?	Income
D	Could you list all members of your household? Has been employed?	Demography
Q	Has your household been affected by any of the following events in the last 12 months? (Chronic /severe illness or accident of a household member)	Shocks and Crisis
	Average distance from village to district health	Using the google map
J	Did the household get any money, food or any type of assistance from these relatives in the last 12 month?	Remittance
J	Did the household get any money, food or any type of assistance from the government in the last 12 month?	Remittance
K	Over the past 12 month did you or anybody else in the household borrow money from an institution?	Credits
H	What type of fuel is usually used for cooking?	Housing, water and sanitation
O	Has your household planted any CASH crops in the last 12 month, Did you buy the seeds?	Agriculture activities
L	Reasons why people don't always have enough or the kinds of the foods	Food security, consumption
H	Where does this household obtain most of its water?	Housing, water and sanitation
H	Where does this household obtain most of its water?	Housing, water and sanitation
Q	Has your household been affected by any of the following events in the last 12 months, Did the household experience in severe water shortage?	Shocks and Crisis

	Has your household been affected by any of the following events in the last 12 months, Did the household loss of crops due to drought	Shocks and Crisis
Q	Has your household been affected by any of the following events in the last 12 months, Did the household loss of crops due to floods	Shocks and Crisis
Q	Has your household been affected by any of the following events in the last 12 months, Did the household experience in crop disease or crop pest?	Shocks and Crisis
Q	Has your household been affected by any of the following events in the last 12 months, how did your household cope with this shock?	Shocks and Crisis
Q	Has your household been affected by any of the following events in the last 12 months, how did your household cope with this shock? Has your household been affected by any of the following events in the last 12 months, how did your household cope with this shock?	Shocks and Crisis

Appendix 2: Annual rainfall statistic of Oudomxay province from 2005-2013

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
	(mm)												
2005	3.6	0.4	143.7	98.6	169.2	219.8	333.4	456.5	119.1	27.8	15.1	34.6	1,622
2006	0.0	54.8	43.6	128.2	102.1	101.4	303.7	283.7	53.0	68.6	2.1	0.0	1,341
2007	1.5	23	29.2	128.2	238.9	146.0	146.1	293.1	192.2	95.2	45.4	0.1	1,339
2008	65.9	29.8	73.4	115.7	103.1	218.0	452.5	384.2	327.5	145.9	74.8	13.4	2,004
2009	0.0	0.0	28.4	131.4	163.0	262.1	329.4	207.3	172.4	28.4	9.4	8.5	1,340
2010	30.4	2.6	37.3	159.2	161.3	103.0	277.1	198.9	109.5	36.7	2.1	34.5	1,153
2011	13.6	0.0	102.8	222.6	264.9	212.8	253.9	233.2	395.6	65.6	13.0	0.6	1,779
2012	56.6	2	12.5	117.3	254.7	204.7	357.3	478.5	72.7	54.9	69.2	1.1	1,682
2013	25.7	23.2	54.1	122.6	80.8	169.2	461.2	386.6	231.4	55.7	68.9	124.6	1,804
Mean	*21.9*	*15.1*	*58.3*	*136.0*	*170.9*	*181.9*	*323.8*	*346.9*	*185.9*	*64.3*	*33.3*	*24.2*	*1,563*

Source: (Asian Development Bank 2016).

Appendix 3. Example of Livelihood vulnerability index calculation

The following is the example of how to calculate the Livelihood vulnerability Index for Huaylor village in detail.

Huaylor								
Primary indicators	Sub-indicators	Unit	Original value (s_v)	Max value	Min value	Indexed Value($index\ s_v$)	Primary indicator value (M_v)	Overall LVI (LVI_v)
1.Socio-demographic profile	1.1	%	70.00	100	0	0.700	0.455	0.465
	1.2	%	63.33	100	0	0.633		
	1.3	%	3.33	100	0	0.033		
2.Livelihood strategies	2.1	%	100	100	0	1.000	0.978	
	2.2	%	93.33	100	0	0.933		
	2.3	%	100	100	0	1.000		
3.Health	3.1	%	0.00	100	0	0.000	0.100	
	3.2	Km	13.00	35	7.5	0.200		
4.Social Network	4.1	%	90.00	100	0	0.900	0.500	
	4.2	%	53.33	100	0	0.533		
	4.3	%	6.67	100	0	0.067		
5.Food Security	5.1	%	100	100	0	1.000	0.533	
	5.2	%	20.00	100	0	0.200		
	5.3	%	40.00	100	0	0.400		
6.Water Access	6.1	%	36.67	100	0	0.367	0.256	
	6.2	%	40.00	100	0	0.400		
	6.3	%	0.00	100	0	0.000		
7.Natural disasters and climate variability	7.1	%	30.00	100	0	0.300	0.373	
	7.2	%	16.67	100	0	0.170		
	7.3	%	73.33	100	0	0.730		
	7.4	%	53.33	100	0	0.530		
	7.5	%	13.33	100	0	0.130		

Firstly, the study has to standardize all value of sub-indicators from the original value by using the $index\ s_v$ equation. The example below demonstrates calculating for the sub-indicators in the socio-demographic profile primary indicator.

Equation (1) $index\ s_v = \frac{sv - s_{min}}{s_{max} - s_{min}}$ $index\ s_v = \frac{70-0}{100-0} = \frac{70}{100} = 0.700$

After finishing standardizing one sub-indicator, the study continues to use the same equation in order to standardize all the sub-indicators for the seven primary indicators and gets the result as demonstrated in the table above.

Secondly, the standardized value of each sub-indicator is averaged from all sub-indicators by using M_v equation in order to calculate the value for each primary indicator. After that, repeat for all the primary indicators by using the same equation

Equation (2) $M_v = \frac{\sum_{i=1}^{n} index_{svi}}{n}$ $M_v = \frac{0.700+0.633+0.033}{3} = 0.455$

Thirdly, the study used all values from primary indicators derived from equation 2 in order to calculate the Livelihood Vulnerability Index for Huaylor village.

Equation (3) $LVI_v = \frac{\sum_{i=1}^{7} W_{Mi} M_{vi}}{\sum_{i=1}^{7} W_{Mi}}$

$$LVI_v = \frac{0.455 * 3 + 0.978 * 3 + 0.100 * 2 + 0.500 * 3 + 0.533 * 3 + 0.256 * 3 + 0.373 * 5}{22}$$
$$= 0.465$$

These are the 3 steps that were use to derive the Livelihood Vulnerability Index and that were used in the same way for all 15 villages.

Appendix 4. Example of Livelihood vulnerability index calculation by using IPCC contributing factors

The following is the example on how to calculate the Livelihood Vulnerability Index based on the IPCC's definition of Huaylor village in detail. Therefore, the remaining villages will also use the same equation and methods.

Huaylor					
LVI-IPCC	Primary indicators	Number of Sub-indictors	Primary indicator value (M_{vi})	Contributing factors to IPCC value (CF_v)	$LVI - IPCC_v$
Adaptive capacity (A_v)	Inverse (Socio-demographic profile)	3	0.545	0.356	0.006
	Inverse (Livelihood strategies)	3	0.022		
	Inverse (Social Network)	3	0.500		
Sensitivity (S_v)	Health	2	0.100	0.321	
	Water Access	3	0.256		
	Food Security	3	0.533		
Exposure (E_v)	Natural disasters and climate variability	5	0.373	0.373	

First, the study has to invert all the sub-indicators for the adaptive capacity which include socio-demographic profile, livelihood strategies and social network. For instance, Percent of head of household who did not attend school, inverse to percent of head of household who did attend school.

Secondly, use the primary indicators value for calculating each contributing factor value which included exposure, adaptive capability, and sensitivity by using the CF_v equation. The following is the example of the calculation for adaptive capacity.

$$CF_v = \frac{\sum_{i=1}^{n} W_{Mi} M_{vi}}{\sum_{i=1}^{n} W_{Mi}} \quad CF_v = \frac{0.545*3+0.022*3+0.500*3}{9} = 0.356$$

After finishing for adaptive capacity, use the same equation for the remaining contributing factors.

Thirdly, once exposure, sensitivity, and adaptive capacity were calculated, the three contributing factors were combined using the following equation:

$$LVI - IPCC_v = (E_v - A_v) * S_v \qquad LVI - IPCC_v = (0.373 - 0.356) * 0.321 = 0.006$$

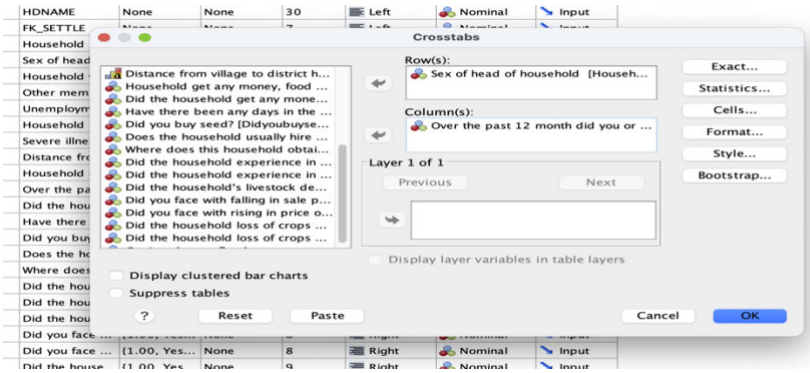
Appendix 5. Example of crosstab analysis

For crosstab analysis, the study used SPSS software with the same dataset which calculated the Livelihood Vulnerability index in order to differentiate the percentage for sex of head of household in various aspects. The following is the example of how the study conducted a crosstab analysis for all 15 villages.

For instance, the study aimed to see the different percentage for the sex of household head that borrowed money from the micro finance institution.

In SPSS, the study used the dataset in an Excel file pasted to the SPSS for both questionnaire and response for all 450 variables of 15 villages.

After that use the function crosstab function by going to *Analyze* > *Descriptive Statistics* > *Crosstabs*. Then, insert the Sex of head household and borrow the money from the micro finance institution as the following picture shows and click *Ok.*



The result of crosstab analysis:

			Over the past 12 month did you or anybody else in the household borrow money from Micro-finance institution?		Total
			Yes	No	
Sex of head of household	Male	Count	65	102	167
		% Sex of head of household	38.9%	61.1%	100.0%
	Female	Count	119	164	283
		% Sex of head of household	42.0%	58.0%	100.0%
Total		Count	184	266	450
		% Sex of head of household	40.9%	59.1%	100.0%

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